All the Stuff of the Universe

A Physical Model for Everything We Know

The four universal motions and a physical model of gravity, light, magnetism and electricity

Robert de Hilster and David de Hilster

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Preface

We did not set out to find a physical model of the universe.

What I did, for years, was collect. Whenever I came across a physical model of something—a picture of how a thing actually works, in parts you could point at and motions you could follow—I kept it. I was not trying to prove anything. I simply preferred models that said what was there.

Three of those collections matter most to this book. Glenn Borchardt's neomechanics and Infinite Universe Theory gave me the idea that there are no partless parts and that the levels go on without end. Ionel Dinu's water experiments, done in his daughter's swimming pool, showed me how two circulations meet and what they do to each other. And Jeff Yee's models, which grow orbital-like structures out of particles, showed me that a physical picture of the inside of an atom was possible. Their names come up again where their work does.

My father, Robert, an engineer, had spent about ten years on a particle model of gravity. Then he asked what the same particles could do about light: what is a ray of light *made of*? A question that physics had taught almost everyone to stop asking. He cracked it. Light is not a point and it is not a disturbance in nothing. It is groups of particles travelling together, rank behind rank, and the colour is the spacing between the ranks. Chapter 1 sets it out, and Chapter 2 tells how we came to it.

I had spent years collecting models, and with that one answer they began to fit together. If light was particles in formation, then gravity, magnetism and electricity might be the same particles doing different things. They are. Moving at random is gravity. Moving in orbits is magnetism. Flowing is electricity. Travelling in groups is light. Those are the four universal motions, and they are what this book is about.

What followed was years of the most satisfying work either of us has ever done. We checked the idea against one phenomenon after another. Where it held, we went on. Where it did not, we rebuilt it. Where we still do not know, the book says so in plain boxes.

I do not know of another case in which a father and son together found the shape of something like this, and I will not pretend it is not a part of why the work has meant so much to us.

As far as we have been able to find, no one has described an entire physical model of the universe in words and pictures alone. This book does it that way on purpose. It is not a rejection of mathematics. The mathematics of physics is magnificent at saying *how much*. We were asking *what*, and for that question we found that the equations are best left out of the way until the picture is clear. Nothing in this book asks you to change what has been measured. It asks what the measurements are measurements *of*.

It is not finished, and we have tried not to pretend that it is. The G2 fields that hold an atom together and shape its orbitals have not yet been found. The double slit is a proposal and not a solution. Chapter 24 says plainly how the model can be tested and what a failed test would mean, and Chapter 25 describes the particle simulations that would settle a good deal of it. Each chapter opens with a note of how firmly its claims rest, and ends with a short list of what you can now say.

Read it a question at a time, in order. If something does not fit, tell us. A model like this is only as good as the places where it has been pushed.

David de Hilster

Chapter 1

What Is Actually in the Room

STANDING: DERIVED. *Light is made of groups of G1s, so its wave behaviour and colour follow from the motions. What fixes the amount an atom sheds is open (Chapter 15).*

Switch on a lamp. The room fills with light.

Something is in that room now which was not there a moment ago. It left the lamp, crossed to the walls, to the book in your hands, to the back of your eye. It made the trip in about a hundred-millionth of a second. There is a great deal of it, it is still arriving, and it will stop arriving the instant you flip the switch back.

So here is the question this book is about. It is not a difficult question, and it is not a modern one. Children ask it and are usually answered with a word.

> *What, physically, is in the room?*

Not what it does. Not how to calculate it. What is it made of?

Most books on physics would answer that question somewhere near the end, after several hundred pages of groundwork. This one answers it now, in the first chapter, because the answer is the whole point and everything that follows is support for it.

> *Particles. Very small ones, travelling in groups, one group behind the next.*

That is the whole of it. The rest of this chapter is what that sentence means, and how much of the world it accounts for before we have used a single equation.

1.1 They Were in the Lamp Already

Start with the one thing most people assume and almost nobody is told outright: nothing was manufactured when you flipped the switch.

The particles now crossing the room were, a moment earlier, inside the lamp. They were not energy waiting to be converted into light. They were not stored in some compressed form. They were particles, sitting where they had been sitting, held by the atoms of the filament.

To see how they were held, we have to let go of the picture of the atom that most of us were given at school: a miniature solar system, a nucleus in the middle, and one or two electrons circling it like planets.

In this model an atom is a nucleus holding a *population* of far smaller particles. We call them G1 particles. Not one of them. Not two. Very many, in orbit around the nucleus, held in a particular arrangement.

What holds them there is not charge. Nothing in this book carries a charge, and nothing in it has a plus or minus sign built into it. (What physics calls charge will turn out to be a count of these particles.) What holds the population in place is gravity—not the gravity that holds you to the floor, but the same kind of thing one level further down, operating between much smaller and much faster particles. Chapter 12 takes that apart properly. For now the only thing you need is the shape of it: the nucleus holds a crowd, and something physical keeps the crowd in place.

Now the useful part of the picture. A given atom, left alone, settles at a certain number of G1 particles. Think of a room with a certain number of chairs. Not a box with walls, but an arrangement that can accommodate a particular crowd in a particular pattern.

The number is not arbitrary and it is not the same for every element. Each kind of atom has its own nucleus, its own arrangement, and therefore its own settled count. That is the whole of what makes one element different from another in this model: not a different kind of matter, but a different arrangement holding a different number of the same particles.

Push energy into the filament and each atom takes on more G1 particles than its arrangement can support. It is a room with people standing in the aisles. Something has to give, and sooner or later the atom sheds the surplus.

Notice that this already explains something the textbook treats as a brute fact. An atom does not shed its surplus in any amount it likes. It goes from one arrangement it can hold to another arrangement it can hold, and the difference between those two is a definite number of particles. That is why hot hydrogen glows in a few precise colours rather than smearing across the spectrum, and why those colours are the same in a laboratory and in a star forty light years away. The discreteness that forced quantisation into physics would then be a fact about what a given room can seat.

That is an explanation of the right shape rather than a finished one, and

the difference matters. Saying which colours a particular element gives you would mean knowing which arrangements its atoms can actually hold, and that is the one thing this model has not worked out.

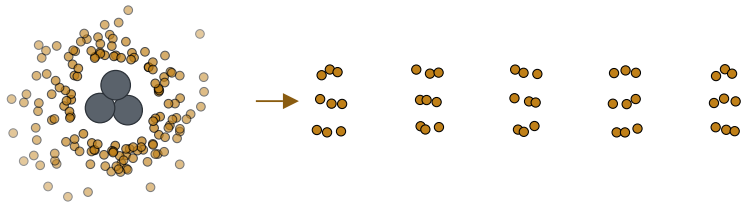


Figure 1.1: Emission, with nothing created. On the left an atom holding a population of G1 particles; it took on more than its arrangement could keep, and on the right the surplus is leaving—together, in step, group behind group.

That is all emission is.

That sentence disposes of a great deal. In the standard account, an electron absorbs energy, jumps to a higher orbit, later falls back, and *emits a photon*. Ask where that photon was while the electron was up there and the question has no answer. It was not inside the electron, which is said to have no parts. It was not sitting in the atom waiting. The photon is made at the moment of emission, out of nothing, by something.

A population does not have that problem. A population can grow and shrink. It can take some on and let some go. Nothing has to be created and nothing has to be destroyed—things only have to move.

1.2 How Small, and How Many

Two questions arrive at this point and they deserve straight answers, including where the straight answer is *we do not know yet*.

How small is a G1? Smaller than anything physics currently counts as a particle of matter. It has to be, because these are the things that stream through solid objects constantly without being stopped by them—the same particles that, moving at random rather than in formation, are what we experience as gravity. A floor is almost entirely empty space at the scale we are talking about, and the traffic goes through it the way a cloud of gnats goes through a tennis net.

How many are in the population an atom holds? Many. More than the one or two electrons the schoolroom picture gives an atom, by an enormous factor. Beyond that we cannot give you a number, and this is the first of several places in this book where the honest answer is that the arithmetic has not been done. There is a chapter near the end that collects every one

of these admissions in one place, because a model that hides them is not worth reading.

What we can say is what kind of thing the answer will be. It will be a count of particles, because in this model everything is a count of particles.

1.3 Why It Is Light and Not Just a Spray

Here is the piece that matters most, and it is the reason the word *wave* has followed light around for three hundred years.

When the atom sheds its surplus, the particles do not leave as a shapeless scatter in all directions. They leave the way they were already moving: together, in step, group after group, all in the same direction at the same speed.

That is what we call luminic motion—groups of similar particles travelling together. And it is the whole of the wave.

Picture a flock of birds, but a very particular kind of flock. A single straight line of birds, wingtip to wingtip, all flying forward together. That line is one wave. Now picture another line just like it following behind, and another behind that, line after line, each separated from the next by a gap. That whole procession, sweeping forward, is a beam of light.

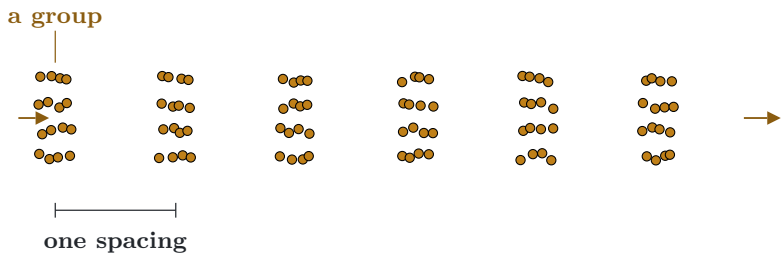


Figure 1.2: The wave is the formation. The frequency is the spacing between groups—a real length, which you could measure with a ruler if you could freeze the stream in flight.

Notice what is *not* in that picture. Nothing is bobbing up and down. Nothing is oscillating. No medium is being disturbed, because there is no medium. The wave is not a wiggle travelling through something—the wave is the arrangement of the particles themselves, and the waviness in every textbook diagram is just the succession of ranks arriving one after another. Line, gap, line, gap, line.

The argument is old. Newton held that light was corpuscular—little bodies, fired in straight lines—and he was attacked for it by Hooke and Huygens, who pointed out that light bends around edges and that beams cross without disturbing one another, which is what waves do and particles do not. History sided with the wave. Then the twentieth century found

that light also arrives in countable lumps, could not drop either picture, and settled the matter by declaring the contradiction a deep truth of nature and giving it a name.

Wave-particle duality is not an explanation. It is the record of an argument nobody won.

Both sides were working from the same unexamined assumption: that whatever light is made of, each individual piece of it has to account for the whole behaviour by itself. Newton tried to make one corpuscle carry a colour. The wave camp tried to make a disturbance with no medium to disturb. Neither thought to ask whether the wave might belong to the *group*.

This is Robert de Hilster's contribution, and it dates from 2015. It is a small idea to state and a large one to absorb, because it quietly dissolves a problem that physics has carried since Newton. The contradiction only exists if you demand that each individual particle somehow *be* a wave. Stop demanding that, and let the wave belong to the group instead of the member, and there is nothing left to reconcile. The particles are real. The wave is real. The wave is what the particles are doing.

1.4 Why It Has a Colour

Now look at the gaps.

The groups are spaced out along the line of travel, and that spacing is a distance—a real length, in metres, which you could measure with a ruler if you could freeze the procession in flight.

That spacing is colour.

Tightly spaced groups, arriving in quick succession, are what the eye reads as blue and violet. Widely spaced groups, arriving further apart, read as red. Everything else lies in between, and the whole visible spectrum is a range of spacings.

So colour is not a property that any single particle carries. No particle is blue. This turns out to be just as well, because a single object cannot have a rhythm any more than one bus passing your house can have a timetable—an argument we will make properly in its own chapter, because it does more damage to the standard picture than anything else in this book.

What sets the spacing is how much the atom sheds. A large release packs the groups tightly together; a smaller one spreads them out. This is why a filament runs from red through orange to white as you drive more current through it, and why a cooling ember slides back down the same scale. You are not changing the colour of anything. You are changing how much each atom is letting go of, and therefore how closely packed the departing ranks are.

1.5 Isn't That Just a Photon With Extra Steps?

It is the obvious objection and it deserves a direct answer. Physics already says light arrives in countable lumps. If a G1 group is a lump of light, what has actually changed?

Three things, and they are not cosmetic.

The lump has parts. A photon is defined as indivisible, with no size and no interior. A group has members—a specific number of them, arranged in a specific way, occupying a specific length of space. Everything in the rest of this book depends on the lump having an inside, because the explanations work by saying what the parts are doing.

The frequency belongs to something. A photon is said to have a frequency, which is a property of a repeating series, while being a single object that never repeats. In a procession the frequency is the spacing between successive groups: a length you could in principle lay a ruler against. The property finally has an owner.

The lump is not what travels; it is what gets taken. This is the subtlest difference and the most useful one. In the standard account the photon is indivisible all the way along: it leaves as one thing and arrives as one thing. Here the procession is extended and continuous, and the lumpiness appears at the receiving end, because an atom takes up a formation or does not. The quantisation is a fact about absorbers, not about travellers. Hold on to that one; it does more work later than anything else in this chapter.

So: not a photon with extra steps. A photon is a lump with no inside and a property it cannot own. This is a procession of real things, and the lumps are what happens when it meets something able to receive it.

1.6 Crossing the Room

Look up from the page for a moment and consider the volume of air in front of you.

Light from the lamp is crossing it. So is light from the window, from the screen, from every lit surface in the room, and from every surface those surfaces illuminate. It is going in every direction at once, all the time, through the same space. And none of it gets scrambled. The book in your hands does not flicker when someone walks past the window.

That is a genuinely awkward fact for anything that is supposed to fill space. If light were a disturbance running through a medium, or a set of planar fields stacked at right angles, then a room with a hundred light sources would be a hopeless tangle of intersecting disturbances, and the wonder would be that anybody could see anything at all.

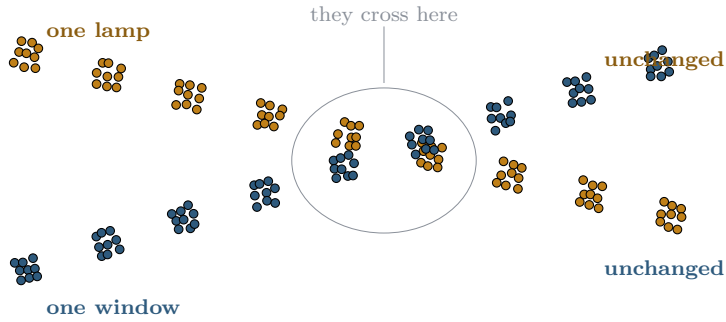


Figure 1.3: Two processions crossing. Both come out the other side unchanged, which is an awkward fact for anything that fills space and an unremarkable one for traffic.

For traffic it is unremarkable. Two streams of very small bodies pass through a volume that is almost entirely empty, and they mostly miss each other. Collisions do happen—collisions are how everything in this model happens—but they are rare enough that the formations come through intact.

You can watch this every day and it costs nothing. It is one of the quietest pieces of evidence that light is a population of things rather than a condition of space.

1.7 Arriving

The procession reaches the back of your eye.

There it meets atoms of a particular kind, holding their own populations of G1 particles, and some of those atoms are able to take on particles arriving at that particular spacing. They capture them. Their populations go up. Something downstream of that fires, and you see the lamp.

The important word is *able*. A receiving atom does not simply absorb whatever lands on it. What it can take depends on the arrangement it is holding and the formation that arrives—which is why a leaf is green, why sodium street lights are orange, and why a cold gas in front of a star leaves black lines in the spectrum where particular formations have been taken out of the beam and kept. A later chapter follows that through.

1.8 Why the Leaf Is Green

Most of the light leaving your lamp never reaches your eye directly. It lands on a wall, a table, the cover of this book—and what happens there is the same transaction, run at a surface.

The atoms of the surface are holding their own populations. A procession

arrives, and some of those atoms are able to take on particles arriving at that particular spacing. Those groups are captured and kept. The rest are not, and carry on—scattered off in new directions, a great many of them toward you.

So the colour of an object is a statement about what its atoms *could not* take. A leaf is green because its atoms are able to absorb the tightly spaced formations we call blue and the widely spaced ones we call red, and are not able to take the middle of the range, which therefore bounces off and reaches you. The green was never in the leaf. It is what the leaf declined.

This also settles an old confusion about mixing colours. Mixing paint is subtractive—each pigment removes more of the range, so the more you add the closer you get to black, which is a surface that takes almost everything and returns almost nothing. Mixing light is additive, because you are adding processions rather than absorbers. Nothing mysterious divides those two cases. One is about what is being sent and the other about what is being refused.

And a black surface in sunlight gets hot, which in this picture is not a metaphor. It is taking particles on and keeping them.

1.9 The Books Balance

Follow the particles all the way round and nothing anywhere was created or destroyed.

G1 particles were held by atoms in the filament. They were released, in formation, when the atom had more than it could keep. They crossed the room as a procession, passing through other processions on the way. They were captured by atoms at the back of your eye, which now hold more than they did.

The same particles throughout. And that last step only works *because* they are the same: what arrived was made of exactly the stuff the receiving atom already holds, which is why it could be taken up at all. A model in which light is one kind of thing and matter is another has to explain how the one turns into the other. Here there is nothing to explain, because it never stopped being the same stuff.

1.10 How This Book Marks Its Claims

Not every claim in this book rests equally firmly, and a reader should be able to see which is which without having to dig. So each chapter opens with a line giving its *standing*.

Derived means the chapter follows from the four motions and the mechanism is stated from start to finish. **Proposed** means a mechanism is offered and the places where it is weak are named. **Open** means the

chapter waits on the G2 fields, which have not yet been found. **Framing** means an argument or a definition rather than a mechanism. A chapter can carry a note when part of it differs from the rest. Appendix D collects the standings and what each chapter lets you say.

1.11 What You Can Now Say

You can say what is in the room.

You can say where it came from, which is that it was already in the lamp. You can say why it behaves like a wave, which is that it travels in ranks. You can say what its colour is, which is the distance between those ranks. You can say why a room full of crossing light is not a blur, and what happens at the moment you see something.

None of that required an equation. Not one has appeared in this chapter, and none was needed, because an equation was never what the question was asking for—it asks how much, and we were asking what.

That distinction turns out to be the whole argument of this book, and it is the subject of Chapter 3. First, a short account of how we found it.

What you can now say

- Light is made of particles that were already in the lamp, travelling in ranks.
- It behaves like a wave because the ranks are spaced, and its colour is the distance between them.
- A room full of crossing light is not a blur, because the groups pass through one another.
- None of this needed an equation: an equation answers how much, and the question was what.

What we have not modelled

This chapter says what light is made of, that colour is the spacing between groups, and that the spacing is set by how much an atom sheds. What it cannot say is what fixes that*—why sodium sheds the amount it does and gives that orange rather than another colour. That depends on the arrangement of the G2 fields which has a chapter of its own later on.*

Chapter 2

How We Found It

STANDING: FRAMING. *How the model was found. A history, not an argument: nothing in this chapter is offered as evidence for it.*

The last chapter said what light is made of. This one says how two people who were not looking for it came to say so.

2.1 A Question at a Premiere

On 7 December 2013, at the Arts Theater in Long Beach, David de Hilster premiered a documentary. *Einstein Wrong—The Miracle Year* had taken eight years to make. It follows his mother, Patricia de Hilster, who has no scientific training, as she travels to meet people who say the most famous physicist of the twentieth century was mistaken, and tries to decide what she thinks.

That night David asked his father a plain question. After eight years of filming, did he think Einstein was wrong?

Robert de Hilster said he did not know. He had never studied it.

He is an engineer, and for more than forty years he had designed and researched digital switching systems for telecommunications. He had been working on something else.

2.2 A Collector

David de Hilster was not looking for a theory either. In 1993, in Long Beach, he had met Dr. Ricardo Carezani, who had an objection to relativity, and he had spent the next two decades doing something that had no name: collecting physical models. Not of light in particular. Of anything anyone had a mechanical picture of.

Three collections mattered most. Glenn Borchardt's neomechanics and

Infinite Universe Theory gave him no partless parts and levels without end. Ionel Dinu's experiments with rotating cylinders in water, in his daughter's swimming pool and then in a larger one, showed what two circulations do to each other. And Jeff Yee's simulations showed that something like an atom's orbitals could grow out of particles with no charge anywhere in the model.

What he did not have was the model that would make the others fit together.

2.3 Waves of Particles

In May of 2015, a year and a half after that premiere, Robert de Hilster came up with a particle model of light. It was not one particle carrying a wave. It was many particles travelling together, with the wave belonging to the formation and the colour to the spacing between them. He told the family in June.

David was giving a talk at his father's house when Robert de Hilster stopped him, moved his fists together to show what he meant, and explained. David knew at once what he was looking at. He had spent twenty years looking at other people's attempts, and he could tell a picture that replaced a mystery with a mechanism from one that made the mystery go away.

Robert de Hilster did not know there was a problem. He went and read about the wave-particle duality for several days, and decided his model might indeed solve it. Then he asked himself why it should be him: *I'm an engineer. I'm not a scientist.*

2.4 Why Robert

The answer has two parts, and one of them was in Robert de Hilster's working life.

Telecommunications runs on pulse-code modulation: sample a sound wave at small intervals, turn the amplitude at each instant into a pulse, send the pulses down a wire, and rebuild the wave at the other end. A man who has done that for a career has the idea of making a wave out of a string of separate things built into the way he thinks.

The other part was ten years spent on a particle model of gravity. Having asked what particles could do about gravity, he asked what they could do about light.

Put the two together and the model follows. A string of particles gives both amplitude and frequency: the amplitude is how many are at a point, and the frequency is how far apart they are. There is a trace of it in an email he had sent David some time before the talk: a white paper headed *A particle theory of light! and gravity too*, with a line about a row of dots

matched to a sine wave, and a note that the figure was not yet available. He had meant to draw it and never did. David read it without the picture and did not see what it meant until his father moved his fists together.

2.5 Four Motions

Within months, the rest followed. The gravitic motion was the subject of Robert de Hilster's ten years. The luminic motion was his new model of light. The magnetic motion came from Dinu's circulations. And David added the electric motion, a flow of the same particles along a path. Then came the step that turned four ideas into one model: gravity, magnetism, electricity and light all travel at one speed, so there is one particle and four ways for it to move.

The name *luminic* came much later. It was almost ten years before they had a word for what Robert de Hilster had described in an afternoon.

2.6 What This Story Is Not

It is not evidence. A model is not made true by who found it or by how, and the rest of this book does not lean on this chapter. Neither of us is an academic physicist, and the model sits outside the mainstream. That is a fact about its position, not an argument either way.

What the story does show is how the model was built: from the working life of an engineer, the collecting of a son, and the work of other people whose names are in these pages. It is one answer. There may be a better one, and if this one fails, we would want to know. The chapters that follow are written so that you can find out.

What you can now say

- The model of light as particles in ranks came from an engineer working on gravity, who did not know there was a duality to solve.
- The four motions have several sources: Robert de Hilster for gravitic and luminic motion, Dinu for magnetic, and David for electric, and the two of them for the step to one particle.
- The story says how the model was found, not whether it is true. That is settled by what is in the room.

Chapter 3

A Description Is Not a Model

STANDING: FRAMING. *An argument about what a physical model has to supply. It makes no mechanism claim of its own.*

Chapter 1 answered the lamp question. Before going on to gravity, magnetism and electricity, it is worth stopping to ask why that answer had to be written at all—why a question a child can ask has no standard reply.

Put the same question to a physicist and you will be told that the lamp emitted photons, that a photon is a quantum of the electromagnetic field, and that the field has a value at every point in space. Every one of those statements is standard. Not one of them names a material.

This is not an oversight, and the people giving the answer are not being evasive. They are reporting the state of the subject. Somewhere along the way physics stopped requiring that its objects be made of anything, and the requirement was not abandoned in an argument that someone won. It was quietly dropped, because the mathematics kept working without it.

3.1 The Distinction This Book Turns On

> **Mathematics is a description of how to predict. It is not a physical model.**

A physical model says what exists and how it moves. Mathematics then describes what follows from that. The two are not rivals and the order is not optional: when you have only the mathematics, you have a precise description of something you have not identified.

Because this is the point most easily misread, let us be blunt about what is not being claimed.

We are not against equations. We are against an equation standing in for a thing nobody will name.

The equations of physics are among the most successful things human beings have ever made. Nothing in this book asks you to discard a single measurement, and nothing in it would survive contact with reality if the arithmetic stopped working. Ohm's law is as good tomorrow as it was yesterday. So is Maxwell's set, so is Newton's, so is Coulomb's.

The complaint is narrower, and it is about order. Physics learned to predict so well that it stopped noticing it had never said what it was predicting *about*—and then, over time, began treating the question as naive. A student who asks what a field is made of is told that the question is not well-posed. That is a remarkable thing to say to someone asking what the world contains.

3.2 An Equation Taken to Its Limit

The clearest case of a description with nothing behind it comes from a colleague of the authors, Dr. Bill Lucas. In his paper "The Universal Electrodynamic Force" he set out to write one force law that covers every electrical, magnetic and gravitational interaction, and the result is a single long expression of terms in velocity, acceleration and distance. It is a remarkable piece of fitting. Ask what any term in it is *made of*, and the equation has nothing to say. That is not a criticism of Lucas; it is what happens when description is pushed as far as it will go. The better the equation, the more completely it can stand in for a picture that was never drawn.

3.3 What a Physical Model Owes You

If a description is not a model, it is fair to ask what a model has to deliver. Four things, and they can all be checked by a reader with no mathematics at all.

It says what the thing is made of. Not what it does, not what it is equivalent to, not what it can be treated as. A name for a substance, or an admission that there isn't one yet.

It says how that stuff moves. A picture of the mechanism, in which things are in places and go somewhere, and the motion accounts for the effect.

It does not invent a new entity for each new phenomenon. Every time a model meets something it cannot handle and answers by adding a fresh object—a new force, a new field, a new carrier—it is admitting its vocabulary was incomplete. A model with one kind of thing and a few ways

for it to move is making a far riskier claim than one that can mint a new particle whenever it is cornered.

It can be killed. It has to say what would count against it. A picture that accommodates any result is not a model of anything.

Those are the standards this book is asking to be held to. They are also the standards by which the next few pages find the standard account wanting—so it is only fair to say in advance that the four motions fail the fourth test in places, and the chapters ahead mark every one of them.

3.4 Four Ways of Not Answering

The pattern repeats across three centuries, and it is worth seeing it four times because the repetition is the argument.

Gravity. Newton gave the world an equation that will place a spacecraft within a few metres after a journey of a billion kilometres. Asked what gravity physically *is*, he declined—famously, and in print. *Hypotheses non fingo*: I feign no hypotheses. He could measure the attraction and predict the planets, but the mechanism by which one body reaches across empty space to pull another was something he would not claim to know.

That is an honest refusal, and it is worth noticing what it is not. Newton did not say the question was meaningless. He said he could not answer it, and left it for posterity. Posterity's reply, three centuries later, was to describe gravity as the curvature of spacetime—which tells you what the geometry does without saying what is bending, or what it is made of, or how a region of nothing acquires a shape.

The field. A field is defined as a quantity having a value at every point of space. Read that again as a claim about what exists. It is a definition of a bookkeeping scheme: here is a rule for assigning numbers to places. Ask what is *at* the place and you are given the number again. The field is one of the most useful constructions in science and nobody will tell you what it is made of, because within the formalism there is nothing to tell.

The photon. A single, partless, sizeless object, which nonetheless carries a frequency—a property that everywhere else in nature belongs to a repeating series rather than to an individual. This one is so sharp that it gets a chapter of its own.

The wavefunction. It predicts spectra to a dozen decimal places, and it is the most accurate instrument of prediction ever built. Ask what it is made of and the discipline splits into interpretations—many worlds, pilot waves, collapse, consistent histories—which is exactly what a field does when it has a superb description and no model. Interpretations are what you argue about when the mathematics is settled and the ontology never was.

3.5 The Moment of the Choice

The clearest case is also the most celebrated, and it is usually told the wrong way round.

In 1861 James Clerk Maxwell published *On Physical Lines of Force*, and it is exactly what the title says. He built a machine. Space was filled with rotating vortex cells, and between them ran small particles acting like the idle wheels in a gear train—the vortices standing for magnetism, the little particles for electric current. He drew it; the plate is in the paper. From that machinery he obtained the displacement current, and out of the constants fell the speed of light.

So it is simply not true that physics never tried to say what the stuff was. The most capable physicist of the century tried, and he tried with gears.

But he never said what the vortices were made of. Not their substance, not their size, not their mass, not where they came from or what held them in place. And he said so himself, in the paper:

> *I do not bring it forward as a mode of connexion existing in nature...*

Within four years he had dropped the machinery and kept the equations, and physics has kept them ever since.

That is the moment, and it is the whole thesis in one episode. A mechanism without a substance is not a physical model; it is a diagram of a relationship. Maxwell knew the difference, which is why he let the gears go.

So the charge in this book is not the easy one, and it survives the counter-examples:

> Even when physics tried, it never said what the stuff was.

3.6 Earning the Equation

It would be a poor argument if it stopped at complaint, so here is the positive half, and it is the relationship with mathematics that the rest of this book tries to have.

Take the oldest equation in the subject: the inverse square. In Newton's hands it is assumed—observed in the data, written down, and used. It works, and nothing in the theory says why the exponent is two rather than some other number.

Now put it in a model where gravity is a rain of particles arriving from every direction, and where two bodies are pushed together because each blocks part of the rain falling on the other. How much of the rain does a body block? Exactly the share of the sky it covers from where the other

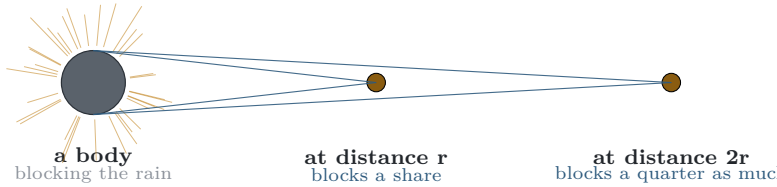


Figure 3.1: The share of the rain a body blocks is the share of the sky it covers. Double the distance and that share falls to a quarter, which is an inverse square arrived at rather than assumed.

body is standing. Move twice as far away and it covers a quarter as much sky.

The exponent is two because space has three dimensions and a shadow spreads. The equation falls out of the picture without being put in by hand.

That is what earning an equation looks like, and it is the test the four motions are trying to meet everywhere: first say what is physically there and how it moves, then let the mathematics describe what follows. Done in that order the equations are consequences. Done in the other order they are assumptions wearing the costume of explanations.

3.7 The Model Predicting the Mathematics

A reader who has followed the complaint this far is owed the obvious retort. Fine: the mainstream has the mathematics and no model. You have a model and no mathematics. That is not obviously the better half of the bargain.

So it matters that the shadowing picture has now been carried all the way through to the equations, and it is worth listing what came out, because the list is the argument.

The inverse square itself is exact. Not asymptotic, not a far-field approximation, not a leading term with corrections—the integral over the blocked cone equals $\pi R^2/d^2$ identically, for every separation from touching to arbitrarily far apart. Most equations in physics are limits of something. This one is not.

Newton's third law comes out rather than going in. The force expression is symmetric under exchanging the two bodies, because the body that casts the shadow and the body that catches it swap roles and the product is unchanged. The equality of action and reaction is a property of the formula, not a principle laid alongside it.

Newton's law of gravitation appears in full, in the limit where matter is nearly transparent to the sea—the product of the masses, strict attraction, superposition, the shell theorem, and the interior solution rising linearly from zero at the centre of a uniform sphere. And G stops being a brute constant: it comes apart into a solid angle, a property of matter, and a

property of empty space. Even the universality of G becomes a derived fact, true only because matter happens to be optically thin; make matter appreciably opaque and G would differ from one pair of bodies to the next.

Coulomb's law then needs no derivation at all. Nothing in the shadowing argument mentions a scale—no planet's size, no body's mass, not even the particles' speed—so the same result holds at every level that has a sea and bodies to block it. Electricity is that result read one level down. The two great force laws of physics are one equation instantiated twice, which is the question Chapter 22 says physics has shrugged at for two centuries.

Charge quantisation arrives as a theorem. If charge is a blocking area and blocking areas simply add, then a body built from N identical constituents has exactly N times the charge, for the same reason that a stack of N identical filters blocks N times as much light. In standard physics the exactness of charge quantisation is an unexplained empirical fact. Here there is nothing left to explain.

And the 4π in Coulomb's constant, which textbooks describe as an artefact of choosing rationalised units, turns out to be the solid angle of a sphere—the same 4π that appears in G, present in both for the same physical reason.

3.8 The Test a Description Cannot Take

One more result belongs here, and it is the one we would point to if allowed only one.

The same derivation has two branches, depending on whether bodies stop all of the sea crossing them or only a little. Follow the first branch—total blocking—and it predicts that Newton's constant should not be constant at all, but should fall as the two bodies get denser or larger. Calibrate it on the Earth and the Moon, then apply it to the Earth and the Sun, and to the Sun and Jupiter, and it returns three different values of G spanning a factor of 446.

Three centuries of celestial mechanics kill it. No laboratory, no new measurement, nothing but bodies whose masses and orbits have been known since before anyone thought of this.

That is the point of the whole chapter in one result. The model was pushed into mathematics, the mathematics produced a number, and the number destroyed one of the model's own branches. A description cannot do that, because it was fitted to the measurements in the first place and has nothing to say about cases it was not fitted to. Only a claim about what is physically there can be caught out by arithmetic it never anticipated.

The surviving branch—matter nearly transparent, the sea flooding straight through every body—is the one that reproduces Newton exactly. It was not chosen because it was prettier. The other one was eliminated.

3.9 This Was Tried Before

Honesty requires an immediate footnote to that argument, because the idea is not ours and it has a bad reputation.

Nicolas Fatio de Duillier put a version of it to Newton himself in the 1690s, and Georges-Louis Le Sage formulated it in 1748: gravity as a push from a rain of tiny bodies, with shadowing doing the work of attraction. Newton knew about it. So did most of the eighteenth century. It was not ignored—it was considered, and rejected, for two reasons that sound fatal.

Drag. If space is full of particles streaming in every direction, the planets are moving through a hail of them, and they should slow down. The Earth has been going round for a long time and shows no sign of it.

Heat. Every particle that strikes a body deposits something. A world under constant bombardment from all sides should be glowing hot, and it is not.

Both objections are correct, and both assume something the objectors had no reason to question: that the particles are slow and heavy enough for their impacts to register. The version in this book is not that version. These particles move at the speed of light and are unimaginably small—small enough to pass through the Earth in enormous numbers without being stopped, which is the only way the model works in the first place. The drag and the heating fall away with the mass.

That is not a refutation of the objection; it is a statement of where the argument now sits, and the burden is ours. Chapter 5 takes up the calculation: how the drag works out, what it would take for it to cancel, and what is still unfinished.

What should be said plainly is that the idea was dismissed under assumptions that are not the ones being made here, and a discarded idea that was discarded for the wrong reason is worth another look.

3.10 Three Objections Worth Taking Seriously

A reader who knows some physics will have three replies ready, and the argument is better for meeting them now.

"Mathematics is not merely descriptive—it constrains." True, and it does not rescue the position. A conservation law rules out whole classes of behaviour without saying what is behaving. Dimensional analysis will tell you an equation is wrong without telling you what the quantities are made of. A constraint on a description is still a constraint on a description. It narrows the space of possible accounts; it does not supply one.

"Your model will need mathematics too." It will, and that is the order, not a contradiction. The moment the four motions want to predict

the 0.7 volts across a diode, or the spacings in the hydrogen spectrum, they will need numbers, and at present they do not have them. This book is a physical account that owes a quantitative one. Saying so is not a weakness in the argument; pretending the equations are optional would be.

"Asking what is really there is metaphysics, not physics." This is the serious objection, and the answer is historical. The question was ordinary physics until it became inconvenient. Newton asked it and admitted he could not answer. Faraday asked it constantly. Maxwell asked it in 1861 and drew a machine. Nobody ever published the argument that it should not be asked. The question was abandoned, not refuted—and a question that has been abandoned can be picked up again.

3.11 Why It Is Worth the Trouble

There is a practical reason to want a model and not only a description, and it is not philosophical tidiness.

A description tells you what happens where you have measured. A model tells you what is happening everywhere else, including in places you have not looked—and that is where predictions come from. If light is a procession of particles, then something is physically arriving at every point the procession reaches, whether or not anything there registers it. That is a claim with consequences, and some of them are uncomfortable: later in this book it leads to the proposal that the dark bands in an interference pattern are still being struck by particles, which would be a strange thing to find and a telling thing not to find.

A description has nothing to say about that question. It was built from the places where measurements were taken, and it is silent about the rest by construction.

This is also why a model can be wrong in a way a description cannot. Ask a formalism what a field is made of and it does not answer. Ask this model and it answers, and if the answer turns out to be false, that part is rebuilt. That exposure is not a weakness of the approach. It is the whole of what makes it worth doing.

3.12 What Follows

The rest of this book answers the lamp question three more times—for gravity, for magnetism, and for electricity—with one kind of particle and four ways for it to move. In each case you will be able to say what is in the room.

Where the model cannot yet say something, it says so in the chapter where the gap matters, in a box like the one below, rather than gathered into an appendix where nobody reads it. There are a number of them. We

would rather you saw every one, because a model that cannot be shown where it is weak cannot be tested.

A note on what this book does not claim

Nothing here is offered as finished. The four universal motions are a proposal about what exists, argued from mechanism, and several of the arguments in this book have joints we can point to and have not closed—the configuration of the G2 fields chief among them.

The quantitative account described above has been begun rather than finished. Gravitic motion has been carried through to the equations; the other three motions have not, and magnetic motion in particular still owes a demonstration that its two rules, one for attraction and one for repulsion, give forces of matching size. The results listed above should be read as a demonstration that the programme can be carried out, not as the programme. A model that cannot be shown where it is weak cannot be tested, and a model that cannot be tested is not worth your time.

What you can now say

- A description tells you what happens where it has been measured; a model says what is there. Mathematics is the first, and physics gradually stopped requiring the second.
- Newton, the field, the photon and the wavefunction are four places where an excellent description stands in for an object nobody names.
- Maxwell built a machine of vortices and idle wheels, said he did not claim it existed in nature, and let the gears go. The question was abandoned, not answered.
- An equation can be earned: the inverse square falls out of a rain of particles, where it is only assumed in Newton's hands.

Chapter 4

One Particle, Four Motions

STANDING: FRAMING. *The definitions the rest of the book is built from, and the statement that the four motions are a physical Turing machine.*

Chapter 1 said that light is particles travelling in groups. That raises an obvious question, and a much larger one standing behind it.

The obvious question is: what are the particles? The larger one is why a book about light should turn, three chapters later, into a book about gravity and magnetism and electricity as well.

This chapter answers both, and the answer is the entire model. Everything after this is application.

> *There is one kind of particle. There are four things it can be doing. That is all there is.*

4.1 The Fingerprint

Start with the fact that makes the whole thing possible, and notice that it is a measurement rather than an argument.

A change in a magnetic field propagates at the speed of light. An electrical signal travels along a wire at close to it. Light, of course, travels at the speed of light. And in 2017 a burst of gravitational waves from two colliding neutron stars arrived at Earth within two seconds of the light from the same event, after a journey of 130 million years—which pins the speed of a gravitational disturbance to the speed of light to about one part in 10^{15}.

Be exact about what that last measurement does and does not say. It establishes that a *disturbance* in gravity travels at the speed of light. It is not a direct measurement of the Newtonian attraction propagating, which

is a harder thing to observe and remains inferred rather than clocked. We rest the argument on the disturbance, because that is what has actually been measured.

So: four phenomena, one speed. Not close to one another—the same, to the limit of our instruments.

Now a careful person is left with exactly two conclusions and no third.

The first: there are four different things, with four different natures, and some further law has been arranged on top of them so that all four travel at precisely one speed. A conspiracy of equality—four travellers, four kinds, and an extra rule imposed to keep them in step.

The second: there are not four travellers. There is one. It always moves at one speed because it is one kind of thing, and one kind of thing has one nature.

The first conclusion requires five things to explain one fact. The second requires one thing, and the fact explains itself. Newton would not have hesitated, and said as much about this kind of reasoning three centuries before anyone could measure the speeds: nature is sparing, and does not multiply causes without need.

> A speed is a property of the traveller. If the speed is identical, the traveller is identical.

That is the fingerprint, and it is the single strongest argument in this book. It is also the reason the four motions exist at all. Robert and David de Hilster did not set out to rebuild physics; they set out to give light a physical description, and then noticed that whatever they had built would have to be doing the other three jobs as well.

4.2 The Particle

We call it the G1 particle. The name is a label, not a theory—G for gravity, 1 for the level we live on.

What can be said about it is short, and the shortness is the point. It is a body. It has mass. It moves at the speed of light. It is very small, small enough that enormous numbers of them pass through solid matter without being stopped. It carries no charge, because there is no charge in this model anywhere.

What cannot yet be said is also short, and more important. We cannot give you its size, or its mass, or its internal structure. Those are numbers the model owes and does not have.

Notice what is *not* in that description: anything about gravity, or light, or magnetism, or electricity. The particle has no properties corresponding to the four phenomena, because the phenomena are not properties of the particle. They are things it is doing.

4.3 Four Things It Can Be Doing

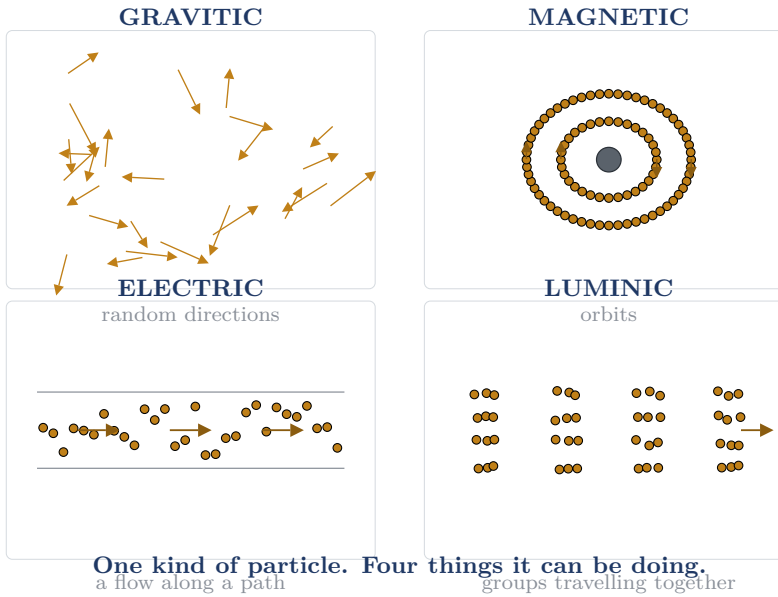


Figure 4.1: The same particle in all four panels. What differs is not the thing but the pattern it is moving in.

Gravitic motion is random. Particles travelling in straight lines in every direction at once, with no organisation at all. This is the raw material, and it is what we experience as gravity.

Magnetic motion is orbits. Particles going round, caught in closed paths rather than flying straight. Where you find circulation, you find what we call a magnetic field.

Electric motion is flow. Particles moving in a directed stream along a path, not circling a centre and not scattering at random. In a wire that is a current.

Luminic motion is groups travelling together. Particles in formation, rank behind rank, all going the same way at the same speed. That is light, and it is where Chapter 1 began.

Every one of those has something familiar attached to it. The random rain is what holds you in your chair. The orbits are what you feel when two magnets refuse to meet. The flow is what crosses the room when you flip a switch. The formation is what you are using to read this page. Four everyday facts, four patterns, one kind of particle doing all of it.

Notice where this list of motions comes from. Textbooks classify motion as linear, circular, rotational, periodic, random, harmonic, and so on, and those categories come from how engineers describe the motions of machines.

They are empirical headings, useful and man-made. The four motions here were not chosen from a catalogue. Each one was read off a fundamental force in nature: scatter from gravity, orbit from magnetism, flow from electricity, formation from light. None of them is a machine's motion.

The cleanest statement of this is Newton's, in a dialogue elsewhere on our website in which we put the model to him and he lost patience with our phrasing:

> *One actor. Four dances. The particle is the noun; the motion is the verb.*

That is very little. Four phenomena that every textbook treats as separate subjects, with separate laws, separate units and separate chapters, become four adverbs. Not four substances. Four ways of going.

4.4 How It Was Arrived At

The model was not deduced from first principles, and it is more honest to say how it happened. Chapter 2 tells the story.

Magnetism came first, and not from either author: Ionel Dinu's cylinders in water, in 2006. Light came next, from Robert de Hilster in May 2015. The electric motion followed from David de Hilster. And then came the realisation that turned separate ideas into one model. All of these phenomena travel at the same speed—and gravity does too. If the speeds are the same, the travellers are the same, and what had looked like four descriptions of four things was one description of one thing, doing different jobs.

> It sounded crazy at first. But after working with one particle and its four movements, it works surprisingly well.

That is the authors' own summary, and we have not improved on it.

4.5 Why Gravity Comes First

The four are not equal partners, and one of them is the parent of the other three.

Gravitic motion—the random rain—is the simplest. It is the least organised thing particles can do: no pattern, no direction, no coordination. And it is the foundation, because the other three are what random motion *becomes* when it meets structure.

Let a crowd of randomly moving particles encounter an array of massive bodies, and some of them will be bent into closed paths: that is magnetism. Let the bodies line up to form channels, and the random motion becomes a directed stream: that is electricity. Let a body release a crowd it has been holding, all at once and all in step, and you have formation: that is light.

> Order does not come down from above and impose itself on chaos. Order is what chaos does when it meets structure.

That is an unusual shape for a physical theory, and it is worth noticing. The least organised motion in the model is the organising one.

4.6 The Level Below

But what does the bending? A moving particle does not curve by itself, and saying "the atoms bend it" only names where the bending happens, not what performs it.

The answer requires one more idea, and it is the idea that turns a model of light into a model of everything.

Look at the two most famous equations in physics side by side. Newton's law of gravitation: two masses multiplied, divided by the square of the distance. Coulomb's law for the electric force: two charges multiplied, divided by the square of the distance. The same form. The same shape. Different constants and different quantities on top, but the identical structure underneath.

When two laws wear the same face, there are two possibilities. Either it is a coincidence, or the thing is the same thing. Physics has treated it as a coincidence for two centuries. We do not believe it for a moment.

> Coulomb's law has the form of a gravitational law because it *is* a gravitational law, operating one level down.

Below the G1 particles there are smaller and faster ones, which we call G2 particles. Their random motion is a second gravity—a finer rain, at a smaller scale—and it is what Coulomb measured and called the electric force. That finer rain is what bends G1 particles into orbits, channels and formations. The nuclei of atoms decide *where* the bending happens, by blocking the G2 rain; the rain itself is what does the pushing.

So the engine of the whole model is a single sentence:

> Every level is organised by the gravity of the level below it.

4.7 No Partless Parts

If there is a level below ours, the obvious question is whether it stops.

Here we take an idea from Glenn Borchardt, whose Infinite Universe Theory supplies the architecture this model sits inside: *there are no partless parts.* Nothing is fundamental. There is no final indivisible brick. Every particle, however small, is built of smaller ones, without end.

So a G1 is made of G2 particles, and a G2 is made of G3 particles, and it never bottoms out. And if that is true downward it is true upward too: our level sits inside a larger one, which sits inside a larger one, for ever.

One point here reads like a contradiction and is not, so it is worth settling now. A G1 particle is *made of* G2 particles. The space between G1 particles is also *filled with free* G2 particles, and that rain is the second gravity. Both at once.

That is not strange. It is the arrangement we already live in. A rock is made of atoms; the space between rocks is filled with the free G1 particles whose random motion we call gravity. One level down, the same picture with smaller pieces. The pattern repeats because the model says it repeats, which is the whole content of an infinite universe.

4.8 Isn't That an Aether?

A reader who knows the history will have been waiting to ask this since the second page, and the short answer is no.

An aether is a *medium*: a continuous substance filling space, which waves travel through by disturbing it. Every medium we know of is held together by something—the atmosphere by gravity, a solid by the bonds between its atoms—and nobody has ever been able to say what holds an aether together in open space, which is why it would disperse.

This model has no medium in it anywhere. It has bodies, moving through empty space, colliding. That is a different kind of claim, and it is open to a different set of objections. A later chapter makes that argument properly, including where it puts us at odds with Borchardt, whose architecture we otherwise take whole.

4.9 What Becomes One Thing

Total up what this buys. The list is longer than it looks, and every item on it is a thing that physics currently treats as separate.

Wave and particle stop being in tension. The particles are real, the wave is real, and the wave is the formation the particles are in. There was never a contradiction to resolve—only an assumption to drop.

Coulomb's law and Newton's become one law. Not analogous, not formally similar: the same mechanism at two scales, which is why the equations have the same shape.

Charge stops being a property and becomes a count. How many particles a body is holding, relative to the number it settles at. Nothing is less than nothing.

Current and magnetic field stop being two things that mysteriously accompany each other. Drive particles along a wire and some are

guided inside while others spiral around the outside; the forward part is the current and the circling part is the field. One helical motion, named twice.

Inertial mass acquires a candidate cause. Newton named the resistance of matter to being accelerated and offered no reason for it. Here the rain is a candidate, because a body changing its motion meets the rain asymmetrically. Chapter 5 sets out what that would require, and why the same calculation decides whether the idea works or that part has to be rebuilt.

The levels stop being separate subjects. Atomic physics and gravitation become the same physics with different particles, which is a claim with teeth: anything true of one level ought to have an analogue on the next.

None of these is established by this chapter. Each is a chapter of its own further in, and several of them are still arguments rather than results. But they are all consequences of the same two sentences—one particle, four motions—and that is the economy the model is offering in exchange for being taken seriously.

4.10 What the Model Forbids Itself

A model is defined as much by what it refuses to do as by what it claims, and this one has tied its own hands in four ways. They are worth stating plainly, because every one of them is a place where a test could send us back to rebuild.

No new entity per phenomenon. If something cannot be built out of particles moving in these four ways, the answer is not to invent a fifth thing. There is no provision for it.

No charge. Not redefined, not reinterpreted—absent. Nothing in this book has a plus or minus built into it.

No action at a distance, and no pull. Only push, delivered by contact, with the appearance of attraction produced by shadowing.

No unexplained continuum. No fields as substances, no fabric of space, nothing that fills a volume without being made of countable things.

Those four restrictions are what make the model worth testing. A picture that can reach for a new ingredient whenever it meets trouble cannot be wrong about anything.

The authors' claim for this vocabulary is a large one, and we make it openly. A Turing machine has a tiny fixed set of operations whose combinations can express any computation. The four motions are the same kind of thing in matter: a small fixed set of ways for bodies to move, whose combinations should build every physical condition that can exist. We call the model a physical Turing machine and stand behind that. What has been shown is how far it reaches in the chapters of this book; what is claimed is that it reaches everywhere, and that the equations of mainstream

physics, which describe what these motions do, can in time be derived from it. Where it cannot yet explain something, the claim is that the G2 fields have not yet been found.

What we have not modelled

The argument from shared speed is the strongest thing here, and it is an inference rather than a proof: identical speeds are consistent with one particle and do not by themselves establish it. The particle's size and mass are not known. And the G2 fields that do all the organising in this chapter have no worked-out physical description—we can say what they do without yet being able to say how they are arranged, which has a chapter of its own later in the book.

What you can now say

- Gravity, magnetism, electricity and light all travel at one speed, so they are one particle: a G1, doing four different things.
- The four motions are random (gravitic), orbits (magnetic), flow (electric) and groups together (luminic). The particle is the noun and the motion is the verb.
- Every level is organised by the gravity of the level below it, and a G1 is made of G2 particles, without end.
- There is no medium, no charge, no pull and no new entity per phenomenon. The four motions are a physical Turing machine for matter.

Chapter 5

Gravity: Why Things Fall Together

STANDING: DERIVED. *The shadowing mechanism and the inverse square follow from the motions. The answer to Maxwell's heating objection and to the drag objection (the time-inside rule) is a proposal with its weak points named. The sea's required density, the drag on a planet and the push rule are open (Chapter 24).*

Drop something. It falls.

That is possibly the least surprising sentence in this book, and it hides the oldest unanswered question in physics. Not *how fast* it falls—that was settled with great precision three hundred years ago—but why it goes down at all. What reaches out from the Earth and takes hold of a dropped cup?

Newton gave the world an equation for it and declined to say. Einstein replaced the reaching-out with a curvature of spacetime, which relocates the question rather than answering it: a region of nothing acquires a shape, and nothing is said about what is bending. In both accounts something invisible, unnamed and unmade-of-anything is doing the work.

The four universal motions give a different answer, and the first thing to say about it is that it is not a refinement of the usual picture. It is a reversal.

> *Nothing pulls. There is no attraction anywhere in this book. There is only push.*

5.1 A Rain From Every Direction

Space is not empty. It is filled—saturated—with G1 particles moving in every direction at once, at enormous speed, in enormous numbers. A constant, disordered rain arriving from above, below, left, right, behind, all the time.

Take a single object sitting alone in that rain. It is being struck constantly, from all sides, and the impacts cancel. As much arrives from the left as from the right. The object feels nothing, which is exactly what an object alone in space does feel.

Now put a second object nearby, and the symmetry breaks.

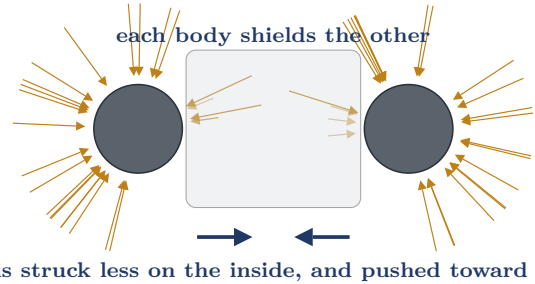


Figure 5.1: Nothing pulls. The rain arrives from every direction and cancels—except where something is in the way.

Each body blocks some of the rain that would otherwise have struck the other. Not all of it: most of the traffic goes straight through, because matter is almost entirely empty space at this scale. But some is stopped, and the side of each body that faces the other is therefore struck slightly *less* than the side facing away.

The far side is pushed harder than the near side. The net effect is a shove toward the other body.

That is gravity. The apple does not reach for the Earth and the Earth does not reach for the apple. The Earth stands between the apple and the rain coming up from below, and the rain from above drives the apple down.

5.2 What Makes a Field Gravitic

The word *gravitic* is used throughout this book for any rain of this kind, at any level, so it is worth saying exactly what such a rain is. The bodies that make it up:

- travel in straight lines;
- travel in random directions;
- are similar to one another in size and mass;
- have similar speeds;
- are very much faster than the bodies they act on;
- are very much smaller than the bodies they act on;

- can be any kind of moving body, because the rule is about the pattern and not the material; and
- occur at every level of the universe, large or small, each level with its own organising particle or body.

Two remarks on that list. First, the figure of "most of the traffic goes straight through" is not a convenience. An atom is almost entirely empty space, about 99.999 per cent by volume, so a rain of much smaller particles passes through matter with ease, and only the share that strikes is stopped. Second, gravitic motion is the foundation of the other three. Orbits, flows and formations all need something to curve and steer them, and in this model that is the random rain. The other three motions do not exist without it.

5.3 Why It Falls Off as It Does

Chapter 3 used this mechanism to make a point about mathematics, and the point is worth restating here as physics rather than method.

How much of the rain does a body block? Exactly the share of the sky it covers, seen from wherever the other body is standing. Move twice as far away and it covers a quarter as much sky. The shielding therefore falls off as the square of the distance—not because anyone put a square into the model, but because that is what a shadow does in a space with three dimensions.

The inverse square was the first thing physics discovered about gravity and the last thing it explained. Here it is the first thing that falls out.

5.4 Why It Goes With Mass

The other half of Newton's law is that the force goes with the mass of each body. In the standard account that is a brute fact: mass is what gravity acts on, and gravity is what acts on mass, and the circle closes without touching anything physical.

In this model mass is a count of how much is in the way. A body made of more matter has more in it to intercept the rain, so it shields more, so the imbalance it creates is larger.

But that proportionality has a limit, and the limit has to be stated rather than stepped around. If a body shields by blocking, then its outer layers shadow its inner ones. Pile up enough matter and the interior is already in shadow and contributes nothing further; the shielding stops scaling with mass and starts scaling with cross-section. Taken far enough, gravity would fall below Newton's prediction for the most massive objects.

So the model only reproduces Newton's law in one regime: where matter is nearly transparent to the rain, so that almost everything passes through

and almost nothing is doubly shadowed.

That sounds like a convenient assumption until you notice the model already requires it for an entirely separate reason. Gravity is feeble—the weakest force by an enormous margin—and the reason given later in this chapter is that almost all of the rain goes straight through. Those are the same requirement. The transparency that makes gravity weak is the transparency that keeps it proportional to mass.

That is a genuine piece of internal consistency, and it is also a place the model can be caught, because the two requirements have to be satisfied by one number: how opaque ordinary matter is to the G1 sea.

That number now has a name and a measured bound. It is the same quantity Quirino Majorana was hunting in 1919 when he weighed a lead sphere with mercury between it and the Earth—the gravitational shielding coefficient—and a century of experiments has pushed its upper limit down to about 5×10^{-24} square metres per kilogram, the tightest figure coming from lunar laser ranging. Work out where the Earth would cross over into self-shadowing and you get a value around 10^{-11}. Matter sits about twelve orders of magnitude inside the transparent regime, which is comfortably on the right side of the line.

So the transparency the model needs is not a hope. It is measured, and it is enormous. What it costs is taken up at the end of the chapter, because a sea that matter is nearly invisible to has to be correspondingly ferocious to push the planets around at all.

5.5 Maxwell's Objection, Which Is the Serious One

Chapter 3 introduced Fatio and Le Sage and noted that their version was dismissed over drag and heating. It is time to be more precise, because one of those two objections is far worse than the other, and it came from the man this book keeps returning to.

In an article on the atom written for the *Encyclopaedia Britannica* in 1875, James Clerk Maxwell examined the shadowing idea and did the arithmetic. If the particles bounce off perfectly elastically they carry their energy away and there is no net attraction. If they are to push bodies together they must lose energy to the bodies they strike, and then, he wrote, "if any appreciable fraction of this energy is communicated to the body in the form of heat, the amount of heat so generated would in a few seconds raise it, and in like manner the whole material universe, to a white heat."

That is not a hand-wave. It is a magnitude, calculated by somebody competent, and it is the reason the idea was abandoned rather than merely doubted. Poincaré restated the difficulty in 1908, in *Science et Méthode*, and it has stood since. Among those who still work on push gravity, heating

is generally regarded as the serious objection and drag the lesser one.

5.6 Why the Heating Looks Undodgeable

It would be convenient to answer Maxwell by saying the particles pass through almost everything and barely interact. That is what this book has said, and by itself it will not do, because of a structural point that took us some time to appreciate.

A shadow requires that something be taken out of the flux.

If every particle passed through a body unchanged, the body would cast no shadow and there would be no gravity. The shielding exists precisely to the extent that particles are stopped, absorbed, or have their momentum changed—and whatever is taken out of the flux carries energy, which has to go somewhere. It goes into the body.

So the strength of gravity and the rate of heating are not independent quantities that can be tuned separately. They are two consequences of the same interception. Make the particles interact less and gravity weakens in exact proportion. Make gravity strong enough to hold the Earth in orbit and you have specified how much energy is being deposited in the Earth.

That is Maxwell's objection in its sharpest form, and for most of the time we were writing this book we did not have an answer to it.

We now think the argument above has a hole in it, and that the hole is the word *absorbed*.

5.7 Deflection Casts a Shadow Too

Read the objection again and notice what it assumes. It assumes that the only way to remove a particle from the flux is to *stop* it, and that a stopped particle hands over everything it was carrying.

But a shadow does not require stopping. It requires only that the particle stop arriving *from that direction*. A particle elastically deflected off a heavy, bound scatterer is gone from the beam just as completely as one that was swallowed—the second body never receives it, the shadow is intact, the force is unchanged—and it leaves carrying almost all of its kinetic energy with it.

The asymmetry between the two transfers is the whole answer. A light particle of mass m bouncing off a target of mass M delivers momentum of order mc, but energy only of order m^2c^2/M. The momentum transfer is full strength; the energy transfer is suppressed by the mass ratio m/M. For a particle many levels below a nucleon that ratio is minute. So gravity and heating are *not* locked together after all: they are locked together only if a particle gives up everything on contact, and that assumption is not forced.

Notice how little that costs. It is not an extra mechanism bolted on to save the model; it is a correction to an assumption that was smuggled

in—that a particle which pushes a body must also give up everything it had. The force needs the push. It never needed the rest.

Deflection also turns out to be what the drag problem needs, later in this chapter, though for a different reason and by a different route. The two objections are not one objection, and we should not pretend otherwise. What they share is that both were answered by looking harder at what a particle does when it meets matter, rather than by adjusting how fast or how many.

There is a price even here, and it should be stated: deflected particles are not destroyed, they are redirected, and some of them are redirected back into the shadow they were supposed to leave empty. Any elastic version of the model has to show that the refilled fraction is small, or that the scattering throws particles preferentially forward. That has not been shown.

5.8 The Second Answer, From Inside the Model

The argument just given is one a mainstream physicist could follow and check, and it is deliberately framed that way. But the four universal motions have an answer of their own, and it rejects the question rather than satisfying it.

Maxwell framed the objection in terms of energy: the sea carries energy, the energy has to go somewhere, the only place is heat. In this model energy is a calculation—a quantity of bookkeeping—and not a thing that has to be deposited anywhere. What exists is particles moving, and colliding or not colliding. So the objection has to be put in those terms, and in those terms it comes apart in four places.

Heat is a frequency. Heat is not motion in general; it is a jiggling of matter, and jiggling needs a rhythmic, repeated push. Thermal radiation is light, and light here is groups of particles travelling together and arriving in regular succession. That regularity is the frequency, and the frequency is what matter registers as heat. It is why heat can be seen at all: an infrared camera reads a body's temperature directly off the frequencies it emits.

Gravitic motion supplies no frequency. G1 particles arrive singly, from random directions, with no relation between one arrival and the next. A sequence of isolated pushes at random times has no period, so it cannot set anything jiggling, however dense the sea. What it produces is an overall pressure—which is all gravity ever needed. And this matches what is actually observed: no body has ever been warmed by sitting in a gravitational field.

The sea has no container, so it has no temperature. The natural rejoinder is that random molecular impacts *do* warm things—a hot gas warms the wall of its container. But temperature in kinetic theory belongs to particles that are trapped, striking each other and the walls repeatedly

until they come into balance. A gas warming a wall is that balance being shared. The G1 sea is in no such state: it flies through unbounded space, passes through atoms with ease, almost never strikes matter and never strikes itself. It has no temperature at all, so there is nothing for it to share.

A single hit is too small to make an atom vibrate. A gas warms a wall because atoms strike atoms—projectile and target comparable in size and bound by the same forces. A G1 is a different kind of object entirely, many levels below the atom. The push it delivers is smaller than the smallest vibration the atoms of a body can take up, so the body cannot respond to it piece by piece; it responds as a whole. The struck nucleon is bound in a nucleus and the nucleus in the body, and the push is carried by the entire body moving together. A push taken up by the whole body is a drift, and drift is gravity. A push taken up by individual atoms is vibration, and vibration is heat. Laboratory physics knows the same split: in the Mössbauer effect a recoil too small to excite a crystal's vibrations is absorbed by the crystal as a whole, and the struck nucleus is left without any jiggle at all.

Taken together: rare uncorrelated pushes with no rhythm, from a sea with no temperature, each too small for any atom to take up, delivered by particles that leave again. There is no step at which heat could arise.

We set both out. The first is the answer in the language of the people who raised the objection. The second is the answer in ours, and it is the one the model stands on.

5.9 Why It Never Pushes Apart

Gravity has a peculiarity that is so familiar nobody asks about it: it only ever attracts. Magnetism does both. Electricity does both. Gravity has never once been observed to repel anything, and in the standard account that is simply how it is—mass comes in one sign, so the force comes in one direction.

Here there is a reason, and it falls straight out of the mechanism.

Shadowing can only ever *remove* impacts. A body can block some of the rain arriving at its neighbour; there is no way for it to add any. So the imbalance always runs the same way—less on the facing side, more on the far side—and the push is always inward. To get repulsion you would need a body that somehow increased the rain on the far side of its neighbour, and nothing in the model can do that.

One sign, for a structural reason. Not a brute fact about mass.

5.10 Why It Is So Weak

The other oddity about gravity is its feebleness. It is the weakest force in physics by an enormous margin—a child's magnet lifts a paperclip against the gravitational pull of the entire Earth. Physics records the ratio and does not explain it.

In this model the weakness is expected, because gravity is a *residual*.

Almost all of the rain goes straight through. Matter is overwhelmingly empty space at the scale of a G1, and the overwhelming majority of particles pass through a planet without touching anything. Gravity is produced only by the small fraction that does collide—and then only by the still smaller difference between what arrives on one side and what arrives on the other.

Everything else in this book is produced by particles that are organised: orbiting, flowing, in formation. Gravity is produced by the leftovers of the disorganised ones. It would be surprising if it were strong.

5.11 Why Things Orbit Instead of Falling In

A push-only model has one obvious-looking problem, and it is worth facing directly. If the Earth is being shoved toward the Sun, why has it not arrived?

The answer is the same as in the standard account, and it is not a dodge. A shove toward the Sun changes the Earth's direction without stopping it. The Earth is already travelling sideways at some speed, and the inward push bends that motion into a curve rather than arresting it. Keep bending a fast sideways motion toward a centre and you get an orbit, which is a continuous fall that keeps missing.

What is different here is that both halves of that sentence now have mechanisms. The inward push is shadowing. The persistence of the sideways motion needs no cause at all, as the next section argues: a body in motion goes on. Newton needed a force law and a law of inertia and offered a cause for neither. Here the push has a mechanism, and so has the resistance to being pushed.

5.12 Inertia: The Harder Half

Newton's first law says that a body in motion continues in motion unless acted on by a force, and it is often presented as the deep mystery—what keeps a thing going?

We think that is the wrong question, and that asking it has obscured a better one.

Persistence needs no cause. A body moving through a void continues because nothing is stopping it; the first law is close to a statement about what empty space means rather than a claim requiring a mechanism. Proposing

that the rain *propels* a moving body is both unnecessary and, as we shall see in a moment, dangerous.

The real puzzle is in the second law. Why does matter *resist* being accelerated? Why does a loaded trolley take more pushing than an empty one, and why in exact proportion to how much matter is in it? Newton gave that resistance a name—inertial mass—and no cause whatever. It has sat there, unexplained and unremarked, for three hundred years.

Here the rain is a candidate.

A body sitting still in the rain is struck equally from every side. A body *moving* is not: it meets more particles head-on than it does from behind, exactly as walking in still air produces a wind in your face. That asymmetry depends on how fast the body is going, and on how much of it there is to be struck.

Which gives the model one mechanism for two different things, and a very sharp requirement:

> If the asymmetry acts at constant velocity it is **drag**, and a planet would spiral in. If it acts against *changes* in velocity it is **inertia**, and the resistance is proportional to how much matter is there to be struck. The model needs the first to be negligible and the second to be substantial.

If that requirement comes out wrong in either direction the model is in trouble. Too much asymmetry and the Earth's orbit decays. Too little and inertia has no cause here after all, and we have gained nothing over Newton.

The drag half of it has now been computed, and the answer is worth following because it starts out catastrophic.

Work the anisotropy through for a body moving at speed u through a sea moving at v, and the retarding force comes out proportional to u/v and to the body's blocking area. Divide by the gravitational force and the body's own properties cancel, leaving a pure ratio. For the Earth, with the sea at the speed of light, that ratio is 9.4×10^{11}. Because the drag is proportional both to the mass and to the speed, the implied stopping time is the same for every object at every speed: about five millionths of a second. The model in that form does not merely lose the Earth's orbit over an aeon. It forbids a thrown ball.

This is the objection that drove Laplace to demand very large particle speeds, and Poincaré to demand more than $10^{18}c$, and no choice of sea intensity, opacity or speed escapes it—the ratio above has all three cancelled out of it.

The escape is not a faster sea. It is how often a particle gets deflected at all. Let the chance of a G1 interacting with matter depend on the relative speed w as w^{-p}. The number of deflections a body suffers per second from a given direction then goes as $w\,\sigma(w)$, which is w^{1-p}, and the leading drag coefficient comes out proportional to $1 - p$. At $p = 1$ it vanishes—and not

merely to leading order. At exactly $p = 1$ the product is the same in every direction, so the body takes the same number of pushes per second from ahead as from astern, each the same size and each along its own particle's line. They cancel exactly, at every speed.

Gravity is untouched by this, because the shadow is an anisotropy in *space* rather than in the body's motion: a body at rest meets the same relative speed from every direction, so the shadowing derivation goes through unchanged. Only the response to the body's own motion is cancelled.

5.13 The Time Inside

And here is the part that makes this something other than a lucky number.

$p = 1$ is not chosen to make the problem go away. It is what you get by asking the obvious physical question: what decides whether a passing G1 is deflected by a nucleon at all? It is how long the two are in contact. For an interaction this weak, the chance of being deflected is simply proportional to the time spent inside the target—and that time is inversely proportional to how fast the particle is closing. So the chance goes as $1/w$, and nothing has been fitted.

Now put that together with the asymmetry. A moving body does meet more particles ahead of it than behind. But the ones ahead are closing faster, so each of them spends proportionally less time inside the matter it crosses, and is proportionally less likely to be deflected at all. More arrivals, each less likely to do anything. The two effects are the same factor, and they cancel.

Physics already knows this behaviour under another name. Slow neutrons are captured by nuclei with a probability that goes as $1/v$—the "$1/v$ law", one of the first things anyone learns about neutron capture—and for exactly the reason given above: the slower the neutron, the longer it loiters near the nucleus, and the likelier it is to be taken. We are not proposing a new kind of interaction. We are proposing that G1 particles meet matter the way slow neutrons meet nuclei, and that the drag cancellation follows from the clock rather than from a coincidence.

We think that is a far better position to be in than the one we started from, because it is a position that can be settled. It names a number, and the number decides.

5.14 What the Simulations Actually Show

None of this would be worth much if the story were all there was, and two simulations on our website bear on it. Both are the authors' own, and it is worth being precise about what each one demonstrates, because it is easy to credit them with more than they deliver.

The first contains 3,500 particles moving in random directions and two larger bodies. Half the particles pass through the bodies and half collide. There is no force law anywhere in the program—no attraction term, no inverse square. There are particles, bodies, and collisions. The two bodies move toward each other and accelerate as they close.

That is the real result, and it is a good one: **shadowing alone produces attraction-like behaviour**, from nothing but random motion and contact.

The second takes a single body, gives it one shove, and then leaves it alone with the random particles. It keeps moving, at a steady velocity, with no apparent slowdown.

It is tempting to read that as the rain sustaining the motion. It is not. A body with no drag would do exactly the same thing in an empty vacuum with no rain at all. What the second simulation demonstrates is a **null result on drag**—under these conditions, the bombardment does not noticeably retard a moving body.

That is genuinely valuable, because drag is the objection that has sunk every previous version of this idea. But it is evidence of an absence, not a demonstration of a cause, and the distinction matters enough to be worth the paragraph.

5.15 Two Gravities

One extension, which Chapter 4 introduced and which the rest of the book leans on constantly.

Everything above describes the rain of G1 particles, which organises matter at our scale—apples, moons, stars. Inside the atom there is a second rain, made of much smaller and much faster G2 particles, doing the same job one level down. That finer rain is what holds an atom's particles in their orbits, and it is what Coulomb measured and called the electric force.

The mechanism is identical: shadowing, pushing, shielding. Only the scale changes. This is why Coulomb's law and Newton's law have the same form, and it is the single most economical claim in the model—one trick, used twice, because the universe has more than one level and the same thing happens at each.

5.16 What Stays

Nothing in the arithmetic changes. Newton's equation is as accurate tomorrow as it was yesterday; it is simply no longer the end of the conversation.

What we have not modelled

The open problems here are numbers rather than worries.

The drag cancellation fails for a body that shields its own interior, and the failure is large. *The time-inside rule cancels the drag exactly for a single nucleon, and therefore for any thin layer of matter. A planet is not a thin layer. A particle deflected in the Earth's outer kilometres no longer reaches its inner ones along the line it was travelling, so a body's blocking area is not simply proportional to how much matter is in it—it is the saturating function set out earlier in this chapter. The cancellation is exact only in the part of that function which is linear. The next term survives.*

Worked through, the surviving drag on the Earth—three eighths of the optical depth, as a fraction of the uncancelled drag—comes to about an eighth of the Sun's pull on it. Planetary ephemerides bound any such anomalous tangential acceleration at around a part in 10^{12}*. Taken as stated, the mechanism would stop the Earth's orbital motion within a few years, so the place to look is the self-shielding of a large body. The same self-shielding affects any other choice of exponent too.*

And no measurement can make it smaller. *It would be convenient if a better figure for matter's opacity relieved this, since that is the quantity everything else in this chapter turns on. It does not. The surviving drag is the optical depth multiplied by the drag-to-gravity ratio, and the first rises with opacity while the second falls with it, in exact proportion. The opacity cancels out of the product completely. What is left depends only on the Earth's density and radius, its orbital speed and distance from the Sun, and the Sun's mass— quantities known to several figures, none of them adjustable. The number cannot be argued down. It will be closed by finding a mistake in the calculation, or by a mechanism that restores the cancellation through a body that shields itself, or not at all.*

And underneath it sits a larger assumption, which is where we now think the real question is. *We checked the calculation above independently rather than taking it on trust, and it holds—the surviving term is exactly three eighths of the optical depth, confirmed to six figures. But the check turned up something the arithmetic alone does not show.*

Everything above depends on a claim made earlier in this chapter almost in passing: that each deflected particle delivers a push of a fixed size, along the direction it was already travelling, and that the body's own motion changes neither*. Call it the* push rule*. It is a real assumption and it is doing most of the work.*

Consider what ordinary scattering would give instead. In the frame of the moving body, a particle arrives carrying momentum set by their relative *velocity, and if it bounces away in a random direction the body keeps that relative momentum. But relative momentum always has a component pointing backwards along the body's motion—it is why a car gets wet on the front in vertical rain. So every deflection would retard the body a little, whether or not the arrivals are anisotropic, and the time-inside rule would not touch it, because the time-inside rule balances* how many *particles arrive from each side and says nothing about what each one carries.*

That drag is not a small correction. It works out at three times the full uncancelled drag—about 10^{12} *times the Sun's pull on the Earth, against the eighth of it the self-shielding term gives. It appears at first order in the opacity where self-shielding appears at second.*

So the honest ordering is this. If the push really is fixed in size and direction

regardless of the body's motion, then the drag very nearly cancels and what survives is the self-shielding eighth. If instead the push is the relative momentum, as it would be for anything scattering off a moving target in the ordinary way, the cancellation never happens at all and no exponent can rescue it. The whole escape rests on that one point, and it has not been established here. We would rather a reader went after it than after the three eighths.

The sea has to be far denser than nuclear matter. *Transparency and strength pull against each other: the more invisible matter is to the sea, the more intense the sea must be to produce the gravity we measure. The required intensity goes as the inverse square of the opacity, so every tightening of the shielding bound makes this worse not in proportion but as the square—and the bound has been tightened. The current lunar-ranging limit puts the floor at roughly* 3×10^{37} *joules per cubic metre: about a thousand times the energy density of nuclear matter, in every cubic centimetre of what looks like empty space. Chapter 24 sets out how that figure was arrived at and why it grew by three orders of magnitude while this book was being written. It is the largest number here, and the one most in need of working out.*

The simple version is dead, and it was killed by the solar system. *If bodies stopped every particle crossing them, Newton's constant would not be constant, and Chapter 3 gives the factor-of-446 result that refutes it. The surviving reading—nearly transparent matter—reproduces Newton's law exactly, with G coming apart into a solid angle, a property of matter, and a property of the vacuum.*

Elastic deflection partly refills the shadow, *as set out earlier in this chapter, and neither remedy has been shown.*

There is a preferred frame. *The sea is isotropic in exactly one frame, and the drag calculation makes that frame detectable in principle. The model is not Lorentz invariant, and says so. What follows from that—an absolute rest frame, and gravitational effects whose simultaneity depends on the observer—has not been worked out.*

And one prediction, which is the other side of the same coin. *The residual opacity means a body's interior is slightly shadowed by its own outer layers, so its gravitational mass falls short of its inertial mass by an amount that depends on its size and density rather than on its mass alone. That is a violation of the equivalence principle, and the model puts numbers on it: roughly* 9×10^{-13} *for the Moon,* 5×10^{-12} *for the Earth,* 2×10^{-10} *for the Sun. Those sit close to the sensitivity of current lunar-ranging and Eötvös experiments. A detection at that level would be a measurement of the opacity, and through it the first direct measurement of the G1 sea. A confident null result at an order of magnitude better would tell us the opacity is smaller than assumed, and send us back to the self-shielding.*

What you can now say

- Gravity is a push, not a pull: two bodies each shadow the other from a

random rain, and are driven together.

- The inverse square is the share of the sky a body covers, and it is arrived at, not assumed.
- Gravity only attracts because a shadow can only remove, and it is weak because most of the rain goes straight through.
- Maxwell's heat objection and the drag objection have answers inside the model, and the work still open on them is named.

Chapter 6

The Impossible Photon

STANDING: DERIVED. *A frequency needs a repeating series, so a single point cannot have one. The rest follows from light being a procession.*

A bus passes your house at eight in the morning. Just once. It rolls by, turns the corner, and is gone.

What is its frequency?

The question has no answer, and not because the measurement is difficult. Frequency means *how often*—how many times something happens in a stretch of time. One bus, passing one time, has no how-often. It just went by. To ask about its frequency you would need a second bus, and a third, and a rhythm between them: one every ten minutes, six an hour. Frequency lives in the spacing between repeated things. Take away the repetition and the frequency does not become hard to measure. It stops existing.

Hold on to that bus, because it dismantles one of the strangest claims in modern physics.

6.1 The Claim That Does Not Survive the Question

Physics says light is made of photons: individual, indivisible particles. And in the same breath it says each photon has a frequency. A red photon has a lower one, a violet photon a higher one, and the energy of the photon is calculated directly from it.

Now put those two statements side by side and ask the bus question.

If a photon is a single particle—one thing—what is doing the repeating?

A lone particle, like a lone bus, has no how-often. So when physics attaches a frequency to a single photon, it is attaching a property of repetition to a thing which, by its own definition, never repeats. It is describing the spacing of a series while insisting there is only one member in it.

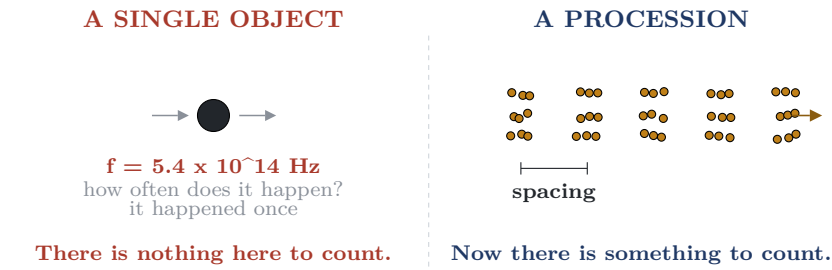


Figure 6.1: Frequency is a property of a series. It has nowhere to live on a thing that never repeats.

This is not a subtlety or a matter of interpretation. It is an incoherence sitting inside the foundational object of quantum optics, in the same way that a one-bus timetable is incoherent. One of anything cannot carry a frequency, because frequency is the name we give to the rhythm between things.

Physics has lived with it for over a century by not looking directly at it. The mathematics works beautifully—every angle, every energy, every spectral line. But the physical claim underneath was never coherent, and no amount of predictive success makes it so.

6.2 Why Physics Needed the Photon

It would be cheap to leave it there, as though the photon were a careless invention. It was not. It was forced on physics by experiments that nothing else could explain, and any account that wants to remove it has to say what happens to that evidence.

In 1900 Max Planck found he could only reproduce the spectrum of a hot body by assuming energy was emitted in discrete lumps rather than continuously. He regarded it as a mathematical trick and disliked it.

In 1905 Albert Einstein took the lumps seriously and applied them to the photoelectric effect—light falling on a metal and knocking particles out of it. The experimental facts were bizarre. Below a certain frequency of light, *nothing* comes out, no matter how bright the light is. Above it, things come out immediately even if the light is very dim. And the energy of what comes out depends on the frequency of the light, not on its brightness.

A continuous wave cannot do that. A dim wave should take time to accumulate enough energy, and a bright enough red light should eventually do what a faint blue one does. Neither happens. Einstein's explanation was that light arrives in packets, each carrying an energy fixed by its frequency: one packet, one interaction, and a packet too small does nothing however many of them arrive.

Robert Millikan spent a decade trying to disprove that equation and confirmed it instead. Arthur Compton showed in 1923 that the packets carry momentum too. The photon was not adopted casually. It was the only thing that fitted.

6.3 What the Evidence Actually Shows

Here is where the argument turns, and it turns on a distinction that is easy to miss.

Every one of those experiments demonstrates that light is **absorbed** in discrete amounts. Not one of them demonstrates that light **travels** as discrete objects.

Planck's lumps were about what a hot body could emit. Einstein's were about what an electron could take up. Millikan measured the energies of what came out. Compton measured a transfer. In every case the discreteness was observed at the moment something interacted with matter—at an emitter or at an absorber.

What happened in between was never observed, because it cannot be. You find out about light by letting it hit something.

So there are two ways to account for the lumpiness, and physics has only seriously pursued one of them.

> *Either the traveller is lumpy, or the receiver only accepts in lumps.*

The standard account chose the first. The four universal motions choose the second—and Chapter 1 has already said why: an atom takes up a formation or it does not, in the same way and for the same reason that it can only sit in one arrangement or another. The quantisation is a fact about absorbers, not about what crosses the room.

6.4 The Photoelectric Effect, Without Packets

Take the hardest case and work it through.

Light of the wrong colour falls on a metal, and however bright it is, nothing comes out. In the standard picture that is because each packet is too small, and a thousand small packets cannot combine.

In this picture, what arrives is a procession with a particular spacing between its groups. Whether an atom in the metal can take it up depends on whether that formation matches an arrangement the atom can hold—the same selectivity that makes a sodium lamp orange, makes a leaf green, and puts dark lines in the spectrum of a star. Light of the wrong spacing is not

too feeble to be absorbed. It is the wrong shape, and a great deal of the wrong shape is still the wrong shape.

Turn the brightness up and you send more processions of the same spacing. Nothing changes, which is exactly what is observed.

Change the colour and you change the spacing. Now the formation matches, and the atom takes it up—immediately, because the arriving groups do not have to accumulate. The particle that leaves carries off what was taken, and how much that is depends on the formation absorbed rather than on how many processions arrived. Which is to say: on frequency, not on intensity.

Both strange facts fall out, and nothing had to be indivisible.

What does not fall out is a number. This account says why brightness fails and why colour succeeds; it does not tell you the threshold frequency for caesium. The number depends on which arrangements a metal's atoms can hold, which is the work of the G2 fields, and it will come from there.

6.5 The Catastrophe That Started It

Planck's problem deserves more than the sentence it got above, because it is where the quantum entered physics and because the four universal motions have to account for it too.

Heat a body and it glows. Classical physics, applied honestly, predicted that a hot body should radiate more and more strongly at shorter and shorter wavelengths, without limit—so that every warm object in the universe should be pouring out ultraviolet and worse. It was called the ultraviolet catastrophe, and it is not a small discrepancy. It is an infinity where the measurement gives a modest number.

Planck removed it by allowing energy to be emitted only in whole lumps, with bigger lumps required at shorter wavelengths. Since a body at a given temperature can rarely muster a big one, the short-wavelength end is suppressed, and the predicted curve comes down to meet the measured one.

Notice where Planck put the restriction. Not on light—on *emission.* His lumps were about what a hot body is able to give off.

That is exactly the shape of the answer in this model, and for a reason already in place. An atom holds a population of G1 particles and can sit in one stable arrangement or another; what it sheds, going from one to the next, is a definite quantity. A large release packs the departing groups tightly—short spacing, blue and beyond. A small one spreads them out. At a given temperature most atoms have only a modest surplus to shed, so most of what leaves is widely spaced, and tightly spaced light is rare. The curve falls off at the short end because atoms are not often carrying enough to produce it.

No restriction had to be placed on light at all. The restriction is on what an atom can hold and therefore on what it can let go of, which is where

Planck found it in the first place, and where it has been quietly relocated ever since.

6.6 What Becomes of $E = hf$

The most famous equation in this corner of physics says the energy of a photon is its frequency multiplied by a constant. If there is no photon, what is the equation describing?

Something fairly simple, in this picture. Frequency is the spacing between groups, and spacing is set by how much the atom released: a bigger release packs the ranks more tightly. So tight spacing and large release are two descriptions of the same event, and $E = hf$ is the statement that they track each other.

What arrives at an absorber is a quantity of particles, and more of them—more tightly packed—does more when taken up. The energy is a count.

Planck's constant is then the conversion between the two ways of counting: how much release corresponds to how much packing. It should be derivable from the structure of atoms and the geometry of a departing formation.

We cannot derive it. That is a debt, and a large one, and it is recorded at the end of this chapter with the others.

6.7 Newton Reached for Size, and Missed

The photon is not the first attempt to put colour inside a single object, and the earlier one failed in a way worth seeing.

Newton held that light was corpuscular—little bodies streaming from luminous sources in straight lines—and on that much his instinct ran the same way as this book. But he had to say what made one colour differ from another, and the only property he had given his corpuscles was size. Red was large and slow, violet small and fast, and a prism sorted them by how much each size was bent.

It does not work, and the reason it does not work is the bus again. If colour were size, a single corpuscle would carry its colour on its own, and we are back to one bus with a timetable. Worse, size explains nothing: there is no reason a slightly larger particle should look *red* rather than loud, or heavy, or sharp. A diameter was swapped for a colour and the swap was called an explanation.

Newton's scheme ran into trouble on other grounds too—to make refraction come out he needed light to travel faster in glass than in air, which turned out to be false—but the colour-by-size idea was hollow from the beginning.

He had the right raw material and the wrong property. He looked for

colour inside one thing, when colour was never going to live inside a single thing at all.

6.8 Where a Frequency Can Live

Everything above is the negative half. The positive half is one sentence, and the next chapter spends a chapter on it:

> Light is many particles travelling together, and the frequency is the spacing between the groups.

Now there is something to count. The groups arrive one after another, and the rhythm of their arrival is a real quantity with real units, belonging to the procession rather than to any member of it. The particles can be identical. None of them is red or violet. What differs between colours is how closely packed the ranks are.

Give this model a single particle and it makes no claim of frequency at all—correctly, because one particle has none. Give it a stream and the frequency appears, for the only reason frequency ever appears anywhere: because something is happening repeatedly, with spacing in between.

6.9 What Is Left of the Photon

Not nothing. The word still names something real; it just does not name a particle.

What a detector registers as "a photon" is the smallest bundle of G1 particles it is able to take up—a quantity set by the instrument's threshold and by what its atoms can hold. That bundle is real, it is countable, and it is why single-photon experiments see discrete clicks.

The error was never in counting the clicks. It was in concluding that something indivisible had crossed the room to make each one.

That conclusion gets its hardest test in the double-slit experiment, where the clicks arrive one at a time and nevertheless build up a pattern that seems to require each one to have gone two ways at once. It is the strongest argument for the photon that exists, and this book takes it seriously enough to give it a chapter of its own, later, after the atom has been dealt with.

What we have not modelled

The account of the photoelectric effect above is qualitative. It says why brightness does not help and why colour does, and it does not predict the threshold frequency for a given metal, or the slope relating frequency to the energy of what comes out. That slope is Planck's constant, and deriving it from a count of particles and the geometry of their arrival is one of the largest debts in this book.

Compton scattering is not addressed here at all. Momentum transfer between light and matter ought to be straightforward for a model made of moving bodies, and we have not worked it through.

What you can now say

- A single particle cannot have a frequency, because frequency belongs to a series, so a photon as one indivisible thing is not coherent.
- Every experiment that led to the photon showed that light is absorbed in lumps, not that it travels in lumps.
- The photoelectric effect follows from spacing: the wrong spacing is the wrong shape for the atom, however bright.
- What a detector calls a photon is the smallest bundle of G1 it can take up.

Chapter 7

Light: A Procession, Not a Point

STANDING: DERIVED. *Light as a procession of groups, and what the prism does to it, follow from the luminic motion.*

The last chapter took something away. This one puts something in its place, and the replacement has to do everything the photon did and more, because a model that only demolishes is not worth anyone's time.

7.1 What a Luminic Wave Is

luminic motion—the third of the four motions—is groups of particles travelling together. Set out properly, a luminic wave has seven characteristics, and it is worth having them in one place because the rest of the chapter uses all of them.

- It consists of **groups** of particles, not single particles.
- The groups are **regularly spaced** along the line of travel.
- The particles are **similar** in size and mass—they are all G1 particles.
- They share an **overall speed**.
- They are **far smaller** than the bodies they affect.
- The pattern occurs at **every level** of the universe, not only ours.
- And it **carries information** across distance, which is the whole reason anybody cares.

Nothing in that list is unusual except the first, and the first is what changes everything. Once the wave belongs to the group rather than the member, there is no longer anything a single particle is being asked to do that a single particle cannot do.

7.2 White Light, and Newton's Second Experiment

Everybody knows Newton split sunlight with a prism in 1666 and found the colours hiding inside the white. Rather fewer remember what he did next, and the second experiment is the more important one.

He took the spread of colours and passed it through a second prism, which recombined it back into white light.

That is a decisive result, and it rules out an entire class of explanations. Whatever a prism does, it does not *make* the colours. If it made them, a second prism would make more of them, not undo the first. The colours must have been present in the white light all along, and the prism must be sorting something that was already there.

So in this model, white light is not a special kind of light. It is a jumble: processions at every spacing at once, travelling together with no order among them. Tightly spaced ranks, widely spaced ranks, everything between, arriving mixed. That mixture is what the eye reports as no colour at all.

The picture of white light has its own small history, and it is worth keeping. Robert de Hilster was the first to try it, drawing separate red, green and blue lines to stand for the waves that together make white. David de Hilster turned those lines into trains of particles with different wavelengths, colour-coded so that he and his father could tell them apart. The colour then came off. What was left was a mixture of processions at every spacing, with nothing to tell them apart but the spacing itself, and when David de Hilster showed his father that drawing, Robert de Hilster said: "That's it!" The two had struggled for some time to agree on a model of white light, and this was the one they both accepted.

The same is true of the luminic wave itself. It began as a single drawing by Robert de Hilster in May 2015, followed by David de Hilster's first attempt to draw a sine wave out of groups of particles; then more realistic versions, generated with scripts so that no two particles are alike; and, most recently, an animation of luminic waves in three dimensions. None of these is a proof. Each is a way of looking at the same claim.

7.3 The Clue Nobody Uses

Now the question conventional optics records and does not explain.

A triangular prism throws a rainbow. A flat pane of window glass, made of exactly the same material, does not—and neither does a rectangular block. Put the block in the beam and white light goes in and white light comes out.

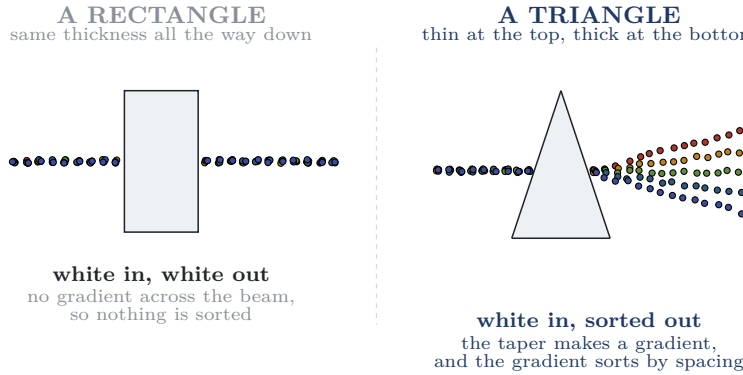


Figure 7.1: The same glass in both cases. What differs is not the material but the shape, and therefore the gradient the light passes through.

That is a very large clue and it is normally passed over as a geometric accident—a matter of parallel faces and cancelling refractions. But notice what it tells you. The sorting is not a property of glass. It is a property of *glass arranged in a particular way*, and the way in question is a taper: thin at one end, thick at the other.

Mass distribution sorts light. That is the fact to be explained, and a model which has nothing physical in the glass has no way to begin.

7.4 How a Gradient Sorts

In the four universal motions, a body with mass is surrounded by G2 gravitic motion, and a body whose mass *varies across space* is surrounded by a gradient in it.

A rectangular block has no taper. The same thickness of glass sits above the top of the beam as below the bottom of it, so whatever field it has is the same across the beam's whole width. Nothing is sorted because nothing differs.

A wedge is not like that. It is thin at one end and thick at the other, so the G2 field is weaker where the glass is thin and stronger where it is thick, and the beam crosses a gradient as it passes through.

A gradient deflects. And—this is the part that does the work—it deflects a procession by an amount that depends on the spacing of its groups. Tightly spaced ranks are turned through one angle, widely spaced ranks through another, and what entered as a jumble leaves as an ordered fan: red at one

edge, violet at the other, the rest in between.

Newton had the structure of this explanation three hundred years ago. A mixture goes in, the medium sorts it, an ordered spectrum comes out. What he lacked was anything in the glass to do the sorting with, so he reached for the only property his corpuscles had—size—and Chapter 6 described how that failed. He did not need a different shape of answer. He needed a gravity inside the glass, and there was no such idea available to him.

A rainbow is a sorting, not a painting. The prism is a sieve, not a dye works.

7.5 The Rainbow Is the Same Event

A rainbow is this, at enormous scale and with the prisms supplied by the weather.

Sunlight meets countless water droplets. Each droplet is a small body of mass—and crucially, a *curved* one, so the thickness of water along a light path varies continuously from the middle of the droplet to its edge. That is a taper, and therefore a gradient, and therefore a sorting. Every droplet does what the wedge does, and the geometry of a sphere sends the sorted light back at a characteristic angle, which is why the bow is an arc and why it sits where it does relative to the sun behind you.

Nothing abstract anywhere in it. Real particles, sorted by a real field with a real gradient, arriving in an order you can see.

7.6 Straight Lines and Sharp Shadows

One more thing light does, which the wave tradition always found awkward and which costs this model nothing at all.

Light travels in straight lines, and objects cast shadows with edges. That was Newton's strongest argument for corpuscles: waves spread around obstacles, and light mostly does not. A procession of particles travelling in straight lines through empty space does exactly what is observed, for the plainest possible reason—nothing is acting on it, so it does not turn.

The qualification is in the word "mostly". Light does bend very slightly around edges, and that small spreading is real, and it is the subject of a later chapter, where it turns out to be the same gradient mechanism as the prism, acting at the sharp boundary of an obstacle instead of across a wedge.

7.7 Bouncing

Reflection is the easiest thing light does and the easiest thing for this model to say.

A procession meets a surface. Some of its particles are taken up by atoms that can hold them—that is absorption, and it is why surfaces have colours. The rest are turned back. A polished surface is one whose atoms are arranged regularly enough that the turned-back particles keep their formation, so what leaves is still a procession and still carries the picture: a mirror. A rough surface scatters the formation in all directions, so what leaves carries brightness but no image: a wall.

The difference between a mirror and a wall is not a different physics. It is the difference between a formation that survives the bounce and one that does not.

7.8 Bending, and the Trap Newton Fell Into

Refraction is harder, and this is the place to be careful rather than confident.

Light entering glass bends toward the perpendicular, and it also travels more slowly inside the glass than outside it. Both are measured facts, and the second one killed Newton's version of a particle theory. His corpuscles bent toward the normal because the glass attracted them—which means the component of their motion into the glass had to *increase*, which means light should travel faster in glass than in air. Foucault measured it in 1850 and found the opposite.

Now notice the uncomfortable thing. This model also has glass attracting light. Glass is mass, mass shadows the G2 rain, and G1 particles are pushed toward it. Applied naively at a flat surface, that is Newton's argument with new vocabulary, and it inherits Newton's problem.

We do not think the naive version is right, and we are not going to pretend we have the replacement. Something has to account for light moving more slowly through a medium while still being turned toward it, and the obvious candidate is that the slowing is not a change in the speed of the particles at all but a consequence of their being repeatedly captured and released by the atoms they pass—so that the procession's *progress* is delayed while each particle still moves at the only speed a G1 has. That is a familiar idea in conventional optics too, and in this model it has the merit of requiring no new entity.

It is a sketch. It is not worked out, and until the G2 fields are, refraction is a place where the model has work to do.

7.9 Why a Laser Is Easy Here

The positive half ends with something the model gets cheaply that other pictures find awkward.

A laser produces light that is coherent: all one colour, all in step, staying in a tight beam over enormous distances. Explaining that in terms of a

disturbance travelling through a medium takes some doing—what kind of medium produces such precise, non-spreading behaviour?

In a formation model there is nothing to explain. Coherent light is processions whose groups are in lockstep: same spacing, same direction, released together rather than at random. An ordinary lamp emits from billions of atoms shedding independently, so the formations leave jumbled. A laser is an arrangement that makes a great many atoms release in unison.

The difference between a lamp and a laser is the difference between a crowd and a parade, and that is the whole of it.

7.10 What This Chapter Owes

Three debts, and the first is the one a physicist will raise immediately.

Polarisation. Light can be polarised: passed through one filter and then blocked by a second at right angles to the first. A wave with a direction of oscillation handles that neatly, and it is the single best argument the wave picture has. A procession of particles has to say what is being oriented. The obvious candidate is the rank itself—a group of particles lying in a plane has an orientation, and a filter might pass ranks aligned one way and stop those aligned another. That is a plausible answer and we want to be clear that it is nothing more: it has not been worked out, tested, or made to produce a number.

The speed. Why light travels at the speed it does is not answered here. In this model that speed is a property of the G1 particle, which is to say the question becomes "why do G1 particles move at that speed", and we cannot answer that either.

The angles. The gradient account says a wedge sorts by spacing. It does not yet say by how much. That number depends on the G2 field of the glass, and waits with the rest.

What we have not modelled

One point of internal housekeeping, since this book means to be visible about such things. Our own earlier writing on dispersion offered two different mechanisms in the same piece: in one, the prism sorts spacings that were already present; in the other, the gradient squeezes the groups closer together and thereby produces *the colours.*

Those cannot both be right, and Newton's second experiment settles it. If a prism manufactured colour by compressing spacings, a second prism would compress them further rather than restoring white. Recombination works, so the prism sorts. This chapter commits to the sorting account, and the squeezing account should be treated as withdrawn.

Refraction is the serious gap. *As set out above, the naive version of our own mechanism reproduces Newton's error and predicts light travelling faster in glass, which is false. The capture-and-release sketch offered instead is a sketch.*

Until it is worked through, refraction waits on the G2 fields with the rest.

Beyond that: the debts above are all quantitative, and they wait on the same thing—a worked physical description of the G2 field, which is the subject of its own chapter later on.

What you can now say

- A luminic wave is groups of G1 travelling together, and the wave belongs to the group, not to any one particle.
- White light is a mixture of spacings, and a prism sorts it. Newton's second experiment shows that it sorts and does not make colour.
- A triangular prism sorts and a rectangular block does not because mass distribution sorts light, and a rainbow is the same event.
- Light travels in straight lines, a mirror keeps the formation, a wall does not, and a laser is a parade where a lamp is a crowd.

Chapter 8

Magnetism: Particles in Orbit

STANDING: DERIVED. *A magnetic field is circulating G1s and nothing else. How strong a given magnet is, and why iron differs, are not modelled.*

Hold two magnets near each other and you can feel something through the gap. Turn one around and the something reverses. Children find this uncanny and they are right to: it is the most obviously physical action-at-a-distance most people ever handle, and the standard account of it names a field and stops.

Newton worked on magnetism and got nowhere. He said so. Gravity only ever attracts; magnetism does both, and it has poles, and the poles cannot be separated. He set it aside as one of his few open defeats.

8.1 Magnetism Is Orbits

The second of the four universal motions is magnetic motion, and it is the simplest of the four to state.

A magnetic field is G1 particles caught in orbits.

The same particles as gravity and light. No new substance, no new entity. Gravity is those particles moving at random; magnetism is those particles going round.

Set out properly, the bodies in a magnetic motion:

- travel in **orbits**;
- are guided by a gravitic field around a central body or bodies;
- cause **attraction** when two opposite magnetic motions approach each other;

- cause **repulsion** when two like magnetic motions approach each other;
- are similar in size and mass;
- can vary in speed with the shape of the orbit; and
- occur at every level of the universe.

Any orbiting body in a gravitic field is, in this sense, a magnetic motion, and that is why it is the *second gravity* of a pair: the orbit is made by the random rain, and the orbit in turn gives rise to a field of its own.

This is not our idea. It comes from Ionel Dinu, who in 2006 ran experiments with rotating cylinders in water, in his daughter's swimming pool, and argued that magnetic behaviour is what circulation does. It arrived with experimental backing before the framework existed to hold it, and it is the only one of the four motions that came to this work from outside it.

What makes them go round is the level below. A line or lattice of nuclei lays down channels—gravity tubes—and the G2 rain pushes passing G1 particles along them, exactly as described in Chapter 5. The nuclei are the sources; the finer rain does the work. Around a bar magnet those channels carry the orbits well outside the metal, which is why you can feel the thing through the air.

8.2 What Dinu Actually Did

Because this is the one motion that came from outside, it is worth saying what the evidence looks like.

Dinu's apparatus is water and cylinders. Set a cylinder spinning in the water and it drags the water around with it, producing a circulation—a real one, visible, made of something you can put your hand in. Then introduce a second spinning cylinder nearby and watch what the two do to each other.

They attract and repel, and which one they do depends on their relative directions of spin, in exactly the pattern two magnets follow. Nothing in the water has a pole, a charge, or a field in the textbook sense. There is water, and there is circulation, and the behaviour falls out.

Dinu did not stop at the first pool. His second experiment was in a larger one, and there the effect was larger and clearer. That is what you would expect if the behaviour belongs to the circulation itself and not to the walls of the first pool.

That is not a proof that magnetism *is* circulation. Analogies are not arguments, and water is not G1 particles. What it does establish is that the characteristic behaviour of magnets—two-way force, dependence on relative orientation, no isolated poles—is what circulating media do generally, and does not require a special substance to produce it. Given the choice between

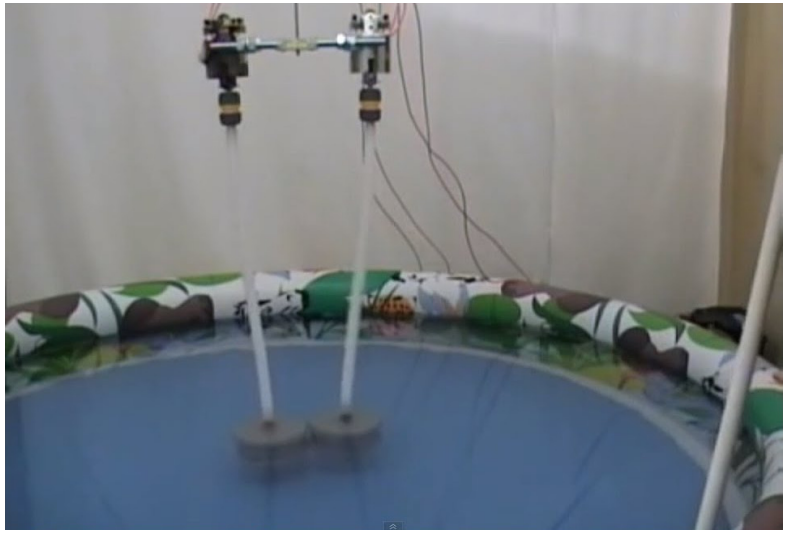


Figure 8.1: Dinu's first experiment: two cylinders rotating in water in a small pool. Still from Ionel Dinu, *Experiments with Cylinders Rotating in Water*. Used with permission.

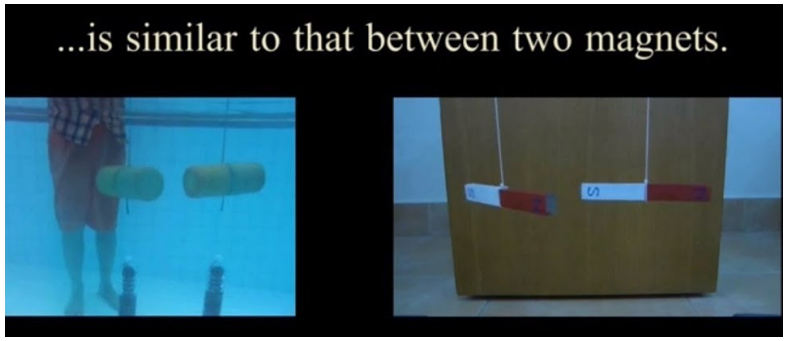


Figure 8.2: In the larger pool, the force between two rotating cylinders (left) is compared with the force between two magnets (right). Still from Ionel Dinu, *Unravelling the Nature of the Magnetic Field*. Used with permission.

inventing a new kind of field and pointing at something fluids already do, we take the second.

8.3 Why Poles Cannot Be Cut Apart

Here is the model's cleanest win, and it concerns a fact every schoolchild is told and nobody explains.

Cut a bar magnet in half and you do not get a north pole in one hand and a south pole in the other. You get two smaller magnets, each with both. Cut again and the same thing happens. Physics has searched for an isolated magnetic pole—a monopole—for nearly a century, with real effort and real money, and has never found one. Its absence is recorded as a deep fact about nature and left there.

In this model there is nothing to find.

A pole is not an object. It is a *direction of circulation*—one way round is one pole, the other way round is the other. Asking for a magnetic monopole is asking for a whirlpool with only one sense of spin, or a wheel that turns clockwise at one end and not at all at the other. The question is malformed, so the search was always going to come back empty.

Cut the magnet and each piece still contains circulating particles, and circulation still has two senses. Of course you get two magnets.

That is a genuine prediction, and an unusually strong one: this model says the monopole search cannot succeed. If a magnetic monopole is ever found, this account of magnetism has to be rebuilt.

8.4 The Rule for Two Circulations

Two magnets brought together attract or repel depending on which way round they are. In the standard account this is read off the poles and justified by the field equations. Here it is a statement about traffic.

Take two circulations side by side and look at the place where they meet.

If both turn the same way, then at the facing surfaces one is moving up while the other is moving down. The traffic opposes, the flows fight, and the two push apart.

If they turn opposite ways, the facing surfaces are moving in the same direction. The traffic runs together, the flows cooperate, and the two draw together.

Gears work on exactly this principle, which is why a gear train alternates direction down the line. It is also the reason the rule sounds reversed depending on how you state it, and that has caused enough confusion—including in our own diagrams—to be worth one sentence of warning:

> Same rotation means the traffic opposes, which is repulsion. Opposite rotation means the traffic runs together, which is

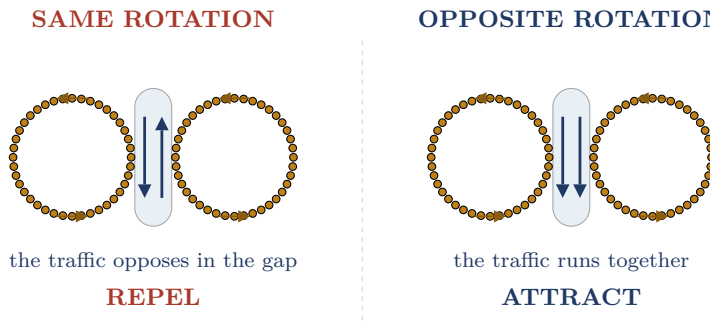


Figure 8.3: Rotation sense and gap traffic always read opposite to each other. Check one of them, never both.

attraction. Check the rotations or check the arrows in the gap, but never both, or you will invert the answer.

8.5 What the Traffic Actually Does

"The flows fight" and "the flows cooperate" are descriptions of an outcome, not mechanisms, and this book has spent too many pages objecting to that move to make it here. So here is what is physically happening in the gap.

The two cases are not one mechanism with a sign on it. They are two different things, and that turns out to be the point.

When the traffic runs together, the two swarms are drawn together by G2 gravitic motion. Two swarms of G1 particles moving the same way, side by side, are two populations of bodies sitting in the G2 sea—and every G1 blocks some of that sea. So each swarm shadows the other, and the two are pushed together by the G2 rain that is not blocked. It is precisely the mechanism of Chapter 5, one level down: shadowing, the same subtraction, the same inverse square.

And the atoms come with them. The G1 particles in question are not free—they are in orbit around their nucleons, bound to them. Pull on the swarm and the nucleons follow, because the swarm cannot go anywhere without dragging what it circles. The force arises between the circulating populations and is delivered to the whole system of G1 particles and nucleons together. That is how a force between two swarms of particles becomes a force between two lumps of iron.

When the traffic opposes, the swarms are heading at one another, and they veer. Two populations running into each other do not slide past quietly. The G1 particles are knocked off course by the encounter, and the deflection carries the rotating systems apart—again with the nucleons coming along, for the same reason.

Now notice what that resolves, because it is the difficulty Chapter 10

will meet.

Shadowing has one sign. It can only ever pull, because a shadow can only remove arrivals and never add them, and two shadows always add rather than cancelling. A model that tried to get both attraction and repulsion out of blocking alone was never going to succeed, and that is exactly the difficulty charge runs into. The resolution is that it does not have to. Attraction is shadowing. Repulsion is deflection. The sign is not carried by the G2 sea at all—it is carried by *which way the two swarms are running*, which selects between two different physical processes. A direction has a sign where a blocking area cannot.

This also settles which of the rule's two registers is the real one. The gap traffic is physical: it is what the G1 particles are actually doing where the two systems meet, and it is what the mechanism acts on. The rotation sense is bookkeeping derived from it—true, useful, and one step removed. If you are ever unsure, work from the traffic, because that is where the physics is.

One more warning, and it is sharper than it looks. This chapter described Dinu's cylinders in water, and in water the mechanism genuinely is fluid: the circulation is carried by a medium whose parts collide with one another, and the forces between the cylinders are pressure effects of exactly the Bernoulli kind. That is what makes the demonstration so persuasive, and it is *not* what is happening here. G1 particles do not collide with each other the way water molecules do; a sea whose particles scattered off one another could not cast the sharp, persistent shadows that gravity requires. The water tank was how the rule was found. It is not how the rule works. A reader who carries the fluid picture across from the tank will get the right answer for the wrong reason, and will be badly misled the moment the two accounts come apart.

8.6 Two Sizes of the Same Thing

The orbits come at two very different scales, and keeping them apart matters because they do different jobs.

The small ones belong to a single atom. Every atom holds a population of G1 particles in orbit around its nucleons. Where two atoms sit side by side, those two populations pass each other in the gap between them. Their rotations run opposite ways, so the traffic there runs together—and by the rule above, that is attraction. The atoms are held to one another.

That is **atomic polarity**, and it is what chemistry handles by giving atoms partial charges. No charge is needed here, and no additional loops are strung across the gap. There is nothing that would make them and nothing that requires them. The atoms are bonded by the orbits they already have.

The large ones belong to no single atom. They run right around whole groups of atoms in a lattice, thousands at a time, carrying well beyond

the metal. These are the ones we are used to: the arcs in the iron filings, the pull through a fridge door.

8.7 What Makes a Magnet a Magnet

Every piece of iron contains those large loops. What distinguishes a magnet is not that it has them but that they *agree*.

In an ordinary lump of iron the loops point every which way and their effects cancel, and you can carry it around without it sticking to anything. Magnetise the bar and you have not created anything or added anything. You have persuaded the loops to line up.

Which immediately explains two things that are otherwise just facts to memorise.

Heat a magnet and it loses its magnetism, because heat is disordered motion and disordered motion knocks the loops out of alignment. Hammer it and the same thing happens for the same reason. In both cases nothing has been destroyed—the circulation is still there, it has simply stopped agreeing with itself.

And it reframes why only some materials can be magnetised at all. It becomes a question of whether a lattice will hold an alignment once it has one, rather than whether a substance possesses some magnetic quality that iron has and copper lacks. Reframing is not yet explaining: what decides whether a given lattice holds its alignment is exactly the thing we cannot calculate, and it is listed at the end of the chapter.

8.8 The Earth Is One Too

A compass needle points north because the planet is a magnet, and the planet is a magnet for the same reason a bar of iron is: there are G1 particles in orbit around it, on a very large scale, running out of one polar region and back in at the other.

That is the picture every textbook draws—the dipole arcs looping from pole to pole—and in this model the arcs are traffic rather than geometry. The lines are where the particles are going.

It matters later in this book, because the same shape turns up at the other end of the scale. A later chapter will argue that every nucleon inside every atom carries its own field of exactly this kind, one level down, made of G2 particles instead of G1 particles—and that those fields are what shape the atomic orbitals. The Earth is the familiar example of a thing that recurs at every level, which is precisely what an infinite-levels model predicts should happen.

What sets the planetary circulation going, and what sustains it, we do not explain. Conventional geophysics has a dynamo in the molten core;

whatever drives it, this model has to end up with the same traffic.

8.9 A Current Is a Magnet Too

One more fact belongs here, although its full treatment is in Chapters 9 and 17.

Run a current through a wire and a magnetic field appears around it, circling the wire. Wind the wire into a coil and you have an electromagnet, which behaves exactly like a bar magnet and switches off when you stop the current. This is the deepest clue in the whole of electromagnetism, and the standard account records it as a law—Ampère's—without saying why a flow of charge should conjure a ring of magnetism out of empty space.

In this model it is nearly a tautology. Electricity is G1 particles flowing. Magnetism is G1 particles orbiting. A current in a wire has some of them doing both at once, which Chapter 9 shows in detail: the current does not cause a separate magnetic thing to appear.

That is why the two phenomena have never been separable, and why Maxwell had to write them as one set of equations. They were always one motion.

8.10 The Filings Are a Record

Scatter iron filings on paper over a magnet and they arrange themselves into arcs. Every textbook prints the picture and calls the arcs field lines.

They are not lines and they are not a cause. Each filing is a small magnet with its own orbiting population, and it turns to lie along the traffic going past it, for exactly the reason set out above. What you are looking at is a crowd of tiny compasses reporting the direction of something real that is flowing through that space.

Faraday, who invented the term, understood lines of force as a record of what was happening. The habit of treating them as the thing itself came later, and it is the same move this book keeps objecting to: a description promoted to an explanation because it worked well enough that nobody asked.

What we have not modelled

This chapter says what a magnetic field is made of and why two magnets do what they do. It does not produce a number anywhere.

No field strengths. *Nothing here predicts how strong a given magnet should be, how the force should fall off with distance, or why iron is so much more susceptible than nickel. The permeability of free space is not derived.*

The orbits are asserted, not shaped. *Saying that gravity tubes guide G1 particles into closed paths around a lattice is the right kind of statement, but*

nobody has shown that a real lattice produces real closed orbits of the right size. That is a simulation waiting to be run, and it could fail.

***Why alignment persists** is unexplained. We say a magnet is iron whose loops agree, and we do not say what holds the agreement in place against thermal jostling—which is the whole question of why permanent magnets are permanent.*

***Why head-on encounters deflect.** The mechanism above is in two halves and only one of them reduces to something already derived. Co-moving swarms drawn together by G2 shadowing is Chapter 5 read one level down, and that derivation exists. Swarms running at each other veering off course does not yet have the same standing. We can say that it happens and that it must, since without it the model has no repulsion at all—but not why a head-on encounter should deflect G1 particles while a side-by-side one lets them settle together. Both encounters are between the same particles through the same G2 sea. What differs is the geometry and the relative speed, and the model owes an account of how those select between the two outcomes.*

***And none of it is a number.** The division of labour—shadowing for attraction, deflection for repulsion—is the right shape, and it is the model's own structure rather than a patch. But the two have to come out* equal and opposite *in the right circumstances, since two magnets attract and repel with the same strength at the same distance. Two different mechanisms producing forces of matching size is a demand, not a result, and nobody has shown it. This is the sharpest well-posed problem in the book and also the most tractable, because it can be tested the way the shadowing was: put both rules in a simulation and see whether two rotating systems push apart as hard as they pull together.*

What you can now say

- A magnetic field is G1 caught in orbits, and nothing else.
- A pole is a direction of circulation, so a monopole is not a thing that can exist.
- Same rotation means the traffic opposes and repels; opposite rotation means it runs together and attracts. Check one, never both.
- A magnet is iron whose loops agree, a current is a magnet too, and iron filings are tiny compasses reporting real traffic.

Chapter 9

Electricity: A Pipe Already Full

Standing: Derived. *A wire is a pipe already full, and the lattice guides the traffic. How the G2 field steers the tubes is open.*

Flip a switch and the lamp across the room comes on at once. Not soon afterwards—at once, as far as anyone can tell without instruments.

Everyone knows something travels down the wire. Rather fewer have been told what, and the usual answer creates more trouble than it settles.

9.1 The Fourth Motion

electric motion is the last of the four, and the simplest to state after the other three.

> *Electric motion is G1 particles flowing along a path—not scattering at random, not circling a centre, but streaming in a direction.*

Random is gravity. Orbits are magnetism. Formation is light. A directed stream is electricity. Same particle, fourth pattern.

9.2 The Gas of Free Electrons

The picture the standard account gives of conduction is worth stating, because the model departs from it. In 1900 Paul Drude proposed that a metal is a lattice of fixed positive ions with a gas of free electrons moving between them—a classical gas, like air in a room, bouncing off the ions and drifting when a field is applied. It accounted for Ohm's law and for the relation between electrical and thermal conduction.

But it had an embarrassment, and the embarrassment is instructive. If a metal contains a gas of free electrons, that gas should store heat the way any gas does. Each particle should carry its share of thermal energy, and the metal's heat capacity should be substantially larger than the lattice alone would give.

It is not. The measured electronic contribution is smaller than the classical prediction by a factor of around a hundred, and it varies with temperature in a way the classical model does not produce. By about 1911 this was understood to be a straightforward failure, and it was not resolved until Sommerfeld replaced the classical gas with a quantum one obeying Fermi–Dirac statistics—at which point the heat capacity came out right and, as a bonus, the Wiedemann–Franz prediction improved.

So the standard account of conduction has a specific shape. The carriers behave like a gas when you ask them to carry current, and emphatically not like a gas when you ask them to hold heat, and the reconciliation is a quantum statistical rule about which states they are allowed to occupy.

9.3 A Suggestion About the Heat

The four universal motions have something to say here, and we offer it as a suggestion rather than a result.

In this model what occupies a wire is not a gas. A gas is a population in thermal equilibrium with its container, free to take up energy from it and give it back. What is in a wire is *traffic*: G1 particles moving through gravity tubes at close to the speed of light, guided by the lattice rather than bouncing around inside it.

Traffic of that kind would not store heat the way a gas does. The particles are not in thermal equilibrium with the metal—they are passing through it. What does store heat is the lattice itself, and whatever fraction of the G1 particles has been scattered out of the channels into disordered motion.

That is the right shape of answer to Drude's problem, arrived at without a quantum statistical rule. Whether it is the *correct* answer depends on a calculation nobody has done, and it is recorded at the end of this chapter as a debt rather than a triumph.

Set out properly, the bodies in an electric motion:

- travel in a path that is **not an orbit**;
- are guided by a line of bodies that form a gravitic tube;
- carry **no charge**;
- are similar to one another in size and mass;
- can share an overall speed;

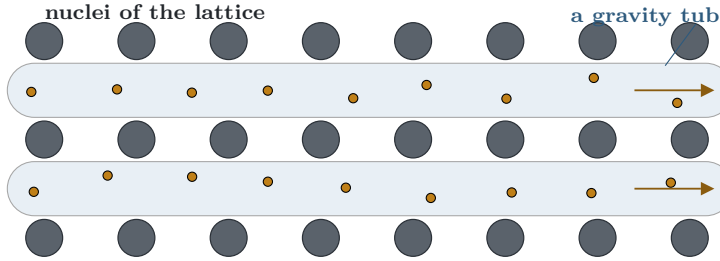
- are much smaller than the bodies that guide them; and
- occur at every level of the universe.

Copper is the familiar case, but the pattern is not special to wires. The same thing happens wherever bodies are guided along a structured path of larger ones: the molecules of the air can serve as the guide for lightning.

9.4 What Makes the Path

A river needs banks. If G1 particles were simply released into a wire they would scatter back into the random rain, so something must hold them to a course.

The atoms do it. In a metal the nuclei sit in a regular lattice—in copper, a face-centred cubic arrangement with atoms 2.556 Ångströms apart—and that grid of nuclei lays down channels running the length of the wire. Each nucleus shadows the G2 rain, and the combined effect is a set of corridors along which passing G1 particles are steered. We call them gravity tubes.



The nuclei lay the channels. The G2 rain they shadow steers the G1 particles along them.

Figure 9.1: The nuclei lay down channels, and passing G1 particles are steered along them. The tube belongs to the lattice.

The tube belongs to the lattice. The G2 field is the means by which the nuclei do the steering, not the tube itself—a distinction worth keeping, because the same words get used loosely and the two are not the same thing.

A conductor, then, is not a material with a special property called conductivity. It is a material whose atoms are arranged in a way that produces good channels. An insulator is one whose arrangement does not.

9.5 The Wire Was Never Empty

Here is the part that changes the picture most, and it is visible in the simulation of copper that has been running on our website for some time.

That simulation puts 1,200 real copper nuclei in their real lattice and treats each G1 as a body moving under gravity—pulled toward every nucleus by an inverse square, with no cutoff and no shortcut. Watch it with nothing injected and you do not see an empty wire. You see a bound cloud of G1 particles already drifting through the channels, threading between the atoms rather than orbiting any one of them.

> A wire is not a pipe waiting to be filled. It is a pipe that is already full.

So switching on a circuit does not supply the wire with anything. The particles are in there. What the source supplies is a *direction*—a reason for a population that was already drifting to drift one way instead of at random.

That single fact dissolves a good deal of confusion, and it is why the lamp lights immediately. Nothing has to travel from the switch to the lamp before the lamp can work. The lamp's own stretch of wire is already full, and it starts moving when the imbalance reaches it.

Put numbers on how strange the usual account is. Run ten amps through an ordinary copper wire and the drift velocity of the carriers comes out at about a quarter of a millimetre per second—slower than a growing fingernail. The signal, meanwhile, travels at something like two-thirds of the speed of light, depending on the cable. The gap between those two figures is a factor of roughly a million million.

A model in which the thing that carries the current is the thing that crawls has to explain that factor away, and does so by handing the job to a field. A model in which the wire is already full does not have the problem: the slow number is the slow process, the fast number is the fast one, and Chapter 11 separates them.

9.6 What Pushes

An imbalance between the two ends of the circuit is what sets the population moving, and the push itself is G2 motion: a steady stream of the smaller, faster particles rather than a random rain of them. We call it the F2 force, and it is what a meter reads as voltage.

That is a strong claim and it earns a whole chapter later, because it is the same G2 motion that does duty as Coulomb's force when it is random. Random G2 motion is the attraction between charges; streaming G2 motion is the push along a wire. One substance, two patterns—which is the model's habit everywhere else as well.

9.7 Why It Spirals

One more thing the wire does, and it is the hinge between this chapter and magnetism.

When G1 particles are driven along a conductor they do not all go straight. Some are guided through the metal along the channels; others, at the surface, wrap around the outside of the wire and travel in a spiral.

Particles going round in circles is magnetism. So a current in a wire produces a magnetic field around the wire—not as a separate consequence requiring its own law, but because the same population is doing two of the four motions at once. The forward part is what we call current; the circling part is what we call the field. Chapter 17 works that through.

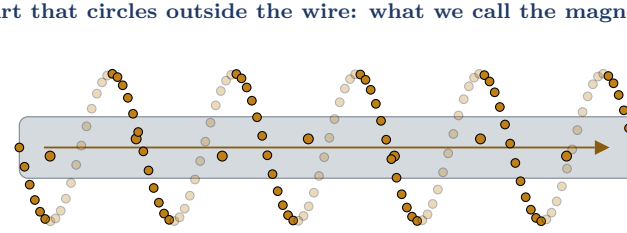


Figure 9.2: One motion, named twice. The part that advances is the current; the part that circles outside is the magnetic field.

9.8 Resistance, Sketched

A current meets resistance, wires warm up, and a resistor turns electrical energy into heat. What is happening?

In this picture, some of the G1 particles passing through a lattice are not channelled cleanly. Where the stream aligns with the open corridors between rows of atoms it threads through with little disturbance; where it does not, it scatters. Scattered particles are knocked out of the directed flow and into disordered motion, and disordered motion in matter is what heat is.

Resistance is then a measure of how badly a given lattice channels, and heating is the flow being converted into randomness—electric motion decaying back into gravitic motion, one rung down the ladder of organisation.

We call this a sketch deliberately. It has the right shape and produces no numbers, and the resistor is the component this model has worked out least.

What we have not modelled

Nothing here is quantitative. *Ohm's law is not derived. Resistivity is not derived, nor its variation with temperature, nor why copper conducts some forty times better than stainless steel.*

Resistance is the weakest part. *The account above—scattering out of the channels—is a plausible story and no more. Until a simulation on a real lattice reports how much current gets through for a given push, this model describes resistance rather than explaining it.*

Superconductivity is not addressed. *Kamerlingh Onnes found in 1911 that mercury's resistance vanishes entirely below about four degrees above absolute zero—not falls, vanishes. A model built on channels through a lattice ought to have something to say about that: a cold lattice is a still lattice, and a still lattice should channel better than a jostling one. That is a suggestive direction and nothing more. We have not worked it out, and the behaviour is abrupt in a way that a gradual improvement in channelling does not obviously produce.*

The heat capacity suggestion is untested. *The account above—that traffic passing through a lattice would not store heat the way a gas in equilibrium does—has the right shape and no arithmetic behind it. If it is right it is a point in the model's favour on a question that embarrassed the classical picture for a quarter of a century. If it is wrong it is one more thing to explain.*

What you can now say

- Electric motion is G1 flowing along a gravity tube, a channel laid down by a lattice of nuclei.
- A wire is a pipe that is already full, so switching on supplies a direction and not particles.
- The push is the F2, a steady stream of G2, and what a meter reads as voltage.
- The part of the flow that circles outside the wire is the magnetic field, and resistance is scattering out of the channels.

Chapter 10

Charge: A Count, Not a Kind

STANDING: DERIVED. *Charge as a count follows from what atoms hold and trade. The account of why the count comes in steps is a proposal about how atoms let go.*

You can owe a friend five marbles. You cannot hold minus five of them. Empty your pockets and the smallest number you can end up with is none.

Now open a physics textbook. The electron, it says, carries a charge of -1.602×10^{-19} coulombs. Not a debt, not a shortfall against some other amount: a negative quantity, built into the particle, as much a part of it as its mass.

Ask what that minus sign is attached to. What is there in an electron that is less than nothing?

The question is never answered because it is never asked. Charge is introduced as a property that comes in two kinds, the kinds are labelled plus and minus, and the lesson moves on.

10.1 Where Plus and Minus Came From

The labels are older than the particles, and their history is instructive.

In 1733 Charles du Fay found that rubbed glass and rubbed amber behaved as though they held two different kinds of electricity, which he called vitreous and resinous. Two substances, two names.

In 1747 Benjamin Franklin replaced the two substances with one. There was a single electric fluid, he proposed, and every body held some amount of it. A body with more than its usual share he called plus; one with less he called minus. Plus and minus were not two kinds of anything—they were two comparisons with one amount, exactly as a bank balance is above or below where it started.

That was the clearer idea and it did not survive. Over the following century the signs drifted from the bodies onto the stuff itself, and when J. J. Thomson found the electron in 1897 it was handed the minus sign outright. What had begun as *more* and *less* had become two opposite substances again: du Fay's two kinds wearing Franklin's labels.

Franklin guessed wrong about which body holds the extra, as Chapter 11 sets out. His structure was right.

10.2 What Charge Is Said to Be

Ask a physicist what charge is and you will be given a list of what it does. It comes in two signs. Like signs repel and unlike signs attract. It is conserved. It comes in fixed steps. It is the source of the electric field and the thing the field acts on.

Every item is true as a description of behaviour, and none of it is a description of a thing. Charge is defined entirely by its effects, and then the effects are explained by the charge. It is the same move Chapter 3 was about: a map so good that nobody asks what it is a map of.

10.3 Charge Is a Count

In the four universal motions the particles that move in a wire, that make up light, and that every atom holds in orbit are G1 particles, and a G1 has no charge at all. It is not slightly charged or charged in some hidden way. There is nothing on it to carry a sign.

What exists is the *number* of them a body holds. Every atom holds a population in orbit around its nucleons, and each kind of atom settles at its own number. Push more in and it holds a surplus. Take some away and it is short.

That number is the charge. It is a count of particles, and like every count it starts at zero and goes up.

- An atom holding **more** than its settled number is what we have been calling *negative*.
- One holding **fewer** is what we have been calling *positive*.
- One sitting at its number is *neutral*.

This is Franklin's structure put back, with the labels as history fixed them. One kind of particle, and a number above or below the usual.

10.4 A Battery, Counted

The plainest example is in a drawer in most houses.

Take a rechargeable nickel cell. One electrode is built around nickel, the other around cadmium or a metal hydride. The nickel side holds fewer G1 particles, so it is the end we call positive. The other side holds more, so it is the end we call negative. Neither side carries a different kind of anything. Both are made of atoms holding G1 particles, and one holds more of them.

That difference is the battery's charge. Connect the two ends and G1 particles run out of the fuller side, through the wire and whatever it powers, into the nickel side. As they go the difference shrinks, and when it is used up the battery is flat. Recharging pushes them back the other way and restores the difference.

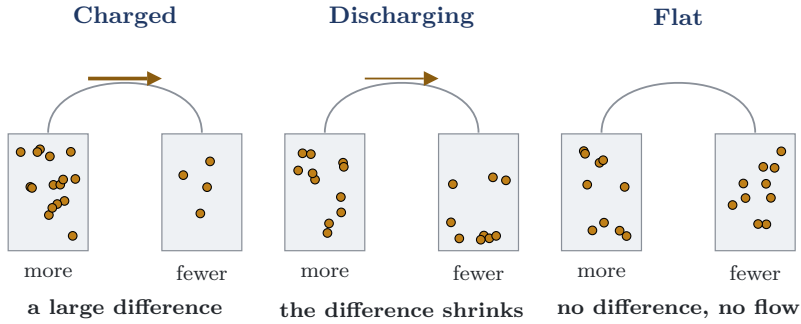


Figure 10.1: A battery, counted. The same two electrodes, three times: the particles run from the fuller side to the emptier until the counts match.

Charged, *discharged* and *recharged* turn out to mean exactly what they sound like.

10.5 Why Charge Comes in Steps

The step is real. Robert Millikan's oil drops in 1909 always carried a whole multiple of one smallest amount, and nobody has ever measured less.

But a smallest amount you can *separate* is not the same as an indivisible particle, and Chapter 13 makes that case in full. Water leaves a dripping tap in equal drops because of how the tap lets go, not because water comes in drops. An atom takes on and gives up G1 particles in bundles of a characteristic size, and that bundle is what the experiments have been weighing.

The step is a fact about how atoms trade, not about a smallest piece of charge.

10.6 What the Count Does

A count on its own does nothing. Three things follow when two bodies with different counts are near each other.

The particles flow. Connect them and G1 particles run from the one holding more to the one holding fewer—from negative to positive—until the counts settle. That flow is current.

Unlike counts draw together. The pull between a surplus and a shortfall is G2 gravitic motion, shadowing in exactly the way Newtonian gravity does one level up. That is why Coulomb's law has the same shape as Newton's.

Like counts push apart. Two bodies both holding a surplus each carry a large orbiting population. Where those populations meet they meet in the same sense, and by the Dinu rule of Chapter 8, orbits meeting that way repel.

Notice that the third of those is a magnetic explanation for an electrostatic fact. That is either an elegant economy or an overreach, and it is listed below as something that has to be demonstrated rather than asserted.

10.7 A Count, or an Area?

There is a second way of saying what charge is, arrived at from the other direction, and the two need to be put side by side because at first glance they disagree.

Chapter 22 describes the electric force as gravitic motion one level down: G2 particles raining in every direction, bodies blocking some of what passes through them, and two bodies pushed together because each shadows the other. Carry that through and match it to Coulomb's law, and charge comes out as a *blocking area*—how much of the G2 sea a body stops—in exactly the way that mass, one level up, is how much of the G1 sea it stops.

So which is it: a count of particles, or an area?

They are the same thing, and the reason is worth following, because it closes one of this chapter's own gaps.

Count the G1 particles a body holds. Every one of them is itself a body in the G2 sea, and every one of them is the same size as every other—they are identical particles. So each one blocks the same amount. A body holding N surplus G1 particles therefore presents N units of extra blocking area, no more and no less. The count and the area are two readings of one quantity, related by a fixed amount per particle.

That is also, finally, an answer to why the steps are exact. Section 10.5 above gave the practical reason—atoms trade in bundles—but left the exactness unexplained. Here it is forced: blocking areas simply add, so N identical blockers block exactly N times as much, for the same reason that a stack of N identical filters passes exactly N filters' worth of shadow.

Charge comes in whole multiples not approximately but exactly, and nothing further is needed to make it so. In standard physics the exactness of charge quantisation is a celebrated unexplained fact. Here there is nothing left over to explain.

It also shows what Coulomb's constant is made of. Coulomb's constant turns out to have the same anatomy as Newton's: one over the total solid angle of the sky, times the intensity of that level's sea, times the square of whatever converts a body's amount into a blocking area. The famous 4π in $1/4\pi\varepsilon_0$, which textbooks explain away as an artefact of choosing rationalised units, is the solid angle of a sphere.

10.8 Where That Leaves the Minus Sign

Now the difficulty, and it is a real one. Setting the two accounts beside each other does not only tidy things up—it makes the oldest problem in this chapter worse, and in a more specific way.

Blocking is a one-signed business. A shadow can only ever *remove* arrivals from a direction; nothing can add any. And two shadows always add—there is no arrangement of blockers that blocks less than the blockers do separately.

Set that against what charge actually does.

A deficit cannot be an area. This chapter's whole proposal is that positive means *fewer*—a body short of its settled number. A surplus of N G1 particles is N units of extra blocking, which is fine. But a shortfall of N is not negative blocking area. There is no such thing. The count reading handles both directions symmetrically and the area reading cannot.

Neutral bodies should not be neutral. A body sitting at its settled number still contains an enormous number of G1 particles, every one of them blocking G2 particles. Its total blocking area is not zero, it is huge. By the shadowing law it should pull on every other body in sight with a force proportional to that area—which is to say, every neutral object should exert a powerful electric attraction on every other neutral object. They do not. Shadows cannot cancel, and charge demonstrably does.

So the shadowing account delivers the *form* of Coulomb's law, the inverse square, the bilinear product, the 4π and the exact quantisation—and it cannot deliver the two signs or the cancellation. This chapter has already said where the sign is supposed to come from: not from gravitic motion at all, but from magnetic motion, with rotation carrying what blocking cannot. Gravitic motion supplies the size of the force; magnetic motion supplies its direction.

That is a clean division of labour and it is the model's own structure rather than a patch invented for the occasion—and Chapter 8 now says how it works. The short version is that attraction and repulsion are not one mechanism with a sign attached but two different processes, selected by

which way the two bodies' orbiting swarms are running where they meet. Swarms moving together shadow each other's G2 rain and are drawn in. Swarms running at each other veer off course and are driven apart. The sign is carried by a direction, which can have one, rather than by a blocking area, which cannot.

What that does not yet do is produce numbers, or explain why a head-on encounter deflects where a side-by-side one does not. So the minus sign now has a source rather than an apology, and the quantitative half of electricity remains unbuilt.

10.9 Charge Is Not Polarity

One distinction is worth keeping sharp, because chemistry blurs it.

When two atoms bond, chemistry describes the result by handing each a *partial charge*—a fraction of a plus or a minus. In the four universal motions that is a different thing altogether. A bond is made by the G1 particles already orbiting each atom's nucleons passing each other in the gap. That is atomic polarity, and it is a matter of *direction*: which way the two populations run where they meet. Charge is a matter of *number*: how many a body holds.

The two are connected. The count is the cause, and the direction is what the count does. But a sentence that gives only the direction has described the effect and left out the thing.

The marbles were right all along. You can have more, you can have fewer, and you can have none. What you cannot have is minus five.

What we have not modelled

The settled number is not calculated. *Each element settles at its own count, and nothing here says what sets it or how large it is.*

The size of the step is not derived. *That it comes in whole steps is now forced rather than assumed—identical blockers add exactly. How* big *one step is, and how many G1 particles are in the bundle an atom trades, is still open. The constraint runs the other way at present: matching Coulomb's law fixes the product of the G2 sea's intensity and the square of the electron's blocking area in it, so a guess at either one delivers the other, and nothing yet delivers the first.*

Neutrality waits on the G2 fields. *Shadows add; they never cancel. A neutral body is full of blockers, so the sign and the cancellation have to come from the other half of the division of labour: the direction carried by orbiting populations. That is where the G2 magnetic fields come in, and they have not yet been described.*

Like repelling like needs to be shown. *Orbiting populations meeting in the same sense is a consistent account of why two surpluses push apart. It remains an account until a simulation shows it happen.*

The quantitative account is half-built. *Coulomb's constant now has an anatomy—a solid angle, a sea intensity, a blocking area—in the same shape as*

Newton's. What it does not yet have is numbers, because the sea's intensity is unmeasured and the electron's size in it is unknown, and the one equation available relates them to each other rather than fixing either.

What you can now say

- Charge is a count of G1 held against the number an atom settles at: more is negative, fewer is positive, at its number is neutral.
- Plus and minus go back to what Franklin meant, and the minus sign stops being a substance.
- A battery stores a difference in count, and a flat battery is a difference used up.
- Charge is how many; polarity is which way. The two are connected but are not the same.

Chapter 11

Current: What Actually Moves

STANDING: DERIVED. *What moves in a wire, and why the hole is bookkeeping, follow from charge being a count.*

Flip the switch and the lamp comes on at once. Now work out how fast the carriers of the current are said to move along the copper. The answer, from any textbook, is a fraction of a millimetre per second. Slower than a snail. A carrier leaving the switch would need hours to reach the lamp.

Both facts are true. Physics reconciles them by saying the carriers crawl while something else—the field—races ahead and sets them all moving at once, which moves the question rather than answering it.

Underneath sit two older questions that are rarely put side by side: which way does the current really go, and what is it that goes?

11.1 Franklin's Arrow

Every circuit diagram draws current leaving the positive terminal, running round the loop and returning to the negative. That arrow was fixed by Franklin in 1747, and it was a guess.

He pictured a single electric fluid, called a body with more of it than usual plus, and supposed the fluid ran from plus to minus. He had no way of knowing which body really held the extra. He made a choice and labelled it, and in doing so made two guesses at once: which body holds the surplus, and which way the flow goes.

Both turned out to be wrong. But the arrow was on every diagram long before anybody could check, and it is still there.

11.2 What the Experiments Found

The check took a vacuum pump and about forty years.

In 1858 Julius Plücker and in 1869 Johann Hittorf pumped the air out of glass tubes and put a voltage across two metal plates. A glow streamed off the *negative* plate and travelled in straight lines, casting a shadow of any object in its path. Eugen Goldstein named them cathode rays in 1876. In 1895 Jean Perrin caught them in a metal cup and found they carried negative charge, and in 1897 Thomson bent them with magnets and showed they were far lighter than any atom.

Inside solid wires the evidence came from two other directions. In 1879 Edwin Hall put a current-carrying strip into a magnetic field and found a small voltage across its width, whose sign tells you whether the movers behave as positive or negative. In most metals they behaved as negative. And in 1916 Tolman and Stewart spun a coil of wire and stopped it dead; the carriers sloshed on for an instant, like water in a pipe, and the pulse matched Thomson's particles.

Whatever moves leaves the negative side. That is not a matter of interpretation.

11.3 Why Physics Ended Up With Holes

Hall's test did not always agree. In some metals, and later in most semiconductors, it read positive—as though the carriers were positive things going the other way. Nothing in the electron picture could explain it. The answer physics adopted was the hole, and *What the Hole Was For*, below, says where it came from and what it became. It drifts opposite to the electrons, which happens to be the way Franklin's arrow points, so it ended up carrying the arrow.

11.4 What Moves

In the four universal motions, what moves through a wire is G1 particles. They carry no charge. They are the same particles that make up light and that every atom holds, and in a wire they run **from the negative terminal to the positive**.

That is the same direction mainstream physics gives its electrons, and it is worth being clear that direction is not where this model parts company with the textbook. It follows from what charge is. The end we call negative is the end holding more, and particles run from where there are more to where there are fewer. A battery does nothing cleverer than keep one end fuller than the other.

The difference is in what moves and what it leaves behind. The movers

are real particles rather than a charge with nothing underneath it. And when a G1 leaves an atom it does not leave a hole: it leaves an atom holding one fewer G1, which is a count, not an object. Nothing travels back the other way.

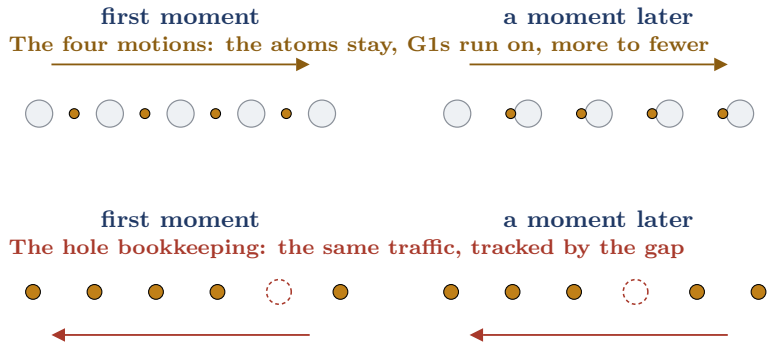


Figure 11.1: The same wire, told two ways. Above, the particles that move. Below, the gap that the bookkeeping follows, which appears to go the other way.

11.5 What the Hole Was For

The hole was a reasonable idea, and this book's objection is only fair if the reason for it is granted.

Band theory describes the electrons in a solid by the energy states available to them. In a nearly full band, tracking every occupied state is hopeless arithmetic and tracking the few empty ones is easy—so you describe the band by its vacancies, and the mathematics comes out right. Peierls and Heisenberg found that if you treat each vacancy as a particle with positive charge, every prediction lands, including the positive Hall readings that nothing else could produce.

As a calculational device that is elegant and entirely defensible. The trouble is what happened next. The vacancy was given a charge, then a mass, then an effective mass that can be negative, then a velocity and a lifetime—a full inventory of properties belonging to a place where an electron is not.

The parking-lot analogy everyone is taught is honest about this. Cars shuffle one way and the gap moves the other; the gap has a direction and a speed and you can point at it. But nobody thinks the gap has a mass, or that the gap is what moves the cars.

The inventory is longer than it sounds. A hole is given a charge of $+e$. It is given an effective mass that is tabulated for each material and differs from the electron's. It has a mobility, a drift velocity and a momentum; it

scatters and diffuses; it has a lifetime and it recombines; and it is called, without qualification, a charge carrier. Physicists will say, if pressed, that a hole is a quasiparticle, an emergent description and not a thing. That is an honest answer, and it is also an admission that the physical account is a placeholder with an absence doing the work of an object.

11.6 The Same Move, Three Times

This is not a quirk of semiconductor physics. It is a habit. A photon is a single structureless point that is given a frequency, a property only a repeating series can have (Chapter 6). A field is a number assigned to each point of space that is given energy, momentum and the power to push (Chapter 17). A hole is a place where an electron is not that is given a charge, a mass and the job of carrying the current.

Three times a bookkeeping device was promoted to an object, because the mathematics kept working and nobody needed to look underneath. The four motions are an attempt to look underneath each time, and the answer keeps coming back the same: there are particles, and they are moving.

11.7 Two Speeds, Because Two Things Are Happening

Here the lamp puzzle comes apart. Two different processes are going on in the same piece of copper, and physics has been averaging them together.

Fast. G1 particles running down the gravity tubes between the atoms, never captured, at close to the speed of light. This is the current, and it is why the lamp lights at once.

Slow. G1 particles entering one atom's orbital system, being held there, and later passing to the next. Being taken in, held and released is a slow business. This is also real, and it is what the drift velocity number measures.

The snail-speed figure is not a strange fact about electricity. It is a careful measurement of the slower of two processes. No field has to be invented to explain why the lamp lights at once, because the thing that lights it was always moving fast.

11.8 What Stays the Same

Nothing in the arithmetic changes. Ohm's law, Kirchhoff's laws and every circuit equation work exactly as before, and every meter reads what it read yesterday. Those relationships do not care which way you label the current; reverse the label and every current flips its sign.

So the arrow on the schematic can stay, as a label. Electrical engineers who track the flow out of the negative terminal—as Robert de Hilster did through forty years of designing telecommunications switching systems—are following what the particles actually do. Engineers who keep Franklin's arrow are not wrong either; they are counting from the other end.

What changes is not the circuit diagram. It is the answer to the question underneath it.

Flip the switch again. The lamp lights at once because something is already racing down the wire, and it was never the snail.

What we have not modelled

The positive Hall readings are not yet modelled. *Some metals and most semiconductors give a Hall voltage of the sign a positive carrier would produce. That is what the hole was invented to describe. In this model it has to come from G1 particles moving through a particular lattice, and the arrangement of that lattice and its G2 fields is exactly what has not yet been worked out. When it is, this is one of the first things it should show.*

The two speeds need numbers. *What fraction of G1 particles thread the tubes without being caught? What decides whether an arriving particle is captured or passes through? Those figures would turn this into a prediction.*

Nothing is quantitative. *Resistance, conductivity and signal speed should all eventually come out of a count of particles moving through a lattice.*

What you can now say

- Franklin's arrow was a guess; the G1 run from the end holding more to the end holding fewer, negative to positive.
- What moves is real particles, and a hole is an atom one G1 short, which is a count and not an object.
- There are two speeds because two processes are going on: fast along the tubes, slow through the atoms.
- The lamp lights at once because the wire is already full and something is already racing.

Chapter 12

The Atom Without Charge

STANDING: PROPOSED. *The per-nucleon fields and the orbital shapes are proposed. They are expected to follow once the G2 fields are found.*

Everyone carries a picture of the atom: a nucleus at the centre, electrons circling it like planets. It is one of the most recognisable images in science and it is wrong in a way its own discipline admits freely.

Real atoms do not have planetary orbits. They have lobed, dumbbell and clover-shaped regions—the S, P, D and F orbitals of every chemistry textbook—and nothing in a solar-system picture produces shapes like that. Quantum mechanics describes them superbly as probability distributions and declines to say what is distributed.

12.1 What Holds It Together

Start with the force. The nucleus is supposed to hold its electrons by electrostatic attraction, governed by Coulomb's law: two charges multiplied, divided by the square of the distance.

Chapter 4 already noted what is odd about that equation. It has the identical form to Newton's law of gravitation. Two quantities multiplied, divided by distance squared, with a different constant in front.

The four universal motions take the obvious reading. Coulomb's law looks like a gravitational law because it *is* one, operating one level down, carried by G2 particles instead of G1 particles. The nucleus holds its population the way a star holds its planets—by shadowing a rain and letting the imbalance push—with no charge anywhere in the account.

That is the first half of the atom, and it buys the orbits. It does not buy their shapes.

12.2 Where the Shapes Come From

Gravity alone gives you circles and ellipses. Atoms have clover leaves.

The missing ingredient is magnetism, and the key point is where it lives.

> *Every nucleon carries its own magnetic field—one per nucleon, not one for the nucleus as a whole.*

Each one is a dipole, with two poles and a tilt of its own, in exactly the way the Earth has a magnetic field. These are G2 magnetic fields: circulating G2 particles, one level below the G1 orbits they are shaping.

A nucleus with several nucleons therefore sits inside a tangle of overlapping dipoles pointing in different directions. Those fields attract, repel and settle into balance by the Dinu rule of Chapter 8, and in doing so they push the orbiting G1 particles off simple ellipses and into the complicated, lobed paths we actually measure.

The orbital shapes in every chemistry book are not probability clouds standing in for our ignorance. They are the shape of the traffic pattern.

12.3 The Nucleons Really Do Have Magnetic Fields

That is a strong claim to make—one field per nucleon, each with poles and a tilt—and it would be a weak chapter that simply asserted it. So it is worth saying that physics has measured exactly this, and found it puzzling.

In 1933, in Hamburg, Otto Stern measured the magnetic moment of the proton by deflecting a beam of molecular hydrogen through a magnetic field. He won the Nobel Prize for it ten years later. The proton has a magnetic moment. So, measured directly by Alvarez and Bloch in 1940, does the neutron.

Two features of those measurements are worth dwelling on.

The proton's moment is the wrong size. A simple point particle with charge and spin, of the kind Dirac's theory describes, should have a moment of about one nuclear magneton. The proton's is +2.793. That discrepancy is not small and it was not expected, and it is one of the observations that told physics nucleons are not elementary—that there is something inside them with structure.

The neutron has one at all. Its moment is −1.913 nuclear magnetons, measured with great precision. The neutron is electrically neutral. A magnetic moment is supposed to come from moving charge, and here is a particle with no net charge and a substantial moment, which conventional physics accounts for by giving it an internal distribution of charges that cancel overall while circulating.

Look at what that explanation requires. Charge that is there but sums

to nothing, arranged so as to circulate, inside a particle that is defined as having no charge.

In this model neither result is awkward, because neither needs charge. Magnetism is circulation—G2 particles going round—and a nucleon is a body with circulation about it whether or not anything in it is "charged", because there is no such property. That the proton's and the neutron's moments differ, and that neither is a tidy whole number, is what you would expect of two different arrangements of smaller things in motion.

We are not claiming these measurements as evidence *for* the four motions. They are consistent with it, and they are the thing the model requires to exist, and they exist. That is worth more than an assertion and less than a proof.

12.4 Two Levels, Four Motions Each

This is economical: the same four motions appear twice.

At our level, G1 particles do all four: random for gravity, orbits for magnetism, flow for current, formation for light. One level down, G2 particles do the same four inside the atom, and three of them already do work we can point to. Their random motion is what Coulomb measured. Their orbital motion is the per-nucleon dipole. Their steady streaming is the F2 force that pushes current along a wire.

No new physics was required to go from the solar system to the atom. The same grammar, with smaller words.

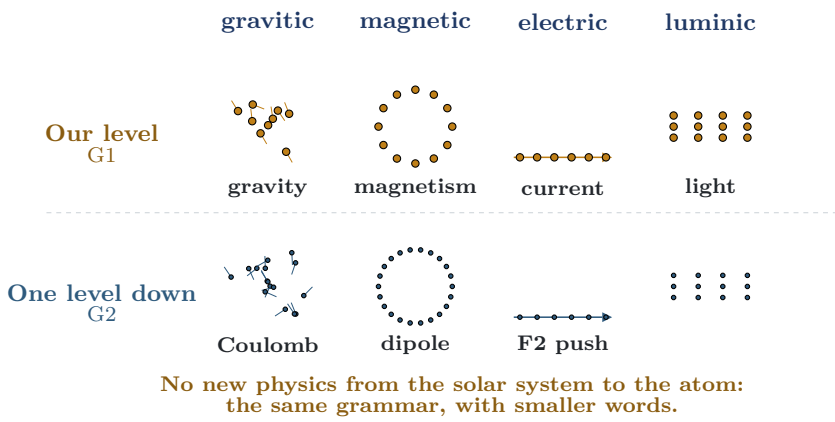


Figure 12.1: Four motions at two levels. G1 particles do all four at our level; one level down G2 particles do the same four inside the atom.

12.5 Why the Planetary Picture Had to Go

What is wrong with the schoolroom atom is not that it is a simplification.

A planet orbits because gravity pulls it inward while its sideways motion carries it along, and the orbit is a compromise between the two. That works for a solar system and it does not work for an atom, for a reason physics discovered early and has never been comfortable with: a charged particle moving in a curved path should radiate energy continuously, lose it, and spiral into the nucleus. Classical atoms collapse in about sixteen picoseconds.

The resolution was to forbid it. Bohr postulated that certain orbits simply do not radiate, and later quantum mechanics replaced the orbits with probability distributions that do not have paths at all. Both are ways of saying that the electron does not do what a moving charge would do, because we observe that it does not.

Here the problem never arises, because there is no charge to radiate and no single object going round. There is a population of uncharged particles held in a traffic pattern. Nothing is accelerating in a curve while carrying a property that demands it radiate, so nothing has to be forbidden from doing so.

12.6 Charge Has Nothing Left to Do

Once G2 gravity does the holding and G2 magnetism does the shaping, the property called charge has no remaining job.

It was introduced to explain attraction and repulsion between atomic parts. Attraction is shadowing. Repulsion between like surpluses is two orbiting populations meeting in the same sense. The orbital shapes come from the nucleons' dipoles. Nothing is left over that charge is needed for. The nucleons themselves need none either: they are held together by the same G2 gravitic and magnetic motion.

And charge never had a physical description of its own. Ask what it is and you are given a list of what it does, which is the pattern Chapter 3 was about. A property defined entirely by its effects, which the effects then explain, can be removed without loss if something real takes over the work.

12.7 A Debt to Jeff Yee

This part of the model owes a great deal to Jeff Yee, whose Energy Wave Theory simulates electron clouds and produces orbital-like structures from particle interactions.

His framework is ultimately an aether theory and ours is not—Chapter 23 sets out why that difference matters to us. But his simulations were the

first sign that cloud structures of the right kind can emerge from a model with no charge in it anywhere, and that is the demonstration this chapter rests on. It was his work that convinced David de Hilster that G2 gravitic and magnetic motion could produce electron clouds without charge.

What we have not modelled

Every diagram of a G2 field in this chapter is a ***symbol****. The Earth-like dipole drawn beside each nucleon says* there is a field here and it has poles*; it does not claim to show the shape, because the shape is not known.*

We can say what the G2 motions do. We cannot say how they are arranged: how G2 particles are distributed around a single nucleon, what their paths look like, how two nucleons' fields combine, which geometries are stable, or how many G1 particles a given arrangement can hold.

That gap is the largest in this book and it has a chapter of its own—Chapter 15—rather than a paragraph here. It is the place where the physical Turing machine has not yet been run: when the G2 fields are found, the orbitals follow.

What you can now say

- Coulomb's law looks like Newton's because it is gravity one level down, carried by G2.
- Every nucleon carries its own G2 magnetic field, and those overlapping fields shape the S, P, D and F orbitals.
- The atom needs no charge, so the old problem of an orbiting charge radiating does not arise.
- The G2 fields have not yet been drawn, and the diagrams in this book are symbols.

Chapter 13

The Electron Is Not One Thing

STANDING: PROPOSED. *A reading of the electron experiments as a population of G1s traded in bundles. The experiments are untouched; the bundle size is not yet derived.*

A tap drips. Every drop is much the same size. Nobody concludes that water is made of drops.

The drop size is a fact about the tap—about surface tension and the geometry of the opening and how much has to gather before the rest lets go. Change the tap and you change the drop. The water was continuous all along.

Hold on to that tap, because it is the whole of this chapter.

13.1 The Name Came First

Before any of the experiments, a point of history that reads like a joke at the expense of the whole subject.

The word *electron* was not coined for a particle. George Johnstone Stoney had drawn attention in 1874 to the fact that electricity in electrolysis seemed to come in a natural unit; the paper was printed in 1881, and in 1891 he proposed the name *electron* for the unit. His own statement of it, in the *Philosophical Magazine* of 1894, is titled "Of the 'Electron,' or Atom of Electricity." What he was naming was **a quantity of charge**. Nobody had found an object, and Stoney was not claiming one.

Six years later Thomson found something coming out of a cathode, and over the following decade the name slid off the quantity and onto the thing. Thomson himself never used it: he called them *corpuscles*, and went on calling them corpuscles for years after everyone else had stopped.

So the word was built to name a unit of electricity and was afterwards attached to a particle. This chapter argues that the transfer was a mistake and that the original sense was the right one. We did not arrange that; the history simply happens to say it out loud.

13.2 What the Experiments Measured

Three results built the electron, and all three are solid.

In 1897 J. J. Thomson deflected cathode rays with magnets and electric fields and measured a ratio—charge to mass—that was the same whatever gas he used and whatever metal the cathode was made of. Something universal was coming out of matter, and it was far lighter than any atom.

In 1909 Millikan suspended charged oil drops in an electric field and found that the charge on a drop was always a whole multiple of one smallest amount.

And every chemistry since has worked on the assumption that atoms contain a countable number of these things, arranged in shells.

Be precise about what each man measured, because the distinction carries the chapter.

Thomson measured a ratio. Not a charge and not a mass—the relationship between them.

The limitation is built into the method. A charged body moving through a magnetic field is pushed sideways by an amount that depends on its speed; the same body in an electric field is pushed sideways by an amount that does not. Thomson arranged both fields across the same stretch of the beam and turned them against each other until the deflections cancelled. At that balance the speed falls straight out of the two field strengths—it is simply the electric field divided by the magnetic one—and with the speed known, either deflection on its own then yields the ratio of mass to charge.

What came out was about a thousandth of the smallest value then known, the one for a hydrogen ion in electrolysis. And it did not move: he changed the gas in the tube, he changed the metal of the cathode, and the number stayed where it was. Something came out of every kind of matter, the same every time, far lighter per unit of charge than the lightest atom.

But notice what the balance of two deflections cannot give you. It fixes the *ratio* and nothing else. Thomson said so himself—the value of m/e was determined, and m and e separately were not—and he spent the next two years trying to get at one of them alone. A ratio is a relationship. You can know it exactly while remaining entirely ignorant of whether the thing it describes is one object or a crowd of them, which is the point this chapter turns on.

Thomson's own first reading, incidentally, was a crowd. He took the atom to contain a *large number* of corpuscles, and the count stayed unsettled for a decade—by 1906 he had revised it down to a number of the order of

the atomic weight. The number of these things in an atom was an open question, argued down by orders of magnitude, for as long as the particle had a name.

Millikan measured the charge itself, which nobody had done. He sprayed oil from an atomiser into a chamber between charged plates and timed individual droplets rising and falling, repeatedly, on the same drop. From the rise and fall he could calculate what the droplet carried. He began in 1909 and published his definitive results in 1913.

The arithmetic has a quantity in it that is easy to miss: the viscosity of air. A droplet's fall is resisted by the air it falls through, so to get the charge you must know how sticky the air is, and Millikan took that figure from a measurement made by one of his own students. The measurement had a subtle error in it. His published value for the elementary charge, 1.592×10^{-19} coulombs, is accordingly about half a percent below the modern 1.602×10^{-19}, and the discrepancy went unexplained for roughly twenty years before anyone traced it to the air.

We mention it for what it shows about how the quantum of charge came to be trusted, not to cast doubt on it. The error was found because the value disagreed with one arrived at by an entirely different route—from the Faraday constant and Avogadro's number—and when the drop data were reworked with a correct viscosity, the two agreed. That is how the quantity was established: by two independent roads arriving at the same place. It is a very good way to establish a number. It is not a way of seeing an object, and nobody has claimed it was.

And it was contested at the time, which is a part of the story usually left out.

Felix Ehrenhaft, in Vienna, ran comparable experiments on small metal particles and reported charges *smaller* than Millikan's supposed minimum. He maintained it for years. The disagreement was serious enough to acquire a name—the Battle over the Electron—and it was eventually settled in Millikan's favour by the weight of other work. Historians who later examined Millikan's notebooks found he had recorded many more droplets than he published, and they disagree about whether the exclusions were legitimate housekeeping or something less defensible.

We raise this for one reason only, and not to reopen it: the quantum of charge is extremely well established and we do not dispute it. But the indivisibility of what carries it was a *conclusion*, argued over by competent people, and not something anybody saw.

Now look at what those experiments establish. They establish that something comes out of matter in units of a characteristic size, with a characteristic ratio of charge to mass. They do not establish that the unit has no parts.

13.3 A Quanta, Not a Particle

In the four universal motions an electron is not a particle. It is a **quanta**: a population of G1 particles that an atom holds, and that it can take on and let go of in bundles of a characteristic size.

Millikan's smallest amount is the size of the bundle an atom trades. Thomson's ratio is a property of that bundle. Both are real, repeatable and exactly as measured. Neither requires anything indivisible.

The tap drips. Every drop the same. And the water was never made of drops.

13.4 One Particle, Four Jobs

Before the weights, one thing worth noticing about what Thomson found.

Cathode rays behaved identically whatever gas filled the tube and whatever metal the cathode was made of. Something universal was coming out of every kind of matter. That was taken as evidence for a universal particle, and so it is—but notice which particle.

In this model the thing coming out is G1 particles, and the same G1 particles are doing three other jobs at the same time. They are what a wire carries when a current flows. They are what an atom sheds when it emits light. They are what rains through everything as gravity. Thomson had found the particle that does everything, and it was named after only one of its roles.

That is why the charge-to-mass ratio came out the same every time. It is not a fact about a special electrical particle. It is a fact about the bundle of G1 particles that atoms trade.

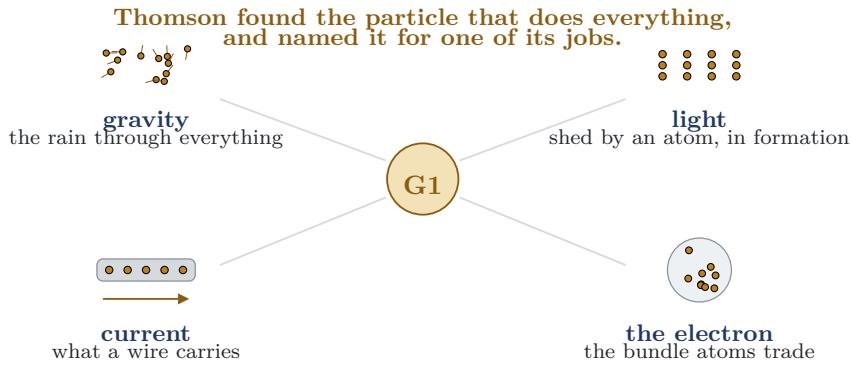


Figure 13.1: One particle, four names. The G1 particles Thomson found are the same ones that fall as gravity, run in a wire and leave an atom as light.

13.5 Why the Weights Are Not Whole

Here is a fact that fits this picture uncomfortably well.

If atoms were made of a whole number of identical protons, neutrons and electrons, atomic weights ought to come out as whole numbers. They do not. Chlorine comes in at 35.45. Even a single isotope does not oblige: oxygen-16 weighs 15.9949, not 16.

Chemistry explains the first with isotopes—chlorine is a mixture of chlorine-35 and chlorine-37, and 35.45 is the average—and that is correct as far as it goes.

It does not explain the second. Take a single pure isotope and the number still misses. Oxygen-16 has eight protons and eight neutrons and ought to be a clean 16 of something; it weighs 15.9949. Carbon-12 only comes out at exactly 12 because the unit was *defined* by it. Every other nuclide is somewhere awkward, and the discrepancy is attributed to binding energy converted to mass by $E = mc^2$—which is a conversion rather than an account, and which quietly concedes that the parts do not add up.

A population explains it immediately. If what an atom holds is a crowd of G1 particles rather than a fixed number of indivisible electrons, there is no reason for the total to land on an integer. A count of thousands, settling where the arrangement allows, will give you 15.9949 as readily as 16.

The proton-to-electron mass ratio makes the same point from the other side. It is 1836.15. If both were fundamental indivisible objects, that is a very strange number to find between them—there is no reason for nature to choose it and no account of why it is not something else. If both are populations of the same kind of particle, differing in how many, then a ratio near 1836 with a fraction on the end is precisely what you would expect. It is a headcount.

Chemistry has been living with fractional weights for two centuries and explaining them away one mechanism at a time. A model in which the things being weighed are crowds predicts fractions as the default and whole numbers as the accident.

13.6 What an Energy Level Is

"An electron in the 2p orbital" is not a particle on a rung. It is a population of G1 particles held in a particular shape by a particular arrangement of G2 fields.

Which disposes of the oldest puzzle in atomic physics. A point particle cannot move from one orbit to another without crossing the space between, and quantum mechanics handles this by declaring that it does not cross—it is simply in one place and then the other. That is not a mechanism; it is a refusal to supply one.

A population has no such difficulty. It grows and shrinks. Adding G1

particles changes the arrangement the G2 fields can support, and the cloud settles into a different shape. Nothing jumps, because nothing had to be in one place to begin with.

13.7 What Stays

Nothing here asks you to discard a measurement. Thomson's ratio stands. Millikan's quantum stands. What is replaced is the inference that was drawn from them.

What we have not modelled

How many G1 particles are in an electron? *Unknown. The model says a bundle; it does not say how big. Nor does it say whether the number is the same every time, which is a sharper question than it looks: if an atom trades a population rather than an object, small variations ought to be possible, and Millikan's result says the charge is the same to many decimal places. Either the arrangement fixes the number exactly, or something else does, and we cannot say which.*

Why is the bundle that size? *Unknown, and it is the same question as Millikan's quantum and as Planck's constant. All three are asking for the number the model has not produced.*

The ratio is not derived. *1836.15 ought to come out of the two populations and the structure holding them. It does not come out of anything here.*

What you can now say

- The electron is a quanta: a population of G1 an atom holds and trades in bundles.
- Thomson measured a ratio and Millikan the size of a bundle; neither shows that the bundle has no parts.
- Atomic weights are not whole numbers because what is weighed is a crowd, and so is the ratio 1836.15.
- An energy level is a size of population, and nothing jumps.

Chapter 14

How an Atom Emits Light

STANDING: DERIVED. *Absorption and emission follow from an atom holding and shedding a population of G1s. The doublet is an open difficulty.*

Strike a match. Run a current through a neon tube. Drop sodium into a flame and watch it burn orange. Light comes out of atoms constantly, and every textbook explains it in two sentences: an electron absorbs energy and jumps to a higher level; later it falls back, and as it falls it emits a photon.

Read that again, because a great deal is hidden in those verbs.

What jumped? An electron is supposed to be a point—no size, no parts, no interior. How does a point move between orbits without crossing the space between? And when it comes back down, where was the photon stored? If the electron has no parts there is nothing in it to let go of, so the photon must be made at the instant of emission, out of nothing, by something.

Ask a physicist and the answer is that the photon is created by an excitation of the electromagnetic field. That is a sentence about bookkeeping. It tells you which number goes up and which goes down. It does not tell you what physically left the atom or where it was a moment earlier.

14.1 The Atom as a Container

Chapter 13 did the necessary demolition: the electron is a population of G1 particles, not a point. Everything in this chapter follows from that one change.

An atom is a container. Not a box with walls, but a region of motion that can hold a certain population in a certain arrangement, set by the G2 gravitic and magnetic fields described in Chapter 12.

Think of a room with a certain number of chairs. There are arrangements it can support and arrangements it cannot, and the ones it can support are

separated by definite differences.

14.2 Absorption Is Taking On More

Here is the piece that makes the model click, and it is almost too simple to state.

The light arriving at an atom is already made of G1 particles. It is groups of them, flying in formation. When that formation reaches an atom, some of those particles are captured by the atom's G2 gravitic motion and swept into the population it already holds.

Nothing jumped. Nothing teleported between orbits. The atom is holding more G1 particles than it was holding a moment ago, and a fuller cloud sits in a wider, differently shaped arrangement because that is what the G2 fields can support with that many particles in them.

That is what an excited state is. Not a particle on a higher rung of an invisible ladder. A larger population.

14.3 Emission Is Letting Them Go

An atom holding more than its stable arrangement wants will sooner or later shed the surplus—jostled by a collision, or simply because that population cannot be sustained.

And it does not shed them as a shapeless spray. They leave the way the G2 magnetic motion was already moving them: together, in step, group after group, in the same direction at the same speed.

Groups of similar particles travelling together at the same speed is the definition of luminic motion. So the moment those G1 particles leave in formation, the atom has emitted light—not because anything was created, but because particles that were orbiting are now streaming.

> The atom never manufactures a photon. It releases particles it was already holding.

Follow the cycle and the books balance without a single act of creation. Particles arrive in a stream, are captured and held, are released, and stream away. What the atom emits is made of exactly the same stuff as what it absorbed, because it *is* the same stuff.

14.4 What an Energy Level Really Is

"The electron is in the second energy level" sounds like a statement about where something is. In this model it is a statement about *how many*: a higher level is a larger population, as an earlier section said. Chapter 13

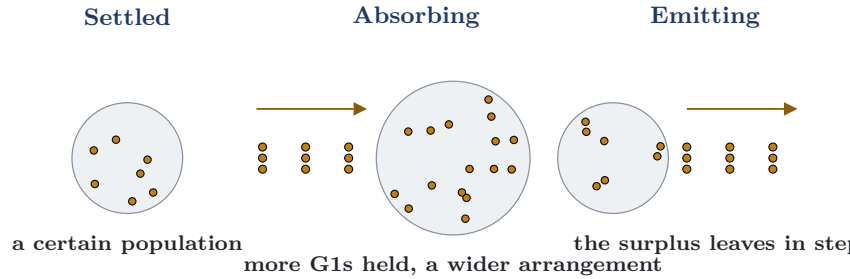


Figure 14.1: An atom as a container. Taking on a formation of G1 particles makes a larger population in a wider arrangement; letting the surplus go sends it away in formation.

disposed of the quantum jump on those terms, and nothing more is needed here except to say what it leaves. The ladder was never a ladder. It was a series of crowd sizes that a room can hold.

14.5 Why the Lines Are Sharp

Heat hydrogen and it does not glow in every colour. It glows in a few precise ones, the same ones every time, anywhere in the universe. This is the observation that forced quantisation into physics, and it is usually presented as a brute fact: energy levels are discrete because they are.

Here the discreteness is structural. An atom's G2 fields form a specific geometry, and that geometry can hold G1 particles in certain stable arrangements and not others—for the same reason a given room has certain seating plans and not others. Going from one stable arrangement to the next always means shedding the same quantity, in the same formation, with the same spacing between groups.

Same spacing, same colour. Every time, in every hydrogen atom that has ever existed.

Change the element and you change the nucleus, which changes the field geometry, which changes the stable arrangements and therefore the spacings that can be released. That is why every element has its own fingerprint of lines, and why the composition of a star can be read from its light.

And it explains a detail that is usually passed over. Spectral lines have *widths*. They are not infinitely sharp, and the widths vary with temperature and pressure in ways spectroscopists use routinely. In this picture that is expected: a release is a crowd leaving, and a crowd leaving under jostling will not have perfectly uniform spacing every time. The line is sharp because the arrangement is definite, and it has a width because the departure is

physical.

14.6 The Dark Lines

It explains the absences too, and this is where absorption and emission meet.

In 1814 Joseph von Fraunhofer, a Bavarian glass and lens maker, turned a prism on sunlight and found the spectrum crossed by hundreds of thin dark lines. He catalogued them, labelled the strongest with letters, and could not say what they were. His "D" line sat at exactly the place where a sodium flame put a bright one, and he noticed the coincidence without being able to explain it.

The explanation came in 1859, when Gustav Kirchhoff and Robert Bunsen established that these lines are chemical signatures—that each element produces its own set and that a dark line in a spectrum means that element lay between you and the light.

In this model the mechanism is the one already described, run in reverse. Shine white light—every spacing at once—through a cool gas, and the atoms capture the formations that match what they are able to hold. Those groups are taken out of the stream and the colour they carried goes missing.

A dark line is not the shadow of something destroyed. It is the record of particles that stopped and stayed.

14.7 An Element Found in the Sun

The strongest evidence that spectra report atomic structure is a story worth telling in full, because it is the sort of thing a model of emission has to be able to account for.

On 18 August 1868, during a total eclipse observed from Guntur in India, Jules Janssen examined the spectrum of the solar prominences and saw a bright yellow line. Norman Lockyer, working independently in England, saw it too. It sat near the two yellow sodium D lines Fraunhofer had catalogued, and it was slightly displaced from both. Lockyer labelled it D_3.

It matched no element known on Earth.

Lockyer and the chemist Edward Frankland proposed that the line belonged to an element not yet found here, and named it helium, after Helios. The suggestion was not universally welcomed—claiming a new element on the strength of one line in the sun was a considerable thing to do.

William Ramsay isolated helium on Earth in 1895, twenty-seven years later.

Think about what that required to be true. A particular arrangement of matter, in the atmosphere of a star ninety-three million miles away, released

particles in a formation with a particular spacing. That spacing survived the journey intact. It arrived, was sorted by a prism, and landed at a position on a photographic plate that no terrestrial substance had ever produced. And twenty-seven years later somebody found the same arrangement of matter in a rock and it made the same line.

Spectra are not a code we have learned to read by correlation. They are a direct report of what atoms are holding.

14.8 Where the Colour Comes From

A single particle cannot have a frequency—Chapter 6 made that case at length. So the colour of emitted light cannot live inside any one G1. It lives in the formation.

And it does. The colour is the spacing between the groups as they fly away. A large release packs the groups tightly together and we see blue and violet. A smaller release spreads them out and we see red.

Wave-particle duality was never a paradox of nature. It was the shadow cast by insisting that a single object carry a property only a procession can have.

14.9 The Problem of the Doublet

One detail in all this is a difficulty for us and we would rather raise it ourselves.

Sodium's D line is not one line. It is two, at 588.995 and 589.592 nanometres—less than six tenths of a nanometre apart, which is a separation of about one part in a thousand. Many elements show such close pairs and triplets, and they are not a curiosity: the pattern of these splittings is one of the most thoroughly measured things in physics.

Quantum mechanics accounts for them with fine structure, attributing the split to an interaction between the electron's spin and its orbital motion.

This model explains why an element produces *discrete* lines—an atom can sit in certain arrangements and not others, and the step between two arrangements is a definite quantity. It does not explain why two arrangements should sit so extraordinarily close together, nor why the pattern of near-pairs is as regular across the periodic table as it is.

Something about the G2 configuration would have to produce pairs of stable states differing by one part in a thousand. That is not obviously impossible—a nucleon's magnetic field has an orientation, and two arrangements differing only in some orientation might well be close in capacity. But this is so far a direction rather than a worked mechanism, and the doublets are waiting on the G2 configuration.

What we have not modelled

This chapter explains why spectral lines are sharp and why each element has its own. It does not yet work out the value of any one of them.

Doing that would mean knowing which arrangements a given nucleus can hold, how many G1 particles each one takes, and how much is shed in going from one to the next. All three are the same unknown, and it is the subject of the next chapter.

What this model gives so far is the structure *of atomic spectra—why they are discrete, why they are elemental fingerprints, why absorption and emission mirror each other. The* values *come when the G2 configuration is worked out. It does not produce the 656.3 nanometres of hydrogen's red line, and it does not produce the six tenths of a nanometre between the sodium doublet. Those two numbers are what the G2 simulations should eventually produce.*

What you can now say

- Absorption is an atom taking on more G1; emission is it letting them go, in formation.
- An atom never manufactures a photon; it releases particles it was already holding.
- Spectral lines are sharp and elemental because an atom can sit in certain arrangements and not others.
- A dark line is a formation that was taken and kept, and the colour of the light is the spacing of the groups.

Chapter 15

The Configuration of the Atom

STANDING: OPEN. *The open edge of the model, collected in one place: what the G2 fields are and how they hold an atom's arrangement.*

This chapter is the open edge of the whole model, collected in one place so that the rest of the book can point at it instead of repeating it. Wherever a chapter has said that a G2 field holds something, shapes something, or pushes something, it has been leaning on what follows.

The short version:

> *The model says what the G2 motions do. It does not yet say how they are arranged.*

Those are different claims, and keeping them apart is the difference between an honest research programme and an overclaim.

15.1 What Is Settled

The model is specific about what the G2 motions *do*, and that specificity is what the rest of the book is built on. None of it is vague and none of it needs charge.

- **G2 gravitic motion holds G1 particles in orbit.** This is what Coulomb's law was describing, which is why Coulomb's equation and Newton's have the same form.
- **Each nucleon carries its own G2 magnetic field**, the way the Earth carries one, and those overlapping fields bend the G1 orbits into the S, P, D and F shapes.

- **A steady stream of G2 particles is the F2 force**—what a circuit calls voltage.
- **In a lattice, the nuclei's wells form gravity tubes** that guide G1 particles through the metal.
- And we can say what they are *in kind*: particles, moving. Nothing else.

15.2 What Is Not Settled

What cannot be written down is the arrangement. Every one of these is open.

- How G2 particles are distributed around a single nucleon, and what their paths look like.
- How the fields of two nucleons combine—and of ninety-two.
- Which geometries are stable and which fly apart.
- How many G1 particles a given arrangement can hold, which is what shell capacities are.
- Why those numbers and those spacings rather than others.

The roles are specified. The structure is not.

That is why every drawing of a G2 field in this book is a symbol rather than a measurement.

15.3 Where the Gap Shows Up

A great deal rests on it. The list is long, and we would rather print it than have it discovered.

Chapters 14 and 13 depend on which arrangements are stable and how many particles each can hold. Chapter 17 identifies the electric field as G2 motion without being able to draw it. Chapters 16, 20 and the account of current all lean on the F2 force and on gravity tubes that are named rather than drawn. The chapters on diffraction and the pinhole camera turn on a strong G2 field at an edge whose structure has not been written down.

None of those chapters is waiting on this to be *true*. They are waiting on it to be *detailed*. The difference matters: a model that names a mechanism and cannot yet draw it is in a different position from one that names a number and cannot explain it.

15.4 Why There Is an Answer to Find

It would be easy to read that list as a confession that the model does not know what it is doing. It is closer to the opposite, and the reason is worth stating carefully.

The four universal motions are not four phenomena that happen to have been noticed. They are a complete vocabulary of motion for bodies of one kind: random is gravitic, orbits are magnetic, flows are electric, groups travelling together are luminic. The claim of this work is that all fundamental forces can be described by combinations of these four, at every scale, with every force reduced to physical collisions.

If that holds, the model has the character of a **physical Turing machine**. A Turing machine has a tiny fixed instruction set—move, read, write—and the reason it matters is that combinations of those few operations can express any computation that can be carried out at all. The four motions are the same kind of thing in matter rather than mathematics: a small fixed set of ways for bodies to move, whose combinations can build any physical condition that can exist.

That changes what the configuration problem *is*. It is not a mystery about whether an answer exists.

> The answer is already inside the vocabulary. Some arrangement of G2 particles in motion produces the orbitals we measure, and nothing outside the four motions has to be added to describe it. What is left is to find which arrangement it is.

A search is work. It is not magic and it is not a hole in the theory. It is the ordinary situation of knowing the alphabet and not yet knowing the word.

This also explains why nothing new may be introduced to close the gap. Whenever a model reaches for a fresh fundamental object—a charge, a field as a substance, a force carrier—it is admitting its vocabulary was incomplete. The four motions do not get to do that. If the configuration of the atom cannot be built out of particles moving in these four ways, the problem is not a missing ingredient. The arrangement being tried is the wrong one, and the search goes on among the arrangements the four motions allow.

15.5 Why Every Diagram Here Is a Symbol

One consequence is worth stating in its own right, because readers reasonably assume that a drawing in a physics book is a claim about shape.

The Earth-like dipole we draw beside each nucleon says *there is a field here and it has poles*. It does not claim the field is that shape, that size, or that orientation. We draw it that way because it is the most familiar

picture of a dipole and because the alternative—drawing nothing—would leave readers with no picture at all.

That is a real cost of being honest about this gap. A model whose selling point is that everything can be visualised has, at its centre, something it cannot draw. We would rather print that sentence than let a diagram quietly overclaim.

15.6 What Success Would Have to Look Like

"Produce the orbitals" is too loose to be a target. A simulation can produce lobed clouds and still be worthless. So here is what would actually count, in descending order of difficulty.

The shapes. Spherical for s, dumbbell for p, clover for d, and the more complicated f arrangements. Those are not arbitrary pictures; they are what the measurements say, and a G2 configuration that produced spheres and nothing else would have failed.

The capacities. An s arrangement holds two, p holds six, d holds ten, f holds fourteen. Those numbers run $2, 6, 10, 14$, and the shells they build run $2, 8, 18, 32$. Quantum mechanics obtains them from the rules governing its quantum numbers. We would have to obtain them from geometry—from how many G1 particles a given arrangement of nucleon dipoles can hold before it stops being stable.

If a simulation returns anything close to those numbers without having been told them, that is a result worth a great deal, because the whole of chemistry is built on them. If it returns capacities of four and nine, then that arrangement of nucleon dipoles is not the right one, and the search goes on in the G2 geometry.

The order. Shells fill in a particular sequence, and it is not the obvious one—4s before 3d, which is why the transition metals sit where they do in the periodic table. A configuration account that got the shapes and the capacities right and the filling order wrong would still be missing something real.

15.7 A Word About What We Lean On

Since this is the chapter for admissions, here is one about our own sources.

Chapter 12 credits Jeff Yee, whose simulations of electron clouds persuaded David de Hilster that structures of this kind can emerge from a model with no charge in it. That is the single most important precedent we cite for the central claim of this chapter.

We should be straightforward about its standing. Yee's work is largely self-published, it has not been through peer review, and we are not aware of an independent replication of what his simulations produce. We are

reporting the effect it had on us, which is a fact about us rather than a verified fact about nature.

That is not a criticism of him—almost everyone in this book's acknowledgements publishes outside the usual channels, ourselves included, and we are hardly in a position to make it a disqualification. It is a statement about how much weight a reader should put on it, which is less than the weight we have historically put on it ourselves.

The programme described below would settle the question independently, which is the proper response to a precedent one cannot check.

15.8 How to Close It

Not with more force equations fitted to data. Fitting a curve to a measurement produces a description, and the complaint this book makes about mainstream physics is that a description has been allowed to stand in for an explanation. Doing the same thing one level down would be no better.

The way to close it is **physical model simulation**, in which the particles themselves are the model. Give a simulation real G1 particles, real G2 motions, and nothing else. Let it run. Find out which configurations hold together and which fly apart.

Some of the apparatus exists. Jeff Yee's simulations of electron clouds were the first sign that such clouds can emerge from a model with no charge in it anywhere. Our own copper-lattice simulation is already the right kind of tool—real particles under the pull of 1,200 real nuclei, with no artificial cutoffs. What is needed is to point that kind of simulation at the G2 level and let it answer the questions above directly.

15.9 It Can Fail

Completeness cuts both ways, and this has to be said plainly.

That the vocabulary *can* express an arrangement is no guarantee that the arrangement a simulation finds is the one nature uses—a universal machine computes wrong answers perfectly well. So the programme can fail. A simulation given nothing but particles and motion might produce no stable configurations at all. It might produce configurations that look nothing like the orbitals we measure. It might reproduce the shapes and get the capacities wrong, or get the capacities right and the spacings wrong.

Any of those would mean that arrangement is not the one nature uses, and the search would continue with another. That is exactly what makes the programme worth running. It is the difference between an open problem and an excuse.

> We can say what the G2 fields do. We cannot yet say what they look like. Saying so is not a weakness of the model; pretending

otherwise would be.

What you can now say

- The G2 motions are specified in what they do and not yet in how they are arranged.
- The answer is already inside the four motions, so what is left is a search, not a mystery.
- Every diagram of a G2 field is a symbol and not a measurement.
- The way to close the gap is physical model simulation, with nothing in the box but particles and motion.

Chapter 16

Induction: What Crosses the Gap

STANDING: DERIVED. *Induction follows from a wire's own population being relocated by changing traffic. Lenz's law is the Dinu effect.*

In 1831 Michael Faraday wound a coil of wire, connected it to a needle that could show a current, and pushed a bar magnet into it. Nothing was touching. Nothing was connected. The needle swung.

Then he stopped pushing and left the magnet sitting inside the coil, and the needle fell back to zero—with the magnet still there, as magnetic as ever. He pulled it out and the needle swung the other way.

Every power station on Earth runs on that trick. So does every transformer on every pole and the charger your phone sits on. And the explanation offered is a sentence: *a changing magnetic field induces an electromotive force in the conductor.*

That sentence names what happens with great precision and says nothing about what occurs. Three questions it will not answer. What crossed the gap? Why must it be moving—why is a perfectly good stationary field worth nothing? And why does the coil push back?

16.1 A Magnet Is a River

Start with what is actually in the room. As Chapter 8 set out, a magnetic field is G1 particles caught in orbits, and around a magnet those orbits run far outside the metal—out at one pole, around through the space beside it, back in at the other.

The lines drawn around a magnet in every textbook are the streamlines of real traffic. There is no condition of space. Something is physically going past.

16.2 A Wire Is a Pipe That Is Already Full

The second half of the picture is the wire, and Chapter 9 has it: a lattice of nuclei whose wells form channels, with a bound cloud of G1 particles already drifting through them.

So the wire does not need to be given particles. Induction never has to create a current out of nothing. It only has to persuade a population that is already there to move.

16.3 Current and Field Are One Motion

Here is the piece that makes induction mechanical rather than magical, and it has already been said twice in this book from the other direction.

When G1 particles are driven through a conductor, some are guided along inside it and some spiral around the outside. The part that advances is what we name *current*. The part that circles is what we name *the magnetic field*. They were never two phenomena linked by a law. They are one helical motion, named twice.

Push current along a wire and a field wraps around it—that is Ampère's law, and the four motions say why. And it hands you the converse for free:

> **Push on the part that circles the wire, and particles advance along it.**

That converse is induction.

16.4 Why Nothing Happens Unless Something Moves

Now the question that defeats the field account. Why does a magnet sitting still in a coil do nothing at all?

Think of two tanks of water joined by a pipe at the bottom. While one side is higher than the other, water moves. Once the levels match, it stops—and notice that nothing has gone away. All the water is still there, the pipe is still open. What ended was not the water but the *difference*.

A wire's G1 population behaves the same way. How its helical traffic sits—how many are circling, how fast, how far out—has a settled arrangement, and that arrangement depends on how much outside traffic is threading through the coil. Bring a magnet near and you change what the settled arrangement *is*. While the coil's particles are relocating toward the new arrangement they are moving along the wire, and that movement is the current.

Hold the magnet still and the coil reaches its new arrangement. Relocation finishes. The needle drops to zero with the magnet still sitting

there—not because the magnet stopped doing anything, but because the levels matched.

A current is not a state. It is a population on its way somewhere.

16.5 The Whole Thing, Step by Step

Push a magnet into a coil and here is the sequence, with nothing in it but particles and motion.

1. The magnet's river of orbiting G1 particles threads through the loop of wire.
2. Moving the magnet changes how much of that traffic is threading it, moment by moment.
3. The coil's own helical population is now sitting in the wrong arrangement for the traffic it finds itself in—an imbalance, the same kind the battery and capacitor chapters call voltage.
4. The imbalance relieves itself the only way the lattice allows: G1 particles shift around the loop.
5. Because circling and advancing are one helical motion, shifting around the loop *is* moving along the wire. The needle swings.
6. Stop moving the magnet and the arrangement settles. The shifting ends. The needle returns to zero.

Nothing was induced into existence. Nothing acted at a distance. A population that was already in the wire moved, because particles that were already around the magnet came through and changed what it would take for that population to sit still.

16.6 Lenz's Law Is the Dinu Effect

The induced current always runs the way that opposes what you are doing. Push the magnet in and the coil pushes back; pull it out and the coil tries to hold on. In the standard account this is Lenz's law, usually justified by saying that otherwise you would get energy for nothing—a true statement that explains nothing about the mechanism.

Here it is not a separate law at all. The coil's induced flow is a circulation. The magnet's aligned orbits are a circulation. Two circulations have met, and the rule for what two meeting circulations do was set out in Chapter 8: same rotation repels, opposite rotation attracts.

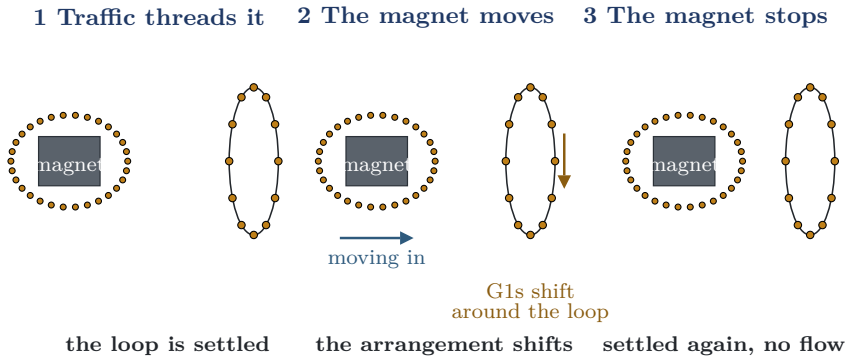


Figure 16.1: A magnet moving past a loop, in three frames. Only while the magnet moves does the arrangement change and the particles shift around the loop.

Approach, and the arrangement the coil relocates into is the one that opposes you. Withdraw, and the relocation runs backwards and the coil tries to hold on. The famous opposition is the Dinu rule, read off a diagram we already had.

16.7 Why a Transformer Needs AC

Put two coils on one iron core and the model predicts a transformer without an equation.

Connect a battery to the primary and you get a steady river through the core. The secondary settles into its new arrangement almost at once and then does nothing, forever, while the battery goes on supplying current. Hook a lamp to it and the lamp stays dark—except at the instant you close or open the switch, because that is the only moment anything changes. Which is exactly what a transformer connected to DC actually does.

Connect an alternating source and the river reverses dozens of times a second. The secondary is never given time to finish settling, so its particles are always relocating, so current flows the whole time.

Two details come free. **The turns ratio:** the same sweeping traffic acts on however much wire you give it, so ten times the turns is ten times the population being relocated. **The iron core:** iron's atoms carry orbits that can be aligned, which makes iron a bundle of ready-made gravity tubes. It does not concentrate a field—it gives the traffic a good road.

16.8 The Spark When You Break the Circuit

Switch a coil on and the current does not arrive all at once; it climbs. The model says why. The arriving G1 particles have to populate the coil's own circulation before many of them get all the way through—the coil is filling its orbits, and what is left over is the current you measure. That slow climb is inductance.

Now switch it off, and you get the effect everyone who has built a relay circuit has been bitten by: a fat blue spark across the opening contacts, at a voltage far above anything the battery could supply.

In the standard account the collapsing field induces a large back-EMF, which is a correct description and names no mechanism. Here it is a traffic problem. The coil is holding a large circulating population, maintained by the current. Break the circuit and the road those particles were using is gone—but the population is still there and still moving, and it has nowhere to go.

So it goes across the gap. The spark is a real crowd of real particles forced out of a channel that has just been removed, and its violence is proportional to how many were circulating, which is why a big inductor bites harder than a small one. It is also why the standard fix works: put a diode across the coil and you give the population somewhere to go, and the spark stops.

16.9 What Else Falls Out

The same picture accounts for a handful of things that are usually taught as separate subjects.

A magnet falls slowly down a copper pipe. No circuit is needed. The lattice channels let G1 particles drift in closed loops in the solid wall. Those loops are circulations, turning the same way as the approaching magnet's, so they repel it. The drag you see is particles dragging on particles.

An induction cooktop heats the pan and not the air. The same loops, driven hard, in a metal that resists their relocation.

Magnetic shielding. A box of mu-metal does not block a field. It offers better channels, and the traffic takes the better road, round the box and not through it.

Wireless charging. The pad's coil drives a circulation that reaches past itself, the phone's coil sits inside that traffic, and G1 particles physically arrive. Chapter 21 takes this up.

A generator. Spinning a coil in a magnet's river keeps the threading traffic permanently changing, so the population never settles. The work you put in is spent against the Dinu repulsion, which is why a generator gets harder to turn the moment a load is switched on.

A persistent current in a superconductor is a circulation that never has to settle again, because nothing in the lattice is taking particles out of it, and the Meissner effect is that surface circulation refusing the incoming river: same sense, repelled. This is a direction to work out, not a worked result.

Faraday had no theory when he pushed that magnet into that coil. He had a thing he could do with his hands and a needle that moved. Nearly two centuries later the equation describing it is in every textbook and the question he actually asked—what crosses the gap—is in none of them.

Particles are going across. They were in orbit around the magnet, and when you moved it they changed what the wire's own particles would have to do in order to sit still.

What we have not modelled

The direction has to be derived, not assumed. *Everything above rests on the claim that when threading traffic increases, the coil's population relocates into the arrangement that opposes it. That is Lenz's law restated in our vocabulary, and it ought to* follow *from the Dinu rule rather than be asserted alongside it.*

The numbers are still to come. *This model says why a rate of change matters: a population relocates while it settles. How much it relocates, and how fast, come out of a count of particles in a real lattice, and the simulation below is how they will be found.*

The experiment that would settle it *is within reach: the copper-lattice simulation, with an external orbiting population added and the ability to move it. Does a net drift appear along the wire when it sweeps past? Does the drift reverse when the sweep reverses? Does it stop when the sweep stops, while the population is still sitting there? And does the circulation it creates run the way that opposes the approach? Those four checks are Faraday's induction, the reversal, the requirement for change, and Lenz's law.*

What you can now say

- What crosses the gap is G1 in orbit around the magnet, meeting the G1 already in the wire.
- Current and magnetic field are one helical motion named twice, so driving the one drives the other.
- Change is needed because current is a population on its way to a new arrangement, and it stops when it arrives.
- Lenz's law is the Dinu effect, a transformer needs AC to keep the population from settling, and the spark is a crowd with nowhere to go.

Chapter 17

Fields: What Is in the Room, Again

STANDING: FRAMING. *What a field is in this model, and what a field-line map records. The standing of the mechanisms is that of Chapters 8 and 16.*

Every textbook prints the picture: two sine waves threading down an axis, one electric and one magnetic, riding perpendicular to each other through empty space. It is one of the most reproduced images in physics and it is sold as a picture of what light is.

It is a graph of a mathematical relationship dressed up as a physical object.

17.1 What Maxwell Actually Did

Maxwell's achievement was real but not the one he is usually credited with. He took the experimental relationships Faraday and Ampère had uncovered and wrote them down as a tightly connected set of equations. That much is solid.

Then he noticed that the constants in those equations, combined, produced a velocity—and that the velocity was the speed of light. From that coincidence of numbers he made a leap: light itself must be an electromagnetic disturbance.

That leap is the problem. He did not unify electricity, magnetism and light by explaining what they are. He unified the force equations and extrapolated a physical wave out of a numerical match. The famous picture is what you get when you plot the variables of that extrapolation onto coordinate axes, and axes are bookkeeping, not substance.

17.2 What Maxwell Actually Built

Chapter 3 told this briefly. Here is the detail, and it is worth the space—because *On Physical Lines of Force*, published across four parts of the *Philosophical Magazine* in 1861 and 1862, is a stranger and more sympathetic document than its reputation suggests.

Maxwell filled space with rotating vortex cells, and between each pair of cells he placed a layer of small particles, borrowing a term from engineering:

> *In mechanism, when two wheels are intended to revolve in the same direction, a wheel is placed between them so as to be in gear with both, and this wheel is called an "idle wheel."*

The vortices were magnetism. And the particles between them were not a bookkeeping device. He says what they are:

> *These particles, in our theory, play the part of electricity. Their motion of translation constitutes an electric current...*

And in Part III, more plainly still:

> *According to our theory, the particles which form the partitions between the cells constitute the matter of electricity.*

The matter of electricity. Not a field, not a quantity—matter. A reader of this book will recognise how close that is to the thing we are arguing, and it was written in 1862.

From that machinery he obtained the velocity of transverse waves in his medium, and compared it with Fizeau's optical measurement:

> *The velocity of transverse undulations in our hypothetical medium, calculated from the electro-magnetic experiments of MM. Kohlrausch and Weber, agrees so exactly with the velocity of light calculated from the optical experiments of M. Fizeau, that we can scarcely avoid the inference that light consists in the transverse undulations of the same medium...*

17.3 And What He Said About It

Now the passage that matters most, and which we had been paraphrasing from memory until we went and read it.

> *The conception of a particle having its motion connected with that of a vortex by perfect rolling contact may appear somewhat awkward. I do not bring it forward as a mode of connexion existing in nature, or even as that which I would willingly assent*

> *to as an electrical hypothesis. It is, however, a mode of connexion which is mechanically conceivable, and easily investigated, and it serves to bring out the actual mechanical connexions between the known electro-magnetic phenomena; so that I venture to say that any one who understands the provisional and temporary character of this hypothesis, will find himself rather helped than hindered by it...*

I do not bring it forward as a mode of connexion existing in nature.

He is not being evasive. He is being scrupulous, and the whole paper is like this. Elsewhere he writes that he assumed something "perfectly arbitrarily"; that he had "found great difficulty in conceiving of the existence of vortices in a medium, side by side, revolving in the same direction"; that his answers are offered "by way of provisional answer". A man who did not care about the difference between a working picture and a claim about the world does not write sentences like those.

So the charge this book makes is not that Maxwell was careless. It is narrower. He built a mechanism out of named parts, said outright that he was not claiming those parts existed, got the speed of light out of it—and then, by 1864, dropped the machinery and kept the equations. What the stuff actually is went with the machinery.

17.4 The Questions the Picture Cannot Answer

Treat the diagram as a literal claim and the cracks appear at once.

What is each field made of? The electric field oscillates "up". In what medium? Out of what material? The picture labels two planes and colours them and never says what is being displaced. A wave is a disturbance in something. Name the something.

How do the two travel together? Two fields of unspecified material, bolted at right angles, moving in lockstep forever. As a physical arrangement this is a mystery wearing the costume of an answer.

How do countless rays share the same space? Light from every star, every lamp and every reflecting surface is crossing the room you are in, from all directions, without colliding or scrambling. The diagram shows one tidy ray on a clean axis. Reality has uncountably many, overlapping in every orientation.

17.5 Two Fields, One Level Apart

Before replacing them, it is worth seeing how oddly matched the two fields in that picture are.

They are drawn as equals: perpendicular partners of the same standing, each generating the other, locked together for ever. But ask what each is supposed to act on and the symmetry breaks immediately. The electric field acts on charge. The magnetic field acts on *moving* charge, at right angles to its motion—a force whose direction is given by a rule about which way your fingers point. Nothing in the picture explains why one of the two should care about motion and the other should not, or why the force should come out sideways.

In this model they are not partners at all. They are one level apart, and the asymmetry is exactly what you would expect.

17.6 What Is Actually There

The four universal motions replace both fields with motion.

The magnetic field is G1 particles in orbit, and nothing else. Chapter 8 made that case. The arcs the iron filings lie along are the streamlines of real traffic.

The electric field is G2 motion, in two patterns. Random G2 motion is the attraction Coulomb measured—gravity one level down, by shadowing. A steady stream of G2 particles is the F2 force, the push that drives G1 particles along a wire and that a meter reads as voltage.

So the two fields are not perpendicular partners of equal standing. They are *one level apart*: G1 particles orbiting at our scale, G2 particles raining and streaming one level below.

And light is neither of them. Light is G1 particles in formation, which is a third thing again, and the reason the textbook picture had to bolt two fields together to make it is that neither field was ever what light is made of.

And the sideways force stops being strange. A moving G1 meeting a region of circulating G1 particles is traffic meeting traffic. What happens depends on how the two flows are oriented where they meet—which is the Dinu rule again, and rules about meeting circulations naturally produce results at right angles to both. The right-hand rule is a mnemonic for a geometry, and the geometry is two streams crossing.

17.7 A Weather Map Is Not the Weather

Look at a weather map. The isobars curve across the country, bunched where it is windy and spread where it is calm. You can point at them, and you can predict a storm from them. Nobody has ever suggested that an

isobar is pushing the air. The lines are a drawing of what the air is doing, and the air is the thing that exists.

Ask what an electric field is and the same kind of drawing is handed back as the answer. A field is a quantity defined at every point in space: a number or an arrow assigned to each place, telling you the force a test object would feel if it were there. That is a map, and an extraordinarily good one. But at some point the map stopped being a description of something and became the something. The field is now said to carry energy, carry momentum, push on charges and propagate through empty space, and nobody says what it is made of.

Ask directly and there are two answers. Either the field is "a fundamental entity", which means the asking has stopped, or it is "an excitation of the vacuum", which pushes the question down a level and leaves it there. Neither says what is in the room.

Something is in the room. It is just not a field.

17.8 Field Lines Are a Record

Faraday drew lines of force as a way of recording what he observed. He was explicit that they were a representation.

What the filings report is the direction of traffic. Each filing is a small magnet with its own orbiting population, so it turns to lie along the flow. The pattern is a record of what is moving. It was never the cause of the movement.

The habit of treating the lines as the thing itself came later, and it is the move this book keeps objecting to: a description so good that nobody asked what it described.

17.9 Charge Had Nothing Left to Do

If the electric field is G2 gravitic motion, then charge—the property the field is supposed to act on—has nothing to do.

And it never had a physical description. Ask what charge is and you get a list of what it does. As Chapter 10 set out, negative, neutral and positive are three counts of one thing: how many G1 particles an object holds against the number it settles at.

17.10 One Helix, Two Names

Chapters 9 and 16 said it already: a G1 driven along a wire travels a helix, and the forward part is what we call current while the circling part is what we call the magnetic field. They are not coupled. They are one motion with two names, which is why driving either one drives the other.

17.11 What Stays

None of this touches the equations. Maxwell's relationships stay exactly as accurate tomorrow as they were yesterday, and so do Coulomb's and Faraday's. What is replaced is the claim that the symbols in them name substances.

Not a field. Particles, going past.

What we have not modelled

No physical description of the G2 fields. *This chapter identifies the electric field as G2 motion and can say what that motion does. It cannot draw it. See Chapter 15.*

Like repelling like needs working through. *Random flow produces attraction by shadowing, which is how gravitic motion works and gives us Coulomb's pull. Two surpluses pushing* apart *is attributed to their orbiting populations meeting in the same sense. That is a magnetic answer to an electrostatic question and it needs demonstrating.*

Nothing is quantitative. *Coulomb's constant, the permittivity and permeability of free space, and the fact that those two combine to give the speed of light, are all unexplained here. That last one is particularly pointed: it is the coincidence Maxwell leapt from, and a model claiming one particle behind all of it ought eventually to say why those constants are related in that way.*

What you can now say

- The textbook picture of light as two perpendicular waves is a graph of a relationship, not a thing in the room.
- Maxwell built a mechanism, said he was not claiming it existed, and then kept the equations.
- The magnetic field is G1 in orbit and the electric field is G2 motion; they are one level apart, and light is neither.
- Field lines are a record of traffic, and charge has nothing left to do.

Chapter 18

Diffraction and the Double Slit

STANDING: PROPOSED. *The double slit is not solved. This is an explicit proposal, with its weak joints named.*

> *This chapter is an attempt, not a result. The double slit is one of the places where the four motions have not been worked out, and both authors have taken runs at it without being satisfied. What follows is a first pass, built only out of what the model already commits to, with its weak joints listed at the end rather than buried.*

Cut two narrow slits in a card and send light through them at a wall. You do not get two bright lines. You get a row of bright and dark bands, far wider than the slits, in a rhythm you can measure with a ruler.

Thomas Young did this in 1803 and it was taken as proof that light is a wave. The twentieth century then made it strange in three steps. Turn the source down until it is supposed to be releasing one photon at a time, and the bands still appear—built up dot by dot. Do it with electrons and the same thing happens. Put a detector at one slit to see which one each particle went through, and the bands vanish; remove it and they come back.

18.1 The Question Nobody Asks First

Before asking what happened at the slits, ask something earlier.

> What, physically, was sent?

The standard account is that each particle goes through both slits as a wave of probability, interferes with itself, and is collapsed to a single place

by the act of measurement. Ask what a probability is made of, such that a card can bend it, and you are told that the question is a category error: the mathematics predicts the fringes to many decimal places and that is all there is to say. That is a defensible position for a working physicist and a poor one for anyone who wants to know what the world is made of.

The whole paradox is loaded into the answer normally assumed without comment: *one indivisible particle*. If one indivisible thing travels toward two gaps then of course the experiment is impossible, and every strange device in the standard story exists to rescue that opening assumption.

The four universal motions never make it, and did not avoid it in order to solve this problem. Light was ruled out as a single particle years earlier, on separate grounds, in Chapter 6. And the electron was ruled out as a point in Chapter 13.

So what approaches the card is a procession of groups, spread across a region far wider than the gap between two slits. Part goes through one slit, part through the other. Nothing was in two places, because nothing was ever one place to begin with.

That disposes of the headline mystery and almost nothing else.

18.2 Why Anything Changes Direction at All

A fair objection comes first. If the procession travels in a straight line and nothing acts on it, each half carries straight on, the two never meet, and there are no fringes. Something has to spread them.

Only one thing can turn a G1: mass. A slit edge is made of atoms, and beside a sharp boundary of mass the G2 field is strong and its gradient steepest. This is David de Hilster's conjecture from the first attempt on the problem—that G1 particles passing near the edges of a slit are deflected by the strong G2 field there—and it carries more of the load than anything else in this account.

Two details decide everything. **The pull is toward the mass**, so a particle skimming the upper rim is drawn up and one skimming the lower rim is drawn down: a slit fans its traffic outward both ways rather than aiming it. Particles down the middle pass far from both rims and carry on straight, which is why a single slit gives a strong beam straight ahead with weaker spreading to either side—the envelope, arrived at as a cause.

And a G2 field is *random*, as all gravitic motion is. The rim does not steer each particle along one calculated arc; it strikes them at random as they pass. That randomness is in **direction**, not in **timing**: nothing stops a particle and holds it, so it still arrives when a particle on that path would arrive. Hold on to that distinction—it decides the detector question later.

Without the fan the two halves never overlap and there is no pattern at all, which is why the experiment is done with narrow slits.

18.3 Nose to Nose, or Nose to Tail

Now the real problem. Two half-processions reach the wall having covered slightly different distances. Why a rhythm of bright and dark rather than one bright smudge?

Because a procession has a rhythm already. The groups are spaced, and the spacing is a real length. Call it s.

Take one spot on the wall. Only two things can happen.

The path difference is a whole number of spacings. Groups from one slit land on top of groups from the other—nose to nose. What arrives is a procession at spacing s, at full strength.

The path difference is half a spacing. Groups land in each other's gaps—nose to tail. What arrives is half-strength groups at spacing $s/2$: the wrong rhythm and half the density.

Notice the condition for the first: path difference equal to a whole number of spacings. That is the standard fringe formula, arrived at without a wave. What has changed is that *wavelength* is no longer the period of an abstract oscillation. It is the gap between two real clumps of real particles.

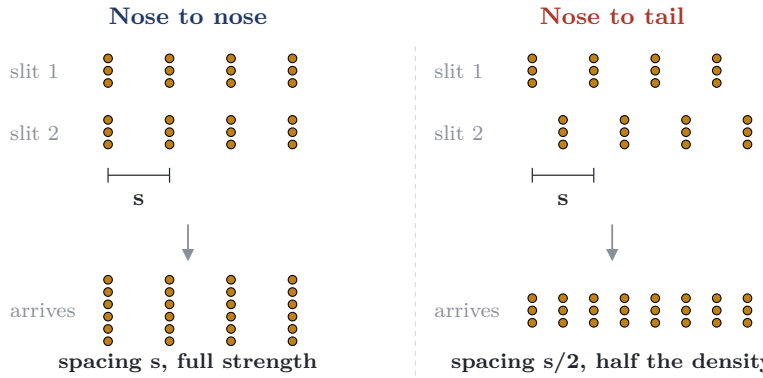


Figure 18.1: The two ways two half-processions can meet at a spot on the wall. A whole number of spacings puts groups on groups; half a spacing puts groups in each other's gaps.

18.4 Two Effects, Two Causes

Look closely at a real double-slit pattern and it is not a uniform row of equal bands. It is a set of sharp fringes sitting underneath a broad hump: bright in the middle, dying away at the edges. Standard optics calls this the single-slit envelope and obtains it from a second, separate calculation.

The model needs two causes for that, and it has two.

The fringes come from the spacing of the procession. They are about timing—whether groups arrive nose to nose or nose to tail.

The envelope comes from the slit edges. Particles passing close to a rim are deflected and particles passing well clear are not, which fans each half-procession out, strongly in the middle and weakly to the sides. That is about geometry, and it has nothing to do with rhythm.

Two phenomena, two separate physical causes, matching the two separate terms that optics has always needed. That is worth something, and it is the part of this chapter we are most confident in.

18.5 Why the Dark Bands Are Dark

This is where a particle model has to earn its keep and where this one is most exposed. Particles cannot cancel. Whatever went in is still there.

The answer the model already has is that a wall does not detect particles—it absorbs *formations*. That is the mechanism of Chapter 14, put there to explain the dark lines in a stellar spectrum.

At a bright band, what arrives is a full-strength procession at spacing s: exactly the formation the screen's atoms can take. It is absorbed and a dot appears. At a dark band, what arrives is half-strength groups at spacing $s/2$. Wrong rhythm, wrong density, not taken.

Nothing was destroyed. The particles still went to the dark band; they arrived in a formation the detector cannot accept. Dark is a fact about the receiver.

That is a real claim and it can be killed. It says the dark bands are still being struck, and that the energy has to go somewhere. A measurement showing a dark fringe receives nothing whatever would take this apart.

18.6 One at a Time

Turn the source down so only one thing is in the apparatus at a time. Each arrival is a single dot, and the fringes build up anyway. The standard reading is that each particle interfered with itself.

Here the premise is false. **You cannot send one particle.** The smallest thing a source can release is a release—a quanta leaving in formation. Turning the source down does not make the released object smaller; it makes the releases rarer.

So one quanta goes through, spread across both slits, and lands as one dot. Why one dot, if a whole population arrived?

Because **the dot is quantised by the atom that absorbs it, not by the thing that travelled**. An atom takes up a formation or it does not. One absorption, one dot. The arriving quanta was extended; the record it leaves is a point, because the recording medium is made of atoms and an

atom is a yes-or-no device.

And a faint release is a small population. Passing the slits, those few are struck at random by the G2 particles crowding the edge, and the kicks scatter them across the fan. A single faint release does not march straight ahead; its handful of particles fan out over the whole region where the pattern will appear, and wherever enough arrive together in a formation the detector can take, that spot fires.

Be blunt about what a photo detector is here. It registers when it takes up a quanta of G1 particles. **That quanta is exactly what is being called a photon.** The instrument was never detecting an indivisible particle of light; it was detecting the smallest bundle it can absorb, and the bundle was named after the threshold of the instrument.

So the build-up has two causes working together. The random G2 kicks decide *where a release can land*. The nose-to-nose condition decides *where a landing can be recorded*. Scatter, then select.

18.7 Why Watching Breaks It

Put a detector at one slit and the fringes die. In the standard telling this is where physics becomes philosophy.

Here it is dull, which is the point. A detector cannot register a formation without *taking* it. There is no reading without absorbing, and absorbing is the end of that formation's flight. Whatever continues is a fresh release, timed by the detector, with no inherited relationship to the half that went through the other slit. Nose to nose and nose to tail both require the two halves to keep time. Destroy the timing and you destroy the alternation.

Recall the distinction from earlier: the rim is random in direction, which spreads the traffic without touching the rhythm. A detector is random in *timing*, which is the other thing entirely.

And there is a second reason, harder to get around. **A detector is made of the same four motions as the experiment.** It is matter, so it is nucleons, so it carries G2 fields of its own—and putting it at a slit places those fields exactly where the slit's own G2 landscape does its work. You have not inspected the apparatus. You have rebuilt it.

A detector also registers light by taking up G1 particles. The thing it uses to detect is the thing it is detecting. There is no neutral probe available, because there is nothing to make one out of except the particles already in the experiment.

So "measurement disturbs the system" is not a principle discovered in the 1920s and not a statement about observers. It is a statement about construction. **There is no such thing as a detector that does not affect the experiment**—not because nature forbids it, but because there is nothing to build one out of that is not already part of the experiment.

18.8 Electrons Do It for the Same Reason

Fire electrons at the slits and the fringes come back. For mainstream physics this is where the problem becomes universal, because matter itself has to be a wave.

Here nothing new is required. An electron beam is a stream of released quanta of G1 particles. The quanta is wide, it meets both slits, and the halves arrive in step or out of step as before. The electron's so-called wavelength is the spacing of the groups within the release.

It even runs the right way qualitatively: accelerate the electrons harder and the fringes tighten, which says a harder-driven release packs its groups more closely—the same statement as the spacing-is-colour rule.

18.9 What This Buys

- No superposition. Nothing is in two places; a wide thing covers two gaps.
- No self-interference. Two halves of one procession meet, which is an ordinary thing for traffic to do.
- No collapse and no observer. Measuring means taking, and taking ends a formation.
- Wavelength becomes a length. The fringe formula survives intact with a physical referent underneath it.
- The fringes and the envelope get two different causes, as the mathematics has always quietly required.
- Light and electrons need one explanation instead of two, because in this model they were never different in kind.

  The experiment never showed that one thing went through two slits. It showed that whatever went through was wider than the card.

What we have not modelled

The dark band is the weakest joint. *Everything turns on a screen atom refusing a formation of the wrong spacing and half the density. The model needs a real account of what an atom will and will not take, and does not have one.*

Half spacing ought to mean a different colour. *If spacing is colour, the formation arriving at a dark band is light of half the wavelength. That is a strange and strong prediction. Either something stops it being absorbed as such, or this part of the account is rebuilt.*

Planck's constant is not derived. *A harder-driven release packing its groups tighter is the right shape for the de Broglie relation and is not that relation.*

The spread is not calculated. *The G2 gradient at the rim gives the fan and therefore the envelope, and nobody has said by how much.*

Prism and edge bend colours opposite ways. *In a prism violet deviates more than red; at an edge red spreads more than violet. If a G2 gradient does both jobs, the model owes an account of why passing* through *mass and passing* by *it sort the spacings in opposite senses. We do not have it.*

What you can now say

- This is an attempt, not a result, and its weak joints are named.
- What is sent is a wide procession, not one indivisible particle, so nothing is in two places.
- The fringes come from the spacing of the procession and the envelope from the slit edges: two effects with two causes.
- A detector cannot register a formation without taking it, so watching changes the experiment.

Chapter 19

The Pinhole Camera

STANDING: PROPOSED. *The sweet spot is derived from the model's own account of the hole's rim. It makes a testable claim (Chapter 25).*

Take a sealed box and make a small hole in one wall. On the opposite wall, upside down and surprisingly sharp, you get a picture of whatever is outside.

No lens. No glass of any kind. Nothing to focus or align. Mozi described it in China in the fifth century BC and Alhazen studied it carefully around 1020. It is the plainest optical instrument that exists, which is what makes it useful: whatever light is, the pinhole is light doing its job with nothing in the way.

A model that cannot explain a hole in a box is not a model of light.

This chapter is the control experiment for the last one. Same apparatus, one hole instead of two—and here the model is on much firmer ground, which is worth seeing side by side with where it is not.

19.1 What the Standard Account Says, and Where It Stops

Conventional optics handles the pinhole with ray diagrams. Light travels in straight lines, the hole admits one ray from each point of the scene, the rays cross at the hole, the image is inverted. Shrink the hole and the image sharpens until diffraction takes over, at which point it blurs again, and there is a tidy formula for the optimum diameter.

All of that is correct and none of it is an explanation, because the central object is never specified. A ray is a line drawn on paper. Ask what is travelling along it and the answer switches register: an electromagnetic wave, or a photon, depending which chapter you are in. Ask what the wave is made of and you are told it is an oscillation of fields. Ask what a field is

made of and the conversation ends.

But there is a sharper objection available here, and it is worth making carefully because it is not the usual complaint about interpretation.

Look at how the optimum-diameter formula is actually obtained. There are two blur terms. The first is the geometric one: a hole of diameter d admits a cylinder of traffic from each point of a distant scene, so each point paints a disc of diameter d on the film. That term comes from ray optics, in which light is a line travelling in a straight line. The second is the diffraction term, roughly $2.44\lambda f/d$ for a round aperture, which comes from wave optics, in which light is an extended disturbance that spreads when confined. Set the two equal and you get the sweet spot.

Those two terms come from two mutually exclusive accounts of what light is. Ray optics is known to be the limit of wave optics as the wavelength goes to zero—it is not an approximation that coexists with the wave picture, it is what the wave picture degenerates into when you throw the wavelength away. The derivation keeps the wavelength in one term and discards it in the other, in the same equation, and adds the results.

In practice this works, and it is a good illustration of why nobody minds. But it leaves a visible seam, and the seam shows: the published constant in $d = c\sqrt{\lambda f}$ is not agreed. The naive balance just described gives $c \approx 1.56$. Lord Rayleigh's wave analysis of 1891 is usually quoted as 1.9, which is the figure most pinhole photographers use. At least one treatment of pinhole astronomy works out to a substantially larger constant again. A formula assembled from two incompatible pictures does not have a well-defined coefficient, and the literature reflects that.

What is *not* in dispute is the shape of the relation. The optimum diameter goes as the square root of the focal length times the wavelength. That scaling is solid, it is measured, and it is the thing a rival account has to reproduce. We return to it below, because the model gets part of it and not all of it.

19.2 The Image Is Selection, Not Bending

Every point of every lit object is shedding groups of G1 particles continuously, in every direction it can. That is what emission is.

Now the box. A wall is a mass that stops G1 groups; a hole is the absence of that mass. So the wall is a filter on *direction* and nothing else: of all the traffic leaving a given point of the scene, the only bundle that gets in is the narrow one that happened to be aimed at the hole.

Once through, it keeps going in a straight line, because nothing is acting on it, and lands in exactly one place. Do that for every point of the scene and every point gets its own landing place—a one-to-one map from the world onto the wall. That map is the image.

> The pinhole does not form an image. It discards almost all of the traffic, and the image is what is left.

The inversion needs no explanation at all. Straight lines through a single point cross. It is not an optical effect; it is geometry.

19.3 The Sieve and the Eclipse

Two old observations test that claim harder than any box can, because in neither case is there an instrument at all.

The first is in the *Problemata*, a work in the Aristotelian corpus: during a partial eclipse of the sun, the light coming through a sieve, or through the overlapping leaves of a tree, falls on the ground not as round spots but as *crescents*. Anyone can confirm it at the next partial eclipse, and people do. The dappled light under a tree is normally a carpet of small bright discs—images of the sun, not gaps between leaves—and when the moon takes a bite out of the sun, every one of those discs grows the same bite.

Nothing was built. The gaps between leaves are ragged, of all different sizes and shapes, and none of them was manufactured to any tolerance. They work anyway, because selection by direction does not require precision. A gap of any shape sitting between a source and a surface discards all the traffic except the narrow bundle aimed through it, and the picture assembles itself.

The second observation follows from the first and is more pointed. Cut a square hole, or a triangular one, or a ragged one, and point it at the sun. Provided the hole is small compared with the distance to the screen, the patch of light on the screen is *round*—an image of the sun—not square, not triangular, not ragged. Make the hole larger and at some point the patch stops being round and becomes a picture of the hole instead.

That crossover is the whole of this chapter in one demonstration. A small hole images the *source*, because what reaches each point of the screen is selected by direction and the directions map the source. A large hole images the *hole*, because the admitted bundle from each source point is now wide enough to overlap its neighbours completely and all that survives is the silhouette of the opening. There is no bending in either case and no mechanism to switch between them. One geometry, read at two ratios.

19.4 Why Nothing Is Ever Out of Focus

A pinhole camera has no focal length and no focus setting. A fingertip an inch away and a mountain ten miles off are rendered with the same sharpness at the same time. Photographers call this infinite depth of field and treat it as a quirk.

Here it is the absence of a mechanism. Focusing is what you must do when you have *bent* light and need all the bent paths from one object point to reconverge at one image point—which happens at exactly one distance, and that is the focal plane. The pinhole never bends anything. A straight line from a point lands in one place no matter how far away the point was.

Nothing needs to be brought together, so nothing can be out of focus. The lens, not the pinhole, is the special case.

19.5 Why a Million Bundles Cross Without a Tangle

Inside the box, the bundle from the top of the scene and the bundle from the bottom pass through each other on their way to opposite ends of the wall. They cross at the hole and again elsewhere, millions of times over, and the picture is not smeared.

For a field model this is an embarrassment. For a particle model it is the expected result: matter is overwhelmingly empty and these particles are overwhelmingly small, so two streams crossing are two sets of tiny bodies passing through a volume that is almost entirely vacant.

The camera obscura is a daily, visible demonstration that light is traffic rather than a filled field.

19.6 The Two Blurs

Now the detail everyone who has built one runs into. Make the hole smaller and the image gets sharper—up to a point. Past that point, smaller makes it *worse*, and much dimmer. There is a sweet spot.

The model gives two blurs with two causes, pulling opposite ways.

The first is bookkeeping. A hole of any real size admits not one direction from each scene point but a small cone of them, so each point paints a small disc and neighbouring discs overlap. Shrink the hole and the cone narrows. This blur gets better as the hole gets smaller.

The second is physical. The rim is made of atoms, and a mass with a sharp boundary carries a strong G2 field whose gradient is steepest right at the edge. A G1 group passing close to that rim is deflected by it—the same mechanism as the slit edges in Chapter 18, and the pinhole is where it is easiest to see. In a large hole almost everything passes well clear of the rim; in a tiny hole almost nothing does.

One blur shrinks with the hole and the other grows. The sharpest image is at the crossover, which is the whole content of the optimum-diameter formula—now with a physical cause on both sides rather than a geometric cause on one side and a wave on the other.

The dimming comes free: fewer admitted directions and a smaller opening

mean fewer groups per second getting in. It is severe. The best hole for a box a hundred millimetres deep is a little under half a millimetre across, which makes the aperture about $f/224$; at a hundred and fifty millimetres it is roughly $f/275$. A conventional lens works near $f/2$ to $f/8$. That is a shortfall of thousands of times in collected traffic, which is why a pinhole photograph is exposed in seconds or minutes where a camera uses a hundredth of a second, and it needs no separate explanation here—the hole discards almost everything by design, and the exposure time is the bill for it.

19.7 Where the Sweet Spot Comes From

The two blurs can be pushed further than "they pull opposite ways," and it is worth doing, because this is the one place in the chapter where the model can be held to a number.

Write d for the hole diameter and f for the distance to the back wall. The first blur is the geometric one and the model gets it for the same reason everyone else does: a distant point sends a parallel bundle, the hole passes a cylinder of diameter d, the disc on the wall has diameter d. So the first blur is proportional to d, and notice it does not depend on f at all.

The second blur needs two quantities the model has not supplied. Call w the reach of the rim's G2 field—the width of the annulus inside the opening within which a passing G1 group is appreciably deflected—and call θ the typical angle it is deflected through. Then two things follow.

The deflected traffic lands over a disc of diameter about θf, so unlike the geometric blur this one grows in proportion to the distance to the wall. And the *fraction* of the traffic that gets deflected is the area of the rim annulus divided by the area of the hole,

$$\frac{\pi d w}{\pi d^2/4} \;=\; \frac{4w}{d},$$

which grows as the hole shrinks. That single ratio is the quantitative version of what was said loosely above: in a large hole almost everything passes well clear of the rim, in a small hole almost nothing does.

Put the two together. The blur, weighted by how much of the light is in each part, goes roughly as

$$B(d) \;\approx\; d \;+\; \frac{4w\theta f}{d}.$$

One term rising, one term falling. Minimise it and the hole that gives the sharpest picture is

$$d_{\text{best}} \;=\; 2\sqrt{w\,\theta\,f}.$$

That is the right form. The optimum goes as the square root of the focal length, which is the measured behaviour and the part of the standard

formula nobody disputes, and it falls out of the model's two blurs without anything being fitted. The model did not have to be told that small holes want short boxes.

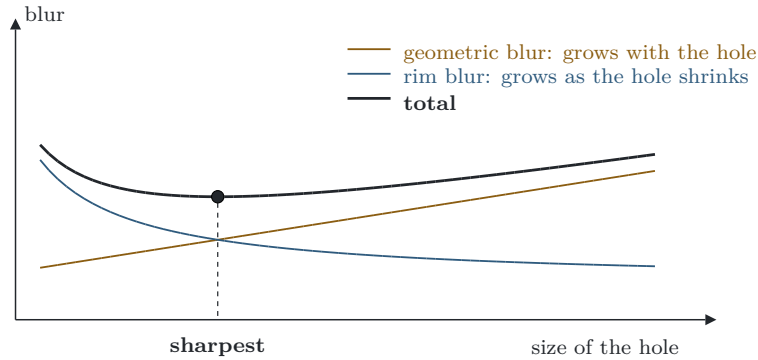


Figure 19.1: The two blurs of the pinhole pull in opposite directions, and the sharpest picture is at their crossover.

So the model's own two blurs give an optimum hole, and the factors in it are the two things the G2 field of the rim will have to supply: how far its reach extends, and through what angle it turns a passing group. Both belong to the arrangement of the atoms in the rim, which is the work this book keeps coming back to. Until the G2 fields are worked out, they are two unknowns.

The relation also makes a claim that does not depend on knowing either of them. The weight of the halo relative to the sharp spot should go as $1/d$, which can be measured with a set of machined holes and a long afternoon.

19.8 A Round Rim Bends in Every Direction

A slit has two straight edges and throws a flat fan. A pinhole's edge is a *ring*, surrounding the opening on every side, so it throws a cone—outward in all directions at once.

So each point of the scene lands as a sharp spot, the part that went through the middle untouched, wrapped in a faint halo made of everything the rim got hold of. Shrink the hole and the proportions invert: the halo swallows the spot and the image goes soft.

19.9 What the Pinhole Says About the Double Slit

Put the two experiments side by side and they are the same apparatus counted differently. One hole: one admitted bundle per scene point, flying straight, landing in one place. Two holes: the same thing twice, except that two halves of one procession arrive at the same spot having travelled different distances, and the rhythm of the procession starts to matter.

The rim effect is present in both and does the same job—the envelope under the fringes there, the halo around every spot here. That is a genuine consistency.

And there is one thing the pinhole cannot tell you. Here the rim's kicks are random in direction and that is all the pinhole ever needs; a spray is a spray. The double slit asks the harder question, because its fringes depend on the two halves keeping time. The pinhole is blind to that distinction. The double slit is the experiment that tests it.

What we have not modelled

The reach and the angle. *The section above reduces what the model owes on the pinhole to two quantities: the reach of the rim's G2 field, and the angle it deflects through. Nothing in the model fixes either independently yet. Fixing one of them from the atomic structure of the rim would turn the other into a genuine prediction, and that is the smallest piece of work that would take this chapter from an account to a test.*

Colour dependence. *Since a spacing is a colour, the rim must treat groups of different spacing differently, so that blue is turned through a smaller angle than red, or reached less far, or both. The model does not say which, and this is the same question left open at the end of Chapter 18. Like the rest, it waits on the G2 fields.*

What you can now say

- A pinhole does not form an image; it discards almost everything, and the image is what is left.
- Nothing is ever out of focus because nothing is bent.
- A million bundles cross inside the box without a tangle because they are traffic through nearly empty space.
- The sharpest hole sits where two blurs cross, and each has a physical cause.

Chapter 20

Circuits That Work

STANDING: PROPOSED. *Robert's particle accounts of the capacitor, diode and transistor. The doping description is close to a translation of the standard one.*

A circuit is where physics stops being a picture and starts being a thing on a bench that either works or does not. If the four motions cannot say what happens inside a battery, a diode and a capacitor, they are a story about the universe with nothing to show for themselves.

This chapter is short on claims and honest about what is sketched. Robert spent forty years designing telecommunications switching systems, and the circuit analyses here come from that side of the family.

20.1 The Battery

Chapter 10 already counted it. One electrode holds more G1 particles than it settles at; the other holds fewer. That difference is the charge, and connecting the two ends lets G1 particles run from the fuller side through the circuit to the emptier one until the difference is used up.

There is an experiment anyone can do. Take a battery and a compass and move the compass around it. The needle deflects—there is a magnetic field around a battery sitting on a table doing nothing. In this model that is unsurprising: some of the G1 particles the battery holds are in orbit, and orbiting G1 particles are a magnetic field. The battery is not inert. It is a standing imbalance with traffic circulating around it.

20.2 The Capacitor

Two plates, not touching. Connect them to a battery through a resistor and current flows briefly, then stops, and the capacitor is charged. Disconnect it and the charge stays.

In this picture, G1 particles pile up on one plate and are drawn away from the other. They cannot cross the gap, so the piling continues only until the imbalance it creates pushes back as hard as the battery pushes—until the F2 force of the capacitor matches the F2 force of the source. Then the flow stops, which is what a charging curve is: a current that falls away as the difference closes.

Nothing is stored in the gap. What is stored is a count of particles on one side that are not on the other.

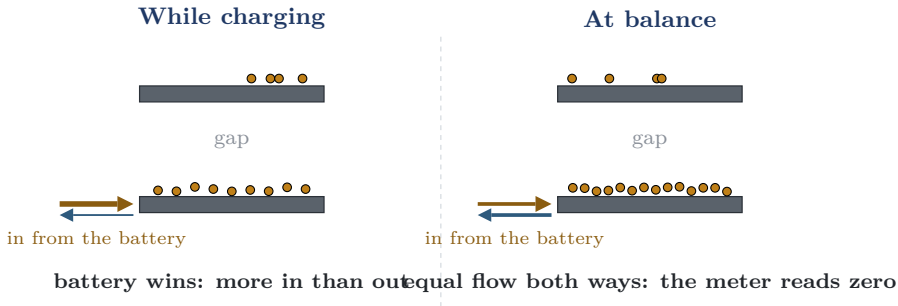


Figure 20.1: The capacitor charging and at balance. At balance particles still leave both sides at the same rate, so a meter reads zero.

Robert's account of the charging circuit follows the particles, and it changes what the usual diagram is showing. When the switch closes, G1 particles leave the negative terminal of the battery and flow to the lower plate. At the start the battery holds more than the capacitor, so the battery wins: it pushes more particles onto the plate than the plate can push back. As the plate fills, the capacitor begins pushing them back out through its own negative terminal. The battery is still winning, so the plate keeps filling, until the capacitor's count matches the battery's.

At that point there is nothing to stop G1 particles leaving the battery, and nothing to stop them leaving the capacitor. Each pushes out as many as the other does. Measure the current in the loop and the reading is zero, even though particles are moving in both directions. Robert's answer to "is there current in the fully charged circuit?" is therefore yes: there is flow, and at balance it cannot be detected.

He also objects to the usual drawing, in which an arrow of "current" charges the plate. That arrow is the flow of holes, the absence of a particle, and an absence cannot charge anything. The better drawing shows the G1 particles themselves running to the negative plate. Chapter 11 makes the same point about the moving hole.

20.3 The Diode

A diode passes current one way and blocks it the other, and every textbook explains it with holes and depletion regions.

Strip that out and what is left is a junction between two regions of lattice with different settled counts—one doped to hold more G1 particles than it would naturally, the other to hold fewer. The device is not a valve with moving parts. It is a standing imbalance that either helps or hinders depending on which way you drive.

Which is also why a diode has a forward voltage: you have to push hard enough to overcome the standing imbalance before anything crosses. This model says plainly why there is a threshold.

It does not hand you the number, and the number is informative. A silicon diode turns on at roughly 0.7 volts and a germanium one at roughly 0.3, and those figures track the two materials' band gaps—1.12 electron-volts for silicon against 0.67 for germanium. The threshold is a property of the material, not of the device, which is exactly what a standing imbalance in a lattice ought to produce.

So the model gets the shape right and owes the proportionality. Something about how tightly a given lattice holds its population should set how hard you must push to move particles across a junction in it, and that something ought to be calculable from the lattice. It has not been calculated.

Forward, Reverse, and the Knee

Robert's analysis of the junction diode goes further than the sketch above, and it is worth setting out because it answers the questions an engineer would ask.

The diode has two regions. The N region holds many G1 particles; the P region holds very few. The F2 force rain surrounds the whole diode from every direction, and in most directions it balances. The direction that matters is through the diode, top to bottom. Somewhere along it there is a line, which Robert calls the F2 balance, where there are as many G1 particles on one side as on the other and the forces from either end meet.

Forward. G1 particles enter at the N end. The region is crowded and there is very little open space, yet the F2 force is strong enough to accelerate them through and keep them going to the far side.

Reverse. G1 particles enter at the P end, helped along by the F2 force, and accelerate until they reach the balance line. Past it the opposing F2 force is strong and slows them. They do not get all the way through. Both the G1 flow and the current are blocked past that line.

The knee. Why does the forward curve show almost no current, then turn sharply upward? At low current the F2 force around the diode is small, and a crowded N region needs a strong one to push particles out, so only a

few make it. But every particle that does get through adds to the flow, and a larger flow raises the F2 force around the diode. That in turn speeds the G1 particles, and a faster G1 passes through more easily, so fewer are lost on the way. The knee is that feedback taking hold. A slow G1 is held by the atoms of the diode; a fast one is not.

The second knee. The same thing explains the knee in the third quadrant. As reverse current rises, the F2 force rises with it, until the diode breaks down in the avalanche region.

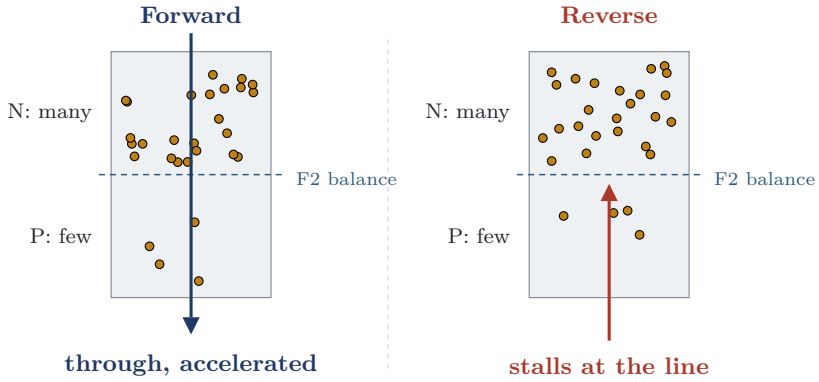


Figure 20.2: The junction diode. Forward, particles are accelerated through the crowded N region; reverse, they stall at the F2 balance line.

This account does not use a depletion layer, because a depletion layer is a statement about charge, and in this model charge is a count of G1 particles. What the textbook shows as a layer widening and narrowing is, here, the standing imbalance and where the forces on either side of it balance.

20.4 The Transistor

A transistor is two such junctions back to back, with a thin middle region, and what happens at one junction controls what gets through the other. It has three connections: the base, the emitter and the collector.

Robert's analysis follows the G1 particles through it and arrives at a conclusion that will surprise anyone who has been taught to call a transistor an amplifier.

The particles split. Both batteries in the circuit send G1 particles into the transistor, and they all enter at the emitter. Call that number G_E. From there the stream divides: part leaves through the collector, G_C, and part through the base, G_B. A split does not involve a gain. The ratio usually called gain is the ratio of collector current to base current, and in terms of particles that is the ratio of the two arms of the emitter's split.

Why the split favours the collector. The emitter current is the sum

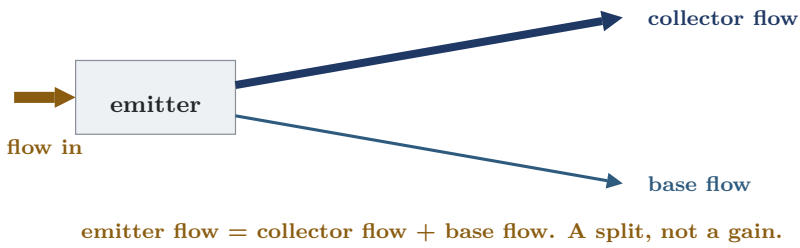


Figure 20.3: The transistor splits the emitter's flow between collector and base. The ratio of the two arms is a split, not a gain.

of the base and collector currents. How it divides depends on the physical size of the parts: the collector is the largest, the base the smallest, and the emitter is in between. Those sizes guarantee that the collector's share is the bigger one, and so that the ratio of collector to base is a large positive number. A base current of 0.3 mA against a collector current of 10 mA, as on the standard characteristic curve, is a ratio of about 33. Robert's point is that the curve shows the two arms of a split and omits the emitter current that is the sum of them. The graph, he says, should include it. That graph has not yet been drawn.

The ac case. Put an ac source between ground and the emitter, as in the standard amplifier circuit, and the G1 particles entering the emitter divide into the input arm and the collector arm. The collector voltage looks larger than the input voltage, but the two are just two arms of the same split, and the ratio of the two arms is not a gain. What the usual drawing leaves out is the emitter ac voltage, which is the sum of the other two; without it there is neither base current nor collector current.

Doping. The three regions are doped differently: the base is missing G1 particles, the emitter has many, and the collector has only a few. The F2 force surrounds the transistor from all sides, balances in most directions, and in the vertical direction sets a balance point where the forces from either end meet, as in the diode.

Where the particles come from. Each battery emits G1 particles in proportion to its voltage rating. If in some interval a 3 V battery emits 6 and a 12 V battery emits 24, then 30 enter the emitter in that interval. For the circuit to be stable, each side of the transistor must gain and lose the same number. Robert works the balance with a spreadsheet, one for the base circuit and one for the collector circuit, iterating until the values stop changing. The values settle and repeat, which is the circuit reaching balance.

His conclusion is stated plainly on the website, and we repeat it with its source: *the transistor does not have gain.* What the transistor has is a split, and a standing imbalance that decides how the split falls. The figures and the spreadsheets are on the website.

20.5 What a Semiconductor Is

Before the hole, the material.

Silicon conducts badly on its own. What makes it useful is *doping*: adding a trace of another element whose atoms settle at a different count. Add phosphorus, whose atoms hold one more than silicon wants, and the lattice carries a surplus—n-type. Add boron, whose atoms hold one fewer, and it carries a shortfall—p-type. The proportions are tiny; one dopant atom in ten million changes the material's behaviour entirely.

In this model that is exactly what it sounds like. A doped lattice is one whose settled count has been shifted, and the device is built by putting a region with a surplus next to a region with a shortfall.

That is not a reinterpretation of the standard account. It is close to a translation of it. Where the two part company is what carries the current in the p-type side.

20.6 The Hole, and Why It Is Not Needed

Semiconductor physics says that current in some materials is carried by *holes*: absences where an electron is not, given a charge, a mass and a lifetime. Chapter 11 followed how physics came to that, from the positive Hall readings in beryllium, zinc and p-type semiconductors to the vacancy that band theory turned into a carrier. It is a bookkeeping device for tracking a crowd by the places where it is thin, promoted into a particle.

In the four motions the hole is not needed. G1 particles move from the end holding more to the end holding fewer, and when one leaves an atom it leaves an atom holding one fewer G1—a count, not an object. In a p-type region the standing shortfall is exactly what the diode and the transistor above depended on: a region doped to hold fewer. Nothing travels the other way and there is nothing to assign a mass to.

What G1 particles moving through a particular lattice do to produce a positive Hall sign is a question about the arrangement of that lattice and its G2 fields. It is listed with the other open items below, and it will be answered where they are, in the simulation of a real lattice.

20.7 Resistors

The least worked-out component, and we would rather say so than bluff.

A resistor is a stretch of lattice that channels badly, so a fraction of the G1 particles driven into it are scattered out of the directed flow into disordered motion, which is heat. More scattering, more resistance, more heat.

That accounts for the existence of resistance and for the fact that resistors

get warm. It also says what a resistor is for: fewer G1 particles come out than went in, and the gap is what a voltmeter reads across it. A resistor is simply a component built to lose a chosen number of them. How many a given lattice keeps, and why that changes with temperature, are questions about the arrangement of the nuclei and their G2 fields, and they wait on the same work as everything else in this chapter.

What we have not modelled

What this chapter has not modelled. *It says what is happening in a diode, a capacitor, a transistor and a resistor in terms of where the G1 particles go. It does not yet say how many a particular lattice holds, or how tightly, and so it does not yet produce figures such as a diode's turn-on voltage or a resistor's value. That information lies in the arrangement of each lattice and the G2 fields around its nuclei.*

The positive Hall effect. *In some metals, such as beryllium and zinc, the sideways deflection of a current is in the direction a positive carrier would give. The usual name for the carrier is the hole, and this book has argued that an absence cannot carry anything. What G1 particles moving one way through those lattices do to produce that sign is not yet worked out. It is a question for the physical model simulation of a real lattice.*

Closing these is the same job as everywhere else: physical model simulations on a real lattice, counting what goes in and what comes out—the copper simulation pointed at a component instead of a plain wire. The model is a physical Turing machine, and what it cannot yet say it will say once the G2 fields are found.

What you can now say

- A battery is a standing imbalance in count, and a capacitor at balance still has flow in both directions.
- A diode is an F2 balance line you can only push through one way.
- A transistor splits its emitter flow between collector and base, and a split is not a gain.
- The hole is not needed, and a resistor is a stretch of lattice that keeps some of the G1 that enter.

Chapter 21

All Four at Once: Inside a Phone

STANDING: FRAMING. *Chapters 5 to 20 applied to one device. Its standing is theirs.*

Everything so far has been taken one motion at a time. That is how you build an argument and it is not how the world arrives.

So here is an object most readers have within reach, in which all four motions are doing visible work at the same moment. At each step we will say what the standard account offers, and then where it stops—because the gap between those two is the whole subject of this book, and it is easiest to see in something ordinary.

21.1 The Screen

What happens. A lit pixel is a region of matter being driven to hold more G1 particles than it settles at. It sheds the surplus in formation, and the formation crosses the air to your eye, where atoms able to take up groups at that spacing capture them.

The colour of the pixel is the spacing between the departing groups. Red, green and blue subpixels are three different release sizes; every other colour on the screen is a mixture of the three arriving together—possible precisely because what arrives is traffic rather than one object with one value stamped on it.

What the textbook says. Electrons in the emissive layer drop to a lower energy state and emit photons, whose wavelength determines colour.

Where it stops. It does not say where the photon was before it was emitted, because by its own account it was nowhere—it is created at the instant of emission. It does not say what a wavelength is a property of,

given that a photon is said to have no parts and no extent. Chapters 6 and 14 made both complaints at length; the point here is that they apply to the object in your hand.

21.2 The Battery and the Wires

What happens. A lithium cell holds a standing imbalance: one electrode holding more G1 particles than it settles at, the other fewer. Close the circuit and they run from the fuller end to the emptier one, down gravity tubes laid by the lattice of the copper traces.

They move at two speeds at once—fast along the open channels, slowly through the orbital systems of individual atoms—which is why the phone responds the instant you touch it rather than some hours later.

What the textbook says. Chemical reactions at the electrodes create a potential difference, which drives a current of electrons through the circuit.

Where it stops. It does not reconcile its own two numbers. The carriers are said to drift at a fraction of a millimetre per second while the signal travels at a large fraction of the speed of light, and the reconciliation—that the field propagates while the carriers crawl—hands the explanation to a field whose composition is never specified. One unexplained thing is covered by another.

21.3 The Speaker and the Buzz

What happens. A current is driven through a coil sitting beside a permanent magnet. That is one circulation of G1 particles placed next to another, and the Dinu rule decides what they do: same rotation and they push apart, opposite and they draw together. Reverse the current thousands of times a second and the coil is pushed and pulled, and the cone attached to it moves air.

The vibration motor is the same arrangement with an off-centre weight. The tingle in your hand is two orbiting populations meeting.

What the textbook says. The current-carrying coil experiences a Lorentz force in the magnet's field, $F = IL \times B$.

Where it stops. It does not say what B is made of. It gives a rule for the direction—hold your fingers thus—and no account of why a force should come out sideways at all. A mnemonic involving the reader's hand is a confession that the geometry has no mechanism underneath it.

21.4 The Radio

What happens. The antenna drives G1 particles back and forth along a conductor. As Chapter 17 set out, particles driven along a conductor travel

a helix—forward along it, circling outside it. Reverse the drive fast enough and groups are flung clear and travel away in formation.

That is a radio wave, and it is the same thing as the light from the screen. Same particles, same motion, different spacing between groups—wide enough that no eye responds, close enough that an antenna a few centimetres long does.

What the textbook says. Accelerating charges radiate electromagnetic waves, which propagate at the speed of light.

Where it stops. At what radiates. The wave is said to be a self-sustaining oscillation of electric and magnetic fields, each generating the other, travelling through vacuum—and Chapter 17 asked the obvious questions. Made of what? Oscillating in what? Why perpendicular? How do countless such waves cross the same room without tangling?

21.5 What Crosses the Gap to the Charger

Here is the one we would most like you to sit with, because it is where the hand-waving is hardest to miss.

Put the phone on a wireless charging pad. There is a gap—usually around five millimetres of plastic and air—and nothing is touching. Leave it there and the battery fills. Energy is unquestionably crossing that gap, in quantity, for hours.

Ask anyone—a child, a grandmother, a stranger on the bus—how the energy gets into the phone, and they will say that something passes from the pad up into the device. It leaves the charger, crosses the small gap, and arrives. The standard account does not say that. It says a field is produced, and the field induces a current in the phone, so that the energy is, in that telling, conjured inside the phone and not carried across. The obvious question follows. If the current in the phone is induced, something has to be carrying it, and the electrons have to be sitting in the phone already, waiting to be pushed. Then what arrived from the pad? The grandmother's answer is the more honest one: something comes across.

What happens in the pad. A coil is driven with alternating current somewhere between about 110 and 205 kilohertz, and the power delivered is adjusted by sliding that frequency along a resonance curve. A second coil sits in the phone.

What the textbook says. "The alternating current in the transmitter coil produces a changing magnetic field, which induces a current in the receiver coil."

Where it stops. Read that sentence again and ask what it tells you about the five millimetres.

It names three things—a current, a field, an induced current—and describes the relationship between them with complete precision. It says nothing whatever about what is *in* the gap. A field is produced; a field

induces. What physically travels from the pad to the phone? What is in the air between them that is not there when the pad is switched off?

The question is not rhetorical and it is not naive. Energy is being delivered at a measurable rate. Something is carrying it. The pad gets warm and the phone gets warm, which means some of whatever is crossing is being deposited where it was not wanted. These are physical facts about a physical object, and the standard account answers them with a noun that has never been given a composition.

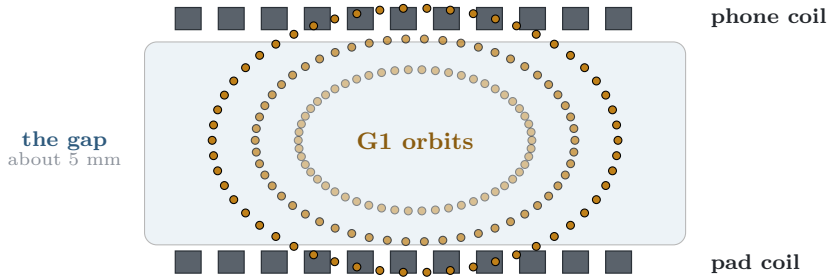


Figure 21.1: What is in the gap: orbiting G1 particles from the pad's coil run out through the plastic and the phone's casing and through the receiving coil.

What the four motions say. The pad's coil has G1 particles driven round it, which means G1 particles in orbit—and those orbits run outside the coil, through the plastic, through the gap, through the phone's casing and through the receiving coil. That traffic is what is in the gap. It is not a condition of the space between the two devices; it is particles, going past, in large numbers.

The phone's coil is a wire like any other: a lattice of nuclei with a population of G1 particles already drifting through its channels. Chapter 16 described what happens next. The arriving traffic changes what it would take for that population to sit still, and while it relocates, it moves along the wire—which is a current, which charges the battery.

And the reason the pad must use alternating current rather than direct follows immediately, without an equation. A steady current would give a steady circulation; the phone's population would settle into its new arrangement once and then stop, and the battery would not charge. Reverse the drive a hundred thousand times a second and the population is never allowed to finish settling, so it is always relocating, so current flows the whole time.

The heat is accounted for too: it is the fraction of the traffic scattered out of the channels into disordered motion, on both sides of the gap.

> A changing magnetic field induces a current. That is true, and it is a description of a relationship between three quantities. The

four motions say what is in the five millimetres.

21.6 And Gravity, Holding It All Down

The phone stays on the pad because the Earth shields it from the rain arriving from below, and the rain from above pushes it down.

What the textbook says. The phone's mass curves spacetime, or is attracted by the Earth's gravitational field, depending which era you ask.

Where it stops. At what is bending, or what the field is made of. Newton declined to say and was honest about declining. The modern answer describes the geometry of a region of nothing and does not say what acquires the shape.

21.7 One Particle, Four Dances

That is the claim of this book standing in your hand.

Gravity holding it to the table. Electricity running through its traces. Magnetism moving its speaker. Light leaving its screen, radio leaving its antenna, and orbiting particles crossing the gap to the charger. Six phenomena that a physics course would teach across four separate terms, with separate laws, separate units and separate equations.

One kind of particle. Four things it can be doing.

And at every step the standard account gives a precise description of a relationship and declines to name a material. It is not that the descriptions are wrong—every one of them works, and the phone is proof. It is that a century of being right about the relationships has been allowed to stand in for knowing what is there.

Whether the four motions are the correct answer is what the remaining chapters say could be settled. But the question is a fair one, and you are holding the reason it is fair.

What you can now say

- One particle is doing all four motions in a single object: gravity, electricity, magnetism and light.
- What crosses the gap to a wireless charger is orbiting G1, particles going past.
- The speaker is the Dinu rule, and the radio is a helix flung clear in formation.
- At every step the standard account names a relationship and the four motions name what is in the room.

Chapter 22

Levels, Up and Down Without End

STANDING: FRAMING. *The principle of no partless parts and what an infinity of levels costs. An argument rather than a mechanism.*

Everything in this book has used two levels. G1 particles organise our world; G2 particles organise the atom. The obvious question is whether it stops.

22.1 No Partless Parts

Chapter 4 introduced the principle that the model sits inside, and it comes from Glenn Borchardt, whose Infinite Universe Theory supplies the architecture: *there are no partless parts.* Nothing is fundamental, every particle is built of smaller ones, and it never bottoms out. A G1 is made of G2 particles, a G2 of G3 particles, and so on without end, and if that is true downward it is true upward: our level sits inside a larger one, for ever.

This is not a decorative extra. It is load-bearing, because it is what licenses the move the model makes constantly: when something cannot be explained at one level, look to the level below, and expect to find the same four motions there.

22.2 Where the Idea Comes From

Borchardt sets this out in *The Ten Assumptions of Science*, and *infinity* is the eighth of them: the universe is infinite, in the microcosmic direction and the macrocosmic direction alike. The rest of his framework—univironmental determinism, neomechanics, a cosmology that replaces the Big Bang—follows from a small set of such assumptions taken together.

We should be plain about two things.

First, we take one assumption and not the system. What this book needs from Borchardt is infinite levels and no partless parts. We are not committed to his cosmology, and we part company with him on light, which is the subject of the next chapter.

Second, this is not accepted science. Infinite Universe Theory sits outside the mainstream of cosmology, it is published largely outside the usual channels, and Borchardt is candid about that himself. We mention it because a reader is entitled to know whose shoulders we are standing on and how firmly those shoulders are planted.

What makes the assumption worth adopting is not its provenance. It is that it does work, and the next three sections are that work.

22.3 Why Two Equations Have the Same Face

The clearest evidence is one this book has returned to repeatedly.

Newton's law of gravitation and Coulomb's law have identical form. Two quantities multiplied, divided by the square of the distance, with a different constant in front. Physics has treated that for two centuries as a curiosity.

If levels repeat, it is not a curiosity. It is the same mechanism seen twice, with smaller and faster particles the second time—and the different constant is what you would expect from different particles, not from different physics.

There is a detail in the two constants that makes the point harder to dismiss as numerology. Both carry a factor of 4π—it sits in the denominator of Coulomb's constant, written $1/4\pi\varepsilon_0$, and in the standard presentation it is explained away as bookkeeping, an artefact of the "rationalised" unit system that could have been put somewhere else.

On the shadowing account it is nothing of the kind. It is the total solid angle of a sphere, and it is there because the derivation begins by spreading the sea's momentum over all 4π steradians of sky. Run the derivation at both levels and the two constants come out with the same anatomy: one over the total solid angle, times the intensity of that level's sea, times the square of whatever converts a body's "amount" into a blocking area. Newton's constant decomposes the same way Coulomb's does, into a solid angle, a property of matter, and a property of the vacuum. Two constants that look alike because somebody chose convenient units would not do that.

The model predicts that this should keep happening. Whatever organises the G2 level should look, in its own terms, like what organises ours. Any phenomenon found at one scale ought to have an analogue at the next, and a discovery that something at the subatomic level has *no* analogue anywhere above it would be evidence against infinite levels.

22.4 The Number Nobody Derives

There is a second piece of evidence, and it is sharper than the shape of the two laws, because it is a number.

Take a hydrogen atom: one proton, one electron. Both forces act between them. Compute the ratio of the electric force to the gravitational force and you get

$$\frac{F_e}{F_g} \;=\; \frac{k\,e^2}{G\,m_p m_e} \;\approx\; 2.3 \times 10^{39}.$$

Electricity beats gravity by a factor of two thousand billion billion billion billion. The same calculation for two protons gives 1.2×10^{36}, and for two electrons 4.2×10^{42}. The numbers are not in dispute; they follow from measured constants and a reader can check them in a minute.

What *is* in dispute is where such a number could possibly come from.

Paul Dirac noticed it in a letter to *Nature* in 1937 and refused to accept it as a brute fact. A pure number of that size, he reasoned, cannot be a coincidence, and he observed that it is close to another large number—the age of the universe measured in atomic time units. He proposed that the two are related because gravity is *weakening*: G falls off roughly as $1/t$, so the ratio grows as the universe ages, and it is large today because today is late.

It was a real attempt at an explanation, and it is dead. If G varied as $1/t$ it would be shrinking now at about seven parts in 10^{11} per year, and lunar laser ranging—bouncing pulses off the reflectors left by Apollo and measuring the Moon's orbit over half a century—bounds any change at a few parts in 10^{13} per year, with the newer orbital solutions reaching 10^{14}. Dirac's rate is excluded by at least two orders of magnitude, and by rather more on the recent analyses.

So the number stands unexplained. No accepted theory derives 10^{39}; it is put in by hand, as the measured values of G, k, e and the two masses, and physics declines to ask why those values and not others. The weakness of gravity relative to everything else is among the oldest open questions in the subject and there is no answer in the textbooks, only a name for the gap.

Now notice what the number is, if levels repeat. It is a *ratio between two levels*—the strength of the shadowing done by G1 particles against the strength of the shadowing done by G2 particles. In this model it is not a coincidence and not a brute fact. It is a fact about the relative size, speed and population of the particles on two adjacent rungs, and it should in principle be calculable from them.

We cannot yet calculate it. But the first step of that route has now been walked, and it is worth seeing what it buys and what it does not.

Work the shadowing derivation through at level 2 and match it to

Coulomb's law term by term, and the number above comes out as

$$\frac{\rho_{G2}}{\rho_{G1}} \left(\frac{s_e}{S_e} \right)^2 ,$$

where the ρ's are the intensities of the two seas and the s's are the electron's blocking areas in each of them. So the factor of 10^{39} is a statement that the electron blocks the G2 sea enormously more effectively than it blocks the G1 sea, or that the G2 sea is enormously more intense, or some combination. Those are claims about the sizes of things and the densities of seas—the kind of claim that can be investigated—rather than a number that simply is what it is.

That is genuinely different from where the mainstream stands, and genuinely less than a derivation. It is one equation in two unknowns. Fixing either one fixes the other, and nothing yet fixes either. What the model has done is convert an unexplained constant into a constrained relationship between two levels, which is the first thing any explanation has to do and nothing like the last.

22.5 Physics Already Works in Levels

It would be misleading to present levels as our idea and a unified fundamental description as the mainstream one. Modern physics is organised in levels too, and quite deliberately.

The framework is called effective field theory, and the principle is that a theory need only be valid up to some energy—some scale—above which it is replaced by a different description. Fluid dynamics works without atoms; chemistry works without quarks; nuclear physics works without knowing what happens at the scale of grand unification. Kenneth Wilson made this systematic with the renormalisation group, which describes how a theory's parameters change as you move between scales, and received the Nobel Prize for it in 1982. It is one of the genuine triumphs of twentieth-century physics, and a reader should not come away thinking the mainstream is naive about scale. It is not.

The disagreement is narrower than it looks, and it is about two things.

First, whether the ladder ends. Mainstream physics generally expects a bottom rung at the Planck length, about 1.6×10^{-35} metres, below which the notion of distance is thought to fail. Notice how that length is obtained: by combining G, c and $\hbar$ until the units come out as a length. Nothing has been observed there. It is some sixteen orders of magnitude below anything any accelerator has probed. Calling it the floor is a dimensional argument, not a measurement, and dimensional arguments have been wrong about floors before.

Second, whether the levels are made of the same thing. In effective field theory each level gets its own degrees of freedom, its own fields, its own

Lagrangian, and there is no expectation that the description repeats—the mathematics at one scale may bear no resemblance to the mathematics at the next. Here the claim is stronger: the levels repeat *in kind*. The same four motions, the same bodies, the same shadowing, all the way down. That is the assertion that makes the identical form of Newton's and Coulomb's laws expected rather than curious.

22.6 Made Of, and Acted On By

A G1 is *made of* G2 particles, and the space between G1 particles is also *filled with free* G2 particles. Chapter 4 showed that this is not a contradiction: a rock is made of atoms and sits in a space full of free G1 particles, and one level down it is the same picture with smaller pieces. The pattern repeats because the model says it repeats, and that is the whole content of an infinite universe.

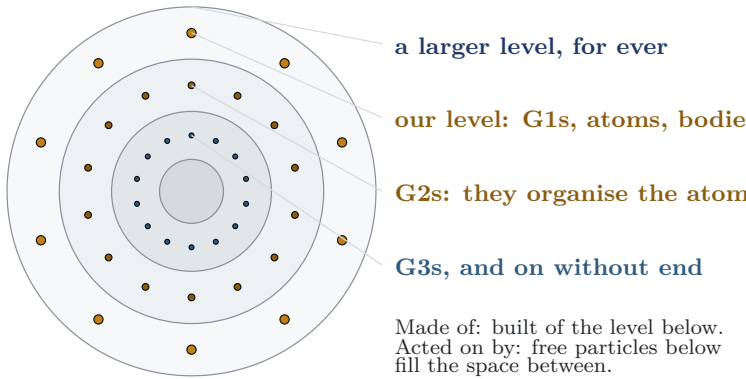


Figure 22.1: Levels without end. Each is built of the one below and acted on by it, and the same four motions are expected at every one.

22.7 An Old Argument, With a New Use

The idea is not new, and its history is worth a paragraph because it shows what is different here.

Greek atomism asked exactly this question and split over it. Democritus held that division must stop somewhere, at bodies that cannot be cut—*atomos*, uncuttable. Anaxagoras took the other side: in everything there is a portion of everything, and there is no smallest. The argument was never settled by evidence, because there was none to be had.

Then chemistry found atoms and appeared to settle it for Democritus. The settlement lasted about a century, and it is worth laying the retreat

out with dates, because the pattern is the argument.

Dalton gave atoms a quantitative footing in 1803, and they were understood to be indivisible—the name says so. Thomson found the electron in 1897, so they were not. Rutherford found the nucleus in 1911, and the atom became a system with parts and mostly empty space. The neutron arrived in 1932. Then in 1964 Gell-Mann and Zweig proposed that nucleons themselves are composite, and the deep inelastic scattering experiments at Stanford in 1968 and 1969 found the constituents, which is what the 1990 Nobel Prize was given for.

Four times in a hundred and sixty-five years the thing named "uncuttable" was cut. Each time the discipline rebuilt its foundations one level down, and each time it called the new floor final.

The present candidates are quarks and leptons, held to be pointlike and structureless. Perhaps they are. But the track record of the claim is not good, and the four universal motions decline to make it a fourth time.

What is different here is that the infinite regress does *work*. In Greek atomism the question was metaphysical—it changed nothing about what you expected to observe. Here it changes a great deal: it is what licenses looking one level down for the mechanism of Coulomb's law, and what predicts that the same four motions should be found there.

22.8 What an Infinity of Levels Costs

What this commits us to is not free.

It means there is no fundamental particle to find, and the search for one is a search for something that does not exist. It means every explanation in physics is provisional in a particular way—always complete at its own level and always deferring the next question downward.

Some readers will find that unsatisfying. A model that explains gravity by appeal to smaller particles, and those by smaller ones again, can look like an infinite regress dressed as an answer.

We think the opposite. A regress is vicious when each step adds a new kind of thing to avoid a difficulty. Here each step adds nothing new: the same four motions, the same kind of body, the same shadowing. The explanation does not get more complicated as it goes down. It gets more of the same.

And the alternative is worse. A final indivisible particle would be a thing with properties and no explanation for them—exactly the move this book has objected to from the first chapter. Somewhere the regress has to stop, and stopping it means pointing at something and refusing to say what it is made of.

What we have not modelled

The ratio is constrained, not predicted. *The factor of* 2.3×10^{39} *has been turned into a relation between two sea intensities and two blocking areas, which is progress, but it is one equation in two unknowns at every level. Until something independent fixes the G2 sea's intensity or the electron's size in it, the relation records the number rather than producing it. A model claiming the rungs of the ladder are alike still owes an account of why they differ by this much and not some other amount.*

The constraint does bite, which is worth noticing. *Requiring the level-2 law to reproduce Coulomb's exactly fixes the product of the G2 sea's intensity and the square of the electron's blocking area in it—one definite number. Assume the electron blocks G2 particles over something like the classical electron radius and the implied G2 intensity follows immediately; assume the Bohr radius instead and it comes out seventeen orders of magnitude smaller. So the model converts a question about charge into a question about the size of the electron, and those are not independent any more. Somebody now has to decide which radius is the right one, and that is the sort of thing Chapter 25 exists for.*

We have still never worked below G2. *Nothing fixes the size of a G3, or the ratio between successive rungs, or how many levels down one would have to go before anything observable changed. Those are the same unknowns as at level two, and they are approached the same way, by working the levels down one at a time.*

What you can now say

- There are no partless parts: every particle is made of smaller ones, and every level sits inside a larger one.
- Newton and Coulomb have the same face because it is the same mechanism one level apart.
- The ratio of about 10 to the 39 between electric and gravitational force is a ratio between two levels, not a brute fact.
- Atomism has been cut four times in 165 years, and the model declines to call the next floor final.

Chapter 23

No Medium Anywhere

STANDING: FRAMING. *Why the model needs no medium, and how it differs from the aether. An argument.*

A reader who knows the history has been waiting since Chapter 7 to ask one question, and it deserves a chapter rather than a footnote.

Is this just an aether?

Space full of particles, carrying light, filling every volume, present everywhere—that does sound like the thing physics spent the nineteenth century building and the twentieth century abandoning. If the four motions are a rebadged luminiferous aether, they inherit every objection that killed it.

They are not, and the difference is worth being precise about.

23.1 What an Aether Is

An aether is a **medium**: a continuous substance filling space, which waves travel through by disturbing it. The wave is not made of anything—it is a pattern of displacement *in* something, the way a ripple is not made of water but is water moving.

That is the aether's defining feature and it is the source of its problem.

23.2 The Container Problem

The aether hypothesis has deep intuitive roots. We watch waves on water and in air, and it feels obvious that light, also a wave, needs something to wave in.

But look at what makes those familiar media work. Water waves and sound waves do not propagate freely—they propagate because the medium is *contained*. The atmosphere is a layer of gas held against the Earth by

gravity. A solid conducts vibration because its lattice is bound together. Every wave-carrying medium we know of exists because some force holds it in place.

Now ask what contains an aether in open space. There is no answer. It has no gravitational container, no lattice, no boundary condition of any kind. Newton gave us the principle himself: a body in motion stays in motion unless acted upon. An uncontained medium filling the vacuum would simply disperse.

The aether hypothesis borrows an intuition from one physical situation and quietly drops the constraint that makes that situation possible.

23.3 The Experiment That Killed It

The container problem is an argument. What finished the aether was a measurement, and a book that claims not to be an aether theory had better face it directly.

In 1887 Albert Michelson and Edward Morley split a beam of light, sent the halves along two perpendicular arms, and recombined them. If the Earth were moving through a stationary aether, light travelling along the direction of motion should take measurably longer than light travelling across it, and the recombined beams should shift against one another as the apparatus was turned.

The predicted shift was about four tenths of a fringe. They measured at most about a fiftieth of that, and on average much less.

It has been repeated ever since with improving technology—Joos in 1930 with a larger and more sensitive apparatus, and modern optical resonator experiments which by 2009 had bounded any such effect at the level of one part in 10^{17}. There is no aether wind. Whatever light is, its speed does not depend on which way the Earth happens to be going.

23.4 Which Is a Problem for Us Too

Here is a place where the model has work to do, and we would rather say so than have a reader notice first.

That result touches the four universal motions directly, and we do not yet have the full answer.

Our space is full of particles. The Earth is moving through them. Chapter 5 actually *requires* that motion through the rain produce an asymmetry—that is what the whole account of inertia rests on. So the model expects the Earth to meet a different flux ahead than behind.

Does that make the speed of light directional? It depends on something the model has not settled: what the speed of a G1 is measured relative to. If light travels at c relative to whatever emitted it, that is an emission

theory, and emission theories were ruled out by observations of binary stars long ago. If it travels at c relative to the local rain, the rain is a preferred frame, and Michelson and Morley should have found it.

We can say what we think is *not* the answer. The rain is not a medium that light propagates through, so the specific thing Michelson and Morley were testing—a wave dragged by its carrier—is not what we are proposing. That is a genuine difference and it may be the whole of the escape.

What sets a G1's speed is a question Chapter 7 said we cannot yet answer, and the escape stays open until it is. Michelson and Morley's null result is on the list of tests in Chapter 24: if the model cannot show why an asymmetric flux leaves the speed of light the same in every direction, that part of the mechanism has to be rebuilt.

23.5 Why This Is Not That

The four motions posit no medium. They posit **bodies moving through empty space**.

That is a different kind of claim in three ways that matter.

Nothing is continuous. There are countable particles with gaps between them. Nothing fills a volume; things occupy positions in it.

Nothing needs containing. The particles are not held anywhere. They are in flight, and flight is what they do. There is no boundary condition to supply because nothing is being kept in place.

The wave is not a disturbance. A luminic wave is not a pattern travelling through a substance—it *is* the particles, in formation. There is no displacement, nothing oscillating, no medium doing the carrying. Remove the particles and you have not removed a wave's medium. You have removed the wave.

That third point is the one that does the work. Every objection to the aether concerns the properties a medium would have to have: rigid enough to carry transverse waves at enormous speed, tenuous enough not to drag the planets, present everywhere and detectable nowhere. A model with no medium is not required to supply any of them.

23.6 Three Centuries of Almost

This matters more than an abstract disagreement, because the aether is not a dead idea. It is a live one, and it is live among exactly the people who ought to be our closest allies.

The communities of physicists working outside the mainstream—the Natural Philosophy Alliance, its successor the John Chappell Natural Philosophy Society, and the various institutes and journals around them—contain a great many people doing the thing this book argues for: demanding a

physical model, refusing to accept an equation as an explanation, asking what things are made of. We have more in common with them than with anyone else.

And a large proportion of them are trying to do it with an aether. Some form of medium for gravity. Some form of medium for light. And with Ionel Dinu's fluid-dynamical work on circulation, a medium for magnetism as well—because the natural reading of a demonstration done in a tank of water is that there is a fluid.

So it is worth asking how long this has been going on.

René Descartes published his plenum in 1644—a universe filled with matter rather than empty, which was the aether under another name. **Christiaan Huygens published the *Traité de la Lumière* in 1690**, proposing that light is a wave propagating through an aether, and that is the version which survived and became the luminiferous aether of the nineteenth century.

Which makes the aether programme more than three hundred years old.

In all that time nobody has said what it is made of in a way that survived the next experiment. Nor has anyone since told us what contains it, or how something rigid enough to carry transverse waves at the speed of light can be tenuous enough to let the planets through unimpeded, or why three centuries of increasingly sensitive experiments have failed to find it.

That is not a criticism of anyone's intelligence. Some very good minds have worked on it. It is an observation about a research programme: when an idea has had three hundred and thirty-five years and has not yet produced the thing it keeps promising—a statement of what the stuff is—at some point the honest move is to try without it.

> We are not claiming to be cleverer than the people still working on the aether. We are suggesting that the reason it has not worked for three centuries is that there is nothing there to find.

23.7 Where We Part From Borchardt

This is also where we disagree with the man whose architecture we otherwise take whole.

From Glenn Borchardt comes the infinite universe and *no partless parts*—the framework of Chapter 22, which runs through everything here. His insistence that light must have a physical model is exactly right, and it is the same instinct that produced this book.

But the conclusion he draws—that aether is the answer, and that no competing physical model exists—is where we think the argument goes wrong, on both counts.

Aether is not a satisfying physical model. It relocates the mystery into an undefined, uncontained substance and leaves it there. And the claim that no

alternative exists is simply not so: Robert de Hilster's model demonstrates that you can have a mechanical, visualisable account of light with no aether in it at all.

We expect Borchardt's broader contributions to stand. We think his defence of aether for light will be seen as the weak link in an otherwise strong framework, and the container problem alone ought to give any careful reader pause.

23.8 And Where We Part From Yee

The same distinction separates us from Jeff Yee, whose simulations Chapter 12 credits and whose work convinced us that electron clouds can emerge from a model with no charge in it.

His Energy Wave Theory is ultimately an aether theory. Ours is not. We take his demonstration and decline his medium, which is an uncomfortable thing to do to someone whose work you have leaned on, and better said openly than left for a reader to notice.

What we have not modelled

There is a real objection on the other side of this and it should be recorded.

An aether theory gets some things cheaply that we have to work for. A continuous medium with the right properties delivers polarisation naturally, and transverse-wave behaviour, and a definite propagation speed set by the medium's own stiffness. We have to produce all three from the geometry of formations, and as Chapter 7 admitted, polarisation is a plausible sketch and the speed of light is not explained at all.

So this is not a chapter claiming victory. It is a chapter saying the two approaches have different debts, and that ours do not include inventing a substance nobody can contain.

What you can now say

- An aether is a continuous medium that needs containing, and the four motions have no medium anywhere.
- A luminic wave is the particles themselves in formation, so removing them removes the wave.
- Michelson and Morley's null result is a test the model must meet, and it waits on what sets the speed of a G1.
- The model parts from Borchardt and from Yee on the same point: the aether.

Chapter 24

How the Model Is Tested, and What Failure Means

STANDING: FRAMING. *How the model is tested, and what failure means: rebuilding the mechanism that failed.*

Most chapters in this book end with a box admitting what they could not do. This chapter gathers them, and says what a failed test would mean.

That is an unusual thing to print. The ordinary practice is to make the case as strongly as possible and let critics find the weaknesses, and a book following that practice would be about forty pages shorter. We have done the opposite deliberately, for a reason worth stating once: **a model that cannot be shown where it is weak cannot be tested, and a model that cannot be tested is not worth your time.** It is also worth saying what a failure does and does not mean. The four motions are a physical Turing machine: one particle, four ways of moving, and a set of rules for what follows. When a test goes the wrong way, it tells us that a particular arrangement or mechanism in the machine is wrong. The response is to rebuild that part from the same four motions, and never to add a fifth thing. A phenomenon the model cannot yet explain is a place where the G2 fields have not yet been found.

So here is the list. It is organised by how much damage each item would do.

24.1 Tests Where Failure Means Rebuilding

These are not difficulties. They are places where the model makes a definite physical claim. If one of them goes the wrong way, the mechanism we have proposed at that point is wrong, and that part of the model has to be rebuilt.

A magnetic monopole is found
the model claimed: a pole is a direction, not an object
rebuilt: the account of magnetism (Ch. 8)

Drag on planets, or none at all
the model claimed: drag cancels and inertia has a cause
rebuilt: the drag and inertia account (Ch. 5)

A white-hot Earth
the model claimed: momentum arrives without the heat
rebuilt: the account of gravity (Ch. 5)

Simulations produce nothing
the model claimed: some G2 arrangement gives the orbitals
rebuilt: that G2 arrangement (Ch. 15)

A dark fringe gets no energy
the model claimed: particles still strike the dark bands
rebuilt: the account of fringes (Ch. 18)

Nothing is abandoned and nothing is added.

Figure 24.1: Five tests and what each would rebuild. A wrong answer sends the work back to the mechanism at fault.

A magnetic monopole. Chapter 8 argued that a pole is a direction of circulation, not an object, and that an isolated one is therefore not a thing that can exist. Find one and that argument has to be rebuilt, and with it the account of magnetism the rest of the model leans on.

This has been looked for hard, and the search is one of the more determined negatives in physics. IceCube—a cubic kilometre of Antarctic ice instrumented as a detector—published an eight-year search in 2022 which found nothing and set a flux limit of about 2×10^{-19} per square centimetre per second per steradian for relativistic monopoles. Other searches cover a wide range of masses, and MoEDAL sits at the Large Hadron Collider looking for monopoles produced in collisions.

Decades of effort, across many orders of magnitude, and nothing. Mainstream physics treats that as a puzzle, since several respected theories predict monopoles should exist. We treat it as the expected result, and that is a genuine difference between the two accounts—one of us is surprised and the other is not.

Drag on the planets, or none at all. Chapter 5 put the whole weight of gravity and inertia on one calculation: a body moving through the rain meets an asymmetric flux. If that asymmetry bites at constant velocity, orbits decay and this mechanism is ruled out by the solar system. If it does not bite at all, inertia has no cause here and the model has gained nothing over Newton. The arithmetic has been done for both cases, and the items below report where it stands.

Maxwell's white-hot Earth. In 1875 Maxwell argued that if the

particles that make gravity give up their energy to the bodies they strike, even a small fraction of it appearing as heat would raise those bodies to a white heat in seconds. Chapter 5 explains why that cannot be dodged by making the particles pass through more freely: the interception that makes the shadow is the interception that deposits the energy. If the momentum-to-energy ratio of very light, very fast particles cannot close that gap, the shadowing account of gravity would have to be rebuilt, and with it the foundation the other three motions are built on.

Simulations that produce nothing. Chapter 15 rests the atom on the claim that some arrangement of G2 particles produces the orbitals we measure. Run the simulations properly and they may produce no stable configurations, or configurations unlike anything observed. That would not be a gap. It would mean that arrangement of G2 particles is the wrong one, and the search would continue in another.

A dark fringe that receives nothing. Chapter 18 claims the dark bands in an interference pattern are still being struck by particles that the screen cannot absorb. If a careful measurement shows a dark fringe receives no energy whatever, the account of interference has to be rebuilt.

A directional speed of light, or the lack of one. This cuts both ways and is the sharpest unresolved tension in the book. Chapter 5 requires that motion through the rain produce an asymmetry—inertia depends on it. Michelson and Morley, and every repetition since, find the speed of light independent of the Earth's motion to one part in 10^{17}. Either the model can show why an asymmetric flux does not make light directional, or it is in conflict with the most precisely confirmed null result in physics.

Drag on a body that shields its own interior. Chapter 5 shows that a body moving through the rain should be stopped dead—every object, at every speed, inside a few millionths of a second—unless the chance of a G1 being deflected falls off as the inverse of the relative speed. It does, and for a reason rather than a coincidence: deflection depends on time spent inside the target, and that time goes as $1/w$. For a single nucleon, or any thin layer, the drag cancels exactly.

It does not cancel for a planet, because a planet shadows its own insides. The surviving drag on the Earth works out at roughly an eighth of the Sun's pull, against an observational bound near a part in 10^{12}. That is not a near miss. It is enough to stop the Earth in a few years, and the Earth is still going.

This is the one item on this list that is not a worry about what might be found but a conflict with what has already been measured. It cannot be relieved by a better value for matter's opacity—that quantity cancels out of the result exactly—so it will be settled by an error in the calculation, by a mechanism that restores the cancellation through a self-shielding body, or by rebuilding that part of the mechanism.

And the assumption it rests on. Chapter 5 sets out why we now

think the deeper falsifier is not that residual but the rule beneath it: that a deflected particle's push is fixed in size and direction however fast the body is moving. If the push is instead the relative momentum—which is what scattering off a moving target ordinarily gives—the drag does not cancel at all, no choice of exponent recovers it, and the drag comes out about 10^{12} times the Sun's pull on the Earth, not the eighth that self-shielding gives. That is a single, well-posed physical question, and more of the model hangs on it than on anything else in this chapter.

24.2 Tests That Would Hurt Badly

The positive Hall effect. Some metals and most semiconductors give a Hall voltage of the sign a positive carrier would produce. That is what the hole was invented to describe, and we have not yet shown it with G1 particles alone. It is an open item rather than a threat: it depends on the arrangement of a particular lattice and its G2 fields, which is the same work as everything else in the atom.

Refraction. Chapter 7 admitted that the naive version of our own mechanism reproduces Newton's error and predicts light travelling faster in glass, which is false. We offered capture-and-release as a sketch. Until it works, refraction waits on the G2 fields like the rest.

The sea's intensity. Transparency and strength pull in opposite directions: the more invisible matter is to the G1 sea, the fiercer that sea must be to hold the planets in their orbits. The measured bound on shielding forces the sea above roughly 3×10^{37} joules per cubic metre, about a thousand times the energy density of nuclear matter; the figure is worked out later in this chapter. Nothing refutes this. It is simply very hard to believe, and every future tightening of the shielding bound makes it worse as the square. A reader who rejects the model on this ground alone is not being unreasonable.

Polarisation. The best argument the wave picture has. Our candidate is the orientation of a rank, and it is a sketch.

The half-spacing prediction. Chapter 18 argues that what arrives at a dark fringe is a procession at half the original spacing. If spacing is colour, that is light of half the wavelength—and a measurement finding no such thing, where the model says it should be, would break the account of interference.

Neutrality. Chapter 10 identifies charge with how much of the G2 sea a body blocks, which is what makes charge come in exact whole steps. But blocking only ever adds—two shadows are never less than one—while charge cancels, which is why a neutral atom pulls on nothing. A body at its settled count is still full of blockers. On the shadowing reading it should attract everything near it, and it does not. Something must carry a sign and nothing in gravitic motion can.

Like failing to repel like. Chapters 10 and 17 both attribute the repulsion of two surpluses to their orbiting populations meeting in the same sense. That is a magnetic explanation for an electrostatic fact. A simulation that produces attraction between two such bodies, or nothing at all, removes the model's account of half of electrostatics.

24.3 Things We Simply Have Not Done

This is the longest list and the least dramatic. None of it refutes anything. All of it is work.

No constant in physics has its *value* derived here. Not Planck's, not Coulomb's, not the permittivity or permeability of free space, not the speed of light, not the gravitational constant, not the fine structure constant.

Two of them now have an anatomy, which is less than a derivation and more than nothing. Newton's constant and Coulomb's come apart the same way—a solid angle, the intensity of a sea, and a factor converting a body's amount into a blocking area—so neither is any longer a brute number, and the 4π in Coulomb's constant turns out to be a real solid angle rather than a convention. But in both cases the pieces are known only through their product. Nothing fixes them separately, so nothing predicts either constant's value, and a model that explains why two constants resemble each other while predicting neither has done something real and something small.

No spectral line is predicted. No component value: not the diode's 0.7 volts, not a resistivity, not Ohm's law itself. The size of a G1 is unknown, its mass is unknown, and how many are in an electron is unknown.

The configuration of the G2 fields—the thing half this book leans on—has no worked-out description at all.

Smaller items, each named in the chapter it belongs to: why permanent magnets stay permanent; why superconductors stop resisting abruptly rather than gradually; whether the two speeds in a wire are in the right proportion; why sodium's D line is two lines six tenths of a nanometre apart rather than one; and whether traffic passing through a lattice really would fail to store heat the way Drude's electron gas was wrongly expected to.

24.4 One Thing the Model Predicts

A list of ways to be wrong is not the same as a prediction, and a reader is entitled to ask for at least one number the model produces that the standard account does not. There is one, and it comes from the same transparency that everything else in this chapter has been turning on.

If matter is nearly but not perfectly transparent to the G1 sea, a body's outer layers shadow its interior very slightly. The interior therefore contributes a little less than its share, and the body's gravitational mass falls

fractionally short of its inertial mass—by an amount proportional to its size times its density, not to its mass. Two bodies of the same mass but different density would fall at fractionally different rates.

That is a violation of the equivalence principle, and the model puts figures on it: about 9×10^{-13} for the Moon, 5×10^{-12} for the Earth, 2×10^{-10} for the Sun. It is the only place in this book where the mechanism produces a number that general relativity says should be exactly zero.

Now the part we would rather raise ourselves, because it is the one a critic would reach for.

Lunar laser ranging has been testing precisely this for half a century, by watching whether the Earth and the Moon fall toward the Sun at the same rate. They do, to about one or two parts in 10^{13}. The figures above differ by roughly 4×10^{-12} between the two bodies—some twenty times larger than that bound. Taken at face value, the model's own prediction is already excluded.

It is not, and the reason is worth setting out carefully, because it is exactly the kind of thing that is easy to get wrong in one's own favour.

The prediction and the bound are the same measurement. The shielding coefficient used to generate those figures traces to Eckhardt's 1990 limit, and Eckhardt obtained that limit *by running a lunar laser ranging test of the equivalence principle*. The quantity we are calling a prediction is the quantity that was measured in order to fix the constant that the prediction is computed from. There is no independent comparison to be made, and the apparent falsification above is an artefact of treating one measurement as two.

So this is not a failure of the model. But it does not get off free either, and the real finding is the second one.

The bound usually quoted is more than three decades old. The same analysis has been redone with a modern data set—Williams, Turyshev and Boggs, working from the lunar ranging solution—and it reports a shielding coefficient of $(3 \pm 5) \times 10^{-23}\,\mathrm{cm^2/g}$, consistent with zero and about forty times tighter than Eckhardt's figure of 1990. Their treatment is the same one in every respect that matters: they write the shortfall as $m_g/m_i = 1 - hf\rho r$, and for a uniform sphere they give $f = 3/4$, which is our $\frac{3}{4}\kappa\rho R$ exactly. Our result is a century-old published one, as Appendix A says. They also note, following Russell, that f is larger for a centrally condensed body—about 0.98 for the Earth rather than 0.75—so if anything we have been understating the effect by a further third.

The consequence lands on the sea. Because the required intensity goes as $1/\kappa^2$, tightening the opacity by forty multiplied the floor by sixteen hundred: from the 2×10^{34} joules per cubic metre that the older bound allowed, which is roughly the energy density of nuclear matter, to about 3×10^{37}. That is about a *thousand times* nuclear matter density, in every cubic centimetre of what looks like empty space.

That is the honest outcome of this check, and it is worse than the thing we were worried about. The model survives the equivalence-principle test because the test is what calibrated it. What it does not survive comfortably is the price of the calibration.

One line from that paper is worth quoting, because it conveys the scale better than our arithmetic does: for a body's gravitational attraction to be diminished by half, they note, you would need a column of matter with the density of water stretching at least halfway from the solar system to the centre of the galaxy. That is how transparent matter has been measured to be, and it is the number this model has to pay for.

But something does survive, and it is a prediction of a different kind. We cannot predict the *size* of a violation, because the size is what was measured to fix our constant. We can predict its *shape*. If the mechanism is shadowing, a body's gravitational shortfall depends on how much matter a G1 must cross to reach its middle—its density times its radius—and not at all on what that matter is made of. Lead and aluminium of the same size and density would fall identically; a dense small ball and a light large one of the same mass would not.

That is worth saying because it cuts against the grain of the field. Almost every equivalence-principle experiment ever built has hunted for a *composition* dependence—different materials falling differently—because that is what the theories being tested predict. This model says to look somewhere else entirely: at column density, with composition held irrelevant. A violation of that shape, at any size, would be a measurement of matter's opacity and through it the first direct measurement of the G1 sea. A violation that tracked composition instead would belong to somebody else's theory.

24.5 What That Adds Up To

An honest summary of where this stands:

> The four motions are at present a *qualitative* model. They explain the shapes of many results and predict the value of none.

That is a real limitation and we are not going to dress it up. The model says what everything in the room is made of and how it moves, and it has not yet been run far enough to produce figures. We claim that it can be: the equations of mainstream physics describe what these motions do, and in time they should be derivable from the model, as Newton's inverse square already falls out of the shadowing.

The gap is work, and the next chapter is about what to run.

What you can now say

- Every test here is a place where the model makes a definite physical claim.
- If one fails, that mechanism is rebuilt from the same four motions, and never by adding a fifth thing.
- The four motions are at present a qualitative model, and the gap is work.
- The model also makes predictions, including a small violation of the equivalence principle.

Chapter 25

The Simulations That Would Settle It

STANDING: PROPOSED. *A programme of particle simulations, not a result. The first run has reported; the other runs have not been made.*

The weak points in the last chapter all have the same shape: a mechanism that behaves correctly in words and has not been made to produce figures.

There is one way to close that, and it is not more equations fitted to measurements. Fitting a curve produces a description, and the complaint this book has made throughout is that descriptions have been allowed to stand in for explanations. Doing the same thing one level down would be no improvement.

25.1 Particles as the Model

What is needed is **physical model simulation**: put real particles in a box, give them nothing but motion and collisions, and find out what happens.

The distinction matters. A conventional simulation implements the known force law and shows you its consequences, which tells you nothing you did not put in. A physical model simulation implements only bodies and contact, and the force laws—if the model is right—come out the other end as results.

Our copper-lattice simulation is already of the second kind. It places 1,200 real copper nuclei in their real face-centred cubic arrangement and treats every G1 as a body under gravity, with no artificial cutoff: every particle feels every nucleus at every instant. Nothing in it knows about conductivity. What it shows—a bound cloud drifting through channels, particles threading the open corridors and scattering where they do not—was not programmed in.

25.2 Why This Is Now Possible and Was Not

This programme is being proposed in this century and not the eighteenth because Fatio and Le Sage could not have done it, and that is most of why their idea died.

A shadowing model is a statement about enormous numbers of particles. You cannot check it on paper. The force between two bodies is a small residual in a very large flux, and establishing that the residual goes as the inverse square, and that it scales with mass up to some limit, means tracking collisions—not a few hundred of them but as many as a machine will carry.

That is now routine. N-body and molecular-dynamics codes handle millions of interacting particles as a matter of course; the techniques were built for galaxies and proteins and work just as well for anything else that is numerous and governed by contact. Our own copper simulation tracks every G1 against 1,200 nuclei with no cutoff, which would have been impossible on any machine before about 1990 and is now something a laptop does while you watch.

So the objection that killed Le Sage—that his idea was untestable—is no longer true. It was true for two hundred and fifty years. It stopped being true recently enough that nobody has got round to the work.

25.3 The First Run Has Reported

The first item on the list below has been done, and it is worth setting out what it returned before proposing eight more.

The run is the plainest possible version of Chapter 5: millions of particles given isotropically random directions and random impact points, two spheres, exact ray–sphere intersection to decide whether the first body lies upstream on each ray, and the transferred momentum summed. No force law appears anywhere in it. There is no inverse square in the program, no attraction term, nothing but bodies and whether a ray hits one.

Three things came out.

The force is attractive and goes as the inverse square, matching the analytic prediction within Monte-Carlo error across the whole range tested—a ratio of simulated to predicted force of 1.018 at one separation, 0.975 at another, 1.001 at a third.

Newton's third law came out of the sampling. Swap the two bodies' radii—make the big one small and the small one big—and the force comes back the same to within error. Nothing in the program enforces that. It falls out of the fact that the body which casts the shadow and the body which catches it trade places in the arithmetic.

The interior works too. A separate run placed a test body *inside* a sphere and recovered Newton's interior solution—the field rising linearly from zero at the centre—to six significant figures, and showed it switching

off as the sphere is made opaque, exactly as it should, since nothing reaches the middle of a body that stops everything.

Now the careful part, because it is easy to credit this with more than it delivers.

The simulation and the algebra rest on the same postulates. Sampling an integral by Monte Carlo is still evaluating that integral, so the run tests nothing whatever about whether the postulates are true. What separates the two routes is narrower and more interesting: **the algebra makes one assumption the simulation does not.** Before any force is computed, the analytic derivation replaces the hail of discrete particles with a smooth isotropic flux of a given intensity. That is a continuum idealisation, and it is introduced at the very first step. The simulation never writes it down. It samples individual directions and impact points, and the isotropy emerges from the sampling instead of being imposed on it.

So what the run establishes is that the continuum idealisation is *faithful*—that treating discrete random bombardment as a smooth flux costs nothing. In most of physics that would be a technical footnote. In a framework whose entire ontology is discrete particles it is not, because a reader is entitled to object that a derivation which quietly swaps the corpuscles for a continuous field has stopped being a particle theory at the point it mattered. This answers that objection directly, which is the whole reason the distinction drawn in the last section is worth drawing.

One more remark, offered conservatively. The shadowing force has been derived analytically many times over three centuries, and evaluated by numerical quadrature at least once. Shadowing attractions have been simulated at particle level in neighbouring physical systems—the depletion force between large spheres in a bath of small ones, granular depletion, shadowing forces in dusty plasmas, worldline methods for the Casimir effect. But we have not found an instance, anywhere in the push-gravity literature, of this force being obtained by generating corpuscles with random directions and impact points, tracing each one, and summing what it delivers. The physics is three hundred years old. The instrument appears to be new, and the instrument is the part that matters, because it extends without modification to arbitrary shapes, to three bodies with overlapping shadows, and—most importantly—to the questions below, where what is wanted is whether a proposed rule *produces* a behaviour rather than what a known rule integrates to.

25.4 Nine Runs Worth Making

Here is the programme, in rough order of how much it would settle. The first five are the apparatus we have, and the first of those has now reported; the last four are new builds.

1. Shadowing, quantitatively. *Done, as described above.* Two bodies



Figure 25.1: The nine runs: which chapter each would settle, and where each stands.

in a rain of small fast particles; the force measured against separation and against the bodies' sizes. The inverse square came out, the third law came out, and the interior field came out. What remains of this run is the mass-proportionality limb: at what point does a body begin to shadow its own interior badly enough that the force stops tracking mass? The analytic answer says ordinary matter is some twelve orders of magnitude away from that threshold, and the simulation agrees in all three regimes, but the crossover itself has not been mapped.

2. Drag and inertia. *Half done, and not by simulation.* The drag half has been worked analytically: for a body in motion the retarding force depends on how the chance of interacting varies with relative speed, and when that chance goes as the inverse of the speed—which is what the time a particle spends inside its target gives—the drag cancels exactly at every speed. That is the escape Chapter 5 describes. It holds for a thin layer and fails for a body thick enough to shadow its own interior, which is where the model currently stands in conflict with the ephemerides, and that failure is the most useful thing a simulation could attack: build a body many layers deep, move it, and measure what survives. The inertia half is untouched, and it is the half that would be a gain rather than a rescue. Put a body under acceleration in the sampled rain and measure what resists it. The model needs retardation at constant velocity to be negligible and resistance to acceleration to be substantial; one run compares them.

3. G2 configurations. The central one. Give a simulation nucleons with G2 gravitic and magnetic motion and a population of G1 particles, and let it settle. Do stable arrangements form? Are they lobed? Do the capacities match shell capacities? This is Chapter 15, and Chapter 24 says plainly that it may produce nothing, in which case the arrangement is rebuilt.

4. Induction. Add an external orbiting population to the copper lattice and move it. Does a net drift appear along the wire? Does it reverse when the sweep reverses, stop when the sweep stops, and run the way that opposes the approach? Those four checks are Faraday's result, the reversal, the requirement for change, and Lenz's law.

5. Edge deflection. G1 particles passing a sharp boundary of mass. How much are they deflected as a function of how close they pass? Is the deflection random in direction but not in timing, as Chapter 18 requires? Does it depend on group spacing, and in which sense? That last one addresses the prism-versus-edge contradiction we have not resolved.

6. Glass. Send luminic waves—processions of G1 particles in formation—through a lattice of randomly placed atoms, which is what glass is, and see whether the formations come out the other side intact.

This is the one we would run first after the gravity checks, because it tests more of the book than any other single run. Does a procession survive passage through matter without being scrambled? If it does, transparency is explained: glass is transparent because its atoms do not disturb the ranks. If the formations come apart, the account of light in Chapter 7 has to be rebuilt, because light demonstrably does get through windows.

It also bears directly on the weakest point in that chapter. A procession threading a lattice is slowed—not because any particle slows, but because passage through the atoms delays its progress, which is the capture-and-release sketch we offered for refraction and could not defend. A simulation would either produce a delay of the right size or it would not. The refractive index of glass is 1.5; a run that reports a progress delay anywhere near that would be the most useful number this programme could produce.

And a lattice that is *ordered* rather than random is a crystal, which should behave differently. If the model is right, that difference ought to appear without being put in.

7. An atom. G1 particles orbiting a nucleus of nucleons, each nucleon carrying its own G2 magnetic field, with G2 gravitic motion doing the holding. Let it settle and see what shape the population takes.

This is the same question as run 3, built from scratch, and it is the one that tests the model hardest. Chapter 15 says some arrangement of G2 particles produces the orbitals we measure. Here is where that claim is either cashed or refused.

8. Two bodies, each with orbiting populations. Give two assemblies of nucleons their own orbiting G1 particles and bring them together, in both relative senses of rotation.

This tests the Dinu rule directly—same rotation should repel, opposite should attract—and it tests the thing Chapter 10 admitted was asserted rather than shown: that two bodies both holding a surplus push apart because their orbiting populations meet in the same sense. That is a magnetic explanation offered for an electrostatic fact, and it is one of the

model's louder promises. A run would confirm it or show that the rule has to be rebuilt.

This one is harder than the others and belongs later. It needs the atom to work first.

9. A component. The copper simulation pointed at a junction rather than a plain wire. Does a standing imbalance form? Does it pass traffic one way and stall it the other? Does a number resembling a forward voltage appear?

25.5 What Each Run Has to Report

A simulation that produces a pretty animation has demonstrated that someone can write a pretty animation. To count as evidence, each of these has to report numbers against a prediction made beforehand, and the predictions are not difficult to state.

For run 1: the exponent in the force law, which should come out at two, and the separation at which proportionality to mass starts to fail.

For run 2: two forces—retarding at constant velocity, resisting under acceleration—expressed as a ratio. The model needs that ratio to be very large. Any value near one says that mechanism has to be rebuilt.

For run 3: the number of stable configurations found, their shapes, and the population each will hold. Those are to be compared against the SPDF shapes and the shell capacities, which were not put into the simulation.

For run 4: the sign of the induced drift relative to the sweep. One bit of information, and Lenz's law rides on it.

For run 5: deflection as a function of impact distance and of group spacing, and whether the scatter is random in direction only or in timing too. One number here would settle a great deal, because Chapter 19 reduces the whole pinhole account to two quantities: the rim field's reach and the angle it deflects through. Measure either one and the other becomes a prediction.

For run 6: whether a procession survives the lattice at all, and if it does, the progress delay through it. The refractive index of glass is 1.5. A run reporting a delay near that is the single most useful number this programme could produce; a run reporting formations that come apart sends Chapter 7 back to be rebuilt.

For run 7: the number of stable arrangements, their shapes, and how many G1 particles each will hold—against the SPDF shapes and the capacities 2, 6, 10 and 14, none of which are to be put into the simulation.

For run 8: one bit, twice. Do two assemblies with opposed rotations come together, and do two with matching rotations push apart? The second is the one the model has promised and never shown.

For run 9: a threshold voltage, if one appears at all.

Every one of those is a number that can disagree with the world.

25.6 What Would Make This Credible

Two conditions, and they are not negotiable.

The simulations must be able to fail, and the failures must be published. A simulation tuned until it produces the desired result has demonstrated the tuning.

Nothing may be added that is not in the model. The temptation, when a run produces nothing, is to introduce one more interaction to make it work. That is exactly the move Chapter 4 forbade. If the configuration of the atom cannot be built from particles moving in four ways, the answer is not a fifth thing. The answer is a different arrangement of the same four motions, and the search goes on there.

And the parameters must be fixed before the run, not after. A shadowing simulation has free quantities in it—how many particles, how fast, how large, how often they collide. Choose those to make the answer come out and you have fitted a curve, which is the very thing this book has spent its whole length objecting to. Set them from physical reasoning, publish them, then run.

25.7 Why We Think It Is Worth Doing

Because the vocabulary is complete, as Chapter 15 argued. If all forces reduce to combinations of four motions of one particle, then the answer is already inside the vocabulary and the work is a search rather than a mystery.

And because the alternative is to keep writing. We have written a good deal, and there is a point past which more prose adds nothing. Everything in Chapter 24 is a number waiting to be produced, and no amount of careful argument will produce it.

> This book has gone as far as words can take the idea. What comes next is arithmetic, and it is not ours to assume it will go our way.

One run has now reported, and it went our way. That is one out of nine, on the easiest question of the nine—the one where the answer was already known analytically and the simulation was checking the arithmetic rather than discovering anything. The runs that test the model hardest are further down the list and have not been built. We would rather say that plainly than let a single confirmation stand in for the programme.

- The way to close the debts is physical model simulation, and the first run has reported.
- Nine runs are proposed, from shadowing to drag, the atom, induction, glass and a diode.
- Each run has to report a number against a prediction made beforehand, and it must be able to fail.
- If a run fails, the arrangement is rebuilt and the search goes on.

Chapter 26

An Evening with Newton

STANDING: FRAMING. *A dialogue that walks through the argument of the book.*

> *A staged conversation. Robert de Hilster and David de Hilster sit on a centred stage with Sir Isaac Newton, a man pulled three centuries out of his own time and visibly delighted to be here. The house lights are up. The audience surrounds the three men.*

DAVID: Good evening. My father and I have spent a good portion of our lives building something we call the four universal motions. And tonight we have, let us say, an unusual guest to put it to. Sir Isaac, thank you for joining us.

NEWTON: I confess I do not entirely understand the machinery that brought me here, and that is a rare and uncomfortable sensation for me. But I am told you have been busy with my universe. So. Let us be busy together.

ROBERT: That is exactly the spirit we hoped for. I want to say something plainly at the start, because it matters to us. Everything we are going to tell you tonight is Newtonian. Not Newtonian in flavour—Newtonian in substance. Particles with mass, moving through space, pushing on one another by contact. No fields with minds of their own. No mathematics standing in for things we refuse to name. Just bodies in motion.

NEWTON: *(settling back, pleased)* Then you and I are already friends. I spent my life resisting the temptation to dress ignorance in elegant clothing. Tell me where you begin.

I. Gravity as Random Motion

DAVID: We begin where you began. Gravity. But we ask a question you left open. You gave the world a law—every mass attracts every other, falling

off as the square of the distance. The most successful equation ever written. But you never said why.

NEWTON: *(a flicker of old irritation)* No. I did not. And I was attacked for it. *Hypotheses non fingo*—I feign no hypotheses. I could measure the attraction. I could predict the planets. But the cause of it, the mechanism by which one body reaches across empty space to pull another—that I could not honestly claim to know. I left it for posterity. I gather posterity has not been kind.

ROBERT: Posterity invented curved spacetime and called it solved. We think you would have found that unsatisfying.

NEWTON: Space that bends? Without anything doing the bending? *(shakes head)* Tell me your answer instead.

ROBERT: Our answer is that there is no pull at all. There is only push. Space is not empty. It is filled—saturated—with tiny particles moving in every direction at once, at enormous speed. A constant, random rain coming at you from all sides.

NEWTON: Random in every direction.

ROBERT: Completely. And because it comes from everywhere equally, on a single body it cancels. You feel nothing. But put two bodies near each other, and each one blocks some of the rain coming toward the other. Each one casts a shadow.

NEWTON: *(very still now)* So the side of one body facing the other is struck less.

DAVID: Less. And so it gets pushed toward the other body—not pulled. What you called attraction is bodies being pushed into each other's shadows.

NEWTON: *(slowly)* By God. That is a pressure differential. The apple does not reach for the Earth. The Earth shields the apple from the rain above, and the rain below drives it down. *(he is already working it)* And the inverse square—of course. A shadow spreads. The shielding from a body diminishes with the square of the distance because the solid angle it subtends diminishes with the square of the distance. The geometry demands it. I did not have to assume it. It would fall out of the picture on its own.

ROBERT: *(quietly, to David)* I told you he would get there before we finished the sentence.

NEWTON: *(almost to himself)* Others proposed this. Fatio. Le Sage, after my time, I am told. Push, not pull. It was dismissed.

DAVID: It was. For two reasons. They said the particles would slow the planets through drag, and that the bombardment would heat everything to nothing. Both objections treated a particle meeting matter as a simple collision. Ours are unimaginably small and fast, and what happens when one meets matter turns out to matter more than how fast it goes. The version that was refuted is not the version we are proposing.

NEWTON: *(nodding)* You rescued a discarded truth by looking harder at what happens when a particle meets matter. That is a respectable kind

of work. I will accept this readily. It offends nothing in me. It answers something in me. Go on. This was the easy part, I suspect.

(A thought arriving.) Though I must press you on one thing before we leave it. If space is thick with these particles, and a planet is ploughing through them—

DAVID: —it should slow down. Yes. That is the objection that buried Le Sage, and it is the hardest one. We have worked it through. In the plain version the drag would stop everything in millionths of a second. It cancels only if the chance of a particle being deflected falls off in step with its speed relative to the body, and we have a reason to think it does, though it is not finished: the cancellation fails for a body as large as the Earth, and a great deal rests on one assumption about the push each particle delivers.

NEWTON: *(nodding slowly)* An honest answer, which is rarer than a correct one. And the same bombardment, I suppose, is what keeps a body in motion?

ROBERT: We are careful there now. A body in a void continues because nothing stops it—that needs no cause. What the rain might explain is the *resistance* a body puts up when you try to change its motion. Your second law, not your first.

NEWTON: *(very quietly)* The m. *(he sits with it)* Nobody has ever told me why there is an m. I wrote it down because the measurements required it, and I have been waiting three hundred years for somebody to say what it is. *(a long pause)* You are telling me it might be the rain pushing back.

DAVID: It might. The same calculation decides that and the drag, and it has to come out small in one case and large in the other. If it does not, that part of the machinery has to be rebuilt.

NEWTON: Then that is the first thing you should compute, and I would not sleep until it was done.

II. The Second Gravity

DAVID: Here is where it gets interesting. What holds an atom together?

ROBERT: Mainstream physics says there is a separate force down there—the electric force, governed by Coulomb's law. Like charges repel, opposite charges attract. And the equation for it is—

NEWTON: *(cutting in)* Let me guess. An inverse square.

ROBERT: *(grinning)* Force proportional to the product of the two charges, divided by the square of the distance between them.

NEWTON: *(sitting bolt upright)* But that is my equation. That is the *form* of my equation. You are telling me the law that governs the very small has the same shape as the law that governs the heavens?

DAVID: Identical shape. The only difference is what you put in place of the masses, and the constant out front.

NEWTON: *(intensely)* When two equations have the same form, sir, it is one of two things. Either it is a coincidence—and I have never in my life trusted a coincidence in mathematics—or it is a clue. The form is the same because the thing is the same.

ROBERT: That is exactly our argument.

NEWTON: So what is your claim—that the force inside the atom is also gravity?

DAVID: A second gravity. We call it G2. The first—the rain we just described—is made of particles we call G1. But G1 particles are themselves made of something smaller and faster, and down inside the atom it is a rain of G2 particles doing the shielding, the pushing, the holding-together.

NEWTON: A finer rain. *(working it)* And the constant is different in Coulomb's law because the particles are different—smaller, faster—but the mechanism is the same. Shadowing. Pushing. *(leaning back, exhaling)* So gravity is not one thing operating at one scale. It is the same trick, played again with smaller pieces, at the next level down. I like this enormously. It is economical. I always believed Nature was pleased with simplicity, and affects not the pomp of superfluous causes. You are showing me a Nature that found one good idea and used it twice.

DAVID: Not twice, Sir Isaac. That is the next part.

III. No Partless Parts

NEWTON: *(narrowing his eyes)* Not twice. Then how many times?

ROBERT: Here we owe a debt to a man named Glenn Borchardt, and his central principle is one that will either thrill you or trouble you. There are no partless parts.

NEWTON: Meaning nothing is fundamental. Nothing is the final, indivisible brick.

DAVID: Nothing. Every particle, no matter how small, is made of smaller particles still. The G1 is built of G2. The G2 is built of G3. And it never stops.

NEWTON: *(very quietly)* And no top, I should think, if you are consistent. Our world sits inside a larger one, which sits inside a larger one, forever.

ROBERT: Infinitely up and infinitely down. And the four motions occur at every level. The same dance, all the way up and all the way down, with no first step and no last.

NEWTON: *(He stands. He cannot help himself.)* You must understand what this does to a man like me. I was haunted by the infinitely small. The calculus—my fluxions—I built it by letting quantities shrink toward nothing, and the philosophers savaged me for it. I am told a bishop later called them "ghosts of departed quantities." I never had a physical picture of what it meant to divide and divide without end.

DAVID: And now?

NEWTON: And now you hand me a universe that is actually like that. My mathematics of the infinitely small was not a trick after all. It was a description of the architecture. *(he sits, somewhat overcome)* That is a strange comfort to receive three hundred years late. *(a dry smile)* A turtle standing on a turtle, and so on without end—and yet you have made the turtles do work. Each level holds the one above together. I shall need a moment with that one. But continue. You mentioned magnetism. That, I never cracked.

IV. Magnetism

NEWTON: Magnetism defeated me honestly. The lodestone attracts iron, and it also repels—and attraction-and-repulsion from the same stone resisted every model I could build. Gravity only ever attracts. Magnetism does both, and it has poles, and the poles cannot be separated. I set it aside. It is one of my few open defeats. So. What is a magnet?

ROBERT: Here we lean on Ionel Dinu, who did something beautifully simple: experiments underwater, with vortices and swirling water, to model what magnetism might physically be. What he found pointed to this—magnetism is orbital motion. Particles going in circles.

NEWTON: Orbits. *(immediately engaged)* Now that is a word I own. And the two poles?

DAVID: The two directions of circulation. One way around is one pole, the other way around is the other. That is why you can never separate them—they are not two things, they are two senses of the same rotation. Cut the magnet in half and each half still has a clockwise end and a counterclockwise end.

NEWTON: *(softly)* Of course it does. You cannot have a whirlpool with only one direction of spin. And attraction versus repulsion?

ROBERT: Bring two magnets together. If their particles orbit the same way, then where they meet the flows run against each other and they grind—they repel. If they orbit opposite ways, the flows at the meeting place run together—

NEWTON: —they mesh. Like gears turning the proper opposite ways. *(he claps once, sharply)* The interlocking of two rotations! That is mechanical. That is something I can hold in my hand. *(marvelling)* So you have not added anything to the world. You have only made the same rain go around in a circle. Random motion gives me gravity. Circular motion gives me magnetism. *(he looks at his own hands)* The lodestone that defeated me was only ever a vortex I could not see. I should have liked to have known that. It cost me sleep.

V. Light: Waves of Birds

DAVID: Now the one you will have the strongest opinions about.

NEWTON: *(immediately combative, and delighted to be so)* Light is mine. I split the sunbeam and found the colours hiding inside the white. And I argued—against Hooke, against Huygens, against the whole quarrelsome lot—that light is corpuscular. Particles. That is why light casts sharp shadows and travels in beams.

ROBERT: And you were attacked for it, because light also does things that only waves seem able to do.

NEWTON: *(grudgingly)* Bending round edges, and beams that cross without a collision. Yes. Hooke and Huygens had the better of me there. And then, I am told, physics later decided light is somehow both at once, and declared the contradiction a deep truth and stopped asking. *(witheringly)* "Wave-particle duality." A confession dressed as a discovery. You do not resolve a paradox by naming it.

ROBERT: *(quietly)* No. You do not. And this is the piece I am proudest of, so let me give it to you carefully. You were right that light is particles. Your only mistake—and it was the natural mistake—was thinking each particle had to carry the wave inside itself.

NEWTON: *(leaning in)* And it could not. A single body cannot be a wave. I felt the failure but could not name it.

ROBERT: Because a wave is not a property of one particle. A wave is a property of many—a whole line of them, side by side, travelling together. Don't put the wave inside the corpuscle. The wave *is* the line of corpuscles.

NEWTON: *(absolutely motionless)* Say that again.

ROBERT: Picture a flock of birds. A single straight line of them, wingtip to wingtip, all flying forward together. That line is one wave. Now another line behind it, and another, each separated by a gap. That whole procession, flying at the speed of light, is a beam of light. Each line is a wave. The gap between the lines is what gives the beam its frequency.

NEWTON: *(stunned)* So there is no single body rising and falling. There is no—bobbing.

ROBERT: None. Nothing moves up and down. The "wave" is not a wiggle. The wave is a rank of particles flying abreast.

NEWTON: *(he sits back as if struck)* The wave is the rank. The beam is the column of ranks. The particle is the single soldier in the line. And of course a single soldier cannot be a marching column—that was my error stated in one sentence. *(he is quiet for a long moment)* I was so close. I had the particle. I only needed to stop demanding that each particle carry the whole wave on its own back. The answer to my failure was not a different idea. It was more of my own idea.

DAVID: And when that beam reaches your eye it arrives as a drumbeat. Line strikes, gap, line strikes, gap. That rhythm of blows is the frequency.

NEWTON: *(slowly)* A frequency of impacts. Not a vibration carried by one thing, but a count of arrivals. *(a flicker of delight)* That I can measure. *(eagerly)* Then colour must follow from the spacing of the blows. Tell me I am right.

ROBERT: You are. Tight spacing is blue. Wide spacing is red. No particle is "blue." Colour is how closely packed the ranks are.

NEWTON: *(very softly)* So the colours I found hiding in the white light were never colours in the particles. They were spacings. *(he shakes his head slowly)* It is more elegant than what I had. I do not say that easily. Why did I not think of it? I had the corpuscle. I had the prism. I had every piece but the one that mattered—that the wave belongs to the line, not to the bird.

ROBERT: You were a giant standing on the one spot from which you could not see your own feet. It happens to giants.

DAVID: There is one more thing about the prism, and it is where you came closest of all. You explained the rainbow by size—corpuscles of different sizes, bent by different amounts. The mixture idea was right. The sorting idea was right. Only the thing being sorted was wrong.

NEWTON: Not size, then. What?

ROBERT: A triangular prism is thick at the base and thin at the top, so the G2 gravitic field inside it varies across the glass. As the light crosses that gradient it is bent—and how much depends on the spacing of the ranks. The prism did not sort your corpuscles by size. It sorted processions by their rhythm.

NEWTON: *(sitting back, quietly)* But the shape of my answer was right. A mixture goes in. The medium sorts it. An ordered spectrum comes out. I had the structure of the explanation three hundred years ago. I simply reached for size because size was the only property I had given my corpuscles. I had no gravity inside the glass to reach for. *(a long pause)* You did not overturn me here. You finished me.

VI. Electric Motion

DAVID: The fourth motion is the one furthest from anything you worked on.

NEWTON: Electricity barely existed as a science in my day. We had amber that crackled and lodestones that pulled, and we lumped them together in ignorance. Teach me.

ROBERT: If random motion gives you gravity and circular motion gives you magnetism, electric motion is the flow. The same particles, streaming along a path.

NEWTON: A river needs its banks. What holds them to their course?

DAVID: The atoms do. In a copper wire the nuclei sit in an orderly lattice, and that lattice lays down channels through itself—we call them

gravity tubes. The particles flow down these, guided by the atoms, at nearly the speed of light.

NEWTON: *(slowly)* So the wire is not merely a vessel the particles happen to pass through. The wire's own atoms carve the channel. The lattice makes the riverbed, and the stream of G1 particles is the river. And your positive and negative?

ROBERT: Directions, to begin with. As with magnetism—a magnet's two poles were two senses of one rotation. Positive and negative are the same idea for a flow instead of a spin. Which way the stream runs.

NEWTON: *(holding up a hand)* A moment. A body sitting quite alone—charged, as your century has it—with nothing flowing anywhere. What is positive about *it*? There is no stream there to have a direction.

ROBERT: A count. It is holding more G1 particles than it settles at, or fewer. More, and we have been calling it negative. Fewer, and positive. Sitting at its number, neutral.

DAVID: Give two such bodies a path between them and the difference sets the stream running. The count is the cause. The direction is what the count does.

NEWTON: *(satisfied)* Good. No new substance anywhere—only a count, and a direction for the count to drive. *(he begins to sit back, then stops, struck by something)* But wait. You have a flow of particles inside the wire. Particles in a stream do not all stay perfectly in the channel, do they? Not if they are the same particles that, in a magnet, were so eager to fall into orbits. *(intently)* What happens at the surface of the wire?

ROBERT: *(to David)* He is about to solve it himself.

DAVID: Some of them spill into orbits. The stream runs straight down the tubes inside the wire—but at the surface, particles wrap around it, spiralling outside even as the main current drives forward.

NEWTON: *(rising from the chair)* Circles. Outside the wire. *(the realisation breaking over him)* But you told me an hour ago what circular motion of these particles is. Circular motion is magnetism. So a flow of particles down a wire must, of necessity, throw off circles around it—and those circles are a magnetic field. The electricity does not merely accompany the magnetism. The electricity *produces* it.

ROBERT: A current in a wire creates a magnetic field around the wire. It was discovered long after your time, and to this day mainstream physics describes it precisely and never says why a flow should conjure a ring of magnetism out of empty space. They write the law. They do not give the cause.

NEWTON: *(quietly, almost reverent)* And you give the cause in a single breath. It is one particle. Flowing, it is electric. The portion that curls at the edge is orbiting—and orbiting is magnetic. They were never two phenomena. They were one particle doing two of its four dances at once, in the same place, at the same moment. *(he shakes his head)* I did

not even know there was a riddle here. You have answered a question I was never alive to ask.

VII. One Particle, Four Motions

NEWTON: *(gathering himself, and now taking command)* Let me see if the old man has kept up. You have given me four phenomena that the world thinks are four different things. And you have told me they are not four things. They are—

DAVID: Go on. You tell us.

NEWTON: They are one thing, moving in four ways. When it moves randomly I get gravity. In circles, magnetism. In ranks, light. In a flow, electricity. One actor. Four dances. The particle is the noun; the motion is the verb.

ROBERT: *(genuinely moved)* That is better than we say it in the book. We may steal it.

NEWTON: *(waving this off, intent)* But you have a further argument sitting under the table. You have not yet told me why I should believe the particle is truly the same in all four—and not four similar particles that happen to behave alike.

DAVID: That is the right question. And here is the fact that settles it, which you could not have had because the measurement did not exist in your century. We can now measure how fast each of these things travels. They all travel at the same speed. The speed of light.

NEWTON: *(rising slowly)* The same speed. All four.

ROBERT: To the limit of our instruments.

NEWTON: *(working it aloud)* Then a careful man is left with exactly two conclusions and no third. *(one finger)* The first: there are four different things, and some further law has been arranged so as to drive all four to travel at precisely one speed. A conspiracy of equality. *(a second finger)* Or: there are not four travellers at all. There is one. And it always moves at one speed because it is one kind of thing, and one kind of thing has one nature.

DAVID: Which would you take?

NEWTON: *(without hesitation)* The second. Always the second. The first asks me to believe in four particles and an extra law to discipline them—five things to explain one fact. The second asks me to believe in one particle, and the fact explains itself. A speed is a property of the traveller. If the speed is identical, the traveller is identical. Nature is sparing. She does not multiply causes without need, and here there is no need. *(quietly, almost to himself)* And if it is one particle, then the four phenomena cannot differ in their substance—for the substance is the same in all of them. They can differ only in how it moves. You have not given me four forces. You have given me one particle and a choice of four dances. And the speedometer is

your proof. You did not even have to argue it. You only had to point at the dial and let me draw the cheaper conclusion myself.

VIII. The Organising Motion

NEWTON: One thing remains unsettled in me. You keep returning to the random rain as though it were the parent of the others. Why is gravity first among equals?

DAVID: Because the other three are made out of it. Random motion is the raw material—the simplest thing particles can do. And when that rain meets the structure of matter, it gets organised into the other three. Here is the heart of it: the particles at one level are organised by the gravity of the level below.

NEWTON: Say what you mean by it.

DAVID: The nuclei sit in matter like a vast grid of little suns, and they bend the straight-line paths of passing particles into curves. But the force doing the bending is not G1's own gravity. It is the G2 rain beneath, acting on the G1 particles the same way G1 acts on apples and moons. The nuclei decide where the bending happens. The finer rain does the pushing. How that finer rain arranges itself inside an atom we have not yet found; it is the open edge of the whole model.

NEWTON: *(leaning in)* Then show me each of the three.

DAVID: Let the atoms bend the random rain around a centre and you get the circles of magnetism. Let them release a crowd in a coordinated front and you get the ranks of light. Let them channel it along a lattice and you get the flow of electricity. The random motion is the seed. The other three are what it grows into when it meets the structure of the world.

NEWTON: *(very slowly, and this clearly delights him most of all)* So the simplest motion—mere randomness, mere chaos—is the organising one. Order does not come down from above and impose itself. Order emerges from chaos meeting structure. And the hand that does the sorting reaches up from the level beneath. *(he is silent a moment)* That is almost theological. I spent my life believing that God set the world in motion and prescribed its laws from on high. And here you show me a world that generates its own laws from below—from the bottom that has no bottom—out of nothing but particles and their endless, mindless motion. I do not know whether to be unsettled or exalted. Perhaps both. The best ideas have always made me feel both.

IX. Closing

ROBERT: Sir Isaac, we will let you go soon. But I have to ask the question everyone here is thinking. We have taken your physics, kept every particle,

kept every push, kept the inverse square, and used it to rebuild gravity, magnetism, light and electricity from one particle and four motions. After all that—what is your verdict?

NEWTON: *(He rises. He takes his time. The room is silent.)* My verdict is that you have done to me the kindest and the cruellest thing one natural philosopher can do to another. You have shown me that I was right—and that I stopped too soon.

I was right that gravity needed no pull, only I never found the push. You found it. I was right that light was particles, only I tried to make one particle carry the wave when I needed a multitude. I was right to distrust action at a distance, right to want mechanism, right to believe Nature is sparing. Every instinct I had, you have vindicated. You simply had three more centuries, and a few good friends I never met, and the courage to keep asking why after the equations already worked.

(he turns to the audience) They will tell you these two men stand outside the mainstream of physics. Dissident, is the word, I am told. *(a thin smile)* I was a dissident. Hooke thought me one. The Cartesians thought me one. The mainstream of my day held that the planets were swept along by great whirlpools of invisible fluid, and I stood against the whole of fashionable opinion and said: no—particles, forces, mathematics, and let us not pretend to know causes we cannot demonstrate. Being outside the crowd is not evidence that you are wrong. Sometimes it is merely evidence that you arrived early.

(he turns back) Whether you are right, gentlemen—that I cannot certify from a single evening in a chair. That is for experiment, and for the patient cruelty of time, which spares no theory it does not love. But I can tell you this. You have done physics the way I would have wished it done. You refused to hide behind the equation. You demanded a picture. You asked what is actually there, and how does it actually move—and you did not flinch when the answer was strange.

(beat) That is not dissident science. That is just science, practised by people stubborn enough to still be doing it.

(he extends his hand to each of them) Carry on. And when you find the bottom of it—*(a wry look)*—though I gather there is no bottom—send word back. I shall be curious.

DAVID: *(taking his hand)* Thank you, Sir Isaac.

ROBERT: *(taking his hand)* It was the honour of our lives.

NEWTON: *(to the audience, as the lights begin to dim)* One particle. Four motions. Infinitely up, infinitely down. *(he shakes his head, smiling)* I built a clockwork. These men built a living thing—and made it out of my own gears.

Good night.

What you can now say

- Everything here is Newtonian in substance: particles, contact, no fields with minds of their own.
- Gravity is push, and the inverse square falls out of the shadow.
- The four motions of one particle, all at one speed, is the cheaper conclusion.
- Newton's verdict is the book's own: he was right and stopped too soon, and what remains is for experiment.

Appendix A

Where the Mathematics Goes

This book contains little mathematics, and that is a deliberate choice which deserves an explanation rather than an excuse.

It is not because the authors dislike equations, and it is not because the model dispenses with them. It is because of the order set out in Chapter 3: a physical model says what exists and how it moves, and the mathematics then describes what follows. Put the equations first and you have a description of something you have not identified.

But an order of work is only worth defending if somebody eventually does the second half. One of the four motions has now been carried through to the equations, and this appendix carries it, so that a reader can check the claim made in Chapter 3 rather than take it on trust. The other three have not, and the second half of this appendix is the list of what they owe.

Gravitic motion, carried through

The sea. Space holds particles of number density n and mass m_G flying at speed v in random directions. The number travelling within solid angle $d\Omega$ about a direction $\hat{n}$ is $n\,d\Omega/4\pi$, so the momentum delivered per unit area per unit time from that direction is

$$dI(\hat{n}) \;=\; \frac{n\,m_G v^2}{4\pi}\,d\Omega \;=\; \frac{\rho_G}{4\pi}\,d\Omega, \qquad \rho_G \equiv n\,m_G\,v^2.$$

The whole sea enters through the single quantity ρ_G, which has the units of a pressure. Nothing here names a level: n, m_G and v belong to whichever rung is under discussion.

One body feels nothing. A sphere of radius R presents the same area

πR^2 to every direction, so

$$\mathbf{F} \;=\; \frac{\rho_G \pi R^2}{4\pi} \int_{4\pi} \hat{n}\, d\Omega \;=\; \mathbf{0},$$

since the directions cancel over a complete sky. This is the structural fact the whole model rests on: the force cannot come from the bombardment, only from bombardment that is *missing*. Gravity is a subtraction.

The blocked cone. Seen from body 2, body 1 covers a disc of angular radius $\theta_{\max}$, where $\sin\theta_{\max} = R_1/d$. Every particle that would have come from inside that cone was stopped. Taking the surviving axial component, with $d\Omega = 2\pi \sin\theta\, d\theta$,

$$\int_{\text{cone}} \cos\theta \; d\Omega \;=\; 2\pi \int_0^{\theta_{\max}} \sin\theta \cos\theta \, d\theta \;=\; \pi \sin^2\theta_{\max} \;=\; \frac{\pi R_1^2}{d^2}.$$

This is where the inverse square comes from, and it is exact. There is no far-field approximation and no expansion in R_1/d: the identity holds for every separation from contact outward, confirmed by direct numerical integration to twelve significant figures from $d/R_1 = 1.0000001$ out to $d/R_1 = 5000$. The obliquity factor $\cos\theta$ and the solid-angle element cancel each other exactly.

The force.

$$F \;=\; \frac{\rho_G}{4\pi} \cdot \frac{\pi R_1^2}{d^2} \cdot \pi R_2^2 \;=\; \frac{\pi \rho_G}{4} \, \frac{R_1^2 R_2^2}{d^2}.$$

Read left to right, the three factors are the momentum arriving per steradian, the steradians body 1 removes from body 2's sky, and the area body 2 has to catch the deficit with.

Exchange the labels and the expression is unchanged, so the two forces are equal and opposite: Newton's third law is a property of the formula rather than a principle laid beside it.

Why the exponent cannot be anything else. Strip the derivation to three steps. A blocking area A_1 at distance d removes A_1/d^2 steradians of sky, which is what solid angle means in three dimensions. The momentum per steradian is a constant set by the sea. The second body collects that deficit over its own area A_2. So $F = (\rho_G/4\pi) A_1 A_2/d^2$, and the only d-dependence anywhere is the solid angle. In D dimensions the same argument returns $1/d^{\,D-1}$.

Partial transparency. Real bodies stop only a fraction. With κ the opacity of a body to its own level's sea, the effective blocking area of a uniform sphere is

$$S \;=\; \pi R^2\, \Phi(\tau), \qquad \Phi(\tau) = 1 - \frac{2}{\tau^2}\Big[1 - (1+\tau)e^{-\tau}\Big], \qquad \tau \equiv 2\kappa\rho R.$$

Replacing πR_i^2 by S_i carries the two-body law through unchanged. Note that Φ contains no d: **the inverse square survives at every opacity**,

from perfectly transparent to perfectly opaque. What opacity changes is not the distance law but what the force couples to:

$$\tau \gg 1:\ \Phi \to 1,\ S = \pi R^2; \qquad \tau \ll 1:\ \Phi \to \tfrac{2}{3}\tau,\ S = \kappa m.$$

Newton's law, and what his constant is made of. In the transparent limit $S_i = \kappa m_i$, and the force becomes

$$F \;=\; \frac{\rho_G}{4\pi}\frac{S_1 S_2}{d^2} \;=\; \frac{\kappa^2 \rho_{G1}}{4\pi}\frac{m_1 m_2}{d^2}, \qquad \text{so} \qquad G \;=\; \frac{\kappa^2 \rho_{G1}}{4\pi}.$$

The product of masses, strict attraction, superposition, the shell theorem and the interior solution all follow. Newton's constant comes apart into three pieces: a solid angle, a property of matter, and a property of the vacuum. Its universality becomes a derived fact rather than a postulate—G is the same for every pair of bodies only because matter happens to be optically thin.

Coulomb's law needs no derivation of its own. No step above named a scale, so the result holds at every level with a sea and bodies to block it. Matching the level-2 force to Coulomb's term by term gives

$$q \;=\; \sqrt{\varepsilon_0 \rho_{G2}}\; s, \qquad \frac{1}{4\pi\varepsilon_0} \;=\; \frac{\rho_{G2}}{4\pi}\left(\frac{s_e}{e}\right)^2,$$

with s a body's blocking area in the G2 sea. Set that beside $G = \kappa^2\rho_{G1}/4\pi$ and the two constants have identical anatomy. The 4π in Coulomb's constant, conventionally explained as an artefact of rationalised units, is the same physical solid angle as the one in G.

Two results that bite. The approach to the transparent limit gives

$$\frac{m_{\text{grav}}}{m_{\text{inertial}}} \;=\; 1 - \tfrac{3}{4}\kappa\rho R + O\big((\kappa\rho R)^2\big),$$

a shortfall depending on a body's size and density rather than its mass—which is a violation of the equivalence principle and the model's sharpest observational signature (Chapter 24). This result is not ours. It is Majorana's apparent-mass function, re-derived by Poincaré and by Russell, and the modern lunar-ranging literature writes it in exactly this form, with 3/4 as the coefficient for a uniform sphere. Russell also gives the coefficient for a centrally condensed body, $(2n+3)^2/(12n+12)$ for a density profile $\rho(r) = \rho_0(1 - r^2/R^2)^n$, which is about 0.98 for the Earth rather than 0.75. And for a body moving at speed u, with the chance of interaction scaling as w^{-p} in the relative speed w, the number of deflections per second goes as $w\,\sigma(w) \propto w^{1-p}$, so the leading drag coefficient is proportional to $1 - p$ and vanishes identically at $p = 1$, at every speed rather than merely to leading order. That exponent is what a deflection probability proportional to time-inside-the-target delivers. The cancellation survives only while blocking area is linear in the amount of matter; the next term of $\Phi(\tau)$ leaves a residual of $\frac{3}{8}\tau$ times the drag, and κ cancels out of that product exactly, which is why no improvement in the opacity measurement can reduce it.

What the other three motions owe

From magnetic motion. The rule by which two rotating populations modulate what they exchange—and, harder, why attraction by shadowing and repulsion by deflection should come out equal in size at equal distance, since two magnets attract and repel with the same strength. The permeability of free space. Field strength against distance. Why iron is more susceptible than nickel, and what holds alignment against thermal jostling.

From luminic motion. Planck's constant, as the conversion between how much an atom releases and how tightly the departing groups are packed. The relation between group spacing and deflection in a gradient, which would deliver the refractive index of Chapter 7 and the fringe envelope of Chapter 18 together. Chapter 19 reduces the whole of its account to two quantities, the reach of a rim's field and the angle it deflects through, so a single measurement of either would turn the other into a prediction.

From electric motion and G2 configurations. Shell capacities and the SPDF shapes. Spectral line positions. The size of the bundle an atom trades, which is Millikan's quantum. The proton-to-electron mass ratio of 1836.15. Ohm's law, resistivity and its variation with temperature, the forward voltage of a diode, and the ratio between the fast and slow processes of Chapter 11.

From the G1 particle itself. Its mass, its size, and the number density of the rain. These are the deepest debts, because almost everything above is expressed in terms of them. At present the model fixes only *products*—$\kappa^2\rho_{G1}$ at level one, $\rho_{G2}s_e^2$ at level two—never the factors separately, which is why it can relate constants to each other and predict none of their values.

What would count as progress

Not a derivation of one of these numbers by any means available. A derivation that uses nothing but particles, motion and collisions—because a number obtained by adding an assumption would tell you about the assumption.

The drag calculation used to be first on this list, as the most self-contained and the most dangerous. Its analytic half has now been done. The drag cancels exactly when the chance of a deflection goes as the inverse of the relative speed, which is what the time a particle spends inside its target gives. That holds for a thin layer; for a body thick enough to shadow its own interior a residual survives, and beneath it sits the question of whether a deflected particle's push is fixed in size and direction, as the cancellation assumes. Those are what is left of that calculation, and Chapter 5 sets them out. The two calculations we would most want next are the inertia half of the same problem, which would turn a rescue into a gain, and a demonstration that the attraction and repulsion rules of Chapter 8 give

forces of matching size.

A programme that begins with its hardest calculations is behaving properly. The first of them has now reported, and what it left open is stated above. As everywhere in this book, what cannot yet be calculated waits on the same thing: a worked description of the G2 fields.

Appendix B

Glossary

The first section collects ordinary physics words that the model reads differently. The rest are grouped by the part of the book they belong to. Where a term is someone else's, the entry says whose.

Ordinary terms, as the model reads them

These are words physics already uses. In each entry, *usually* says what the word is normally taken to mean and *here* says what it means in this book. The model does not change what has been measured; it says what is there.

Charge *Usually:* a property of matter that comes in two kinds, plus and minus, measured in coulombs. *Here:* a count: how many G1 particles a body holds against the number it settles at. More is what we call negative, fewer positive, and at its number the body is neutral. There is one kind of thing, not two (Chapter 10).

Coulomb's law *Usually:* the force between two charges, growing with their product and falling with the square of the distance. *Here:* gravity one level down. The random motion of G2 particles shadows bodies exactly as the random motion of G1 particles does, which is why the two laws have the same form.

Polarity *Usually:* the two opposite ends of a magnet or a charged body, or the uneven spread of charge across a bond. *Here:* for a magnet, the two senses of one rotation, which is why they cannot be separated. Between atoms, the bond made by their own orbiting populations passing each other in the gap, with no charge and no extra loops.

Magnetic pole *Usually:* a north or south end where field lines leave or enter. *Here:* a direction of circulation, not an object. The two poles

are the two senses of one rotation, so an isolated pole is not a thing that can exist (Chapter 8).

Magnetic field *Usually:* an influence, drawn as lines, that fills the space round a magnet or a current. *Here:* circulating G1 particles and nothing else. The lines are a record of the traffic, as iron filings are (Chapter 17).

Electric field *Usually:* a quantity assigned to each point of space that tells what force a charge would feel. *Here:* G2 motion, in two patterns: the random motion that Coulomb measured, and the steady stream that is the F2 force.

Field *Usually:* a number or a vector assigned to every point of space, to which energy and momentum are then given. *Here:* a population of particles moving in one of the four ways. The map drawn of it is a record of what that traffic does, not a thing in addition to the particles.

Voltage *Usually:* a difference of electric potential. *Here:* the push of the F2 force, a steady stream of G2 particles along a conductor. In a battery or capacitor it is the difference in the counts the two sides hold.

Current *Usually:* a flow of charge, drawn by convention from plus to minus. *Here:* G1 particles running from where there are more to where there are fewer, from negative to positive: the same direction as the electron flow of the textbooks. Nothing runs back the other way.

Resistance *Usually:* opposition to current. *Here:* a stretch of lattice that channels badly, so some of the driven G1 particles are scattered out of the directed flow into disordered motion, which is heat (Chapter 20).

Hole *Usually:* a vacancy in a nearly full band, treated as a positive particle with a charge, a mass and a velocity. *Here:* a place where an atom holds one fewer G1: a count, not an object. The gap appears to move the other way because the particles move this way (Chapter 11).

Electron *Usually:* a point particle carrying a charge of $-e$. *Here:* a quanta: a population of G1 particles an atom holds, takes on and lets go in bundles of a characteristic size. The measured ratios and smallest amount are properties of that bundle (Chapter 13).

Photon *Usually:* a single indivisible particle of light that has a frequency. *Here:* what a detector registers when a quanta is taken up. Light itself is a procession of groups of G1 particles, and the frequency belongs to the series, not to a single point (Chapter 6).

Frequency and wavelength *Usually:* how often an oscillation repeats, and the length of one repeat. *Here:* frequency is the rhythm between successive groups of G1 particles and wavelength is the real gap between two clumps of real particles.

Energy level *Usually:* a rung on a ladder of allowed energies for an electron. *Here:* a statement of how many, not where: a higher level is a larger population held by the atom. The ladder is a series of crowd sizes a room can hold.

Quantum jump *Usually:* an electron moving instantly from one level to another with nothing in between. *Here:* nothing jumps. The atom takes on more G1 particles or lets some go, and holds a larger or smaller population than a moment before.

Interference *Usually:* waves adding and cancelling where they overlap. *Here:* groups of G1 particles arriving nose to nose or nose to tail. Particles cannot cancel; the dark band is a place where what arrives has the wrong rhythm and half the density (Chapter 18).

Diffraction *Usually:* the bending of waves round edges and through openings. *Here:* G1 particles passing near the rim of an opening are deflected, at random in direction but not in timing, by the strong G2 field beside the mass of the edge.

Refraction *Usually:* light changing speed and direction on entering glass or water. *Here:* a place where the model has work to do. Capture-and-release is offered as a sketch and is not worked out (Chapter 7).

Inertia *Usually:* the resistance of matter to being accelerated, taken as a basic property. *Here:* proposed to come from the asymmetric flux met by a body accelerating through the rain. Persistence of motion needs no cause; the resistance to acceleration is the part that needs one (Chapter 5).

Attraction *Usually:* a pull between bodies. *Here:* in gravity there is no pull anywhere: bodies are pushed together by the rain of G1 particles that each shadows from the other.

Empty space *Usually:* a void, or a field-filled nothing. *Here:* not empty. It is saturated with G1 particles moving in every direction, and the space between G1 particles is filled with free G2 particles (Chapter 5).

Particles and levels

G1 particle The particle at our level of the universe. Carries no charge. Travels at the speed of light. Gravity, magnetism, electricity and light are all G1 particles, differing only in how they are moving.

G2 particle The particle one level down: much smaller, much faster. Its random motion is what Coulomb's law describes; its orbits are the per-nucleon fields that shape atomic orbitals; its steady stream is the F2 force.

G3 particle The particle one level below the G2. Mentioned to show that the pattern does not stop: a G1 is made of G2 particles, a G2 of G3 particles, and so on without end.

Level One rung of the ladder of scales. The model uses two throughout: G1 particles organise our world and G2 particles organise the atom. The same four motions are expected to be found at every level, up and down.

No partless parts Borchardt's principle, adopted here: nothing is fundamental, every particle is made of smaller ones, infinitely up and infinitely down.

Infinite Universe Theory Glenn Borchardt's framework, from which the model takes the principle of no partless parts and infinite levels. The model is not committed to all of it (Chapter 22).

Aether A hypothetical medium thought to fill space and carry light. The model has none: the particles are the only thing in the room and light is made of them (Chapter 23).

Physical Turing machine The authors' name for the four universal motions: a small fixed set of ways for bodies to move, whose combinations should build any physical condition that can exist, as a few operations build any computation. The mainstream equations describe what these motions do and, in time, should be derivable from them. Where the model cannot yet explain a phenomenon, the claim is that the G2 fields have not yet been found.

The four motions

Gravitic motion Particles travelling in straight lines in random directions. Produces gravity, by shadowing. The foundational motion—the other three are what random motion becomes when it meets structure.

Magnetic motion Particles caught in orbits. A magnetic field is circulating G1 particles and nothing else. Poles are the two senses of one rotation, which is why they cannot be separated.

Electric motion Particles flowing in a directed stream along a path. In a wire, G1 particles running down channels laid by the lattice.

Luminic motion Groups of particles travelling together, group behind group. This is light. The wave is the formation; the frequency is the spacing between groups; the colour is that spacing.

Four universal motions Random, orbiting, flowing and grouped travel: the whole set of ways the particles move. Everything else in the book is these four, alone or combined. Shortened to four universal motions in the text.

Helical motion Circling and advancing at once. A current-carrying wire's G1 particles move this way: the part that advances is what we call current and the part that circles outside is what we call the magnetic field. One motion, named twice.

Gravity

Shadowing effect The mechanism of gravity. Two bodies each block part of the random rain arriving at the other, so each is struck less on the facing side and they are pushed together. Produces an inverse square because a shadow spreads.

Gravity tube A channel laid down by a line or array of nuclei, along which G1 particles are guided. The tube belongs to the lattice; the G2 field is the means by which the nuclei do the guiding.

Sea, rain The G1 particles moving at random in every direction through space, whose shadowing by bodies is gravity. *Rain* is the same thing seen as arrivals on a body. One level down the same words are used for the G2 particles (Chapter 5).

Le Sage's theory The idea that gravity is a push from a rain of tiny, fast particles that bodies shadow. Proposed by Fatio de Duillier in the 1690s and taken up by Le Sage in the eighteenth century, and the ancestor of the shadowing mechanism here (Chapter 3).

Opacity, optical depth Opacity is how much of the sea a kind of matter stops, written κ. Optical depth is opacity times the thickness of a body: small means the sea passes through, large means the body shadows itself (Appendix A).

Self-shielding The outer layers of a body shield its inner layers from the sea, so a thick body gives up less than its share. It is the source of the drag that survives the time-inside rule for a planet (Chapter 5).

Inverse square The way a force falls off with distance because a shadow, or a stream of particles from a point, spreads over a surface that

grows as the square of the distance. The model gets the form from the geometry of the spreading rather than from a stated law.

Drag problem The objection that a body moving through the random rain should meet more particles ahead than behind and be slowed. It led Laplace, and later Poincaré, to demand very large particle speeds. The time-inside rule answers it (Chapter 5).

Heating objection Maxwell's objection of 1875 to shadowing: if the particles lose enough energy to the bodies they strike to push them together, the heat so produced would soon raise them to a white heat. The model answers it with deflection, which delivers the push without delivering the energy (Chapter 5).

Time-inside rule The chance that a passing G1 is deflected by a nucleon is proportional to the time it spends inside it, which goes as $1/w$ for closing speed w. More arrivals from ahead are each proportionally less likely to act, and the two cancel, removing the drag.

Push rule The assumption that each deflected particle delivers a push of a fixed size, along the direction it was already travelling, whatever the body's own motion. The drag cancellation rests on it. If the push is instead the relative momentum, as ordinary scattering off a moving target gives, the drag does not cancel at all (Chapter 5). Called P4 in the authors' technical paper on the inverse-square law.

Deflection A particle turned from its path without being stopped. It is gone from the beam as completely as a stopped one, so the shadow is intact, but it leaves carrying nearly all its energy.

Matter, charge and the atom

Neutral A body holding the count of G1 particles its atoms settle at. Not a cancellation of two kinds of charge but a count at its number.

Negative and positive Names for more and fewer than the settled count. Franklin's labels, kept because they are in use, with nothing of a different kind behind them.

Quanta A population of G1 particles held by an atom, or released by one. What has been called an electron is a quanta; so is what a detector registers as a photon.

Bundle The characteristic number of G1 particles an atom trades at a time. It is what Millikan's smallest amount and Thomson's ratio were measuring.

Atomic polarity The bond between neighbouring atoms, made by their own orbiting populations passing each other in the gap. Needs no charge, and involves no additional loops.

Nucleon A proton or neutron. In the model each one carries its own magnetic field, made by G2 particles circulating inside it, and the overlap of these fields shapes the atom's orbitals (Chapter 12).

Orbital One of the S, P, D and F shapes of chemistry. In the model the shapes come from the overlapping per-nucleon fields, not from probability clouds, and are expected to follow once the G2 fields are found.

Lattice The ordered arrangement of atoms in a solid. The lattice lays down the channels (gravity tubes) that guide the G1 particles of a current.

Semiconductor A material, such as silicon, whose settled count has been shifted by a trace of another element. A surplus region is n-type and a shortfall region p-type.

Doping Adding a trace of another element whose atoms settle at a different count, so the lattice carries a surplus or a shortfall.

Light and the atom

Procession A string of groups of G1 particles, group behind group. The picture of light in the model; the spacing is a real length and sets the colour.

Rank A group seen as a row of particles marching in step. The wave of light belongs to the ranks, and the colour is the spacing between them (Chapter 1).

Group A cluster of G1 particles travelling together within a procession.

Spacing The distance between successive groups in a procession. This is the frequency and the colour of the light.

Emission and absorption An atom lets go of a formation of G1 particles (emission) or takes one on (absorption). Which lines appear is decided by which arrangements an atom can sit in (Chapter 14).

Spectral line A sharp colour an element emits or absorbs, the same everywhere. Sharp because an atom can sit in certain arrangements and not others.

Dark line A formation that was taken and kept by an atom, so it is missing from the light that passed through. The spacing of the groups removed is the line's colour.

Doublet A spectral line that is really two close lines, such as sodium's D line. Stated in the book as a difficulty: the model explains discrete lines but not yet the fine splitting (Chapter 14).

Nose to nose, nose to tail The two ways two half-processions can meet at a spot. Nose to nose, groups land on groups and arrive at full strength; nose to tail, groups land in each other's gaps. The model's account of bright and dark bands (Chapter 18).

Fringes and envelope The two parts of a double-slit pattern. The fringes come from the spacing of the procession; the broad envelope comes from deflection at the slit edges.

Sweet spot The best pinhole size for a camera, at which two blurs are equal. The book derives it from the model's own account of the hole's rim and not from ray and wave optics (Chapter 19).

Electricity, circuits and induction

Dinu effect The rule for two meeting circulations. Same rotation means the traffic opposes in the gap, which is repulsion; opposite rotation means it runs together, which is attraction. Check the rotations or the gap arrows, never both. Named for Ionel Dinu, whose experiments with rotating cylinders in water began in his daughter's swimming pool and were repeated in a larger pool, where the effect was larger and clearer (Chapter 8).

F2 force A steady stream of G2 particles. The push that drives G1 particles along a conductor. What a meter reads as voltage.

Battery Two electrodes that hold different counts of G1 particles. Connected, particles run from the fuller side to the emptier until the counts match, and then the battery is flat.

Capacitor Two plates across a gap. At balance particles still leave both sides at the same rate, so a meter reads zero, though there is flow.

Diode A junction of a region with a surplus beside a region with a shortfall. It lets particles through one way and not the other.

Transistor In the book's account, a device in which a small flow splits a larger one. It does not multiply anything (Chapter 20).

Induction A changing arrangement of traffic round a wire moves the wire's own G1 particles. Nothing is created and nothing acts at a distance: a population already in the wire is relocated. It stops when the magnet stops (Chapter 16).

Lenz's law The rule that induced current opposes what produced it. In the model it is not separate but the Dinu effect applied to the coil.

Transformer Two coils on one core. It needs alternating current because only a changing arrangement keeps the secondary's particles relocating.

Method and standing

Open problem A place where the book says plainly that the model has no answer yet, marked in a box. Most reduce to the same thing: the G2 fields have not yet been found.

Simulation A particle model run on a computer: the proposed way to test what the four motions produce. The book lists nine runs worth making (Chapter 25).

Rebuilding What a failed test means in this book: the mechanism that failed is rebuilt. The model is not abandoned and nothing is added to it (Chapter 24).

Standing The label at the head of each chapter saying how firmly its claims rest: derived, proposed, open or framing (Chapter 1 and Appendix D).

What you can now say The box that ends each chapter, listing what the chapter has made it possible to say.

Appendix C

A Father and a Son

The son

In 1993, in Long Beach, California, David de Hilster met a physicist, Dr. Ricardo Carezani.

That is the whole of the inciting incident, and it cost him the next thirty years. Carezani had an objection to relativity. David—a software engineer by trade rather than a physicist—found he could not dismiss it as easily as he expected to, and found, as people who start pulling at this thread usually do, that there was a whole world of them.

There are thousands of such people around the world—the Natural Philosophy Wiki lists some 3,700 scientists, most of them working outside the mainstream—who meet at conferences, publish in journals nobody else reads, and share one conviction: that modern physics took a wrong turn and papered it over with mathematics. They disagree with each other about nearly everything else.

What David spent decades doing was collecting their models. Not light particularly—*physical models in general*, for gravity, for magnetism, for light, for whatever anyone had a mechanical picture of. And he found them. That is the part worth stating plainly, because it is not the usual story of a long fruitless search: the models were out there, in quantity, and he gathered them.

What he did not have was the one that made the others fit together.

The film

In 2005 he began the one documentary film he has made, and the decision he made about how to tell it is the reason it is worth mentioning here.

He did not make a film about physicists. He took his mother.

Einstein Wrong—The Miracle Year follows Patricia de Hilster, an or-

dinary suburban woman with no scientific training, as she travels to meet the people who say the most famous scientist of the twentieth century was mistaken, and tries to work out what she thinks. She is the film's star. The audience learns alongside her. It is a device that only works if you genuinely believe a non-specialist can follow the argument—which is, as it happens, the same conviction that produced this book.

It took eight years. Among the crises along the way was Robert de Hilster's health, and, David says, Robert de Hilster hijacked the film. It premiered on 7 December 2013 at the Arts Theater in Long Beach.

Chapter 2 tells what David asked his father that night.

The father

Robert de Hilster is a retired electrical engineer. He spent over forty years in telecommunications as a researcher and designer of digital switching systems—a field in which a model that does not work is found out quickly, by equipment that does not switch.

But the engineering is not the interesting part. What matters, for a book arguing that physics should be built out of things you can picture, is the kind of mind that produced it, and that was visible long before the career.

When David was a boy, his father built things in the house.

He built a **time-lapse photography machine** out of an old phonograph, a relay, an electrical clock and an 8mm film camera. Four objects, none of them designed for the purpose, none of them designed for each other. The clock keeps time, the relay turns an instruction into a movement, the phonograph turns, and the camera takes a frame. Assembled, they do something none of them does alone.

And he built a **pipe organ**—from wood, surgical tubing, bicycle inner tubes, fishing line, clothes pins, and a vacuum cleaner.

Read that list again. A vacuum cleaner is a machine for pulling air; run it the other way and it is a machine for pushing air, which is what an organ needs. Inner tubes hold air under pressure. Surgical tubing carries it where it is wanted. Fishing line and clothes pins turn a finger on a key into a valve opening somewhere else. Wood becomes the pipes.

Nobody sells those parts as an organ kit. Somebody looked at a room full of ordinary objects, understood what each one *does* rather than what it is called, and assembled a musical instrument out of the functions.

That is the disposition this entire book rests on.

A man who builds an organ out of a vacuum cleaner has a particular relationship with explanations. He is not satisfied by being told that a thing works; he wants to know by what arrangement of parts, because that is how he has solved every problem he has ever solved. Put such a person in front of the claim that light is an excitation of a field, and ask him what the field

is made of, and he will not let it go—not out of contrariness, but because in his experience that question has always had an answer, and the answer has always been the interesting part.

There is a small pleasure in the fact that an organ's pipes are arranged in what organ builders call *ranks*, and that what he eventually proposed was a model of light in which the wave is a rank. We do not suggest the one led to the other. But a man who had spent an afternoon tuning ranks of homemade pipes was perhaps unusually well prepared to notice that a wave might belong to a row of things rather than to any one of them.

For about ten years he had been working on a particle model of gravity, while his son was off interviewing other people about theirs. He did not know there was a problem called the wave-particle duality of light.

A year and a half after that premiere, in May of 2015, he came up with the particle model of light that Chapter 2 tells about.

How it came about

The talk at his father's house, why it was Robert de Hilster and not someone else, and how the four motions came together are told in Chapter 2.

On standing outside

Where the work stands, and why that is not an argument either way, is said in Chapter 2. Chapter 24 lists the tests the model must pass, and what failing one would mean.

Chapter 23 is uncomfortable reading for our closest allies. A great many of the people in those conference halls are trying to do this with an aether, and we think they have been trying for more than three hundred years without once saying what it is made of. We would rather say so to their faces than imply it behind their backs.

What we ask of a reader is the thing we have tried to practise: judge the argument on whether it says what things are made of and how they move, and on whether it is honest about where it fails.

Debts

To **Glenn Borchardt**, for the infinite universe and the principle that there are no partless parts—the architecture everything here sits inside, and the one idea in this book that is not about particles.

To **Ionel Dinu**, for magnetism as orbital motion, and for doing the experiments rather than only describing them.

To **Jeff Yee**, for simulations that showed electron clouds can emerge from a model with no charge in it anywhere.

To **Patricia de Hilster**, who agreed to be filmed not understanding something, in public, for eight years, so that other people could follow it.

And to Sir Isaac Newton, who asked what gravity was made of, admitted he could not say, and left the question for posterity—where it sat, untouched, for three hundred years.

Appendix D

What You Can Now Say

Each chapter ends with a short list of what it has made it possible to say. They are collected here, in order, so the whole claim can be read in one place. Beside each chapter is its standing, as marked at its head: *derived* means it follows from the four motions with the mechanism stated; *proposed* means a mechanism is offered and its weak joints are named; *open* means it waits on the G2 fields; *framing* means an argument or a definition rather than a mechanism claim.

The map

Derived Chapters 1, 5, 6, 7, 8, 9, 10, 11, 14, 16.

Proposed Chapters 12, 13, 18, 19, 20, 25.

Open Chapter 15.

Framing Chapters 2, 3, 4, 17, 21, 22, 23, 24, 26.

Chapter by chapter

Chapter 1. What Is Actually in the Room (derived)

- Light is made of particles that were already in the lamp, travelling in ranks.
- It behaves like a wave because the ranks are spaced, and its colour is the distance between them.
- A room full of crossing light is not a blur, because the groups pass through one another.

- None of this needed an equation: an equation answers how much, and the question was what.

Chapter 2. How We Found It (framing)

- The model of light as particles in ranks came from an engineer working on gravity, who did not know there was a duality to solve.
- The four motions have several sources: Robert de Hilster for gravitic and luminic motion, Dinu for magnetic, and David for electric, and the two of them for the step to one particle.
- The story says how the model was found, not whether it is true. That is settled by what is in the room.

Chapter 3. A Description Is Not a Model (framing)

- A description tells you what happens where it has been measured; a model says what is there. Mathematics is the first, and physics gradually stopped requiring the second.
- Newton, the field, the photon and the wavefunction are four places where an excellent description stands in for an object nobody names.
- Maxwell built a machine of vortices and idle wheels, said he did not claim it existed in nature, and let the gears go. The question was abandoned, not answered.
- An equation can be earned: the inverse square falls out of a rain of particles, where it is only assumed in Newton's hands.

Chapter 4. One Particle, Four Motions (framing)

- Gravity, magnetism, electricity and light all travel at one speed, so they are one particle: a G1, doing four different things.
- The four motions are random (gravitic), orbits (magnetic), flow (electric) and groups together (luminic). The particle is the noun and the motion is the verb.
- Every level is organised by the gravity of the level below it, and a G1 is made of G2 particles, without end.
- There is no medium, no charge, no pull and no new entity per phenomenon. The four motions are a physical Turing machine for matter.

Chapter 5. Gravity: Why Things Fall Together (derived)

- Gravity is a push, not a pull: two bodies each shadow the other from a random rain, and are driven together.

- The inverse square is the share of the sky a body covers, and it is arrived at, not assumed.
- Gravity only attracts because a shadow can only remove, and it is weak because most of the rain goes straight through.
- Maxwell's heat objection and the drag objection have answers inside the model, and the work still open on them is named.

Chapter 6. The Impossible Photon (derived)

- A single particle cannot have a frequency, because frequency belongs to a series, so a photon as one indivisible thing is not coherent.
- Every experiment that led to the photon showed that light is absorbed in lumps, not that it travels in lumps.
- The photoelectric effect follows from spacing: the wrong spacing is the wrong shape for the atom, however bright.
- What a detector calls a photon is the smallest bundle of G1 it can take up.

Chapter 7. Light: A Procession, Not a Point (derived)

- A luminic wave is groups of G1 travelling together, and the wave belongs to the group, not to any one particle.
- White light is a mixture of spacings, and a prism sorts it. Newton's second experiment shows that it sorts and does not make colour.
- A triangular prism sorts and a rectangular block does not because mass distribution sorts light, and a rainbow is the same event.
- Light travels in straight lines, a mirror keeps the formation, a wall does not, and a laser is a parade where a lamp is a crowd.

Chapter 8. Magnetism: Particles in Orbit (derived)

- A magnetic field is G1 caught in orbits, and nothing else.
- A pole is a direction of circulation, so a monopole is not a thing that can exist.
- Same rotation means the traffic opposes and repels; opposite rotation means it runs together and attracts. Check one, never both.
- A magnet is iron whose loops agree, a current is a magnet too, and iron filings are tiny compasses reporting real traffic.

Chapter 9. Electricity: A Pipe Already Full (derived)

- Electric motion is G1 flowing along a gravity tube, a channel laid down by a lattice of nuclei.
- A wire is a pipe that is already full, so switching on supplies a direction and not particles.
- The push is the F2, a steady stream of G2, and what a meter reads as voltage.
- The part of the flow that circles outside the wire is the magnetic field, and resistance is scattering out of the channels.

Chapter 10. Charge: A Count, Not a Kind (derived)

- Charge is a count of G1 held against the number an atom settles at: more is negative, fewer is positive, at its number is neutral.
- Plus and minus go back to what Franklin meant, and the minus sign stops being a substance.
- A battery stores a difference in count, and a flat battery is a difference used up.
- Charge is how many; polarity is which way. The two are connected but are not the same.

Chapter 11. Current: What Actually Moves (derived)

- Franklin's arrow was a guess; the G1 run from the end holding more to the end holding fewer, negative to positive.
- What moves is real particles, and a hole is an atom one G1 short, which is a count and not an object.
- There are two speeds because two processes are going on: fast along the tubes, slow through the atoms.
- The lamp lights at once because the wire is already full and something is already racing.

Chapter 12. The Atom Without Charge (proposed)

- Coulomb's law looks like Newton's because it is gravity one level down, carried by G2.
- Every nucleon carries its own G2 magnetic field, and those overlapping fields shape the S, P, D and F orbitals.
- The atom needs no charge, so the old problem of an orbiting charge radiating does not arise.

- The G2 fields have not yet been drawn, and the diagrams in this book are symbols.

Chapter 13. The Electron Is Not One Thing (proposed)

- The electron is a quanta: a population of G1 an atom holds and trades in bundles.
- Thomson measured a ratio and Millikan the size of a bundle; neither shows that the bundle has no parts.
- Atomic weights are not whole numbers because what is weighed is a crowd, and so is the ratio 1836.15.
- An energy level is a size of population, and nothing jumps.

Chapter 14. How an Atom Emits Light (derived)

- Absorption is an atom taking on more G1; emission is it letting them go, in formation.
- An atom never manufactures a photon; it releases particles it was already holding.
- Spectral lines are sharp and elemental because an atom can sit in certain arrangements and not others.
- A dark line is a formation that was taken and kept, and the colour of the light is the spacing of the groups.

Chapter 15. The Configuration of the Atom (open)

- The G2 motions are specified in what they do and not yet in how they are arranged.
- The answer is already inside the four motions, so what is left is a search, not a mystery.
- Every diagram of a G2 field is a symbol and not a measurement.
- The way to close the gap is physical model simulation, with nothing in the box but particles and motion.

Chapter 16. Induction: What Crosses the Gap (derived)

- What crosses the gap is G1 in orbit around the magnet, meeting the G1 already in the wire.
- Current and magnetic field are one helical motion named twice, so driving the one drives the other.

- Change is needed because current is a population on its way to a new arrangement, and it stops when it arrives.
- Lenz's law is the Dinu effect, a transformer needs AC to keep the population from settling, and the spark is a crowd with nowhere to go.

Chapter 17. Fields: What Is in the Room, Again (framing)

- The textbook picture of light as two perpendicular waves is a graph of a relationship, not a thing in the room.
- Maxwell built a mechanism, said he was not claiming it existed, and then kept the equations.
- The magnetic field is G1 in orbit and the electric field is G2 motion; they are one level apart, and light is neither.
- Field lines are a record of traffic, and charge has nothing left to do.

Chapter 18. Diffraction and the Double Slit (proposed)

- This is an attempt, not a result, and its weak joints are named.
- What is sent is a wide procession, not one indivisible particle, so nothing is in two places.
- The fringes come from the spacing of the procession and the envelope from the slit edges: two effects with two causes.
- A detector cannot register a formation without taking it, so watching changes the experiment.

Chapter 19. The Pinhole Camera (proposed)

- A pinhole does not form an image; it discards almost everything, and the image is what is left.
- Nothing is ever out of focus because nothing is bent.
- A million bundles cross inside the box without a tangle because they are traffic through nearly empty space.
- The sharpest hole sits where two blurs cross, and each has a physical cause.

Chapter 20. Circuits That Work (proposed)

- A battery is a standing imbalance in count, and a capacitor at balance still has flow in both directions.
- A diode is an F2 balance line you can only push through one way.

- A transistor splits its emitter flow between collector and base, and a split is not a gain.
- The hole is not needed, and a resistor is a stretch of lattice that keeps some of the G1 that enter.

Chapter 21. All Four at Once: Inside a Phone (framing)

- One particle is doing all four motions in a single object: gravity, electricity, magnetism and light.
- What crosses the gap to a wireless charger is orbiting G1, particles going past.
- The speaker is the Dinu rule, and the radio is a helix flung clear in formation.
- At every step the standard account names a relationship and the four motions name what is in the room.

Chapter 22. Levels, Up and Down Without End (framing)

- There are no partless parts: every particle is made of smaller ones, and every level sits inside a larger one.
- Newton and Coulomb have the same face because it is the same mechanism one level apart.
- The ratio of about 10 to the 39 between electric and gravitational force is a ratio between two levels, not a brute fact.
- Atomism has been cut four times in 165 years, and the model declines to call the next floor final.

Chapter 23. No Medium Anywhere (framing)

- An aether is a continuous medium that needs containing, and the four motions have no medium anywhere.
- A luminic wave is the particles themselves in formation, so removing them removes the wave.
- Michelson and Morley's null result is a test the model must meet, and it waits on what sets the speed of a G1.
- The model parts from Borchardt and from Yee on the same point: the aether.

Chapter 24. How the Model Is Tested, and What Failure Means (framing)

- Every test here is a place where the model makes a definite physical claim.
- If one fails, that mechanism is rebuilt from the same four motions, and never by adding a fifth thing.
- The four motions are at present a qualitative model, and the gap is work.
- The model also makes predictions, including a small violation of the equivalence principle.

Chapter 25. The Simulations That Would Settle It (proposed)

- The way to close the debts is physical model simulation, and the first run has reported.
- Nine runs are proposed, from shadowing to drag, the atom, induction, glass and a diode.
- Each run has to report a number against a prediction made beforehand, and it must be able to fail.
- If a run fails, the arrangement is rebuilt and the search goes on.

Chapter 26. An Evening with Newton (framing)

- Everything here is Newtonian in substance: particles, contact, no fields with minds of their own.
- Gravity is push, and the inverse square falls out of the shadow.
- The four motions of one particle, all at one speed, is the cheaper conclusion.
- Newton's verdict is the book's own: he was right and stopped too soon, and what remains is for experiment.

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