

Chapter 1

Prediction Without Understanding

The universe was getting on with things long before we wrote equations about it. Stars formed, atoms joined together and light crossed space. Our calculations help us describe those things, but nature does not need a calculation to make them happen. That simple thought is where this book begins.

Physics lets us do remarkable things. We can predict an eclipse, build a computer and send a message across an ocean using light. Clearly, our theories get a great deal right. Yet knowing what to expect is not always the same as knowing why it happens. A calculation can give the right answer while leaving us puzzled about the process behind it.

Think of a particle arriving at a detector. A mark appears on a screen. Quantum mechanics, the theory we use for atoms and particles, can calculate the chance of a mark appearing in each place. Over many experiments, those chances agree closely with what we find. But on this occasion one mark appears. How did that particular possibility become something that happened?

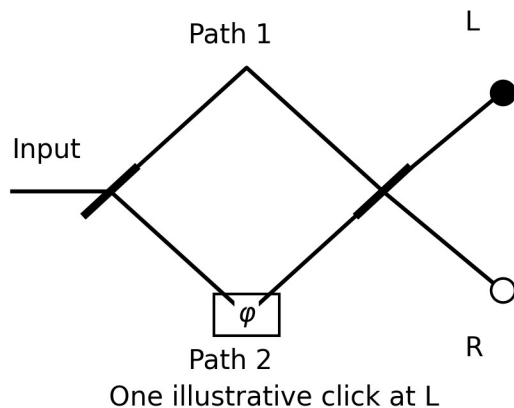
Phase Differential Theory, or PDT, is my attempt to answer that question. I start by asking how things hold together. An object may bend when we push it and recover when we let go. Push it differently and it may change for good. I suspect that, at a much deeper level, events also depend on what an arrangement can withstand and what it can no longer keep doing.

What a prediction tells us

Imagine a light experiment with two paths leading to two detectors. The paths are arranged so that the light can produce interference. This means that bringing the two contributions together changes the result. They can strengthen or cancel one another, depending on their phase difference. For now, think of phase as where something is in a repeating cycle. Chapter 3 will explain it properly.

Figure 1.1 shows the effect. Adjust the phase difference and more detections occur at one output, fewer at the other. At some settings the outputs are equally likely. We can predict these changes and check them in the laboratory. The calculation tells us how the balance should change as we turn the control.

A Coherent paths and one record



B Repeated-run prediction

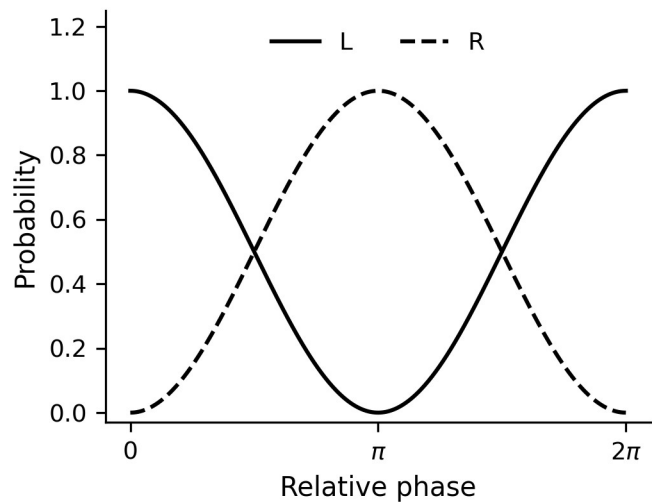


Figure 1.1 Light reaching the outputs by two paths can interfere. Changing the phase difference changes the chance of detection at each output. The curves show those chances for an ideal balanced instrument. Each detection leaves one record. The drawing does not tell us that a particle secretly followed one particular path.

Now choose a setting where either detector might register the next arrival. After many trials, the totals should approach the predicted balance, with some variation. But those totals do not tell us the order of the results. Left then right gives the same totals as right then left. In practical work, the totals may be all we need. Reliable probabilities let us build useful instruments. Feynman explained both the power of these calculations and the difficulty of picturing what lies behind them. [6]

Even so, each individual result does something. The detector changes, and its signal can open a shutter or start another experiment. The result matters because other things now depend on it. A probability tells us what might happen. The recorded signal tells the next piece of equipment what to do.

I want to understand how these two aspects fit together. Why do many events follow such reliable patterns, and how does each event come about? Quantum mechanics uses a rule called the Born rule to calculate the probabilities. PDT asks whether an explanation of how a record forms could also explain why those probabilities work. [3]

How things keep going

We usually begin by picturing objects, such as particles, planets or instruments. Then we ask how they affect one another. That is a useful way to calculate. But it leaves another question in the background. What allows an object to exist and remain recognisably the same thing while all this happens?

Take a solid object sitting on a table. It looks still, although the particles inside it remain active. The object keeps its shape because their arrangement holds together through that activity. Its stability does not require everything inside it to stop. It requires the right relationships to last.

In PDT, I propose that matter holds together through phase relationships. By this I mean organised comparisons between cycles, which I will explain in the next few chapters. An object's properties

would depend on how those relationships work together. An encounter with something else might leave that organisation intact, alter it, or make it impossible to maintain.

A bridge offers a familiar comparison. A small load may make it flex and recover. A greater load may change its shape permanently. What happens depends on how the bridge is built and how the force acts on it. The equations describe those limits. They do not create them.

A bridge bending does not prove anything about a quantum event. It helps explain the question I am asking. Can the relationships involved keep working as an interaction develops? They need not all match. Two cycles can keep a steady difference between them. What matters is whether the whole arrangement can continue in a particular way.

I call the proposed change into one definite event a phase snap. Before it happens, there may be several possible ways for an encounter to develop. As the encounter proceeds, some may become physically impossible. My proposal is that, when only one remains, it becomes the event that actually occurs.

There is an assumption here. Giving an arrangement limits does not prove that exactly one possibility will survive. PDT takes the link between one surviving possibility and one actual event as a principle. I cannot present that step as something already proved simply by describing how other possibilities might be ruled out.

Chance and what actually happens

Sometimes we call an event random because we do not know enough to predict it. A tossed coin depends on details of the throw that we rarely measure. Weather is harder still. Tiny differences can grow until a forecast becomes unreliable. Lorenz showed why a process can follow definite rules and still be difficult to predict in practice. [8]

Quantum chance is harder to explain this way. Results from pairs of particles show patterns that cannot be accounted for by simply giving each particle its own hidden set of local instructions. Bell's theorem sets out the restriction. [1] A deeper explanation must respect it. We cannot treat a photon as a tiny object carrying a private answer sheet for every test.

I suspect that the explanation may involve the encounter as a whole. Preparing a particle already involves other things. The detector adds further interactions when it receives it. It seems reasonable to ask whether the result depends on those relationships, rather than expecting the arriving particle to contain the whole answer by itself.

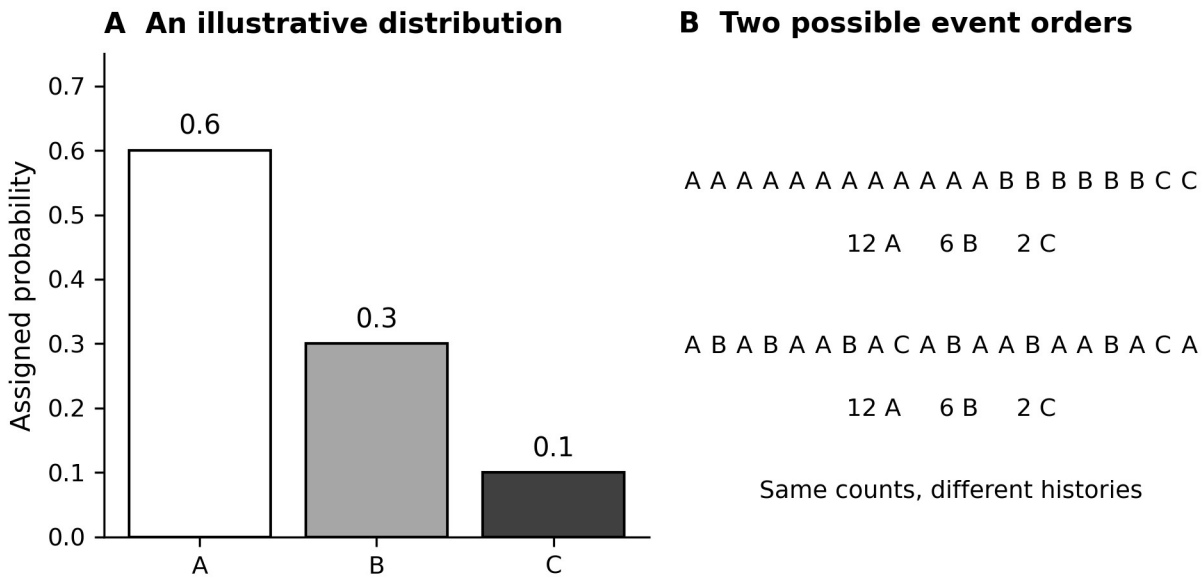


Figure 1.2 This invented example gives A a chance of 0.6, B a chance of 0.3 and C a chance of 0.1. The two sequences have identical totals in different orders. Actual samples can differ in their totals too. Probabilities describe a pattern across trials without naming the next result.

Figure 1.2 makes the distinction easier to see. Two sequences can have the same totals but unfold differently. The probabilities tell us how likely different sequences are. The question I am pursuing is how the sequence we actually experience comes about, one event after another.

An answer need not let us predict everything. The relevant details may be beyond our reach. We can understand a process without forecasting every instance of it. We know a great deal about how waves form, for example, without being able to name every ripple that will reach a beach.

Repeating an experiment means repeating the conditions we can control. It does not mean reproducing every detail of the room and its surroundings. If PDT makes some of those details important, it must explain how they affect an individual result while still producing the probabilities we already measure. Calling the details hidden would not be enough.

Perhaps there is no further explanation of a particular quantum event. I do not want to assume that before trying to find one. That is what I value in Einstein's concern about whether quantum theory gives a complete description, even though later work has ruled out some answers he might have hoped for. [4]

Where the idea leads

The same question extends beyond detectors. A piece of matter survives countless encounters. Light travels from one place to another. A clock repeats a movement while other things change. I want to know how such activity can produce something that lasts. In PDT, phase describes the repeating relationships, and phase snap describes the proposed step into a definite event.

I picture matter as an arrangement of phase relationships that keeps holding together. If that is right, changing an object's motion also involves the organisation that sustains it. This is where I look for the origin of inertia, the familiar resistance we feel when we try to start or stop a heavy object.

Energy lets us compare and measure such changes. A body can store energy and pass it to something else. Clocks let us compare how long changes take. Later in the book, I ask how gravity and the history of the universe might fit this picture. Even an apparently quiet object may have a great deal going on that makes its continued existence possible.

These are proposals about nature. Some have mathematical support, but the mathematics has not proved the entire picture. My aim is to explain the idea clearly enough for you to judge it. What draws me to it is the possibility that the stability of matter and the formation of events have a common explanation.

Quantum mechanics remains essential to that search. Its equations already describe phase and interference with great success. I am asking whether we can explain more about the world behind those equations, while keeping the results they get right.

Other approaches have wrestled with the same difficulty. Bohr, Everett and researchers studying decoherence offered different ways to understand quantum results. [2, 5, 11] We will meet their ideas as we need them. PDT begins with my commitment to one actual history, in which interactions leave results that affect what happens next.

You will not need to master every equation to follow the book. I will explain what each is doing when it appears. The appendices give longer arguments and describe circumstances in which PDT would fail. Here, the purpose of the maths is to make a physical idea clearer and to show what would have to be measured.

This way of thinking changes the questions I ask. How does a solid remain solid while its particles move? How can a detector's unread result control another experiment? Familiar things can hide difficult questions. Following those questions may help us see what our usual descriptions leave unexplained.

Philosophy helps me choose what to ask. It cannot decide what an experiment will find. The proposed picture must eventually lead to calculations and observations that can be checked. Otherwise it remains a way of thinking about the world, rather than an explanation we can test.

We have begun with a large ambition, but a small event will keep us grounded. A mark appears on a screen. Something has happened, and it has consequences. Whatever PDT becomes, it must explain that everyday fact about a quantum experiment.

Bridge to Chapter 2

The next chapter follows the detector itself. It is made of ordinary matter, yet we ask it to turn quantum possibilities into a definite reading. What changes inside the equipment when that reading forms? Looking closely at the instrument will help us see why this remains a real question.

References and further reading

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