

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. Nature had not waited for someone to check its homework. Our calculations describe what happens. This book asks what makes it happen.

Physics lets us do remarkable things. We can predict an eclipse, build a computer and send messages across an ocean using light. I am certainly not proposing we hand those achievements back. But a correct prediction can leave a question unanswered. A timetable tells us when a train should arrive. I still want to know what makes the engine work.

Now think of a particle arriving at a detector. A mark appears on a screen. Quantum mechanics, the theory we use for atoms and particles, calculates the chance of a mark appearing in each place. Over many experiments, it does this wonderfully well. But here is today's puzzle. Why did this particular mark appear here?

Phase Differential Theory, or PDT, is my attempt to explore that question. I begin with how things hold together. Push something gently and it may bend, then recover. Push harder and it may change for good. Could events, at a much deeper level, also depend on what something can withstand before it has to change?

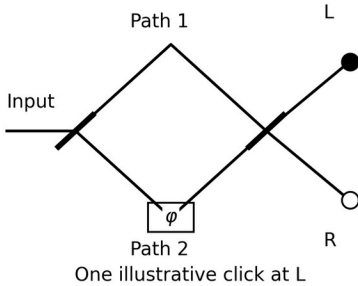
Why knowing the odds does not explain the result

Imagine light travelling through an instrument with two paths and two exits. A detector at each exit records arrivals. Bring the light from the paths together and the waves can strengthen or cancel one another. That is interference. What happens depends on where the waves are in their repeating motion when they meet. We call that comparison phase difference. Chapter 3 will make it familiar.

In Figure 1.1, follow the two curves. As we turn a control that changes the phase difference, one exit becomes more likely and the other less likely. Where the curves cross, the chances are equal. We can check

these predictions in the laboratory. The graph is simply a picture of how the odds change.

A Coherent paths and one record



B Repeated-run prediction

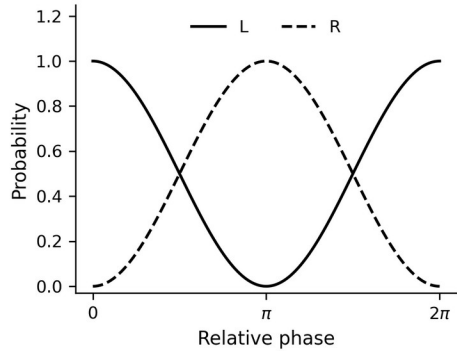


Figure 1.1 Two paths lead to two detectors. Turning the phase control changes the odds at each exit, shown by the curves. Each arrival leaves one record. The picture does not mean that the particle secretly chose one path all along.

Choose a setting where either detector might click next. After many trials, the totals should come close to the predicted balance. But totals leave out the order. Left then right gives the same score as right then left. For building an instrument, reliable odds may be exactly what we need. Feynman described both the power of these calculations and the difficulty of picturing what produces the results. [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 the pattern and the individual event. Quantum mechanics gives the odds using the Born rule, named after Max Born. Could understanding how the detector makes a record also explain why those odds come out as they do? That is a question for PDT. [3]

How things hold together while their parts keep moving

We usually start with objects, such as particles, planets or instruments. Then we ask how they affect one another. But there is a question hiding

underneath. What lets an object remain the same thing while all this happens to it?

Consider a mug sitting on a table. It looks still, although its particles remain active. Somehow all that activity continues to give us a mug. This is reassuring when it contains hot tea. Staying the same does not require everything inside to stop. It requires the structure to hold together.

My proposal is that matter holds together because its repeating activities maintain a dependable pattern. What keeps that pattern going, and what could change it or make it impossible to continue?

The engineer in me reaches for a bridge. A small load may make it flex and recover. A greater load may change its shape for good. What happens depends on its construction and the force applied. The equations describe what the bridge can withstand. The bridge does not consult them before deciding whether to bend.

A bending bridge does not prove anything about a quantum event. It gives us a useful question. Can the parts keep working together as conditions change? Working together need not mean doing the same thing. Two cycles can stay a steady distance out of step and still form a lasting pattern.

I call the proposed change into one definite event a phase snap. Several endings may be possible at first. As the particle and its surroundings affect one another, some endings may become impossible. My proposal is that, when only one remains, it becomes the event.

That last step is an assumption. Limits do not guarantee one survivor. PDT takes the step from one remaining possibility to one actual event as a starting rule. Naming it does not prove it. The idea still has to earn its keep.

Chance and the puzzle of one definite event

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 that way. Pairs of particles give patterns that cannot be reproduced by putting a private list of local answers inside each particle. Bell's theorem tells us why. [1] A photon cannot simply arrive with an answer sheet for every test. We will tackle that puzzle in Chapter 4.

I suspect we need to look at the whole encounter: the preparation, the arriving particle and the detector. Could their relationships fix the result? Perhaps we are asking too much when we expect the particle to carry the answer alone.

Figure 1.2 shows the difference. Think of a football score. Knowing the final score does not tell you who scored first or when the match became exciting. Likewise, the odds describe possible sequences. I am asking how the sequence we actually experience comes about, one event at a time.

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.

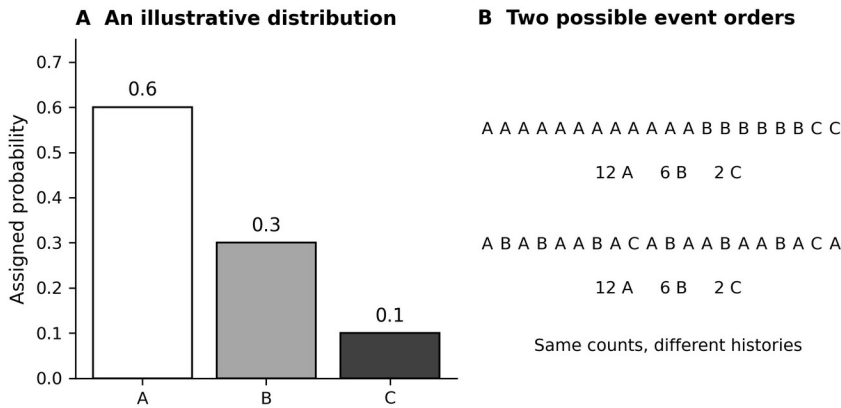


Figure 1.2 In this invented example, A has a 60 per cent chance, B a 30 per cent chance and C a 10 per cent chance. Both lists have the same totals, in a different order. Real samples can differ in their totals too. Knowing the odds does not name the next result.

Repeating an experiment means repeating what we can control. We cannot reproduce every detail of the room. If I suggest that an

overlooked detail matters, I owe you an explanation of how. PDT must also give the odds that experiments already confirm. Calling something hidden is not much help unless we say what it does.

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]

Could one idea explain matter and events

I picture matter as a pattern of phase relationships that keeps holding together. If this is right, starting or stopping an object must also involve that pattern. Here I look for the origin of inertia, the resistance we notice when we push something heavy. Your reluctant shopping trolley will return later.

Energy lets us measure changes, storage and transfers. Clocks let us compare how long changes take. Later, I ask how gravity and the universe's history might fit this picture. Even a quiet object may need continuing activity to remain itself.

This is my picture of nature, and I want you to follow it before judging it. Mathematical support for some parts does not prove the whole. Could matter lasting and events happening have something important in common?

Quantum mechanics remains essential. Its equations describe phase and interference with great success. Can we explain more about the world behind them while keeping their correct predictions?

I am far from the first person to worry about this. Bohr, Everett and researchers studying decoherence offered different answers. Decoherence is about what happens when a quantum system interacts with its surroundings. [2, 5, 11] We will unpack those ideas as we go. My starting point is one actual history, with each event affecting what can happen next.

You do not need to solve the equations to follow me. Read the explanation in words first. The symbols are there for a closer look, and the appendices carry the longer arguments. They should support the

conversation, not guard the entrance. There is still no surprise exam at the end of Chapter 7.

Philosophy helps me choose the questions. Maths must show what follows; experiments must test whether nature agrees. Liking an idea cannot settle that. Without testable calculations and observations, it remains a proposal.

Bridge to Chapter 2

Let us leave that detector running and go home. By morning it may have made thousands of records, perhaps even started another experiment. It has managed all this without waiting for our opinion. In Chapter 2, The Measurement Problem Is Not a Detail, we follow the equipment through the night. What turns a list of possible readings into the one that greets us in the morning?

References and further reading

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