

Chapter 5

The Misplaced Primitive

A house contains bricks, but a heap of the same bricks is poor accommodation. All the ingredients are there. The roof is the problem. To explain a house, we need to know how the pieces fit and hold together. Could a similar question help us think about matter itself?

A theory needs a starting ingredient, something it takes as given rather than explains. Mathematicians call it a primitive. Nothing rude is intended. I want to ask whether we chose the right ingredient. Could we look beneath the object and explain what keeps it there?

We often start with an object and its state, the description used to calculate what it might do. That works well. My question comes earlier. What lets the object exist and keep being that sort of thing while the world gets on with disturbing it?

What lets a chair remain the same chair

Move a chair across the room and it remains the same chair. You do not need to introduce yourself to it again. Warm it gently and it may expand a little, while keeping its shape and purpose. Being the same thing clearly allows some changes.

Other changes go too far. Loosen the chair's joints enough and sitting down becomes an adventure. Its name may still be chair, but its connections no longer do their job. That is the physical question beneath identity. What must keep working for a thing to remain the kind of thing it is?

I ask the same question about particles. In PDT, a particle would be a lasting pattern of phase relationships. Its mass and charge would depend on how that pattern holds together and responds to encounters. Those properties become things to explain, rather than numbers entered at the start.

That is a direction, not a completed particle design. The structure must yield measurable answers. Renaming mass as phase while inserting the

same unexplained number resembles renaming a leaking pipe. The label improves; the floor stays wet.

We must also be careful with the house analogy. A house uses bricks that are already material objects. If we want to explain what matter is, we cannot go on indefinitely replacing each piece with smaller pieces that already possess the properties we are trying to explain.

So I start with differences and relationships, before assigning mass or position. Phase describes relationships that repeat around a cycle. Could a pattern of them last as matter? That possibility interests me. The work is to show which patterns could survive and what they would do.

The first statement says only that two things can be distinguished.

$$A \neq B$$

A and B are different. That is all the first statement says. It has not given them a mass, a location or a material. The next expression gives phase labels a circular form.

$$\Phi: X \rightarrow S^1$$

This is a simple labelling example. X is the collection being labelled and S^1 means a circle, like a clock face. The fuller foundations also assign phase to comparisons along routes. Endpoint labels alone cannot describe every such comparison. We have not yet built a particle.

Why changing the labels does not change the world

Suppose we move the zero on a ruler. The numbers change, but the gap between two marks does not. Relabelling the ruler will not make a shelf fit an awkward alcove. A theory should likewise distinguish new labels from a change in the world.

Phase works similarly. Shift all the labels together and the gaps stay unchanged. Shift one compared with another and the light pattern may change. Quantum mechanics already makes this distinction. [1] We must tell a change in our labels from a change that makes the experiment behave differently.

The next equations record that idea. The first adds two contributions, ψ_1 and ψ_2 . The second works out their combined effect. Notice the extra term for how they meet. You need not calculate it to follow me. The relationship affects the answer.

$$\psi = \psi_1 + \psi_2$$

$$|\psi|^2 = |\psi_1|^2 + |\psi_2|^2 + 2 \operatorname{Re}(\psi_1^* \psi_2)$$

Each contribution is written as $\psi_j = A_j e^{i\varphi_j}$. A_j gives its size and φ_j its phase. The expression below describes the extra effect of combining them. It depends on their phase difference, which is why adding two waves is different from just adding their brightnesses.

$$2 A_1 A_2 \cos(\varphi_2 - \varphi_1)$$

The star and Re are instructions for calculating that extra effect. We need not unpack them here. Our question is simpler. If both phases shift by the same amount, α , does anything we can measure change? The next line writes that shift in symbols.

$$\psi \mapsto e^{i\alpha} \psi$$

It does not. Moving both phases together leaves their gap and the combined strength unchanged. Move one relative to the other and the result can change. That is the message behind the symbols.

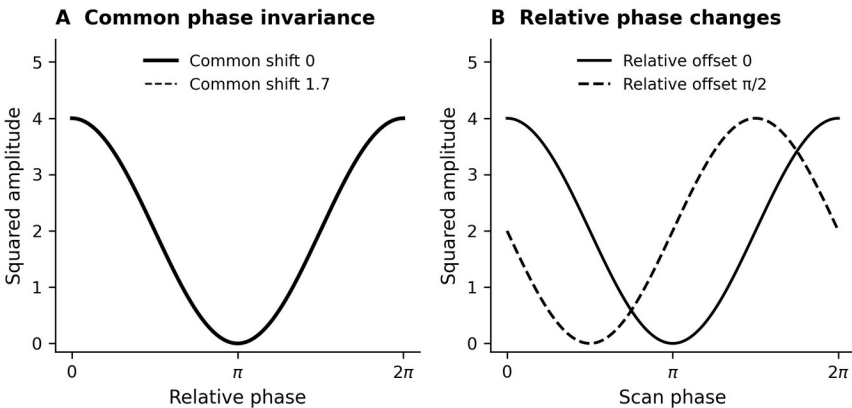


Figure 5.1 On the left, both phases shift together and the curves stay on top of each other. On the right, their gap changes and the pattern moves. The vertical scale shows squared wave size, not a probability. The physical difference comes from changing how the contributions line up.

Quantum mechanics already includes this information. PDT asks whether the relationships are the physical starting point and the state is their description. A calculation can keep working while we ask what makes it work.

Electric potential gives a related example. It describes conditions that can push an electric charge. Think of height on a hill. Changing the point called zero leaves the slope alone. Figure 5.2 does this to the potential. Its slope, and therefore the electric field, stays the same.

$$E = -\nabla V$$

Here E means electric field, V means electric potential, and ∇ tells us how the potential changes from place to place. The minus sign gives the direction. Think of moving a hill's height labels without changing its slope. The climb stays just as steep.

This does not make every difference in physics a phase difference. It shows why comparisons deserve attention. Some numbers can change because we choose new labels, while the physical effect stays the same. We need to know which is which.

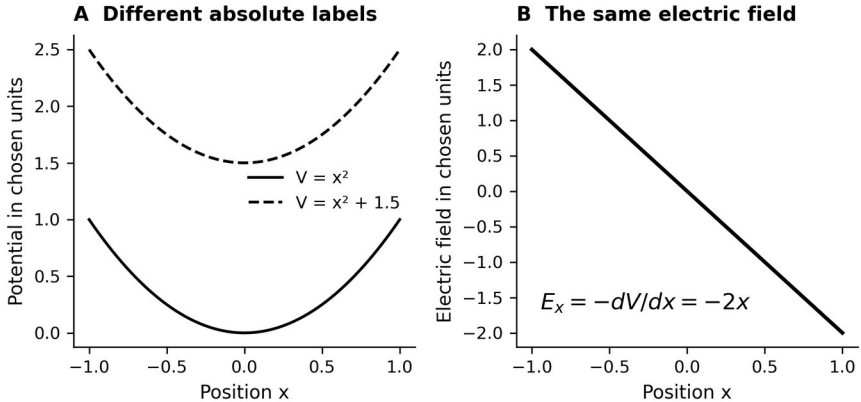


Figure 5.2 The two curves have different height labels but the same slopes. They therefore give the same electric field, shown on the right. Potential and phase are different quantities. Both examples help us see the difference between relabelling something and changing its effect.

How separate comparisons form a connected picture

One comparison is not enough for a whole structure. We need to connect them. Compare A with B, then B with C. How do the two steps fit? A sensible rule should let us put them together without confusion.

Here my engineering instincts help. One measurement tells us little about a building. Connected measurements locate corners and expose mistakes in the plan. A notebook of unrelated distances would give us plenty of numbers, but very little help in finding the door.

Putting suitable comparisons together is called composition. Think of joining stages of a journey. One connects to the next, making a route we can follow. PDT asks whether connected relationships could also form something that survives encounters with the world.

The comparison from A to B is D_{AB} . The next, from B to C, is D_{BC} . Together they give D_{AC} along this route. The equation below records those joined steps.

$$D_{BC} \circ D_{AB} = D_{AC}$$

Read it from right to left, as the notation requires. First go from A to B, then from B to C. Together, that is a route from A to C. It does not say every other route would give the same result. The journey may matter.

A state describes the structure and how it is doing. That description need not be an extra ingredient inside the thing. Temperature is not a tiny object tucked among the atoms. Likewise, a state can tell us something useful without being what the world is ultimately made of.

We also need to explain which changes an object can survive. Move the chair and its place in the room changes. Break its joints and its structure fails. Saying everything is related does not explain the difference. PDT must show which relationships keep the chair together and which can change freely.

The boundary of an object matters too. A chair can be distinct from the room while exchanging heat and forces with its surroundings. PDT needs to explain both the relationships that sustain the object and those connecting it to other things.

What a push or a pull reveals about structure

Imagine two model bridges that look identical. One is firmly joined. The other is balanced together for the photograph. Lift them and the difference becomes memorable. A picture of the shape did not tell us which connections would hold.

A response tells us what a photograph cannot. Will the object bear a load, bend or recover? Those abilities depend on its construction before anyone tries it. A test reveals them by making something happen to the object. The response matters as well as the shape.

With a particle, we cannot inspect a familiar construction in the same way. We learn through interactions. Mass describes a regular feature of its response. PDT asks whether the structure that lets the particle exist could also explain that response.

If the same structure explained several properties, we would understand why those properties came together. We would have more than a list of mass, charge and other numbers. Different lasting structures might produce different properties. A model would need to calculate them for this to count as an explanation.

One experiment need not reveal the whole structure. Different interactions can reveal different aspects. We may need several descriptions of the same thing, each useful for a particular question. PDT asks whether a common underlying organisation connects them.

Persistence means staying recognisably the same through change. Enough of the organisation survives for the object to keep behaving as that kind of thing. Move your chair and it is still a chair. Persistence does not require a quiet afternoon.

When a lasting structure reaches its limits

Gentle warming may let an object expand and recover. Greater heating may change its structure permanently. The material can still be present while the arrangement we recognised has gone. Continuing to exist in some form is different from continuing as the same thing.

PDT's proposed phase structures would have limits set by their organisation and encounters. A new encounter could remove a previously possible continuation.

A phase snap would establish an event and new conditions. Some structures could survive while others change. A detector click need not rebuild the world; most surroundings continue while the record has its particular effects.

Both survival and change need explaining. If every encounter destroyed a structure, what could last? If none could change it, what could happen? PDT proposes persistence only while conditions allow the structure to continue.

Decoherence can remove observable interference without dismantling an object. [2] Losing that effect and losing the structure that holds the object together are different changes. Our explanation must distinguish them.

A state is useful, but should it be our first physical ingredient? Perhaps relationships explain why something lasts, giving the state an object to describe.

We began with a house and its bricks. Rearranging ingredients changes what they make. Could relationships also explain the ingredients themselves? The maths must show how far that bigger idea can go.

Bridge to Chapter 6

Before I ask phase to explain the furniture of the universe, we should check what it can actually tell us. A clock face makes the problem wonderfully ordinary. It can show three o'clock without saying which day it is. Chapter 6, What Φ Is and Is Not, separates the reading from the journey. We need that distinction if yesterday's encounters can change what happens today.

References and further reading

- [1] Feynman, R. P., Leighton, R. B., and Sands, M. (1965). The Feynman Lectures on Physics, Volume III, Chapter 1, Quantum Behavior. Addison-Wesley. https://www.feynmanlectures.caltech.edu/III_01.html
- [2] Zurek, W. H. (2003). Decoherence, einselection, and the quantum origins of the classical. Reviews of Modern Physics, 75, 715–775. <https://doi.org/10.1103/RevModPhys.75.715>