

Chapter 5

The Misplaced Primitive

A house contains bricks, but a heap of the same bricks is not a house. To explain the building, we need to know how its walls and supports fit together. The ingredients matter, and so does their arrangement. Starting with one or the other changes the questions we notice.

Physicists call a theory's starting ingredient a primitive. It means something the theory begins with, rather than explains in terms of something more basic. Every theory needs a starting point. The question is whether that choice helps us explain the world or makes us overlook something that still needs explaining.

Often we begin with a system and its state. The state is a mathematical description used to calculate what the system might do. This works extremely well. PDT asks an earlier question. What makes it possible for that system to exist as an identifiable thing in the first place?

I start with what keeps a thing together through change. An object can move or warm up and remain recognisable because enough of its organisation survives. In PDT, the state describes that object. The deeper question is how its relationships sustain something that can be described at all.

What makes it the same object

Move a chair across the room and it remains the same chair. Warm it gently and the material may expand without losing its shape or function. Its identity does not depend on staying in one place or remaining completely unchanged.

Enough of its structure must remain. Some changes leave the important connections intact, while others do not. For everyday objects, the boundary can be unclear. Even so, there is a physical question beneath the name. What allows this arrangement to keep behaving as the same kind of thing?

PDT asks this about particles too. I propose that a particle is a lasting structure of phase relationships. Its properties would depend on how those relationships hold together and respond to interactions. Mass and charge would then need to be explained through that structure, rather than simply assigned as numbers at the start.

This is a proposed direction, not a claim that every particle's structure has been calculated. A successful model would have to connect the structure with measurable properties. Calling mass and charge features of phase would achieve little if we still had to insert the same unexplained numbers.

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.

That is why I begin with differences and relationships. I allow a distinction before assigning familiar properties such as mass or position. Phase gives the relationships a cyclic form. I then ask whether arrangements of them could sustain matter. Showing which arrangements work, and what they predict, is the difficult part.

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

$$A \neq B$$

A and B are different. Nothing here yet tells us their mass, location or material nature. The next expression gives phase labels a circular form.

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

X names the set receiving the labels. S^1 means a circle. The arrow says that each member of X is assigned a place on that phase circle. This notation supplies a starting structure, not a complete physical object.

Changing the labels or changing the world

Suppose we move the zero on a measuring scale. The labels change, but the gap between two marks stays the same. A theory should not predict a new physical event just because we renamed the same positions.

Phase works similarly. Shift every relevant phase label by the same amount and the differences remain unchanged. Shift one relative to another and an interference pattern can change. Quantum mechanics already uses this distinction between changing all the labels together and changing a physical comparison. [1]

The next equations show it. The first combines two contributions, written as ψ_1 and ψ_2 . The second calculates the squared size of their sum, which matters for the resulting intensity or probability.

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

We write each contribution as $\psi_j = A_j e^{i\varphi_j}$. A_j gives its size and φ_j gives its phase angle. The expression below is the part of the combined result that depends on the gap between those angles. It explains why adding contributions can differ from simply adding their separate intensities.

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

In the longer equation, the star means taking the complex conjugate, and Re means keeping the real part. These are mathematical operations used in calculating the interference. The next expression shifts the phase of the whole result by the same angle, α .

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

That common shift leaves the relative phase and the squared size unchanged. The main point is simple. Changing every phase together does not have the same effect as changing one relative to another.

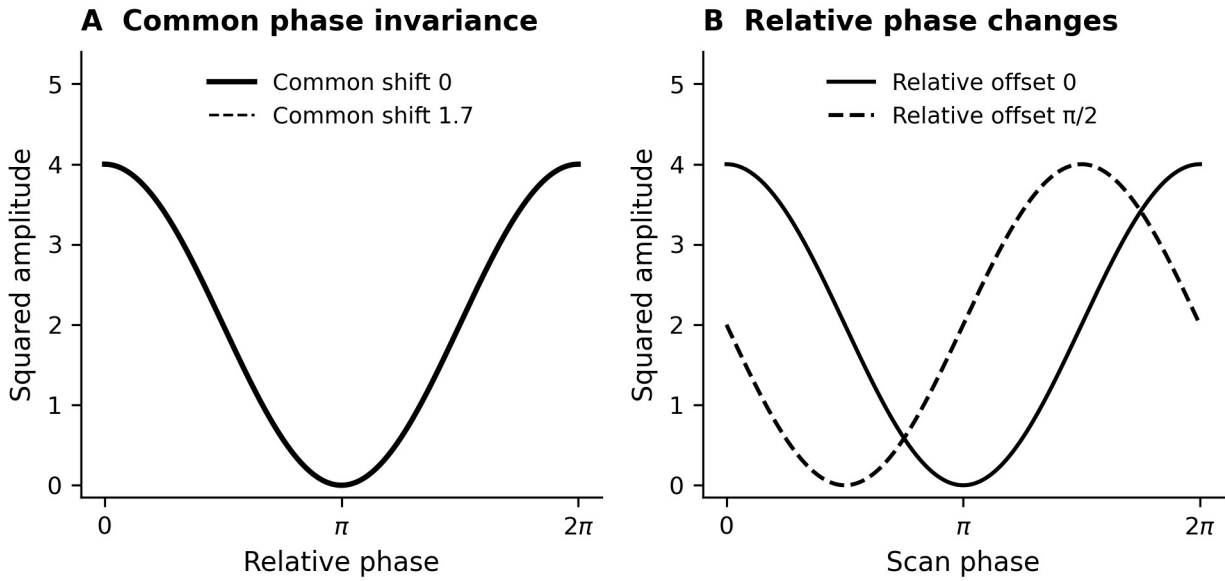


Figure 5.1 On the left, shifting both phases together leaves the interference pattern unchanged, so the curves lie on top of each other. On the right, changing their relative phase moves the pattern. The plotted squared amplitude has not been normalised to a probability. The comparison illustrates information already used in quantum mechanics.

PDT is not claiming to discover information that quantum mechanics ignores. Quantum states already contain these phase relationships. I am asking whether the physical relationships come first and the state describes them. The calculation could remain useful while its underlying explanation changes.

Electric potential gives another example of the distinction between labels and differences. We can choose a different zero for the potential without changing the electric field. Figure 5.2 shows two potential curves separated by a constant amount. Their slopes are the same, so they give the same field.

$$E = -\nabla V$$

Here E means electric field, not the energy discussed in Chapter 7. V means electric potential. The symbol ∇ describes how the potential changes from place to place. The minus sign sets the direction. Raising the whole potential curve leaves that change, and therefore the field, unchanged.

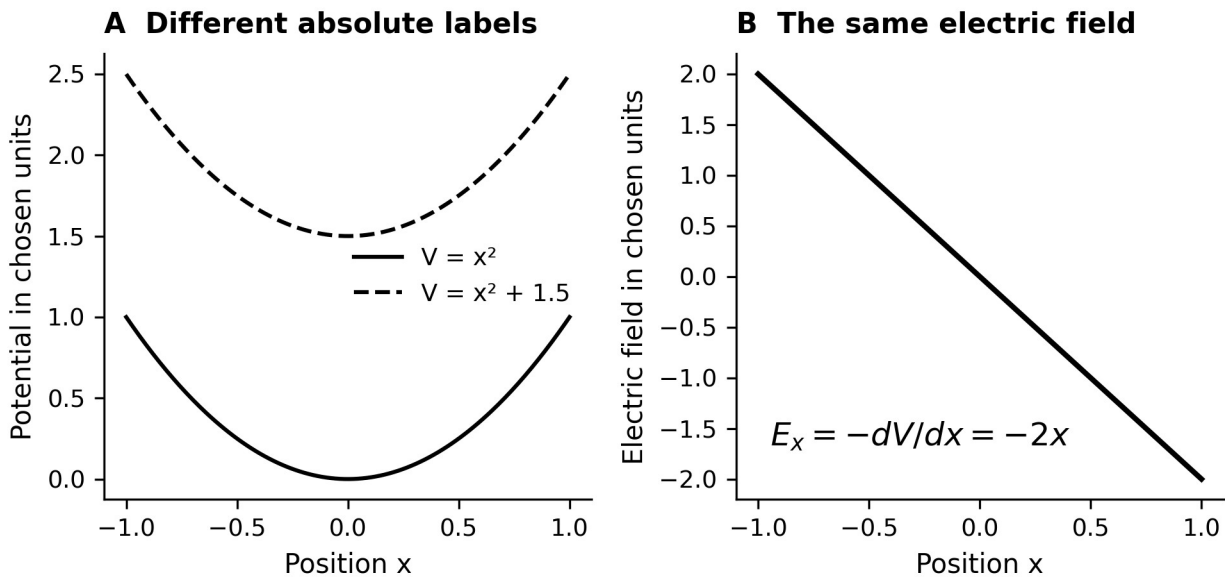


Figure 5.2 The two potential curves differ by a constant amount. Their slopes match, giving the same electric field. Moving the reference level changes the labels without changing this physical effect. Electric potential and phase are different quantities, although both examples show why comparisons matter.

This does not turn every difference in physics into a phase angle. It shows why I take relationships seriously. In these examples, some labels can change freely while a measurable comparison stays fixed. We need to identify what changes physically, rather than mistake a new description for a new situation.

For that reason, an arbitrary label seems a poor starting ingredient for reality. I give priority to comparisons that retain their meaning when we relabel them. They help us separate a change in the world from a change in our bookkeeping.

Joining comparisons together

One comparison cannot describe a whole arrangement. We need to join comparisons consistently. If we compare A with B and then B with C, the theory needs a rule for combining those steps. The result should not depend merely on which labels we happened to write first.

A survey gives a useful analogy. One distance tells us little about an entire building. Several linked measurements can locate points, constrain the plan and expose mistakes. The connections between the measurements provide information that a list of unrelated numbers would lack.

Joining relationships in this way is called composition. It lets several comparisons describe one connected arrangement. If that arrangement can hold together through interactions, it may be a candidate for the lasting structure I associate with a material thing.

Call the chosen comparison from A to B D_{AB} , and the compatible comparison from B to C D_{BC} . Combining those two gives D_{AC} , the comparison along that specified route.

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

Read the equation from right to left. First take the step from A to B, then the step from B to C. It identifies their combination. It does not say that every other route or comparison from A to C must give the same result.

A state can then describe the arrangement and its current condition. We already use useful descriptions without treating them as separate ingredients. Temperature is not an extra tiny object among the atoms. Likewise, a state can accurately describe something without being the most basic thing in the explanation.

We also need to distinguish changes that preserve an object from changes that destroy its structure. Moving the chair changes its relationship to the room. Breaking its joints can stop it being a usable chair. A relational theory must explain why some connections matter to its identity while others can vary. Saying that everything is related would not answer that question.

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.

The successful predictions of state descriptions must still emerge from this account. I would not regard an appealing philosophy as progress if it lost results we can already calculate. The aim is to explain why those calculations work by understanding what their states describe.

Learning about a thing by what it does

Picture two assemblies with the same outline, one firmly joined and the other loosely balanced. In a photograph they may look alike. Lift them and their difference becomes obvious. The picture did not tell us which relationships would hold when disturbed.

An object's response tells us something its appearance alone may hide. Can it bear a load, bend or recover? Those capacities belong to its physical construction before anybody tests it. The test reveals them by bringing the object into a new interaction.

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 it could, the particle's properties would have a common reason. We would not simply begin with a list of mass, charge and other numbers. Different lasting structures might produce different characteristic properties. A model would have to calculate that connection for it to become 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.

This is what I mean by persistence. The object keeps enough of its organisation to carry recognisable responses into its next encounter. It can change in some respects without losing every feature that makes it that kind of thing.

When an object can no longer stay the same

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.

I apply that question to PDT's proposed phase structures. They need not withstand every possible interaction. Their limits would depend on how they are organised and what happens to them. Reaching a limit can remove ways in which they could otherwise continue.

A phase snap would establish an event and new conditions for what follows. Some structures could remain intact through it while others change. A detector clicking need not rebuild the entire world. Most surrounding arrangements continue while the new record has its particular effects.

Both survival and transformation need explaining. If every encounter destroyed an object's identity, ordinary stability would be puzzling. If identity lasted unconditionally, change would be puzzling. PDT proposes that lasting forms depend on conditions, and some changes in those conditions alter what can last.

An interference effect can also disappear while an object remains. Decoherence helps explain how interactions with the surroundings remove interference accessible to us. [2] Losing that effect does not automatically mean losing the material structure of the object. These are different changes that a careful account must distinguish.

So I think of a state as describing an arrangement that has to hold together. Giving that arrangement a complete mathematical description does not automatically explain why it exists. We can still ask what sustains the structure represented by the numbers.

That is the suspicion behind the title *The Misplaced Primitive*. States are useful descriptions. I question whether they should be the first physical ingredient in the explanation. Perhaps the relationships that sustain objects can explain why there are states to describe.

The house helped us see that the same ingredients can make different things when arranged differently. PDT asks a deeper version of the question. Could relationships help explain the material ingredients themselves? That is the proposal, and the mathematics must show how far we can take it.

Bridge to Chapter 6

We now need to be precise about the phase symbol Φ . It cannot stand for everything we have not yet explained. Chapter 6 asks what a phase value tells us, what it leaves out, and why the route to a value may matter as much as the value itself.

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>