

Chapter 6

What Φ Is and Is Not

A clock face can tell you the hour without telling you the day. The hands return to the same positions, but the world has moved on. Phase has a similar limitation. It tells us where we are in a cycle. It does not, on its own, tell us how many times we have been round or what happened along the way.

The Greek letter Φ , pronounced phi, represents the phase assignment introduced earlier. We can reach the same phase after different journeys, just as the clock can show three o'clock on different days. That matters when we try to use phase to describe a physical history.

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

In this notation, X names whatever receives a phase label, and S^1 means the phase circle. The arrow assigns labels on that circle. It does not yet tell us that X is ordinary physical space.

Before connecting phase with energy, we need to separate three things. Where are we in a cycle? How many cycles have passed? Has an interaction left a lasting change? These can be related, but one number need not contain all three answers.

The last question matters to PDT's idea of persistence. Something from the past can affect the present because a consequence has survived. A stored signal, an altered structure or a continuing relationship can carry that consequence into the next encounter.

What are we comparing

A quarter turn is a clear difference, but between what? It could compare two light contributions arriving together. It could compare a cycle with a nearby reference. Or it could compare an earlier reading with a later one. The same number can answer different physical questions.

An interferometer is an instrument that brings contributions together so their phase difference affects the output. [1] Comparing readings taken at different times also requires a way to keep the earlier information. In both cases, we need a physical means of comparison. Writing a difference on paper does not explain how it is measured.

The Greek letter Δ , pronounced delta, means a difference. So $\Delta\Phi$ means a phase difference. It is useful shorthand, but we must still say which phases are compared and how that comparison affects the experiment.

$$\Delta\Phi = \varphi_2 - \varphi_1$$

The symbols φ_1 and φ_2 label the two angles. We subtract one from the other. If we have not kept a separate count of turns, we set complete turns aside. That is the meaning of taking the result modulo 2π .

This prevents an easy mistake in the PDT story. A phase compared with a laboratory clock may differ from a phase relationship that helps hold an object together. We must identify which relationship matters. Otherwise we could use the right word for the wrong physical comparison.

We also need to know how the parts affect one another. Which phase relationship changes the response? How does the encounter alter it? What survives afterwards? These questions turn a general idea about relationships into something a model can actually describe and test.

Phase strain means the demands an interaction places on the proposed structure. Those demands may depend on how its parts are linked, on its surroundings and on changes left by earlier encounters. One phase difference cannot be assumed to measure all of that.

As Chapter 3 showed, a steady phase difference can be perfectly stable. We now need to ask what a present reading tells us about the past. A circle is good at showing where something is. It is less good at remembering how it got there.

The journey behind the reading

Imagine a wheel disappearing behind a screen. When it reappears, it has the same orientation. It might have stood still or completed several turns. The final view cannot decide. To distinguish the journeys, we need some other information.

A turn counter could keep that information. Watching continuously could do so too. Figure 6.1 compares a phase reading that starts again after each turn with a record that keeps counting. They describe different aspects of the same movement.

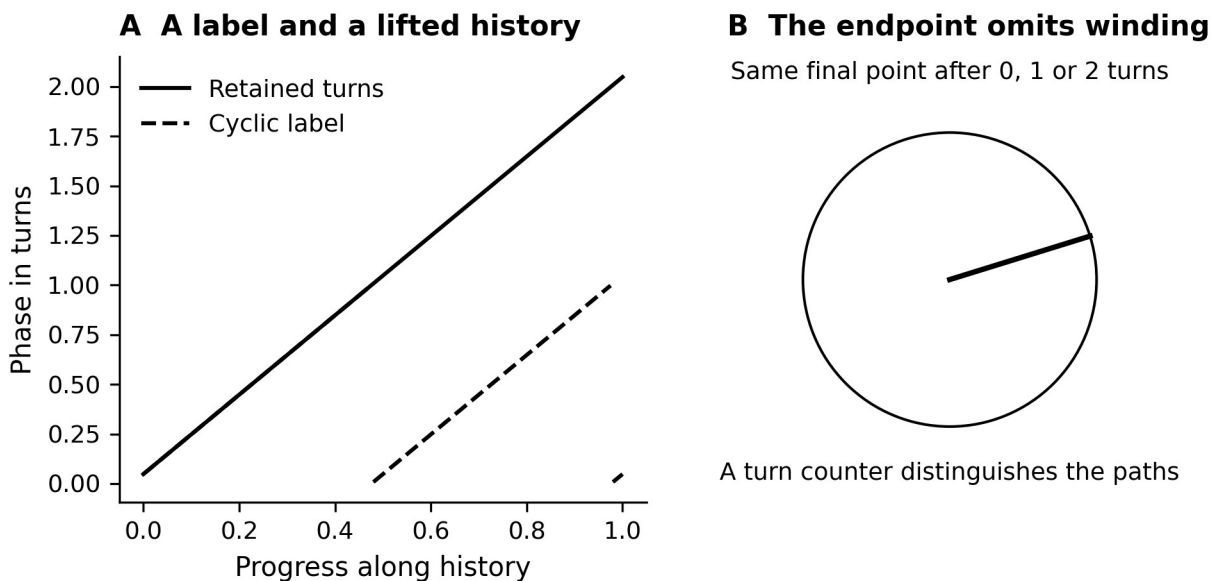


Figure 6.1 The dashed line starts again after each full turn. The solid line keeps the accumulated count. Different journeys can finish at the same phase. If the journey affects what happens next, something in the physical arrangement must retain information about it.

This matters whenever we talk about a burden building up over time. The arrangement must carry the accumulated change somehow. Counting turns on paper does not create a physical memory. A counter, or another lasting change, can preserve information that the final phase reading alone has lost.

Ordinary materials offer a comparison. Two pieces can look alike yet respond differently because they were treated differently earlier. Their pasts matter through differences in their condition now. We do not need to imagine the past acting as an extra force from outside the present.

This is the sense in which I use memory in PDT. An earlier interaction leaves something that survives and influences a later one. Our usual measurements may miss it. A phase reading alone may therefore be incomplete, while a fuller description includes the change that was retained.

Conventional physics can describe memory too. PDT gains nothing by invoking an unspecified past whenever a calculation becomes difficult. We have to say what carries the information, how it survives and how it affects the next encounter.

Returning to a position is therefore different from restoring the whole situation. The wheel may return while its counter advances. Resetting both removes more of the record, but perhaps the counter already sent its reading elsewhere. How much history remains depends on which parts of the arrangement we include.

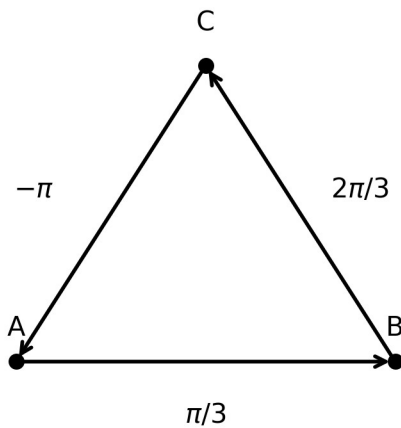
How we make a comparison

Consider three clocks in different places. To compare them, we need to know how their readings were brought together. Did signals travel between them? Was one clock carried to another? The journey and conditions along it can matter. The readings alone do not explain the comparison.

With phase labels, simple subtraction is straightforward. Compare A with B, B with C and C with A using one consistent convention. Each label appears once with a plus sign and once with a minus sign. The differences cancel around the loop, allowing for complete turns.

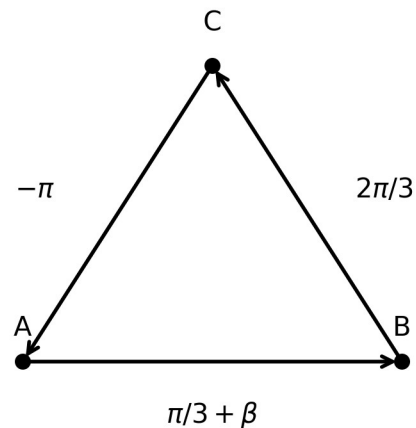
Now suppose the comparison involves carrying a reference along a physical route. Its journey can change it. Taking it round a loop may then reveal a difference that was not contained in the original labels. Figure 6.2 shows why we must separate endpoint labels from changes acquired along the route.

A Differences of vertex labels



Loop sum = 0

B Added transport information



Loop sum = β modulo 2π

Figure 6.2 On the left, subtracting the three endpoint labels around the triangle gives no leftover difference. On the right, transport adds a change called β along one link. The loop now has a remainder. That extra information comes from the transport rule, not from subtracting the original labels.

Mathematics uses the term connection for a rule specifying these comparisons along a route. You do not need the formal details here. The important distinction is between numbers attached to places and what happens while travelling between them. The second requires information beyond the first.

In PDT, making a comparison is part of the physical story. A signal travels or a reference is carried, and the surroundings can affect that process. We cannot assume that drawing a link between two points tells us everything about what occurs along it.

This will matter later when we discuss space and gravity. Phase labels give us a starting structure. A transport rule adds something further. I want the addition to be visible, so we do not mistake new physical information for something already supplied by the original labels.

What a clock adds

A clock compares changes. We count a regular process and use it to time something else. For that to work, the clock must keep enough information to distinguish one reading from another. In PDT, I propose that time is understood through the order and comparison of physical changes. Repeating cycles supply regularity, and lasting records let us distinguish successive events.

Clocks are part of this world too. Their journeys and the way we compare them matter, including the differences described by relativity. I am not picturing a master clock elsewhere that tells every process when to act. Each clock measures time through its own physical behaviour.

In this view, we assign a duration by comparing one change with another. The duration can be precise and have real consequences. Describing time through physical relationships does not make it imaginary. It identifies what we use to measure it and what PDT seeks to explain.

A useful clock needs more than a repeating motion. It must distinguish this return from the last and connect its readings with the events being timed. Phase helps describe the cycle. A count helps keep track of successive cycles. The instrument combines both.

A stopped clock makes the distinction clear. Its hands still show a reading, but they no longer move with the events around it. The display has retained a record while losing the process that made it useful for measuring passing time.

I propose a similar distinction at the foundations. Phase gives us recurrence. Events and their surviving effects let us compare what happened before and after. A single turning angle has not, by itself, explained the history in which those events occur.

A jump on paper or a physical event

A phase graph can jump when we reset the count after a full turn. That is like a clock moving from twelve back to one. The jump comes from our way of labelling the cycle. A phase snap must be a physical change in what can happen, rather than an effect of where we put zero.

Echo experiments show why appearances can mislead. In Hahn's spin echo experiment, a collective signal faded as spins got out of step. Suitable control made a signal return by reversing the relevant dephasing. [2] Some information had survived even when the signal was no longer visible.

Apparent loss was not enough to establish permanent loss.

PDT must respect that distinction. If the arrangement can recover the signal, the relevant information remains available somewhere in the process. A snap makes the stronger claim that

alternatives have been physically ruled out and one remaining possibility becomes actual. Losing sight of a signal is not sufficient evidence for that.

Φ therefore keeps a specific job. It describes phase, the cyclic part of the relationships. It does not automatically describe energy, every interaction or every memory. Nor is it the same as phase space, the name classical mechanics uses for the full collection of positions and momenta.

Return to the clock face. Its hands show a position in a cycle. A counter can distinguish successive turns. Comparing its reading with other events lets it measure an interval. We need these different pieces of information because one phase value cannot tell the whole story.

Bridge to Chapter 7

We can now ask how phase relationships connect with energy and mass. Chapter 7 starts with the familiar effort of pushing a loaded trolley. It asks what PDT would need to explain about matter for the phase picture to account for such an ordinary, measurable response.

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] Hahn, E. L. (1950). Spin Echoes. Physical Review, 80, 580–594.
<https://doi.org/10.1103/PhysRev.80.580>