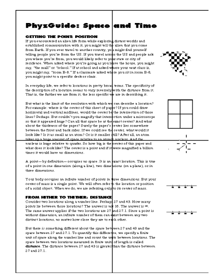
PhyzGuide: Space and Time

GETTING THE POINT: POSITION

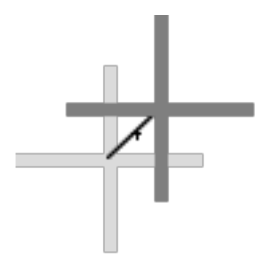
If you encountered an alien life form while exploring distant worlds and established communication with it, you might tell the alien that you come from Earth. If you ever travel to another country, you might find yourself telling people you're from the US. If you travel across the US and people ask you where you're from, you would likely refer to your state or city of residence. When asked where you're going as you leave the house, you might say, "the mall" or "school." If at school and asked where your next class is, you might say, "room B-8." If a classmate asked where you sit in room B-8, you might point to a specific desk or chair.

In everyday life, we refer to locations in pretty broad terms. The specificity of the description of a location seems to vary inversely with the distance from it. That is, the farther we are from it, the less specific we are in describing it.

But what is the limit of the resolution with which we can describe a location? For example: where is the center of this sheet of paper? If you could draw horizontal and vertical midlines, would the center be the intersection of those lines? Perhaps. But couldn't you magnify that intersection under a microscope so that it appeared huge? Can all that space be at the exact center? And what about the thickness of the paper? Surely the paper's center lies somewhere between the front and back sides. If we could see the center, what would it look like? Is it as small as an atom? Or is it smaller still? After all, an atom takes up a huge amount of space relative to an atomic nucleus. And the nucleus is huge relative to quarks. So how big is the center of this paper and what does it look like? The center is a point and if it were magnified a billion times it would have no dimensions.



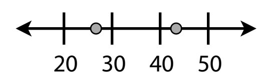
A point—by definition—occupies no space. It is an exact location. This is true of a point in one dimension (along a line), two dimensions (on a plane), or in three dimensions.



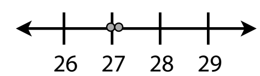
Your body occupies an infinite number of points in three dimensions. But your center of mass is a single point. We will often refer to the location or position of a solid object. When we do, we are referring only to its center of mass.

FROM HITHER TO THITHER: DISTANCE

Consider two locations along a number line. Perhaps 27 and 43. How many points lie between those locations? The answer is not 16. The answer is ∞. The same answer applies if the two locations are 27 and 27.1. Since a point is without dimension, an infinite number of them can exist between any two distinct locations, no matter how close they are to each other.



But there *is* something different about the space between 27 and 43 and the space between 27 and 27.1. To quantify this difference, we specify a finite unit of space along the number line and count the units between locations. The space between two locations measured in finite units of length is called **distance**. The distance between 27 and 43 is greater than the distance between 27 and 27.1.



THE CORRECT TIME... EXACTLY: CLOCK READING

We often refer to locations in time with the same broad descriptions we use in describing locations in space. The dinosaurs roamed the earth from 65 to 225 million years ago. Columbus came across the New World in 1492 CE. The current time can easily be specified in terms of the year, month, day, and time to the second.

But consider this, how long does a given time last? How long does 12 noon last each day? One minute? One second? Is it still 12 noon at 12:00:00.01 pm? Time advances in a smooth, continuous way. It does not advance in one second jumps. So any given clock reading does not last for *any* length of time. 12 noon comes and goes in an instant. (An instant is a point in time; it is without temporal dimension.)

FROM THEN TO NOW: INTERVAL

How many instants pass from 12:00 pm to 12:01 pm? And how many instants pass between 12:00 pm to 12:00:01 pm? Since instants occupy no time, the number of instants between any two clock readings is infinite.

Still, there is something greater about the period between 12:00 pm and 12:01 pm compared to the period between 12:00 pm and 12:00:01 pm. To quantify this difference, we specify a finite unit of time to count the units between clock readings. The period between two clock readings measured in finite units of time is called **interval**. The interval between 12:00 pm and 12:01 pm is greater than the interval between 12:00 pm and 12:00:01 pm.

How long does a clock reading last?

THE SPACE-TIME CONNECTION

An object in motion will be in different places at different times. That is, we can specify a moving object's position at one clock reading, wait, then specify the object's position at a second clock reading.

Suppose a young inchworm were crawling along an old yardstick which happened to be near a wristwatch. We notice that at 10:43:29, the inchworm's head is aligned with the 9.25-inch mark. And at 10:43:56, the inchworm's head is aligned with the 24.75-inch mark.

Distance: We can determine the distance traveled by the inchworm by calculating the difference between its final position and initial position. We use the symbols x_1 for initial position, x_2 for final position, and Δx for distance traveled (change in position).

$$\Delta x = x_2 - x_1 = 24.75 \text{ in} - 9.25 \text{ in} = 15.50 \text{ in}$$

Interval: We can determine the interval (Δt) during which the inchworm traveled by calculating the difference between its final clock reading (t_2) and initial clock reading (t_1).

$$\Delta t = t_2 - t_1 = 10{:}43{:}56 - 10{:}43{:}29 = 27 \text{ s}$$

We are now able to know something new about our inchworm: its speed! Speed is the rate at which position changes. We find it by comparing the distance to the interval by means of a quotient. That is, speed = distance/interval. We use the symbol v for speed. (It seems we should use s for speed, but we don't. We use v.)

$$v = \Delta x/\Delta t = 15.50 \text{ in} / 27 \text{ s} = 0.57 \text{ in/s}$$

The inchworm traveled with a speed of 0.57 inches per second while we watched it.

Speed is the space-time connection!