SPH3U: Defining Velocity

Recorder: _____
Manager: _____
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R 1 2 3 4

To help us describe motion carefully we have been measuring positions at different moments in time. Now we will put this together and come up with an important new physics idea.

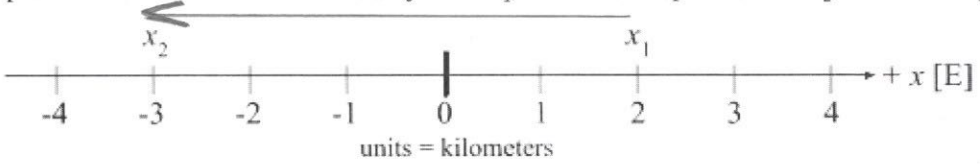
A: Events

When we do physics (that is, study the world around us) we try to keep track of things when interesting events happen. For example when a starting gun is fired, or an athlete crosses a finish line. These are two examples of **events**.

An *event* is something that happens at a certain place and at a certain time. We can locate an event by describing *where* and *when* that event happens. At our level of physics, we will use one quantity, the position (x) to describe where something happens and one quantity time (t) to describe when. Often, there is more than one event that we are interested in so we label the position and time values with a subscript number (x_2 or t_3).

B: Changes in Position - Displacement

Our trusty friend Emmy is using a smartphone app that records the events during her trip to school. Event 1 is at 8:23 when she leaves her home and event 2 is at 8:47 when she arrives at school. We can track her motion along a straight line that we will call the x-axis, we can note the positions of the two events with the symbols x_1, for the initial position and x_2, for the final position.



1. **Interpret.** What is the position of x_1 and x_2 relative to the origin? Write your answer two ways: mathematically, using a sign convention, and in words describing the direction.

   math: x_1 = 2 km x_2 = − 3 km

   words: x_1: 2 km East of the origin x_2: 3 km west of origin

2. **Reason and Interpret.** What direction did Emmy move in? Use the sign convention and words to describe the direction. How far is the final position from the starting position? Use a ruler and draw an arrow (just above the axis) from the position x_1 to x_2 to represent this change.

   − 5 km 5 km west

The change in position of an object is called its *displacement* (Δx) and is found by subtracting the initial position from the final position: $\Delta x = x_f - x_i$. The Greek letter Δ("delta") means "change in" and always describes a final value minus an initial value. The displacement can be represented graphically by an arrow, called the *displacement vector*, pointing from the initial to the final position. Any quantity in physics that includes a direction is a *vector*.

3. **Reason.** Is position a vector quantity? Explain. (Hint: to describe Emmy's position, do we need to mention a direction?)

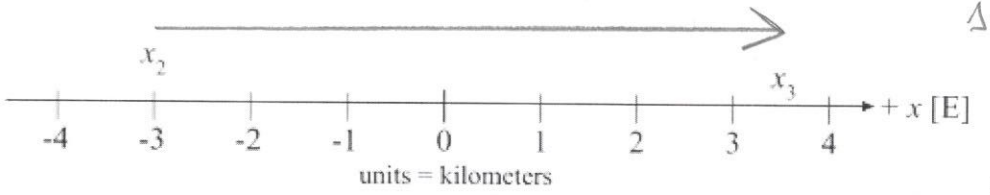
   Yes - we need to know how far she is from the origin, but also which side of the origin.

4. **Calculate and Interpret.** Calculate the displacement for Emmy's trip. What is the interpretation of the number part of the result of your calculation? What is the interpretation of the sign of the result?

   $\Delta x = x_f - x_i$
   $= x_2 - x_1$
   $= -3 - 2$
   $\Delta x = -5$ km

   $\Delta x = -5$ km
   walked west. walked 5 km

5. **Calculate and Represent.** Emmy continues her trip. Calculate the displacement for the following example. Draw a displacement vector that represents the change in position.



$\Delta x = x_3 - x_2$

$= 3.5 - (-3)$

$= 3.5 + 3$

$\Delta x = 6.5$ km

C: Changes in Position and Time

In a previous investigation, we have compared the position of the physics buggy with the amount of time taken. These two quantities can create an important ratio.

When the velocity is constant (constant speed and direction), the *velocity* of an object is the ratio of the displacement between a pair of events and the time interval. In equal intervals of time, the object is displaced by equal amounts.

1. **Reason.** Write an algebraic equation for the velocity in terms of v, x, Δx, t and Δt. (Note: some of these quantities may not be necessary.)

$$v = \frac{\Delta x}{\Delta t}$$

2. **Calculate.** Consider the example with Emmy between events 1 and 2. What was her displacement? What was the interval of time? Now find her velocity. Provide an interpretation for the result (don't forget the sign!).

$\Delta x = -5$ km

$\Delta t = 24$ mins

$v = \frac{-5 \text{ km}}{24 \text{ min}} = -0.208\overline{3}$

$\doteq -0.2$ km/min

In physics, there is an important distinction between *velocity* and *speed*. Velocity includes a direction while speed does not. There is also a similar distinction between *displacement* and *distance*. Displacement includes a direction while distance does not.

D: Velocity and Speed

Your last challenge is to find the velocity of Penny from her position-time graph. The positive direction is east. Event 1 is the start of the race, event 2 is when she turns around, and event 3 is when she touches the wall to finish.

1. **Calculate.** What is Penny's displacement during each half of the race? Use the appropriate symbols!

Interval 1-2

$\Delta x = 50$ m

Interval 2-3

$\Delta x = -50$ m

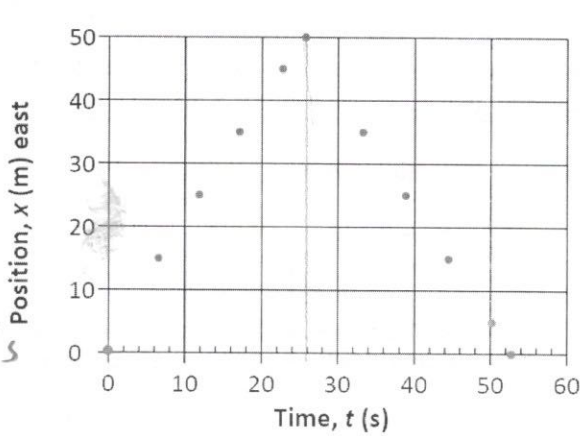
2. **Calculate.** Find her velocity during each half of her race.

$\Delta t = 26.0$

$v = \frac{\Delta x}{\Delta t} = \frac{50}{26} = 1.92$ m/s

$\Delta t = 52.5 - 26 = 26.5$

$v = \frac{\Delta x}{\Delta t} = \frac{-50}{26.5} = -1.89$ m/s



3. **Calculate.** Find her speed during each half of the race.

1st half: 1.92 m/s

2nd half: 1.89 m/s

Homework: Representations of Motion

Each column in the chart below shows five representations of one motion. The small numbers represent the events. Remember that the motion diagram is a dot pattern. If the object remains at rest, the two events will be located at the same point. If it changes direction, shift the dots just above or below the axis. See the example below. Remember that in the motion diagrams the origin is marked by a small vertical line. The positive *x*-direction is east. ← − → +

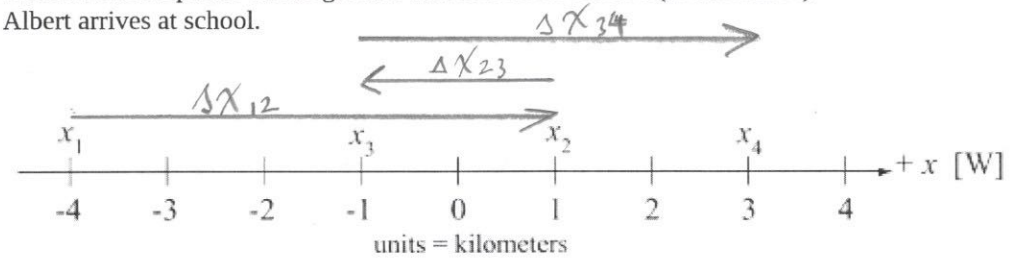
Situation 1	Situation 2	Situation 3	Situation 4
Description 1-2: moves slowly east at constant velocity 2-3: at rest 3-4: moves quickly west at constant velocity	**Description** 1-2 quickly west at constant v 2-3 slowly east at constant v 3-4 at rest	**Description** 1-2 walk slowly west at constant v 2-3 at rest 3-4 walk quickly west at constant v	**Description** 1-2: It starts at the origin and remains at rest for a while. 2-3: It move quickly in the positive direction (east) with a constant velocity 3-4: It moves slowly in the negative direction (west) with a constant velocity.
Position Graph	**Position Graph**	**Position Graph**	**Position Graph**
Velocity Graph	**Velocity Graph**	**Velocity Graph**	**Velocity Graph**
Motion Diagram	**Motion Diagram**	**Motion Diagram**	**Motion Diagram**
Velocity Vectors (velocity during each interval) 1-2: → 2-3: • 3-4: ←	**Velocity Vectors** (velocity during each interval) 1-2: ← 2-3: → 3-4: •	**Velocity Vectors** (velocity during each interval) 1-2: ← 2-3: • 3-4: ←	**Velocity Vectors** (velocity during each interval) 1-2: • 2-3: → 3-4: ←

SPH3U Homework: Defining Velocity Name:

A: Where's My Phone?

Albert walks along Glebe Ave. on his way to school. Four important events take place. The $+x$ direction is west.

Event 1: At 8:15 Albert leaves his home.
Event 2: At 8:28 Albert realizes he has dropped his phone somewhere along the way. He immediately turns around.
Event 3: At 8:37 Albert finds his phone on the ground with its screen cracked (no insurance).
Event 4: At 8:41 Albert arrives at school.



1. **Represent**. Draw a vector arrow that represents the displacement for each interval of Albert's trip and label them Δx_{12}, Δx_{23}, Δx_{34}.

2. **Calculate.** Complete the chart below to describe the details of his motion in each interval of his trip.

Interval	1-2	2-3	3-4
Displacement expression	$\Delta x_{12} = x_2 - x_1$	$\Delta x_{23} = x_3 - x_2$	$\Delta x_{34} = x_4 - x_3$
Displacement result	$\Delta x_{12} = 1-(-4) = 5$ km	$-1-1 = -2$ km	$3-(-1) = 4$ km
Interpret direction	west	east	west
Time interval expression	$\Delta t_{12} = t_2 - t_1$	$\Delta t_{23} = t_3 - t_2$	$\Delta t_{34} = t_4 - t_3$
Time interval result	$28-15 = 13$ mins	$37-28 = 9$ mins	$41-37 = 4$ mins
Velocity	$V = \frac{\Delta x}{\Delta t} = \frac{5}{13} = 0.4$ km/min	$\frac{-2}{9} = -0.2$ km/min	$\frac{4}{4} = 1$ km/min

3. **Reason.** Why do you think the size of his velocity is so different in each interval of his trip? Explain.

1-2: walking @ normal pace
2-3: slow because looking for phone
3-4: going quickly because late (and respects school timelines!)

4. **Explain.** Why is the sign of the velocity different in each interval of his trip?

1-2 and 3-4 → going west towards school
2-3 → going east back for phone

5. **Calculate.** What is his displacement for the **entire trip**? (Hint: which events are the initial and final events for his whole trip?)

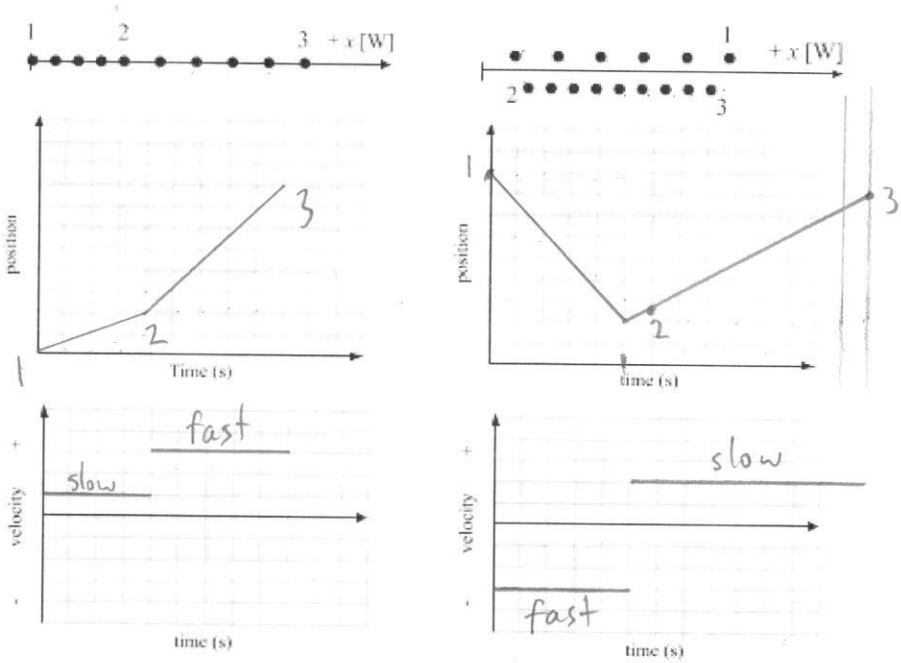
$\Delta x_{14} = x_4 - x_1 = 3-(-4) = 7$ km

6. **Interpret**. Explain in words what the result of your previous calculation **means**.

Difference in position between start and end was 7 km (west).

SPH3U: Velocity-Time Graph Homework Name:

1. Two motion diagrams track the movement of a student walking in a straight line.

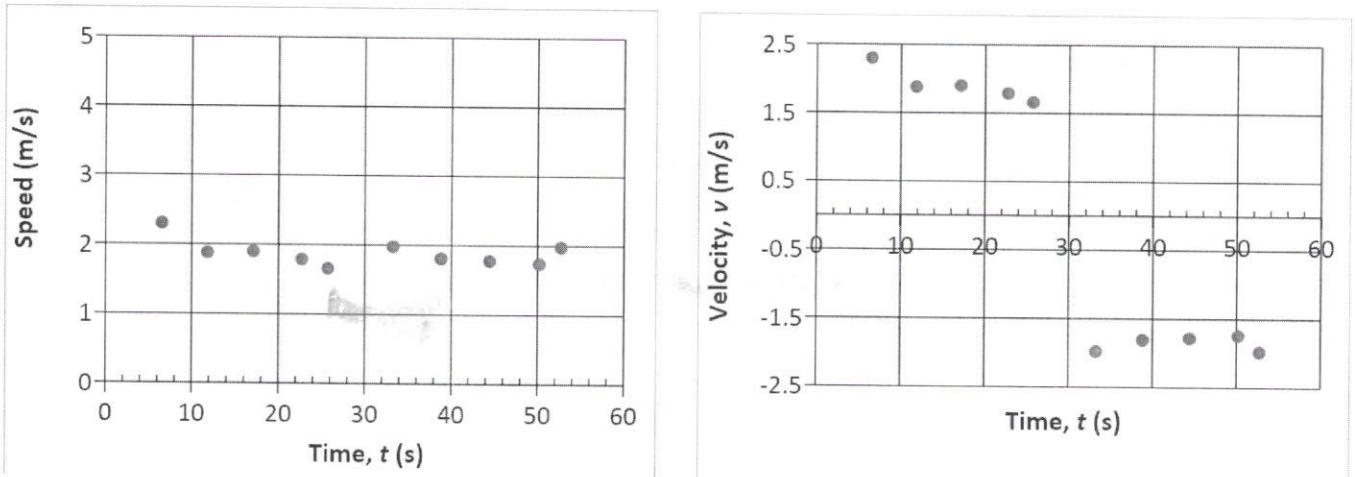


(a) **Represent.** Sketch a position-time graph for each motion diagram. The scale along the position axis is not important. Use one grid line = 1 second for the time axis.

(b) **Represent.** Sketch a velocity-time graph for each motion diagram. The scale along the velocity axis is not important.

(c) **Interpret.** Label each section of each representation as "fast" or "slow". Is each set consistent?

2. The two graphs below show data from Penny Oleksiak's 100-m gold-medal race.



(a) **Read.** What is Penny's speed at 22 s? What is her velocity at 22 s?

1.8 m/s 1.8 m/s [away from start]

(b) **Read.** What is Penny's speed at 33 s? What is her velocity at 33 s?

2.0 m/s -2.0 m/s or 2.0 m/s [towards start]

(c) **Interpret.** Is Penny's speed constant? What about her velocity? What is your evidence?

some fluctuations, but mostly constant (1.9 m/s) because all dots are roughly at same height

not constant: first half velocity is positive (away), second half is negative (towards start)