

Which of the following could be an equation for energy?

A) mv^2

E has units of $J = N m = kg m^2/s^2$
 $= [M] [L]^2 / [T]^2$

B) mg

C) Ft

mv^2 has units of $kg (m/s)^2 = kg m^2/s^2$

D) p^2

E) F^2

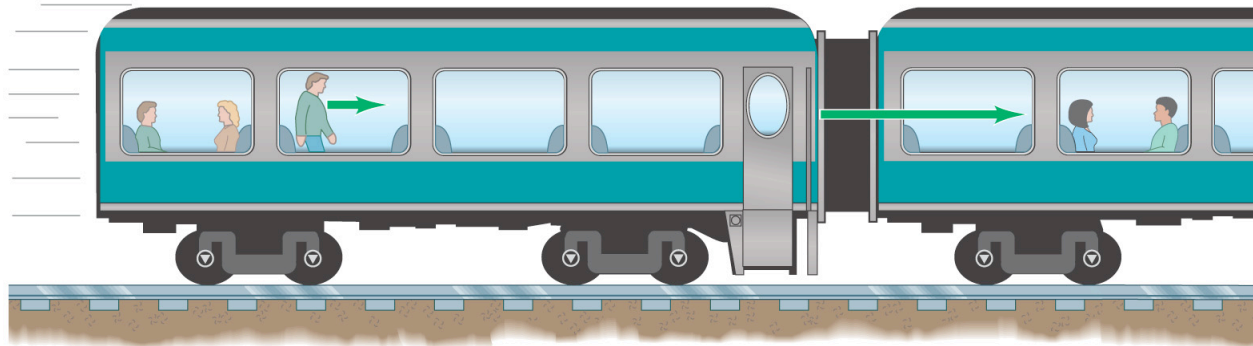
Recall: t – time; v – velocity; p – momentum; F – force;
g – acceleration; m - mass

Ch. 2 – “Kinematics in 1D”

Kinematics – study of motion irrespective of considering what caused the motion.

Dynamics – study of motion considering its cause (forces)

A description of motion (position, distance, or speed) requires specifying a “**Reference Frame**”.



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Ch. 2 – “Kinematics in 1D”

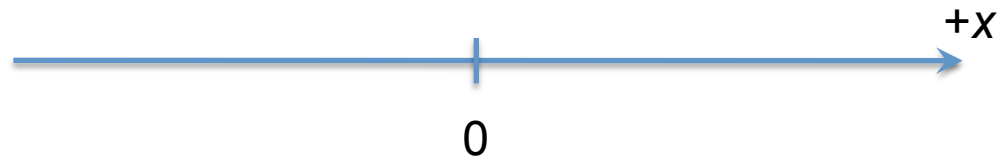
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1D:

- origin
- positive direction



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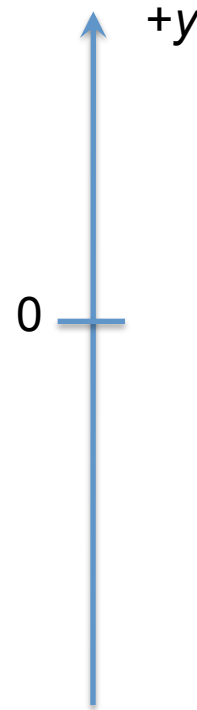
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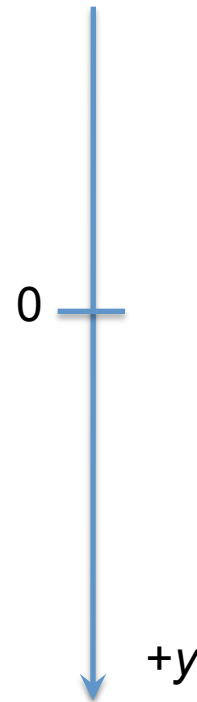
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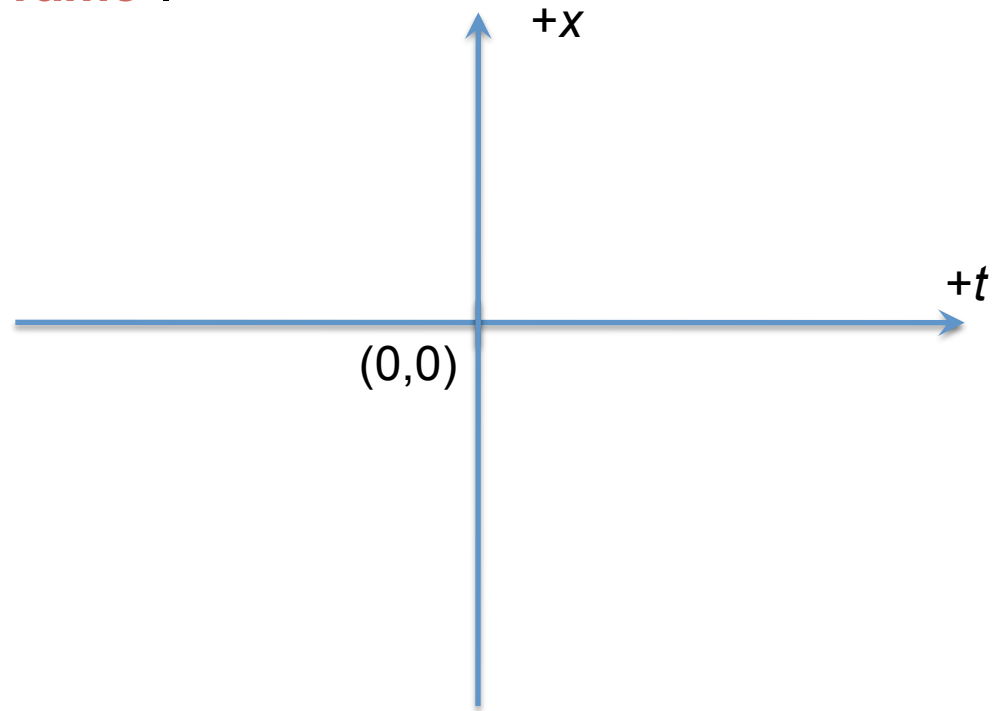
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Ch. 2 – “Kinematics in 1D”

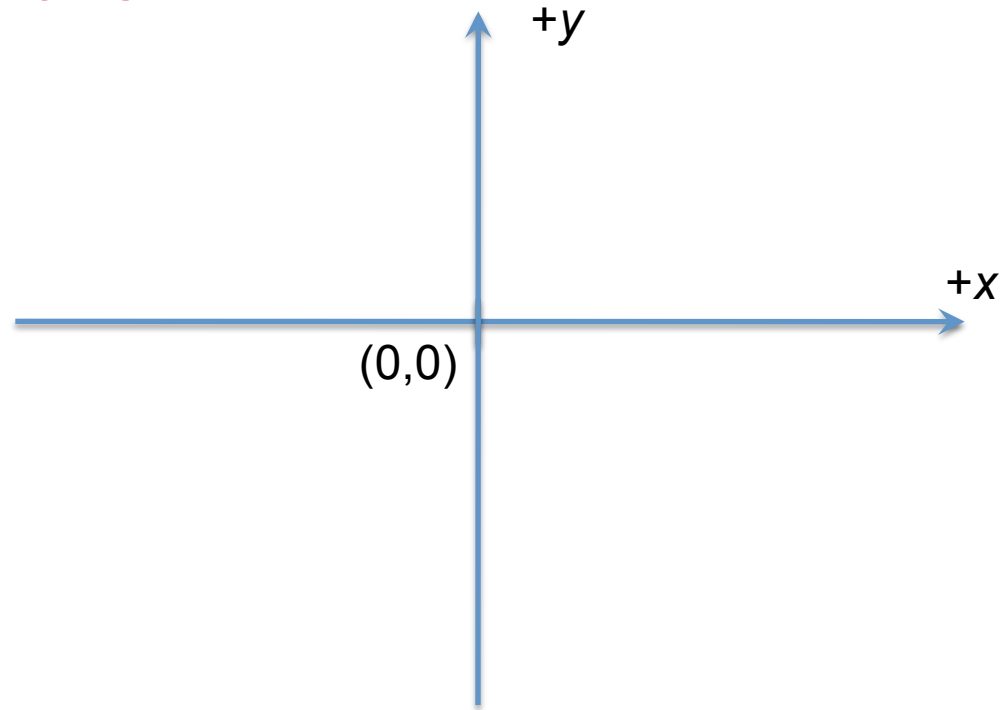
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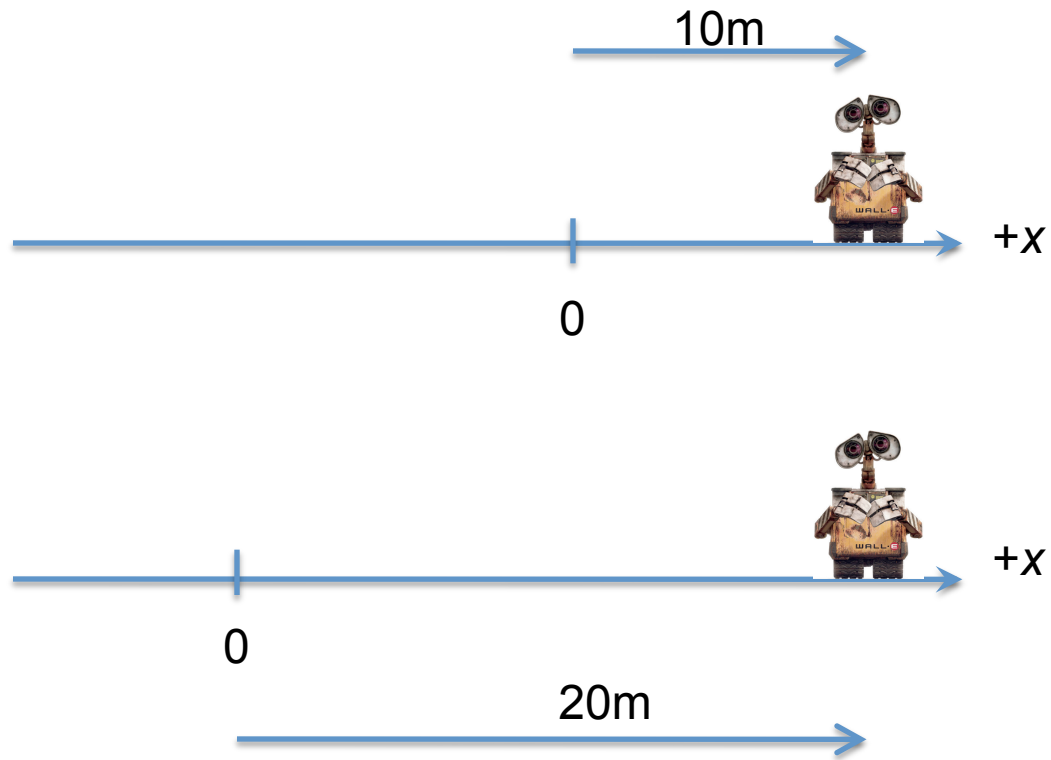
2D: (Ch.3)

- origin
- x-y grid



For example:

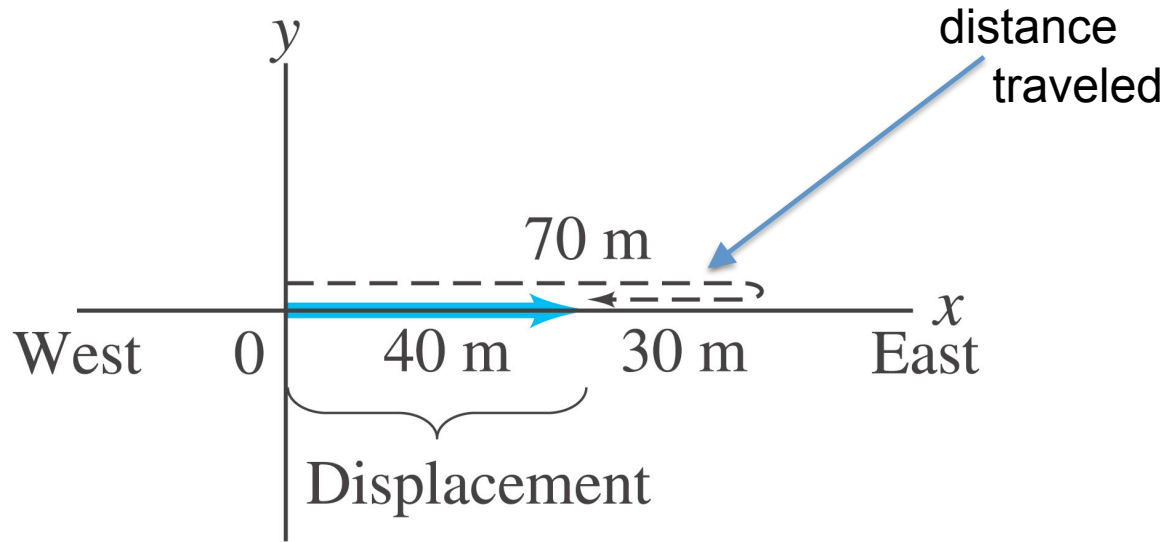
Position depends on the Reference Frame:



“Displacement” and “Distance Traveled” are another story

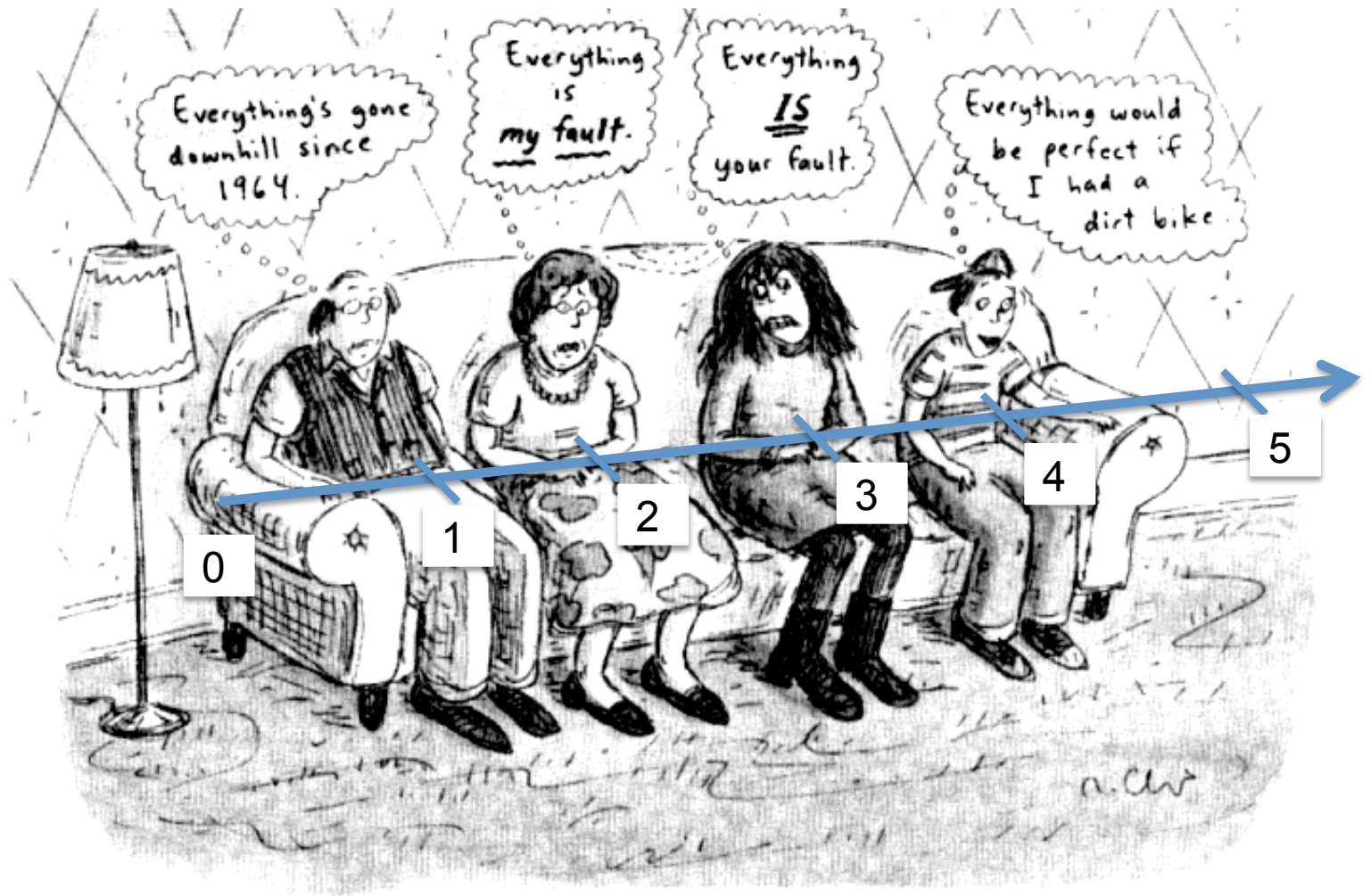
Displacement is the distance between a starting and ending point.

In contrast with **distance traveled** – which is measured along the actual path taken.



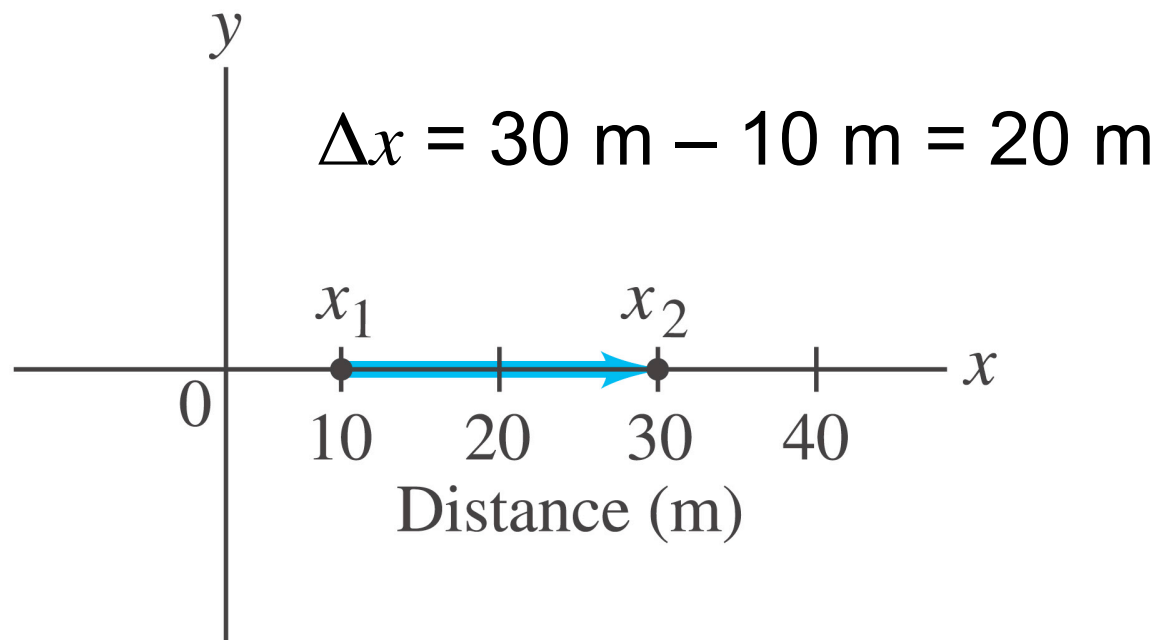
What's the distance between the father and son?

- A) 1 unit
- B) 2 units
- C) 3 units
- D) 4 units
- E) 5 units



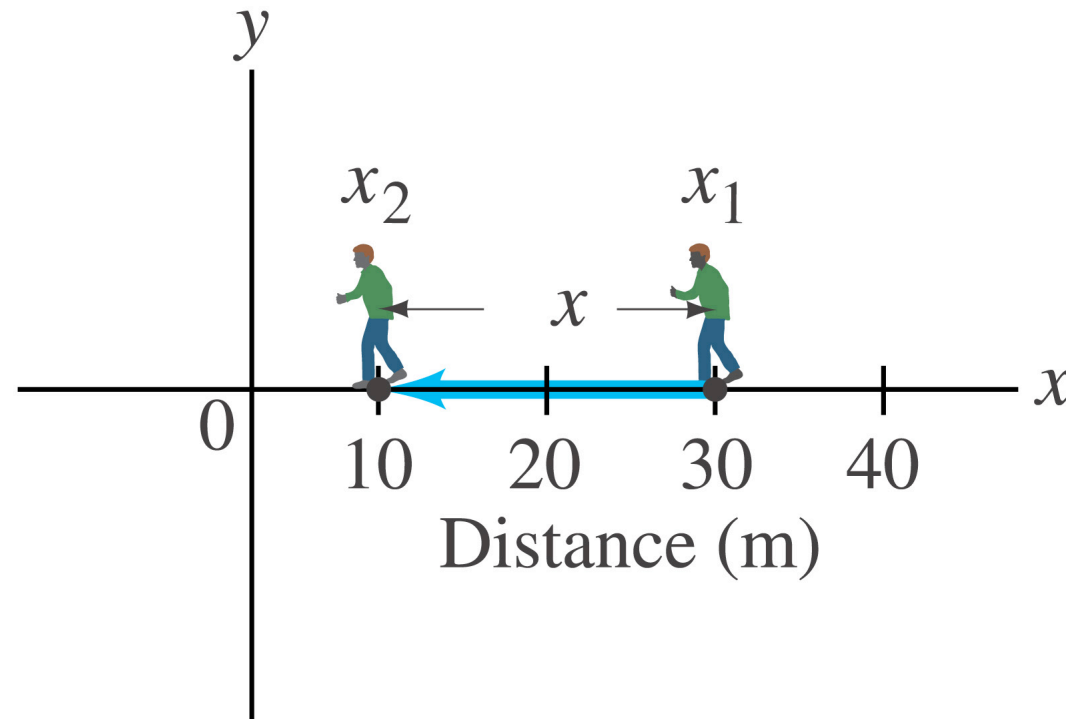
Mathematical representation of “Displacement”

$$\Delta x = x_2 - x_1$$



What is the **displacement** of the walking gentleman?

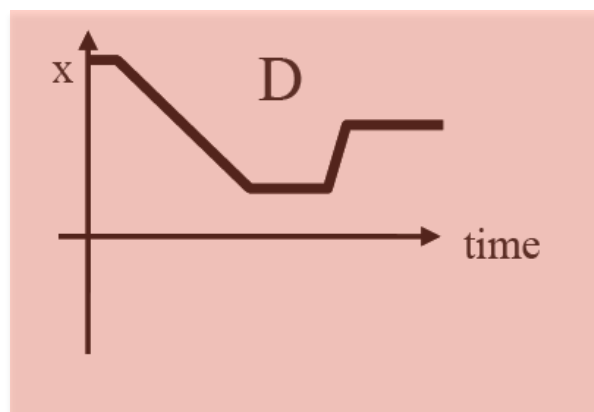
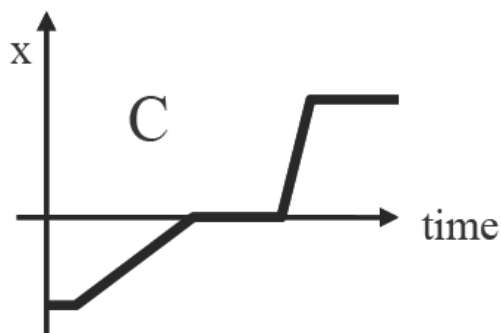
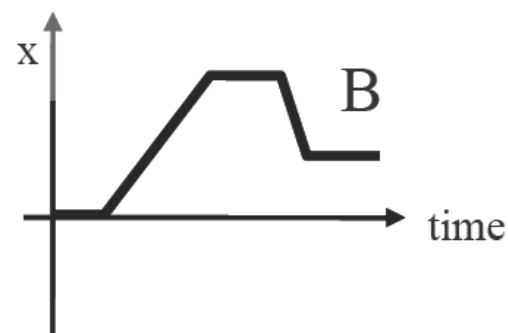
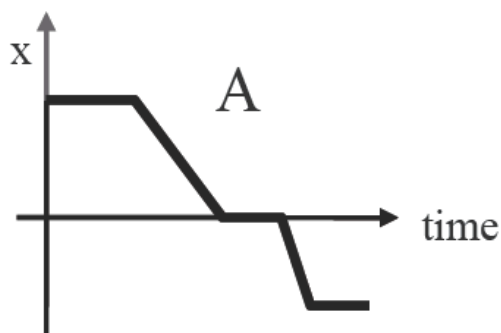
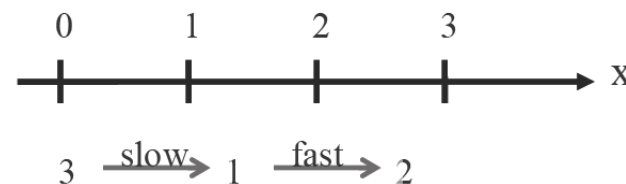
- A) 10 m
- B) 30 m
- C) 20 m
- D) -20 m**
- E) -10m



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$$\Delta x = x_2 - x_1 = 10 \text{ m} - 30 \text{ m} = -20 \text{ m}$$

A person initially at rest at Point 3 stays there for a little while and then strolls along the x-axis to Point 1, stays there for a moment and then runs to Point 2 and remains there. Which graph depicts this motion best?



Note: we'll go on to understand how the slope of a position vs. time graph reflects velocity.

E: None of these!

Moving on to: Speed and Velocity

Speed = how far an object travels in a given time interval

$$\text{average speed} = \frac{\text{distance traveled}}{\text{time elapsed}}$$

\bar{s}

$$\begin{array}{l} + \\ - \\ + \end{array} \geq 0$$

Velocity includes directional information:

$$\text{average velocity} = \frac{\text{displacement}}{\text{time elapsed}}$$

\bar{v}

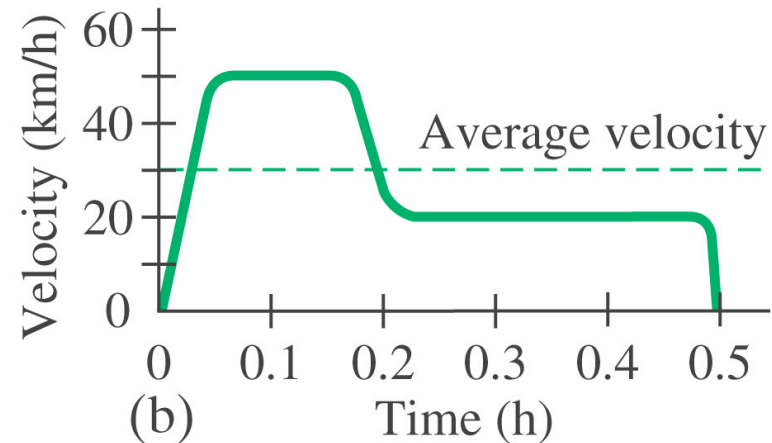
$$\begin{array}{l} \frac{\Delta x}{\Delta t} \\ > \\ = \\ < \end{array} 0$$

Velocity = speed + direction

Instantaneous speed or velocity changes with time:

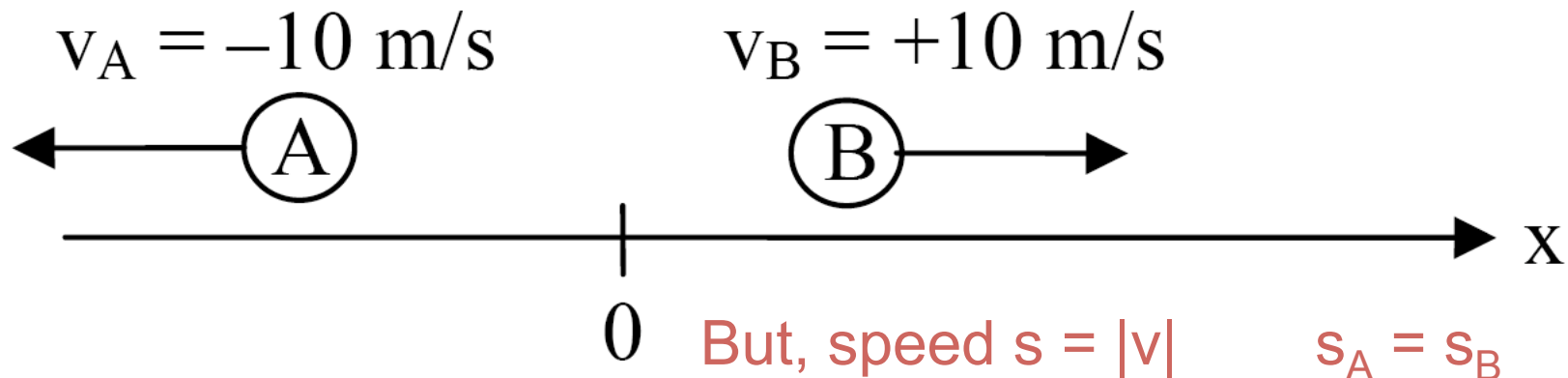
The **instantaneous velocity** is the average velocity, in the limit as the time interval becomes infinitesimally short.

$$v = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t}$$



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Objects can have a positive or negative average or instantaneous velocity:



What does the odometer in your car attempt to measure?

- A) Displacement.
- B) Distance traveled.
- C) Position.
- D) Instantaneous velocity.
- E) Average velocity.

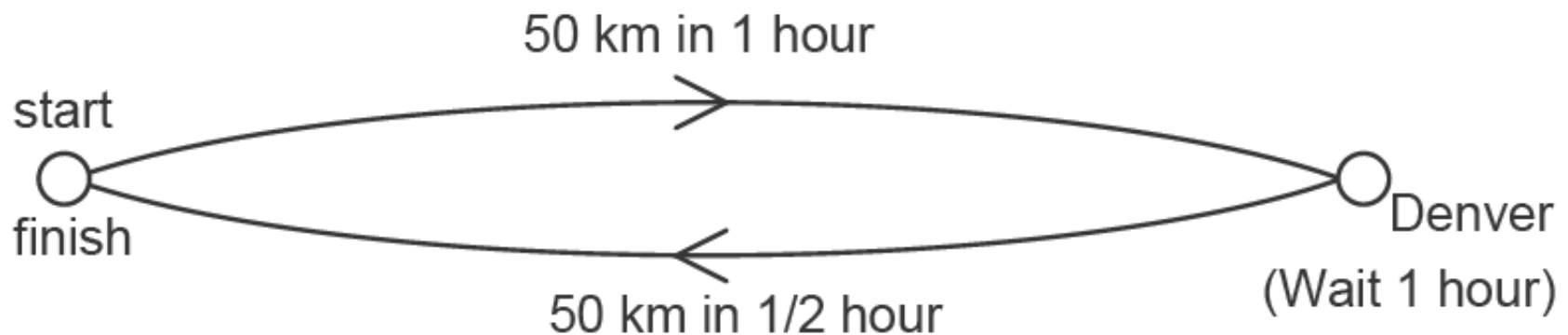
What does the GPS in your car attempt to measure?

- A) Displacement.
- B) Distance traveled.
- C) Position.
- D) Instantaneous velocity.
- E) Average velocity.

What does the speedometer in your car attempt to measure?

- A) Average speed.
- B) Instantaneous speed.**
- C) Average velocity.
- D) Instantaneous velocity.
- E) The time rate of change of acceleration.

A person starts in Boulder, drives to Denver 50 km away in 1 hr, stays in Denver for an hour, then speeds back to Boulder in 30 minutes.

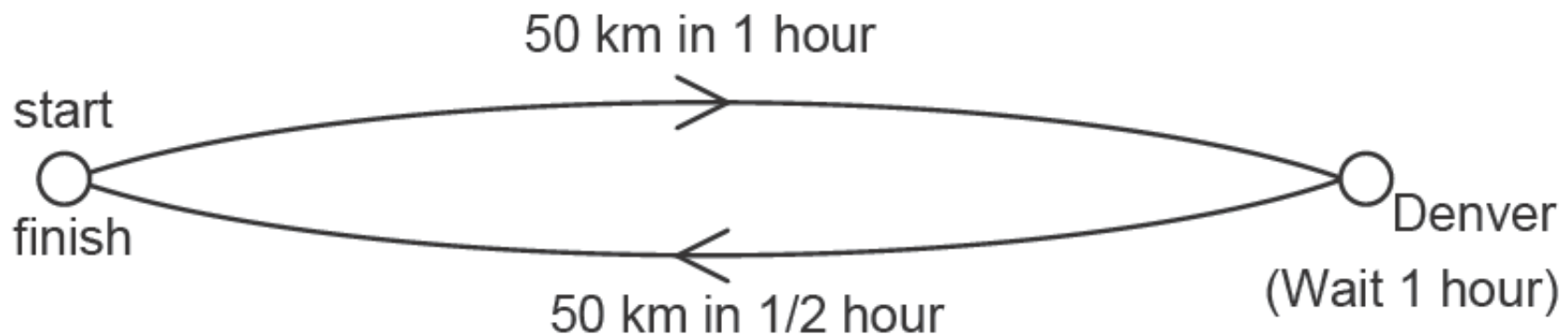


What's the average **speed** of this round trip?

- A) Zero B) -67 km/hr C) 40 km/hr D) 67 km/hr E) None of these.

$$\begin{aligned}\text{Average speed} &= \text{distance traveled/elapsed time} \\ &= 100 \text{ km}/2.5 \text{ hr} = 40 \text{ km/hr}\end{aligned}$$

A person starts in Boulder, drives to Denver 50 km away in 1 hr, stays in Denver for an hour, then speeds back to Boulder in 30 minutes.



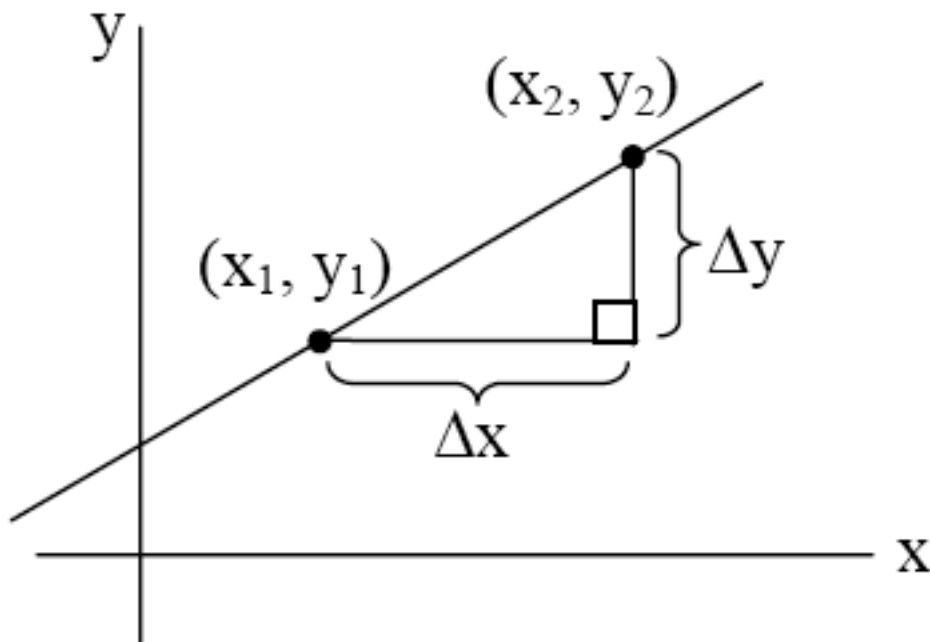
What's the average **velocity** of this round trip?

- A) Zero B) 67 km/hr C) 40 km/hr D) 75 km/hr E) None of these.

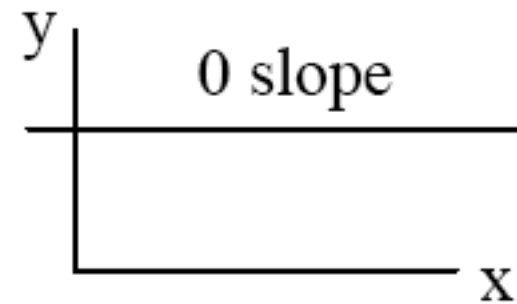
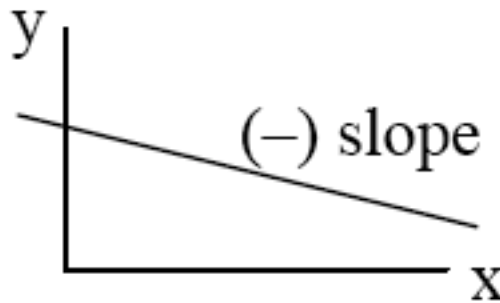
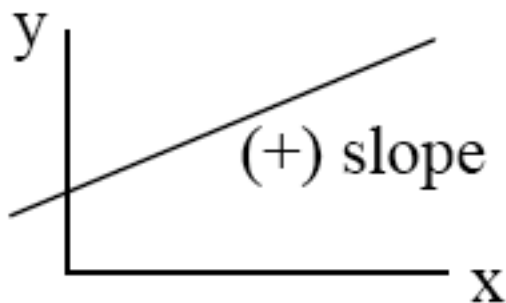
$$\begin{aligned}\text{Average velocity} &= \text{displacement/elapsed time} \\ &= 0 \text{ km}/2.5 \text{ hr} = 0 \text{ km/hr}\end{aligned}$$

Graphs of position versus time & relation to velocity

Review: Slope of a line

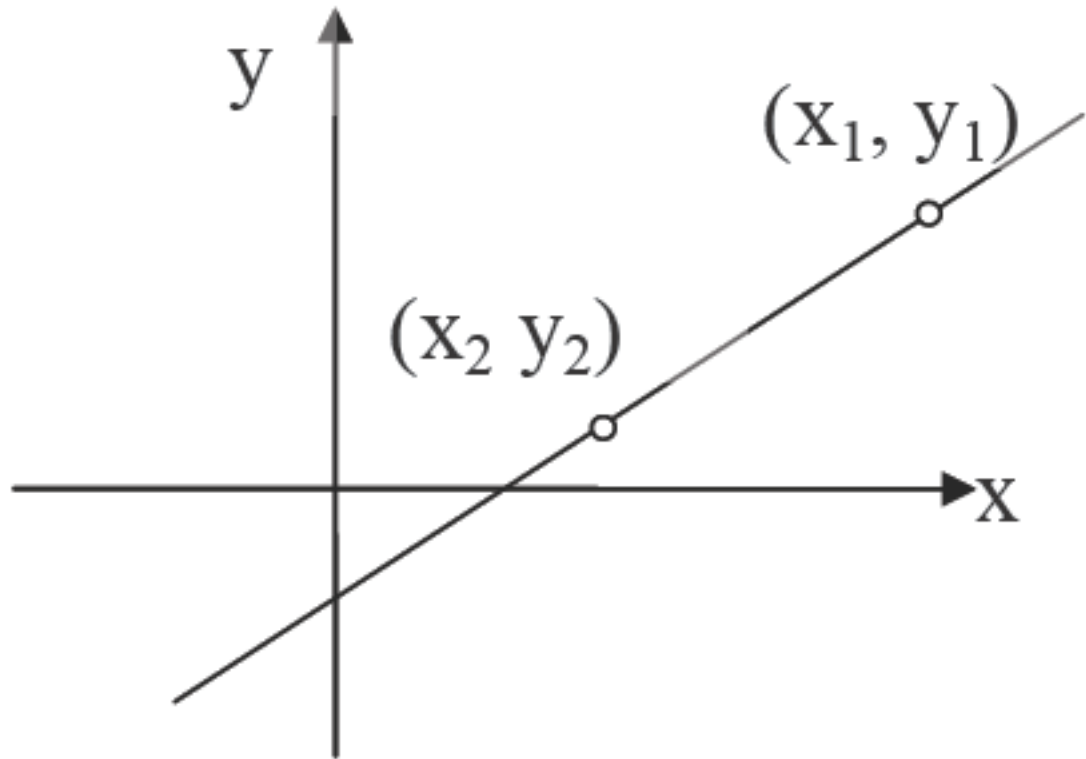


$$\begin{aligned}\text{slope} &= \frac{\text{rise}}{\text{run}} = \frac{\Delta y}{\Delta x} \\ &= \frac{y_2 - y_1}{x_2 - x_1}\end{aligned}$$



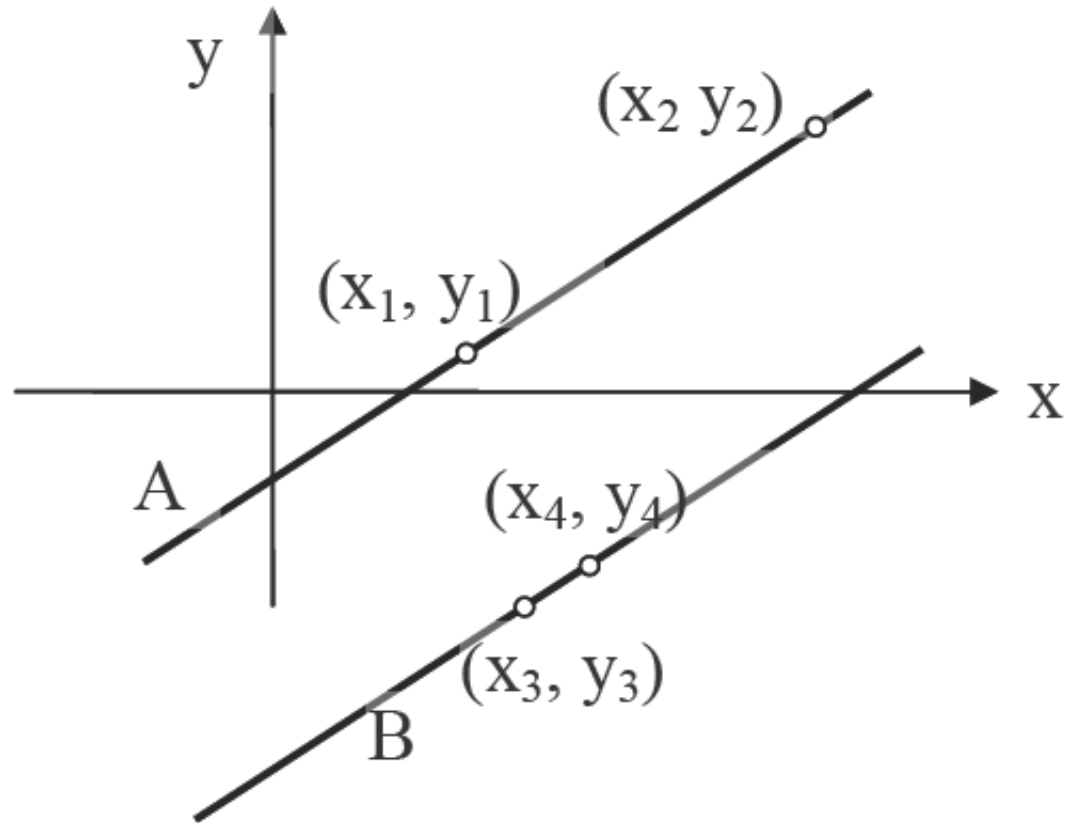
What is the slope of this line?

- A) Positive
- B) Negative
- C) Zero



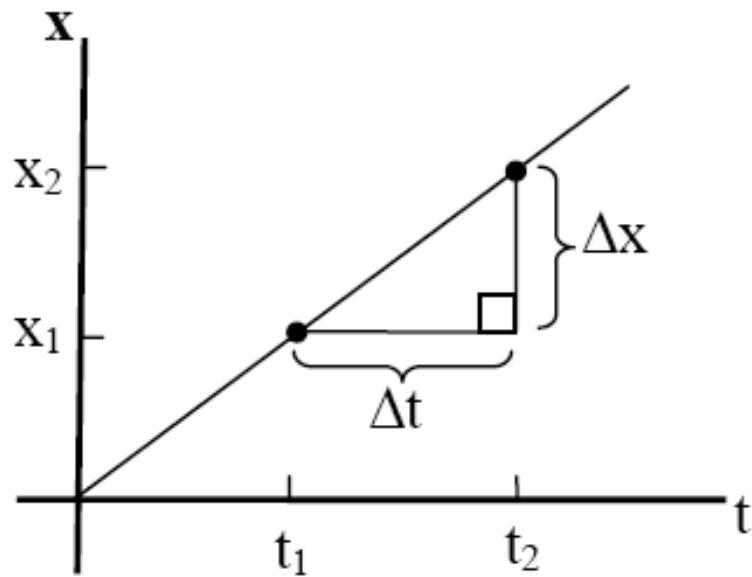
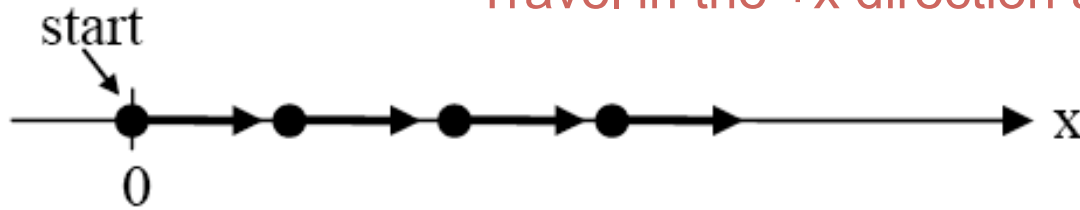
Which line (A or B) has larger slope?

- A) Line A
- B) Line B
- C) Lines A and B have the same slope.
- D) Impossible to tell



Graphs of position versus time & relation to velocity

Travel in the +x direction at a constant velocity v:



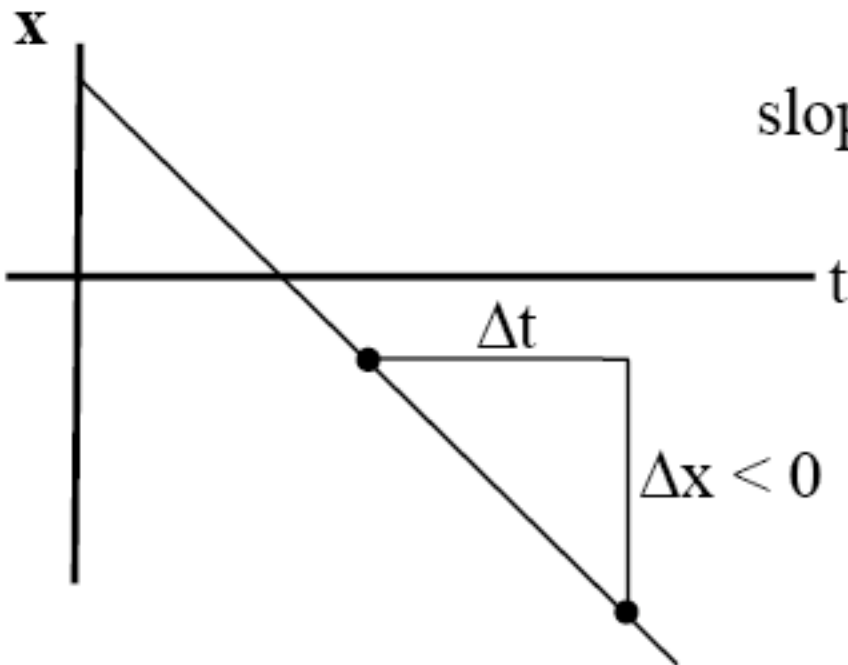
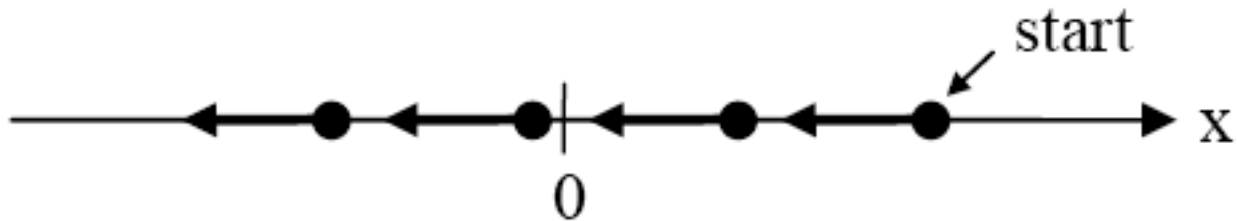
$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\cancel{\Delta y}}{\cancel{\Delta x}} = \frac{\Delta x}{\Delta t} = v$$

y-axis is x, x-axis is t .

Note: constant v \rightarrow slope constant \rightarrow graph of x versus t is a straight line

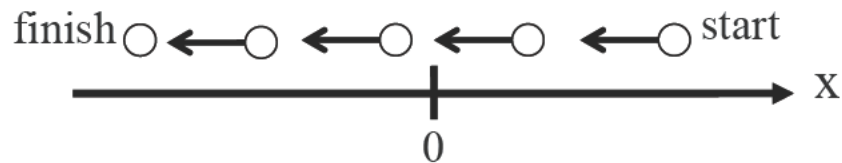
Graphs of position versus time & relation to velocity

Travel in the -x direction at a constant velocity v:

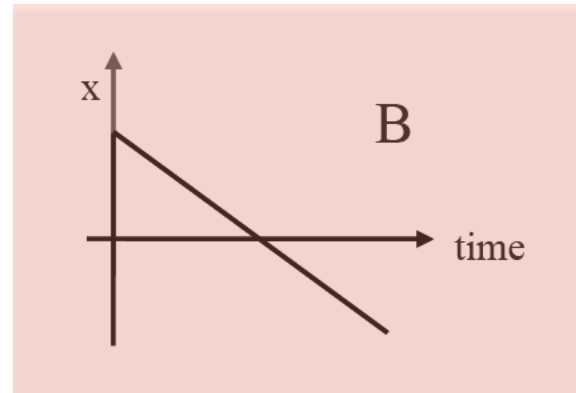
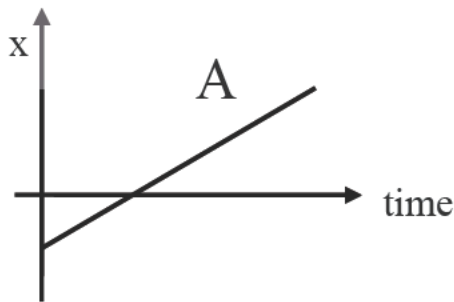


$$\text{slope} = v = \frac{\Delta x}{\Delta t} < 0$$

An object starts at $x = +5$ and moves left along the x-axis at a constant speed:



Which graph represents this motion?

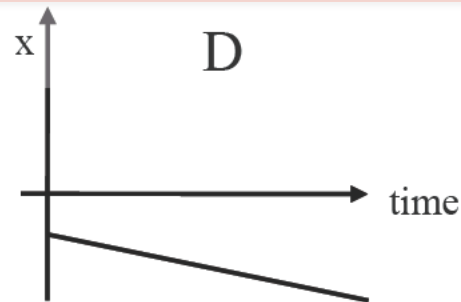
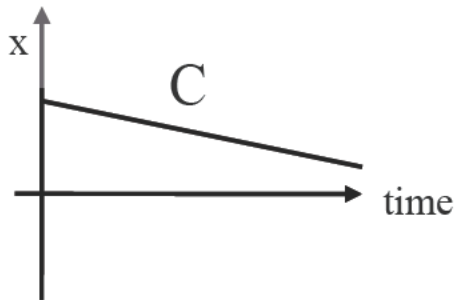


Note:

Initial position
 $x(0) = 5$

Slope negative.

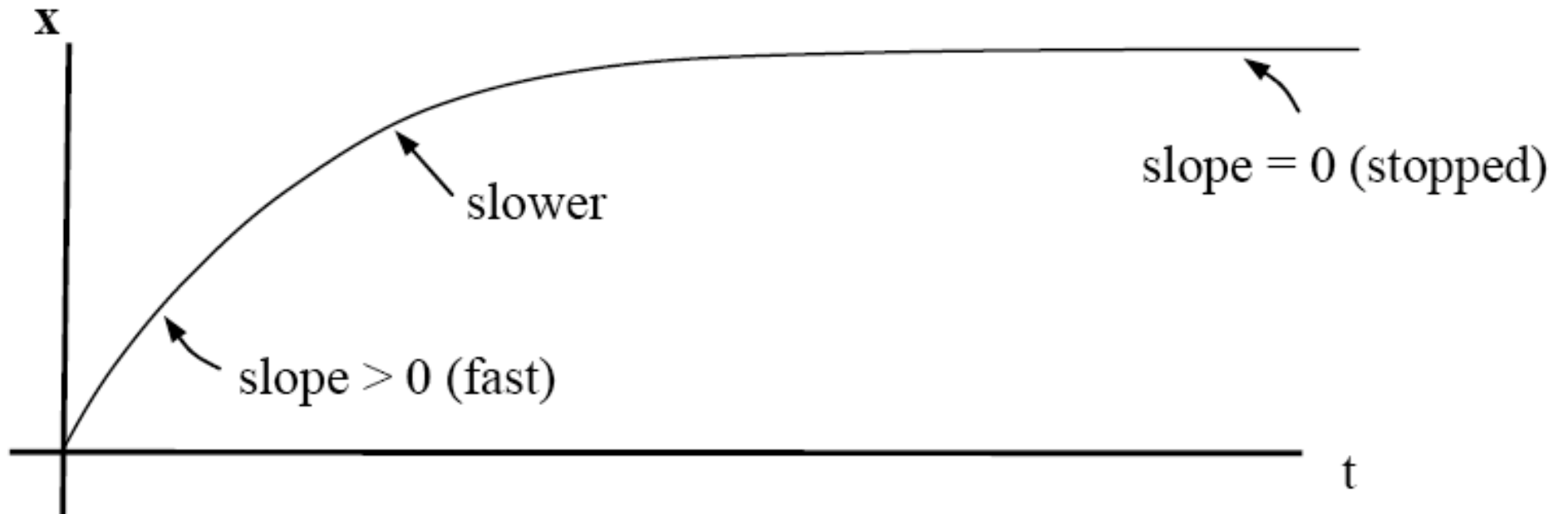
y-intercept positive.



E: None of these!

Graphs of position versus time & relation to velocity

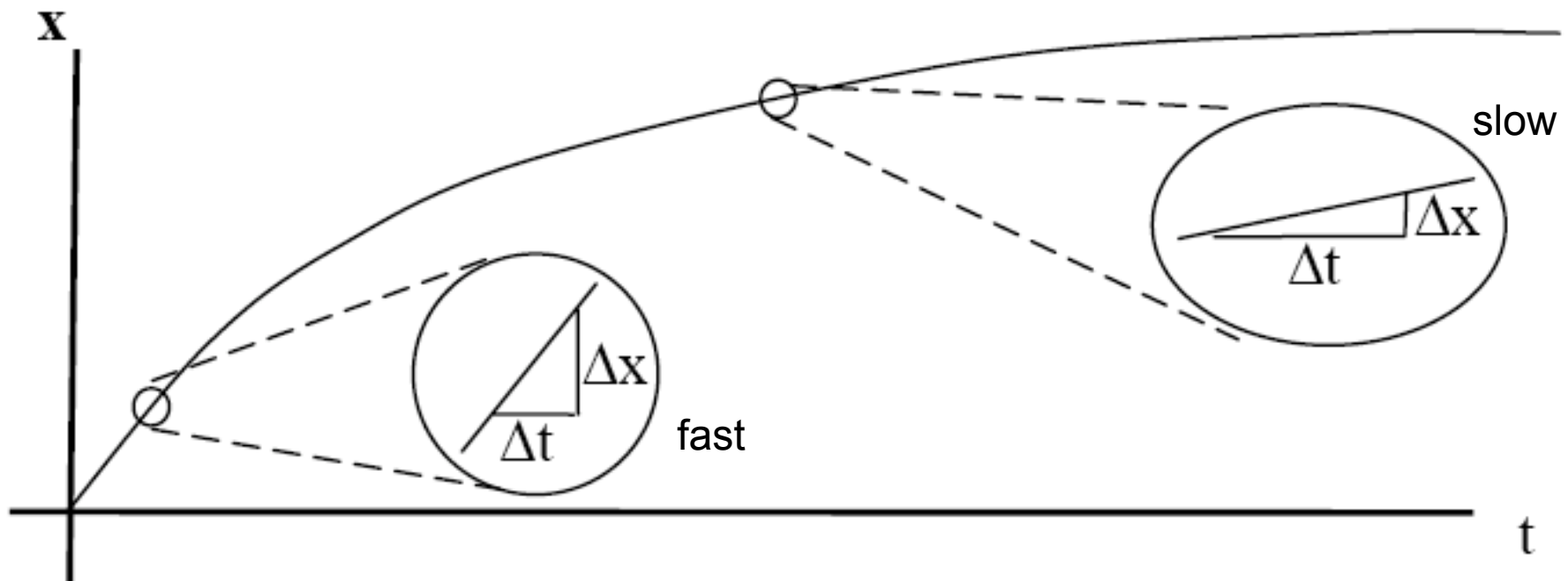
What if $v \neq \text{constant}$?



Slope of the graph gives information about the instantaneous velocity.

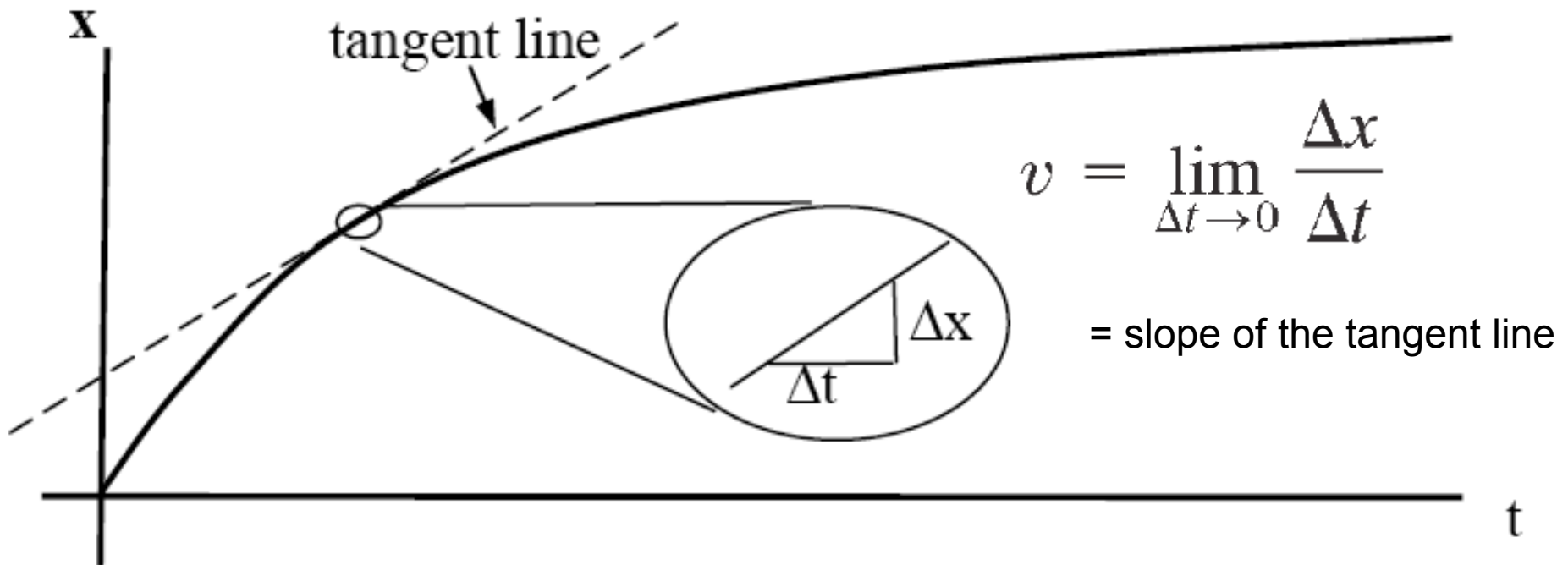
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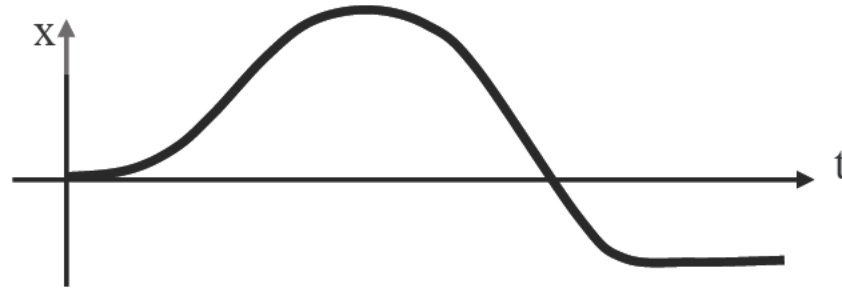
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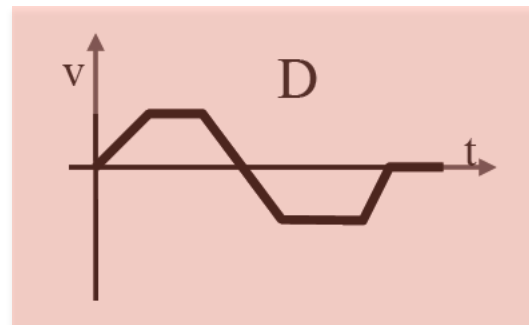
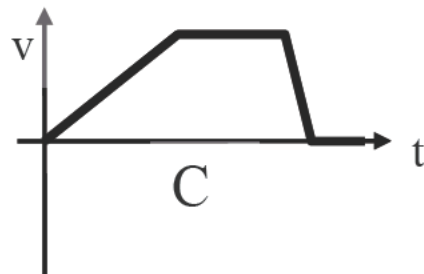
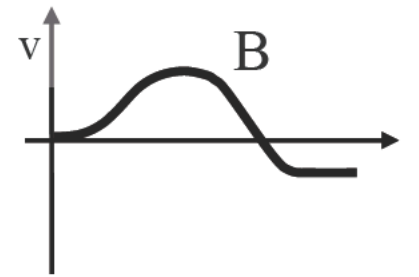
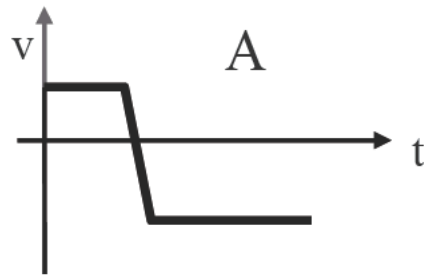


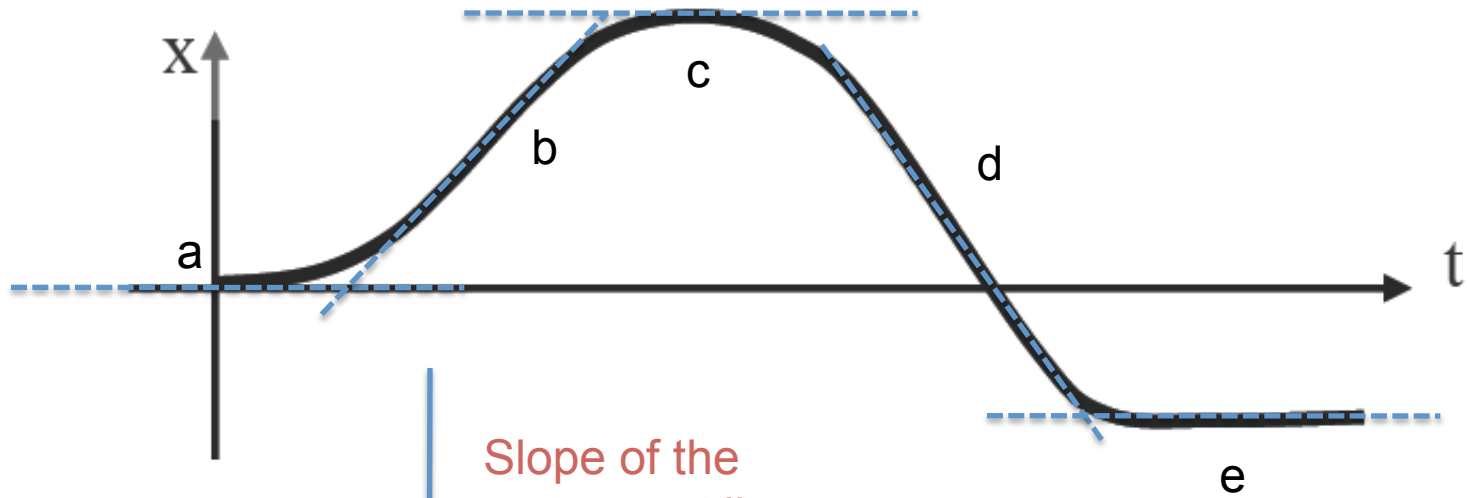
The instantaneous velocity is the slope of the line tangent to the x vs t curve at the point.

A train moves along a straight track and its position vs. time looks like:

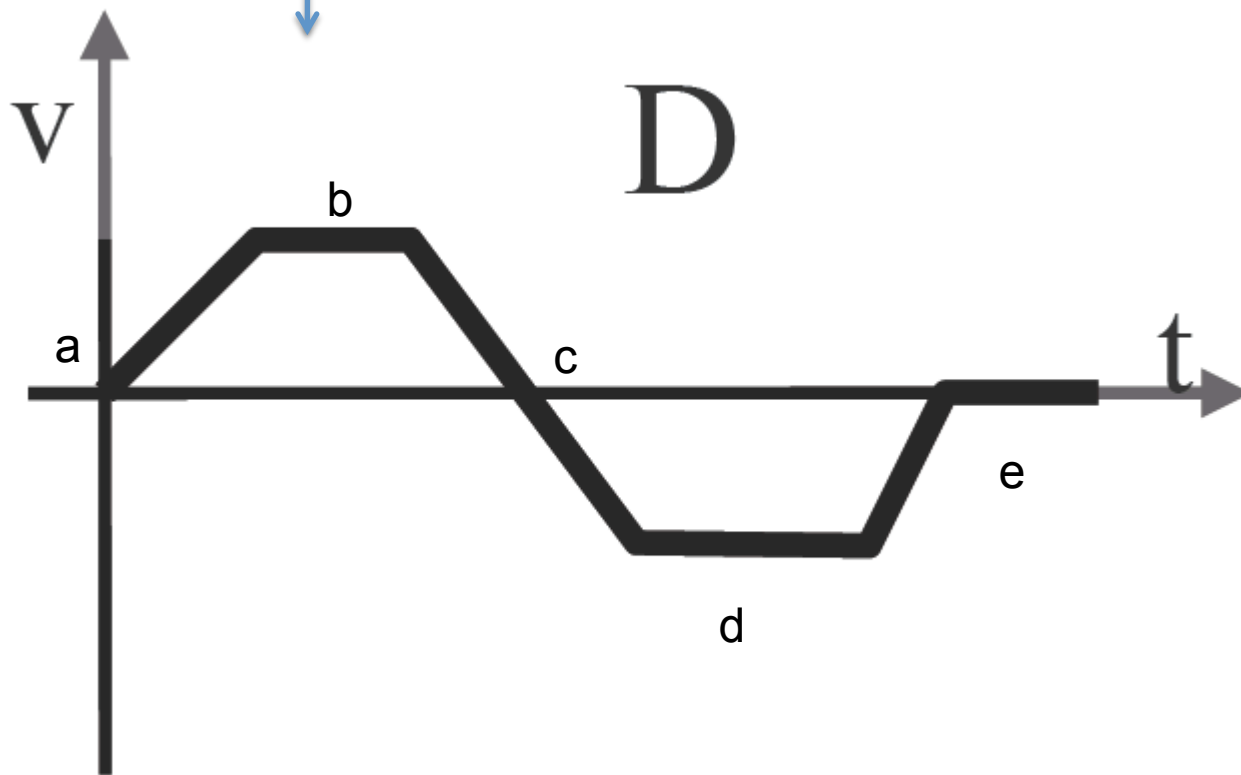


Which graph best depicts its **velocity** vs. time?





Slope of the
tangent line



Remember

- Complete your CAPA assignment and upload the solutions on-line by 10 PM this evening.
- Finish reading Ch. 2 by Monday's class.
- Monday is a holiday (MLK Day). If you have Lab/ Recitation section that day please attend another section next week (preferably with your own TA).
- To prepare for next week's Recitation, you will need to print out Tutorial 1 & bring to Recitation.