Physics 131- Fundamentals of Physics for Biologists I

Professor: Arpita Upadhyaya

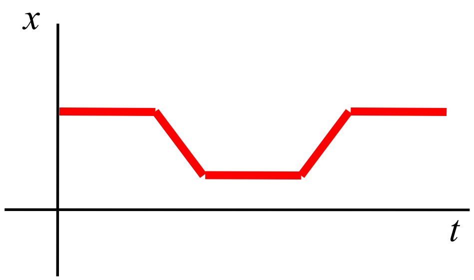
- Quiz 2
- Velocity
- Acceleration

Example

- A ball rolls is rolling at a constant speed along a horizontal track as shown. It comes to a hill and has enough speed to get over it. By thinking about its speed as it goes, sketch a graph of the <u>position</u> of the ball as a function of time.

Please make your selection...

(1)



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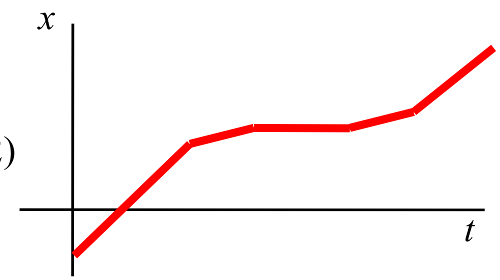

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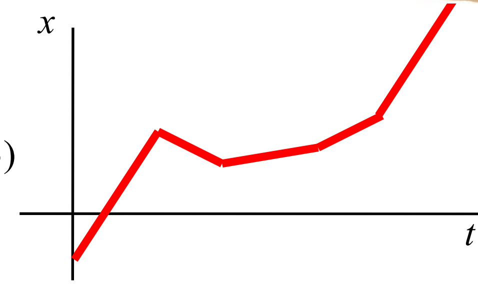

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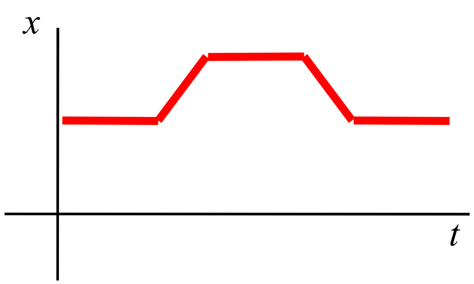

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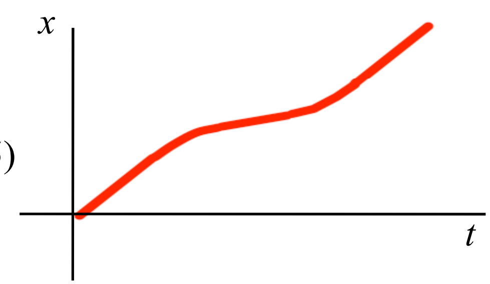

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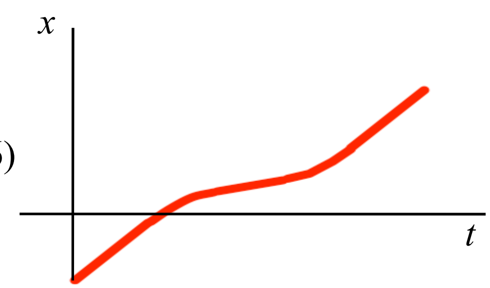
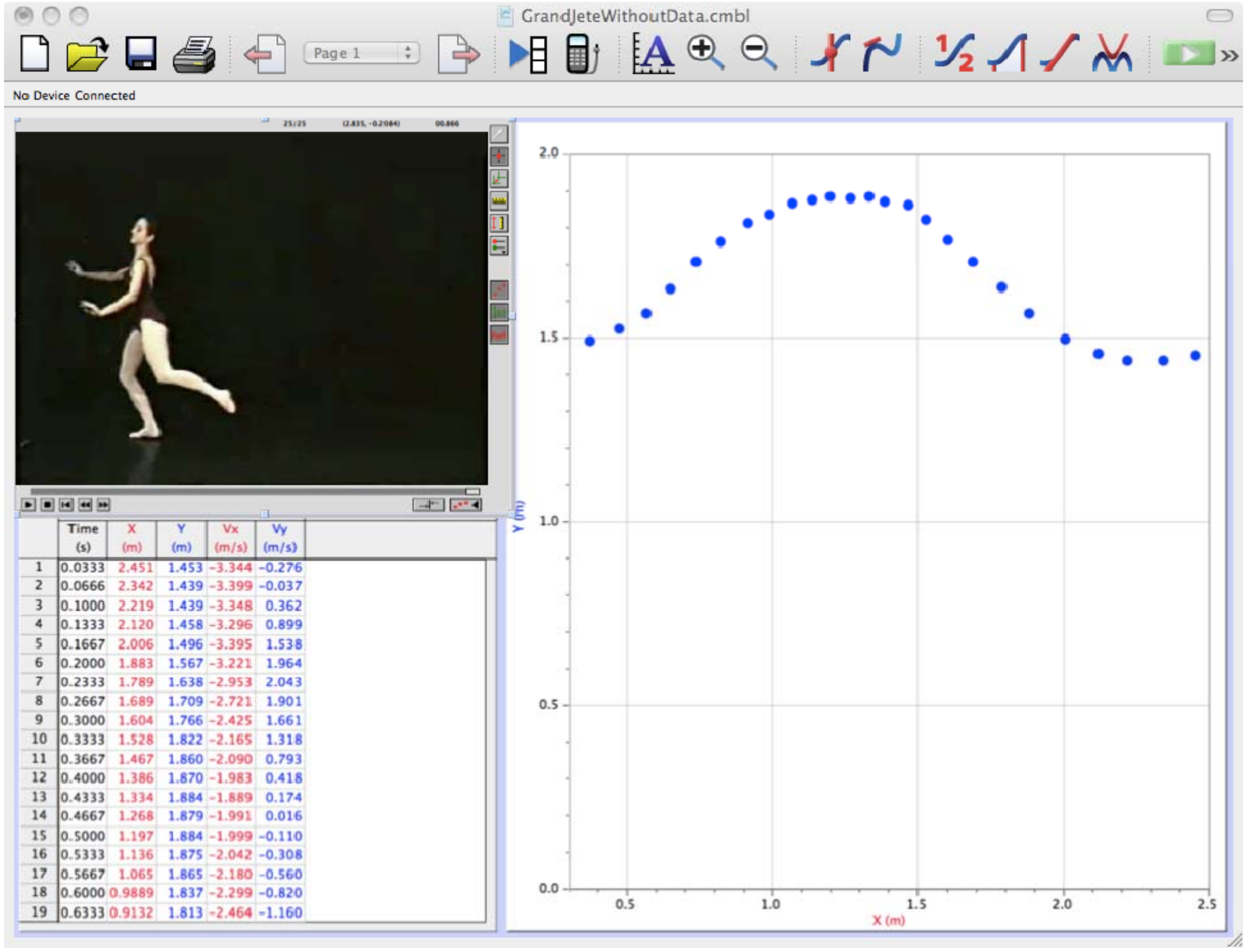


(7) other

Sketch what you think *x-t* and *y-t* plots would look like.

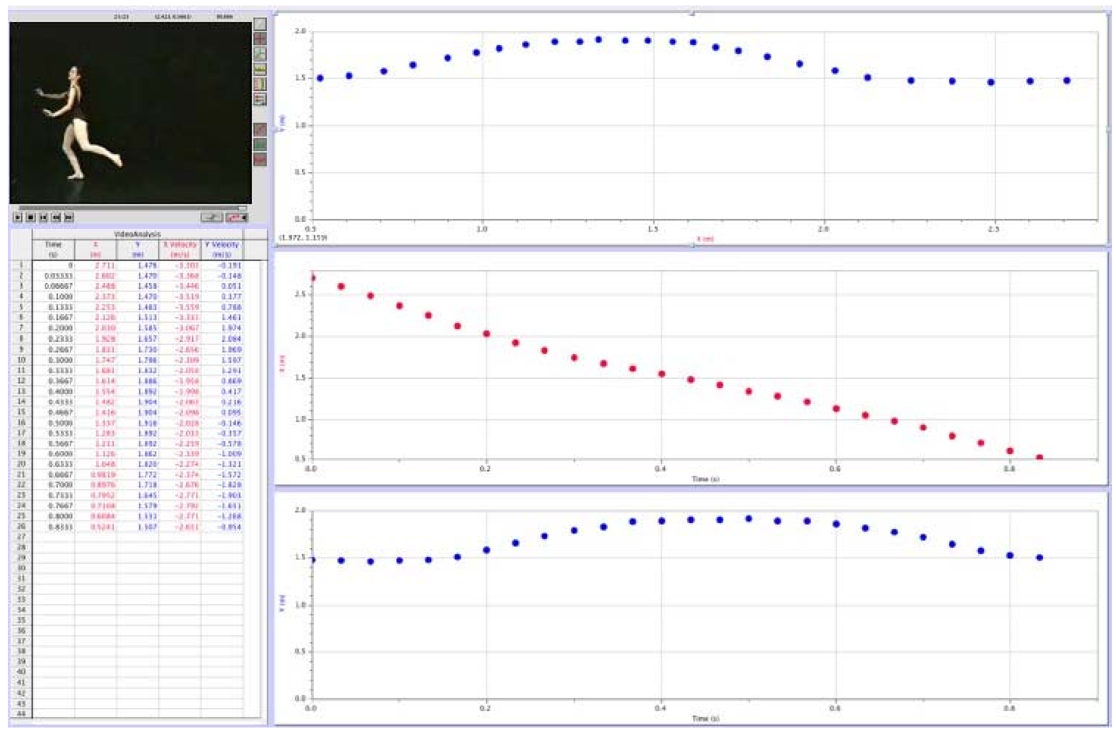


	Time (s)	X (m)	Y (m)	Vx (m/s)	Vy (m/s)
1	0.0333	2.451	1.453	-3.344	-0.276
2	0.0666	2.342	1.439	-3.399	-0.037
3	0.1000	2.219	1.439	-3.348	0.362
4	0.1333	2.120	1.458	-3.296	0.899
5	0.1667	2.006	1.496	-3.395	1.538
6	0.2000	1.883	1.567	-3.221	1.964
7	0.2333	1.789	1.638	-2.953	2.043
8	0.2667	1.689	1.709	-2.721	1.901
9	0.3000	1.604	1.766	-2.425	1.661
10	0.3333	1.528	1.822	-2.165	1.318
11	0.3667	1.467	1.860	-2.090	0.793
12	0.4000	1.386	1.870	-1.983	0.418
13	0.4333	1.334	1.884	-1.889	0.174
14	0.4667	1.268	1.879	-1.991	0.016
15	0.5000	1.197	1.884	-1.999	-0.110
16	0.5333	1.136	1.875	-2.042	-0.308
17	0.5667	1.065	1.865	-2.180	-0.560
18	0.6000	0.9889	1.837	-2.299	-0.820
19	0.6333	0.9132	1.813	-2.464	-1.160

Figuring out velocity

- We have looked at the *x*-*y*, *x*-*t*, and *y*-*t* plots.
- Velocity is the derivative of the position wrt time. Which plots can we get velocity from? Why?
- What will they look like?

$$\vec{v} = \frac{d\vec{r}}{dt}$$



Reading Questions: Derivatives

Do doctors ever need to analyze derivatives on graphs? And if yes, what is an example of a graph they would need to look at?

What are other examples of uses of derivatives besides position/distance>velocity>acceleration?

Can one use derivatives when dealing with all aspects of motion, like position, distance, even when dealing micro-cellular level?

Reading Questions: Velocity

Does velocity play an important role in the way cells communicate with each other and interact with each other at perfect timing?**

How would you calculate the average velocity for an object that used both a mixture of constant and inconsistent speeds over a certain distance?**

Are velocity and derivatives related in any way?**

Why do we mean velocity to be a vector? **

Foothold ideas: Velocity

- Average velocity is defined by

$$\langle \vec{v} \rangle = \frac{\Delta \vec{r}}{\Delta t} = \frac{\text{vector displacement}}{\text{time it took to do it}}$$

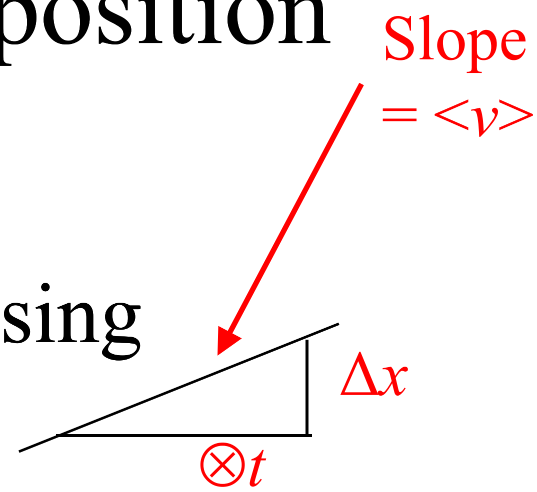
Note: an average velocity goes with a <u>time interval</u>.

- Instantaneous velocity is what we get when we consider a very small time interval (compared to times we care about)

$$\vec{v} = \frac{d\vec{r}}{dt}$$

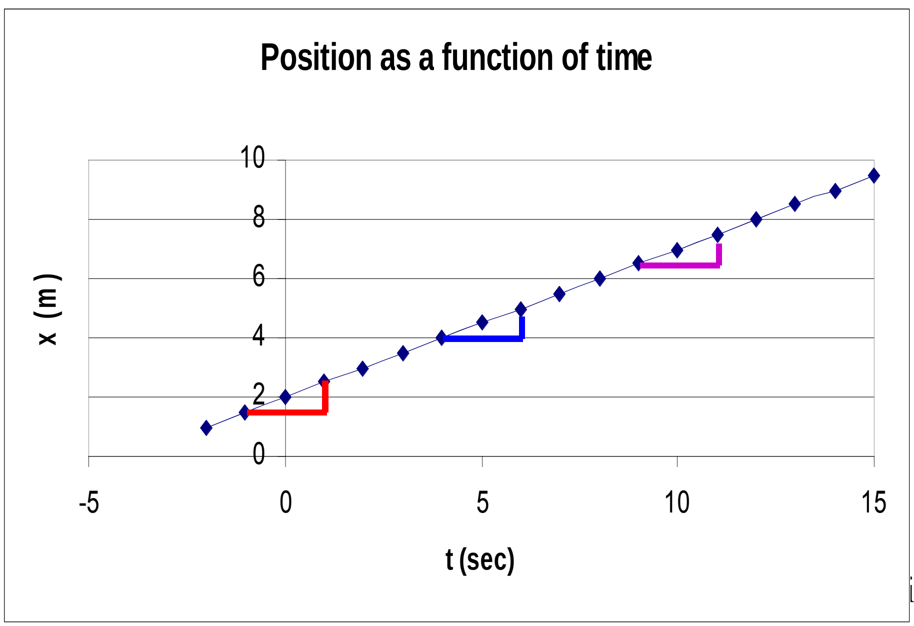
Note: an instantaneous velocity goes with a <u>specific time</u>.

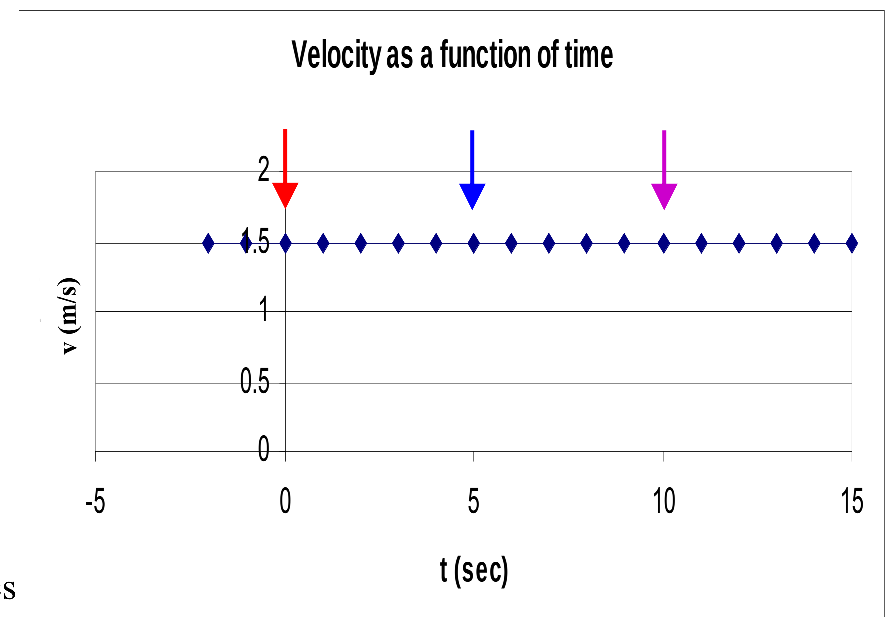
Graphing velocity: Figuring it out from the position



- You can figure out the velocity graph from the position graph using

$$\langle v \rangle = \frac{\Delta x}{\Delta t} \qquad \Delta x = \langle v \rangle \Delta t$$





Graphing Velocity: Figuring it out from the motion

- An object in uniform motion has constant velocity.
- This means the instantaneous velocity does not change with time. Its graph is a horizontal line.
- You can make sense of this by putting your mind in “velocity mode” and running a mental movie.

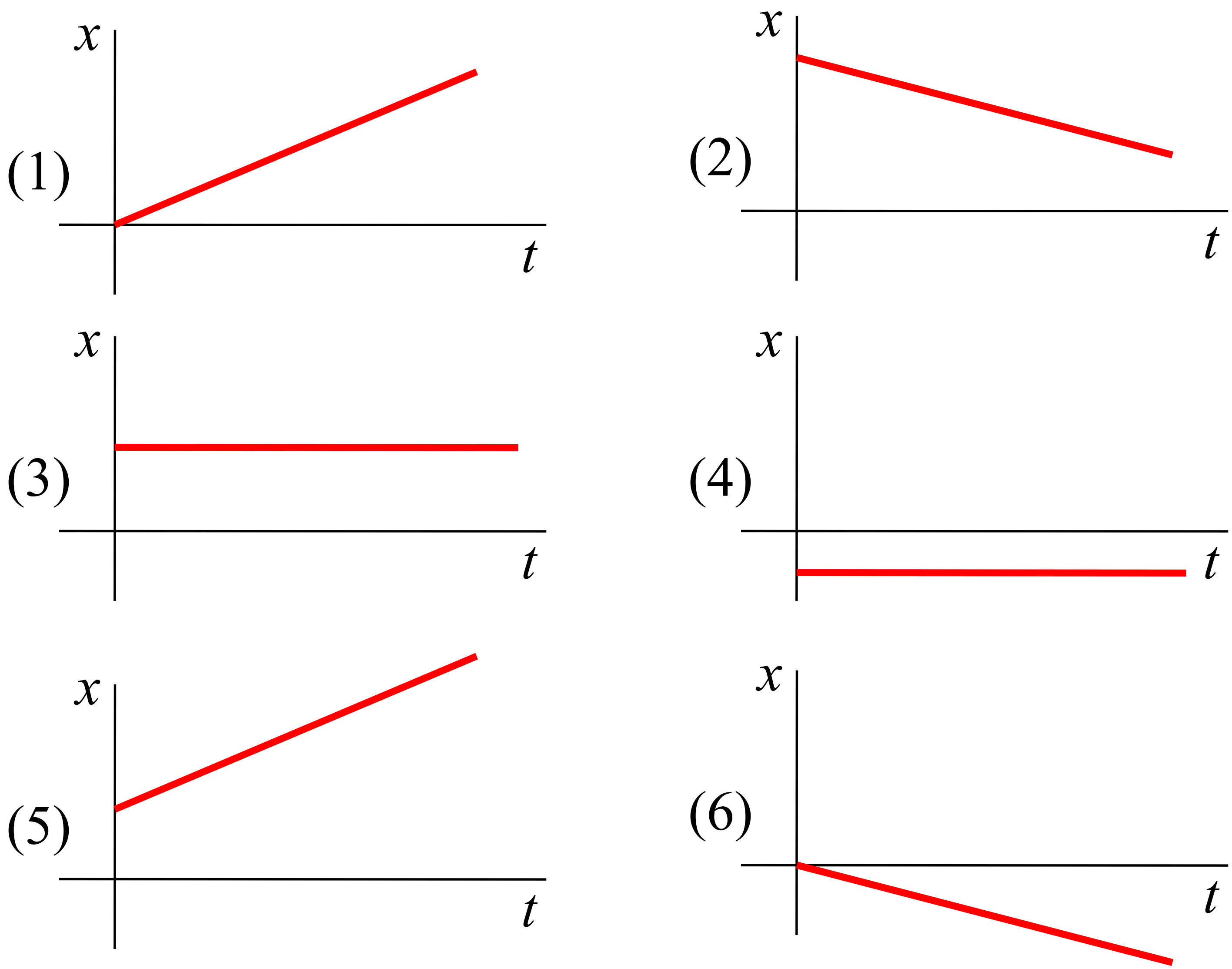
The sonic ranger (motion detector)

- The sonic ranger measures distance to the nearest object by echolocation.
  - A speaker clicks 30 times a second. A microphone detects the sound bouncing back from the nearest object in front of it.
  - The computer calculates the time delay between and using the speed of sound (about 343 m/s at room temperature) it can calculate the distance to the object.

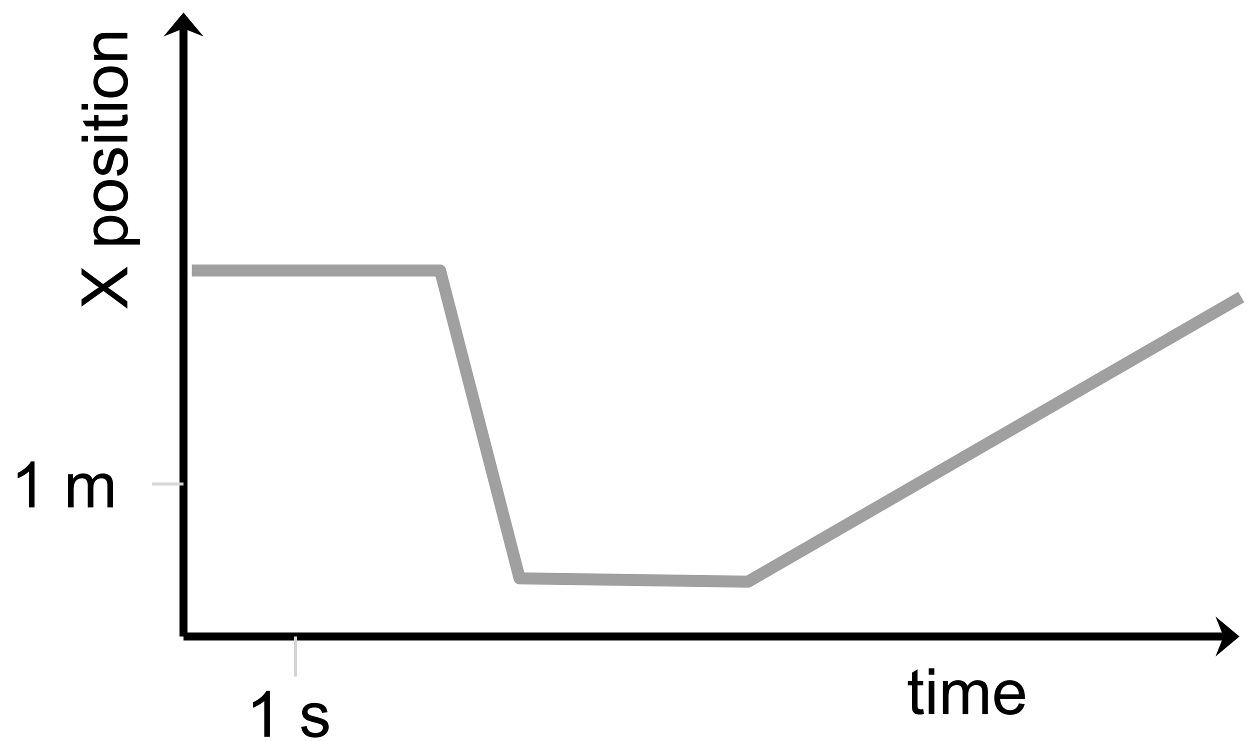
Example

- If I place the sonic ranger at the left side of the room and you walk slowly towards it at almost a constant velocity what will the ***position*** graph look like?
- Generate the graph on your whiteboard.

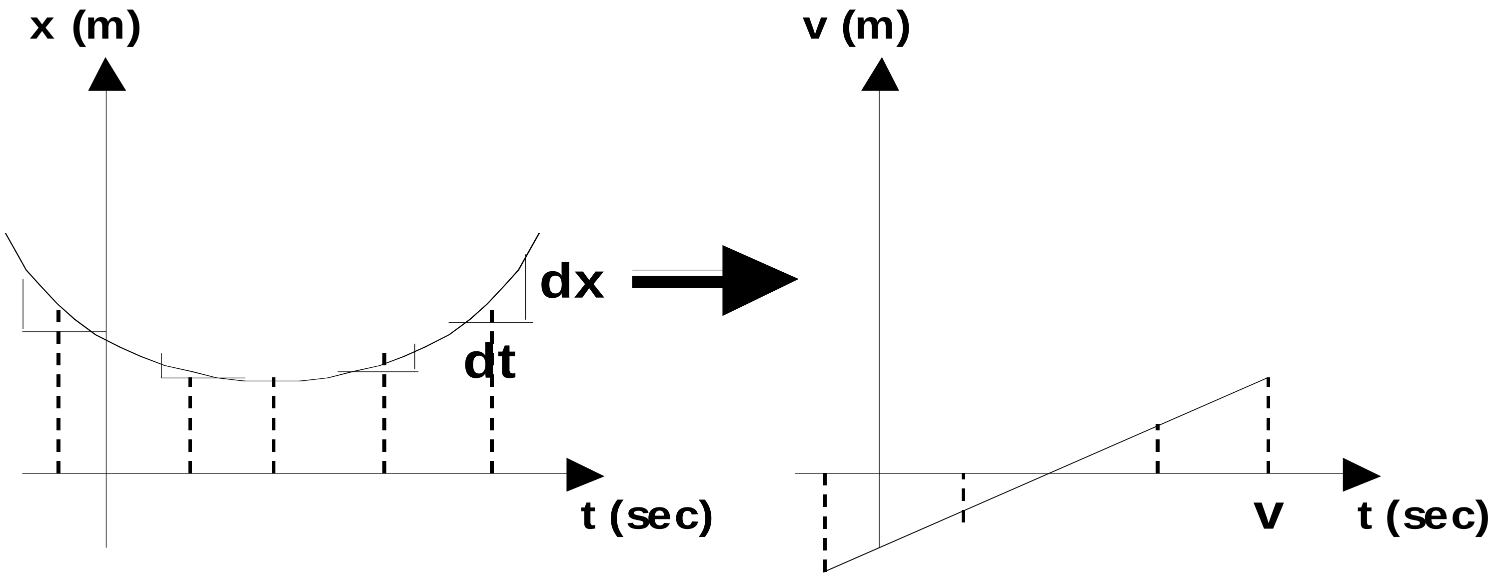
Position



Describe in your own words the motion captured in this position vs time graph



Position to velocity



$$v(t) = \frac{dx}{dt}$$

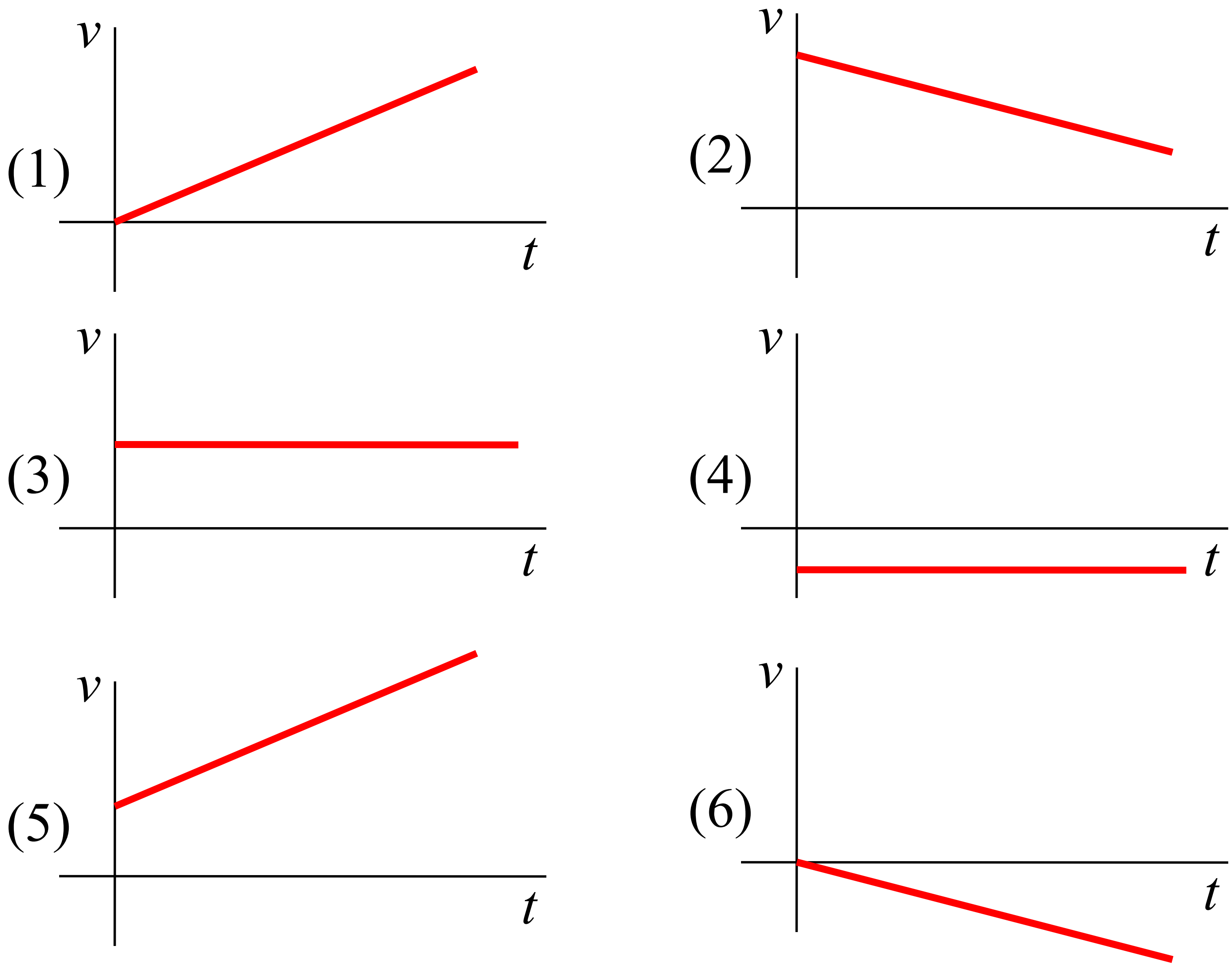
Ratio of change in position that takes place to the (small) time interval

Difference of two positions at two (close) times

$$v(t) = \frac{x(t + \Delta t/2) - x(t - \Delta t/2)}{\Delta t}$$

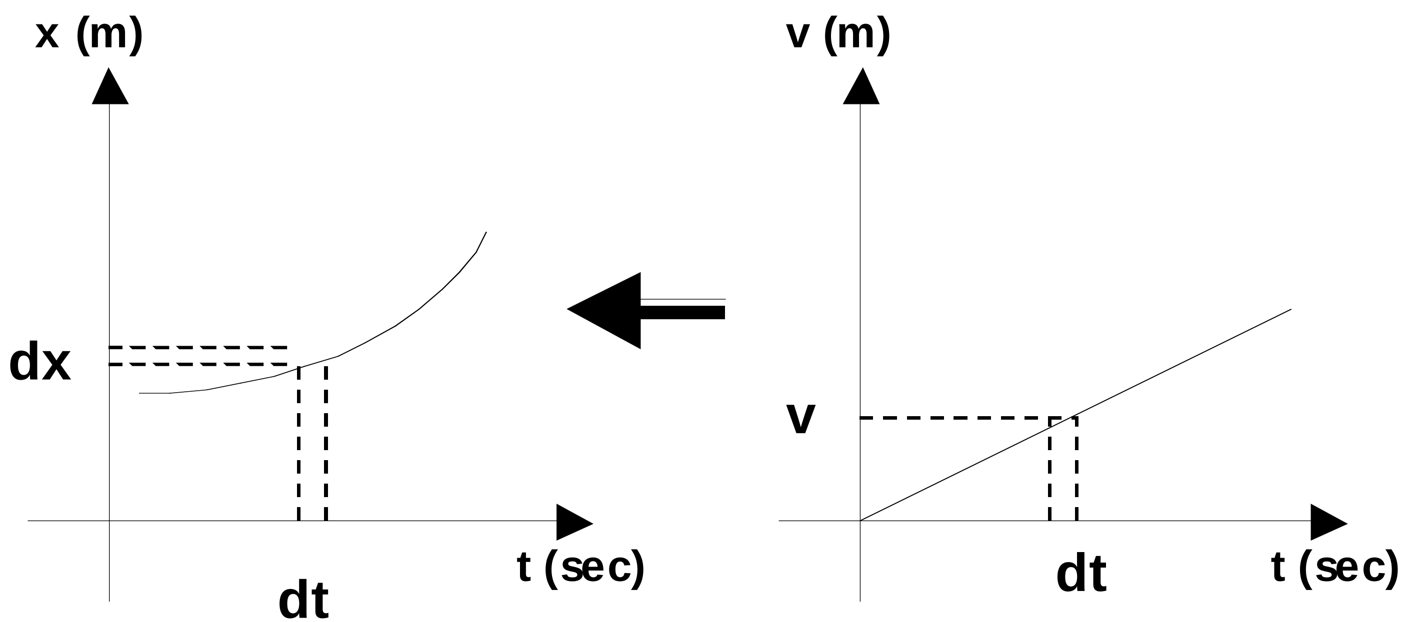
Example

- If I place the sonic ranger at the left side of the room and you walk slowly towards it, at almost a constant velocity what will the ***velocity*** graph look like?
- Discuss with your group and sketch the consensus graph on your whiteboard.


(1)
(2)
(3)
(4)
(5)
(6)
v
t


TurningPoint

Predicting Position from Velocity



change in position that takes place in a small time interval

$$dx = v(t)\,dt$$

sum ("Σ") in the changes in position over many small time intervals

$$x = \sum dx = \int v(t)\,dt$$

Predicting the Future with differential equations

Suppose we know the value of something as a function of time at a given time, *f*(*t*), and we know its derivative, *df/dt* at that time. We can use that to predict the future!

$$\frac{df}{dt} = \frac{\Delta f}{\Delta t} = \frac{f_{end} - f_{beginning}}{\Delta t}$$

$$f_{end} - f_{beginning} = \left(\frac{df(t)}{dt}\right)\Delta t$$

$$f(t+\Delta t) - f(t) = \left(\frac{df(t)}{dt}\right)\Delta t$$

$$f(t+\Delta t) = f(t) + \left(\frac{df(t)}{dt}\right)\Delta t$$

Example of a Differential Eqn.

- Epidemiology: Number of people infected by a disease is proportional by the number of people in the population
- A simple model for the spread of infection

$$\frac{dI(t)}{dt} = AI(t) - BI(t)$$

$A =$ rate at which population gets infected

$B =$ rate at which infected people are cured (or die)

$$\frac{dI}{dt} = (A - B)I$$

Foothold ideas: 1D Velocity

- Velocity is the **rate of change** of position
- Average velocity

  = (how far did you go?)/(how long did it take you?)

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

- Instantaneous velocity = same (but for short Δt)

$$v = \frac{dx}{dt}$$

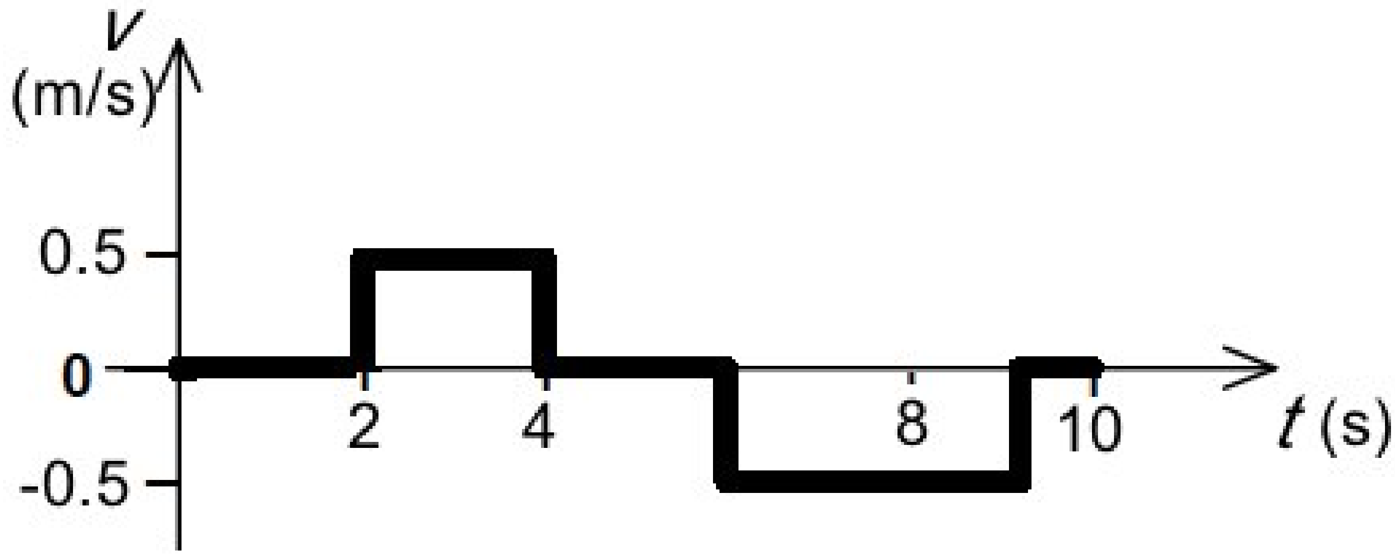
Can this velocity be negative as well as positive?

The 1D velocity is defined as $v = \frac{dx}{dt}$
What is true about this velocity?

1. It is always positive.
2. It is only negative if x is negative.
3. It can be positive or negative but only for positive x.
4. It can be positive or negative for both positive and negative x.

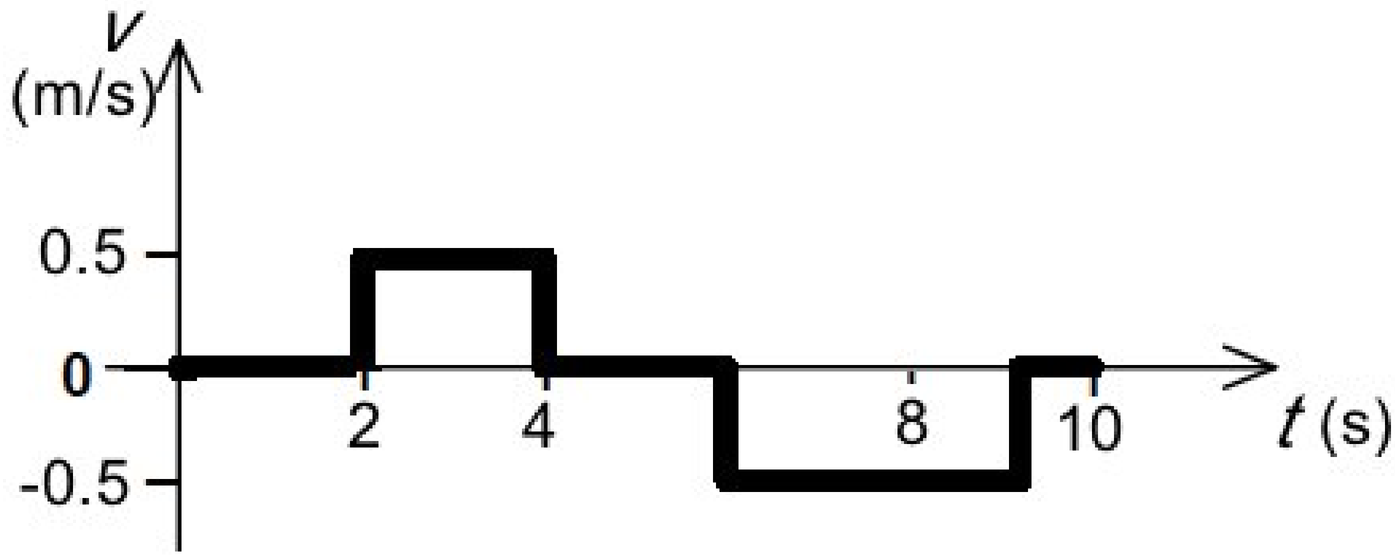
Example

- Describe in words how do you have to walk to make the sonic ranger produce the following velocity graph.



Example

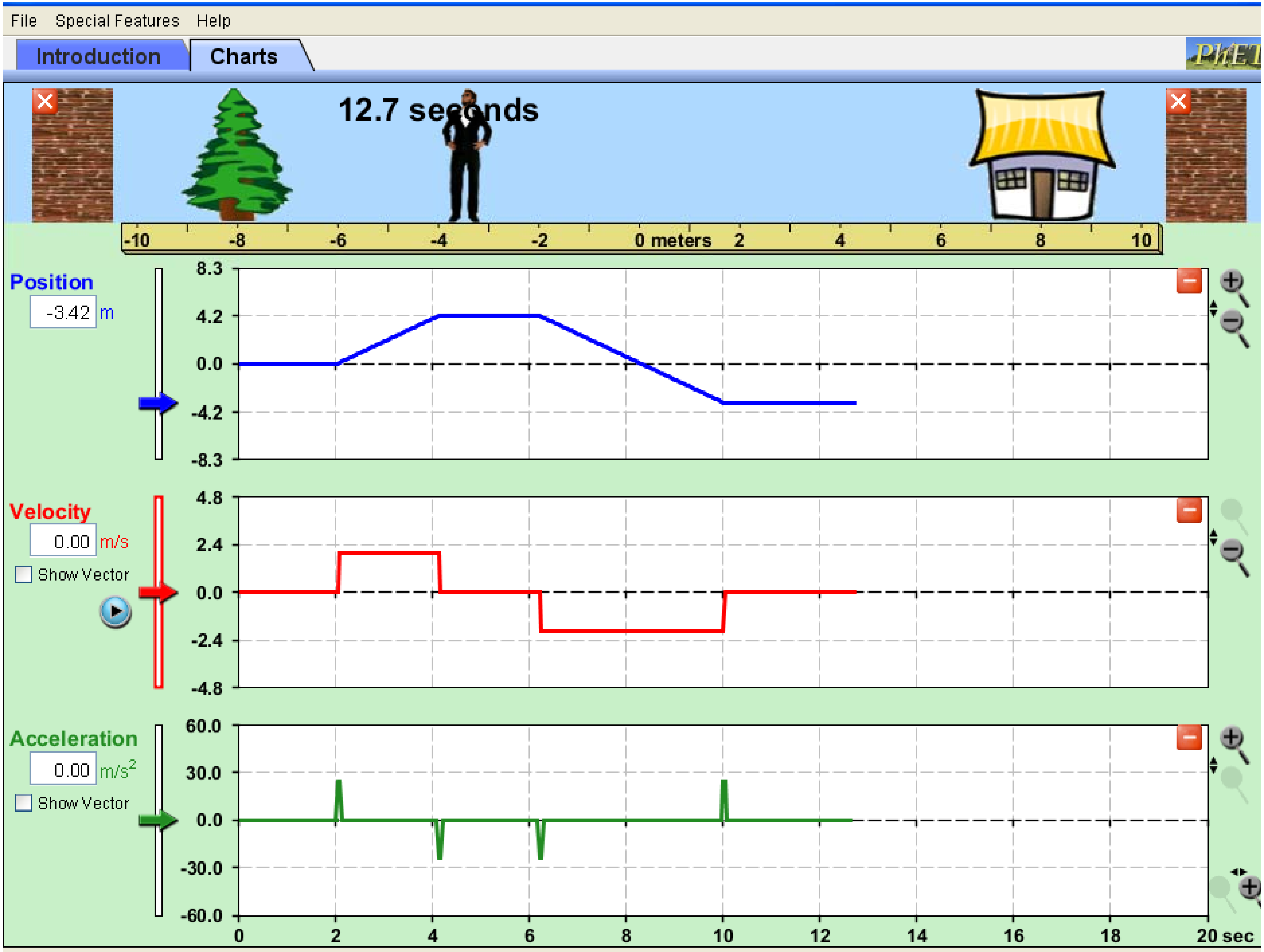
- How do you have to walk to make the sonic ranger produce the following velocity graph?



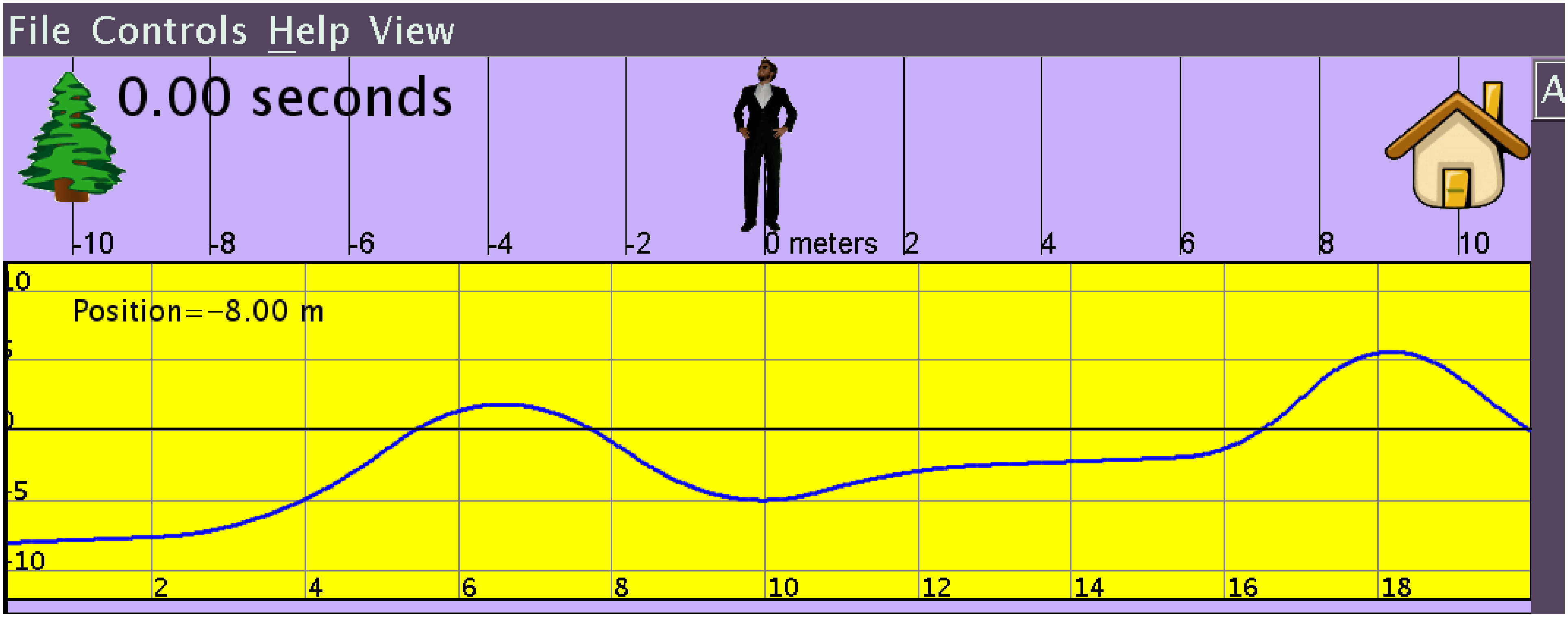
- On the whiteboard, draw the position graph.

Position graph

1. 1
2. 2
3. 3
4. 4



File
Special Features
Help
Introduction
Charts
PhET
12.7 seconds
-10
-8
-6
-4
-2
0 meters
2
4
6
8
10
Position
-3.42
m
8.3
4.2
0.0
-4.2
-8.3
Velocity
0.00
m/s
Show Vector
4.8
2.4
0.0
-2.4
-4.8
Acceleration
0.00
m/s²
Show Vector
60.0
30.0
0.0
-30.0
-60.0
0
2
4
6
8
10
12
14
16
18
20 sec

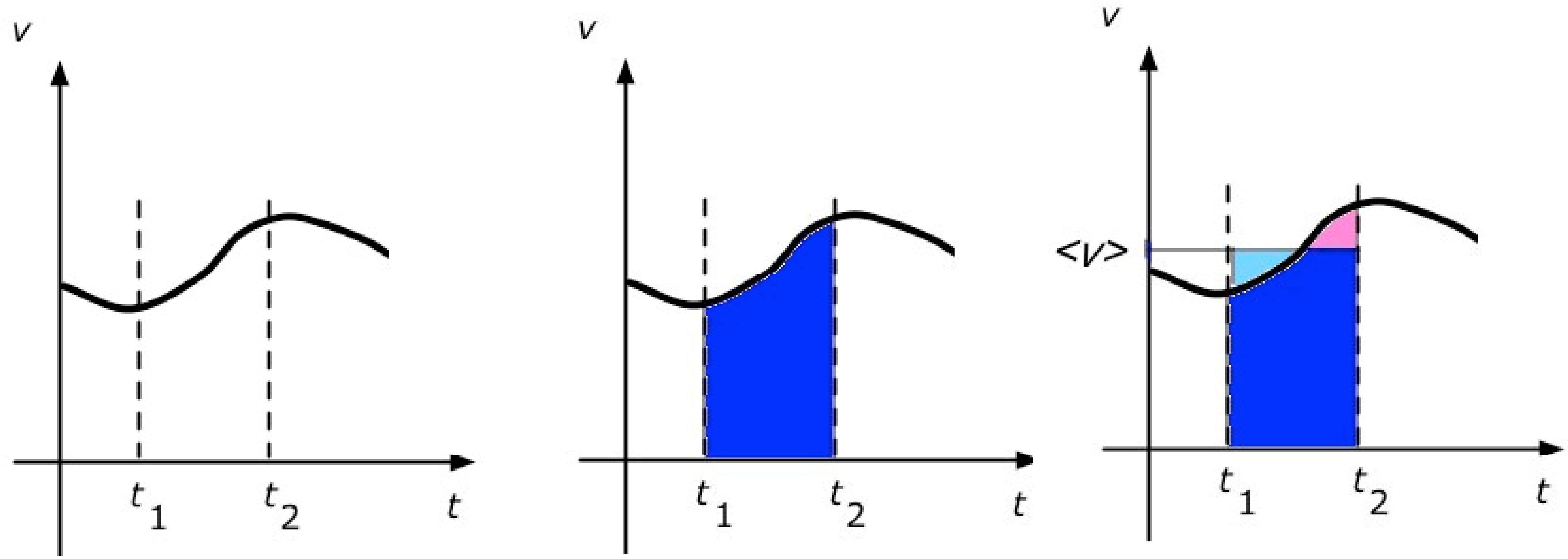


How many times does the man's speed go to zero?

1. Never
2. Once
3. Twice
4. Three times
5. Four times

Average Velocity: graphical

What does this mean?



v is a function of t, $v(t)$

What is the average velocity between times t_1 and t_2?

The total displacement between those two times is the area under the curve. (Why?)

Adjust <v> (a constant) so $\Delta x = \langle v \rangle \Delta t$

The value of the Average Velocity

1. Lies in the middle between the initial and final velocity
2. Has to be somewhere between the initial and final velocity, depends on how velocity changes with time
3. Neither
4. Don't know