Physics 111 - Class 3A
Kinematics I

September 19, 2022

Class Outline

- Logistics / Announcements
- Introduction to Chapter 3
- Clicker Questions
- Activity: Calculus and Kinematics
- Debrief: Calculus and Kinematics

Physics 111

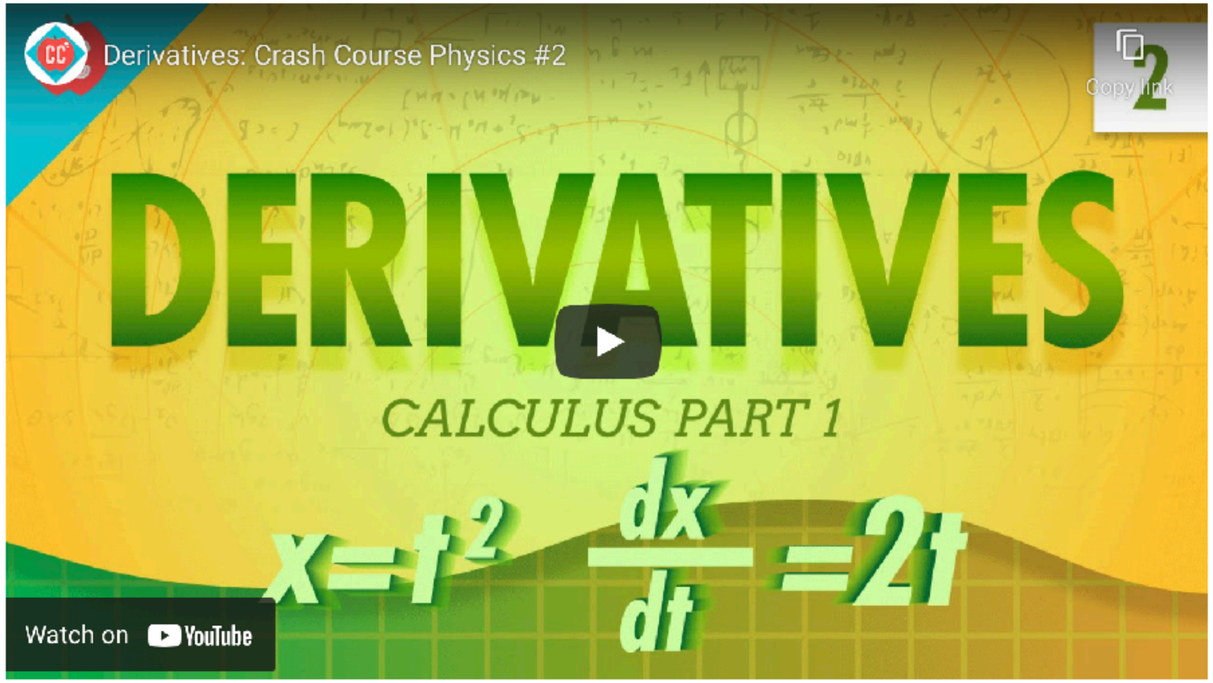
Search this book...

Videos

Below are the assigned videos for this week. The videos are collapsible so once you're done with one, you can move to the next one. In the sidebar on the right, you can use the checklists to keep track of what's done.

Summary of Calculus from Crash Course Physics

Derivatives



Integrals

Required Videos

Contents

Checklist of items

- [ ] Calculus: Derivatives
- [ ] Calculus: Integrals
- [ ] Vectors and 2D Motion
- [ ] Introduction to Displacement and the Differences Between Displacement and Distance
- [ ] Introduction to Velocity and Speed and the differences between the two
- [ ] Introduction to Acceleration with Prius Brake Slamming Example Problem
- [ ] Introduction to Free-Fall and the Acceleration due to Gravity

Figure 3.1 A JR Central L0 series five-car maglev (magnetic levitation) train undergoing a test run on the Yamanashi Test Track. The maglev train's motion can be described using kinematics, the subject of this chapter. (credit: modification of work by "Maryland GovPics"/Flickr)

Chapter Outline

Our universe is full of objects in motion. From the stars, planets, and galaxies; to the motion of people and animals; down to the microscopic scale of atoms and molecules—everything in our universe is in motion. We can describe motion using the two disciplines of kinematics and dynamics. We study dynamics, which is concerned with the causes of motion, in Newton's Laws of Motion; but, there is much to be learned about motion without referring to what causes it, and this is the study of kinematics. Kinematics involves describing motion through properties such

Position Graphs

Time t_i (min)	Position x_i (km)	Displacement Δx_i (km)
$t_0 = 0$	$x_0 = 0$	$\Delta x_0 = 0$
$t_1 = 9$	$x_1 = 0.5$	$\Delta x_1 = x_1 - x_0 = 0.5$
$t_2 = 18$	$x_2 = 0$	$\Delta x_2 = x_2 - x_1 = -0.5$
$t_3 = 33$	$x_3 = 1.0$	$\Delta x_3 = x_3 - x_2 = 1.0$
$t_4 = 58$	$x_4 = -0.75$	$\Delta x_4 = x_4 - x_3 = -1.75$

Jill sets out from her home to deliver flyers for her yard sale.

A) The table describes her movements. Draw a sketch of her movements.
B) Create a plot of Jill's Position vs. Time

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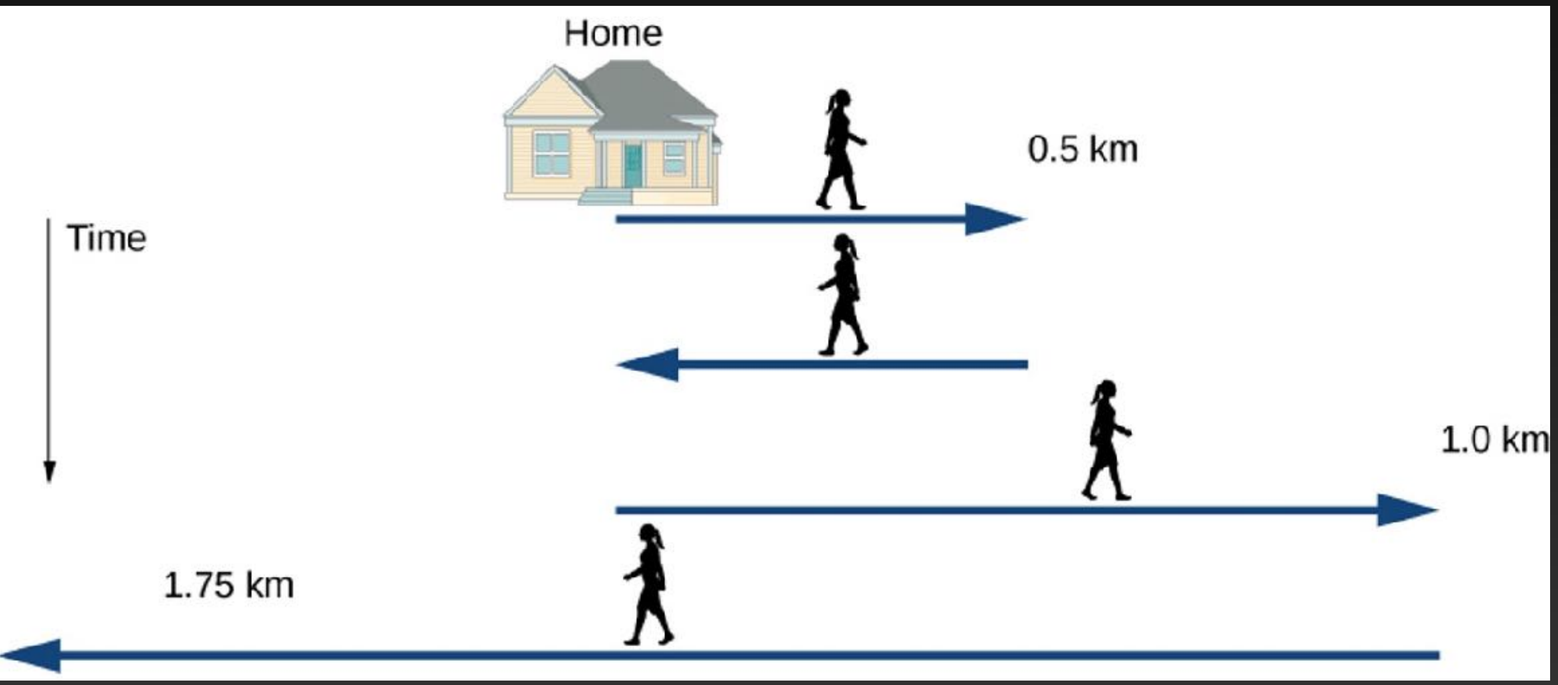

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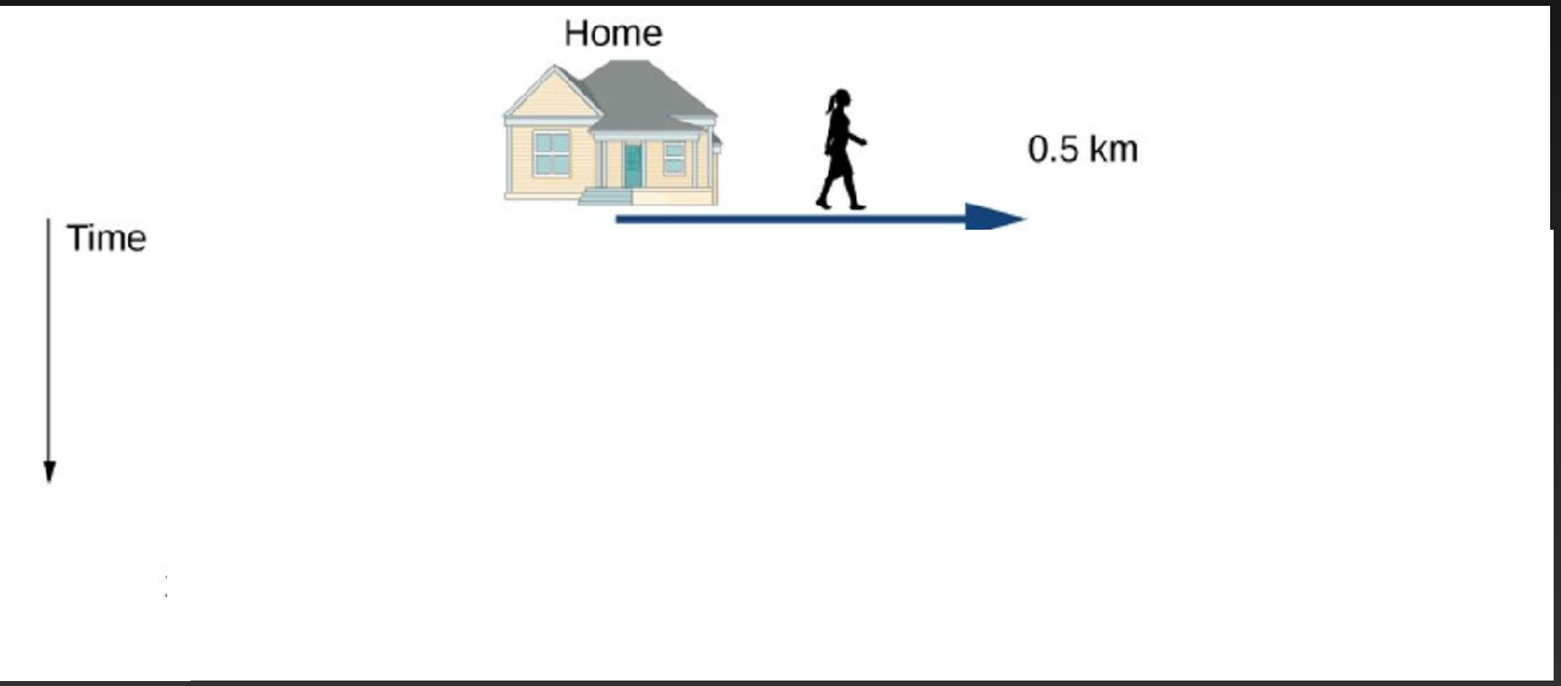

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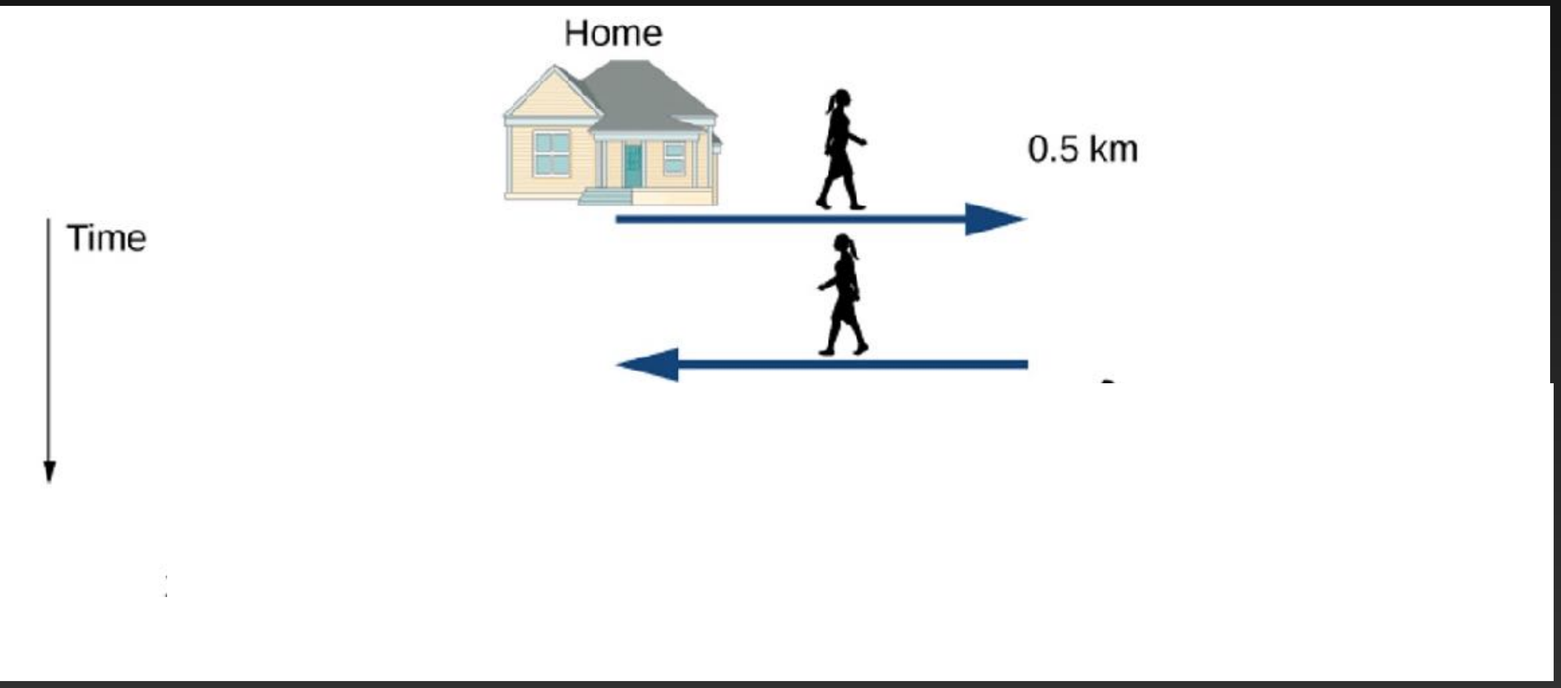

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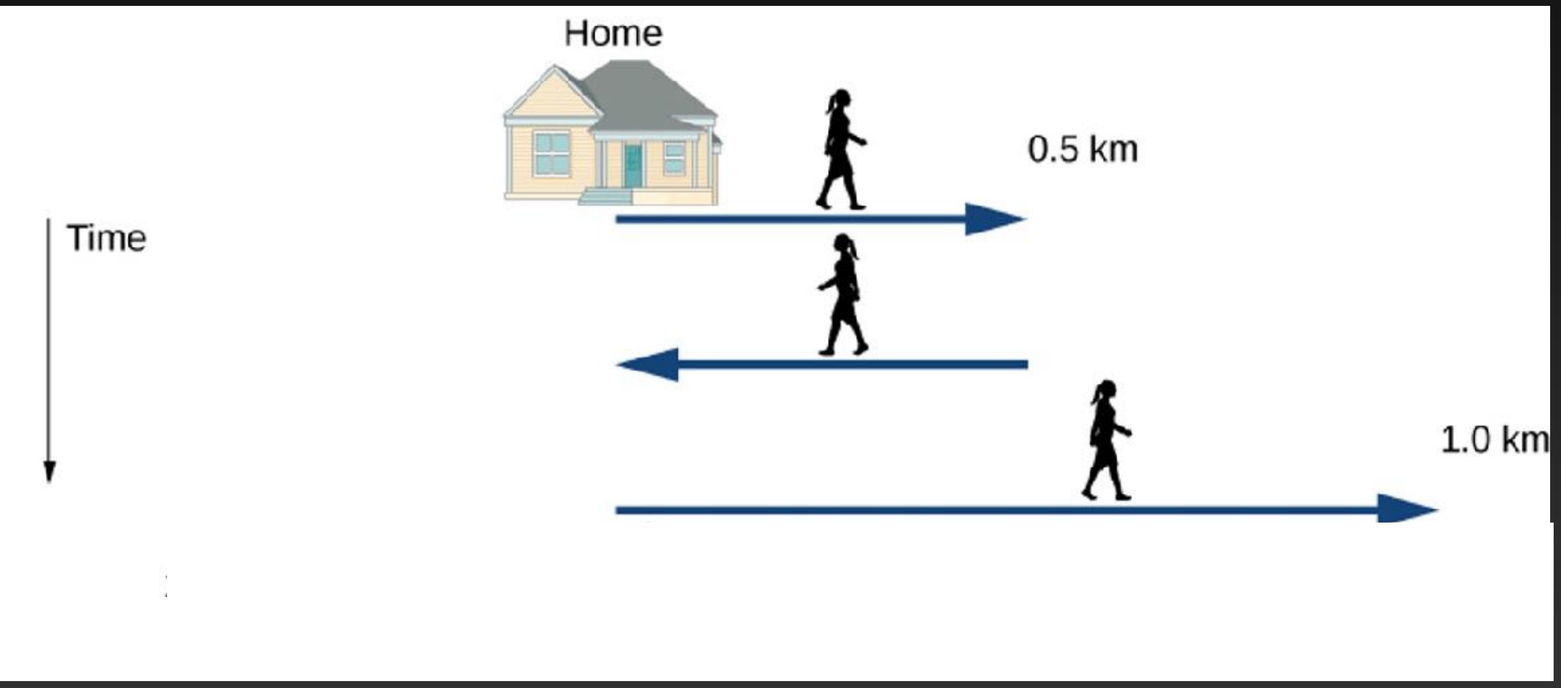

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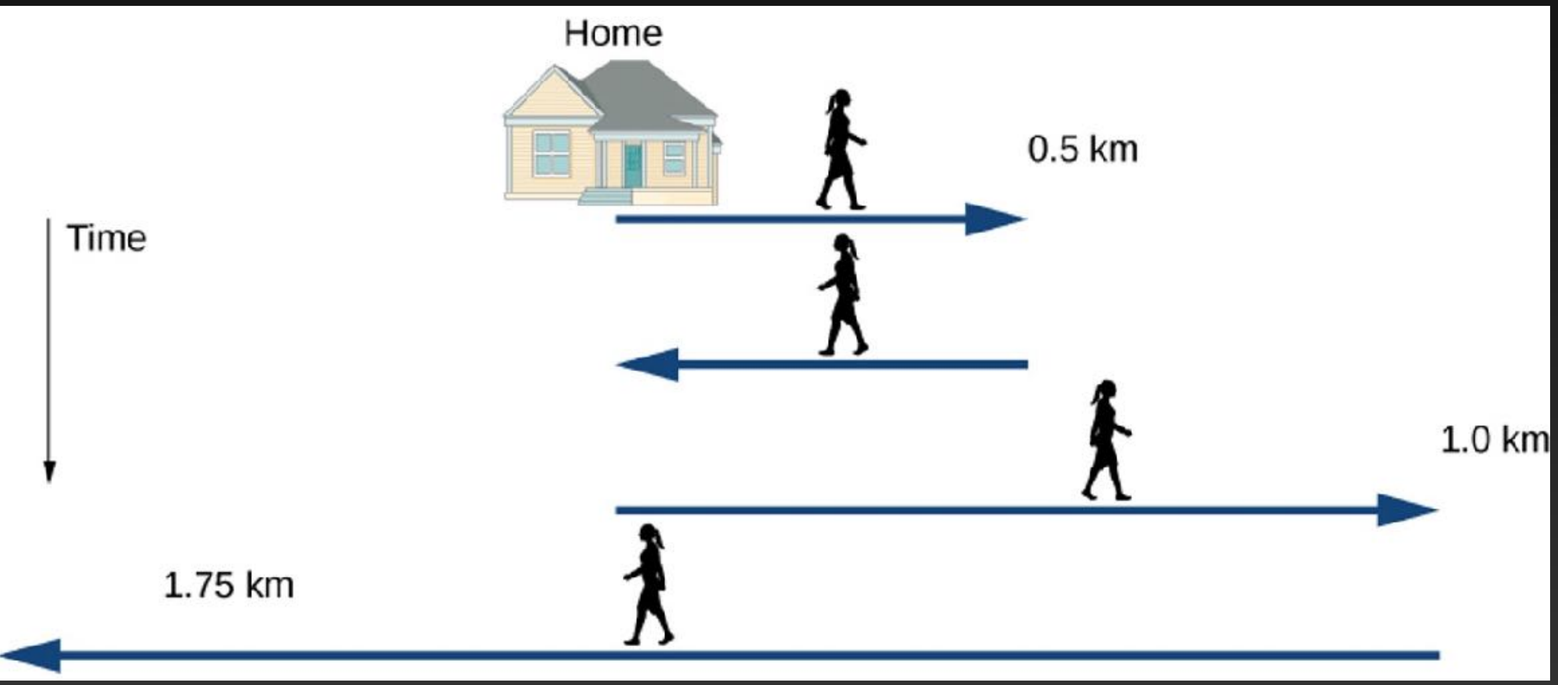

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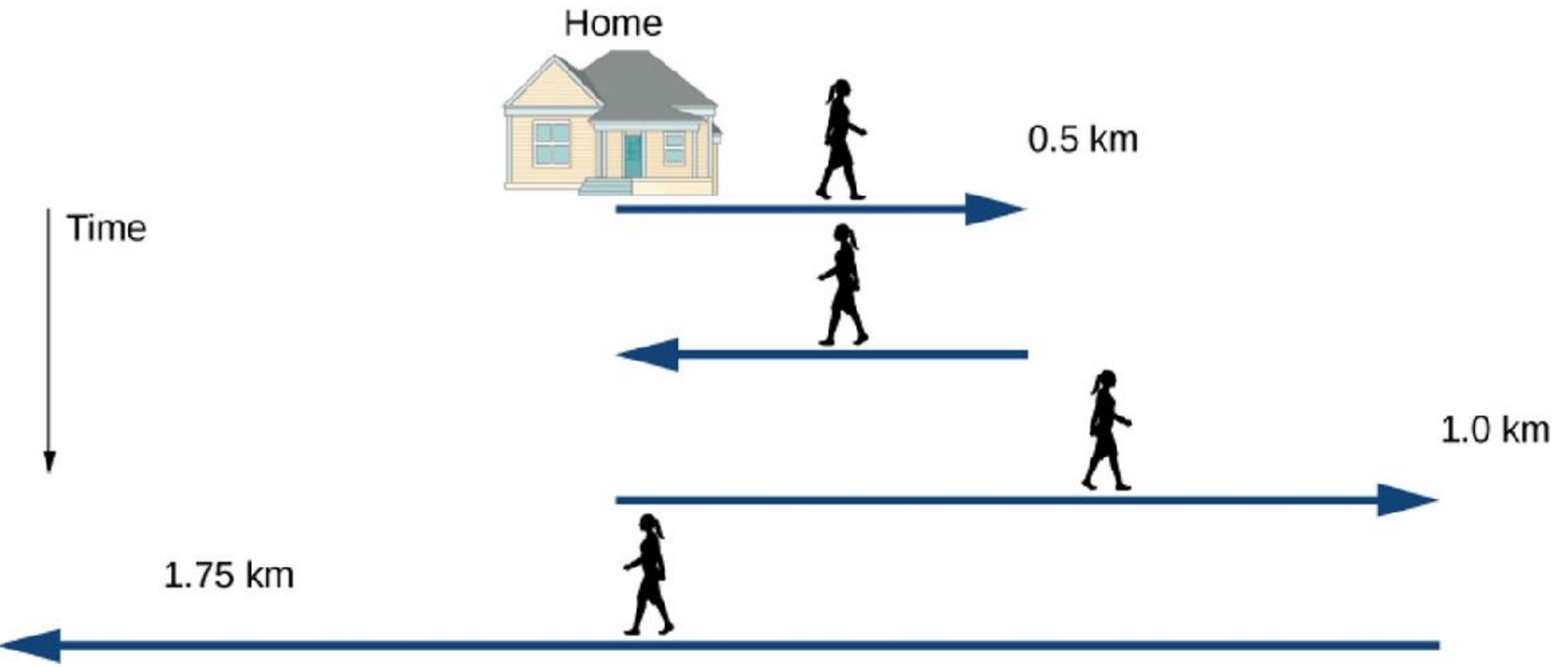

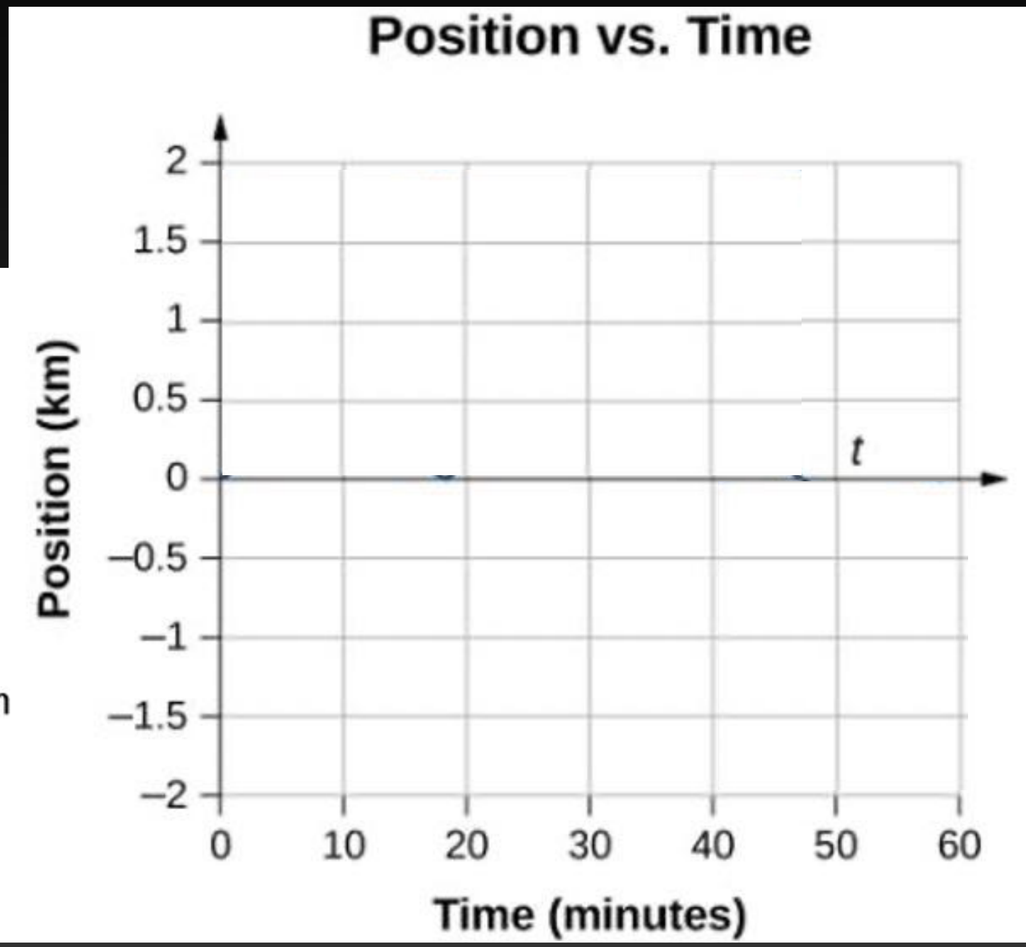

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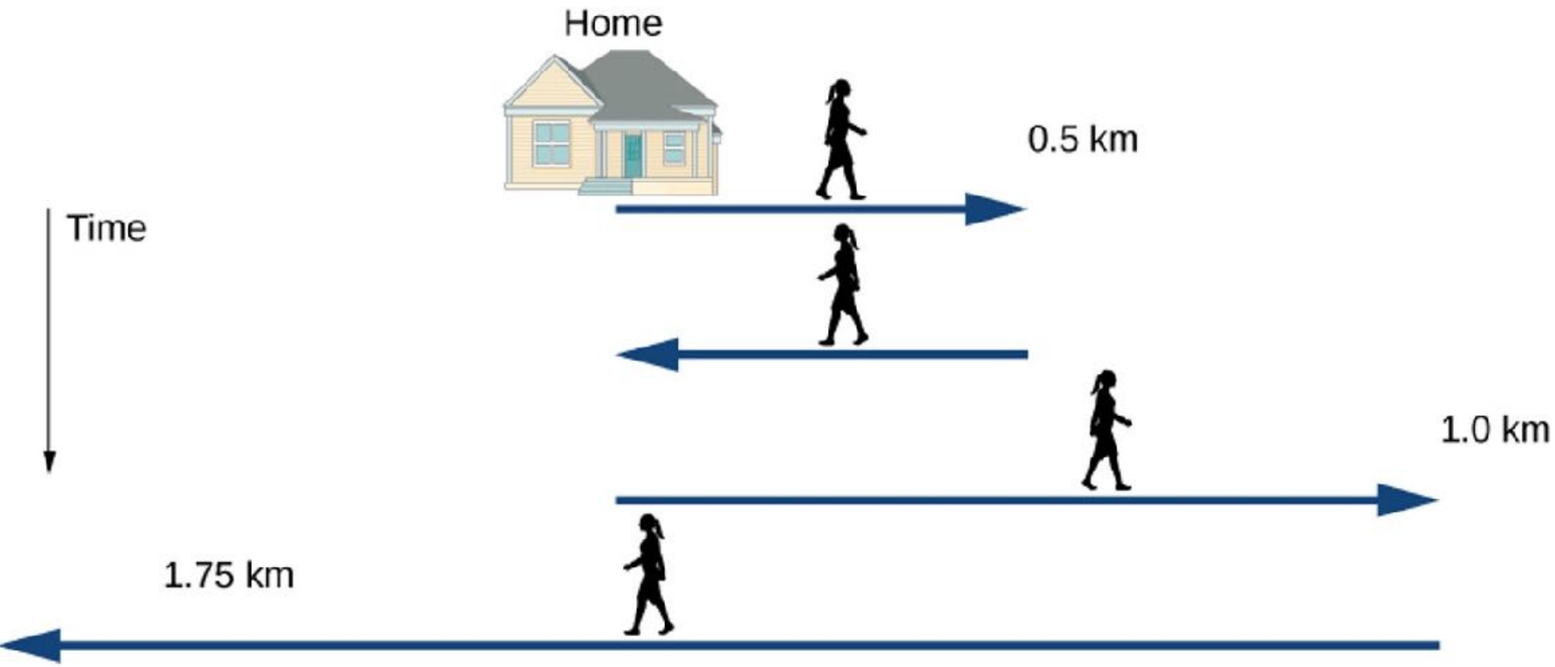

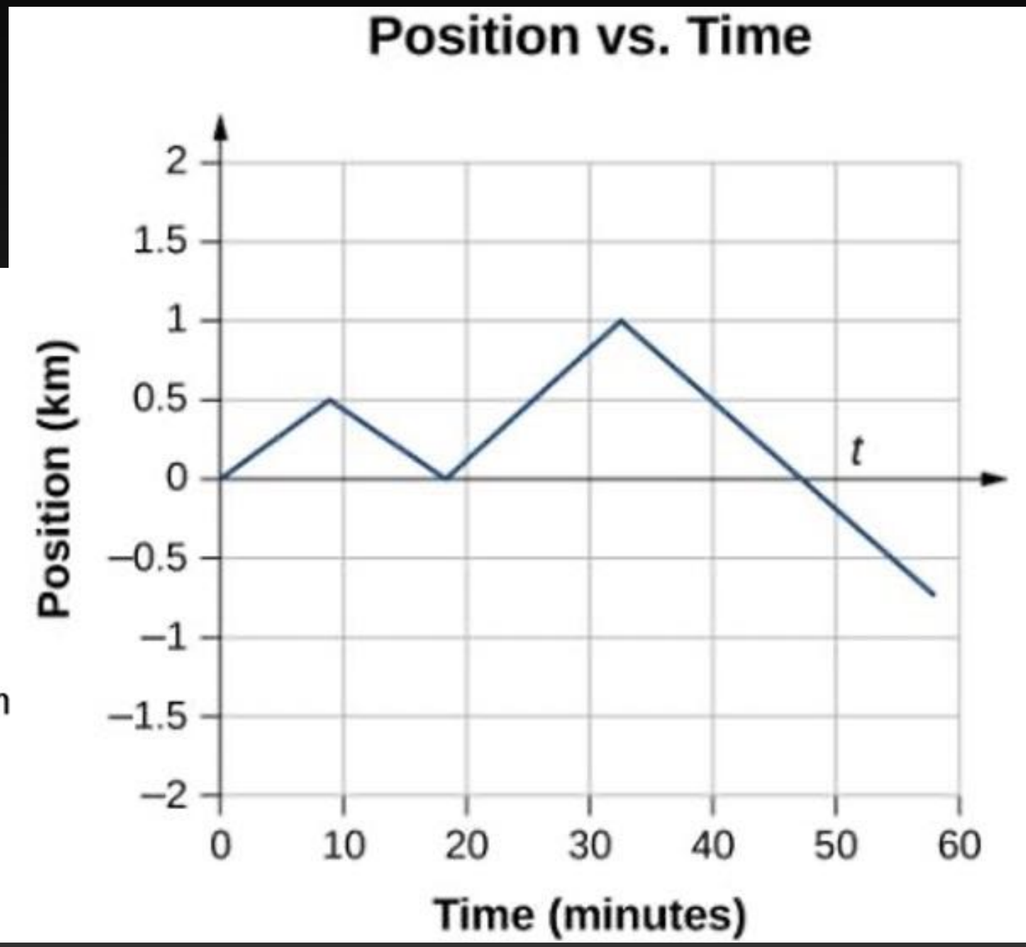

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Key Equations

Displacement	$\Delta x = x_{\mathrm{f}} - x_{\mathrm{i}}$
Total displacement	$\Delta x_{\mathrm{Total}} = \sum \Delta x_{\mathrm{i}}$
Average velocity (for constant acceleration)	$\overline{v} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$
Instantaneous velocity	$v(t) = \frac{dx(t)}{dt}$
Average speed	$\text{Average speed} = \overline{s} = \frac{\text{Total distance}}{\text{Elapsed time}}$
Instantaneous speed	$\text{Instantaneous speed} = \lvert v(t) \rvert$
Average acceleration	$\overline{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0}$
Instantaneous acceleration	$a(t) = \frac{dv(t)}{dt}$
Position from average velocity	$x = x_0 + \overline{v}t$

Key Equations

Average velocity	$\overline{v} = \frac{v_0+v}{2}$
Velocity from acceleration	$v = v_0 + at$ (constant a)
Position from velocity and acceleration	$x = x_0 + v_0 t + \frac{1}{2}at^2$ (constant a)
Velocity from distance	$v^2 = v_0^2 + 2a\,(x - x_0)$ (constant a)
Velocity of free fall	$v = v_0 - gt$ (positive upward)
Height of free fall	$y = y_0 + v_0 t - \frac{1}{2}gt^2$
Velocity of free fall from height	$v^2 = v_0^2 - 2g(y - y_0)$
Velocity from acceleration	$v(t) = \int a(t)dt + C_1$
Position from velocity	$x(t) = \int v(t)dt + C_2$

Another perspective on Kinematics

Equation

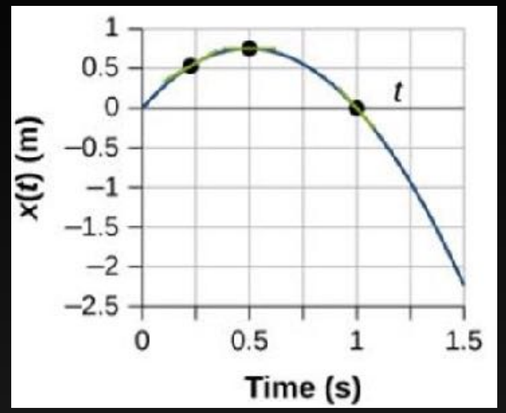
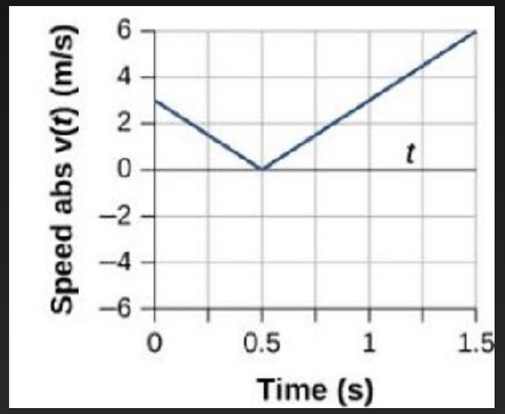
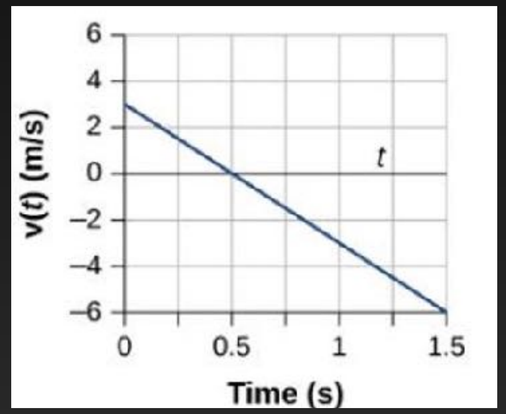
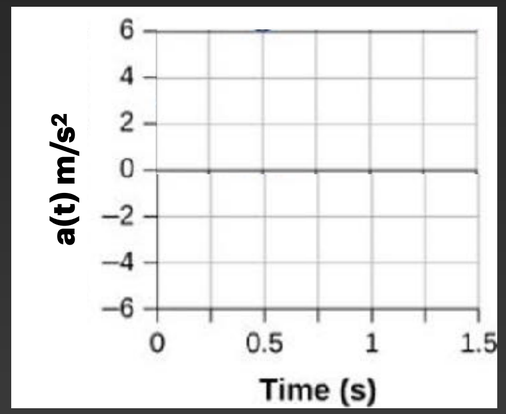
Calculus

Graphical

Displacement

Velocity

Acceleration

Equation		Calculus	Graphical
$x(t) = x_0 + v \cdot t$	Displacement		
$v(t) = v_0 + a \cdot t$	Velocity		
$a(t) = \frac{v_f - v_1}{t_1 - t_0}$	Acceleration		

Clicker Questions

CQ.3.1

Billy drops a ball from a height of $1\ \mathrm{m}$. The ball bounces and reaches a height of $0.8\ \mathrm{m}$, after the first bounce, 0.5 m after the second bounce, and lastly 0.2 m after the third bounce. The ball is caught at that final height. Up is the positive direction. What are the total displacement of the ball and the total distance traveled by the ball?

a) The displacement is equal to $-4\ \mathrm{m}$ and the distance is equal to $4\ \mathrm{m}$.

b) The displacement is equal to $-1\ \mathrm{m}$ and the distance is equal to $1\ \mathrm{m}$.

c) The displacement is equal to $4\ \mathrm{m}$ and the distance is equal to $1\ \mathrm{m}$.

d) The displacement is equal to $-1\ \mathrm{m}$ and the distance is equal to $4\ \mathrm{m}$.

A B C D E

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c) The displacement is equal to $4\ \mathrm{m}$ and the distance is equal to $1\ \mathrm{m}$.

✔ d) The displacement is equal to $-1\ \mathrm{m}$ and the distance is equal to $4\ \mathrm{m}$.

Detailed solution: The displacement is equal to $-1\ \mathrm{m}$ and the distance is equal to $4\ \mathrm{m}$.

A B C D E

CQ.3.2

Alan starts from his home and walks 1.3 km east to the library. He walks an additional 0.68 km east to a music store. From there, he walks 1.1 km north to a friend's house and an additional 0.42 km north to a grocery store before he finally returns home along the same path. What is his final displacement and total distance traveled?

a) Displacement is 0 km and distance is 7 km.

b) Displacement is 0 km and distance is 3.5 km.

c) Displacement is 7 km towards west and distance is 7 km.

d) Displacement is 3.5 km towards east and distance is 3.5 km.

A B C D E

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c) Displacement is 7 km towards west and distance is 7 km.

d) Displacement is 3.5 km towards east and distance is 3.5 km.

Detailed solution: Distance

$= d = 2\,(1.3\text{km} + 0.68\text{km} + 1.1\text{km} + 0.42\text{km}) = 4.0\text{km}$

A B C D E

CQ.3.3

Daniel set a timer before he started on a walk. He walked $1.2\,\text{km}$ north and then turned and walked $1.6\,\text{km}$ east. He then turned and walked straight back to his starting point. The timer showed that the trip took him $56.5\,\text{minutes}$. What was his average speed (in km/h) for the entire trip?

a) $5.1\,\text{km/hr}$

b) $-5.1\,\text{km/hr}$

c) $0\,\text{km/hr}$

d) $3.0\,\text{km/hr}$

A B C D E

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b) $-5.1\,\text{km/hr}$

c) $0\,\text{km/hr}$

d) $3.0\,\text{km/hr}$

Detailed solution: $d_3 = \sqrt{{d_1}^2 + {d_2}^2} = \sqrt{(1.2\,\text{km})^2 + (1.6\,\text{km})^2} = 2.0\,\text{km}$

$$v_{avg} = \frac{\Delta d}{\Delta t} = \frac{(1.2\,\text{km}+1.6\,\text{km}+2.0\,\text{km})}{56.5\ \text{min}} \times \left(\frac{60\,\text{min}}{1\,\text{h}}\right) = 5.1\,\text{km/h}$$

A B C D E

CQ.3.4

A car is moving on a straight road at a constant speed in a single direction. Which of the following statements is true?

a) Average velocity is zero.

b) The magnitude of average velocity is equal to the average speed.

c) The magnitude of average velocity is greater than the average speed.

d) The magnitude of average velocity is less than the average speed.

A B C D E

CQ.3.4

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✔ b) The magnitude of average velocity is equal to the average speed.

c) The magnitude of average velocity is greater than the average speed.

d) The magnitude of average velocity is less than the average speed.

Detailed solution: The magnitude of its velocity will be equal to the speed if the direction of motion is not changing.

A B C D E

Debrief

Displacement x(t)	Velocity v(t)	Acceleration a(t)
$x(t) = 4t^2 + 3t + 2$	$v(t) = 8t + 3$	$a(t) = 8$
$x(t) = 2t^2 + 8$		
$x(t) = 8t^3 + 3t$	$v(t) = 24t^2 + 3$	
$x(t) = -t^3 + 5t^2 + 3t$		

Debrief

Displacement x(t)	Velocity v(t)	Acceleration a(t)
$x(t) = 4t^2 + 3t + 2$	$v(t) = 8t + 3$	$a(t) = 8$
$x(t) = 2t^2 + 8$	$v(t) = 4t$	$a(t) = 4$
$x(t) = 8t^3 + 3t$	$v(t) = 24t^2 + 3$	$a(t) = 48t$
$x(t) = -t^3 + 5t^2 + 3t$	$v(t) = -3t^2 + 10t + 3$	$a(t) = -6t + 10$

See you next class!

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