APPENDIX 3: MECHANICS

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Appendix 3.1: Working with the Modes of Representation

1. Define the following terms:
   a) interpolation
   b) independent variable
   c) dependent variable
   d) line of "best fit"

2. Some of the variables affecting the rate of growth of a plant are amount of sunlight, temperature, amount of water, and amount of fertilizer added. Write the procedure designed to show how the amount of water affects the rate of growth of a plant. Be specific.

3. Sketch a graph that shows each of the following mathematical relationships. Include the following in your response:
   - Describe what is happening with the dependent variable as the independent variable is ***increasing***.
   - If the x-axis had data values of 2, 4, 8, and 9, what would be the corresponding values on the y-axis?
   - Describe a simple situation from your own experiences that might produce a graph of the shape you have drawn.

   a) 2nd power
   b) square root
   c) $y = 5$
   d) $y = 1/x$

In the following examples, you will be working with the *four modes of representation*: visual, numerical, graphical, and symbolic.

In each example, include a statement that answers the following:

✓ **Visual Mode:** What would you see if you or a friend witnessed the event?

✓ **Numerical Mode:** Describe any relationships you see between the variables in the data.

✓ **Graphical Mode:** Plot the graph and state, in words, any patterns or relationships you see.

✓ **Symbolic Mode:** Using your skills in manipulating data, determine a mathematical relationship between the variables, and state this in *equation form* as words and symbols.

4. An object is dropped from the top of a smokestack near a mine in Thompson. The distance the object has fallen is measured at certain times, as indicated in the data below.

Time (s)	1.1	1.8	2.5	3.8	4.5
Distance (m)	5.4	17	31	72	98

Use the ***four modes of representation*** outlined on the previous page as you work through this example.

5. An object travels in a circle of fixed radius. The speed, v, is measured for the object travelling around the circle with different periods, T. The following data were collected.

Time (s)	0.95	1.2	1.5	1.9	2.5
Speed	13	10	8.3	6.7	4.9

Use the ***four modes of representation*** outlined on the previous page as you work through this example.

6. A mass suspended from a spring vibrates within a certain period. When the mass is changed, it is noticed and recorded that the period also changes.

Mass (kg)	0.50	0.75	0.90	1.10	1.50	1.90
Time (s)	0.44	0.55	0.60	0.65	0.78	0.88

Use the ***four modes of representation*** outlined on the previous page as you work through this example.

7. Until the plate tectonics model accounted for the separation of the continents, the idea of an *expanding Earth* was treated very seriously by geophysicists. According to one model, the radius of Earth changed with its volume as follows (we won't use units this time!):

Volume	4.52	14.14	25.25	30.92	34.27	42.45
Radius	1.03	1.50	1.82	1.95	2.02	2.16

Use the ***four modes of representation*** outlined on the previous page as you work through this example.

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Appendix 3.2: A Vector Journey

Object: To determine the displacement between two points on a plane (the floor of the school).

Apparatus: Measuring device such as a metre stick or a measuring tape.

Procedure:

- Start at a given point.
- Using a metre stick or measuring tape, measure the vectors in the north-south direction and the east-west direction that are needed to proceed from the starting point to the end point of your journey.
- The front of the school is (north, south, east, west?) and the gym side of the school is (north, south, east, west?).
- Use any lines on the floor to aid you in maintaining the proper direction.
- List all the vector displacements measured to the nearest 0.1 m in the order that the measurements were made.
- Add these vector displacements in the order that they were made, using a scale diagram.
- Add the collinear vectors for the east-west direction and for the north-south direction. Add these mathematically, using Pythagoras and trigonometry. Include a sketch.
- Repeat these steps for your second vector journey.
- Choose two of the following journeys, making sure they are from different floors.

Teachers: The following "vector journeys" are samples. Please modify as required

Main Floor	Start	Finish
	Phys. Ed. Office door	Room ______ door
	Pay phone	Counter in the general office
	Door to Room ______	Door to Library
	Vending machine	Door to Computer Lab
Lower Level		
	Cafeteria door	Back stairwell
	Teacher's desk	Eyewash station in the science lab
	Door to room ______	Door to chemical storage room
Upper Level		
	Stereo in the student lounge	Door to Room ______
	Front stairs	Stereo in the student lounge

Report:

- For each journey, list the displacements measured in the order they were measured.
- Write a description of your journey.
- Show the work in determining the displacement for each journey, both by a scale diagram and through mathematical calculations.
- How do the displacements found by the different methods compare?

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Appendix 3.3: Journal Entry on Vectors

Part A

Using the Three-Point Approach Frame (supplied to you), define and illustrate the following terms.

Vector	Magnitude	Quantity
Scalar	Direction	Unit
Vector diagram	Scale	Collinear vectors
Vector components	Reference system	Resultant

Part B

Answer the following questions in your journal.

1. Find the components of the following vectors:

   a) $\vec{A}$ = 358 km 16.0° north of west

   b) $\vec{B}$ = 0.255 m/s/s NW

   c) $\vec{N}$ = 1.25 m/s 50.2° south of east

2. What is the vector for which the components are 38.3 m E and 71.6 m S?

3. Add the following vectors, using the algebraic method: $\vec{A}$ = 6.35 m N and $\vec{B}$ = 9.23 m W. Write a description of the steps performed to add these vectors.

4. Add the vectors $\vec{A}$ and $\vec{B}$ from the previous question, using a scale diagram. Again, write a description of the steps performed to add these vectors, using a scale diagram.

5. A plane is flying at 225 km/h east. Some time later, it is flying at 225 m/s south. What is the change in velocity?

6. Given the vectors:

   $\vec{A}$ = 0.250 m E; $\vec{B}$ = 0.350 m E; $\vec{C}$ = 0.150 m N

   Determine:

   a) $\vec{A} + \vec{B} + \vec{C}$, in that order, using a ***scale diagram***.

   b) $\vec{B} - \vec{C}$. Write a description of the steps performed in finding this difference.

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Appendix 3.4: A Vector Sampler

1. Distinguish between a vector and a scalar. Illustrate each with an example.

2. Determine the components of the vector $\vec{M}$ = 45.7 m/s 18.7° east of south.

3. A boat can travel in still water at 2.78 m/s. The boat is on a river that flows at 1.24 m/s in a southerly direction. Calculate the velocity of the boat relative to the shore if:

   a) the boat heads upstream.

   b) the boat heads downstream.

   c) the boat heads in an easterly direction across the river.

4. For the boat and the river in Question #3, what heading must the boat take to land on the western shore of the river directly west of the starting point on the east shore?

5. A plane flies at an airspeed of 225 km/hour west. A south wind is blowing at 105 km/hour. Determine the velocity of the plane as observed from the ground.

6. Given the vectors:

   $\vec{K}$ = 28 900 m South, $\vec{L}$ = 17 400 m West

   $\vec{M}$ = 21 200 m East, $\vec{N}$ = 15 700 m North

   Determine the following using the suggested strategy:

   a) $\vec{K} + \vec{L} + \vec{N}$, in that order using a *scale diagram*.

   b) $\vec{M} - \vec{N}$, using *trigonometry.*

   c) $\vec{K} + \vec{L} + \vec{M} + N$, using *trigonometry*.

   d) $\vec{M} - \vec{L}$

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Appendix 3.5: Analysis of Data Using *Microsoft Excel*

Instead of manually drawing your graphs of the raw data and then manipulating the data, you can easily do the graphing in *Excel*. Follow the same three steps, namely:

1. Draw the graph of the raw data.
2. If the line is not straight, use proportioning to determine the variance and manipulate the data to create a new data chart.
3. Graph these manipulated data and find the equation, using

   Dependent Variable = (Constant) x Independent Variable,

   where the constant is the **slope** of the graph.

Using *Excel*:

Open *Excel* and enter the following data:

Pressure (ATM)	Volume (L)
1.25	20.0
2.00	12.5
3.33	8.02
4.24	5.82
6.89	3.50

1. Graphing the Raw Data

Select the two columns including the headings.

Select the Chart Wizard.

Step 1: Select the X-Y Scatter option, then choose the “Scatter connected by smooth lines” type of graph. Click “Next.”

Step 2: This should be fine. Click “Next.”

Step 3: Fill in the titles. Y = Volume (L), X = Pressure (ATM).

Select the “Gridlines” tab and select major axis and minor axis for both X and Y. This produces a grid on your graph.

Click “Next.”

Step 4: Select “Place object in Sheet 1.”

Click “Finish.”

This gives you a graph of the **raw data**. Note that the line is a curve representing an **inverse** or **indirect** relation.

2. Manipulating the Data

You must now manipulate the data so that you can obtain a **straight-line** graph. The graph suggests you must take the reciprocal of the **pressure** and make a new chart.

Make two headings: **1/Pressure (ATM^{-1})** and **Volume (L)**.

In the first cell below the **1/Pressure** heading, type =1/.

Then, select the first cell below the **pressure** heading in the raw data.

The designation of that cell (i.e., A2) should appear. You should now see 1/A2.

Press **Enter** and the calculated value of the reciprocal of the pressure appears.

Select this calculated value and a box with a cross in the lower right-hand corner will appear. Drag this cross down the column and the remaining values will be calculated for 1/Pressure.

Select the volume readings, then cut and paste into the new table.

Here is what you should have:

1/Pressure (ATM)$^{-1}$	Volume (L)
0.800	20
0.500	12.5
0.300	8.02
0.236	5.82
0.145	3.5

Now, repeat the steps in “Graphing the Raw Data” to make a graph of the manipulated data.

Your graph should be **almost** a straight line.

To make the **Best Fit Line**, select Chart from the menu bar, then select Add Trendline. Under the Type tab, choose Linear.

Select OK.

Resize the graph to make it larger.

Click on the graph in between gridlines to call up the Format Plot Area.

In the Area section, select white as the colour and click OK.

You now have a straight-line graph!

3. Making the Equation

The proportional relationship is:

Volume α 1/Pressure

and the equation is V = (K)(1/P).

From the graph, find the slope. Pay attention to units.

$$\text{Slope} = \frac{\Delta V}{\Delta(1/P)} = \frac{25\ \text{L}}{\text{ATM}^{-1}}$$

$$\text{Volume} = \frac{25\ \text{L}}{\text{ATM}^{-1}}\ (1/\text{Pressure})$$

To find the **slope** of the graph, use the Linset function.

Syntax =Index(Linset(array of Y values, array of X values),1)

All other relations are analyzed in the same way except for the manipulation of the raw data.

Here are the formulas you need, in *Excel*, in order to manipulate the data for:

1. Second power (exponent of "2")

   =POWER(number, power)

   Example =Power(8,2)

   Press Enter to obtain 64

   In the table you are making, in the Formula Bar (where your typing appears), replace the "number" with the cell designation of the first reading, (i.e., = POWER(A2,2)). Then proceed to change the rest of the data.

2. Third power (exponent of "3")

   =POWER(number,3)

3. Inverse square (exponent of "–2")

   =POWER(number,–2)

4. Square root (exponent of "½")

   =POWER(number,0.5)

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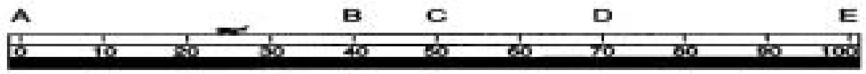
Appendix 3.6: Describing Motion in Various Ways

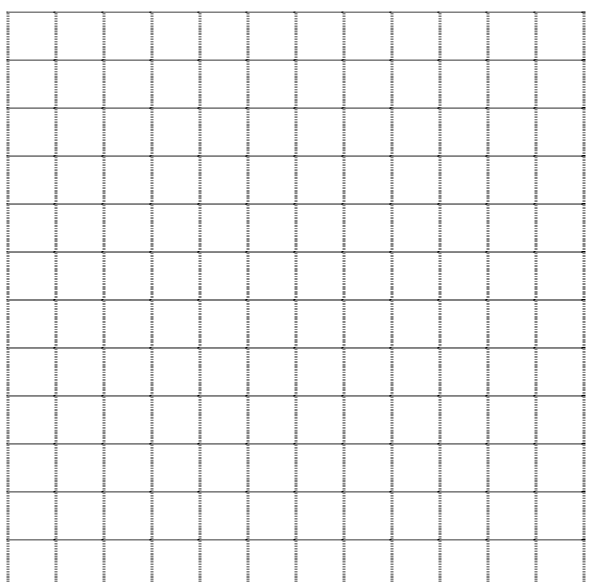


1. A somewhat confused ladybug is moving back and forth along a metre ruler. Determine both the displacement and distance travelled by the ladybug as it moves from:
   a) A to B
   b) C to B
   c) C to D
   d) C to E and then to D.

2. In the diagram above, EAST points to the RIGHT. During which of the intervals in #1 is the ladybug moving in the EASTERLY direction? In the WESTERLY direction?

3. Below is a table showing the position above the ground floor of an elevator at various times. On the graph to the right of the table, plot a graph of position-time.

Time (seconds)	0	4	8	12	16	20	24
Position above the ground floor (m)	4.0	8.0	8.0	16	20	20	12



4. A troubled student is waiting to see the principal. He paces back and forth in the hallway in front of the principal's office. The hallway runs north and south. The door to the office is our origin, 0 m. Here is a description of the student's motion.

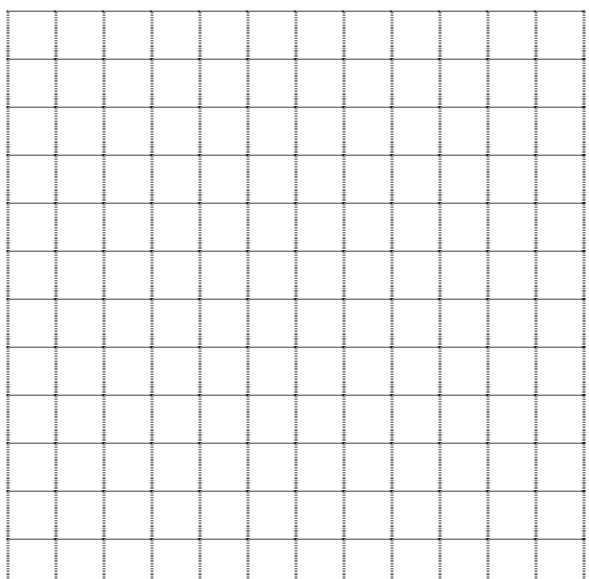
   The student starts at 5.0 m N. He walks to the south for 7.0 m during 10 s. He stands still for 5.0 s. He turns around and walks 15.0 m N during 15.0 s. He stops to say "Hello" to a friend and remains still for 10.0 s. Finally, the principal calls him to the office door. It takes the student 10.0 s to reach the door.

   a) What is the total time the student spent in the hallway?

   b) What was the distance travelled by the student during his pacing?

   c) What was the average speed of the student during his pacing?

   d) On the graph below, plot time on the horizontal axis and position on the vertical axis. Use straight-line segments to join the points of position-time that you plot.



   e) What is the total displacement for the student's journey? Find this from the graph.

   f) What is the average velocity for the whole journey?

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Appendix 3.7: Introducing Motion: Position, Time, Distance and Speed, Displacement, and Velocity

Purpose: To determine the position of a person moving in a straight line at different instants in time.

To interpret a position-time graph to obtain distance travelled, speed, displacement, and velocity.

Apparatus

50 metres of hallway or field, stopwatches, measuring tape

Procedure

Part A:

- Using the measuring tape, mark off 5-m intervals along the edges of some floor tiles. Place a piece of masking tape at each 5-m mark. Mark these positions using small signs, like yardage markers along the sidelines of a football field.
- Have a student with a stopwatch stand at each of the markers.
- Have one student begin at the 0-m mark. When the student begins to move, all timers start timing with the stopwatches.
- The student is instructed to walk at a constant rate the full length of the course. As the walking student passes each timer, the timer will stop the stopwatch.
- The timers will then share their times and positions with the group.

Observations

Description of motion:

Draw a picture of the motion:

Time (seconds)											
Position (metres)											

On the graph below, label time on the horizontal axis and position on the vertical axis and plot the points from the data table. Draw in the line of best fit.

Procedure

Part B

The student will start from the 0-m mark this time and walk more quickly than before but at a constant rate over the whole course. Again, the timers will start timing when the student begins to move and stop timing when the student passes the timers' positions.

Observations

Description of motion:

Draw a picture of the motion:

Time (seconds)											
Position (metres)											

Plot this information on the graph above, using a different colour for these points. Draw in the line of best fit.

Procedure

Part C

The student will start from the 0-m mark this time and run at a constant rate over the whole course. Again, the timers will start timing when the student begins to move and stop timing when the student passes the timers' positions.

Observations

Description of motion: Draw a picture of the motion:

Time (seconds)											
Position (metres)											

Plot this information on the graph, using a third colour for these points. Draw in the line of best fit.

1. Using the descriptions of the motion, how do the starting points compare for the three trials?

2. From the graph, determine the starting point for each of the three trials. Compare these to the answers in Part B.

3. From the description of the motions, what is the same about all three motions?

4. From the description of the motion, what is different about the three motions?

5. On the graph, what is different about the three lines?

Procedure

Part D

The student will start from last mark this time and walk quickly but at a constant rate over the whole course, ending up at 0 m. Again, the timers will start timing when the student begins to move and stop timing when the student passes the timers' positions.

Observations

Description of motion:

Draw a picture of the motion:

Time (seconds)											
Position (metres)											

Plot this information on the graph (in Part A), using a fourth colour for these points. Draw in the line of best fit.

Analysis

1. How does this fourth line differ from the other three lines on the graph?

2. From the description of the motions, can you relate something about the line to the motion it represents?

   Line 1:

   Line 2:

   Line 3:

   Line 4:

Procedure

Part E

Station two timers at the 10-m mark. The student will start from the 0-m mark this time and walk quickly to the 10-m mark. The first timer will stop the stopwatch. The student will stay at the 10-m mark for a slow count of 5. At the count of 5, the second timer will stop his stopwatch and the student will resume her journey covering the whole course at a slower pace than before. Again the timers will start timing when the student begins to move and stop timing when the student passes the timers' positions.

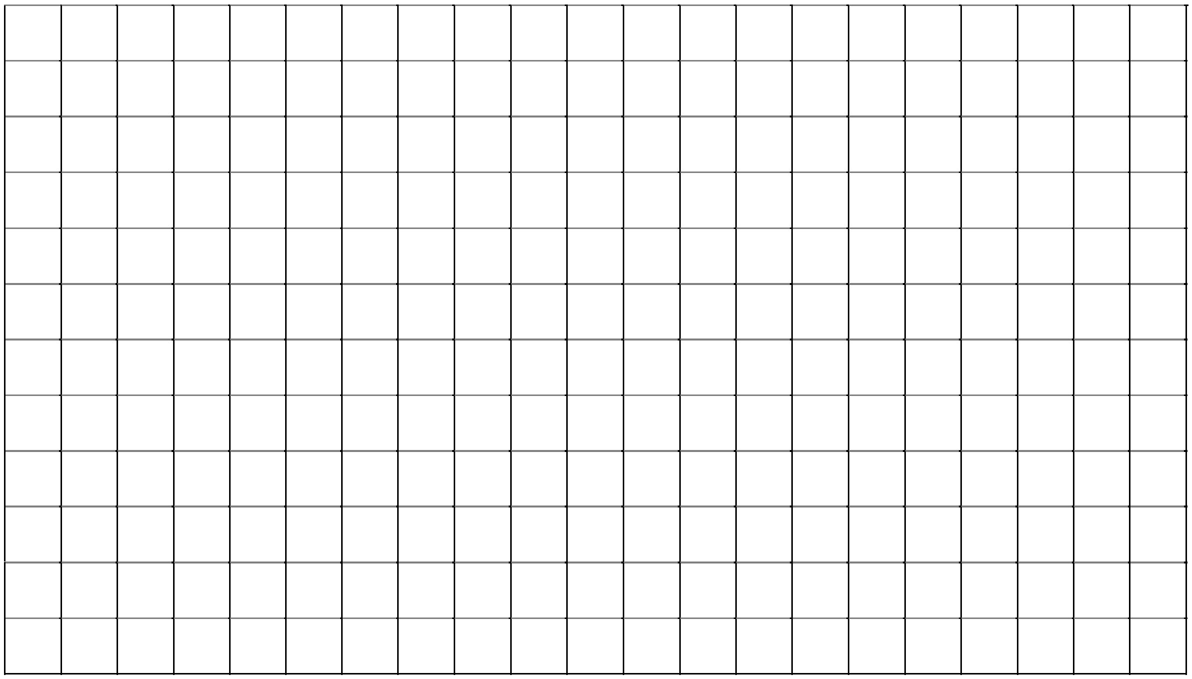
Observations

Description of motion:

Draw a picture of the motion:

Time (seconds)											
Position (metres)											

Plot this information on the graph below. Plot position on the vertical axis and plot time on the horizontal axis. **Do not draw a line of best fit.** Instead, draw a line of best fit for each section.



Analysis

1. What is different about each section of the graph drawn on the previous page?

2. Go back to the description of the motion. What does the graph look like when the student is moving quickly? Not moving? Moving slowly?

Conclusion

Describe the information one is able to obtain **directly** from a position-time graph.

We can obtain more indirect information from a position-time graph by looking at the line. Describe the information we can obtain **indirectly** from a position-time graph.

Questions

1. Distinguish between distance travelled and displacement.

2. Distinguish between average speed and average velocity.

3. For each trial (A through E), calculate the total distance travelled. Obtain the information from the graph.

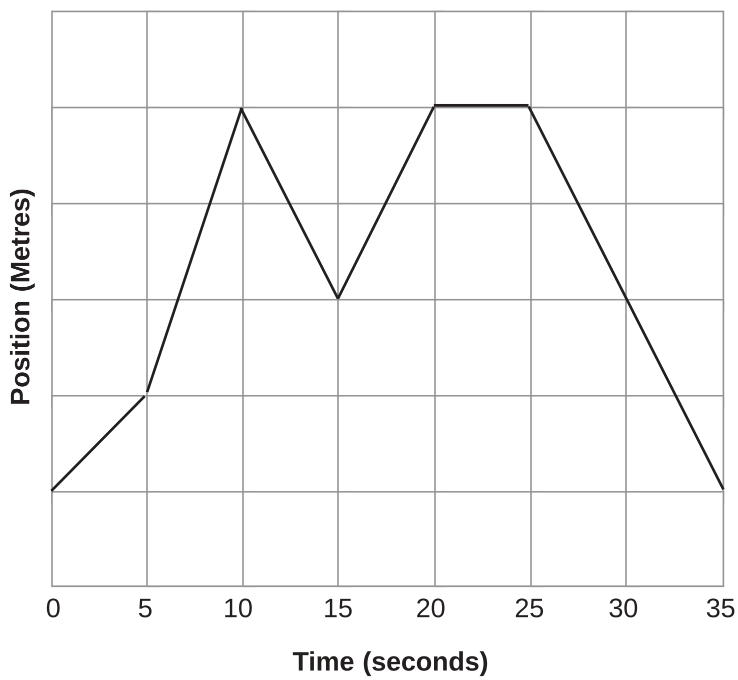
4. For each trial (A through E), calculate the total time for the journey. Obtain the information from the graph.

5. For each trial (A through E), calculate the average speed. Show the equation and the work for each calculation.

6. For each trial (A through E), calculate the **displacement** for the whole journey. Obtain the information from the graph.

7. For each trial (A through E), calculate the **average velocity** for the journey. Show the equation and the work for each calculation.

8.



The graph of position-time above shows the position of a soccer linesman running along the sideline of a soccer field during a soccer game.

The 0-m mark is located at the goal line at the south end of the field. All the positions are marked north of that starting point.

a) Where does the linesman start his journey?

b) During which time intervals is the linesman moving to the north?
   To the south?
   Not moving?

c) What is the distance travelled and the displacement for each interval listed below? Include direction with displacement.

Time Interval	Distance Travelled	Displacement
0–5 seconds		
5–10 seconds		
10–15 seconds		
15–20 seconds		
20–25 seconds		
25–35 seconds		

d) Calculate the average speed and the average velocity of the linesman for each time interval.

Time Interval	Average Speed	Average Velocity
0–5 seconds		
5–10 seconds		
10–15 seconds		
15–20 seconds		
20–25 seconds		
25–35 seconds		

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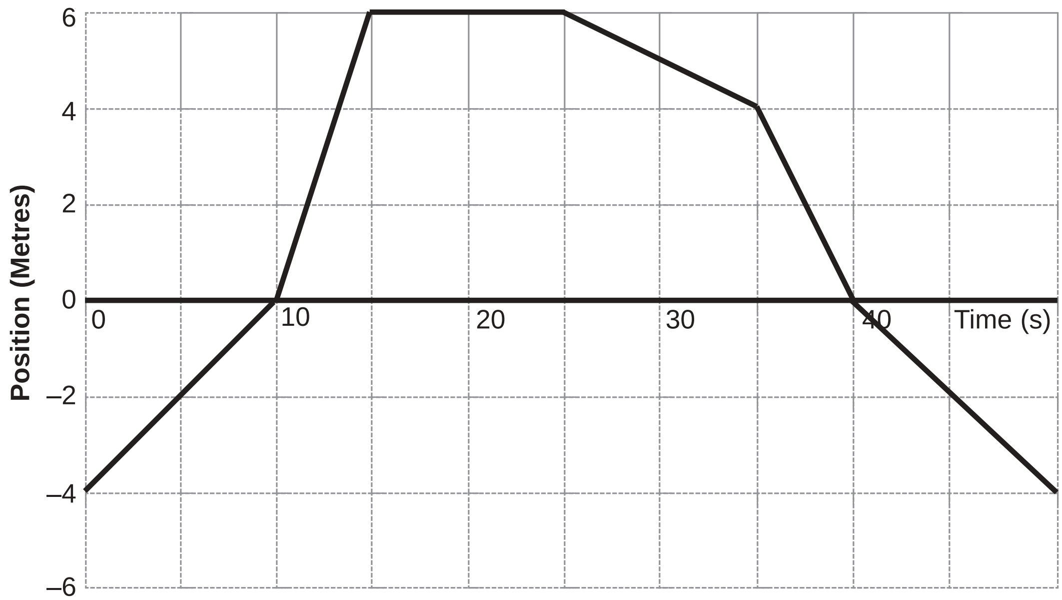
Appendix 3.8: Motion: Interpreting Position-Time Graphs



The position-time graph above represents the motion of a remote-controlled toy truck as it moves back and forth along a straight line. The origin marks the position of the boy who controls the truck. The boy has not yet learned how to make the truck change its direction.

A positive position marks positions to the right of the boy, and a negative position marks positions to the left of the boy.

1. During which time intervals is the truck to the right of the boy?

   To the left of the boy?

2. During which time intervals is the truck moving in the positive direction?

   In the negative direction?

   Not moving?

3. What is the position of the truck at 0 seconds? _____ 15 seconds? _____

   30 seconds? _____ 45 seconds? _____

4. When is the truck in front of the boy?

5. Describe, in words, the position-time story of the motion that the truck showed during this 50-second interval.

The graph of position-time gives **directly** some information about the motion. This tells the position-time version of the story of this motion (that is, where the truck is at a particular instant in time).

The graph of position-time also gives **indirect** information about the motion of the truck. The following questions deal with obtaining this indirect information, such as distance travelled, displacement, average speed, and average velocity.

6. How far did the truck travel during the following time intervals?

0–10 s ________ 10–15 s ________ 15–25 s ________

25–35 s ________ 35–40 s ________ 40–50 s ________

7. What was the displacement of the truck during the following intervals?

0–10 s ________ 10–15 s ________ 15–25 s ________

25–35 s ________ 35–40 s ________ 40–50 s ________

8. Average speed is given by the distance travelled divided by the time interval. Calculate the average speed for each interval:

0–10 s ________

10–15 s ________

15–25 s ________

25–35 s ________

35–40 s ________

40–50 s ________

9. The following relationship is used to calculate average velocity:

average velocity = displacement/time interval or $\vec{v}_{\text{average}} = \frac{\overrightarrow{\Delta d}}{\Delta t}$.

This relationship also represents the slope of the line on a position-time graph. Calculate the average velocity for each time interval by calculating the slope of the line segment. Show your work.

Run = Δt **Time Interval**	**Rise = Δd** **Displacement**	**Slope = $\vec{v}_{\text{average}} = \frac{\overrightarrow{\Delta d}}{\Delta t}$**

10. How do the signs (+, –) of the velocities in Question #9 above compare with the direction of motion in Question #2?

11. In terms of the truck's motion, what does a negative velocity mean?

A positive velocity?

A velocity of 0 m/s?

12. Draw a chord joining the initial position of the truck at 0 s to its final position at 50 s. The slope of this chord represents the average velocity for the whole journey. Calculate the ***average velocity*** for the whole journey represented by the position-time graph.

13. Displacement is a **vector** quantity. It is always stated with a direction. Distance travelled is just how far an object moves without regard to direction. Distance is a **scalar** quantity.

    From the chart on the previous page, determine the distance travelled during each time interval and then calculate the total distance travelled during the 50-s interval.

    Calculate the **average speed** of the truck.

14. The average speed for any time interval can be found by drawing a chord joining the position at the first instant in time to the position at the second instant in time. The slope of this chord gives the average velocity for that interval.

    Calculate the average velocity for the time interval from 5 s to 35 s.

    Calculate the average velocity for the time interval from 15 s to 50 s.

Summary for Analyzing Position-Time Graphs:

1. What information is given directly from a position-time graph?

2. What information is given indirectly from a position-time graph?

3. How is average speed calculated from a position-time graph?

4. How is average velocity calculated from a position-time graph?
   a) For a given interval?

   b) For the whole journey?

5. Just by looking at a position-time graph, what can you tell from the slope?

6. Relate the velocity-time version of the story of the motion of the truck.

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Appendix 3.9: Journal Entry: Kinematics (Position and Velocity)

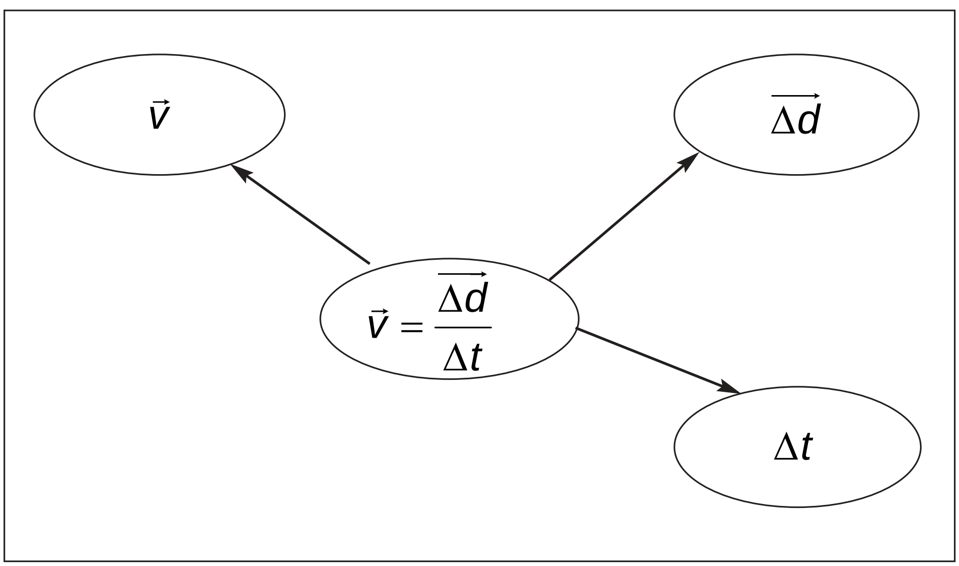
Part A

1. On the Three-Point Approach form, define and illustrate the following terms:

Frame of reference	Kinematics	Clock reading
Time interval	Position	Displacement
Slope	Rate	Speed
Uniform motion	Constant velocity	Tangent
Instantaneous velocity	Constant speed	

2. On the Compare and Contrast Frame, compare and contrast the following:
   a) velocity and speed
   b) average velocity and average speed

3. Complete the Category Concept Map for the following:



Part B

1. What is the average velocity of a child making one revolution of a merry-go-round? Explain.

2. Sylvia claims that the average speed and the average velocity for the ferry trip between Saint John, NB, and Digby, NS, are the same. Is she correct? Explain.

3. A hunter travels 1.25 km east for 20.0 minutes. He then travels 0.650 km south for 12.0 minutes. Finally, he travels 2.15 km west for 25.0 minutes.

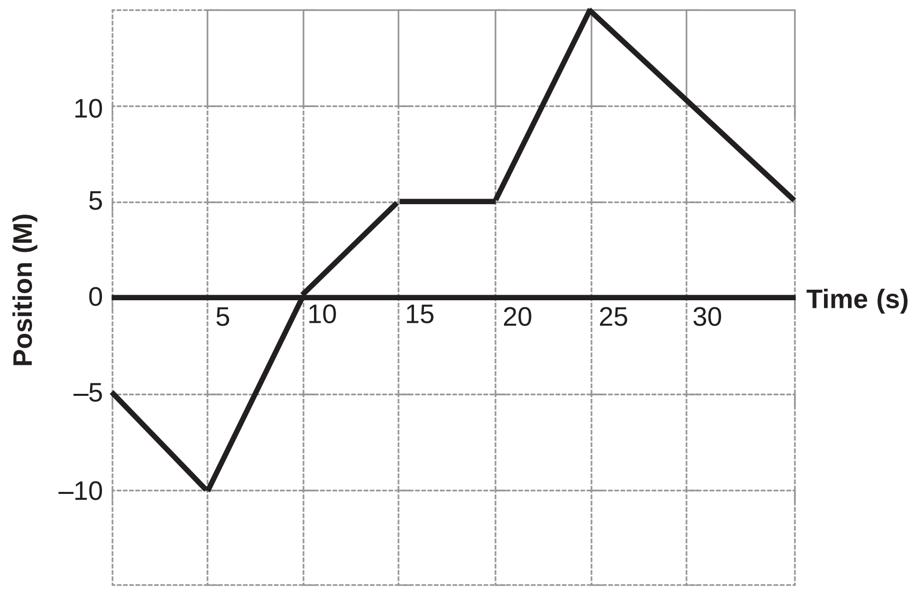
   a) What distance did the hunter travel?

   b) What is the displacement of the hunter?

   c) What is the average speed of the hunter in m/s?

   d) What is the average velocity of the hunter in m/s?

4.



The graph above depicts the motion of a student who, while waiting to see the principal, is pacing the hallway outside the principal's door. The principal's door is at the origin.

a) Make a chart finding the velocity for each interval.

b) Draw a graph of this velocity-time data.

c) Calculate the average speed and the average velocity for this journey.

d) Write a story describing the motion of this student depicted by your graph of velocity-time.

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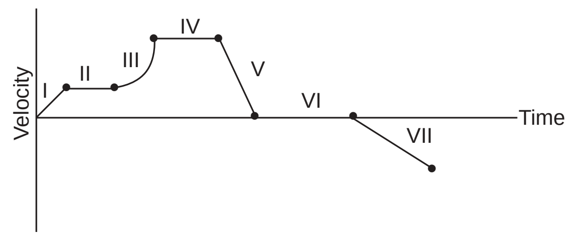
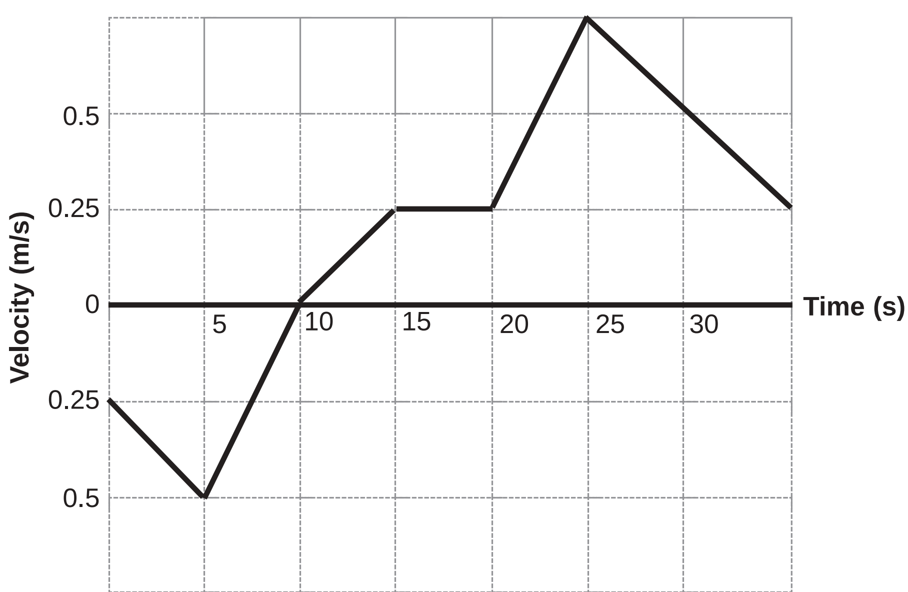
Appendix 3.10: Kinematics: Position, Velocity, and Acceleration Graphs

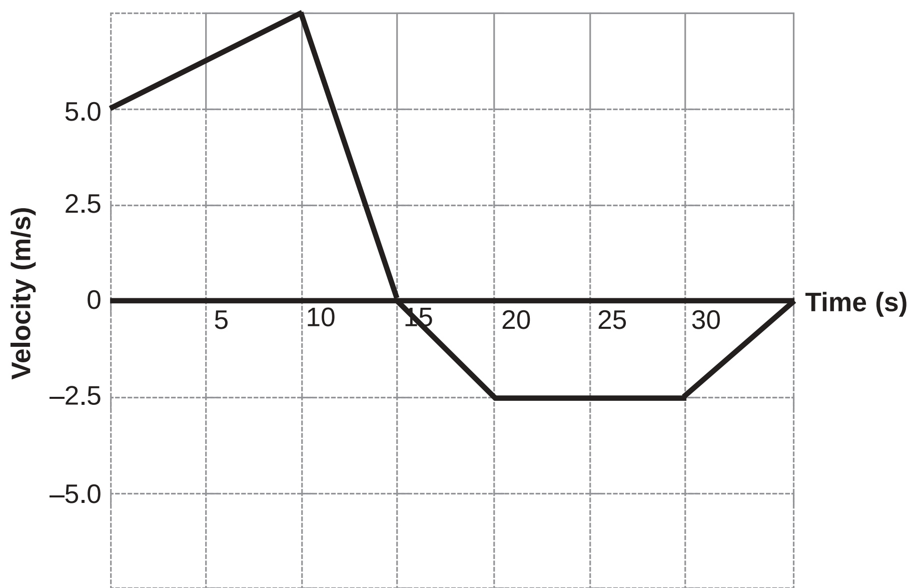


1. The graph above represents the velocity as a function of time for an object that is moving back and forth along a straight line.
   a) For each interval:
      i) indicate whether the velocity is positive, negative, or zero.
      ii) indicate whether the velocity is steady, increasing at a steady rate, increasing at a rate that is not steady, decreasing at a steady rate, decreasing at a rate that is not steady.
      iii) indicate whether the acceleration is positive, negative, or zero.
   b) Over which interval would the object travel through the greatest distance? Assume that each segment of the graph lasts for the same amount of time. Explain your answer.



2. For the graph of velocity-time given above, plot a graph of position-time.
   a) Make a table indicating how the positions were calculated. At t = 0 s, x = 3.0 m.
   b) Plot the graph of position-time.

3. For the velocity-time graph used in Question #2 on the previous page, plot a graph of acceleration-time.
   a) Make a table showing how the acceleration was calculated for each interval.
   b) Draw the acceleration-time graph.
   c) Determine the average acceleration between 5 s and 20 s.
4. A basketball is thrown straight upwards. The ball slows down as it rises, comes to a stop, and returns to the person's hand with the same speed with which it was thrown upwards. One beneath each other, draw graphs of position-time, velocity-time, and acceleration-time for this motion.

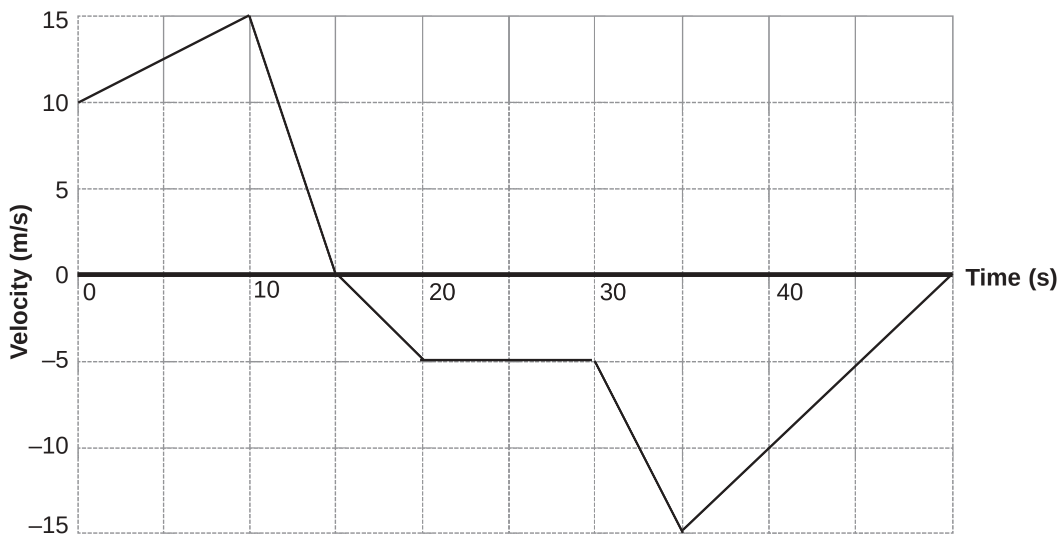


5. For the graph above, if the positive direction is west, determine the following:
   a) the instantaneous acceleration at 20 s.
   b) the instantaneous acceleration at 10 s; at 30 s.
   c) the time interval during which the speed is the largest.
   d) the time interval(s) during which the displacement is negative.

SLA
Student Learning Activity

Appendix 3.11: Kinematics and Graphing Skills Builder

1. a) For the graph below, make a chart and draw the graph for position-time. Assume the object starts at 7 at a position of –12 m.



   b) For the graph above, plot a graph of acceleration-time.

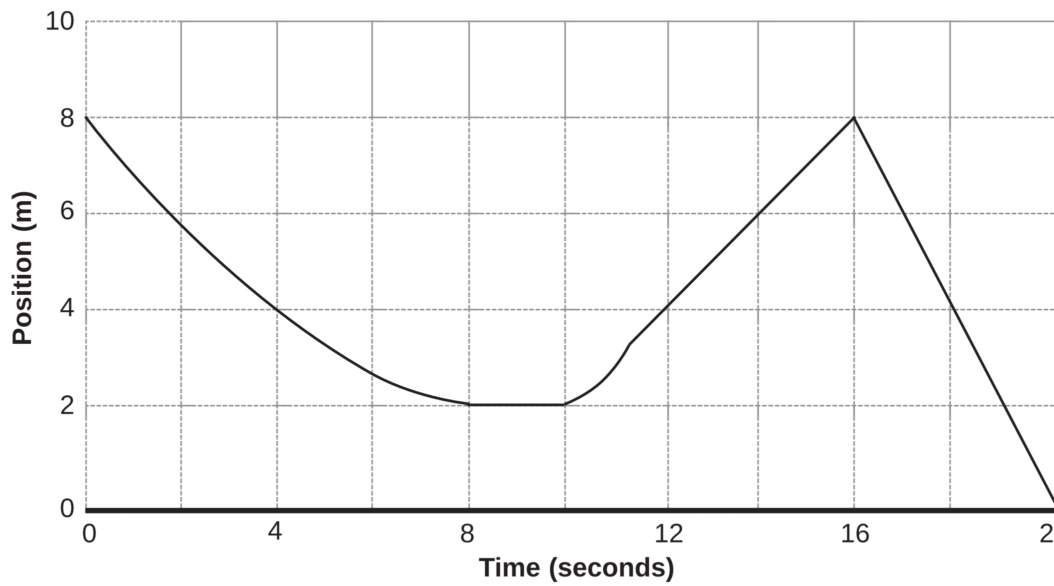
   c) Calculate the average velocity.

   d) Calculate the average acceleration.

2. For the graph below:

   a) determine the instantaneous velocity at 5.0 s.

   b) demonstrate the time intervals when the velocity was positive and when it was negative.

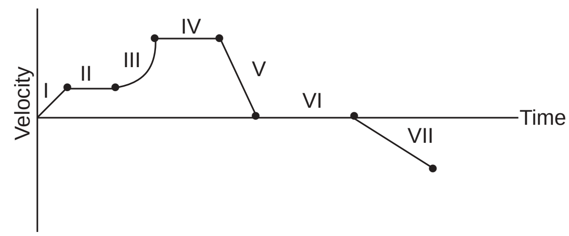


3. Describe how to obtain the instantaneous acceleration from a graph.

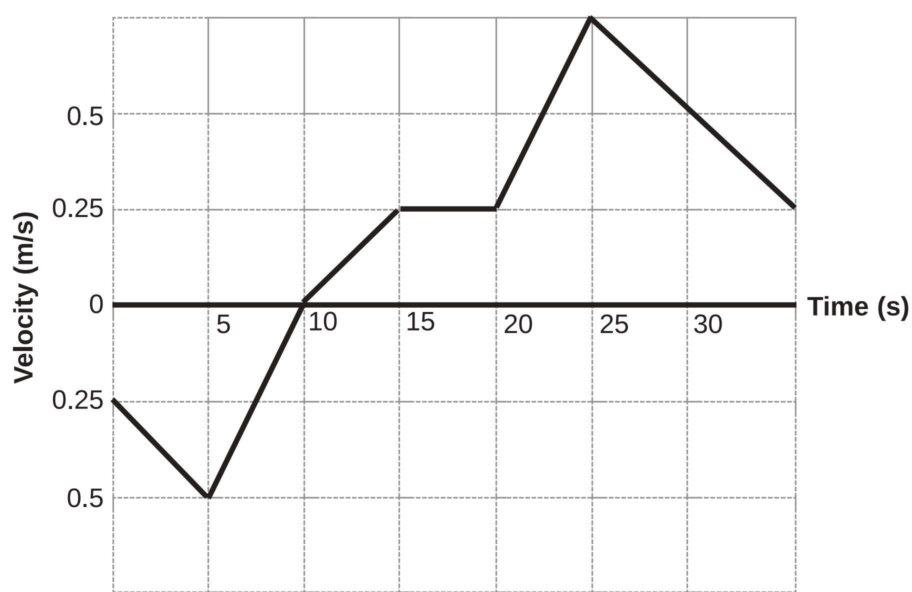
4. A basketball coach assigns his players to run the lines on the basketball court. A player must start at one endline of the basketball court, run to the centre line, stop, touch the line, and return to the endline from which she started, stop, and then touch that line. She must then run to the far endline, stop, touch the line, run back to the starting endline, and stop. Draw possible graphs of this motion, one below the other, of position-time, velocity-time, and acceleration-time.

SLA
Student Learning Activity

Appendix 3.12: Kinematics: Position, Velocity, and Acceleration Graphs, and Their Equations



1. The graph above represents the velocity as a function of time for an object that is moving back and forth along a straight line.
   a) For each interval:
      i) indicate whether the velocity is positive, negative, or zero.
      ii) indicate whether the velocity is steady, increasing at a steady rate, increasing at a rate that is not steady, decreasing at a steady rate, decreasing at a rate that is not steady.
      iii) indicate whether the acceleration is positive, negative, or zero.
   b) Over which interval would the object travel through the greatest distance? Assume that each segment of the graph lasts for the same amount of time. Explain your answer.



2. For the graph of velocity-time given above, plot a graph of position-time.
   a) Make a table indicating how the positions were calculated.
      At t = 0 s, x = 3.0 m.
   b) Plot the graph of position-time.

3. For the velocity-time graph used in Question #2, plot a graph of acceleration-time.
   a) Make a table showing how the acceleration was calculated for each interval.
   b) Draw the acceleration-time graph.
   c) Determine the average acceleration between 5 s and 20 s.

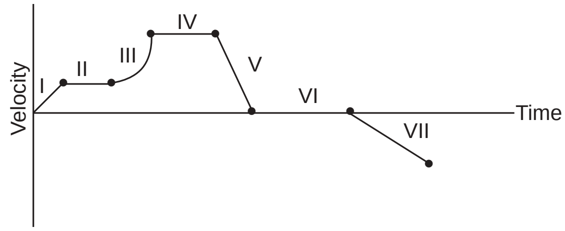
4. A Corvette can accelerate from a dead stop to 100 km/h in 10.2 s.
   a) Determine the acceleration of the car in m/s/s.
   b) How far did the car travel during this time?

5. A sprinter accelerates from rest to a velocity of 9.25 m/s while travelling 25.0 m. The sprinter then runs at a constant velocity for the next 75.0 m.
   a) Determine the time it took for the sprinter to reach a speed of 9.25 m/s.
   b) How long did it take the sprinter to run the 100 metres?

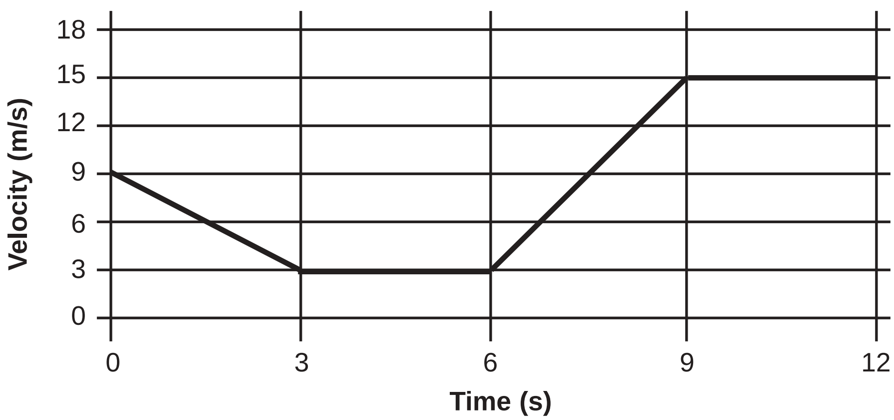
6. You are driving your car at 15.8 m/s E as you approach an intersection. Having good reflexes, it takes you 0.450 s to react and step on the brakes. The brakes cause the car to accelerate at 8.50 m/s/s W.
   a) What distance will the car travel during the braking before it slows to 10.8 km/h E?
   b) What is the time interval during which the car is brought to a stop?

SLA
Student Learning Activity

Appendix 3.13: Kinematics Sampler: Graphs, Equations, and Problem Solving



1. The graph above represents the velocity as a function of time for an object that is moving back and forth along a straight line.
   a) For each interval:
      i) indicate whether the velocity is positive, negative, or zero.
      ii) indicate whether the velocity is steady, increasing at a steady rate, increasing at a rate that is not steady, decreasing at a steady rate, decreasing at a rate that is not steady.
      iii) indicate whether the acceleration is positive, negative, or zero.
   b) Over which interval would the object travel through the greatest distance? Assume that each segment of the graph lasts for the same amount of time. Explain your answer.



2. The graph above represents velocity as a function of time for an object moving back and forth along a straight line.
   a) Plot a graph of acceleration versus time for this object.
   b) Plot a graph of position versus time for this object.

3. A ball is thrown to the floor, bounces, and returns to the thrower's hand. Sketch graphs showing the position of the ball as a function of time, the velocity of the ball as a function of time, and the acceleration of the ball as a function of time. Assume that the ball is in contact with the ground for a negligible time interval and that the ball rises off the ground with the same speed it had when it first hit the floor. Assume upward to be the positive direction and the ground to be the zero point.

4. The table below shows the velocity of a car at various times. By looking at the table, but without substituting into any formulas, determine the acceleration of the car. Explain your answer in words.

Time (seconds)	**Velocity (m/s)**
0.0	2.5
1.0	3.2
2.0	3.9
3.0	4.6
4.0	5.3
5.0	6.0

5. A car has an initial speed of 16.7 m/s and accelerates at 2.5 m/s^2 for another 8.1 seconds. What is the final speed of the car?

6. A car is initially moving at 28.4 m/s. In a panic stop, the car can decelerate (slow down) with an acceleration of –3.8 m/s^2. (The acceleration is negative because the car is slowing down.) What is the least amount of time it will take for this car to come to rest?

7. A car moving with a uniform (constant) acceleration takes 3.5 seconds to accelerate from 22 m/s to 34 m/s. Through what distance does the car move during this period of acceleration?

8. What acceleration must a car have if, starting from rest, it travels 30 metres in 3.5 seconds?

9. A rocket is blasting off with a constant upward acceleration of 18.7 m/s^2. Through what vertical height will the rocket rise as its speed changes from 3.6 m/s to 8.5 m/s?

10. A sprinter running at a speed of 12.5 m/s is approaching the finish line and, in a final burst of willpower, she forces herself to accelerate over the last 3.5 metres of the race. If this period of acceleration lasted for a time interval of 0.24 seconds, what was the sprinter's speed as she crossed the finish line?

11. A motorist is driving at a speed of 32 m/s on a stretch of highway where the speed limit is equivalent to 25 m/s. A truck coming in the opposite direction is flashing its headlights, which the speeding motorist interprets as a signal that a police cruiser is hiding just around a bend in the road 20 metres ahead of the motorist's current location. What must the car's acceleration be (assuming it is constant) if the car is to slow down to the speed limit just as it rounds the bend and passes the police cruiser?

12. A car initially moving at 17.1 m/s undergoes a 2.5-s period of constant acceleration during which it travels 63.5 metres. At what rate was the car accelerating?

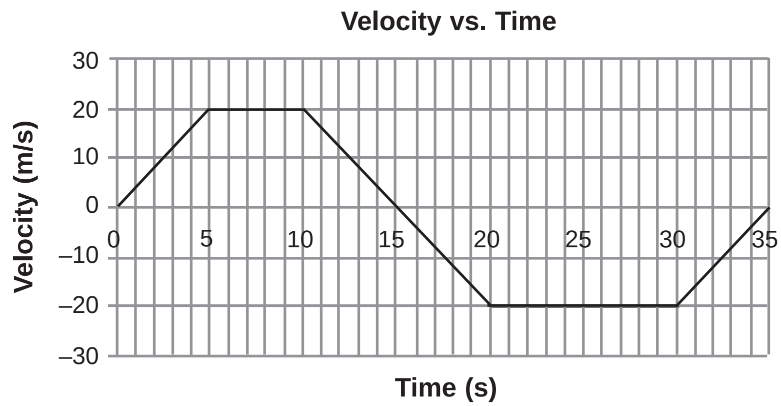
13. A baseball pitcher throws a fastball at a speed of 47 m/s. When the catcher receives the ball, he pulls his hand back through a distance of 0.35 metres in the process of making the catch. What was the acceleration of the ball as it was being caught, assuming that the acceleration was constant?

14. A car is moving at 26.5 m/s when the driver sees a red light. If the driver takes 0.45 seconds to step on the brakes and the braking causes the car to accelerate at –8.5 m/s^2, through what distance will the car travel as it comes to rest?

15. An elevator starts from rest at the ground floor of a building and rises to the top floor without stopping anywhere in-between. The elevator accelerates at 1.5 m/s^2 for 5 s, continues for an additional 15 s at the speed that it had after its initial period of acceleration, and then takes 1.8 s to come to rest with a uniform deceleration.
    a) Through what vertical distance does the elevator rise during its initial period of acceleration?
    b) What is the speed of the elevator after it stops accelerating?
    c) Through what vertical height does the elevator rise during the period that it is moving at a constant speed?
    d) Through what vertical height does the elevator rise during the time it takes to come to rest at the top of the building?
    e) Through what total vertical height has the elevator risen?

16. The acceleration of an object due to gravity near the surface of the Moon is approximately 1.6 m/s^2 and there is no air friction on the Moon. An astronaut throws a rock vertically upward on the lunar surface. What is the acceleration of the rock when
    a) it is still rising?
    b) it is at its highest point?
    c) it is falling back to the lunar surface again?

17. The graph below shows velocity versus time for a car that is initially moving northward along a straight north-south road. Answer the following questions based on this graph.



a) At what time, after it starts out, does the car first reach its maximum speed in the northward direction?

b) At what time, after it starts out, does the car first begin to slow down?

c) At what time, after it starts out, does the car reach its maximum distance north of its starting point?

d) At what time does the car first start heading back south again?

e) Does the car ever come to rest after it has begun to head south again? If so, at what time?

f) Is there any time interval during the 35 s shown on this graph during which the car begins to head back north again after it first began heading south? If so, what is the interval?

g) At the 35-s mark, is the car at its starting point, north of its starting point, or south of its starting point? Explain how you reached your conclusion. (You should be able to arrive at the answer just by looking at the pattern of the graph and without doing a detailed numerical calculation.)

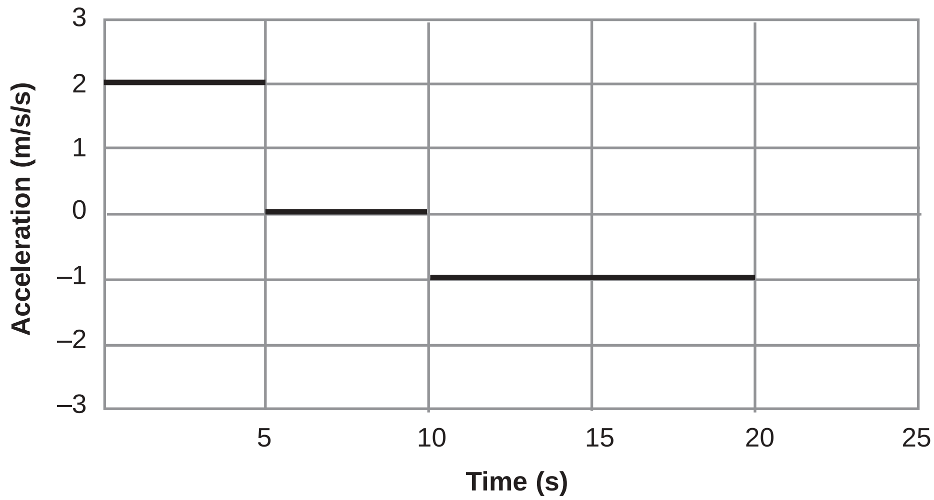
h) What is the maximum distance the car goes north of its starting point?

i) At what time, after it starts out, does the car first return to its starting point?

j) Draw a graph of the car's displacement versus time.

k) Draw a graph of the car's acceleration versus time.

18. The figure below is a graph of acceleration versus time for an object that is moving along a straight east-west path. At time t = 0 s the velocity of the object is also zero, and we are assuming east to be the positive direction.



a) Use a piece of graph paper with carefully numbered and labelled axes to draw a graph of velocity versus time for this object.

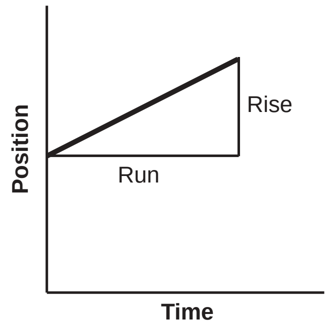
b) Find the displacement of the object (with respect to its starting point) at 20 s. Be sure that you give a direction as well as a magnitude. Use the area under a velocity-time graph method rather than the kinematic formulas.

c) Now assume that, rather than starting from rest, the initial velocity of the object was 4 m/s. Redraw the velocity-versus-time graph under this new assumption.

d) Based on the new graph, calculate how many additional metres are added to the magnitude of the displacement at 20 s because of this change in the initial velocity. Notice that you should be able to calculate the change in the displacement without first calculating the new displacement. Explain how you can do this.

Appendix 3.14: Kinematics Graphs Transformation Organizer

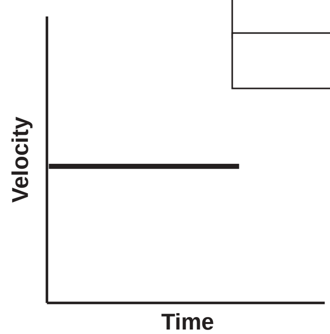
Going Down:
Take Slopes



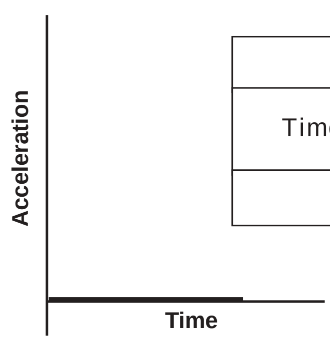
Run	Rise	Slope
Time Interval	Displacement	Velocity
(s)	(m)	(m/s)

	Area = $(V)(\Delta t)$	$d_f = d_i + \Delta d$
Time Interval	Displacement	Position at End of Interval
(s)	(m)	(m)

Area under V-T gives P-T graph.



Run	Rise	Slope
Time Interval	Change in Velocity	Acceleration
(s)	(m/s)	(m/s/s)



	Area = $(a)(\Delta t)$	$v_r = v_i + \Delta v$
Time Interval	Change in Velocity	Velocity at End of Interval
(s)	(m/s)	(m/s)

Area under A-T gives V-T graph.

Going Up:
Take Areas

SLA
Student Learning Activity

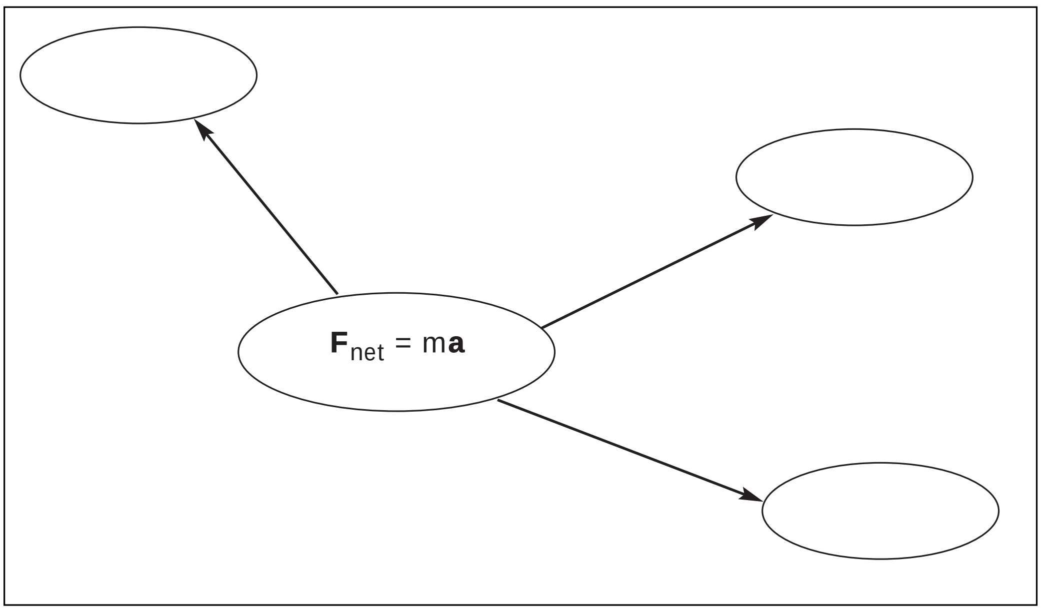
Appendix 3.15: Journal Entry: Dynamics and Diagrams

Part A

1. Using the Three-Point Approach Frame, define and illustrate the following terms.

Dynamics	Force	Newton
Free-body diagram	Inertia	Unbalanced force
Inertia of rest	Inertia of motion	Applied force

2. Use a Category Concept Map to relate the quantities in Newton's Second Law, $\mathbf{F}_{net} = m\mathbf{a}$.



3. Use a Compare and Contrast Frame to compare and contrast the following:
   a) gravitational mass and inertial mass
   b) mass and weight
   c) normal force and force of friction

4. Explain your strategy for solving problems that contain both kinematics and dynamics information.

Part B

1. Use Newton's Laws of Inertia to explain the following.
   a) A person dressed for the winter is standing outdoors in the middle of a pond on frictionless ice. What would the person do, without help from anyone else, in order to reach the shore?
   b) A car is driving on an icy road. It tries to turn around a curve but continues in a straight line and ends up in the ditch.
   c) You are riding on a bus that is moving at 5 m/s south. You toss a coin straight upwards into the air. You do not move your hand. The coin lands in your hand.
   d) According to a legend, a horse, having studied physics, learned Newton's laws. When it was told to pull a cart, it refused, saying that if it pulled the cart forward, according to Newton's Third Law, there would be an equal but opposite reaction force. Thus, there would be balanced forces acting on the cart and, according to Newton's Second Law, the cart would not accelerate. How would you reason with this horse?

2. A horizontal force of 75.0 N accelerates a person on a skateboard, with total mass of 65.0 kg, at 0.900 m/s/s.
   a) What is the net force acting on the skateboard and its rider?
   b) Draw a free-body diagram of this situation.
   c) What is the force of friction in this case?

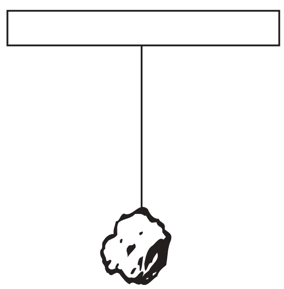
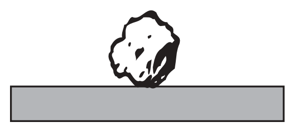
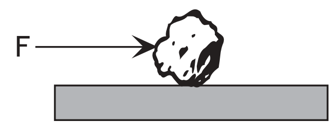
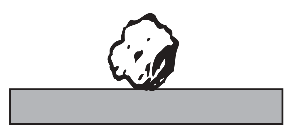
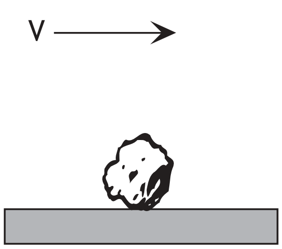
3. Two forces act on a sled of mass 80.0 kg. One force of 125 N acts in a southerly direction. A second force of 175 N acts in a westerly direction. The sled is pulled over a level snow-covered surface and accelerates at 1.50 m/s^2.
   a) Draw a free-body diagram showing the view from the top.
   b) What is the net force accelerating the sled?
   c) What is the sum of the two given forces?
   d) What is the force of friction on the sled?
   e) If the sled starts from rest, what is the displacement during the first 3 seconds?

4. A force of 50.0 N acting 35° from the horizontal is pulling a toboggan and passenger, total mass of 50.0 kg, along a level snow-covered surface. From rest, the toboggan moves 5.00 m in 3.5 s.
   a) Calculate the acceleration.
   b) What is the net force pulling the toboggan forward?
   c) Draw a free-body diagram (side view).
   d) Determine the force of friction.

BLM
Blackline Master

Appendix 3.16: Free-Body Diagrams: Linear Motion

In each case in the pictures below, the rock is acted upon by one or more forces. All drawings are in the vertical plane, and friction is negligible except where noted. Draw accurate free-body diagrams showing all forces acting on the rock. Draw all forces as though they were acting on the centre of mass, even though forces like friction and the normal force act on the surface at the point of contact. Use a ruler and pencil so that you can correct errors. Label the forces using $\mathbf{F_g}$ for the weight or force of gravity, **T** for tension, $\mathbf{F_f}$ for force of friction, and $\mathbf{F_N}$ for normal force.

1. Equilibrium 	2. Equilibrium 	3. Rock is pushed but remains motionless. Friction acts. 
4. Rock is falling, no friction. 	5. Rock is sliding at constant speed on a frictionless surface. 	6. Rock is falling at a constant (terminal) velocity. 
7. Rock is decelerating because of kinetic friction. 	8. Rock is rising. No friction. 	9. Rock is at the top of its flight, momentarily motionless. 

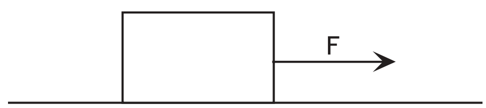
BLM

Blackline Master

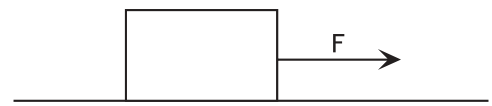
Appendix 3.17: Free-Body Diagrams 2: Linear Motion

In each case in the pictures below, the block is acted upon by two or more forces. All drawings are in the vertical plane, and friction is negligible except where noted. Draw free-body diagrams showing all forces acting on the block. Draw all forces as though they were acting on the centre of mass, even though forces like friction and the normal force act on the surface at the point of contact. Use a ruler and pencil, so that you can correct errors. Label the forces using $\mathbf{F_g}$ for the weight or force of gravity, $\mathbf{F_f}$ for force of friction, and $\mathbf{F_N}$ for normal force.

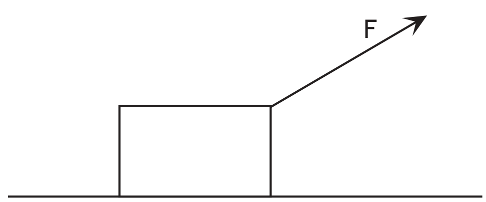
1. The object is pulled horizontally. No friction.



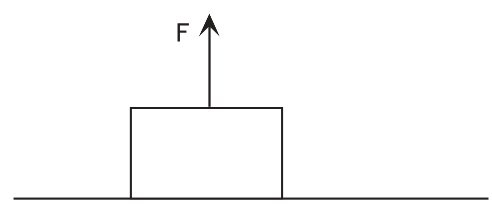
1. The object is pulled horizontally at constant velocity. Kinetic friction acts.



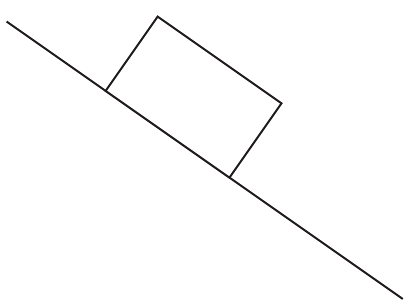
3. The object is pulled by a force acting in the direction shown. Static friction acts. The object is motionless.



4. The object is pulled straight upwards. It is motionless.



5. The object is resting on the plane. No friction acts.



6. The object remains motionless. Static friction acts.