Chapter 2

Analyzing Motion: Enrichment

Note to Teachers:

The concepts involved in motion—position, velocity, acceleration, and time—should be developed using the four modes of representation: visual, numeric, graphical, and symbolic. Students need concrete experiences with these concepts. Some additional activities are provided, along with typical results.

To reinforce the concepts of motion, some extended student activities are supplied, along with answers. Many of these activities can be done by students working collaboratively in groups. Students helping other students has benefit for all involved.

Students are required to perform calculations. At this time, you may wish to introduce the concept of significant digits and the rules for significant digits in calculations. Some information is provided, with a very simple mnemonic device to aid students in determining which digits are significant.

Position and Displacement

SUGGESTED ACTIVITY:

Mark off a reference system on the board or on the wall. The origin is clearly marked as 0 m. The positions of +1 m, –1 m, +2 m, –2 m, et cetera, are marked off. A student stands at one of these positions, marked as $\vec{d}_1$. The student then moves to a second position, marked as $\vec{d}_2$.

Ask students to determine the distance traveled.

Ask students to determine the displacement.

The displacement, $D\vec{d} = \vec{d}_2 - \vec{d}_1$, can be calculated. Here, displacement can be seen as distance traveled with a direction.

The importance of direction can be illustrated as follows. If a student starts at +1 m and has a displacement of +2 m, the final position is +3 m. However, if the student starts at +1 m and the displacement is –2 m, the final position is –1 m. The direction is important because the student, while starting at the same spot, has different final positions.

Ask students to start at a given position and to predict the final position, given the displacement. Students can determine the initial position, given the final position and the displacement. The use of the number line is very helpful for the students to visualize the situation.

Vectors and Scalars

Once students are introduced to the concepts of vectors and scalars, they should include direction with all vector quantities.

Instruct students in recognizing quantities from the units attached. For example, 5 m indicates distance. A value such as +5 m or 5 m east or 5 m [E] indicates displacement. Students also need to practise using the name that accompanies a symbol. Many times an equation is memorized without any understanding of the meaning of the symbols.

As students encounter new quantities, they should be encouraged to keep track of them—name, symbol, unit, vector, or scalar.

When measuring quantities in science, it is necessary to specify the direction for some quantities. Most quantities we measure are scalars. These are measured with a size or magnitude but without regard to direction. For example, temperature is a scalar. While it can be positive or negative, it does not have a direction like right or left, or east or west associated with it.

Other quantities require that a direction be given along with the size or magnitude. Force is a vector. You can pull on a door handle with a force of 25 newtons east or you can push on the door handle with a force of 25 newtons west. Although these two forces have the same magnitude, they act in different directions. One force will open the door; the other force will not.

In the study of motion, two similar quantities, speed and velocity, are often confused. Speed describes how fast an object is moving, regardless of direction. The speedometer of a car measures speed. It indicates how fast the car is moving, but does not include the direction. For example, 100 km/h is a typical speed for a car on the highway.

Velocity, though, is a vector. If we start at a point and travel at 100 km/h east for one hour, we will end up 100 km east of our starting point. If we travel at 100 km/h west, starting from the same point, we will end up 100 km west of the starting point. These two velocities, 100 km/h east and 100 km/h west, are definitely different velocities. It is the direction that makes them different.

In summary, **scalars are quantities with size or magnitude only.** We give the value of such a quantity with a number for its size and a unit to tell us the type of quantity.

A vector is a quantity with both magnitude and direction. We describe the value of a vector with a number for its size, a unit to tell us the type of quantity, and a direction.

For each quantity, give the unit and state whether it is a vector or scalar quantity.

Table 1

Quantity	Symbol of the Quantity	Unit	Vector or Scalar
Time Instant			
Time Interval			
Distance Traveled			
Displacement			
Mass			
Length			
Speed			
Acceleration			
Velocity			
Force			
Energy			

Significant Digits

The Purpose of Significant Digits

Systems of measurement were invented in order to compare quantities. Only the size of the object used to define a unit of measure is known exactly. The metre was once defined as the distance between two scratches on a bar of platinum-iridium alloy at 0°C. All other measurements of distance are estimated. Not all measurements, however, are known to the same accuracy, which refers to how close the measurement is to the true value. A micrometer, for example, will yield a more accurate measurement of a hair's diameter than will a metrestick.

Recording a Measurement Using Significant Digits

When recording a measurement, include every digit that is absolutely certain plus the first digit that must be estimated. This is the definition of a significant digit. Significant digits are part of the measurement.

For example, suppose the length of a table is measured with a ruler calibrated to 10 centimetres. A proper measurement would be recorded as 2.64 metres. This indicates the table has a length of 2 metres plus 60 centimetres plus a little bit more. The table is definitely less than 2.7 metres but greater than 2.6 metres. The first two digits are known exactly and the third digit is estimated (a guess). The measurement has three significant digits. A measurement of the same table with a ruler calibrated to centimetres could yield 2.642 metres.

The final significant digit will always be one unit smaller than the calibration of the measuring instrument. For example, the first measurement above was recorded to the nearest centimetre, and the ruler was calibrated to only the nearest 10 centimetres. The second measurement was recorded to the nearest tenth of a centimetre, and the ruler was calibrated to the nearest centimetre.

Zeros are to be recorded if they are significant. If a table was measured and the end of the table coincided with a mark on the ruler (e.g., 2.6 metres), a zero must be recorded. If the ruler is calibrated in 10 centimetres, record zeros until the next smaller unit, one centimetre, is recorded. In this case, the measurement would be 2.60 metres. If the metrestick was calibrated in centimetre units, then zeros are recorded until one millimetre is recorded. Here, the measurement would be 2.600 metres.

Rules for Significant Digits

The following rules are used to determine the number of significant digits in a given measurement.

1. All non-zero digits are significant.

   E.g., 374 (3 sig digs), 8.1 (2 sig digs)
2. All zeros between non-zero digits are significant.

   E.g., 50407 (5 sig digs), 8.001 (4 sig digs)
3. Leading zeros in a decimal are not significant.

   E.g., 0.54 (2 sig digs), 0.0098 (2 sig digs)
4. Trailing zeros are significant if they are to the right of a decimal point.

   E.g., 2370 (3 sig digs), 16000 (2 sig digs), 160.0 (4 sig digs)
5. In numbers greater than 1, trailing zeros are not significant unless stated so.

   E.g., 37000 (2 sig digs)

The last three zeros may or may not be part of the measurement. To show that they are, we use scientific notation. All the zeros written in the number in scientific notation are significant.

37000 with 3 sig. digits would be 3.70×10^4

37000 with 4 sig. digits would be 3.700×10^4

37000 with 5 sig. digits would be 3.7000×10^4

37000.0 has 6 sig. digits

ACTIVITY 1

Determine the number of significant digits in each of the following numbers

1) 5.897	2) 8.000	3) 10001
4) 0.333	5) 8.001	6) 0.008000
7) 7	8) 0.009	9) 947.000
10) 10000	11) 12000	12) 10000.0
13) 10321	14) 55040	15) 375000

ACTIVITY 2

State the number of significant digits in each measurement.

1) 2509 m	2) 7.62 km	3) 0.00055 m
4) 0.0670 m	5) 5.060×10^5 m	6) 9.0000×10^{-5} m
7) 240 m	8) 2.4 m	9) 2400 m
10) 2400.0 m	11) 0.005050 m	12) 50 m

ANSWERS—ACTIVITY 1

1) 4	2) 4	3) 5
4) 3	5) 4	6) 4
7) 1	8) 1	9) 6
10) 1	11) 2	12) 6
13) 5	14) 4	15) 3

ANSWERS—ACTIVITY 2

1) 4	2) 3	3) 2
4) 3	5) 4	6) 5
7) 2	8) 2	9) 2
10) 5	11) 4	12) 1

Alternate Rule for Significant Digits

Here is an alternate rule for determining significant digits. The rule is really a mnemonic device. Students are easily confused about the number of significant digits, especially if zeros are present. This rule will allow students to achieve success in working with significant digits, which should, in turn, encourage them to keep using them.

This method is called the "Atlantic-Pacific" method.

If the number in question does not contain a decimal, think "A" for Absent. If the number in question does contain a decimal, think "P" for Present.

Next, imagine a map of North America with north pointing to the top of the page. The "A" now stands for Atlantic and the "P" now stands for Pacific. Imagine an arrow starting from the correct coast being drawn towards the number. Once the arrow hits a non-zero digit, that digit and all digits after it are significant.

EXAMPLE 1

How many significant digits are shown in the number 37 500?

There is no decimal, so we think of "A" for "Absent." Therefore, an arrow must come in from the Atlantic Ocean (i.e., the right side), as shown below.

37 500 ‹

The first non-zero digit that the arrow hits would be the 5. The 5 and all digits after it, in this case to the left of the 5, are significant.

ANSWER—EXAMPLE 1

There are three significant digits in the number 37 500, the 3, 7, and the 5.

EXAMPLE 2

How many significant digits are shown in the number 0.040500?

There is a decimal, so we think of "P" for "Present." Therefore, an arrow must come in from the Pacific Ocean (i.e., the right side), as shown below.

fi 0.040500

The first non-zero digit that the arrow hits would be the 4. The 4 and all digits after it, in this case to the right of the 4, are significant.

ANSWER—EXAMPLE 2

There are five significant digits in the number 0.040500: the 4, 0, 5, 0, and 0.

Example 2 employs three separate rules for significant digits and zeros.

Uniform Motion

The following activity is an alternative to the activity with the toy vehicle pulling the ticker tape to record its position. This activity involves the participation of the whole class and produces velocities of various sizes and directions. It also provides the students with an opportunity to describe motion in a variety of ways.

The activity is intended to establish two important types of information that can be obtained from a Position-Time graph. The first type of information is found by reading the Position-Time graph directly. This provides the position of a moving object at a given instant in time, or the instant in time at which the object is at a given position.

The second type of information is found indirectly from the graph: it involves a calculation or interpretation. This indirect information is the slope of the line on the Position-Time graph. The slope gives the velocity of the object. The steepness of the slope gives the speed or magnitude of the velocity, while the sign of the slope gives the direction of the velocity.

Students can work collaboratively on the analysis of the results of the following activity.

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 traveled, 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 a crack in the 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 students with stopwatches 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 walks the full length of the course at a constant rate. As the walking student passes each timer, the timer will stop the stopwatch.
- The timers then share their times and positions with the group.

Observations:

Description of motion:

Draw a picture of the motion:

Table 2A

Time (Sec)											
Position (Metres)											

On the following graph, 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 starts from the 0-m mark this time and walks more quickly than before, but at a constant rate over the whole course. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

Description of motion:

Draw a picture of the motion:

Table 2B

Time (Sec)											
Position (Metres)											

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

Procedure:

PART C

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

Observations:

Description of motion:

Draw a picture of the motion:

Table 2C

Time (Sec)										
Position (Metres)										

Plot this information on the previous graph, using a third different 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 motions, what is different about the three motions?

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

Procedure:

PART D

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

Observations:

Description of motion:

Draw a picture of the motion:

Table 2D

Time (Sec)										
Position (Metres)										

Plot this information on the graph, using a fourth different 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

At the 10-m mark, station two timers. The student starts from the 0-m mark this time and walks quickly to the 10-m mark. The first timer stops the stopwatch. The student stays at the 10-m mark for a slow count of 5. At the count of 5, the second timer stops her stopwatch and the student resumes her journey, covering the whole course at a slower pace than before. Again the timers start timing when the student begins to move and stop timing when the student passes the timers' position.

Observations:

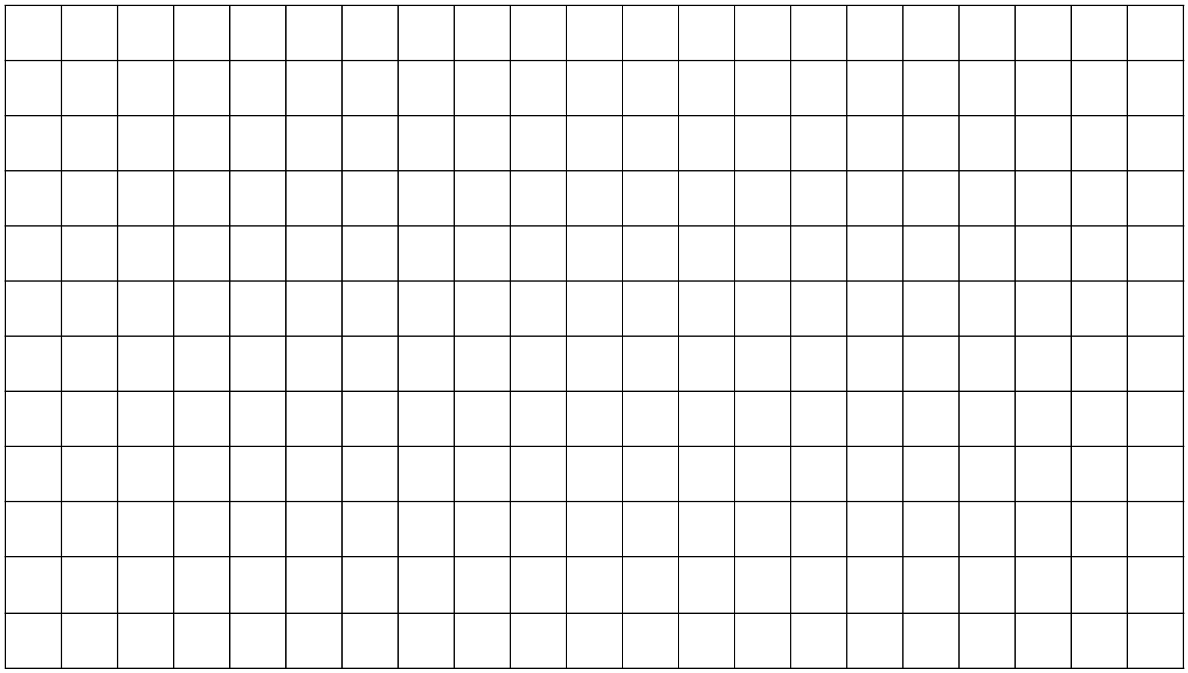
Description of motion:

Draw a picture of the motion:

Table 2E

Time (Sec)											
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?

2. Go back to the description of the motion. What does the graph look like when the student was 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 traveled and displacement.

2. Distinguish between average speed and average velocity.

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

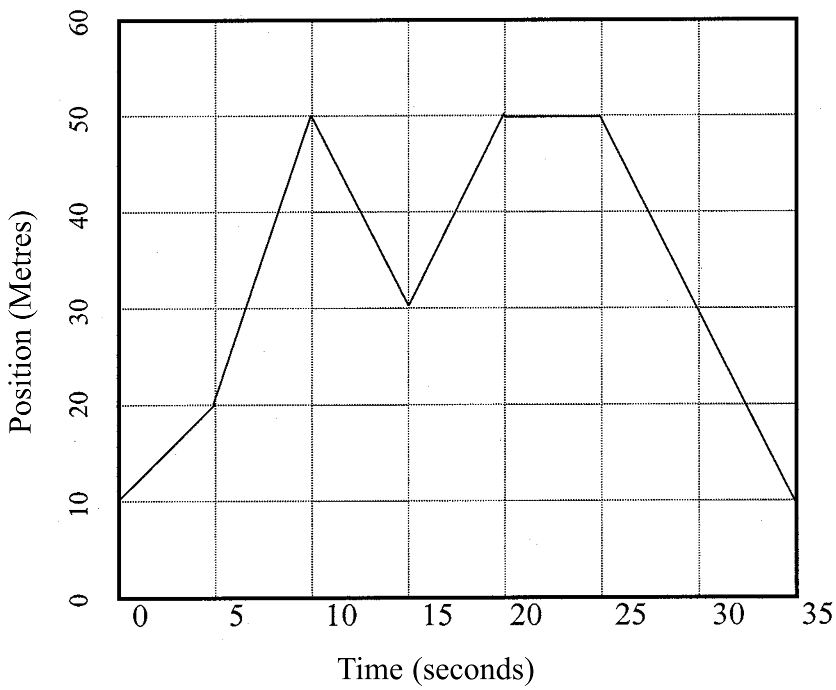
4. For each trial (A through E), calculate the total time for the journey. Obtain the information from the graph

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 traveled and the displacement for each interval listed below? Include direction with displacement.

Table 3

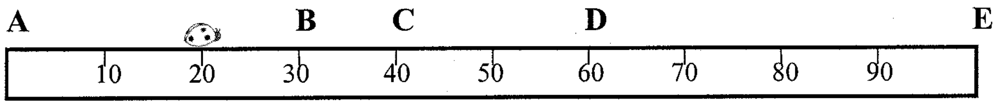
Time Interval	Distance Traveled	Displacement
0–5 seconds		
5–10 seconds		
10–15 seconds		
15–20 seconds		
20–25 seconds		
25–35 seconds		

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

Table 4

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

Describing Motion in Various Ways



1. A somewhat confused ladybug is moving back and forth along a metrestick. Determine both the displacement and distance traveled 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 below the table, plot a graph of Position-Time.

Table 5

Time (Sec)	0	4	20	32	36	60	72
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.

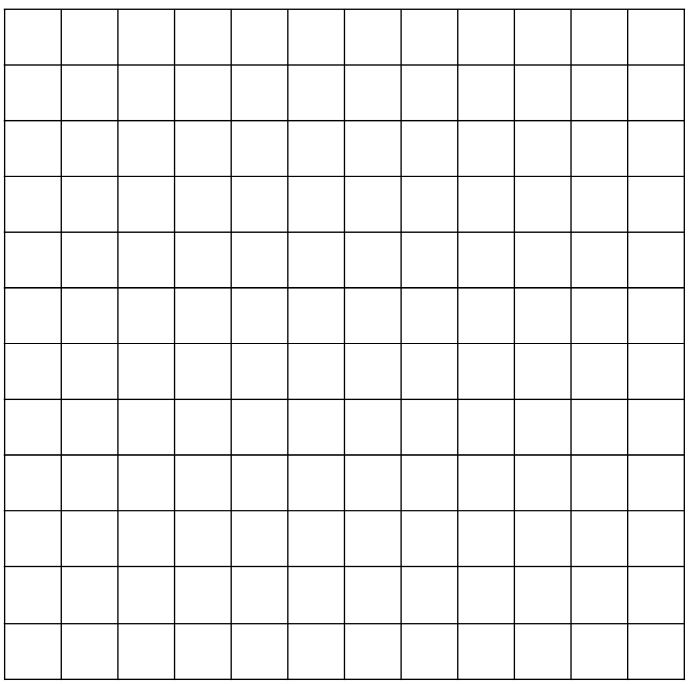
   The student starts at 5.0 m N. He walks to the south for 7.0 m during 10.0 s. He stands still for 5.0 s. He turns around and walks 15.0 m N during 15.0 s. He stops to say "Hello" to a friend and remains still for 10.0 s. Finally, the principal calls him to the office door. It takes the student 10.0 s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

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

   b. What was the distance traveled 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.



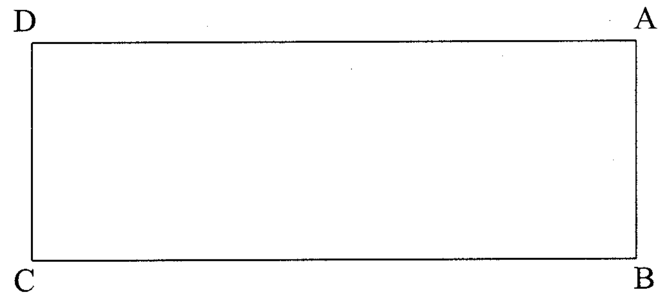
   e. What is the total displacement for the student's journey? Find this from the graph.

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

Velocity, Displacement, Time Problem Set

Questions 1–4 use the information below.

A city block is laid out in a grid running in the north-south and east-west directions. The blocks measure 135 m in length in the east-west direction, and 45.0 m in width in the north-south direction. A city block is drawn below.



1. On your bicycle, you travel from A to B during 9.00 s.
   a. What is your average speed?
   b. What is your average velocity?
2. If you travel from A to B to C to D, what is your
   a. distance traveled?
   b. displacement?
3. If the journey in #2 took 55.0 s, calculate
   a. your average speed.
   b. your average velocity.
4. You travel around the block in 90.0 s. Calculate your average speed and your average velocity.
5. Fargo is located 375 km south of Winnipeg. If it takes 4.00 h to travel from Winnipeg to Fargo, calculate your average velocity.
6. You make the return trip to Winnipeg from Fargo also in 4.00 h. What was your average velocity?
7. Jim lives on the same street as his school. The front of the school is located 1020 m [E] of Jim's house. If Jim walks at 3.00 m/s [E], calculate the time it takes Jim to walk from his house to the front of the school.
8. An airplane flies at a velocity of 215 km/h [W] for 2.75 hours. What is the displacement for this journey?

Relating Position-Time Graphs to Velocity-Time

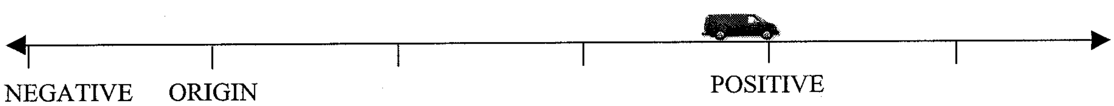
Position-Time graphs can be read directly to give the position of an object at an instant in time. This interpretation of a P-T graph tells us where an object is at a given time. This information generates the Position-Time version of the story of the motion.

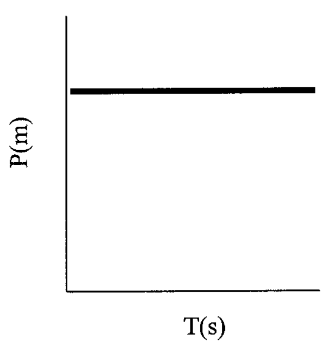
Slopes of P-T Graphs for Uniform Motion

The slope of a P-T graph gives us the velocity of the object $\vec{v}_{average} = D\vec{d} / Dt$. This allows us to tell the Velocity-Time version of the story of the motion. Remember that slope refers to the steepness of a line. Therefore, the steeper the line on a P-T graph, the greater the magnitude or size (speed) of the velocity will be for that time interval or instant in time.

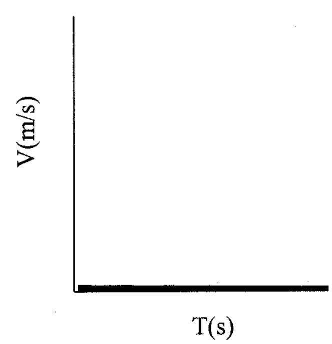
Since velocity is a **vector** quantity, it is important that the direction of the velocity is always included. Think of velocity as **speed with direction**.

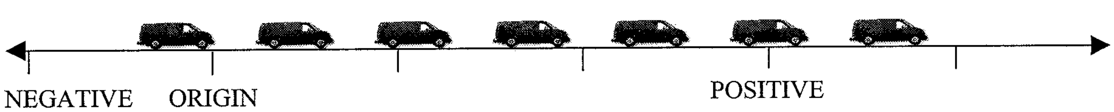
Here are some typical examples of P-T graphs with various slopes. Straight lines on P-T graphs yield constant slopes, and constant velocities (speed and direction remain the same). All the time intervals are equal for the time between the positions of the van.

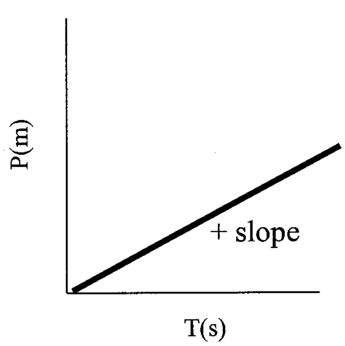




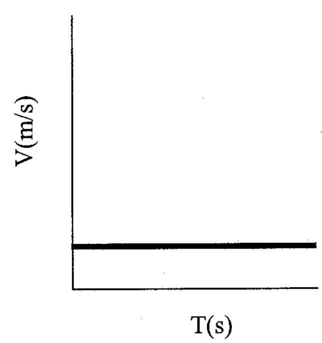
This graph indicates the object stayed at the same position or did not move. The slope is 0m/s. The velocity is 0m/s.

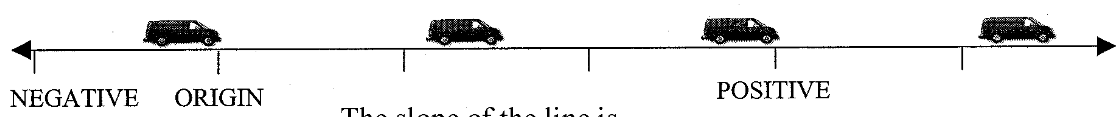


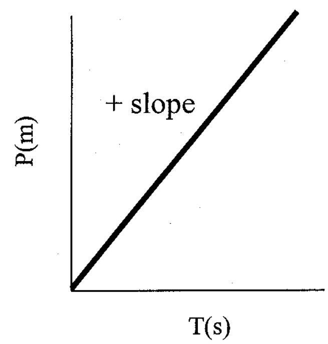




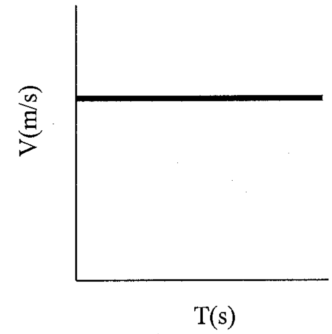
The slope of the line is positive with a low value. The velocity has a low positive value. The speed is low and the direction is positive. The line is straight so the velocity is constant. The object is moving away from the origin to the right.

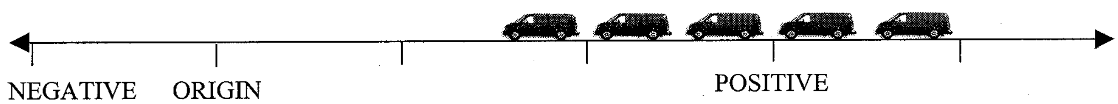


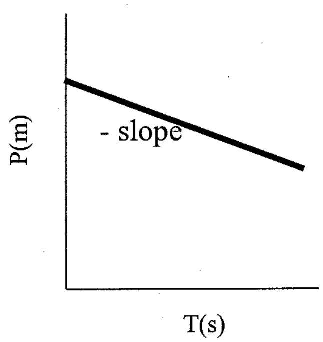




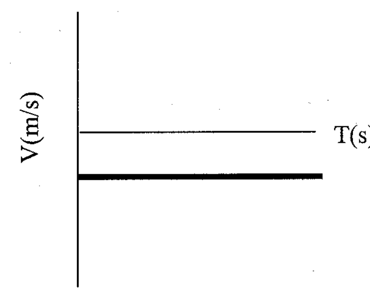
The slope of the line is positive with a higher value than the previous one. The velocity is positive with a larger value (speed) than the previous one. The object is moving away from the origin to the right.

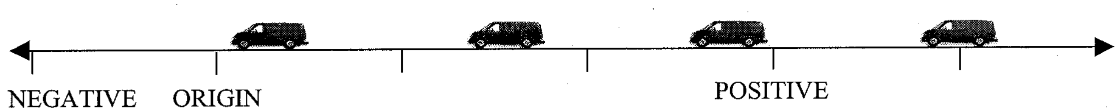


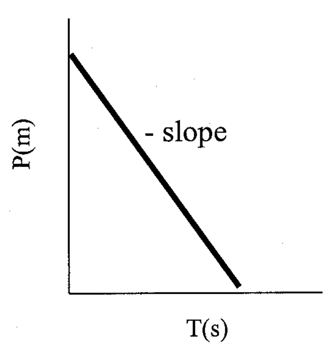




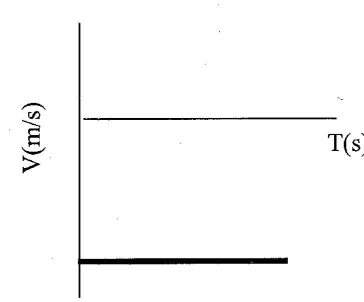
The slope of the line is negative with a low value. The velocity has a low negative value (speed). The line is straight so the velocity is constant. The object is to the right of the origin and moving left towards the origin.

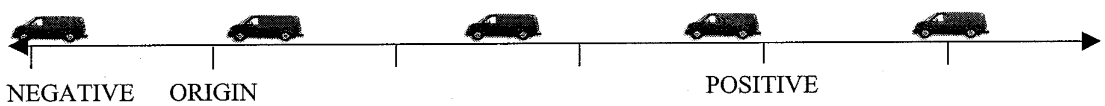


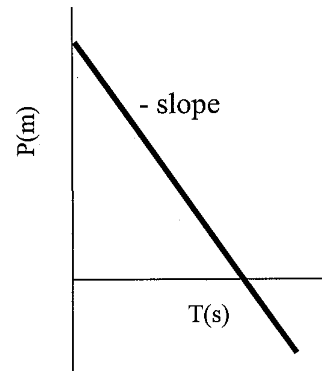




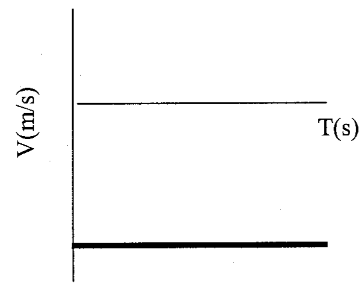
The slope of the line is negative with a larger size than the previous one. The velocity is negative with a larger value (speed) than the previous one. The object is to the right of the origin and moving towards it.







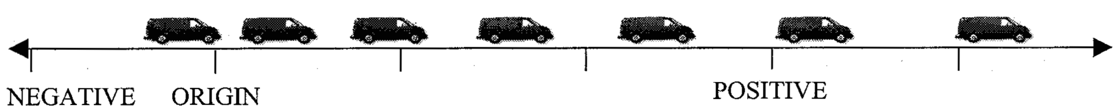
The slope of the line is the same as the previous case. The velocity is negative and has the size (speed). The object is to the right of the origin and moving towards it. The object passes the origin and moves to the left of it.

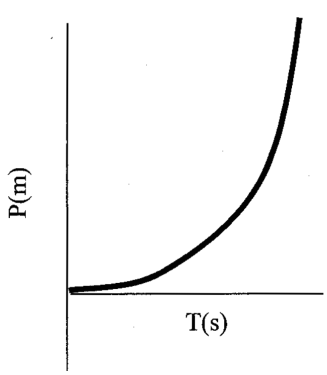


Position-Time Graphs for Non-Uniform Motion

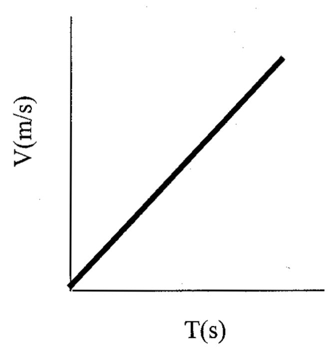
In this type of motion, objects are speeding up or slowing down. Therefore, the velocity is not constant. Since the slope on a P-T graph gives the velocity, a changing velocity will mean that the slope on the P-T graph must also change. A line with a changing slope is a curve. The slope of the curve at a given moment will calculate the velocity at that instant, the instantaneous velocity.

So, if the slope on a P-T graph becomes more positive (the line becomes steeper), the instantaneous velocities are becoming more positive (larger speed in the positive direction).

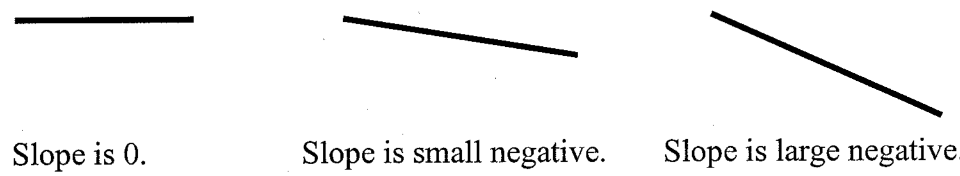




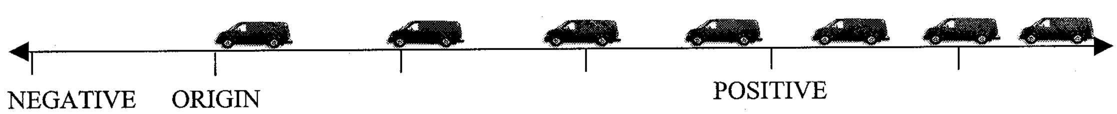
The slope at 0 seconds is 0 m/s. The slope of the graph is becoming more positive, larger in the positive direction. The velocity is increasing in the positive direction (speeding up in the positive direction). This is accelerated motion.

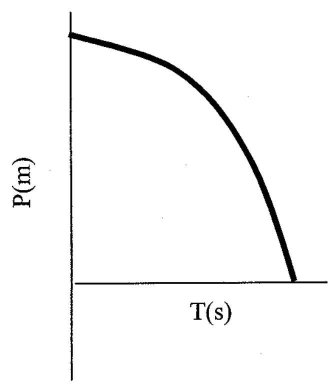


Objects can also speed up traveling in the negative direction. If an object starts from rest (slope on P-T graph = 0 m/s) and speeds up in the negative direction, the slope on the P-T graph will become more and more negative.

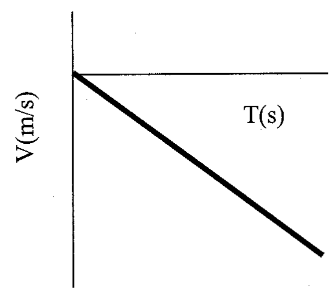


Again, the P-T graph will be a curve for which you calculate the instantaneous velocity, using the slope of the line at that moment in time. Here, the velocity becomes more negative (larger speed in the negative direction).





The object starts at rest to the right of the origin and moves towards the origin. The slope becomes more negative. The velocity becomes more negative (speeding up in the negative direction). The object's last position is at the origin.



Accelerated Motion

For the class activity, students should be reminded to measure the distance between the dots from a position on one dot to the same point on the next dot.

Also, for the class activity, some information in the tables is incorrect.

Table C should have a heading of Position (cm).

Table D has the same unit error for Position as Table C. Also in Table D, the construction of the table does not lend itself to performing the required calculations. Two alternate arrangements are presented below.

Table 6

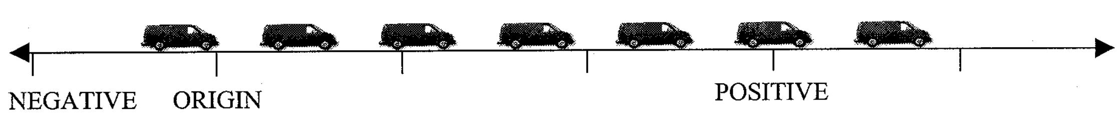
Time (s)	Displacement (cm)	Average Velocity (cm/s)
0–1		
1–2		
2–3		
3–4		
4–5		
5–6		
6–7		
7–8		

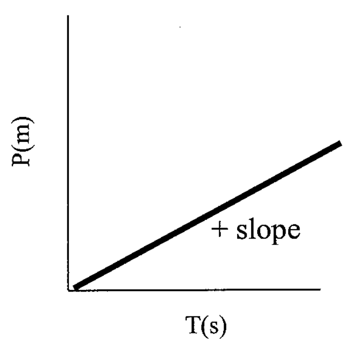
Table 7

Time (s)	Position (cm)	Displacement During Time Interval (cm)	Average Velocity (cm/s)
0			
1			
2			
3			
4			
5			
6			
7			
8			

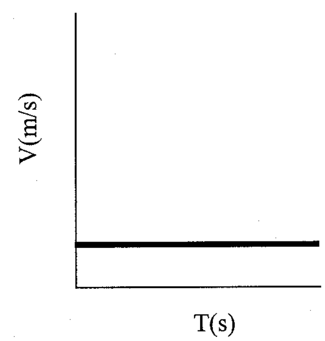
Acceleration—Non-Uniform Velocity

Up until now, most of the graphs of Position-Time have been straight-line graphs. The slope of a Position-Time graph gives the velocity. If the line is straight, the velocity is constant or uniform over that time interval. In these cases, since the velocity was uniform, there was no acceleration.

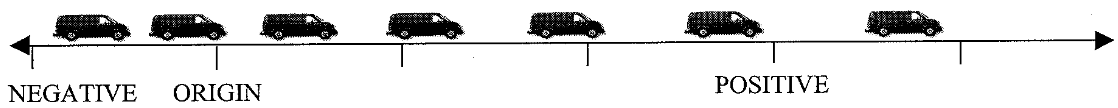


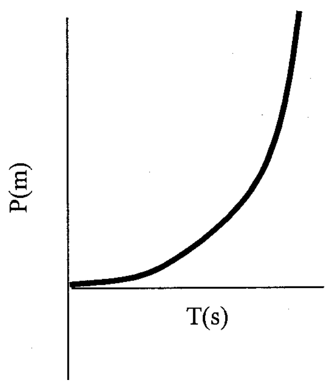


The slope of the line is positive with a low value. The velocity has a low positive value. The speed is low and the direction is positive. The line is straight so the velocity is constant. The object is moving away from the origin to the right.

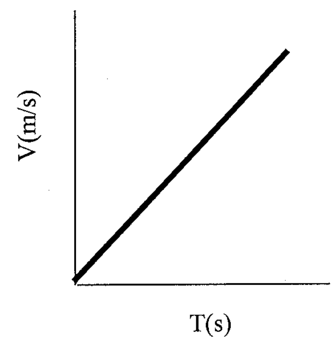


A few graphs of Position-Time were curves. On these graphs, the slope of the line still gave the velocity, but only the velocity at that instant (or instantaneous velocity). Since the slope of the curve on the Position-Time graph was always changing, so too was the instantaneous velocity always changing from one instant to the next. In these cases, the velocity was non-uniform or changing. There was an acceleration.





The slope at 0 seconds is 0 m/s. The slope of the graph is becoming more positive, larger in the positive direction. The velocity is increasing in the positive direction (speeding up in the positive direction). This is accelerated motion.



Acceleration involves an object speeding up or slowing down while moving in a straight-line path. Acceleration illustrates how velocity changes with time.

Acceleration is defined as the rate at which an object changes its velocity. It is a vector quantity, meaning that the direction in which acceleration acts is important.

The chart on the right shows that the velocity of an object is changing with time. For each second, the velocity changes by 3 m/s. The acceleration of this object is 3 m/s/s.

Since the acceleration is always 3 m/s/s, the acceleration is a uniform acceleration.

Table 8

Time (s)	Velocity (m/s)
0	0
1	3
2	6
3	9
4	12

Acceleration is calculated using the following relationship:

$$\text{Average acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

$$= \frac{\text{final velocity} - \text{initial velocity}}{\text{time interval}}$$

In symbols, the following equation is used to calculate acceleration:

$$\vec{a}_{ave} = \frac{\vec{v}_{final} - \vec{v}_{initial}}{t_{final} - t_{initial}}$$

$$\vec{a}_{ave} = \frac{D\vec{v}}{Dt}$$

For example, the average acceleration for the time interval from 1 s when the velocity is 3 m/s, to 4 s when the velocity is 12 m/s, would be found as follows:

$$\text{Time}_{initial} = 1\text{ s} \quad \text{velocity}_{initial} = 3\text{ m/s}$$

$$\text{Time}_{final} = 4\text{ s} \quad \text{velocity}_{final} = 12\text{ m/s}$$

$$\begin{aligned} \vec{a}_{ave} &= \frac{D\vec{v}}{Dt} \\ &= \frac{12\text{ m/s} - 3\text{ m/s}}{4\text{ s} - 1\text{ s}} \\ &= \frac{+9\text{ m/s}}{3\text{ s}} = +3\text{ m/s/s} \end{aligned}$$

Acceleration is expressed in units of velocity over time. The units of velocity and time determine the units of acceleration.

Typical units of acceleration are:

$$\frac{\text{velocity}}{\text{time}} = \frac{\text{m/s}}{\text{s}} = \text{m/s/s} \quad \text{or} \quad \frac{\text{velocity}}{\text{time}} = \frac{\text{km/h}}{\text{s}} = \text{km/h/s}$$

Remember, acceleration is a vector. Always include a direction with your answer.

The Meaning of the Sign of Acceleration

The sign of the acceleration gives the direction in which the acceleration acts. A positive acceleration acts to the right and a negative acceleration acts to the left. A positive acceleration does not always mean that an object is speeding up. Sometimes an object with a positive acceleration is slowing down.

Making sense of the sign of acceleration (and whether an object is speeding up or slowing down) requires that the sign of velocity also be considered. The following table summarizes the different situations that can occur.

Table 9

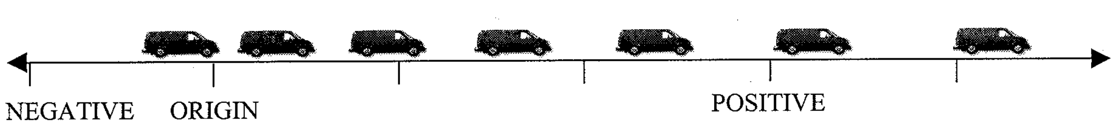
Sign (direction) of velocity	Sign (direction) of acceleration	What you see
+ (right)	+ (right)	Moving right, speeding up
+ (right)	– (left)	Moving right, slowing down
– (left)	– (left)	Moving left, speeding up
– (left)	+ (right)	Moving left, slowing down

The table may look very confusing. It is better to remember a simple rule. You will notice that if the velocity and acceleration have the **same** sign, the object will be **speeding up**. If velocity and acceleration have **opposite** signs, the object will be **slowing down**.

THE MEANING OF THE SIGN OF ACCELERATION—STUDENT ACTIVITY

In the following graphics, the time intervals between successive images of the van are all equal. For the directions, positive is to the right, and negative is to the left.

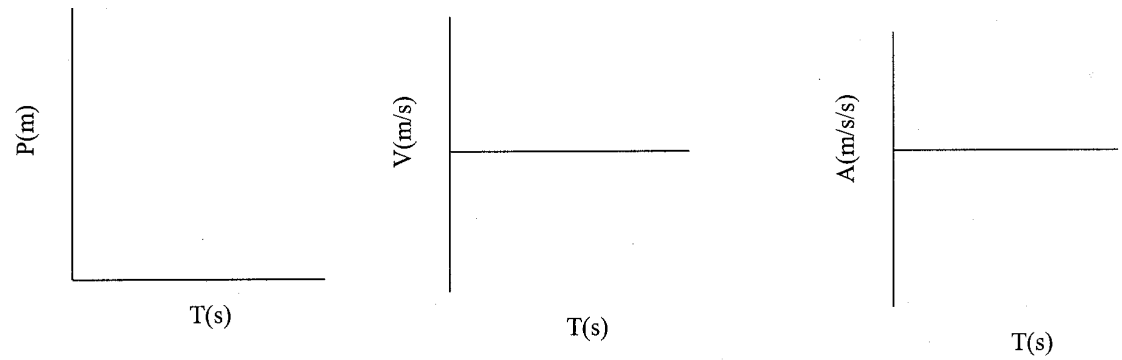
1. For the graphic below, describe the motion of the van.



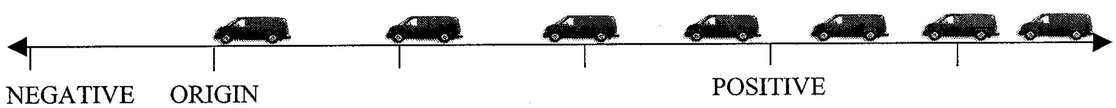
What is the sign of the velocity?

What is the sign of the acceleration?

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



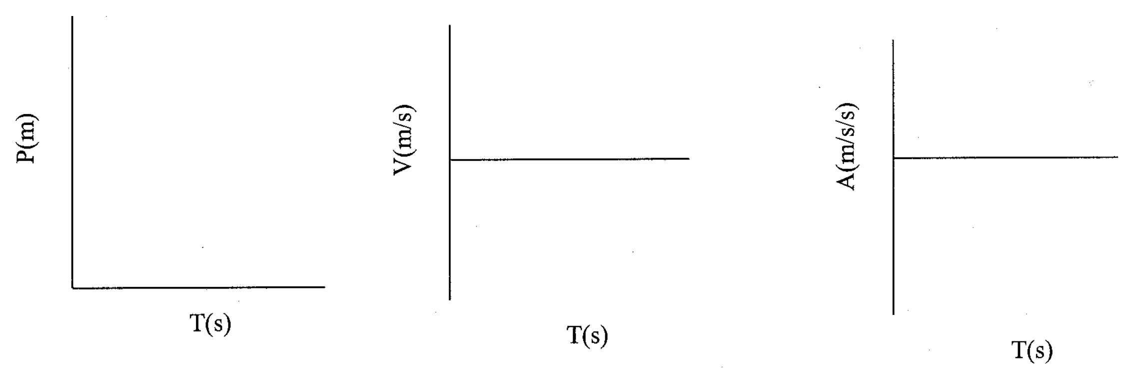
2. For the graphic below, describe the motion of the van.



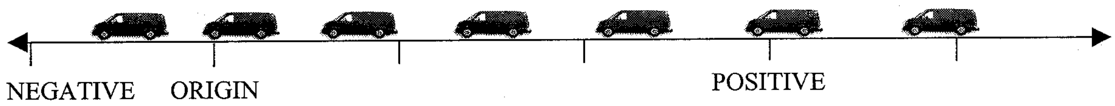
What is the sign of the velocity?

What is the sign of the acceleration?

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



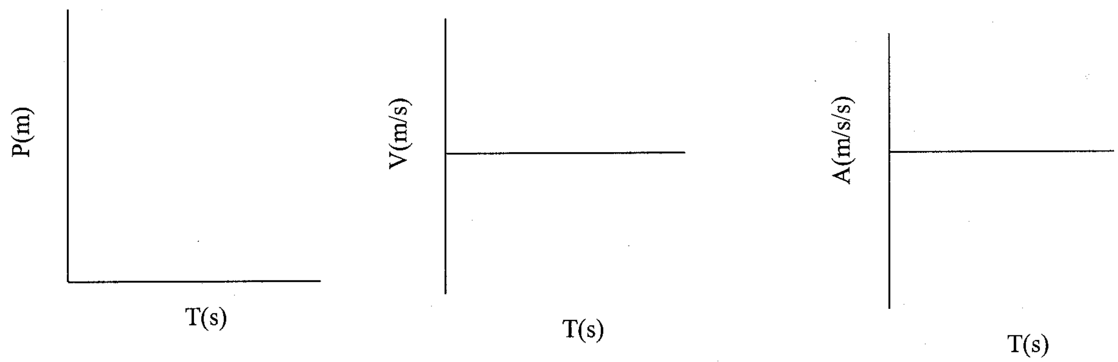
3. For the graphic below, describe the motion of the van.



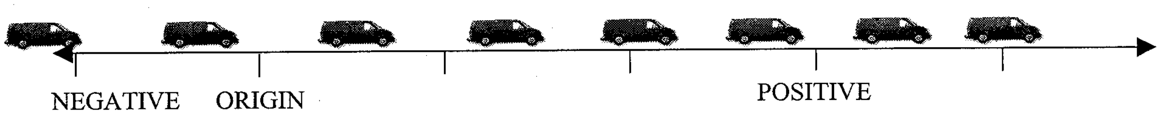
What is the sign of the velocity?

What is the sign of the acceleration?

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.



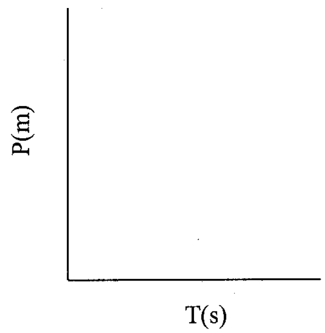
4. For the graphic below, describe the motion of the van.

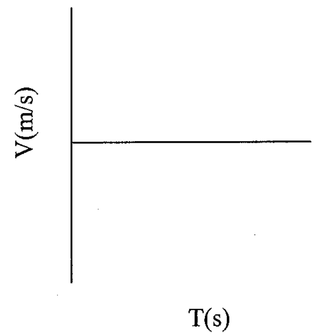


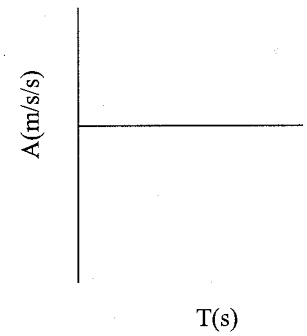
What is the sign of the velocity?

What is the sign of the acceleration?

Sketch the lines for the Position-Time graph, the Velocity-Time graph, and the Acceleration-Time graph that describe this motion.







5. From the data in the table below, describe the motion of the object.

Table 10

Time (s)	Velocity (m/s)
0	10
1	9
2	8
3	7
4	6
5	5

What is the sign of the velocity?

What is the sign of the acceleration?

6. From the data in the table below, describe the motion of the object.

Table 11

Time (s)	Velocity (m/s)
0	–4
1	–8
2	–12
3	–16
4	–20
5	–24

What is the sign of the velocity?

What is the sign of the acceleration?

7. From the data in the table below, describe the motion of the object.

Table 12

Time (s)	Velocity (m/s)
0	–11
1	–9
2	–7
3	–5
4	–3
5	–1

What is the sign of the velocity?

What is the sign of the acceleration?

8. From the data in the table below, describe the motion of the object.

Table 13

Time (s)	Velocity (m/s)
0	0.25
1	0.50
2	0.75
3	1.00
4	1.25
5	1.50

What is the sign of the velocity?

What is the sign of the acceleration?

Acceleration, Velocity, Time Problem Set

1. A car can accelerate from a standstill to 100 km/h [E] in 9.60 s. Calculate the average acceleration.
2. An object is falling at –4.20 m/s. A downward motion has a negative direction. At a time 2.50 s later, the object is falling at –28.7 m/s. What was the average acceleration?
3. A curling stone is sliding at +1.72 m/s. After 2.25 s, the curling stone is sliding at +1.00 m/s. What was the average acceleration?
4. Albertine rides her bicycle on a hill with a downward slope. If Albertine coasts down the hill with an average acceleration of 1.68 m/s/s, what is her change in velocity during 5.25 s?
5. Albertine reaches the bottom of the hill coasting along at 9.25 m/s. She begins to coast up a second hill where the average acceleration is –1.20 m/s/s. What is the change in Albertine's velocity during 3.00 s of coasting up this hill? What is her final velocity?
6. A car traveling at 18.0 m/s [E] brakes for a red light and comes to a stop. The car accelerates at an average rate of –3.60 m/s/s. What is the length of the time interval over which the car is braking?
7. A dragster racing on a quarter-mile track (about 400 m) has an average acceleration of 11.2 m/s/s [E] reaching a velocity of 72.0 m/s [E]. What was the time needed to race this distance?

Concept Map: Speed, Velocity, and Acceleration

Give the name of each of the following equations.

For each symbol in the following equations, give the name the quantity, a definition, its unit, and whether it is a vector or scalar. Write the information around each rectangle.