Describing Motion Verbally with Distance and Displacement

Read from **Lesson 1** of the **1-D Kinematics** chapter at **The Physics Classroom**:

> http://www.physicsclassroom.com/Class/1DKin/U1L1a.html
> http://www.physicsclassroom.com/Class/1DKin/U1L1b.html
> http://www.physicsclassroom.com/Class/1DKin/U1L1c.html

MOP Connection: Kinematic Concepts: sublevels 1 and 2

Motion can be described using words, diagrams, numerical information, equations, and graphs. Using words to describe the motion of objects involves an understanding of such concepts as position, displacement, distance, rate, speed, velocity, and acceleration.

Vectors vs. Scalars

1.   Most of the quantities used to describe motion can be categorized as either vectors or scalars. *A vector is a quantity that is fully described by both magnitude and direction. A scalar is a quantity that is fully described by magnitude alone.* Categorize the following quantities by placing them under one of the two column headings.

displacement, distance, speed, velocity, acceleration

Scalars	Vectors

2.   A quantity that is *ignorant of direction* is referred to as a _____.
      a. scalar quantity   b. vector quantity

3.   A quantity that is *conscious of direction* is referred to as a _____.
      a. scalar quantity   b. vector quantity

Distance vs. Displacement

As an object moves, its location undergoes change. There are two quantities that are used to describe the changing location. One quantity - **distance** - accumulates the amount of total change of location over the course of a motion. Distance is the amount of ground that is covered. The second quantity - **displacement** - only concerns itself with the initial and final position of the object. Displacement is the overall change in position of the object from start to finish and does not concern itself with the accumulation of distance traveled during the path from start to finish.

4.   True or False: An object can be moving for 10 seconds and still have zero displacement.
      a. True   b. False

5.   If the above statement is true, then describe an example of such a motion. If the above statement is false, then explain why it is false.

6.   Suppose that you run along three different paths from location A to location B. Along which path(s) would your distance traveled be different than your displacement? _____
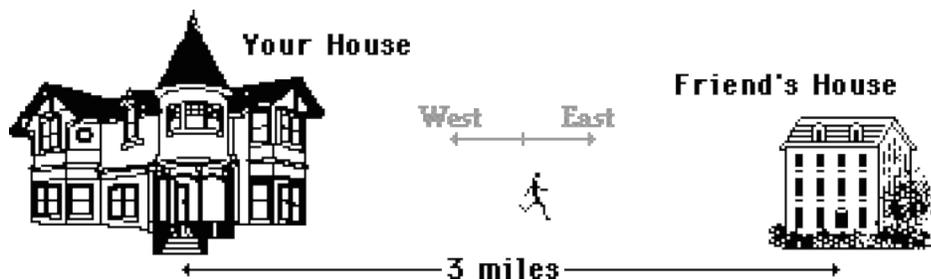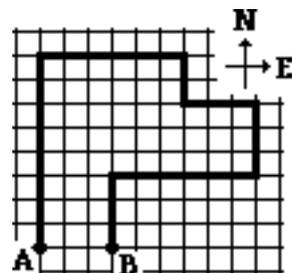
7. You run from your house to a friend's house that is 3 miles away. You then walk home.

a. What distance did you travel? _____

b. What was the displacement for the entire trip? _____

Observe the diagram below. A person starts at A, walks along the bold path and finishes at B. Each square is 1 km along its edge. Use the diagram in answering the next two questions.

8. This person walks a distance of _____ km.

9. This person has a displacement of _____.
    a. 0 km   b. 3 km   c. 3 km, E   d. 3 km, W
    e. 5 km   f. 5 km, N   g. 5 km, S   h. 6 km
    i. 6 km, E   j. 6 km, W   k. 31 km   l. 31 km, E
    m. 31 km, W   n. None of these.

10. A cross-country skier moves from location A to location B to location C to location D. Each *leg* of the back-and-forth motion takes 1 minute to complete; the total time is 3 minutes. (The unit is *meters*.)
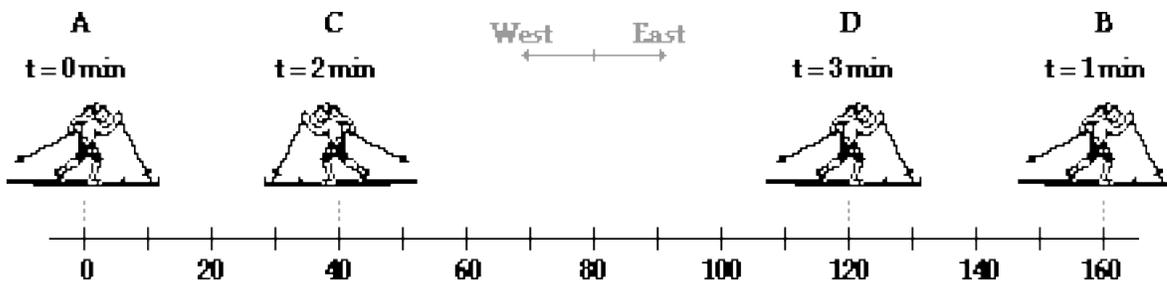
a. What is the distance traveled by the skier during the three minutes of recreation?

b. What is the net displacement of the skier during the three minutes of recreation?

c. What is the displacement during the second minute (from 1 min. to 2 min.)?

d. What is the displacement during the third minute (from 2 min. to 3 min.)?

Describing Motion Verbally with Speed and Velocity

Read from **Lesson 1** of the **1-D Kinematics** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/1DKin/U1L1d.html

MOP Connection: Kinematic Concepts: sublevels 3 and 6

Review:
1. A _____ quantity is completely described by magnitude alone. A _____ quantity is completely described by a magnitude with a direction.
    a. scalar, vector   b. vector, scalar

2. Speed is a _____ quantity and velocity is a _____ quantity.
    a. scalar, vector   b. vector, scalar

Speed vs. Velocity
Speed and velocity are two quantities in Physics that seem at first glance to have the same meaning. While related, they have distinctly different definitions. Knowing their definitions is critical to understanding the difference between them.

     Speed is a quantity that describes how fast or how slow an object is moving.

     Velocity is a quantity that is defined as the rate at which an object's position changes.

3. Suppose you are considering three different paths (A, B and C) between the same two locations.
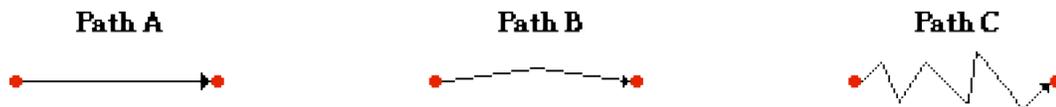
     Along which path would you have to move with the greatest speed to arrive at the destination in the same amount of time?   _____ Explain.

4. **True** or **False**: It is possible for an object to move for 10 seconds at a high speed and end up with an average velocity of zero.
    a. True   b. False

5. If the above statement is true, then describe an example of such a motion. If the above statement is false, then explain why it is false.

6. Suppose that you run for 10 seconds along three different paths.
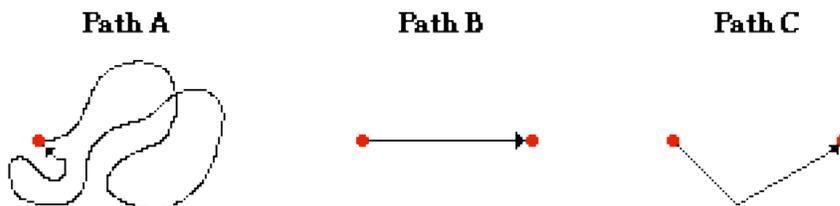
     Rank the three paths from the lowest average speed to the greatest average speed. _____

     Rank the three paths from the lowest average velocity to the greatest average velocity. _____

## Calculating Average Speed and Average Velocity

> The average speed of an object is the rate at which an object covers distance. The average velocity of an object is the rate at which an object changes its position. Thus,
>
> $$\text{Ave. Speed} = \frac{\text{distance}}{\text{time}} \qquad\qquad \text{Ave. Velocity} = \frac{\text{displacement}}{\text{time}}$$
>
> Speed, being a scalar, is dependent upon the scalar quantity distance. Velocity, being a vector, is dependent upon the vector quantity displacement.

7. You run from your house to a friend's house that is 3 miles away in 30 minutes. You then immediately walk home, taking 1 hour on your return trip.
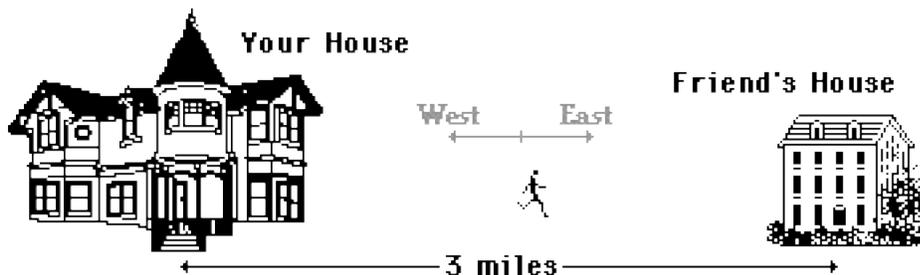
a. What was the average speed (in mi/hr) for the entire trip? _____

b. What was the average velocity (in mi/hr) for the entire trip? _____

8. A cross-country skier moves from location A to location B to location C to location D. Each *leg* of the back-and-forth motion takes 1 minute to complete; the total time is 3 minutes. The unit of length is meters.
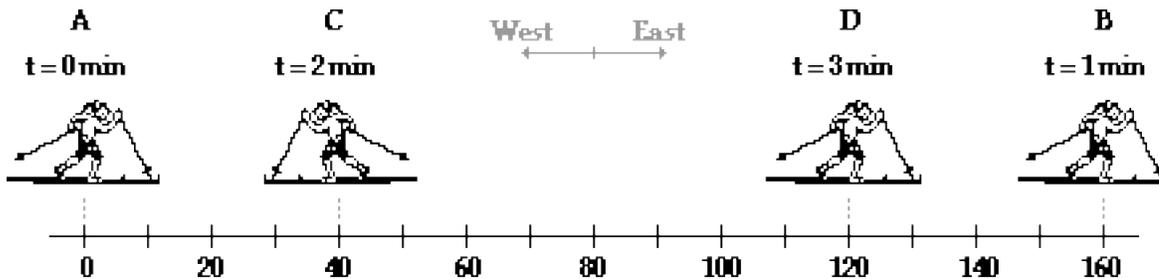
Calculate the average speed (in m/min) and the average velocity (in m/min) of the skier during the three minutes of recreation. **PSYW**

Ave. Speed =   **Ave. Velocity =**

Instantaneous Speed vs. Average Speed

The instantaneous speed of an object is the speed that an object has at any given instant. When an object moves, it doesn't always move at a steady pace. As a result, the instantaneous speed is changing. For an automobile, the instantaneous speed is the speedometer reading. The average speed is simply the average of all the speedometer readings taken at regular intervals of time. Of course, the easier way to determine the average speed is to simply do a distance/time ratio.

9. Consider the data at the right for the first 10 minutes of a teacher's trip along the expressway to school. Determine ...
    a. ... the average speed (in mi/min) for the 10 minutes of motion.

    b. ... an estimate of the maximum speed (in mi/min) based on the given data.

Time (min)	Pos'n (mi)
0	0
1	0.4
2	0.8
3	1.3
4	2.1
5	2.5
6	2.7
7	3.8
8	5.0
9	6.4
10	7.6

10. The graph below shows Donovan Bailey's split times for his 100-meter record breaking run in the Atlanta Olympics in 1996.
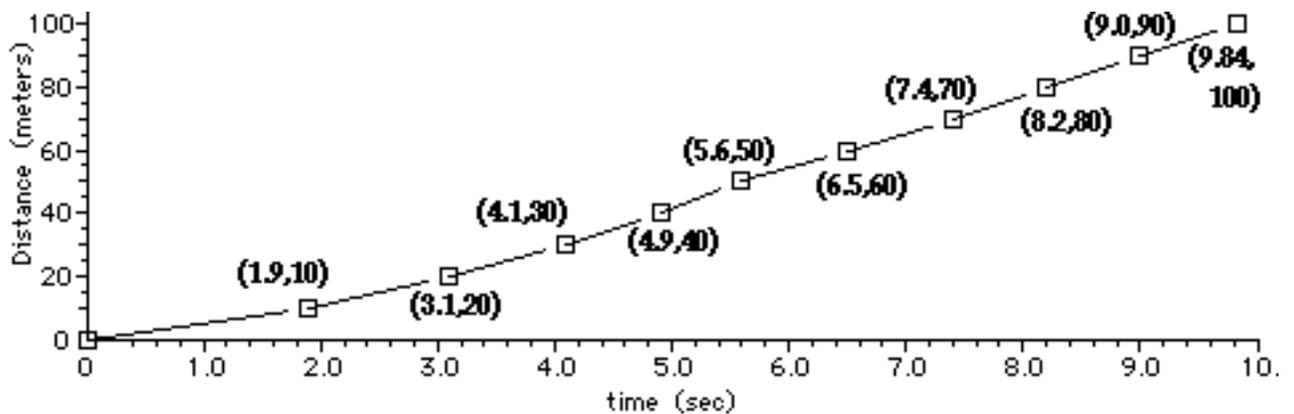
a. At what point did he experience his greatest average speed for a 10 meter interval? Calculate this speed in m/s.   **PSYW**

b. What was his average speed (in m/s) for the overall race? **PSYW**

Problem-Solving:
11. Thirty years ago, police would check a highway for speeders by sending a helicopter up in the air and observing the time it would take for a car to travel between two wide lines placed 1/10th of a mile apart. On one occasion, a car was observed to take 7.2 seconds to travel this distance.
    a. How much time did it take the car to travel the distance in hours?

    b. What is the speed of the car in miles per hour?

12. The fastest trains are magnetically levitated above the rails to avoid friction (and are therefore called MagLev trains…cool, huh?). The fastest trains travel about 155 miles in a half an hour. What is their average speed in miles/hour?

13. In 1960, U.S. Air Force Captain Joseph Kittinger broke the records for the both the fastest and the longest sky dive…he fell an amazing 19.5 miles! (Cool facts: There is almost no air at that altitude, and he said that he almost didn't feel like he was falling because there was no whistling from the wind or movement of his clothing through the air. The temperature at that altitude was 36 degrees Fahrenheit *below* zero!) His average speed while falling was 254 miles/hour. How much time did the dive last?

14. A hummingbird averages a speed of about 28 miles/hour (Cool facts: They visit up to 1000 flowers per day, and reach maximum speed while diving … up to 100 miles/hour!). Ruby-throated hummingbirds take a 2000 mile journey when they migrate, including a non-stop trip across Gulf of Mexico in which they fly for 18 hours straight! How far is the trip across the Gulf of Mexico?

Acceleration

Read from **Lesson 1** of the **1-D Kinematics** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/1DKin/U1L1e.html

MOP Connection: Kinematic Concepts: sublevels 4 and 7

Review:
The instantaneous velocity of an object is the _____ of the object with a _____.

The Concept of Acceleration
1. Accelerating objects are objects that are changing their velocity. Name the three controls on an automobile that cause it to accelerate.

2. An object is accelerating if it is moving _____. Circle all that apply.
    a. with changing speed   b. extremely fast   c. with constant velocity
    d. in a circle   e. downward   f. none of these

3. If an object is NOT accelerating, then one knows for sure that it is _____.
    a. at rest   b. moving with a constant speed
    c. slowing down   d. maintaining a constant velocity

Acceleration as a Rate Quantity
Acceleration is the rate at which an object's velocity changes. The velocity of an object refers to how fast it moves and in what direction. The acceleration of an object refers to how fast an object changes its speed or its direction. Objects with a high acceleration are rapidly changing their speed or their direction. As a rate quantity, acceleration is expressed by the equation:

$$\text{acceleration} = \frac{\Delta \text{ Velocity}}{\text{time}} = \frac{v_{final} - v_{original}}{\text{time}}$$

4. An object with an acceleration of 10 m/s^2 will ____. Circle all that apply.
    a. move 10 meters in 1 second   b. change its velocity by 10 m/s in 1 s
    c. move 100 meters in 10 seconds   d. have a velocity of 100 m/s after 10 s

5. Ima Speedin puts the pedal to the metal and increases her speed as follows: 0 mi/hr at 0 seconds; 10 mi/hr at 1 second; 20 mi/hr at 2 seconds; 30 mi/hr at 3 seconds; and 40 mi/hr at 4 seconds. What is the acceleration of Ima's car?

6. Mr. Henderson's (imaginary) Porsche accelerates from 0 to 60 mi/hr in 4 seconds. Its acceleration is _____ .
    a. 60 mi/hr   b. 15 m/s/s   c. 15 mi/hr/s   d. -15 mi/hr/s   e. none of these

7. A car speeds up from rest to +16 m/s in 4 s. Calculate the acceleration.

8. A car slows down from +32 m/s to +8 m/s in 4 s. Calculate the acceleration.

Acceleration as a Vector Quantity

Acceleration, like velocity, is a vector quantity. To fully describe the acceleration of an object, one must describe the direction of the acceleration vector. A **general rule of thumb** is that if an object is moving in a straight line and slowing down, then the direction of the acceleration is opposite the direction the object is moving. If the object is speeding up, the acceleration direction is the same as the direction of motion.

9. Read the following statements and indicate the direction (up, down, east, west, north or south) of the acceleration vector.

	Description of Motion	**Dir'n of Acceleration**
a.	A car is moving eastward along Lake Avenue and increasing its speed from 25 mph to 45 mph.	
b.	A northbound car skids to a stop to avoid a reckless driver.	
c.	An Olympic diver slows down after splashing into the water.	
d.	A southward-bound free quick delivered by the opposing team is slowed down and stopped by the goalie.	
e.	A downward falling parachutist pulls the chord and rapidly slows down.	
f.	A rightward-moving Hot Wheels car slows to a stop.	
g.	A falling bungee-jumper slows down as she nears the concrete sidewalk below.	

10. The diagram at the right portrays a Hot Wheels track designed for a phun physics lab. The car starts at point A, descends the hill (continually speeding up from A to B); after a short straight section of track, the car rounds the curve and finishes its *run* at point C. The car continuously slows down from point B to point C. Use this information to complete the following table.
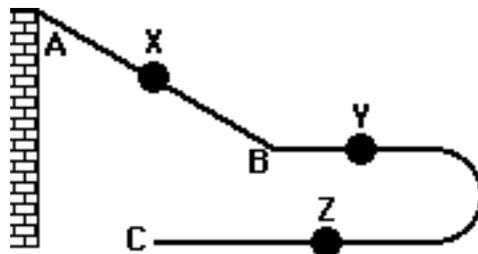
Point	Direction of Velocity of Vector	Direction of Acceleration Vector
X	_____ Reason: _____	_____ Reason: _____
Y	_____ Reason: _____	_____ Reason: _____
Z	_____ Reason: _____	_____ Reason: _____

Describing Motion with Diagrams

Read from **Lesson 2** of the **1-D Kinematics** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/1DKin/U1L2a.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L2b.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L2c.html**

MOP Connection: Kinematic Concepts: sublevel 5

Motion can be described using words, diagrams, numerical information, equations, and graphs. Using diagrams to describe the motion of objects involves depicting the location or position of an object at regular time intervals.

1. Motion diagrams for an amusement park ride are shown. The diagrams indicate the positions of the car at regular time intervals. For each of these diagrams, indicate whether the car is accelerating or moving with constant velocity. If accelerating, indicate the direction (right or left) of acceleration. Support your answer with reasoning.

	Acceleration: Y/N	Dir'n
a. Reason: _____ _____		
b. Reason: _____ _____		
c. Reason: _____ _____		
d. Reason: _____ _____		
e. Reason: _____ _____		

2. Suppose that in diagram D (above) the cars were moving leftward (and traveling backwards). What would be the direction of the acceleration? _____ Explain your answer fully.

3. Based on the oil drop pattern for Car A and Car B, which of the following statements are true? Circle all that apply.
    a. Both cars have a constant velocity.
    b. Both cars have an accelerated motion.
    c. Car A is accelerating; Car B is not.
    d. Car B is accelerating; Car A is not.
    e. Car A has a greater acceleration than Car B.
    f. Car B has a greater acceleration than Car A.

4. An object is moving from right to left. It's motion is represented by the oil drop diagram below. This object has a _____ velocity and a _____ acceleration.

    a. rightward, rightward
    b. rightward, leftward
    c. leftward, rightward
    d. leftward, leftward
    e. rightward, zero
    f. leftward, zero

5. Renatta Oyle's car has an oil leak and leaves a trace of oil drops on the streets as she drives through Glenview. A study of Glenview's streets reveals the following traces. Match the trace with the verbal descriptions given below. For each match, verify your reasoning.

    Diagram A:

    Diagram B:

    Diagram C:

	Verbal Description	Diagram
i.	Renatta was driving with a slow constant speed, decelerated to rest, remained at rest for 30 s, and then drove very slowly at a constant speed. Reasoning: _____ _____	
ii.	Renatta rapidly decelerated from a high speed to a rest position, and then slowly accelerated to a moderate speed. Reasoning: _____ _____	
iii.	Renatta was driving at a moderate speed and slowly accelerated. Reasoning: _____ _____	

Name: _____

Describing Motion Numerically

Read from **Lesson 1** of the **1-D Kinematics** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/1DKin/U1L1d.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L1e.html**

MOP Connection: Kinematic Concepts: sublevel 8

Motion can be described using words, diagrams, numerical information, equations, and graphs. Describing motion with numbers can involve a variety of skills. On this page, we will focus on the use tabular data to describe the motion of objects.

1. Position-time information for a giant sea turtle, a cheetah, and the continent of North America are shown in the data tables below. Assume that the motion is uniform for these three objects and fill in the blanks of the table. Then record the speed of these three objects (include units).

Giant Sea Turtle

Time (hr)	Position (mi)
0	0
1	0.23
2	0.46
3	_____
4	0.92
5	_____
6	_____

Speed = _____

Cheetah

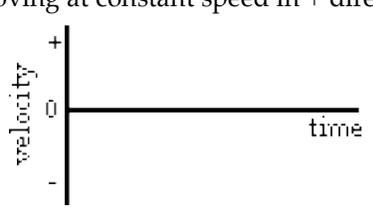| Time (s)	Position (m)
0	0
0.5	12.5
1	_____
1.5	_____
2	_____
2.5	_____
3	75.0

Speed = _____

North America

Time (yr)	Position (cm)
0	0
0.25	_____
0.50	0.50
0.75	0.75
1.0	_____
1.25	_____
1.50	1.50

Speed = _____

2   Motion information for a snail, a Honda Accord, and a peregrine falcon are shown in the tables below. Fill in the blanks of the table. Then record the acceleration of the three objects (include the appropriate units). Pay careful attention to column headings.

Snail

Time (day)	Position (ft)
0	0
1	11
2	_____
3	_____
4	44
5	_____
6	66

Acceleration = _____

Honda Accord

Time (s)	Velocity (mi/hr)
0	60, E
0.5	54, E
1	_____
1.5	42, E
2	_____
2.5	_____
3	24, E

Acceleration = _____

Peregrine Falcon

Time (s)	Velocity (m/s)
0	0
0.25	_____
0.50	18, down
0.75	27, down
1.0	_____
1.25	_____
1.5	54, down

Acceleration = _____

3. Use the following equality to form a conversion factor in order to convert the speed of the cheetah (from question #1) into units of miles/hour. (**1 m/s = 2.24 mi/hr**) **PSYW**

4. Use the following equalities to convert the speed of the snail (from question #2) to units of miles per hour. Show your conversion factors.

    GIVEN: **2.83 x 10^5 ft/day = 1 m/s**   **1 m/s = 2.24 mi/hr**

5. Lisa Carr is stopped at the corner of Willow and Phingsten Roads. Lisa's borrowed car has an oil leak; it leaves a trace of oil drops on the roadway at regular time intervals. As the light turns green, Lisa accelerates from rest at a rate of 0.20 m/s^2. The diagram shows the trace left by Lisa's car as she accelerates. Assume that Lisa's car drips one drop every second. Indicate on the diagram the instantaneous velocities of Lisa's car at the end of each 1-s time interval.
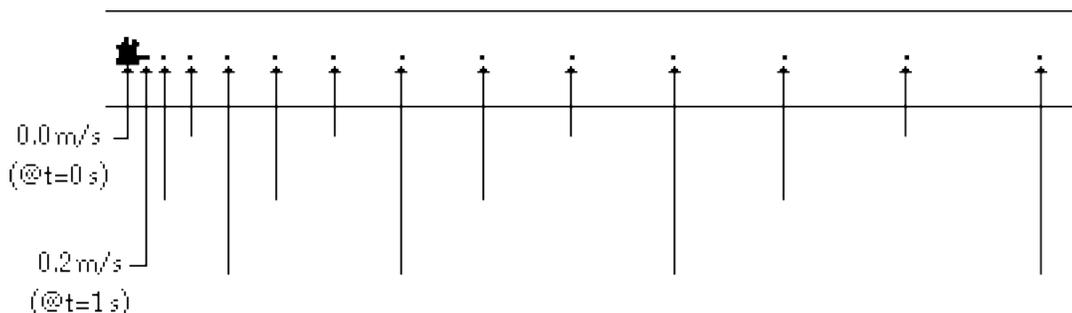
6. Determine the acceleration of the objects whose motion is depicted by the following data.

Data Set A		Data Set B		Data Set C		Data Set D	
t(s)	v(m/s)	t(s)	v(m/s)	t(s)	v(m/s)	t(s)	v(m/s)
0	32	0	12	0	24	0	32
1	28	0.5	10	1	21	0.5	28
2	24	1.0	8	2	18	1.0	24
3	20	1.5	6	3	15	1.5	20
4	16	2.0	4	4	12	2.0	16
5	12	2.5	2	5	9	2.5	12
6	8	3.0	0	6	6	3.0	8

a = _____ m/s/s   a = _____ m/s/s   a = _____ m/s/s   a = _____ m/s/s

Describing Motion with Position-Time Graphs

Read from **Lesson 3** of the **1-D Kinematics** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/1DKin/U1L3a.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L3b.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L3c.html**

MOP Connection: Kinematic Graphing: sublevels 1-4 (and some of sublevels 9-11)

Motion can be described using words, diagrams, numerical information, equations, and graphs. Describing motion with graphs involves representing how a quantity such as the object's position can change with respect to the time. The key to using position-time graphs is knowing that the slope of a position-time graph reveals information about the object's velocity. By *detecting* the slope, one can infer about an object's velocity. "As the slope goes, so goes the velocity."

Review:
1.   Categorize the following motions as being either examples of + or - acceleration.

   a. Moving in the + direction and speeding up (getting faster)   _____

   b. Moving in the + direction and slowing down (getting slower)   _____

   c. Moving in the - direction and speeding up (getting faster)   _____

   d. Moving in the - direction and slowing down (getting slower)   _____

Interpreting Position-Graphs
2.   On the graphs below, draw two lines/curves to represent the given verbal descriptions; label the lines/curves as A or B.

A Remaining at rest	A Moving slow	A Moving in + direction
B Moving	B Moving fast	B Moving in - direction

A Moving at constant speed	A Move in + dirn; speed up	A Move in - dirn; speed up
B Accelerating	B Move in + dirn; slow dn	B Move in - dirn; slow dn

3.   For each type of accelerated motion, construct the appropriate shape of a position-time graph.

Moving with a + velocity and a + acceleration	Moving with a + velocity and a - acceleration

Moving with a - velocity and a + acceleration	Moving with a - velocity and a - acceleration
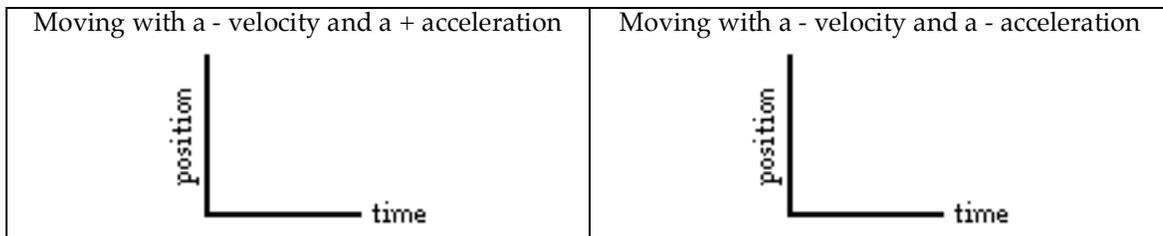
4. Use your understanding of the meaning of slope and shape of position-time graphs to describe the motion depicted by each of the following graphs.

 Verbal Description:	 Verbal Description:
 Verbal Description:	 Verbal Description:
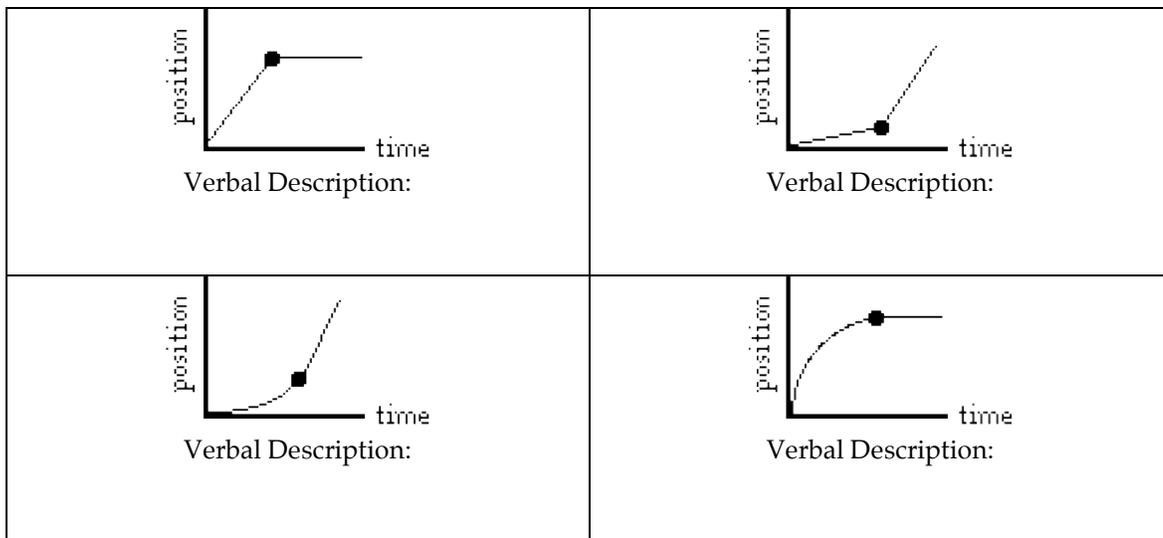
5. Use the position-time graphs below to determine the velocity. **PSYW**

 PSYW:	 **PSYW**:
 PSYW:	 **PSYW**:
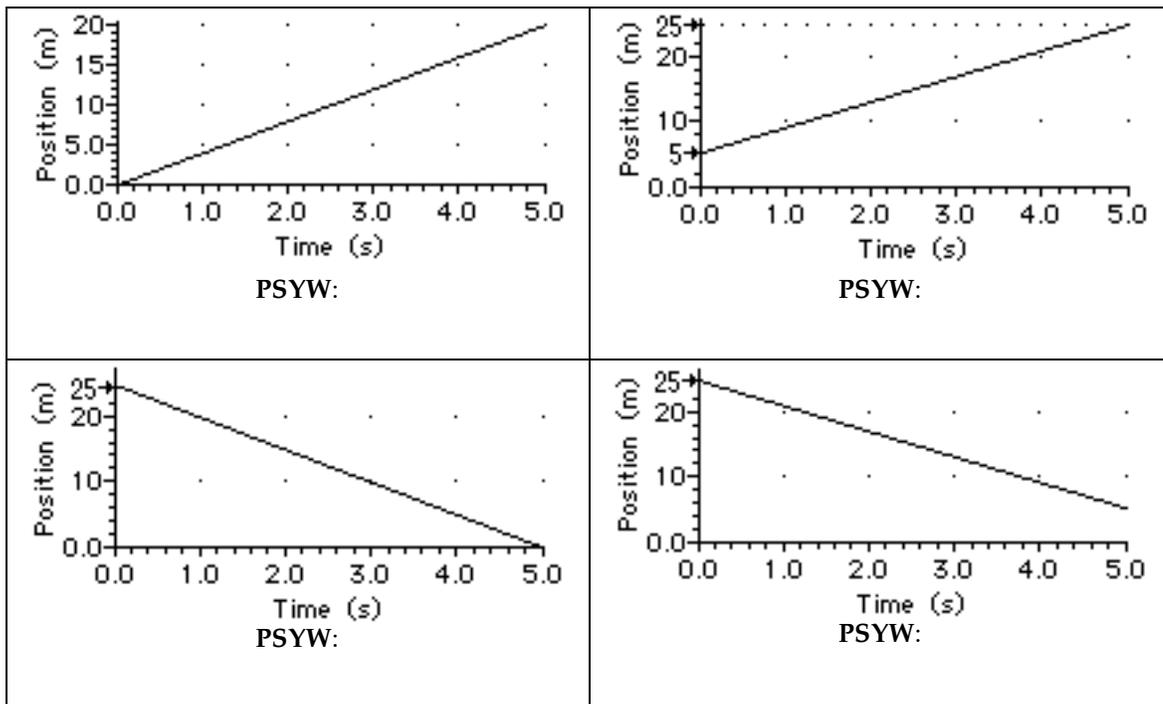
Describing Motion with Velocity-Time Graphs

Read from **Lesson 4** of the **1-D Kinematics** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/1DKin/U1L4a.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L4b.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L4c.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L4d.html**

MOP Connection: Kinematic Graphing: sublevels 5-8 (and some of sublevels 9-11)

Motion can be described using words, diagrams, numerical information, equations, and graphs. Describing motion with graphs involves representing how a quantity such as the object's velocity = changes with respect to the time. The key to using velocity-time graphs is knowing that the slope of a velocity-time graph represents the object's acceleration and the area represents the displacement.

Review:
1.   Categorize the following motions as being either examples of + or - acceleration.

   a. Moving in the + direction and speeding up (getting faster)   _____

   b. Moving in the + direction and slowing down (getting slower)   _____

   c. Moving in the - direction and speeding up (getting faster)   _____

   d. Moving in the - direction and slowing down (getting slower)   _____

Interpreting Velocity-Graphs
2.   On the graphs below, draw two lines/curves to represent the given verbal descriptions; label the lines/curves as A or B.

A Moving at constant speed in - direction B Moving at constant speed in + direction	A Moving in + direction and speeding up B Moving in - direction and speeding up
A Moving in + direction and slowing down B Moving in - direction and slowing down	A Moving with + velocity and - accel'n B Moving with + velocity and + accel'n
A Moving with - velocity and - accel'n B Moving with - velocity and + accel'n	A Moving in + dir'n, first fast, then slow B Moving in - dir'n, first fast, then slow
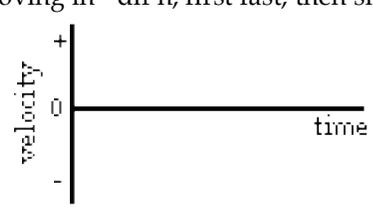
3. Use the velocity-time graphs below to determine the acceleration. **PSYW**

PSYW: PSYW:
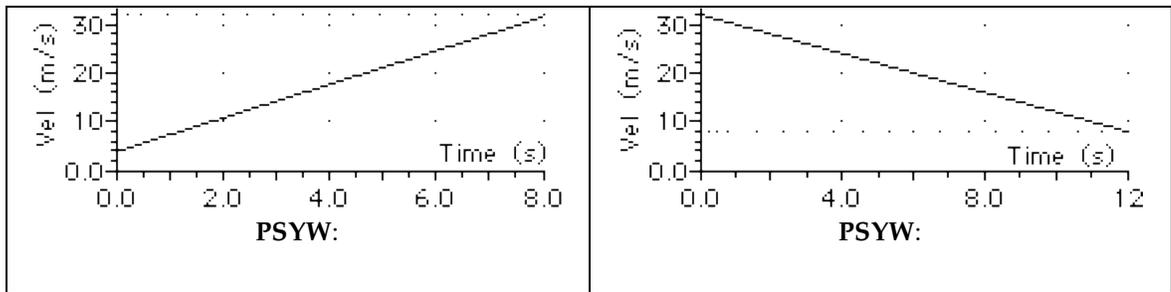
4. The area under the line of a velocity-time graph can be calculated using simple rectangle and triangle equations. The graphs below are examples:

If the area under the line forms a ...
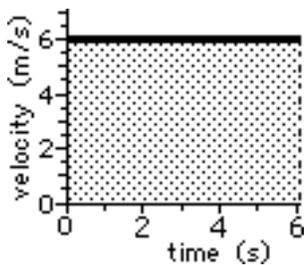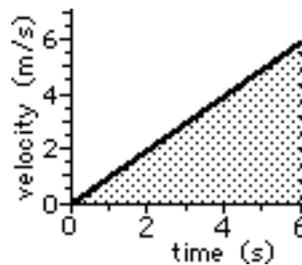
... **rectangle**, then use	... **triangle**, then use	... **trapezoid**, then make it into a rectangle + triangle and add the two areas.
area = base*height	area = 0.5 * base*height	
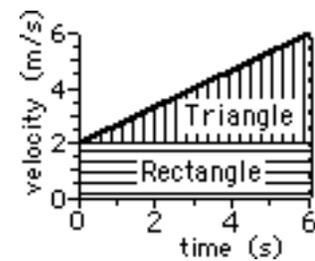
$A_{total} = A_{rectangle} + A_{triangle}$

A = (6 m/s)*(6 s) = **36 m**   A = 0.5 * (6 m/s)*(6 s) = **18 m**

$A_{total} = (2m/s)*(6 s) + 0.5 * (4 m/s) * (6 s) =$ **24 m**

Find the displacement of the objects represented by the following velocity-time graphs.
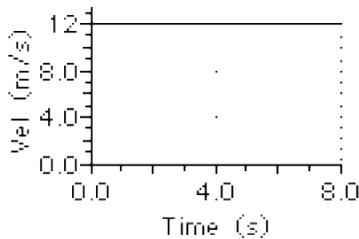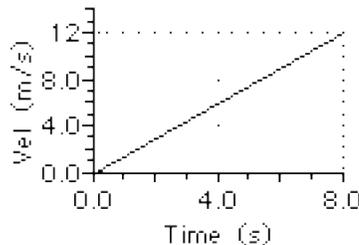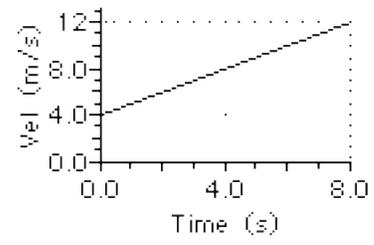
PSYW: PSYW: PSYW:

5. For the following pos-time graphs, determine the corresponding shape of the vel-time graph.
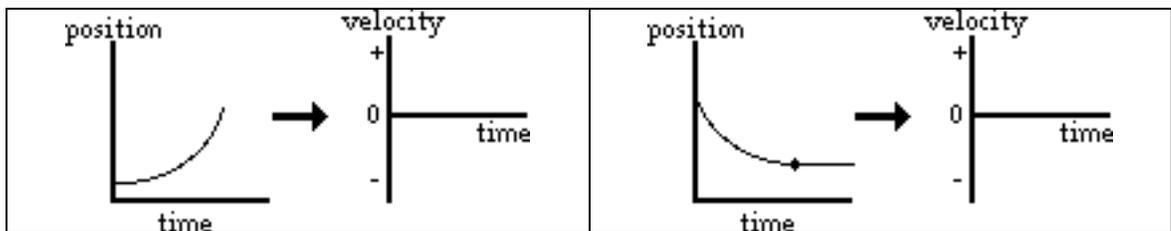
Describing Motion Graphically

Study **Lessons 3 and 4** of the **1-D Kinematics** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/1DKin/1DKinTOC.html

MOP Connection: Kinematic Graphing: sublevels 1-11 (emphasis on sublevels 9-11)

1.   The slope of the line on a position vs. time graph reveals information about an object's velocity. The magnitude (numerical value) of the slope is equal to the object's speed and the direction of the slope (upward/+ or downward/-) is the same as the direction of the velocity vector. Apply this understanding to answer the following questions.

   a.   A horizontal line means _____ .

   b.   A straight diagonal line means _____ .

   c.   A curved line means _____ .

   d.   A gradually sloped line means _____ .

   e.   A steeply sloped line means _____ .
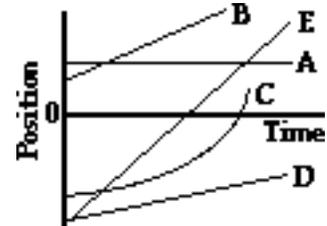
2.   The motion of several objects is depicted on the position vs. time graph. Answer the following questions. Each question may have less than one, one, or more than one answer.

   _____ a. Which object(s) is(are) at rest?

   _____ b. Which object(s) is(are) accelerating?

   _____ c. Which object(s) is(are) not moving?

   _____ d. Which object(s) change(s) its direction?

   _____ e. Which object is traveling fastest?

   _____ f. Which moving object is traveling slowest?

   _____ g. Which object(s) is(are) moving in the same direction as object B?
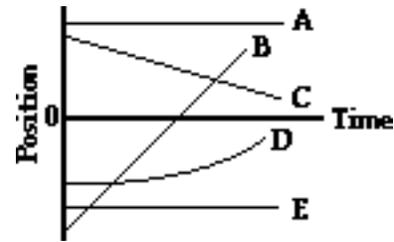
3.   The slope of the line on a velocity vs. time graph reveals information about an object's acceleration. Furthermore, the area under the line is equal to the object's displacement. Apply this understanding to answer the following questions.

   a.   A horizontal line means _____ .

   b.   A straight diagonal line means _____ .

   c.   A gradually sloped line means _____ .

   d.   A steeply sloped line means _____ .
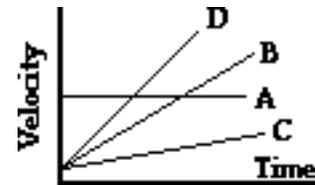
4.   The motion of several objects is depicted by a velocity vs. time graph. Answer the following questions. Each question may have less than one, one, or more than one answer.

   _____ a. Which object(s) is(are) at rest?

   _____ b. Which object(s) is(are) accelerating?

   _____ c. Which object(s) is(are) not moving?

   _____ d. Which object(s) change(s) its direction?

   _____ e. Which accelerating object has the smallest acceleration?

   _____ f. Which object has the greatest acceleration?

   _____ g. Which object(s) is(are) moving in the same direction as object E?
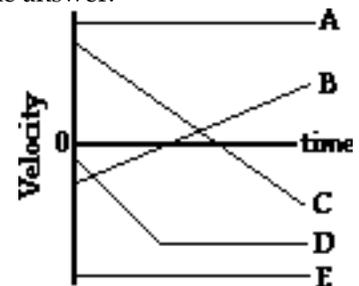
Motion in One Dimension

5. The graphs below depict the motion of several different objects. Note that the graphs include both position vs. time and velocity vs. time graphs.

| Graph A | Graph B | Graph C | Graph D | Graph E |
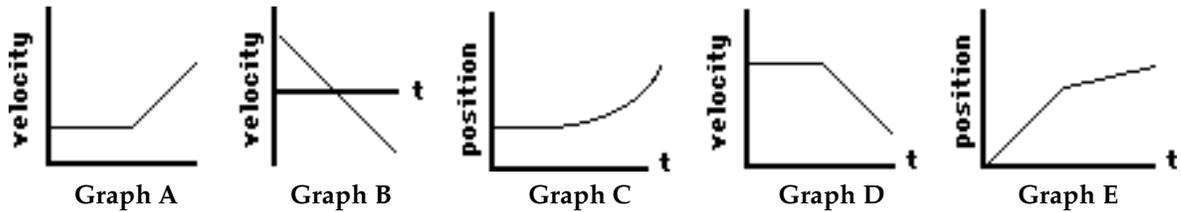
The motion of these objects could also be described using words. Analyze the graphs and match them with the verbal descriptions given below by filling in the blanks.

Verbal Description	Graph
a. The object is moving fast with a constant velocity and then moves slow with a constant velocity.	
b. The object is moving in one direction with a constant rate of acceleration (slowing down), changes directions, and continues in the opposite direction with a constant rate of acceleration (speeding up).	
c. The object moves with a constant velocity and then slows down.	
d. The object moves with a constant velocity and then speeds up.	
e. The object maintains a rest position for several seconds and then accelerates.	

6. Consider the position-time graphs for objects A, B, C and D. On the *ticker tapes* to the right of the graphs, construct a dot diagram for each object. Since the objects could be moving right or left, put an arrow on each *ticker tape* to indicate the direction of motion.
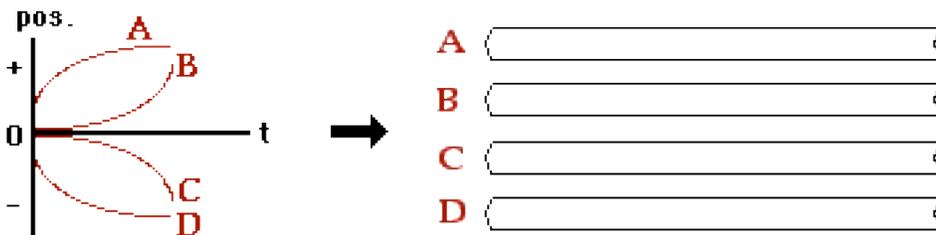
7. Consider the velocity-time graphs for objects A, B, C and D. On the *ticker tapes* to the right of the graphs, construct a dot diagram for each object. Since the objects could be moving right or left, put an arrow on each *ticker tape* to indicate the direction of motion.
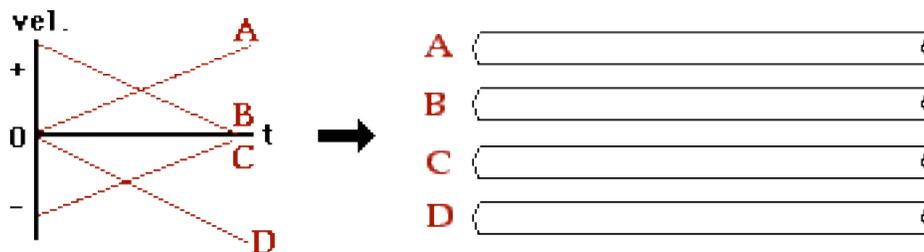
Interpreting Velocity-Time Graphs

The motion of a two-stage rocket is portrayed by the following velocity-time graph.
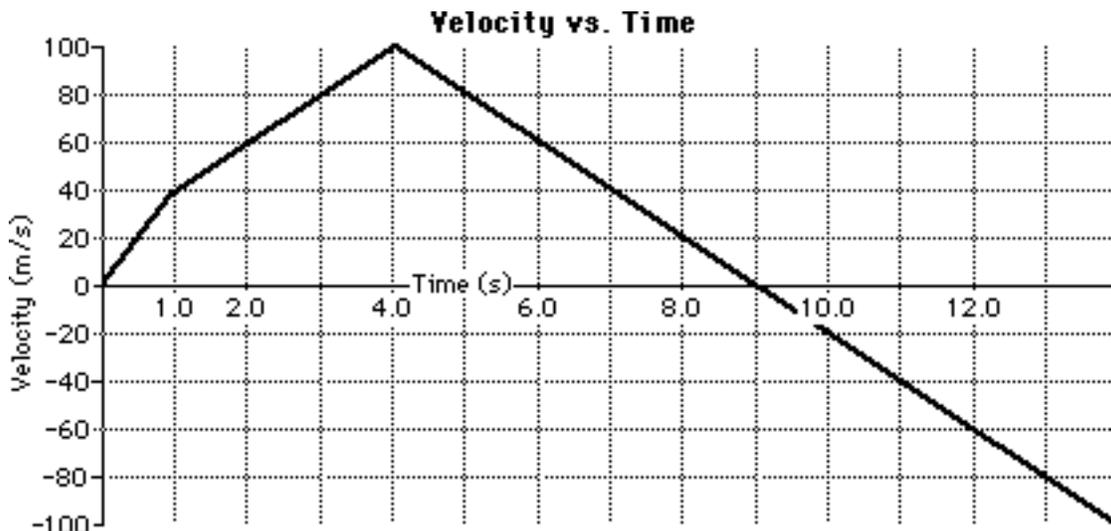
Several students analyze the graph and make the following statements. Indicate whether the statements are correct or incorrect. Justify your answers by referring to specific features about the graph.
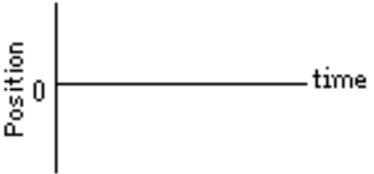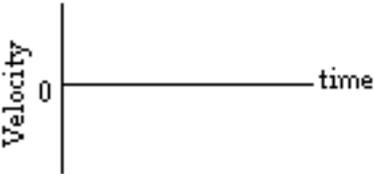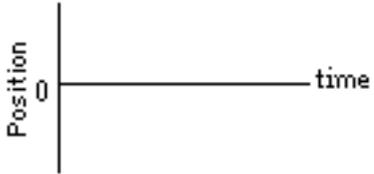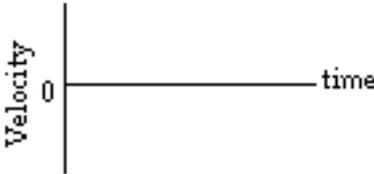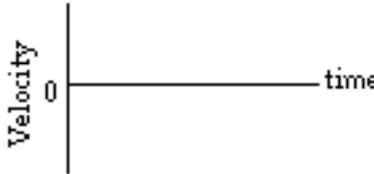
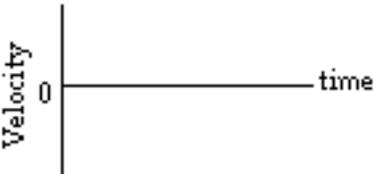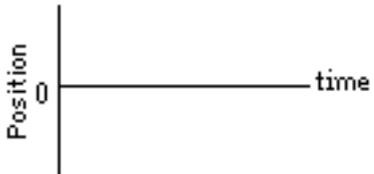| **Student Statement**	**Correct?** **Yes or No**
1. After 4 seconds, the rocket is moving in the negative direction (i.e., down). Justification: _____	_____
2. The rocket is traveling with a greater speed during the time interval from 0 to 1 second than the time interval from 1 to 4 seconds. Justification: _____	_____
3. The rocket changes its direction after the fourth second. Justification: _____	_____
4. During the time interval from 4 to 9 seconds, the rocket is moving in the positive direction (up) and slowing down. Justification: _____	_____
5. At nine seconds, the rocket has returned to its initial starting position. Justification: _____	_____

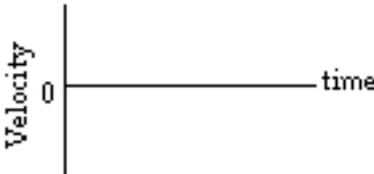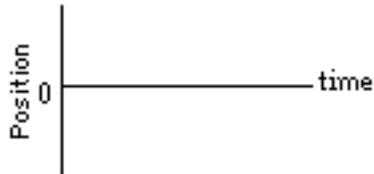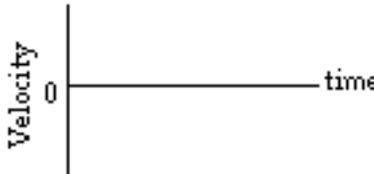# Graphing Summary

Study **Lessons 3 and 4** of the **1-D Kinematics** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/1DKin/1KinTOC.html

MOP Connection: Kinematic Graphing: sublevels 1-11 (emphasis on sublevels 9-11)

Constant Velocity Object moves in + Direction	**Constant Velocity** Object moves in - Direction	**Constant + Acceleration** Object moves in + Direction
Velocity Dir'n: + or -	Velocity Dir'n: + or -	Velocity Dir'n: + or - Speeding up or Slowing Down?

Constant + Acceleration Object moves in - Direction	**Constant - Acceleration** Object moves in - Direction	**Constant - Acceleration** Object moves in + Direction
Velocity Dir'n: + or - Speeding up or Slowing Down?	Velocity Dir'n: + or - Speeding up or Slowing Down?	Velocity Dir'n: + or - Speeding up or Slowing Down?

Kinematic Graphing - Mathematical Analysis

Study **Lessons 3 and 4** of the **1-D Kinematics** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/1DKin/1KinTOC.html

1.   Consider the following graph of a car in motion. Use the graph to answer the questions.

a.   Describe the motion of the car during each of the two parts of its motion.

0-5 s: _____

5-15 s: _____

b.   Construct a *dot diagram* for the car's motion.

c.   Determine the acceleration of the car during each of the two parts of its motion.

<u>0-5 s</u>   <u>5-15 s</u>

d.   Determine the displacement of the car during each of the two parts of its motion.

<u>0-5 s</u>   <u>5-15 s</u>

e.   Fill in the table and sketch position-time for this car's motion. Give particular attention to how you connect coordinate points on the graphs (curves vs. horizontals vs. diagonals).

Time (s)	Pos'n (m)
0	0
5	
10	
15	

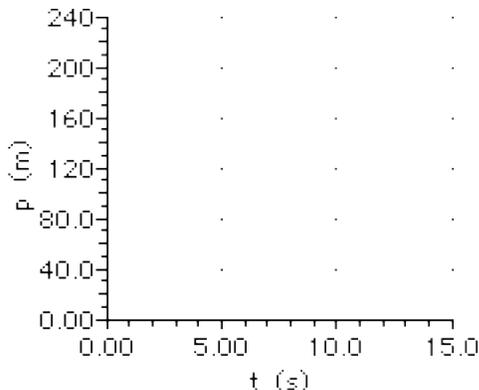**Motion in One Dimension**

2. Consider the following graph of a car in motion. Use the graph to answer the questions.
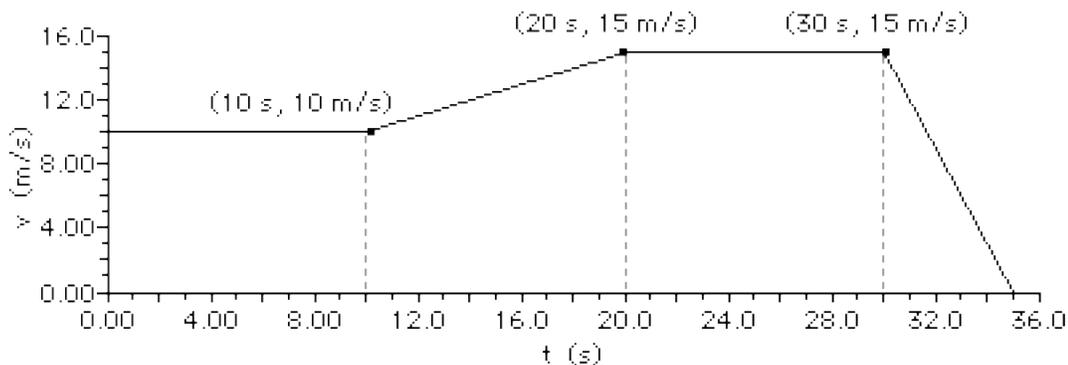
a. Describe the motion of the car during each of the four parts of its motion.

0-10 s: _____

10-20 s: _____

20-30 s: _____

30-35 s: _____

b. Construct a *dot diagram* for the car's motion.

c. Determine the acceleration of the car during each of the four parts of its motion. **PSYW**

      0-10 s   10-20 s   20-30 s   30-35 s

d. Determine the displacement of the car during each of the four parts of its motion. **PSYW**

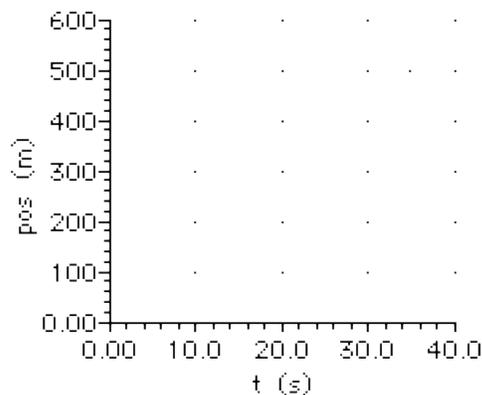   0-10 s   10-20 s   20-30 s   30-35 s

e. Fill in the table and sketch position-time for this car's motion. Give particular attention to how you connect coordinate points on the graphs (curves vs. horizontals vs. diagonals).

Time (s)	Pos'n (m)
0	0
5	
10	
15	
20	
25	
30	
35	

Describing Motion with Equations

Read from **Lesson 6** of the **1-D Kinematics** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/1DKin/U1L6a.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L6b.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L6d.html**

MOP Connection: None

Motion can be described using words, diagrams, numerical information, equations, and graphs. Describing motion with equations involves using the three simple equations for average speed, average velocity, and average acceleration and the more complicated equations known as kinematic equations.

Definitional Equations:

$$\text{Average Speed} = \frac{\text{distance traveled}}{\text{time}} \qquad\qquad \text{Average Velocity} = \frac{\text{displacement}}{\text{time}}$$

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{change in time}}$$

Kinematic Equations:

You should be able to use the following kinematic equations to solve problems. These equations appropriately apply to the motion of objects traveling with a constant acceleration.

$$v_f = v_i + a\,t \qquad d = \frac{v_i + v_f}{2}\,t \qquad d = v_i\,t + \frac{1}{2}\,a\,t^2 \qquad v_f^2 = v_i^2 + 2\,a\,d$$

A Note on Problem Solving

A common instructional goal of a physics course is to assist students in becoming better and more confident problem-solvers. Not all good and confident problem-solvers use the same approaches to solving problems. Nonetheless, there are several **habits** which they all share in common. While a good problem-solver may not religiously adhere to these habitual practices, they become more reliant upon them as the problems become more difficult. The list below describes some of the habits which good problem-solvers share in common. The list is NOT an exhaustive list; it simply includes some commonly observed habits which good problem-solvers practice.

Habit #1 - Reading and Visualizing
All good problem-solvers will read a problem carefully and make an effort to visualize the physical situation. Physics problems begin as word problems and terminate as mathematical exercises. Before the mathematics portion of a problem begins, a student must translate the written information into mathematical variables. A good problem-solver typically begins the translation of the written words into mathematical variables by an informative sketch or diagram which depicts the situation.

Habit #2 - Organization of Known and Unknown Information
Physics problems begin as word problems and terminate as mathematical exercises. During the algebraic/mathematical part of the problem, the student must make substitution of known numerical information into a mathematical formula (and hopefully into the correct formula). Before performing such substitutions, the student must first equate the numerical information contained in the verbal statement with the appropriate physical quantity. It is the habit of a good problem-solver to conduct this task by writing down the quantitative information with its unit and symbol in an organized fashion, often recording the values on their diagram.

Habit #3 - Plotting a Strategy for Solving for the Unknown
Once the physical situation has been visualized and diagrammed and the numerical information has been extracted from the verbal statement, the strategy plotting stage begins. More than any other stage during the problem solution, it is during this stage that a student must think critically and apply their physics knowledge. Difficult problems in physics are multi-step problems. The path from known information to the unknown quantity is often not immediately obvious. The problem becomes like a jigsaw puzzle; the assembly of all the pieces into the whole can only occur after careful inspection, thought, analysis, and perhaps some wrong turns. In such cases, the time taken to plot out a strategy will pay huge dividends, preventing the loss of several frustrating minutes of impulsive attempts at solving the problem.

Habit #4 - Identification of Appropriate Formula(e)
Once a strategy has been plotted for solving a problem, a good problem-solver will list appropriate mathematical formulae on their paper. They may take the time to rearrange the formulae such that the unknown quantity appears by itself on the left side of the equation. The process of identifying formula is simply the natural outcome of an effective strategy-plotting phase.

Habit #5 - Algebraic Manipulations and Operations
Finally the mathematics begins, but only after the all-important thinking and physics has occurred. In the final step of the solution process, known information is substituted into the identified formulae in order to solve for the unknown quantity.

It should be observed in the above description of the habits of a good problem-solver that the majority of work on a problem is done prior to the performance of actual mathematical operations. Physics problems are more than exercises in mathematical manipulation of numerical data. Physics problems require careful reading, good visualization skills, some background physics knowledge, analytical thought and inspection and a lot of strategy-plotting. Even the best algebra students in the course will have difficulty solving physics problems if they lack the habits of a good problem-solver.

Motion Problems

Read from **Lesson 6** of the **1-D Kinematics** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/1DKin/U1L6a.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L6b.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L6c.html**
> **http://www.physicsclassroom.com/Class/1DKin/U1L6d.html**

MOP Connection: None

Show your work on the following problems.
1. An airplane accelerates down a run-way at 3.20 m/s^2 for 32.8 s until is finally lifts off the ground. Determine the distance traveled before take-off.

2. A race car accelerates uniformly from 18.5 m/s to 46.1 m/s in 2.47 seconds. Determine the acceleration of the car and the distance traveled.

3. A feather is dropped on the moon from a height of 1.40 meters. The acceleration of gravity on the moon is 1.67 m/s^2. Determine the time for the feather to fall to the surface of the moon.

4. A bullet leaves a rifle with a muzzle velocity of 521 m/s. While accelerating through the barrel of the rifle, the bullet moves a distance of 0.840 m. Determine the acceleration of the bullet (assume a uniform acceleration).

5. An engineer is designing a runway for an airport. Several planes will use the runway and the engineer must design it so that it is long enough for the largest planes to become airborne before the runway ends. If the largest plane accelerates at 3.30 m/s^2 and has a takeoff speed of 88.0 m/s, then what is the minimum allowed length for the runway?

6. A student drives 4.8-km trip to school and averages a speed of 22.6 m/s. On the return trip home, the student travels with an average speed of 16.8 m/s over the same distance. What is the average speed (in m/s) of the student for the two-way trip? (Be careful.)

7. Rennata Gas is driving through town at 25.0 m/s and begins to accelerate at a constant rate of -1.0 m/s^2. Eventually Rennata comes to a complete stop. Represent Rennata's accelerated motion by sketching a velocity-time graph. Use kinematic equations to calculate the distance which Rennata travels while decelerating. Then use the velocity-time graph to determine this distance. **PSYW**

8. Otto Emissions is driving his car at 25.0 m/s. Otto accelerates at 2.0 m/s^2 for 5 seconds. Otto then maintains a constant velocity for 10 more seconds. Determine the distance Otto traveled during the entire 15 seconds. (Consider using a velocity-time graph.)

9. Chuck Wagon travels with a constant velocity of 0.5 mile/minute for 10 minutes. Chuck then decelerates at -.25 mile/min^2 for 2 minutes. Determine the total distance traveled by Chuck Wagon during the 12 minutes of motion. (Consider using a velocity-time graph.)

Free Fall

Read **Sections a**, **b** and **d** from **Lesson 5** of the **1-D Kinematics** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/1DKin/U1L5a.html

MOP Connection: None

1. A rock is dropped from a rest position at the top of a cliff and free falls to the valley below. Assuming negligible air resistance, use kinematic equations to determine the distance fallen and the instantaneous speeds after each second. Indicate these values on the odometer (distance fallen) and the speedometer views shown to the right of the cliff. Round all odometer readings to the nearest whole number.

    Show a sample calculation below:

2. At which of the listed times is the acceleration the greatest? Explain your answer.

3. At which of the listed times is the speed the greatest? Explain your answer.

4. If the falling time of a free-falling object is doubled, the distance fallen increases by a factor of _____. Identify two times and use the distance fallen values to support your answer.
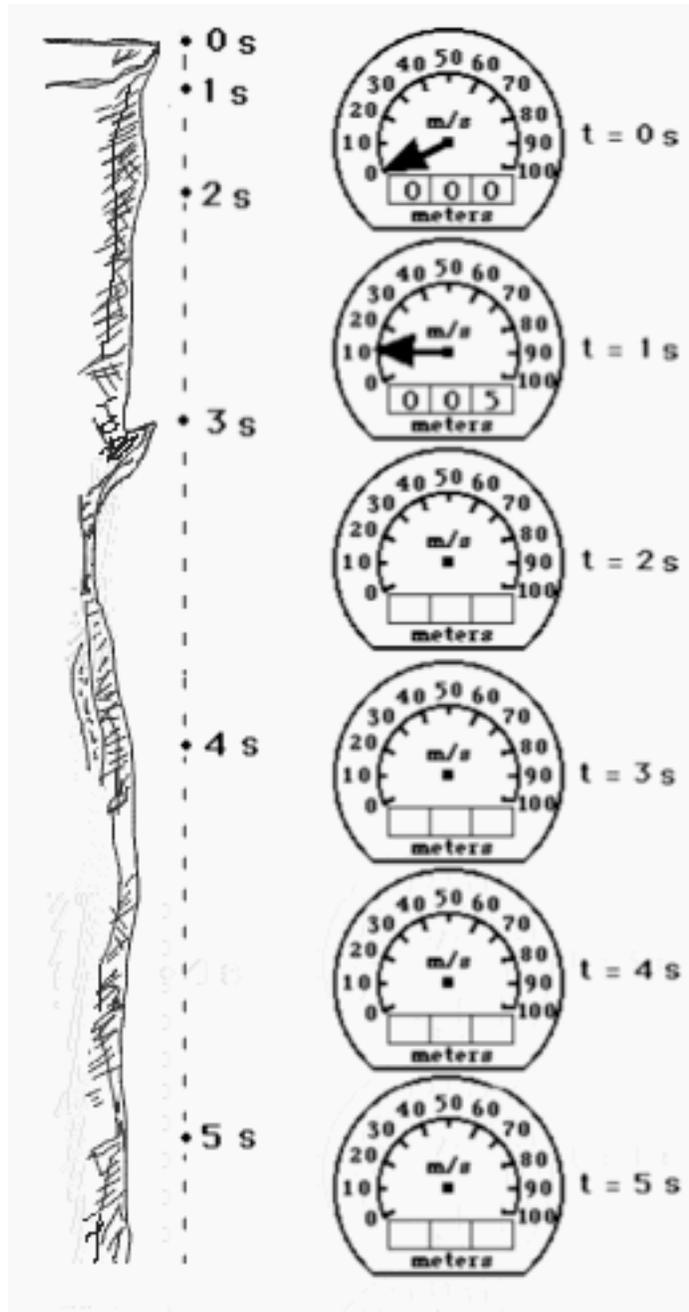
5. Miss E. deWater, the former platform diver of the Ringling Brothers'
    Circus, dives from a 19.6-meter high platform into a shallow bucket of
   water (see diagram at right).

    a. State Miss E. deWater's acceleration as she is falling from the
    platform. _____ What assumption(s) must you make in order to
    state this value as the acceleration? Explain.

    b. The velocity of Miss E. deWater after the first half second of fall is
    represented by an arrow. The size or length of the arrow is
    representative of the magnitude of her velocity. The direction of the
    arrow is representative of the direction of her velocity. For the
    remaining three positions shown in the diagram, construct an arrow of
    the approximate length to represent the velocity vector.

    c. Use kinematic equations to fill in the table below.

Time (s)	Vel. (m/s)	Dist. Fallen (m)	Ht (m)
0	0	0	19.6
0.5			
1.0			
1.5			
2.0			

Show your work below for one of the rows of the table.
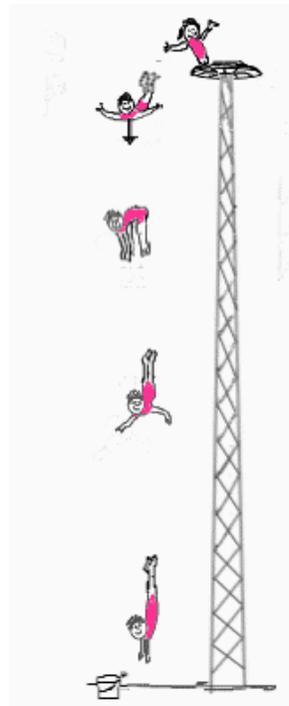
6. Michael Jordan was said to have a hang-time of 3.0 seconds (at least according to a popular NIKE
    commercial). Use kinematic equations to determine the height to which MJ could leap if he was
    wearing NIKE shoes and had a hang-time of 3.0 seconds.