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 which is fully described by both magnitude and direction. A scalar is a quantity which 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
speed	displacement
distance	velocity
	acceleration

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

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

Distance vs. Displacement

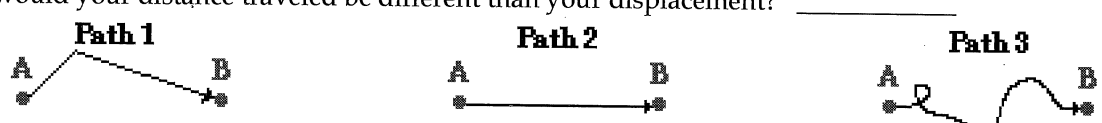
As an object moves, its location undergoes change. There are a two quantities which are used to describe the changing location. One quantity - **distance** - accumulates the amount of total change of location over the course of a motion. Distance is the amount of ground which is covered. The second quantity - **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.

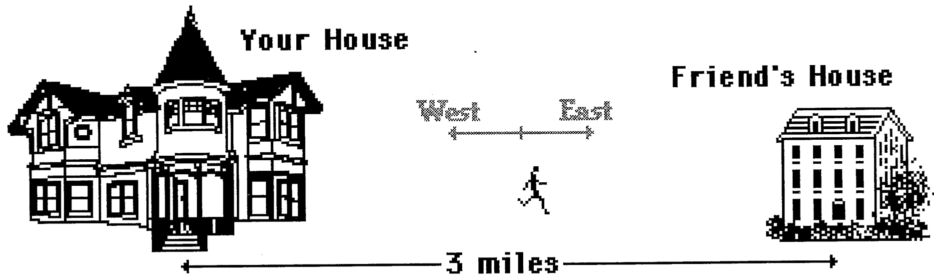
   - rocking back and forth
   - riding in circles

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? ____________



displacement ≠ distance   displacement = distance   displacement ≠ distance

7. You run from your house to a friend's house that is 3 miles away. You then walk home.

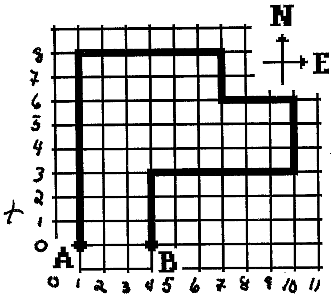


a. What distance did you travel? $3 + 3 = 6$ miles

b. What was the displacement for the entire trip? 0 miles

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.

$8\,km + 4\,km + 2\,km + 3\,km + 3\,km + 6\,km + 3\,km$

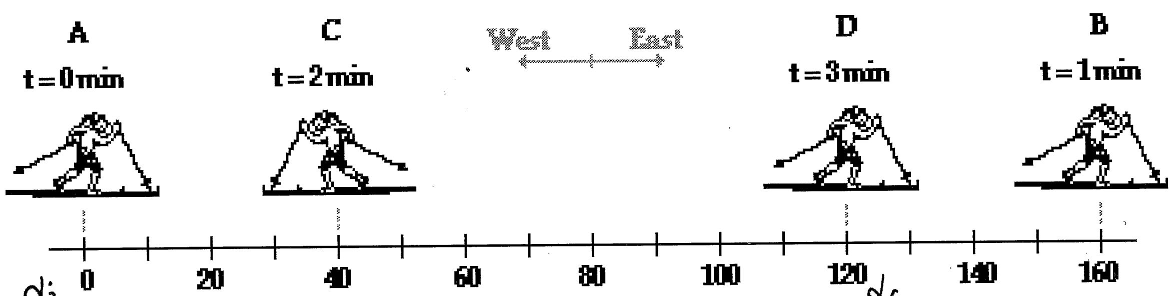


8. This person walks a distance of 31 km.

9. This person has a displacement of ________ km. $\Delta \vec{d} = 4\,km - 1\,km = +3\,km = 3\,km$ east

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.



a. What is the distance traveled by the skier during the three minutes of recreation?

$d = 160\,m + 120\,m + 80\,m = 360\,m$

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

$d_f = 120\,m$
$d_i = 0\,m$

$\Delta \vec{d} = d_f - d_i = 120\,m - 0\,m = +120\,m = 120\,m$ East

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

$d_f = d_{2min} = 40\,m$
$d_i = d_{1min} = 160\,m$

$\Delta \vec{d} = d_f - d_i = 40\,m - 160\,m = -120\,m = 120\,m$ West

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

$d_f = d_{3min} = 120\,m$
$d_i = d_{2min} = 40\,m$

$\Delta \vec{d} = d_f - d_i = 120\,m - 40\,m = +80\,m = 80\,m$ east

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 <u>scalar</u> quantity is completely described by magnitude alone. A <u>vector</u> quantity is completely described by a magnitude with a direction.
   a. scalar, vector b. vector, scalar
2. Speed is a <u>scalar</u> quantity and velocity is a <u>vector</u> quantity.
   a. scalar, vector b. vector, scalar

Speed vs. Velocity

Speed and velocity are two quantities in Physics which 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 which describes how fast or how slow an object is moving.

Velocity is a quantity which 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.

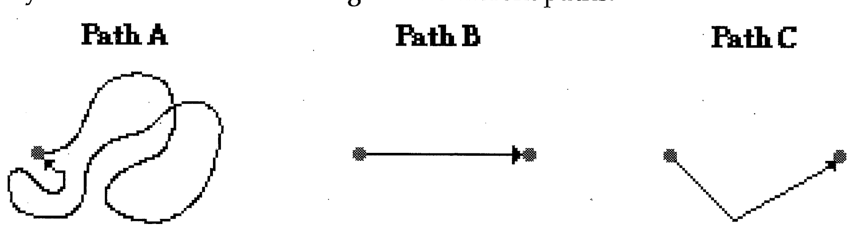
   Along which path would you have to move with the greatest speed to arrive at the destination in the same amount of time? <u>Path C</u> Explain.

   The greator distonce covered gives The highest speed

4. True or False: It is possible for an object to move for 10 seconds at a high speed and end up with no overall change in position.
   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.

   spinning in a circle

6. Suppose that you run for 10 seconds along three different paths.



   Rank the three paths from the lowest speed to the greatest speed. <u>B, C</u> A

   Rank the three paths from the lowest velocity to the greatest velocity. <u>A, B</u> and C are equal velocity

Calculating Average Speed and Average Velocity

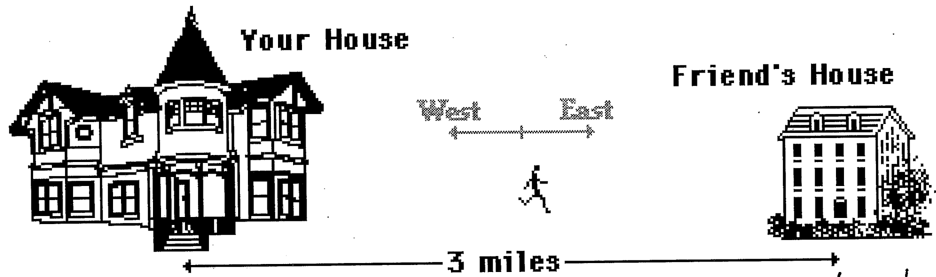
The average speed of an object is the rate at which an object covers distance. The average velocity of an object is the rate at which an object changes its position. Thus,

$$\text{Ave. Speed} = \frac{\text{distance}}{\text{time}} \qquad \text{Ave. Velocity} = \frac{\text{displacement}}{\text{time}}$$

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.

Total Distance = 3+3
= 6miles
Total time = 1 +0.5
= 1.5 hr

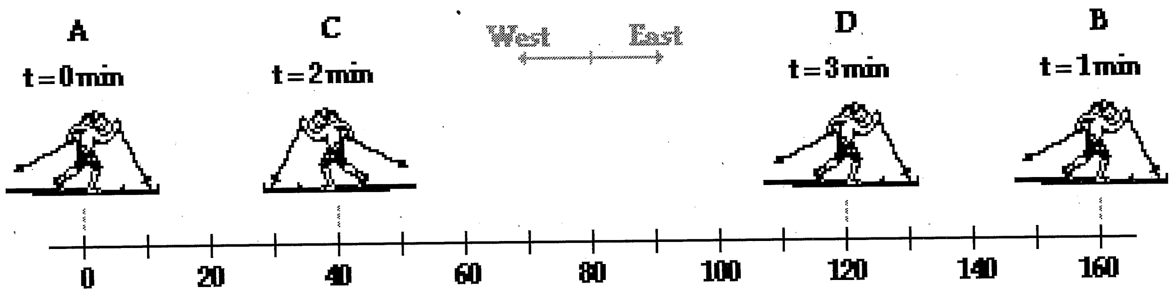


$\Delta d = d_f - d_i$
$= 0 - 0$
$= 0$ miles
$\Delta t = 1.5$ hr

a. What was the average speed (in mi/hr) for the entire trip? $V_{avg} = \frac{6 \text{ miles}}{1.5 \text{ hr}} = 4$ miles/hr

b. What was the average velocity (in mi/hr) for the entire trip? $\vec{V}_{avg} = \frac{0}{1.5 \text{ hr}} = 0$ miles/hr

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.



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 = $\frac{\text{distance}}{\text{time}}$

$= \frac{160m + 120m + 80m}{3 \text{ min}}$

$= \frac{360m}{3 \text{ min}}$

$= 120 m/min$

Ave. Velocity = $\frac{\text{displacement}}{\text{time}}$

$= \frac{(120 - 0)m}{3 \text{ min}}$

$= \frac{120 m}{3 \text{ min}}$

$= 40 m/min$

Instantaneous Speed vs. Average Speed

The instantaneous speed of an object is the speed which 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.

$$V_{avg} = \frac{\text{distance}}{\text{time}} = \frac{7.6\,m}{10\,min} = \frac{0.76\,\text{miles}}{min}$$

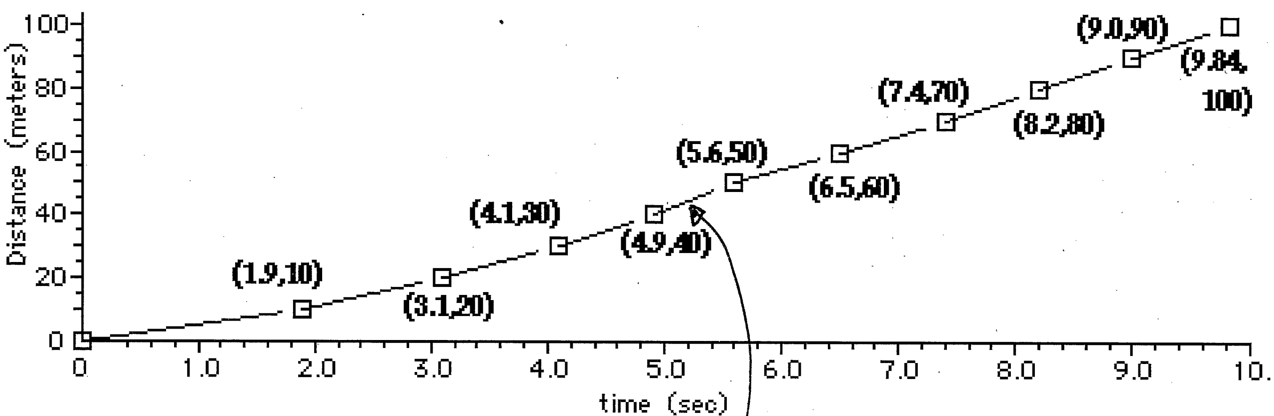
Time (min)	Pos'n (mi)	
0	0	
1	0.4	0.4 miles/min
2	0.8	0.4 miles/min
3	1.3	0.5 miles/min
4	2.1	0.8 miles/min
5	2.5	0.4 miles/min
6	2.7	0.2 miles/min
7	3.8	1.1 miles/min
8	5.0	1.2 miles/min
9	6.4	1.4 miles/min
10	7.6	1.2 miles/min

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

For any given minute the distance travelled is the difference between the final position and the starting position. For example between minute 7 and 8 the teacher travelled from 3.8 - 5 miles = 1.2 miles

$$\text{avg speed} = \frac{1.2\,\text{miles}}{1\,\text{minute}} = 1.2\,\text{miles/minute}$$. The maximum speed occured probably between minute 8 and 9 and was at least 1.4 miles/minute (or 84 mi/hr)

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**

This section has the steepest slope so the greatest speed.

$$V_{avg} = \frac{\text{distance}}{\text{time}} = \frac{(50-40)\,m}{(5.6-4.9)\,s} = \frac{10\,m}{0.7\,s} = 14.3\,m/s$$

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

$$V_{avg} = \frac{\text{Total distance}}{\text{Total Time}} = \frac{100\,m}{9.84\,s} = 10.162\,m/s$$

$$= 10.2\,m/s$$

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?

$$V_{avg} = \frac{\text{distance}}{\text{Time}} \qquad t = \frac{7.2\,s}{} \left(\frac{1\,min}{60\,s}\right)\left(\frac{1\,hr}{60\,min}\right)$$
$$= 0.0020\,hr$$
$$= 2.0\times10^{-3}\,hr$$

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

$$V_{avg} = \frac{\text{distance}}{\text{time}} = \frac{0.1\,miles}{2.0\times10^{-3}\,hr} = 50\,miles/hr$$

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?

$d = 155$
$t = 0.5hr$

$$V_{avg} = \frac{155\,miles}{0.5\,hr} = 310\,miles/hr$$

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?

$d = 19.5\,miles$
$v = 254\,mi/hr$

$$V_{avg} = \frac{d}{t} \Rightarrow t = \frac{d}{v} = \frac{19.5\,miles}{254\,miles/hr} = 0.07677\,hr = 4.60\,min$$
$$= 276\,sec.$$

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?

$V_{avg} = 28\,miles/hr$
$t = 18\,hrs$

$$V_{avg} = \frac{d}{t} \Rightarrow d = vt$$
$$= (28\,miles/hr)(18\,hrs)$$
$$= 504\,miles$$

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 speed of the object with a direction

The Concept of Acceleration

1. Accelerating objects are objects which are changing their velocity. Name the three controls on an automobile which cause it to accelerate. brake, accelerator, stearing wheel

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

 - an object that is moving in a circle has a changing velocity even if the speed stays constant

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

 velocity is changing

 may be changing direction

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:

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

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?

t	V
0	0
1	10
2	20
3	30
4	40

$$\vec{a} = \frac{\Delta \vec{V}}{t} = \frac{20 mi/hr - 10 mi/hr}{1s} \quad \pm(10 mi/hr)/s$$

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

$$\vec{a} = \frac{\Delta V}{\Delta t} = \frac{60 mi/hr}{4s} \quad \pm(15 mi/hr)/s$$

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

$v_i = 0$
$v_f = +16 m/s$
$t = 4 s$

$$\vec{a} = \frac{16 m/s - 0}{4 s} = (4 m/s)/s = 4 m/s^2$$

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

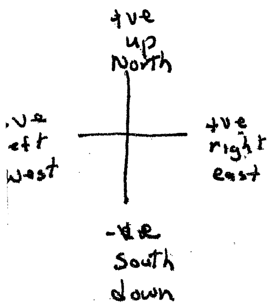
$v_i = +32 m/s$
$v_f = +8 m/s$
$t = 4 s$

$$\vec{a} = \frac{v_f - v_i}{t} = \frac{8 m/s - 32 m/s}{4 s} = \frac{-24 m/s}{4 s} = -6 m/s^2$$

Acceleration as a Vector Quantity

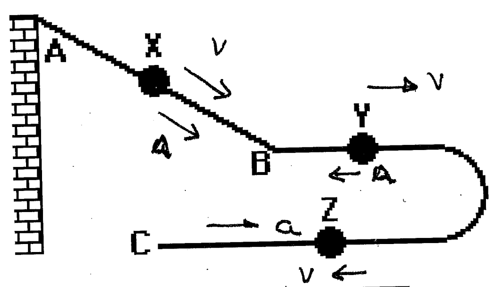
Acceleration, like velocity, is a vector quantity. To fully describe the acceleration of an object, one must describe the direction of the acceleration vector. A **general rule of thumb** is that if an object is moving in a straight line and slowing down, then the direction of the acceleration is opposite 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. same direction as velocity	+ve east
b.	A northbound car skids to a stop to avoid a reckless driver. opposite direction to velocity	-ve south
c.	An Olympic diver slows down after splashing into the water. opposite direction to velocity	Velocity negative (down) acceleration positive (up)
d.	A southward-bound free kick delivered by the opposing team is slowed down and stopped by the goalie. opposite direction to velocity	North +ve
e.	A downward falling parachutists pulls the chord and rapidly slows down. opposite direction to velocity	up +ve
f.	A rightward-moving Hot Wheels car slows to a stop. opposite direction to velocity	left -ve
g.	A falling bungee-jumper slows down as she nears the concrete sidewalk below. opposite direction to velocity	up +ve

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	down The ramp & To The right Reason: speeding up down The ramp	down The ramp Reason: Same direction as velocity
Y	along The ramp To right Reason: slowing down from friction - moving right	opposite to velocity Reason: Friction slowing car down $\vec{a}$ To The left
Z	along ramp to left Reason: changed direction on The Curve - moving left	Opposite To velocity Reason: Friction slowing car down $\vec{a}$ To The right

Describing Motion with Diagrams

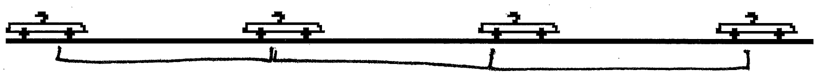
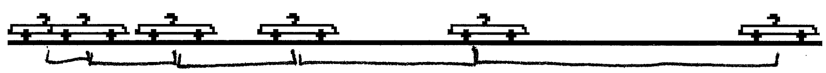
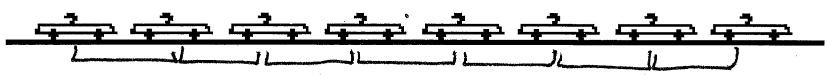
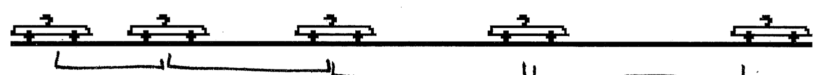
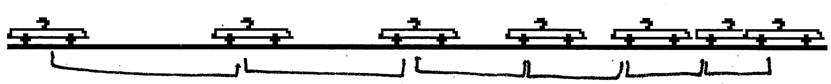
Read from **Lesson 2** of the **1-D Kinematics** chapter at **The Physics Classroom**:

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

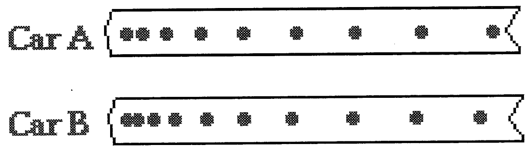
Motion can be described using words, diagrams, numerical information, equations, and graphs. Using diagrams to describe the motion of objects involves depicting the location or position of an object at regular time intervals.

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.

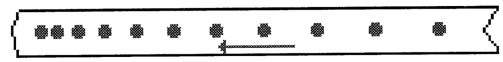
	Acceleration: Y/N	Acceleration: Dir'n	
a.  Reason: equal distance - equal time	N	— ⌀	constant velocity
b.  Reason: increasing distance - equal time	Y	→ +ve	velocity +ve
c.  Reason: equal distance - equal time	N	— ⌀	constant velocity
d.  Reason: increasing distance - equal time	Y	→ +ve	velocity +ve
e.  Reason: decreasing distance - equal time	Y	← -ve	velocity +ve

2. Suppose that in diagram D (above) the cars were moving leftward (and traveling backwards). What would be the direction of the acceleration? opposite to $\vec{a}$ Explain your answer fully.

a) no acceleration (constant velocity)
b) decreasing distance - equal time (-ve velocity) (+ve acceleration)
c) no acceleration (constant velocity) (no acceleration)
d) decreasing distance - equal time -ve velocity (+ve acceleration)
e) increasing distance - equal time (-ve velocity) (-ve acceleration)



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 _-ve_ velocity and a _+ve_ 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.

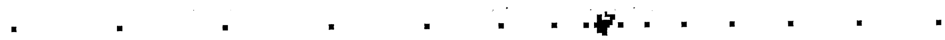
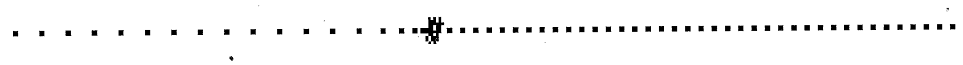
Diagram A: 

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: steady spacing, big spot at stop, steady pacing	C
ii.	Renatta rapidly decelerated from a high speed to a rest position, and then slowly accelerated to a moderate speed. Reasoning: large distance between original dots, big spot at stop. gradually increasing distance at the end	A
iii.	Renatta was driving at a moderate speed and slowly accelerated. Reasoning: distance between spots increases	B

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	0.00
1	0.23
2	0.46
3	0.69
4	0.92
5	1.15
6	1.38

Speed = $v = \frac{\Delta d}{\Delta t} = \frac{(1.38-0)\,mi}{(6-0)\,hr}$
$= 0.23\,mi/hr$

Cheetah

Time (s)	Position (m)
0	0.0
0.5	12.5
1	25.0
1.5	37.5
2	50.0
2.5	62.5
3	75.0

Speed = $v = \frac{\Delta d}{\Delta t} = \frac{75-0}{3-0}$
$= 25\,m/s$

North America

Time (yr)	Position (cm)
0	0.00
0.25	0.25
0.50	0.50
0.75	0.75
1.0	1.00
1.25	1.25
1.5	1.50

Speed = $\frac{1.50\,cm - 0}{1.5 - 0\,yr} = 1\,cm/yr$

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	22
3	33
4	44
5	55
6	66

Acceleration = no acceleration

$v_6 = \frac{\Delta d}{\Delta t} = \frac{66-55\,ft}{6-5}$ $= 11\,ft/day$

$v_1 = \frac{11-0}{1-0}$ $= 11\,ft/day$

$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{11 - 11\,ft/day}{6-1\,day} = \frac{0}{5} = (0\,ft/day)/day$

Honda Accord

Time (s)	Velocity (mi/hr)
0	60, E
0.5	54, E
1	48E
1.5	42, E
2	38E
2.5	32E
3	24, E

Acceleration = $12\,m/s^2$ W

$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{54-60}{0.5}$
$= (-12\,m/s)\,s$

Peregrine Falcon

Time (s)	Velocity (m/s)
0	0
0.25	9, down
0.50	18, down
0.75	27, down
1.0	36, down
1.25	45, down
1.5	54, down

Acceleration = $36\,m/s^2$ down

$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{54-0\,m/s\ down}{1.5-0\ s}$
$= (36\,m/s)/s$
$= 36\,m/s^2$ down

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**

$\vec{v} = 25\ m/s \left(\frac{2.24\ mi/hr}{1\ m/s}\right) = 56\ mi/hr$

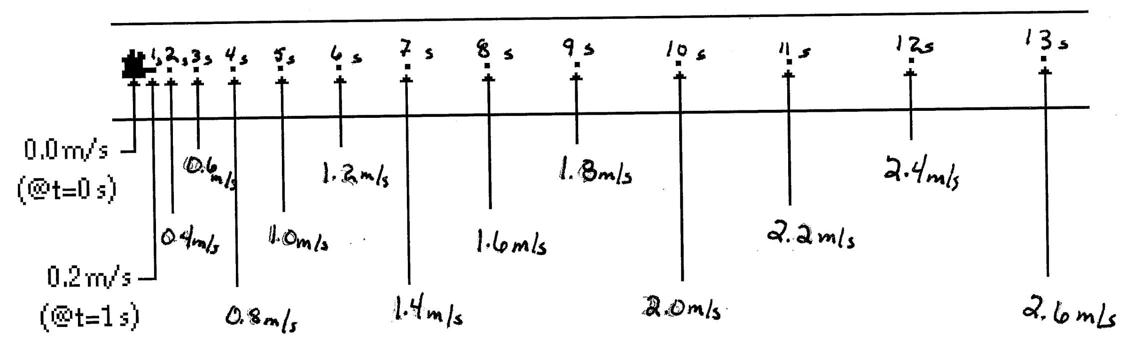
4. Use the following equalities to convert the speed of the snail (from question #2) to units of miles per hour. Show your conversion factors.

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

$v = 11\ ft/day \left(\frac{1\ m/s}{2.83\times10^5\ ft/day}\right)\left(\frac{2.24\ mi/hr}{1\ m/s}\right) = 8.7\times10^{-5}\ mi/hr$

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.

$\frac{\Delta v}{\Delta t} = \frac{0.20\ m/s}{1s}$



6. Determine the acceleration of the objects whose motion is depicted by the following data.

28-32 = -4 m/s
28- 28 = -4 m/s
8-12 = -4 m/s

Data Set A

t(s)	v(m/s)
0	32
1	28
2	24
3	20
4	16
5	12
6	8

Data Set B

t(s)	v(m/s)
0	12
0.5	10
1.0	8
1.5	6
2.0	4
2.5	2
3.0	0

Data Set C

t(s)	v(m/s)
0	24
1	21
2	18
3	15
4	12
5	9
6	6

Data Set D

t(s)	v(m/s)
0	32
0.5	28
1.0	24
1.5	20
2.0	16
2.5	12
3.0	8

a = -4 m/s/s

$a = \frac{8-32}{6-0}$

$= -4\ m/s^2$

a = -4 m/s/s

$\vec{a} = \frac{\Delta v}{\Delta t}$

$= \frac{0-12}{3-0}$

$= (-4\ m/s)/s$

a = - 3 m/s/s

$\vec{a} = \frac{6-24}{6-0}$

$= \frac{-18}{6}$

$= -3\ m/s/s$

a = -8 m/s/s

$a = \frac{8-32}{3.0-0}$

$= -8\ m/s/s$

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.

velocity +ve a. Moving in the + direction and speeding up (getting faster) +ve $\vec{a}$

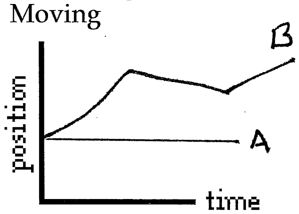
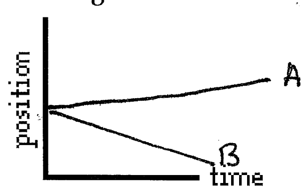
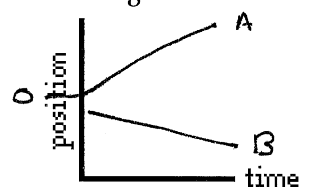
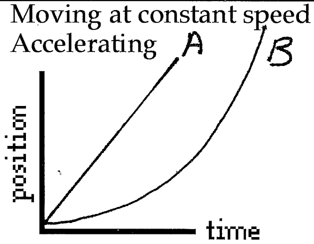
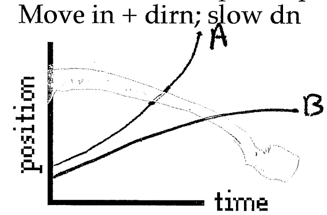
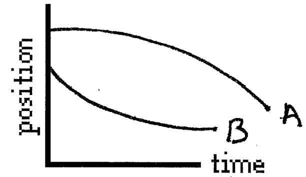
velocit +ve b. Moving in the + direction and slowing down (getting slower) -ve $\vec{a}$

velocity -ve c. Moving in the - direction and speeding up (getting faster) - ve $\vec{a}$

velocity +ve d. Moving in the - direction and slowing down (getting slower) +ve $\vec{a}$

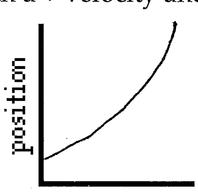
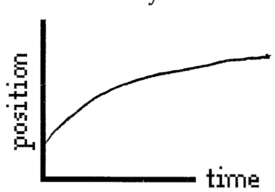
Interpreting Position-Graphs

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

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

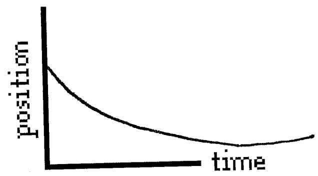
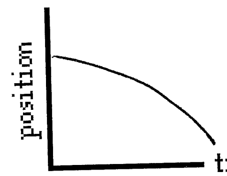
$\vec{v} > 0$
$\vec{a} > 0$

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

$\vec{v} > 0$
$\vec{a} < 0$

moving right, speeding up

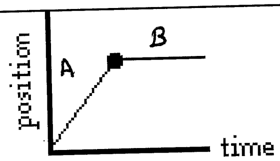
moving right
slowing down

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

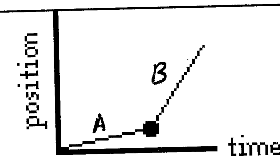
moving left
slowing down
$v < 0$
$a > 0$

moving right
speeding up
$v < 0$ $a < 0$

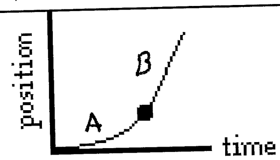
4. Use your understanding of the meaning of slope and shape of position-time graphs to describe the motion depicted by each of the following graphs.



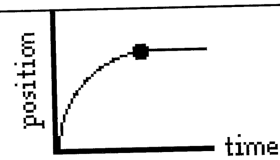
Verbal Description:
A - moves with a steady speed in a +ve direction
B - stand still $v = 0$



Verbal Description:
A - moves in +ve direction at a slow speed
B moves in +ve direction at a faster speed

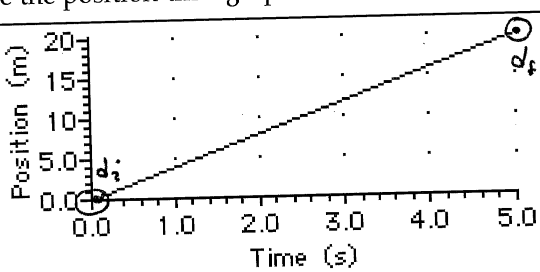


Verbal Description:
+ve accelerates in a +ve direction to dot then a steady velocity in the +ve direction

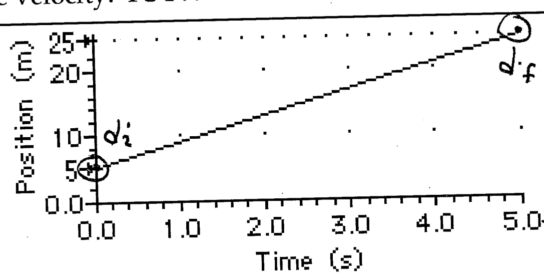


Verbal Description:
negative acceleration in the positive direction and then stop

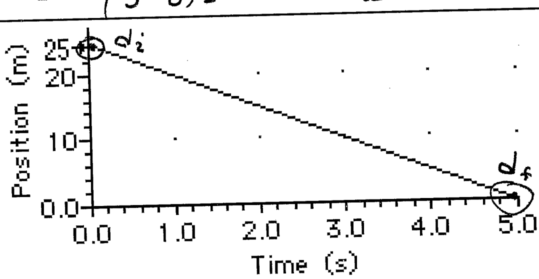
5. Use the position-time graphs below to determine the velocity. **PSYW**



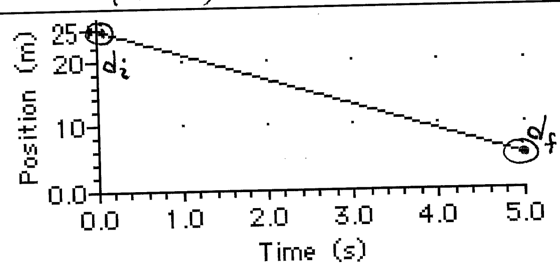
PSYW:
$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{(20-0)m}{(5-0)s} = 4 m/s$



PSYW:
$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{(25-5)m}{(5-0)s} = 4 m/s$



PSYW:
$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{(0-25)m}{(5-0)s} = -5 m/s$



PSYW:
$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{5-25}{5-0} = \frac{-20m}{5s} = -4m/s$

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) +ve $\vec{a}$
   b. Moving in the + direction and slowing down (getting slower) -ve $\vec{a}$
   c. Moving in the - direction and speeding up (getting faster) -ve $\vec{a}$
   d. Moving in the - direction and slowing down (getting slower) +ve $\vec{a}$

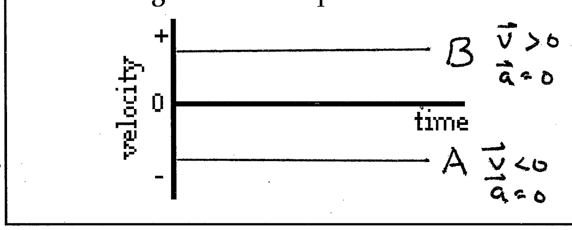
Interpreting Velocity-Graphs

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

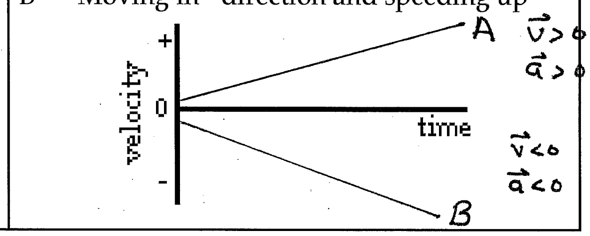
$\vec{v}$

A+B steady speed + velocity

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



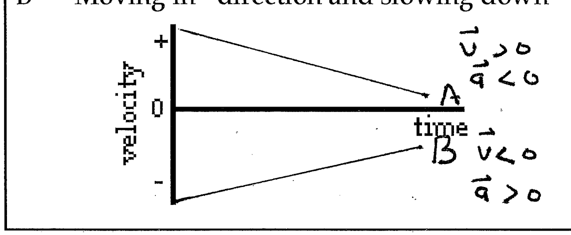
speeding up

speeding up

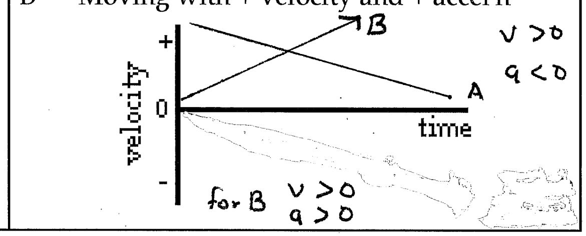
A slowing down

B slowing down

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



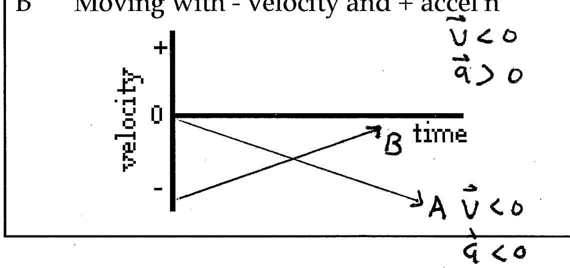
A slowing down

B speeding up

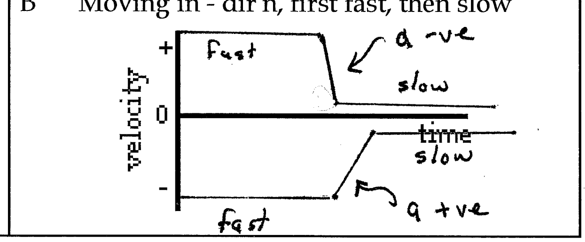
A speeding up

B slowing down

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

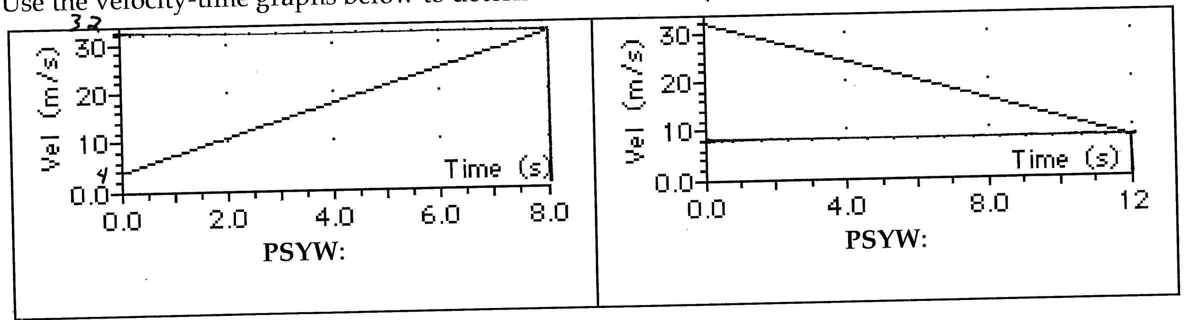


A² steady speeds quickly slowing down

$$\vec{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{8\,m/s - 32\,m/s}{(12-0)\,s} = \frac{-24\,m/s}{12\,s} = -2\,m/s^2$$

3. Use the velocity-time graphs below to determine the acceleration. PSYW

$$\vec{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{(32-4)\,m/s}{(8-0)\,s} = (3.5\,m/s)/s = +3.5\,m/s^2$$



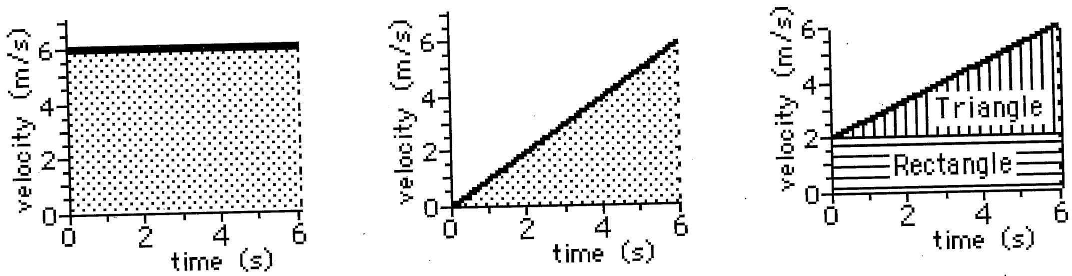
4. The area under the line of a velocity-time graph can be calculated using simple rectangle and triangle equations. The graphs below are examples:

If the area under the line forms a ...

... **rectangle**, then use area = base*height

... **triangle**, then use area = 0.5 * base*height

... **trapezoid**, then make it into a rectangle + triangle and add the two areas.



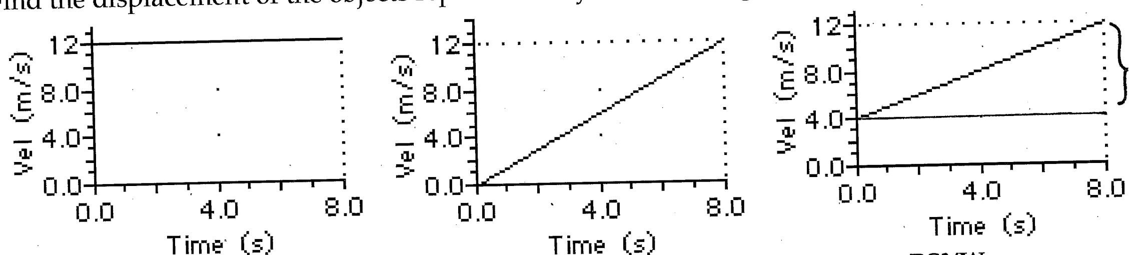
A = (6 m/s)*(6 s) = **36 m**

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

$A_{total} = A_{rectangle} + A_{triangle}$

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.



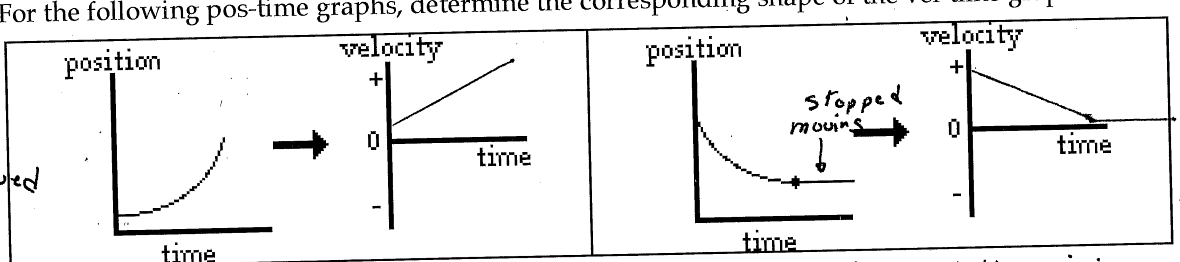
PSYW:
$d = (12\,m/s)(8\,s) = 96\,m$

PSYW:
$d = \frac{1}{2}(8\,s)(12\,m/s) = 48\,m$

PSYW:
$d = \frac{1}{2}(8\,s)(8\,m/s) + (8\,s)(4\,m/s) = 32\,m + 32\,m = 64\,m$

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

object is moving away from origin
velocity is +ve
acceleration is +ve
since line is curved
∴ velocity is increasing in a +ve direction



- object is moving toward the origin
- object is still in the positive position
∴ velocity is +ve
- slowing down and then stopping so acceleration is -ve and
then zero

Describing Motion Graphically

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)

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.

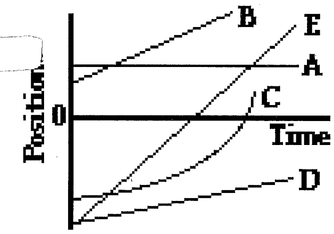
   a. A horizontal line means stopped A.

   constant velocity b. A straight diagonal line means constant velocity.

   speeding up c. A curved line means changing velocity.

   d. A gradually sloped line means low velocity.

   e. A steeply sloped line means high velocity.



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

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

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

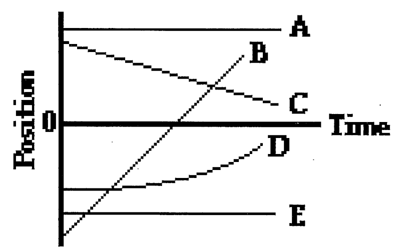
   B d. Which object(s) change(s) its direction?

   B e. Which object is traveling fastest?

   C f. Which moving object is traveling slowest?

   D g. Which object(s) is(are) moving in the same direction as object B?

A and E are at rest which is about as slow as you can get.



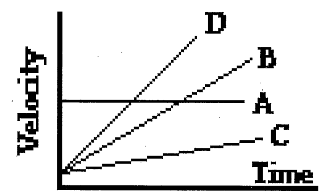
3. The slope of the line on a velocity vs. time graph reveals information about an object's acceleration. Furthermore, the area under the line is equal to the object's displacement. Apply this understanding to answer the following questions.

   a. A horizontal line means constant velocity.

   b. A straight diagonal line means $\vec{a} > 0$ or $\vec{a} < 0$.

   c. A gradually sloped line means slow $\vec{a}$.

   d. A steeply sloped line means high $\vec{a}$.



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.

   None a. Which object(s) is(are) at rest? but - B, C each have a point when their velocities are zero

   B, C, D b. Which object(s) is(are) accelerating?

   none c. Which object(s) is(are) not moving?

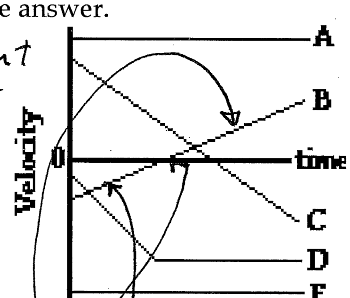
   B C d. Which object(s) change(s) its direction?

   A, E e. Which accelerating object has the smallest acceleration? $\vec{a} = 0$

   C f. Which object has the greatest acceleration?

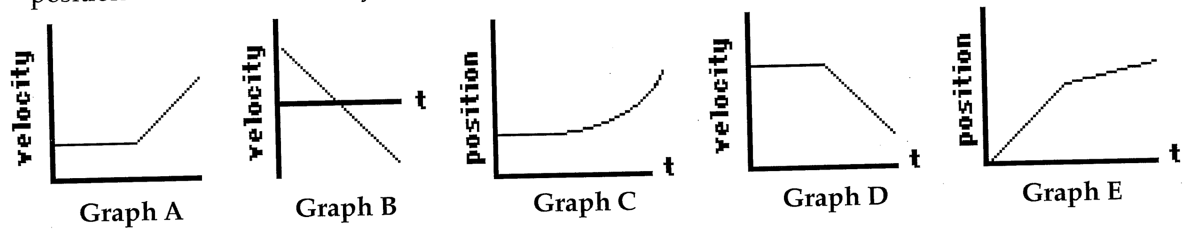
   C D, E g. Which object(s) is(are) moving in the same direction as object E?

Note B has a shallower slope and therefore less $\vec{a}$ Then C



-moving in a -ve direction
stop
- start moving in the +ve direction

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.

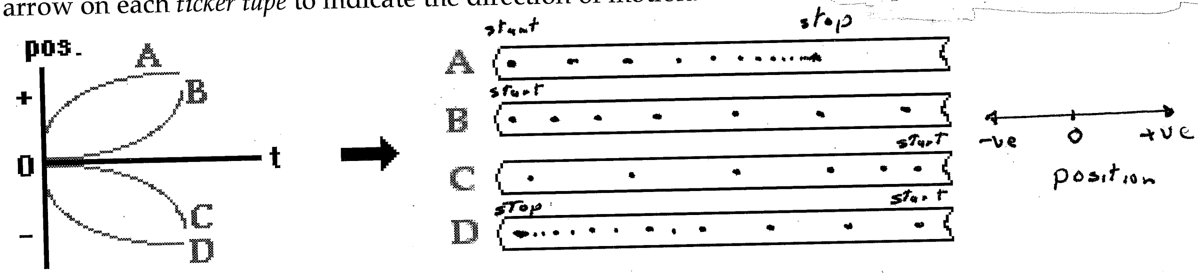


The motion of these objects could also be described using words. Analyze the graphs and match them with the verbal descriptions given below by filling in the blanks.

Verbal Description	Graph
a. The object is moving fast with a constant velocity and then moves slow with a constant velocity.	D
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).	B
c. The object moves with a constant velocity and then slows down.	E
d. The object moves with a constant velocity and then speeds up.	A
e. The object maintains a rest position for several seconds and the slowly accelerates at a constant rate.	C

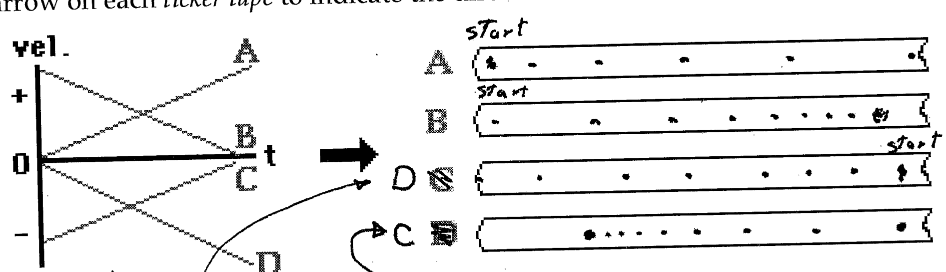
6. Consider the position-time graphs for objects A, B, C and D. On the *ticker tapes* to the right of the graphs, construct a dot diagram for each object. Since the objects could be moving right or left, put an arrow on each *ticker tape* to indicate the direction of motion.

A - +ve velocity - slowing down
B - +ve velocity speeding up
C -ve velocity speeding up
D - -ve velocity slowing down to stop



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.

A - +ve velocity starts at zero and increases
⇒ initially at rest
distance between pts increases in +ve direction (+ve acceleration)

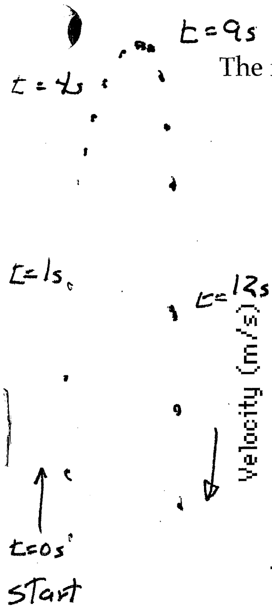


B - +ve velocity slows to zero
⇒ initially moving right slows to stop
(-ve acceleration)

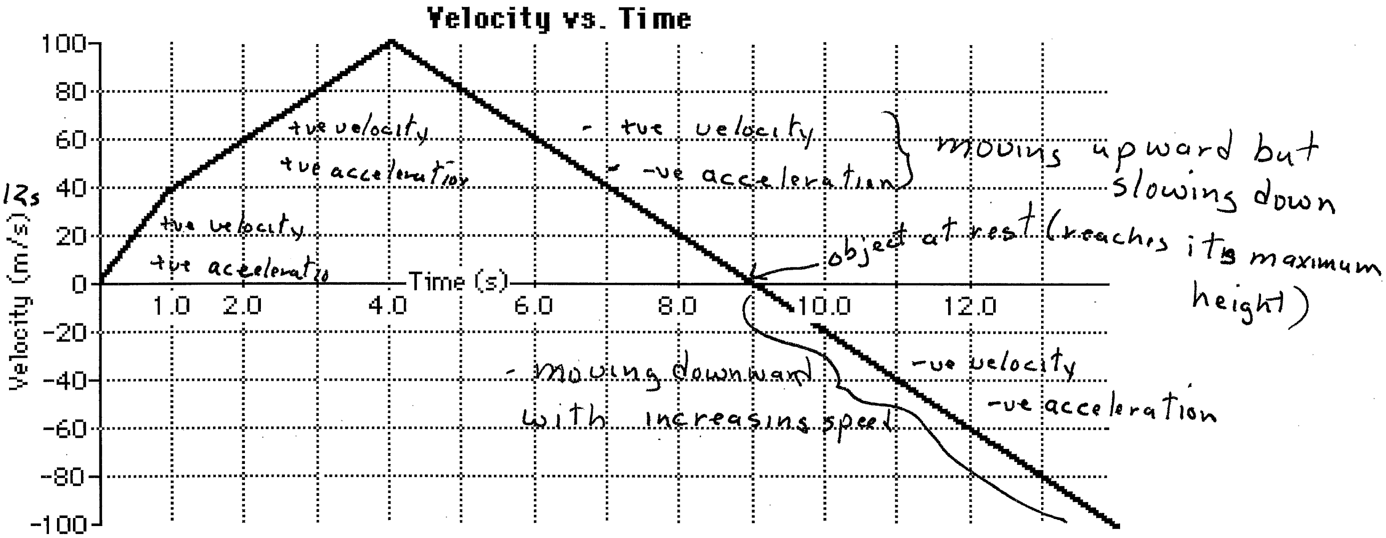
D) -ve velocity starts at zero and gets faster to the left (-ve acceleration)

C) -ve velocity slows to zero (+ve acceleration)

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: velocity is +ve, acceleration is +ve (rocket is moving up)	No
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: velocity is highest at t=4.0s when the rocket is travelling 100m/s	No
3. The rocket changes its direction after the fourth second. Justification: The rocket does not change its direction until the 9th second	No
4. During the time interval from 4 to 9 seconds, the rocket is moving in the positive direction (up) and slowing down. Justification: It has stopped accelerating upwards and now gravity is _____ it back down	Yes
5. At nine seconds, the rocket has returned to its initial starting position. Justification: at 9 seconds the rockets upward motion stops and it starts moving back down	No

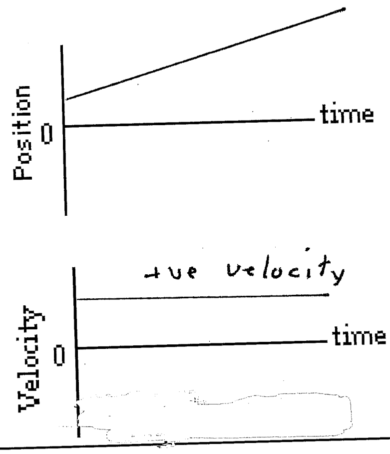
Graphing Summary

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

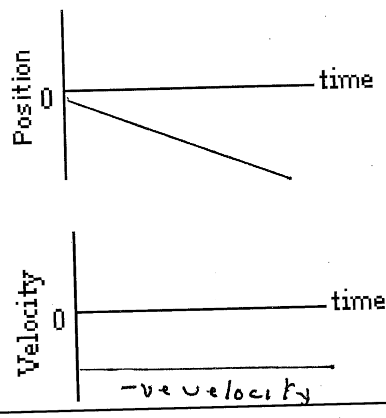
http://www.physicsclassroom.com/Class/1DKin/1KinTOC.html

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

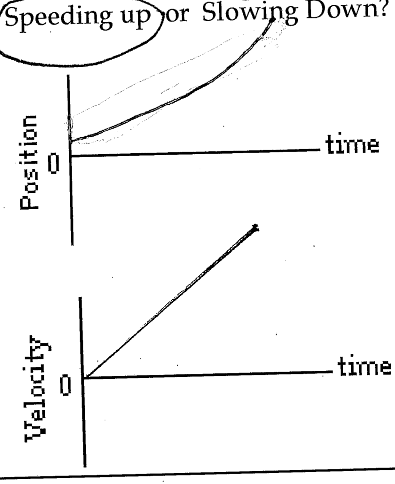
Constant Velocity
Object moves in + Direction
no acceleration
Velocity Dir'n: + or -



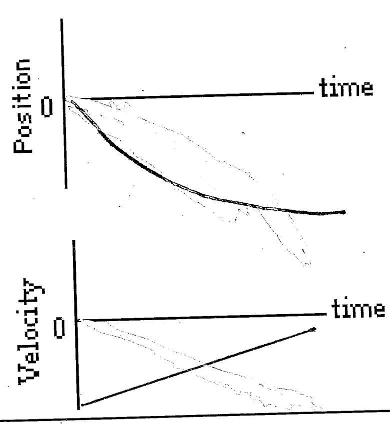
Constant Velocity
Object moves in - Direction
no acceleration
Velocity Dir'n: + or -



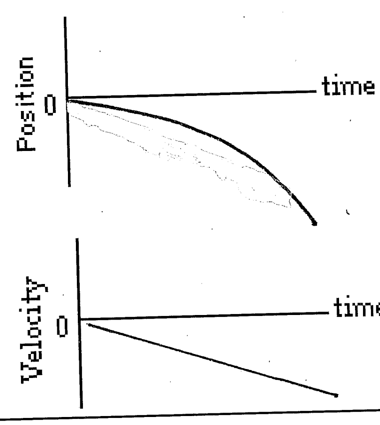
Constant + Acceleration
Object moves in + Direction
velocity and acceleration both +ve
Velocity Dir'n: + or -
Speeding up or Slowing Down?



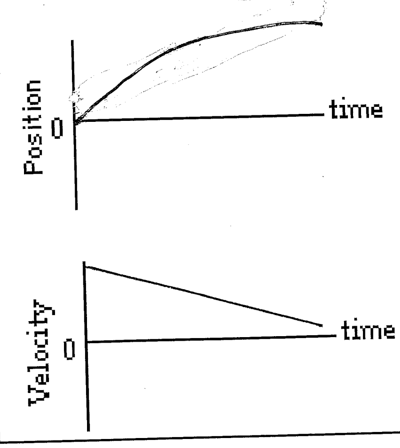
Constant + Acceleration
Object moves in - Direction
accel +ve velocity -ve
Velocity Dir'n: + or -
Speeding up or Slowing Down?



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



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

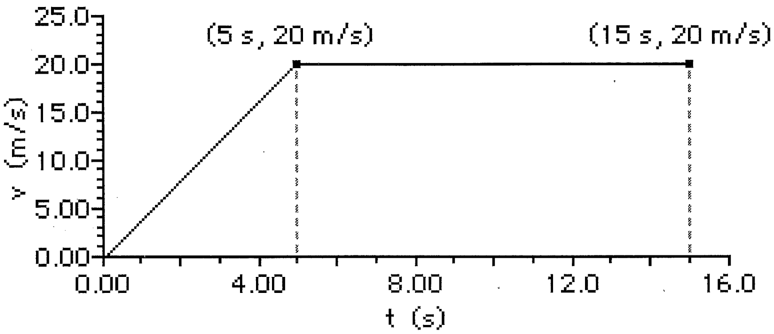


Kinematic Graphing - Mathematical Analysis

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: velocity increasing from 0 m/s to 20.0 m/s

5-15 s: velocity constant at 20 m/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.

0-5 s

$$\vec{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{20\,m/s - 0}{(5-0)s} = 4\,m/s^2$$

5-15 s

$$\vec{a} = \frac{20\,m/s - 20\,m/s}{15\,s - 5\,s} = 0\,m/s$$

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

0-5 s

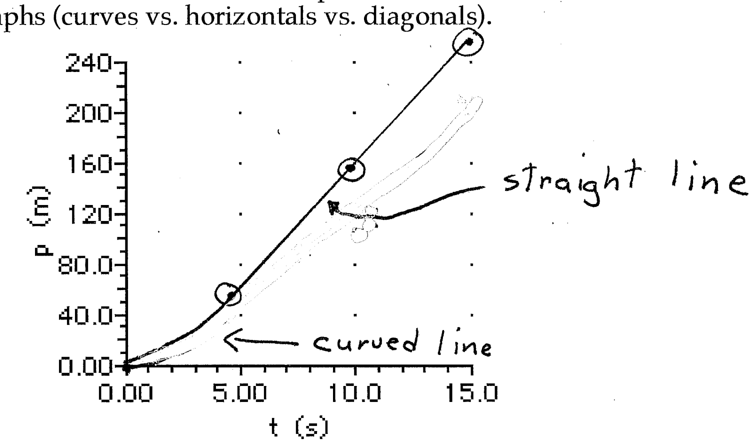
$$\vec{d} = \tfrac{1}{2}(5\,s)\,20\,m/s = \tfrac{1}{2}(100\,m) = 50\,m$$

5-15 s

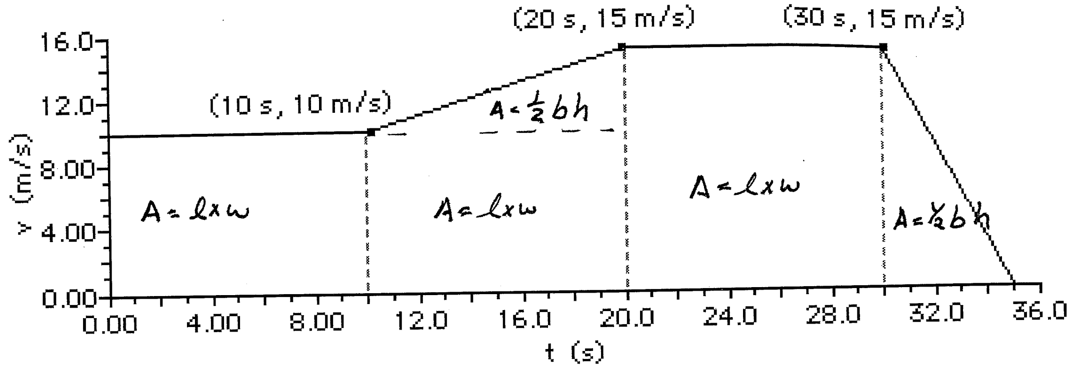
$$d = (15\,s - 5\,s)(20-0)\,m/s = (10)(20)\,m = 200\,m$$

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	50m
10	150m
15	250m



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: steady velocity at 10 m/s (+ve $\vec{v}$, 0 $\vec{a}$)

10-20 s: accelerating in the same direction as velocity (+ve $\vec{v}$, +ve $\vec{a}$)

20-30 s: constant (steady velocity) at 15 m/s

30-35 s: acceleration in opposite direction to velocity (+ve $\vec{v}$, −ve $\vec{a}$)

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

$v_i = 10$ m/s

stop

t=0 t=10 t=15 t=20 t=30 t=35

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
$\Delta\vec{v} = 0 \Rightarrow \vec{a} = 0$	$\vec{a} = \frac{(15-10)\,m/s}{(20-10)\,s} = \left(\frac{5}{10}\right) m/s^2 = 0.5\,m/s^2$	$\Delta\vec{v} = 0 \Rightarrow \vec{a} = 0$	$\vec{a} = \frac{0-15\,m/s}{(35-30\,s)} = -3\,m/s^2$

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
$\vec{d} = (10\,m/s)(10\,s) = 100\,m$	$\vec{d} = \frac{1}{2}(20-10)(15-10)\,m + (20-10)(10-0)\,m = \frac{1}{2}(10)(5) + (10)(10) = 25\,m + 100\,m = 125\,m$	$d = (30-20)(15-0) = 150\,m$	$\vec{d} = \frac{1}{2}(35-30)(15-0) = 37.5\,m$

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).

$\vec{d}_{15\,sec} = (15-0)(10) + \frac{1}{2}(15-10)(12-10) = 150 + 5 = 155\,m$

Time (s)	Pos'n (m)
0	0
5	50m
10	100m
15	155m
20	225
25	300
30	375
35	412.50