# 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 $\qquad$ .
a. scalar quantity
b. vector quantity
3. A quantity that is conscious of direction is referred to as a $\qquad$ .
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? $\qquad$

Path 1


## Path 2



Path 3

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? $\qquad$
b. What was the displacement for the entire trip? $\qquad$
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 $\qquad$ km .
9. This person has a displacement of $\qquad$ .
a. 0 km
b. 3 km
c. $3 \mathrm{~km}, \mathrm{E}$
d. $3 \mathrm{~km}, \mathrm{~W}$
e. 5 km
f. $5 \mathrm{~km}, \mathrm{~N}$
g. $5 \mathrm{~km}, \mathrm{~S}$
h. 6 km
i. $6 \mathrm{~km}, \mathrm{E}$ j. $6 \mathrm{~km}, \mathrm{~W}$
k. 31 km

1. $31 \mathrm{~km}, \mathrm{E}$
m. $31 \mathrm{~km}, \mathrm{~W}$
n. None of these.

2. 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 $\qquad$ quantity is completely described by magnitude alone. A $\qquad$ quantity is completely described by a magnitude with a direction.
a. scalar, vector
b. vector, scalar
2. Speed is a $\qquad$ quantity and velocity is a $\qquad$ 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? $\qquad$ 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. $\qquad$
Rank the three paths from the lowest average velocity to the greatest average velocity. $\qquad$

## 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,

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

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.


Friend's House

## Frient


a. What was the average speed (in $\mathrm{mi} / \mathrm{hr}$ ) for the entire trip? $\qquad$
b. What was the average velocity (in mi/hr) for the entire trip? $\qquad$
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 $\mathrm{m} / \mathrm{min}$ ) and the average velocity (in $\mathrm{m} / \mathrm{min}$ ) of the skier during the three minutes of recreation. PSYW

## Ave. Speed =

Ave. Velocity =
$\qquad$

## 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 $\mathrm{mi} / \mathrm{min}$ ) 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 $\mathrm{m} / \mathrm{s}$. PSYW
b. What was his average speed (in $\mathrm{m} / \mathrm{s}$ ) 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 $1 / 10$ th 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: $\quad$ Kinematic Concepts: sublevels 4 and 7

## Review:

The instantaneous velocity of an object is the $\qquad$ of the object with a $\qquad$ _.

## 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 $\qquad$ . 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 $\qquad$ .
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:

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

4. An object with an acceleration of $10 \mathrm{~m} / \mathrm{s}^{2}$ will $\qquad$ Circle all that apply.
a. move 10 meters in 1 second
b. change its velocity by $10 \mathrm{~m} / \mathrm{s}$ in 1 s
c. move 100 meters in 10 seconds
d. have a velocity of $100 \mathrm{~m} / \mathrm{s}$ after 10 s
5. Ima Speedin puts the pedal to the metal and increases her speed as follows: $0 \mathrm{mi} / \mathrm{hr}$ at 0 seconds; $10 \mathrm{mi} / \mathrm{hr}$ at 1 second; $20 \mathrm{mi} / \mathrm{hr}$ at 2 seconds; $30 \mathrm{mi} / \mathrm{hr}$ at 3 seconds; and $40 \mathrm{mi} / \mathrm{hr}$ at 4 seconds. What is the acceleration of Ima's car?
6. Mr. Henderson's (imaginary) Porsche accelerates from 0 to $60 \mathrm{mi} / \mathrm{hr}$ in 4 seconds. Its acceleration is
$\qquad$ _.
a. $60 \mathrm{mi} / \mathrm{hr}$
b. $15 \mathrm{~m} / \mathrm{s} / \mathrm{s}$
c. $15 \mathrm{mi} / \mathrm{hr} / \mathrm{s}$
d. $-15 \mathrm{mi} / \mathrm{hr} / \mathrm{s}$
e. none of these
7. A car speeds up from rest to $+16 \mathrm{~m} / \mathrm{s}$ in 4 s . Calculate the acceleration.
8. A car slows down from $+32 \mathrm{~m} / \mathrm{s}$ to $+8 \mathrm{~m} / \mathrm{s}$ 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 <br> Acceleration |
| :--- | :--- | :--- |
| a. | A car is moving eastward along Lake Avenue and increasing its speed <br> 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 kick delivered by the opposing team is <br> slowed down and stopped by the goalie. |  |
| e. | A downward falling parachutist pulls the chord and rapidly slows <br> down. |  |
| f. | A rightward-moving Hot Wheels car slows to a stop. |  |
| g. | A falling bungee-jumper slows down as she nears the concrete <br> 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.


$\qquad$

## 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.

2. Suppose that in diagram D (above) the cars were moving leftward (and traveling backwards). What would be the direction of the acceleration? $\qquad$ 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 $\qquad$ velocity and a $\qquad$ 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.


| 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. <br> Reasoning: $\qquad$ |  |
| ii. Renatta rapidly decelerated from a high speed to a rest position, and then slowly accelerated to a moderate speed. <br> Reasoning: $\qquad$ |  |
| iii. Renatta was driving at a moderate speed and slowly accelerated. <br> Reasoning: $\qquad$ |  |

## 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 <br> (hr) | Position <br> (mi) |
| :---: | :---: |
| 0 | 0 |
| 1 | 0.23 |
| 2 | 0.46 |
| 3 | - |
| 4 | 0.92 |
| 5 |  |
| 6 |  |

Speed $=$ $\qquad$

| Time <br> $(\mathrm{s})$ | Position <br> $(\mathrm{m})$ |
| :---: | :---: |
| 0 | 0 |
| 0.5 | 12.5 |
| 1 | - |
| 1.5 | - |
| 2 | - |
| 2.5 | 75.0 |

Speed $=$ $\qquad$

| Time <br> $(\mathrm{yr})$ | Position <br> $(\mathrm{cm})$ |
| :---: | :---: |
| 0 | 0 |
| 0.25 | - |
| 0.50 | 0.50 |
| 0.75 | 0.75 |
| 1.0 | - |
| 1.25 | - |
| 1.5 | 1.5 |

Speed $=$ $\qquad$

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.

| Time <br> (day) | Position <br> $(f t)$ |
| :---: | :---: |
| 0 | 0 |
| 1 | 11 |
| 2 | - |
| 3 | - |
| 4 | - |
| 5 | 66 |

Acceleration $=$ $\qquad$
Honda Accord

| Time <br> $(\mathrm{s})$ | Velocity <br> $(\mathrm{mi} / \mathrm{hr})$ |
| :---: | :---: |
| 0 | $60, \mathrm{E}$ |
| 0.5 | $54, \mathrm{E}$ |
| 1 | - |
| 1.5 | $42, \mathrm{E}$ |
| 2 | - |
| 2.5 | $24, \mathrm{E}$ |

Acceleration $=$ $\qquad$
Peregrine Falcon

| Time <br> $(\mathrm{s})$ | Velocity <br> $(\mathrm{m} / \mathrm{s})$ |
| :---: | :---: |
| 0 | 0 |
| 0.25 | -18, down |
| 0.50 | 27, down |
| 0.75 |  |
| 1.0 | -54, down |
| 1.25 | 1.5 |

Acceleration $=$ $\qquad$
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. ( $\mathbf{1} \mathbf{~ m} / \mathrm{s}=\mathbf{2 . 2 4} \mathbf{~ m i} / \mathbf{h r}$ ) 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:
$2.83 \times 10^{5} \mathrm{ft} /$ day $=1 \mathrm{~m} / \mathrm{s}$
$1 \mathrm{~m} / \mathrm{s}=2.24 \mathrm{mi} / \mathrm{hr}$
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 $0.20 \mathrm{~m} / \mathrm{s}^{2}$. 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

| $\mathbf{t}(\mathbf{s})$ | $\boldsymbol{\nabla}(\mathbf{m} / \mathbf{s})$ |
| :---: | :---: |
| 0 | 32 |
| 1 | 28 |
| 2 | 24 |
| 3 | 20 |
| 4 | 16 |
| 5 | 12 |
| 6 | 8 |

$\mathrm{a}=$ $\qquad$ $\mathrm{m} / \mathrm{s} / \mathrm{s}$
Data Set B

| $\mathbf{t}(\mathbf{s})$ | $\boldsymbol{\nabla}(\mathbf{m} / \mathbf{s})$ |
| :---: | :---: |
| 0 | 12 |
| 0.5 | 10 |
| 1.0 | 8 |
| 1.5 | 6 |
| 2.0 | 4 |
| 2.5 | 2 |
| 3.0 | 0 |

$\mathrm{a}=$ $\qquad$ $\mathrm{m} / \mathrm{s} / \mathrm{s}$

| $\mathbf{t}(\mathbf{s})$ | $\mathbf{\nabla}(\mathbf{m} / \mathbf{s})$ |
| :---: | :---: |
| 0 | 24 |
| 1 | 21 |
| 2 | 18 |
| 3 | 15 |
| 4 | 12 |
| 5 | 9 |
| 6 | 6 |

$\mathrm{a}=$ $\qquad$ $\mathrm{m} / \mathrm{s} / \mathrm{s}$

Data Set D

| $\mathbf{t}(\mathbf{s})$ | $\mathbf{\nabla}(\mathbf{m} / \mathbf{s})$ |
| :---: | :---: |
| 0 | 32 |
| 0.5 | 28 |
| 1.0 | 24 |
| 1.5 | 20 |
| 2.0 | 16 |
| 2.5 | 12 |
| 3.0 | 8 |

$\mathrm{a}=$ $\qquad$ $\mathrm{m} / \mathrm{s} / \mathrm{s}$

## 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.htm1 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)
$\qquad$
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.

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空 |
| :---: | :---: |


| Moving with a - velocity and a + acceleration | Moving with a - velocity and a - acceleration |
| :---: | :---: |
| n time | time |

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.

|  <br> Verbal Description: |  <br> Verbal Description: |
| :---: | :---: |
|  <br> Verbal Description: |  <br> Verbal Description: |

5. Use the position-time graphs below to determine the velocity. 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 with - velocity and - accel'n |  |  |
| :--- | :--- | :--- | :--- |
| B | Moving with - velocity and + accel'n | A | Moving in + dir'n, first fast, then slow <br> Moving in - dir'n, first fast, then slow |

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



$$
\mathrm{A}=(6 \mathrm{~m} / \mathrm{s})^{*}(6 \mathrm{~s})=36 \mathrm{~m}
$$

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

$A=0.5^{*}(6 \mathrm{~m} / \mathrm{s})^{*}(6 \mathrm{~s})=\mathbf{1 8} \mathbf{m}$
... trapezoid, then make it into a rectangle + triangle and add the two areas.

$\mathrm{A}_{\text {total }}=\mathrm{A}_{\text {rectangle }}+\mathrm{A}_{\text {triangle }}$

$$
\begin{gathered}
A_{\text {total }}=(2 \mathrm{~m} / \mathrm{s})^{*}(6 \mathrm{~s})+ \\
0.5^{*}(4 \mathrm{~m} / \mathrm{s})^{*}(6 \mathrm{~s})=24 \mathrm{~m}
\end{gathered}
$$

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



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 $\qquad$ .
b. A straight diagonal line means $\qquad$
c. A curved line means $\qquad$
d. A gradually sloped line means $\qquad$ _.
e. A steeply sloped line means $\qquad$ .

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.
$\qquad$ a. Which object(s) is(are) at rest?
b. Which object(s) is(are) accelerating?
c. Which object(s) is(are) not moving?
$\qquad$ 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 $\qquad$ .
b. A straight diagonal line means $\qquad$ .
c. A gradually sloped line means $\qquad$ -.
d. A steeply sloped line means $\qquad$ .

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.
$\qquad$ a. Which object(s) is(are) at rest?
$\qquad$ b. Which object(s) is(are) accelerating?
$\qquad$ c. Which object(s) is(are) not moving?
$\qquad$ d. Which object(s) change(s) its direction?
e. Which accelerating object has the smallest acceleration?
$\qquad$ f. Which object has the greatest acceleration?

$\qquad$ g. Which object(s) is(are) moving in the same direction as object E?
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. $\quad$The object is moving fast with a constant velocity and then moves slow with a <br> constant velocity. |  |  |
| b.The object is moving in one direction with a constant rate of acceleration <br> (slowing down), changes directions, and continues in the opposite direction <br> 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?

1. After 4 seconds, the rocket is moving in the negative direction (i.e., down).

Justification: $\qquad$
Yes or No
$\qquad$
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: $\qquad$
$\qquad$
3. The rocket changes its direction after the fourth second.

Justification:
$\qquad$
4. During the time interval from 4 to 9 seconds, the rocket is moving in the positive direction (up) and slowing down.

Justification: $\qquad$
$\qquad$
5. At nine seconds, the rocket has returned to its initial starting position.

Justification:
$\qquad$

## 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 + 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? |
|  |  |  |
|  <br> time |  <br> time |  <br> time |

## 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/1DKinTOC.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: $\qquad$
5-15 s: $\qquad$
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.

$$
\underline{0-5 \mathrm{~s}} \quad \underline{5-15 \mathrm{~s}}
$$

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

$$
\underline{0-5 \mathrm{~s}} \quad \underline{5-15 \mathrm{~s}}
$$

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).

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: $\qquad$
$10-20 \mathrm{~s}$ : $\qquad$
20-30 s: $\qquad$
30-35 s: $\qquad$
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
$\underline{0-10 \mathrm{~s}}$
$\underline{10-20 \mathrm{~s}}$
$\underline{20-30 \mathrm{~s}}$
30-35 s
d. Determine the displacement of the car during each of the four parts of its motion. PSYW

$$
\begin{array}{llll}
\underline{0-10 \mathrm{~s}} & \underline{10-20 \mathrm{~s}} & \underline{20-30 \mathrm{~s}} & \underline{30-35 \mathrm{~s}}
\end{array}
$$

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) | Posn (m) |
| :---: | :---: |
| 0 | 0 |
| 5 |  |
| 10 |  |
| 15 |  |
| 20 |  |
| 25 |  |
| 30 |  |
| 35 |  |


$\qquad$

## Inertia and Mass

## Read from Lesson 1 of the Newton's Laws chapter at The Physics Classroom:

http://www.physicsclassroom.com/Class/newtlaws/u211a.html http://www.physicsclassroom.com/Class/newtlaws/u2l1b.html

MOP Connection: Newton's Laws: sublevel 1

1. Inertia is $\qquad$
2. The amount of inertia possessed by an object is dependent solely upon its $\qquad$ -.
3. Two bricks are resting on edge of the lab table. Shirley Sheshort stands on her toes and spots the two bricks. She acquires an intense desire to know which of the two bricks are most massive. Since Shirley is vertically challenged, she is unable to reach high enough and lift the bricks; she can however reach high enough to give the bricks a push. Discuss how the process of pushing the bricks will allow Shirley to determine which of the two bricks is most massive. What differences will Shirley observe and how can this observation lead to the necessary conclusion?
4. Would Shirley Sheshort be able to conduct this same study if she was on a spaceship in a location in space far from the influence of significant gravitational forces? $\qquad$ Explain your answer.
5. If a moose were chasing you through the woods, its enormous mass would be very threatening. But if you zigzagged, then its great mass would be to your advantage. Explain why.
6. Inertia can best be described as $\qquad$ .
a. the force that keeps moving objects moving and stationary objects at rest.
b. the willingness of an object to eventually lose its motion
c. the force that causes all objects to stop
d. the tendency of any object to resist change and keep doing whatever it's doing
7. Mass and velocity values for a variety of objects are listed below. Rank the objects from smallest to greatest inertia. $\qquad$ $<$ $\qquad$ < $\qquad$ $<$ $\qquad$

| $\nabla=2 \mathrm{~m} / \mathrm{s}$ |
| :---: |
| $\mathrm{m}=10 \mathrm{~kg}$ |
| Orject $A$ |


| $\nabla=0 \mathrm{~m} / \mathrm{s}$ |
| :---: |
| $\mathrm{m}=20 \mathrm{~kg}$ |

Oiject B

$\qquad$

## Pre-Conceptions

Students typically have many pre-conceived notions regarding concepts in Physics. It has always proven useful to bring these ideas to the forefront of your mind and to make an effort to evaluate their correctness. The following statements pertain in one way or another to common notions regarding central concepts of this unit. Identify each statement as being either true (T) or false (F).

## Force and Motion - What Do You Believe?

The following statements pertain in one way or another to common notions regarding force and motion. Identify each statement as being either true (T) or false (F).
T or F? Statement

1. A force is required to keep an object moving in a given direction.
2. An upward moving object must be experiencing (or at least usually does experience) an upward force.
3. A rightward moving object must be experiencing (or at least usually does experience) a rightward force.
4. A ball is moving upwards and rightwards towards its peak. The ball experiences a force that is directed upwards and rightwards.
$\qquad$ 5. If a person throws a ball with his hand, then the force of the hand upon the ball is experienced by the ball for at least a little while after the ball leaves the hand.
5. A cannonball is shot from a cannon at a very high speed. The force of the explosion will be experienced by the cannonball for several seconds (or a least a little while).
$\qquad$ 7. If an object is at rest, then there are no forces acting upon the object.

## Mass and Weight - What Do You Believe?

The following statements pertain in one way or another to common notions regarding mass and weight. Identify each statement as being either true (T) or false (F).
T or F? Statement

1. Objects do NOT weigh anything when placed in a vacuum.
2. All objects weigh the same amount when placed in a vacuum, regardless of their mass.
3. An object weighs less on the moon than it does on the Earth.
4. The mass of an object on the moon is the same as its mass on the Earth.
5. A high-speed object (say, moving at $200 \mathrm{mi} / \mathrm{hr}$ ) will weigh less than the same object when at rest.
6. A high-speed object (say, moving at $200 \mathrm{mi} / \mathrm{hr}$ ) will possess measurably more mass than the same object when at rest.
7. Weight is measured in pounds; mass is measured in Newtons.
8. A free-falling object still has weight.
9. Weight is the result of air pressure exerted upon an object.
$\qquad$

## Balanced vs. Unbalanced Forces

## Read from Lesson 1 of the Newton's Laws chapter at The Physics Classroom:

http://www.physicsclassroom.com/Class/newtlaws/u211c.html
http://www.physicsclassroom.com/Class/newtlaws/u2l1d.html
MOP Connection: Newton's Laws: sublevels 2 and 3

Review: An object at rest ... $\qquad$ ;

An object in motion .... $\qquad$ ;
unless $\qquad$

1. The amount of force required to keep a $6-\mathrm{kg}$ object moving with a constant velocity of $2 \mathrm{~m} / \mathrm{s}$ is $\qquad$ N.
a. 0.333
b. 2
c. 3
d. 6
e. 12
f. ... nonsense! A force is NOT required to keep an object in motion.
2. Renatta Oyle is having car troubles. She is notorious for the trail of oil drops that she leaves on the streets of Glenview. Observe the following oil traces and indicate whether Renatta's car is being acted upon by an unbalanced force. Give a reason for your answers.

3. Each one of the dot diagrams in question \#2 can be matched to a force diagram below. The force diagrams depict the individual forces acting upon the car by a vector arrow. The arrow direction represents the direction of the force. The arrow length represents the strength of the force. Match the dot diagrams from \#2 to a force diagram; not every force diagram needs to be matched.


Dot Diagram(s):
$\qquad$


Dot Diagram(s): $\qquad$
$\qquad$
4. If the net force acting upon an object is 0 N , then the object MUST $\qquad$ . Circle one answer.
a. be moving
b. be accelerating
c. be at rest
d. be moving with a constant speed in the same direction
e. either cord.
5. These graphs describe the motion of Carson Busses at various times during his trip to school. Indicate whether Carson's vehicle is being acted upon by an unbalanced force. Give a reason in terms of a description of what the car is doing (speeding up, slowing down, or constant velocity).

|  |  |  |
| :---: | :---: | :---: |
| Unbalanced Force? Yes or No? <br> Reason/Description: | Unbalanced Force? Yes or No? Reason/Description: | Unbalanced Force? Yes or No? <br> Reason/Description: |

6. A free-body diagrams show all the individual forces acting upon an object. The net force is the vector sum of all these forces $\left(\sum \mathrm{F}\right)$. Determine the net force and state if there is an acceleration.
a.
b.
$\qquad$
Accel'n? Yes or No

$\sum \mathrm{F}=$ $\qquad$
Accel'n? Yes or No

$\sum \mathrm{F}=$ $\qquad$
Accel'n? Yes or No
c.
7. During an in-class discussion, Anna Litical suggests to her lab partner that the dot diagram for the motion of the object in \#6b could be

Anna's partner objects, arguing that the object in \#6b could not have any horizontal motion if there are only vertical forces acting upon it. Who is right? $\qquad$ Explain.
8. During an in-class discussion, Aaron Agin asserts that the object in \#6a must be moving to the left since the only horizontal force acting upon it is a "left-ward" force. Is he right? $\qquad$ Explain.
9. The diagrams below depict the magnitude and direction of the individual forces acting upon an object. Which objects could be moving to the right? Circle all that apply.


## Net Force Help Sheet

Understanding the influence of individual forces upon the acceleration of objects demands familiarity with the variety of types of forces. Quickly internalize the following.

| Type of Force | Explanation |
| :---: | :---: |
| Weight (W) or Force of Gravity (Fgrav) | The force of gravity is the force at which the earth, moon, or other massively large object attracts another object towards itself. By definition, this is the weight of the object. All objects upon earth experience a force of gravity which is directed "downward" towards the center of the earth. The force of gravity on earth is always equal to the weight of the object as found by the equation: $F_{\text {grav }}=\mathrm{m}^{*} \mathrm{~g} \quad \text { where } \mathrm{g}=9.8 \mathrm{~N} / \mathrm{kg} \text { (on Earth) }$ |
| Normal Force (Fnorm or FN) | The normal force is the support force exerted upon an object which is in contact with another stable object. For example, if a book is resting upon a surface, then the surface is exerting an upward force upon the book in order to support the weight of the book. On occasions, a normal force is exerted horizontally between two objects which are in contact with each other. |
| Spring <br> ( $\mathrm{F}_{\text {spring }}$ or $\mathrm{F}_{\mathbf{s}}$ ) | The spring force is exerted by a spring upon the objects connected to each of its two ends. Spring forces may result from either a compressed or a stretched spring. The magnitude of a spring force is dependent upon the elasticity of the spring (usually denoted by its spring constant $\mathbf{k}$ ) and upon the amount of compression or stretch ( $\mathbf{x}$ ) of the spring from its equilibrium position. The general equation for spring force is $\mathbf{F}_{\text {spring }}=\mathbf{k}^{*} \mathbf{x}$ |
| Sliding <br> Friction Forces ( $\mathrm{F}_{\text {frict }}$ or $\mathrm{F}_{\mathrm{f}}$ ) | The frictional force is the force exerted by a surface as an object moves across it. The sliding friction force opposes the motion of the object. For example, if a book moves across the surface of a desk, then the desk exerts a frictional force in the opposite direction of its motion. The frictional force can often be calculated using the equation: $F_{\text {frict }}=\mu^{*} \mathbf{F}_{\text {norm }}$ |
| Air Resistance <br> ( $\mathrm{Fair}_{\text {or }}$ R) | The air resistance is a special type of frictional force which acts upon objects as they travel through the air. The force of air resistance always opposes the motion of the object. This force will frequently be neglected due to its negligible magnitude. It is most noticeable for objects which travel at high speeds (e.g., a skydiver or a downhill skier) or for objects with large surface areas. |
| Tension ( $\mathrm{F}_{\text {tens }}$ or T) | The tension is the force which is transmitted through a string, rope, wire or cable when it is pulled tight by forces acting from each end. The tensional force is directed along the wire and pulls equally on the objects on either end of the wire. |
| Applied Force ( $\mathrm{Fapp}_{\text {or }} \mathrm{F}_{\mathrm{a}}$ ) | The applied force is the force which is applied to an object by a person or another object. If a person is pushing a desk across a room, then there is an applied force acting upon the object. The applied force is the force exerted on the desk by the person. |

## The Net Force

The net force is the vector sum of all the individual forces acting upon an object. In other words, $F_{\text {net }}=F_{1}+F_{2}+F_{3}+\ldots$ where $F_{1}, F_{2}$, and $F_{3}$ represent the various forces acting upon an object. Like any force, the net force is a vector and has a direction. Being the vector sum of all the forces, there may be some negative signs present in the net force equation to indicate that one force is opposite in direction to another force. According to Newton's second law, the net force is related to mass and acceleration

$$
\mathbf{F}_{\text {net }}=\Sigma \mathbf{F}=\mathbf{m}{ }^{*} \mathbf{a}
$$

## Other Noteworthy Items:

1. Scales are devices which are equipped with springs that are compressed or stretched when objects are placed upon the scales. These springs allow the scales to measure the magnitude of other forces (i.e., normal forces, tensional forces, gravitational forces, etc.) acting upon the object.
2. Pulleys are objects which change the direction of a force but not its magnitude.

## Problem-Solving Strategy:

To solve problems involving several forces acting upon a single object:

1. Sketch a free-body diagram (FBD). To simplify the diagram, represent the object by a "box". Draw arrows representing all the forces acting on the object. The direction of each arrow should indicate the direction of the force.
2. Label each arrow on the FBD with a symbol to indicate the type of force it is. Use the table above to help you label the forces appropriately.
3. Write down all given information in variable form (e.g., $\mathrm{m}=2.0 \mathrm{~kg} ; \mathrm{a}=1.5 \mathrm{~m} / / \mathrm{s}$, right). Write down the desired end - what the problem asks to be determined or calculated (e.g., find $F_{\text {app }}$ ).
4. The net force is the vector sum of all the individual forces acting on the object. The "summing" of individual forces is simplified if the horizontal and vertical forces are summed separately. Indicate this in the form of equations based upon the FBD.

| Horizontal | $\sum \mathrm{F}_{\mathrm{x}}=\mathrm{F}_{\text {right }}-\mathrm{F}_{\text {left }}$ (assumes that rightward is the + direction) |
| :--- | :--- |
| Vertical | $\sum \mathrm{F}_{\mathrm{y}}=\mathrm{F}_{\mathrm{up}}-\mathrm{F}_{\text {down }}$ (assumes that up is the + direction) |

5. Write the net force equations $\left(\sum F_{x}=m * a_{x}\right.$ and $\left.\sum F_{y}=m * a_{y}\right)$.
6. Solve the problem for the desired information by relating the \#4 and the \#5 equations.


Perhaps the most difficult (and most critical) principle of mechanics is the principle of net force and acceleration. You will probably be tempted to approach Fnet problems in a memorization mode. Avoid such an approach; nothing could lead you into a state of frustration more readily. Rather, internalize the meaning of the various forces, learn to recognize their presence by careful analysis of a problem, and base your problem-solving strategies on an understanding of such concepts and upon the application of good logic and reasoning. Approach Fnet problems in logic mode.
$\qquad$

## Mass and Weight

## Read from Lesson 2 of the Newton's Laws chapter at The Physics Classroom:

http://www.physicsclassroom.com/Class/newtlaws/u2l2b.html \#mass
MOP Connection: Newton's Laws: sublevel 6

1. The standard metric unit for mass is $\qquad$ and the standard metric unit for weight is $\qquad$ .
2. An object's mass refers to $\qquad$ and an object's weight refers to $\qquad$ . Fill in each blank.
a. the amount of space it takes up
b. the force of gravitational attraction to Earth
c. how dense an object is
d. the amount of stuff present in the object
3. Complete the following table showing the relationship between mass and weight.

| Object | Mass | Approx. Weight |
| :---: | :---: | :---: |
| Melon | 1 kg |  |
| Apple |  | $\sim 1.0 \mathrm{~N}$ |
| Pat Eatladee | 25 kg |  |

4. Different masses are hung on a spring scale calibrated in Newtons.

The force exerted by gravity on $1 \mathrm{~kg}=\sim 10 \mathrm{~N}$.
The force exerted by gravity on $5 \mathrm{~kg}=\sim$ $\qquad$ N.

The force exerted by gravity on $70 \mathrm{~kg}=\sim$ $\qquad$ N.
5. The value of g in the British system is $32 \mathrm{ft} / \mathrm{sec}^{2}$. The unit of force is
 pounds. The unit of mass is the slug. Use your weight in pounds to calculate your mass in units of slugs. PSYW
6. You might be wondering about your metric weight. Using conversion factors, convert your weight in pounds to units of N . (Use $1 \mathrm{~N}=0.22$ pounds) PSYW
7. What is the mass and weight of a $10-\mathrm{kg}$ object on earth?

$$
\text { Mass }=\ldots \quad \text { Weight }=
$$

$\qquad$

What is the mass and weight of a $10-\mathrm{kg}$ object on the moon where the force of gravity is $1 / 6$-th that of the Earth's?

$$
\text { Mass }=\square \text { Weight }=
$$

8. Conclusion: The $\qquad$ of an object is independent of the object's location in space.
$\qquad$

## Newton's Second Law of Motion

## Read from Lesson 3 of the Newton's Laws chapter at The Physics Classroom:

http://www.physicsclassroom.com/Class/newtlaws/u2l3a.html http://www.physicsclassroom.com/Class/newtlaws/u2l3b.html

## MOP Connection: Newton's Laws: sublevel 7

1. The acceleration of an object is $\qquad$ related to the net force exerted upon it and
$\qquad$ related to the mass of the object. In equation form: $a=F_{n e t} / \mathrm{m}$.
a. directly, inversely
b. inversely, directly
c. directly, directly
d. inversely, inversely
2. Use Newton's second law to predict the effect of an alteration in mass or net force upon the acceleration of an object.
a. An object is accelerating at a rate of $8 \mathrm{~m} / \mathrm{s}^{2}$ when it suddenly has the net force exerted upon increased by a factor of 2 . The new acceleration will be $\qquad$ $\mathrm{m} / \mathrm{s}^{2}$.
b. An object is accelerating at a rate of $8 \mathrm{~m} / \mathrm{s}^{2}$ when it suddenly has the net force exerted upon increased by a factor of 4 . The new acceleration will be $\qquad$ $\mathrm{m} / \mathrm{s}^{2}$.
c. An object is accelerating at a rate of $8 \mathrm{~m} / \mathrm{s}^{2}$ when it suddenly has the net force exerted upon decreased by a factor of 2 . The new acceleration will be $\qquad$ $\mathrm{m} / \mathrm{s}^{2}$.
d. An object is accelerating at a rate of $8 \mathrm{~m} / \mathrm{s}^{2}$ when it suddenly has its mass increased by a factor of 2 . The new acceleration will be $\qquad$ $\mathrm{m} / \mathrm{s}^{2}$.
e. An object is accelerating at a rate of $8 \mathrm{~m} / \mathrm{s}^{2}$ when it suddenly has its mass decreased by a factor of 4 . The new acceleration will be $\qquad$ $\mathrm{m} / \mathrm{s}^{2}$.
f. An object is accelerating at a rate of $8 \mathrm{~m} / \mathrm{s}^{2}$ when it suddenly has the net force exerted upon increased by a factor of 2 and its mass decreased by a factor of 4 . The new acceleration will be
$\qquad$ $\mathrm{m} / \mathrm{s}^{2}$.
g. An object is accelerating at a rate of $8 \mathrm{~m} / \mathrm{s}^{2}$ when it suddenly has the net force exerted upon increased by a factor of 4 and its mass increased by a factor of 2 . The new acceleration will be
$\qquad$ $\mathrm{m} / \mathrm{s}^{2}$.
h. An object is accelerating at a rate of $8 \mathrm{~m} / \mathrm{s}^{2}$ when it suddenly has the net force exerted upon increased by a factor of 3 and its mass decreased by a factor of 4 . The new acceleration will be
$\qquad$ $\mathrm{m} / \mathrm{s}^{2}$.
3. These force diagrams depict the magnitudes and directions of the forces acting upon four objects. In each case, the down force is the force of gravity. Rank these objects in order of their acceleration, from largest to smallest: $\qquad$ $>$ $\qquad$ $>$ $\qquad$ $>$ $\qquad$


Object D

$\qquad$

## Net Force and Acceleration

Read from Lesson 3 of the Newton's Laws chapter at The Physics Classroom:
http://www.physicsclassroom.com/Class/newtlaws/u2l3a.html http://www.physicsclassroom.com/Class/newtlaws/u2l3b.html http://www.physicsclassroom.com/Class/newtlaws/u2l3c.html

## MOP Connection: Newton's Laws: sublevels 3 (front), 8 and 9 (back)

1. Luke Autbeloe drops a 5.0 kg fat cat (weight $=\sim 50.0 \mathrm{~N}$ ) off the high dive into the pool below (which on this occasion is filled with water). Upon encountering the water in the pool, the cat encounters a 50.0 N upward restraining force. Which one of the velocity-time graph best describes the motion of the cat? $\qquad$ Accompany your answer with a description of the cat's motion.


Description of cat's motion while falling through air:

Description of cat's motion after hitting the water:
2. Which one of the following dot diagrams best describes the motion of the falling cat from the time that they are dropped to the time that they hit the ground? $\qquad$ The arrows on the diagram represent the point at which the cat hit the water. Support your answer with sound reasoning:


3 Several of Luke's friends were watching the motion of the falling cat. Being "physics types", they began discussing the motion and made the following comments. Indicate whether each of the comments are correct or incorrect? Support your answers.

| Student Statement: |
| :--- |
| a. Once the cat hit the pool, the forces are balanced and the cat will stop. <br> Yeason: <br> Yes or No |
| b.Upon hitting the pool, the cat will accelerate upwards because the pool applies <br> an upward force. <br> Reason: |
| c. |
| Upon hitting the pool, the cat will bounce upwards due to the upwards force. <br> Reason: |

## Newton's Laws

4. For each force diagram, determine the net or resultant force ( $\left.\sum \mathrm{F}\right)$, the mass and the acceleration of the object. Identify the direction (the second blank) of the two vector quantities. NOTE: Fgrav stands for the weight of the object.

| a. $\mathrm{F}_{\mathrm{grav}}=600 \mathrm{~N}$ $\begin{aligned} & \sum \mathrm{F}=\square \\ & \mathrm{m}= \\ & \end{aligned}$ | b. $\mathrm{F}_{\mathrm{air}}=40 \mathrm{~N}$ $\mathrm{F}_{\mathrm{grav}}=600 \mathrm{~N}$ $\sum \mathrm{F}=$ $\qquad$ , $\qquad$ <br> $\mathrm{m}=$ $\qquad$ <br> $\mathrm{a}=$ $\qquad$ $\qquad$ |
| :---: | :---: |
| c. | d. $\begin{aligned} F_{\text {nomm }} & =8000 \mathrm{~N} \\ \mathrm{~F}_{\text {frict }}=4000 \mathrm{~N} & \underbrace{-}_{\square} \\ \mathrm{F}_{\mathrm{grav}} & =8000 \mathrm{~N} \end{aligned}$ <br> $\Sigma \mathrm{F}=$ $\qquad$ $\qquad$ <br> $\mathrm{m}=$ $\qquad$ <br> $\mathrm{a}=$ $\qquad$ $\qquad$ |
| e. $\mathrm{F}_{\mathrm{gra⿻}}=20 \mathrm{~N}$ <br> $\Sigma \mathrm{F}=$ $\qquad$ , $\qquad$ <br> $\mathrm{m}=$ $\qquad$ $a=$ $\qquad$ $\qquad$ | f. <br> $F_{\text {grav }}=40 \mathrm{~N}$ <br> $\sum \mathrm{F}=$ $\qquad$ , <br> $\mathrm{m}=$ $\qquad$ $a=$ $\qquad$ $\qquad$ |

$\qquad$

## Newton's Second Law

Read from Lesson 3 of the Newton's Laws chapter at The Physics Classroom:
http://www.physicsclassroom.com/Class/newtlaws/u213c.html http://www.physicsclassroom.com/Class/newtlaws/u213d.html

MOP Connection:
Newton's Laws: sublevels 8 and 9
Free-body diagrams are shown for a variety of physical situations. Use Newton's second law of motion ( $\sum \mathrm{F}=\mathrm{m} \bullet \mathrm{a}$ ) to fill in all blanks. Use the approximation that $\mathrm{g}=\sim 10 \mathrm{~m} / \mathrm{s} / \mathrm{s}$.
a.

d.

$\mathrm{m}=$
$\mathbf{a}=$
$\Sigma \mathbf{F}=$

b.

$\mathrm{m}=10000 \mathrm{~kg}$
$\mathrm{a}=8.0 \mathrm{~m} / \mathrm{s} / \mathrm{s}$, down $\Sigma \mathrm{F}=$ $\qquad$
e.

$\mathrm{m}=0.500 \mathrm{~kg}$
$\mathbf{a}=$
$\Sigma F=124 \mathrm{~N}$, right
h.

$m=$
$\mathbf{A}=$
$\Sigma \mathbf{F}=$

$\mathrm{m}=800 \mathrm{~kg}$
$\mathrm{a}=6.0 \mathrm{~m} / \mathrm{s} / \mathrm{s}$, up
$\Sigma \mathrm{F}=$ $\qquad$
f.

$\mathrm{m}=$ $\qquad$
$\mathrm{a}=1.50 \mathrm{~m} / \mathrm{s} / \mathrm{s}$, right
$\Sigma \mathrm{F}=$ $\qquad$
i.

$m=20.00 \mathrm{~kg}$
$\mathrm{a}=2.0 \mathrm{~m} / \mathrm{s} / \mathrm{s}$, right
$\Sigma \mathbf{F}=$ $\qquad$
$\qquad$

## Air Resistance and Terminal Velocity

## Read from Lesson 3 of the Newton's Laws chapter at The Physics Classroom:

 http://www.physicsclassroom.com/Class/newtlaws/u2l3e.html
## MOP Connection: Newton's Laws: sublevel 11

1. When falling under the influence of air resistance and dropped from the same height, which will fall to the ground at a faster rate?
a. a mouse
b. an elephant
c. the same
2. Which of the following variables will have a direct effect upon the amount of air resistance experienced by an object? (That is, for which of these quantities will an increase lead to a resulting increase in the air resistance force?)

a. speed
b. air density
c. cross-sectional area
3. Consider the dragster's motion below. Speedometer readings and the forward propulsion force ( $\mathrm{Fapp}_{\text {) }}$ are shown. The top (or terminal) speed is 120 mph . Draw Fair force arrows on each diagram to illustrate how the amount of air resistance changes during the course of its motion.



30 mph


60 mph


90 mph
 Draw $\mathrm{F}_{\text {air }}$ force arrows to show how the force of air resistance changes on the falling skydiver. At $\mathbf{A}$, the diver has just jumped; and at $\mathbf{E}$, the diver has just reached terminal velocity.

5. Fill in the blanks in the following paragraph.

As an object moves faster and faster, the amount of air resistance $\qquad$ (increases, decreases) until a state of terminal velocity is reached. Once terminal velocity is reached, the force of air resistance is $\qquad$ (greater than, less than, equal to) the force of gravity. Hence,
the object will $\qquad$ (continue to accelerate, stop its motion,
stop its acceleration, move back up to its starting position).
$\qquad$

## Skydiving

Read from Lesson 3 of the Newton's Laws chapter at The Physics Classroom: http://www.physicsclassroom.com/Class/newtlaws/u213e.html

MOP Connection: Newton's Laws: sublevel 11
A 90-kg (approx.) skydiver jumps out of a helicopter at 6000 feet above the ground. As he descends, the force of air resistance acting upon him continually changes. The free-body diagrams below represent the strength and direction of the two forces acting upon the skydiver at six positions during his fall. For each diagram, apply Newton's second law $\left(\mathrm{F}_{\text {net }}=\mathrm{m} \bullet \mathrm{a}\right)$ to determine the acceleration value.


1. At which two altitudes has the skydiver reached terminal velocity? $\qquad$
2. At which altitude(s) is the skydiver in the state of speeding up? $\qquad$
3. At which altitude(s) is the skydiver in the state of slowing down? $\qquad$
4. At 2900 feet, the skydiver is $\qquad$ . Choose two.
a. moving upward
b. moving downward
c. speeding up
d. slowing down
5. Explain why air resistance increases from 6000 feet to 4500 feet.
6. Explain why air resistance decreases from 3000 feet to 1500 feet.

## Newton's Second Law Problem-Solving

Study from Lessons 3 of the Newton's Laws chapter at The Physics Classroom:

> http://www.physicsclassroom.com/Class/newtlaws/u213c.html http://www.physicsclassroom.com/Class/newtlaws/u2l3d.html

For the following problems, construct a free-body diagram and show your work clearly.

1. A rightward force of 302 N is applied to a $28.6-\mathrm{kg}$ crate to accelerate it across the floor. The coefficient of friction between the crate and the floor is 0.750 . Determine the acceleration of the crate.
2. During a football workout, two linemen are pushing the coach on the sled. The combined mass of the sled and the coach is $300 . \mathrm{kg}$. The coefficient of friction between the sled and the grass is 0.800 . The sled accelerates at a rate of $0.580 \mathrm{~m} / \mathrm{s} / \mathrm{s}$. Determine the force applied to the sled by the lineman.
3. A $405-\mathrm{N}$ rightward force is use to drag a large box across the floor with a constant velocity of 0.678 $\mathrm{m} / \mathrm{s}$. The coefficient of friction between the box and the floor is 0.795 . Determine the mass of the box.
4. A $6.58 \times 10^{3} \mathrm{~N}$ upward tension force is exerted on a 521- kg downward-moving freight elevator. Determine the acceleration of the elevator.

## Newton's Laws

5. A basketball star exerts a force of 3225 N (average value) upon the gym floor in order to accelerate his $76.5-\mathrm{kg}$ body upward. (a) Determine the acceleration of the player. (b) Determine the final speed of the player if the force endures for a time of 0.150 seconds.
6. At the end of the Giant Drop free fall ride, riders experience a large upward normal force to bring their falling bodies to a stop. Determine the normal force value required to accelerate a $52.1-\mathrm{kg}$ physics student with an upward acceleration of $27.4 \mathrm{~m} / \mathrm{s} / \mathrm{s}$.
7. A hockey player accelerates a puck $(\mathrm{m}=0.167 \mathrm{~kg})$ from rest to a velocity of $50 \mathrm{~m} / \mathrm{s}$ in 0.0121 sec . Determine the acceleration of the puck and the force applied by the hockey stick to the puck. Neglect resistance forces.
8. A falling skydiver is accelerating in the downward direction at $3.29 \mathrm{~m} / \mathrm{s} / \mathrm{s}$. The mass of the skydiver (including parachute gear) is 67.2 kg . Determine the air resistance force on the skydiver (and accompanying parachute).
9. A $67.2-\mathrm{kg}$ falling skydiver opens his parachute and instantly slows down at a rate of $7.2 \mathrm{~m} / \mathrm{s} / \mathrm{s}$. Determine the air resistance force on the skydiver (and accompanying parachute).
$\qquad$

## Newton's Third Law

## Read from Lesson 4 of the Newton's Laws chapter at The Physics Classroom:

> http://www.physicsclassroom.com/Class/newtlaws/u214a.html
> http://www.physicsclassroom.com/Class/newtlaws/u214b.html

## MOP Connection: Newton's Laws: sublevel 12

A force is a push or pull resulting from an interaction between two objects. Whenever there is a force, there are two objects involved - with both objects pushing (or pulling) on each other in opposite directions. While the direction of the pushes (or pulls) are opposite, the strength or magnitudes are equal. This is sometimes stated as Newton's Third Law of motion: for every action, there is an equal and opposite reaction. A force is a push or a pull and it always results from an interaction between two objects. These forces always come in pairs.


1. For each stated action force, identify the reaction force.

2. Identify by words the action-reaction force pairs in each of the following diagrams.

3. TRUE or FALSE:

As you sit in your seat in the physics classroom, the Earth pulls down upon your body with a gravitational force; the reaction force is the chair pushing upwards on your body with an equal magnitude.
If False, correct the answer.
4. Shirley Bored sits in her seat in the English classroom. The Earth pulls down on Shirley's body with a gravitational force of 600 N . Describe the reaction force of the force of gravity acting upon Shirley.

5. Use Newton's third law (law of action-reaction) and Newton's second law (law of acceleration: $\mathrm{a}=$ $F_{\text {net }} / \mathrm{m}$ ) to complete the following statements by filling in the blanks.
a. A bullet is loaded in a rifle and the trigger is pulled. The force experienced by the bullet is
$\qquad$ (less than, equal to, greater than) the force experienced by the rifle. The resulting acceleration of the bullet is $\qquad$ (less than, equal to, greater than) the resulting acceleration of the rifle.
b. A bug crashes into a high speed bus. The force experienced by the bug is $\qquad$ (less than, equal to, greater than) the force experienced by the bus. The resulting acceleration of the bug is $\qquad$ (less than, equal to, greater than) the resulting acceleration of the bus.
c. A massive linebacker collides with a smaller halfback at midfield. The force experienced by the linebacker is $\qquad$ (less than, equal to, greater than) the force experienced by the halfback. The resulting acceleration of the linebacker is $\qquad$ (less than, equal to, greater than) the resulting acceleration of the halfback.
d. The 10-ball collides with the 14 -ball on the billiards table (assume equal mass balls). The force experienced by the 10 -ball is $\qquad$ (less than, equal to, greater than) the force experienced by the 14 -ball. The resulting acceleration of the 10 -ball is $\qquad$ (less than, equal to, greater than) the resulting acceleration of the 14-ball.

# Momentum, Impulse and Momentum Change 

## Read from Lesson 1 of the Momentum and Collisions chapter at The Physics Classroom:

http://www.physicsclassroom.com/Class/momentum/u411a.html
http://www.physicsclassroom.com/Class/momentum/u411b.html
MOP Connection: Momentum and Collisions: sublevels 1 and 2

## Momentum

1. The momentum of an object depends upon the object's $\qquad$ . Pick two quantities.
a. mass - how much stuff it has
b. acceleration - the rate at which the stuff changes its velocity
c. weight - the force by which gravity attracts the stuff to Earth
d. velocity - how fast and in what direction it's stuff is moving
e. position - where the stuff is at
2. Momentum is a $\qquad$ quantity.
a. scalar
b. vector
3. Which are complete descriptions of the momentum of an object? Circle all that apply.
a. $2.0 \mathrm{~kg} / \mathrm{s}$
b. $7.2 \mathrm{~kg} \bullet \mathrm{~m} / \mathrm{s}$, right
c. $6.1 \mathrm{~kg} \bullet \mathrm{~m} / \mathrm{s}^{2}$, down
d. $4.2 \mathrm{~m} / \mathrm{s}$, east
e. $1.9 \mathrm{~kg} \bullet \mathrm{~m} / \mathrm{s}$, west
f. $2.3 \mathrm{~kg} \bullet \mathrm{~m} / \mathrm{s}$
4. The two quantities needed to calculate an object's momentum are $\qquad$ and $\qquad$ .
5. Consider the mass and velocity values of Objects A and B below. Compared to Object B, Object A has $\qquad$ momentum.
a. two times the
b. four times the
c. eight times the
d. the same
e. one-half the
f. one-fourth the

g. ... impossible to tell without knowledge of the F and a.
6. Calculate the momentum value of ... . (Include appropriate units on your answers.)
a. ... a $2.0-\mathrm{kg}$ brick moving through the air at $12 \mathrm{~m} / \mathrm{s}$.
b. ... a $3.5-\mathrm{kg}$ wagon moving along the sidewalk at $1.2 \mathrm{~m} / \mathrm{s}$.
7. With what velocity must a $0.53-\mathrm{kg}$ softball be moving to equal the momentum of a $0.31-\mathrm{kg}$ baseball moving at $21 \mathrm{~m} / \mathrm{s}$ ?

## Impulse and Momentum Change

8. Insert these words into the four blanks of the sentence: mass, momentum, acceleration, time, impact, weight, impulse, and force. (Not every word will be used.)

In a collision, an object experiences a(n) $\qquad$ acting for a certain amount of $\qquad$ and which is known as a(n)

$\qquad$ ; it serves to change the $\qquad$ of the object.
9. $\mathrm{A}(\mathrm{n})$ $\qquad$ causes and is equal to a change in momentum.
a. force
b. impact
c. impulse
d. collision
10. Calculate the impulse experienced by .... . (Show appropriate units on your answer.)
a. ... a $65.8-\mathrm{kg}$ halfback encountering a force of 1025 N for 0.350 seconds.
b. ... a $0.168-\mathrm{kg}$ tennis ball encountering a force of 126 N that changes its velocity by $61.8 \mathrm{~m} / \mathrm{s}$.
11. Determine the impulse ( $\mathbf{I}$ ), momentum change $(\Delta \mathbf{p})$, momentum ( $\mathbf{p}$ ) and other values.

A 7-ball collides with the 8-ball.
A moving medicine ball is caught by a girl on ice skates.
$\mathbf{I}=$ $\qquad$ $\Delta \mathbf{P}=$ $\qquad$
$\mathbf{P}_{1}=$ $\qquad$

$m=10 \mathrm{lg}$
$\nabla=6 \mathrm{~m} / \mathrm{s}$
$I=-50 \mathrm{H} \cdot \mathrm{s}$ $\Delta \mathbf{P}=$ $\qquad$


A car is at rest when it experiences a forward propulsion force to set it in motion. It then experiences a second forward propulsion force to speed it up even more. Finally, it brakes to a stop.

$$
\begin{aligned}
& \mathbf{I}= \\
& \Delta \mathbf{P}= \\
& \hline
\end{aligned}
$$

$\mathbf{I}=$ $\qquad$ $\mathrm{I}=$ $\qquad$
$\Delta \mathbf{p}=$ $\qquad$
$\Delta \mathbf{P}=$ $\qquad$


$$
\mathbf{F}_{\mathbf{a p p}}=4000 \mathrm{~N}
$$


$\mathbf{P}_{1}=$ $\qquad$
$\mathrm{FaPP}=6000 \mathrm{~N}$


$\mathrm{F}_{\text {frit }}=80000 \mathrm{~N}$


Stopped

$\mathrm{P}_{2}=$ $\qquad$
$\mathrm{P}_{3}=$ $\qquad$
$\mathrm{P}_{4}=$ $\qquad$

A tennis ball is at rest when it experiences a forward force to set it in motion. It then strikes a wall where it encounters a force that slows it down and finally turns it around and sends it backwards.

$$
\begin{aligned}
& \mathbf{I}= \\
& \Delta \mathbf{P}= \\
& \hline
\end{aligned}
$$

|  | $\mathrm{F}_{\mathrm{apP}}=60 \mathrm{~N}$ <br> $t=0.1 \mathrm{~s}$ |
| :---: | :---: |
| Stopped |  |
| $Q 8$ |  |

$\mathbf{I}=$ $\qquad$

$$
\Delta \mathbf{p}=
$$

$\qquad$

$$
\mathbf{I}=
$$

$\qquad$
$\Delta \mathbf{P}=$ $\qquad$

$\mathrm{F}_{\text {wall }}=120 \mathrm{~N}$

$\mathbf{P}_{2}=$ $\qquad$ $\mathbf{P}_{3}=$ $\qquad$ $\mathbf{P}_{4}=$

## Controlling a Collision

Read from Lesson 1 of the Momentum and Collisions chapter at The Physics Classroom:
http://www.physicsclassroom.com/Class/momentum/u411a.html
http://www.physicsclassroom.com/Class/momentum/u4l1b.html
MOP Connection: Momentum and Collisions: sublevel 3

## Review:

1. A halfback $(\mathrm{m}=80 \mathrm{~kg})$, a tight end $(\mathrm{m}=100 \mathrm{~kg})$, and a lineman $(\mathrm{m}=120 \mathrm{~kg})$ are running down the football field. Consider their ticker tape patterns below.


The lineman's velocity is $3 \mathrm{~m} / \mathrm{s}$ (right). The tight end's velocity is $\qquad$ $\mathrm{m} / \mathrm{s}$ and the halfback's velocity is $\qquad$ $\mathrm{m} / \mathrm{s}$. Which player has the greatest momentum and how much momentum does he have? $\qquad$ Explain.
2. A football fullback is running down the field at constant speed until he encounters a defensive back. The dot diagram depicts the motion of the fullback.

Indicate on the dot diagram (by means of an arrow) the approximate location at which the fullbackdefensive back collision occurs.
Which direction (right or left) does the force upon the fullback act? $\qquad$ Explain how you know.

What happens to the momentum of the fullback upon colliding with the defensive back?


Using the $F \bullet t=m \bullet \Delta v$ Equation to Analyze Impulses and Momentum Changes:
3. Two cars of equal mass are traveling down Lake Avenue with equal velocities. They both come to a stop over different lengths of time. The dot diagrams for each car are shown below.


Which car (A or B) experiences the greatest acceleration? $\qquad$ Explain.

Which car (A or B) experiences the greatest change in momentum? $\qquad$ Explain.

Which car (A or B) experiences the greatest impulse? $\qquad$ Explain.

Which car (A or B) experiences the greatest force? $\qquad$ Explain.

## Momentum and Collisions

4. When a boxer recognizes that he/she will be hit by an opposing fist, he/she rides the punch. Use physics to explain why.

5. Mountain climbers use nylon safety ropes due to their tendency to stretch considerably under stress. Use physics to explain why.

Consider the diagram at the right for

Case A


## Case B

 the next three questions. The diagram depicts Before and After velocities of an $800-\mathrm{kg}$ car in two different collisions with a wall. In case A, the car rebounds upon collision. In case B, the car hits the wall, crumples up and stops. Assume that the collision time for each collision is the same.6. In which case does the car experience the greatest momentum change?
a. Case A
b. Case B
c. Both the same
d. Insufficient information
7. In which case does the car experience the greatest impulse?
a. Case A
b. Case B
c. Both the same
d. Insufficient information
8. The impulse encountered by the $800-\mathrm{kg}$ car in case A has a magnitude of $\qquad$ $\mathrm{N} \cdot \mathrm{s}$.
a. 0
b. 800
c. 3200
d. 4000
e. 7200
f. Not enough information to determine.
9. Evaluate the potential hazard to a passenger involved in a head-on collision in which the two cars stick together compared to when they rebound upon impact. Explain.
10. The diagram below depicts the changes in velocity of a ball that undergoes a collision with a wall. Indicate which case (A or B) has the greatest change in velocity, greatest acceleration, greatest momentum change, and greatest impulse. Support each answer.

| $(10) \xrightarrow{\mathbf{v}_{\mathbf{i}}=10 \mathrm{~m} / \mathrm{s}} \underset{\mathbf{v}_{\mathbf{f}}=5 \mathrm{~m} / \mathrm{s}}{\substack{\text { Case } A}}$ |  |
| :---: | :---: |
| Greatest $\Delta \mathrm{v}$ ? ___ Explanation: ___ |  |
| Greatest a? ___ Explanation: |  |
| Greatest $\Delta \mathrm{p}$ ? ___ Explanation: |  |
| Greatest F $\Delta t$ ? ___ Explanation: |  |

# Simple Computations with Impulse $=$ Momentum Change 

Read from Lesson 1 of the Momentum and Collisions chapter at The Physics Classroom:
http://www.physicsclassroom.com/Class/momentum/u4l1b.html http://www.physicsclassroom.com/Class/momentum/u4l1c.html

A car with a mass of 1000 kg is at rest at a stoplight. When the light turns green, it is pushed by a net force of $2000 \mathbf{N}$ for 10 s .

1. What is the value of the acceleration that the car experiences?

2. What is the value of the change in velocity that the car experiences?
3. What is the value of the impulse on the car?
4. What is the value of the change in momentum that the car experiences?
5. What is the final velocity of the car at the end of 10 seconds?

The car continues at this speed for a while.
6. What is the value of the change in momentum the car experiences as it continues at this velocity?
7. What is the value of the impulse on the car as it continues at this velocity?

The brakes are applied to the car, causing it to come to rest in 4 s.
8. What is the value of the change in momentum that the car experiences?
9. What is the value of the impulse on the car?
10. What is the value of the force (average) that causes the car to stop?
11. What is the acceleration of the car as it stops?


There is a disease known as formula fixation that is common among physics students. It particularly infects those who perceive physics as an applied math course where numbers and equations are simply combined to solve algebra problems. However, this is not the true nature of physics. Physics concerns itself with ideas and concepts that provide a reasonable explanation of the physical world. When students divorce the mathematics from the ideas, formula fixation takes root and even mathematical problem solving can become difficult. Do you have formula fixation? Test your health by trying these computational problems.
12. A force of 800 N causes an $80-\mathrm{kg}$ fullback to change his velocity by $10 \mathrm{~m} / \mathrm{s}$. Determine the impulse experienced by the fullback. PSYW
13. A $0.80-\mathrm{kg}$ soccer ball experiences an impulse of $25 \mathrm{~N} \bullet \mathrm{~s}$. Determine the momentum change of the soccer ball. PSYW
14. A $1200-\mathrm{kg}$ car is brought from $25 \mathrm{~m} / \mathrm{s}$ to $10 \mathrm{~m} / \mathrm{s}$ over a time period of 5.0 seconds. Determine the force experienced by the car. PSYW
15. A $90-\mathrm{kg}$ tight end moving at $9.0 \mathrm{~m} / \mathrm{s}$ encounters a $400 \mathrm{~N} \bullet \mathrm{~s}$ impulse. Determine the velocity change of the tight end. PSYW
16. A $0.10-\mathrm{kg}$ hockey puck decreases its speed from $40 \mathrm{~m} / \mathrm{s}$ to $0 \mathrm{~m} / \mathrm{s}$ in 0.025 s . Determine the force that it experiences. PSYW
17. A Real Brain Twister: A $0.10-\mathrm{kg}$ hockey puck is at rest. It encounters a force of 20 N for 0.2 seconds that sets it into motion. Over the next 2.0 seconds, it encounters 0.4 Newtons of resistance force. Finally, it encounters a final force of 24 N for 0.05 seconds in the direction of motion. What is the final velocity of the hockey puck? PSYW

[^0]
[^0]:    You may have been tricked, but those were not intended as trick questions. The questions were intended to test your understanding of the concepts of momentum change, impulse, mass, force, time and velocity change. How is your understanding level progressing? Do you have formula fixation?

