Period 3 Activity Sheet Solutions: Motion and Forces

3.1 What are Speed and Velocity?

Your instructor will discuss the concepts of speed and velocity as rates.

a) Using a timer and a meter stick, measure the speed of a toy tank in meters per second as it moves across the table. Explain how you made your measurements.

You might run the tank beside the meter stick, starting the timer when the front of the tank reaches one end of the stick and stopping the timer when the front of the tank reaches the other end.

b) Convert this speed into miles per hour. (Hint: 1 mile = 1,609 meters) In your calculation, show units and how they cancel. **If speed = 1.5 m/sec,**

$$\frac{1.5\ \cancel{\text{meters}}}{1\ \cancel{\text{second}}} \times \frac{1\ \text{mile}}{1{,}609\ \cancel{\text{meters}}} \times \frac{60\ \cancel{\text{seconds}}}{1\ \cancel{\text{minute}}} \times \frac{60\ \cancel{\text{minutes}}}{1\ \text{hour}} = \frac{3.4\ \text{miles}}{\text{hour}}$$

c) You travel from Columbus to Cincinnati and return to your starting point in 4 hours. The total distance traveled is 220 miles. What is your average speed?

$$s = \frac{D}{t} = \frac{220\ \text{miles}}{4\ \text{hrs}} = \frac{55\ \text{miles}}{\text{hour}} = 55\ \text{MPH}$$

d) Use a distance table to find the distance between two cities of your choice.

1) City #1 ________________________ City #2 ________________________

2) Distance between the cities _____________________

3) Calculate how long it would take to travel between the cities if you drove at a constant speed of 65 miles per hour.

Use $t = \frac{D}{s}$ **where** D **= the distance you measured in 2) and** s **= 65 miles/hour**

e) Your instructor will discuss velocity. What is the difference between speed and velocity? Give an example of each rate.

Speed tells you how fast an object is moving, but does not indicate the direction of its motion. Velocity tells you how fast and in which direction the object is moving. For example, 60 MPH indicates speed, but 60 MPH due south indicates velocity.

3.2 What Causes Changes in Velocity?

a) How does force acting on an object change its velocity?

1) Stack three wooden blocks under one end of a board to form a ramp. Roll a metal cart down the ramp and note the cart's velocity after it leaves the ramp.

2) Remove one of the blocks supporting the ramp. Roll the cart down this ramp. Is the velocity of the cart after it leaves the ramp less than, equal to, or greater than its velocity after rolling down the higher ramp in part 1?

After the cart rolls down the ramp supported by two blocks, its velocity is less than after it rolls down the ramp supported by three blocks.

3) Explain what caused the cart to move faster after it left the higher ramp.

The greater force of gravity as a result of a higher ramp pulls the cart down the higher ramp with a greater increase in velocity.

b) Stack two blocks under one end of the ramp and roll a cart down the ramp. Using a timer and a meter stick, measure the velocity of the cart in meters per second **after it leaves the ramp.**

Use $s = \frac{D}{t}$ **where** D **= distance rolled across the table and** t **= time to roll across the table**

c) Group Discussion Question: Was there a change in the velocity of the cart as it left the ramp? Why or why not?

The velocity changed because the direction of the cart's motion changed from motion down the slope of the ramp to horizontal motion across the table.

3.3 How Can We Detect and Measure Changing Velocity (Acceleration)?

a) In activity 3.2 we found that the force of gravity causes the velocity of a cart to increase as it rolls down a ramp. We now calculate the rate of change in velocity (the acceleration) of the cart as it rolls down the ramp.

1) Use two blocks to support the wooden ramp. Hold the cart at rest at the top of the ramp. What is its **initial velocity**? __**0**__

2) Measure how long it takes the cart to roll down the raised board. Stop the timer when the front wheels of the cart touch the table. ________________

3) What did you measure in activity 3.2.b for the cart's **final velocity**? _______

4) Use your answers to questions 1), 2), and 3) to calculate the cart's acceleration as it rolls down the board.

$$a = \frac{v_{final} - v_{initial}}{t} = \frac{v_f - v_i}{t}$$

b) If a car starts from rest and accelerates at a constant rate of $5\ \frac{\text{miles / hour}}{\text{second}}$ (5 miles per hour each second), how fast in miles per hour is the car traveling after 10 seconds?

$$v_{final} = v_{initial} + a\,t = 0\ \text{mi/hr} + \left(\frac{5\ \text{mi/hr}}{\cancel{\text{sec}}} \times 10\ \cancel{\text{sec}}\right) = 50\ \text{mi/hr}$$

c) Which of the following could cause a car to accelerate? A gas pedal? A brake pedal? A steering wheel? Explain why or why not each causes an acceleration.

All three could cause a car to accelerate. Acceleration is a change in speed, direction, or both.

d) Group discussion question: A speedometer indicates a car's speed. Design an acceleration meter that indicates whether or not a car is accelerating. Explain your design and how it works.

3.4 What is the Relationship between Force, Mass, and Acceleration?

a) Your instructor will demonstrate the force a fan exerts on a cart.

1) How many newtons of force does the fan exert at low speed? ____________

2) How many newtons of force does the fan exert at high speed? ___________

3) Observe the rate of change in velocity (the acceleration) of the cart as it moves along the track with its fan running at low speed.

4) How does the acceleration of the cart change when the fan runs at high speed?

The fan cart's velocity increases faster (it accelerates faster) when the fan runs at high speed.

5) Describe how the amount of force acting on an object is related to its acceleration.

The greater the amount of force, the greater the acceleration.

b) Next we increase the mass of the cart to illustrate the relationship between mass and acceleration.

1) Add one 0.5 kg mass to the cart and allow it to run along the track with the fan set at high speed. How does the cart's acceleration now compare to its acceleration with the fan set at high speed but without added mass?

The cart accelerates at a slower rate.

2) Add a second 0.5 kg mass to the cart. How does the acceleration now compare to its acceleration with only one 0.5 kg mass?

The amount of change in the cart's velocity of the cart is even less.

3) For a given amount of force, explain how the mass of an object is related to its acceleration.

The greater the mass of the moving object, the slower its acceleration.

c) The precise relationship between force, mass, and acceleration that you have observed is known as Newton's second law of motion, ***F = M a.***

Use Newton's second law to find the acceleration of a cart with a mass of 1.5 kg, which experiences a force of 5.0 newtons in the direction of the acceleration. (Ignore any frictional forces.)

$$F = M a; \quad a = \frac{F}{M} = \frac{5.0\ \text{N}}{1.5\ \text{kg}} = \frac{5.0\ \cancel{\text{kg}}\ \text{m/s}^2}{1.5\ \cancel{\text{kg}}} = 3.3\ \text{m/s}^2$$

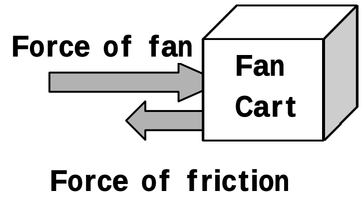
3.5 What Is Net Force?

a) Your instructor will demonstrate two carts with attached fans moving on two different tracks. Both carts start from rest and accelerate due to the applied force from the fan.

1) Does the first cart accelerate all the way along the track to the end of the track?
_Yes, its velocity continues to increase as it moves along the track.__

2) Draw an arrow on the diagram to indicate the direction of the force of friction opposing the force of the fan.

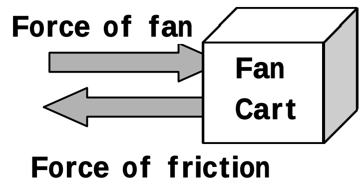
Is the force of friction larger, smaller, or the same as the force of the fan? _**smaller**_



3) Does the second cart accelerate all the way to the end of the track? _**No, the cart accelerates from rest to a constant velocity. It then moves along the track at that constant velocity.**_

4) Draw an arrow on the diagram to indicate the direction of the force of friction opposing the force of the fan.

When the cart is moving at a constant velocity, how do the amounts of these two forces compare? _**they are equal**_



5) When this cart is moving at a constant velocity, what is the amount of the net force acting on the cart? _**0**_

6) When this cart first started to move, was the net force acting on it zero or greater than zero? __ **greater than zero.**_

7) Considering the motion of the cart along the entire length of the track, is the force ***F*** in ***F = M a*** the force of the fan, the force of friction, or the combination of these forces (the net force)? __***F*** **is the net force**.__

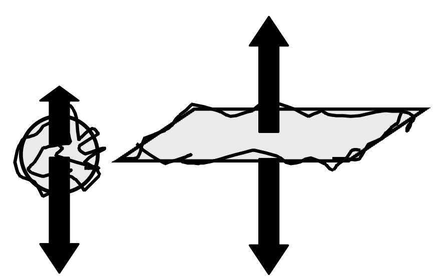
8) Explain how ***F = M a*** correctly describes what happens when the net force on the cart is zero. **When the net force, F, is zero, the cart is not accelerating, so the acceleration, *a*, also = 0.**

3.6 What Forces Act on a Falling Object?

a) Crumple a sheet of paper into a tight ball. Slightly crumple just the edges of a second sheet of paper. Drop both sheets from the same height and observe the rate of their fall. On which sheet of paper is the net force larger? _**The crumpled ball falls faster, so the net force on it is greater.**__

1) On the diagrams, arrows show the force of gravity acting down equally on each sheet of paper. What other force acts on each sheet of paper as it falls? _**the force of air resistance due to friction as the paper collides with air molecules**_

2) Draw arrows on each diagram to show the direction and relative size of this force.



b) A parachute is designed so that once the chute opens, the force of air resistance is equal to the force of gravity.

1) What is the net force on the parachutist after the chute has opened? __**0**__

2) From ***F = M a***, what can you conclude about the velocity of the parachutist after the chute has opened? __**Since the net force, *F*, = 0, the acceleration, *a* = 0. Therefore, the parachutist falls at a constant velocity.**_