Name _____ **Section** _____

Per 8 Activity Sheet: Work, Efficiency, and Complex Machines

8.1 How Much Work is Done by Machines? How Efficient Are They?

a) **Block and Tackle** Your instructor will use the block and tackle to lift blocks.

1) How much weight did the block and tackle lift? _____

2) How high off the floor were the cement blocks raised? _____

3) Find the work done on the blocks to raise them. This is the **work out**.

_____

4) How much force was needed to raise the blocks? _____

5) Through what distance was the rope pulled to lift them? _____

6) Find the work done when you pull the block and tackle rope. This is the **work in**.

_____

7) Calculate the efficiency of the block and tackle.

_____

b) **Winch** Try a "tug of war" game with the winch in the front of the classroom.

1) Suppose you move the handle of the winch in a circle a distance of 112 meters (distance in). When you do, the winch rope moves 2 meters (distance out).

If you exert a force of 280 newtons on the winch handle (force in), calculate how much work in must you do to move the winch handle a distance of 112 m.

_____

2) If the force out on the rope is 8,400 newtons, how much work out does the winch do as it pulls the rope a distance of 2 m?

_____

3) Calculate the efficiency of the winch.

_____

c) **Wheels and Axles** The plastic bottle illustrates a wheel and axle trading force for distance. The middle of the bottle represents the wheel and the neck of the bottle represents the axle. We will hang a weight from the wheel (the center of the bottle) to do work on a weight attached to the axle (the neck of the bottle).

1) Measure the circumference of the middle of the bottle. _____
   Take ½ of this length to find the **distance in.** _____
   (We use ½ of the length because the bottle can move only ½ turn.)

2) Measure the circumference of the neck of the bottle. _____
   Take ½ of this length to find the **distance out.** _____

3) Attach a 5 newton weight to the string around the neck of the bottle (the axle). This is the **force out.**

4) Calculate how much force must hang from the string around the middle of the bottle (the wheel) to balance the 5 N force hanging from the bottle neck. This is the **force in.**

   (Hint: Assume that the bottle is frictionless, so that W_{out} done on the weight to raise it equals W_{in}. Then use $F_{in} \times D_{in} = F_{out} \times D_{out}$)

   _____

5) Check your prediction. With the 5 N weight hanging from the bottle neck, hang weights totaling the force you found in part 4 from the middle of the bottle. If the work in equals the work out, the bottle should balance without rotating. Describe what happens when you attach the weights.

d) Group Discussion Question: If the bottle does not balance exactly, there may be another reason other than an error in your calculation of the force in. What could cause the work in to be not exactly equal to the work out in this system? Do you think the efficiency of this system is more than 1, equal to 1, or less than 1?

8.2 How Do Hydraulic Systems and Gears Work?

a) **Hydraulic Machines** The two connected syringes represent a hydraulic machine

1) Press the plunger of the small syringe in. Using a ruler, measure the **distance in** the small plunger moves _____ and the **distance out** the large plunger moves. _____

2) Calculate the theoretical mechanical advantage of the syringe set.

   _____

Name _____ **Section** _____

3) Suppose that a force in of 3 newtons is required to exert a force out on the large plunger of 12 newtons. Calculate the actual mechanical advantage of the syringe system.

_____

4) Calculate the efficiency of the syringe system.

_____

5) List several devices that operate on the same principle as the syringes.

b) **Gears**

1) Examine the gear toy. To make the edge of the outer gears turn the fastest, should the center gear be smaller or larger than the outer gear? Make a prediction and then experiment to check your guess.

Prediction: _____ **Answer:** _____

2) Find a combination of 3 or more gears that make the yellow "flipping eyes" gear flip at the fastest rate. (Use 2 or more gears plus the flipping eyes gear. Put the flipping eyes farthest from the center.)

3) Find a combination or 3 or more gears that make the flipping eyes gear flip at the slowest rate.

4) Draw a sketch of your gear setups showing which gears you used.

Eyes Flip Fastest **Eyes Flip Slowest**

8.3 What Are the Efficiency and Mechanical Advantage of Complex Machines?

a) Examine the toy on your table made from a Capsela set and list the simple machines you see.

b) If a hydraulic machine with a mechanical advantage of 5 and an efficiency of 60% is connected to a block and tackle with a mechanical advantage of 4 and an efficiency of 50%, what is the overall mechanical advantage of the complex machine?

_____

c) What is the overall efficiency of the hydraulic machine and the block and tackle combined?

_____

d) Is it possible to combine simple machines to form a complex machine with a greater overall mechanical advantage than its component machines? _____

e) Is it possible to combine simple machines to form a complex machine with a greater overall efficiency than its component machines? _____

Explain why or why not.