Name:

10.1 Machines and Mechanical Advantage

Question: How do simple machines work?

1 Setting up the experiment

Table 1: Input and output forces

Number of pulleys	Input force (N)	Output force (N)
1		

a. Compare the input and output forces using a single pulley. Is one larger than the other, or are they the same strength?

2 The block and tackle machine

Table 2: Input and output forces

Number of strings	Input force (N)	Output force (N)
1		
2		
3		
4		

3 Mechanical advantage

a. Use your data from Table 2 to calculate the mechanical advantage for each arrangement of the ropes and pulleys. Record your calculations in Table 3.

Table 3: Mechanical advantage

Number of pulleys	Output force (N)	Input force (N)	Mechanical advantage
1			
2			
3			
4			

b. What is the relationship between the mechanical advantage and the configuration of the block and tackle machine?

c. Explain in a few sentences why the mechanical advantage of a block and tackle machine should be what you proposed in (b). (This is a difficult question. HINT: The force in a string is the same anywhere in the string.)

d. Describe how friction affects the mechanical advantage of a machine like the block and tackle. Would friction increase the mechanical advantage, decrease it, or have no effect?

4 A mechanical advantage problem

a. Which pulley (the one on the left or the right) moves?

b. Which group could use the smaller force to move the opposing team?

Name:

10.2 Work

Question: What are the consequences of multiplying forces in a machine?

1 Doing the experiment

Table 1: Force and distance data

Mechanical advantage	Output force (N)	Output distance (m)	Input force (N)	Input distance (m)
	Both are the same for each trial			
1				
2				
3				
4				

2 Analyzing your data

a. As the mechanical advantage increases, what happens to the length of the string you have to pull to raise the hanger?

b. You may have heard the saying "Nothing is free." Explain why this is true of the ropes and pulleys. (HINT: What do you trade for using less input force to lift the lower pulley block?)

c. Write down a rule that describes the relationship between mechanical advantage and the input and output distances for the block and tackle machine.

3 What is work?

There are no questions to answer in Part 3.

4 Calculating work

Table 2: Output and input work

Mechanical advantage	Output work (joules)	Input work (joules)
1		
2		
3		
4		

a. For each mechanical advantage, how do output and input work compare?

b. Is output work ever greater than input work? Can you explain this?

c. Explain any differences between input and output work in your data.

5 The relationship between work and energy

There are no questions to answer in Part 5.

Name:

10.3 Energy and Conservation of Energy

Question: How is motion on a track related to energy?

1 The energy of the ball

a. Write down equations for the potential and kinetic energy of the ball. (note, the ball *rolls*)

b. Where is the kinetic energy largest? Where is it smallest?

c. Where is the potential energy largest and smallest?

2 Measuring the speed of the ball

Table 1: Height, time, speed and energy data

Position (cm)	Height (m)	Time through photogate (sec)	Speed (cm/s)	Potential Energy (J)	Kinetic Energy (J)	Total Energy (J)
5						

3 Graphing the data

a. Use your measurements to make a graph showing the relationship between speed and height. Plot the position of the photogate on the track on the *x*-axis. Plot both the speed and the height on the *y*-axis. You should have two separate lines on your graph. Use two different colors or types of lines (dotted and solid) to connect each set of points.

Title: ______________________________

y label: ______________________________

x label: ______________________________

b. Plot a similar graph showing the potential energy, kinetic energy, and total energy on the y-axis and the position on the x-axis.

Title: ____

y label: ____________________

x label: ______________________________

4 Analyzing the data

a. What can you tell from your first graph? Describe the relationship between the speed of the ball and the height. Where is the speed of the ball the greatest? Where is it the least? Does this agree with your hypothesis?

____

____

____

____

____

b. Does the uphill or downhill direction of the ball affect its speed, or is height the only important factor?

____

____

____

c. What can you say about the energy graph? Where is the potential energy largest and smallest? Where is the kinetic energy largest and smallest? How are the potential and kinetic energy related to the total energy?

5 Conservation of energy

a. Right before the ball is released at the top of the hill, which type of energy does it have? What is the total energy of the ball?

b. What happens to the ball's kinetic energy as it moves down the hill? What happens to its potential energy?

c. Use the law of conservation of energy to derive a formula that relates the speed of the ball to its height (h) and the initial height (h_0) from which it was released.

d. According to the equation you derived in part (c) above, what is the effect of mass on the speed of the ball? Measure the speed of the steel and plastic balls at the same position to test this hypothesis.

Name:

11.1 Efficiency

Question: How efficient is the straight track?

1 Setting up the straight track

There are no questions to answer in Part 1.

2 Collecting data

Table 1: Time, height, and mass data for plastic ball

Trial	Time through photogate (sec)	Initial height (m)	Final height (m)	Mass of ball (kg)
1				
2				
3				
Average				

Table 2: Time, height, and mass data for steel ball

Trial	Time through photogate (sec)	Initial height (m)	Final height (m)	Mass of ball (kg)
1				
2				
3				
Average				

3 Potential and kinetic energy

Table 3: Potential and kinetic energy

Type of ball	Location on track	Speed (m/sec)	Kinetic energy (J)	Potential energy (J)	Total energy (J)
plastic	top				
	bottom				
steel	top				
	bottom				

4 Efficiency

a. Compare the total energy of each ball at the top of the track to its total energy at the bottom. Did each ball's total energy increase, decrease, or remain unchanged?

b. Calculate the efficiency for each ball.

c. Compare the two efficiencies. Why might they be slightly different?

d. The law of conservation of energy states that energy cannot be created or destroyed. If the efficiencies were less than 100 percent, does this mean the law of conservation of energy is not true? Was energy lost? Where did the energy go? Write a short paragraph explaining your answer. (HINT: The motion of the ball includes rotation as well as linear motion.)

e. CHALLENGE! If the efficiency for the steel ball were 100 percent, how fast would it be moving at the bottom of the track?

Extra space for notes and performing calculations:

Name:

11.2 Energy and Power

Question: How powerful are you?

1 Lifting power

Table 1: Lifting data

Name	Weight (N)	Distance (m)	Time (sec)	Work (J)	Power (W)
		1.5			

2 Comparing the data

a. Why is the object's weight used in the calculation of work done?

b. How did the amount of work done by each person compare? Why?

c. What determined the power of each person? Explain.

d. A typical light bulb has a power of 75 watts. How does this compare to your power output while lifting the object?

e. Discuss two ways you could increase the amount of work you do in this activity.

f. Discuss two ways you could increase your power output in this activity.

3 Stair-climbing work and power

Table 2: Stair-climbing data

Name	Weight (N)	Vertical distance (m)	Time (sec)			Avg. time (sec)	Work (J)	Power (W)

4 What did you learn?

a. How did the work done by the different people compare? In the first part of the Investigation, every group member did the same amount of work. Why was this not the case with the stairs?

b. Which person had the greatest power? Which two factors determined each person's power?

c. Calculate the average work done and the average power for all of the stair climbers.

d. How do the average amounts of work and power for the stair climbing compare with your own work and power when lifting the object in the first part of the Investigation?

e. The human body is able to do work because energy is absorbed when we eat food. In physics, we usually measure work and energy in joules but food energy is usually measured in Calories. One Calorie is equal to 4,186 joules. Select one of the people who climbed the stairs and calculate the work done in Calories. These Calories come from food that is "burned" by the person's body. You may be surprised by how small the number is.

f. Imagine that two people having equal weights climb the same flight of stairs. One runs and the other walks. Do they do the same number of Calories of work (in the physics sense)? Do they have the same power output? Explain.

Extra space for notes and performing calculations:

Name:

11.3 Energy Flow in Systems

Question: Where did the energy go?

1 An energy flow diagram

There are no questions to answer in Part 1.

2 Drawing energy flow diagrams

Draw an energy flow diagram for each scenario described below. Your diagram must have enough detail to show at least three forms that energy takes. A short description (a few words) should accompany each different form of energy on your diagram. You may make your diagram as complex as you wish by including more forms of energy.

a. A car drives down a hill and then up and over the top of another hill.

b. A seagull in flight swoops down and snatches a fish to eat out of the water.

c. A calculator operates from a solar cell.

d. A camper uses a wood fire to heat up a pot of water for tea. The pot has a whistle that lets him know when the water boils.

e. A bicyclist rides at night, switching on her bike's generator so that the headlight comes on. The harder she pedals, the brighter the headlight glows.

Name:

12.1 Momentum

Question: What are some useful properties of momentum?

1 Conservation of momentum and energy

There are no questions to answer in Part 1.

2 Making a collision

There are no questions to answer in Part 2.

3 Observing and analyzing the collision

a. Describe the motion of the projectile ball before and after the collision.

b. Describe the motion of the target ball before and after the collision.

4 The discovery of the nucleus of the atom

There are no questions to answer in Part 4.

5 An experiment in momentum conservation

There are no questions to answer in Part 5.

6 Collecting the data

Table 1: Time and speed data

Projectile before collision		Projectile after collision		Target after collision	
Time (t_0)	Speed (v_0)	Time (t_p)	Speed (v_p)	Time (t_t)	Speed (v_t)

7 Analyzing the data

a. Calculate the speeds of the projectile and target balls before and after the collision. Enter the results in Table 1.

b. Write down the law of momentum conservation for the two balls using the variables in the diagram.

c. Solve the momentum conservation equation for the mass of the target ball. Your answer should be a formula of the form m_t = ??? where the right-hand side of the equation includes only the mass of the projectile ball and the speeds before and after the collision.

d. Calculate the mass of the target ball from the formula you derived in Part c. Measure the actual mass of the target ball. How close did your estimate come?

e. Give at least one reason the predicted mass and measured mass may be different and cause the deviation you observed.

Name:

12.2 Force is the Rate of Change of Momentum

Question: How are force and momentum related?

1 Force, momentum, and the second law

a. Which collision creates the greater change in momentum? Remember, you need to consider the sign of the velocity before and after the collision when you calculate the change in momentum.

2 Observing elastic and inelastic collisions

There are no questions to answer in Part 2.

3 Reflecting on what you observed

a. Compare the velocities of the rubber ball and the clay ball just before they collided with the wood block. Are the velocities different or are they the same?

b. Compare the momentum of the rubber ball and the clay ball just before they collided with the block. Does the rubber ball have more, less, or about the same momentum as the clay ball?

c. Did the clay ball knock over the block? Explain the observations using the fact that force is equal to be rate of change of momentum. Which ball experienced a greater change in momentum during the collision with the wood block?

Extra space for notes and performing calculations:

Name:

12.3 Angular Momentum

Question: How does the first law apply to rotational motion?

1 Thinking about angular momentum

a. List three variables that determine the angular momentum of the rotating mass on a string.

b. Discuss with your group what would happen if the radius of the circle were suddenly made smaller. Assume that the mass stays constant. How can the angular momentum stay the same when the radius decreases? Write a hypothesis describing what you believe will happen in an experiment where you are observing a mass revolving at the end of a string and the string is shortened during the motion.

2 Setting up the experiment

There are no questions to answer in Part 2.

3 Observing the conservation of angular momentum

There are no questions to answer in Part 3.

4 Reflecting on what you observed

a. Explain how the conservation of angular momentum and the concept of moment of inertia apply to explain your observations from Part 3.

b. In many diving competitions, the diver jumps from the board or platform, turns one or two complete somersaults, and straightens out to land in the water with arms and head straight down and feet straight up in the air. While completing the somersault, the diver's body is tucked in tightly. Before entering the water, the diver's body extends to straighten out. Use the conservation of angular momentum to explain how a diver can spin rapidly in a somersault and then reduce rotational speed to enter the water vertically.

c. Angular momentum behaves like a vector. Unlike the linear momentum vector however, the angular momentum vector does *not* point in the direction of an object's velocity. Instead, the angular momentum vector points along the axis of rotation. You can use your right hand to determine its direction. When the fingers of your right hand curl in the direction of rotation, your thumb points in the direction of the angular momentum vector. The law of conservation of angular momentum applies to the *direction* of the angular momentum vector as well as its magnitude.

It takes torque to change the direction of the angular momentum vector. The inverse is also true. If the direction of the angular momentum vector changes, reaction torques act back on the rotating object to resist the change. For example, it is harder to balance a bicycle that is standing still than a bicycle that is rolling. Use the conservation of angular momentum to explain why this is true.