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LAB 20. WORK AND ENERGY

Supplies

Ramps: dynamics cart, auxiliary mass, hinged track, clamp stand, string, pulley, 50-g, 100-g, and 200-g hook masses

Levers: lever support, meter stick, meter stick sleeve clamps, hook, spring force meter, weights, clamp stand

Rollerball: ramp, small balls, stopwatch (or cellphone app), elevating blocks, drag meters made from halved cups and auxiliary weights, meter stick, tape measure, balance

Investigation 1: Ramp

How difficult is it to pull something uphill?

A string running over the pulley at the end of the ramp connects a mass hanger to a dynamics cart. For a given hanging mass (less than the cart mass), find the height of the ramp that keeps the cart and hanging weight from accelerating either up or down.

1. Measure and record the mass of the cart. Mass M = ______________________.
2. Measure the distance from the beginning of the ramp to the support rod. Distance D = _____________.
3. Mark the point on the side wall of the ramp directly underneath the support rod.
4. Place the needed mass (50 g, 100 g, 150 g, 200 g, 250 g, or 300 g) on the hanger. Run the string over the pulley at the end of the ramp.
5. Adjust the height of the rod supporting the ramp so that the cart rolls neither up nor down. Tighten the rod clamp to lock the ramp into place.
6. Measure the height h of the point marked on the side wall of the ramp above the table. Record the value.
7. Complete steps 4–6 for each hanging mass.

Ramp Data Table

Hanging mass m (g)	Height h	hM	Dm
50			
100			
150			
200			
250			
300			

Investigation 2: Levers

What factors determine the output force of a lever?

A **simple machine** is a device that transforms an input force to a different output force. Your task is to find out how you can predict the output force (basically, that is how hard the machine can pull). There are different categories of **levers**, but all attach a load and an input force to different places on a rigid, hinged bar. In this activity your lever is a meter stick fitted with clamps that allow pulls at specific locations.

Balancing

1. Support the meter stick from the stand exactly in the center (50 cm). If necessary, adjust slightly so that the meter stick is level when resting.
2. Hang one weight on one side of the fulcrum and the other weight on the other side of the fulcrum so that the bar balances exactly.
3. Record the masses (m_1 and m_2) and positions (x_1 and x_2) of the two weights in the table. Include the masses of the sleeve clamps.
4. Repeat with three different balancing positions of the two weights.
5. Repeat with three different pairs of hanging weights.

Lever Data Table 1

Position of fulcrum: _____________

m_1	m_2	x_1	x_2	r_1	r_2	m_1r_1	m_2r_2

6. Convert the positions x_1 and x_2 of the hanging weights to positions relative to the fulcrum r_1 and r_2. Use the formula $r = x – h$, where h is the position of the fulcrum. Enter these values in the next two columns of the table.
7. Compute the products m_1r_1 and m_2r_2. Enter these in the final two columns of the table.

Lifting

In this activity, you will explore how the weight of an object depends on its distance from the fulcrum. The force meter that you will use measures the tension on the hook from the extension of the spring. It works best when the meter hangs from a rigid support; it is unstable when held in the hand.

1. Support the meter stick from the stand near one end. Position two sleeve clamps on the bar: one, closer to the fulcrum, with its wire loop hanging below the bar; and the other, farther from the fulcrum, with its wire loop above the bar.
2. Record the mass of the hanging mass m.
3. Hang the force meter from a stand, and hang the mass from the force meter. Record the reading on the force meter F_1. This is weight of the mass. Remove the mass from the hook.
4. Hook the force meter to the clamp farthest from the fulcrum. Hang the force meter so that it levels the bar. Record the position of the force meter x_2 and the tension F_0 on the force meter from the meter stick alone.
5. Hang the mass from the clamp closest to the fulcrum. Level the bar by adjusting the height of the force meter. Record the position of the hanging mass x_1 and the reading on the force meter F_h.
6. Re-position the hanging mass (x_1). Again level the bar by lifting it with the force meter. Record the reading on the force meter in the table.

Lever Data Table 2

Position of fulcrum: ________

m	F_0	F_1	F_h	x_1	x_2	F_2	r_1	r_2	F_1r_1	F_2r_2

7. Repeat steps 4–6 with another position of the force meter (x_2).
8. Repeat steps 2–7 with two more hanging masses (m).
9. Calculate r_1 and r_2, the distances of the two clamps from the fulcrum. Also calculate F_2, the load on the force meter due to the hanging mass: $F_2 = F_h - F_0$. Enter the results in the table.
10. Calculate the products F_1r_1 and F_2r_2. Enter in the table.

Investigation 3: Rollerball

What determines how far a rolling ball can drag a frictional load?

Here you will determine the factors that influence two outcomes: (1) how far a rolling ball can carry a "drag meter", and (2) how fast the ball rolls. You will also look for a relationship between the speed of the ball and the drag distance. Factors that you should consider are mass and composition of the ball and the height of the incline accelerating the ball.

You may need to calibrate your drag meters against each other: no single drag meter is likely to be able to do a good job measuring all the conditions you are likely to explore. Find several ball-launch conditions that drag at least two of the drag meters distances that are reproducible and easily measured. Try to find a consistent relationship between drag lengths of the different meters from the same starting conditions. Continue this process until you can confidently compare measurements from the different meters.

To achieve the best control over and knowledge of the experimental variables, you will accelerate all balls by rolling them down inclined rails. Always record settings such as rail slope and ball release height.

The easiest way to measure the speed of a rolling ball is to time how long it takes to roll a known level distance. The speed is the distance divided by the time interval.

Questions to consider

- How do the spring meters measure force?
- What were the conditions making the levers balance?
- Why did you calculate mr or Fr for the levers?
- How did your group determine which factors affected rollerball drag length?
- What determines how far a ball drags a drag meter?
- What determines the speed of a ball leaving a ramp?
- What is the relationship between the speed of a ball and how far it drags a meter?

Getting Credit

Show this completed worksheet to your instructor for check-off. Also show your data sheet from Investigation 3. Answer the questions your instructor asks.