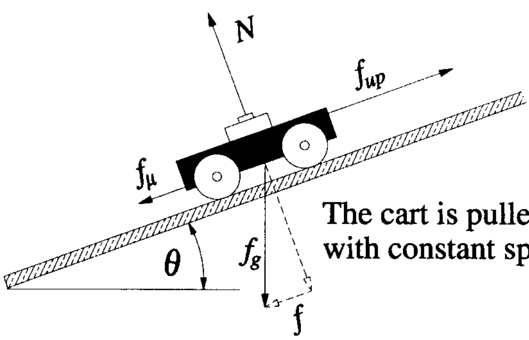
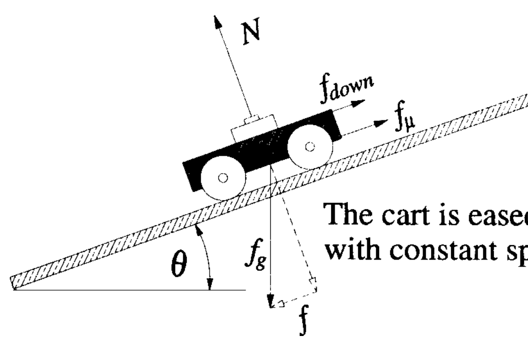
Name **Section #**

Work & Simple Machines—The Inclined Plane

Purpose

We use machines such as the screw, the pulley, and the inclined plane to do work in lifting heavy loads because of our inability to exert sufficiently large forces. What is surprising is that we have to do more work with the machine than without it—a consequence of friction. You will determine whether the law of *Conservation of Energy* accounts for the difference between W_i the work input, or the work you have to do using the machine, and W_o the work output, or the useful work accomplished by the machine. The ratio of the *work output* to the *work input* describes the machine's *efficiency.* You will measure the efficiency of a ramp when it is inclined at angles $\theta = 5, 10, 15,$ and 20 degrees.





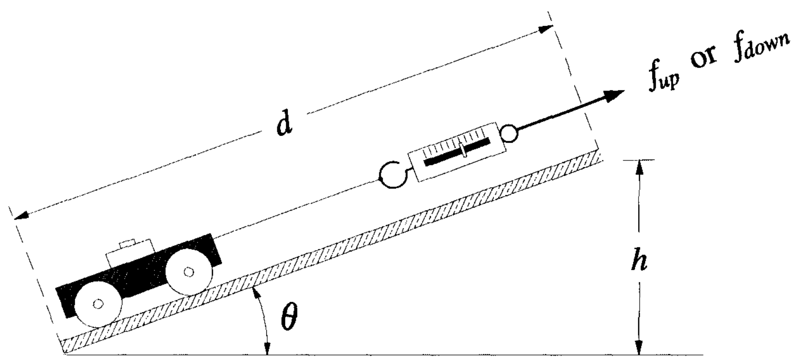
Theory

Energy conservation requires that when we displace a load an amount d, the *Work input* = *Work output* + *Work against friction* or, $W_i = W_o + W_\mu$ where $W_i = f_{up} d$, $W_o = f_g h$, and $W_\mu = f_\mu d$. f_{up} is the force you must apply, parallel to the incline, in order to move the load up the ramp with constant speed. f_g is the load's weight. The height h to which the load is lifted is $h = d \sin\theta$. To determine the frictional force f_μ between the ramp and the load, we introduce a new force f_{down} which is the force you must apply, parallel to the incline, in order to allow load to move slowly down the ramp at constant speed. Under these conditions, the frictional force is: $f_\mu = \dfrac{f_{up} - f_{down}}{2}$.

This last assertion can be proven as follows: Let f represent the component of the weight f_g, parallel to the incline, needed to move the load up or down the ramp in the absence of friction. Then since f_μ is in the direction opposite of the load's motion, $f_{up} = f + f_\mu$, and $f_{down} = f - f_\mu$ From which, $f_{up} - f_{down} = (f + f_\mu) - (f - f_\mu) = 2 f_\mu$.

The efficiency e of your ramp at a particular angle of inclination is given by $e = \left(\dfrac{W_o}{W_i} \right) 100\%$.

To determine whether energy is conserved, you will compare your experimental value for W_μ, the work against friction with the value you expected to obtain by applying conservation of energy, namely: the experimental value is $W_\mu = f_\mu d$ while the expected value should be $W_\mu^* = W_i - W_o = f_{up} d - f_g h$. Then calculate the percent difference between them as follows: $\% \ difference = \left(1 - \frac{W_\mu^*}{W_\mu}\right) 100\%$



Procedure

Set up the inclined plane so that it makes an angle of 5 degrees with the horizontal. Weigh a cart with a 1 kilogram mass and record it in the table below as f_g. This will be your load. Move this load slowly up the incline by pulling it with the spring scale for a measured distance d of 25 cm. Make sure that the string connecting the load with the scale is always parallel with the incline and the load is moving slowly with constant speed. Have someone in your group look down from above the stand and someone else look at the side to help you keep the string parallel to and directed up the incline. The product of your spring scale reading f_{up} and the displacement d is the work input W_i. Allow the load to move down the incline with constant speed by pulling the load with the scale, oriented parallel to the plane. The spring scale reading, in this case, is f_{down}. You will probably find that there is only a small difference between your readings of f_{up} and f_{down}. For this reason try to make your readings accurate to the nearest $\frac{1}{10}$ of a newton. Enter your data and calculations in the following tables. Repeat this procedure for incline orientations of 10°, 15°, and 20°.

Displacement along the incline, $d = 0.25$ m; Load weight, f_g =										
θ	h (m)	f_{up} (N)	f_{down} (N)	f_μ (N)	W_i (J)	W_o (J)	W_μ (J)	W_μ^* (J)	% Difference	e
5°										
10°										
15°										
20°										

Questions

1. Does *conservation of energy* account for the difference between the work input and the work output? Use your data to justify your answer.

2. Your data should show that the efficiency of your ramp as a simple machine increased as its angle of inclination with the horizontal was increased. What do you think is responsible for this increase in efficiency with increasing angle?

3. Discuss possible sources of error in the experiment which might have caused a difference between the measured and expected values for the work done by friction.

4. The ideal mechanical advantage of an inclined plane is found from the ratio of its length to its height. The real or actual mechanical advantage of an inclined plane is found from the ratio of the load's weight to the actual force needed to pull it up the incline, that is, $\frac{f_g}{f_{up}}$. Compute the ideal and actual mechanical advantages for each trial. What happens to the difference between the ideal and real mechanical advantages as the angle of the incline increases? Try to account for any trend that you discover.

θ	Ideal Mechanical Advantage	Actual Mechanical Advantage	Percent Difference
5°			
10°			
15°			
20°			