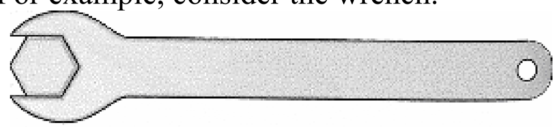
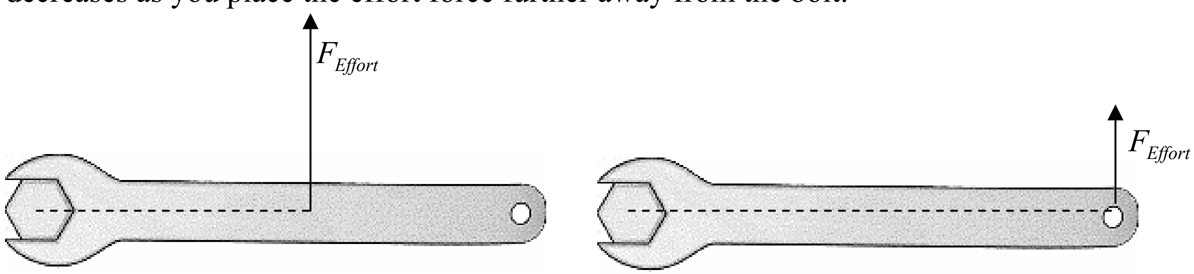
Theory: A simple machine is a device that enables one to perform some task with greater ease. We use simple machines everyday; door handles, ramps, stairs, wheels and axles are all examples of simple machines. These devices give us **mechanical advantage**. Mechanical advantage allows one to perform the same task with less effort. For example, consider the wrench.



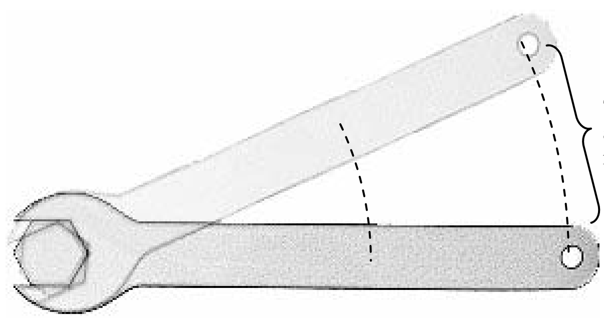
The longer the wrench, the less effort required. On the surface, it would appear that using a longer wrench is less "work". From a physics perspective, this is not true. No matter how long the wrench is, the amount of work required to turn the bolt will be the same. Consider the following formula defining work:

$$W = F\Delta d$$

by analysis of the formula, a **decrease** in **force** would have to be matched with an **increase** in the **distance** in which the force is applied. Let's look at the wrench again. The effort required to turn the bolt decreases as you place the effort force further away from the bolt.

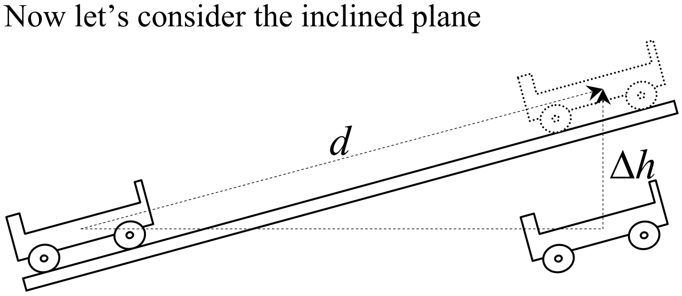


However, the **distance** that the **effort force** works through **increases** the further away from the bolt the effort is applied.



Therefore if the **effort force** is reduced by half, the **effort distance** has to double.

Now let's consider the inclined plane



The amount of energy required to raise the cart can be found in two ways.

Raising the cart straight up

$W_{up} = \Delta E_g = mg\Delta h$

Moving the cart along the plane

$W_{plane} = F \cdot d$

According to the **law of conservation of energy**, the total energy within a closed system is **constant**. Ideally, this means that since we can move the cart to the same height two different ways, the **amount of**

energy required to do this job is the **same**. (Of course this excludes the energy-robbing force of friction which will be considered later. It does play as a factor)

Based on this premise of **equal energy** for **equal work**, we can equate our two work equations for the plane.

$$W_{plane} = W_{up}$$
$$F \cdot d = mg\Delta h$$
$$F = \frac{mg\Delta h}{d}$$
$$\boxed{F_E = \frac{m_c g\Delta h}{d_E}}$$

Where F_E is the **ideal effort force**, m_c is the mass **of the cart** in kg, Δh is the height increase in m and d_E is the distance the cart travels along the plane. The longer the incline (d_E), the lower the effort force that is required.

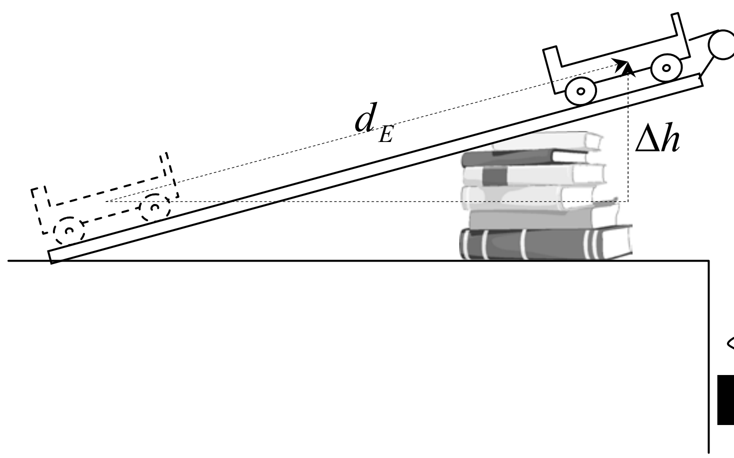
Efficiency: No machine is 100% efficient, the laws of thermodynamics state that every machine loses a portion of input energy to mechanical losses. These can be in the form of sound, vibration, light and heat. The efficiency of this type of simple machine can be found by the following formula

$$\%\,Efficiency = \frac{m_c g\Delta h}{F_E \cdot d_E}$$

Where F_E is the **ACTUAL effort force,** d_E is the distance along the ramp the load moves, m_c is the mass of the cart, g is the acceleration due to gravity ($9.8m/s^2$), Δh is the change in height of the load.

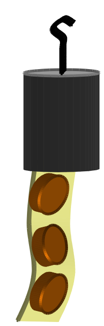
Apparatus:

- 1 dynamics cart
- several masses
- several pennies or small change
- 1 inclined plane
- 1.5m of string
- 1 balance scale
- 1 electronic scale
- 1 pulley
- Several old text books
- Masking tape



Procedure:

1. Setup the inclined plane as illustrated in the above diagram
2. Determine the mass of the carts using the balance scale as demonstrated by your teacher
3. Firmly attach the string to the dynamics cart. At the other end create a loop to attach the mass.
4. Place the empty dynamics cart at the bottom of the inclined plane and carefully draw the string over the pulley.
5. Carefully load masses to the string until the cart begins to move up the plane at a constant velocity. You may have to use masking tape and pennies for fine tuning your hanging mass in order to achieve constant velocity.



6. Record the total mass of the hanging masses (m_h). Use the electronic scale to record the mass of any pennies that you may have used (include the tape). This mass will be used to determine your effort force (F_E). Note: the effort force that is pulling the cart up the ramp is equal to the **weight** of the hanging mass. $F_E = m_h g$

7. Allow the cart to move to the top of the inclined plane, carefully record the height change (Δh) of the cart and the distance the cart travelled along the plane (d_E)

8. Repeat steps 1-7 but with an additional 1kg place on the dynamics cart.

9. Repeat steps 1-8 but at a different angle of incline

Observations and Analysis

Record your data using the following chart

Trial	dynamics cart m_c (kg)	hanging mass m_h (kg)	Actual effort force F_E (N)	Δh (m)	d_E (m)
1					
2					
3					
4					

1) For each trial calculate the change in gravitation potential energy of the cart as it moves up the plane.

2) For each trial calculate the work done by the actual effort force as it moves up the plane.

3) Compare the result from questions 1) and 2) for each trial. Should they be equal? If they are not, which one is larger? Account for the differences in the two values.

4) For each trial, calculate the ideal effort force and determine the efficiency of our ramp system. Does the efficiency change depending on the angle and/or the mass of the load? Account for the variations in efficiency if any.

5) Explain why there is a difference between the **actual effort force** and the **ideal effort force**.