

The Inclined Plane

The purpose of this activity was to evaluate the relationship between the work input and the work output of an inclined plane at various heights. The inclined plane was made using a 1.47m board, with a stationary pulley at one end, leaned on the ring of a ring stand on a table. The height of the inclined plane was measured from the tabletop to the bottom of the end of the board above the ring. [See Figure 1.]

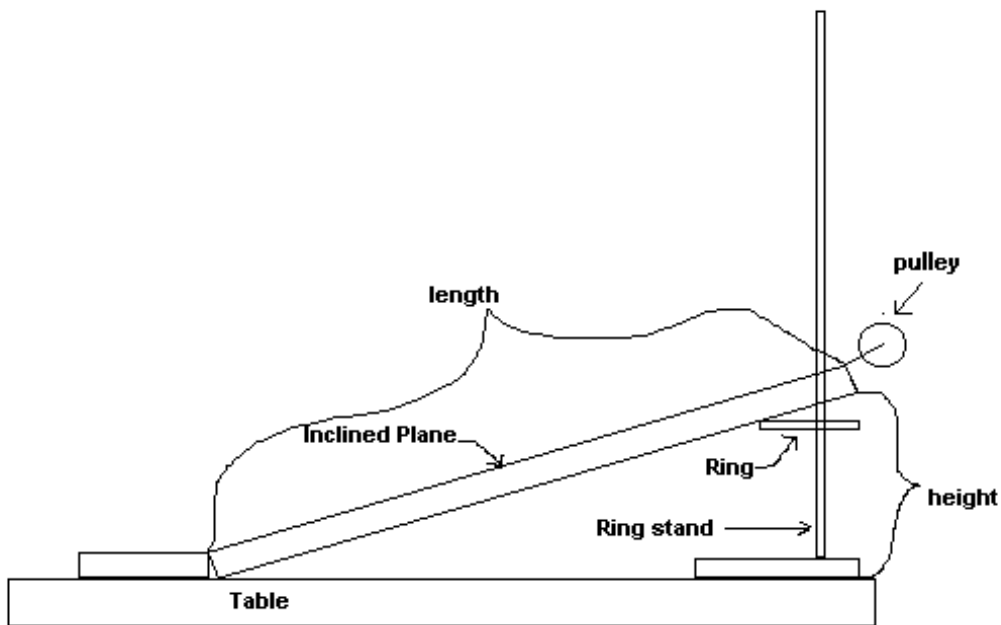


Figure 1. Inclined plane apparatus

The height of the inclined plane was set at 10.0cm and a cord was attached to an octagonal object with a mass of 1000.0g. The cord was threaded onto the pulley and the other end of the cord was attached to a spring scale. The end of the cord with the spring scale was pulled to move the object up the inclined plane. The force used to move the object was recorded from the spring scale. This was

repeated for an inclined plane height of 20.0cm, 30.0cm and 40.0cm. Table 1 shows the measurements that were taken during this activity.

Table 1: Measured values

Height (cm)	Mass (g)	Length (m)	Force (N)
10.0	1000.0	1.47	2.0
20.0	1000.0	1.47	3.0
30.0	1000.0	1.47	4.0
40.0	1000.0	1.47	5.0

The two distance measurements, the height of the inclined plane and the length of the inclined plane, represent resistance distance (d_R) and effort distance (d_E) respectively. The force measurement from the spring scale represents the effort force (F_E) and the mass of the object converted to Newtons represents the resistance force (F_R). The general formula for work is $W = F \cdot d$, where W is work in Joules, F is the force in Newtons and d is the distance in meters. Work output (W_O) is the amount of work that is done by the simple machine to lift an object a certain distance. The formula is $W_O = F_R \cdot d_R$. The resistance force is the mass of the object times the acceleration due to gravity. The resistance distance is the height of the inclined plane. Work input (W_I) is the amount of work done by a person to move an object a certain distance. The formula is $W_I = F_E \cdot d_E$. The effort force is the strength of the push or pull measured by the spring scale. The effort distance is the length of the inclined plane. The calculation section shows how to convert the height of the inclined plane from centimeters to meters (1.1), convert the mass of the object to a force in Newtons (1.2), calculate work output (1.3), work input (1.4) and efficiency(1.5).

Calculations:

$$10\text{cm} \left(\frac{1\text{m}}{100\text{cm}} \right) = 0.10\text{m} \quad (1.1)$$

$$1000.0\text{g} \left(\frac{1\text{kg}}{1000\text{g}} \right) \left(\frac{9.8\text{N}}{1\text{kg}} \right) = 9.8\text{N} \quad (1.2)$$

$$\begin{aligned} W_O &= F_R \cdot d_R \\ W_O &= 9.8\text{N} \cdot 0.10\text{m} \\ W_O &= 0.98\text{J} \end{aligned} \quad (1.3)$$

$$\begin{aligned} W_I &= F_E \cdot d_E \\ W_I &= 2.0\text{N} \cdot 1.47\text{m} \\ W_I &= 2.94\text{J} \end{aligned} \quad (1.4)$$

$$\begin{aligned} \text{Efficiency} &= \left(\frac{W_O}{W_I} \right) 100 \\ \text{Efficiency} &= \left(\frac{0.98\text{J}}{2.94\text{J}} \right) 100 \\ \text{Efficiency} &= 33\% \end{aligned} \quad (1.5)$$

Table 2 shows the measurements converted to the correct units and the calculated values for work input and work output.

Table 2: Calculated values

$d_R(\text{m})$	$F_R(\text{N})$	$d_E(\text{m})$	$F_E(\text{N})$	$W_O(\text{J})$	$W_I(\text{J})$	Efficiency (%)
0.1	9.8	1.47	2	0.98	2.94	33
0.2	9.8	1.47	3	1.96	4.41	44
0.3	9.8	1.47	4	2.94	5.88	50
0.4	9.8	1.47	5	3.92	7.35	53

To illustrate the relationship between work output and work input, the two quantities were graphed. Work output depends on work input, so these are the dependent and independent variables respectively. The graph is shown in Figure 2. The slope of the line is found by using the relationship $m = \frac{\Delta y}{\Delta x}$. Since

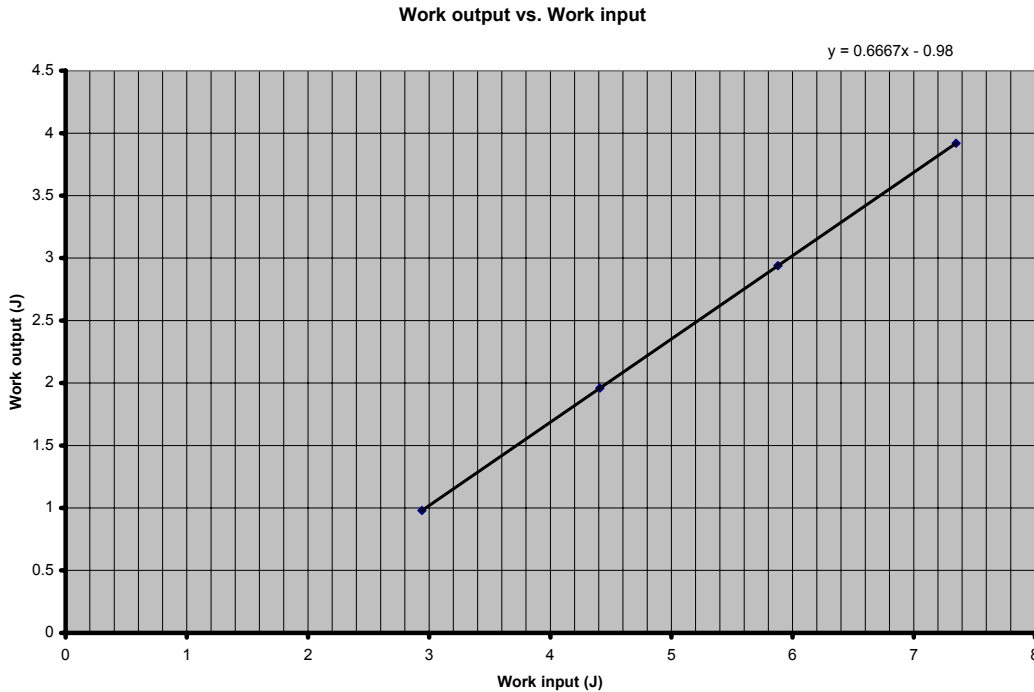


Figure 2: Work output vs. work input

the work output is the quantity on the y-axis and the work input is the quantity on the x-axis, the slope of the line can be expressed as $m = \frac{W_O}{W_I}$. There is no unit for the slope since both W_O and W_I are in Joules. The slope of the line actually represents the efficiency of the inclined plane. The graph gives a straight line, which would indicate that the efficiency of the inclined plane is constant. The calculations show that, efficiency increases as the height of the inclined plane increases. The slope of a straight line does not change, so if the graph is true, the efficiency of the inclined plane is not affected by the height of the inclined plane. The data that was collected may have error in it either from flaws in the

apparatus or from human error in reading the measuring instruments. Since the graph of the values and the calculations for the values do not agree, more testing is required before a valid conclusion can be reached.