6 – Efficiency

Efficiency is a measure of how much...of the energy that goes into a machine actually gets used.

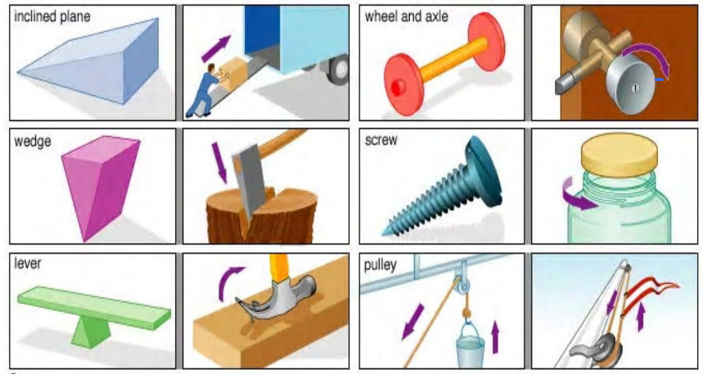
Machines are useful because they allow us to use less force over a longer distance to do the same work.

The 2nd Law of Thermodynamics states that whenever work is done, some energy is converted to heat.

Therefore: $W_{in} > W_{out}$

Work in: total energy supplied to a machine

Work out: amount of energy actually used



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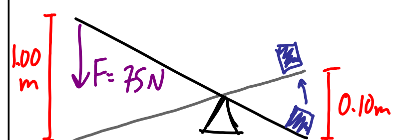
The Efficiency of a machine is:

$$Eff = \frac{W_{out}}{W_{in}} \times 100\%$$

$$Eff = \frac{P_{out}}{P_{in}} \times 100\%$$

There are no units for efficiency, it is expressed as... a ratio or a percentage.

Ex: A lever is used to lift a 50.0 kg object 10.0 cm. To do this we must apply a force of 75 N to the end of the lever which displaces 1.00 m. Find the efficiency of the lever.



$W_{in} = Fd = (75\,N)(1.00\,m) = 75\,J$

$W_{out} = \Delta E = mg\Delta h = (50.0\,kg)(9.8\,N/kg)(0.10\,m) = 49\,J$

$Eff = \frac{W_{out}}{W_{in}} \times 100\% = \frac{49\,J}{75\,J} \times 100\% = 65\%$

Worksheet 7.7: Efficiency

1) A 5.00 x 10^2 W electric motor lifts a 20.0 kg object 5.00 m in 3.50 s. What is the efficiency of the motor?

$P_{in} = 5.00 \times 10^2\,W$

$P_{out} = \frac{\Delta E_p}{t} = \frac{mg\Delta h}{t} = \frac{(20.0\,kg)(9.8\,N/kg)(5.00\,m)}{3.50\,s} = 280\,W$

$Eff = \frac{P_{out}}{P_{in}} \times 100\% = \frac{280\,W}{500\,W} \times 100\% = 56\%$

2) If a 1.00 x 10^2 W motor has an efficiency of 82%, how long will it take to lift a 50.0 kg object to a height of 8.00 m?

$P_{in} = 100\,W$

$P_{out} = ?$

$Eff = \frac{P_{out}}{P_{in}} \times 100\%$

$P_{out} = \frac{Eff}{100\%} \times P_{in} = 82\,W$

$P_{out} = \frac{\Delta E_p}{t}$ $\quad t = \frac{\Delta E_p}{P_{out}} = \frac{mg\Delta h}{P_{out}} = \frac{(50.0\,kg)(9.8\,N/kg)(8.00\,m)}{82\,W} = 48\,s$

3) A 955.0 kg car is accelerates uniformly from rest to 16.0 m/s while moving 18.0 m across a level surface. If the car uses 125 000 W of power, what is the efficiency of the car?

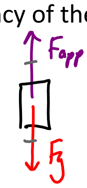
$P_{in} = 125\,000\,W$

$P_{out} = \frac{\Delta E_k}{t} = \frac{\frac{1}{2}m\Delta v^2}{t} = \frac{\frac{1}{2}(955.0\,kg)(16.0\,m/s)^2}{2.25\,s} = 54328\,W$

To find t: $a = \frac{v^2 - v_o^2}{2d} = 7.111\,m/s^2$ $\quad t = \frac{v - v_o}{a} = 2.25\,s$

$Eff = \frac{P_{out}}{P_{in}} \times 100\% = \frac{54\,328\,W}{125\,000\,W} = 43.5\%$

An 8.5 x 10^2 kg elevator is pulled up at a constant velocity of 1.00 m/s by a 10.0 kW motor. Calculate the efficiency of the motor.



$F_{app} = F_g = mg = (850\,kg)(9.8\,N/kg) = 8330\,N$

$P_{out} = Fv = (8330\,N)(1.00\,m/s) = 8330\,W$

$Eff = \frac{P_{out}}{P_{in}} \times 100\% = \frac{8330\,W}{10\,000\,W} \times 100\% = 83\%$

1) 56% 2) 48 s 3) 43% 4) 83%