4.8 Power and Efficiency

Power is the rate of doing work. Power is measured in J/s or Watts (W).

$$P = \frac{W}{t} = \frac{\Delta E}{t}$$

ex. The Nose route of El Capitan is a 915 m vertical climb in Yosemite Park, California. Alex Honnold and Tommy Caldwell recently crushed the old record with a time of 1 hour, 58 minutes. If Alex weighed 72 kg when he set the record, what was his average power output during the climb?

$$P = \frac{W}{t} = \frac{\Delta E_p}{t} = \frac{mg\Delta h}{t} = \frac{(72\,kg)(9.8\,m/s^2)(915\,m)}{7080\,s}$$

3600 s
+3480
7080 s

work was put into raising his E_p

$P = 91.19\ W$

$P = 91\ W$ average power output

ex. A 1.00×10^3 kg car accelerates from rest to a velocity of 15.0 m/s in 4.00 s. Calculate the power output of the car. Ignore friction.

$$P = \frac{W}{t} = \frac{E_k}{t} = \frac{\frac{1}{2}mv_f^2}{t} = \frac{\frac{1}{2}(1000\,kg)(15\,m/s)^2}{4.00}$$

acceleration increases E_k

$P = 28\,100\ W$

Another useful formula... Since $P = \frac{W}{t} = \frac{Fd}{t}$ and $v = \frac{d}{t}$

Therefore: $P = Fv$ Note: this is only useful for ***constant*** velocity.

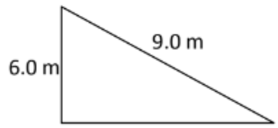
ex. Stu Dent uses 140 N to push a block up a ramp at a constant velocity of 2.2 m/s. What is Stu's power output?

$$P = Fv = (140\,N)(2.2\,m/s)$$

$P = 310\ W$

December 12, 2018

1) A 45.0 kg student runs at a constant velocity up the incline shown. If the power output of the student is 1.50×10^3 W, how long does it take the student to run the 9.0 m along the incline?



2) A 20.0 kg object is lifted vertically 2.50 m in 2.00 s at a constant velocity. Calculate the power output of the student.

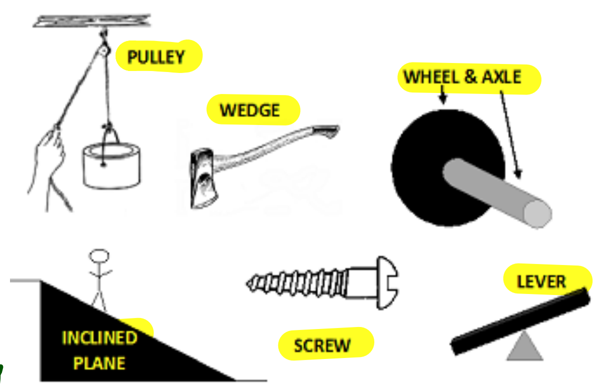
3) A 2.00 kg object is accelerated uniformly from rest to 3.00 m/s while moving 1.5 m across a level frictionless surface. Calculate the power output.

4) An 8.5×10^2 kg elevator is pulled up 32.0 m at a constant velocity of 1.40 m/s. Calculate the power output of the motor.

1) 1.8 s 2) 245 W 3) 9.0 W 4) 12000 W

Efficiency is a measure of how much work is done by a machine compared to how much energy goes into it. Machines are particularly 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.



Simple Machines

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

Work in = total energy supplied by the machine

Work out = amount actually used (converted to a useful form)

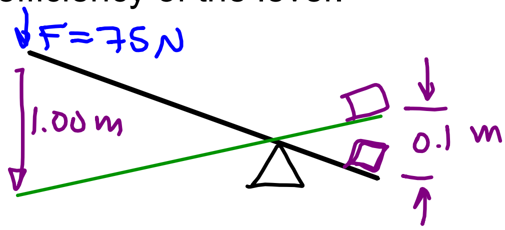
The efficiency of a machine is:

$$\text{Eff} = \frac{W_{out}}{W_{in}} \times 100\% \quad \text{OR} \quad \text{Eff} = \frac{P_{out}}{P_{in}} \times 100\%$$

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

* use the decimal equivalent to do calculations

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.



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

$$W_{out} = \Delta E = mg\Delta h = (50\ kg)(9.8\ m/s^2)(0.1\ m) = 49\ J$$

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

Practice:

1) A 5.00 x 10^2 W electric motor lifts a 20.0 kg object 5.00 m in 3.5 S. What is the efficiency of the motor?

2) A 955 kg car accelerates uniformly from rest to 16.0 m/s while moving 18.0 m across a level surface. If the car uses 325 000 W of power, what is the efficiency of the car?

2) If a 100.0 W motor has an efficiency of 82%, how long will it take to lift a 50.0 kg object to a height of 8.0 m?

4) An 850 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.

1) 56% 2) 48% 3) 16.7% 4) 83%