Power P

- The rate at which work is done
- The rate at which energy is transformed.

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

- scalar quantity
- units: $J\,s^{-1}$ or W (watt)

Power and average speed:

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

$$P = F\frac{\Delta x}{\Delta t}$$

v_{ave} ← average speed (scalar)

$$\boxed{P = F\,v_{ave}}$$

* Can only use this equation if the force acting on the body is constant.

Efficiency

The efficiency of a machine or process:

$$\varepsilon = \frac{\text{energy out}}{\text{energy in}} \times 100\%$$

NOT IN The Data Booklet

or

$$\varepsilon = \frac{\text{power out}}{\text{power in}} \times 100\%$$

Consider that 100 J of chemical energy is used in a model power station and 90 J of electrical energy is produced in the same time:

$$\varepsilon = \frac{90\,J}{100\,J} \times 100\%$$

$$\varepsilon = 90\%$$

The power station is 90% efficient at transforming chemical energy to electrical energy.

We may know that fuel is burned in the power station at a rate of 3.6×10^4 J per hour.

Power input: $\frac{3.6 \times 10^4\,J}{1\,h} = \frac{3.6 \times 10^4\,J}{3600\,s} = 10\,W$

If the power output is 7.5 W

$$\varepsilon = \frac{\text{Power out}}{\text{power in}} \times 100\%$$

$$\varepsilon = \frac{7.5\,W}{10\,W} \times 100\%$$

$$\varepsilon = 75\%$$

The kilowatt hour

Not an SI unit but is a common unit

kilowatt · hour = ?

$P \cdot \Delta t$ = ? work/energy

You are charged by NS "Power" for the kWh you have used ....
This is NOT Power but rather energy

Definition of a kilowatt hour:

The kilowatt hour (kWh) is a unit of energy equivalent to one kilowatt (1 kW) of power expended for one hour (1 h) of time.

$$E = P\Delta t$$

$$1\,kWh = 1\,kW \cdot 1\,h$$

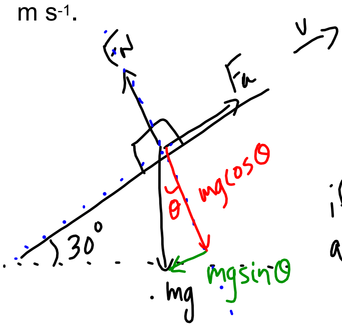
$$= (1000\,J s^{-1})(3600\,s)$$

$$1\,kWh = 3.6 \times 10^6\,J$$

$$1\,kWh = 3.6\,MJ$$

Example

Calculate the power necessary to move a body of mass 1.5 kg up a smooth (frictionless) plane inclined at an angle of 30^{o} to the horizontal with a speed of 5.0 m s^{-1}.



$F_a = mg\sin\theta$

if the body has a constant velocity of $5.0\,ms^{-1}$

$P = Fv$

$P = F_a v$

$P = (mg\sin\theta)v$

$P = (1.5kg)(9.81ms^{-2})(\sin 30^{o})(5.0ms^{-1})$

$P = 37W$

Example

Coal, when burned, produces approximately 30 MJ of energy for each kg burned. A typical coal fired power station produces electrical energy at the rate of 500 MW. If the efficiency of a typical power station is 45%, calculate the mass of coal burned each hour. (1 tonne = 10^{3} kg)

MJ/s

INPUT: $30MJ\ kg^{-1}$

OUTPUT: $0.45(30MJ\ kg^{-1}) = 13.5MJ\ kg^{-1}$

$$\frac{x\ kg}{hr} = \frac{1kg}{13.5\cancel{MJ}}\left(\frac{500\cancel{MJ}}{1s}\right)\left(\frac{3600s}{1h}\right) = 1.3\times10^{5}\ kg\,h^{-1}$$

1.3×10^{2} tonnes per hour

Example

A 2000 W electric heater is used for an average of 10 hours for each of 90 days during winter. What is the total energy used by the heater in joules? If the cost of electrical energy is 20 cents per kilowatt hour, calculate the total cost of running the heater for this period.

$$xJ = 90\cancel{d}\left(\frac{10\cancel{h}}{1\cancel{d}}\right)\left(\frac{3600s}{1\cancel{h}}\right)\left(\frac{2000J}{1s}\right) = 6.5\times10^{9}\ J$$

or 6.5 GJ

OR

$\div 3.6\times10^{6}\,J/kWh$

$= 1800\,kWh$

$\#$ of kWh $= (2\ kW)(900\ h)$

$= 1800\ kWh$

Cost $= (1800\,kWh)(\$0.20)$

$= \$360$