Kinetics : Power & Efficiency

Power

Power is by definition the rate of working.
Since **work = force x distance moved**, it follows that :

$$\text{power} = \frac{\text{force} \times \text{distance moved}}{\text{time}}$$
$$\equiv \frac{\text{Newtons} \times \text{metres}}{\text{seconds}}$$
$$\equiv \text{Nms}^{-1}$$

1 joule is the work done when 1 newton moves its point of application through 1 metre,

$$1 \text{ joule} = 1 \text{ newton} \times 1 \text{ metre}$$
$$1\text{J} = 1 \text{ Nm}$$

1 watt is a rate of working of 1 joule per second

$$1\text{W} = 1 \text{ Js}^{-1}$$

Example

A military tank of mass 20 metric tonnes moves up a 30^o hill at a uniform speed of 5 ms^{-1} . If all the frictional forces opposing motion total 5000N, what is the power delivered by the engine?
(g = $10ms^{-2}$, answer in kW)

If the tank is moving at constant speed then the forces forwards are balanced by the forces backwards.

m is the tank's mass, then $mg\sin 30^o$ is the component of the weight down the hill
R is the total of resistive forces down the hill
T is the tractive force forwards up the hill

$mg\sin 30^o + R = T$

T = (20,000 x 10 x 0.5) + 5000 = 105,000N

power = force x speed

power of tank engine = 105,000 x 5 = 525,000W

Ans. 525 kW

Efficiency

Efficiency is the ratio of useful work out divided by total work done, expressed as a percentage.

$$\text{efficiency}(\%) = \frac{\text{useful work out}}{\text{total work done}} \times 100$$

Example

A pump running at an efficiency of 70% delivers oil at a rate of 4 kgs^{-1} with a speed of 3 ms^{-1} to an oil heater .
if the vertical distance moved by the oil is 10 m, what is the power consumption of the pump?
(g = 10 ms^{-2}, answer to 1 d.p.)

E_f = 70%, m=4kg, v=3 ms^{-1} , h=10 m, g=10 ms^{-2}

work/sec. to raise oil 8 m high = mgh = 4x10x10 = 400 J/s
work/sec. to produce discharge speed = 0.5x4x3x3 = 18 J/s
total work/sec. = 400 + 18 = 418 W

418 W represents 70% of the power supplied

therefore total power consumption of pump =

$$\frac{418}{70} \times \frac{100}{1} = \frac{41800}{70} = 597.143$$

Ans. power consumption of pump is 597.1W (1.d.p.)