Power and Efficiency

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Learning Outcome

I highly recommend you to finish this checklist to determine whether you've achieved the learning objectives.

- ☐ Define and use the equation for power using $P = {}^{W}/_{t}$ and derive $P = Fv$
- ☐ Recall and understand that the *efficiency* of a system
- ☐ Use the concept of efficiency to solve problems

Leadin

With the deepening of the 1st industrial revolution both the power and efficiency of machinery has been improved hugely.

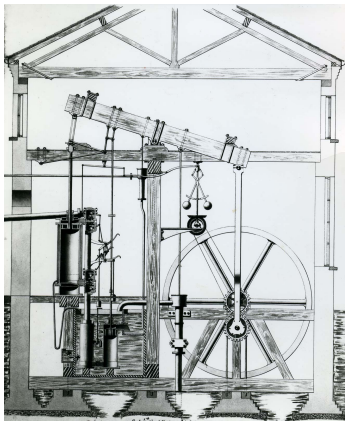


Figure 1: James Watt improved steam engine

Power

Definition of Power

The power P of the motor is the *rate at which it does work over a unit of time*. Expressed in formula:

$$P = \text{\_\_\_\_\_}$$

Task

Derive the SI base unit of W,watt.

Figure 2: A gas stove might reach a power of 5.2 kW

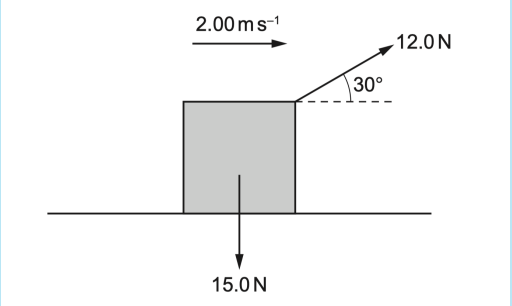
Moving Power

Let's deduce the power of a force. How to reach $P = F \cdot v$

But one thing to notice is that, the both the force and velocity are vectors, thus there might be an angle between $\vec{F}$ and $\vec{v}$, thus the power might be influenced by the angle, the real power is determined by $P = F \cdot v \cos\theta$.

Task

An object of weight 15.0 N is pulled along a horizontal surface at a constant velocity of 2.00 $\mathrm{m\,s^{-1}}$. The force pulling the object is 12.0 N at 30° to the horizontal, as shown.



What is the power used to move the object?

Efficiency

As previous mentioned, a gas stove might deliver 5.2 kJ in one second. So it might not require a long time to boil a bottle of water.

Task

Assume a bottle contains 2 kg of water, the specific capacity of water is $4.2 \times 10^3\,\mathrm{J\,kg^{-1}\,K^{-1}}$. The stove heat the water from 20 °C to boiling point. Calculate the total energy required to boil the water. According to the power formula, calcualte the ideal time require to boil the water.

But in reality, more time are needed, like 8-10 minutes. That means a lot of energy are actually wasted.

Task

List several factors which may consume the extra energy.

So, the concept of efficiency has been introduced in order to measure the extent to which energy is *efficiently converted into useful work done*.

$$\eta = \frac{\text{useful output energy}}{\text{total input energy}} \times 100\%$$

The following shows a Sankey diagram to show the input and output of energy. What is the efficiency of the car engine. Read the story of mazda's engine, it can improve the efficiency of heat engine.

Figure 3: A sankey diagram shows the energy flow in a car engine

Power indicates how fast work is done; while efficiency is the measure of the extent to which energy is successfully converted into useful output. The two concepts might be easily confused.

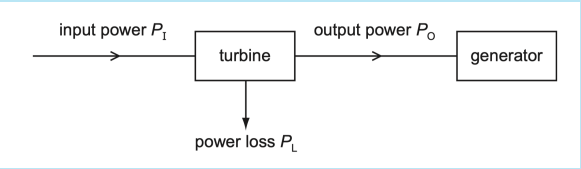
Task

A stone falls from the top of a cliff, 80 m high. When it reaches the foot of the cliff, its speed is $38\,\mathrm{m\,s^{-1}}$.

- calculate the initial g.p.e of the stone (suppose the stone is 0.1 kg)
- calculate the final k.e. of the stone
- calculate the energy wasted

- calculate the efficiency
- state one possible form of energy that has been transformed

A steam turbine is used to drive a generator. The input power to the turbine is P_I and the output power P_O . The power loss in the turbine is P_L , as shown below.



What is the efficiency of the turbine

Read the story of horsepower, and convert horsepower to watt.