AS Level Physics

Chapter 5 – Mechanics

5.9.1 Power and Efficiency

Notes

POWER

Energy cannot be created nor destroyed but it can be transferred from one form to another or can be transferred from one object to another by:

- Work done
- Electricity
- Waves
- Heating

POWER – is the **amount of energy transferred** from one form to another **per second**

Or

Power – is the rate of doing work

You can calculate power using the equation below:

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

"**W**" is used for both the unit Watt and Work done. Be careful when using them

Where:

- **P** = Power measured in Watts (W)
- **W** = Work done or energy transferred measured in Joules (J)
- **t** = Time measured in seconds (s)

POWER

- **The WATT (W)**

The unit of power is the **WATT (W)**.

1 WATT (W) is defined as a rate of energy transfer

or

energy transfer equal to 1 joule per second (Js^{-1}).

- **P = Fv**

There is another equation for power that can be derived:

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

$$But\ W = Fs$$

$$Therefore: P = \frac{Fs}{t}$$

$$But: v = \frac{s}{t}$$

$$\boldsymbol{So: P = Fv}$$

P = Power
W = Work done
t = Time
F = Force
s = distance
v = velocity

This is the equation you use when a force (F) applied to an object does work by moving the object through a distance (s) in a time (t).

In other words, this equation links power, force and speed.

POWER

Example 1:

The average daily food intake for a typical human being would give about 12 MJ of energy. This energy is used by the body to keep warm, to move about, etc… Calculate the power used by the person in the course of a single day.

$$Power = \frac{energy\ transferred}{time}$$

$$P = \frac{12\ MJ}{24\ hours}$$

Always remember to convert into SI units.

$$P = \frac{12 \times 10^6\ J}{24\ hours \times 60\ minutes \times 60\ seconds}$$

$$P = \frac{12 \times 10^6\ J}{86400\ s}$$

$$\mathbf{P = 140\ W}$$

POWER

Example 2:

A car is travelling at a speed of $12\ ms^{-1}$ and is kept going against the frictional force by a driving force of 550 N in the direction of motion. Find the power supplied by the engine to keep the car moving.

$$Use: P = Fv$$

$$Substitute: P = (550\ N)(12\ ms^{-1})$$

$$\mathbf{P = 6600\ W}$$

EFFICIENCY

To calculate efficiency of any device or system you use the equation below:

$$efficiency\ (\%) = \frac{useful\ energy\ output}{total\ energy\ input} \times 100\ (\%)$$

Or

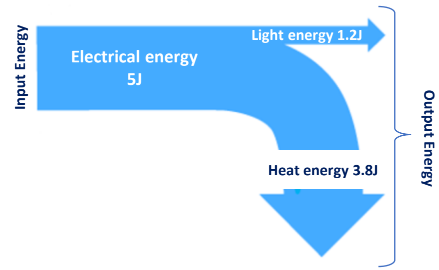
$$efficiency\ (\%) = \frac{useful\ power\ output}{total\ power\ input} \times 100\ (\%)$$

Efficiency is never 100% because devices or systems loss energy in the form of wasted energy (e.g. heat and sound). An electric heater is the closet device to 100% efficiency.

Efficiency can be represented using **Sankey Diagrams** (discussed in 4.1 Work and Conservation of Energy Pack).

Sankey diagrams show all the energy transfers that occur in a process. The thicker the line or arrow, the larger the amount of energy involved.

EFFICIENCY



A light-emitting diode (LED) is supplied with 5 J of electrical energy each second, and produces 1.2 J of light and 3.8 J of heat energy. What is its efficiency?

Step 1: Identify the useful output energy. In this case, it is light energy = 1.2 J.

Step 2: Calculate the efficiency:

$$efficiency\ (\%) = \frac{useful\ energy\ output}{total\ energy\ input} \times 100$$

$$efficiency = \frac{1.2\ J}{5.0\ J} \times 100$$

$$\mathbf{efficiency = 24\%}$$

This means 100% electrical energy (5 J) is inputted into the LED and 24% is converted into useful light energy (1.2 J) and 76% is wasted as heat energy (3.8 J).

POWER AND EFFICIENCY EXAMPLE

A motor applies a force of 25 kN to raise an object to a height of 17 metres in 20 seconds.

a) Calculate the power output of the motor.

b) If 850 kJ of electrical energy was supplied to the motor in this time what is the efficiency of the motor?

a) Power output of the motor:

$$Use: Power = \frac{work\ done}{time}$$

$$Therefore: Power = \frac{Force \times distance}{time}$$

Always remember to convert into SI units.

$$Power = \frac{25\ kN \times 17\ m}{10\ s}$$

$$Power = \frac{25{,}000\ N \times 17\ m}{20\ s}$$

$$Power = \frac{425\ 000\ J}{20\ s} = 21{,}250\ W$$

$$\mathbf{Power = 21\ kW}$$

POWER AND EFFICIENCY EXAMPLE

b) Efficiency of the motor:

$$Use: efficiency = \frac{useful\ energy\ output}{total\ energy\ input} \times 100$$

$$efficiency = \frac{425\ 000\ J}{850\ kJ} \times 100$$

$$efficiency = \frac{425\ 000\ J}{850\ 000\ J} \times 100$$

$$efficiency = 0.5 \times 100$$

$$\mathbf{efficiency = 50\%}$$

Please see '5.9.2 Power and Efficiency Worked Examples' pack for exam style questions.

For more revision notes, tutorials, worked examples and more help visit www.tutorpacks.co.uk.