AS Level Physics

Chapter 3 – Electric Circuits

3.4.1 Power

Notes

Power

Power (P) is defined as the rate of transfer of energy.

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

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

Where:
P = **Power** measured in **watts, W.**
E = **Energy transferred** measured in **joules, J.**
t = **Time taken** measured in **seconds, s.**

Electrical Power

Electrical Power (P) is the rate at which an appliance or device will convert electric energy into other forms of energy.

Consider a device or component with a potential difference, V, across its terminals and a current I flowing through it in time Δt.

- The charge flowing through it is $Q = I\Delta t$
- The work done or energy transferred by the charge carriers is $W = QV = (I\Delta t)V = IV\Delta t$

$$W = ItV$$

Where:
W = **Work done or energy transfer** measured in **Joules, J.**
I = **Current** measured in **Amps, A.**
V = **Voltage** measured in **Volts, V.**
t = **Time taken** measured in **seconds, s.**

Electrical Power

The work done, W, is equal to the energy transfer (ΔE) in the component or device.

Therefore, because $electrical\ power = \frac{energy}{time}$, the electrical power ($P$) supplied to the device is given by:

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

So electrical power is:

$$P = IV$$

Where:
P = **Electrical Power** measured in **watt, W.**
I = **Current** measured in **Amps, A.**
V = **Voltage** measured in **Volts, V.**

Also, we know $V = IR$, $P = IV = I \times IR$

$$P = I^2R$$

Where:
P = **Electrical Power** measured in **watt, W.**
I = **Current** measured in **Amps, A.**
R = **Resistance** measured in **Ohms, Ω.**

Also, we know $I = \frac{V}{R}$, $P = IV = \frac{V}{R} \times V$

$$P = \frac{V^2}{R}$$

Where:
P = **Electrical Power** measured in **watt, W.**
V = **Voltage** measured in **Volts, V.**
R = **Resistance** measured in **Ohms, Ω.**

The Kilowatt-hour (kWh)

The amount of energy supplied by mains electricity is measured in kilowatt hours (kWh), which is also referred to as a 'unit'.

One kilowatt hour is the energy transfer when 1kW of power is supplied for exactly 1 hour.

You can calculate the amount of energy an appliance uses in kWh, as long as you are given the power the appliance uses and for how long it is used for. For example:

A 1kW fan used for 1hour transfers 1kWh of energy.

A 3kW fan used for 5hours transfers 15kWh of energy.

Knowing the above you can use the formula below:

$$Energy\ (kWh) = Power\ (kW) \times Time(h)$$

Normally:
$Energy(J) = Power\ (W) \times time(s)$
But to get energy in kWh you need to convert power to kW from watts and time to hours instead of seconds.

$$1kWh = 1000W \times 3600s = 3.6 \times 10^6 J$$

$1kW = 1000W$

$1\ hour = 3600\ seconds$

The joule is the SI unit of energy, however we don't use joules but instead use kWh because 1 joule is a very small amount of energy compared with the amount of energy used every month by a household.

The Kilowatt-hour (kWh)

Worked Example:

A 2000W fan is on for 5 minutes.

a) How much energy does it use in J and kWh.

b) The cost of electricity is 11.75 pence per kWh. What is the cost of using the fan?

a) Use $\boldsymbol{Energy = Power \times time}$

Energy Joules:

$$E = Pt = 2000W \times 5mins \times 60seconds$$

$$E = \mathbf{600,000\ J}$$

Energy in kilowatt hour:

$$E = Pt = 2.0kW \times \frac{1}{12}\ hours = \mathbf{0.17kWh}$$

b) Use $\boldsymbol{cost\ (p) = power\ rating\ (kW) \times time\ used\ (h) \times cost\ per\ kWh}$

$$Cost = 2.0kW \times \frac{1}{12}h \times 11.75p$$

$$\boldsymbol{Therefore\ cost = 1.958\ pence}$$

Fuses

- Electrical appliances are protected from overloading by a component called the “fuse”. They are usually located in the plug.
- Fuses are made of a thin copper wire encased in a ceramic casing.
- Fuses prevent fires and protect users getting electrocuted.
- Fuses work by melting the thin copper wire because it gets so hot that it melts above a certain value of current, causing the circuit to break.
- Therefore, it is important to chose a fuse whose rating is slightly higher than the maximum current drawn by the device.
- The Fuse rating (i.e. current) can be calculated using the appliances voltage and power rating and substituting it into the formula below:

$$P = IV$$

- Most domestic appliances use 3A, 5A or 13A fuses.

Fuses

- **Worked Example**

What fuse should you use in the plug of a 1kW electric heater that is plugged into a 230V household mains?

Step 1: Write down what you know and what you want to know:

$$P = 1kW = 1000W, V = 230V, I = ?$$

Step 2: Select and rearrange the equation you need:

$$P = IV \text{ so } I = \frac{P}{V}$$

Step 3: Calculate the answer:

$$I = \frac{1000W}{230V} = 4.3A$$

So a 5A fuse is needed.

Please see '3.4.2 Power worked examples' pack for exam style questions.

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