UNIT G482	Module 2	2.2.5	Power

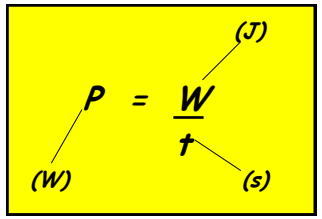
- ***Candidates should be able to*** :
  - *Describe **power** as the rate of energy transfer.*
  - ***Select** and **use** the power equations :*

    $P = VI$ $\qquad P = I^2R$ $\qquad P = V^2/R$
  - *Explain how a **fuse** works as a safety device.*
  - *Determine the correct fuse for an electrical device.*
  - ***Select** and **use** the equation :* $W = IVt$
  - *Define the **kilowatt-hour (kWh)** as a unit of energy.*
  - ***Calculate** the energy **in kWh** and the **cost** of this energy when solving problems.*

- ***ELECTRICAL ENERGY (W) & POWER (P)***

- ***POWER (P)** is the rate at which energy is transferred or consumed.*

  i.e. $\text{power} = \dfrac{\text{energy transferred}}{\text{time taken}}$



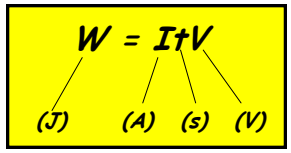
***ELECTRICAL POWER (P)** of an appliance or device is the rate at which it transfers electrical energy into other energy forms.*

- *Electrical power is measured in* ***watt (W)***

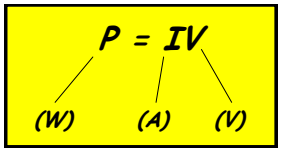
Electrical Power Equations

*Consider an amount of charge **(Q)** which flows under the influence of a pd **(V)**.*

Then, energy transferred, $W = QV$ (and since $Q = It$)



Also, electrical power, $P = \dfrac{W}{t} = \dfrac{ItV}{t}$



- *Also, since $V = IR$, $P = IV = I \times IR$*

$$P = I^2R$$

(W) (A) (Ω)

- *Also, since $I = V/R$, $P = IV = V/R \times V$*

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

(V) (W) (Ω)

NOTE

$P = IV$

*This equation gives the rate of production of **ALL** forms of energy, So it can be used for **ANY** device*

$P = I^2R$ $P = V^2/R$

*These two equations are only **VALID** when **ALL** the electrical energy is transferred to heat energy, so it can only be used for a **PURE RESISTOR**.*

- **PRACTICE QUESTIONS (1)** *2*

1 (a) Calculate the **rate** at which energy is transferred by a **230 V** mains supply when it is providing a current of **10.9 A** to an electric heater.

(b) What **power** is supplied to an electric heater of resistance **54 Ω** when it is connected to a **230 V** mains supply.

(c) Calculate the **resistance** of a **60 W** filament lamp if it draws a current of **270 mA** when it is connected to the mains supply.

2 A large power station supplies electricity to the National Grid at a voltage of **25 kV**. What is the **power output** of the station when the current is **25 kA** ?

3 An electric kettle takes **2.0 minutes** to boil a quantity of water when it is connected to a **240 V** electrical supply. Assuming that all the electrical energy is converted into **2.4×10^5 J** of heat energy, calculate the **current** taken from the supply.

4 A **230 V** electrical appliance has a power rating of **1.4 kW**.
Calculate : (a) The **energy transfer** in the appliance in **2.5 minutes**.

(b) The **current** taken by the appliance.

5 An electrical heating element is designed so that it dissipates energy at the rate of **1600 W** when it is connected to a **240 V** supply. If the element is made of **nichrome** wire of diameter **0.6 mm** and of resistivity **1.1×10^{-6} Ω m**, calculate its **length**.

6 Calculate the **power loss** along a **45 cm** long connecting lead having a resistance of **4×10^{-3} Ω m^{-1}** if it is carrying a current of **375 mA**.

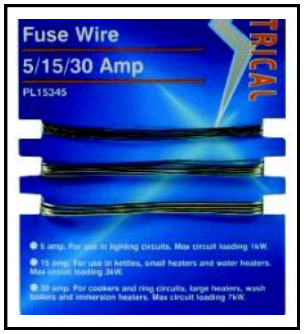
- ***FUSES***

- *Large currents can cause overheating of connecting wires which can damage the wiring, produce fumes from melting insulation and, in extreme cases, result in electrical fires.*

*A **FUSE** is an EXCESSIVE CURRENT PROTECTION device.*

*It essentially consists of a metal wire or strip which **melts** as soon as the **current exceeds the value for which the fuse is rated**.*

*This **breaks** the circuit in which the fuse is connected and so **protects** all the components in the circuit from damage due to excessive current.*



- *Fuses are commonly marked with the **maximum current** (called the fuse **CURRENT RATING**) which they can carry before melting.*

FUSE SELECTION

This can best be illustrated by looking at an example.

- *What is the **current rating** for the most suitable fuse for use with an electric immersion heater rated at **5 kW, 230 V**. Choose from the following fuses :*

  3 A / 5 A / 13 A / 15 A / 20 A / 25 A / 30 A / 45 A

- ***Calculate the current through the immersion heater**.*

$$I = \frac{P}{V} = \frac{5000}{230} =$$ **21.74 A**

- ***Choose the fuse with the current rating which is GREATER THAN AND CLOSEST TO the I-value calculated for the heater**.*

The most suitable fuse is therefore : **25 A**

- **PRACTICE QUESTION (2)**

1 An electric kettle is rated at **2.0 kW, 230 V**. Determine a suitable **current rating** for the fuse required in the 3-pin plug used for this kettle. Choose from **3 A, 5 A, 13 A, 15 A and 20 A**.

2 An LCD television set has a rating of **170 W** on the **230 V** mains. which of the following fuses would be the most suitable to fit in the plug ? **3 A, 5 A, 13 A or 15 A**.

• *ELECTRICAL ENERGY UNIT - THE KILOWATT-HOUR (kWh)*

As we already know : **ENERGY = POWER x TIME**

*If power is in **watts** and time is in **seconds**, then the unit of energy is the **joule**. This is an inconvenient unit for commercial use because one joule is a very small quantity of energy as shown below.*

ENERGY (J) = POWER (W) x TIME (s)
= 1000 x 3600
= 3.6×10^6 J

Consequently, commercial and domestic electricity supplies are measured in a much larger unit, the **KILOWATT-HOUR (kWh)**

*The quantity of **energy transferred to other energy forms** by a device having a power rating of **1 KILOWATT (kW)** when it is used for **1 HOUR (h)**.*

*The number of **kWh** or '**units**' which have been consumed and hence the **cost** of using an electrical appliance for a given time may be calculated from :*

Cost (p) = **power rating** (kW) x **time used** (h) x **cost per kWh**

• HOMEWORK QUESTIONS 4

1 A **12 V** battery supplies a current of **2.6 A** to a circuit for a period of 3.5 minutes. Calculate :

(a) The **quantity of charge** which flows through the battery in this time.

(b) The **energy transferred to the charge by the battery.**

(c) The **energy transferred by the charge to the circuit components.**

2 (a) A **230 V** electric heater draws a current of **6.52 A.** Assuming that all the electrical energy supplied is transferred to heat energy, calculate the **amount of heat produced** when the heater is switched on for **30 minutes.**

3 A **230 V** electric kettle transfers **6.75×10^6 J** of energy in **5 mins.** Calculate the **current** supplied to the kettle.

4 A power station generates **250 MW** of electricity which is then transmitted through the National Grid at a pd of **320 kV.** If the transmission cables have a resistance of **6.0 Ω,** calculate :

(a) The **transmission current.**

(b) The **power loss** in the cables.

5 An electric cooker is rated at **9 kW, 230 V.**

(a) What is the **current** drawn by the appliance when it is fully switched on ?

(b) Choose a suitable fuse for this cooker from the values below :
13 A, 15 A, 20 A, 30 A, 45 A.

6 A **150 W** light bulb draws a current of **750 mA** from a power supply. What is the electrical **resistance** of the bulb ?

7 A room is illuminated for a time of **14 hours per week** by four **60 W** light bulbs.

(a) Calculate the number of **kilowatt-hours** consumed in **a year**.

(b) How much will this **cost** if electricity costs **7.5 p per unit ?**

8 (a) Define the **kilowatt-hour (kWh)**.

(b) On average a student uses a computer of power rating **110 W** for **4.0 hours** every day. The computer draws a current of **0.48 A**.

(i) For a period of **one week**, calculate :

1. The number of **kilowatt-hours** supplied to the computer.
2. The **cost** of operating the computer if the cost of each **kWh** is **7.5 p**.

(ii) Calculate the **electric charge** drawn by the computer over a period of **one week**.

(OCR AS Physics - Module 2822 - Jan 2005)