- ***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. $\text{power} = \dfrac{\text{energy transferred}}{\text{time taken}}$

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

(W) (J) (s)

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* $Q = It$*)*

$$W = ItV$$

(J) (A) (s) (V)

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

$$P = IV$$

(W) (A) (V)

- *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***.

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 $\mathbf{2.4 \times 10^5}$ **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 $\mathbf{1.1 \times 10^{-6}}$ **Ω m**, calculate its **length**.

6 Calculate the **power loss** along a **45 cm** long connecting lead having a resistance of $\mathbf{4 \times 10^{-3}}$ **Ω** $\mathbf{m^{-1}}$ 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__.***

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

- ***__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

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.**

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