Chapter 21 – Practical Electricity

(A) Electrical Power

1. State four applications of the heating effect of electricity.

- Home:
  - Used in electric kettles
  - Used in electric irons
  - Used in water heaters

- Industry:
  - Used in electric machines

2. Write down four formulas for calculating electrical power.

- $P = I^2R$
- $P = V^2 / R$
- $P = VI$
- $P = E / t$

3. State the SI unit of power.

- Watt (W)

4. An electric lamp is rated as '60 W, 240 V'. Explain what this rating means.

- It means that when 240 V is connected to the lamp, 60 J of electrical energy is converted to light and other forms of energy every second.

5. Calculate the power used in each of the following cases:

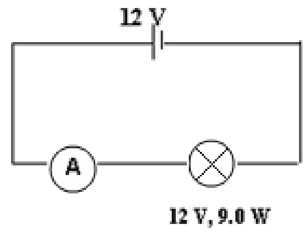
(a) An electric lamp of resistance 60 Ω carrying a current of 4 A.

- $P = I^2R$
  $= (4\ A)^2\ (60\ \Omega)$
  $= \underline{960\ W}$

(b) An electric lamp of resistance 50 Ω connected to a mains supply of 240 V.

- $P = V^2 / R$
  $= (240\ V)^2 / (50\ \Omega)$
  $= \underline{1\ 152\ W}$

6. A 12 V battery supplies current to a bulb as shown below:



(a) Calculate the ammeter reading.

❖
$$P = VI$$
$$9.0\ W = (12\ V)\ (I)$$
$$I = \underline{0.75\ A}$$

(b) How should a resistor S be connected to the circuit such that the value of the current through the circuit is 0.5 A? Calculate this value of S.

❖ S should be connected in series with the bulb.

❖
$$P = V^2 / R$$
$$9.0\ W = (12V)^2 / (R)$$
$$R = 16\ \Omega$$

⇨ Resistance of bulb = 16 Ω

$$V = IR$$
$$12\ V = (0.5\ A)\ (16\ \Omega + R_s)$$
$$R_s = \underline{8\ \Omega}$$

(c) What is the power dissipated by this resistor S?

❖
$$P = I^2R$$
$$= (0.5\ A)^2\ (8\ \Omega)$$
$$= \underline{2\ W}$$

(d) How should a resistor T be connected to the circuit such that the value of the current through the battery is 1 A? Calculate this value of T.

❖ T should be connected in parallel with the bulb.

❖
$$V = IR$$
$$12\ V = (I)\ (16\ \Omega)$$
$$I = 0.75\ A$$

⇨ Current through bulb = 0.75 A

⇨ Current through resistor T = 1 – 0.75 A
= 0.25 A

$$V = IR$$
$$12\ V = (0.25\ A)\ (R_T)$$
$$R_T = \underline{48\ \Omega}$$

(B) Electrical Energy

7. Write down a formula for calculating electrical energy.

- Energy = Power x Time

8. A 5 kW immersion heater is used to heat water for a bath. If it takes 40 minutes to heat up the water, how much electrical energy is converted into thermal energy?

- E = Pt
  = (5 x 1 000 W) (40 x 60 s)
  = 12 000 000 J

9. An electric lamp of resistance 50 Ω and carrying a current of 3 A, is switched on for 25 minutes. Calculate the energy used.

- $P = I^2R$
  $= (3\text{ A})^2 (50\ \Omega)$
  = 450 W
- E = Pt
  = (450 W) (25 x 60 s)
  = 675 000 J

10. An electric motor which is connected to a 50 V supply and which takes a current of 3 A, is switched on for 100 s. Calculate the energy used.

- P = VI
  = (50 V) (3 A)
  = 150 W
- E = Pt
  = (150 W) (100 s)
  = 15 000 J

11. An electric appliance of resistance 800 Ω connected to a mains supply of 200 V is used for 1 hour. Calculate the energy used.

- $P = V^2 / R$
  $= [(200\text{ V})^2 / 800\ \Omega$
  = 50 W
- E = Pt
  = (50 W) (1 x 3600 s)
  = 180 000 J

12. The bulb of a torch is labelled 2.5 V, 0.3 A. Calculate the resistance of the filament of the bulb and the energy converted in 10 minutes.

❖ $V = IR$
$2.5\ V = (0.3\ A)(R)$
$R = \underline{8.33\ \Omega}$

❖ $P = VI$
$= (2.5\ V)(0.3\ A)$
$= 0.75\ W$

❖ $E = Pt$
$= (0.75\ W)(10 \times 60\ s)$
$= \underline{450\ J}$

<u>(C) Kilowatt Hour (kWh)</u>

13. The kilowatt hour is a commercial unit.

(a) What physical quantity does it measure?

❖ Energy.

(b) Write down how it is calculated.

❖ Energy (kWh) = Power (kW) x Time (h)

(c) How many joules (J) is one kWh equivalent to?

❖ $1\ kWh = 1\ kW \times 1\ h$
$= 1\,000\ W \times 3\,600\ s$
$= \underline{3\,600\,000\ J}$

14. How many kWh units of electrical energy will be used in a day by a

(a) 3 kW electric fire;

❖ $E = Pt$
$= (3\ kW)(24\ h)$
$= \underline{72\ kWh}$

(b) 60 W electric lamp?

❖ $E = Pt$
$= (60 \div 1\,000\ kW)(24\ h)$
$= \underline{1.44\ kWh}$

15. The following appliances were used for different time intervals on an average day:

- **Five lamps at 60 W each for 6 hours**
- **Air conditioner at 3 kW for 5 hours**
- **Television at 100 W for 4 hours**
- **Electric kettle at 750 W for 40 mins**

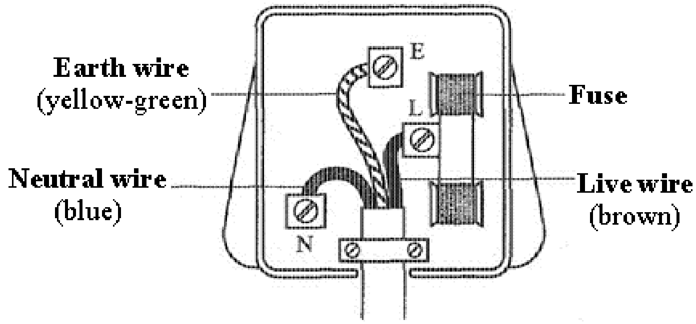
If electricity costs 15 cents per kWh, calculate the total cost for one month of 30 days.

❖ $\text{Cost} = \{[(60 \div 1\,000\ kW) \times 6\ h \times 5] + [3\ kW \times 5\ h] + [100 \div 1\,000\ kW) \times 4\ h]$
$+ [(750 \div 1\,000\ W) \times [40 \div 60\ h)]\} \times 30\ \text{days} \times 15\ \text{cents}$
$= \underline{7\,965\ \text{cents}}$

(D) Plug

16. Draw a diagram of the inside of a mains plug. Indicate clearly the live, neutral and earth wire.

- ❖ Answer:



(D1) Live, Neutral & Earth Wires

17. State the purpose of the following wires in a mains plug with regards to current flow:

(a) Live

- ❖ Carries current to the appliance.

(b) Neutral

- ❖ Enables current to flow through the appliance.

Comment:

√ *It takes two wires to complete an electrical circuit. The live wire leads from the source of electricity to the load, while the neutral wire goes from the load back to the electrical source.*

(c) Earth

- ❖ Conducts current to the earth when there is a current leakage.

18(a) Is the presence of the earth wire always required in a plug for an electrical appliance to work?

- ❖ No.

(b) What is the primary objective of the earth wire?

- ❖ For safety reasons.

Comment:

√ *The earth wire is an additional wire for ensuring safety. It is not actually necessary for electricity to flow, since the live and neutral wires already complete the circuit.*

19(a) To what type of electrical devices are earth wires especially applicable to?

- ❖ To devices where the outer casing is an electrical conductor (e.g. metal).

<u>Comment:</u>

√ *If the outer casing (surface) is a conductor, and a person touches it when the appliance is faulty, he will get an electrical shock. On the other hand, if the casing is not a conductor (e.g. one made of plastic), electricity will not flow to the person at all.*

(b) Does electricity usually flow in the earth wire?

- ❖ No.

<u>Comment:</u>

√ *Electricity will flow in the earth wire only in the event of an electrical failure.*

(c) Where is the earth wire connected to?

- ❖ Connected to the interior metallic body of the appliance.

20(a) An electrical appliance becomes faulty and the live wire touches the metal casing that has not been made safe by Earthing. Describe what happens when a person touches the metal case.

- ❖ When the person touches the metal casing, a large current will be conducted from the live wire through the person to Earth.
- ❖ Thus the person becomes electrocuted.

(b) Describe how the presence of a Earth wire will make the electrical appliance safe even though the live wire is in contact with the metal casing.

- ❖ When the live wire touches the metal case, the Earth wire will act like the neutral wire and completes the circuit.
- ❖ The large current that flows will now be conducted from the live wire through the earth wire to Earth.
- ❖ Thus, any person that touches the electrical appliance will be safe as the electrical current will flow through the Earth wire rather than through the person's body.

<u>Comment:</u>

√ *Electric currents flow through the Earth wire instead of through the human body because the Earth wire has a much lower electrical resistance compared to the human body. In the absence of the Earth wire, however, a current will have no other alternative but to flow through the human body to reach the ground.*

(D2) Fuse

21. What is a fuse?

- A fuse is a short length of wire inside a protective case.
- When a current larger than the fuse rating flows, the fuse wire becomes hot and melts, thus breaking the circuit and preventing a fire from starting.

22. State the purpose of the fuse.

- To protect electrical appliances from damage caused by excessive currents.

23. State three common fuse ratings.

- 3 A
- 5 A
- 13 A

Comment:

√ *Fuse ratings also come in 1 A, 2 A, 7 A and 10 A.*

24. What should be the rating of a fuse relative to the current that flows through a device?

- The rating of a fuse should be slightly larger than the current that flows through a device.

25. What current is taken by a 3 kW electric appliance connected to a 240 V mains? What fuse rating should be used in the plug?

- $$P = VI$$
  $$3\ 000\ W = (240\ V)\ (I)$$
  $$I = 12.5\ A$$

⇨ A <u>13 A fuse</u> should be used in the plug.

26. A 240 V power line is protected by a 13 A fuse. What is the maximum number of 1 kW, 240 V electric kettles that can be operated on this power line?

- $$P = VI$$
  $$1\ 000\ W = (240\ V)\ (I)$$
  $$I = 4.1666\ A$$

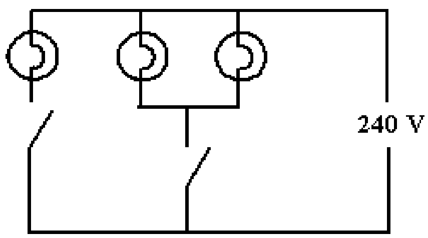
⇨ Each lamp takes a current of 4.1666 A

⇨ Number of lamps possible = 13 A / 4.1666 A
= <u>3</u>

27. There are 3 filament lamps, each marked '240 V, 60 W'.

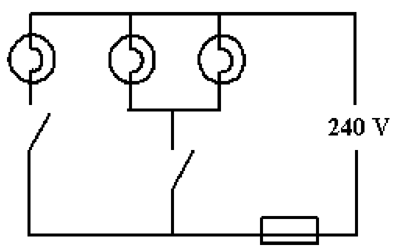
(a) Sketch a lighting circuit to show how these 3 lamps can be operated from a 240 V mains supply with one switch controlling one lamp only and another switch controlling the remaining two at the same time.

❖ Answer:



(b) A fuse is to be inserted into the circuit. Select and explain an appropriate fuse. Add this fuse to your sketch.

❖ Diagram:



❖
$$P = VI$$
$$60\text{ W} = (240\text{ V})(I)$$
$$I = 0.25\text{ A}$$

⇨ Each lamp takes a current of 0.25 A.

❖ The fuse should be able to carry slightly more than the normal operating current. Thus, an appropriate 1 A fuse can be inserted as the total current drawn from the three lamps is 0.75 A.

<u>(D3) Connection of Switches, Fuses and Circuit Breakers to Wires</u>

28. To which wire are switches, fuses and circuit breakers connected?

❖ To the live wire.

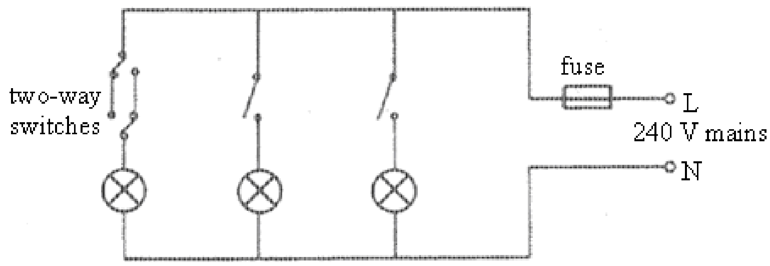
29. Explain why switches, fuses and circuit breakers are connected to the live wire, and not to the neutral wire.

❖ The live wire is at a high alternating voltage, whereas the neutral wire is at 0 V.
❖ If the above components are connected to the live wire, and in the event that the switch is opened, or fuse blown, or the circuit breaker turned off, the circuit will be completely disconnected from the high voltage.
❖ If, however, the components are connected to the neutral wire, no current would flow when the switch is off. However, the circuit is still "live". Thus, a person will be electrocuted if he touches the live wire, because a current will then flow from the live wire, through his body, and down to earth which is at 0 V.

(E) Lighting Circuits

30. Draw a diagram of a typical lighting circuit comprising of a three switches, three bulbs and a fuse.

- ❖ Answer:



31. A typical lighting circuit consists of bulbs connected in parallel. Give three advantages that a parallel circuit has over a series circuit.

- ❖ All the bulbs in a parallel circuit can function independently. On the other hand, all the bulbs in a series circuit must be switched on or off at the same time.
- ❖ If any one bulb in a parallel circuit becomes faulty, the others can still function, unlike in the case of a series circuit.
- ❖ Each bulb in a parallel circuit will be able to receive its operational voltage from the mains supply, thus enabling it to light up to its normal brightness. On the other hand, each bulb in a series circuit may not receive its operational voltage if there are excessive numbers of bulbs connected.

Comments:

√ *In a parallel circuit, the p.d. across each branch is equal to the voltage supply. In a series circuit, the sum of the p.d. across each electrical component is equal to the voltage supply. (Thus, in a series circuit, the p.d. across each component may not be of its optimal voltage as the e.m.f. is shared among all components.)*

√ *The p.d. across a bulb will determine the current through it, which in turn affects the brightness of the bulb. This will be discussed in Section F under.*

(F) Brightness of Lamps

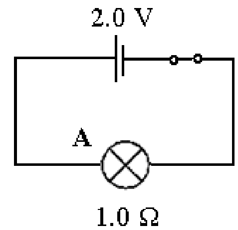
32(a) What is the brightness of a lamp determined by?

- ❖ The current through the lamp.

(b) Explain your answer to (a) above.

- ❖ "Brightness" is a measure of power, which is given by $P = I^2R$.
- ❖ The larger the current, the larger the power, and hence the greater the brightness.

33(a) A simple circuit comprising of a switch, cell and lamp A is as shown below:



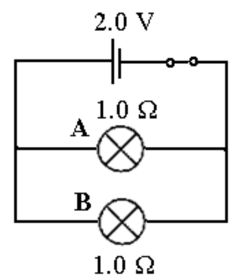
(i) Write down the potential difference across lamp A.

- ❖ 2.0 V

(ii) Determine the current flowing across lamp A.

❖
$$V = IR$$
$$2.0\ V = (I)\ (1.0\ \Omega)$$
$$I = \underline{2.0\ A}$$

(b) Suppose another lamp B of similar resistance is now connected to the circuit in part (a).



(i) Determine the current flowing across both lamps.

❖ Lamp A:
$$V = IR$$
$$2.0\ V = (I)\ (1.0\ \Omega)$$
$$I = \underline{2.0\ A}$$

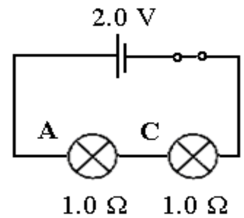
❖ Lamp B:
$$V = IR$$
$$2.0\ V = (I)\ (1.0\ \Omega)$$
$$I = \underline{2.0\ A}$$

> *Comment:*
>
> √ *The p.d. across two electrical components connected in parallel is the same.*

(ii) State and explain whether there is any change in the initial brightness of lamp A [from part (a)] after the addition of lamp B.

- ❖ No, there is no change.
- ❖ This is because there is no change in the magnitude of the current flowing across lamp A before and after the addition of lamp B.

(c) Suppose another lamp C also of similar resistance is connected to the original circuit as follows.



(i) Determine the current flowing across both lamps.

- ❖ Effective resistance of both lamps = 1.0 Ω + 1.0 Ω

  = 2.0 Ω

$$V = IR$$
$$2.0\ V = (I)\ (2.0\ \Omega)$$
$$I = 1.0\ A$$

  - ⇨ Current flowing across lamp A = <u>1.0 A</u>
  - ⇨ Current flowing across lamp B = <u>1.0 A</u>

(ii) State and explain whether there is any change in the initial brightness of lamp A [from part (a)] after the addition of lamp C.

- ❖ Lamp A becomes dimmer.
- ❖ This is because the current flowing through lamp A is now smaller.

<u>*Comment:*</u>

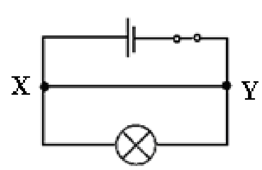
√ *This question again shows that a parallel circuit will not affect the brightness of lamps, unlike a series circuit.*

<u>(G) Short Circuit</u>

34. What is a short circuit?

- ❖ When the terminals of an electrical source are connected with wires <u>without any electrical component</u> in the circuit, a very large current will flow through the circuit as the wires are of very low resistance. This is called a short circuit.

35. State and explain if the bulb in the below circuit will light up.



- ❖ No, the bulb will not light up.
- ❖ A short circuit will occur, where the current will travel through wire XY instead of through the bulb. (This is so as wires are of a much lower resistance than bulbs.)
- ❖ Since no current flows through the bulb, it will not light up.

36. Give an example of a short circuit in a home setting.

- ❖ An example would be the live wire being connected directly to the neutral or earth wire (due to damaged insulation), without any electrical appliance in the circuit.

37. Explain how, if a short circuit occurs, the fuse in the plug prevents the continued flow of current.

- ❖ A short circuit will produce a large current which then results in over-heating of the cables.
- ❖ The fuse in the plug contains a thin wire which heats up.
- ❖ As the melting point of the thin wire is low, it melts which stops the flow of current.

Comment:

√ *A short circuit results in a large electrical current because of its low electrical resistance. This is so as a short circuit comprises only electrical wires, without any electrical appliance being connected.*

(H) Electrical Hazards

38. State two dangers of electricity.

- ❖ Electric Shock
- ❖ Fire

(H1) Electric Shocks

39. State two causes of electric shocks.

- ❖ Damaged insulation
- ❖ Damp conditions

40. Discuss how damaged insulation can lead to electric shocks.

- ❖ Short circuits may result between the live and neutral wires due to damaged insulation.
- ❖ If a person comes into contact with the exposed wires, he may get an electric shock.

41. Discuss how damp conditions can lead to electric shocks.

- Water is a conductor of electricity.
- Thus, if a wet hand comes into contact with electrical appliances, electricity can be conducted from the appliance to the body, causing an electric shock.

Comment:

√ *Pure water does not conduct electricity well. However, the presence of impurities in water will cause it to be a conductor of electricity.*

(H2) Fires

42. State two causes of fire due to electricity.

- Damaged insulation
- Overheating of wires

43. Discuss how damaged insulation can lead to fires.

- Short circuits may result between the live and neutral wires due to damaged insulation.
- The large current that flows can produce enough heat to start a fire.

44. Discuss two situations that result in the overheating of wires, eventually leading to fires.

- If a power outlet is overloaded, the current drawn from the mains may be larger than what the electrical wires can safely carry, causing overheating to occur.
- If thin wires are used for electrical appliances that require high power, heat can build up very quickly in the wires.
  - ⇨ In the above two instances, the excessive heat produced can cause insulation to melt, leading to fires.

Comment:

√ *From the formula $R = (\rho l)/A$, we know that thin wires have high resistance because of their small cross-sectional area. Such high resistance will in turn cause these wires to heat up very quickly (from $P = I^2R$).*

<u>(I) Safety Precautions</u>

45. Give three safety precautions with respect to your daily usage of electricity.

- ❖ Do not overload power sockets by connecting too many electrical appliances to the same socket.
- ❖ Do not touch electrical appliances, sockets and switches with wet hands.
- ❖ Wear insulating footwear such as rubber shoes when handling electricity.

46. Give three safety precautions with respect to electrical wiring.

- ❖ Use of a fuse with the correct current rating for each electrical appliance.
- ❖ Presence of circuit breakers.
- ❖ Use of double insulation.

<u>Comment:</u>

√ *Fuses have already been discussed in an earlier section. Thus, we will now touch on circuit breakers and double insulation.*

<u>(I1) Circuit Breakers</u>

47. Fill in the blanks:

A circuit breaker is an __________-operated electrical __________ that will click off all circuits in the house in the presence of excessive currents.

- ❖ automatically
- ❖ switch

<u>Comment:</u>

√ *A circuit breaker uses an electromagnet to attract an iron bolt when the current is large enough. The bolt moves away from its original position to release a plunger. This leaves a gap and the circuit is broken.*

48. State two advantages of circuit breakers over fuses as a safety precaution against electrical hazards.

- ❖ Circuit breakers operate more quickly in switching off circuits.
- ❖ Unlike fuses which can operate only once before getting replaced, circuit breakers are reusable as they can be easily reset to resume normal operation.

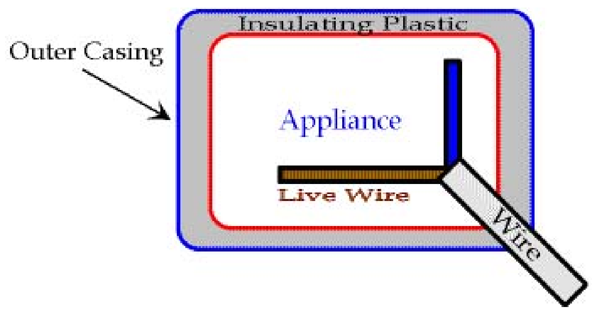
(I2) Double Insulation

49. What is double insulation?

- ❖ Double insulation refers to the use of two layers of insulation, where the electric cables are insulated from the internal metal parts which are in turn insulated from the external metal parts of the appliance.

Comment:

√ *An appliance which is double insulated has the whole of its inside contained in an insulating material (e.g. plastic), underneath an outer casing as shown below:*



50(a) What is one consequence of double insulation with regards to circuit wiring?

- ❖ Only the live and neutral wires are required; the earth wire is unnecessary.

(b) Briefly explain your answer to (a).

- ❖ Because of the two layers of insulation, the live wire will not be able to reach the external metal parts of the appliance.
- ❖ As such, the equipment does not have to be earthed.

51(a) Are fuses and circuit breakers required if double insulation is already in use?

- ❖ Yes.

(b) Explain your answer in (a).

- ❖ The fuses and circuit breakers act as an additional buffer / precaution in case the wires used are damaged.