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PHYSICS

Class 10th (KPK)

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Current Electricity

Comprehensive Question

Give an extended response to the following questions.

Q1. Define electric current. In what units it is measured? Discuss briefly the direction of current through the conductor.

Ans. Electric Current:

'Time rate of flow of charge is called current'.

Mathematical form:

A charge 'ΔQ' flowing through any cross-sectional area in time 'Δt', corresponds to a current 'I' that is defined mathematically as

$$I = \frac{\Delta Q}{\Delta t}$$

Explanation:

When charge flow, they can be positive, negative, or both. For example, the current in metals is due to flow of negatively charged electrons. The current in the beam of a particle accelerator is due to positively charged protons, while in some cases such as gases and electrolytes; the current is due to the flow of both positive and negative charges. Moving charges, whether positive or negative, are referred to as charge carriers. The total current is $I=I_{+}+I_{-}$

Unit:

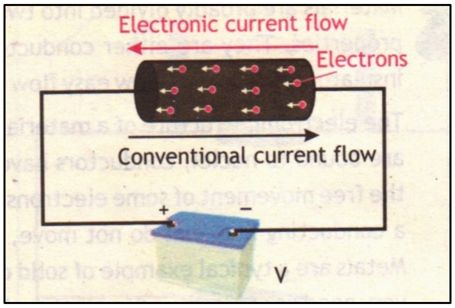
The SI unit of current is **ampere** and is represented by capital letter A. When one coulomb charge flows through any cross-sectional area in one second, the current is one ampere.

1A=1C/s.

Since coulomb is large amount of charge, therefore ampere is also a large unit of current. In real life situations, we deal with small values of current like milli Amperes (mA=10^{-3} A) and micro-amperes(μA = 10^{-6} A).

Direction of Current through Conductor:

In conductors (e.g. metals), the actual flow of current is due to electrons which flow from negative terminal to the positive terminal of battery.



Direction of Conventional Current:

Before the discovery of electron, the current was assumed to flow from positive to negative terminal of the battery even for conductors. This assumed direction of current is now called conventional current.

Or

The direction of conventional current is the direction in which positive charges flow.

Q2. What is Potential difference and emf? Differentiate between them.

Ans. <u>Potential Difference:</u>

The electric potential at one point can be higher, lower or equal to potential difference at other point. '**The difference of electric potential between two points is called potential difference'.**

<u>Explanation:</u>

In an electric circuit which has an electric device (electric bulb) connected across battery through conducting wires as shown in figure. The charge leaving the positive terminal of the battery has potential energy in device; part of this energy is lost (converted to other forms of energy). Thus, there is a difference of potential energy per coulomb of charge (q) from once side of the electric device to the other, which is termed as potential difference.

$$\Delta V = \frac{\Delta U}{q}$$

<u>EMF:</u>

The potential difference developed and maintained by source of electrical energy is called electromotive force (emf or ξ).

OR

An electromotive force is a source of energy with the help of which current can be maintained in a close circuit.

<u>Explanation:</u>

To sustain steady current in a circuit, emf source (A device which converts a non-electrical energy into electrical energy) is required which maintains a constant potential difference across its ends. Battery is an emf source with positive and negative terminals.

When battery is connected through conducting wires with a device. The positive charges enter the negative terminal of the battery. Therefore, work has to be done inside the battery to bring the positive charge from lower potential to higher potential. The influence that makes current flow from lower to higher potential (inside the battery) is called electromotive force (emf or E). If W is the work done by battery in taking a charge q from negative terminal to positive terminal, then electromotive force (emf or E) of the battery is:

$$E = \frac{W}{q}$$

Thus electromotive force (emf) is also defined as **the energy spent per unit positive charge by the source to move it from negative terminal to the positive terminal within source**.

Unit:

The unit of electromotive force is same as units for electric potential or potential difference as J/C=V.

$$1V = \frac{1J}{1C}$$

Q3. State and explain Ohm's Law. What are its limitations?

Ans: <u>OHM's LAW:</u>

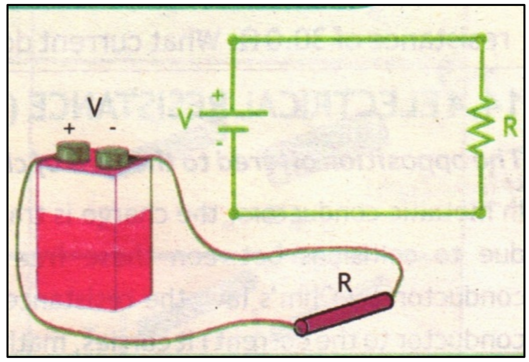
<u>Statement:</u>

The current in a conductor is directly proportional to the applied voltage across the conductor as long as temperature and the physical state of the conductor is kept constant.

<u>Explanation:</u>

If we connect an ohmic device first to 1.5V battery, and then we double the battery voltage to 3V, the current will also double. The current/flows though ohmic device when voltage V is applied across its ends, then according to ohm's Law, we have

$I \propto V$ Or $I = kV$



Where k is the constant of proportionality and is equal to 1/R, where R is the opposition to the flow of current therefore

$$I = \frac{V}{R}$$

Here R is called resistance and is independent of the value of V and I and depends upon the nature of the conductor (its material), the dimensions of the conductor (such as length and cross-sectional area) and temperature of the conductor. All devices do not obey Ohm's Law. The devices that follow Ohm's law are called Ohmic devices and are commonly referred to as 'resistors'

<u>Limitations of Ohm's law:</u>

For Ohm's law to hold good, the resistance 'R' must not change. However, only metallic conductors (for example copper, silver and gold wires) show this behavior and that too only over limited range of voltages. Many important devices do not obey Ohm's law. Even a light bulb has resistance that depends on its temperature and does not obey Ohm's law.

Q4. What is resistance and in what units we measure resistance?

Ans. <u>Electrical Resistance (R):</u>

The opposition offered to the flow of charges is called electrical resistance.

<u>Explanation:</u>

In metallic conductors, the charge is transported by free electrons. Resistance is due to collisions between these free electrons and fixed atoms inside the conductor. By Ohm's law, the resistance is the ratio of the voltage V across the conductor to the current I it carries, mathematically

$$R = \frac{V}{I}$$

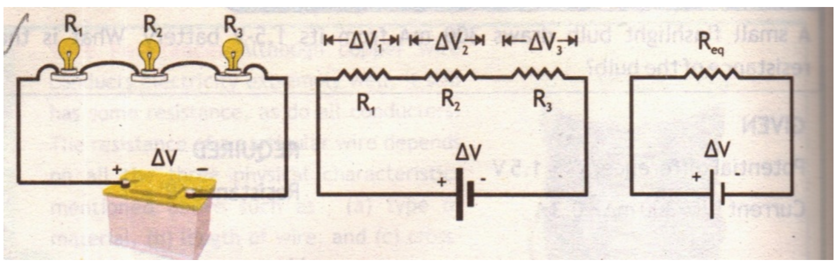
Unit:

The SI unit of resistance is ohm and is represented by Greek letter (omega) Ω. The resistance of wire is one ohm if potential difference of one volt applied across its ends and causes a current of one ampere to flow through it.

$$1\,\Omega = \frac{1V}{1A}$$

Q5. What is series combination of resistors? How we can determine equivalent resistance for different resistors connected in series?

Ans. **Series Combination of resistors:** When the resistors are connected end to end in such a way that there is a single path for the flow of current are said to be connected in series. Three resistors (e.g. light bulbs) having resistances R_1, R_2 and R_3 are shown in the figure as series combination.



(i) In a series connection, the same amount of charge passes through all resistors in a given time interval and therefore current is same in all resistors, such that

$I_1=I_2=I_3=I$ ------------ (1)

(ii) The potential difference applied across the series combination of resistors divides between the resistors:

$\Delta V = \Delta V_1 + \Delta V_2 + \Delta V_3$ ----------- (2)

Since by Ohm's Law, the potential difference across the battery is also applied to the equivalent resistance R_{eq} so,

$\Delta V = IR_{eq}$

Where R_e is the equivalent resistance; a single resistor that has the same effect on the circuit as the series combination of all resistors when it is connected to the battery. Therefore, the voltage across each resistor by Ohm's Law can be written as

$\Delta V_1 = I_1R_1$ and $\Delta V_2 = I_2R_2$ and $\Delta V_3 = I_3R_3$

Hence equation 2 can be written as $IR_e = 1_1R_1 + 12R_2 + 13R_3$ ------------ (3)

Putting equation 1 in equation 3, we get

$IR_e = IR_1 + IR_2 + IR_3$

Or

$IR_e = I(R_1 + R_2 + R_3)$

Therefore, $R_e = R_1 + R_2 + R_3$ ------------ (4)

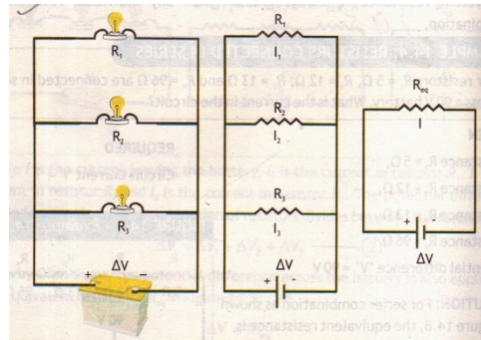
(iii) Generally for 'n' number of resistors connected in series

$R_e = R_1 + R_2 + R_3 +$ ------------ $+R_n$ --------- (5)

From equation (4) and equation (5), it is clear that in series combination the equivalent resistance is always greater than any individual resistance in combination.

Q6. What is parallel combination of resistors? How we can determine equivalent resistance for different resistors connected in parallel?

Ans. <u>Parallel Combination of resistors:</u>



When the resistors are connected in different branches of the circuit in such a way that there is more than one path for the flow of current, resistors are said to be connected in parallel. Consider three light bulbs as resistors having resistance R_1, R_2 and R_3 are shown in the figure as parallel combination.

(i) In a parallel combination of resistors the potential difference across each resistor is the same (since their ends are connected) while the current is split between them since it has multiple available paths.

$\Delta V_1 = \Delta V_2 = \Delta V_3 = \Delta V$ ----------- (1)

Where ΔV is the terminal voltage of the battery, ΔV_1 is the voltage across resistor R_1, ΔV_2 is the voltage across resistor R_2 and ΔV_3 is the voltage across resistor R_3.

(ii) The total current I in parallel combination of resistors divide between the resistors:

$I = I_1 = I_2 = I_3$ ------------ (2)

Since by Ohm's Law, the current in the equivalent resistance R_{eq} in Figure is

$I = \frac{V}{R_{eq}}$

Where R_e is the equivalent resistance; a single resistor that has the same effect on the circuit as the parallel combination of all resistors when it is connected to the battery. Therefore, the current through each resistor by Ohm's Law is

$$I_1 = \frac{V_1}{R_1} \text{ and } I_2 = \frac{V_2}{R_2} \text{ and } I_3 = \frac{V_3}{R_3}$$

Hence equation (2) can be written as

$\frac{V}{R_e} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$ ---------------- (3)

Putting equation (1) in equation (3) we get

$$\frac{V}{R_e} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

Or

$$\frac{V}{R_e} = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

Therefore

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \text{ ---------------- (4)}$$

(iii) Generally for 'n' number of resistors connected in parallel

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots\ldots + \frac{1}{R_n} \text{ ---------------- } (5)$$

From equation (4) and equation (5) it is clear that in parallel combination the equivalent resistance is always smaller than any individual resistance in combination.

Q7. Explain the factors on which the resistance of metallic conductor depends.

Ans: Factors on which Resistance depends:

Since the resistance is provided by collisions of the free electrons with the lattice atoms, thus, any factor that affects the number of collisions will also affect a material's resistance. These factors include

1. Length
2. Cross-sectional Area
3. Temperature
4. Material

Explanation:

1. The resistance 'R' of a conductor depends upon the length 'L' of the conductor. Resistance is directly proportional to the length. So resistance increases with increase in length of conductor and vice versa. i.e.

   $R \propto L$

2. The resistance 'R' of a conductor also depends upon the area of cross-section 'A' of the conductor. Resistance is inversely proportional to the area of cross-section. So resistance decreases by increasing the area of cross-section of conductor and vice versa. i.e.

$$R \propto \frac{1}{A}$$

3. The resistance of a conductor also depends upon the temperature of a conductor. As temperature increases the resistance of conductor also increases and vice versa.

4. The resistance of a conductor also depends upon nature of material of conductor. As, by keeping length cross-sectional area and temperature constant, resistance also varies by using different materials. (i.e. silver, copper, iron)

Q8. What are Ohmic and non-Ohmic devices? Sketch and interpret the VI characteristic graph to justify metallic conductor, filament lamp and thermistor as ohmic or non-ohmic materials.

Ans <u>Ohmic Conductors:</u>

The conductors or materials for which Ohm's law hold are called ohmic conductors. Thus, these conductors obey

$I \propto \Delta v$

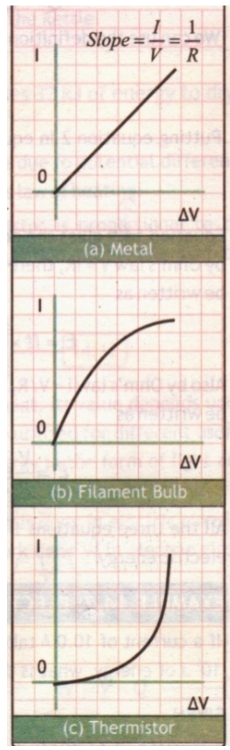
It means that if we plot a graph between current "I" and potential difference "ΔV" (called IV graph), for constant resistance, we will get a straight line with slop $\frac{1}{R}$ as shown in graph 14.1 (a). Only metals show ohmic behavior.

Non-Ohmic Conductor:

The Conductors or materials for which ohm's law does not holds are called non-ohmic conductors. The graph of "I" versus "ΔV" for such materials are non-linear, as shown in graph. Some examples of ohmic and non-ohmic materials and devices are as follow:

A. Metallic Conductors:

For metallic conductors and some alloys, the graph of 'I' verses 'V' is a straight line as shown in graph (a). For example, when the potential difference doubled, the current through metallic conductors also doubles.



(a) Metal
(b) Filament Bulb
(c) Thermistor

B. Filament Bulb:

The graph of filament bulb shows that current saturates as it is increased and at large value even a large change in voltage V will show small change in current I as shown in graph (b). This is because the tungsten wires in the filament of the bulb heats up with the increase in applied potential difference and free electrons collide more with lattice atoms causing the resistance to increase and consequently the rate and the rate of change in current decreases.

C. Thermistor:

Thermistor is a device whose resistance changes significantly (highly) with temperature. Usually thermistor's resistance decreases with increase in temperature. The IV Graph of the thermistor shows that resistance decreases sharply. Thus, at a large value even for a small change in applied voltage ΔV, it will show a large change in current I as shown in graph (c).

Q.9 Explain the concept of electric energy and electric power. What is the commercial unit for the consumption of electric energy?

Ans: <u>Electrical Energy:</u>

The electrical energy lost or work done by a charge Q, going through a potential difference V, can be written as

$$V = \frac{W}{Q} = \frac{E}{Q}$$

Or

E=Q×V ----------------------- eq (1)

We can use the definition of current

$$I = \frac{Q}{t}$$

Or

Q= I xt -------------------------eq(2)

Putting equation (2) in equation (1), we get

E= I xt×V --------------------eq (3)

Equation (3) gives the equation for electrical energy consumed in a device. Also by Ohm's law V=IR, therefore, the electrical energy E from equation (3) can also be written as

E= I xt×IR or $E=I^2Rt$ ------------------eq(4)

Also by Ohm's law I=V/R, therefore, electrical energy from equation (3) can also be written as

$$E = \frac{V}{R}t \times V$$

Or

$$E = \frac{V^2}{R}t \; ------ \text{eq}(5)$$

All the three equations (3), (4), and (5) are equally valid for calculation of electric energy.

Unit of Electric Energy:

The unit of energy is joule or kilowatt-hour.

Kilowatt- hour (kWh) /Commercial unit of Electric energy:

The electric meter in our homes measures energy (in kWh). Electrical energy is consumed in large quantities for which joule is a very small unit; therefore, kilowatt-hour (kWh) is preferred. It is the amount of energy consumed by a device of power 1kW running continuously for one hour

E =1kWh

=1000 W x 1hr

$=1000 \frac{J}{s} \times 3600s$

$E = 3.6 \times 10^6$ J

kWh is the unit for which the tariff (cost of electricity) is decided by electricity supply company.

Electric Power:

The time rate at which the work is done in electric circuit is called electric power. The electric power is the work done W in electric circuit divided by time t.

Mathematically,

$$P = \frac{W}{t} \; ----eq(1)$$

By definition of electric potential V

$V = \frac{W}{Q}$ or W=V× Q ------------eq(2)

By definition of current

$$I = \frac{Q}{t}$$

Or

Q= I xt ----------eq(3)

Putting equation (3) in equation (2), we get W=V$\times$ Ixt ---------------------eq(4)

Putting equation (4) in equation (1), we get

$$P = \frac{V \text{ x } Ixt}{t}$$

Or

P=IV --------- eq (5)

Equation (5) gives the relation for electric power. As by Ohm's law V=IR, therefore, the electrical power P from equation (5) can also be written as

$$P = I \times IR \quad \text{or} \quad P = I^2R \text{-----------eq (6)}$$

Also by Ohm's law I=V/R, therefore, electrical power from equation (5) can also be written as

$$P = \frac{V}{R} \text{x} V \qquad \text{or} \qquad P = \frac{V^2}{R} ------eq(7)$$

All three equations (5), (6) and (7) are equally valid for calculation of electric power.

Units of Power:

The S.I unit for electrical power is watt (W). A Power of 1W is said to be consumed in an electrical circuit if potential difference of 1V, causes a current of 1A to flow through a circuit.

1W= 1A x 1V

Q.10 State the function of live, neutral and earth wires in domestic main supply.

Ans. In domestic electrical connections, we have three different types of wires:
Live wire, Neutral wire and Earth wire.

1. **Live Wire:**

   The live wire carries current to the appliance at a high voltage. In fact, it is that carries the 220V AC used by most of our home appliances.

2. **Neutral Wire:**

   The neutral wire completes the circuit and carries current away from the appliance. (This simply means that the current should flow from a source, through the appliance and back to source). The neutral wire is earthed at the local sub- station and so there is no potential difference between it and earth. (i.e. 0V)

3. **Earth Wire:**

   The Earth wire is a safety wire and connects the metal case of the appliance to the earth. The earth wire is for our protection; in case the wire makes a contact with mental casing of an appliance. When this happens, the current will pass to the earth instead of our body, thus saving us.

Q.11 Explain why the domestic appliances are connected in parallel?

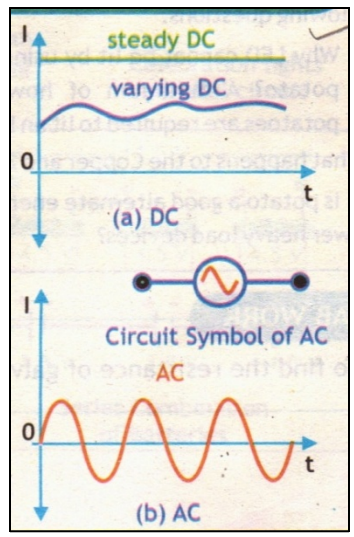
Ans. In domestic appliances, we use parallel circuit, because in parallel circuit the potential difference or voltage remains the same. So we can operate any appliance (i.e.TV, refrigerator, fan) any time due to same voltage.

If we use series circuit, then the potential difference or voltage will be divided into parts. Under such conditions appliances like refrigerator, electric iron etc. cannot be operated at low voltage.

In case of parallel circuit each appliance can be turn ON and OFF independently and we can operate any appliance according to our need and desires. In case of series circuit, if we switch ON the circuit, everything connected in the circuit will turn ON and vice versa.

Q.12 Differentiate between alternating current and direct current.

Ans. Direct Current (DC):



In a direct current (DC), the charge flows in one direction only. Graphs for steady DC and varying DC are shown in figure (a). The current from cell or battery is direct current because of fixed positive and negative terminals.

Alternating current (AC):

In an alternating current (AC), the direction of charge flow, reverses regularly and therefore, the current also changes direction, as shown in the graph in figure (b). When alternating voltage is applied, the current first flows in one direction and then in the opposite direction.

The direction of current in the circuit depends upon the charging polarity of alternating voltage source. The circuit symbol for AC is also given in figure (b). Electric generators can produce either DC or AC.

Or

Direct Current	Alternating Current
In direct current (DC), electric charge flow only in one direction.	In alternating current (AC), flow of electric charge changes its direction periodically.
Direct current (DC) cannot transfer at long distance because of very large energy loss.	Alternating current (AC) safe to transfer over long distance and can provide more power.
Direct current (DC) is the current of constant magnitude.	Alternating current (AC) is the current magnitude varying with time.
Direct current (DC) provides a constant voltage or current.	In alternating current (AC), the voltage level also reverses along with the current.
The frequency of direct current (DC) is zero.	The frequency of alternating current (AC) is 50Hz or 60Hz depending upon country.
The source of availability is battery or cell.	Alternating current (AC) is obtained from generator or mains.

Q.13 What are the hazards of electricity? What safety measures are taken in household electricity to safeguard for these hazards?

Ans. <u>Electricity Hazards:</u>

1. Electric Shock:

Electric shock occurs if current flows from an electric circuit through a person's body to earth. This can happen if there is a damaged insulation or faulty wiring. The typical resistance of dry skin is about 10,000Ω, so if a person touches a wire carrying electricity at 240 V, an estimate of the current flowing through them to earth would be I= V/R = 240/10,000 =0.024A = 24 mA. For wet skin, the resistance is lowered to about 1000 Ω (since water is a good conductor of electricity) so the current would increase to around 240 mA.

It is the size of the current (not the voltage) and the length of time for which it acts, which determines the strength of an electric shock.

The path the current takes influences the effect of the shock; some parts of the body are more vulnerable than others. A current of 100 mA through the heart is likely to be fatal. Damp conditions increase the severity of an electric shock because water lowers the resistance. Wearing rubber-soled shoes or standing on a dry insulating floor increases the resistance between a person and earth and will reduce the severity of an electric shock.

1. Safety Measures:

- Switch off the electrical supply to an appliance before starting repairs.
- Use plugs that have an earth pin and a cord grip; an insulating casing (a rubber or plastic case) is preferred.
- Do not allow appliances or cables to come into contact with water. For example, it is dangerous to hold a hair straightener with wet hands in a bathroom. Keep electrical appliances well away from baths tubs and wash basins.
- Do not have long cables trailing across a room, because the insulation can become damaged.

2. Fire Risk:

If the electrical wiring in the walls of house becomes overheated, a fire may start. Wires become hot when they carry electrical currents-the larger the current carried, the hotter a particular wire will become, as we studied in joules law.

Safety Measures:

To reduce the risk of fire through overheated cables, the maximum current in a circuit should be limited by taking these precautions:

- Use Plugs that have a correct fuse.
- Do not attach too many appliances to a circuit (for example an extension box).
- Don't overload circuits by using too many adapters.
- Thick wires have lower resistance, therefore appliances such as heaters requiring large amounts of power (and hence current) must not be operated with thin wires.

- Damaged insulation or faulty wiring which leads to a large current flowing to earth through flammable material can also start a fire.

CONCEPTUAL QUESTIONS

Give a brief response to the following questions.

Q1. As water is made of atoms having protons (charge +e) and electrons (charge-e), does the water flowing through pipe carry an electric current? Explain.

Ans: All matter is made up of atoms. Each atom as a whole is neutral i.e. number of electrons in an atom is equal to the number of protons. Since electron and proton both carry equal and opposite charges, so they neutralize each other. The same is the case with water molecules, it consists of two hydrogen atoms and one oxygen atom. The water molecules as a whole is neutral, as it is composed of neutral atoms. Thus, pure water with no impurities is a good insulator. So, water flowing through a pipe does not carry any current, as no net charge flows in it. And, current is the rate of flow of a net charge through a conductor.

Q2. A car has two headlights, when the filament in one headlight burns out, the other headlight stays on. Are the headlights connected in series or in parallel?

Ans: For serious combination, current flows along a single path. On the other hand, for parallel combination, there are more than one path for the flow of electric current.

Car headlights are connected in parallel. That's why when the filament of one headlight burns outs, the other headlight stays on. If they were in series, one bulb burning out would break the circuit and both would go out when the filament of one failed.

Q3. Qurat-ul-Ain needs a 100-Ω resistor for a circuit, but she only has a box of 300-Ω resistors. What can she do?

Ans: If she connects them in parallel with one another, then the total resistance decreases. This is possible, if she takes three resistors of300 Ω and connect them in parallel. The equivalent resistance in this case will be exactly equal to 100 Ω. The equivalent resistance of three resistors connected in parallel is given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{eq}} = \frac{1}{300} + \frac{1}{300} + \frac{1}{300}$$

$$\frac{1}{R_{eq}} = \frac{1+1+1}{300}$$

$$\frac{1}{R_{eq}} = \frac{3}{300}$$

$$\frac{1}{R_{eq}} = \frac{1}{100}$$

$\Rightarrow R_{eq}$=100Ω

Thus, the parallel combination of three resistors each of 300Ω is equivalent to 100 Ω.

Q4. A number of light bulbs are connected to a single power outlet. Will they provide more illumination when connected in series or in parallel? Why?

Ans: To get more illumination from bulb they must be connected in parallel because in parallel combination,

1. The potential difference across each bulb remains the same means undivided.
2. The equivalent resistance decreases in parallel combination.
3. By switching OFF any bulb, there is no effect on the brightness of the other bulbs.

Q5. Explain why light bulbs almost always burn out just as they are turned on and not after they have been on for some time.

Ans: Incandescent light bulbs are most likely to burn out when they have just been turned ON. The metallic filament of an incandescent bulb works by resisting the flow of electric current. This resistance causes the filament to get very hot, to the point that it gives OFF both heat and light.

Most conductive materials carry current better when they are cold. Thus, when we first turn an incandescent bulb ON, the initial flow of electricity called the in-rush current is quite high, as the filament heats up its resistance increases. Due to this high current, more power is dissipated in the form of heat and light and the bulb filament burns out. Once the bulb is shiny, the temperature is staying relatively constant and the filament us un-likely to break.

Q6. Explain why is it possible for birds to perch safely on high tension wires without being electrocuted?

Ans: The reason is that a bird to perch on a high voltage wire has the two claws at same potential. Due to zero potential difference between the two claws, no current flow through the body of the bird therefore, the bird is not electrocuted.

Q7. An electrician working on "live" circuits wears insulated shoes and keeps one hand behind his or her back. Why?

Ans: Wearing insulated shoes increase the overall resistance of the worker which reduces the dangers of electric shock. The electrician working on live wire keeps his other hand behind for safety purposes. If he keeps one hand on live wire and the other hand on neutral or on other conducting material (i.e. earth) he will get an electric shock. The Possibility of touching ground or other conductor, the electrician keeps his one hand on his back. In this way, he can work safely without any danger of electric shock.

Q8. Explain why is it dangerous to turn on a light bulb when you are in a bath tub?

Ans: The human body is a good conductor of electricity and current may pass through his/her body when touches switch because the bathtub is at the earth which is at zero potential, where the switch is at high potential. Therefore, when a person in a bathtub he/she should avoid to turn ON the switch of light bulb because he/she, may get an electric shock.

Q9. Why circuit breaker, fuses and switches are installed to 'live wire'?

Ans. Circuit breakers, fuses and switches are used to protect an electric circuit from damage caused by an excess current flow due to a fault, over load or short circuit.

As basic function is to stop the current flow after fault is detected. If we want to have a better control over electricity we have to control it from its source i.e. live wire.

Live wire has a potential difference of 220 volt with respect to neutral wire of zero potential. Electric current enters our homes through live wire and leaves through neutral. Therefore, circuit breakers, fuses and switches should be installed on the live wires to control current at the very beginning.

Due to excess current flow the circuit breakers trip and fuses may blow and opens the circuit. So, they will disconnect the appliance from high voltage live wire.

ASSIGNMENTS

14.1 While starting an engine of a truck, its battery sets 720C of charge in motion for 4. 00sec.How much current is flowing?

Given data:

Charge=ΔQ=720 C

Time =Δt=4.00 sec

Required:

Current =I=?

Solution:

We know that

$$I = \frac{\Delta Q}{\Delta t}$$

Putting values

$$I = \frac{720}{4.00}$$

$$I = 180\ A$$

14.2 A heating element on an electric range operating on 240V has a resistance of 30.0Ω. What current does it draw?

Given data:

Potential difference=V=240V

Resistance=R=30.0 Ω

Required:

Current=I=?

Solution:

We know that

V=IR

$$\Rightarrow I = \frac{V}{R}$$

Putting values, we get

$$I = \frac{240}{30.0}\,A$$

$$I = 8A$$

14.3 Calculate the resistance of wire when the current through it is 2.0 A and the voltage across its end is 3.0 V.

Given data:

Current =I=2.0A

Potential difference=V=3.0V

Required:

Resistance of wire=R=?

Solution:

We know that

V=IR

$$\Rightarrow R = \frac{V}{I}$$

Putting values, we get

$$R = \frac{3.0}{2.0}\Omega$$

$$R = \frac{3}{2}\Omega$$

$$R = 1.5\ \Omega$$

14.4 Four resistors all having similar resistance of 15 Ω are connected in series across a 30V battery. What is the current in the circuit?

Given data:

Resistance =R_1=15 Ω

Resistance =R_2=15 Ω

Resistance =R_3=15 Ω

Resistance =R_4=15 Ω

Voltage =V=30 V

Required:

Circuit current=I=?

Solution:

For series combination the equivalent resistance is

$$R_{eq} = R_1 + R_2 + R_3 + R_4$$

Putting values

$$R_{eq} = 15 + 15 + 15 + 15$$

$$R_{eq} = 60\ \Omega$$

By ohm's law

$$V = IR_{eq}$$

$$I = \frac{V}{R_{eq}}$$

Putting values

$$I = \frac{30}{60} A$$

$$I = 0.5\ A$$

14.5 Three resistors of 60Ω, 30 Ω and 20 Ω are connected in parallel across a 90 V battery. Calculate the current flowing through the circuit.

Given data:

Resistance $=R_1=60\ \Omega$

Resistance $=R_2=30\ \Omega$

Resistance $=R_3=20\ \Omega$

Voltage of battery=V= 90V

Required:

Current in circuit=I=?

Solution:

For parallel combination the equivalent resistance of the circuit is

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Putting values

$$\frac{1}{R_{eq}} = \frac{1}{60} + \frac{1}{30} + \frac{1}{20}$$

$$\frac{1}{R_{eq}} = \frac{1 + 2 + 3}{60}$$

$$\frac{1}{R_{eq}} = \frac{6}{60}$$

$$\Rightarrow R_{eq} = \frac{60}{6}\ \Omega$$

$$R_{eq} = 10\ \Omega$$

Now the current flowing through circuit is given by

$$V = IR_{eq}$$

$$I = \frac{V}{R_{eq}}$$

Putting values

$$I = \frac{90}{10} A$$

$$I = 9.0\ A$$

14.6 For how long a clothes dryer is operated, if it uses 32 kJ of energy to dry cloths at 220 V, running 16A of current through it?

Given data:

Energy=E=32 kJ

=32×10^3J

Voltage =V=220V

Current=I=16A

Required:

Time for operating the dryer=t=?

Solution:

We know that

$$E = I \times t \times V$$

$$\Rightarrow t = \frac{E}{I \times V}$$

$$t = \frac{32 \times 10^3}{16 \times 220}$$

$$t = \frac{32 \times 10^3}{3520}$$

$$t = \frac{32 \times 10^3}{3520}$$

$$t = 0.00909 \times 10^3 sec$$

$$t = 9.09\ sec$$

14.7 Calculate the resistance of 40W automobile headlight designed for 12 V.

Given data:

Power=P= 40 W

Voltage =V=12 V

Required:

Resistance=R=?

Solution:

We know that

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

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

Putting values, we get

$$R = \frac{(12)^2}{40}$$

$$R = \frac{144}{40}\,\Omega$$
$$R = 3.6\,\Omega$$

14.8 A 100W bulb is left on, in an outdoor storage room to keep paint from freezing. The 100W rating refers to the power dissipated in the bulb's filament, which is a resistor. If electricity costs 8.11 Rs/ kWh, about how much does it cost to burn the light bulb for three months during winters?

Given data:

Power=P=100W

=0.1×10^3W

=0.1 kW

Time=t=3 months

=90 days

=90×24 hours

=2160 hours

Tariff rate =8.11 Rs/kWh

Required:

Cost of electricity=C=?

Solution:

We know that

Cost of electricity= E× Tariff rate

$cost = P \times t \times \text{Tariff rate}$ (E=P×t)

$$cost = 0.1 \times 2160 \times 8.11$$
$$cost = 1751.76\ Rs$$

NUMERICAL QUESTIONS

1. **A small electric heater has resistance of 15 ohms, when the current in it is 2 amperes. What voltage is required to produce this current?**

Given data:

Resistance=R=15Ω

Current=I=2 A

Required:

Voltage=V=?

Solution:

We know that

$$V = IR$$

Putting values

$$V = 2 \times 15$$
$$V = 30V$$

2. **If a potential difference of 10V is maintained across a 1m length of the Nichrome wire having resistance of 3.1 Ω, what is the current is the wire?**

Given data:

Potential difference =V=10V

Length of wire =L=1m

Resistance=R= 3.1 Ω

Required:

Current in the wire=I=?

Solution:

We know that

$$V = IR$$

$$\Rightarrow I = \frac{V}{R}$$

Putting values, we get

$$I = \frac{10}{3.1}$$

$$I = 3.22A$$

Or

$$I = 3.2\ A$$

3. **What resistor would have a 15mA current if connected across terminals of a 9.0V battery?**

Given data:

Current=I=15mA

$I = 15 \times 10^{-3} A$

Voltage=V=9.0V

Required:

Resistance=R=?

Solution:

We know that

$$V = IR$$

$$\Rightarrow R = \frac{V}{I}$$

Putting values, we get

$$R = \frac{9}{15 \times 10^{-3}}$$

$$R = 0.6 \times 10^{3}\ \Omega$$

$$R = 600.0\ \ \Omega$$

Or $$R = 600\ \ \Omega$$

4. Consider a circuit with three resistors R_1=250.0 Ω, R_2=150.0 Ω , R_3=350.0 Ω, connected in parallel with a 24.0V battery. Find the total current supplied by the battery.

Given data:

Resistance =R_1=250.0 Ω

Resistance =R_2=150.0 Ω

Resistance =R_3=350.0 Ω

Voltage of battery=V=24.0V

Required:

Current in circuit=I=?

Solution:

For parallel combination the equivalent resistance of the circuit is

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Putting values

$$\frac{1}{R_{eq}} = \frac{1}{250.0} + \frac{1}{150.0} + \frac{1}{350.0}$$

$$\frac{1}{R_{eq}} = \frac{1}{250} + \frac{1}{150} + \frac{1}{350}$$

$$\frac{1}{R_{eq}} = \frac{21 + 35 + 15}{5250}$$

$$\frac{1}{R_{eq}} = \frac{71}{5250}\ \Omega$$

$$\Rightarrow R_{eq} = \frac{5250}{71}\ \Omega$$

$$R_{eq} = 73.9\ \Omega$$

Or

$$R_{eq} = 74\ \Omega$$

Now the circuit current is given by

$$V = IR_{eq}$$

$$I = \frac{V}{R_{eq}}$$

Putting values

$$I = \frac{24.0}{74} A$$

$$I = 0.3\ A$$

5. **An electric hair dryer is rated at 1,875 watts when operating on 120Volts. What is the current flowing through it? If the hair dryer is used for 3 minutes, how much energy does it consume?**

Given data:

Power=P=1875 W

Voltage=V=120 V

Time=t=3min

=3×60 sec

=180 sec

Required:

Current=I=?

Energy consumed=E=?

Solution:

We know that

$$P = IV$$

$$\Rightarrow \mathrm{I} = \frac{P}{V}$$

Putting values, we get

$$\mathrm{I} = \frac{1875}{120} A$$

$$\mathrm{I} = 15.625\ A$$

Or

$$\mathrm{I} = 15.6\ A$$

Now, we know that

$$E = P \times t$$

Putting values, we get

$$E = 1875 \times 180$$

$$E = 337500\ J$$

$$E = 337.5 \times 10^{-3}\ J$$

$$E = 337.5\ kJ$$

6. **A battery with an emf of 12 V is connected to a 545 Ω resistor. How much energy is dissipated in the resistor in 65 sec?**

Given data:

Battery emf=V=12V

Resistance=R=545 Ω

Time=t=65 sec

Required:

Energy dissipated=E=?

Solution:

We know that

$$E = P \times t - - - (1)$$

We also know that

$$P = \frac{V^2}{R} - - - (2)$$

Putting eq (2) in eq (1), we get

$$E = \frac{V^2}{R} \times t - - - (3)$$

Putting value in eq (3), we get

$$E = \frac{(12)^2}{545} \times 65$$

$$E = \frac{144}{545} \times 65$$

$$E = 0.264 \times 65$$

$$E = 17.1\, J$$

Or

$$E = 17\, J$$

Energy dissipated=$E = 17$ J

7. **If the unit of electricity cost 8.11 Rs/kWh, what is cost of running two 160 W fans and four 100W light bulbs for 6 hours in school?**

Given data:

Tariff rate=8.11 Rs/kWh

Power of two 160W fans=P_1= (160×2) W

P_1=320 W

Power of four 100 W bulbs=P_2= (100×4) W

P_2=400W

Total power=P=P_1+P_2

P= (320+400) W

P=720 W

P=0.720×10^3 W

P=0.720 kW

Time=t=6 hours

Required:

Cost of electricity=C=?

Solution:

We know that

Cost of electricity= E× Tariff rate

$cost = P \times t \times$ Tariff rate (E=P×t)

$$cost = 0.720 \times 6 \times 8.11$$
$$cost = 35.0\ Rs$$

Cost of electricity consumed=35.0 Rs