Ch-12
Electricity

Charge
It is a characterstic unit of matter by means of which matter experiences electric forces. It can be either negative (electron) or proton (positive)

"coulumb" is the SI unit of charge, represented by C.

One coulomb is defined as that amount of charge which repels an equal and similar charge with a force of 9×10^9 N when placed in a vaccum at a distance of 1 meter from it.
charge on an electron = -1.6×10^{-19} coulomb.

Net Charge (Q) - Total Charge

1C Net charge is equivalent to the charge contained in nearly 6×10^{18} electrons.

$\boxed{Q = ne}$ (n is number of electrons)

Static and current electricities :- static electricity deals with the electric charges at rest while the current electricity deals with the electric charges in motion.

Conductor :- The materials which can allow the flow of electrons through itself is called conductor. It has large number of free

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electrons For eg:- copper, silver, aluminium etc.

Insulator:- The material which cannot allow the flow of electrons through itself is called insulator.
It has less or no free electrons. For example; rubber, glass, plastic, ebonite etc.

Electric Current is expressed as the amount of charge flowing through a particular area in unit time.

- Quantitively, electric current is defined as the rate of flow of electric charge.

- Current, $I = \frac{\text{Charge flowing } (Q)}{\text{Time taken } (t)}$

- The S.I unit of current is ampere (A), where 1 ampere = 1 coloumb / second.

- Ampere → defined as one coulomb of charge flowing per second.

- Smaller units :- $1 mA = 10^{-3} A$, $1 \mu A = 10^{-6} A$

- Ammeter :- It is device to measure current in a circuit. It is always connected in series in a circuit.

Conventional current: conventionally, the direction of motion of positive charges is taken as the direction of current. The direction of conventional current is opposite to that of the negatively

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charged electrons.

Electrostatic potential :- Electrostatic potential at any point in an electric field is defined as the amount of work done in bringing a unit positive charge from infinity to that point. Its unit is volt. Positive charges move from higher to lower potential regions. Electrons, being negatively charged, move from lower to higher potential regions

Electrical potential difference :- (pd) between two points in an electric ~~current~~ circuit, carrying some current, is the amount of work done to move a unit charge from one point to another.

- Potential difference, pd = $\frac{\text{work done (W)}}{\text{Quantity of charge moved (Q)}}$
- The S.I unit of pd is volt (V), where 1 volt = 1 Joule/Coulomb.
- **One volt** → When 1 joule of work is done in carrying one coulomb (1C) of charge from one point to another of a current carrying conductor then the potential difference is said to be 1V.
- Voltmeter → It is a device to measure potential difference. It is always connected in parallel to the component across which the potential difference is to be measured.

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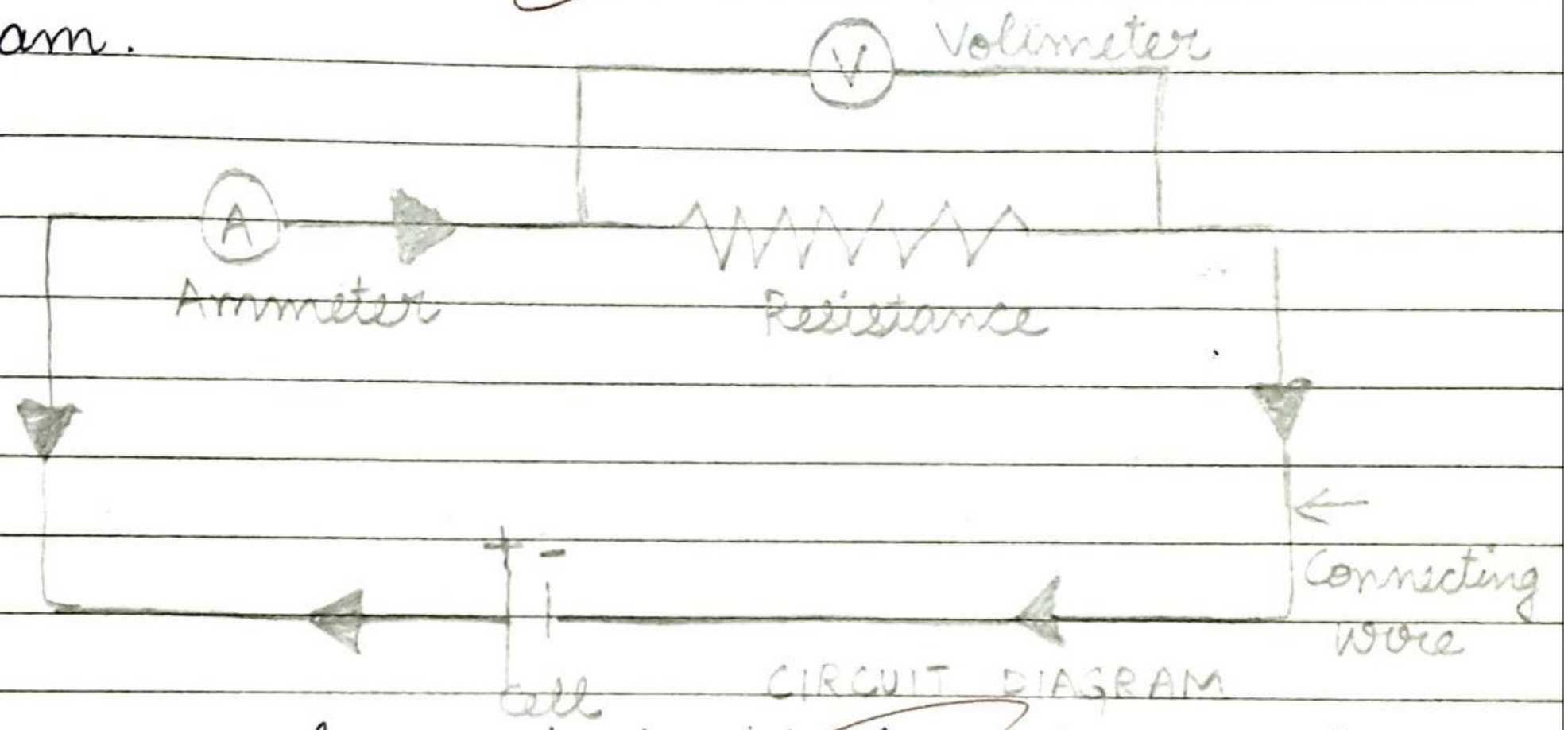
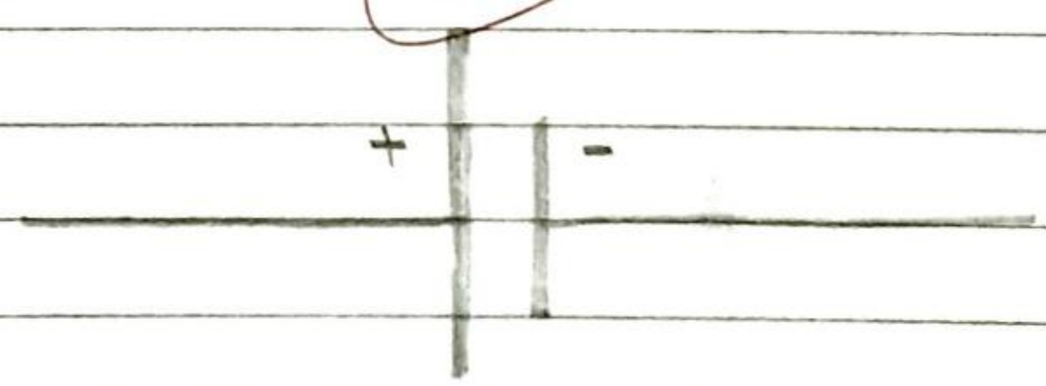
Electric circuit :- A continuous conducting path between the terminals of a source of electricity is called an electric ~~current~~ circuit

- A drawing showing the way various electric devices are connected in a circuit is called a circuit diagram.



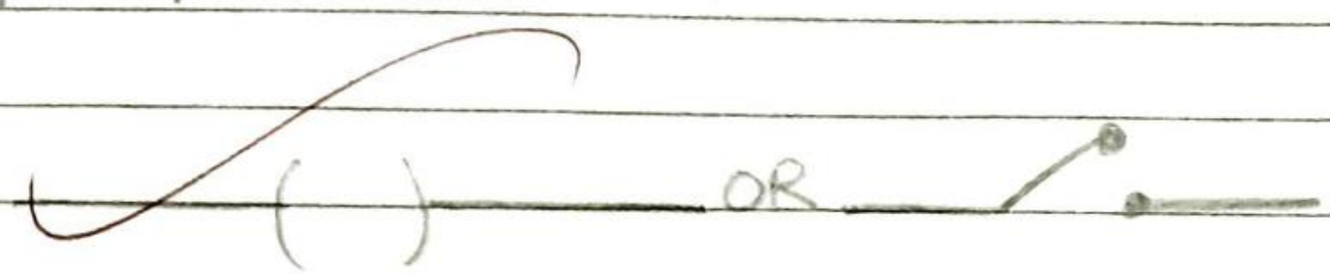
- Some commonly used circuit elements are given below:-

1. Cell



2. Battery

3. Key (switch) open.



4. Key (closed)

5. Joint wire

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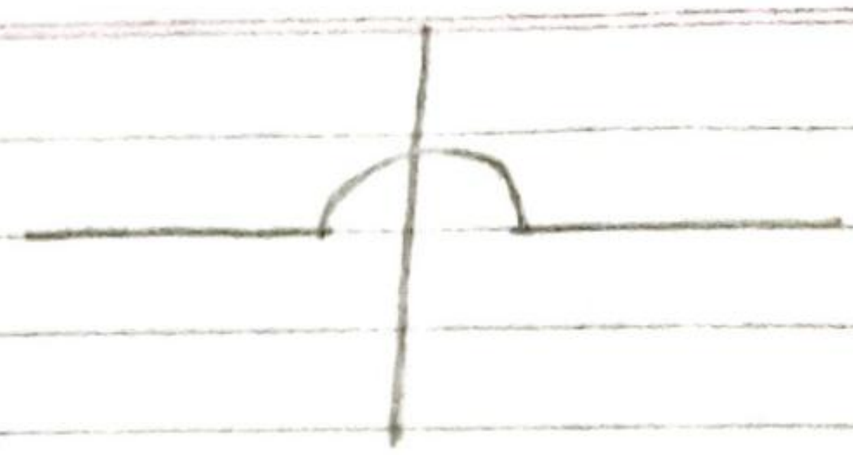
(6) wires with no join 

(7) Bulb

NCERT Ques/Ans

Ques 1:- What does an electric circuit mean?

Ans. A continuous closed path made of electric components through which an electric current flows is known as an electric circuit. A simple circuit consists of the following components :-

(a) Conductors
(b) Cell
(c) Switch
(d) Load

Ques 2 - Define the unit of current.

Ans The unit of current is ampere. Ampere is defined by the flow of one coulomb of charge per second.

Ques 3 - Calculate the number of electrons constituting one coulomb of charge?

Ans. The value of charge of an electron is $1.6 \times 10^{-19} C$. According to the charge quantization, $Q = ne$ where n is the number of electrons and e is the charge of an electron.

Substituting the values in above equation, the number of electrons in a coulomb of charge can be calculated as follows:-

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$1C = n \times 1.6 \times 10^{-19}$

$$n = \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18}$$

Therefore, the number of electrons constituting one coulomb of charge is 6.25×10^{18}.

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Q1. Name the device that helps to maintain a potential difference across the conductor.

Ans. Battery consisting of one or more electric cells is one of the devices that help to maintain a potential difference across a conductor.

Q2. What is meant by the saying that the potential difference between two points is 1V?

Ans. When 1 J of work is done to move a charge of 1C from one point to another, it is said that the potential difference between two points is 1V.

Q3. How much energy is given to each coulomb of charge passing through a 6v battery?

Ans. We know that the potential difference between the two points is given by the equation,

$V = W/Q$ where,

W is the work done in moving the charge from one point to another. Q is the charge from the above equation, we can find the energy given to each coulomb as follows:-

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$W = V \times Q$

Substituting the values in the equation, we get

$W = 6V \times 1C = 6J$

Hence, 6J of energy is given to each coulomb of charge passing through a 6V of battery.

OHM's LAW

This law states that the current passing through a conductor is directly propotional to the potential difference cross its ends, provided the physical conditions like temperature, density etc. remains unchanged.

$$V \propto I \text{ or } V = RI$$

Where "R" is the proportionality constant for the given metal at given temperature and is called resistance

RESISTANCE

It is the property of a conductor to resist the flow of charges through it. Or it is the property of a conductor that opposes the flow of current. It is represented by 'R' and symbol is Ω

S.I unit of resistance is "Ohm".

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

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- **OHM** :- It is the S.I unit of resistance. A conductor has a resistance of one ohm. if a current of one ampere flows through it on applying potential difference of one volt across its ends.

$$1 \text{ ohm} = \frac{1 \text{ Volt}}{1 \text{ Ampere}} \quad \text{or} \quad 1\,\Omega = \frac{1V}{1A}$$

- **Resistor** :- A component that is used to resist the flow of electrons in the circuit is called resistor. In practical application, resistors are used to increase or decrease the electric current

- **Variable resistance** :- The component of an electric circuit which is used to regulate the current without changing the voltage from the source, is called variable resistance

- **Rheosat** :- This is a device used to provide variable resistance. Represented by "Rh".

- Factors on which resistance of a conductor depends:- The resistance R depends of a conductor) :-

i) Directly on its length L i.e $R \propto L$ $R \propto L$
ii) inversely on its area of cross section A i.e $R \propto 1/A$
iii) on the nature of material of the conductor on. On combining the above factors, we get

$R \propto \frac{L}{A}$ $\quad R \propto \frac{L}{A}$ $\quad \boxed{R = \rho \frac{L}{A}}$

The proportionality constant (rho) ρ is called

resistivity of conductor.

- **Resistivity** :- It is defined as the resistance offered by a cube of a material of side 1m when current flows perpendicular to its opposite faces. Its S.I unit is ohm-meter (Ωm)

- **Resistivity** $\rho = \frac{RA}{L}$

- Resistivity of an alloy (homogeneous mixture of metals) is generally higher than of its constituent. Example - Constantan (Alloy of Cu & Ni)

- Alloys have high resistivity and donot oxidize (burn) readily at high temperature, for this reason they are commonly used in electrical heating devices, like electric iron, heater, toasters etc. For example "Tungsten" as filament of electric bulb.

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Ques 1. On what factors does the resistance of a conductor depend?

Ans The resistance of the conductor depends on the following factors:-

a. Temperature of the conductor.
b. Cross-sectional area of the conductor
c. Length of the conductor
d. Nature of the material of the conductor.

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Ques2. Will current flow more easily through a thick wire or a thin wire of the same material, when connected to the same source? why?

Ans. Resistance is given by the equation,

$R = \rho \frac{l}{A}$ where,

ρ is the resistivity of the material of the wire,
l is the length of the wire.
A is the area of the cross-section of the wire.

From the equation, it is evident that the area of the cross section is inversely propotional to the resistance

Therefore, thinner the wire, more the resistance and vice-versa. Hence, current flows more easily through a thick wire than a thin wire

Ques3. Let the resistance of an electrical component remain constant while the potential difference across the two ends of the component decreases to half of its former value. What change will occur in the current through it?

Ans. The change in the current flowing through the electrical component can be determined by Ohm's law

$$I' = \frac{V'}{R'} = \left(\frac{\frac{V}{2}}{R}\right) = \frac{1V}{2R} = \frac{1}{2}$$

According to Ohm's Law, the current is given by

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

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Now, the potential difference is reduced to half keeping the resistance constant,
Let the new voltage be $V^2 = \frac{V}{2}$

Let the new resistance be $R' = R$ and the new amount of current I'.

The change in the current can be determined using Ohm's Law as follows:
Therefore, the current flowing through the electrical component is reduced by half.

Ques 4. Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal?

Ans. The melting point of an alloy is much higher than a pure metal because of its resistivity. At high temperatures, alloys donot melt easily / readily Therefore, alloys are used in heating appliances such as electric toasters and electric irons.

Ques 5. Use the data in the table given below and answer the following questions :-

	Materials	Resistivity (Ωm)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}

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Alloys	Manganese	1.84×10^{-6}
	constantan (alloy of Cu & Ni)	49×10^{-6}
	Manganin (alloy of Cu, Mn & Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn, Fe)	100×10^{-6}
Insulators	Glass	$10^{-10} - 10^{14}$
	Hard Rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

a) Which among iron and mercury is a better conductor
b) Which material is the best conductor?

Ans a) Iron is a better conductor than mercury because the resistivity of mercury is more than the resistivity of iron.

b) Among all the materials listed in the table, Silver is the best conductor because the resistivity of silver is lowest among all, i.e, 1.60×10^{-8}.

Ques6 Explain the following:-

a. Why is the tungsten used almost exclusively for filament of electric lamps?

b. Why are the conductors of electric heating devices, such as bread toasters and electric irons, made of an alloy rather than a pure metal?

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In case of series arrangement, if one electric appliance fails to then the entire the circuit is switched off

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(c) Why is the series arrangement not used for domestic circuits?

(d) How does the resistance of a wire vary with its area of cross section?

(e) Why are copper and aluminium wires usually employed for electricity transmission?

Ans a) The resistivity and melting point of tungsten is very high. Due to this property, it doesn't burn readily when heated. Electric lamps operate at high temperature. Hence, tungsten is a choice of metal for the filament of electric lamps.

b) The conductors of electric heating devices are alloys because of their high resistivity. Due to its high resistivity it produces large amount of heat.

c) Resistance is inversely propotional to the area of cross section. When the area of cross section increases the resistance decreases and vice versa

d) Copper and aluminium are good conductors of electricity and have low resistivity because of which they are usually employed for electricity transmission.

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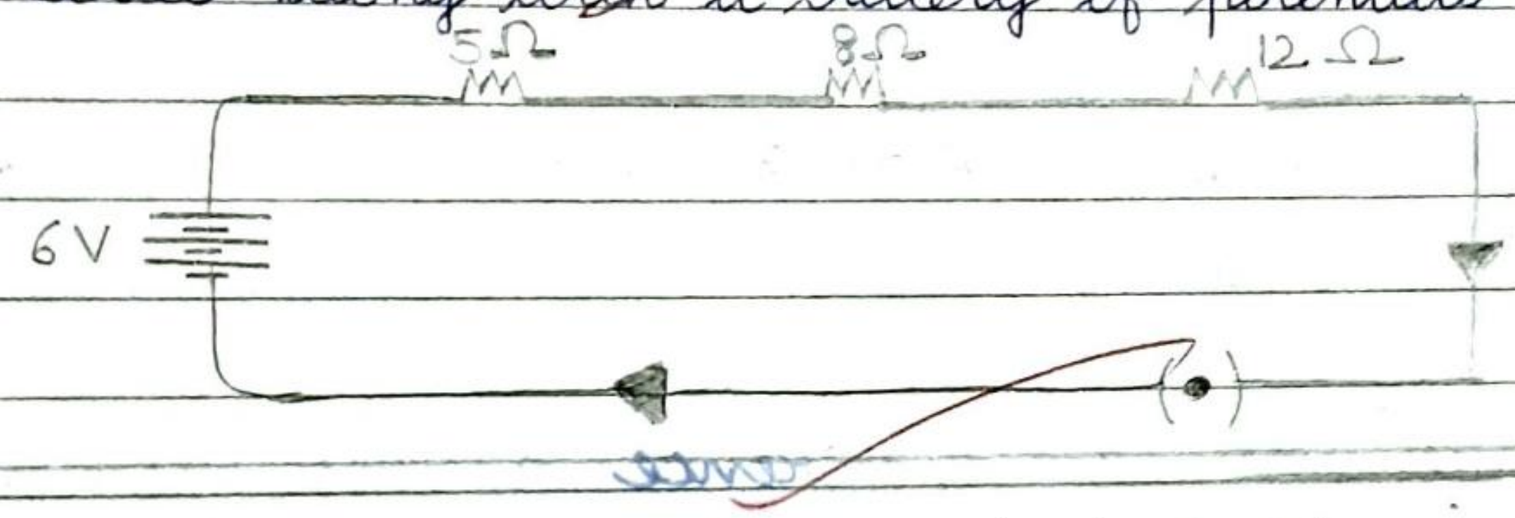
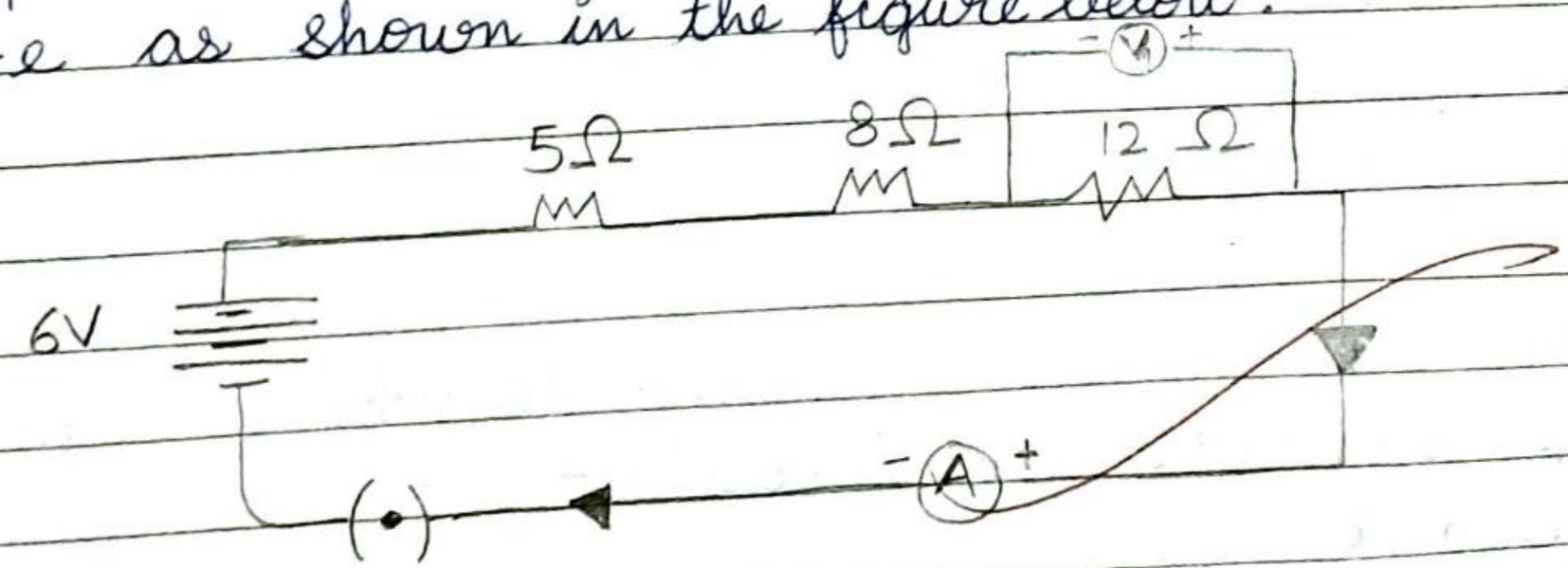
Ques1 Draw a schematic diagram of a circuit consisting of a battery of three cells of 2V each, a 5 Ω resistor, a 8 Ω resistor and a 12 Ω resistor, and a plug key all connected in series.

Ans. A battery of three cells of 2V each equals to battery of potential 6V. The circuit diagram below shows three resistors of resistance 12 Ω, 8 Ω and 5 Ω connected in series along with a battery of potential 6V.



Ques2 Redraw the circuit of Question 1, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the potential difference across the 12 Ω resistor. What would be the readings in the ammeter and the voltmeter.

Ans. An ammeter should always be connected in series with resistors while the voltmeter should be connected in parallel to the resistor to measure the potential differenc-e as shown in the figure below.



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using Ohm's Law, we can obtain the reading of the ammeter and the voltmeter

The total resistance of the circuit is $5\,\Omega + 8\,\Omega + 12\,\Omega = 25\,\Omega$

we know that the potential difference of the circuit is 6V, hence the current flowing through the circuit or the resistors can be calculated as follows :-

$$I = \frac{V}{R} = \frac{6}{25} = 0.24A$$

Let the potential difference across the $12\,\Omega$ resistor be V_1

From the obtained current, VI can be calculated as follows :-

$V_1 = 0.24A \times 12\,\Omega = 2.88V$ (using $V = IR$)

Therefore, the ammeter reading will be 0.24A and the voltmeter reading be 2.88 V.

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Ques1:- Judge the equivalent resistance when the following are connected in parallel -

(a) $1\,\Omega$ and $106\,\Omega$

(b) $1\,\Omega$, $10^3\,\Omega$, and $10^6\,\Omega$

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Ans (a) when $1\,\Omega$ and 10^6 are connected in parallel, the equivalent resistance is given by

$$\frac{1}{R} = \frac{1}{1} + \frac{1}{10^6}$$

$$R = \frac{10^6}{1+10^6} \approx \frac{10^6}{10^6} = 1\,\Omega$$

Therefore, the equivalent resistance is $1\,\Omega$.

(b) When $1\,\Omega$, $10^3\,\Omega$ and $10^6\,\Omega$ are connected in parallel the equivalent resistance is given by

$$\frac{1}{R} = \frac{1}{1} + \frac{1}{10^3} + \frac{1}{10^6}$$

Solving, we get

$$R = \frac{10^6 + 10^3 + 1}{10^6} = \frac{1000001}{1000000} = 0.999\,\Omega$$

Therefore, the equivalent resistance is $0.999\,\Omega$.

Ques2 An electric lamp of $100\,\Omega$, a toaster of resistance $50\,\Omega$, and a water filter of resistance $500\,\Omega$ are connected in parallel to a 220V source. What is the resistance of an electric iron connected to the same source that takes as much current as all three appliances, and what is the current through it?

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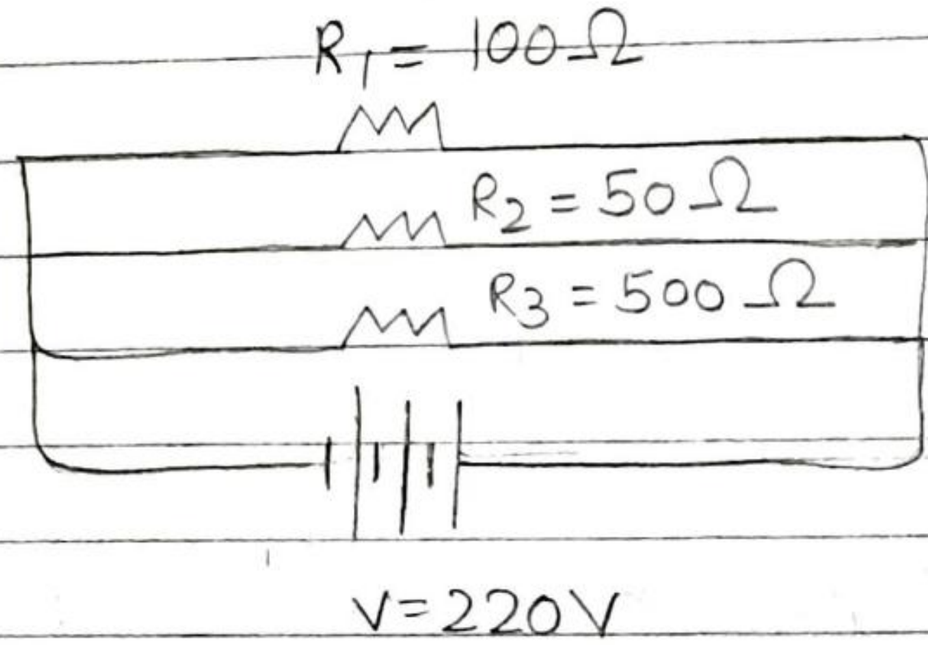
Ans. The electric lamp, the toaster and the water filter, connected in parallel to a 220V source can be shown as using a circuit diagram as follows :-



The equivalent resistance of the resistors can be calculated as follows :-

Ques

$$\frac{1}{R} = \frac{1}{100} + \frac{1}{50} + \frac{1}{500}$$

Ans

$$= \frac{5+10+1}{500} = \frac{16}{500}$$

$$R = \frac{500}{16}\ \Omega$$

Ques

Now, using Ohm's Law, the current flowing across the circuit can be calculated as follows

Ans

$$I = \frac{V}{R} = \frac{220}{\frac{500}{16}}$$

$$I = \frac{220 \times 16}{500} = 7.04A$$

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As the appliances are connected in parallel, the current drawn across all of them is 7.04A. Hence, the current drawn by the electric iron connected in parallel to the same source is 7.04 A. We can find the resistance of the iron box using Ohm's Law as follows :-

$$R = \frac{V}{I} = \frac{220\,V}{7.04\,A} = 31.25\ \Omega$$

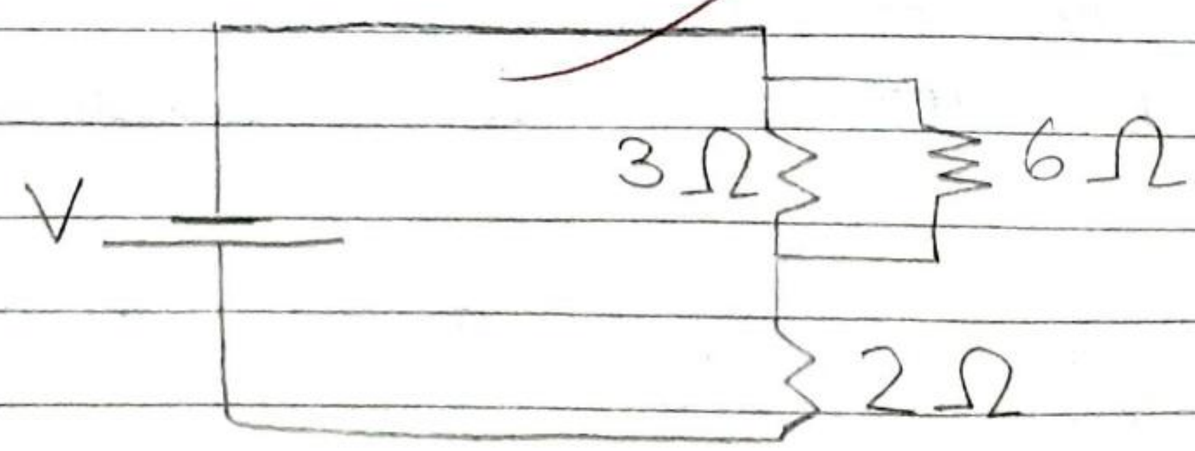
The resistance of the electric iron box is 31.25 Ω.

Ques3. What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?

Ans. When the electrical devices are connected in parallel there is no division of voltage among the appliances. The potential difference across the devices is equal to supply voltage. Parallel connection of devices also reduces the effective resistance of the circuit.

Ques4. How can three resistors of resistances 2 Ω, 3 Ω, and 6 Ω be connected to give a total resistance of (a) 4 Ω, (b) 1 Ω?

Ans(a) The circuit diagram below shows the connection of three resistors :-



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From the circuit above, it is understood that 3 Ω and 6 Ω are connected in parallel. Hence, their equivalent resistance is given by -

$$\frac{1}{R} = \frac{1}{3} + \frac{1}{6}$$

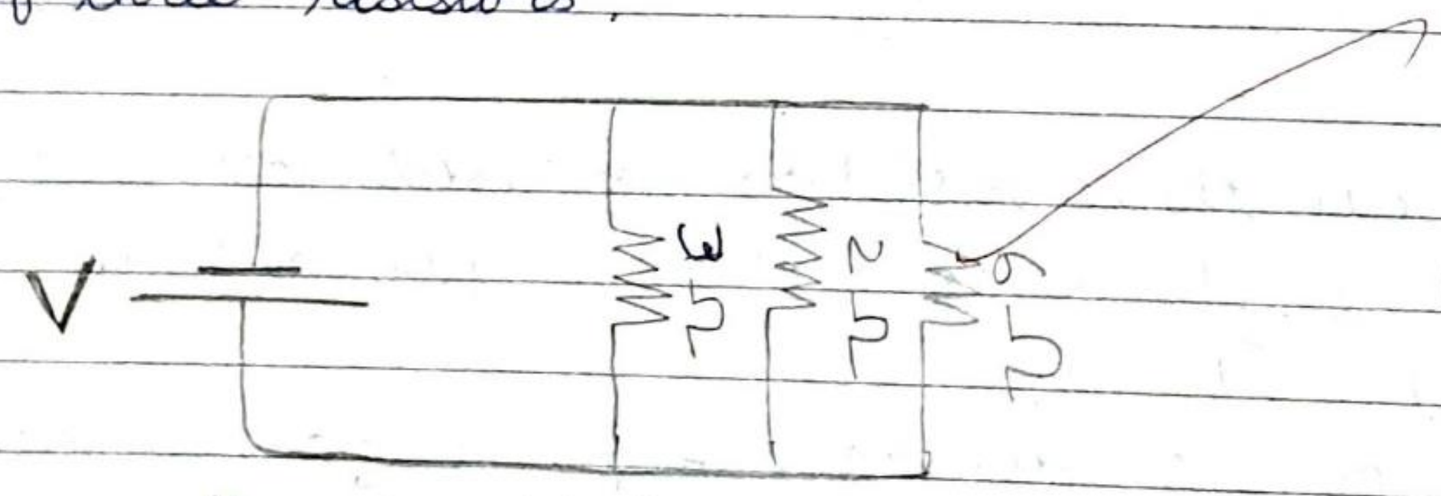
$$R = \frac{1}{\frac{1}{6} + \frac{1}{3}} = \frac{6 \times 3}{6+3} = 2\,\Omega$$

The equivalent resistor 2 Ω is in series with the 2 Ω resistor. Now the equivalent resistance can be calculated as follows:-

$$R_{eq} = 2\,\Omega + 2\,\Omega = 4\,\Omega$$

Hence, the total resistance of the circuit is 4 Ω.

(b) The circuit diagram below, shows the connection of three resistors.



From the circuit, it is understood that all the resistors are connected in parallel. Therefore, their equivalent resistance can be calculated as follows:-

$$R = \frac{1}{\frac{1}{2} + \frac{1}{3} + \frac{1}{6}} = \frac{1}{\frac{3+2+1}{6}} = \frac{6}{6} = 1\,\Omega$$

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Ques5 What is (a) the highest (b) the lowest total resistance that can be secured by combinations of four coils of resistance 4 Ω, 8 Ω, 12 Ω, 24 Ω?

Ans (a) If the four resistors are connected in series, their total resistance will be the sum of their individual resistances and it will be the highest. The total equivalent resistance of the resistors connected in series will be $4\,\Omega + 8\,\Omega + 12\,\Omega + 24\,\Omega = 48\,\Omega$

(b) If the resistors are connected in parallel, then their equivalent resistances will be the lowest. Their equivalent resistance connected in parallel is:-

$$R = \frac{1}{\frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{24}} = \frac{24}{12} = 2\,\Omega$$

Hence, the lowest total resistance is 2 Ω.

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Ques1:- Why does the cord of an electric heater not glow while the heating element does?

Ans:- The heating element of an electric heater is made of an alloy which has a high resistance. When the current flows through the heating element, the heating elements becomes too hot and glows red. The cord is usually made of copper or aluminium which has low resistance. Hence, the cord doesn't glow.

Ques Compute the heat generated while transferring 96000 coulomb of charge in one hour through a potential

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difference of 50 V.

Ans. The heat generated can be computed by Joule's Law as follows :-

$H = VIt$

where, V is the voltage, V = 50 V

I is the current

t is the time in seconds, 1 hour = 3600 seconds.

The amount of current can be calculated as follows:

$$\text{Amount of Current} = \frac{\text{Amount of charge}}{\text{Time flow of charge}}$$

Subsitituting the value, we get,

$$I = \frac{96000}{3600} = 26.66\ A$$

Now, to find the heat generated,

$H = 50 \times 26.66 \times 3600 = 4.8 \times 10^6\ J$

The heat generated is 4.8×10^6 J

Ques3. An electric iron of resistance 20 Ω takes a current of 5A. Calculate the heat developed in 30 s.

Ans. The amount of heat generated can be calculated using the Joule's Law of heating, which is given by the equation

$H = VIt$

Subsitutiing the values in the above equation, we get,

$H = 100 \times 5 \times 30 = 1.5 \times 104\ J$

The amount of heat developed by the electric iron

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in 30 seconds is 1.5×10^4 J.

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Ques-1 What determines the rate at which energy is delivered by a current?

Ans Electric power is the rate of consumption of electrical energy by electric appliances. Hence, the rate at which energy is delivered by a current is the power of the appliance.

Ques2. An electric motor takes 5A from 220V line. Determine the power of the motor and the energy consumed in 2h.

Ans. The power of the motor can be calculated by the equation,

$$P = VI$$

Substituting the values in the above equation, we get

$$P = 220\ V \times 5A = 1100\ W$$

The energy consumed by the motor can be calculated using the equation,

$$E = P \times T$$

Substituting the values in the above equation, we get

$$P = 1100\ W \times 7200 = 7.92 \times 10^6\ J$$

The power of the motor is 1100 W and the energy consumed by the motor in 2 hours = 7.92×10^6 J

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Ques1 - A piece of wire of resistance R is cut into five equal parts. These parts are then connected in parallel. If the equivalent resistance of this combination is R', then the ratio R/R' is _____.

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(a) $1/25$ (b) $1/5$ (c) 5 (d) 25

Ans :- (d) 25

Explanation :-

The resistance is cut into five equal parts, which means that the resistance of each part is $R/5$. We know that each part is connected to each other in parallel, hence the equivalent resistance can be calculated as follows:

$$\frac{1}{R_1} = \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} + \frac{5}{R} = \frac{5+5+5+5+5}{R} = \frac{25}{R}$$

$$\frac{R}{R_1} = 25$$

The ratio of R/R_1 is 25

Ques2 :- Which of the following does not represent electric power in a circuit? a) I^2R b) IR^2 c) VI d) V^2R

Ans IR^2

Explanation :-

Electrical power is given by the expression $P = VI$ (1)

According to Ohm's Law,

$V = IR$

Substituting the value of V in (1), we get

$P = (IR) \times I$

$P = I^2R$

Similarly, from Ohm's Law,

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

Substituting the value of I in (1), we get

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

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From this, it is clear that the equation IR^2 does not represent electrical power in a circuit.

Ques3:- An electric bulb is rated 220V and 100W. When it is operated on 110V, the power consumed will be _____

(a) 100 W (b) 75 W (c) 50 W (d) 25 W

Ans 25 W

Explanation :-

The energy consumed by the appliance is given by the expression

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

The resistance of the light bulb can be calculated as follows :-

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

Subsituting the values, we get

$$P = \frac{(110)^2}{484} = 25W$$

Therefore, the power consumed when the electric bulb operates at 110V is 25 W.

Ques4:- Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then parallel in a circuit across the same potential difference. The ratio of heat produced in series and parallel combination would be :-

(a) 1:2 (b) 2:1 (c) 1:4 (d) 4:1

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Ans. Let R_S and R_P be the equivalent resistance of the wires when connected in series and parallel respectively

For the same potential difference V, the ratio of the heat produced in the circuit is given by:-

$$\frac{H_S}{H_P} = \frac{\frac{V^2}{R_S}t}{\frac{V^2}{R_P}t} = \frac{R_P}{R_S}$$

The equivalent resistance of resistors connected in series R_S is $R+R = 2R$

The equivalent resistance of resistors connected in parallel R_P is $\frac{1}{\frac{1}{R}+\frac{1}{R}} = \frac{R}{2}$

Hence, the ratio of the heat produced in series and parallel combinations would be

$$\frac{H_P}{H_S} = \frac{\frac{R}{2}}{2R} = \frac{1}{4}$$

Hence, the ratio of the heat produced 1:4.

Ques 5 How is a voltmeter connected in the circuit to measure the potential difference between two points?

Ans To measure the voltage between any two points, the voltmeter should be connected in parallel between the two points.

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