CLASS XII PHYSICS STUDY MATERIAL AND ASSIGNMENT III

CURRENT ELECTRICITY

INTRODUCTION

When we turn on a light, you are using the sort of electricity that flows along the wires, like water flows along pipes. This is called current electricity. It is usually made up of billions of electrons flowing along a wire. These electrons do not move along a wire by themselves. They have to be pushed by potential difference, produced by the battery.

Direct current, DC

In DC, all the electrons moves in the same direction, in all the time that the electricity flows. This type of current is produced by the batteries in torches cars and similar devices.

Alternating current, AC

In AC, the direction of electron movement changes many times each second. The electrons move one way, then the other, and so on.

Electric current

In an isolated metallic conductor, the free electrons move randomly like the molecules of a gas and so the net rate of flow of charge through any hypothetical plane is zero. If potential difference is applied across the ends of the conductor, an electric field is set up at every point within the conductor. This field exerts force on free electrons in opposite to direction of field and will give them a resultant motion. This flow of electrons constitutes an electric current. **It can be defined as the rate at which charge passes through any specified surface area.** Thus

$$i = \frac{dq}{dt}.$$

SI unit of electric current is C/s. 1 C/s = 1A.

Charge that passes through any cross-section of the wire in time interval from $t1$ to $t2$ can be obtained by integrating I , ie.

$$q = \int_{t_1}^{t_2} i\,dt.$$

Example

The current through a wire depends on time as i =(2 +3t)A. Calculate the charge crossed through a cross section of the wire in 10 s.

Solution

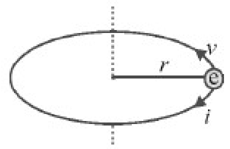
$$I = \frac{dq}{dt} \Rightarrow dq = (2+3t)dt \Rightarrow \int_0^{10} dq = \int_0^{10} (2+3t)\,dt \Rightarrow q = \left(2t + \frac{3t^2}{2}\right)_0^{10}$$

$$q = 2t + \frac{3}{2} \times 100 = 20 + 150 = 170 \text{ C}$$

More about electric current

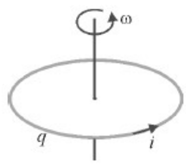
1. The current is the same for all cross-sections of a conductor of non-uniform cross-sections.
2. Current is due to flow of electrons in in conductors which is known as conduction current.
3. In liquids the flow of current occur due to both types of ions.
4. In gases it is due to positive ions and electrons. In semiconductors, it is due to flow of holes and electrons.
5. An electron moving on a circular path of radius r with a speed v constitute current given by,

$$i = \frac{q}{t} = \frac{e}{\frac{2\pi r}{v}} = \frac{ev}{2\pi r}$$



6. If charge q is distributed over the rotating ring uniformly or non-uniformly, current at any section of ring is given by

$$i = \frac{q}{t} = \frac{q}{2\pi/\omega} = \frac{q\omega}{2\pi}$$



Current density ($\vec{J}$)

It is defined as the current per unit area through an infinitesimal area normal to the direction of current flow.

1. The current density at a point P is given by $\boxed{\vec{J} = \frac{di}{dA}\hat{\mathbf{n}}}$

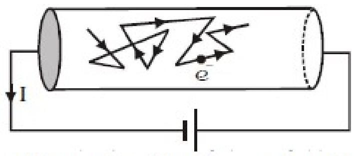
2. If cross-sectional area is not normal to the current, then $\boxed{J = \frac{di}{dA\cos\theta} \text{ or } i = \int \vec{J} \cdot d\vec{A}}$

3. For uniform distribution of current $J = I/A$.

4. It is a vector quantity. Its SI unit is A/m^2.

DRIFT VELOCITY

Drift velocity is defined as the velocity with which the free electrons get drifted towards the positive terminal under the effect of the applied external electric field. In addition to its thermal velocity, due to acceleration given by applied electric field, the electron acquires a velocity component in a direction opposite to the direction of the electric field. The gain in velocity due to the applied field is very small and is lost in the next collision.



At any given time, an electron has a velocity $\vec{v}_1 = \vec{u}_1 + \vec{a}\tau_1$, where $\vec{u}_1$ = the thermal velocity and

$\vec{a}\tau_1$ = the velocity acquired by the electron under the influence of the applied electric field.

τ_1 = the time that has elapsed since the last collision. Similarly, the velocities of the other electrons are

$$\vec{v}_2 = \vec{u}_2 + \vec{a}\tau_2, \vec{v}_3 = \vec{u}_3 + \vec{a}\tau_3, \ldots \vec{v}_N = \vec{u}_N + \vec{a}\tau_N.$$

The average velocity of all the free electrons in the conductor is equal to the drift velocity $\vec{v}_d$ of the free electrons

$$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + \vec{v}_3 + \ldots \vec{v}_N}{N} = \frac{(u_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + \ldots + (\vec{u}_N + \vec{a}\tau_N)}{N} = \frac{(\vec{u}_1 + \vec{u}_2 + \ldots + \vec{u}_N)}{N} + \vec{a}\left(\frac{\tau_1 + \tau_2 + \ldots + \tau_N}{N}\right)$$

$$\because \frac{\vec{u}_1 + \vec{u}_2 + \ldots + \vec{u}_N}{N} = 0 \;\therefore\; \vec{v}_d = \vec{a}\left(\frac{\tau_1 + \tau_2 + \ldots + \tau_N}{N}\right) \Rightarrow \vec{v}_d = \vec{a}\tau = -\frac{e\vec{E}}{m}\tau$$

Note : Order of drift velocity is 10^{-4} m/s

Mobility μ defined as the magnitude of the drift velocity per unit electric field: $\mu = \frac{|\mathbf{v}_d|}{E}$ but $\upsilon_d = \frac{e\,\tau\, E}{m}$

Hence,

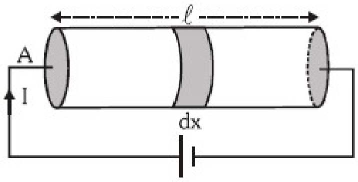
$$\mu = \frac{\upsilon_d}{E} = \frac{e\tau}{m}$$

where τ is the average collision time for electrons.

The SI unit of mobility is m^2/ Vs

RELATION BETWEEN CURRENT DENSITY, CONDUCTIVITY AND ELECTRIC FIELD

Let the number of free electrons per unit volume in a conductor = n



Total number of electrons in dx distance = n (Adx)

Total charge $dQ = n\,(Adx)e$

Current $I = \dfrac{dQ}{dt} = nAe\dfrac{dx}{dt} = neAv_d$, Current density $J = \dfrac{I}{A} = nev_d$

$$= ne\left(\frac{eE}{m}\right)\tau \qquad \because v_d = \left(\frac{eE}{m}\right)\tau \Rightarrow J = \left(\frac{ne^2\tau}{m}\right)E \Rightarrow J = \sigma E, \qquad \text{where conductivity } \sigma = \frac{ne^2\tau}{m}$$

σ depends only on the material of the conductor and its temperature.

In vector form $\vec{J} = \sigma\vec{E}$ *Ohm's law (at microscopic level)*

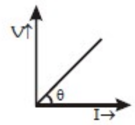
NOTE: 1. Resistivity=$\rho=1/\sigma=m/(ne^2\tau)$ 2. resistance= $R=\rho L/a$ where L=length of uniform conductor

3 If a wire is remouled then $R \;\alpha\; L^2$ and $R \;\alpha\; 1/a^2$ a=area of uniform conductor

RELATION BETWEEN POTENTIAL DIFFERENCE AND CURRENT (Ohm's Law)

If the physical conditions of the conductor (length, temperature, mechanical strain etc.) remains same, then the current flowing through the conductor is directly proportional to the potential difference across it's two ends i.e. $I \propto V \Rightarrow V = IR$ where R is a proportionality constant, known as electric resistance. *Ohm's law (at macroscopic level)*

- Ohm's law is not a universal law. The substances, which obey ohm's law are known as ohmic.
- Graph between V and I for a metallic conductor is a straight line as shown.



Slope of the line $= \tan\theta = \dfrac{V}{I} = R$

LIMITATIONS OF OHM'S LAW

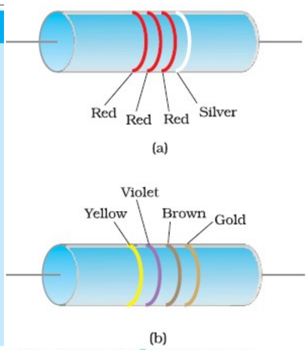
Although Ohm's law has been found valid over a large class of materials, there do exist materials like GaAs and devices like diodes and transistors used in electric circuits where the proportionality of *V* and *I* does not hold and therefore they are called non-ohmic devices.

COLOUR CODE FOR CARBON RESISTORS

Carbon resistors are small in size and hence their values are given using a colour code.

RESISTOR COLOUR CODES

Colour	Number	Multiplier	Tolerance (%)
Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
No colour			20



(a) $(22 \times 10^2\ \Omega) \pm 10\%$,
(b) $(47 \times 10\ \Omega) \pm 5\%$.

The resistors have a set of co-axial coloured rings on them whose significance are listed in above Table. The first two *bands* from the end indicate the first two significant figures of the resistance in ohms. The third band indicates the decimal multiplier (as listed in Table). The last band stands for tolerance or possible variation in percentage about the indicated values. Sometimes, this last band is absent and that indicates a tolerance of 20% (Fig. 3.8).

For example, if the four colours are orange, blue, yellow and gold, the resistance value is $36 \times 10^4\ \Omega$, with a tolerence value of 5%.

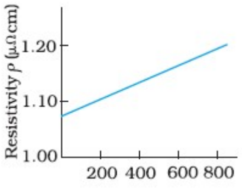
TEMPERATURE DEPENDENCE OF RESISTIVITY

Over a limited range of temperatures, that is not too large, the resistivity of a metallic conductor is approximately given by,

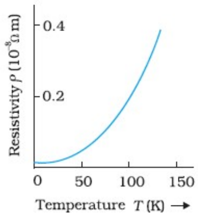
$\rho_T = \rho_0\,[1 + \alpha\,(T - T_0)]$ where ρ_t is the resistivity at a temperature T and ρ_0 is the same at a reference temperature T_0.

Note α is called the *temperature co-efficient of resistivity,* having the dimension (Temperature)–1.

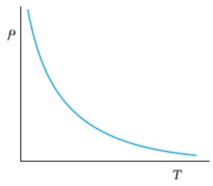
The equation above implies that for a ohmic resistor ρ_T vs T graph would be a straight line as in case of nichrome.



ρ_T of nichrome as a function of absolute temperature T.



Resistivity ρ_T of copper as a function of temperature T.



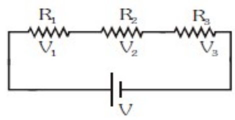
Temperature dependence of resistivity for a typical semiconductor.

Explanation of temperature dependence of resistivity of conductors and semiconductors

Resistivity of a material is given by $\rho = \frac{1}{\sigma} = \frac{m}{ne^2\tau}$ As we increase temperature, average speed of the electrons, which act as the carriers of current, increases resulting in more frequent collisions. The average time of collisions τ thus decreases with temperature. In a metal, *n* is not dependent on temperature to any appreciable extent and thus the decrease in the value of τ with rise in temperature causes ρ to increase as we have observed. Fo semiconductors, however, *n* increases with temperature. This increase more than compensates any decrease in τ so that for such materials, ρ decreases with temperature.

COMBINATION OF RESISTORS

Series Combination



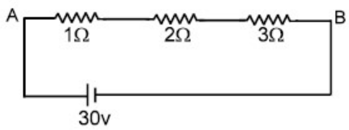
- Same current passes through each resistance
- Voltage across each resistance is directly proportional to it's value

  $V_1 = IR_1, V_2 = IR_2, V_3 = IR_3$
- Sum of the voltage across resistance is equal to the voltage applied across the circuit.

  $V = V_1 + V_2 + V_3 \Rightarrow IR = IR_1 + IR_2 + IR_3 \Rightarrow R = R_1 + R_2 + R_3$ Where R = equivalent resistance

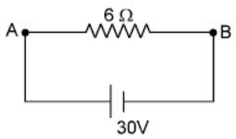
Example

Find the current in the circuit



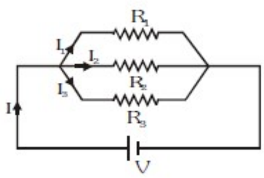
Solution

$R_{eq} = 1 + 2 + 3 = 6\ \Omega$ the given circuit is equivalent to



current $i = \frac{v}{R_{eq}} = \frac{30}{6} = 5A$

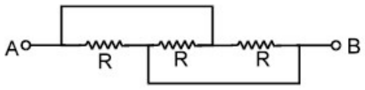
Parallel Combination



- There is same drop of potential across each resistance.
- Current in each resistance is inversely proportional to the value of resistance. $I_1 = \frac{V}{R_1}$, $I_2 = \frac{V}{R_2}$, $I_3 = \frac{V}{R_3}$
- Current flowing in the circuit is sum of the currents in individual resistance.

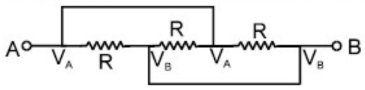
$$I = I_1 + I_2 + I_3 \Rightarrow \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \Rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

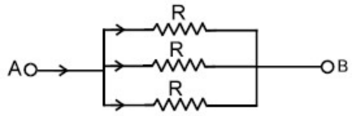
Example

Find equivalent Resistance 

Solution

Here all the Resistance are connected between the terminals A and B

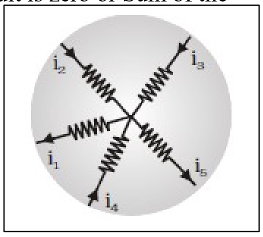


Modified circuit is So $R_{eq} = \frac{R}{3}$ 

KIRCHHOFF'S LAW

First law (Junction Law or Current Law)

In an electric circuit, the algebraic sum of the current meeting at any junction in the circuit is zero or Sum of the currents entering the Junction is equal to sum of the current leaving the Junction.



$\sum i=0$

$i_1 - i_2 - i_3 - i_4 + i_5 = 0$ => $i_1 + i_5 = i_2 + i_3 + i_4$

This is based on law of conservation of charge.

Second law (loop rule or potential law)

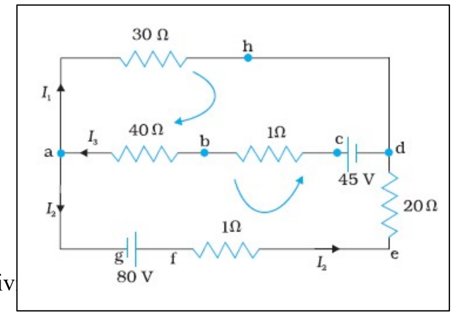
In any closed circuit the algebraic sum of all potential differences and e.m.f. is zero.

$\sum E + \sum IR = 0$

Sign Convention

while moving from negative to positive terminal inside the cell, e.m.f. is taken as positive while moving in the direction of current in a circuit the potential drop (i.e. IR) across resistance is taken as negative.

This law is based on law of conservation of energy.



Example

As per the given circuit at junction 'a' the current leaving is $I_1 + I_2$ and current entering is I_3.

The junction rule says $I_3 = I_1 + I_2$.

For the loop 'ahdcba' the loop rules give

$-30I_1 - 40\, I_3 - (1)\, I_3 + 45 = 0$

and 'for the loop ahdefga' $-30I_1 + 20\, I_2 + (1)\, I_2 - 80 = 0$.

ELECTRO MOTIVE FORCE (E. M. F.) OF CELL

The potential difference across the terminals of a cell when it is not giv

OR

The energy given by the cell in the flow of unit charge in the whole circuit (including the cell) is called the emf of the cell.

INTERNAL RESISTANCE OF CELL

Resistance offered by the electrolyte of the cell when the electric current flows through it is known as internal resistance.

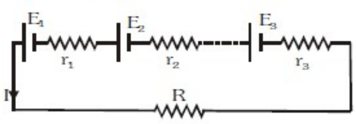
TERMINAL VOLTAGE (V) OF CELL

1. The potential difference across the terminals of a cell equals emf of the cell when no current is flowing through cell or in open circuit.• V = E
2. When I current is drawn from cell, then terminal voltage is less than it's e.m.f. which is given by V = E – Ir When current is drawn from the cell potential difference is less than emf of cell.
3. V = E + Ir when current enters cell from its positive terminal during charging .So terminal potential difference is greater than emf of cell.
4. In short circuit current from cell is maximum and terminal potential difference is zero.

COMBINATION OF CELLS

- Series combination

  When the cells are connected in series the total e.m.f. of the series combination is equal to the sum of the e.m.f.'s of the individual cells and internal resistance of the cells also come in series.



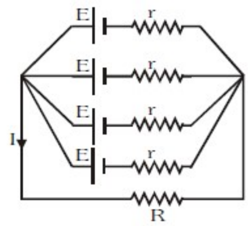
Equivalent internal resistance $r = r_1 + r_2 + r_3 + \ldots$ Equivalent emf = $E = E_1 + E_2 + E_3 + \ldots$

Current $I = \dfrac{E_{net}}{r_{net} + R}$, If all n cell are identical then $I = \dfrac{nE}{nr + R}$

• If $nr >> R$, $I = \dfrac{E}{r}$ = current from one cell • If $nr << R$, $I = \dfrac{nE}{R} \simeq n$ current from one cell

Parallel combination

When the cells are connected in parallel, the total e.m.f. of the parallel combination remains equal to the e.m.f. of a single cell and internal resistance of the cell also come in parallel. If m identical cell connected in parallel then total internal resistance of this combination $r_{net} = \dfrac{r}{m}$. Total e.m.f. of this combination = E



Current in the circuit $I = \dfrac{E}{R + \dfrac{r}{m}} = \dfrac{mE}{mR + r}$

If $r << mR$ $\qquad I = E/R$ = Current from one cell

If $r >> mR$ $\qquad I = \dfrac{mE}{r} = m$ current from one cell

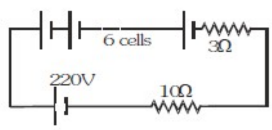
Example

A battery of six cells each of e.m.f. 2 V and internal resistance 0.5 Ω is being charged by D. C. mains of e.m.f. 220 V by using an external resistance of 10 Ω. What will be the charging current.

Solution

Net e.m.f of the battery = 12V and total internal resistance = 3Ω

Total resistance of the circuit = 3 + 10 = 13 Ω



Charging current $I = \dfrac{\text{Net e.m.f.}}{\text{total resistance}} = \dfrac{220 - 12}{13} = 16\ A$

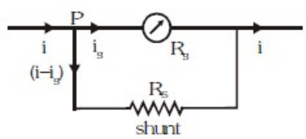
GALVA NOMETER

The instrument used to measure strength of current, by measuring the deflection of the coil due to torque produced by a magnetic field, is known as galvanometer.

CONVERSION OF GALVANOMETER INTO AMMETER

A galvanometer can be converted into an ammeter by connecting low resistance called shunt in parallel to its coil.

• The value of shunt resistance to be connected in parallel to galvanometer coil is given by : $R_S = \dfrac{R_g i_g}{i - i_g}$



Where $\quad i$ = Range of ammeter

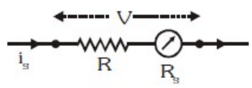
i_g = Current required for full scale deflection of galvanometer.

R_g = Resistance of galvanometer coil.

CON VERSION OF GALVANOMETER INTO VOLTMETER

• The galvanometer can be converted into voltmeter by connecting high resistance in series with its coil .The high resistance to be connected in series with galvanometer coil is given by

$R = \dfrac{V}{i_g} - R_g$

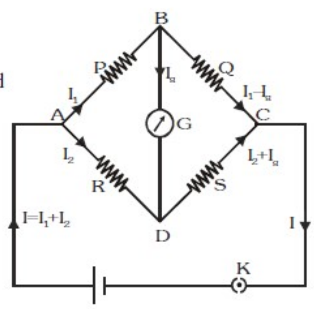


WHEAT STONE BRIDGE

• The configuration in the adjacent figure is called Wheat Stone Bridge.

• If current in galvanometer is zero ($I_g = 0$) then bridge is said to be balanced

$V_D = V_B \Rightarrow I_1P = I_2R\ \&\ I_1Q = I_2S \Rightarrow \dfrac{P}{Q} = \dfrac{R}{S}$

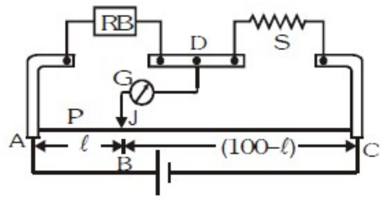


• If $\dfrac{P}{Q} < \dfrac{R}{S}$ then $V_B > V_D$ and current will flow from B to D.

• If $\dfrac{P}{Q} > \dfrac{R}{S}$ then $V_B < V_D$ and current will flow from D to B.

METRE BRIDGE

It is based on principle of whetstone bridge. It is used to find out unknown resistance of wire. AC is 1 m long uniform wire R.B. is known resistance and S is unknown resistance. A cell is connected across 1 m long wire and Galvanometer is connected between Jockey and midpoint D. To find out unknown resistance we touch jockey from A to C and find balance condition. Let balance is at B point on wire.



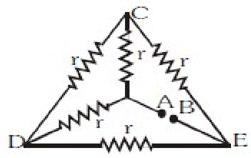
AB = ℓ cm P = r ℓ

BC = (100 – ℓ) cm Q = r(100 – ℓ) where r = resistance per unit length on wire.

At balance condition : $\frac{P}{Q} = \frac{R}{S} \Rightarrow \frac{r\ell}{r(100-\ell)} = \frac{R}{S} \Rightarrow S = \frac{(100-\ell)}{\ell}R$

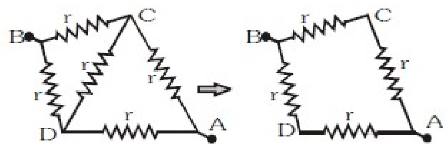
Example

In the adjoining network of resistors each is of resistance r Ω. Find the equivalent resistance between point A and B



Solution

Given circuit is balanced Wheat stone Bridge $\therefore \frac{1}{R_{AB}} = \frac{1}{2r} + \frac{1}{2r} = \frac{1}{r}$ R_{AB} = r



POTENTIOMETER

It is a long piece of uniform wire, sometimes a few meters in length across which a standard cell is connected. The wire is sometimes cut in several pieces placed side by side and connected at the ends by thick metal strip. A current *I* flows through the wire which can be varied by a variable resistance (rheostat, *R*) in the circuit. Since the wire is uniform, the potential difference between A and any point at a distance l from A is ε(l)=Øl

Where Ø is the potential drop per unit length.

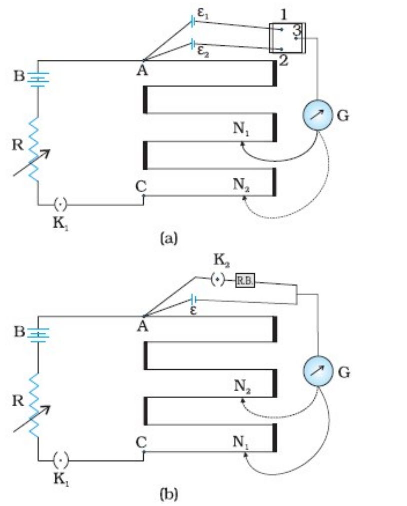
Comparision of the emf's of any two cells

Figure (a) shows an application of the potentiometer to compare the emf of two cells of emf ε_1 and ε_2. The points marked 1, 2, 3 form a two way key. Consider first a position of the key where 1 and 3 are connected so that the galvanometer is connected to ε_1. The jockey is moved along the wire till at a point N_1, at a distance l_1 from A, there is no deflection in the galvanometer. We can apply Kirchhoff's loop rule to the closed loop AN_1G31A and get,

$$\phi l_1 + 0 - \varepsilon_1 = 0 \quad (1)$$

Similarly, if another emf ε_2 is balanced against l_2 (AN_2)

$$\phi l_2 + 0 - \varepsilon_2 = 0 \quad (2)$$



G is a galvanometer and *R* a variable resistance (rheostat). 1, 2, 3 are terminals of a two way key
fig(a) circuit for comparing emfs of twocells;
fig (b) circuit for determining internal resistance of a cell.

From the two equations

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

Measurement of internal resistance of a cell

Refer to Fig. (b).

For this the cell (emf ε) whose internal resistance (r) is to be determined is connected across a resistance box through a key K_2, as shown in the figure. With key K_2 open, balance is obtained at length l_1 (AN_1). Then,

$$\varepsilon = \phi\, l_1$$

When key K_2 is closed, the cell sends a current (I) through the resistance box (R). If V is the terminal potential difference of the cell and balance is obtained at length l_2 (AN_2),

$$V = \phi\, l_2$$

So, we have $\varepsilon/V = l_1/l_2$

But, $\varepsilon = I(r + R)$ and $V = IR$. This gives

$$\varepsilon/V = (r+R)/R$$

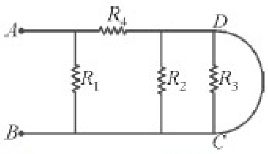
From Eq. [3.94(a)] and [3.94(b)] we have

$$(R+r)/R = l_1/l_2$$

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

EXERCISES

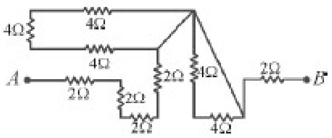
1. The equivalent resistance between A and B is



(a) $R_1 + R_2 + R_3$ (b) R_2

(c) $\frac{R_2 R_4}{R_2 + R_4} + R_1$ (d) $\frac{R_1 R_4}{R_1 + R_4}$

2. The equivalent resistance between A and B is



(a) 10 Ω (b) 20 Ω

(c) 15 Ω (d) none

3.Consider a current carrying wire (current I) in the shape of a circle. Note that as the current progresses along the wire, the direction of **j** (current density) changes in an exact manner, while the current I remain unaffected. The agent that is *essentially* responsible for this is

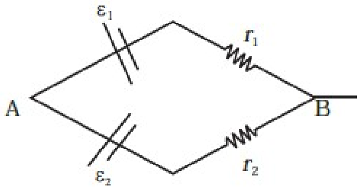
(a) source of emf.

(b) electric field produced by charges accumulated on the surface of wire.

(c) the charges just behind a given segment of wire which push them just the right way by repulsion.

(d) the charges ahead.

4.Two batteries of emf ε_1 and ε_2 ($\varepsilon_2 > \varepsilon_1$) and internal resistances r_1 and r_2 respectively are connected in parallel as shown in Fig.



(a) The equivalent emf ε_{eq} of the two cells is between ε_1 and ε_2

(b) The equivalent emf ε_{eq} is smaller than ε_1 .

(c) The ε_{eq} is given by $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ always.

(d)ε_{eq} is independent of internal resistances r_1 and r_2.

5.A resistance R is to be measured using a meter bridge. Student chooses the standard resistance S to be 100Ω. He finds the null point at l_1 = 2.9 cm. He is told to attempt to improve the accuracy. Which of the following is a useful way?

(a) He should measure l_1 more accurately.

(b) He should change S to 1000Ω and repeat the experiment.

(c) He should change S to 3Ω and repeat the experiment.

(d) He should give up hope of a more accurate measurement with a meter bridge.

6. Two cells of emf's approximately 5V and 10V are to be accurately compared using a potentiometer of length 400cm.

(a) The battery that runs the potentiometer should have voltage of 8V.

(b) The battery of potentiometer can have a voltage of 15V and R adjusted so that the potential drop across the wire slightly exceeds 10V.

(c) The first portion of 50 cm of wire itself should have

a potential drop of 10V.
(d) Potentiometer is usually used for comparing resistances and not voltages.

7.A metal rod of length 10 cm and a rectangular cross-section of 1cm ×1/2 cm is connected to a battery across opposite faces. The resistance will be
(a) maximum when the battery is connected across 1cm×1/2 cm faces.
(b) maximum when the battery is connected across 10cm × 1 cm faces.
(c) maximum when the battery is connected across 10 cm ×1/2 cm faces.
(d) same irrespective of the three faces.

8. Which of the following characteristics of electrons determines the current in a conductor?
(a) Drift velocity alone.
(b) Thermal velocity alone.
(c) Both drift velocity and thermal velocity.
(d) Neither drift nor thermal velocity.

9. A metallic resistor is connected across a battery. If the number of collisions of the free electrons with the lattice is somehow decreased in the resistor (for example, by cooling it), the current will
(a) increase (b) decrease
(c) remain constant (d) become zero

10. Two resistors have resistances R_A and R_B respectively with $R_A < R_B$. If the resistivities of their materials are A and B , then
(a) A > B (b) A = B (c) A < B
(d) The information is not sufficient to find the relation between A and B.

11. The product of resistivity and conductivity of a cylindrical conductor depends on
(a) temperature (b) material
(c) area of cross-section (d) none of these

12. As the temperature of a metallic resistor is increased, the product of its resistivity and conductivity
(a) increases (b) decreases
(c) remains constant (d) may increase or decrease

13. When no current is passed through a conductor
(a) the free electrons do not move
(b) the average speed of a free electron over a large period of time is zero
(c) the average velocity of a free electron over a large period of time is zero
(d) the average of the velocities of all the free electrons at an instant is zero.

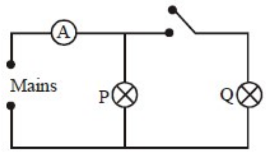
14. A current passes through a wire of nonuniform cross-section. Which of the following quantities are independent of the cross-section ?
(a) the charge crossing in a given time interval
(b) drift speed (c) current density
(d) free-electron density.

15. If a 0.1 % increase in length due to stretching, the percentage increase in its resistance will be
(a) 0.2% (b) 2% (c) 1% (d) 0.1%

16. The electric field E, current density J and conductivity σ of a conductor are related as
(a) σ= E/j (b)σ = j/E (c) σ= jE (d) σ= 1/jE

17**.** The resistance of a wire is 10Ω. Its length is increased by 10% by stretching. The new resistance will now be
(a) 12Ω (b)1.2Ω (c) 13Ω (d) 11Ω

18. How will the reading in the ammeter A of figure be affected if another identical bulb Q is connected in parallel to P as shown. The voltage in the mains is maintained at a constant value.



(A) The reading will be reduced to one-half
(B) The reading will not be affected
(C) The reading will be doubled of the previous one
(D) The reading will be increased four-fold

19. A uniform wire of resistance 50Ω is cut into 5 equal parts. These parts are now connected in parallel. The equivalent resistance of the combination is
(a) 2 Ω (b) 10 Ω (c) 250 Ω (d) 6250 Ω

20**.** Consider the following two statements
(A) Kirchhoff's junction law follows from conservation of charge.
(B) Kirchhoff's loop law follows from conservative nature of electric field.

(a) Both A and B are correct.
(b) (b) A is correct but B is wrong.
(c) B is correct but A is wrong.
(d) (d) Both A and B are wrong.

21.A wire carries a current of 2.0 A. What is the charge that has flowed through its crosssection in 1.0 s ? How many electrons does this correspond to ?

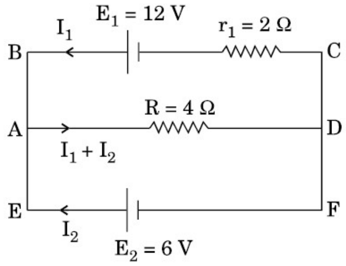
22. The current in a wire varies with time according to the relation i = (3.0 A) + (2.0 A/s) t
(a) How many coulombs of charge pass a cross-section of the wire in the time interval between t = 0 and t = 4.0 s ?
(b) What constant current would transport the same charge in the same time interval ?

23. How many electrons per second pass through a section of wire carrying a current of 0.7 A ?

24.How does the random motion of free electrons in a conductor get affected when a potential difference is applied across its ends ?

25.

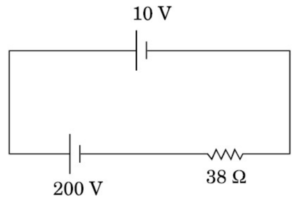
In the electric network shown in the figure, use Kirchhoff's rules to calculate the power consumed by the resistance R = 4 Ω.



26. How does the mobility of electrons in a conductor change, if the potential difference applied across the conductor is doubled, keeping the length and temperature of the conductor constant?

27. Two bulbs are rated (P1, V) and (P2, V). If they are connected (i) in series and (ii) in parallel across a supply V, find the power dissipated in the two combinations in terms of P1 and P2.

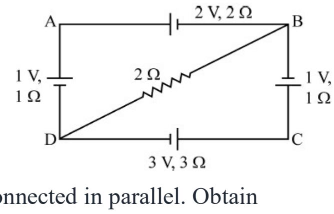
28. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38Ω as shown in the figure. Find the value of current in the circuit.



29. In a potentiometer arrangement for determining the emf of a cell, the balance point of the cell in open circuit is 350 cm. When a resistance of 9Ω is used in the external circuit of the cell, the balance point shifts to 300 cm. Determine the internal resistance of the cell.

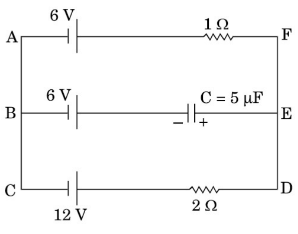
30. Define the term 'conductivity' of a metallic wire. Write its SI unit.
(b) Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wire in terms of number density and relaxation time. Hence obtain the relation between current density and the applied electric field E.
How does the mobility of electrons in a conductor change, if the potential difference applied across the conductor is doubled, keeping the length and temperature of the conductor constant ?

31. Using Kirchhoff's rules, calculate the potential difference between B and D in the circuit diagram as shown in the figure.

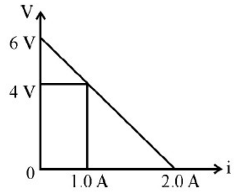


32. Two cells of emfs ε_1 & ε_2 and internal resistances r_1 & r_2 respectively are connected in parallel. Obtain expressions for the equivalent. (i) resistance and (ii) emf of the combination

33. In the given circuit, with steady current, calculate the potential difference across the capacitor and the charge stored in it.

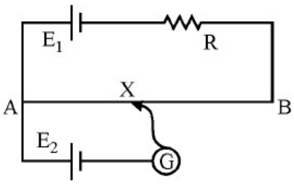


34. The figure shows a plot of terminal voltage ‘V’ versus the current ‘i’ of a given cell. Calculate from the graph (a) emf of the cell and (b) internal resistance of the cell.

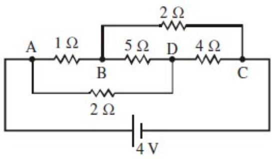


35. Draw a circuit diagram of a meter bridge used to determine the unknown resistance R of a given wire. Hence derive the expression for R in terms of the known resistance S.
(b) What does the term ‘end error’ in a metre bridge circuit mean and how is it corrected ? How will the balancing point be affected, if the positions of the battery and galvanometer are interchanged in a metre bridge experiment ? Give
reason for your answer.
36. (a) State the working principle of a potentiometer with help of the circuit diagram, explain how the internal resistance of a cell is determined.
(b) How are the following affected in the potentiometer circuit when
(i) the internal resistance of the driver cell increases and (ii) the series resistor connected to the driver cell is reduced ? Justify your answer.
How can a given potentiometer be made more sensitive ?
37. Two metallic wires, P1 and P2 of the same material and same length but different cross-sectional areas, A1 and A2 are joined together and connected to a source of emf. Find the ratio of the drift velocities of free electrons in the two wires when they are connected (i) in series, and (ii) in parallel.

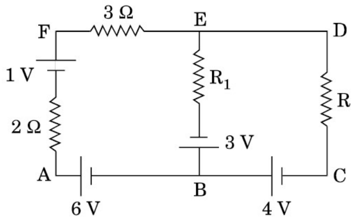
38. (i) In the circuit diagram given below, AB is a uniform wire of resistance 15 W and length 1 m. It is connected to a cell E1 of emf 2V and negligible internal resistance and a resistance R. The balance point with another cell E2 of emf 75 mV is found at 30 cm from end A. Calculate the value of R.



(ii) Why is potentiometer preferred over a voltmeter for comparison of emf. of cells ?
39. Plot a graph showing variation of voltage vs the current drawn from the cell. How can one get information from this plot about the emf of the cell and its internal resistance ? Calculate the current drawn from the battery by the network of resistors shown in the figure.



40. Use Kirchhoff ’s rules to determine the potential difference between the points A and D when no current flows in the arm BE of the electric network shown in the figure.



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ERRATA: ASSIGNMENT 1

27. Given the electric field in the region **E**= 2*x directed towards +ve x axis.*Find the net electric flux through the cube and the charge enclosed by it if a= 3m.