PHYU12

No. of Printed Pages: 4

Register Number | | | | | | | |

12

PART – III

(இயற்பியல் / **PHYSICS**)

(English Version)

Time Allowed : 2.00 Hours] [Maximum Marks : 50

Instructions: (1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.

(2) Use **Blue** or **Black** ink to write and underline and pencil to draw diagrams.

Note : (i) Answer **all** the questions. 10x1=10

(ii) Choose the most appropriate answer from the given **four** alternatives and write the **option code** and the **corresponding answer**.

1. An electric dipole consists of two charges of 0.1 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 10^5 N/C. What maximum torque does the field exert on the dipole?

   (a) 4×10^{-4} Nm (b) 4×10^{4} Nm (c) 4×10^{-5} Nm (d) 4×10^{5} Nm

2. If voltage applied on a capacitor is increased from V to 2V, choose the correct conclusion.

   (a) Q remains the same, C is doubled (b) Q is doubled, C doubled

   (c) C remains same, Q doubled (d) Both Q and C remain same

3. A toaster operating at 240V has a resistance of 120 Ω. The power is

   (a) 240W (b) 400W (c) 2W (d) 480W

[Turn over

4. As the temperature increases, the electrical resistance
   (a) Increases for both conductors and semiconductors
   (b) Decreases for both conductors and semiconductors
   (c) Increases for conductors but decreases for semiconductors
   (d) Decreases for conductors but increases for semiconductors

5. An electric dipole is placed at an alignment angle of 30^0 with an electric field of 2×10^5 NC^{-1}. It experiences a torque equal to 8 Nm. The charge on the dipole if the dipole length is 1 cm is
   (a) 4 mC (b) 8 mC (c) 5 mC (d) 7 Mc

6. In meter bridge for measurement of resistance, the known and the unknown resistance are interchanged. The error so removed is
   (a) end correction (b) gross error
   (c) random error (d) due to temperature effect

7. The temperature coefficient of resistance of a wire is 0.00125 per °C. At 20°C, its resistance is 1 Ω. The resistance of the wire will be 2 Ω at
   (a) 800 °C (b) 700 °C (c) 850 °C (d) 820 °C

8. Two identical conducting balls having positive charges q_1 and q_2 are separated by a centre to centre distance r. If they are made to touch each other and then separated to the same distance, the force between them will be
   (a) less than before (b) same as before (c) more than before (d) zero

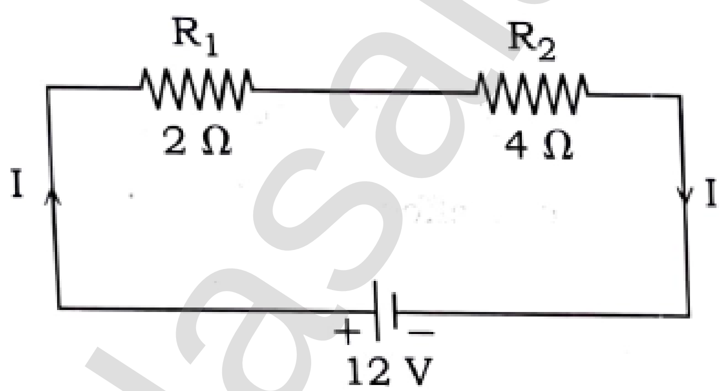
9. The electric field due to point charge at a distance of 3 m from it is 500 NC^{-1}. The magnitude of the charge is $[\frac{1}{4\pi\epsilon_0} = 9\text{x}10^9\ Nm^2\ C^{-2}]$
   (a) 2.4 μC (b) 1.0 μC (c) 2.0 μC (d) 0.5 μC

10. A carbon resistor of (47 ± 4.7) k Ω to be marked with rings of different colours for its identification. The colour code sequence will be....
   (a) Yellow – Green – Violet – Gold (b) Yellow – Violet – Orange – Silver
   (c) Violet – Yellow – Orange – Silver (d) Green – Orange – Violet – Gold

PART – II

Note : Answer **any five** questions. Question No. **18** is **compulsory.** 5x2=10

11. State Joule's law of heating.
12. Define electric flux. Give its SI unit.
13. Distinguish between electric energy and electric power.
14. State the principle of Potentiometer.
15. What is called electric dipole? Give an example.
16. During lightning, it is safer to sit inside car than in an open ground or under tree. Why?
17. Distinguish between Polar molecules and Non - Polar molecules.
18. Calculate the equivalent resistance for the circuit which is connected to 12 V battery and also find the potential difference across 2Ω and 4Ω resistors in the circuit.



PART – III

Note : Answer **any five** questions. Question No. **26** is **compulsory.** 5x3=15

19. State and explain Kirchhoff's rules.
20. Obtain an expression for energy stored in the parallel plate capacitor.
21. Explain the equivalent resistance of a series resistance network.
22. The resistance of a nichrome wire at 0^0C is 10Ω. If its temperature coefficient of resistance is $0.004/^0$C, find its resistance at boiling point of water. Comment on the result.

[Turn over

23. Derive an expression for torque experienced by an electric dipole placed in the uniform electric field.
24. What is Seebeck effect? State the applications of Seebeck effect.
25. List the properties of electric field lines.
26. A parallel plate capacitor has square plates of side 5 cm and separated by a distance of 1 mm. (a) Calculate the capacitance of this capacitor. (b) If a 10 V battery is connected to the capacitor, what is the charge stored in any one of the plates? (The value of $\varepsilon_o = 8.85 \times 10^{-12}$ Nm^2 C^{-2})

PART – IV

Note : Answer **all** the questions. 3x5=15

27. Obtain an expression for electric field due to an infinitely long charged wire.

(OR)

Explain in detail the construction and working of Van de Graaff generator.

28. Calculate the electric field due to a dipole on its axial line.

(OR)

Explain the determination of the internal resistance of a cell using voltmeter.

29. Obtain the condition for bridge balance in Wheatstone's bridge.

(OR)

Describe the microscopic model of current and obtain general form of Ohm's law.

$-\infty \pm \infty\Phi\infty\Psi\infty\Omega\infty -$

HIGHER SECONDARY SECOND YEAR : FIRST MID – TERM TEST: AUGUST 2022
PHYSICS ANSWER KEY

Note:

1. Answers written with **Blue** or **Black ink** only to be evaluated.
2. Choose the most suitable answer in Part A from the given alternatives and write the **option code** and the **corresponding answer**.
3. For answers in Part-II, Part-III and Part-IV like reasoning, explanation, narration, description and listing of points, students may write in their own words but without changing the concepts and without skipping any point.
4. In numerical problems, if formula is not written, marks should be given for the remaining correct steps.
5. In graphical representation, physical variables for X-axis and Y-axis should be marked.

PART – I

Answer all the questions. **10x1=10**

Q. No.	Answer	Q. No.	Answer
1	(a) $4\text{x}10^{-4}$ Nm	6	(a) end correction
2	(c) C remains same, Q doubled	7	(d) 820 °C
3	(d) 480W	8	(c) more than before
4	(c) Increases for conductors but decreases for semiconductors	9	(d) 0.5 μC
5	(b) 8 mC	10	(b) Yellow – Violet – Orange – Silver

PART – II

Answer **any five** questions. Question number **18 is compulsory**. 5x2=10

11	**Joule's law of heating.** It states that the heat develops in an electrical circuit due to the flow, current varies directly as **(i) the square of the current (ii) the resistance of the circuit and (iii) the time of flow (*i. e*) H = I^2Rt**	2
12	**Electric flux:** The **number of electric field lines crossing a given area** kept normal to the electric field lines is called electric flux (Φ_E). Its **S.I unit is Nm^2C^{-1}.** It is a **scalar quantity**.	2

13

S. No.	Electric Energy	Electric Power
1	Work has to be done to move the charge from One end to other end of the conductor and this work-done is called electric energy. **dW = dU = VdQ**	The rate at which the electrical potential energy is delivered is called electric power. P = $\frac{dU}{dt}$; = VI
2	Its SI Unit is joule (J)	Its SI Unit is watt (W)
3	Its practical unit is **kilowatt hour (kwh) 1 kwh = 3.6x10^{6}J**	Its practical unit is **horse power(HP)1 HP = 746 W**

Any 2 point 2 x 1 = 2

14

Principle of potentiometer.
Let 'I' be the current, 'r' be the resistance per unit length and 'l' be the balancing length, then emf is ξ = Ir $\boldsymbol{l}$ (or) $\xi \propto \boldsymbol{l}$ -------------1 Mark
The emf is <u>directly proportional to the balancing length</u>. …………1 Mark

2

15

Electric dipole: Two equal and opposite charges <u>separated by a small distance</u> constitute an electric dipole. ---------------1 ½ Mark
Example: <u>CO, HCl, NH_4, H_2O</u> ……………….. ½ Mark

2

16

The metal body of the car <u>provides electrostatic shielding</u>, where the <u>electric field is zero</u>. During lightning the <u>electric discharge</u> passes through the body of the car.

2

17

Polar Molecules	Non- Polar Molecules
A polar molecule is one in which **the** <u>positive and negative charges are separated</u> even in the absence of an external electric field. They have a permanent dipole moment. **(e.g) H_2O, N_2O, HCl, NH_4**	A non-polar molecule is one in which <u>centres of positive and negative charges coincide</u>. It has no permanent dipole moment. **(e.g) H_2, O_2, CO_2**

2

18

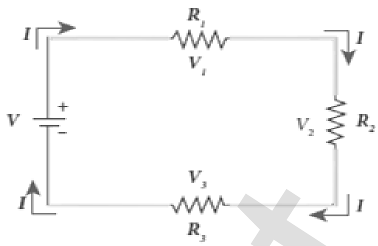
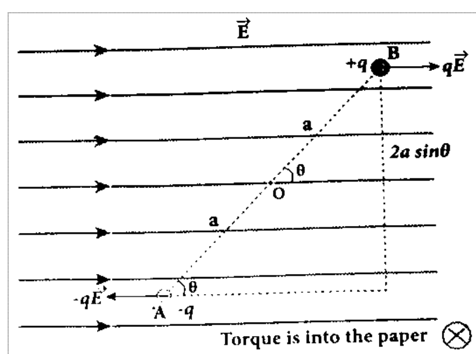
The resistors are connected in series, the effective resistance in the circuit = 2 Ω + 4 Ω = 6 Ω …………………… ½ Mark
The Current I in the circuit = $\frac{V}{R_{eq}} = \frac{12}{6}$ = 2A …………………… ½ Mark
Voltage across 2Ω resistor
$V_1 = IR_1$ = 2A x 2 Ω = 4 V …………………… ½ Mark
Voltage across 4 Ω resistors
$V_2 = IR_1$ = 2A x 4 Ω = 8 V …………………… ½ Mark

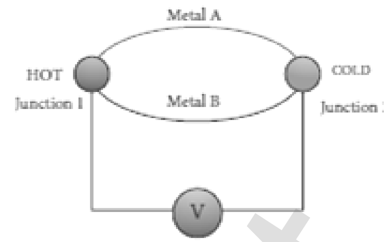
2

PART – III

Answer **any five** questions. Question number **26 is compulsory**. 5x3=15

19	**Kirchhoff first law (current law) :** It states that the **algebraic sum of currents** at any junction in a circuit **is zero**. ($\sum I = 0$). **Explanation:** It is a statement of conservation of electric charge. Thus all charges that enter a given junction in a circuit must leave that junction. **Current entering the junction** is taken as **positive** and **current leaving the junction** is taken as **negative.** Applying this law at junction 'A' $I_1 + I_2 - I_3 - I_4 - I_5 = 0$ (or) $I_1 + I_2 = I_3 - I_4 - I_5$ ---------------------- 1 ½ Marks **Kirchhoff second law (voltage law) :** It states that in a closed circuit the **algebraic sum of the products of the current and resistance of each part of the circuit is equal** to the total emf included in the circuit ($\sum IR = \sum \xi$) **Explanation:** It is a statement of conservation of energy for an isolated system. The product 'IR' is taken as positive when we proceed along the direction of current and taken as negative when we proceed opposite to the direction of current. Similarly, The emf is considered as positive, when we proceed from negative to positive terminal of the cell and as negative, when we proceed from positive to negative terminal of the cell. ---------------------- 1 ½ Marks	3
20	**Energy stored in capacitor:** Capacitor is a device used to **store charges and energy.** When a battery is connected to the capacitor, electrons of total charge '-Q' are transferred from one plate to other plate. For this work is done by the battery. This **work done is stored as electrostatic energy in capacitor.** ....1 Mark To transfer 'dQ' for a potential difference 'V', the work done is **$dW = VdQ = \frac{Q}{C}dQ$** $[\because V = \frac{Q}{C}]$ ....½ Mark The total work done to charge a capacitor, $W = \int_0^Q \frac{Q}{C}dQ$; $= \frac{1}{C}\left[\frac{Q^2}{2}\right]_0^Q$; $= \frac{Q^2}{2C}$ ....1 Mark This work done is stored as electrostatic energy of the capacitor, (i.e) $U_E = \frac{Q^2}{2C} = \frac{1}{2}CV^2$ $[\because Q = CV]$ ....½ Mark	3

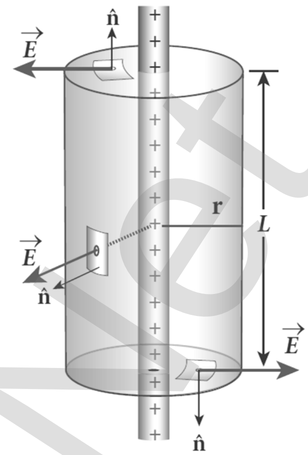
21	**Resistors in Series:** When two or more resistors are connected end to end, they are said to be in series. Let **R_1, R_2, R_3 be the resistances of three resistors connected in series.** Let **"V" be the potential difference** applied across this combination. In series connection i) Current through each resistor will be same (I) ii) But potential difference across different resistor will be different.  (a) Three resistors in series Let **V_1, V_2, V_3 be the potential difference** across R_1, R_2, R_3 respectively, then from Ohm's law. $V_1 = IR_1$; $V_2 = IR_2$, $V_3 = IR_3$ Total potential difference, $V = V_1 + V_2 + V_3$; $= IR_1 + IR_2 + IR_3$ $V = I[R_1 + R_2 + R_3]$ ……………. (1) Let Rs be the equivalent resistance in series connection, then $V = IR_s$ ………..(2) From equation (1) and (2), we have $IR_s = I\,[R_1 + R_2 + R_3]$; $\therefore R_s = R_1 + R_2 + R_3$ When resistances are connected in series, **the equivalent resistance** is the **sum of the individual resistances**. The equivalent resistance in series connection will be **greater than each individual resistance.**	3
22	$R_T = R_0\,(1 + \alpha T)$; $= 10[1+(0.004 \times 100^0]$ ------------------- 1 Mark $R_T = 10(1+0.4) = 10 \times 1.4$; $R_T = 14\ \Omega$ ---------------------- 1 Mark **As the temperature increases the resistance of the wire also increases.** ----------1Mark	3
23	<u>**Torque experienced by the dipole in electric field:**</u> Let a dipole of moment $\vec{p}$ is placed in an uniform electric field $\vec{E}$ The force on '+q' $= +\,q\vec{E}$; '−q' $= -\,q\vec{E}$ Then the <u>total force acts on the dipole is zero.</u> The total torque on the dipole about the point 'O' $\lvert\vec{\tau}\rvert = \lvert\overline{OA}\rvert\lvert -q\vec{E}\rvert \sin\theta + \lvert\overline{OB}\rvert\lvert q\vec{E}\rvert \sin\theta$  <u>$\tau = (OA + OB)\,qE \sin$;</u> <u>$\tau = 2\,aqE \sin\theta$ $\because [OA = OB = a]$</u> <u>$\boldsymbol{\tau = pE\sin\theta}$ (Where, $2\,aq = p \rightarrow$ dipole moment)</u> In vector notation, $\vec{\tau} = \vec{p} \times \vec{E}$. The torque is maximum, when $\theta = 90^0$	3

24	**Seebeck effect:**  Seebeck discovered that in a closed circuit consisting of two dissimilar metals, when the junctions are maintained at different temperatures an emf (potential difference) is developed. This is called Seebeck effect. The current that flows due to the emf developed is called **thermoelectric current.** The two dissimilar metals connected to form two junctions is known as **thermocouple.** If hot and cold junctions are interchanged, the direction of current also reversed. Hence Seebeck effect is **reversible.** ……………1 ½ Marks **Applications:** Seebeck effect is used in **thermoelectric generators** (Seebeck generators). This effect is **utilized in automobiles as automotive thermoelectric generators.** Seebeck effect is **used in thermocouples and thermopiles.** **(Any 3 applications :** 3 x ½ = 1 ½ Marks**)**	3
25	**Properties of electric field lines:** 1) They starts from **positive charge and end at negative charge** or at infinity. 2) The electric field vector at a point in space is tangential to the electric field line at that point. 3) The **electric field lines are denser in a region where the electric field has larger magnitude and less dense in region where the electric field** is of smaller magnitude. (i.e) the number of lines passing through a given **surface area perpendicular to the line is proportional to the magnitude of the electric field.** 4) **No** two electric field lines **intersect** each other 5) The number of electric field lines that emanate from the positive charge or end at a negative charge is **directly proportional to the magnitude of the charges.**	3
26	**(a)** The capacitance of the capacitor is $C = \frac{\epsilon_0 A}{d}$; $\frac{8.854 \times 10^{-12} \times 25 \times 10^{-4}}{1 \times 10^{-3}}$ $= 221.2 \times 10^{-13}$ F; $C = 22.12 \times 10^{-12}$ F; $= 22.12\ pF$ ------------- 1 ½ Marks **(b)** The charge stored in any one of the plates is Q = CV, Then $Q = 22.12 \times 10^{-12} \times 10 = 221.2 \times 10^{-12}$C $Q = 221.2\ pC$ ------------- 1 ½ Marks	3

PART – IV

Answer **all** the questions. 3x5=15

27 **Electric field due to infinitely long charged wire:**



Consider an infinitely long straight wire of uniform linear charge density 'λ'. Let 'P' be a point at a distance 'r' from the wire. Let 'E' be the electric field at 'P'. Consider a cylindrical Gaussian surface of length 'L' and radius 'r' 5

The electric flux through the **top surface**,

$\Phi_{tap} = \int \vec{E}.\overrightarrow{dA} = \int E\, dA \cos 90^0 = 0$

The electric flux through the **bottom surface**,

$$\Phi_{bottom} = \int \vec{E}.\overrightarrow{dA} = \int E\, dA \cos 90^0 = 0$$

Then the total electric flux through the **curved surface**,

$\Phi_{curve} = \int \vec{E}.\overrightarrow{dA} = \int E\, dA \cos 90^0 = E\int dA$

$$\Phi_{curve} = E\, 2\pi rL$$

Then the **total electric flux** through the **Gaussian surface**,

$$\Phi_E = \Phi_{tap} + \Phi_{bottom} + \Phi_{curve}\ ;\ \Phi_E = E\,(2\pi rL)$$

By Gauss law, $\Phi_E = \frac{Q_{in}}{\varepsilon_0}$; $E\,(2\pi rL) = \frac{\lambda L}{\varepsilon_0}$;

$E = \frac{\lambda}{2\pi\varepsilon_0 r}$ In vector notation, $\vec{E} = \frac{\lambda}{2\pi\varepsilon_0}\hat{r}$

Here $\hat{r} \rightarrow$ unit vector perpendicular to the curved surface outwards.

If $\lambda > 0$, then $\vec{E}$ points perpendicular outward ($\hat{r}$) from the wire and if $\lambda < 0$, then $\vec{E}$ points perpendicular inward ($-\hat{r}$).

(OR)

Van de Graff Generator:

It is designed by Robert Van de Graff.

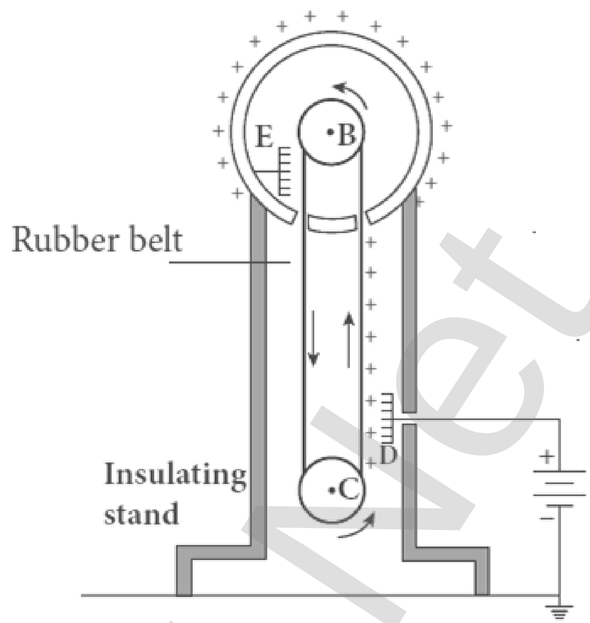
It produces large **electro static potential difference** of about **10^7 V**

Principle: Electro static induction, Action of points

Construction:

It consists of large **hollow spherical conductor 'A'** fixed on the insulating stand.**Pulley 'B'** is mounted at the centre of the sphere and another **pulley 'C'** is fixed at the bottom. A belt made up of insulating material like silk or rubber runs over the pulleys. 5

The **pulley 'C'** is driven continuously by **the electric motor**. Two comb shaped metallic conductor D and E are fixed near the pulleys. The comb 'D' is maintained at a **positive potential of 10^4 V** by a power supply. The upper **comb 'E'** is connected to the inner side of the **hollow metal sphere.**



Working:

Due to the high electric field near comb 'D', air between the belt and comb 'D' gets ionized. **The positive charges are pushed towards the belt and negative charges are attracted towards the comb 'D'.**

The positive charges stick to the belt and move up. When the positive charges reach the comb 'E' a large amount of negative and positive charges are induced on either side of comb 'E' due to electrostatic induction.

As a result, the positive charges are pushed away from the **comb 'E' and they reach the outer surface of the sphere.**

These positive charges are distributed uniformly on the outer surface of the hollow sphere. At the same time, **the negative charges neutralize the positive charges in the belt due to corona discharge before it passes over the pulley.** When the belt descends, it has almost no net charge.

This process continues until the outer surface produces the **potential difference of the order of 10^7 V** which is the limiting value.

Beyond this, the charge starts leaking to the surroundings due to ionization of air. It is prevented by enclosing the machine in a gas filled steel chamber at very high pressure.

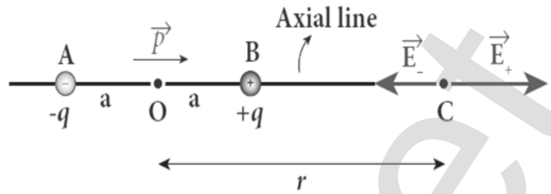
Applications:

The high voltage produced in this **Van de Graff generator** is used to **accelerate positive ions (Protons and Deuterons**) for nuclear disintegrations and other applications.

28 **Electric field due to dipole on its axial line:**

Consider a dipole AB along X - axis. Its dipole moment be p = 2qa and its direction be along − q to + q .

Let 'C' be the point at a distance 'r' from the midpoint 'O' on its axial line.



Electric field at C due to +q

$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$

Electric field at C due to −q

$\vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$

Since +q is located closer to point 'C' than −q , $\vec{E}_+ > \vec{E}_-$.

By superposition principle, the total electric field at 'C' due to dipole is,

$\vec{E}_{tot} = \vec{E}_+ + \vec{E}_-$

$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$

$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$;

$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{(r+a)^2-(r-a)^2}{(r-a)^2\,(r+a)^2}\right]\hat{p}$

$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{r^2+a^2+2ra-r^2-a^2+2ra}{((r-a)\quad(r+a))^2}\right]\hat{p}$

$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{4ra}{(r^2-a^2)^2}\right]\hat{p}$

Here the direction of total electric field is the dipole moment $\hat{p}$

If $r \gg$a , then neglecting a^2. We get $\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{4ra}{r^4}\right]\hat{p}$;

$= \frac{1}{4\pi\varepsilon_0} q\left[\frac{4a}{r^3}\right]\hat{p}$

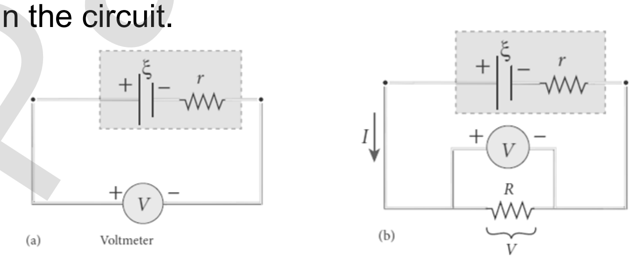
$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$ [q 2a$\hat{p}$ = $\vec{p}$] 5

(OR)

Internal resistance of a cell:

A real battery is made of electrodes and electrolyte. There is resistance to the flow of charges within the battery and this resistance is called internal resistance (r)

The **emf of the cell** is measured by **connecting high resistance** voltmeter across it without connecting the external resistance R. This circuit may be considered as open, the voltmeter reading gives the emf (ξ) of the cell. Then external resistance is included in the circuit and current 'I' is established in the circuit. 5



This circuit is then considered as close, the voltmeter reading gives the potential difference (V) across 'R'

By Ohm's law, = IR (or) $I = \frac{V}{R}$ ....(1)

Due to internal resistance of the cell, the voltmeter reads the value "V" which is less than the emf (ξ). It is because, certain amount of voltage (Ir) has dropped across the internal resistance 'r'. Hence

$V = \xi - Ir$ – – – – (2) (or) $Ir = \xi - V$

$\therefore$ $r = \frac{\xi - V}{I}$; = $\left[\frac{\xi - V}{V}\right]R$

Since ξ, V and R are known, internal resistance 'r' and total current 'I' can be determined.

The power delivered to the circuit is, I = I ξ ; = I (V + Ir); = I (IR + Ir)

$P = I^2R + I^2r$

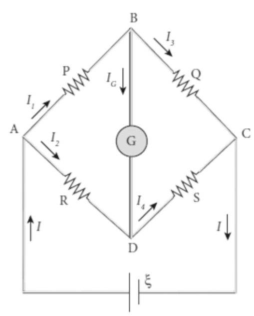
where, $I^2R \rightarrow$ power delivered to R

$I^2r \rightarrow$ power delivered to r

29

Wheatstone's bridge:

An important application of **Kirchhoff's laws is the Wheatstone's bridge.** It is **used** to compare resistances and also helps in **determining the unknown resistance in the electrical network**. The bridge consists of four resistances P, Q, R, S connected as shown. A galvanometer 'G' is connected between B and D. A battery 'ξ' is connected between A and C . Let I_1, I_2, I_3, I_4 currents through various branches and I_G be the **current through the galvanometer**.



Applying Kirchhoff's current law at B and D,

$I_1 - I_G - I_3 = 0$ – – – – (1)

$I_2 + I_G - I_4 = 0$ – – – – (2)

Applying Kirchhoff's voltage law ABDA and ABCDA,

$I_1 P + I_G G - I_2 R = 0$ – – – – (3)

$I_1 P + I_3 Q - I_2 R - I_4 S = 0$ – – – – (4)

At balanced condition, the potential at B and D are same, and hence the **galvanometer** shows **zero deflection**. So **$I_G = 0$**

Put this in equation (1), (2) and (3)

5

$I_1 - I_3 = 0$ (or) $I_1 = I_3$ ---- (5)

$I_2 - I_4 = 0$ (or) $I_2 = I_4$ ---- (6)

$I_1P - I_2R = 0$ (or) $I_1P = I_2R$ ---- (7)

Put equation (5) and (6) in (4)

$I_1P + I_1Q - I_2R - I_2S = 0$; $I_1(P + Q) - I_2(R + S) = 0$

$\therefore I_1(P+Q) = I_2(R + S)$ ---- (8)

Divide equation (8) by (7)

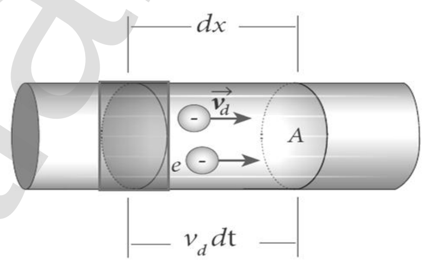
$\frac{I_1(P+Q)}{I_1P} = \frac{I_2(R+S)}{I_2R}$; $\frac{(P+Q)}{P} = \frac{(R+S)}{R}$

$1 + \frac{Q}{P} = 1 + \frac{S}{R}$;

$\frac{Q}{P} = \frac{S}{R}$ (or) $\mathbf{\frac{P}{Q} = \frac{R}{S}}$

(OR)

Microscopic model of current and Ohm' law:



Area of cross section of the conductor = A

Number of electrons per unit volume = n,

Applied electric field $= \vec{E}$

Drift velocity of electrons $= \boldsymbol{vd}$,

Charge of an electrons = e

Let 'dx' be the distance travelled by the electron in time 'dt', then

$v_d = \frac{dx}{dt}$ (or) $dx = v_d\ dt$

The number of electrons available in the volume of length 'dx' is

$= A\ dx \times n$; $= A\ v_d\ dt \times n$ 5

Then the total charge in this volume element is, $dQ = A\ v_d\ dt\ n\ e$

By definition, the current is given by $I = \frac{dQ}{dt}$; $= \frac{A\, v_d\, dt\, n\, e}{dt}$; $\mathbf{I = n\, e\, A\, V_d}$

Current density (J):

Current density (J) is defined as the current per unit area of cross section of the conductor. $J = \frac{I}{A}$; $= \frac{n\, e\, A\, v_d}{A}$. $J = ne\, v_d$. Its **unit is $\mathbf{Am^{-2}}$**

In vector notation, $\vec{J} = ne\vec{v}_d$; $\vec{J} = ne\left[-\frac{e\tau}{m}\vec{E}\right]$; $= -\frac{ne^2\tau}{m}\vec{E}$

Where, $\frac{ne^2\tau}{m} = \sigma \rightarrow$ Conductivity; $\therefore \vec{J} = -\sigma\vec{E}$

But conventionally, we take the direction of current density as the direction of electric field. So the above equation becomes, $\vec{J} = \sigma\vec{E}$

This is called microscopic form of Ohm's law.