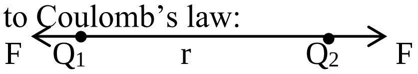
<u>Electrostatics, Field, Potential & Flux</u> :

Long Answer Question

1. *State Coulomb's law. Define electric intensity and potential due to a point charge.*

Ans: Coulomb's law deals with electrostatics interaction between two point charges along the joining line.

According to Coulomb's law:



(i) The force of interaction between two point charges is repulsive if charge are of same nature and is attractive if the charge are of opposite in nature.

(ii) The magnitude of force is directly proportional to product of charges

$F \propto Q_1 Q_2$

(iii) The magnitude of force is inversely proportional to square of distance.

$F \propto 1/r^2$

$F \propto Q_1 . Q_2 / r^2$

Or, $F = (1/4\pi\epsilon_0) Q_1 . Q_2 / r^2$

Where $\epsilon_0 = 8.85 \times 10^{-12} C^2/N\text{-}m^2$ is called Space Electric constant or permittivity of vacuum.

The force experienced by unit positive charge at any point is called electric field intensity.

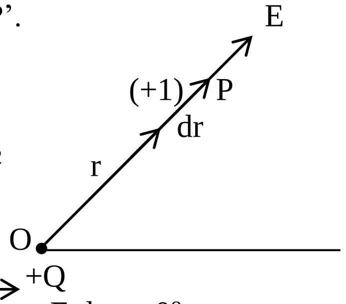
$\vec{E} = \vec{F} / Q$ N/C

The negative value of work done in bringing unit positive charge from reference point to present point is called Electric potential.

$V_p = -\int_{Ref.}^{Present} \vec{E} . \vec{dr}$ J/C or Volt

There is a point charge Q at 'O' and there ise unit point charge at 'P'.

$E = (1/4\pi\epsilon_0) Q / r^2$



$dV = -dW = -\vec{E} . \vec{dr} = -E.dr \cos 0^o$

$= (-Q/4\pi\epsilon_0) dr/r^2$

Integrating both side.

$\int_0^{V_p} V_p = (-Q/4\pi\epsilon_0) \int_{r=\infty}^{r=R} dr/r^2$

$V_p = (1/4\pi\epsilon_0) Q/r$ J/C

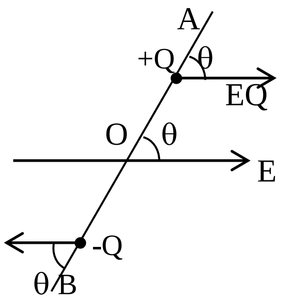
The dimensional formula electric field and electric potential are $[MLT^{-2}I^{-1}]$ and $[ML^2T^{-3}I^{-1}]$.

2. *Define electric dipole moment. Derive expression for electric potential and field intensity at any point due to an electric dipole.*

* *

Anns: The physical quantity which measures ability of electric dipole system to experience torque in any electric field.

AB is an electric dipole system of length 2l and Q charge on the poles. The dipole is kept in the uniform electric field E at an angle θ. The torque experienced by the dipole

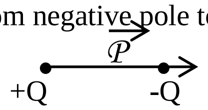


$\overline{i} = -2l\theta E \sin\theta$

The magnitude of electric dipole moment is numerically equal to magnitude of torque experienced by dipole in the field of unit strength kept at right angle to the field

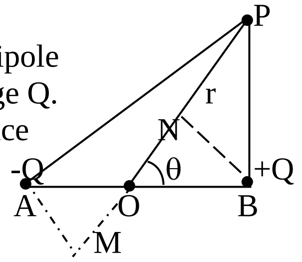
$|\vec{\mathcal{P}}| = |\vec{i}| = 2l\theta$

The direction of dipole moment is assigned along the axis from negative pole to positive pole.



Where $\mathcal{P} = 2lQ$

AB is an electric dipole of length 2l and pole charge Q. P is a point at radial distance 'r' and angular position.



E Pot. at P due to positive point charge.

$V_{PB} = (1/4\pi\epsilon_0) Q/PB$

E Pot. at P due to negative point charge.

$V_{PA} = -(1/4\pi\epsilon_0) Q/PA$

In OBN and OAM

$ON = OM = l\cos\theta$

$PB = PA = OP - ON = r - l\cos\theta$

$PA = PA = OP + OM = r + l\cos\theta$

E Pot. at P due to the dipole system.

$V_{PA} = (Q/4\pi\epsilon_0)[(1/r - l\cos\theta) - (1/r + l\cos\theta)]$

$V_{PA} = (1/4\pi\epsilon_0)\, 2lQ\cos\theta / r^2 - l^2\cos^2\theta$

$= (1/4\pi\epsilon_0) \mathcal{P}\cos\theta / r^2$

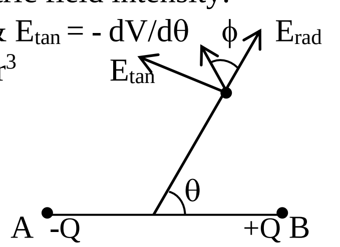
Where r>>l cosθ)

From definition of electric field intensity.

$E_{rad} = -dV/dr$ & $E_{tan} = -dV/d\theta$

$E_{rad} = (1/4\pi\epsilon_0) 2\mathcal{P}\cos\theta / r^3$

$E_{tan} = (1/4\pi\epsilon_0) \mathcal{P}\sin\theta / r^3$



The resultant field intensity

$E_R = \sqrt{E^2_{rad} + E^2_{tan}} = [(1/4\pi\epsilon_0)(\mathcal{P}/r^3)\sqrt{3\cos^2\theta + 1}$

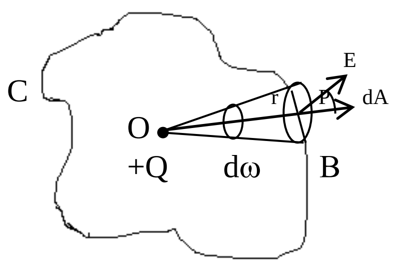
$\tan\phi = E_{tan} / E_{rad} = 1/2\tan\theta$

3. *State and prove Gauss Theorem. Derive expression for electric field near uniform areal charge distribution.* *Or,*
Derive expression for electric field due to long uniform linear charge distribution.

Ans: According to Gauss theorem total electric flux intercepted by a closed surface is equal to $1/\in_0$ times the algebric sum of charges enclosed by the surface.

$\phi_E = (1/\in_0)Q$

ABC is a closed surface containing point charge Q at P. There is an elementary area dA at P at radial distance r.



From coulomb's law electric field at P

$E = (1/4\pi\in_0)Q/r^2$

Electric flux intercepted by the surface dA

$d\phi_E = \vec{E}.\vec{dA} = E.dA\cos\theta = (Q/4\pi\in_0)\, dA\cos\theta/r^2$

The elementary area dA subtend a solid angle dω at O. Where $dA\cos\theta/r^2 = d\omega$

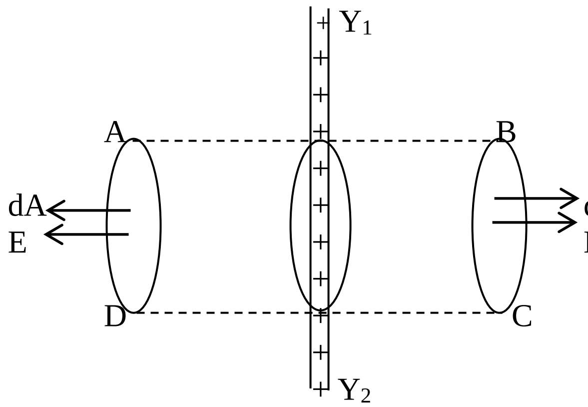
$d\phi_E = (Q/4\pi\in_0)\, d\omega$

Integrating both side

$\int_0^{\phi_E} d\phi_E = Q/4\pi\in_0 \int_0^{4\pi} d\omega$

$\mathbf{\phi_E = (1/\in_0)Q}$

4 . **Y_1Y_2 is charge sheet having uniform areal charge distribution**. The areal charge density is σ c/m^2. ABCD is a cylindrical Gaussian surface which substends an area dA on the surface.



The flux intercepted by the cylindrical Gaussian surface. **

** $d\phi_E = 2EdA$

The charge enclosed in the surface .

$dQ = \sigma dA$

From Gauss theorem

$d\phi_E = dQ/\in_0$

$2EdA = \sigma dA/\in_0$

$E = \sigma/2\in_0$

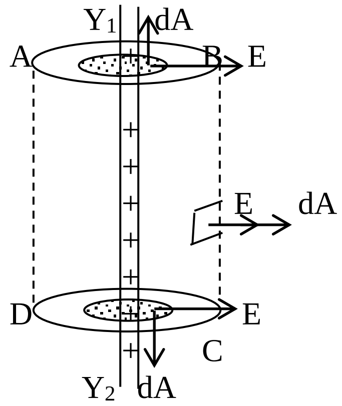
5 Y_1Y_2 is long uniform linear charge distribution.

Its linear charge density is λc/m. ABCD is a coaxial cylindrical Gaussian surface of length l radius r.

Electric flux intercepted by the surface

$\phi_E = E2\pi rl$

Charge enclosed by the surface



$q = \lambda/l$

From Gaussian theorem

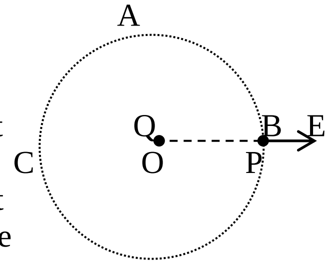
$d\phi_E = q/\in_0$

$E2\pi rl = \lambda l/\in_0$

$E = \lambda/2\pi\in_0 . r$

4. . **6.** *Derive expression for electric field at any point due to a point charge using Gauss theorem.*

Ans: Q is a point charge located at O. ABC is a spherical surface of radius r with point charge at its centre E is a electric field at point P on the surface of Gaussian surface. Which is radial and outwardly. Then electric flux intercepted by the surface.



$\phi_E = \int E.\, dA = E\, 4\pi r^2$

Using Gauss theorem

$\phi_E = q_{in}/\in_0$

$E\, 4\pi r^2 = Q/\in_0$

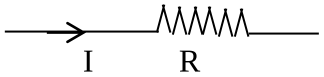
$E = (1/4\pi\in_0)Q/r^2$

Thermo-electric effect :

Long Answer Questions

7. *State Joule's law of heating. Describe experiment for verification of Joule's law of heating.*

Ans: When ever current flows through a resistor there is dissipation of heat to the surrounding.



According to Joule's law of heating the amount of heat generated is

(a) Directly proportional to square of current flowing through the resistor.

$H \propto I^2$

If resistance R and time of flows remains constant.

(b) Directly proportional to value of resistance through which current flows.

$H \propto R$

Where I & t remains constant.

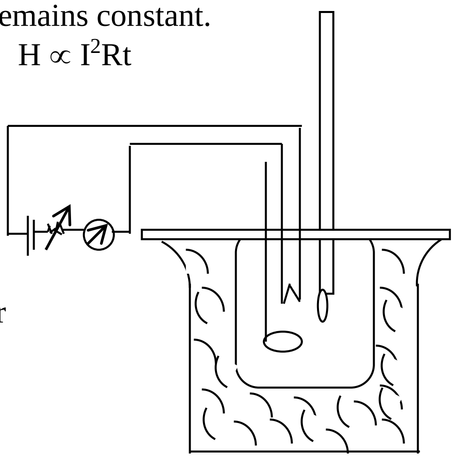
(c) Directly proportional to the time of flow.

$H \propto t$

Where I & t remains constant.

$H \propto I^2Rt$

For verifying Joule's law of heating there is a calorimeter containing a copper beaker with a copper stirrer and sensitive thermometer.



The beaker contains kerosene oil. A resistor is kept submerged into the beaker. The terminals of the resistor is kept connected to a e.m.f. source having a variable resistor along with an ammeter.

Mass of the kerosene oil = m_1

Mass of the copper beaker and stirrer = m_2

Specific heat of the kerosene oil = S_k

Specific heat of the copper = S_c

Initial temperature = t_1°c

Heat observed by the calorimeter and kerosene oil. Which released from the resistor.

$H_1 = (S_k m_1 + S_c m_2)(t_2 - t_1)$ ***

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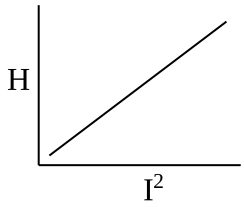
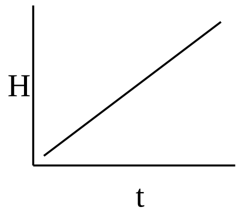
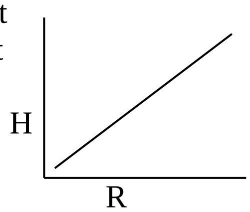
(a) By keeping values of resistance and time of flow of current to be constant different values of heat generated is determined then a graph is plotted.



(b) Same value of current is flown through the resistor for different periods of time and corresponding heat generated is noted.

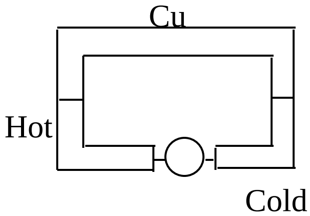


(c) The same value of current is flown through different resistor and corresponding heat generated is calculated then a graph is plotted.



2. 8. What is Seebeck effect.

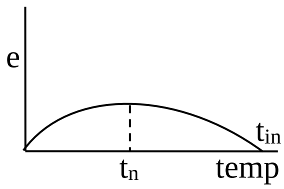
Ans:The flow of current in any thermocouple when the two junction are kept at different temperature is called Seebeck effect.



The contact potential at the junction differs in value. When the two junction are kept at different temperature the e.m.f. developed depends upon temperature of hot junction when the cold junction is maintained at 0°. The dependance is given by the equation

$e = at + \frac{1}{2} bt^2$

Where e = e.m.f. developed in thermocouple due to the Seebeck effect a and b are two constant and t is temp of the hot junction. The e.m.f. rises and in temperature in hot junction.



Neutral temperature: The temperature at which e.m.f. of Seebeck effect attains maximum value is called neutral temperature.

$de/dt = a + bt = 0$

$t_N = -a/b$

Temperature of inversion: The temperature of hot junction at which e.m.f. in the thermocouple ****

****
revsrses its polarity is called temperature of inversion.

$at + \frac{1}{2} bt^2 = 0$

$t_{In} = -2a/b$

The polarity of e.m.f. depends upon nature of elements. On this basis the elements are arranged in an order and is called thermo electric series as Sb, Fe, Zn, Ag, Au Sn, Pb, Cu, Pt, Ni, Bi.

The current at cold junction flows earlier metal to later metel.

9. *What is Peltier effect.*

Ans: When current flows in thermocouple due to applied e.m.f. heat gets evolved at one junction and is absorbed at other junction. This phenomenon of absorption and evolution of heat at the junction due to current flow is called Peltier effect. The amount of heat absorbed or evolved per unit flow of charge Peltier coefficient.

10. *Describe principal and construction of potentiometer. How it is used for determination of e.m.f. of a cell.*

Ans: Potentiometer is an instrument based on principal of comparison of pot difference between two pair of terminals. Where one terminals has standard known potential difference while other terminals have potential difference to be determined.

Potentiometer consists of a conducting wire having uniform resistance per unit length of definite length connected to be terminals of a e.m.f. source, ammeter.

The current in the conducting wire $I_o = E_o/r_o + \lambda L$

Where r_o = internal resistance

L = Length of resistance.

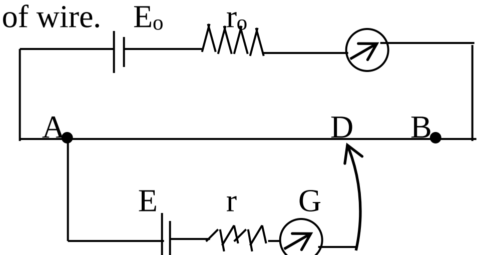
$\lambda = R/L$ = Resistance /unit length.

The potential difference between two points A&B

$$V_o = I_o \lambda L$$

Where $V \propto L$

Potential difference is directly proportional to the length of wire.



For determining e.m.f. of a cell one terminal of the e.m.f. source is connected across one end of *****

*****(the resistive wire where the other end is connected with a sensitive galvanometer.

The end of galvanometer is slid on the wire to the length where deflection of the galvanometer becomes zero. At this position e.m.f. is equal to potential difference between A & D.

$$V_o = I_o \lambda L$$

It can be determined after measuring length AD.

11. *What are Faraday's law of electrolysis. Describe experimental verification of Faraday's law.*

Ans: According to Faraday's laws of electrolysis

(1) The mass of ions collected at each electrode is proportional to the amount of charge passed through $m \propto Q$

$\propto It$

$m = ZIt$

Where I = current flowing, t = time of flow

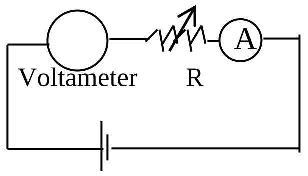
Z = electrochemical equivalent.

For experimental verification the cathode of volt meter is cleaned and dried after weighing is placed in voltmeter. Then current of given value is passed through the voltmeter for given internal of time. Then again the electrode weighed. If

$m_1/m_2 = I_1/I_2$

$m \propto I$ and $m_1/m_2 = t_1/t_2$

Where m_1 and m_2 are amount of mass deposited on the electrodes.



Thus $m \propto I$

(2) When same amount of charge is passed through different electrolytes, the amount of ions deposited is proportional to their chemical equivalents of elements deposited.

When same current is passed through Voltmeter for same period of time m_1, m_2 and m_3 are mass of ions deposited for

$m_1 = Z_1 It$, $m_2 = Z_2 It$ $m_3 = Z_3 It$

Where Z_1, Z_2 and Z_3 are electrochemical equivalent of the ions.

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