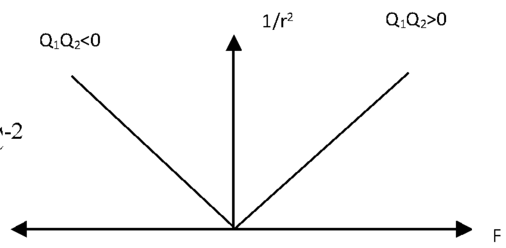
1. ELECTROSTATICS

GIST

- Electrostatics is the study of charges at rest.
- The intrinsic property of fundamental particle of matter which give rise to electric force between objects is called charge.
- Charging a body can be done by friction, induction and conduction.
- Properties of charges:
  - Like charges repel and unlike charges attract.
  - Charges are additive in nature i.e., $Q=\sum_{i=1}^{n} q_i$
  - Charges are quantized. i.e., Q= $\pm$ ne [n=1,2,3,... & e =1.602 X10^{-19} C]
  - Charge on a body is independent of velocity of the body.
  - Charge is conserved.
- The sensitive device which is used to identify whether the body is charged or not is called electroscope.
- Coulomb's law: $\vec{F} = \frac{kq_1q_2}{r^2}\hat{r}$;

  k=$\frac{1}{4\pi\epsilon_0}$ = 8.988 x 10^9 OR 9 x 10^9 Nm^2C^{-2}



ϵ_0= absolute permittivity of free space.

ϵ_0 = 8.855 x 10^{-12} OR 9 x $10^{-12}C^2N^{-1}m^{-2}$.

- The charge is said to be one coulomb when it is separated from similar charge by one-meter experiences a force of repulsion 9 x 10^9 N.
- The period of revolution of charge q_1 of mass m about charge q_2 along the circular path of radius r is T = $\sqrt{\frac{16\pi^3\epsilon_0 mr^3}{q_1q_2}}$
- Principle of superposition: $\vec{F}_{total} = \sum_{i=1}^{n}\vec{F_i}$[Vector sum of individual forces]

$$=\frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r_{12}^2}\hat{r}_{12}+\frac{1}{4\pi\varepsilon_o}\frac{q_1q_3}{r_{13}^2}\hat{r}_{13}+....$$

- <u>Uniform Charge distribution</u>:

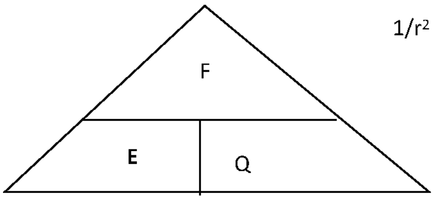
  Linear charge distribution: $\lambda = \frac{\Delta q}{\Delta l}$ [$\lambda \Rightarrow$ linear charge density Unit Cm^{-1}]

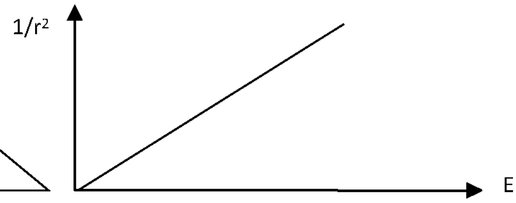
  Surface charge distribution: $\sigma = \frac{\Delta q}{\Delta S}$ [$\sigma \Rightarrow$ surface charge density Unit Cm^{-2}]

  Volume charge distribution: $\rho = \frac{\Delta q}{\Delta V}$ [$\rho \Rightarrow$ Volume charge density Unit Cm^{-3}]
- Force due to continuous charge distribution:

$$\vec{F} = \frac{q_o}{4\pi\epsilon_0}\left[\int_L \frac{\lambda dl}{r^2} + \int_S \frac{\sigma dS}{r^2} + \int_V \frac{\rho dV}{r^2}\right]\hat{r}$$

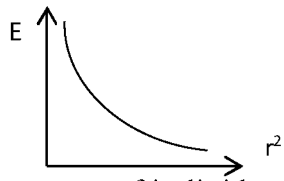
- The comparison of electrostatic and gravitational forces between electron and proton is $\frac{F_e}{F_g} = \frac{ke^2}{Gm_p m_e}$= 2.27 x 10^{39}.





Note: *In the above triangle the quantity shown at the vertex, could be arrived by multiplying the quantities shown at the base, i.e. F=E X Q.*
Any one of the quantity shown at the base is given by the ratio of the quantities shown at vertex & the other quantity shown at the base, i.e. E=F/Q or Q= F/E.

- Electric field: Force experienced by a unit positive charge. It is a vector. SI unit is NC^{-1}. $\vec{E} = \underset{q_o \to 0}{Lt} \frac{\vec{F}}{q_o}$



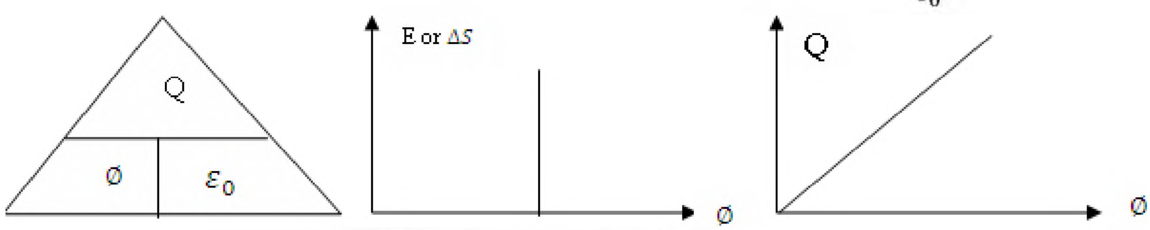
- Field due to a point charge Q at r is $\vec{E} = \frac{kQ}{r^2}\hat{r}$
- Principle of superposition: $\vec{E}_{total} = \sum_{i=1}^{n} \vec{E_i}$ [vector sum of individual fields]
- Electric field due to continuous charge distribution:

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\left[\int_L \frac{\lambda dl}{r^2} + \int_S \frac{\sigma dS}{r^2} + \int_V \frac{\rho dV}{r^2}\right]\hat{r}$$

- Dipole: Two equal and opposite charges separated by a small distance.
- Dipole moment: Product of magnitude of either charge and distance of separation between them. It is a vector. SI unit: Cm, $\vec{p}$= (Q) $2\vec{a}$; direction of $\vec{p}$ is from negative charge to positive charge along the straight line joining both the charges.
- Dipole in a uniform electric field experiences no net translating force but experiences a torque. $\vec{\tau}=\vec{p} \times \vec{E} \Rightarrow \vec{\tau}=|\vec{p}||\vec{E}| \sin\theta\, \hat{n}$
- If θ= 0° ⇒ stable equilibrium; If θ= 180° ⇒ unstable equilibrium.
- Electric field due to a short dipole

- at a point on the axial line: $E_{axial} = \frac{2k\vec{p}}{r^3}$ along the direction of dipole moment
- At a point on the equatorial line: $E_{eq} = \frac{k\vec{p}}{r^3}$ opposite to the direction of dipole moment.

- Properties of electric field lines:
  - ✓ Arbitrarily starts from +ve charge and end at –ve charge
  - ✓ Continuous, without any breaks, never form closed loops
  - ✓ Never intersect
  - ✓ Relative closeness of the field lines represents the magnitude of the field strength.
  - ✓ For a set of two like charges – lateral pressure in between
  - ✓ For a set of two unlike charges – longitudinal contraction in between.
- Area vector: The vector quantity representing the area of a surface whose magnitude is equal to the magnitude of the area and direction is perpendicular to the surface.
- Electric flux: $\emptyset = .\vec{E}.\vec{\Delta S} = |\vec{E}||\vec{\Delta S}|cos\theta$; It is a scalar; SI unit: N m^2C^{-1} or Vm.
- Gauss' theorem in electrostatics: $\emptyset_{total} = \oint_s \vec{E}.\vec{dS} = \frac{q_{total}}{\epsilon_0}$



ϕ is independent of $\vec{E}$ & $\vec{\Delta s}$

- Applications of Gauss' theorem for uniform charge distribution:

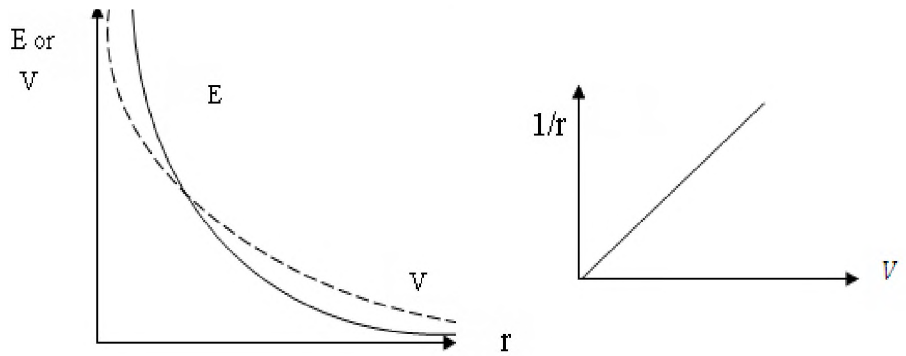
Expression for	**Infinite Linear**	**Infinite plane sheet**	**Thin spherical shell**
Flux ∅	$\frac{\lambda l}{\epsilon_0}$	$\frac{\sigma S}{\epsilon_0}$	$\frac{\sigma 4\pi r^2}{\epsilon_0}$
Magnitude of Field E	$\frac{\lambda}{2\pi r\epsilon_0}$	$\frac{\sigma}{\epsilon_0}$	$\frac{Q}{4\pi r^2\epsilon_0}$[for points on/outside the shell] ZERO [for points inside the shell]
Charge density	$\lambda = \frac{\Delta q}{\Delta l}$	$\sigma = \frac{\Delta q}{\Delta S}$	$\frac{\sigma}{4\pi r^2}$

- Electrostatic Potential: Work done per unit positive Test charge to move it from infinity to that point in an electric field. It is a scalar. SI unit: J/C or V

$$V = W / q_o$$

Electric potential for a point charge: $V = \frac{kq}{r}$

- The electrostatic potential at any point in an electric field is said to be one volt when one joule of work is done in bringing one unit charge from infinity to that point.
- The electric field intensity at any point is the negative gradient of potential at that point. $E = -dV/dr$. $V(\vec{r}) = -\int_{\infty}^{r} \vec{E}\,.\,\overrightarrow{dr}$
- As E= - $\frac{dV}{dr}$ If Vis constant, E$\propto \frac{1}{r}$ and if E is constant, V$\propto r$



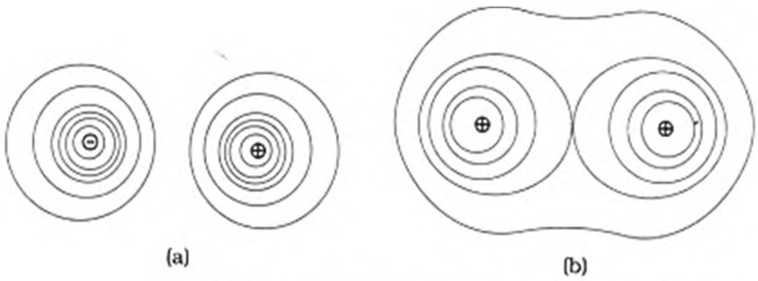
- Electric field is conservative. This means that the work done is independent of the path followed and the total work done in a closed path is zero.
- Potential due to a system of charges: $V_{total} = \sum_{i=1}^{n} \frac{kq_i}{r_i}$
- Potential due to a dipole at a point
  - on its axial line: $V_{axial} = \frac{k|\vec{p}|}{r^2}$ [or]$\frac{k|\vec{p}|}{r^2} cos\theta$
  - on its equatorial line:V_{eq}= 0
- Potential difference $V_A - V_B = kq\left[\frac{1}{r_A} - \frac{1}{r_B}\right]$
- Potential energy of two charges: U = $\frac{kq_1q_2}{r}$
- Potential energy of a dipole : U = $-\vec{p}.\vec{E}$ = p E $[cos\theta_1$ -$cos\theta_2]$
- Equipotential surfaces: The surfaces on which the potential is same everywhere.

✓ Work done in moving a charge over an equipotential surface is zero.

✓ No two equipotential surfaces intersect.

✓ Electric field lines are always perpendicular to the equipotential surfaces.

✓ The relative density of equipotential surface gives intensity of electric field in that region.



Some equipotential surfaces for (a) a dipole. (b) two identical positive charges.

- Electrostatics of conductors

(i) Inside a conductor Electrostatic field is zero

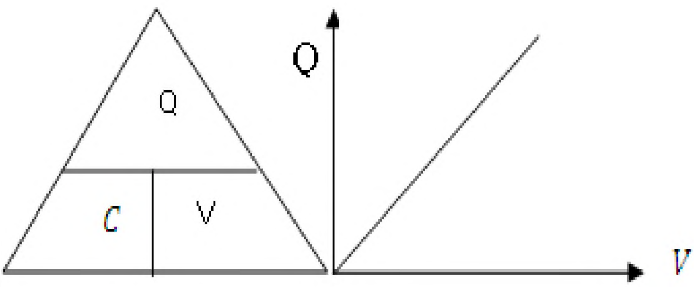
(ii) On the surface E is always Normal to the surface

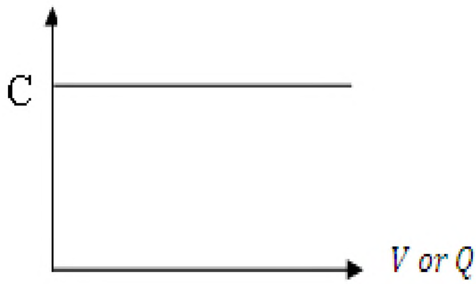
(iii) No excess charge resides inside the conductor

(iv) Charge distribution on the surface is uniform if the surface is smooth

(v) Electric field is zero in the cavity of hollow conductor and potential remains constant which is equal to that on the surface.

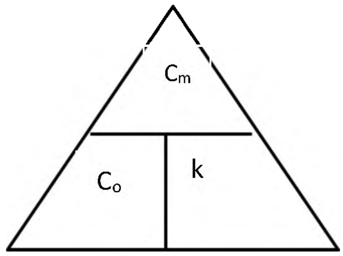
- Capacitor: An arrangement of two conductors separated by a small distance without any electrical contact between them is called capacitor.





- Capacitance: $C = \frac{Q}{V}$, Ratio of charge and potential difference. Scalar. SI unit: farad [F]. The capacitance is said to be one farad when one coulomb of charge increases the potential difference between the plates by one volt.
- Capacitance of a parallel plate capacitor: $C = \frac{\epsilon_0 A}{d}$

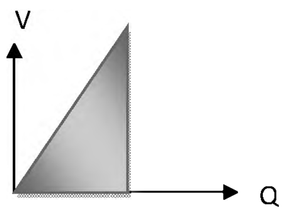
- Capacitance of a parallel plate capacitor with a dielectric medium in between:
  - $C_m = \frac{\epsilon_0 A}{\left(d - t + \frac{t}{k}\right)}$
  - If t=0 => $C_0 = \frac{\epsilon_0 A}{(d)}$
  - If t=d => $C_0 = k\frac{\epsilon_0 A}{(d)}$ => $C_m = k\,C_0$



- Combination of capacitors:

  Capacitors in series: $\frac{1}{c} = \sum_{i=1}^{n} \frac{1}{c_i}$ Capacitors in parallel: $c = \sum_{i=1}^{n} c_i$

- Energy stored in capacitors: $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$
- Area shaded in the graph = U $= \frac{1}{2}QV$
- Energy density : $U_d = \frac{1}{2}\epsilon_0 E^2 = \frac{\sigma^2}{2\epsilon_0}$



- The total energy in series and parallel combinations of capacitors is additive.
- When two charged conductors are touched mutually and then separated the redistribution of charges on them is in the ratio of their capacitances.
- Introducing dielectric slab between the plates of the charged capacitor with:

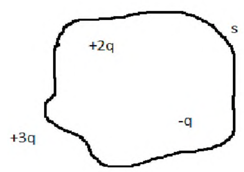
Property	**Battery connected**	**Battery disconnected**
Charge	$K\,Q_0$	Q_0
Potential difference	V_0	V_0/K
Electric field	E_0	E_0/K
Capacitance	KC_0	KC_0
Energy	K times $\frac{1}{2}\epsilon_0 E^2$ [Energy is supplied By battery]	1/K times $\frac{1}{2}\epsilon_0 E^2$ [Energy used for Polarization]

- On connecting two charged capacitors:
  - Common Potential: $V = \frac{C_1V_1+C_2V_2}{V_1+V_2}$
  - Loss of energy: $\Delta U = \frac{1}{2}\frac{C_1 \times C_2}{C_1+C_2}(V_1 - V_2)^2$
- The dielectric is the substance which is essentially an insulator but behaves like a conductor in electrostatic situation.
- The dielectric having atom or molecules whose negative charge centre is not coinciding with positive charge centre is called polar dielectric. They have permanent dipole moments in the order of 10^{-30} Cm.
- The dielectric having atom or molecules whose negative charge centre is coinciding with positive charge centre is called non-polar dielectric.
- The dipole moment developed in non-polar dielectric due to external electric field is called induced dipole moment.
- The induced dipole moment per unit volume is called Polarisation Vector. The direction of polarisation vector is same as that of external electric filed.
- The ratio of electrostatic force in free space to that in medium OR the ratio of electrostatic field in free space to that in medium OR the ratio of absolute permittivity of medium to that of free space is called relative permittivity or dielecric constant of the medium. $\epsilon_r OR \kappa$.
- The ratio of polarisation to ϵ_o times the electric field intensity is called electric susceptibility. $\chi = \frac{P}{\epsilon_o E}$. The dielectrics with constant χ are called linear dielectrics.
- The maximum external electric field the dielectric can withstand without dielectric beakdown is called dielectric strength. SI unit Vm^{-1}.
- The capacitance of a spherical conductor of radius R is C = $4\pi\epsilon_o R$.

CHARGES AND COULOMB'S LAW

QUESTIONS

1. What is the work done in moving a test charge 'q' through a distance of 1 cm along the equatorial axis of an electric dipole? [Hint : on equatorial line V=0] 1
2. Why in Millikan's Oil Drop experiment, the charge measured was always found to be of some discrete value and not any arbitrary value? 1
   Ans: Because charge is always quantized i.e., $Q = n \times e$
3. What is meant by electrostatic shielding? Ans: Electric filed inside a cavity is zero. 1
4. Why an electric dipole placed in a uniform electric field does not undergoes acceleration? 1
   Ans: Because the net force on the dipole is zero. $F_{net} = 0$ as $F = \pm qE$
5. Why electric field lines
   (i) Can never intersect one another? 1
   (ii) Cannot form closed loops?
   Ans : Because
   (i) The direction of Electric field is tangential to field line at any given point. Hence at the point of intersection there will be two tangential directions for two lines. But Electric field is a vector quantity and it can have only one direction at a point. So intersection of field lines is not possible.
   (ii) Electric field lines always start from positive charge and end at negative charge. Hence they can not form closed loops.
6. Show that at a point where the electric field intensity is zero, electric potential need not be zero. 2
   Ans: If $E = 0 \Rightarrow V = constant$ $E = -dV/dr$
7. What is the electric flux through the surface S in Vacuum? 2



8. Write the expression for the electric field, charge density for a uniformly charged thin spherical shell. 2
   Ans: $E = \frac{kQ}{r^2}$; $\sigma = \frac{Q}{4\pi r^2}$

9. 

2

Write the expression for the electric field in the regions I, II, III shown in the above figure.

Ans: $E_I = E_{III} = 0$ $E_{II} = \sigma/\varepsilon_0$

10. Two free protons are separated by a distance of 1 A°. if they are released, what is the kinetic energy of each proton when at infinite separation. [Hint : at infinite distance $K.E = \frac{e^2}{4\pi\epsilon_0 r}$] 2

11. How does the electric flux, electric field enclosing a given charge vary when the area enclosed by the charge is doubled? Ans: (a) ∅= constant (b) E is halved 2

12. The electric field in a certain region of space is $\vec{E} = 10^4 \hat{\imath} NC^{-1}$. How much is the flux passing through an area 'A' if it is a part of XY plane, XZ plane, YZ plane, making an angle 30^0 with the axis? 2

Ans: Φ_{XY} =10A Vm E ΔS COSφ [φ=0] $\varphi_{XZ} = \varphi_{YZ} = 0$ Vm (φ =90^O) =10^4 A cos30 ^{O}Vm

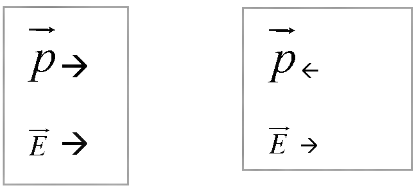
13. An electric dipole ±4μC is kept at co-ordinate points (1, 0, 4) are kept at (2,-1, 5), the electric field is given by $\vec{E}$ = 20 $\hat{\imath}$ NC^{-1}. Calculate the torque on the dipole. 2

Ans: Calculate first dipole moment using $\vec{p}$ =q.2$\vec{a}$

Then calculate torque using $\vec{\tau} = \vec{p} \times \vec{E}$ and hence find $|\vec{\tau}|$ =13.4 N-m

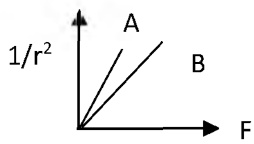
14. Show diagrammatically the configuration of stable and unstable equilibrium of an electric dipole ($\vec{p}$) placed in a uniform electric field ($\vec{E}$). 2

Ans:



Stable Unstable

15. Plot a graph showing the variation of coulomb force F versus $\frac{1}{r^2}$ where r is the distance between the two charges of each pair of charges: (1μC, 2μC) and (2μC, -3μC) Interpret the graphs obtained. 2



[Hint : graph can be drawn choosing –ve axis for force only]

Ans: $|\vec{F_B}| > |\vec{F_A}|$

16. A thin straight infinitely long conducting wire having charge density λ is enclosed by a cylindrical surface of radius r and length l, its axis coinciding with the length of the wire. Find the expression for electric flux through the surface of the cylinder. 2

Ans: Using Gauss's Law obtain: $\Phi = \frac{\lambda l}{\epsilon_0}$

17. Calculate the force between two alpha particles kept at a distance of 0.02mm in air. 2

Ans: $F = 9 \times 10^9 \frac{4\times(1.6\times10^{-19})^2}{(2\times10^{-5})^2}$N

18. Explain the role of earthing in house hold wiring. 2

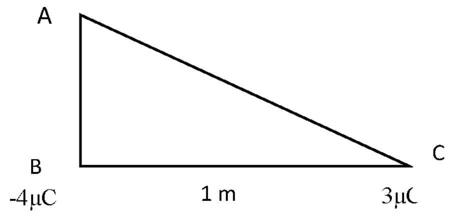
Ans: During short circuit, it provides an easy path or emergency way out for the charges flowing to the ground, preventing the accidents.

19. What is the difference between charging by induction and charging by friction? 2

* In frictional method, transfer of charges takes place from one object to the other.

* During induction, redistribution of charges takes place within the conductor.

20. Two electric charges 3μC, -4μC are placed at the two corners of an isosceles right angled triangle of side 1 m as shown in the figure. What is the direction and magnitude of electric field at A due to the two charges? 2



Ans: E=45×10^3 NC^{-1}

θ=36.9° from line AB

21. A sensitive instrument is to be shifted from a strong electric field in its environment. Suggest a possible way. 2

[Hint : Electrostatic shielding]

22. A charge + Q fixed on the Y axis at a distance of 1m from the origin and another charge +2Q is fixed on the X axis at a distance of √2 m from the origin. A third charge – Q is placed at the origin. What is the angle at which it moves? 3

Ans: Force due to both the changes are equal = KQ^2 & $\perp^r$ to each other so the resultant force will make 45° with X-axis.

23. Two charges 5μC, -3μC are separated by a distance of 40 cm in air. Find the location of a point on the line joining the two charges where the electric field is zero. 3

Ans: Solve for x from the equation: $k\frac{5X10^{-6}}{x^2} = k\,\frac{3X10^{-6}}{(40-x)^2}$

24. Deduce Coulomb's law from Gauss' law.

Ans: $\emptyset = \vec{E}.\vec{S} = Q/\varepsilon_0$ $E \times 4\pi r^2 = Q/\varepsilon_0$ 3

$F = Eq_0 \therefore F = [Qq_o/(4\pi\varepsilon_0 r^2)$

25. State Gauss's law and use this law to derive the electric filed at a point from an infinitely long straight uniformly charged wire. 3

Ans: Statement $\int \overline{E}.\overline{ds} = \frac{q}{\varepsilon_o}$ Derivation for $E = \frac{\lambda}{2\Pi\varepsilon_o r}$

26. Three charges –q, Q and –q are placed at equal distances on a straight line. If the potential energy of system of these charges is zero, then what is the ratio of Q:q [Ans : 1:4] 3

ELECTRIC POTENTIAL

1. Is it possible that the potential at a point is zero, while there is finite electric field intensity at that point? Give an example. 1

Ans: Yes , Centre of a dipole

2. Is it possible that the electric field $\vec{E}$ at a point is zero, while there is a finite electric potential at that point. Give an example. 1

Ans: Yes, Inside charged shell

3. Can two equipotential surfaces intersect? Justify your answer. 1

Ans: No. Otherwise it would mean two directions for force at a point.

4. Is potential gradient a vector or a scalar quantity? 1

Ans: Scalar quantity

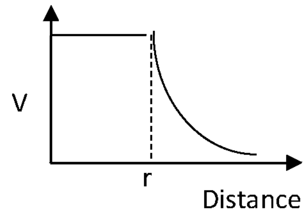
5. Write the dimensional formula of 'ϵ_0' the permittivity of free space. 1

Ans: $[M^{-1}L^{-3}T^4A^2]$

6. An electric dipole is placed in an electric field due to a point charge. Will there be a force and torque on the dipole? 1

Ans: Yes, Both force and torque will act as the Electric Field is non uniform.

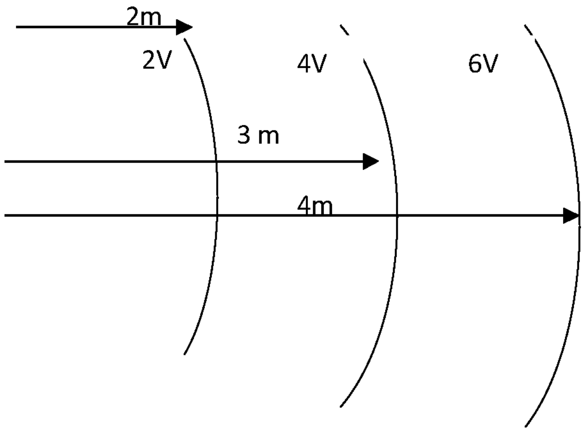
7. Draw the graph showing the variation of electric potential with distance from the Centre of a uniformly charged shell. 1

Ans 

8. Find the ratio of the electric field lines starting from a proton kept first in vacuum and then in a medium of dielectric constant 6. 1

Ans: 6 : 1

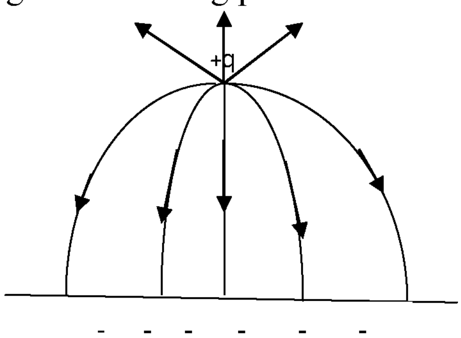
9. Calculate the electric field from the equipotential surface shown below. 1



Ans: 2 V $[E = \frac{-dv}{dr}, dv = 2V, dr = 1m]$

10. Sketch the electric field lines, when a positive charge is kept in the vicinity of an uncharged conducting plate. 1

Ans



11. Two charges are kept as shown. Find dipole moment. 1

Ans: (0,0,2)-q ……………. +q(0,0,-2)

-15 μc +15 μc

12. Compare the electric flux in a cubical surface of side 10 cm and a spherical surface of radius 10 cm, when a change of 5μC is enclosed by them. 1

Ans: Electric flux will be same in both the cases.

13. Explain why the electric field inside a conductor placed in an external electric field is always zero. 1

Ans: Charge lies on the surface of a conductor only

14. Two identical metal plates are given positive charges Q_1 and Q_2, where $Q_1 > Q_2$. Find the potential difference between them, if they are now brought together to form a parallel plate capacitor with capacitance 2

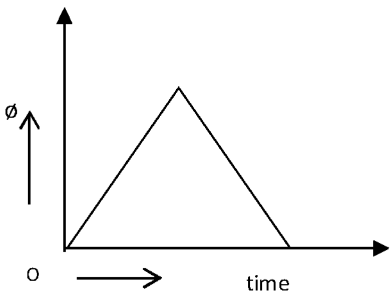
Ans: $(Q_1 - Q_2)/2C$

15. 27 small drops of mercury having the same radius collage to form one big drop. Find the ratio of the capacitance of the big drop to small drop. 2

Ans: [3:1]

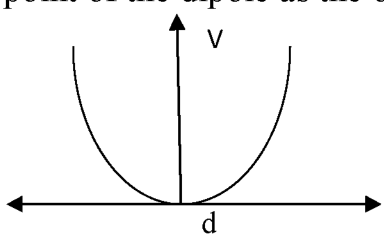
16. A uniformly charged rod with linear charge density λ of length L is inserted into a hollow cubical structure of side 'L' with constant velocity and moves out from the opposite face. Draw the graph between flux and time. 2

Ans



17. Draw a graph showing the variation of potential with distance from the positive charge to negative charge of a dipole, by choosing the mid-point of the dipole as the origin. 2

Ans 2



18. If $\vec{E} = 3\hat{\imath} + 4\hat{\jmath} - 5\hat{k}$, calculate the electric flux through a surface of area 50 units in z-x plane 2

Ans: 200 unit

19. Name the physical quantities whose SI units are Vm, Vm^{-1}. Which of these are vectors? 2

Ans: Vm → electric flux, scalar ; Vm^{-1}→electric field, vector

20. The spherical shell is **to** be charged to a potential of 2 million volt. 2

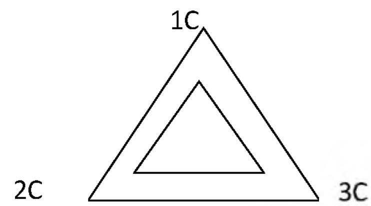
Calculate the minimum radius the shell can have, if the dielectric strength of air is 0.8 kV/mm.
Ans: [2.5m]

21. How will you connect seven capacitors of 2μf each to obtain an effective capacitance of 10/11 μf. 2
Ans: 5 in parallel and 2 in series

22. A proton moves with a speed of 7.45 x 10^5m/s directly towards a free proton initially at rest. Find the distance of the closest approach for the two protons. 2
Ans: 5.56 x 10^{-23}m

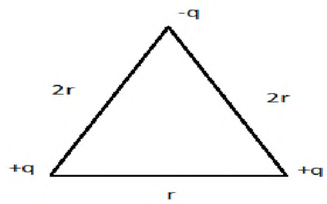
23. Three point charges of 1C, 2C & 3C are placed at the corners of an equilateral triangle of side 1m. Calculate the work done to move these charges to the corners of a smaller equilateral triangle of sides 0.5m. 2

Ans: 9.9 x 10^{10} J

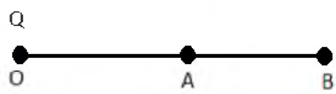


2

24. Suggest an arrangement of three point charges, +q,+q, -q separated by finite distance that has zero electric potential energy



25 A point charge Q is placed at point O as shown. Is the potential difference (V_A-V_B) positive, negative or zero if Q is (i) positive (ii) negative 2



26. Show that the potential of a charged spherical conductor, kept at the Centre of a charged hollow spherical conductor is always greater than that of the hollow spherical conductor, irrespective of the charge accumulated on it. 3
Ans: $V_a-V_b=(q/4\pi\epsilon)(1/r-1/R)$

CAPACITORS

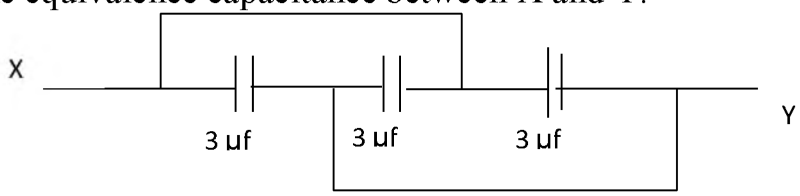
1 What happens to the capacitance of a capacitor when a copper plate of thickness one third of the separation between the plates is introduced in the capacitor? 2

Ans: 1.5 times C_o

2 A parallel plate capacitor is charged and the charging battery is then disconnected. What happens to the potential difference and the energy of the capacitor, if the plates are moved further apart using an insulating handle? 2

Ans: Both Increases

3 Find the equivalence capacitance between X and Y. 2

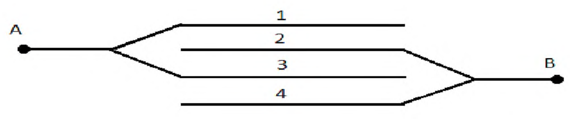


Ans: 9 μf

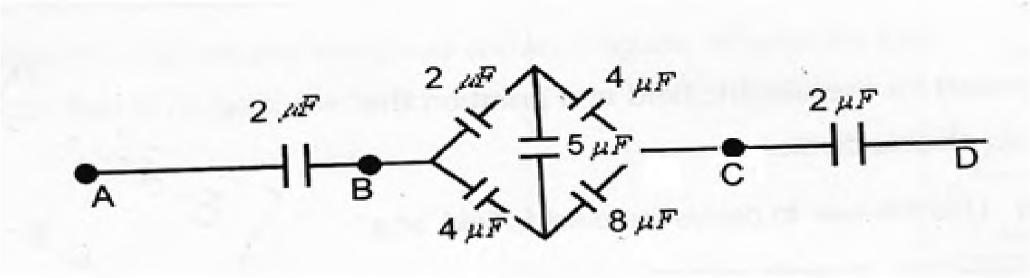
4 A pith ball of mass 0.2 g is hung by insulated thread between the plates of a capacitor of separation 8cm. Find the potential difference between the plates to cause the thread to incline at an angle 15^0 with the vertical, if the charge in the pith ball is equal to 10^{-7}C. 2

Ans: 429 V

5. Find the capacitance of arrangement of 4 plates of Area A at distance d in air as shown. 2



6. What is an equivalent capacitance of the arrangement the shown below 3



If 6V cell is connected across AD. Calculate the potential difference between B&C.

7. A parallel plate capacitor is charged to a potential difference V by d.c. source and then disconnected. The distance between the plates is then halved. Explain with reason for the change in electric field, capacitance and energy of the capacitor. 3

Ans: Use the formulae - Electric field remains same, Capacitance doubled, Energy halved

8. Derive an expression for capacitance of parallel plate capacitor, when a dielectric slab of dielectric constant k is partially introduced between the plates of the capacitor. 3

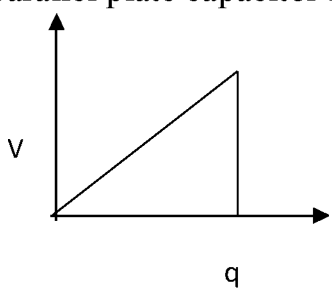
9. A potential difference of 1200 V is established between two parallel plates of a capacitor. The plates of the capacitor are at a distance of 2 cm apart. An electron is released from the negative plate, at the same instant, a proton is released from the +ve plate. 3

(a)How do their (i) velocity (ii) Energy compare, when they strike the opposite plates.

(b) How far from the positive plate will they pass each other?

Ans a. (i)42.84 (ii)equal b. 2.7cm

10. Draw a graph to show the variation of potential applied and charge stored in a capacitor. Derive the expression for energy stored in a parallel plate capacitor from the capacitor. 3

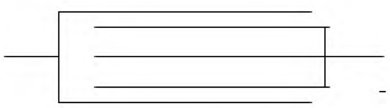


11. Find the capacitance of a system of three parallel plates each of area Am^2 separated by d_1 and d_2 m respectively. The space between them is filled with dielectrics of relative dielectric constant ϵ_1 and ϵ_2. 2

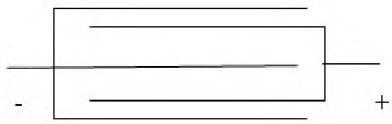
12. Two parallel plate capacitors A and B having capacitance 1μF and 5 μF 3

are charged separately to the same potential 100V. They are then connected such that +ve plate of A is connected to –ve plate of B. Find the charge on each capacitor and total loss of energy in the capacitors.
Ans: 400μC, 500μC and 5/3 x 10J

13. Calculate the capacitance of a system having five equally spaced plates, 3
if the area of each plate is 0.02 m^2 and the separation between the neighboring are 3 mm. in case (a) and (b)



(a)



(b)

Ans: (Hint: Capacitance of a parallel plate capacitor $\varepsilon_o A/d$)
1.18 x 10^{-4} μ F and 2.36 x 10 μ F

14. Net capacitance of three identical capacitors in series is 1μf. What will 2
be their net capacitance if connected in parallel?
Find the ratio of energy stored in the two configurations, if they are both connected to the same source.
Ans: 9μf 1 : 9

15. Two parallel plate capacitors X and Y have the same area of plates and the same separation between them. X has air between the plates and Y contains a dielectric medium of $\varepsilon r=4$. Calculate Capacitance of X and Y if equivalent capacitance of combination is 4 μF.

(i) Potential Difference between the plates of X and Y
(ii) What is the ration of electrostatic energy stored in X and Y

[Ans : 5 μF, 20 μF, 9.6 V, 2.4 V, 4:1]

2. CURRENT ELECTRICITY

GIST

- Electric current is defined as the amount of charge flowing through any cross section of the conductor in unit time. The rate of flow of chrge through the conductor is called electric current. $I = Q/t$. SI Unit Ampere (A).
- The electric current flowing through the conductor is said to be one ampere when one coulomb charge flows through it in one second.
- Current density $|\vec{J}| = I/A$.
- Ohm's law: The electric current passing through a conductor is directly proportional to the potential difference applied across it provided the physical conditions such as temperature, pressure etc., remain constant. $V \alpha I$ i.e. $V = IR$, Where R is the resistance of the conductor. Resistance R is the ratio of V & I
- The device which opposes the flow of electric current through it is called resistor. Resistance is the characteristic property of the conductor which offers opposition for the flow of electric current.
- Resistance $R = \rho l/A = ml/ne^2\tau A$ where ρ is the resistivity of the material of the conductor- length and A area of cross section of the conductor. If l is increased n times, new resistance becomes n^2R. If A is increased n times, new resistance becomes $\frac{1}{n^2}R$.
- Resistivity is the characteristic property of the material which is the resistance of the conductor of unit length and unit area of cross section.
- Resistivity $\rho = m/ne^2\tau$, Where m, n, e are mass, number density and charge of electron respectively, τ-relaxation time of electrons. ρ is independent of geometric dimensions.
- Relaxation time is the average time interval between two successive collisions
- Conductance of the material G =1/R and conductivity σ=1/ρ
- Drift velocity is the average velocity of all electrons in the conductor which drift in opposite direction to the applied electric field. Drift velocity $V_d = (eE/m)\tau$ also $I = neAv_d$
- Mobility (μ) of a charge carrier is the ratio of its drift velocity to the applied electric field $\mu = \frac{V_d}{E}$
- Effect of temperature on resistance: Resistance of a conductor increase with the increase of temperature of conductor $R_T = R_o(1+\alpha T)$, where α is the temperature coefficient of resistance of the conductor. α is slightly positive for metal and conductor, negative for semiconductors and insulators and highly positive for alloys.

- Combination of resistors: $R_{series} = R_1 + R_2 + ... R_n$, $\frac{1}{R_{Parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + ... \frac{1}{R_n}$
- Colour coding :

Black	**B**rown	**R**ed	**O**range	**Y**ellow	**G**reen	**B**lue	**V**iolet	**G**ray	**W**hite
0	1	2	3	4	5	6	7	8	9

<u>Tolerance</u> (i) Gold 5% (ii) Silver 10% (iii) No Color 20%

Example: if colour code of carbon resistor is Red Yellow and Orange with tolerance colour as silver, the resistance of the given resistor is $(24\times10^3 \pm 10\%)\Omega$.

- Cells: E.M.F of a cell is defined as the potential difference between its terminals in an open circuit. Terminal potential difference of a cell is defined as the potential difference between its ends in a closed circuit.
- Internal resistance *r* of a cell is defined as the opposition offered by the cell to the flow of current. r $= \left(\frac{E}{V} - 1\right)R$ where R is external resistances.
- Grouping of cells :

  i) In series grouping circuit, current is given by $I_s = \frac{nE}{R + nr}$,

  ii) In parallel grouping circuit, current is given by $I_p = \frac{mE}{r + mR}$ where n, m are number of cells in series and parallel connection respectively.
- Kirchhoff's Rule:

  i) Junction Rule:-The algebraic sum of currents at a junction in a network is zero. $\sum I = 0$

  ii) Loop rule:-The algebraic sum of potential differences and emfs of a closed loop in a network is zero $\sum V = o$
- Wheatstone bridge is an arrangement of four resistors arranged in four arms of the bridge and is used to determine the unknown resistance in terms of other three resistances. For balanced Wheatstone Bridge, $\frac{P}{Q} = \frac{R}{S}$
- Wheatstone bridge is most sensitive when the resistance in the four arms are of the same order
- In the balanced condition of the bridge on interchanging the positions of galvanometer and battery if there is no effect on the balancing length of the bridge.
- The principle of Metre Bridge: The resistance of the wire of uniform cross section and composition is directly proportional to its length.

- Slide Wire Bridge or Metre Bridge is based on Wheatstone bridge and is used to measure unknown resistance. If unknown resistance S is in the right gap, $s = \left(\frac{100 - l}{l}\right)R$
- Potentiometer is considered as an ideal voltmeter of infinite resistance.
- Principle of potentiometer: The potential drop across any portion of the wire of uniform cross section and uniform composition is proportional to the length of that portion of the wire provided steady current is maintained in it i.e. $v \alpha l$
- Smaller the potential gradient greater will be the sensitivity of potentiometer.
- Potentiometer is used to (i) compare the e.m.f.s of two cells (ii) determine the internal resistance of a cell and (iii) measure small potential differences.
- Expression for comparison of e.m.f of two cells by using potentiometer, $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$ where l_1, l_2 are the balancing lengths of potentiometer wire for e.m.fs ε_1 and ε_2 of two cells.
- Expression for the determination of internal resistance of a cell is given by r=$\left(\frac{l_1 - l_2}{l_2}\right)R$, Where l_1 is the balancing length of potentiometer wire corresponding to e.m.f of the cell, l_2 that of terminal potential difference of the cell when a resistance R is connected in series with the cell whose internal resistance is to be determined
- Expression for determination of potential difference $\frac{\varepsilon}{r+R} * \frac{rl}{L}$. Where L is the length of the potentiometer wire, l is balancing length, r is the resistance of potentiometer wire, R is the resistance included in the primary circuit.
- Joule's law of heating states that the amount of heat produced in a conductor is proportional to (i) square of the current flowing through the conductor,(ii) resistance of the conductor and (iii) time for which the current is passed. Heat produced is given by the relation $H=I^2Rt$
- Electric power: It is defined as the rate at which work is done by the source in maintaining the current in electric circuit. $P = VI = I^2R = V^2/R$. Power P is the product of V & I
- Electrical energy: The total work done by the source in maintaining the current in an electrical circuit for a given time. Electrical energy = VIt = I^2Rt $=(V^2/R)t$ = Pt
- Commercial unit of energy 1KWh= 3.6×10^6J

QUESTIONS

DRIFT VELOCITY, CURRENT, POTENTIAL DIFFERENCE, OHM'S LAW AND RESISTANCE

1. How does the drift velocity of electrons in a metallic conductor vary with increase in temperature? (1)

Ans. remains the same

2. Two different wires X and Y of same diameter but of different materials are joined in series and connected across a battery. If the number density of electrons in X is twice that of Y, find the ratio of drift velocity of electrons in the two wires. (1)

Ans: $V_{dx}/V_{dy} = n_y/n_x = ½$

3. A 4Ω non insulated wire is bent in the middle by 180^0 and both the halves are twisted with each other. Find its new resistance? (1)

Ans: 1Ω

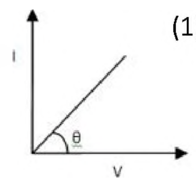
4. Can the terminal potential difference of a cell exceed its emf? Give reason for your answer. (1)

Ans: Yes, during the charging of cell.

5. Two wires of equal length one of copper and the other of manganin have the same resistance. Which wire is thicker? (1)

Ans: Manganin.

6. The V-I graph for a conductor makes angle Θ with V- axis, what is the resistance of the conductor? (1)



Ans: R = Cot Θ

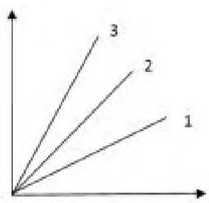
7. It is found that 10^{20} electrons pass from point X towards another point Y in 0.1s. How much is the current & what is its direction? (1)

Ans: 160A; from Y to X

8. Two square metal plates A and B are of the same thickness and material. The side of B is twice that of side o fA. If the resistance of A and B are denoted by R_A and R_B, find R_A/R_B. (1)

Ans: 1

I



1. The V-I graph of two resistors in their series combination is shown. Which one of these graphs shows the series

combinations of the other two? Give reason for your answer.

Ans: 1

10. Plot a graph showing the variation of conductivity σ with the temperature T in a metallic conductor. (2)

(Ans: see fig1)

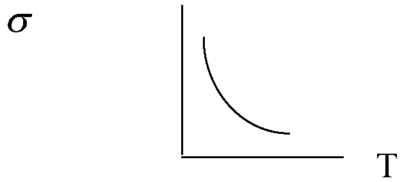


Fig 1

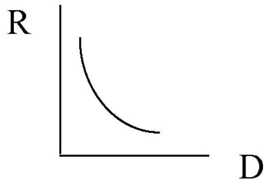


fig2

11. Draw a graph to show the variation of resistance R of the metallic wire as a function of its diameter D keeping the other factor constant. (2)

(Ans: see fig2)

12. Two conducting wires X and Y of same diameter but different materials are joined in series across a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires.
(Ans: $I \alpha n v_d$ i.e. $V_{dx}/V_{dy} = n_y/n_x = ½$) (2)

13 A pd of 30V is applied across a colour coded carbon resistor with rings of blue, black and yellow colours. What is the current to the resistor? (2)

Ans: $R = 60 \times 10^4 \Omega$, $I = 5 \times 10^{-5}$A

14. A non-conducting ring of radius r has charge q distribute over it. What will be the equivalent current if it rotates with an angular velocity ω? (2)

Ans: $I = q/t = q\omega/2\pi$.

15. Two cells each of emf E and internal resistances r_1 and r_2 are connected in series to an external resistance R. Can a value of R be selected such that the potential difference of the first cell is 0. (2)

Ans: $I = 2\mathcal{E}/(R + r_1 + r_2)$ Potential diff. for first cell $V_1 = \mathcal{E} - I r_1 = 0$

$\mathcal{E} = (2 \mathcal{E} r_1)/R + r_1 + r_2$ Solving these we get, $R = r_1 - r_2$

16. Why does Resistance increase in series combination and decrease in parallel combination (2)

Ans: Effective length increases in series combination (R α l).

In parallel combination area of cross section increases (R α 1/A)

17. A piece of silver wire has a resistance of 1Ω. What will be the resistance of the constantan wire of one third of its length and one half of its diameter if

(2)

the specific resistance of the constantan wire is 30 times than that of the silver?

Ans: 40Ω

18. Calculate the current shown by the ammeter in the circuit in fig 1

(2)

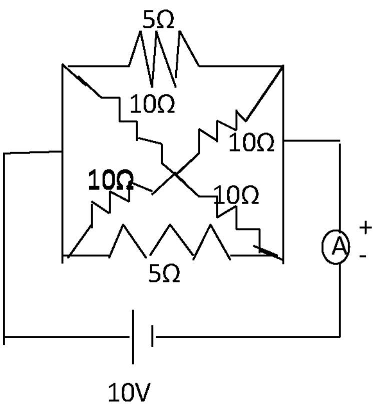


Fig 1.

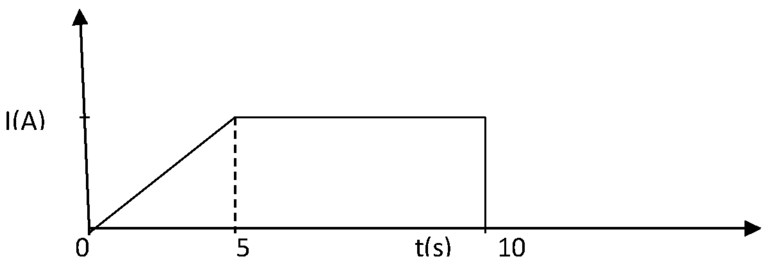


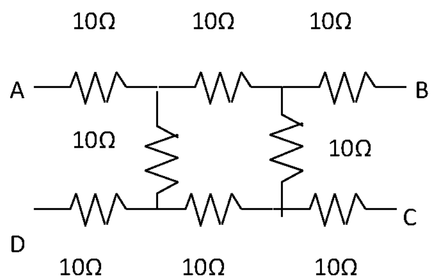
Fig 2.

Ans: R = 2Ω and I = 5A

19. The plot in fig 2 given above shows the variation of current I through the cross section of a wire over a time interval of 10s. Find the amount of charge that flows through the wire over this time period. (2)

Ans: Area under the I-t graph, q = 37.5C

20. Find the resistance between the points (i) A and B and (ii) A and C in the following network (2)



(2)

Ans: (i) R_{AB} = 27.5Ω (ii) R_{AC} = 30Ω

21. Two wires of the same material having lengths in the ratio 1:2 and diameter 2:3 are connected in series with an accumulator. Compute the ratio of p.d across the two wires (2)

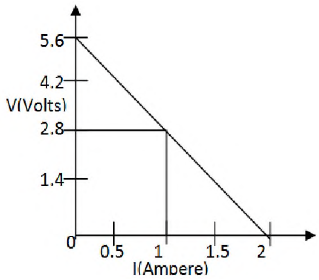
Ans: $R = \rho l/A = 4\rho l/\pi d^2$ $R_A/R_B = 9/8$ $V_A/V_B = I_AR_A/I_BR_B = 9/8$

22. 4 cells of identical emf E_1, internal resistance r are connected in series to a variable resistor. The following graph shows the variation of terminal voltage of the combination with the current output. (3)

(i)What is the emf of each cell used?

(ii)For what current from the cells, does maximum power dissipation occur in the circuit?

(iii)Calculate the internal resistance of each cell



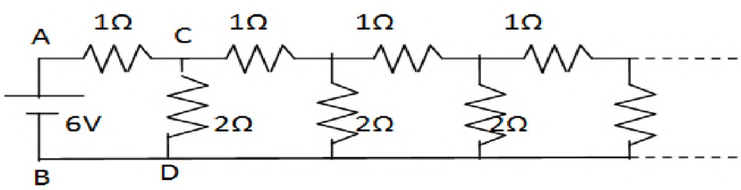
Ans: 4E = 5.6   E = 1.4 V

When I = 1A, V = 2.8/4 = 0.7V

Internal resistance,   r= (E – V)/I = 0.7Ω

The output power is maximum when internal resistance = external resistance = $4r.I_{max}$ = 4E/ (4r +4r) = 1A

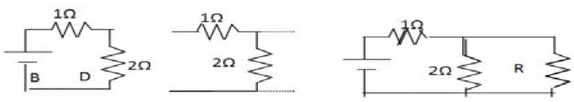
23. An infinite ladder network of resistances is constructed with 1Ω and 2Ω resistances shown. (3)



A 6V battery between A and B has negligible resistance.

(i) Find the effective resistance between A and B.

Ans: Since the circuit is infinitely long, its total resistance remains unaffected by removing one mesh from it. Let the effective resistance of the infinite network be R, the circuit will be

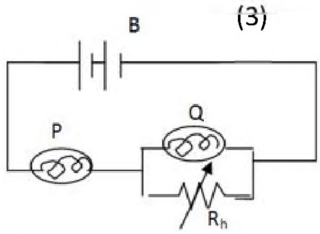


$R = \frac{2R}{R+2} + 1$ $R = 2\Omega$

24. The resistance of a tungsten filament at 150°C is 133Ω. What will be its resistance at 500^0C? The temperature coefficient of tungsten is 0.0045^0C^{-1} at 0^0C. (3)

Ans: Use $R_t = R_0 (1+ \alpha t)$ $R_{500} = 258\Omega$

25. The circuit shown in the diagram contains two identical lamps P and Q. What will happen to the brightness of the lamps, if the resistance R_h is increased? Give reason. (3)



Ans: Brightness of P and Q decrease and increase respectively.

26. A battery has an emf E and internal resistance r. A variable resistance R is connected across the terminals of the battery. Find the value of R such that (a) the current in the circuit is maximum (b) the potential difference across the terminal is maximum. (c) Plot the graph between V and R (3)

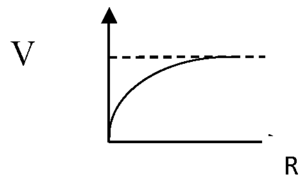
Ans: (a) $I = \mathcal{E} / (r + R)$ (3)

$I = I_{max}$ when $R = 0$ $\quad I_{max} = \mathcal{E} / r$

(b) $V = \mathcal{E} R/(r + R) = \mathcal{E} /(r/R + 1)$

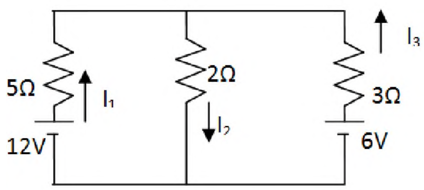
$V = V_{max}$ when $r/R + 1 =$ minimum, $r/R = 0$, $V = \mathcal{E}$

(c)



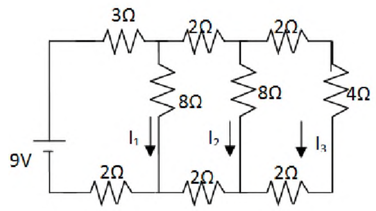
II. KIRCHHOFF'S RULE AND APPLICATIONS

1. Using Kirchhoff's laws, calculate I_1, I_2 and I_3 (3)



Ans: $I_1 = 48/31A$ $\quad I_2 = 18/31A$ $\quad I_3 = 66/31A$ (3)

2. In the circuit, find the current through the 4Ω resistor. (3)



Ans: I = 1A

III. WHEATSTONE BRIDGE AND POTENTIOMETER

1. The emf of a cell used in the main circuit of the potentiometer should be more than the potential difference to be measured. Why? (1)
2. The resistance in the left gap of a metre bridge is 10Ω and the balance point is 45cm from the left end. Calculate the value of the unknown resistance. (1)

Ans S = 12.5Ω

3. How can we improve the sensitivity of a potentiometer? (1)

4. Why is potentiometer preferred over a voltmeter (1)

5. Write the principle of (2)

(i) a meter bridge.

(ii) a potentiometer.

6. How does the balancing point of a Wheatstone bridge get affected (2)

i) Position of cell and Galvanometer are interchanged?

ii) Position of the known and unknown resistances is interchanged?

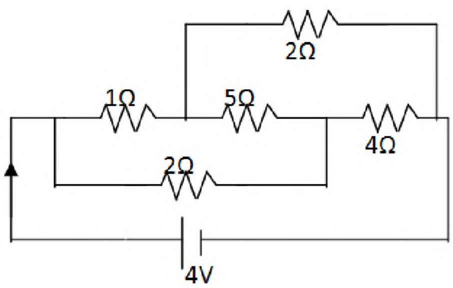
7. Explain with a neat circuit diagram, how will you compare emf of two cells using a potentiometer?

8. With the help of a circuit diagram, describe the method of finding the internal resistance of the Primary Cell using a potentiometer. (3)

9. With the help of a neat circuit diagram describe the method to determine the potential difference across the conductor using a potentiometer. (3)

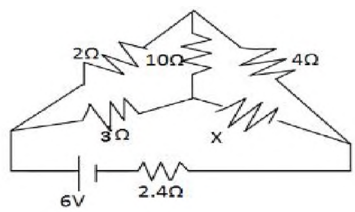
10. Calculate the current drawn from the battery in the given network.

Ans: I = 2A

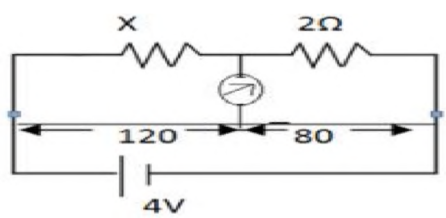


11. Find the value of X and current drawn from the battery of emf 6V of negligible internal resistance (3)

Ans: X = 6Ω and I = 1A



12. Find the value of the unknown resistance X and the current drawn by the circuit from the battery if no current flows through the galvanometer. Assume the resistance per unit length of the wire is $0.01\Omega cm^{-1}$. (3)

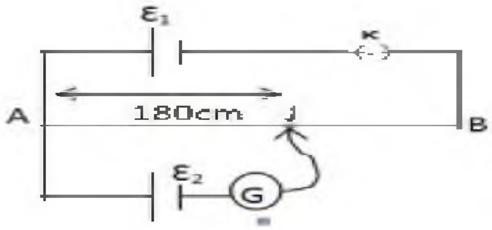


Ans: $X = 3\Omega$

13. In the circuit shown, AB is a resistance wire of uniform cross – section in which a potential gradient of $0.01 V\ cm^{-1}$ exists. (3)

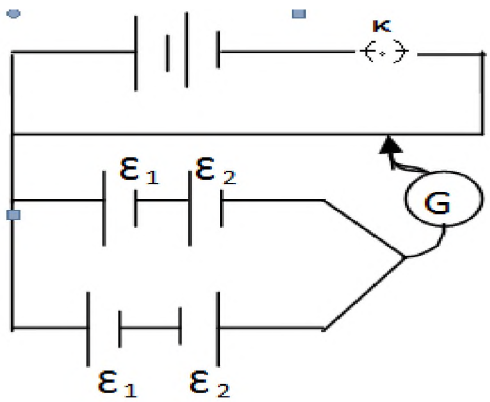
(a)If the galvanometer G shows zero deflection, what is the emf $\mathcal{E}_1$ of the cell used?

(b)If the internal resistance of the driver cell increases on some account, how will it affect the balance point in the experiment?



Ans: (a) PD $V_{AB} = 1.8$ V (b) Balance pt. will shift towards B since V/l decreases.

14. In a potentiometer circuit, a battery of negligible internal resistance is set up as shown to develop a constant potential gradient along the wire AB. Two cells of emfs $\mathcal{E}_1$ and $\mathcal{E}_2$ are connected in series as shown in the combination (1) and (2). The balance points are obtained respectively at 400cm and 240cm from the point A. Find (i) $\mathcal{E}_1/\mathcal{E}_2$ and (ii) balancing length for the cell $\mathcal{E}_1$ only. (3)

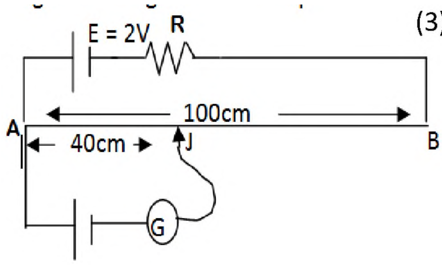


Ans : $\mathcal{E}_1 + \mathcal{E}_2 \; \alpha \; 400$, $\mathcal{E}_1 - \mathcal{E}_2 \; \alpha$ 240,Solving

$\mathcal{E}_1/\mathcal{E}_2 = 4$, $\mathcal{E}_1 \, \alpha \, l_1$,

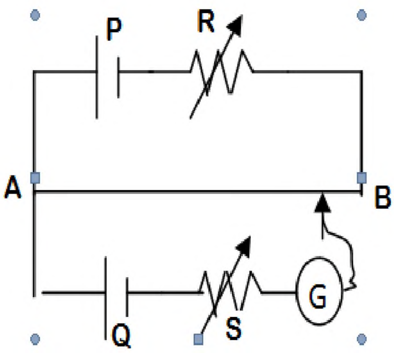
$(\mathcal{E}_1 + \mathcal{E}_2)/\mathcal{E}_1 = 400/l_1$, $l_1 = 320$cm

15. A potentiometer wire of length 100cm having a resistance of 10Ω is connected in series with a resistance and cell of emf 2V of negligible internal resistance. A source emf of 10mV is balanced against a length of 40cm of potentiometer wire. What is the value of the external resistance? (3)



Ans: $I = E/(R + 10) = (2/R + 10)$ Resistance of 40cm wire is 4Ω. At J, $(2/R + 10) \times 4 = 10 \times 10^{-3}$ $R = 790\Omega$

16. In the potentiometer circuit shown, the balance point is at X. State with reason where the balance point will be shifted when (3)



(i) Resistance R is increased, keeping all parameters unchanged.

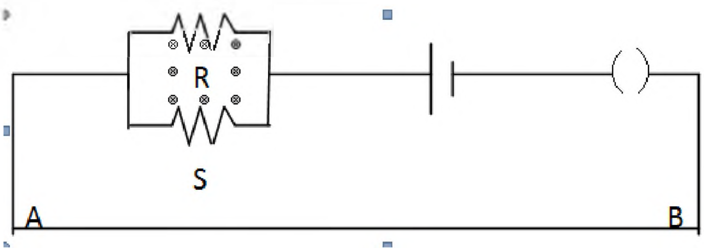
(ii) Resistance S is increased keeping R constant.

(iii) Cell P is replaced by another cell whose emf is lower than that of that cell Q.

Ans: (i) As R is increased V/l will decrease hence X will shift towards B.

(ii) No effect (iii) Balance point is not found.

17. A potentiometer wire has a length L and resistance R_0. It is connected to a battery and a resistance combination as shown. Obtain an expression for the potential difference per unit length of the potentiometer wire. What is the maximum emf of a 'test cell' for which one can get a balance point on this potentiometer wire? What precautions should one take while connecting this test cell to the circuit? (3)



Ans: Total resistance of potentiometer wire $R = R_0 + RS/(R+S)$

Current in the circuit $I = E/ (R_0 + (RS/R+S))$

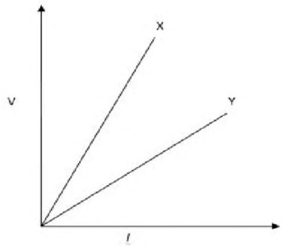
Total potential difference across AB $V = I R_0 = E R_0/ (R_0 + (RS/R+S))$

Therefore, PD per unit length is $V/L = E R_0/L (R_0 + (RS/R+S))$

Max emf of a test cell should be less than V.

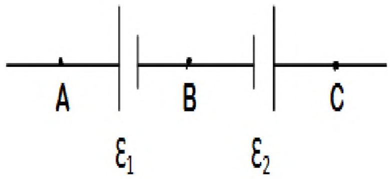
<u>Precaution:</u> Positive terminal of the test cell must be connected to positive terminal of the battery.

18. The variation of potential difference V with length *l* in case of two potentiometers X and Y as shown. Which one of these will you prefer for comparing emfs of two cells and why? (3)



Ans : The potentiometer Y is preferred, as it has low potential gradient (V/l)

19. Two cells of emfs $\mathcal{E}_1$ and $\mathcal{E}_2$ ($\mathcal{E}_1 > \mathcal{E}_2$) are connected as shown in figure When a potentiometer is connected between A and B, the balancing length of the potentiometer wire is 300cm. On connecting the same potentiometer between A and C, the balancing length is 100cm. Calculate the ratio of $\mathcal{E}_1$ and $\mathcal{E}_2$. (3)



Ans: $\mathcal{E}_1 \alpha\ 300$, $\mathcal{E}_1 - \mathcal{E}_2 \alpha\ 100$, $\mathcal{E}_1/\mathcal{E}_2 = 3/2$

IV. ELECTRIC ENERGY AND POWER

1. What is the largest voltage you can safely put across a resistor marked 98Ω - 0.5W? (1)
2. Which lamp has greater resistance (i) 60W and (ii) 100W when connected to the same supply?

Ans: $R = V^2/P$, $R\ \alpha\ 1/P$, 60 lamp has more resistance (1)

3. Nichrome and Cu wires of the same length and same diameter are connected in series in an electric circuit. In which wire will the heat be produced at a higher rate? Give reason.

Ans: $P = I^2R$ $P\ \alpha\ R$ Heat produced is higher in Nichrome wire. (2)

4. An electric bulb rated for 500W at 100V is used in circuit having a 200V supply. Calculate the resistance R that must be put in series with the bulb, so that the bulb delivers 500W. (2)

Ans: Resistance of bulb=V^2/P = 20Ω, I = 5A, for the same power dissipation, current should be 5A when the bulb is connected to a 200V supply. The safe resistance R' = V'/I = 40Ω. Therefore, 20Ω resistor should be connected in series.

5. Two bulbs are marked 220V-100W and 220V-50W. They are connected in series to 220V mains. Find the ratio of heat generated in them. (2)

Ans: $H_1/H_2 = I^2R_1/I^2R_2 = R_1/R_2 = ½$

6. Can a 30W, 6V bulb be connected supply of 120V? If not what will have to be done for it? (3)

Ans: Resistance of bulb R= V^2/P = 36/30 = 1.2Ω Current capacity of the bulb I = P/V = 5A

A resistance R' to be added in series with the bulb to have current of 5 A, I = V'/R + R' =5, R' = 22.8Ω

(I) a wet body and

(II) a dry body.

When will we have serious consequences dry skin or wet skin? Why?

3.MAGNETIC EFFECTS OF CURRENT AND MAGNETISMGIST

- Magnetic field: The region around a magnet or current carrying conductor with in which it influences other magnets or magnetic material. SI unit of magnetic field intensity is Tesla (T).
- Biot-Savart Law: $dB = \mu_0 I dl Sin\theta / 4\pi r^2$ where $\mu_0 = 4\pi \times 10^{-7}$ Tm/A. [Direction of dB can be found by using Maxwell's Right hand thumb rule.]
- Applications:

Magnetic field at the centre of a current carrying circular coil is $B = \mu_0 I/2a$.
Magnetic field at a point on the axis of current carrying coil is $B = \mu_0 N i a^2 / 2(a^2+x^2)^{3/2}$ (N=no. of turns in the coil)

- Ampere's circuital law: It states that the line integral of magnetic field around any closed path in free space is μ_0 times the total current passing through the area of loop. $\oint \vec{B}.\vec{dl} = \mu_o \boldsymbol{I}$.
- Applications:

Magnetic field due to straight infinitely long current carrying straight conductor. $B = \mu_0 \mathbf{I}/2\pi r$.
Magnetic field due to a straight solenoid carrying current $B = \mu_0 n \mathbf{I}$. n= no. of turns per unit length. $B = \mu_0 N \mathbf{I} / L$.
Magnetic field due to toroidal solenoid carrying current. $B = \mu_0 N \mathbf{I} / 2\pi r$. N= Total no. of turns.

- Force on a moving charge [Lorentz Force]: In magnetic field magnetic Lorentz force $\vec{F} = q(\vec{V} \; X \; \vec{B})$. The direction of Force is given by Fleming's left hand rule. In magnetic and electric field Lorentz force $\vec{F} = q[\vec{E} + (\vec{v} \; x \; \vec{B})]$.
- One Tesla is the intensity of magnetic field in which one coulomb of charge moving perpendicular to the field with one m/s experiences a force of one Newton.
- Motion of a charge in Perpendicular magnetic field $F = qvBSin\theta$. If $\theta = 90^o$ then $F = qvB$ (circular path). For parallel or antiparallel to magnetic field then $F = qvBSin0$ (or) $qvBSin180 = 0$(Straight-line path). If $0<\theta<90$, the path is helix. $v\, Cos\theta$ is responsible for linear motion, $v\, Sin\theta$ is responsible for circular motion. Hence trajectory is a helical path. When a charged particle enters in to the magnetic field with some angle θ to it, the radius of circular path followed by it is $r = mv\; sin\theta / qB$, and the pitch of the helical path is $2\pi mv\; cos\theta / qB$
- Cyclotron: The device which is used accelerate the charged particles based on the principle of Lorentz force is called Cyclotron.
- Principle: The charged particle accelerates in uniform electric field and follows circular path in uniform magnetic field.