ELECTROSTATICS

ELECTRIC CHARGE: There exist two type of charges in nature which are arbitrarily designated as Positive (+) and Negative (-).Like charges repel each other while unlike charges attract each other.

SI unit of electric charge is coulomb (C).Chare is quantized, additive and conserve.

Coulomb's Law: F = q_1 q_2 / r^2 where k is a constant. In SI system, in vacuum k is 9 x10^9 Nm^2/C^2.

When the same charges are placed in some material medium, the force between them is found to be less than that in vacuum. We write that

F = $\frac{1}{4\pi\varepsilon}$ q_1 q_2 / r^2 , where ἐ is the permittivity of the medium and ε = ε_0 K, K is called Dielectric constant. The value of K depends upon the nature of the medium.

THE ELECTRIC FIELD

Electric field at any point is defined as the force experienced by a unit positive charge placed at that point.

Mathematically E = $\lim_{q \to \infty} \left(\frac{F}{q}\right)$

If E is electric field at any point , then the force experienced by a charge q at that point is **F = qE**

Field Due to a point Charge: E = $\frac{q}{4\pi\varepsilon 0 r 2}$

THE ELECTRIC DIPOLE: It is a system of two equal and opposite charges separated by a small distance. We define **ELECTRIC DIPOLE MOMENT** **P = 2a x q** where 2a is the length of the dipole and q is the magnitude if either charges.

Dipole in an Electric field: The net force on the dipole would be zero but it will experience a torque which tends to rotate the dipole in the direction of the applied field and is given by

$$\tau = \mathbf{P \times E}$$

POTENTIAL ENERGY OF A DIPOLE: PE of a dipole is equal to the amount of work done in rotating the dipole from a direction perpendicular to the field to the present position i.e. $\theta_0 = 90^0$

$$PE\ (U) = -\ PE\cos\theta = -\ \mathbf{P.E}$$

P is a vector quantity whose direction is from –q to +q charge.

ELECTRIC FLUX: Consider a small area ds placed in an electric field E such that the normal to the area makes an angle θ with the direction of E. Then the electric flux passing through ds is defined as $\triangle S = E \triangle S \cos\theta = \mathbf{E}\triangle\mathbf{S}$

Flux is taken to be positive if the electric field lines points outwards ($\theta < 90^0$) and negative if they point inwards.

ELECTRIC POTENTIAL: It is defined as work done per unit charge. Denoted by V.SI unit is volt.

V = work/Charge = W/q

Potential Difference between two points: $\mathbf{V_B - V_A = W_{AB} / q}$

1 eV = 1.6×10^{-19} J (Electric field is conservative).

Potential due to appoint charge: $E = \frac{q}{4\pi\varepsilon 0 r}$

Gauss's Law: For any closed surface

$$\mathbf{\Phi = Q / \varepsilon_0}$$

Where Q is the net charge enclosed by the surface and Φ is the electric flux.

ELECTROSTATIC SHIELDING: If there is a cavity of any shape inside the conductor, the field there will be strictly zero. Anything placed inside the cavity will be completely shielded.

CAPACITANCE

When a conductor is given some charge, its potential rises such that Q **α V OR Q = C** V, where C is a constant known as capacitance of the conductor.

Thus $C = \frac{Q}{V}$.

SI unit of Capacitance is coulomb/volt which is equivalent to **1 F (farad).**

PARALLEL PLATE CAPACITOR: It consists of two metal plates of same dimensions placed parallel to each other.If A is the area of each plate and d is the separation between the plates then capacitance of parallel plate capacitor is given by

$$C = \varepsilon_0 A / d$$

COMBINATION OF CAPACITORS:

(A) SERIES COMBINATION –

The equivalent capacitance of n capacitors of capacitances C_1, C2, C_3,… Cn connected in series is given by

$$\frac{1}{C} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} + \ldots\ldots + \frac{1}{Cn}$$

(B) PARALLEL COMBINATION:

In this case the Potential Difference across each capacitor is the same. The equivalent capacitance of n capacitors connected in parallel is given by

$$C = C_1 + C_2 + C_3 + \ldots\ldots + C_n$$

ENERGY STORED IN A CAPACITOR:

When a capacitor is charged, work is done by the charging battery. This work is stored in a capacitor in the form of its Potential energy.

The Potential energy stored in a capacitor is given by $U = \frac{1}{2} QV = \frac{1}{2} CV^2 + \frac{1}{2}\frac{Q2}{C}$

LOSS OF ENERGY WHEN TWO CHARGED CAPACITORS ARE CONNECTED IN PARALLEL: Let two capacitors C1 and C2 initially charged to Potentials V1 and V2.The common PD across the combination is given by

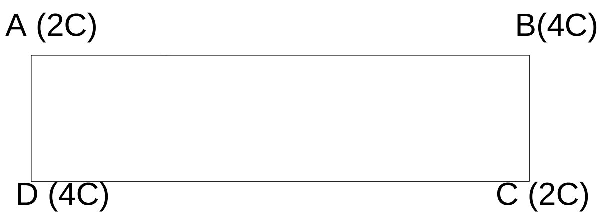
$$V = \frac{Total\,Charge}{Total\,Capacitance} = \frac{C1V1 + C2V2}{C1 + C2}$$

The loss of Energy $\triangle U = \frac{(C2Q1 - Q2C1)}{2C1C2(C1 + C2)}$

MULTIPLE CHOICE QUESTIONS

1. A suitable unit for expressing electric field strength is:
   (a) V/C (b) A-m (c) C/m^2 (d) N/C

2. Four electric charges A, B, C, D are arranged as shown. The electric force will be least between charges:
   (a) A and B (b) A and D (c) B and D (d) A and C



3. A soap bubble is given negative charge. Then its radius:
   (a) decreases (b) increases (c) remains same
   (d) will change but information is insufficient to predict whether it will increase or decrease.

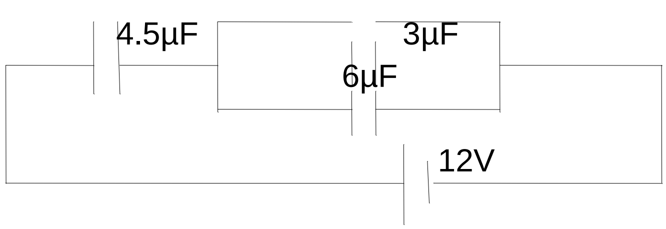
4. Three identical charges are placed at the corners of a n equilateral triangle. If the force between any two charges is F, then the net force on each will be:
   (a) $\sqrt{2}$ F (b) 2 F (c) $\sqrt{3}$ F (d) 3 F

5. A charge Q is divided into two parts and the two parts are separated by a certain distance. The force between them will be maximum if one of the charges is:
   (a) Q/2 (b) Q/3 (c) Q/4 (d) none of these

6. An electric dipole placed in a uniform electric field will have minimum potential energy when the dipole moment is inclined to the field at an angle:
   (a) π (b) π/2 (c) zero (d) 3π/2

7. Two charged metallic spheres of radii 20 cm and 10 cm have 150 μC positive charges each. If they are connected by a conducting wire then the common potential will be:
   (a) 9×10^6 V (b) 4.5×10^6 V (c) 1.8×10^7 V (d) 13.5×10^6 V

8. In the given circuit, the potential difference across 4.5 μF capacitor is:
   (a) 8/3 V (b) 4 V (c) 6 V (d) 8 V



9. Energy of an electrical conductor of capacitance C , when subjected to a potential difference of V is given by:
(a) ½ CV^2 (b) ½ C^2V (c) CV (d) C/2V

10. The SI unit of permittivity of free space is ($\in_0$) is :
(a) C/(N-m) (b) $(N\text{-}m)/C^2$ (c) $C^2/(N\text{-}m)^2$ (d) $C^2/(n\text{-}m^2)$

11. 1 volt equals
(a) 1 J (b) 1 J/C (c) 1 C/J (d) None of these

12. How many electrons will have a charge of 1 coulomb?
(a) 6.2×10^{18} (b) 6.2×10^{19} (c) 5.2×10^{18} (d) 5.2×10^{19}

13. The work done in moving a +ve charge on an equipotential surface is
(a) finite and +ve (b) infinite (c) finite and –ve (d) zero

14. Two charges are placed at a distance apart. If a glass slab is placed between them, force between them will
(a) Remains same (b) increase (c) decrease (d) be zero

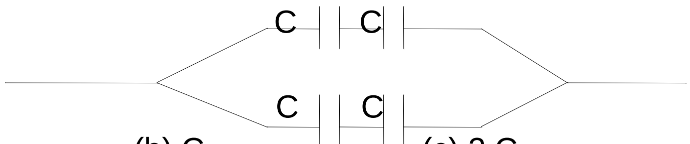
15. Two plates are 1 cm apart and the potential difference between them is 10 volt. The electric field between the plates is
(a) 10 N/C (b) 250 N/C (c) 500 N/C (d) 1000 N/C

16. Three charges 2q,-q and –q are located at the vertices of an equilateral triangle. At the circumcentre of the triangle
(a) E=0 but V≠0 (b) E $\neq 0\, but\, V = 0$ (c) both E & V = 0 (d) both E & V ≠0

17. The ratio of the electric force between two electrons to the gravitational force between them is of the order of
(a) 10^{42} (b) 10^{40} (c) 10^{36} (d) 10^{32}

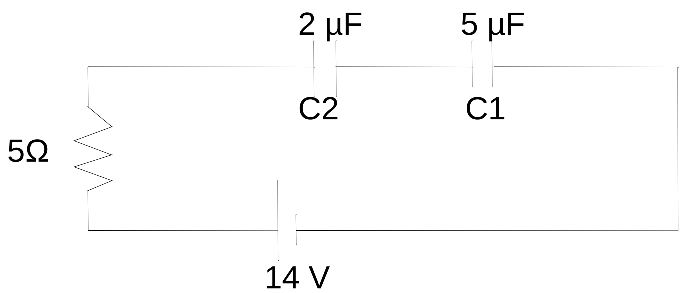
18. Five identical capacitors connected in series have an equivalent capacitance of 4 μF. If all of them are connected in parallel across a 400 V supply, the total energy stored in them
(a) 2 J (b) 4 J (c) 8 J (d) 16 J

19. The equivalent capacitance of the combination shown in the figure is



(a) C/2 (b) C (c) 2 C (d) 4 C

20. In the given circuit in steady state



(a) The p.d. across C1 is 10 V
(b) The p.d. across C2 is 10 V
(c) The charge on C1 is 20 µC
(d) The charge on C2 is 8 µC

21. An electric charge is placed at the centre of a cube of side a. The electric flux through one of the face of the cube is
(a) $q / 6\varepsilon_0$ (b) $q / \varepsilon_0 a^2$ (c) $q / 4\pi\varepsilon_0 a^2$ (d) q / ε_0

22. The capacitance of a parallel plate capacitor does not depend upon
(a) area of plates (b) metal of plates
(c) medium between plates (d) distance between the plates

23. Electric field intensity at a point inside a hollow charged spherical conductor is
(a) zero (b) constant
(c) increases with distance from the centre of the sphere (d) None of these

24. The space between the plates of the capacitor is filed by a liquid of dielectric constant K.The capacitance of the capacitor
(a) Increases by a factor K (b) increases by a factor k^2
(c) Decreases by a factor K (d) decreases by a factor K^2

25. When 10^{12} electrons are removed from a neutral metal sphere, the charge on it becomes
(a) 16 µC (b) – 16 µC (c) 32 µC (d) – 32 µC

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Answer Key

1	2	3	4	5	6	7	8	9	10
d	d	b	c	a	c	a	d	a	d
11	12	13	14	15	16	17	18	19	20
b	a	d	c	d	b	a	c	b	b,c
21	22	23	24	25					
a	b	a	a	a					

CURRENT ELECTRICITY

ELECTRIC CURRENT: If the rate of flow of charge is not constant then the current at any instant is given by $I = \frac{dQ}{dt}$

The SI unit of current is coulomb/second, is called ampere (A).In metals the current is due to motion of electrons whereas in electrolytes and ionized gases, both electrons and positive ions move in opposite direction. The direction of current is taken as the direction in which positive charges move.

ELECTROMOTIVE FORCE AND DRIFT SPEED:

To maintain the potential difference between the two ends of the conductor, work has to be done by an external source to move the charge. Such an agency is called a source of emf.Example - an electrochemical cell or a generator.

The average velocity with which the electrons move in a conductor under a potential difference is called Drift speed.

If E is the applied field, e is the charge of an electron and m is the mass of electron, τ is the time interval between successive collisions, then the drift velocity of electron is given by

$$v_d = \frac{eE\tau}{2m}$$

Ohm's Law: Physical conditions remaining unchanged, the current flowing through a conductor is directly proportional to potential difference applied across its ends i.e. **$V \propto R$ or V = IR, where R – resistance** of the conductor.SI unit of resistance is ohm (Ω)

V-I relation for Ohmic conductors is a straight line graph. However Ohm's law is not valid for semiconductors and electronic devices such as diodes and transistors.

RESISTANCE ABS RESISTIVITY:

R = ρ.L/A or ρ = RA/L, where ρ is called resistivity or specific resistance. It depends on the nature of the metal but Resistance depends on the dimensions of the conductor. SI unit of Resistivity is ohm.metre (Ω.m)

The inverse of resistivity is called conductivity denoted by σ.Its SI unit is Sm^{-1}.

$J = \sigma E$, where J is called current density.

VARIATION OF RESISTANCE WITH TEMPERATURE:

Temperature coefficient of resistance is given by (alpha) $R_t = R_0 (1 + \alpha t)$

Where R_t and R_0 are the resistance at t^0c and 0^0C respectively. Alternatively we can write this equation in another form as **$\alpha = (R_t - R_0) / t$**

For Metals α is Positive so resistance of metals increases with temperature. For semiconductors α is negative so resistance of semiconductors decreases with increase in temperature.

COMBINATION OF RESISTORS:

(a) SERIES GROUPING: **$R_s = R_1+R_2+R_3$**

(b) PARALLEL GROUPING: $\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2} +$

Where R_s and R_p be the equivalent resistance in Series and Parallel grouping of three given resistors R1, R2 and R_3.

<u>SUPERCONDUCTORS</u>: A number of material have the property that below a certain temperature (called Critical temperature), which is generally very close to absolute zero, their resistivity suddenly drops to zero. Such materials are called <u>SUPERCONDUCTORS.</u> A current once established in a superconductor continues for a long time without any driving field.

INTERNAL RESISTANCE OF A CELL AND TERMINAL VOLTAGE:

The resistance offered by the electrolytes in the flow of current through them is called internal resistance of the cell.

Suppose a cell of emf E and internal resistance r is connected across a resistance R then current **V = E – IR, where V is called terminal voltage.**

KIRCHHOFF’s RULES:

FIRST RULE: (**<u>JUNCTION RULE</u>**) The algebraic sum of currents meeting at a junction is always zero. Mathematically $\sum I$ **= 0.**This rule follows the law of conservation of charge.

<u>SECOND RULE: (LOOP RULE):</u> The algebraic sum of the changes of potential around any loop is zero.

Mathematically $\sum IR = \sum E$

This rule follows the law of conservation of energy.

MULTIPLE CHOICE QUESTIONS
CURRENT ELECTRICITY

1. A copper wire is stretched to make it 0.1% longer. What is the percentage change in its resistance
   (a) 0.1 (b) 0.4 (c) 0.2 (d) 0.8

2. A wire 1 m long has a resistance of 1 Ohm. If it is uniformly stretched, so that its length increases by 25%, then its new resistance will increases by:
   (a) 25% (b) 50% (c) 56.25% (d) 77.33%

3. A wire has a resistance of 2.0 Ω at 250C and 2.5 Ω at 1000C.The temperature coeficient of resistance of the wire is
   (a) $3.6 \times 10^{-2}/^0C$ (b) $4.0 \times 10^{-2}/^0C$ (c) $2.5 \times 10^{-2}/^0C$ (d) $3.5 \times 10^{-2}/^0C$

4. A wire has resistance of 10 Ω . It is stretched by one-tenth of its original length.Then its resistance
   (a) 9 Ω (b) 10 Ω (c) 11 Ω (d) 12 Ω

5. The specific resistance of a wire :
   (a) varies with its length (b) varies with its cross section
   (c) varies with its mass (d) does not depend on its length, mass and cross – section.

6. Two wires of same material have lengths 3 cm and 5 cm and radii 1 mm and 3 mm respacively. Theay are connected in series across abattery of 16 V.The P.d. across the shorter wire is
   (a) 2.5 V (b) 6.5 V (c) 10.5 V (d) 13.5 V

7. The electric intensity E, current density J and conductivity σ are related as
   (a) $J = \sigma E$ (b) $j = E/\sigma$ (c) $JE = \sigma$ (d) $J = \sigma^2 E$

8. The specific resistance of a wire
   (a) varies with length
   (b) varies with its cross-section
   (c) varies with its mass
   (d) does not depemnds upon its length, mass and cross-section

9. Three resistances each of 1 Ω are joined in parallel. Three such combinations are put in series. The resultant resistance is

(a) 9 Ω (b) 3 Ω (c) 1 Ω (d) $\frac{1}{3}$ Ω

10. A current of 5 A is flowing in a wire of cross-section area 4 X 10^{-6} m^2.If the free electron density in the wire is 5 X $10^{26}/m^3$, the drift speed of the electron is (in m/s)

(a) $\frac{1}{8}$ (b) $\frac{1}{16}$ (c) $\frac{1}{32}$ (d) $\frac{1}{64}$

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ANSWER KEY

1	2	3	4	5	6	7	8	9	10
c	c	a	d	d	d	a	c	d	d