UNIT-1 ELECTROSTATICS

FORMULA AT A GLANCE

Dipole
Dipole Moment (Cm)
$P = q \times 2a$
(Direction: $-q$ to $+q$)
Torque (Nm)
$\vec{\tau} = \vec{p} \times \vec{E}$
$\tau = pE \sin\theta$

Coulomb's Force (SI Unit: N)

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$
$$= q_2 E$$
$$\vec{F}_{12} = \frac{k q_1 q_2}{r_{21}^2}\hat{r}_{21} \text{ (Vector form)}$$

Dielectric Constant (Relative Permittivity)

$$K_D = \varepsilon_r = \frac{F_0}{F_m} = \frac{\varepsilon_m}{\varepsilon_0}$$
$$= \frac{C_m}{C_0} = \frac{\phi_0}{\phi_m} = \frac{E_0}{E_m}$$
$$\{F_0 \geq F_m\}$$
$$K_D = 1 + \chi$$

Electric Field (SI Unit: NC^{-1})

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2} = \frac{F}{q_2} = -\frac{dV}{dr}$$
$$E_x = \frac{1}{4\pi\varepsilon_0}\frac{q\,x}{r^3}$$
$$E_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{\left(r^2 - a^2\right)^2}$$
$$E_{equatorial} = \frac{1}{4\pi\varepsilon_0}\frac{p}{\left(r^2 + a^2\right)^{\frac{3}{2}}}$$
$$E = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r} \text{ (Line charge)}$$
$$E = \frac{\sigma}{2\varepsilon_0} \text{ (Infinite plane sheet)}$$
$$E = \frac{\sigma}{\varepsilon_0} \text{ (Parallel plate)}$$
$$E = \frac{\sigma}{\varepsilon_0}\frac{R^2}{r^2} = \text{(Spherical shell)}$$
$E = E_0 - E_p$; $E_0 \rightarrow$ Applied electric field

Charge
Q = ± ne

Potential (SI Unit: V or JC^{-1})

$$V_A = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_A} = \frac{W}{q_2} = \int \vec{E}.\vec{dr}$$
$$V_A - V_B = \frac{W_{AB}}{q_2} = \frac{q_1}{4\pi\varepsilon_0}\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

Potential difference b/w inner (radius r_0) and outer shell (radius R) in Van de Graaff generator

$$V_{r_0} - V_R = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_0} - \frac{1}{r_A}\right)$$

Where $q \rightarrow$ charge on inner sphere

For an Electric Dipole

$$V_{\text{any point}} = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2 - a^2\cos^2\theta}$$
$$V_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$$
$$V_{equi} = 0$$

Capacitance (SI Unit: Farad)

$C = \frac{q}{V}$; $C = 4\pi\varepsilon_0 r$ (sphere)

(Series) $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

(Parallel) $C = C_1 + C_2 + C_3$

In parallel plate $C = \frac{A\varepsilon_0}{d}$

Dielectric slab b/w plate,

$$C = \frac{\varepsilon_0 A}{d - 1\left(1 - \frac{1}{K_D}\right)}$$

Conducting slab b/w plates

$$C = \frac{C_0}{\left(1 - \frac{1}{d}\right)}$$

Electrical Energy (SI Unit: J)

$$W = U_A = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_A} = \int \vec{F}.\vec{dr}$$
$$= q_2 V_A$$
$$U_B - U_A = W_{AB} = \frac{q_1 q_2}{4\pi\varepsilon_0}\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

Energy at a point due to dipole placed in an electric field.

$$U = -\vec{p}.\vec{E} = -pE\cos\theta = \int \tau\, d\theta$$

Energy stored in a charged capacitor.

$$U = \frac{q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}qV$$

Electric Flux (SI Unit: Nm^2C^{-1})

$$\phi = \oint_S \vec{E}.d\vec{S} = \oint_S E_n.dS$$
$$= E \times \text{Effective area} = \frac{q}{\varepsilon_0}$$

SYNOPSIS

Properties of electric charge

Quantisation of electric charge. The total charge on any charged body is an integral multiple of the charge of an electron. **$q = +ne$ or $q = -ne$**
Conservation of electric charge. The net positive and negative charges in an isolated system remain constant.
Electric charge is additive. The total charge on a body is the algebraic sum of all the positive and negative charges present on the different parts of the body.

Coulomb's law in electrostatics states that the force of attraction or repulsion between 2 point charges q_1 and q_2 separated by a distance r is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

$$F = k\, q_1\, q_2 / r^2$$

where Coulomb force constant or electrostatic force constant, $k = 1/4\pi\varepsilon_0 = 9 \times 10^9\ Nm^2/C^2$
ε_0 is permittivity of free space and is $= 8.85 \times 10^{-12}\ C^2/Nm^2$
Case 1 : $F > 0$ means $q_1 q_2 > 0$ ie charges are like and force is repulsive.
Case 2 : $F < 0$ means $q_1 q_2 < 0$ ie charges are unlike and force is attractive.

Dielectric constant K [relative permittivity ε_r]
in terms of electric permittivity: it is the ratio of electric permittivity of the medium to the electric permittivity of free space. **$K = \varepsilon_r = \varepsilon / \varepsilon_o$ or $\varepsilon = \varepsilon_r\ \varepsilon_r = k\,\varepsilon_o$**
in terms of force between electric charges : it is the ratio of force between 2 charges separated by a distance in air or vacuum to the force between the same 2 charges in the medium held at the same distance. **$K = F_{vac} / F_{med}$**

Electric field is the region or space around a charged body within which the force of attraction or repulsion can be felt.

Electric field intensity/strength [E] at any point in an electric field is defined as the force experienced by unit positive test charge placed at that point. **$E = F / q_0$.**
The direction of force F acting on the charge is in the direction of E if q is positive and direction of force F is opposite to the direction of E if q is negative.

Electric field intensity at any point due to a point charge **$E = k\,Q/ r^2$**
Electric lines of force are imaginary lines straight or curved such that the tangent at any point gives the direction of electric field intensity at that point.

Properties of electric lines of force

- It begins from positive charge and ends in negative charge.
- No two lines of force will intersect because if it intersects, at the point of intersection, there will be two different directions of electric field that is not possible.

Electric dipole. A pair of equal and opposite charges separated by a short distance.
Electric dipole moment, p Its magnitude is equal to the product of either charge and the distance between the charges.
SI unit : Coulomb metre
It is a vector quantity directed from –q to +q

Electric field at any point on the axial line of the dipole **$E = k\,2pr/(r^2-a^2)^2$**
Case : When the point p is at an infinite distance (r >> a) **$E = k\,2p/\ r^3$**
Electric field at any point on the equatorial line of the dipole **$E = \underline{k\,p/}(r^2+a^2)^{3/2}$**
Case : when the point p is at an infinite distance (r >> a) **$E = k\,p/\ r^3$**

Torque acting on an electric dipole placed in uniform electric field. **$\tau = pE\sin\theta$**
Case 1 : torque is minimum when $\theta = 0$
Case 2 : torque is maximum when $\theta = 90$

Potential energy by a dipole in uniform electric field **$U = pE\ [\cos\theta_1 - \cos\theta_2]$**
Case 1 : pE is minimum or in stable equilibrium when **p** parallel to **E**
Case 2: pE is maximum or in unstable equilibrium when **p** is antiparallel to **E.**

Electric potential due to dipole **$V = kp\cos\theta\ /r^2$**

Case 1: At any point in axial line,$\theta = 0$, **$V = kp\ /r^2$**
Case 2: At any point on the equatorial line $\theta = 90$, **$V = 0$**

Equipotential surface is a surface in an electric field such that there is same electric potential at every point on the surface .

Properties of equipotential surface.
No work is done in moving a test charge from one point to another on an equipotential surface.
No two equipotential surface can intersect each other.

Gauss'sTheorem states that the surface integral of electric field over a closed surface is $1/\varepsilon_o$ times the net charge enclosed by the surface. $\emptyset = q/\varepsilon_o$

Dielectrics are insulators which transmit electric effects without conducting.

Behaviour of a conductor in an electrostatic field:
-Net electrostatic field and net charge in the interior of the conductor is zero.
-The electrostatic field at a point just outside a charged conductor is normal to the surface at every point.

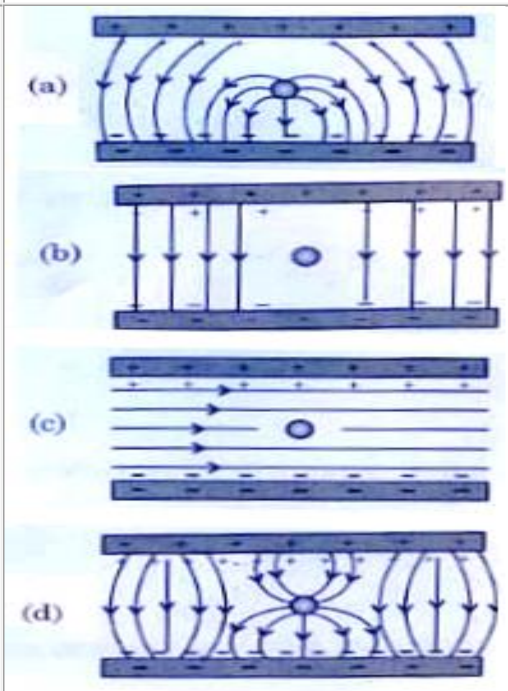
-Since the electric field is zero, electric potential is constant within the conductor and on the surface.
-Charges always reside on the outer surface of the conductor
-Electrostatic shielding: It is the phenomenon of protecting a region of space from the external electric field such that the field inside the cavity is always 0.
-Electric field at the surface of a charged conductor is $E=\sigma/\varepsilon_0$

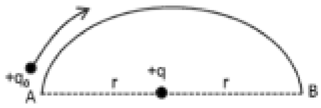
Capacitance: has the ability to store electric charge.
C depends on: -a) Shape and size of the conductor b) Nature of the medium
Dielectric strength is the maximum electric field that a dielectric medium can withstand without breakdown.
Dielectric strength of air = 3 x10^6 V/m and of mica = 100 x 10^6 V/m.
Energy density in a capacitor $u_e = (1/2)\, \varepsilon_0 E^2$

S.No.	Question Details	Marks
	MULTIPLE CHOICE QUESTIONS	
1	For a thin spherical shell of uniform surface charge density , The magnitude of at a distance r, when r > R (radius of shell) is a. $E = \frac{4\pi R^2\sigma}{4\pi\epsilon_0 r^3}$ b. $E = \frac{4\pi R^2\sigma}{4\pi\epsilon_0 r^2}$ c. $E = \frac{R^2\sigma}{4\pi\epsilon_0 r^2}$ d. $E = \frac{4\pi R\sigma^2}{4\pi\epsilon_0 r^2}$	**1**
2	Two insulated charged copper spheres A and B have their centres separated by a distance of 50 cm. What is the mutual force of electrostatic repulsion if the charge on each is 6.5x10^{-5} C? The radii of A and B are negligible compared to the distance of separation. a) 3.5 x 10^{-2} N b) 4.5 x 10^{-2} N c) 1.5 x 10^{-2} N d) 2.5 x 10^{-2} N	**1**
3	A conducting sphere of radius 5 cm is charged to 15 μC. Another uncharged sphere of radius 10 cm is allowed to touch it for enough time. After the two are separated, the surface density of charge on the two spheres will be in the ratio a) 2:1 b) 1:2 c) 1:1 d) 3:1	**1**

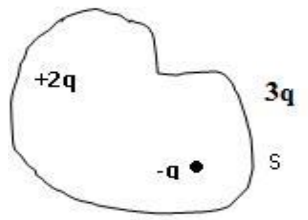
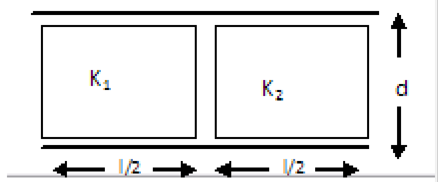
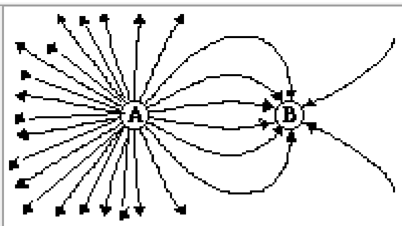
4	An electric dipole is a. a) pair of electric charges of equal magnitude q but positive sign, separated by a distance d b) a pair of electric charges of equal magnitude q but opposite sign, separated by a distance d c) a pair of electric charges of equal magnitude q but negative sign, separated by a distance d d) a pair of electric charges of equal magnitude q separated by a distance d	**1**
5	If a charge q is placed at the centre of the line joining two equal charges Q such that the system is in equilibrium, then the value of q is	**1**
	a) Q/2 b) −Q/2 c) Q/4 d) −Q/4.	**1**
6	On moving a charge of 20 coulomb by 2cm, 2J of work is done, then the potential difference between the points is	**1**
	a) 0.1 V b) 8V c) 2 V d) 0.5 V	**1**
7	A hollow conducting sphere is given a positive charge of 10μC. What will be the electric field at the centre of the sphere if its radius is 2 metres?	**1**
	a) $20NC^{-1}$ b) $8NC^{-1}$ c) $5NC^{-1}$ d) Zero	**1**
8	The dielectric constant K of an insulator will be a) 0.4 b) 4 c) -4 d) Zero	**1**
9	A plane area of 100 cm^2 is placed in uniform electric field of 100 N/C such that the angle between area vector and electric field is 60^0. The electric flux over the surface is a) 1 Nm^2/C b) 2 Nm^2/C c) 3 Nm^2/C d) 0.5 Nm^2/C	**1**
10	When another conductor is brought near a charged conductor, its capacity increases. This is because : a) Combined volume increases b) Combined surface area increases. c) Surface density of charge decreases.	**1**

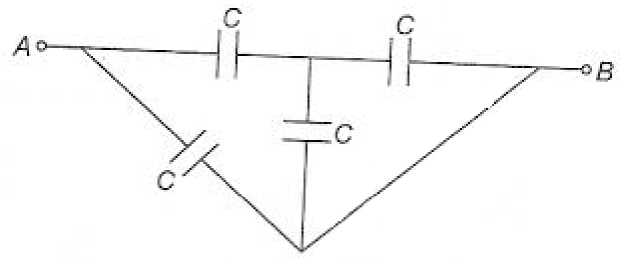
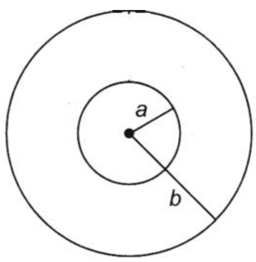
	d) Potential decreases as opposite charges are induced on second conductor	
11	Two plates are 2cm apart, a potential difference of 10 volt is applied between them, the electric field between the plates is :	**1**
	a) 20 V/m b) 500 V/m c) 5 V/m d) 250 V/m	**1**
12	A parallel plate capacitor is charged, and the charging battery is then disconnected. If the plates of the capacitor are moved farther apart by means of insulating handles.	**1**
	a) The charge on the capacitor increases. b) The voltage across the plates decreases. c) The capacitance increases. d) The electrostatic energy stored in the capacitor increases	**1**
13	Two capacitors of value C each are connected in parallel, when this combination is connected in series with an identical combination, the effective capacitance becomes	**1**
	a) C b) 4C c) 2C d) C/2	**1**
14	The ratio of the energy stored by the series combination of two identical capacitors to their parallel combination, when connected to same supply voltage is	**1**
	a) 1 b) 2 c) 4 d) 1/4	**1**
15	Parallel plate capacitor has plate separation of d and capacitance of 25 μF. If a metallic foil of thickness 2d/7 is introduced between the plates with same cross-sectional area as of plate, the new capacitance would become	**1**
	a) 15μF b) 35μF c) 87.5μF d) 7.25μF	**1**
16	Which of the following is NOT the property of equipotential surface?	1
	a) They do not cross each other. b) The rate of change of potential with distance on them is zero. c) For a uniform electric field, they are concentric spheres. d) They can be imaginary spheres.	
17	A negatively charged object X is repelled by another charged object Y. However, an object Z is attracted to object Y. Which of the following is the best possibility for the object Z?	1

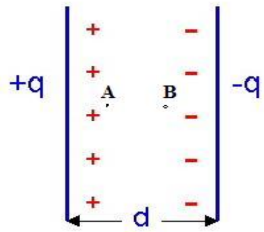
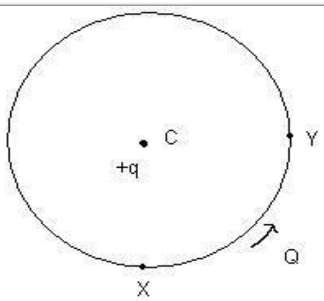
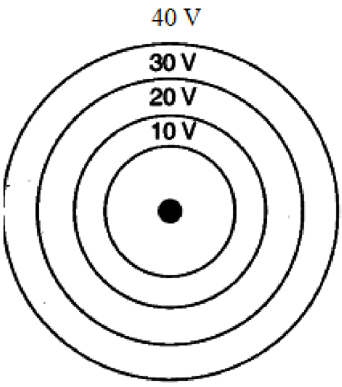
	a)positively charged only b) negatively charged only c) neutral or positively charged d) neutral or negatively charged.	
18	In an experiment three microscopic latex spheres are sprayed into a chamber and became charged with charges +3e, +5e and −3e respectively. All the three spheres came in contact simultaneously for a moment and got separated. Which one of the following are possible values for the final charge on the spheres?	1
	a) +5e, −4e, +5e b) +6e, +6e, −7e c) −4e, +3.5e, +5.5e d) +5e, −8e, +7e	
19	Which of the diagrams correctly represents the electric field between two charged plates if a neutral conductor is placed in between the plates?	1
		
20	A potential difference of 200 V is maintained across a conductor of resistance 100 ΩΩ. The number of electrons passing through it in 1s is:	
	a)1.25×10^{19} b)2.5×10^{18} c)1.25×10^{18} d)2.5×10^{16}	1
	FILL IN THE BLANKS	
1.	Two charges of 10 μC and 20 μC are separated by 20cm. The ratio of forces acting on them will be ________________________	**1**

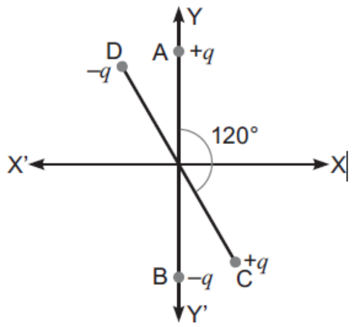
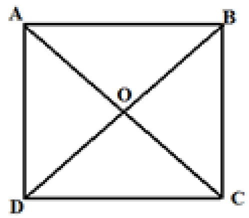
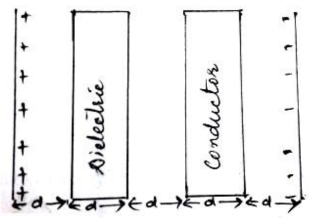
2.	Two particles having charges Q1 and Q2 when kept at a certain distance exert a force F on each other. If the distance between the two particles is reduced to half and the charge on each particle is doubled then the force between the particles would be _____________	**1**
3.	The number of lines of force passing normally through unit area of a surface situated in an electric field is called as _____________	**1**
4.	The work done on a unit positive charge in bringing it from infinity to any point in the field is called ________________	**1**
5.	A particle of charges q0 is moved around a charge +q along the semicircular path of radius r from A to B (see figure). The work done by the Coulomb force is ______________ 	**1**
6.	A and B are two points in an electric field. If 8 joule of work is done in taking 2 coulomb of electric charge from A to B, then the potential difference between A and B will be __________	**1**
7.	A hollow metal sphere of radius 5 cm is charged so that the potential on its surface is 10 V. The potential at the centre of the sphere is ___________	**1**
8.	An electric dipole of dipole moment p is placed in uniform electric field E , with p parallel to E . It is then rotated by an angle of θ . Then work done is _________	**1**
9.	A point charge of value 10^{-7}C is situated at the centre of cube of 1 m side. The electric flux through its total surface area is _____________	**1**
10.	A charge Q is placed at the corner of a cube. The electric flux through all the faces of the cube is ________________	**1**
11.	Capacitor is connected to a battery of 20 V, so that a charge of 100µC is obtained at the plates. The capacitance of the capacitor is _____________	**1**
12.	The capacity of a parallel plate condenser is C. Its capacity when the separation between the plate is halved will be ________________	**1**
13.	Two plates are 2cm apart, a potential difference of 10 volt is applied between them, the electric field between the plates is ____________	**1**
14.	Three capacitors 3µF, 9µF and 18µF are connected first in series and then in parallel. The ratio of the equivalent capacitances in two cases is _____________	**1**
15.	A parallel plate capacitor with a slab of dielectric constant 3 filling the whole space between the plates is charged to certain potential and isolated. Then the slab is drawn out and another slab of equal thickness but dielectric constant 2 is introduced between the plates. The ratio of the energy stored in the capacitor later to that stored initially is ______________	**1**
	ASSERTION AND REASON	

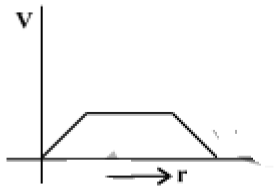
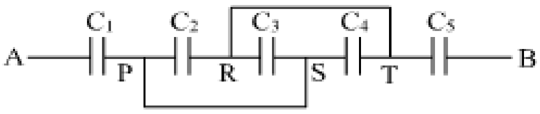
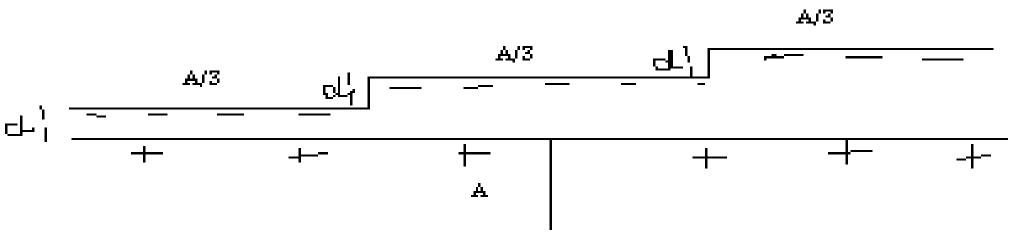
	The following questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses. (a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion. (b) Both Assertion and Reason are correct, but Reason is not a correct explanation of the Assertion. (c) Assertion is correct, Reason is incorrect (d) Both Assertion and Reason are incorrect.	
1	**Assertion :** A metallic shield in form of a hollow shell may be built to block an electric field. **Reason :** In a hollow spherical shield, the electric field inside it is zero at every point.	**1**
2	**Assertion :** Electric lines of force never cross each other. **Reason :** Electric field at a point superimpose to give one resultant electric field.	**1**
3.	**Assertion :** The property that the force with which two charges attract or repel each other are not affected by the presence of a third charge. **Reason :** Force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to other charges, taken one at a time.	**1**
4	**Assertion :** On disturbing an electric dipole in stable equilibrium in an electric field, it returns to its stable equilibrium orientation. **Reason :** A restoring torque acts on the dipole on being disturbed from its stable equilibrium.	**1**
5	Assertion: If the distance between parallel plates of a capacitor is halved and dielectric constant is made three times, then the capacitor becomes 6 times. Reason : Capacity of the capacitor does not depend upon the nature of the material.	**1**
6	Assertion :A parallel plate capacitor is connected across battery through a key. A dielectric slab of constant K is introduced between the plates. The energy which is stored becomes K times. Reason :The surface density of charge on the plate remains constant or unchanged.	**1**
	VERY SHORT ANSWER QUESTIONS	

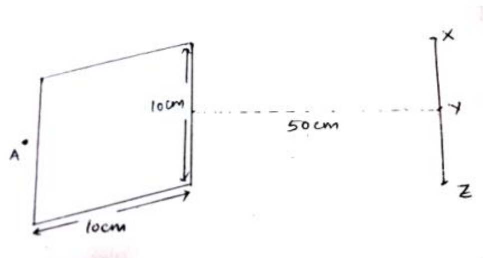
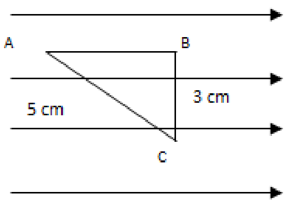
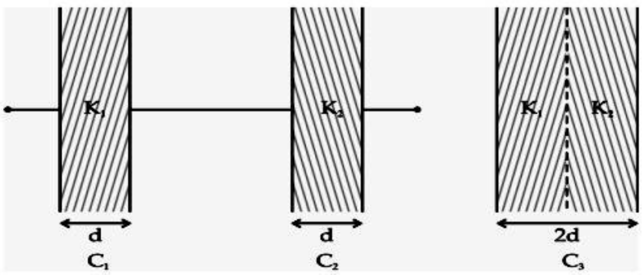
1.	Figure shows three point charges +2q,-q and +3q.Two charges +2q and –q are enclosed within a surface **S** .What is the electric flux due to this configuration through the surface **S.** 	**1**
2.	Why does the electric field inside a dielectric decrease when it is placed in an external field?	1
3.	What does $q_1 + q_2 = 0$ signify in electrostatics?	**1**
4.	What orientation of an electric dipole in uniform electric field corresponds to its stable equilibrium?	**1**
5.	A charge experiences a force of 32N as it is placed at a certain distance on the axial line of an electric dipole, what will be the force on the charge if its distance from the dipole is halved?	**1**
6.	What is the work done in moving a charge of 10nC between two points on an equipotential surface?	**1**
7.	Two dielectric slabs of dielectric constant K_1 and K_2 are filled in between the two plates, each of area A, of the parallel plate capacitor as shown in the figure. Find the net capacitance of the capacitor. 	**1**
8.	Name any two basic properties of electric charge.	**1**
9.	What is the net charge on the capacitor?	**1**
10.	A positive point charge (+q) is kept in the vicinity of an uncharged conducting plate. Sketch electric field lines originating from the point on to the surface of the plate.	**1**
11.	A charge Q is divided in two parts q and (Q-q) and these are kept at some distance r apart. What is the value of q for which the force between these two charges is maximum?	**1**
12.	Draw one equipotential surface (i) in a uniform electric field and (ii) for a point charge ($Q < 0$).	1
13.	The electric field lines drawn for two charges A and B separated by a distance is as shown below. a) What are the signs of A and B? b) Is the ratio of magnitude of the charges (A / B) greater than, less than or equal to 1? 	**1**

14.	Name the physical quantity which has joule per coulomb as its unit. Is it a scalar or a vector quantity?	**1**
15.	An electric dipole of dipole moment 20 x 10^{-6} C-m is enclosed by a sphere of radius 2m. What is the net flux coming out of the surface of the sphere?	**1**
16.	Is the electric potential necessarily zero at a place where the electric field is zero?	**1**
17.	Find the equivalent capacitance between the points A and B. 	**1**
	2 MARKER QUESTIONS	
18.	Two identical metallic spherical shells A and B having charges + 4Q and -10Q are kept a certain distance apart. A third identical uncharged sphere C is first placed in contact with sphere A and then with sphere B, then spheres A and B are brought in contact and then separated. a) Find the charge on the spheres A and B. b) Compare the electrostatic force if the distance between A and B is halved after the final contact between A and B.	**2**
19.	A point charge +Q is placed at the center O of an uncharged hollow spherical conductor of inner radius 'a' and outer radius 'b'.  Find the following. a) The magnitude and sign of the charge induced on the inner and outer surface of the conducting shell. b) The magnitude of electric field vector at a distance i. R = a/2 ii. R = 2b from the center of the shell	**2**

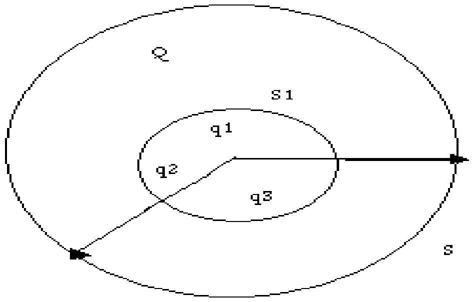
20.	Two protons A and B are placed between two parallel plates having a potential difference V as shown in the figure. A) What is the ratio of electric field intensities at points A and B between the plates of a parallel plate capacitor? B) Will these proton experience equal or unequal force? Justify		2
21.	Two points A and B are 3m and 4m from a charge q. At which point is the potential higher and what is the ratio of the potential at these points?		**2**
22.	What is the work done in moving a 2-micro coulomb point charge from corner A to corner B of a square ABCD, when a 10 micro coulomb charge is placed at the centre of the square?		**2**
23.	Two identical conducting spheres one solid and the other hollow are given equal charges +q each. Which of them will be at higher potential?		**2**
24.	Calculate the distance between two protons such that the electric repulsive force between them is equal to the weight of either.		**2**
25.	The charge + q is lying at the center C of a circle of radius R. What is the amount of work done in carrying another charge +Q from points X to Y on the circumference of the circle? What is the electric potential at X.		**2**
26.	Force of attraction between two points charges placed at distance d apart in a medium is 'F'. What should be the distance apart in the same medium so that the force of attraction between them becomes F/3?		**2**
27.	Concentric equipotential surfaces due to a charged body placed at the center are shown.  Identify the polarity of the of the charge and draw the electric field lines due to it.		**2**
28.	Two fixed-point charges +4e and +e units are separated by a distance a. Where should the third point charge be placed for it to be in equilibrium? [2/3a from the charge +4e]		**2**

29.	Two small identical electrical dipoles AB and CD, each of dipole moment 'p' are kept at an angle of 120° as shown in the figure. What is the resultant dipole moment of this combination? If this system is subjected to electric field E, directed along + X direction, what will be the magnitude and direction of the torque acting on this?  	**2**
30.	A charge of 12mC given to a hollow metallic sphere of radius 0.1m. Find the potential at (i) the surface of the sphere, and (ii) the center of the sphere. [$84\text{x}10^{-7}$V, $84\text{x}10^{-7}$V,]	**2**
31.	Four charges 4C, -3C, -2C and 3C are placed at the corners A, B, C, and D respectively of a square of side 1m. Find the magnitude of the electric field at the center of the square.  	**2**
32.	The electric field at a point due to a point charge is 20 N/C and electric potential at that point is 10 J/C. Calculate the distance of the point from the charge and the magnitude of the charge. .[r = 0.5m,q = $5.5\text{x}10^{-10}$C]	**2**
33.	Plot E versus x graph, taking x=0 at positive plate and x=5d at negative plate.  	**2**
34.	Compare the individual dipole moment and the specimen dipole moment for H_2O molecule and O_2 molecule when placed in i) Absence of external field ii) Presence of external electric field. Justify your answer.	**2**
35.	The electrostatic potential V is changing with distance r according to the following graph.	**2**

	 Draw the graph for the variation of electric field with distance r.	
36.	A charge q is placed at the center of the line joining two equal charges Q. Show that the system of three charges will be in equilibrium if q = -Q/4.	2
37.	A parallel plate capacitor is charged to V volts and the charging battery is disconnected. How will the potential difference between its plates and the energy stored in it be affected when its plates are separated further?	2
38.	a) Find the equivalent capacitance between A and B in the combination given below . Each capacitor is 2µF capacitance.  b) If a dc source of 7V is connected across AB, how much charge is drawn from the source and what is the energy stored in the network?	2
	3 MARKER QUESTIONS	
39.	A point charge is located at the centre of a spherical Gaussian surface. How will the electric flux through the surface be affected, when (i) spherical Gaussian surface is replaced by a Gaussian surface of arbitrary shape (ii) the charge is replaced by an electric dipole (iii) the charge enclosed is doubled in magnitude and (iv) the charge was kept close to the surface but outside it.	**3**
40.	A capacitor is made of a flat plate of area A and second plate having a stair like structure as shown in figure below. If width of each stair is A/3 and height is d. Find the capacitance of the  arrangement.	**3**
41.	Two-point electric charges +q and +9q are separated by a distance of 10a. Find the point on the line joining the two charges where electric field is zero. [2.5a from +q charge]	**3**

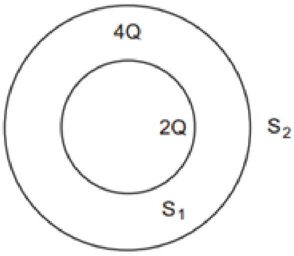
42.	Charges of + 15pC, - 15pC,+ 20pC and – 50pC are placed in order at each of the corners of a square of a side 20cm. Calculate the intensity of electric field at the point of intersection of the diagonals. [3.18 NC^{-1}]	**3**
43.	Two parallel uniformly charged infinite plane sheets, ‘1’ and ‘2’, have charge densities + σ and – 2 σ respectively. Give the magnitude and direction of the net electric field at a point (i) in between the two sheets and (ii) outside near the sheet ‘1’.	**3**
44.	Given a uniformly charged plane sheet of surface charge density σ = 2x 10 17 C/m^2. (i) Find the electric field intensity at a point A, 5mm away from the sheet on the left side. (ii) Given a straight line with three points X, Y & Z placed 50cm away the charged sheet on the right side. At which of these points, the field due to the sheet remain the same as that of point A and why? 	**3**
45.	Three points A, B and C lie in a uniform electric field $\vec{E}$ of **5x10^3 NC^{-1}** as shown in the figure. Find the potential difference between A and C 	**3**
46.	The capacitors C1, and C2, having plates of area A each, are connected in series, as shown in Fig (i) Compare the capacitance of this combination with the capacitor C3, again having plates of area A each, but ‘made up’ as shown in the figure.  Fig (i) Fig (ii)	**3**

47. The flux of the electrostatic fields, through the closed spherical surface **S**, is found to be four times that through the closed sphere **S1**. Find the magnitude of the charge **Q** . Given, q1= 1 μC, q2=-2μC and q3=9.854 μC. [Q=26.562μC]



3

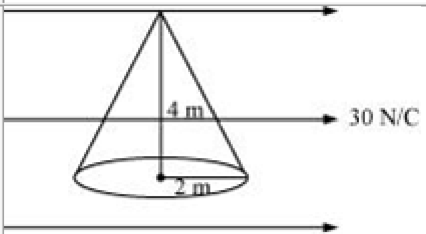
48. Consider two hollow concentric spheres, $\mathbf{S_1}$ and $\mathbf{S_2}$, enclosing charges **2Q** and **4Q** respectively as shown in the figure. Find out the ratio of the electric flux through them.



3

49. A uniform electric field exists in a region (as shown below). In this region, a cone is placed such that its axis is perpendicular to the direction of the electric field.

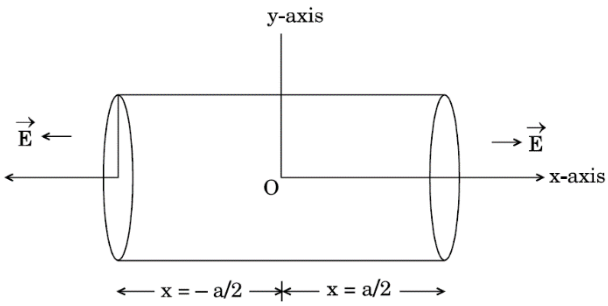
What is the electric flux that enters from the left-hand side of the cone?



3

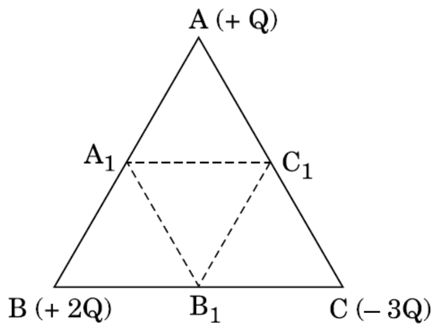
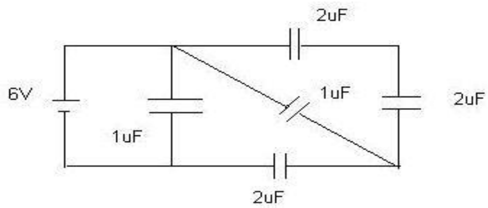
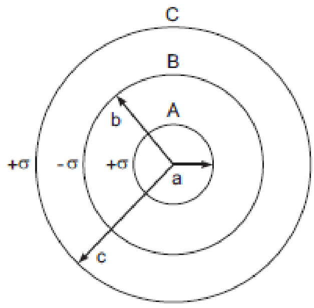
50. A right circular cylinder of length ‘a’ and radius ‘r’ has its centre at the origin and its axis along the x-axis so that one face is at x = + a/2 and the other at x = – a/2, as shown in the figure. A uniform electric field is acting parallel to the x-axis such that

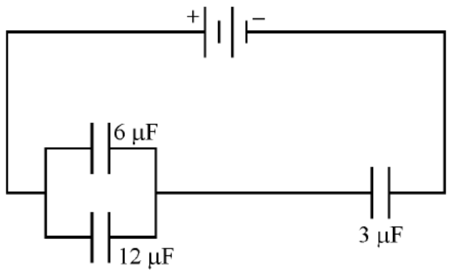
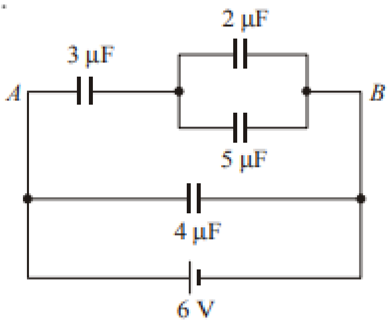
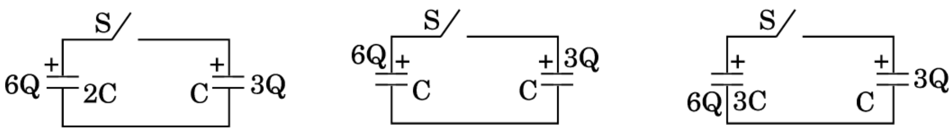
$\vec{E} = E_0 \hat{i}$ for $x > 0$ and $\vec{E} = -E_0 \hat{i}$ for x < 0.



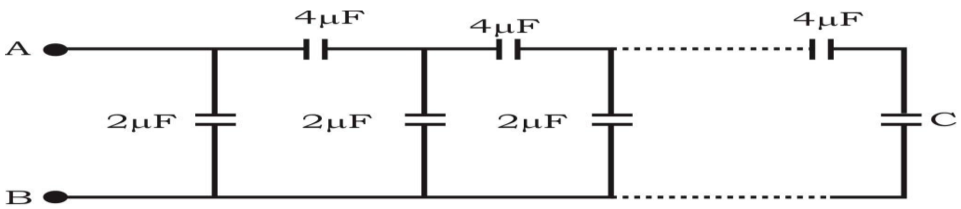
Find out the flux (i) through the flat faces, (ii) through the curved surface of the cylinder. What is the net outward flux through the cylinder and the net charge inside the cylinder ?

3

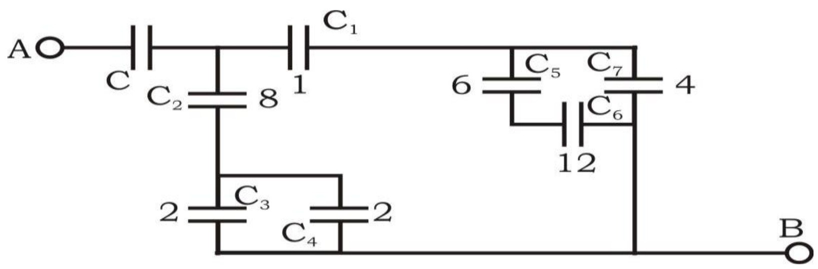
51.	An electric dipole of length 2 cm is placed with its axis making an angle of 60^0 to a uniform electric field of 10^5 NC^{-1}. If it experiences a torque of $8\sqrt{3}$ Nm, calculate the (i) magnitude of the charge on the dipole and (ii) potential energy of the dipole. [(i) $8x10^{-3}$ C (ii) -8J]		**3**
52.	Define electric field intensity. Write its SI unit. Write the magnitude and direction of E field due to an electric dipole of length 2*a* at the mid-point of the line joining the two charges.		3
53.	Two identical circular loops '1' and '2' of radius R each have linear charge densities – λ and + λ C/m respectively. The loops are placed coaxially with their centres $R\sqrt{3}$ distance apart. Find the magnitude and direction of the net electric field at the centre of loop '1'.		3
54.	Three point charges, + Q, + 2Q and – 3Q are placed at the vertices of an equilateral triangle ABC of side *l*. If these charges are displaced to the mid-points A1, B1 and C1 respectively, find the amount of the work done in shifting the charges to the new locations.		3
55.	Calculate the total energy of the given network and the total charge supplied by the source.		3
56.	Three concentric metallic shells ***A, B*** and ***C*** of radii ***a, b*** and ***c*** **(*a* < *b* < *c*)** have surface charge densities **+**σ**, -**σ and **+** σ respectively as shown in the figure. Find the potential on the surfaces **A** and **C.**		3
57.	In the following arrangement, the energy stored in the 6μF capacitor is E. Find the (i) Energy stored in 12 μF capacitor.		3

	(ii) Energy stored in 3 μF capacitor. (iii) Total energy drwan from the cell		
58.	What is the equivalent capacitance of the arrangement shown below? Find the charge on 5μF capacitor in the circuit.		3
59.	Two capacitors of unknown capacitances C1 and C2 are connected first in series and then in parallel across a battery of 100 V. If the energy stored in the two combinations is 0.045 J and 0.25 J respectively, determine the value of C1 and C2. Also calculate the charge on each capacitor in parallel combination.		3
60.	Two capacitors of capacitance 10 μF and 20 μF are connected in series with a 6 V battery. After the capacitors are fully charged, a slab of dielectric constant (K) is inserted between the plates of the two capacitors. How will the following be affected after the slab is introduced : (a) the electric field energy stored in the capacitors (b) the charges on the two capacitors (c) the potential difference between the plates of the capacitors Justify your answer.		3
61.	Three circuits, each consisting of a switch 'S' and two capacitors, are initially charged, as shown in the figure. After the switch has been closed, in which circuit will the charge on the left-hand capacitor (i) increase, (ii) decrease and (iii) remain same ? Give reasons.  (a) (b) (c)		3
62.	An infinite ladder if constructed by connecting several sections of 2μF, 4μF capacitor combination as shown in figure. It is terminated by a capacitor of capacitance C. What value		3

should be chosen for C such that the equivalent capacitance of the ladder between points A and B becomes independent of the number of sections in between?



63. From the given figure, find the value of the capacitance 'C' if the equivalent capacitance between point A and B is to be 1 μ F. All the capacitance are in μF? **3**

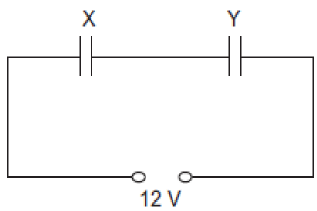


64. Two parallel plate condition *X* and *Y*, have the same area of plates and same separation between them. *X* has air between the plates while *Y* contains a dielectric medium of $\epsilon_r = 4$. **3**

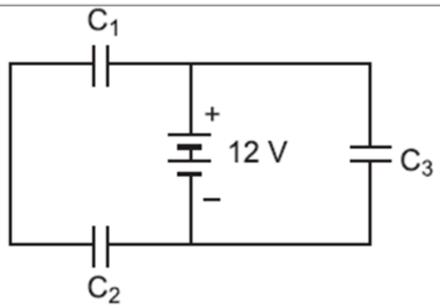
(i) Calculate capacitance of each capacitor if equivalent Capacitance of the combination is 4mF.

(ii) Calculate the potential difference between the plates of *X* and *Y*.

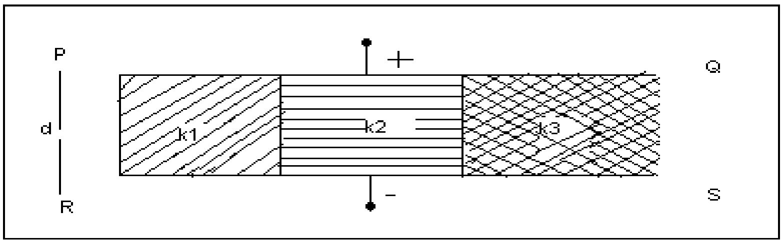
(iii) What is the ratio of electrostatic energy stored in *X* and *Y*?



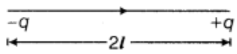
65. Three identical capacitors C_1, C_2 and C_3 of capacitance 6 μF each are connected to a 12 V battery as shown. Find (i) charge on each capacitor (ii) equivalent capacitance of the network (iii) energy stored in the network of capacitors **3**



66. Two parallel plates PQ and RS are kept distance 'd' apart. Area of each plate is 'A'. The space between them is filled with three dielectric slabs of identical size having dielectric constants K_1, K2 and K_3 respectively as shown in the figure. Find the capacitance of the capacitor. **3**

		
	5 MARKER QUESTIONS	
67.	State Gauss's theorem. Apply this to calculate the electric field inside a hollow conducting sphere and outside the charged conducting sphere.	**5**
68.	Show graphically, how charge given to a capacitor varies with the potential difference. From the graph, or otherwise, prove that energy of a capacitor is ½ CV^2. Calculate the energy density of electrostatic field in a parallel plate capacitor.	**5**
69.	Derive an expression for the magnitude of electric field intensity at any point along the equatorial line of a short electric dipole. Give the direction of electric field intensity at that point. For short dipole what is the ratio of electric field intensities at two equidistant points from the center of the dipole, One along the axial line and another on the equatorial line?	**5**
70.	A dielectric slab of thickness t is introduced without touching between the plates of a parallel plate capacitor, separated by a distance d (t<d). Derive an expression for the capacitance of the capacitor.	**5**
	CASE STUDY1	
	Electric Dipole Two-point charges of same magnitude and opposite nature separated by a small distance altogether form an electric dipole. **Electric Dipole Moment**	

The strength of an electric dipole is measured by a vector quantity known as electric dipole moment (p) which is the product of the charge (q) and separation between the charges (2l).



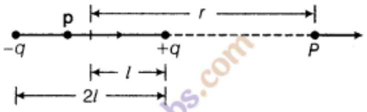
$$\mathbf{p} = q \times 2\mathbf{l}$$

$$\Rightarrow \qquad |\mathbf{p}| = q\,(2l)$$

Direction Its direction is from negative charge ($-q$) to positive charge ($+q$).
SI unit Its SI unit is C-m.

NOTE The line joining the two charges $-q$ and $+q$ is called the dipole axis.

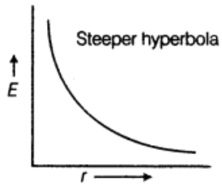
(i) Electric Field at any Point on the Axial Line/End-on Position of Electric Dipole



$$\mathbf{E}_{\text{axial}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2pr}{(r^2 - l^2)^2}$$

When $l << r$, $\mathbf{E}_{\text{axial}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\,\mathbf{p}}{r^3} \Rightarrow |\mathbf{E}_{\text{axial}}| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2|\mathbf{p}|}{r^3}$

$$\mathbf{E} \propto \frac{1}{r^3}$$



The direction of electric field at any point on axial line is along the direction of electric dipole moment.

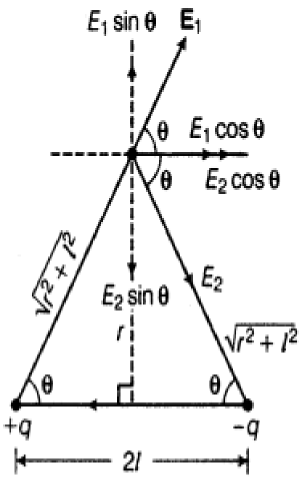
(ii) Electric Field at any Point on Equatorial Line/Broadside on Position/Perpendicular Bisector of Electric Dipole

$$\mathbf{E}_{\text{equatorial}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{-\mathbf{p}}{(r^2 + l^2)^{3/2}}$$

The direction of electric field intensity (**E**) due to dipole at any point on equatorial line is parallel to dipole and opposite to the direction of dipole moment.

If $l << r$,

$$|\mathbf{E}_{\text{equatorial}}| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{|\mathbf{p}|}{r^3}$$



a	In which orientation, a dipole placed in a uniform electric field is in (i) stable (ii) unstable equilibrium?	
b	A dipole of dipole moment p is present in a uniform electric field E . Write the value of the angle between p and E for which the torque experienced by the dipole, is minimum?	
c	An electric dipole of length 4 cm when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$Nm. Calculate the potential energy of the dipole if it has charge ± 8 nC.	

OR

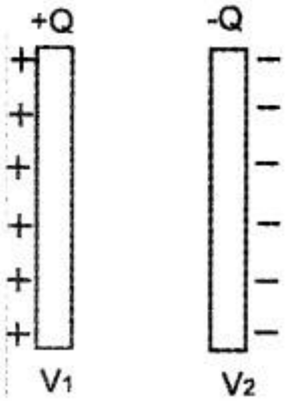
A dipole is present in an electrostatic field of magnitude 10^6N/C. If the work done in rotating it from its position of stable equilibrium to its position of unstable equilibrium is 2×10^{-23}J, then find the magnitude of the dipole moment of this dipole**?**

CASE STUDY 2

Capacitors And Capacitance

Capacitor: Capacitor is a system of two conductors separated by an insulator for storing electric charges.

Capacitance of a capacitor:



Consider two-conductor having charges +Q and -Q and potentials V_1 and V_2. The amount of charge Q on a plate is directly proportional to the potential difference ($v_1 - v_2$) between the plates,

ie. $Q \propto V_1 - V_2$

(or) $Q \propto V$ (where $V = V_1 - V_2$)

$\boxed{Q = CV}$

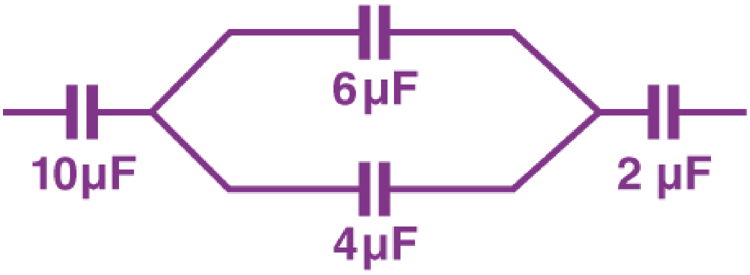
The constant C is called the capacitance of the capacitor. If V = 1, we get Q = C. Hence capacitance of a capacitor may be defined as the amount of charge required to raise the potential difference between two plates by one volt.

Dielectric strength:

When the p.d. between two plates increases, electric field in between two plates increase. This high electric field can ionize the surrounding air (or medium) and accelerate the charges to the oppositely charged plates and neutralize the charge on the plate. This is called electric break down. The maximum electric field that a dielectric medium can withstand without break down (of its insulating property) is called its dielectric strength. The dielectric strength of air is 3×10^6 v/m.

a) Define dielectric constant in terms of a capacitance of a capacitor?

b) A sheet of Aluminium foil of negligible thickness is introduced between the plates of a capacitor. What will be the new capacitance of the capacitor ?

c)	A capacitor of capacitance C is charged fully by connecting it to a battery of emf E. It is then disconnected from the battery. If the separation between the plates of the capacitor is now doubled, how will the following change? (a) Charge stored by the capacitor. (b) Field strength between the plates **OR** In the figure shown below, the charge on the left plate of the $10\mu F$ capacitor is $30\mu C$. The charge on the right plate of the $6\mu F$ capacitor is : 	

ANSWER KEY - MCQ

1	**2**	**3**	**4**	**5**	**6**
B	C	A	B	D	A
7	**8**	**9**	**10**	**11**	**12**
D	B	D	D	B	D
13	**14**	**15**	**16**	**17**	**18**
A	D	B	C	C	B
19	20				
D	A				

ASSERTION AND REASON

1)A 2)B 3)B 4)A 5)B 6)C

<u>**ANSWER KEY – FILL IN THE BLANKS**</u>

1	**2**	**3**	**4**	**5**	**6**
1:1	16F	Electric flux	Electric potential	Zero	4V
7	**8**	**9**	**10**	**11**	**12**
10V	pE (1- cos θ)	1.13×10^4 Nm /C	Q /ε_0	5μF	2C
13	**14**	**15**			
500 V/m	1 : 15	2/3			