EP

12th Standard CBSE

Date : 17-Nov-22

Physics

Reg.No. :

Exam Time : 02:00:00 Hrs

Total Marks : 100

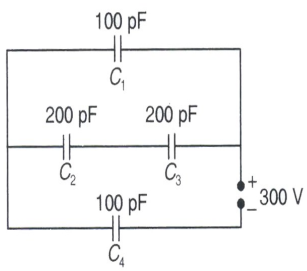
153 x 5 = 765

1) Two tiny spheres carrying charges $1.5\mu C$ and $2.5\mu C$ are located 30 cm apart. Find the potential and electric field:

(a) at the mid-point of the line joining the two charges,and

(b) at a point 10 cm from this mid-point in a plane normal to the line and passing through the mid-point.

2) Obtain the equivalent capacitance of the network in adjoining figure.For a 300V supply,determine the charge and voltage across each capacitor.



3) A spherical conductor of radius 12 cm has a charge of 1.6×10^{7}C distributed uniformly on its surface. What is the electric field.

(a) inside the sphere

(b) just outside the sphere

(c) at point 18 cm from the centre of the sphere?

4) A parallel plate capacitor with air between the plates has a capacitance of 8pF(1pF=10F) $^{-12}$F). What will be the capacitance if the distance between the plates is reduced by half, and the space between them is filled with a substance of dielectric constant 6?

5) Three capacitors of capacitance 2pF, 3pF and 4pF are connected in parallel. (a) What is the total capacitance of the combination? (b) Determine the charge on each capacitor, if the combination is connected to a 100 V supply.

6) Explain what would happen if in the capacitor given in exercise 2.8, a 3mm thick mica sheet were inserted between the plates.

(a) While the voltage supply remained connected.

(b) After the supply was disconnected.

7) A 600 pF capacitor is charged by a 200 V supply. It is then disconnected from the supply and is connected to another uncharged 600 pF capacitor. How much electrostatic energy is lost in the

process?

8) A charge of 8 mC is located at the origin. Calculate the work done in taking a small charge of -2 × 10^{-9}C from a point P (0, 0, 3 cm) to a point Q(0, 4 cm, 0) via a point R(0, 6 cm, 9 cm).

9) What is the area of the plates of a 2F parallel plate capacitor given that the separation between the plates is 0.5 cm? You will realise from your answer why ordinary capacitors are in the range ofμF or less.However, electrolytic capacitors do have a much larger capacitance (0.1F) because of very minute separation between the conductors.

10) A 4 µF capacitor is charged by a 200V supply is then disconnected and the charged capacitor is connected to another uncharged 2 µF capacitors.How much electrostatic energy of the first capacitor is in the form of heat and electromagnetic radiation?

11) Answer carefully:
(a) Two large conducting spheres carrying charges of $Q_1 and Q_2$are brought close to each other.Is the magnitude of electrostatic force between them exactly given by $\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$where r is the distance between their centres?
(b) If Coulomb's law involved$\frac{1}{r^3}$ dependence (instead of $\frac{1}{r^3}$), would Gauss's law be still true?
(c) A small test charge is released at rest at a point in an electrostatic field configuration.Will it travel along the line of force passing through that point?
(d) What is the work done by the field of a nucleus in a complete circular orbit of the electron? What if the orbit is elliptical?
(e) We know that electric field is discontinuous across the surface of a charged conductor.Is electric potential also discontinuous there?
(f) What meaning would you give to the capacity of single conductor?
(g)Guess a possible reason why water has a much greater dielectric constant(=60) than say mica(=6)?

12) On charging a parallel-plate capacitor to a potential V, the spacing between the plates is halved and a dielectric medium of $\epsilon_r = 10$ is introduced between the plates, without disconnecting the dc source. Explain using suitable expression how the
(a) capacitance
(b) electric field
(c) energy density of the capacitor change.

13) Calculate the electric field strength which is required to just support a water drop of mass 10^{-3}kg and having a charge $1.6 \times 10^{-19} C$

14) A particle of mass 10^{-4}kg and charge $5\mu C$ is thrown at a speed of 20 m/s against a uniform electric field of strength $2 \times 10^5 NC^{-1}$. How much distance will it travel before coming to rest momentarily?

15) Two charges each of $1\mu C$ but opposite in sign are 1cm apart. Calculate electric field at a point distant 10cm from the mid point on axial line of the dipole.

16) Two charges $+20\mu C$ and $-20\mu C$ are held 1cm apart. Calculate the electric field at a point on the equatorial line at a distance of 50cm from the centre of the dipole.

17) What is the magnitude of electric intensity due to a dipole of moment $2 \times 10^{-8} C - m$ at a point distant 1m from the centre of dipole, when line joining the point to the centre of dipole makes an angle 60^o with dipole axis?

18) The electric field due to a short dipole at a distance r, on the axial line, from the mid point is the same as electric field at a distance r' on the equatorial line, from its mid point. Determine the ratio r/r'.

19) Two charges $\pm 10\mu C$ are placed $5 \times 10^{-3} m$ apart. Determine the electric field at a point Q, 0.15m away from O, on a line passing through O and normal to the axis of the dipole.

20) An electric dipole consists of two charges of $\pm 0.1\mu C$ separated by a distance of 2.0cm. The dipole is placed in an external field of 105N/C. What maximum torque does the field exert on the dipole?

21) An electric dipole of moment $5 \times 10^{-8} C - m$ is aligned in a uniform electric field of $1.44 \times 10^4 N/C$. Calculate potential energy of the dipole to hold the dipole at 60^o with the direction of electric field.

22) A dipole consisting of an electron and a proton separated by a distance of $4 \times 10^{-10} m$ is situated in an electric field of intensity $3 \times 10^5 NC^{-1}$ at an angle of 30^o with the field. Calculate the dipole moment and the torque acting on it. Charge e on an electron = $1.6 \times 10^{-19} C$

23) The potential difference between a cloud and the Earth is 107V. Calculate the amount of energy dissipated when the charge of 100 is transferred from the cloud to the ground due to lighting bolt.

24) If 20J of work has to be done to move an electric charge of 4C from a point, where potential is 10V to another point, where potential is V volt, find the value of V.

25) Electric field intensity at a point B due to a point charge Q kept at point A is $24NC^{-1}$ and electric potential at B due to the same charge is $12\ JC^{-1}$ Calculate the distance AB and magnitude of charge.

26) Calculate the electric potential at the centre of a square of side $\sqrt{2}m$ having charges $100\mu C, 20\mu C$ and $-60\mu C$ at the four corners of the square.

27) Determine the electric potential at the surface of a gold nucleus. The radius is $6.6 \times 10^{-15} m$ and the atomic number Z=79. Given charge on proton $1.6 \times 10^{-19} C$

28) A metal wire is bent in a circle of radius 10cm. It is given a charge of $200\mu C$ which is spread on it uniformly. Calculate the electric potential at its centre.

29) The electric potential at 0.9m from a point charge is +50V. What is the magnitude and sign of the charge?

30) (a) calculate the potential at a point P due to a charge of $4 \times 10^{-7}C$ located 9 cm away.
(b) Hence obtain the work done in bringing a charge of $2 \times 10^{-9}C$ from infinity to the point P. Does the answer depend on the path along which the charge is brought?

31) An infinite number of charges each numerically equal to q and of the same sign are placed along the X-axis at x=1,x=2,x=4,x=8 and so on. Find electric potential at x=0

32) An ammonia molecule has permanent electric dipole moment =1.47D, where 1D=1 debye unit= $3.34 \times 10^{-30}Cm$. Calculate electric potential due to this molecule at a point 52.0nm away along the axis of the dipole. Assume V=0 at infinity.

33) Calculate the voltage needed to balance an oil drop carrying 10electrons when located between the plates of a capacitor which are 5mm apart. Mass of oil drop is $3 \times 10^{-16}kg$(take g=10 m/s^2)

34) A small particle carrying a negative charge of $1.6 \times 10^{-19}C$ is suspended in equilibrium between the horizontal metal plates 5cm apart, having a potential difference of 3000 V across them. Find the mass of the particle.

35) Two positive point charges of $0.2\mu C$ and $0.1\mu C$ are placed 10cm apart. Calculate the work done in reducing the distance of 5cm.

36) Consider a uniform electric field $\vec{E} = 3 \times 10^3\hat{i}NC^{-1}$. Calculate the flux of this field through a square surface of area 10cm square.
(i)When its plane is parallel to Y-Z plane.
(ii)When the normal to its plane makes an angle of 60° with X-axis.

37) Consider a uniform electric field $\vec{E} = 4 \times 10^3\hat{i}NC^{-1}$ (i)What is the flux of this field through a square of side 10cm on a side whose plane is parallel to Y-Z plane? (ii)What is the flux through the same square if normal to this plane makes an angle of 60° with the X-axis?

38) Careful measurements of the electric field at the surface of a box indicates that the net outwards flux through the surface of box is $16 \times 10^3 Nm^2C^{-1}$Find (i) the net charge inside the box?
(ii)If the net outward flux through the surface of box were zero, could you conclude that there were no charges inside the box? Explain your answer.

39) A uniformly charged conducting sphere 2.4m diameter has a surface charge density of 180.0 $\mu C/m^2$(i)Find the charge on the sphere. (ii)What is the total flux leaving the surface of the sphere?

40) An infinite line charge produces a field of $19 \times 10^4 NC^{-1}$ at a distance of 5 cm. Calculate the linear charge density.

41) Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude $\sigma = 19 \times 10^{-22} Cm^{-2}$

42) A large plane sheet of charges having surface charge density $5 \times 10^{-16} cm^{-2}$ lies in XY plane. Find electric flux through a circular area of radius 1 cm. Given normal to the circular area makes an angle of 60^{o} with Z-axis.

43) Two large metal plates each of area $1m^2$ are placed facing each other at a distance of 5cm and carry equal and opposite charges on their faces. If the electric field between the plates is 1000 NC^{-1}, find the charge on each plate.

44) Calculate the number of electrons which should be removed from a conductor so that it acquires a positive charge of 3.5 nC?

45) An object has an excess charge of $-1.92 \times 10^{-7} C$ How many excess electrons does it have?

46) Which is bigger, a coulomb or charge on an electron? How many electronic charges from one coulomb of charge?

47) How much positive and negative charge is there in a cup of water?

48) If a body gives out 10^9 electrons every second, how much time is required to get a total charge of 1C from it?

49) A metal sphere has a charge of $-6.5\mu C$. When 5×10^{13} electrons are removed from the sphere, what would be the net charge on it?

50) Two bodies A and B carry charges $-3.00\mu C \text{ and } -0.44\mu C$. How many electron should be transferred from A to B so that they acquire equal charges?

51) Force of attraction between two point charges placed at a distance 'd' is F. What distance apart should they be kept in the same medium, so that the force between them is 2F?

52) Two charged particles having charge $2.0 \times 10^{-8} C$ each are joined by an insulating string of length 1m and the system is kept on a smooth horizontal table. Find the tension in the string.

53) A particle of mass m carrying a charge $-q_1$ is moving around a charge $+q_2$ along a circular path of radius r. Prove that period of revolution of charge $-q_1$ about $+q_2$ is given by $T = \sqrt{\frac{16\pi^3 \epsilon_o m r^3}{q_1 q_2}}$

54) An infinite number of charges each equal to $4\mu C$ are placed along X-axis at x=1m, x=2m, x=4m, x=8m and so on. Find the total force on a charge of 1C placed at the origin.

55) Eight identical spherical drops, each carrying charge 1 nC are at a potential of 900V each. All these drops combine together to form a single large drop. Calculate the potential of this large drop. Assume no wastage of any kind. Take capacitance of a sphere of radius r as proportional to r.

56) An isolated sphere has a capacitance 60pF. (i)Calculate its radius. (ii)How much charge should be placed on it to raise its potential to 10^4 V?

57) When 1.0×10^{12} electrons are transferred from one conductor to another, a potential difference of 10V appears between the conductors. Calculate the capacitance of the two conductor system.

58) Calculate the capacity of a sphere of radius 10km.

59) A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is $360\mu C$. When potential across the capacitor is reduced by 120V, the charge stored in it becomes 120 μC. Calculate

(i) the potential V and the unknown capacitance C.

(ii) what will be the charge stored in the capacitor, if the voltage applied had increased by 120 V?

60) A charge of $+2.0 \times 10^{-8}C$ is placed on the positive plate and a charge of $-1.0 \times 10^{-8}C$ on the negative plate of a parallel plate capacitor of capacitance $1.2 \times 10^{-3}\mu F$. Calculate the potential difference between the plates.

61) Two parallel plate air capacitors have their plate areas 100 and 500cm^2 respectively. If they have the same charge and potential and the distance between the plates of the first capacitor is 0.5mm, what is the distance between the plates of second capacitor?

62) What is the area of the plates of a 2 farad parallel plate air capacitor, given that the separation between the plates is 0.5cm?

63) A parallel plate capacitor has plate area 25 cm^2 and a separation of 2 mm between the plates. The capacitor is connected to a battery of 12 V

(a)Find the charge on the capacitor

(b)The plate separation is decreased to 1 mm. Find the extra charge given by the battery to the positive plate.

64) The thickness of air layer between two coatings of a spherical capacitor is 2 cm. The capacitor has same capacitance as the sphere of 1.2m diameter. Find the radii of its surfaces.

65) Calculate the capacitance of a spherical capacitor consisting of two concentric spheres of radii 0.50m and 0.60m. The material filled in the space between the two spheres has a dielectric constant of 6.

66) What is the capacitance of a 1m long hifi cable where the central conductor is 1mm in diameter and the shield is 5mm in diameter?

67) Two capacitors of capacitances $3\mu F$ *and* $6\mu F$ are charged to potentials 2V and 5V respectively. These two charged capacitors are connected in series. Find the potential across each of the two capacitors now.

68) It is required to construct a $10\mu F$ capacitor which can be connected across a 200 V battery. Capacitors of capacitance $10\mu F$ are available but they can withstand only 50V. Design a combination which can yield the desired result.

69) Find the ratio of potential differences that must be applied across the parallel and series combination of two capacitors C_1 and C_2 with their capacitances in the ratio 1:2 so that energy stored in the two cases becomes the same.

70) Find the ratio of potential difference that must be applied across the parallel and series combination of two capacitors C_1 and C_2 with their capacitance in the ratio 1:3 so that energy stored in the two cases becomes the same.

71) A capacitor charged from a 50 V d.c. supply is found to have charge of $10\mu C.$ What is the capacitance of the capacitor and how much energy is stored in it?

72) Keeping the voltage of the charging source constant, what would be the percentage change in the energy stored in a parallel plate capacitor, if the separation between its plates were to be decreased by 10%?

73) A parallel plate capacitor with air inbetween the plates has a capacitance of 8 pF. The separation between the plates is now reduced to half and the space between them is filled with a medium of dielectric constant 5. Calculate the value of capacitance in the second case.

74) An ebonite rod (K=3), 6mm thick is introduced between the plates o a parallel plate capacitor of plate area $4 \times 10^{-2} m^2$ and plate separation 0.01m. Find the capacitance.

75) A parallel plate capacitor contains a mica sheet of thickness $d_1 = 10^{-3} m$ and one fibre sheet of thickness $d_2 = 0.5 \times 10^{-3} m.$ Values of K for mica and fibre are 8 and 2.5 respectively. Fibre breaks down in electric field of $6.4 \times 10^6 Vm^{-1}$. What maximum voltage can be applied to the capacitor?

76) An air filled parallel plate capacitor is to be constructed which can store $12\mu C$ of charge when operated at 1200V. What can be the minimum area of capacitor? The dielectric strength of air is $3 \times 10^7 V/m$

77) Two identical metal plates are given charges q_1 and $q_2 (< q_1)$ respectively. If they are now brought close together to form a parallel plate capacitor with capacitance C, what will be the potential difference between the plates?

78) A capacitor of capacitance C_1 = 1.0 microfarad withstands the maximum voltage V_1 = 6.0 kilo volt. While another capacitor of capacitance C_2 = 2.0 microfarad withstands the maximum voltage V_2 = 4.0 kilovolt. What maximum voltage will the system o these two capacitors withstand if they are connected in series?

79) A rectangular coil of n turns each of area A, carrying current I, when suspended in a uniform magnetic field B, experiences a torque

$\tau = nI\,BA\,sin\theta$

Where is θ the angle which a normal drawn on the plane of coil makes with the direction of magnetic field. This torque tends to rotate the coil and bring it in an equilibrium position. In the stable equilibrium state, the resultant force on the coil is zero. The torque on the coil is also zero and the coil has minimum potential energy.

Read the above passage and answer the following questions:

(i) In which position, a current carrying coil suspended in uniform magnetic field experiences (a) minimum torque and (b) maximum torque?

(ii) a circular coil of 200 turns, radius 5 cm carries a current of 2.0 A. It is suspended vertically in a uniform horizontal magnetic field of 0.20 T, with the plane of the coil making an angle with 60° the field lines. Calculate the magnitude of the torque that must be applied on it to prevent it from turning.

(iii) what is the basic value displayed by the above study?

80) A physics teacher tells his students in the class that in paramagnetic materials, every atom has some permanent magnetic dipole moment. In the absence of an external magnetic field, the atomic dipoles are randomly oriented so that average magnetic moment per unit volume of the material behaves as a magnet. When an external magnetic field is applied, the torque developed tries to align the atomic magnetic dipoles in the direction of the field. That is why the specimen gets magnetized weekly in the direction of the field.

Read the above passage and answer the following questions:

(i) Name any three paramagnetic materials

(ii) Name any two ferromagnetic materials. How is their behavior different from that of paramagnetic materials?

(iii) The teacher asks the students how true is the famous saying: 'Spare the rod and spoil the child', comment.

81) (i) Explain, using suitable diagram, the difference in the behaviour of a

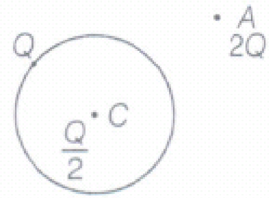
(a) conductor

(b) dielectric in the presence of external electric field. Define the terms polarisation of a dielectric and write its relation with susceptibility.

(ii) A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge Q/2 is placed at its centre C and an another charge +2Q is placed outside the shell at a distance x from the centre as shown in figure. Find

(a) the force on the charge at the centre of the shell and at point A,

(b) the electric flux through the shell.



82) Two metal spheres, one of radius R and the other of radius 2R, both have same surface charge density σ . They are brought in contact and separated. What will be new surface charge densities on them?

83) If one of the electrons of H_2 molecules is removed, we get a hydrogen molecular ion $H^+{}_2$. In the ground state of an $H^+{}_2$, the two protons are separated by roughly 1.5 $\overset{o}{A}$ and the electron is roughly $1\overset{o}{A}$ from each proton. Determine the potential energy of the system. Specify your choice of the zero of potential energy.

84) The electric field at a point on the axial line at a distance of 10 cm from the center of an electric dipole is 3.75 × N/C.Calculate the length of an electric dipole.

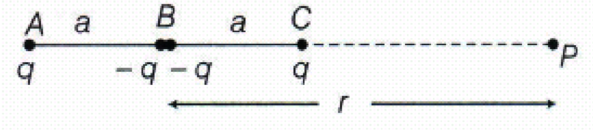
85) Derive the expression for the energy stored in parallel plate capacitor. Hence, obtain the expression for the energy density of the electric field.
A fully charged parallel plate capacitor is connected across an uncharged identical capacitor.Show that the energy stored in the combination is less than stored initially in the single capacitor.

86) Shikhaj was working on a project for science exhibition. He considered a capacitance of $2\mu F$ having a capacity of operating under 1kV potential.When he reached to shop, he found that the shopkeeper is having a capacitors of 1 μF of 400 V rating. Shikhaj calculated minimum number of capacitances of 1 μF each, so he could arrange to form a capacitor of 2 μF .
Answer the following questions based on the above information:
(i) What are the calculations done by Shikhaj?
(ii) What do you think of Shikhaj?

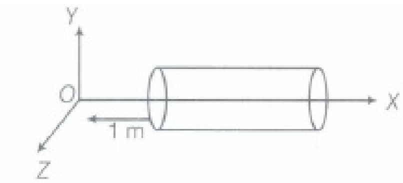
87) In Pradeep's classroom, the fan was running very slowly. Due to which, his teacher was sweating and was restless and tired.All his classmates wanted to rectify this. They called an electrician who came and changed the capacitor only, after which the fan started running fast.
Answer the following questions based on the above information:
(i) What energy is stored in the capacitor and where?
(ii) A thin metal sheet is placed in the middle of a parallel plate capacitor. What will be the effect on the capacitance?
(iii) What values did the classmates have?

88) Three concentric metal shells A, B and C of radius a, b and c (a σ, -σ and +σ , respectively.
(i) Find the potential of three shells at A, B and C.
(ii) If the shells A and C are at the same potential, obtain the relation between the radii a, b and c.

89) Given figure shows a charge array known as an electric quadrupole. For a point on the axis of the quadrupole, obtain the dependence of potential on r for r/a > > 1 and contrast your results with that due to an electric dipole and an electric monopole(i.e. a single charge).

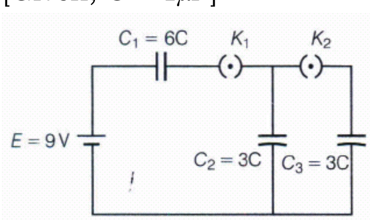


90) A hollow cylindrical box of length 1 m and area of cross-section 25 cm^2 is placed in a three dimensional coordinate system as shown in the figure. The electric field in the region is given by E = 50 x $\hat{i}$, where E is in NC^{-1} and x is in metre. Find

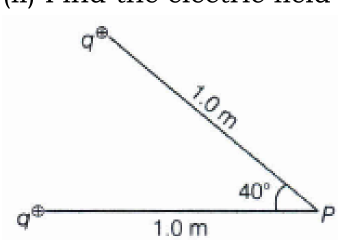


(i) net flux through the cylinder and
(ii) charge enclosed by the cylinder.

91) In the circuit shown in figure, initially K_1 is closed and K_2 is opened. What are the charges on each of the capacitors? Then, K_1 was opened and K_2 was closed (order is important), what will be the charge on each capacitor now?
[Given, C = $1\mu F$]



92) (i) Three equal charges, each equal to q are placed at the three corners of square of side α .Find the electric field at the fourth corner.
(ii) Find the electric field at the point P in figure given below.



93) Geeta has dry hair. A comb ran through her dry hair attracts small bits of paper. She observes that Neeta with oily hair combs her hair, the comb could not attract small bits of paper. She consults her teacher for this and gets the answer. she then goes to the junior classes and shows this phenomenon as a Physics experiment to them.
Read the above passage and answer the following questions.
What according to you are the values displayed by Geeta?
Explain the phenomenon involved.

94) As it is known that all matter is made up of atoms/ molecules. Every atom consists of a central core, called the atomic nucleus, around which negatively charged electrons revolve in circular orbits. Every atom is electrically neutral containing as many electrons as the number of protons in the nucleus. All the materials are electrically neutral, they contain charges, but their charges are exactly balanced.
Read the above passage and answer the following questions.
Everybody whether a conductor or an insulator is electrically neutral. Is it true?
Charging lies in charge imbalance, i.e. excess charge or deficit charge, comment.
How do you visualise this principle being applied in our daily life?

95) A and B are two students in a class who have been assigned to arganise a Republic day function. They have also been instructed to invite personally more than 60 members from all the nearby cultural organisations and VIPs in their area. While student A arranged invitations using a photocopier/fax, students B arranges invitations by writing to them individually.
Answer the following questions based on the above information.
(i) Which student's method would you adopt and why?
(ii) State the principle behind the source used by student A.
(iii) How this principle works?

96) When an electric dipole of moment $|P|$ = q × 2a is held at an angle θ, with the direction of uniform external electric field E, a torque τ = pE sinθ acts on the dipole. This torque tries to align the electric dipole in the direction of the field. When p is along E, $\theta = 0^o$, τ = pE sin0^o = zero. Read the above passage and answer the following questions.
(i) What is the direction of torque acting on an electric dipole held at a angle with uniform external field?
(ii) An electric dipole of length 10 cm having charge $\pm 6 \times 10^{-3}$, C placed at 30^o with respect to a uniform electric field experiences a torque of magnitude $6\sqrt{3}$ N-m. Calculate magnitude of electric field.
(iii) What is the physical significance of this concept in our day-today life?

97) Two persons are standing under a tree and another person near them is inside a car. They were arguing about going out for a movie or to the beach, when a lightning struck the tree with some force. The person inside the car notices his friends satnding under the tree are affected by lightning, he comes out and takes them to the nearby hospital.
Why the person in the car was not affected by lighting?
What quality do you find the person inside the car?
Explain the process that takes place during lighting.
If the total charge enclosed by a surface is zero, then what will be the electric flux over the surface?

98) A dipole is made up of two charges + q and - q separated by a distance 2a. Derive an expression for the electric field E$\vec{e}$ due to this dipole at a point distance r from the centre of the dipole on the equatorial plane. Draw the shape of the graph, between $|E_e|$ and r when r > > a.

If this dipole were to be put in a uniform external electric field $\vec{E}_e$, obtain an expression for the torque acting on the dipole.

99) On our return from an excursion trip in our school,I noticed a bird sitting on a high voltage electric wire. I curiously noticed the bird and found to my surprise that the bird flew off after some time without any electrical shock. This incident made me think of another incident that took place near my house last week where, a boy, who climbed to take a kite, got severe jolt of electric current. I immediately approached my school physics teacher for an explanation. My teacher explained the effect of electrical current which I told my mother that evening.

(a) What are the values associated with the above incident?

(b) What would be the explanation given by the physics teacher?

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100) (a) Define electric dipole moment. Is it a scalar or a vector? Derive the expression for the electric field of a dipole at a point on the equatorial plane of the dipole.

(b) Draw the equipotential surfaces due to an electric dipole. Locate the points where the potential due to the dipole is zero.

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101) While travelling back to his residence in car, Dr. Pathak was caught up in a thunderstorm. It became very dark. He stopped driving the car and waited for the thunderstorm to stop. Suddenly he noticed a child walking alone on the road. He asked the boy to come inside the car till the thunderstorm stopped. Dr. Pathak dropped the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. Pathak for his concern for safety of the child. Answer the following questions based on the above information:

Why is it safer to sit inside a car during a thunderstorm?

Which two values are displayed by Dr. Pathak in his actions ?

Which values are reflected in parent's response to Dr. Pathak?

Give an example of a similar action on your part in the past from everyday life.

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102) An elderly woman went alone to Registrar's office to disburse her property. When she enquired in the office she was asked to get a xerox copy of the do ment which works under electrostatic induction. The xerox shop was far away and across the road. She took the help of a passer-by and got her xerox done.

(a)What values did the passer-by have?

(b)How does a neutral body get charged by electrostatic induction?

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103) During an endoscopic surgery, a surgeon sees the interior of a patient's body on the viewing screen of a video monitor. The surgeon continues to do the surgery with the help of other medical staff and one of the medical staff on noticing the surgeon's gloved fingers coming within a few centimetres of the screen while pointing to a particular part of the image, say to explain a surgical concern to other medical staff, asks the surgeon that whether his gloves would have got contaminated, the surgeon, answers him later, after the completion of the operation.

What is learnt from the above?

Can you find the bacterial source? If yes, name it.

Name the force which plays a role in bacterial contamination.

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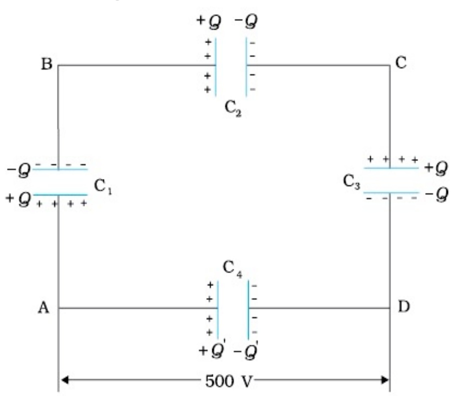
104) 'A' & 'B' are two students in a class who have been assigned to organize Republic Day function. They have also been instructed to invite personally more than 60members from all the nearby cultural organizations and VIPs in their area. While student 'A' arranged invitations using a photocopy/ fax, student 'B' arranges invitations by writing to them individually.
Which student's method would you adopt and why?
State the principle behind the source used by student 'N.

105) Mahesh was travelling in a bus. Suddenly the weather changed and it started raining. After sometime rain stopped and all the passengers opened their windows. But lightning started immediately. Then he suggested to shut the doors and windows of the bus, otherwise it may be dangerous.
(a) What values were shown by Mahesh?
(b) Two charges 5μC and -2μC are placed at points (5 cm, 0, 0) and (23 cm, 0, 0) in a region of space where there is no other external field. Calculate the electrostatic potential energy of this charge system.

106) Arun had to repaint his car when he was reminded by the car company for his regular car service. He told them to do spray painting of mountain dew colour. The company also replied that they usually perform spray painting only as wastage is minimized and (even) painting uniform is achieved.
(a) What values did the car service company have?
(b) If spray painting is done by electrostatic induction, how is even painting achieved ?

107) A network of four 10 μF capacitors is connected to a 500 V supply, as shown in Fig. Determine
(a) the equivalent capacitance of the network and
(b) the charge on each capacitor.
(Note, the charge on a capacitor is the charge on the plate with higher potential, equal and opposite to the charge on the plate with lower potential)



108) Rekha goes to visit a science exhibition. She observes that a participant gives charge to a capacitor continuously and the potential difference between its plates goes on increasing. She advises him not to supply charge to capacitor continuously otherwise it will be discharged giving sparking.
(a) According to you what values are shown by Rekha?
(b) Why do we not supply charge to capacitor continuously?

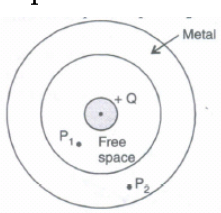
109) (a) State the theorem which relates total charge enclosed within a closed surface S and the electric flux passing through it. Prove it for a single point charge.
(b) An 'atom' was earlier assumed to be a sphere of radius a having a positively charged point nucleus of charge +Ze at its centre. This nucleus was believed to be surrounded by a uniform density of negative charge that made the atom neutral as a whole.
Use this theorem to find the electric field of this 'atom' at a distance r (r

110) Sweta goes to physics laboratory in her practical class. Her teacher reaches late. In the mean time she notices that a student handles a circuit containing capacitor carelessly. She advises him not to handle the capacitor in such way otherwise he may get a severe shock.
(a) According to you what values are displayed by Sweta?
(b) Why does she advise him not to handle capacitor carelessly? Explain.

111) In Akash's classroom the fan above the teacher was running very slowly. Due to which his teacher was sweating and was restless and tired. All his classmates wanted to rectify this. They called for an electrician who came and changed the capacitor only after which the fan started running fast.
(a) What values did Akash and his classmates have?
(b) What energy is stored in the capacitor and where?

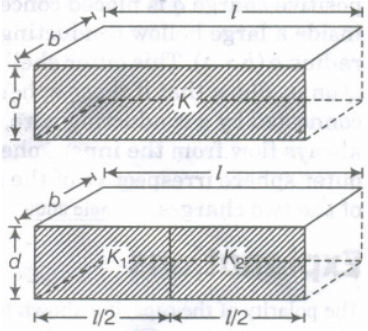
112) (a) Define electric flux. Write its S.I. unit.
(b) Using Gauss's law, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance from it.
(c) How is the field directed if (i) the sheet is positively charged, (ii) negatively charged?

113) (a) Define electric flux. Write its S.1.unit.
(b) A small metal sphere carrying charge +Q is located at the centre of a spherical cavity inside a large uncharged metallic spherical shell as shown in the figure. Use Gauss's law to find the expressions for the electric field at points P_1 and P_2



(c) Draw the pattern of electric field lines in this arrangement

114) (a) Obtain the expression for the potential due to an electric dipole of dipole moment p at a point 'x' on the axial line.
(b) Two identical capacitors of plate dimension l x b and plate separation d have dielectric slabs filled in between the space of the plates as shown in the figures.

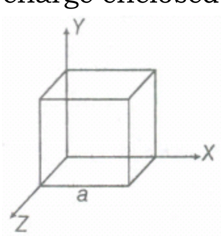


Obtain the relation between the dielectric constants K, K_1 and K_2

115) (i) Derive an expression for the' electric field E due to a dipole of length 2l at a point distant r from the centre of the dipole on the axial line.
(ii) Draw a graph of E versus r for r > > a.
(iii) If this dipole is kept in a uniform external electric field E_o, diagrammatically represent the position of the dipole in stable and unstable equilibrium and write the expressions for the torque acting on the dipole in both the cases.

116) Use Gauss's theorem to find the electric field due to a uniformly charged infinitely large plane thin sheet with surface charge density σ .
(ii) An infinitely large thin plane sheet has a uniform surface charge density $+\sigma$. Obtain the expression for the amount of work done in bringing a point charge q from infinity to a point, distant r, in front of the charged plane sheet.

117) An electric dipole of dipole moment p consists of point charges +q and q separated by a distance 2a apart. , Deduce the expression for the electric field E due to the dipole at a distance x from the centre of the dipole on its axial line in terms of the dipole moment p. Hence, show that in the limit x > > a, E $\longrightarrow$ $2P(4\pi\epsilon_0 x^3)$.
Given the electric field in the region E = 2x $\hat{i}$, find the net electric flux through the cube and the charge enclosed by it.



118) Define electric flux. Write its SI unit. Gauss' law in electrostatics is true for any closed surface, no matter what its shape or size is. Justify this statement with the help of a suitable example.
Use Gauss' law to prove that the electric field inside a uniformly charged spherical shell is zero.

119) Deduce the expression for the torque acting on a dipole of dipole moment p in the presence of uniform electric field E.
Consider two hollow concentric spheres, 81 and 82 enclosing charges 2Q and 4Q respectively as shown in the figure.

120) The surface integral of electrostatic field E produced by any source over any closed surface S enclosing a volume V in vacuum, i.e. total electric flux over the closed surface S in vacuum is $1/\epsilon_0$ times the total charge Q contained inside S, i.e.

$$\phi_E = \oint E.\,dS = \frac{Q}{\epsilon_0}$$

The charges inside S may be point charges or even continuous charge distributions. There is no contribution to "total electric flux from the charges outside S. Further, the location of Q inside S does not affect the value of surface integral.
Read the above passage and answer the following questions
What are the SI units and dimensions of electric flux?
A closed surface in vacuum encloses charges - q, + 3 q and +5 q. Another charge + 4 q lies outside the surface. What is total electric flux over the surface?
A point charge a lies inside a spherical surface of radius r. How will the electric flux be affected, if, radius of the sphere is doubled?
What values of life do you learn from this theorem?

121) (i) If two similar large plates, each of area A having surface charge densities +σ and -σ are separated by a distance.d in air, find the expression for
(a) field at points between the 'two plates and on outer 'side of the plates. Specify the direction of the field in each case.
(b) the potential difference between the plates.
(c) the capacitance of the capacitor so formed.
(ii) Two metallic spheres of radii R and 2R are charged, so that both of these have same surface charge density σ. If they are connected to each other with a conducting wire, in which direction will the charge flow and why?

122) (i) Deduce the expression for the energy stored in a charged capacitor.
(ii) Show that the effective capacitances C of a series combination of three capacitors C_1, C_2 and C_3 is given by

$$C = \frac{C_1C_2C_3}{C_1C_2+C_2C_3+C_3C_1}$$

123) A small sphere of radius a carrying a positive charge q is placed concentrically inside a large hollow conducting shell of radius b (b > a). This outer shell has charge Q on it. Show that if these spheres are connected by a conducting wire, charge will always flow from the inner sphere to the outer sphere irrespective of the magnitude of the two charges.

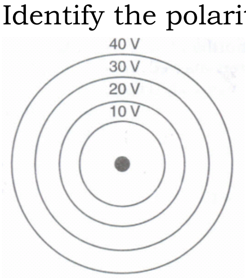
124) Immediatly after school hour, as Bimla with her friends came out, they noticed that there was a sudden thunderstorm accompanied by the lightning. They could not find any suitable place for shelter. Dr. Kapoor who was passing thereby in his car noticed these children and offered them to come in their car. He even took care to drop them to the locality where they were staying. Bimla's parents, who were waiting, saw this and expressed their gratitude to Dr. Kapoor.
(i) What values did Dr. Kapoor and Bimla's parent displayed?
(ii) Why is it considered safe to be inside a car especially during lightening and thunderstorm?
(iii) Define the term 'dielectric strength'. What does this term signify?

125) An old woman who had suffered from a heat stroke was taken to the hospital by her grandson who is in class XII. The grandson has studied in Physics that, how to save person who is suffering from a heat stroke, regular beating of the heat is to be restored by delivering a jolt to the heart using a defibrillator, whose capacity is 70 µF and charged to a 'potential of 5000 V and energy stored is 875 J, 200 J of energy is passed through a person's body in a pulse lasting 2 ms. The old woman gets paniced and refuses to be treated by defibrillator. Her grandson then explained to her the process that would be adopted by medical staff and how the result of that would bring her back to normalcy. The woman was then treated and was back to normal. Answer the following questions based on the above information.
(i) What according to you are the values displayed by the grandson?
(ii) What will be the net charge of the capacitor in defibrillator?

126) A man travelling in a car during heavy rain and thunderstorm, sees a boy standing under a tree. He immediately stops his car and asks the boy to get inside the car and saves him from a possible natural calamity. Answer the following questions based on the above information.
(i) What danger did the boy had while standing under the tree during the thunderstorm?
(ii) How is it safer inside the car during such weather?
(iii) What according to you are the values displayed by the man to help the boy?
(iv) Give another example from everyday life situations which represent display of similar values.

127) (i) Define the 5.1. unit of capacitance.
(ii) Obtain expression for the capacitance of a parallel plate capacitor.
(ill) Derive the expression for the affective capacitance of a series combination of n capacitors.

128) Two isolated metal spheres A and B have radii Rand 2R respectively, and same charge q. Find which of the two spheres have greater:
(i)capacitance and (ii) energy density just outside the surface of the spheres.
(b) (i) Show that the equipotential surfaces are closed together in the regions of strong field and far apart in the regions of weak field. Draw equipotential surfaces for an electric dipole.
(ii) Concentric equipotential surfaces due to a charged body placed at the centre are shown. Identify the polarity of the charge and draw the electric field lines due to it.

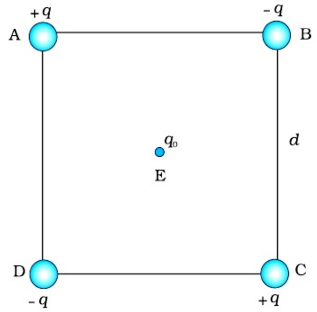


129) Two charges 3×10^{-8} C and -2×10^{-8} C are located 15 cm apart. At what point on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.Let us take the origin O at the location of the positive charge.
The line joining the two charges is taken to be the x-axis; the negative
charge is taken to be on the right side of the origin

130) Four charges are arranged at the corners of a square ABCD of side d, as shown in Fig.

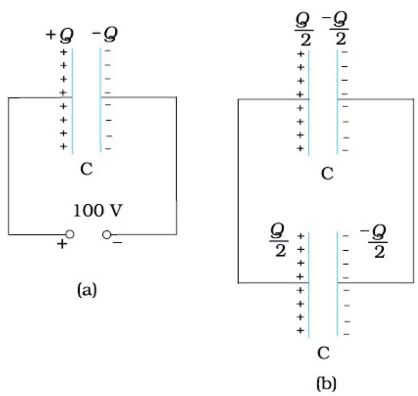
(a) Find the work required to put together this arrangement.

(b) A charge q_0 is brought to the centre E of the square, the four charges being held fixed at its corners. How much extra work is needed to do this?



131) (a) A 900 pF capacitor is charged by 100 V battery [Fig(a)]. How much electrostatic energy is stored by the capacitor?

(b) The capacitor is disconnected from the battery and connected to another 900 pF capacitor [Fig.b)]. What is the electrostatic energy stored by the system?



132) Two charges 5 x 10^{-8} C and –3 x 10^{-8} C are located 16 cm apart. At what point(s) on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.

133) (a) Show that the normal component of electrostatic field has a discontinuity from one side of a charged surface to another given by

$$\left(\mathbf{E}_2 - \mathbf{E}_1\right) \cdot \hat{\mathbf{n}} = \frac{\sigma}{\varepsilon_0}$$

where $\hat{n}$ is a unit vector normal to the surface at a point and σ is the surface charge density at that point. (The direction of $\hat{n}$ is from side 1 to side 2.) Hence show that just outside a conductor, the electric field is $\sigma \hat{n} / \varepsilon_0$

(b) Show that the tangential component of electrostatic field is continuous from one side of a charged surface to another. [Hint: For (a), use Gauss's law. For, (b) use the fact that work done by electrostatic field on a closed loop is zero.]

134) A long charged cylinder of linear charged density λ is surrounded by a hollow co-axial conducting cylinder. What is the electric field in the space between the two cylinders?

135) Two charges –q and +q are located at points (0, 0, –a) and (0, 0, a), respectively.
(a) What is the electrostatic potential at the points (0, 0, z) and (x, y, 0) ?
(b) Obtain the dependence of potential on the distance r of a point from the origin when r/a > > 1.
(c) How much work is done in moving a small test charge from the point (5,0,0) to (–7,0,0) along the x-axis? Does the answer change if the path of the test charge between the same points is not along the x-axis?

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136) The plates of a parallel plate capacitor have an area of 90 cm^2 each and are separated by 2.5 mm. The capacitor is charged by connecting it to a 400 V supply.
(a) How much electrostatic energy is stored by the capacitor?
(b) View this energy as stored in the electrostatic field between the plates, and obtain the energy per unit volume u. Hence arrive at a relation between u and the magnitude of electric field E between the plates

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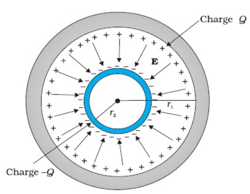
137) A spherical capacitor consists of two concentric spherical conductors, held in position by suitable insulating supports (Fig.) Show



that the capacitance of a spherical capacitor is given by $C = \frac{4\pi\varepsilon_0 r_1 r_2}{r_1 - r_2}$ where r_1 and r_2 are the radii of outer and inner spheres, respectively.

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138) A spherical capacitor has an inner sphere of radius 12 cm and an outer sphere of radius 13 cm. The outer sphere is earthed and the inner sphere is given a charge of 2.5 µC. The space between the concentric spheres is filled with a liquid of dielectric constant 32.
(a) Determine the capacitance of the capacitor.
(b) What is the potential of the inner sphere?
(c) Compare the capacitance of this capacitor with that of an isolated sphere of radius 12 cm. Explain why the latter is much smaller.

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139) A cylindrical capacitor has two co-axial cylinders of length 15 cm and radii 1.5 cm and 1.4 cm. The outer cylinder is earthed and the inner cylinder is given a charge of 3.5 µC. Determine the capacitance of the system and the potential of the inner ccylinder. Neglect end effects (i.e., bending of field lines at the ends).

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140) A parallel plate capacitor is to be designed with a voltage rating 1 kV, using a material of dielectric constant 3 and dielectric strength about 107 Vm–1. (Dielectric strength is the maximum electric field a material can tolerate without breakdown, i.e., without starting to conduct electricity through partial ionisation.) For safety, we should like the field never to exceed, say 10% of the dielectric strength. What minimum area of the plates is required to have a capacitance of 50 pF?

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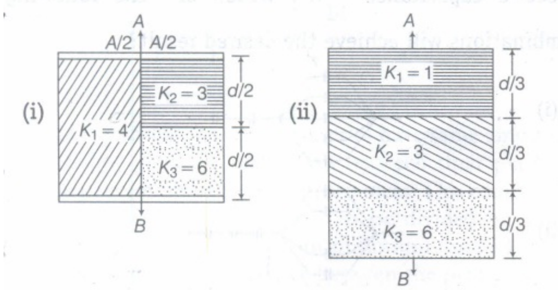
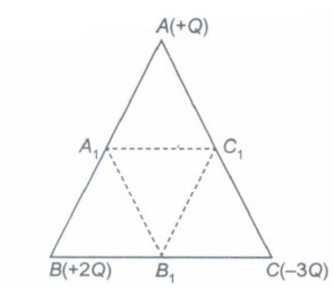
141) (a) Use Gauss' law to derive the expression for the electric field (E) due to a straight uniformly charged infinite line of charge density λ C/m.
(b) Draw a graph to show the variation of E with perpendicular distance r from the line of charge.
(c) Find the work done in bringing a charge q from perpendicular distance r_1 to $r_2 (r_2 > r_1)$.

142) Three point charges q, 2q and 8q are to be placed on a 9 cm long straight line. Find the positions where the charges should be placed such that the potential energy of this system is minimum. In this situation, what is the electric field at the position of the charge q due to the other two charges?

143) Find the equivalent capacitance between A and B. Given area of each plate = A and separation between plate = d.



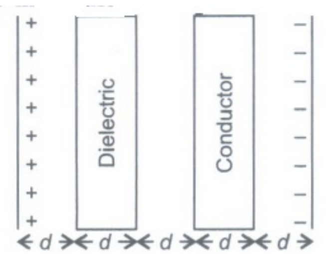
144) (a) Deduce the expression for the potential energy of a system of two charges q_1 and q_2 located at $\vec{r}_1$ and $\vec{r}_2$ respectively in an external electric field.
(b) Three point charges, +Q, + 2Q and -3Q are placed at the vertices of an equilateral triangle ABC of side I. If these charges are displaced to the mid-points A_1, B_1, and C_1 respectively, find the amount of the work done in shifting the charges to the new locations.



145) Derive the expression for the energy stored in a parallel plate capacitor of capacitance C with air as medium between its plates having charges Qand -Q. Show that this energy can be expressed in terms of electric field as $\frac{1}{2}\varepsilon_0 E^2 Ad$ where A is the area of each plate and d is the separation between the plates. How will the energy stored in a fully charged capacitor change when the separation between the plates is doubled and a dielectric medium of dielectric constant 4 is introduced between the plates?

146) Show by graph how q given to a capacitor varies with its potential difference. Using the graph or otherwise, prove that the energy of a capacitor is 1/2 CV^2. Calculate the energy density of the electrostatic field in a parallel plate capacitor.

147) (a) 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 electric field
(ii) presence of external electric field. Justify your answer.
(b) Given two parallel conducting plates of area A and charge densities $+\sigma$ and $-\sigma$ A dielectric slab of constant K and a conducting slab of thickness d each are inserted in between them as shown.
(i) Find the potential difference between the plates.
(ii) Plot E versus x graph, taking x = 0 at positive plate and x = 5d at negative plate.



148) (a) A parallel plate capacitor is charged by a battery to a potential. The battery is disconnected and a dielectric slab is inserted to completely fill the space between the plates. How will (i) its capacitance, (ii) electric field between the
plates, and (iii) energy stored in the capacitor be affected? Justify your answer giving necessary mathematical expressions for each case.
(b) Sketch the pattern of electric field lines due to (i) a conducting sphere having negative charge in it, (ii) an electric dipole.

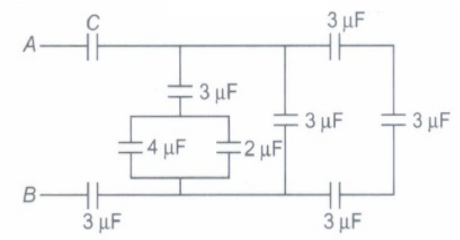
149) A potential difference is set up between the plates of a parallel plate capacitor by a battery and then the battery is removed. If the distance between the plates is decreased, then how the
(a) charge
(b) potential difference,
(c) electric field
(d) energy and
(e) energy density will change?

150) If n similar small drops of mercury, each of capacity C, surface charge density c, energy E and potential V, combine to form a big drop, then calculate the capacity, surface charge density, energy and potential of the big drop.

151) Two charged capacitors are connected by a conducting wire. Calculate common potential of capacitors (ii) ratio of their charges at common potential. Show that energy is lost in this process.

152) (a) Define the capacitance of a capacitor. Obtain the expression for the capacitance of a parallel plate capacitor in vacuum in terms of plate area A and separation d between the plates.
(b) A slab of material of dielectric constant K has the same area as the plates of a parallel plate capacitor but has a thickness $\frac{3d}{4}$ Find the ratio of the capacitance with dielectric inside it to its capacitance without the dielectric.

153) For what value of C does the equivalent capacitance between A and B is 1 μF the given circuit.



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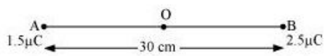
153 x 5 = 765

1)

Two charges placed at points A and B are represented in the given figure. O is the mid-point of the line joining the two charges.



Magnitude of charge located at A, q_1 = 1.5 μC

Magnitude of charge located at B, q_2 = 2.5 μC

Distance between the two charges, d = 30 cm = 0.3 m

(a) Let V_1 and E_1 are the electric potential and electric field respectively at O

V_1 = Potential due to charge at A + Potential due to charge at B

$$V_1 = \frac{q_1}{4\pi\epsilon_0\left(\frac{d}{2}\right)} + \frac{q_2}{4\pi\in_0\left(\frac{d}{2}\right)} = \frac{1}{4\pi\epsilon_0\left(\frac{d}{2}\right)}\left(q_1 + q_2\right)$$

Where, ∈0 = Permittivity of free space

$$\frac{1}{4\pi\in_0} = 9 \times 10^9 \text{NC}^2\ \text{m}^{-2}$$

$$\therefore V_1 = \frac{9 \times 10^9 \times 10^{-6}}{\left(\frac{0.30}{2}\right)}(2.5 + 1.5) = 2.4 \times 10^5\ \text{V}$$

E_1 = Electric field due to q_2 - Electric field due to q_1

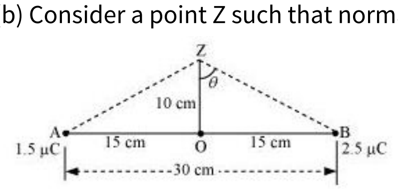
$$= \frac{q_2}{4\pi\epsilon_0\left(\frac{d}{2}\right)^2} - \frac{q_1}{4\pi\epsilon_0\left(\frac{d}{2}\right)^2}$$

$$= \frac{9 \times 10^9}{\left(\frac{0.30}{2}\right)^2} \times 10^6 \times (2.5 - 1.5)$$

= 4 x 10^5 V m^{-1}

Therefore, the potential at mid-point is 2.4 × 10^5 V and the electric field at mid-point is 4 × 10^5 V m^{-1}. The field is directed from the larger charge to the smaller charge.

(b) Consider a point Z such that normal distanceOZ = 10 cm = 0.1 m, as shown in the following figure.



V_2 and E_2 are the electric potential and electric field respectively at Z.

It can be observed from the figure that distance,

$$\text{BZ} = \text{AZ} = \sqrt{(0.1)^2 + (0.15)^2} = 0.18\ \text{m}$$

V_2= Electric potential due to A + Electric Potential due to B

$$= \frac{q_1}{4\pi\epsilon_0(AZ)} + \frac{q_1}{4\pi\epsilon_0(BZ)}$$

$$= \frac{9 \times 10^9 \times 10^{-6}}{0.18}(1.5 + 2.5)$$

= 2 x 10^5 V

Electric field due to q at Z,

$$E_A = \frac{q_1}{4\pi\in(AZ)^2}$$

$$= \frac{9 \times 10^9 \times 1.5 \times 10^{-6}}{(0.18)^2}$$

= 0.416 x 10^6 V/m

Electric field due to q_2 at Z,

$$E_B = \frac{q_2}{4\pi\epsilon_0(BZ)^2}$$

$$= \frac{9 \times 10^9 \times 2.5 \times 10^{-6}}{(0.18)^2}$$

= 0.69 x 10^6 Vm^{-1}

The resultant field intensity at Z,

$$E = \sqrt{E_A^2 + E_B^2 + 2E_AE_B\cos 2\theta}$$

Where, 2θis the angle, ∠AZ B

From the figure, we obtain

$$\cos\theta = \frac{0.10}{0.18} = \frac{5}{9} = 0.5556$$

$$\theta = \cos^{-10}0.5556 = 56.25$$

∴ 2 θ = 112.5 °

cos θ =- 0.38

$$E = \sqrt{\left(0.416 \times 10^6\right)^2 \times \left(0.69 \times 10^6\right)^2 + 2 \times 0.416 \times 0.69 \times 10^{12} \times (-0.38)}$$

= 6.6 x 10^5 V m^{-1}

Therefore, the potential at a point 10 cm (perpendicular to the mid-point) is 2.0 × 10^5 V and electric field is 6.6 ×10^5 V m^{-1}

2) Capacitance of capacitor C_1 is 100 pF.

Capacitance of capacitor C_2 is 200 pF.

Capacitance of capacitor C_3 is 200 pF.

Capacitance of capacitor C_4 is 100 pF.

Supply potential, V = 300 V

Capacitors C_2 and C_3 are connected in series. Let their equivalent capacitance be C' .

$$\therefore \frac{1}{C'} = \frac{1}{200} + \frac{1}{200} = \frac{2}{200}$$

C' = 100 pF

Capacitors C_1 and C' are in parallel. Let their equivalent capacitance be

∴ C'' =C' + C_1

= 1000 + 100 =200 pF

C'' and C_4 are connected in series. Let their equivalent capacitance be C.

$$\therefore \frac{1}{C} = \frac{1}{C''} + \frac{1}{C_4}$$

$$= \frac{1}{200} + \frac{1}{100} = \frac{2+1}{200}$$

$$C = \frac{200}{3} pF$$

Hence, the equivalent capacitance of the circuit is $\frac{200}{3}$pF

Potential difference across C" = V"

Potential difference across $C_4 = V_4$

$\therefore$ $V^n + V_4 = V = 300V$

Charge on C_4 is given by

$Q_4 = CV$

$= \frac{200}{3} \times 10^{-12} \times 300$

$= 2 \times 10^{-8}$ C

$\therefore V_4 = \frac{Q_4}{C_4}$

$= \frac{2 \times 10^{-8}}{100 \times 10^{-12}} = 200 \text{ V}$

$\therefore$ Voltage across C_1 is given below

$V_1 = V - V_4$

= 300- 200 =100 V

Hence, potential difference, V_1, across C_1 is 100 V.

Charge on C1 is given by,

$Q_1 = C_1V_1$

$= 100 \times 10^{-12} \times 100$

$= 10^{-8}$ C

C_2 and C_3 having same capacitances have a potential difference of 100 V together. Since C_2 and C_3 are in series, the potential difference across C_2 and C_3 is given by,

$V_2 = V_3 = 50$ V

Therefore, charge on C_2 is given by,

$Q_2 = C_2V_2$

$= 200 \times 10^{-12} \times 50$

$= 10^{-8}$ C

And charge on C_3 is given by,

$Q_3 = C_3V_3$

$= 200 \times 10^{-12} \times 50 = 10^{-8}$ C

Hence, the equivalent capacitance of the given circuit is $\frac{200}{3}$pF

3)
(1) Given,

Radius of spherical conductor, r = 12cm = 0.12m

Charge is distributed uniformly over the surface, q = 1.6 x 10^{-7} C.

The electric field inside a spherical conductor is zero.

(2) Electric field E, just outside the conductor is given by the relation

$$E = \frac{1}{4\pi\epsilon_o} \cdot \frac{q}{r^2}$$

Here,= permittivity of free space and $\frac{1}{4\pi\epsilon_o} = 9 \times 10^9 Nm^2C^{-2}$

Therefore,

$$E = \frac{9 \times 10^9 \times 1.6 \times 10^{-7}}{(0.12)^2} = 10^5 NC^{-1}$$

Therefore, just outside the sphere the electric field is 4.4 x 10^4 NC^{-1}.

(3) From the centre of the sphere the electric field at a point 18m = E_1.

From the centre of the sphere, the distance of point d = 18 cm = 0.18m

$$E_1 = \frac{1}{4\pi\epsilon_o} \cdot \frac{q}{d^2} = \frac{9 \times 10^9 \times 1.6 \times 10^{-7}}{\left(1.8 \times 10^{-2}\right)^2} = 4.4 \times 10^4 NC^{-1}$$

So, from the centre of sphere the electric field at a point 18 cm away is 4.4 x 10^4 NC^{-1}.

4)
Given,

Capacitance, C = 8pF.

In the first case, the parallel plates are at a distance 'd' and is filled with air.

Air has dielectric constant, k = 1

Capacitance, C $= \frac{k \times \epsilon_o \times A}{d} = \frac{\epsilon_o \times A}{d}$ ....(i)

Here,

A = area of each plate

ϵ_o = permittivity of free space.

Now, if the distance between the parallel plates is reduced to half, then d_1 = d/2

Given, dielectric constant of the substance, k_1 = 6

Hence, the capacitance of the capacitor,

$$C_1 = \frac{k_1 \times \epsilon_o \times A}{d_1} = \frac{6\epsilon_0 \times A}{d/2} = \frac{12\epsilon_o A}{d}$$ ....(ii)

Taking ratios of eqns. (1) and (2), we get,

C_1 = 2 x 6 C = 12 C = 12 x 8 pF = 96pF.

Hence, the capacitance between the plates is 96pF.

5) (1) Given, C_1 = 2pF, C_2 = 3pF and C_3 = 4pF.

Equivalent capacitance for the parallel combination is given by C_{eq} .

Therefore, $C_{eq} = C_1 + C_2 + C_3 = 2 + 3 + 4 = 9pF$

Hence, the total capacitance of the combination is 9pF.

(2) Supply voltage, V = 100V

The three capacitors are having the same voltage, V = 100v

q = VC

where,

q = charge

C = capacitance of the capacitor

V = potential difference

for capacitance, c = 2pF

q = 100 x 2 = 200pC = 2×10^{-10}C

for capacitance, c = 3pF

q = 100 x 3 = 300pC = 3×10^{-10}C

for capacitance, c = 4pF

q = 100 x 4 = 400pC = 4×10^{-10} C

---

6) (a) Dielectric constant of the mica sheet, k = 6

If voltage supply remained connected, the voltage between two plates will be constant.

Supply voltage, V = 100 V

Initial capacitance, C = 1.771×10^{-11} F

New capacitance, $C_1 = kC = 6 \times 1.771 \times 10^{-11}$ F = 106 pF

New charge, $q_1 = C_1V$ = 106 x 100 pC = 1.06×10^{-8} C

Potential across the plates remain 100 V.

(b) Dielectric constant, k = 6

Initial capacitance, C = 1.771×10^{-11} F

New capacitance, $C_1 = kC = 6 \times 1.771 \times 10^{-11}$ F = 106 pF

If the supply voltage is removed, then there will be a constant amount of charge in the plates.

Charge = 1.771×10^{-9} C

Potential across the plates is given by,

$$V1 = q/C1 = \frac{1.771 \times 10^{-9}}{106 \times 10^{-12}}$$

= 16.7 V

---

7)

Given,

Capacitance, C = 600 pF

Potential difference, V = 200 v

Electrostatic energy stored in the capacitor is given by :

$E_1 = \frac{1}{2}CV^2 = \frac{1}{2} \times \left(600 \times 10^{-12}\right) \times (200)^2 J = 1.2 \times 10^{-5}$ J

Acc. to the question, the source is disconnected to the 600pF and connected to another capacitor of 600 pF, then equivalent capacitance (C_{eq}) of the combination is given by,

$\frac{1}{C_{cq}} = \frac{1}{C} + \frac{1}{C}\frac{1}{C_{eq}} = \frac{1}{600} + \frac{1}{600}$

$= \frac{2}{600} = \frac{1}{300}$

C_{eq} = 300 pF

New electrostatic energy can be calculated by:

$\mathrm{E}_2 = \frac{1}{2}\mathrm{CV}^2 = \frac{1}{2} \times 300 \times (200)^2 \text{ J} = 0.6 \times 10^{-5} \text{ J}$

Loss in electrostatic energy,

$E = E_1 - E_2$

E = 1.2 x 10^{-5} – 0.6 x 10^{-5} J = 0.6 x 10^{-5} J = 6 x 10^{-6} J

Therefore, the electrostatic energy lost in the process is 6 x 10^{-6} J.

---

8) Charge located at the origin, q = 8 mC = 8 x 10^{-3} C

The magnitude of the charge taken from the point P to R and then to Q, q_1 = 2 x 10^{-9} C

Here OP= d_1= 3 cm = 3 x 10^{-2} m

OQ = d_2= 4 cm = 4 x 10^{-2} m

Potential at the point P, $V_1 = \frac{q}{4\pi\epsilon_0 d_1}$ Potential at the point Q, $V_1 = \frac{q}{4\pi\epsilon_0 d_1}$

The work done (W) is independent of the path

Therefore, W = $q_1[V_1 - V_2]$

$$= V_2 = q_1\left[\frac{q}{4\pi\epsilon_0 d_2} - \frac{q}{4\pi\epsilon_0 d_1}\right]$$

$$= V_2 = \frac{qq_1}{4\pi\epsilon_0}\left[\frac{1}{d_2} - \frac{1}{d_1}\right]$$

Where, $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \mathrm{Nm}^2\mathrm{C}^{-2}$

Therefore,

$$W = 9 \times 10^9 \times 8 \times 10^{-3} \times \left(-2 \times 10^{-9}\right)\left[\frac{1}{4 \times 10^{-2}} - \frac{1}{3 \times 10^{-2}}\right]$$

= -144 x 10^{-3} x (-100/12)

= 1.2 Joule

Therefore, the work done during the process is 1.2 J

---

9) Capacitance of a parallel capacitor, V = 2 F

Distance between the two plates, d = 0.5 cm = 0.5×10^{-2} m

Capacitance of a parallel plate capacitor is given by the relation,

$$C = \frac{\epsilon_0 A}{d}$$

$$A = \frac{Cd}{\epsilon_0}$$

Where,

ϵ_0 = Permittivity of free space = $8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$

$$\therefore A = \frac{2 \times 0.5 \times 10^{-2}}{8.85 \times 10^{-12}} = 1130\ \text{km}^2$$

Hence, the area of the plates is too large. To avoid this situation, the capacitance is taken in the range of μF.

10) Charge on the $4\mu F$ capacitor when it is charged to 200 V.

$$Q = CV = (4 \times 10^{-6} F)(200\quad V) = 8 \times 10^{-4} C$$

This charged capacitor is then connected to an unchanged capacitor of capacitance $2\mu F$

So $C^{'} = (4 + 2)\mu F = 6\mu F$

The charge capacitor is then capacitor is now shared between the two until they attain a common potential.

The common potential after the combination

$$= \frac{Q}{C^{'}} = \frac{8 \times 10^{-4} C}{6 \times 10^{-6} F} = 1.33 \times 10^2 V = 133V$$

The electrical potential energy of the first capacitor before it is connected to the second

$$= \frac{1}{2}CV^2 = \frac{1}{2}(4 \times 10^{-6})(200)^2$$

$$= 8 \times 10^{-2} J$$

The electrical potential energy of the system after they are connected

$$= \frac{1}{2}C^{'}V^{'2} = \frac{1}{2}\left(6 \times 10^{-6}\right)(200)^2 = 5.30 \times 10^{-2} J$$

Energy in the form of heat and electromagnetic radiation

$$= \left(8 \times 10^{-2} - 5.3 \times 10^{-2}\right) J = 2.7 \times 10^{-2} J$$

11)

(a) No, because charge distribution on the sphere will not be uniform.

(b) No, Gauss's law will not be true.

(c) Not necessarily.It is true only if the line of force is a straight line.The line of force given the direction of acceleration, not that of velocity, in general.

(d) Work done is zero.No matter what the shape of the complete orbit is, the value of work remains zero.

(e) No, potential is continuous.

(f)A single conductor is a capacitor with one of the plates at infinity.

(g) Water molecules have permanent dipole moments.

12)

As the d.c. source remains connected, p.d.(V) between the plates of capacitor remains unchanged even after dielectric is inserted between the plates.

(a)Original capacitance $C_o = \frac{\epsilon_o A}{d}$

New capacitance $C_o = \frac{\epsilon_r \epsilon_o A}{d/2} = 20C_o$

(b Changed electric field,

$E = \frac{V}{d/2} = 2(V/d) = 2E_o$

(c)Original energy density, $U_o = \frac{1}{2}\epsilon_o E^2$

New energy density, $U = \frac{1}{2}\epsilon E^2$

$\frac{1}{2}(\epsilon_r \epsilon_o)(2E_o)^2 = 4E_r(\frac{1}{2} \times \epsilon_o E_o^2)$

$= 4 \times 10U_o = 40U_o$

---

13) Here, m = 10^{-3}kg, $q = 1.6 \times 10^{-19}C$

Force on water drop due to electric field = Weight of water drop

qE = mg

$E = \frac{mg}{q} = \frac{10^{-3} \times 9.8}{1.6 \times 10^{-19}} = 6.125 \times 10^{16} N/C$

---

14) Here, m = 10^{-4}kg

$q = 5\mu C = 5 \times 10^{-6}C; v = 20ms^{-1}$

E=$2 \times 10^5 N/C$

Force on charged particle

$F = qE = 5 \times 10^{-6} \times 2 \times 10^5 = 1N$

As particle is thrown against the field, so

$a = -\frac{F}{m} = -\frac{1}{10^{-4}} = -10^4 m/s^2$

From $v^2 - u^2 = 2as$

$(0)^2 - (20)^2 = 2(-10^4)s$

s = 0.02m

---

15) Here, $q = 1\mu C = 10^{-6}C$

2a=1cm=10^{-2}m , r=10cm=10^{-1}m

On the axial line of dipole,

$E = \frac{2|\vec{p}|r}{4\pi\epsilon_o (r^2 - a^2)^2} = \frac{2q \times 2a \times r}{4\pi\epsilon_o (r^2 - a^2)^2}$

$= \frac{9 \times 10^9 \times 2 \times 10^{-6} \times 10^{-2} \times 10^{-1}}{(10^{-2} - 0.25 \times 10^{-4})^2}$

$= \frac{18}{10^{-4}(1 - 0.0025)^2}$

$E = \frac{18 \times 10^4}{0.9975 \times 0.9975} = 18 \times 10^4 N/C$

---

16) $Here, q = \pm 20\mu C = \pm 20 \times 10^{-6}C$

$2a = 1cm = 10^{-2}m, r = 50cm = \frac{1}{2}m$

As 2a< < r, therefore, intensity on equatorial line of short dipole is

$E = \frac{1}{4\pi\epsilon_o}\frac{P}{r^3} = \frac{q \times 2a}{4\pi\epsilon_o r^3}$

$= \frac{9 \times 10^9 \times 20 \times 10^{-6} \times 10^{-2}}{(1/2)^3}$

$E = 1.44 \times 10^4 N/C$

17) Here, $p = 2 \times 10^{-8}C - m, r = 1m$

$\theta = 60^o, E = ?$

$E = \frac{P}{4\pi\epsilon_o r^3}\sqrt{3cos^2\theta + 1}$

$= \frac{2 \times 10^{-8} \times 9 \times 10^9}{1^3}\sqrt{3(cos60^o)^2 + 1}$

E = 238.1 N/C

18) Here, $\frac{1}{4\pi\epsilon_o}\frac{2p}{r^3} = \frac{1}{4\pi\epsilon_o}\frac{P}{r'^3}$

$\frac{2}{r^3} = \frac{1}{r'^3}$ or $\frac{r^3}{r'^3} = 2$ or $\frac{r}{r'} = 2^{1/3}$

19) Here, q = $\pm 10\mu C = \pm 10 \times 10^{-6}C$

2a = $5 \times 10^{-3}m$, r = 0.15m

The point Q lies on equatorial line of electric dipole.

As r > > a so, $E = \frac{P}{4\pi\epsilon_o r^3} = \frac{q(2a)}{4\pi\epsilon_o r^3}$

$E = \frac{9 \times 10^9 \times 10 \times 10^{-6} \times 5 \times 10^{-3}}{(0.15)^3}$

$= 1.33 \times 10^5 NC^{-1}$

20) Here, q = $0.1\mu C = 10^{-7}C$

2a = 2.0 cm = $2 \times 10^{-2}m, E = 10^5 N/C, \tau = ?$

$\tau = pEsin\theta = q \times 2a \times Esin\theta$

Max value of $\tau = 10^{-7} \times 2 \times 10^{-2} \times 10^5 \times 1$

=$2 \times 10^{-4}N - m$

21) Here, p = $5 \times 10^{-8}C - m\ \theta_1 = 0^o$

E = $1.44 \times 10^4 N/C.\ \theta_2 = 60^o, P.E. = ?$

$P.E. = -pE(cos\theta_2 - cos\theta_1)$

$= -5 \times 10^{-8} \times 1.44 \times 10^4(cos60^o - cos0^o)$

$P.E. = -7.2 \times 10^{-4}(0.5 - 1)$=$3.6 \times 10^{-4}J$

22) Here q=$1.6 \times 10^{-19}C$

$2a = 4 \times 10^{-10}m, E = 3 \times 10^5NC^{-1}, \theta = 30^o$

$p = q \times 2a = 1.6 \times 10^{-19} \times 4 \times 10^{-10}$

=$6.4 \times 10^{-29}Cm$

$\tau = pEsin\theta = 6.4 \times 10^{-29} \times 3 \times 10^5 \times sin30^o$

$= 9.6 \times 10^{-24}Nm$

23) Here q = 100C

Potential difference between cloud and the earth V = 10^7V

Energy dissipated W = qV = 100 $\times 10^7 = 10^9J$

24) Here $W_{AB} = 20J, q_o = 4C$

$V_A = 10V, V_B = V = ?$

As $V_B - V_A = \frac{W_{AB}}{q_o}$

$V - 10 = \frac{20}{4} = 5$

$V = 5 + 10 = 15V$

25) Here, $E = \frac{Q}{4\pi\epsilon_o r^2} = 24NC^{-1}$

$V = \frac{Q}{4\pi\epsilon_o r} = 12JC^{-1}$

Dividing, we get $\frac{V}{E} = r = \frac{12}{24} = 0.5m = AB$

From V=$\frac{Q}{4\pi\epsilon_o r}$; $Q = 4\pi\epsilon_o r \times V$

$Q = \frac{1}{9 \times 10^9} \times 0.5 \times 12 = 0.667 \times 10^{-9}C$

26) Diagonal of the square

$= \sqrt{(\sqrt{2})^2 + (\sqrt{2})^2} = 2m$

Distance of each charge from the centre of the square, r= half the diagonal = $\frac{2}{2}$ = 1m

Potential at the centre of the square

$V = \frac{1}{4\pi\epsilon_o} \frac{\Sigma q}{r}$

$= 9 \times 10^9 \frac{(100 - 50 + 20 - 60) \times 10^{-6}}{1}$

$V = 9 \times 10^4 volt$

27) Here q=ne=$79 \times 1.6 \times 10^{-19}C$

$r = 6.6 \times 10^{-15}m$

Electric potential V=$\frac{1}{4\pi\epsilon_o} \frac{q}{r}$

$= \frac{9 \times 10^9 \times 79 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-15}}$

$= 1.7 \times 10^7 V$

28) Here, q=200μC=$2 \times 10^{-4}C$

r=10cm=0.10m

Electric potential at the centre V=$\frac{1}{4\pi\epsilon_o}\frac{q}{r}$

$= \frac{9\times10^9\times2\times10^{-4}}{0.1} = 18 \times 10^6 V$

29) Here V=50V, r=0.9m

As V=$\frac{1}{4\pi\epsilon_o}\frac{q}{r}$

$50 = \frac{9\times10^9\times q}{0.9}$

As potential is positive, the charge q must be positive.

30)

$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r} = 9 \times 10^9 \text{Nm}^2\text{C}^{-2} \times \frac{4\times10^{-7}\text{C}}{0.09\text{ m}}$

= 4 x 10^4 V

(b) W = qV = 2 x 10^{-9}C x 4 x 10^4 V

= 8 x 10^{-5} J

No, work done will be path independent. Any arbitrary infinitesimal path can be resolved into two perpendicular displacements: One along r and another perpendicular to r. The work done corresponding to the later will be zero.

31) Using superposition principle, we may write electric potential at the origin (x=0) due to various charges as

$V = \frac{1}{4\pi\epsilon_o}[\frac{q}{1} + \frac{q}{2} + \frac{q}{4} + \frac{q}{8} \ ...]$

$V = \frac{q}{4\pi\epsilon_o}[\frac{1}{1} + \frac{1}{2} + \frac{1}{2^2} + \frac{1}{2^3} + ...]$

As sum of infinite G.P. series, S=$\frac{a}{1-r}$

Where a is first term and r is common ratio.

$V = \frac{q}{4\pi\epsilon_o}\{\frac{1}{(1-1/2)}\}=\frac{2q}{4\pi\epsilon_o}$

32) Here,

p=1.47D= $1.47 \times 3.34 \times 10^{-30}Cm$

V=?, r=52nm = $52.0 \times 10^{-9}m$

On the axis of dipole,

$V = \frac{P}{4\pi\epsilon_o r^2} = \frac{9\times10^9\times1.47\times3.34\times10^{-30}}{(52.0\times10^{-9})^2}$

$= 1.63 \times 10^{-5}V$

33) Here, q=ne=$10 \times 1.6 \times 10^{-19}$

$= 1.6 \times 10^{-18} C$

$m = 3 \times 10^{-16} kg \quad r = 5mm = 5 \times 10^{-3} m$

$E = \frac{V}{r} = \frac{V}{5 \times 10^{-3}} Vm^{-1}$

For drop to remain stationary,

mg=qE

$3 \times 10^{-16} \times 10 = 1.6 \times 10^{-18} \times \frac{V}{5 \times 10^{-3}}$

$V = \frac{3 \times 10^{-16} \times 10 \times 5 \times 10^{-3}}{1.6 \times 10^{-18}} = 9.47V$

34) Here, $q = -1.6 \times 10^{-19} C$

$dr = 5cm = 5 \times 10^{-2} m, dV = 3000V, m = ?$

$E = -\frac{dV}{dr} = \frac{-3000}{5 \times 10^{-2}} = -6 \times 10^{4} Vm^{-1}$

As the charged particle remains suspended in equilibrium, therefore

F = mg = qE

or $m = \frac{qE}{g} = \frac{-1.6 \times 10^{-19} \times (-6 \times 10^{4})}{9.8}$

$= 9.8 \times 10^{-16} kg$

35) Here $q_1 = 0.2 \times 10^{-6} C|$

$q_2 = 0.01 \times 10^{-6} C, r_2 = 0.05m, r_1 = 0.10m$

Work done =change in P.E.=Final P.E. - Initial P.E

$= \frac{q_1 q_2}{4\pi\epsilon_o} [\frac{1}{r_1} - \frac{1}{r_1}]$

$= 9 \times 10^{9} \times 0.2 \times 10^{-6} \times 0.01 \times 10^{-6} \times [\frac{1}{0.05} - \frac{1}{0.10}]$

$= 1.8 \times 10^{-4} J$

36) Here , $E = 3 \times 10^{3} \hat{i} NC^{-1}$

A=$(0.1m)^2$=$10^{-2}m^2$

(i)As normal to area is in the direction of electric field, therefore, $\theta = 0^{o}$

$\phi = EAcos\theta = 3 \times 10^{3} \times 10^{-2} cos^{o}$

$= 30Nm^{2}C^{-1}$

(ii)In this case, $\theta = 60^{o}$

$\phi' = EAcos\theta = 3 \times 10^{3} \times 10^{-2} cos60^{o}$

$= 15Nm^{2}C^{-1}$

37) (i)Here, normal to a plane parallel to Y-Z plane is along X-direction.

So, $\Delta\vec{s} = 0.10 \times 0.10\hat{i} = 0.01\hat{i}m^{2}$

Electric flux $\phi_E = \vec{E}.\Delta\vec{s} = 4 \times 10^{3}\hat{i}.0.01\hat{i}$

=40 Nm^2C^{-1}

(ii)Here, $\theta = 60^{o}$

$\phi_E = E\Delta Scos60^{o} = 4 \times 10^{3} \times 0.01 \times cos60^{o}$

$= 20Nm^{2}C^{-1}$

38)

(i)Here $\phi_E = 16 \times 10^3 Nm^2C^{-1}$

Acc. to Gauss theorem $\phi_E = \frac{q}{\epsilon_o}$

So $q = \phi_E \times \epsilon_o = 16 \times 10^3 \times 8.85 \times 10^{-12}$

$=0.14 \times 10^{-6}C = 0.14\mu C$

(ii)No, we can not say that there are no charges at all inside the box. We can only say that algebraic sum of charges inside the box is zero.

39)

Here, $R = \frac{2.4}{2} = 1.2m$

$\sigma = 180.0\mu C/m^2 = 180 \times 10^{-6}Cm^{-2}$

(i)Charge on the sphere q= $4\pi R^2\sigma$

$= 4 \times 3.14 \times (1.2)^2 \times 180 \times 10^{-6}$

$3.53 \times 10^{-3}C$

Electric flux, $\phi_E = \frac{q}{\epsilon_o} = \frac{3.53 \times 10^{-3}}{8.85 \times 10^{-12}}$

40)

Here, E=$19 \times 10^4 NC^{-1}$

r=0.05 m

Electric field of line charge, E=$\frac{\lambda}{2\pi\epsilon_o r}$

Linear charge density $\lambda = 2\pi\epsilon_o Er$

$= 2 \times \frac{22}{7} \times 8.85 \times 10^{-12} \times 19 \times 10^4 \times 0.05$

$=0.5\mu Cm^{-1}$

41)

(a)On the left, the fields of the two plates are equal and opposite, so E=Zero

(b)on the right, the fields of the two plates are equal and opposite, So E=zero

(c)Between the plates, the fields due to both plates are in same direction, so that resultant field is

$E = \sigma 2\epsilon_o + \frac{\sigma}{2\epsilon_o} = \frac{\sigma}{\epsilon_o} = \frac{19 \times 10^{-22}}{8.85 \times 10^{-12}}$

$= 2.14 \times 10^{-10}NC^{-1}$

42)

Here, $\sigma = 5 \times 10^{-16}cm^{-2}, \phi = ?$

r=1cm=$10^{-2}m, \theta = 60^o$

$\phi = E(\Delta S)cos\theta = (\frac{\sigma}{2\epsilon_o})\pi r^2 cos60^o$

$= \frac{5 \times 10^{-16} \times 3.14(10^{-2})^2 \times 1/2}{2 \times 8.85 \times 10^{-12}}$

$= 4.44 \times 10^{-9}Nm^2C^{-1}$

43)

Here A=1m^2, d=5 cm, q=?

E=1000 NC^{-1}

From $E = \frac{\sigma}{\epsilon_o} = \frac{q/A}{\epsilon_o}$

$q = A\epsilon_o E = 1 \times (8.85 \times 10^{-12}) \times 1000$

$= 8.85 \times 10^{-9}C$

44) $q = 3.5nC = 3.5 \times 10^{-9}C$

Charge on one electron , $e = 1.6 \times 10^{-19}C$

no. of electrons that should be removed.

$n = \frac{q}{e} = \frac{3.5 \times 10^{-9}}{1.6 \times 10^{-19}} = 2.187 \times 10^{10}$

45) Here, excess charge

$q = -1.92 \times 10^{-17}C$

Charge on one electron

'e' = $-1.6 \times 10^{-9}C$

No. of excess electrons responsible or this excess charge,

$n = \frac{q}{e} = \frac{-1.92 \times 10^{-18}}{-1.6 \times 10^{-19}} = 120 electrons$

46) A coulomb of charge is bigger than the charge on an electron.

Magnitude of charge on one electron,

$e = 1.6 \times 10^{-19} coulomb$

Number of electronic charges in one coulomb,

$n = \frac{q}{e} = \frac{1}{1.6 \times 10^{-19}} = 0.625 \times 10^{19}$

Note that one coulomb is too big a unit of charge.

47) Suppose the cup contains 250cc or water (H_2O)

Mass of 250 cm^3 of water =250g

Molecular weight of water =2+16=18

Number of molecules in 18 g of water

$= \frac{6.023 \times 10^{23} \times 250}{18}$

As each molecule of water contains 10 electrons, therefore, total number of electrons

$n = \frac{10 \times 6.023 \times 10^{23} \times 250}{18} = 8.365 \times 10^{25}$

As q=ne, therefore

$q = 8.365 \times 10^{25} \times 1.6 \times 10^{-19}C$

$= 1.338 \times 10^{7}C$

48) Here, $n = 10^{9}$ electrons/sec

Charge given/sec,

$q = ne = 10^{9} \times 1.6 \times 10^{-19}C$

Total charge Q=1C

Time required = $\frac{Q}{q} = \frac{1}{1.6 \times 10^{-10}} sec$

$= 6.25 \times 10^{9}s = \frac{6.25 \times 10^{9}}{3600 \times 24 \times 365} year$

=198.18 year

49) Here, $q_1 = -6.5\mu C, and$

$q_2 = ne = 5 \times 10^{13}(1.6 \times 10^{-19})C$

$=8.0 \times 10^{-6}C = 8.0\mu C$

As electrons are removed from the sphere, q_2 is positive. Therefore, net charge on the sphere,

$q = q_1 + q_2 = -6.5\mu C + 8.0\mu C = 1.5\mu C$

---

50) Here, $q_1 = -300\mu C$

$q_2 = -0.44\mu C$

Let n electrons be transferred from A to B , when A and B would carry same charge.

Charge on A=Charge on B

-3.00+ne=-0.44-ne

2 ne=3.00-0.44=2.56(μC)

$n = \frac{2.56}{2e}$

Taking $e = 1.6 \times 10^{-19}C = 1.6 \times 10^{-13}\mu C$

$n = \frac{2.56}{2 \times 1.6 \times 10^{-13}} = 0.8 \times 10^{13} = 8 \times 10^{12}$

---

51) Here, $F = \frac{1}{4\pi\epsilon_o}\frac{q_1q_2}{d^2}$ ....(i)

Let the charges be kept at a distance 'r' apart.

Again, 2F=$\frac{1}{4\pi\epsilon_o}\frac{q_1q_2}{r^2}$.......(ii)

Dividing (i) by (ii)

$\frac{1}{2} = \frac{r^2}{d^2}$

or $r^2 = \frac{d^2}{2}$

$r = \frac{d}{\sqrt{2}} = 0.707d$

---

52) Here $q_1 = q_2 = 2 \times 10^{-8}C, r = 1m$

Tension in the string is the force of repulsion (F) between the two charges.

According to Coulomb's law,

$F = \frac{q_1q_2}{4\pi\epsilon_o r^2} = \frac{9 \times 10^9(2 \times 10^{-8})(2 \times 10^{-8})}{1^2}$

=$3.6 \times 10^{-6}N$

---

53) Here, force of attraction between charges = centripetal force

$\frac{1}{4\pi\epsilon_o}\frac{q_1q_2}{r^2} = \frac{mv^2}{r}$

so $v = \sqrt{\frac{1}{4\pi\epsilon_o}\frac{q_1q_2}{mr}}$

Time period of revolution

$T = \frac{2\pi r}{v} = 2\pi r\sqrt{\frac{4\pi\epsilon_o mr}{q_1q_2}}$

$T = \sqrt{\frac{16\pi^3\epsilon_o mr^3}{q_1q_2}}$

---

54) Here, q=4μC=$4 \times 10^{-6}C, q_o = 1C$

From the principle of superposition, total force acting on 1C charge at the origin due to all the given charges is

$F = \frac{qq_o}{4\pi\epsilon_o}[\frac{1}{r_2^2} + \frac{1}{r_2^2} + \frac{1}{r_3^2} + ...]$

=$9 \times 10^9 \times 4 \times 10^{-6} \times 1[\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{4^2} + ...]$

As sum of infinite geometric progression

$= \frac{a}{1-r} = \frac{1}{1-\frac{1}{4}} = \frac{4}{3}$

F=$9 \times 10^9 \times 4 \times 10^{-6} \times \frac{4}{3} = 4.8 \times 10^4 N$

---

55) Here, $C\alpha r \ or \ C = kr$

Charge on each small drop,

$q = CV = (kr \times 900)C$

Let R be radius of large drop

As volume of large = volume of 8 small drops

$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3 \ or \ R = 2r.$

Capacitance of large drop

---

56) Here, C=60 pF = $60 \times 10^{-12}F$

$V = 10^4 V$

(i)$r = \frac{1}{4\pi\epsilon_o}C = 9 \times 10^9 \times 60 \times 10^{-12}$

=$54 \times 10^{-2}m = 54cm$

(ii)$q = cV = 60 \times 10^{-12} \times 10^4$

$= 60 \times 10^{-8} = 0.6\mu C$

---

57) Here, charge transferred Q=ne

Q=$(1.0 \times 10^{12})(1.6 \times 10^{-19})C$

$= 1.6 \times 10^{-7}C, V = 10volt, C = \ ?$

As $C = \frac{Q}{V} = \frac{1.6 \times 10^{-7}}{10} = 1.6 \times 10^{-8}F$

---

58) Here, C=?, r=10km=10^4m

As C=$4\pi\epsilon_o r = \frac{1}{9\times10^9} \times 10^4 = 1.1 \times 10^{-6}F$

59) If capacity is C μC then as per the statement.

C x V = 360 .... (i)

$C(V-120) = 120$

Dividing, we get $\frac{C(V-120)}{C\times V} = \frac{120}{360} = \frac{1}{3}$

3 V- 360 = V or V = 180 volt

From (i), $C = \frac{360}{V} = \frac{360}{180} = 2\mu F$

New voltage,

V' = V+120 = 180 +120 = 300 volt

New charge, Q'= CV' = 2 x 300 = 600μC

60) Here, $q_1 = 2.0 \times 10^{-8}C,$

$q_2 = -1.0 \times 10^{-8}C$

$C = 1.2 \times 10^{-3}\mu F = 1.2 \times 10^{-9}F, V = ?$

$V = \frac{q_1 - q_2}{2C} = \frac{2.0\times10^{-8} - (-1.0\times10^{-8})}{2\times1.2\times10^{-9}}$

=12.5 V

61) Here, two parallel plate capacitors have same charge q and same potential V, so they have equal capacitances as

C = q/V

$C_1 = C_2$

$\frac{\epsilon_o A_1}{d_1} = \frac{\epsilon_o A_2}{d_2}$

or $d_2 = \frac{A_2}{A_1}d_1$

Now, $A_1 = 100cm^2, A_2 = 500cm^2$

$d_1 = 0.5mm = 0.05cm$

$d_2 = \frac{500\times0.05}{100} = 0.25cm = 2.5mm$

62) Here, A=?, C=2 farad

d=0.5cm = $5 \times 10^{-3}m$

$\epsilon_o = 8.85 \times 10^{-12}C^2N^{-1}m^{-2}$

As $C = \frac{\epsilon_o A}{d}$

$A = \frac{Cd}{\epsilon_o} = \frac{2\times5\times10^{-3}}{8.85\times10^{-12}}m^2$

$= 1.13 \times 10^9 m^2$

63)

Here, $A = 25\ cm^2 = 25 \times 10^{-4} m^2$

d = 2 mm = $2 \times 10^{-3} m, V = 12 volt$

(a) Charge on the capacitor, q = ?

$q = CV = \frac{\epsilon_o A}{d} V$

$\frac{8.85 \times 10^{-12} (25.0 \times 10^{-4}) \times 12}{2 \times 10^{-3}}$

$= 1.35 \times 10^{-10} C$

(b)When plate separation is decreased to half, capacity becomes twice. The charge (q'= C'V), becomes twice. Hence extra charge given by the battery

$q' - q = 2q - q = q = 1.35 \times 10^{-10} C$

64) Here, $\frac{4\pi\epsilon_o ab}{b-a} = 4\pi\epsilon_o R$

$\frac{ab}{b-a} = R$

As b-a=2 cm R=$\frac{1.2}{2} m = 60 cm$

$\frac{ab}{2} = 60\ or\ ab = 120$

As $(b+a)^2 = (b-a)^2 + 4ab = (2)^2 + 4 \times 120 = 484$

b+a=22

2+a+a=22

a=10cm, b=12 cm

65) Here, C=?, $r_a = 0.50 m$

$r_b = 0.60 m, K = 6$

$C = KC_o = K \frac{4\pi\epsilon_o r_a r_b}{r_b - r_a}$

$= \frac{6}{9 \times 10^9} \frac{(0.5)(0.6)}{(0.6-0.5)} = 2 \times 10^{-9} F$

66) Here, C=?L=1m

$r_a = \frac{1}{2} mm = 0.5 mm = 5 \times 10^{-4} m$

$r_b = \frac{5}{2} mm = 2.5 mm = 2.5 \times 10^{-3} m$

For a cylindrical capacitor,

$C = \frac{2\pi\epsilon_o L}{log_e(\frac{r_b}{r_a})} = \frac{4\pi\epsilon_o L}{2 log_e(r_b / r_b)}$

$= \frac{1 \times 1}{9 \times 10^9 \times 2 log_e(\frac{2.5 \times 10^{-3}}{5 \times 10^{-4}})}$

$C = \frac{1}{18 \times 10^9 log_e 5} = \frac{10^{-9}}{18 \times 1.609}$

$= 3.45 \times 10^{-11} F = 34.5 pF$

67) Total charge on two capacitors = $C_1V_1 = C_2V_2$

$(3 \times 2 + 6 \times 5) = 36\mu C$

In series combination, charge is conserved

Potential on $3\mu F$ capacitor = $\frac{36\mu C}{3\mu F} = 12V$

Potential on 6μF capacitor = $\frac{36\mu C}{6\mu F} = 6V$

68) As each capacitor of $10\mu F$ can withstand only 50 V. Design a combination must be connected in series in a row . Capacity C_1 of each row of four capacitors is

$\frac{1}{C_1} = \frac{1}{10} + \frac{1}{10} + \frac{1}{10} + \frac{1}{10} = \frac{4}{10}$

$C_1 = \frac{10}{4} = 2.5\mu F$

For a total capacity of 10μF four such rows of capacitors must be connected in parallel so that

$C_p = 4C_1 = 4 \times 2.5 = 10\mu F$

Hence, we need 16 capacitors with 4 capacitors in series in each row and 4 such rows in parallel.

69) Here $\frac{C_1}{C_2} = \frac{1}{2}\ or\ C_2 = 2C_1$

$C_p = C_1 + C_2 = C_1 + 2C_1 = 3C_1$

$C_s = \frac{C_1C_2}{C_1+C_2} = \frac{C_1 \times 2C_1}{C_1+2C_1} = \frac{2}{3}C_1$

If V_1 is p.d applied across parallel combination and V_2 is p.d applied across series combination, then as

$E_1=E_2$

$\frac{1}{2}C_p. V_1^2 = \frac{1}{2}C_sV_2^2$

$\frac{V_1}{V_2} = \sqrt{\frac{C_s}{C_p}} = \sqrt{\frac{2}{3} \times \frac{C_1}{3C_1}} = \sqrt{\frac{2}{9}} = \frac{\sqrt{2}}{3}$

70) Here $\frac{C_1}{C_2} = \frac{1}{3}$

If $C_1 = C, C_2 = 3C$

$C_p = C_1 + C_2 = C + 3C = 4C$

$C_s = \frac{C_1C_2}{C_1+C_2} = \frac{C(3C)}{C+3C} = \frac{3C}{4}$

If $V_1\ and\ V_2$ are potential differences applied across the parallel and series combination, the as

$\frac{1}{2}C_pV_1^2 = \frac{1}{2}C_sV_2^2$

$\frac{V_1}{V_2} = \sqrt{\frac{C_s}{C_p}} = \sqrt{\frac{3C/4}{4C}} = \frac{\sqrt{3}}{4}$

71) $AsC = \frac{q}{V} = \frac{10 \times 10^{-6}}{50} = 0.2\mu F$

Energy stored, $U = \frac{1}{2}CV^2$

$= \frac{1}{2} \times 0.2 \times 10^{-6} \times (50)^2 = 2.5 \times 10^{-4}J$

72) Energy stored in a parallel plate capacitor is

$U=\frac{1}{2}CV^2=\frac{1}{2}\frac{\epsilon_o A}{d}V^2$

When separation between the plates is decreased by 10%.

$d^{'}=d-\frac{10}{100}d=0.9d$

Change in energy

(U'-U)=$\frac{1}{2}\epsilon_o AV^2[\frac{1}{0.9}-\frac{1}{1}]=\frac{0.1}{0.9}U=\frac{U}{9}$

% age change in energy

$=\frac{(U^{'}-U)}{U}\times 100=\frac{100}{9}=11.1$%

73) Here, capacitance of the capacitor with air inbetween the plates,

$C_o=\frac{\epsilon_o A}{d}=8pF$

When space between the plates is reduced to half and the space is filled with dielectric of constant K=5 the new capacitance becomes

$C=\frac{K\epsilon_o A}{d/2}=2K(\frac{\epsilon_o A}{d})$

$=2\times 5\times 8=80pF$

74) Here t=6mm=$6\times 10^{-3}m$

$A=4\times 10^{-2}m^2, d=0.01m, K=3$

$C=\frac{\epsilon_o A}{d-t(1-\frac{1}{K})}=\frac{8.85\times 10^{-12}\times 4\times 10^{-2}}{0.01-6\times 10^{-3}(1-\frac{1}{3})}$

$=\frac{35.40\times 10^{-14}}{6\times 10^{-3}}=59\times 10^{-12}F=59pF$

75) Let σ be the surface charge density of capacitor plates.

for mica $E_1=\frac{\sigma}{K_1\epsilon_0}$

and for fibre $E_2=\frac{\sigma}{K_2\epsilon_o}$ or $\frac{E_1}{E_2}=\frac{K_2}{K_1}$

As $E_s=6.4\times 10^6V/m$

$E_1=\frac{K_2}{K_1}\times E_2=\frac{2.5}{8}\times 6.4\times 10^6=2\times 10^6V/m$

Maximum voltage or capacitor

$V=E_1d_1+E_2d_2=2\times 10^3+3.2\times 10^3=5200V$

76) Here Q=$12\mu C, V=1200V, A=?$

Dielectric strength = $3\times 10^7V/m$

The electric field between the plates should not exceed 10% of the dielectric strength

i.e., $E=\frac{\sigma}{\epsilon_o}=\frac{Q}{A\epsilon_o}=\frac{10}{100}\times 3\times 10^7=3\times 10^6V/m$

$A=\frac{Q}{\epsilon_o\times 3\times 10^6}=\frac{12\times 10^{-6}}{8.85\times 10^{-12}\times 3\times 10^6}$

$=0.45m^2$

77)

Let A be the area of each metal plate. If they are distance d apart, then the capacitance of the parallel plate capacitor so formed will be

$C = \frac{\epsilon_o A}{d}$

If E_1, E_2 are electric field intensities due to the two plates (in the space between the plates)then

$E_1 = \frac{q_1/A}{2\epsilon_o}$ and $E_2 = \frac{q_2/A}{2\epsilon_o}$

Net electric field between the two plates

$E = E_1 - E_2 = \frac{q_1/A}{2\epsilon_o} - \frac{q_2/A}{2\epsilon_o} = \frac{1}{2\epsilon_o A}(q_1 - q_2)$

The potential difference between the plates of the capacitor,

$V = E \times d = \frac{d}{2\epsilon_o A}(q_1 - q_2)$

$V = \frac{q_1 - q_2}{2(\epsilon_o A/d)} = \frac{q_1 - q_2}{2C}$

78)

Here

$C_1 = 1.0\mu F, V_1 = 6.0kV = 6 \times 10^3 V$

Charge on first capacitor

$q_1 = c_1 V_1 = 1.0 \times 6 \times 10^3 \mu C = 6000\mu C$

Similarly, charge on 2nd capacitor

$q_2 = C_2 V_2 = 2.0 \times 4 \times 10^3 \mu C = 8000\mu C$

In series combination, charge on each capacitor must be the same. As max. charge on C_1 is 6000μC

therefore, max. charge on C_2 must also be 6000μC

Hene maximum voltage for the combination is

$V' = V_1' + V_2' = \frac{6000}{1.0} + \frac{6000}{2.0} = 9000V = 9kV$

79)

As $\tau = nIBA \sin\theta$, therefore, (i) $\tau = 0$, when $\sin\theta = 0$ or $\theta = 0°$, i. e. when the plane of coil is perpendicular to the direction of magnetic field. (ii) $\tau =$ maximum, when $\sin\theta$=maximum=1 or $\theta = 90°$

$\tau_{max} = nIBA \times 1 = nIBA$

It will be so when the plane of coil is parallel to the direction of magnetic field.

(ii) Here, n = 200; r = 0.05m; I = 2.0 A; B = 0.20 T; $\theta = 90° - 60°$=30°

$\tau = nIBA \sin\theta$, therefore, (i) $\tau = 0$, when $\sin\theta = 0$ or $\theta = 30° - 60°$, i. e. ,

$\tau_{max} = nIBA \times 1 = nIBA$

$\tau = nIBA \sin\theta = nIB(\pi r^2)\sin\theta = 200 \times 2.0 \times 0.20\left[(22/7) \times (0.05)^2\right] \times \sin 30°$

$= 0.314 \quad N - m = 0.31\ Nm$

(iii) From the above study, we find that when potential energy of the coil is minimum, both force and torque acting on the coil are zero. The same is true in real life. a person who is humble and boasts of nothing, would be a happy person, with no pulls and pressure of life.

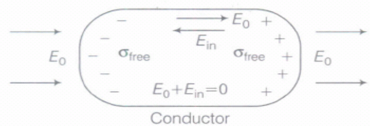
80)

(i) Examples of paramagnetic material are aluminum; chromium; oxygen.

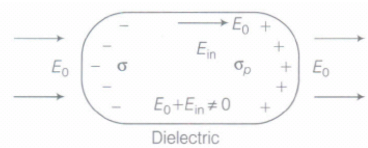
(ii) Iron and cobalt are two ferromagnetic materials. The ferromagnetic substances, but to a much larger degree. For example, relative magnetic permeability of paramagnetic substances is slightly greater than 1

81)

(i) (a) When a capacitor is placed in an external electric field, the free charges present inside the conductor redistribute themselves in such a manner that electric field within the conductor. This happens until a static situation is achieved,i.e. when the two fields cancel each other and the net electrostatic field in the conductor becomes zero.



(b) In contrast to conductors, dielectrics are non-conducting substance, i.e.they have no charge carriers.Thus, in a dielectric, free movement of charges in not possible.It turns out that the external field induces dipole moment by stretching molecules of the dielectric. The collective effect of all the molecular dipole moments is the net charge on the surface of the dielectric which produces a field that opposes the external field. However, the opposing field is so induced, that does not exactly cancel the extent of the effect depends on the nature of dielectric.



Both polar and non-polar dielectrics develop net dipole moment in the presence of an external field.The dipole moment per unit volume is called polarisation and is denoted by P for linear isotropic dielectrics. $P = X^E$

Where, X is constant of proportionality and is called electric susceptibility of the electric slab.

(ii) (a) At point C, inside the shell.

Electric field inside a spherical shell is zero.

Thus, the force experienced by charge at centre C will also be zero.

$\because$ $F_c = qE$ (E_{inside} the shell = 0)

$\therefore$ $F_c = 0$

At point A, $|F_A| = 2Q\left[\frac{1}{4\pi\varepsilon_0}\cdot\frac{3Q/2}{x^2}\right].$

$F = \frac{3Q^2}{4\pi\varepsilon_0 x^2},$ away from shell

Electric flux through the shell,

$\Phi = \frac{1}{\varepsilon_0}$ x magnitude of chargr enclosed by shell

$= \frac{1}{\varepsilon_0} \times \frac{Q}{2} \Rightarrow \Phi = \frac{Q}{2\varepsilon_0}$

82) Radius of sphere A = R

Surface charge density on sphere A = σ

Radius of sphere B = 2R

Surface charge density on sphere B = σ

Before contact, the charge on sphere A is

Q_1 = Surface charge density x Surface area

$\Rightarrow Q_1 = \sigma. 4\pi R^2 \quad ...(i)$

Before contact, the charge on sphere B is

Q_2 = Surface charge density x Surface area

$Q_2 = \sigma 4\pi (2R)^2 = \sigma. 16\pi R^2 ...(ii)$

Let after the contact, the charge on A be Q'_1 and the charge on B Q'_2 .

According to the conservation of charge, the charge before contact is equal to charge after contact.

$Q'_1 + Q'_2 = Q_1 + Q_2$

Putting the values of Q_1 and Q_2 from Eqs. (i) and (ii), we get

$Q'_1 + Q'_2 = 4\pi R^2\sigma + 16\pi R^2\sigma = 20\pi R^2\sigma \quad ...(iii)$

As they are in contact. So, they have same potential.

Potential on sphere A is $V_A = \frac{1}{4\pi\varepsilon_0} . \frac{Q'_1}{R}$

Potential on sphere B is $V_B = \frac{1}{4\pi\varepsilon_0} . \frac{Q'_2}{2R}$

So, $V_A = V_B$

$$\Rightarrow \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_1'}{R} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_2'}{2R}$$

$$\Rightarrow \frac{Q_1'}{R} = \frac{Q_2'}{2R}$$

$$\Rightarrow 2Q_1' = Q_2' \quad ....(iv)$$

Putting the value of Q'_2 in Eq. (iii), we get

$$Q_1' + 2Q_1' = 20\pi R^2\sigma \Rightarrow 3Q_1' = 20\pi R^2\sigma$$

$$\Rightarrow Q_1' = \frac{20}{3}\pi R^2\sigma$$

and $Q_2' = \frac{40}{3}\pi R^2\sigma$ [from eq.(iv)]

Let the new charge densities be σ_1 and σ_2

$$\sigma_1 = \frac{Q_1'}{4\pi R^2} = \frac{20\pi R^2\sigma}{3 \times 4\pi R^2} = \frac{5}{3}\sigma$$

$$\sigma_2 = \frac{Q_2'}{4\pi (2R)^2} = \frac{40\pi R^2\sigma}{3 \times 4\pi \times 4R^2} = \frac{40\sigma}{16 \times 3}$$

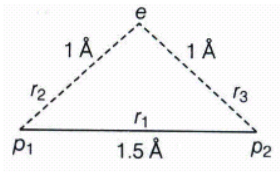
$$\sigma_2 = \frac{10\sigma}{4 \times 3} = \frac{5}{6}\sigma$$

Thus, the surface charge densities on spheres after contact are $\frac{5}{3}\sigma \text{ and } \frac{5}{6}\sigma.$

83) There are two protons p_1 and p_2 with an electron e.

Distance between two protons id given by

$r_1 = 1.5\overset{o}{A} = 1.5 \times 10_{-10}$ m



Distance between proton p_1 and electron e is given by

$r_2 = 1\overset{o}{A}$

$= 1 \times 10^{-10}$ m

Distance between proton p_2 and electron e is given by

$r_3 = 1\overset{o}{A}$

$=1 \times 10^{-10}$ m

The total potential energy of the system,

$$U = \frac{1}{4\pi\varepsilon_0}.\left[\frac{q_{p1}q_{p2}}{r_1} + \frac{q_{p1}q_e}{r_2} + \frac{q_{p2}q_e}{r_{13}}\right]......(i)$$

Given $q_{p1} = q_{p_2}$

$= 1.6 \times 10^{-19}$ C

and $q_e = -1.6 \times 10^{-19}$ C

Putting these values in Eq.(i), we get

$$U = 9 \times 10^9\left[\frac{1.6\times10^{-19}\times1.6\times10^{-19}}{1.5\times10^{-10}...} + \frac{\left(1.6\times10^{-19}\right)\times\left(-1.6\times10^{-19}\right)}{10^{-10}} + \frac{1.6\times10^{-19}\times\left(-1.6\times10^{-19}\right)}{10^{-10}}\right]$$

$$= \frac{9\times10^9\times1.6\times1.6\times10^{-38}}{10^{-10}}\left[\frac{1}{1.5} - 1 - 1\right]$$

$= -30.72 \times 10^{-19}$ J

$$= \frac{-30.72\times10^{-19}}{1.6\times10^{-19}}\text{eV} = -19.2\text{eV}$$

Here, we use that potential energy at infinity is zero.

84)

$We\ know\ that, E_{axial} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\rho r}{(r^2 - r^2)^2}$

$Case I,$

$When\ r = 10cm = 0.1m$

$E_{axial} = 3.75 \times 10^5 N/C$

$3.75 \times 10^5 = 9 \times 10^5 \times \frac{2\rho \times 0.1}{[(0.1)^2 - a^2]^2} \ldots\ldots (i)$

$Case\ II,$

$When\ r = 20cm = 0.2m$

$E_{axial} = 3 \times 10^4 \times \frac{2\rho \times 0.2}{[(0.2)^2 - a^2]^2} \ldots\ldots\ldots (ii)$

Solving the Eqs. (i) and (ii), we get

a = 0.05 m

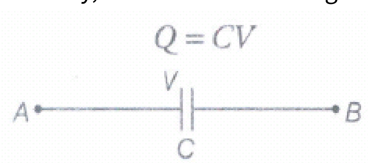
Therefore, lemgth of the dipole is 2z.

So, 2a = 2 x 0.05

or 2a = 0.1 m

85)

Initially, if we consider a charged capacitor, then its charge would be

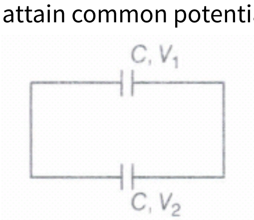


and energy stored is

$U_1 = \frac{1}{2}CV^2$ ....(i)

Then, this charged capacitor is connected to unchanged capacitor.

Let the common potential be V_1 . The charge flows from first capacitor to the other capacitor unless both the capacitors attain common potential



$Q_1 = CV_1$ and $Q = CV_2$

Applying conservation of charge,

$Q = Q_1 + Q_2$

$\Rightarrow CV = CV_1 + CV_2$

$\Rightarrow V = V_1 + V_2$

$\Rightarrow V_1 = \frac{V}{2}$

Total energy stored, $U_2 = \frac{1}{2}CV_1^2 + \frac{1}{2}CV_2^2$

$= \frac{1}{2}C\left(\frac{V}{2}\right)^2 + \frac{1}{2}C\left(\frac{V}{2}\right)^2 \Rightarrow U_2 = \frac{1}{4}CV^2$ ....(ii)

From Eqs. (i) and (ii), we get

$U_2 < U_1$

Hence, energy stored in the combination is less than that stored initially in single capacitor.

86) (i) Total potential difference across each row = 1000 V

Potential difference across each capacitor = 400 V

Number of capacitors in series,

$n = \frac{1000}{400} = 2.5 \approx 3$

Capacitance of capacitors in series, $C_s = \frac{1}{3}\mu F$

Let m be rows of capacitors, for an equivalent capacitance of $2\mu F$, we have

$m \times \frac{1}{3} = 2 \Rightarrow m = 6$

Hence, total number of capacitance required

= m x n = 6 x 3 = 18

Total 6 rows of capacitor in parallel with three capacitors in each row.

(ii) We think that Shikhaj knows the value of money and have the ability to calculate scientifically in daily life.

87)

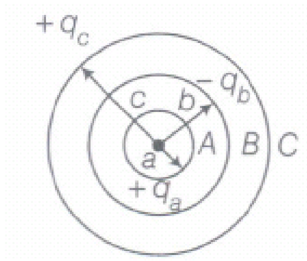
(i) Electrical energy is stored in the capacitor.It is stored in the dielectric.

(ii) No effect. When the metal sheet is placed in the middle the new arrangement is equivalent to a old combination of two capacitors each of plate separation $\frac{d}{2}$ and hence capacitance 2C.

$C_S = \frac{2C \times 2C}{2C + 2C} = C$

(iii) Team work, concern, respect to teacher and responsibility.

88)



(i) Potential of three shells

At shell A

Potential,

$V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_a}{a} - \frac{q_b}{b} + \frac{q_c}{c}\right]$

$= \frac{1}{4\pi\varepsilon_0}\left[\frac{4\pi a^2\sigma}{a} - \frac{4\pi b^2\sigma}{b} + \frac{4\pi c^2\sigma}{c}\right]\left(\because \sigma = \frac{q}{4\pi r^2}\right)$

$= \frac{\sigma}{\varepsilon_0}(a - b + c)$

At shell B

Potential, $V_B = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_a}{a} - \frac{q_b}{b} + \frac{q_c}{c}\right]$

$= \frac{1}{4\pi\varepsilon_0}\left[\frac{4\pi a^2\sigma}{b} - \frac{4\pi b^2\sigma}{b} + \frac{4\pi c^2\sigma}{c}\right]\left[\because \sigma = \frac{q}{4\pi r^2}\right]$

$= \frac{\sigma}{\varepsilon_0}\left[\frac{a^2 - b^2}{b} + c\right]$

At shell C

Potential, $V_C = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_a}{c} - \frac{q_b}{c} + \frac{q_c}{c}\right)$

$= \frac{1}{4\pi\varepsilon_0}\left(\frac{4\pi a^2\sigma}{c} - \frac{4\pi b^2\sigma}{c} + \frac{4\pi c^2\sigma}{c}\right)\left[\because \sigma\frac{q}{4\pi r^2}\right]t)$

$= \frac{\sigma}{\varepsilon_0}\left(\frac{a^2 - b^2 + c^2}{c}\right)$

(ii) Relation between the radii Now,

Now, $V_A = V_C$ (given)

$\frac{\sigma}{\varepsilon}(a - b + c) = \frac{\sigma}{\varepsilon}\frac{\left(a^2 - b^2 + c^2\right)}{c}$

$a - b + c = \frac{a^2 - b^2 + c^2}{c} = \frac{a^2 - b^2}{c} + c$

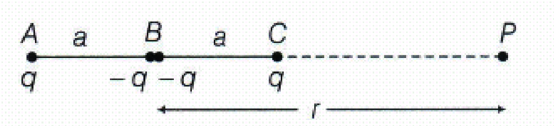
$c(a - b) = a^2 - b^2$

$\Rightarrow \ c = a + b\left[\because \left(a^2 - b^2\right) = (a - b)(a + b)\right]$

89)

Given, AC = 2a, BP = r

AP = r + a and PC = r-a



The potential at P is V.

∴ V = Potential at P value due to A+ Potential at P due to B + Potential at P due to C

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AP} - \frac{2q}{BP} + \frac{q}{CP}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}.\,q\left[\frac{1}{(r+a)} - \frac{2}{r} + \frac{1}{(r-a)}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{r(r-a) - 2(r+a)(r-a) + r(r+a)}{r(r+a)(r-a)}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{r^2 - ra - 2r^2 + 2a^2 + r^2 + ra}{r\left(r^2 - a^2\right)}\right]$$

$$= \frac{q\cdot 2a^2}{4\pi\varepsilon_0 r\left(r^2 - a^2\right)} = \frac{q\cdot 2a^2}{4\pi\varepsilon_0\cdot r\cdot r^2\left(1 - \frac{a^2}{r^2}\right)}$$

According to the question,

If r/a > > 1 Therefore, V = $\frac{q.2a^2}{4\pi\varepsilon_0 . r^3} \Rightarrow V \propto \frac{1}{r^3}$

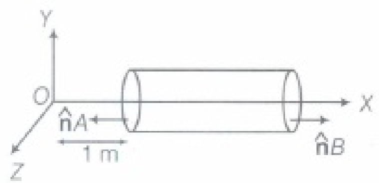
As, we know that electric potential at a point on axial line due to an electric dipole is

$V \propto \frac{1}{r^2}$

In case of electric monopole, $V \propto \frac{1}{r}$.

Then, we conclude that for larger r, the electric potential due to quadrupole is inversely proportional to the cube of the distance r, while due to an electric dipole, it is inversely proportional to the square of r and inversely proportional to the distance r for a monopole.

90)



Given, E = 50 x $\hat{i}$

and ΔS = 25 cm^2

= 25 $\times$ 10^{-4} m^2

As the electric field is only along the X-axis, so flux will pass only through the cross-section of cylinder.

Magnitude of electric field at cross-section A,

E_A = 50 $\times$ 1 = 50 N C^{-1}

Magnitude of electric field at cross-section B,

E_B = 50 $\times$ 2 = 100 NC^{-1}

The corresponding electric fluxes are

$\phi_A = E_A . \Delta S = 50 \times 25 \times 10^{-4} \times cos180^o$

= -0.125 N-m^2 C^{-1}

$\phi_B = E_B . \Delta S = 100 \times 25 \times 10^{-4} \times cos0^o$

= 0.25 N - m^2 C^{-1}

So, the net flux through the cylinder,

$\phi = \phi_A + \phi_B$ = -0.125 + 0.25

= 0.125 N - m^2 C^{-1}

(ii) Using Gauss' law,

$\oint E. dS = \frac{q}{\varepsilon_0}$ [$\therefore \oint E . dS = \phi$]

$\Rightarrow$ $0.125 = \frac{q}{8.85 \times 10^{-12}}$

$\Rightarrow$ q = 8.85 $\times$ 0.125 $\times$ 10^{-12}

= 1.1 $\times$ 10^{-12} C .

91)

In the circuit, when initially K_1 is closed and K_2 is opened, the capacitors C_1 and C_2 acquire potential difference V_1 and V_2, respectively. So we have

$V_1 + V_2 = E$

and $V_1 + V_2 = 9V$

Also, in series combination, $V \alpha 1/C$

$V_1 : V_2 = 1/6 : 1/3$

On solving,

$\Rightarrow \quad V_1 = 3V and V_2 = 6V$

$\therefore$ $Q_1 = C_1 V_1 = 6\mu C \times 3 V$

$= 18\mu C$ [$\because$ C = 1 μF]

$\Rightarrow$ $Q_2 = C_2V_2 = 3\mu C \times 6V = 18\mu C$

and $Q_3 = 0$

Then, K_1 was opened and K_2 was closed, the parallel combination of C_2 and C_3 is in series with C_1 .

[Charge on C_1 remains unchanged]

i.e. $Q'_1 = Q_2 = 18\mu C$

Charge on C_2 is shared between C_2 and C_3 in parallel.

As, $C_2 = C_3$

$Q_2^{'} = Q_2 = \frac{Q_2}{2} = \frac{18}{2} = 9\mu C$

$\therefore$ [$\because$ $Q_2 = 18\ \mu C$]

92) (i) $\frac{\left(2\sqrt{2}+1\right)q}{8\Pi\varepsilon a^2}$

(ii) 19.4 N , 21.8^0 above X-axis

93)

The values displayed by Geeta are curiosity, leadership and compassion.

Frictional electricity Frictional electricity is the electricity produced by rubbing two suitable bodies and transfer of electrons from one body to other.

Further, if the hair are oily or wet, then the friction between the hair and comb reduces and the comb will not attract small bits of paper.

94)

Yes, it is true. Every conductor/insulator is electrically neutral, as it contains equal amounts of positive charge and negative charge.

This statement is true. Charging lies in charge imbalance. When a body loses some electrons, it becomes positively charged because it has excess of protons over electrons. The reverse is also true.

Nature/God has created the universe. In original, all bodies are neutral with no forces of attraction/repulsion. When interests of any two persons clash (i.e. two bodies are rubbed against each other), they become charged. From the charging, the forces of attraction/repulsion arises, i.e. pulls and pressures of life.

Nature/God wants us to live in peace without stress and tensions in life. We get charged over petty things in life and invite all sorts of pulls, pressures and tensions.

95)

(i) Student A, because he is aware of the latest technology and its applications.

(ii) **Electrostatic force** The force of interaction between any two point charges is directly proportional to the square of the distance between them.

(iii) A photocopier/fax is one of the many industrial applications of the forces of attraction and repulsion between charged particles/bodies. Particles of black powder, called toner stick to a tiny carrier bead of the machine due to electrostatic forces between them. The negatively charged toner particles get attracted from carrier bead to a rotating drum, where an image [positively charged] of document being copied has formed. A charged sheet of paper then attracts the toner particles from the drum to itself. Finally, they produce photocopy.

96)

(i) τ = pE sinθ can be rewritten in vector form as τ = p × E

Therefore, the direction of torque τ is perpendicular to both p and E. It is determined by right handed screw rule.

(ii) Here, 2a = 10 cm = 10^{-1} m,

q = 6×10^{-3} C, $\theta = 30^o$

$\tau = 6\sqrt{3}$ N-m,E = ?

From τ = pE sinθ = q(2a)E sinθ

$6\sqrt{3} = 6 \times 10^{-3}\left(10^{-1}\right)$ Esin30^o

$6\sqrt{3} = 6 \times 10^{-4} \times E \times \frac{1}{2} \Rightarrow 6\sqrt{3} = 3 \times 10^{-4}E \Rightarrow$ E = $\frac{6\sqrt{3}}{3 \times 10^{-4}} = 2\sqrt{3} \times 10^4$ NC_{-1}

(iii) From the given paragraph, we find that electric dipole held in an external electric field will be in stable equilibrium only when it is aligned along the external electric field. The same is true in day-today life.

At your work place, your boss always tries to align you along his/her paln. Your job/position is secured/stable after you are perfectly aligned and your personal whims are at the lowest ebb.

97)

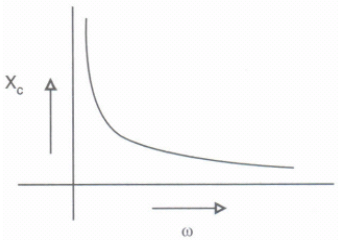
Due to electrostatic shielding, the person in the car was not affected (electric field inside the metallic body is zero).

Helping others, taking a quick decision as to wha is to be done, in case, he is unaware or unable to do on his own.

Lighting is a massive electostatic discharge between electrically charged regions within the clouds or between a cloud and the earth's surface.

As $\phi = \frac{q}{\varepsilon_0}$, therefore, electric flux over the surface will be zero because net charge enclosed by a surface is zero.

98)



The magnitudes of the electric fields due to the two charges + q and - q are given by

$$E_{+q} = \frac{q}{4\pi\epsilon_0}\frac{1}{r^2+2a^2}$$

$$E_{-q} = \frac{q}{4\pi\epsilon_0}\frac{1}{r^2+2a^2}$$

and both are equal The directions of E_{+q} and E_{-q} are as shown in fig. Clearly, the components normal to the dipole axis cancel away. The components along the dipole axis add up. The total electric field is opposite to $\hat{p}$. We have

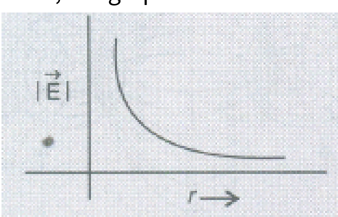
E = - (E_{+q}+ E_{-q}) cos $\theta\,\hat{p}$

$$= \frac{-2qa}{4\pi\epsilon_0(r^2+a^2)^{\frac{3}{2}}}\hat{p}$$

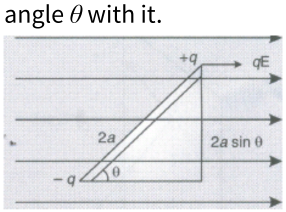
At large diatances (r > > a), this reduces to

$$= \frac{-2qa}{4\pi\epsilon_0(r^3)}\hat{p} \text{ (r > > a)}$$

Thus, the graph takes the form as shown below:



Electric dipole of charges +q and -q separated by distance 2a is shown in figure. It is placed in uniform electric field at an angle θ with it.



Torque on dipole= force x perpendicular distance

= qE x 2a sinθ

= 2 qa E sin θ

= pEsin θ

$\vec{\tau} = \vec{p} \times \vec{E}$

99)

(a) Observation, eagerness to learn.

(b) Both the legs of the bird are at same voltage and hence no current passes; to receive a shock there must be a potential difference between one part of the body and another; if a person hangs from a high voltage wire without touching anything else, he can be quite safe and would not feel shocked.

100)

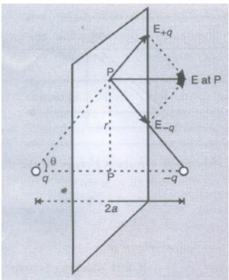
(a) **Electric dipole moment :** The strength of an electric dipole is measured by the quantity electric dipole moment. Its magnitude is equal to the product of the magnitude of either charge and the distance between the two charges.

Electric dipole moment, p = q x d

It is a vector quantity.

In vector form, it is written as $\vec{p}$ = q x 2 $\vec{a}\hat{p}$ where direction of 2 $\vec{a}\ \hat{p}$ is from negative charge to positive charge.

Electric field of dipole at points on the equatorial plane :



The magnitudes of the electric field due to the two charges +q and -q are given by,

$E_{+q} = \frac{q}{4\pi\epsilon_0}\frac{1}{(r^2+a^2)}$ ....(i)

$E_{-q} = \frac{q}{4\pi\epsilon_0}\frac{1}{(r^2+a^2)}$ ....(ii)

∴ $E_{+q} = E_{-q}$

The direction of E_{+q} and E_{-q} are as shown in the figure. The components normal to the dipole axis cancel away. The components along the dipole axis add up.

∴ Total electric field E = - (E_{+q}+ $E_{\_q}$) cos q $\hat{p}$

[Negative sign shows that field is opposite to $\hat{p}$]

$E = \frac{-2qa}{4\pi\epsilon_0(r^2+a^2)^{3/2}}\hat{p}$ ....(iii)

At large distances (r > > a), this reduces to

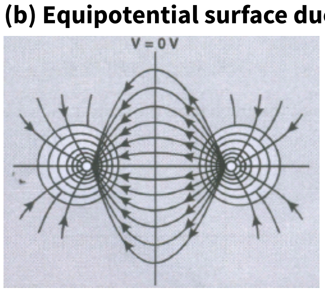
$E = \frac{2qa}{4\pi\epsilon_0 r^3}\hat{p}$ ....(iv)

= 2qa$\hat{p}$

∴ = $\vec{p}$

∴ $E = \frac{-\vec{p}}{4\pi\epsilon_0 r^3}$ (r > > a)

(b) Equipotential surface due to electric dipole:



The potential due to the dipole is zero at the line bisecting the dipole length

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101)

Because during thunder storm car would act as an electrostatic shield.

Dr. Pathak displayed values of safety of human life, helpfulness, empathy and scientific temper. (or any other two relevant values).

Gratefulness, indebtedness. (or any other relevant value)

I once came across to a situation where a puppy was struck in the middle of a busy road during rain and was not able go cross due to heavy flow, so I quickly rushed and helped him

102)

(a) Helping, sharing, respect for elderly people.

(b) For a body to get positively charged, a negatively charged body has to brought close to the neutral body which after earthing gets charged uniformly.

103)

Concentration & involvement in the work by the doctor, reply by the doctor answering the querry without forgetting, observation of the medical attendant.

Yes, charge.

Electrostatic force.

104)

Student A because, he is aware of the latest technology and its applications.

Electrostatic force.

105)

(a) (i) Presence of mind.

(ii) Ability to take prompt decisions.

(iii) Sense of responsibility

(b) Given, $q_1 = 5\mu.C = 5 \times l0^{-9}C$

$q_2 = -2\mu.C = -2 \times l0^{-9}C$.

The distance between the charges

$= x = x_2 - x_1$

= 23 cm - 5cm

= 18 cm

= 0.18 m

Thus, electrostatic potential energy of charges

$$U = \frac{1}{4\pi\epsilon_0} . \frac{q_1 q_2}{x}$$

$$= \frac{9 \times 10^9 \times 5 \times 10^{-9} \times -2 \times 10^{-9}}{0.18}$$

$$= \frac{-9 \times 10^{-8}}{18 \times 10^{-2}}$$

$= - 5 \times 10^{-7}$ J

106)

(a) Customer care, commitment, concern and truthfulness.

(b) Droplets of paint are charged particles which get attracted to any metallic objects by electrostatic forces.

107)

(a) In the given network, C_1, C_2 and C_3 are connected in series. The effective capacitance C′ of these three capacitors is given by

$$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

For $C_1 = C_2 = C_3 = 10$ μF, C′ = (10/3) μF. The network has C′ and C_4 connected in parallel. Thus, the equivalent capacitance C of the network is

$$C = C' + C_4 = \left(\frac{10}{3} + 10\right)\mu F = 13.3\mu\text{F}$$

(b) Clearly, from the figure, the charge on each of the capacitors, C_1, C_2 and C_3 is the same, say Q. Let the charge on C_4 be Q′. Now, since the potential difference across AB is Q/C_1, across BC is Q/C_2, across CD is Q/C_3 , we have

$$\frac{B}{C_1} + \frac{B}{C_2} + \frac{B}{C_3} = 500 \text{ V}$$

Also, $Q'/C_4 = 500$ V.

This gives for the given value of the capacitances

$Q = 500 \text{ V} \times \frac{10}{3}\mu\text{F} = 1.7 \times 10^{-3}\text{C}$ and

$Q' = 500$ V x 10 μF = 5.0 x10^{-3} C

108)

(a) (i) Ability to take prompt decision.

(ii) Presence of mind.

(ii)Knowledge of subject matter.

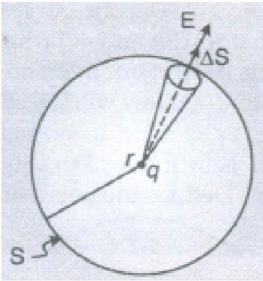
(b) When we supply charge to a capacitor continuously, the potential difference between its plates goes on increasing, consequently a stage will come when the electric field between the plates will exceed the dielectric strength of medium, puncturing the dielectric. Thus it will break the dielectric into positive and negative charges and so the capacitor will be discharged showing sparking.

109)

(a) Electric flux through a closed surface S = $\frac{q}{\epsilon_0}$

q = total charge enclosed by S.

Proof : Let us consider the total flux through a sphere of radius r, which encloses a point charge q at its centre. Divide the sphere into small area elements, as shown in Fig.



The flux through an area element ΔS is

$\Delta\phi = \vec{E}.\Delta\vec{S} = \frac{q}{4\pi\epsilon_0 r^2}\hat{r}.\Delta\vec{S}$

where we have used Coulomb's law for the electric field due to a single charge q. The unit vector $\hat{r}$ is along the radius vector from the centre to the area element. Now, since the normal to a sphere at every point is along the radius vector at that point, the area element Δ S and $\hat{r}$ have the same direction. Therefore,

$\Delta\phi = \frac{q}{4\pi\epsilon_0 r^2}.\Delta S$

since the magnitude of a unit vector is 1.

The total flux through the sphere is obtained by adding up flux through all the different area elements :

$\Delta\phi = \quad \Sigma all\Delta s\frac{q}{4\pi\epsilon_0 r^2}.\Delta S$

Since each area element of the sphere is at the same distance r from the charge,

$\Delta\phi = \frac{q}{4\pi\epsilon_0 r^2} \quad \Sigma all\Delta s\Delta S = \frac{q}{4\pi\epsilon_0 r^2}S$

Now S, the total area of the sphere, equals $4\pi r^2$. Thus,

$\Delta\phi = \frac{q}{4\pi\epsilon_0 r^2} \times 4\pi r^2 = \frac{q}{\epsilon_0}$

(b) Let ρ be the uniform density of negative charge. We then have

$\frac{4\pi a^3\rho}{3} = Ze$

$\therefore\ \rho = (\frac{3Ze}{4\pi a^3})$

Taking a sphere of radius r (centred at the nucleus) as the Gaussian surface, we have

$E(r) \times 4\pi r^2 = \frac{q}{\epsilon_0}$

Where Q is the net charge enclosed by the Gaussian surface. Now

$Q = (+Ze) + (-\rho.\frac{4\pi r^3}{3})$

$= Ze - Ze(\frac{r^3}{a^3}) = Ze(1 - \frac{r^3}{a^3})$

Substituting this value of Q, we get

$E(r) = \frac{Ze}{4\pi\epsilon_0 r^2}(1 - \frac{r^3}{a^3})$

$= \frac{Ze}{4\pi\epsilon_0}(\frac{1}{r^3} - \frac{1}{a^3})$

110)

(a) (i) Ability to take prompt decision.

(ii) Knowledge of subject matter.

(iii) Proper responsibility.

(b) If there is no current in the circuit, the capacitor may have charge. So, by handling a charged capacitor a person may get a severe shock. Thus, the circuit containing a capacitor must be handled carefully.

111) (a) Team work, concern, respect to teacher and responsibility.

(b) Electrical energy in the dielectric of the capacitor

112) (a) Electric flux is defined as the number of electric field lines passing through an area normal to the surface.

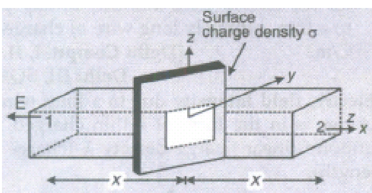
Alternatively

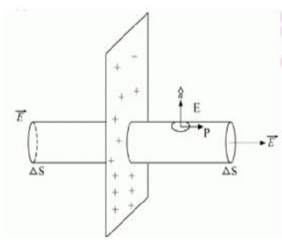
Surface integral of the electric field is defined as the electric flux through a closed surface

$\phi = \oint \vec{E}.\vec{ds}$

SI unit : $\frac{N.m^2}{C}$ or volt. metre

(a)





Outward flux through the Gaussian surface, is

$2EA = \sigma A/\epsilon_0$

$\therefore \quad E = \sigma A/2\epsilon_0$

Vectorically $\vec{E} = \frac{\sigma}{2\epsilon_0}\hat{n}$,

where $\hat{n}$ is a unit vector normal to the plane, away from it.

Hence, electric field is independent of the distance from the sheet.

(c) For positively charged sheet $\longrightarrow$ away from the sheet

For negatively charged sheet $\longrightarrow$ towards the plane sheet

113)

(a) Electric flux over an area in an electric field represents the total number of electric field lines crossing this area and is given by theproduct of surface area and the component of electric field intensity normal to the area.

The S.1.unit of flux is $Nm^2 C^{-1}$

(b) Let point P_1 is at a distance R from the centre O. S_1 isthe Gaussian surface, then according to Gauss's theorem

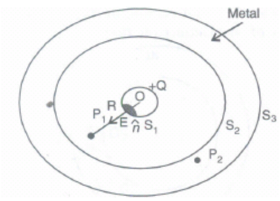
$\oint_s \vec{E}.\overrightarrow{ds} = \oint_s \vec{E}.\hat{n}ds = \frac{q}{\epsilon_0}$

or $E\oint_s ds = \frac{q}{\epsilon_0}$

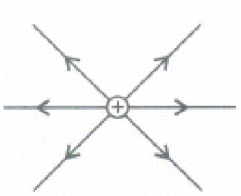
or $E = \frac{q}{\epsilon_0 \times \oint_s ds}$

= $\frac{q}{4\pi\epsilon_0 R^2}$ [As$\oint sds = 4\pi r^2$]

Inside the shell the net charge is zero, so the field is also zero.

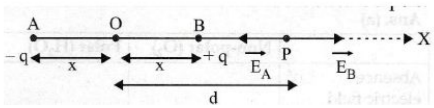


(c) The direction of electric field is shown in figure.



114)

(a) Consider an electric dipole of charges +q and - q separated by 2x distance being placed in free space. Let P be the point at which the electric field is to be determined due to the electric dipole.



The electric field $\vec{E}$ at P is given by

$\vec{E}=\vec{E_A}+\vec{E_B}$

$\left|\vec{E_A}\right|=\frac{1}{4\pi\varepsilon_0}\frac{q}{(d+x)^2}$

$\left|\vec{E_B}\right|=\frac{1}{4\pi\varepsilon_0}\frac{q}{(d-x)^2}$

From diagram, it is clear that $\vec{E_A}<\vec{E_B}$ and they are opposite in direction. Hence,

E= $\left|\vec{E}\right|=\left|\vec{E_B}-\vec{E_A}\right|$

$\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(d-x)^2}-\frac{q}{(d+x)^2}\right]$

$\frac{1}{4\pi\varepsilon_0}\frac{q\times 4dx}{(d^2-x^2)^2}$

$\frac{1}{4\pi\varepsilon_0}\frac{2Pd}{(d^2-x^2)^2}$

Whenx< $E_{axial}=\frac{1}{4\pi\varepsilon_0}\frac{2P}{d^3} along Px$

$Potential(V)=\frac{E_{axial}}{d}.d$

$\frac{1}{4\pi\varepsilon_0}\frac{2P}{d^2}$

(b) The capacitor can be considered as split into two capacitor connected in parallel.

Here $C_1=\frac{K_1\varepsilon_0 l}{2d} and C_2=\frac{K_1\varepsilon_0 l}{2d}$

In parallel combination,

$C_{eq}=C_1+C_2$

$\frac{K_1\varepsilon_0 l}{2d}+\frac{K_2\varepsilon_0 l}{2d}$

$\frac{\varepsilon_0 l}{2d}\left(K_1+K_2\right)$

From this figure

$C_{eq}=\frac{K_2\varepsilon_o l}{2d}$

From eqns. (i) & (ii)

$\frac{K_1\varepsilon_0 l}{2d}=\frac{\varepsilon_o l}{2d}\left(K_1+K_2\right)$

$K=K_1+K_2$

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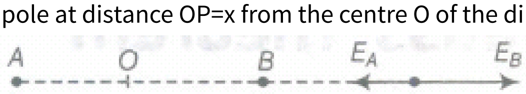
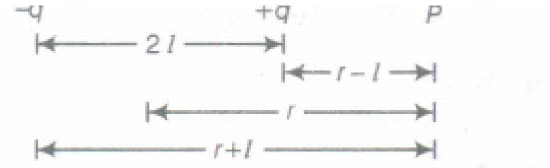
115)

(i) Electric field due to dipole at axial point We have to calculate the field intensity E at a point P on the axial line of the dipole at distance OP=x from the centre O of the dipole.



Resultant electric field intensity at the point P is



$E_p = E_A + E_B$

The vectors E_A and E_B are collinear and opposite,

$\therefore E_p = E_B - E_A$

Here $E_A = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r+l)^2}$

$E_B = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{(r-l)^2}$

$$\therefore E_p = \frac{1}{4\pi\varepsilon_0} \cdot \left[\frac{q}{(r-l)^2} - \frac{q}{(r+l)^2}\right]$$

$$= \frac{1}{4\pi\varepsilon_0} \cdot \frac{4q \times l}{(r^2-l^2)^2}$$

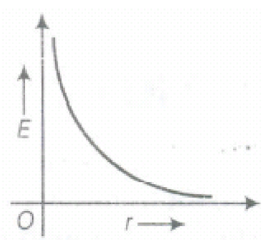
$$\therefore E_p = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2p}{(r^2-l^2)^2}$$

If the length of dipole is short i.e. 2l< $E_p = \frac{2p}{4\pi\varepsilon_0 \cdot r^3}$

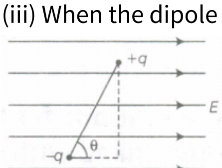
The direction of E_p is along BP produced.

So, $E_p \propto \frac{1}{r^3}$

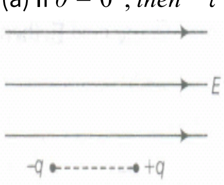
(ii)$E \propto \frac{1}{r^3}$ As r will increase, E will sharply decrease. The shape of the graph will be as given in the figure



(iii) When the dipole were kept in a uniform electric field E_o.The torque acting on dipole, $\tau = p \times E$(1)

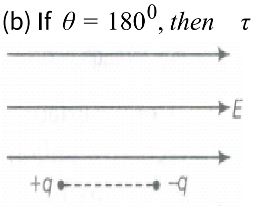


(a) If $\theta = 0^0$, *then* $\tau = 0, \quad p||E$



The dipole is in stable equilibrium,

(b) If $\theta = 180^0$, *then* $\tau = 0, \quad p|| - E$

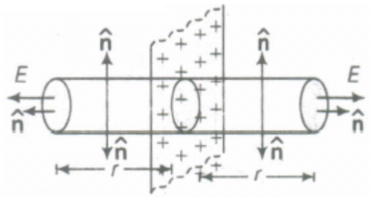


The dipole is in unstable equilibrium.

116)

According to the question, σ is the surface charge density of the sheet. From symmetry, E on either side of the sheet must be perpendicular to the plane of the sheet, having same magnitude at all points equidistant from the sheet. We take a cylinder of cross-sectional area A and length 2r as the Gaussian surface. On the curved surface of the cylinder, E and n are perpendicular to each other.

Therefore, the flux through the curved surface of the cylinder = 0.



Flux through the flat surfaces = EA + EA = 2EA The total electric flux over the entire surface of cylinder.

$\phi_E = 2EA$

Total charge enclosed by the cylinder, q=σA According to Gauss's law,

$\oint E.\, dA = \phi_E = \frac{q}{\epsilon_0}$

$\Rightarrow$ 2AE = $\frac{\sigma A}{\epsilon_0}$

E is independent of r, the distance of the point from the plane charged sheet. E at any point is directed away from the sheet for positive charge and directed towards the sheet in case of negative charge.

Surface charge density of the uniform plane sheet which is infinitely large = $+\sigma$. The electric potential (V) due to infinite sheet of uniform charge density $+\sigma$

V = $\frac{-\sigma r}{2\epsilon_0}$

The amount of work done in bringing a point charge q from infinite to point, at distance r in front of the charged plane sheet.

W = q x V = $q' = \frac{-\sigma r}{2\epsilon_0} = -\frac{\sigma r . q'}{2\epsilon_0}$ joule

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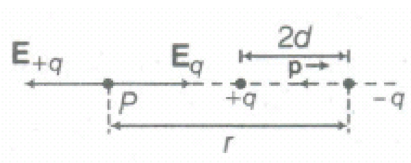
117)

Electric field on an axial line of an electric dipole



Let P be at distance r from the centre of the dipole on the side of charge - q.

Then, the electric field at point P due to charge - q of the dipole is given by

$E_{-q} = \frac{q}{4\pi\epsilon_0 (r+a)^2}\hat{p}$

where, $\hat{p}$ is the unit vector along the dipole axis (from -q toq).

Also, the electric field at point P due to charge +q of the dipole is given by

$E_{+q} = \frac{q}{4\pi\epsilon_0 (r-a)^2}\hat{p}$

The total field at point P is

$E = E_{+q} + E_{-q}$

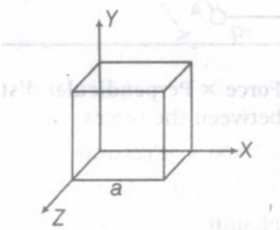
$= \frac{q}{4\pi\epsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$

$\Rightarrow$ E = $\frac{q}{4\pi\epsilon_0} . \frac{4ar}{(r^2-a^2)^2}\hat{p}$

$\because$ r = x

E $\frac{q}{4\pi\epsilon_0} \cdot \frac{4ax}{(x^2-a^2)^2}\hat{p}$

For x > > a, E = $\frac{2P}{4\pi\epsilon_0 x^3}$



Since, the electric field has only x component, for faces normal to X - direction, the angle between E and $_\Delta$S is $\pm\ \frac{\pi}{2}$.

Therefore, the flux is separately

zero for each of the cube except the shaded ones.The magnitude of the electric field at the left face is

E_l = 0 (as, x = 0 at the left face).

face is E_R = 3a (as, x = a at the right face).The corresponding fluxes are

The corresponding fluxes are

$\phi_L = E_L . \Delta S = 0$

$\phi_R = E_R . \Delta S = E_R \Delta S\ cos\ \theta = E_R \Delta\ S\ (\because \theta = 0°)$

$\Rightarrow\ \ \phi_R = E_R a^2$

Net flux (ϕ) through the cube

$= \phi_L + \phi_R$

= 0 + $E_R a^2$.

= $E_R a^2$

q = 2a $(a)^2$ = $2a^3$

We can use Gauss' law to find the total charge q inside the cube.

$\phi = \frac{q}{\epsilon_0}$

$\therefore\ \ \phi = \phi E_0 = 2a^3\epsilon_0$

---

118)

E lectric flux over an area in an electric field represents the total number of electric field lines crossing the area. The SI unit of electric flux is Nm^2C^{-1}.

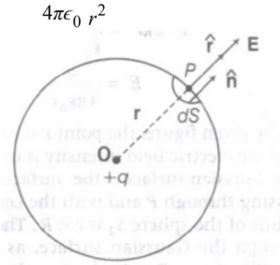
According to Gauss' law in electrostatics, the surface integral of electrostatic field E produced by any sources over any dosed surface S enclosing a volume V in vacuum, i.e. total electric flux over the closed surface S in vacuum, is 1/ Eo times the total charge (q) contained inside S, i.e.

$\phi_E = \oint sE.\ dS = \frac{q}{\epsilon_0}$

Gauss' law in electrostatics is true for an closed surface, no matter what its shape or size is.

So in order to justify the above statement, suppose in isolated positive charge q is situated at the centre O of a sphere of radius r. According to Coulomb's law, electric field intensity at any point P on the surface of the sphere is

E = $\frac{q}{4\pi\epsilon_0}\frac{\hat{r}}{r^2}$



where, $\hat{r}$ is unit vector directed from O to P. Consider a small area element dS of the sphere around P. Let it be represented by the vector$dS + \hat{r}.\, dS.$

where, n is unit vector along out drawn normal to the area element.

$\therefore$ Electric flux over the area element.

$d\phi_E = E.\, dS$

= $\left(\frac{q}{4\pi\epsilon_0}.\frac{\hat{r}}{r^2}\right).(\hat{n}.\, dS)$

E.dS = $\frac{q}{4\pi\epsilon_0}.\frac{dS}{r^2}.\hat{r}.\,\hat{n}$

As normal to a surface of every point is along the radius vector at that point, therefore, $\hat{r}.\,\hat{n} = 1$

E.dS = $\frac{q}{4\pi\epsilon_0}.\frac{dS}{r^2}$

Integrating over the closed surface area of the sphere, we get total normal electric flux over the entire sphere,

$\phi_E \oint SE.\, dS = \frac{q}{4\pi\epsilon_0 r^2}\oint SdS = \frac{q}{4\pi\epsilon_0 r^2} \times total\ area$

or surface of sphere.= $\frac{q}{4\pi\epsilon_0 r^2}(4\pi r^2)$

= $\frac{q}{\epsilon_0}$

Hence, $\oint_S E.\, dS = \frac{q}{\epsilon_0},$ which proves Gauss' theorem.

Electric field inside a uniformly charged spherical shell.

According to Gauss' theorem

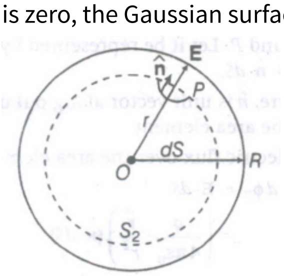
$\oint_S E.\, dS = \oint_S E\,\hat{n}.\, dS = \frac{q}{\epsilon_0}$

or $E\oint_s dS = \frac{q}{\epsilon_0}$

$\therefore \quad E.2\pi r^2 = \frac{q}{\epsilon_0}$

$\Rightarrow$ E = $\frac{q}{4\pi\epsilon_0 r^2}$ ...(i)

In the given figure, the point P where we have to find the electric field intensity is inside the shell. The Gaussian surface is the surface of a sphere S_2 passing through P and with the centre at O. The radius of the sphere S_2 is r < R. The electric flux through the Gaussian surface, as calculated in Eq. (i), i.e. E X $4\pi r^2$. As, charge inside a spherical shell is zero, the Gaussian surface encloses no charge. The Gauss' theorem gives



$E \times 4\pi\, r^2 = \frac{q}{\epsilon_0} = 0$

$\therefore$ E = 0 for r < R .

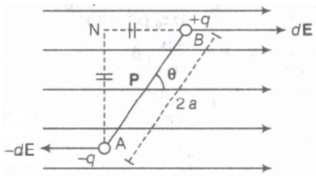
Hence, the field due to a uniformly charged spherical shell is zero at all points inside the shell.

119)

Dipole in a Uniform External field:

Consider an electric dipole consisting of charge -q and +q and of length la placed in a uniform electric field E making an angle 9 with electric field.

Force on charge -q at A = -q E(opposite to E) Electric dipole is under the action of two equal and unlike parallel force, which give rise to a torque on the .dipole.



τ = Force x Perpendicular distance

between the forces

τ = qE(AN) = qE(2a sinθ)

τ = q(la)Esinθ

τ = pEsinθ

$\therefore$ τ =P X E

Charge enclosed by sphere S_1 = 2Q

By Gauss law, electric flux through sphere

S1 is $\phi = 2\theta\epsilon_0$

Charge enclosed by shere,

S_2 = 2Q +4Q= 6Q

$\Rightarrow$ $\phi_1 = 6\theta/\epsilon_0$

The ratio of the electric flux is

$\phi_1/\phi_1 = 2Q\epsilon_0/6Q\epsilon_0$

= 2 / 6 / = 1 / 3

For sphere S_1 the electric flux is $\phi = 2Q/\epsilon_r$

$\phi^{'}/\phi_1 = 2\theta/\epsilon r + 6\phi/\epsilon_0$

= $6\phi/\epsilon_0$

= $\frac{\epsilon_0}{\epsilon r} . \frac{1}{3}$

$\therefore$ $\epsilon_1 > \epsilon_0, \phi < \phi_1$

Therefore, the electric flux through the sphere S_1 decreases with the introduction of the dielectric inside it.

---

120)

SI units of electric flux is $N\text{-}m^2C^{-1}$.

Dimensional formula of electric flux is $[M^1L^1T^{-3}A^{-1}]$.

$\phi = \frac{\Sigma q_{inside}}{\epsilon_0} = \frac{-q+3q+5q}{\epsilon_0} = \frac{7q}{\epsilon_0}$

As $\phi = \frac{q}{\epsilon_0}$, electric flux is not affected by area/shape of the surface. So, the electric flux remains unaffected.

This theorem emphasis that total normal flux from the surface depends only on algebraic sum of charges enclosed by the surface, irrespective of their location. The charges outside the surface do not affect the electric flux. In day-to-day life, the theorem implies that the knowledge you can import depends only on what you have stored within you. You cannot emanate what you have not absorbed or what lies outside your reach?

In the examination, you can write what you have learnt by heart? Extraneous help from outside by unfair means will never serve your purpose.

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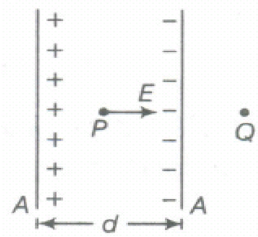
121) (i) According to question



(a) Electric field due to a plate of positive charge at point P = $\frac{\sigma}{2\varepsilon_0}$

Electric field due to other plate = $\frac{\sigma}{2\varepsilon_0}$

Since, they have same direction, so

$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

Outside the plate, electric field be zero because of opposite direction.

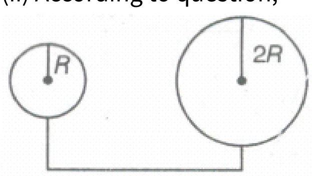
(b) Potential difference between the plates is given by

$$V = Ed = \frac{\sigma d}{\varepsilon_0} \quad \left(\because E = \frac{\sigma}{\varepsilon_0} \right)$$

(c) Capacitance of the capacitor is given by ($\because$ Q= CV)

$C = \frac{Q}{V} = \frac{\sigma A}{\sigma d}\varepsilon_0 = \frac{\varepsilon_0 A}{d}$

(ii) According to question,



Potential at the surface of radius R,

$= \frac{kq}{R} \quad [\because q = \sigma \times 4R^2]$

$\Rightarrow \frac{k\sigma 4\pi R^2}{R} = \sigma k 4\pi R = 4k\sigma\pi R$

Potential at the surface of radius 2R,

$= \frac{kq}{2R} \quad [\because q = \sigma \times 4\pi(2R)^2 = 16\sigma\pi R^2]$

$so, \quad \frac{k\sigma 16\pi R^2}{2R} = 8k\sigma\pi R$

Since, the potential of bigger sphere is more. So, charge will flow from sphere of radius 2R to sphere of radius R.

122)

As, charge on capacitor increases, we have to work more against electrostatic repulsion and this amount of work done will be stored as potential energy in the capacitor.

(i) We know that, q = CV ⇒ V = q/C

dW = Vdq = $\frac{q}{C}$dq

where, q = instantaneous charge,

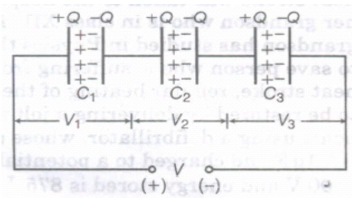
C = instantaneous capacitance and

V = instantaneous voltage

∴ Total work done in storing charge from 0 to q

is given by W =$\int_0^q \frac{q}{C} dq = \frac{q^2}{2C}$

(ii) In series combination of capacitors, same charge lie on each capacitor for any value of capacitance



Capacitors in series combination

Also, potential difference across the combination is equal to the algebraic sum of potential differences across each capacitor.

i.e. V = $V_1 + V_2 + V_3$ ......(i)

where, V_1,V_2,V_3 and V are the potential" differences across C_1,C_2,C_3 and equivalent capacitor, respectively.

∴ q = $C_1 V_1$ ⇒ $V_1 = \frac{q}{C_1}$

∴ Total potential difference [from Eq. (i)]

$$V = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$\frac{V}{q} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

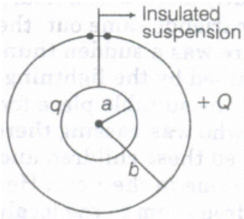
[∵ $\frac{V}{q} = \frac{1}{C}$ where C is equivalent capacitance of combination]

or $\frac{1}{C} = \frac{C_2C_3 + C_3C_1 + C_1C_2}{C_1C_2C_3}$

$$\Rightarrow C = \frac{C_1C_2C_3}{C_1C_2 + C_2C_3 + C_3C_1}$$

123)

Let small sphere has charge q and radius a is placed inside a outer shell of charge + Q and radius b



Electric potential on the small sphere due to its own charge q.

$V_1 = \frac{1}{4\pi\varepsilon_0} . \frac{q}{a}$ .....(i)

where, q = charge on small sphere

a = radius of small sphere

Similarly, electric potential on outer sphere due to its own charge

$V_2 = \frac{1}{4\pi\varepsilon_0} . \frac{Q}{b}$ ....(ii)

where, Q = charge of outer shell

b = radius of outer shell.

Also, same potential V_2 exists at every point inside outer shell due to its own charge, + Q.

Now, net electric potential at inner sphere of radius a

V_i = Electric potential due to its own charge

$V_i = \frac{1}{4\pi\varepsilon_0} \frac{q}{a} + \frac{1}{4\pi\varepsilon_0} \frac{Q}{b}$...(iii)

Net electric potential at outer sphere due to charge on the both spheres

$V_0 = \frac{1}{4\pi\varepsilon_0} \frac{q}{b} + \frac{1}{4\pi\varepsilon_0} \frac{Q}{b}$ ....(iv)

$\therefore \ V_i - V_0 = \frac{q}{4\pi\varepsilon_0} \left(\frac{1}{a} - \frac{1}{b} \right)$ ...(v)

From Eqs. (iii) and (iv). we get

$(\because \ a \frac{1}{b} \Rightarrow V_i - V_o > 0$

Thus, inner sphere has net potential higher than potential of outer sphere for every value of q and Q. Therefore, when they are connected by a wire, positive charge always flow from inner sphere (at higher potential) to outer sphere (at lower potential) irrespective of the magnitude of charge.

124)

(i) Helping attitude, kindness, concern for the children, awareness, application of 'knowledge.

(ii) As car is a good conductor, its made up of metallic body so it will behave as a lightning conductor.

(iii) The maximum electic field that can exist in a dielectric without causing the breakdown of its insulating property is called dielectric strength. It is usually expressed as volts/unit thickness.

125)

(i)Presence of mind, knowledge of subject, concern for his grandmother, empathy helping and caring.

(ii) The net charge of the capacitor in defibrillator is given by

Q=CV [where, C = capacitance V = voltage]

$\Rightarrow$ Q=70 $\times 10^{-6} \times$ 5000=35 $\times 10^{-2}$C

126)

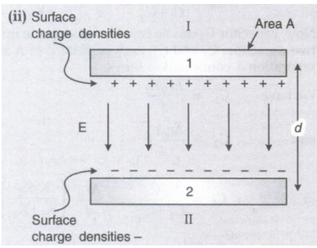
(i) Trees often being much taller than surrounding structures will attract lightning and the tree can get, on fire. The boy might get electrocuted. Also, if the lightning strikes the tree, then the tree might fall on the boy.
(ii) During thunderstorms, it is safer to sit inside a car because car has a metallic body that does not allow the lightning to hit the person sitting inside the car. We know that charges always reside on the surface of metal. Inside the conductor, charge is zero. If lightning strikes the car during a thunderstorm, the charges will be distributed on the surface of the metal body of car. No charges will exist inside the car. Hence, the person sitting inside the car is considered safe are the values displayed.
(iii) Helpfulness, Compassion, General awareness, service to others are the values displayed.
(iv) Advising a person who is doing repair work on air condition system without switching OFF the mains.
Stopping a person entering nuclear medicine ward in a hospital without proper protection or precautions.

127)

When a charge of one coulomb, produces a potential difference of one volt between the plates of capacitor, the capacitance is one farad.1 [Alternatively,

Q Q=CV= > C=-

V When Q = 1coulomb, V = 1volt



Electric field in the region between the plates of capacitor

$E=E_1=E_2$

$$= \frac{\sigma}{2E_0} + \frac{\sigma}{2E_0} = \frac{\sigma}{E_0}$$

Where c is surface charge density =$\frac{Q}{A}$

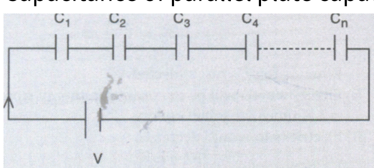
:. Potential difference between the plates

V=Ed

$$= \frac{\sigma}{E_0}d$$

$$V = \frac{Q}{E_0}d$$

Capacitance of parallel plate capacitor



$$C = \frac{Q}{V} = \frac{E_0A}{d}$$

In series combination, charge on each capacitor is

same.

Letitbe Q

$$V_1 = \frac{Q}{C_1}$$

$$V_2 = \frac{Q}{C_2}$$

$$V_n = \frac{Q}{C_n}$$

Total potential

$V=V_{1+}V_2+V_3$ +............+Vn

V=$\frac{Q}{C_1}+\frac{Q}{C_2}+\frac{Q}{C_3}+\ldots.+\frac{Q}{C_n}$

$$\frac{V}{Q} = \frac{1}{C_1}+\frac{2}{C_2}+\frac{3}{C_3}+\ldots.+\frac{Q}{C_n}$$

$$\frac{1}{C} = \frac{1}{C_1}+\frac{2}{C_2}+\frac{3}{C_3}+\ldots.+\frac{Q}{C_n}$$

128) (i) $C_A = 4\pi E_0 R, C_B = 4\pi E_0(2R)$

$C_B > C_A$

$u = \frac{1}{2}E_0 E^2$

$E = \frac{\sigma}{E_0} = \frac{Q}{AE_0}$

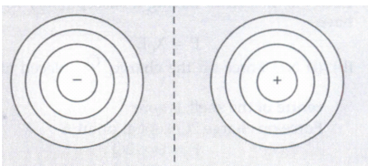
$u \infty \frac{1}{A^2}$

$u_A > u_B$

(b) (i) $E = \frac{dV}{dr}$

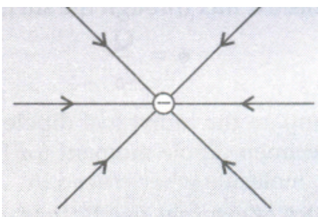
For same change in where Idr' represents the distance between equipotential surfaces.

Diagram of equipotential surface due to a dipole



V = O

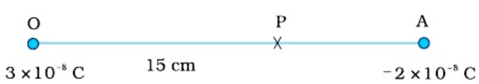
(ii) Polarity of charge-negative



The direction of electronic field is radially inwarde.

129)

Let us take the origin O at the location of the positive charge. The line joining the two charges is taken to be the x-axis; the negative charge is taken to be on the right side of the origin



Let P be the required point on the x-axis where the potential is zero. If x is the x-coordinate of P, obviously x must be positive. (There is no possibility of potentials due to the two charges adding up to zero for x < 0.) If x lies between O and A, we have

$$\frac{1}{4\pi\varepsilon_0}\left[\frac{3\times10^{-8}}{x\times10^{-2}} - \frac{2\times10^{-8}}{(15-x)\times10^{-2}}\right] = 0$$

where x is in cm. That is,

$$\frac{3}{x} - \frac{2}{15-x} = 0$$

which gives x = 9 cm

If x lies on the extended line OA, the required condition is

$$\frac{3}{x} - \frac{2}{x-15} = 0$$

which gives

x = 45 cm

Thus, electric potential is zero at 9 cm and 45 cm away from the positive charge on the side of the negative charge. Note that the formula for potential used in the calculation required choosing potential to be zero at infinity.

130)

(a) Since the work done depends on the final arrangement of the charges, and not on how they are put together, we calculate work needed for one way of putting the charges at A, B, C and D. Suppose, first the charge +q is brought to A, and then the charges –q, +q, and –q are brought to B, C and D, respectively. The total work needed can be calculated in steps

(i) Work needed to bring charge +q to A when no charge is present elsewhere: this is zero.

(ii) Work needed to bring –q to B when +q is at A. This is given by (charge at B) x (electrostatic potential at B due to charge +q at A

$$= -q \times \left(\frac{q}{4\pi\varepsilon_0 d}\right) = -\frac{q^2}{4\pi\varepsilon_0 d}$$

(iii) Work needed to bring charge +q to C when +q is at A and –q is at B. This is given by (charge at C) x (potential at C due to charges at A and B)

$$= +q\left(\frac{+q}{4\pi\varepsilon_0 d\sqrt{2}} + \frac{-q}{4\pi\varepsilon_0 d}\right)$$

$$= \frac{-q^2}{4\pi\varepsilon_0 d}\left(1 - \frac{1}{\sqrt{2}}\right)$$

(iv) Work needed to bring –q to D when +q at A,–q at B, and +q at C. This is given by (charge at D) x (potential at D due to charges at A, B and C)

$$= -q\left(\frac{+q}{4\pi\varepsilon_0 d} + \frac{-q}{4\pi\varepsilon_0 d\sqrt{2}} + \frac{q}{4\pi\varepsilon_0 d}\right)$$

$$= \frac{-q^2}{4\pi\varepsilon_0 d}\left(2 - \frac{1}{\sqrt{2}}\right)$$

Add the work done in steps (i), (ii), (iii) and (iv). The total work required is

$$= \frac{-q^2}{4\pi\varepsilon_0 d}\left\{(0) + (1) + \left(1 - \frac{1}{\sqrt{2}}\right) + \left(2 - \frac{1}{\sqrt{2}}\right)\right\} \quad = \frac{-q^2}{4\pi\varepsilon_0 d}(4 - \sqrt{2})$$

The work done depends only on the arrangement of the charges, and not how they are assembled. By definition, this is the total electrostatic energy of the charges.

(Students may try calculating same work/energy by taking charges in any other order they desire and convince themselves that the energy will remain the same.)

(b) The extra work necessary to bring a charge q_0 to the point E when the four charges are at A, B, C and D is q_0 x (electrostatic potential at E due to the charges at A, B, C and D). The electrostatic potential at E is clearly zero since potential due to A and C is cancelled by thatdue to B and D. Hence no work is required to bring any charge to point E.

131)

(a) The charge on the capacitor is

Q = CV = 900 x 10^{-12} F x 100 V = 9 x 10^{-8} C

The energy stored by the capacitor is

= (1/2) CV^2 = (1/2) QV

= (1/2) x 9 x 10^{-8}C x 100 V = 4.5 x 10^{-6} J

(b) In the steady situation, the two capacitors have their positive plates at the same potential, and their negative plates at the same potential. Let the common potential difference be V′. The charge on each capacitor is then Q′ = CV′. By charge conservation, Q′ = Q/2. This implies V′ = V/2. The total energy of the system

$= 2 \times \frac{1}{2}Q'V' = \frac{1}{4}QV = 2.25 \times 10^{-6}$ J

Thus in going from (a) to (b), though no charge is lost; the final energy is only half the initial energy.

There is a transient period before the system settles to the situation (b). During this period, a transient current flows from the first capacitor to the second. Energy is lost during this time in the form of heat and electromagnetic radiation

132) Given,

q_1 = 5 x 10^{-8} C

q_2 = -3 x 10^{-8}

The two charges are at a distance, d = 16cm = 0.16m from each other.

Let us consider a point “P” over the line joining charges q_1 and q_2.

Let the distance of the considered point P from q_1 be ‘r

Let us consider point P to have zero electric potential (V)

The electric potential at point P is the summation of potentials due to charges q_1 and q_2.

Therefore $V = \frac{1}{4\pi\epsilon_o} \cdot \frac{q_1}{r} + \frac{1}{4\pi\epsilon_o} \cdot \frac{q_2}{d-r}$ ....(i)

Here,

ϵ_o = permittivity of free space.

Putting V = 0, in eqn. (1), we get,

$$0 = \frac{1}{4\pi\epsilon_o} \cdot \frac{q_1}{r} + \frac{1}{4\pi\epsilon_o} \cdot \frac{q_2}{d-r} \quad \frac{1}{4\pi\epsilon_o} \cdot \frac{q_1}{r} = -\frac{1}{4\pi\epsilon_o} \cdot \frac{q_2}{d-r} \quad \frac{q_1}{r} = -\frac{q_2}{d-r} \quad \frac{5 \times 10^{-8}}{r} = -\frac{\left(-3 \times 10^{-8}\right)}{0.16-r}$$

5(0.16 – r) = 3r

0.8 = 8r

r = 0.1m = 10 cm.

Therefore, at a distance of 10 cm from the positive charge, the potential is zero between the two charges.

Let us assume a point P at a distance ‘s’ from the negative charge be outside the system, having potential zero.

So, for the above condition, the potential is given by –

$V = \frac{1}{4\pi\epsilon_o} \cdot \frac{q_1}{s} + \frac{1}{4\pi\epsilon_o} \cdot \frac{q_2}{s-d}$ ....(ii)

Here,

ϵ_o = permittivity of free space.

For V = 0, eqn. (2) can be written as :

$$0 = \frac{1}{4\pi\epsilon_o} \cdot \frac{q_1}{s} + \frac{1}{4\pi\epsilon_o} \cdot \frac{q_2}{s-d} \quad \frac{1}{4\pi\epsilon_o} \cdot \frac{q_1}{s} = -\frac{1}{4\pi\epsilon_o} \cdot \frac{q_2}{s-d} \quad \frac{q_1}{s} = -\frac{q_2}{s-d} \quad \frac{5 \times 10^{-8}}{s} = -\frac{\left(-3 \times 10^{-8}\right)}{s-0.16}$$

5(s – 0.16) = 3s

0.8 = 2s

S = 0.4 m = 40 cm.

Therefore, at a distance of 40 cm from the positive charge outside the system of charges, the potential is zero.

133)

Electric field on one side of a charged body is E_1 and electric field on the other side of the same body is E_2. If infinite plane charged body has a uniform thickness, then electric field due to one surface of the charged body is given by,

$$\overrightarrow{E_1} = -\frac{\sigma}{2\epsilon_0}\hat{n}$$ ....(i)

Where,

$\hat{n}$ = Unit vector normal to the surface at a point

σ = Surface charge density at that point

Electric field due to the other surface of the charged body,

$$\overrightarrow{E_2} = -\frac{\sigma}{2\epsilon_0}\hat{n}$$ ....(ii)

Electric field at any point due to the two surfaces,

$$\overrightarrow{E_2} - \overrightarrow{E_1} = \frac{\sigma}{2\epsilon_0}\hat{n} + \frac{\sigma}{2\epsilon_0}\hat{n} = \frac{\sigma}{\epsilon_0}\hat{n}$$

$$\left(\overrightarrow{E_2} - \overrightarrow{E_1}\right) \cdot \hat{n} = \frac{\sigma}{\epsilon_0}$$ ....(iii)

Since inside a closed conductor, $\overrightarrow{E_1}$ = 0,

$$\vec{E} = \overrightarrow{E_2} = -\frac{\sigma}{2\epsilon_0}\hat{n}$$

Therefore, the electric field just outside the conductor is $\frac{\sigma}{\epsilon_0}\hat{n}$

(b) When a charged particle is moved from one point to the other on a closed loop, the work done by the electrostatic field is zero. Hence, the tangential component of electrostatic field is continuous from one side of a charged surface to the other.

134)

Charge density of the long charged cylinder of length L and radius r is λ.

Another cylinder of same length surrounds the pervious cylinder. The radius of this cylinder is R.

Let E be the electric field produced in the space between the two cylinders.

Electric flux through the Gaussian surface is given by Gauss's theorem as,

ϕ = E (2π d) L

Where, d = Distance of a point from the common axis of the cylinders

Let q be the total charge on the cylinder.

It can be written as

$$\therefore \phi = E(2\pi dL) = \frac{q}{\epsilon_0}$$

Where, q = Charge on the inner sphere of the outer cylinder

ϵ_0 = Permittivity of free space

$$E(2\pi dL) = \frac{\lambda L}{\epsilon_0}$$

$$E = \frac{\lambda}{2\pi\epsilon_0 d}$$

Therefore, the electric field in the space between the two cylinders is $\frac{\lambda}{2\pi\epsilon_0 d}$

135)

(a) Zero at both the points

Charge - *q* is located at (0, 0, - a) and charge + q is located at (0, 0, *a*). Hence, they form a dipole. Point (0, 0, z) is on the axis of this dipole and point (x, y, 0) is normal to the axis of the dipole. Hence, electrostatic potential at point (x, y, 0) is zero

Electrostatic potential at point (0, 0, *z*) is given by,

$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{q}{z-a}\right) + \frac{1}{4\pi\epsilon_0}\left(-\frac{q}{z+a}\right)$$

$$= \frac{q(z+a-z+a)}{4\pi\in_0\left(z^2-a^2\right)}$$

$$= \frac{2qa}{4\pi\epsilon_0\left(z^2-a^2\right)} = \frac{p}{4\pi\epsilon_0\left(z^2-a^2\right)}$$

Where, $\in_0$ = Permittivity of free space

p = Dipole moment of the system of two charges = 2qa

(b) Distance *r* is much greater than half of the distance between the two charges. Hence, the potential (*V*) at a distance *r* is inversely proportional to square of the distance i.e. $V \propto \frac{1}{r^2}$

(c) Zero

The answer does not change if the path of the test is not along the x-axis.

A test charge is moved from point (5, 0, 0) to point (- 7, 0, 0) along the *x*-axis. Electrostatic potential (V_1) at point (5, 0, 0) is given by.

136) Area of the plates of a parallel plate capacitor, A = 90 cm^2 = 90 x 10^{-4} m^2

Distance between the plates, d = 2.5 mm = 2.5 x 10 - *3* m

Potential difference across the plates, *V* = 400 V

(a) Capacitance of the capacitor is given by the relation, $C = \frac{\epsilon_0 A}{d}$

Electrostatic energy stored in the capacitor is given by the relation, $E_1 = \frac{1}{2}CV^2$

$= \frac{1}{2}\frac{\epsilon_0 A}{d}V^2$

Where, $\in_0$ = Permittivity of free space = 8.85 × 10^{-12} C^2 N^{-1} m^{-2}

$\therefore E_1 = \frac{1 \times 8.85 \times 10^{-12} \times 90 \times 10^{-4} \times (400)^2}{2 \times 2.5 \times 10^{-3}} = 2.55 \times 10^{-6}$ J

Hence, the electrostatic energy stored by the capacitor is 2.55 x 10^{-6} J

(b) Volume of the given capacitor,

V' = A x d

= 90 x 10^{-4} x 25 x10^{-3}

=2.25 x 10^{-4} m^3

Energy stored in the capacitor per unit volume is given by,

$u = \frac{E_1}{V'}$

$= \frac{2.55 \times 10^{-6}}{2.25 \times 10^{-4}} = 0.113 \text{ J m}^{-3}$

Again, $u = \frac{E_1}{V'}$

$= \frac{\frac{1}{2}CV^2}{Ad} = \frac{\epsilon_0 A}{2d}V^2 = \frac{1}{2}\epsilon_0\left(\frac{V}{d}\right)^2$

Where,

$\frac{V}{d} =$ Electric intensity = E

$\therefore u = \frac{1}{2}\epsilon_0 E^2$

137) Radius of the outer shell = r1

Radius of the inner shell = r2

The inner surface of the outer shell has charge +Q.

The outer surface of the inner shell has induced charge - Q.

Potential difference between the two shells is given by,

$$V = \frac{Q}{4\pi \in_0 r_2} - \frac{Q}{4\pi \epsilon_0 r_1}$$

Where,

ϵ_0 = Permittivity of free space

$$V = \frac{Q}{4\pi\epsilon_0}\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$$

$$= \frac{Q\left(r_1 - r_2\right)}{4\pi \in_0 r_1 r_2}$$

capacitance of the given system is given by

$$C = \frac{\text{Charge } (Q)}{\text{Potential difference } (V)}$$

$$= \frac{4\pi \in_0 r_1 r_2}{r_1 - r_2}$$

Hence proved.

138)

Radius of the inner sphere, r_2 = 12 cm = 0.12 m

Radius of the outer sphere, r_1= 13 cm = 0.13 m

Charge on the inner sphere, q = 2.5 μC = 2.5 x 10^{-6} C

Dielectric constant of a liquid, $\in_r$ = 32

(a) Capacitance of the capacitor is given by the relation,

$$C = \frac{4\pi \in_0 \in_r r_1 r_2}{r_1 - r_2}$$

Where,

$\in_0$ = Permittivity of free space = 8.85 x 10^{-12} C^2 N^{-1} m^{-2}

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{Nm}^2\text{C}^{-2}$$

$$\therefore C = \frac{32 \times 0.12 \times 0.13}{9 \times 10^9 \times (0.13 - 0.12)}$$

$\approx$ 5.5 x 10^{-9} F

Hence, the capacitance of the capacitor is approximately 5.5 x 10^{-9} F.

(b) Potential of the inner sphere is given by,

$$V = \frac{q}{C}$$

$$= \frac{2.5 \times 10^{-6}}{5.5 \times 10^{-9}} = 4.5 \times 10^2 \text{ V}$$

Hence, the potential of the inner sphere is 4.5 x 10^2 V.

(c) Radius of an isolated sphere, r = 12 x 10^{-2} m

Capacitance of the sphere is given by the relation,

C' = $4\pi \epsilon_0$r

= 4π x 8.85 x 10^{-12} x12 x 10^{-12}

= 1.33 x 10^{-11} F

The capacitance of the isolated sphere is less in comparison to the concentric spheres. This is because the outer sphere of the concentric spheres is earthed. Hence, the potential difference is less and the capacitance is more than the isolated sphere.

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139) Length of a co-axial cylinder, l = 15 cm = 0.15 m

Radius of outer cylinder, r_1 = 1.5 cm = 0.015 m

Radius of inner cylinder, r_2 = 1.4 cm = 0.014 m

Charge on the inner cylinder, q = 3.5 μC = 3.5 x 10^{-6} C

Capacitance of a co-axial cylinder of radii r_1 and r_2 is given by the relation,

$$C = \frac{2\pi \in_0 l}{\log_e \frac{r_1}{r_2}}$$

Where,

$\in_0$ = Permittivity of free space = 8.85 x 10^{-12} x $N^{-1}m^{-2}C^2$

$$\therefore C = \frac{2\pi \times 8.85 \times 10^{-12} \times 0.15}{2.3026 \log_{10}\left(\frac{0.15}{0.14}\right)}$$

$$= \frac{2\pi \times 8.85 \times 10^{-12} \times 0.15}{2.3026 \times 0.0299} = 1.2 \times 10^{-10} \text{ F}$$

Potential difference of the inner cylinder is given by,

$$V = \frac{q}{C}$$

$$= \frac{3.5 \times 10^{-6}}{1.2 \times 10^{-10}} = 2.92 \times 10^4 \text{ V}$$

---

140) Potential rating of a parallel plate capacitor, V = 1 kV = 1000 V

Dielectric constant of a material, $\in_r=3$

Dielectric strength = 107 V/m

For safety, the field intensity never exceeds 10% of the dielectric strength.

Hence, electric field intensity, E = 10% of $10^7 = 10^6$ V/m

Capacitance of the parallel plate capacitor, C = 50 pF = 50 x 10^{-12} F

Distance between the plates is given by,

$$d = \frac{V}{E}$$

$$= \frac{1000}{10^6} = 10^{-3} \text{ m}$$

Capacitance is given by the relation,

$$C = \frac{\epsilon_0 \in_r A}{d}$$

Where,

A = Area of each plate

$\in_0$ = Permittivity of free space = 8.85 x 10^{-12} $N^{-1}C^2m^{-2}$

$$\therefore A = \frac{Cd}{\epsilon_0 \in_r}$$

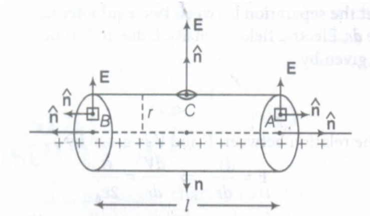
$$= \frac{50 \times 10^{-12} \times 10^{-3}}{8.85 \times 10^{-12} \times 3} \approx 19 \text{ cm}^2$$

Hence, the area of each plate is about 19 cm^2.

141)

(a) **Field due to an infinitely long thin straight charged line**

Consider an infinitely long thin straight line with uniform linear charge density (λ).



Gaussian surface for a long thin straight line of uniform charge density

From symmetry, the electric field is everywhere radial in the plane cutting the wire normally and its magnitude only depends on the radial distance (r). From Gauss' law,

$\phi_E = \oint_S \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$

Now, $\phi_E = \oint_S^S \mathbf{E} \cdot d\mathbf{S} = \oint_S \mathbf{E} \cdot \hat{\mathbf{n}} dS$

$= \oint_A E \cdot \hat{n} dS + \oint_B E \cdot \hat{n} dS + \oint_C E \cdot \hat{n} dS$

$\therefore \quad \oint_S E \cdot dS = \oint_A E^A dS \cos 90^\circ + \oint_B E dS \cos 90^\circ + \oint_C^B E dS \cos 0^\circ$

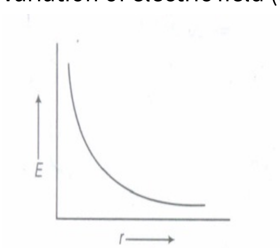
$= \oint_C E dS = E(2\pi r l)$

Charge enclosed in the cylinder, q = λl

$\therefore \quad E(2\pi \alpha l) = \frac{\lambda l}{\varepsilon_0}$ or $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

The direction of the electric field is radially outward from the positive line charge. For negative line charge, it will be radially inward.

(b) Electric field (E) due to the linear charge is inversely proportional to the distance (r) from the linear charge. The variation of electric field (E) with distance (r) is shown in figure .



(c) $v = \int E \cdot dr = \int_{r_1}^{r_2} \frac{\lambda}{2\pi\varepsilon_0 r} dr = \frac{\lambda}{2\pi\varepsilon_0} \cdot \int_{r_1}^{r_2} \frac{1}{r} dr$

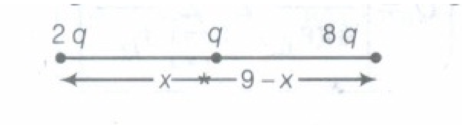
$= \frac{\lambda}{2\pi\varepsilon_0}\left[\log \frac{r_2}{r_1}\right]$

Work done

$$= qv = q\left[\frac{\lambda}{2\pi\varepsilon_0}\left(\log \frac{r_2}{r_1}\right)\right]$$

142)

Consider the given situation as shown in figure.



For potential energy to be minimum the bigger charges should be farthest. Let x be the distance of q from 2q. Then potential energy of the system shown in figure would be

$$U = K\left[\frac{(2q)(q)}{x} + \frac{(8q)(q)}{(9-x)} + \frac{(2q)(8q)}{9}\right]$$

Here, $K = \frac{1}{4\pi\varepsilon_0}$

For Uto be minimum $\frac{2}{x} + \frac{8}{9-x}$ should be minimum.

$$\frac{d}{dx}\left[\frac{2}{x} + \frac{8}{9-x}\right] = 0$$

$$\Rightarrow \quad \frac{-2}{x^2} + \frac{8}{(9-x)^2} = 0$$

$$\Rightarrow \quad \frac{x}{9-x} = \frac{1}{2}$$

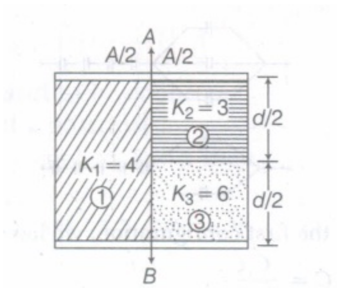
or x =3 cm

i.e. distance of charge q from 2q should be 3 cm.

∴ Electric field at q,

$$E = \frac{K(2q)}{\left(3\times10^{-2}\right)^2} - \frac{K(8q)}{\left(6\times10^{-2}\right)^2} = 0$$

143)



Capacitance, $C_1 = \frac{K_1 \frac{A}{2} \varepsilon_0}{d} = \frac{4 \frac{A}{2} \varepsilon_0}{d} = \frac{2A\varepsilon_0}{d}$ $\left[\because C = \frac{KA\varepsilon_0}{d}\right]$

Capacitance $C_2 = \frac{K_2 \frac{A}{2} \varepsilon_0}{\frac{d}{2}} = \frac{3A\varepsilon_0}{d}$

Capacitance, $C_3 = \frac{K_3 \frac{A}{2} \varepsilon_0}{\frac{d}{2}} = \frac{6A\varepsilon_0}{d}$

C_2 and C_3 are in series, $C' = \frac{C_2 C_3}{C_2 + C_3} = \frac{2A\varepsilon_0}{d}$

C' and C_1 are in parallel $= \frac{4A\varepsilon_0}{d}$

(ii) Capacitance, $C_1 = \frac{K_1 A\varepsilon_0}{d/3} = \frac{3A\varepsilon_0}{d}$

$C_2 = \frac{K_2 A\varepsilon_0}{d/3} = \frac{9A\varepsilon_0}{d}$

and $C_3 = \frac{K_3 A\varepsilon_0}{d/3} = \frac{18A\varepsilon_0}{d}$

$\because$ C_1 ,C_2 and C_3 are in series

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$\because$ Equivalent capacitance $C_{eq} = \frac{2A\varepsilon_0}{d}$

144) (a) Expression for the potential energy of a system of two point charges in an external field:

Work done in bringing the charge q_1 from infinity to r_1 ,

Work done $= q_1V(r_1)$

Work done in bringing the charge qz from infinity to r_2 .

Work done against the external electric field

$= q_2V(r_2)$

Work done = work done against the external electric field + Work done on q_2 against the field due to q_1

$= q_2V(r_2) + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$

Potential energy of the system = the total work done in assembling the configuration

$= q_1V(r_1) + q_2V(r_2) + \frac{q_1q_2}{4\pi\varepsilon_0 r_{12}}$

(b) Electrostatic potential energy of the systems of charges corresponding to initial configuration is

$U_i = \frac{2kQ^2}{l} - \frac{3kQ^2}{l} - \frac{6kQ^2}{l} = -\frac{7kQ^2}{l}$

Electrostatic potential energy of the system of charges corresponding to final configuration is

$U_f = \frac{4kQ^2}{l} - \frac{6kQ^2}{l} - \frac{12kQ^2}{l} = -\frac{14kQ^2}{l}$

The amount of work done in shifting the charges to new locations is

$W = U_f - U_i$

$= -\frac{14kQ^2}{l} - \left(-7\frac{kQ^2}{l}\right) = -\frac{7kQ^2}{l}$

145)

Suppose at any instant of time potential difference between the capacitor plates be V. Then the amount of work required to supply a charge dq to the capacitor is given by

dW = Vdq

To supply a charge Q, the work done is given by

$$W=\int_0^Q Vdq=\int_0^Q \frac{q}{C}dq\left(\because V=\frac{q}{C}\right)$$

$$W=\frac{1}{2}\frac{Q^2}{C}(\because Q=CV)$$

This work done gets stored in the form of electrostatic potential energy

$$\text{or } W=\frac{1}{2}CV^2$$

$$\therefore U=\frac{1}{2}KC_0V^2\left(\because C=KC_0\right)$$

As $C_0=\frac{\varepsilon_0 A}{d}, V=Ed$

$$U=\frac{1}{2}K\frac{\varepsilon_0}{d}E^2d^2A=\frac{1}{2}K\varepsilon_0E^2Ad$$

As we know $C_0=\frac{\varepsilon_0 A}{d}$

When the separation is doubled, then

$$C_0^{'}=\frac{\varepsilon_0 A}{2d}=\frac{C_0}{2}$$

On introducing the dielectric medium of dielectric constant K = 4 between the plates

$$C=KC_0^{'}$$

$$E_{\text{v}}^{'}=\frac{1}{2}\frac{Q^2}{C}=\frac{1}{2}\frac{Q^2}{KC_0^{'}}\left[\because C_0^{'}=\frac{C_0}{2}\right]$$

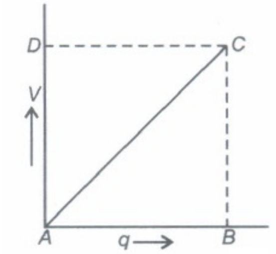
$$E_{\text{v}}^{'}=\frac{1}{2}\left(\frac{Q^2}{4\frac{C_0}{2}}\right)=\frac{1}{2}\left(\frac{1}{2}\frac{Q^2}{C_0}\right)[\because K=4]$$

$$E_{\text{v}}^{'}=\frac{1}{2}E_n$$

The energy stored in the capacitor reduces to one-half of its original value.

146)

As q = CV, V versus q will be a straight line. During the process of giving charge q to the capacitor, the potential difference across the capacitor rises linearly from 0 to V. So, the charge q is given to the capacitor at on average potential difference V/2.



From the graph, area of $ABC = \frac{1}{2}qV$

$\therefore$ Energy stored $= q\left(\frac{V}{2}\right) = \frac{1}{2}CV^2$ [$\because q = CV$]

Energy density, u = $\frac{\text{Energy}}{\text{Volume}} = \frac{\frac{1}{2}CV^2}{Ad}$

$= \frac{1}{2}\frac{\varepsilon_0 A}{d}\frac{(Ed)^2}{Ad} = \frac{1}{2}\varepsilon_0 E^2$

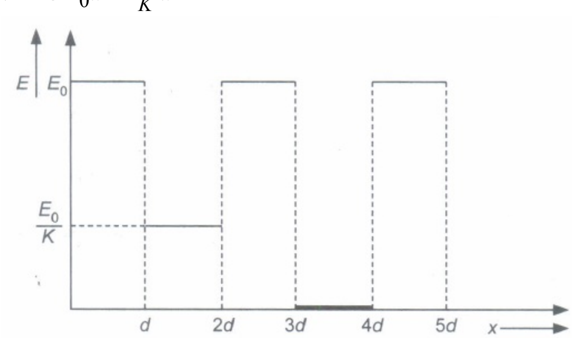
147) (a)

	Non-Polar (O_2)	Polar (H_2O)
(i) Absence of external electric field. Individual Specimen	No dipole moment exists. No dipole moment exists	Dipole moment exists. Dipoles are randomly oriented. $\therefore$ net P = 0
(ii) Presence of external electric field Individual Specimen	Dipole moment exists. (molecules become polarised) Dipole moment exists.	Torque acts on the molecules to align them parallel to $\vec{E}$. Net dipole moment existswhich is parallel to $\vec{E}$.

(b) (i) P.D. between the plates of a capacitor is calculated as

$V = E_0 d + \frac{E_0}{K}d + E_0 d + 0 + E_0 d$

$V = 3E_0 d + \frac{E_0}{K}d$ (ii) E vs x graph



148)

(a) Let C be capacity of the parallel plate capacitor charged to a potential V of the battery. When the battery is disconnected the charge on the capacitor remains the same.

(i) Capacitance: The capacitance of the capacitor becomes K times the original value, i.e. $C = KC_0$

(ii) Electric field: The new potential V is given by

$$V = \frac{Q}{C} = \frac{Q}{KC_0} = \frac{V_0}{K}$$

i.e. potential is reduced by K times. The new electric field E is given by

$$E = \frac{V}{d} = \frac{V_0}{Kd} = \frac{E_0}{K}\left(\because E_0 = \frac{V_0}{d}\right)$$

i.e. the electric field is reduced by K time.

(iii) Energy stored: Let U_0 and U be the energy stored in the capacitor before and after the dielectric is introduced.

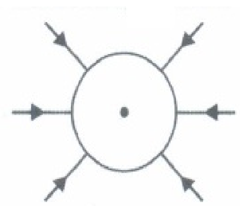
Then $U_0 = \frac{1}{2}C_0V_0^2$ and $U = \frac{1}{2}CV^2$

$$= \frac{1}{2}KC_0\left(\frac{V_0}{K}\right)^2 = \frac{1}{2}\frac{C_0V_0^2}{K} = \frac{U_0}{K}$$

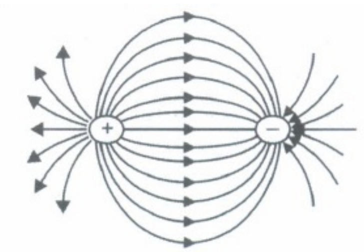
i.e. the energy stored in the capacitor is reduced K times.

(b) The pattern of electric field lines of force of a conducting sphere having a negative charge.

(i) There is no electric field line of force inside the conducting sphere



(ii) The pattern of the electric lines of force of an electric dipole.



149)

As the battery is removed, therefore, the charge will remain conserved. But the capacitance, i.e. $C = \frac{A\varepsilon_0}{d}$ will increase as d decreases.

(a) The charge remains constant.

(b) As $V = \frac{Q}{C} \propto \frac{1}{C}$; so, potential difference decreases.

(c) Since, the electric field, $E = \frac{Q}{A\varepsilon_0}$ is independent of d. Hence, it remains constant.

(d) Energy, $U = \frac{Q^2}{2C} \propto \frac{1}{C}$; Hence, it decreases.

(e) Energy density, $u = \frac{1}{2}\varepsilon_0E^2$ remains constant.

150) If R be the radius of big drop and r be the radius of small drop

$\because$ Volume remains same.

$\therefore V = nV_1$

$\Rightarrow \frac{4}{3}\pi R^3 = n\frac{4}{3}\pi r^3$

$\Rightarrow R = n^{1/3}r$

$\because$ Capacity of each droplet,

$C = 4\pi\varepsilon_0 r$

$\therefore$ Capacity of a big drop, $C' = 4\pi\varepsilon_0 R = 4\pi\varepsilon_0 n^{1/3} r = n^{1/3}C$

If the surface charge density of small drop, $\sigma = \frac{Q}{4\pi r^2}$ and, charge remains conserved.

$\therefore Q' = nQ$

Then surface charge density,

$\sigma' = \frac{Q'}{4\pi R^2} = \frac{nQ}{4\pi\left(n^{1/3}r\right)^2} = n^{1/3}\sigma$

If electrostatic energy of a small drop, $U = \frac{Q^2}{2C}$

$\therefore U'$ = energy of a big drop

$= \frac{(nQ)^2}{2C'}$

$= \frac{n^2Q^2}{2n^{1/3}C} = n^{5/3}U$

If potential of a small drop,

$V = \frac{Q}{C};$

then potential of a big drop,

$V' = \frac{nQ}{n^{1/3}C} = n^{2/3}V$

151) (i) Let q_1 and q_2 be the electric charges on two capacitors having capacitances C_1 and C_2 respectively.

When they are connected, the electric charges flow till potential difference across each capacitor is same.

Since electric charge is conserved.

$$\therefore\ q_1 + q_2 = q_1' + q_2'$$

$$C_1V_1 + C_2V_2 = \left(C_1 + C_2\right)V$$

$$V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} \ldots (i)$$

here V = common potential

V_1 = Initial ..potential difference across C_1

V_2 = Initial potential difference across C_2

(ii) $\frac{q_1'}{q_2'} = \frac{C_1V}{C_2V} = \frac{C_1}{C_2}$

Loss in energy

$$= \Delta U = U_i - U_f$$

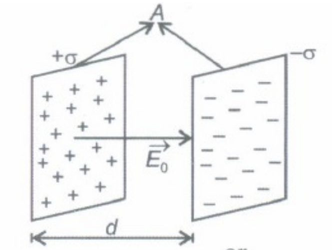
$$= \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2 - \frac{1}{2}\left(C_1 + C_2\right)V^2$$

$$= \frac{1}{2}\left[C_1V_1^2 + C_2V_2^2 - \left(C_1 + C_2\right)\left(\frac{C_1V_1 + C_2V_2}{C_1 + C_2}\right)^2\right]$$

$$\Delta U = \frac{C_1C_2\left(V_1 - V_2\right)^2}{2\left(C_1 + C_2\right)}$$

152)

(a) Capacitance: It is equal to the magnitude of charge in each plate required to raise the potential difference between the plates by unity.



It is the ratio of the magnitude of charge on the plates to the potential difference between the plates.

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

Consider a capacitor with surface charge density σ on its plates. Suppose area of each plate is A and separation between the plates is d.

We know Q = CV

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

Here, $Q = \sigma A$ ...(i)

$V = E_0 d$

$V = \frac{\sigma}{\varepsilon_0} d \left(\because E_0 = \frac{\sigma}{\varepsilon_0} \right) \ldots (ii)$

From equations (1) and (2), we get

$C_0 = \frac{\varepsilon_0 A}{d}$

(b) Given: $t = \frac{3d}{4}$

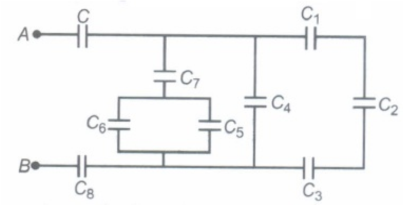
Capacitance Without ditelectric = $C_0 = \frac{A\varepsilon_0}{d}$

Capacitance with dielectric inside

$C = \frac{A\varepsilon_0}{d - t\left(1 - \frac{1}{k}\right)} = \frac{C_0}{1 - \frac{t}{d}\left(1 - \frac{1}{k}\right)}$

$\frac{C}{C_0} = \frac{1}{1 - \frac{3}{4}\frac{d}{d}\left(1 - \frac{1}{k}\right)} = \frac{4k}{k+3}$

153) Given: $C_1 = C_2 = C_3 = C_4 = C_5 = C_6 = C_7 = C_8 = 3\mu F$



Capacitors C_1, C_2 and C_3 are in series.

$\therefore\ C_{123} = \frac{3}{3} = 1\mu F \left[C_5 = \frac{C}{n}\right]$

Now, capacitors C_{123} and C_4 are in parallel.

$\therefore\ C_{1234} = C_{123} + C_4 = 1 + 3 = 4\mu F$ ...(i)

C_5 and C_6 are in parallel.

$C_{56} = C_5 + C_6 = (3 + 3)\mu F = 6\mu F$

C_7 and C_{56} are in series

$\therefore\ C_{756} = \frac{3 \times 6}{3+6} = 2\mu F...(ii)$

Now, C_{1234} and C_{756} are in parallel.

$C_p = (2 + 4) = 6\mu F$

Finally, C, C_p and C_8 are in series.

$\therefore\ \frac{1}{C} + \frac{1}{C_p} + \frac{1}{C_8} = \frac{1}{1} \Rightarrow \frac{1}{C} + \frac{1}{6} + \frac{1}{3} = \frac{1}{1}\frac{1}{C} = 1 - \frac{1}{2} = \frac{1}{2} \Rightarrow C = 2\mu F$