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PHYSICS

BOOKS - AAKASH SERIES

ELECTRIC FIELD AND POTENTIAL

Example

1. Two charges $4\mu C$ and $1\mu C$ are placed at distance of 10 cm. Where should a third charge

be placed between them so that it does not experience any force .

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2. Three charges of equal magnitude q is placed at the vertices of an equilateral triangle of side l. The force on a charge Q placed at the centroid of the triangle is

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3. Calculate the ratio of electric and gravitational force between two protons. Charge of each proton is $1.6 \times 10^{-19} C$, mass is $1.672 \times 10^{-27} kg$ and $G = 6.67 \times 10^{-11} Nm^2 kg^{-2}$

.

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4. Four charges of +q, +q +q and +q are placed at the corners A, B, C and D of s square. The resultant force on the charge at D

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5. A charge Q is to be divided on two objects. What should be the values of the charges on the objects so that the force between the objects can be maximum?

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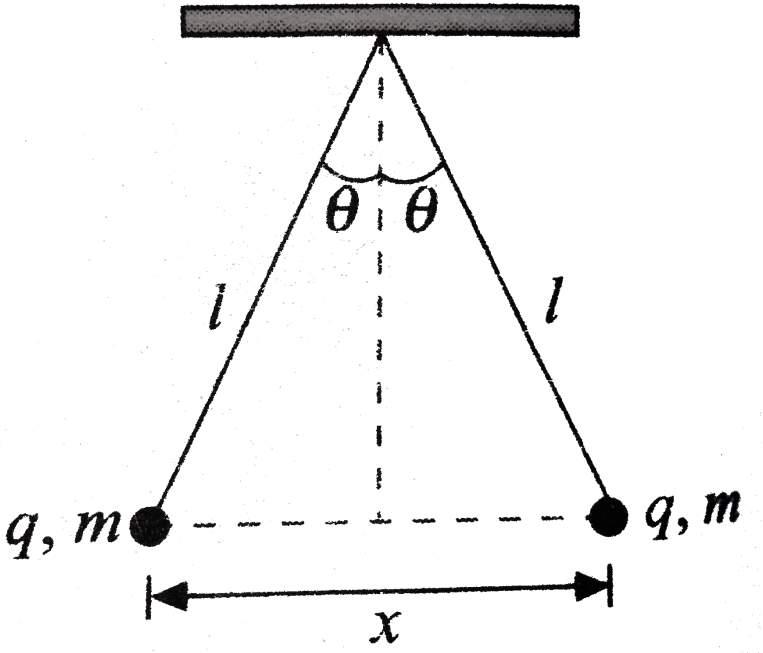
6. Two similar balls, each of mass m and charge q, are hung from a common point by two silk threads, each of length l. Prove that separation between the ball is $x = \left[\frac{q^2 l}{2\pi\varepsilon_0 mg}\right]^{1/3}$, if θ is

small

Find the rate $\frac{dq}{dt}$ with which the charge should leak off each sphere if the velocity of approach varies as $v = a/\sqrt{x}$, where a is a constant.



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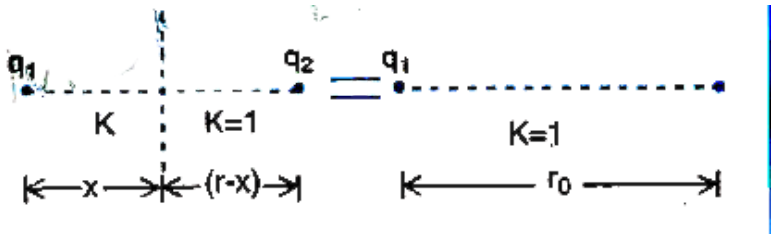
7. Two point charges are seperated by a distance r such that a medium of dielectric constant K is occupied by a length x Now find the coulomb force between those stationary charges.



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8. Two point charges q_1 and q_2 are located at $\overrightarrow{r_1}$ and $\overrightarrow{r_2}$ respectively in an external electric

field E. Obtain the expression for the total work done in assembling this configuration.

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9. A thin circular wire of radius r has a charge Q. If a point charge q is placed at the centre of the ring, then find the increase in tension in the wire.

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10. Charge q_1 is fixed and another point charge q_2 is placed at a distance r_0 from q_1 on a frictionless horizontal surface. Find the velocity of q_2 as a function of seperation r between them (treat as point charges and mass of q_2 is m)

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11. An infinite number of charges each q are placed in the x-axis at distances of 1, 2, 4, 8, ... meter from the origin. If the charges are

alternately positive and negative find the intensity of electric field at origin.

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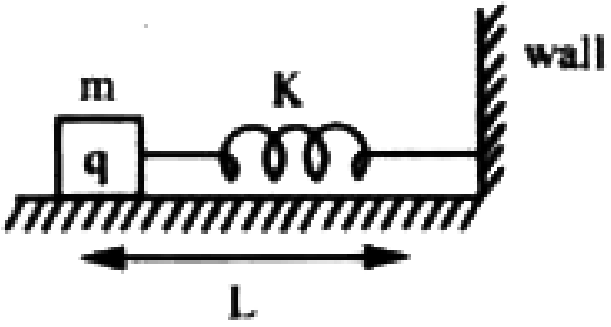
12. A point mass m and charge q is connected with a spring of negligible mass with natural length L. Initially spring is in its natural length. Now a horizontal uniform electric fiedl E is switched on as shown. Find

(a) the maximum separation between the mass and the wall

(b) Find the separation of the point mass and

wall at the equilibrium position of mass.

(c) FInd the enery stored in the spring at the equilibrium position of the point mass



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13. A positive point charge $50\mu C$ is located in the plane xy at a point with radius vector $\overrightarrow{r}_0 = 2\hat{i} + 3\hat{j}$. The electric field vector $\overrightarrow{E}$ at a

point with radius vector $\overrightarrow{r} = 8\hat{i} - 5\hat{j}$, where r_0 and r are expressed in meter, is

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14. A charge q is placed at the centre of the line joining two equal charges Q. The system of the three charges will be in equilibrium if q is equal to

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15. Two point charges q_1 and q_2 (like) are seperated by a distance r and fixed. Locate the point on the line joining those charges where resultant or net field is zero.

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16. Three point charges q are placed on vertices of an equilateral triangle of side length a. The

charge Q that should be kept at centroid of triangle such that the system is in equilibrium is equal to

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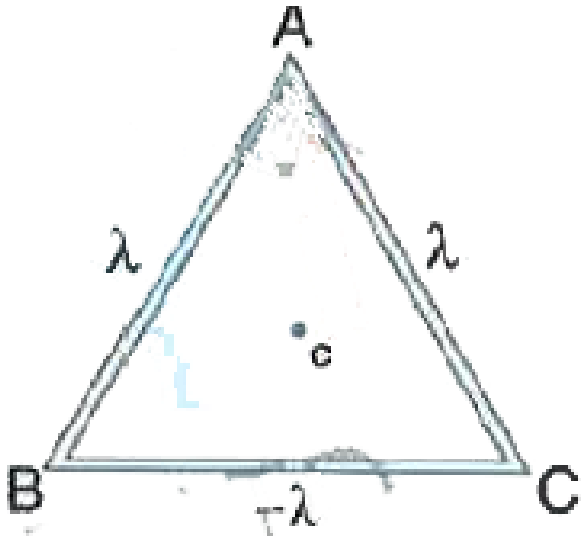
17. Given an equilateral triangle with side L, find E at its centroid. The linear charge density is as

shown in figure.



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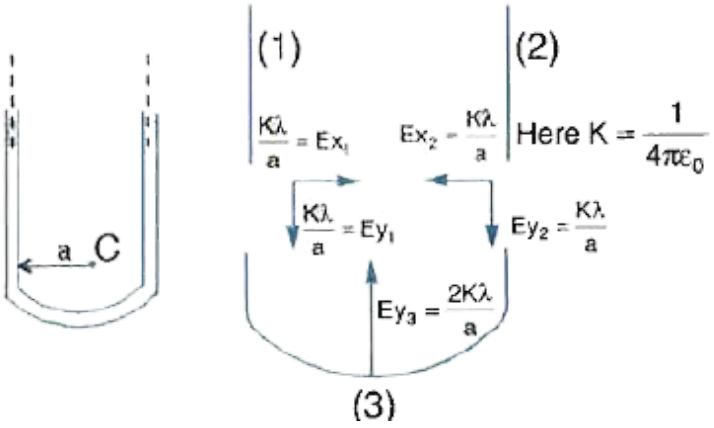
18. Find the electric field at point C of the given U shaped wire which is uniformly charged with linear charge density λ. [C is the centre of the

semi circular section]



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19. A system consists of a thin charged wire ring of radius r and a very long uniformly charged wire oriented along the axis of the ring, with one of its ends coinciding with the center of the ring. The total charge on the ring is q. and he linear

charge density on the straight wire is λ, The interaction force between the ring and the wire is

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20. A point charge Q is located at centre of a fixed thin ring of radius R with uniformly distribute charge -Q. The magnitude of the electric field strength at the point lying on the axis of the ring at a distance x from the centre is $(x > > R)$

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21. There is an infinite straight chain of alternating charges q and $-q$. The distance between the neighbouring charges is equal to a. Find the interaction energy of each charge with all the others.

Instruction . Make use of the expansion of In $(1+\alpha)$ in a power series in α.

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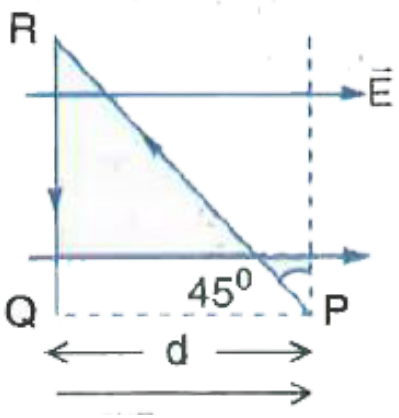
22. A test charge q_0 is moved without acceleration from P to Q in a uniform electric field over the path shown in figure. The points P and Q are seperated by a distance d. Find the potential difference between P and Q.



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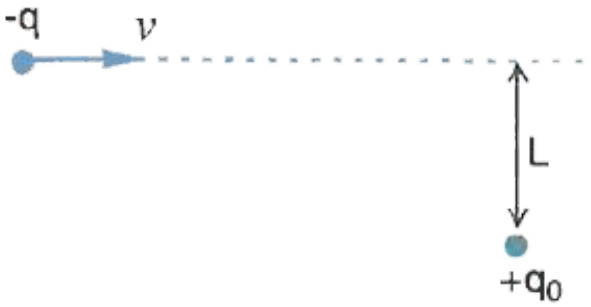
23. A charge $+q_0$ is fixed at a position in space. From a large distance another chaged particle of charge -q and mass m is thrown towards $+q_0$ with an impact parameter L as shown. The initial speed of the projected particle is v. Find the distance of closet approach of the two particles.



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24. Determine the electric field strength vector if the potential of this field depends on x, coordinates as

(a) $V = a\left(x^2 — y^2\right)$ (b) $V = axy$

where, a is a constant.

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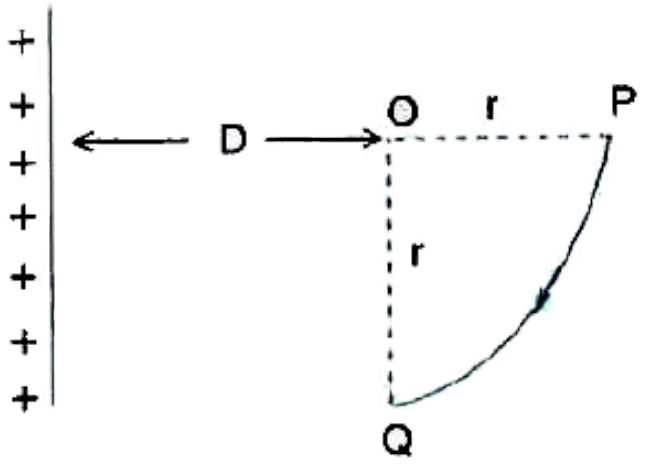
25. A charge q_0 is moved from point P to point q along the arc PQ with centre at O as shown in the figure near a long charged wire. The linear charge density of the wire is λ and it in the same

plane. Find the work done in the process.



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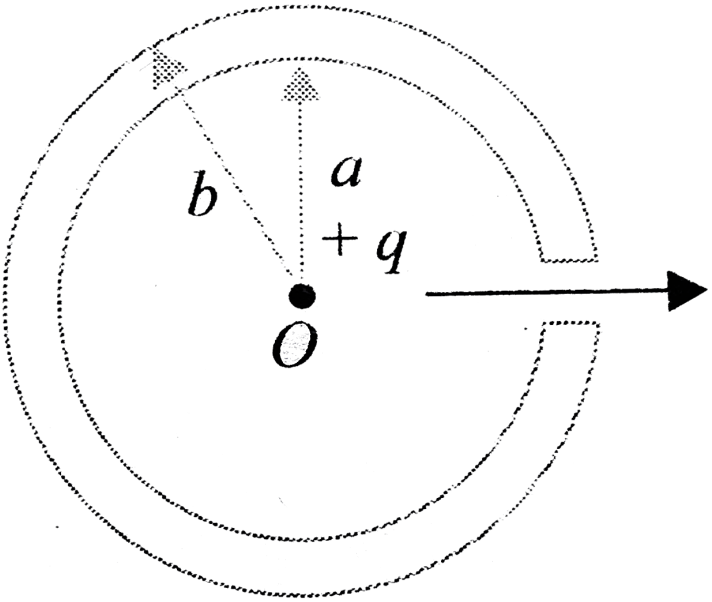
26. A point charge q is located at the center O of an uncharged spherical capacitor provided with a small orifice. The inside and outside radii of the capacitor are a and b, respectively (Fig.

3.116). What amount of work has to be performed to slowly transfer the charge q bit by from the point O through the orifice to infinity ?



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27. Find the V_{ab} in an electric field $E = \left(2\hat{i} + 3\hat{j} + 4\hat{k}\right)\frac{N}{C}$, where $r_a = \left(\hat{i} - 2\hat{j} + \hat{k}\right)m$ and $r_b = \left(2\hat{i} + \hat{j} - 2\hat{k}\right)m$

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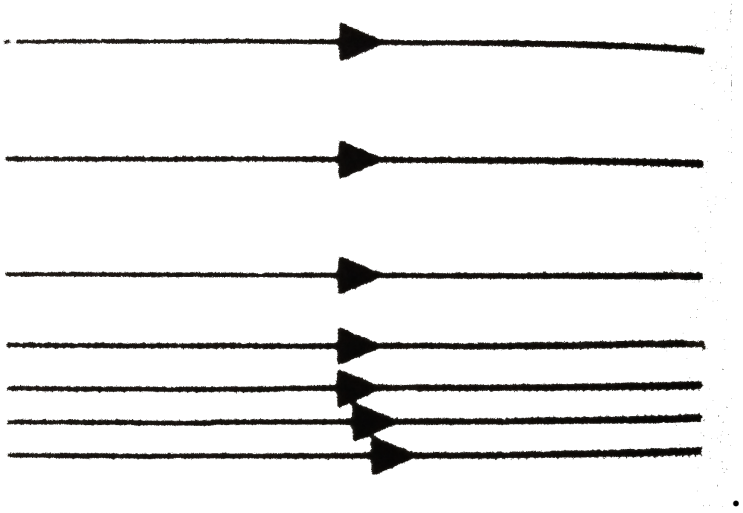
28. Is an electric field of the type shown by the electric lines in fig. physically possible?



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29. A conducting bubble of radius a, thickness t (t << a) has potential V. Now, the bubble collapses into a droplet. The potential of the droplet will be:

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30. In a certain region of space, electric field is along the z-direction throughout. The magnitude of electric field is however not constant, but increases uniformly along the positive z-direction at the rate of $10^5 NC^{-1}m^{-1}$. The force experienced by the system having a total dipole moment equal to 10^{-7}C m in the negative z- direction is

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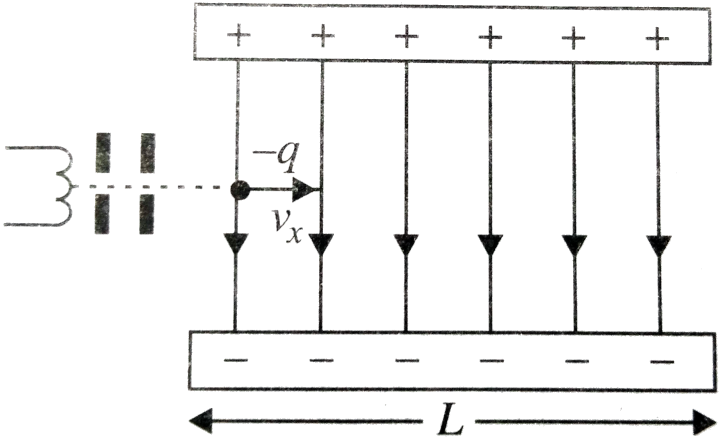
31. A particle of mass m and charge -q enters the region between the two charged plates initially moving along x-axis with speed v_x as shown in figure. The length of plate is L and a uniform electric field E is maintained between the plates. The vertical deflection of the particle at the far edge of the plate is



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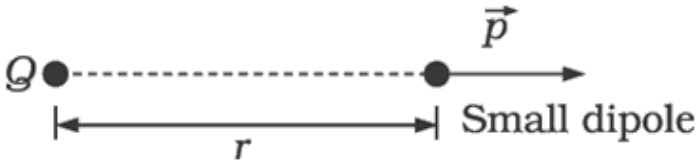
32. For the situation shown in the figure below, find the force experienced by the dipole:



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Exercise Long Answer Questions

1. Coulomb's law relates two charges and distance between them describing the electric

force as beging

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2. Define water potential and solute potential.

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3. Define electric field, field strength, potential and potential difference, between two points?

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Exercise Short Answer Questions

1. State and explain Ohm.s law and hence defined one ohm.

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2. Derive an expression for intensity of electric field are a point in broadside position or on an equatorial line of an electric dipole.

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3. How is the electric potential difference between two points defined ? State its S.I. unit.

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4. State the principle of superposition ? Why do we use the phrase 'algebraic sum' in the statement ?

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5. The electric field of an electric dipole at a point on its axis , at a distance d from the centre of the dipole, varies as

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6. Electric Dipole

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Exercise Very Short Answer Questions

1. Usually it is the negative charge that is transferred when two bodies are rubbed together. Can you explain why?

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2. A metallic sphere is charged negatively, Will its mass increase, decrease or remain the same?

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3. Electrostatic experiments cannot be conducted successfully on humid days. Explain.

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4. At the out set it appears as though the principle of superposition is similar to the additive property. But, it is not so. Can you guess the important difference?

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5. What is meant by the statement "charge is quantized".

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6. Which of the following statement is not a similarity between electrostaic and gravitational forces?

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7. What similarities do electrostatic forces have to gravitational forces?

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8. Can the relative permittivity of a medium be less than 1?

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9. Vehicles carrying inflammable materials usually have chains that hang down and drag on

the ground. Why?

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10. Although ordinary rubber is insulator, the rubber tyres of air crafts are made slightly conducting. Why?

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11. An uncharged body if kept in contact for some time with a charged body gets repelled.

Why?

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12. Electrostatic field lines of forces do not form closed loops. If they form closed loops then the work done in moving a charge along a closed path will not be zero. From the above two statements can you guess the nature of electrostatic force?

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13. The electric lines of force do not intersect. Why?

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14. Consider two charges +q and -q placed at B and C of an equilateral triangle ABC. For this system, the total charge is zero. But the electric field (intensity) at A which is equidistant from B and C is not zero. Why?

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15. A sure test of electrification is

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16. Conductors and insulators

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17. Can there be electric potential at a point with zero electric intensity?

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18. Assertian: Basic difference between an electric line and magnetic line of force is that former is discontinous and the latter is contiuous or endless.

Reason: No electric line of forces exist inside a magnet.

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19. Fig shows electric lines of force emerging from a charged body. Is electric field intensity

more at A or B?

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20. A charged particle is free to move in an electric field. Will it always move along electric lines of force?

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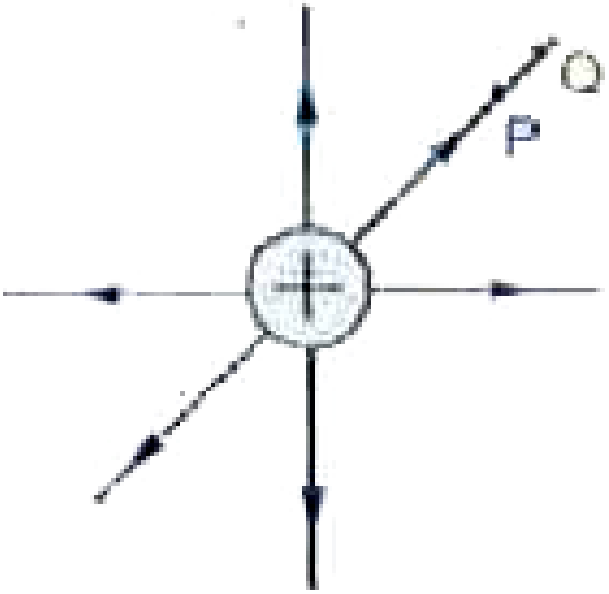
21. Fig shows the electric field lines due to a point positive charge. P and Q are two point in the electric field.



i) What is the sign pf $V_P - V_Q$?

ii) What is the sign of the potential energy difference of a small negative charge between Q

and P?

iii) What is the sign of work done by the field in moving a small positive charge from Q to P?

iv)What is the sign of work done by external agent in moving a positive charge from Q to P?

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22. Electric field intensity in a given region is zero. Can we conclude that electric potential must be zero?

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23. Two nearby points are at the same potential. What is the intensity of electric field in this region?

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Problems Level I

1. Calculate the magnitude of force between two like charges each of magnitude 4C seperated by distance 3 m.

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2. Two charges $4\mu C$ and $1\mu C$ are seperated by 16m. Where do you place a third charge so that it doesn't experience any force.

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3. Calculate the ratio of electric to gravitational force between two electrons.

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4. A charge $4\mu C$ is placed in an electric field of magnitude 8 N/C. Find the force on it.

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5. A charge 2C is moved between two points where potentials are 17 and 8V respectively. What is the work done in moving the charge.

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6. Electric potential at origin is zero. Field in that space is $10\hat{i} + 10\hat{j}NC^{-1}$. Find electric potential at (1, 1).

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7. Two electrons are moving towards each other, each with a velocity of 10^6 m/s. What will be closest distance of approach between them ?

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8. A metal sphere A of radius a is charged to potential V. What will be its potential if it is enclosed By a spherical conducting shell B of radius b and the two are connected by a wire ?

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9. A charged particle P has a mass of 10^{-16}kg and carries a charge of $4.9 \times 10^{-19}C$. Calculate the intensity of the electric field to be applied on it in vertically upward direction, so as to keep it at rest.

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10. Two ball with charges $5\mu C$ and $10\mu C$ are at a distance of 1 m from each other. In order to reduce the distance between them to 0.5 m , the amount of work to be performed is

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11. A constant electric field of intensity 36N/C exists along the z-axis. If P and Q be two points whose coordinates are (10 cm, 0, -20 cm) and (0,

-10 cm, 30 cm) respectively, then find the potential difference $V_P - V_Q$.

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12. The electric potential V is given as a function of distance x (metre) by $V = \left(5x^2 + 10x - 9\right)V$. Value of electric field at $x = 1$ is

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13. Four charges equal to-Q are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium the value of q is

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Problems Level Ii

1. A metal sphere with its centre at A and radius R has a charge 2q on it. The field at a point B outside the sphere is E. If another metal sphere

of radius 3R and having a charge -3q is placed with its centre at point B, find out the resultant electric field at a point mid way between A and B.

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2. Two similar metal spheres are suspended by silk threads from the same point. When the spheres are given equal charges of $2\mu C$ the distance between them becomes 6cm. If length of each thread is 5 cm, the mass of each sphere is (g=10 m/s2)

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3. A body of mass 2 gm is projected horizontally from the top of tower of height 20m with a velocity 10 m/s. The charge on the body is 2C. Electric field is applied vertically downwards and of intensity 10-N/C. Find the time taken by the body to touch the ground (g = 10 m/s^2)

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4. A body of mass 10 gm and having charge 2C is attached to a spring which is suspended from

the ceiling. It vibrates with a time period 1 sec. If an electric field of intensity 100 N/C is now applied in the downward direction, find the time period.

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5. Four charges Q, q, Q and q are placed at the corners A, B, C and D of a square ABCD. If the resultant electric force on the charge at the corner C is zero, find the value of Q/q.

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6. A charge Q is fixed on the X-Y plane at point (0, a). Find the electric field strength component along the X-axis, at any point (x, 0).

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7. Two charges 4q and q are fixed at points (0,9) and (12, 0) respectively on the X-Y plane. Find the coordinates of the point where the electric field strength is zero.

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8. Four point charges $+q, +q, -q$ and $-q$ are placed on the corners of a square of side length 'a' as shown in the figure. The magnitude of electric field at a point which is at a distance $x(>>a)$ from the centre along a line perpendicular to the plane of the square and passing through the centre is

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9. Two point charges $4\mu C$ and $9\mu C$ are separated by 50 cm. The potential at the point between them where the field has zero strength is

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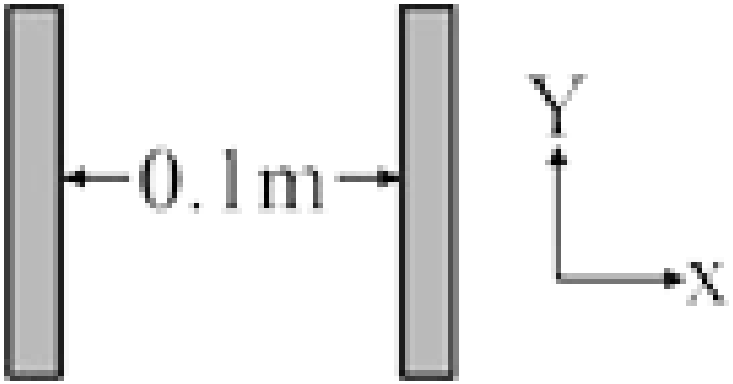
10. Two insulating plates are uniformly charged in such a way that the potential difference between them is $V_2 - V_1 = 20V$ (i.e. plate 2 is at a higher potential). The plates are separated by d = 0.1m and can be treated as infinitely large. An electron is released from rest on the inner

surface of plate 1. What is its speed when it hits plate 2 ? (e=1.6xx10^9 C,m_0=9.11xx10^(-31)Kg)`



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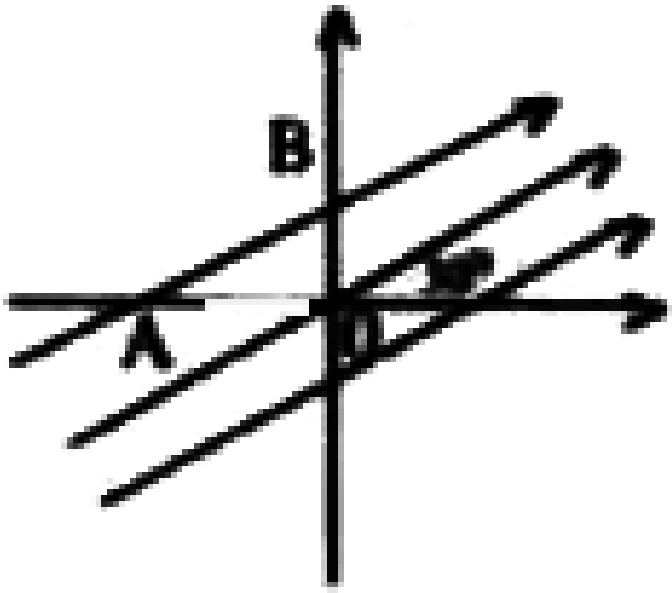
11. A field of 100Vm^{-1} is directed at 30° to positive x-axis. Find $(V_A - V_B)$ if OA = 2m and

OB = 4m



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12. A hollow sphere of radius 2R is charged to V volts and another smaller sphere of radius R is charged to V/2 volts. Now the smaller sphere is

placed inside the bigger sphere without changing the net charge on each sphere. The potential difference between the two spheres would be

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13. Two identical particles of mass m carry a charge Q each. Initially one is at rest on a smooth horizontal plane and the other is projected along the plane directly towards first particle from a large distance with speed v. The closest distance of approach be :

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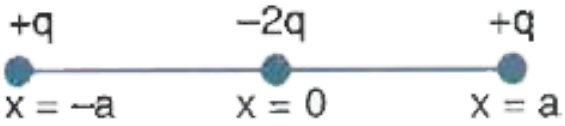
14. Two dipoles that are back to back form a linear quadrapole



i) Calculate E_x for points on the X-axis such that

$x > > a$

ii) Calculate E_y for points on the Y-axis such that

$y > > a$

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15. Two particles of mass m and $2m$ with charges 2q and q are placed in a uniform electric field E and allowed to move for same time. Find the ratio of their kinetic energie

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16. A cone made of insulating material has a total charge Q spread uniformly over its sloping surface. Calculate the work done in bringing a small test charge q from infinity to the apex of the cone. The cone has a slope length L.

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17. Electrical potential .v. in space as a function of co-ordinates is given by, $v = \frac{1}{x} + \frac{1}{y} + \frac{1}{z}$. Then the electric field intensity at (I,I,I) is given by

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18. A solid dielectric (K = 1) sphere of radius R is charged uniformly by a total charge Q. At what distance from the centre will the electrostatic

potential, be the average of that at the centre and at the surface.

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19. A uniform rod of length l and mass m is given a charge Q and is suspended vertically by means of a hinge at the top end. A horizontal electric field E is switched on, in the direction in which the rod can sway freely. Find the angle made by the rod with the vertical in equilibrium.

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20. A rod of length L has a total charge Q distributed uniformly along its length. It is bent in the shape of a semicircle. Find the magnitude of the electric field at the centre of curvature of the semicircle.

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21. A half ring of radius R has a charge of λ per unit length. The potential at the centre of the half ring is :

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22. A hollow copper sphere is placed in front of a point charge Q such that the latter is at a distance r from the centre O of the former. What is the electric field at the centre O, due to the charges induced in the sphere?

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23. Two electric charges $q_1 = q$ and $q_2 = -2q$ are placed at a distance l = 6a apart. Find the

locus of points in the plane of the charges where the field potential is zero

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24. The electric potential in a region is represented as

$V = 2x + 3y - z$

obtain expression for electric field strength.

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25. The electric potential (V) in a certain region of space depends only on x-coordinate of point as $V = -\alpha x^3 + \beta$ (α and β constants). Find the volume charge density (ρ) of this region of space

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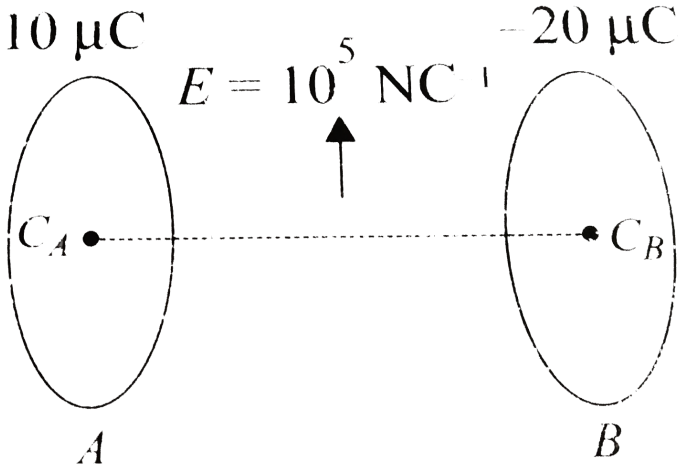
26. Two circular rings A and B each of radius $a = 30cm$ are placed co-axially with their axes horizontal in a uniform electric field $E = 10^5 N/C$ directed vertically upward as

shown in the figure. The distance between the centers of these rings A and B is $h = 40cm$. Ring A has a positive charge $q_1 = 10\mu C$ while ring B has a negative charge of magnitude $q_2 = 20\mu C$. A particle of mass m = 100 gm and carrying a positive charge $q = 10\mu C$ is released from rest at the centre of the ring A. Calculate its velocity when it has moved a distance 40 cm.



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