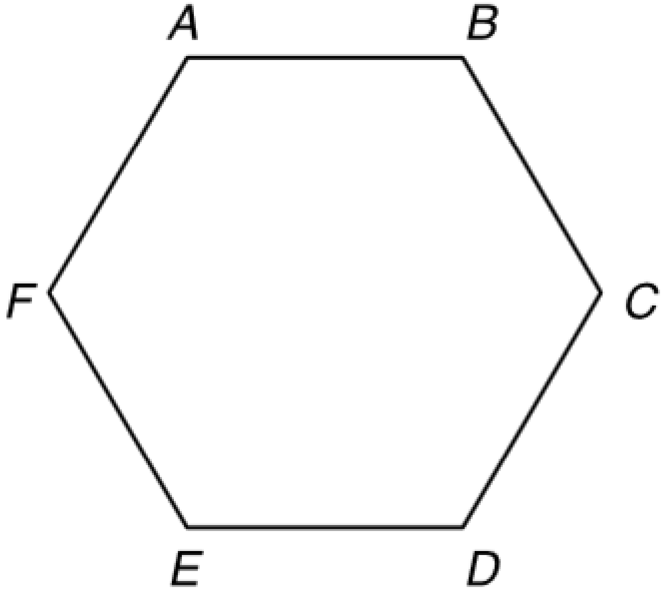
PHYSICS

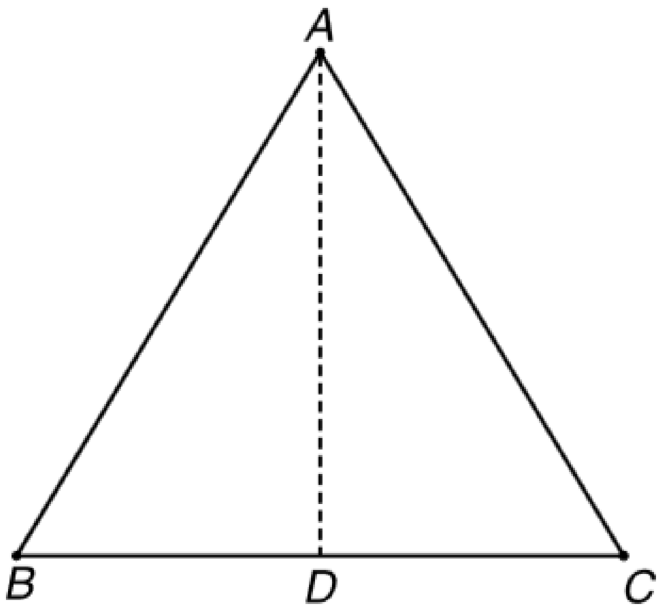
BOOKS - ARIHANT PHYSICS (HINGLISH)

ELECTROSTATICS

Level 1

1. (a) Six equal charges have been placed at the vertices of a regular hexagon. Charge at vertex A is moved to the centre of the hexagon and there it experiences a net electrostatic force of magnitude F. Charge at E is also moved to the centre so as to double the magnitude of the charge at the centre. Calculate the magnitude of the electrostatic force that this central charge experiences now. (b) Three charges of equal magnitude lie on the vertices of an equilateral triangle ABC. All of them are released simultaneously. The charge at A experiences initial acceleration along AD where D is the midpoint of the side BC. Find the direction of initial acceleration of the charge at B.





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2. Two identical small conducting balls have positive charges q_1 and q_2 respectively. The force between the balls when they are placed at a separation is F. The balls are brought together so that they touch and then put back in their original positions. Prove that the force between the balls now, cannot be less than F.

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3. Point charges $-q, 2q, -3q, q, -q, 2q, -3q, q, -q, 2q, -3q,$ and q have been placed at marks $1, 2, 3, 4, 5.....12$ respectively on the circular dial of a clock. Find the electric field intensity at the centre of the dial if distance of each charge from the centre is r.

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4. Let q_1 be a positive charge equal to the magnitude of the total charge on all electrons present in 0.9 mg of pure water and q_2 be the charge on a 6.35 mg copper sphere from which 0.1% of its total electrons have been removed.

Avogadro's number, $N_A = 6 \times 10^{23}$

Molar mass of $H_2O = 18g$

Molar mass of $Cu = 63.5g$

(a) Find force between q_1 and q_2 if they are placed at a separation of 1 km. (b) How does this force compare with the weight of a car having mass of 1200 kg? What conclusion can you draw from the result?

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5. Three point charges $q_1 = q, q_2 = q$ and $q_3 = Q$ are placed at points having poisition vetors $\vec{r_1}, \vec{r_2}$ and $\left(\vec{r}_1 + \vec{r}_2\right)$ respectively. It is known that $\left|\vec{r}_1\right| = \left|\vec{r}_2\right| = \vec{r}$. The net electrostatic force on q_3 is $\sqrt{3}$ times the force applied by either of q_1 or q_2 on q_3. find $\vec{r}_1 \cdot \vec{r}_2$.

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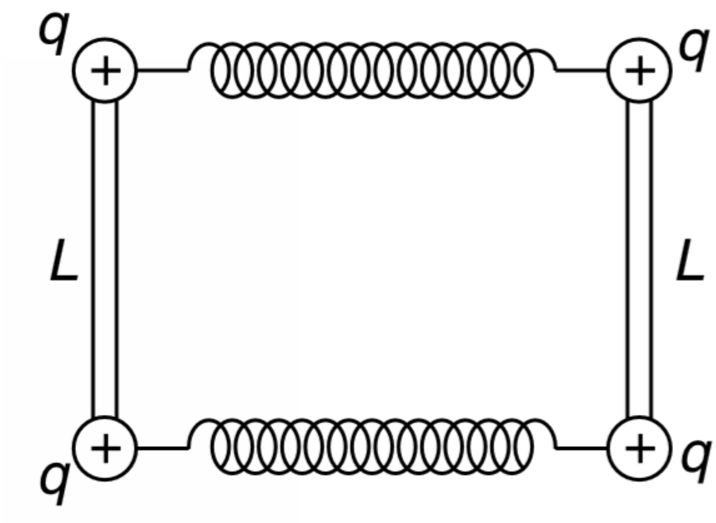
6. Two stiff non conducting rods have length L each and have small balls connected to their ends. The rods are placed parallel to each other and the balls are connected by two identical springs as shown. When each ball is given a charge q, the system stays in equilibrium when it is in the shape of a square. If natural relaxed length of each spring is L/2 find the force constant (k) for them.



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7. Five identical charges, q_1 each, are placed at the vertices of a regular pentagon having side length l_1. The net electrostatic force on any of the charges due to other four is F_1. Find the electrostatic force F_2 on any one of the five identical charges, q_2 each, placed at the vertices of a regular pentagon having side length l_2.

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8. A simple pendulum has a bob of mass m which carries a charge q on it. Length of the pendulum is L. There is a uniform electric field E in the region. Calculate the time period of small oscillations for the pendulum about its equilibrium position in following cases:

(i). E is vertically down having magnitude $E = \frac{mg}{q}$

(ii). E is vertically up having magnitude $E = \frac{2mg}{q}$

(iii). E is horizontal having magnitude $E = \frac{mg}{q}$

(iv). E has magnitude of E=q and is directed upward making an angle 45° with the horizontal

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9. Two identical negative charges are fixed on X axis at equal distances from the origin (O). A particle having positive charge starts at a large distance from O, moves along the Y axis, passes through the origin and moves far away from O in the positive Y direction. Describe qualitatively how its acceleration charges as it moves. Draw a rough graph showing the variation of acceleration (a) vs position of the particle (y). Take the acceleration of the particle to be positive in + Y direction.

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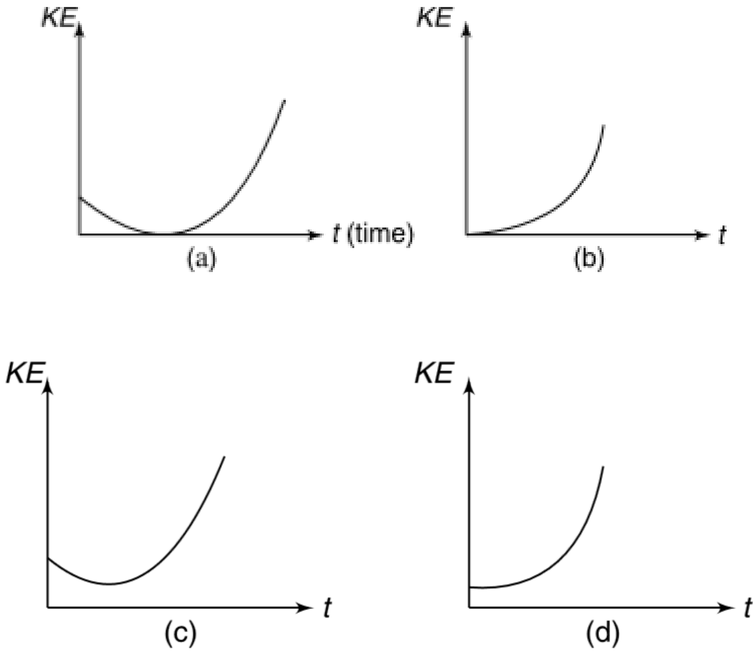
10. An electron is either released from rest or projected with some initial velocity in a uniform electric field. Neglect any other force on the electron apart from electrostatic force. Which of the graphs shown in fig could possibly represent the change in kinetic energy of the electron during its course of motion? Explain the situation in each case.



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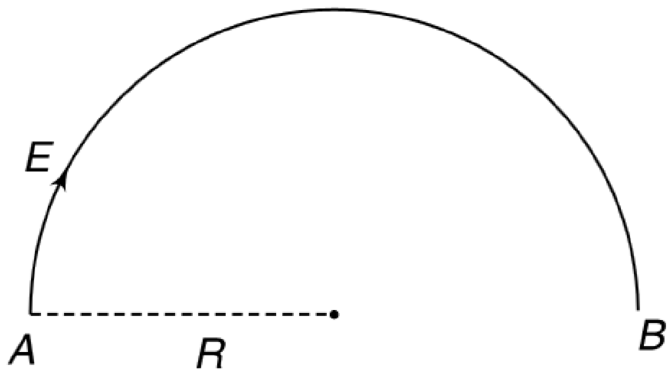
11. In a region of space an electric field line is in the shape of a semicircle of radius R. Magnitude of the field at all point is E. A particle of mass m having charge q is constrained to move along this field line. The particle is released from rest at A.

(a) Find its kinetic energy when it reaches point B.

(b) Find the acceleration of the particle when it is at midpoint of the path from A to B.



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12. Electric field E = – bx + a exists in a region parallel to the X direction (a and b are positive

constants). A charge particle having charge q and mass m is released from the origin X = 0. Find the acceleration of the particle at the instant its speed becomes zero for the first time after release.

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13. A Sphere of radius R_0 carries a volume charge density proportional to the distance (x) from the origin, $\rho = \alpha x$ where α is a positive constant. (a) Calculate the total charge in the sphere of radius R_0. (b) The sphere is shaved off so as to reduce its radius. What should be the radius (R) of the remaining sphere so that it contains half the charge of the original sphere? (c) Find the electric field at a point inside the sphere at a distance r lt R. Give your answer for original sphere of radius R_0 as well as for the smaller sphere of radius R that was left after shaving off the original sphere.

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14. Draw electric field lines for charge distributions given below– (a) Two equal point charges placed at a separation. (b) Two point charges 2q and – q placed at a separation. Describe qualitatively how the lines will appear at a very large distance from the two charges? (c) Three point charges, each equal to + q placed at the vertices of an equilateral triangle.

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15. Three conducting concentric spherical shells of radii R, 2R and 3R carry some charge on them. The potential at the centre is 50 V and that of middle and outer shell is 20 V and 10 V respectively. Find the potential of the inner Shell.

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16. The potential at a point in an electric field is give by $V = Rr$ volt where r is distance of the point from the origin of the co-ordinate system. Find the electric field at a point $r = \left(\hat{i} + 2\hat{j} + 2\sqrt{5}\hat{k}\right)m$

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17. Electric potential in a 3 dimensional space is given by $V = \left(\frac{1}{x} + \frac{1}{y} + \frac{2}{z}\right)$ volt where x,y and

z are in meter. A particle has charge $q = 10^{12} C$ and mass $m = 10^{-9} g$ and is constrained to move in xy plane. Find the initial acceleraton of the particle if it is released at (1,1,1)m.

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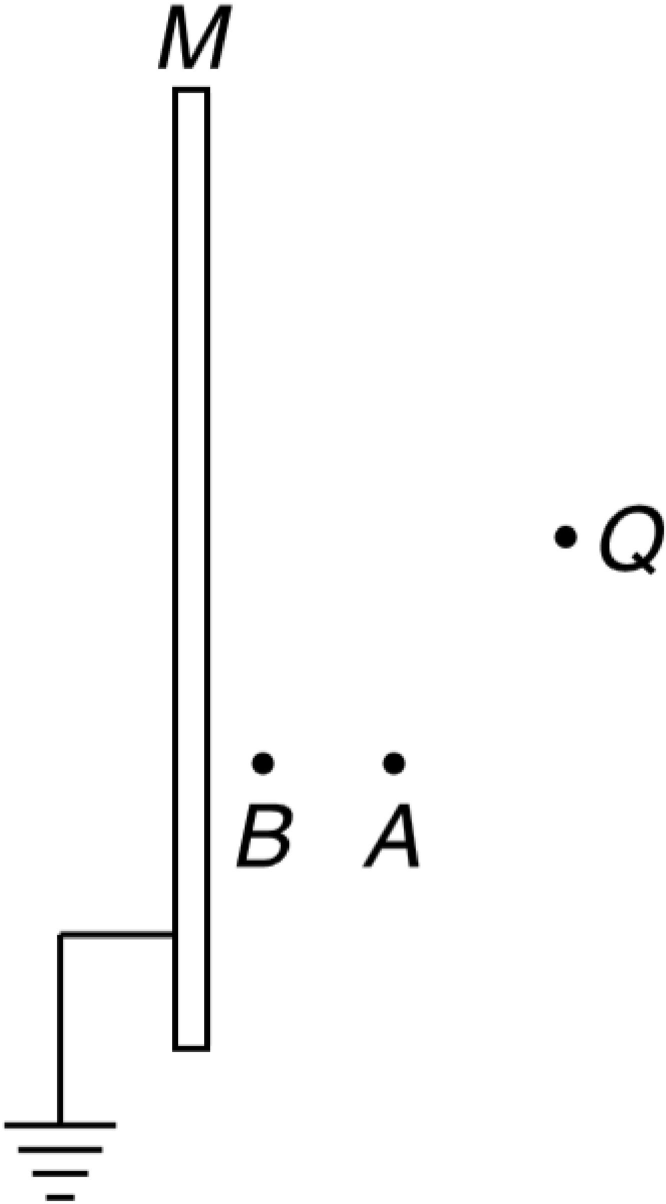
18. A metal plate M is grounded. A point charge + Q is placed in front of it. Consider two points A and B as shown in fig. At which point (A or B) is the electric field stronger? At which point is the potential higher?



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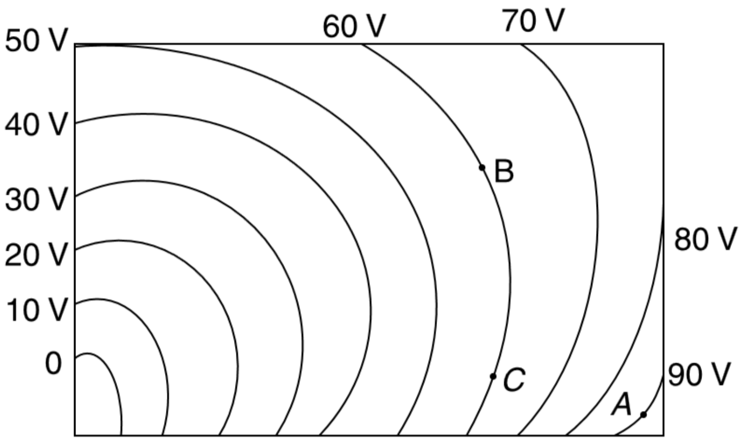
19. Equipotential lines arising from a static charge distribution has been shown in a certain region of space. (a) Draw the electric field lines starting from point A (b) If a charge is released at A, will it move along the field line passing through A? (c) How much work is done by the electric force if a charge moves from B to C? Is the knowledge of path important in this calculation?



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20. (a). The equipotential curves in x,y plane are given by $x^2 + y^2 = V$ when V si potential Draw the rough sketch of electric field lines in x-y plane.

(b). Repeat the above question if the potential field is given by $V = x^2 + y^2 - 4x + 4$

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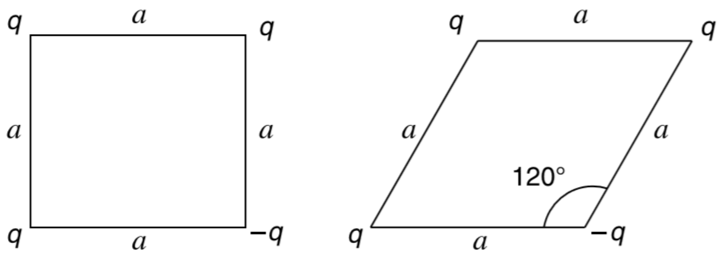
21. Four point charges q, q, q and – q are placed at the vertices of a square of side length a. The configuration is changed and the charge are positioned at the vertices of a rhombus of side length a with – q charge at the vertex where angle is 120°. Find the work done by the external agent in changing the configuration.



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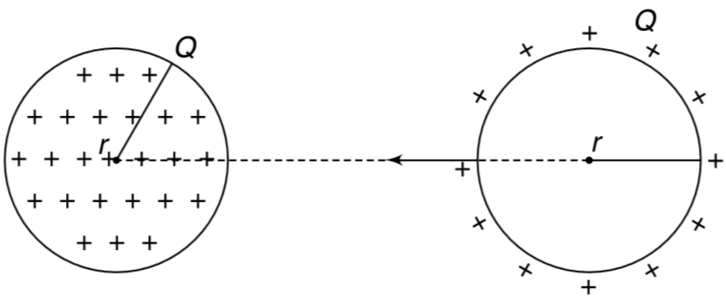
22. There is a ball of radius r having uniformly distributed volume charge Q on it and there is a spherical shell of radius r having uniformly distributed surface charge Q on it. The two spheres are far apart. (a) A point charge q is moved slowly from the centre of the shell (through a small hole in it.) to the centre of the ball. Find work done by the external agent in the process. (b) The two spheres are brought closer so that their centers are separated by 4r. Now calculate the amount of work needed in slowly moving a point charge q from the centre of the shell to the centre of the ball. Assume that charge on one ball does not alter the charge distribution of the other. Does your answers in (a) and (b) differ? Why?



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23. A uniformly charged sphere has charge Q. An electron (charge – e, mass m) revolves around it in a circular orbit of radius r. (a) Write the total energy (i.e., sum of its kinetic energy and electrostatic potential energy in the field of the sphere) of the electron. (b) If the time period of revolution of the electron in circular orbit of radius r is T, then find the time period if the orbital radius is made 4r.

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24. A uniformly charged sphere has radius R and charge Q on it. A negatively charged particle having mass m and charge – q shoots out of the surface of the sphere with speed V. The minimum speed (V_0) for which the particle escapes the attraction of the sphere may be called as escape speed. Will the value of V_0 depend on magnitude of q? [Recall that escape speed of a body from the surface of the earth does not depend on its mass].

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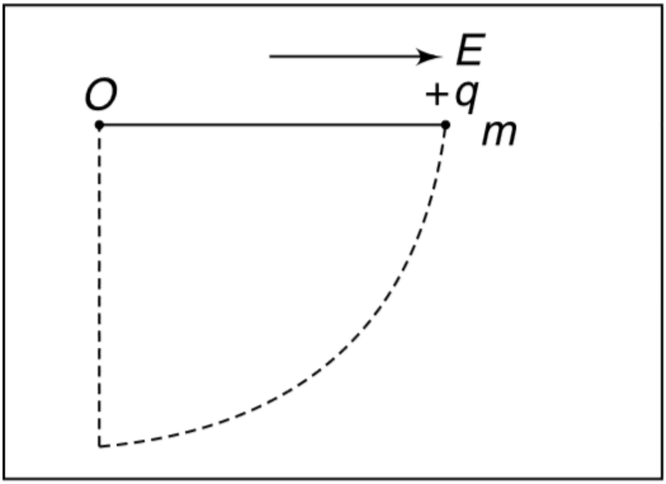
25. There is a uniform horizontal electric field of strength E in a region. A pendulum bob is pulled to make the string horizontal and released. The bob has mass m and charge q. (a) Find the maximum angle (θ_0) that the bob swings before coming to rest momentarily. (b) Find E if the bob comes to rest when the string is vertical.



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26. A conducting sphere of radius R carries a charge Q. It is enclosed by another concentric spherical shell of radius 2R. Charge from the inner sphere is transferred in infinitesimally small installments to the outer sphere. Calculate the work done in transferring the entire charge from the inner sphere to the outer one.

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27. The ratio of energy density in electrif field (u_E) to square of potential (V^2) at a point A at a distnance x from a static point charge Q is η

(a). Write the value of the ratio at a distance 2x from the point charge Q.

(b). Write the dimensional formula for the ratio η

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28. (a). Calculation the largest possible electrostatic energy in $1cm^3$ volume of air.t he dielectric breakdown of air happens when field exceeds $3 \times 10^6 V / m$

(b). A conducting ball of radius 10 cm is placed in distilled water $(\in_r = 80)$ and charged with a charge $Q = 2 \times 10^{-9} C$. Calculated the energy used up in charging the ball.

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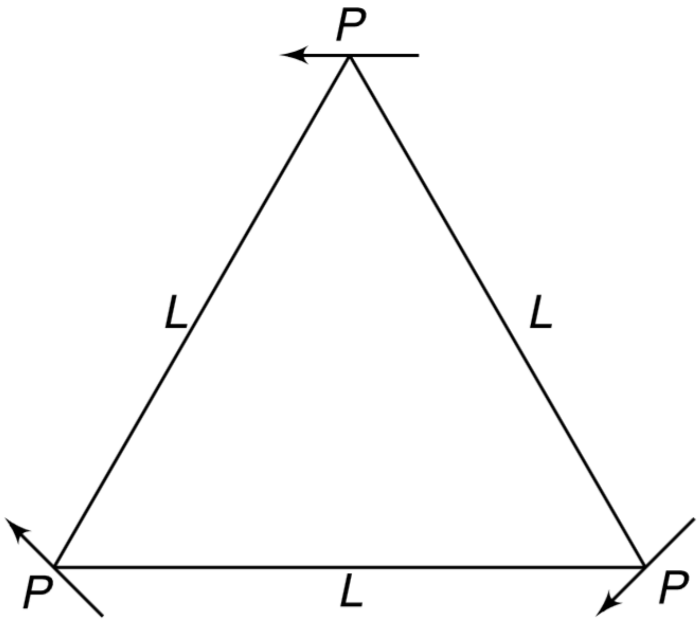
29. Three short electric dipoles, each of dipole moment P, are placed at the vertices of an equilateral triangle of side length L. Each dipole has its moment oriented parallel to the opposite side of the triangle as shown in the fig. Find the electric field and potential at the centroid of the triangle



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30. Short electric dipole of dipole moment P is placed at the centre of a ring of radius R having charge Q uniformly distributed on its circumference. The dipole moment vector is along the axis of the ring. Find force on the dipole due to the ring.

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31. Calculate the electric dipole moment of a system comprising of a charge + q distributed uniformly on a semicircular arc or radius R and a point charge – q kept at its centre.

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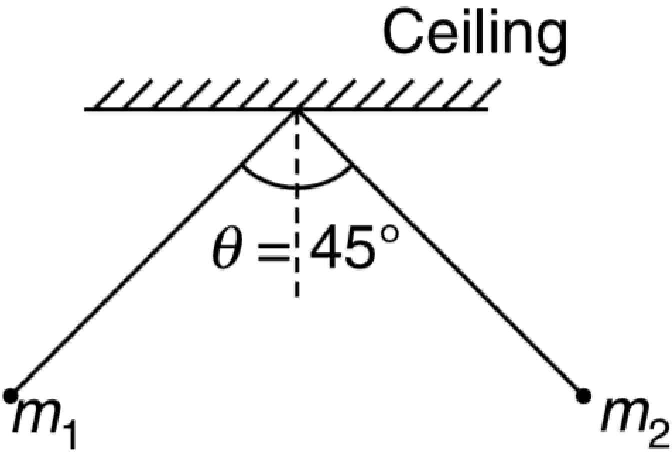
Level 2

1. Two unequal masses, $m_1 = 2m$ and $m_2 = m$ have unequal positive charge on them. They are suspended by two mass-less threads of unequal lengths from a common point such that, in equilibrium, both the masses are on same horizontal level. The angle between the two strings is $\theta = 45^\circ$ in this position. Find the Electrostatic force applied by m_1 on m_2 in this position.



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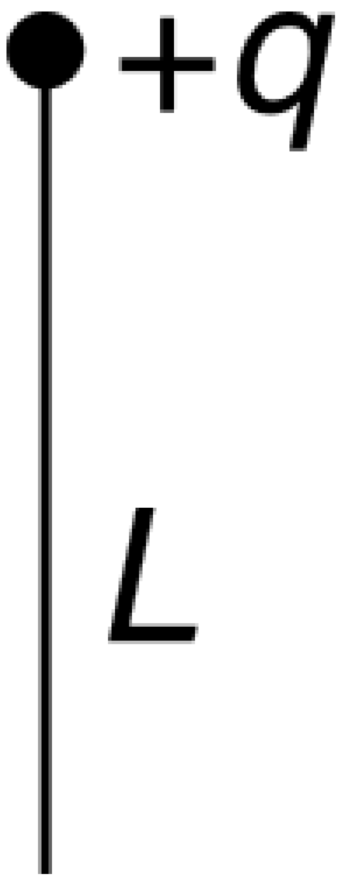
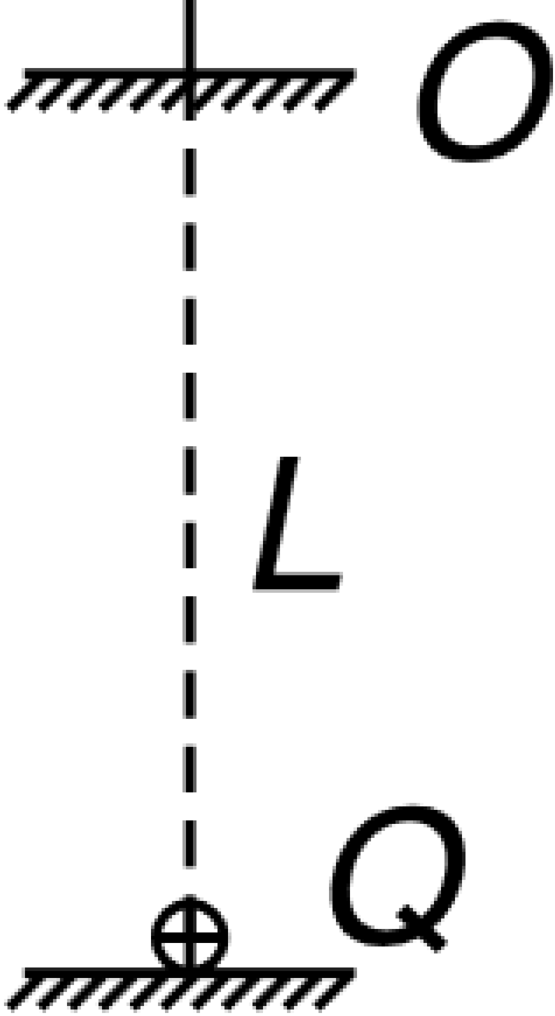
2. A particle of mass m and charge q is attached to a light insulating thread of length L. The other end of the thread is secured at point O. Exactly below point O, there is a small ball having charge

Q fixed on an insulating horizontal surface. The particle remains in equilibrium vertically above the ball with the string taut. Distance of the ball from point O is L. Find the minimum value of Q for which the particle will be in a stable equilibrium for any gentle horizontal push given to it.





O
L
Q

3. Four identical charges, Q each, are fixed at the vertices of a square. A free charge q is placed at the centre of the square. Investigate the nature of equilibrium of charge q if it is to be displaced slightly along any of the two diagonals of the square.

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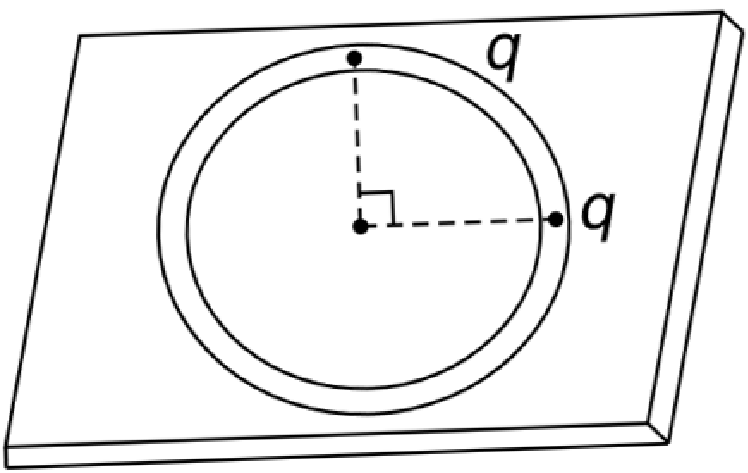
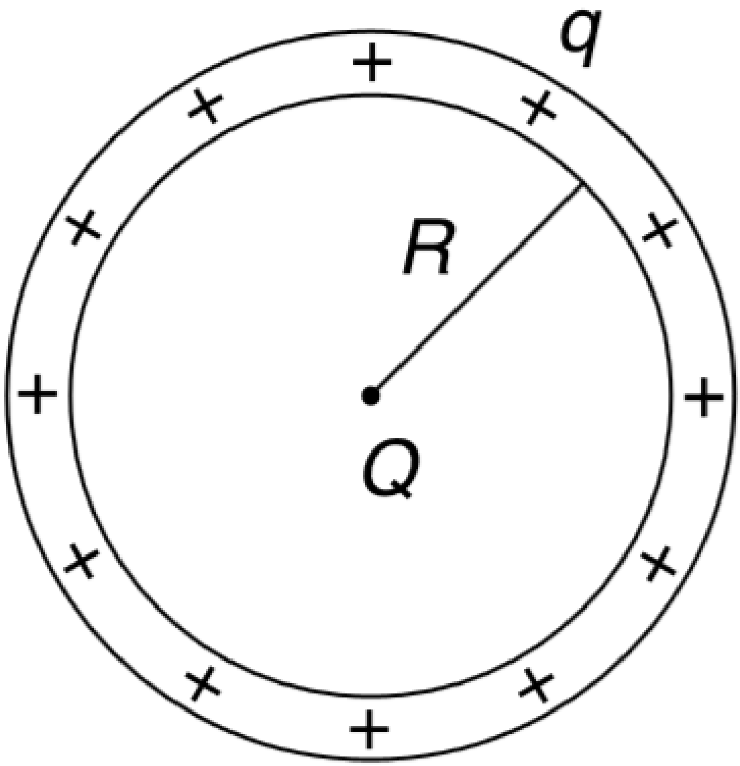
4. A horizontal circular groove is made in a wooden board. Two positive charges (q each) are placed in the groove at a separation of 90° (see figure). Where shall we place (in the groove) a third charge and what shall be its magnitude such that all three of them remain at rest after they are released. Answer for two cases: (a) When the third charge is positive. (b) When the third charge is negative. Neglect friction and assume that the groove is very thin just wide enough to accommodate the particles. [Take $\sin 22.5^\circ = 0.38, \cos 22.5^\circ = 0.92$]



5. Two identical positive charges Q each are placed on the x axis at point (-a,0) and (a,0) A point charge of magnitude q is placed at the origin. For small displacement along x axis, the charge q executes simple harmonic motion if it is poitive and its time period is T_1. if the charge q is negative, it perform oscillations when displaced along y axis. in this case the time period of small oscillations is T_2. find $\frac{T_1}{T_2}$

6. A ring of radius R has uniformly distributed charge q. A point charge Q is placed at the centre of the ring. (a) Find the increase in tension in the ring after the point charge is placed at its centre. (b) Find the increase in force between the two semicircular parts of the ring after the point charge is placed at the centre. (c) Using the result found in part (b) find the force that the point charge exerts on one half of the ring.



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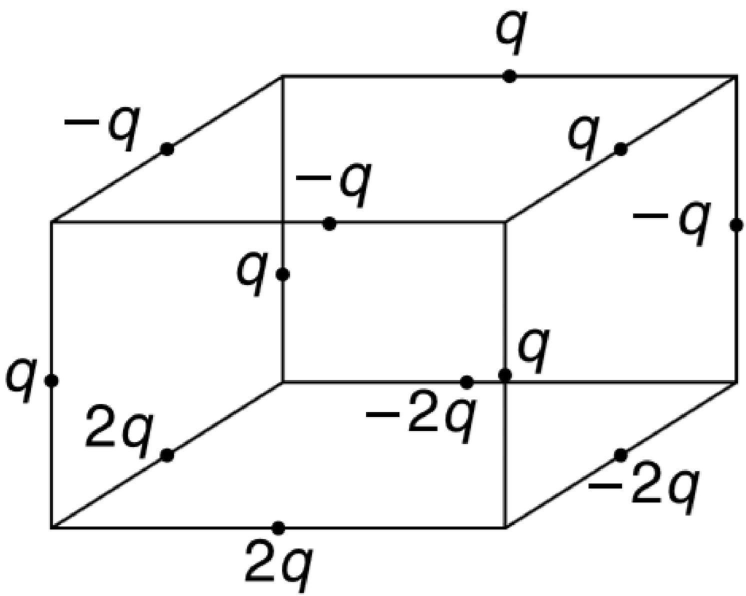
7. Twelve charges have been placed at the centre of each side of a cube as shown in the figure. Find the magnitude of Electric force acting on a charge Q placed at the centre of the cube. Take the side length of the cube to be r.



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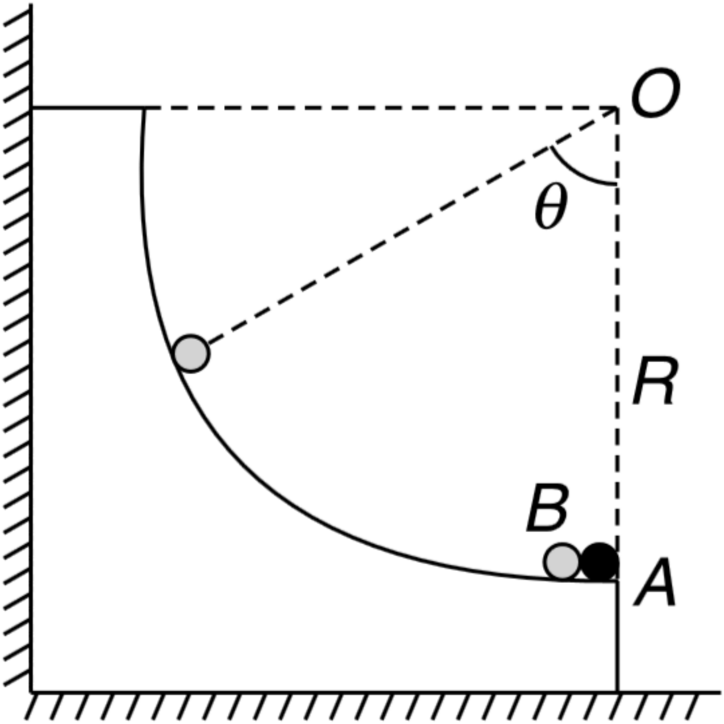
8. A fixed non conducting smooth track is in the shape of a quarter circle of radius R in vertical plane. A small metal ball A is fixed at the bottom of the track. Another identical ball B, which is free to move, is placed in contact with ball A. A charge Q is given to ball A which gets equally shared by the two balls. Ball B gets repelled and ultimately comes to rest in its equilibrium position where its radius vector makes an angle $\theta (\theta < 90^\circ)$ with vertical. Mass of ball is m. Find charge Q that was given to the balls.



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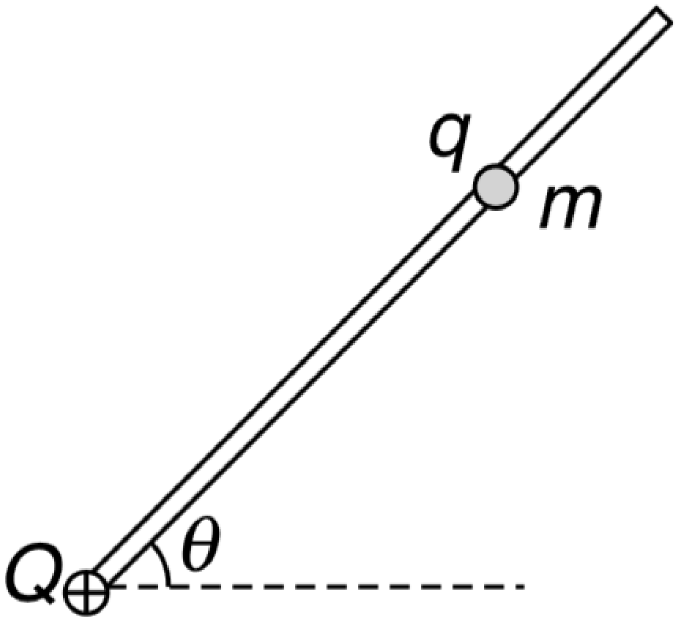
9. A smooth fixed rod is inclined at an angle θ to the horizontal. At the bottom end of the rod there is a fixed charge $+Q$. There is a bead of mas m having charge q that can slide freely on the rod. The equilibrium separation of the bead from fixed charge Q is x_0 Find the frequency of oscillation of the bead if it is displaced a little from its equilibrium position.



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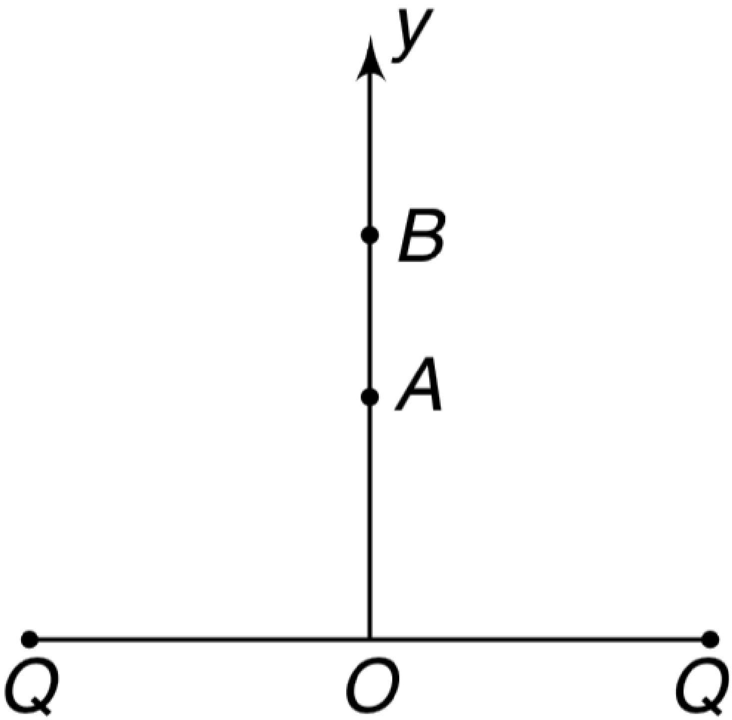
10. Two charges, Q each, are fixed on a horizontal surface at separation 2a. Line OY is vertical and is perpendicular bisector of the line joining the two charges. Another particle of mass m and charge q has two equilibrium positions on the line OY, at A and B. The distances OA and OB are in the ratio $1:3\sqrt{3}$ (a) Find the distance of the point on the line OY where the particle will be in stable equilibrium. (b) Where will the particle experience maximum electric force – at a point above B or at a point between A and B or somewhere between

O and A? Where is the acceleration of particle maximum on y axis from O to B?



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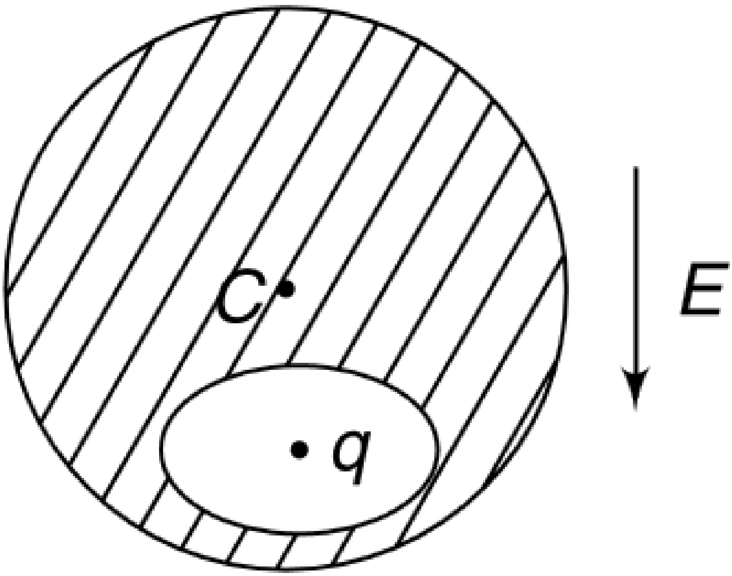
11. A neutral spherical conductor has a cavity. A point charge q is located inside it. It is in equilibrium. An external electric field (E) is switched on that is directed parallel to the line joining the centre of the sphere to the point charge. (a) What is the direction of acceleration of the charge particle inside the cavity after E is switched on. (b) How is the induced charge on the wall of the cavity affected due to the external field.



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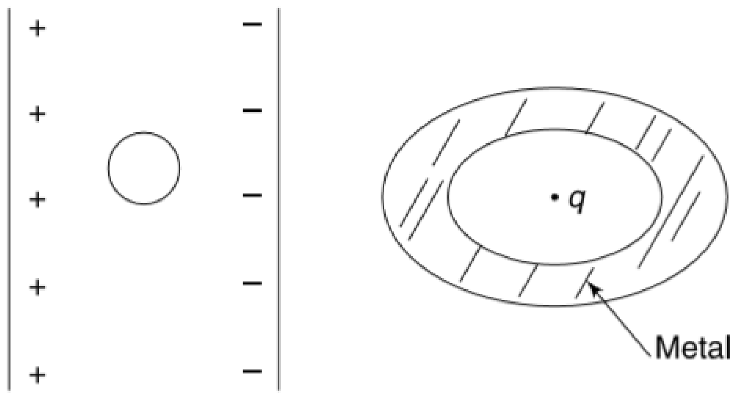
12. Draw electric field lines in following situations:

(a) A small neutral metal sphere is placed between the plates of an ideal parallel plate capacitor. [see figure] (b) A point charge is trapped inside a cavity in a neutral metal block (see figure)



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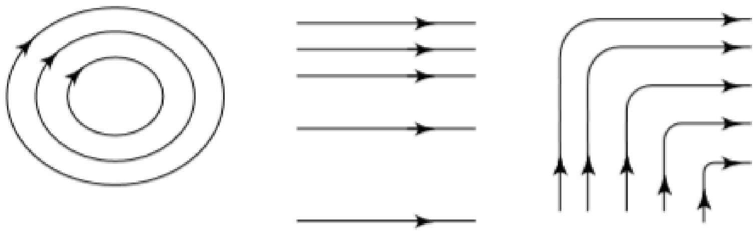
13. Three configurations of electrostatic field lines have been shown in the figure. Are these configurations possible? Explain your answer.



(a) (b) (c)

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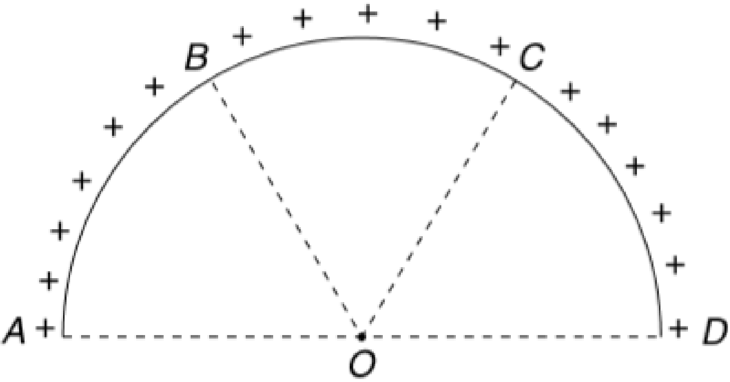
14. A uniformly charged semicircular ring (ABCD) produces an electric field E0 at the centre O. AB, BC and CD are three equal arcs on the ring. Portion AB and CD are cut from either side and removed. Find the field at O due to remaining part BC.



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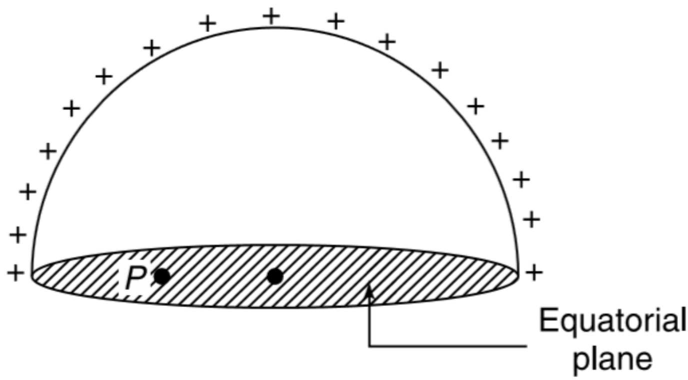
15. Consider a uniformly charged hemispherical shell. What can you say about the direction of electric field at points on the equatorial plane.

(e.g. point P)



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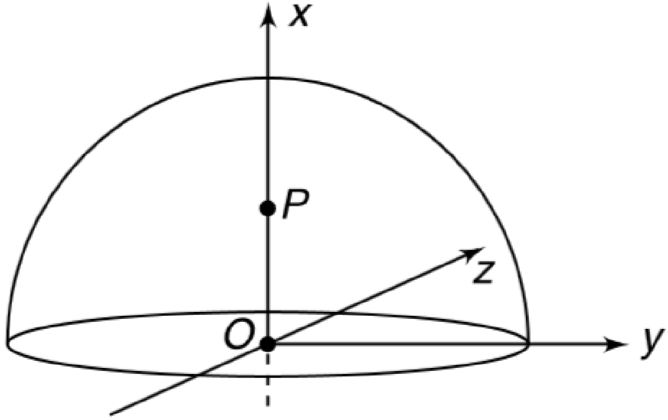
16. Consider a uniformly charged thin spherical shell as shown in figure. Radius of the shell is R.



The electric field at point $P(x, 0, 0)$ is $\overrightarrow{E}$ what is the electric field at a point $Q(-x, 0, 0)$ given $x < R$.

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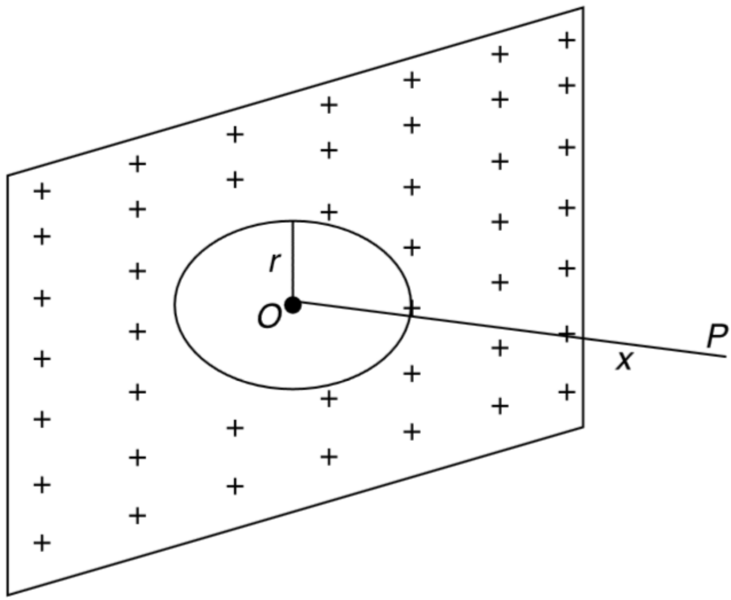
17. There is an infinite non conducting sheet of charge having uniform charge density σ. The electric field at a point P at a distance x from the sheet is E_0. Point O is the foot of the perpendicular drawn from point P on the sheet. A circular portio of radius $r < < x$ centered at O is removed from the sheet. Now the field at point P becomes $E_0 - \Delta E$. Find ΔE.



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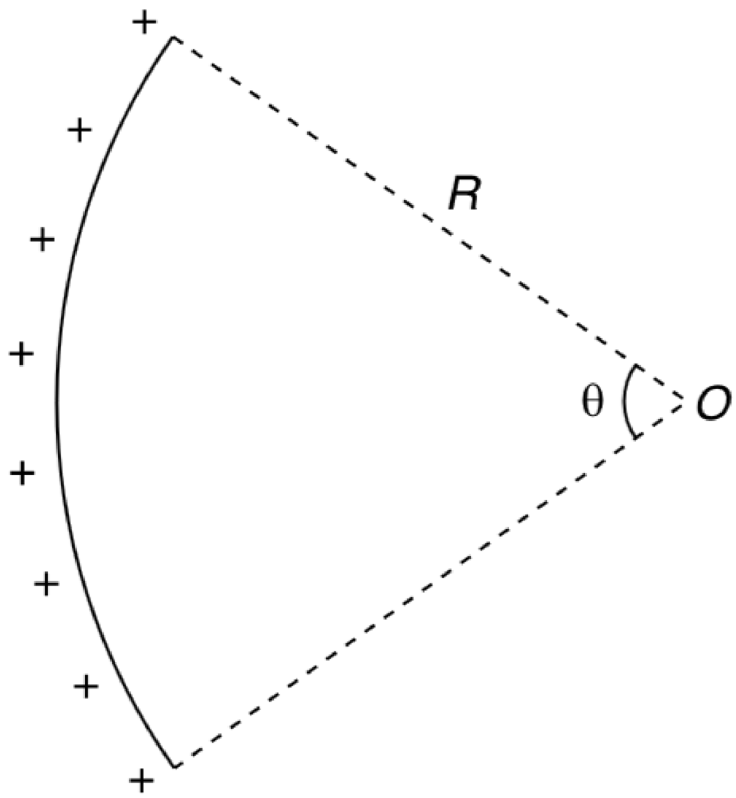
18. A thread having linear charge density λ is in the shape of a circular arc of radius R subtending an angle θ at the centre.

(a). Find the electric field at the centre.

(b). Using the epression obtained in part (a) find the field at the centre if the thread were emicircular

(c). Find the field at centre using the expression obtained in part (a) for the case $\theta \to 0$. Is the result justified?

(d). A thread having total charge Q (uniformly distributed is in the shape of a circular arc of radius R subtending an angle θ at centre. write the expression for the field at the center. Obtain the field when $\theta \to 0$. Make sure you understand the difference in case. (c) and (d).



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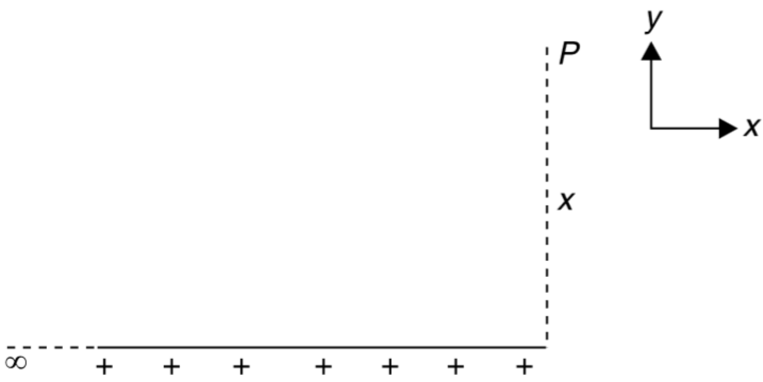
19. (a) There is an infinitely long thread uniformly charged with linear charge density $\lambda C/m$. Using Gauss' law, calculate the electric field (E_0) at a distance x from the thread. (b) Now consider a semi-infinite uniformly charged thread (linear charge density $= \lambda$) as shown in figure. Find the y component of electric field at point P in terms of E_0. Use simple qualitative argument. (c) For the situation described in (b) calculate the x component of electric field at point P using the method of integration. (d) Find the angle that the electric field at P makes with x direction.



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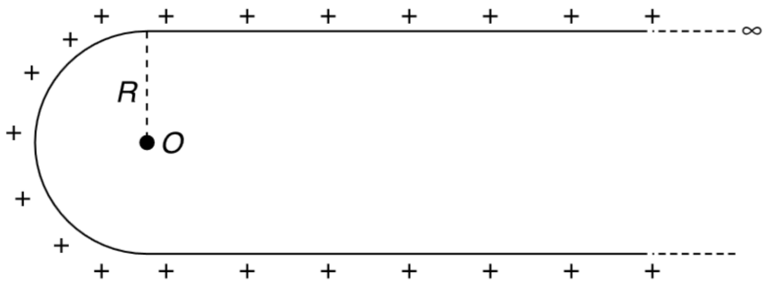
20. An infinitely long line charge is bent in U shape as shown in figure. The semicircular part has radius R and linear charge density is $\lambda C/m$. Using the results obtained in last two problems, calculate the electric field intensity at centre of the circle (point O)



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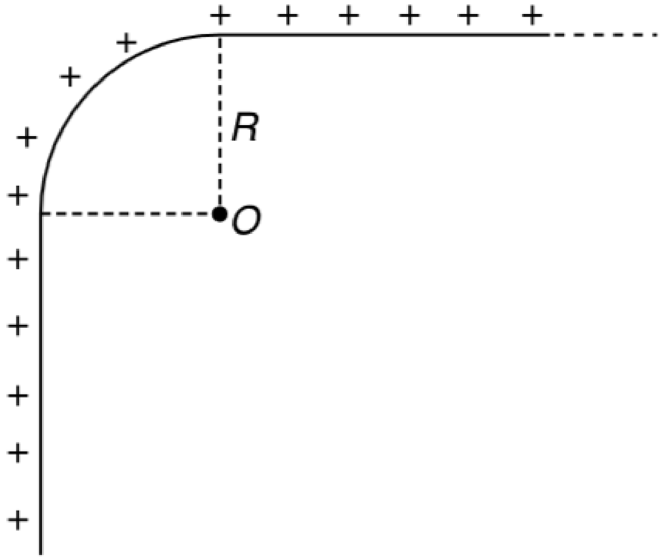
21. Repeat the above problem if the semicircular part is replaced with a quarter circle (see figure).



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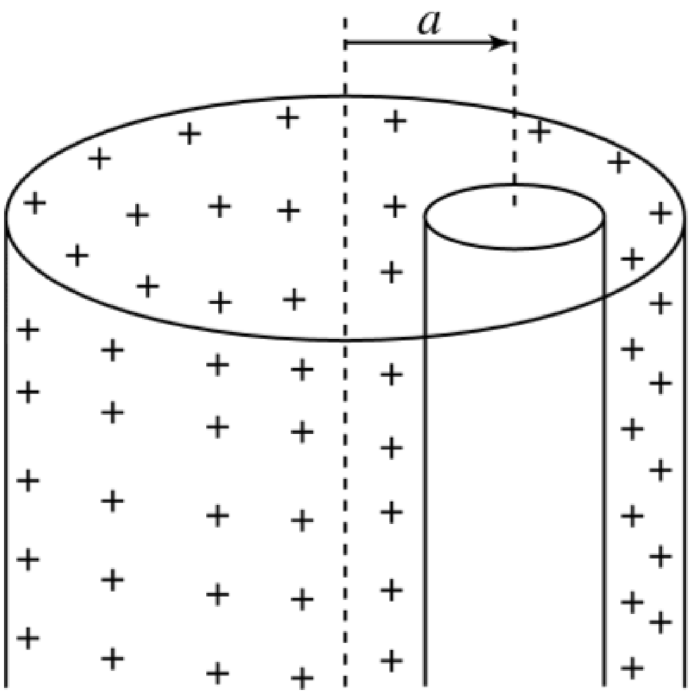
22. (a) There is a long uniformly charged cylinder having a volume charge density of $\rho C / m^3$. Radius of the cylinder is R. Find the electric field at a point at a distance x from the axis of the cylinder for following cases (i) x lt R (ii) x gt R What is the maximum field produced by the charge distribution at any point? (b) The cylinder described in (a) has a long cylindrical cavity. The axis of cylindrical cavity is at a distance a from the axis of the charged cylinder (see figure). Find electric field inside the cavity.



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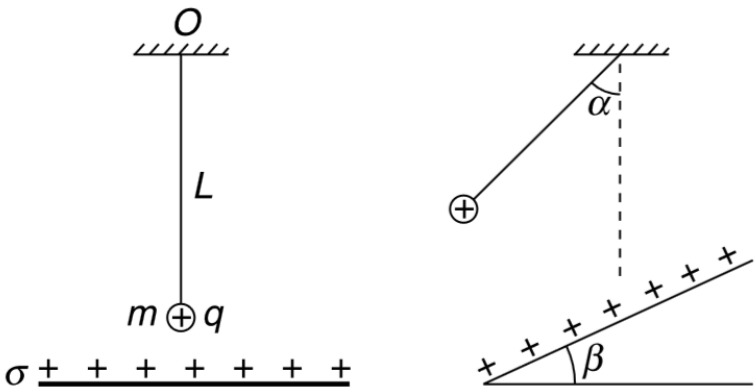
23. A pendulum has a bob of mass m carrying a positive charge q. Length of the pendulum string is L. Beneath the pendulum there is a large horizontal dielectric sheet of charge having uniform surface charge density of $\sigma C / m^2$. [figure (i)] (a) Find the time period of small oscillations for the pendulum (b) Now the dielectric sheet of charge is tilted so as to make an angle β with horizontal. Find the angle (a) that the thread makes with vertical in equilibrium position. Find time period of small oscillations in this case.

[figure (ii)]



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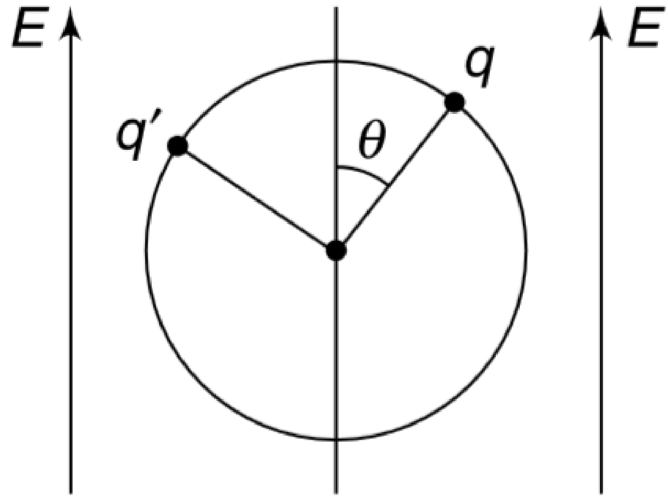
24. 

A uniform non conducting ring has mass m and radius R. tow point charges q and q' are fixed on its circumference at a separation of $\sqrt{2}R$ the ring remains in equilibrium in air with its plane vertical in a region where exists a uniform vertically upward electric field E. Given $E = \frac{4mg}{7q}$

(a) Find angle θ in equilibrium position (see figure). (b) The ring is given a small rotation in the plane of the figure and released. Will it perform oscillations?

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25. An infinitely long time charge has linear charge density $\lambda C / m$ the line charge is along the line $x = 0, z = 2m$ find the electric field at point (1,1,1) m.

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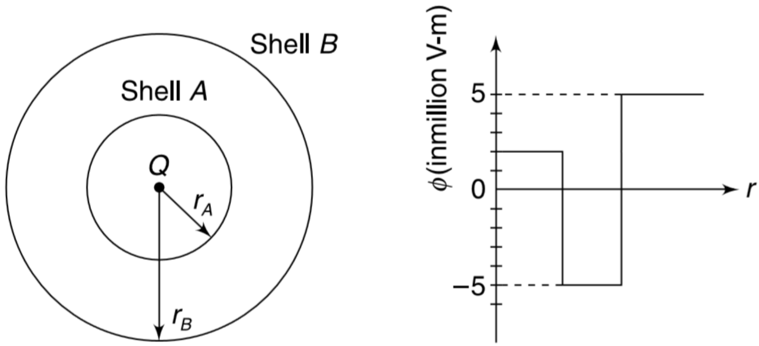
26. 

A charged particle is placed at the centre of two thin concentric spherical charged shells, made of non-conducting material. Figure A shows cross-section of the arrangement. Figure B gives the net flux ϕ through a Gaussian sphere centered on the particle, as a function of the radius r of the sphere. (a) Find charge on the central particle and shell A. (b) In which range of the finite values of r, is the electric field zero?

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27. There are two infinite slabs of charge, both of thickness d with the junction lying on the plane x = 0. The slab lying in the range 0 lt x lt d has a uniform charge density $+\rho$ and the slab lying in the region – d lt x lt 0 has uniform charge density $-\rho$. Find the Electric field everywhere and plot its variation along the x axis. Note: This can be used to model the variation of electric field in the depletion layer of a p – n junction.

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28. In an insulating medium (dielectric constant =1) the charge density varies with y Co-ordinate as $\rho = by$, where b is a positive constant.t he electric field is zero at y=0 and everywhere else it is along y direction. Calculate the electric field as a function of y.

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29. A nonconducting sheet of large surface area and thickness d contains uniform charge distribution of density ρ. Find the electric field at a point P inside the plate, at a distance x from the central plane. Draw a qualitative graph of E against x for $0 < x < d$.

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30. A charge distribution generates a radial electrif field $\overrightarrow{E} = \frac{a}{r^2} e^{-\frac{r}{k}} \hat{r}$, where r is distance from the origin $\hat{r}$ is a unit vector in radial direction away from the origini and a and k are positive constants. The electric field extends around the origin up to a large distance.

(a). Find the charge (q_0) that must be located at the origin to create such a field

(b). Find the quantity of charge (q) that must be spread around the charge q_0 at origin to create such a field.

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31. A pyramid has four faces, all of them being equilateral triangle of side a. A charge Q is placed at the centre of one of the faces. What is the flux of electric field emerging from any one of the other three faces of the pyramid?

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32. A point charge is placed very close to an infinite plane. What is flux through the plane?

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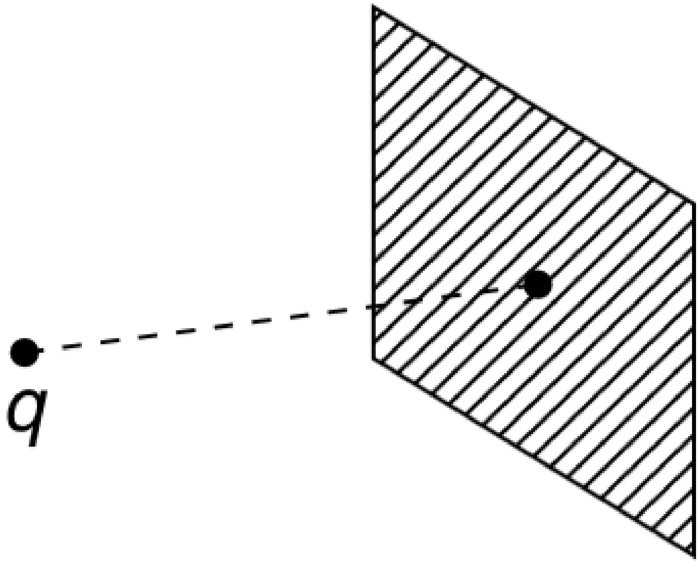
33. Point charge q s placed at a point on the axis of a square non-conducting surface. The axis is perpendicular to the square surface and is passing through its centre. Flux of electric field throught he square caused due to charged q is ϕ. If the square is given a surface change of uniform density σ, find the force on the square surface due to point charge q.



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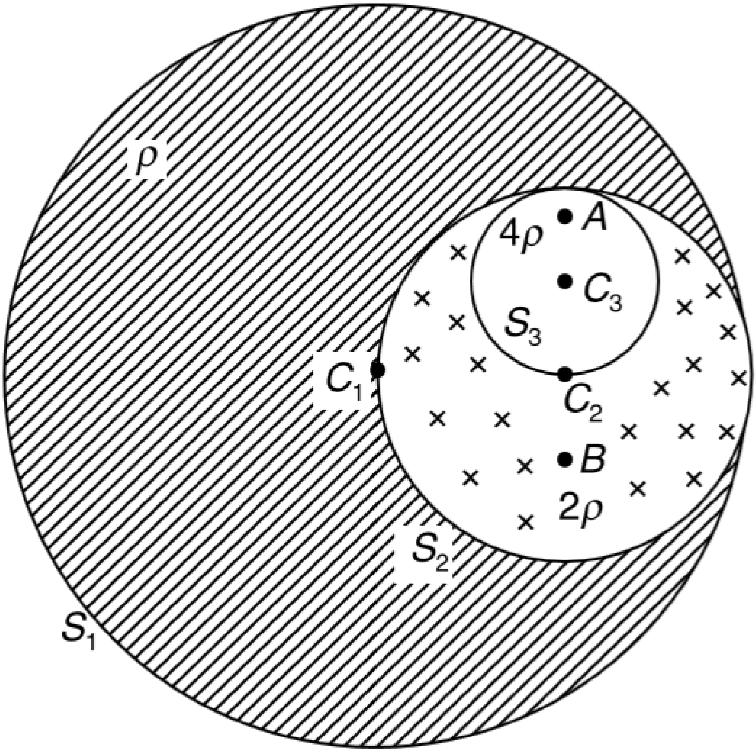
34. In the figure shown sphere S_1, S_2 and S_3 have radii R, $\frac{R}{2}$ and $\frac{R}{4}$ respectively C_1, C_2 and C_3

are centers of the three spheres lying in a plane Angle $\angle C_1C_2C_3$ is right angle. Sphere S_3 has a uniformly spread volume charge density 4ρ. the remaining pat of S_2 has uniform charge density of 2ρ and the left over part of S_1 has a uniform charge density of ρ.

(a) Find electric field at a point A at a distance $\frac{R}{8}$ from C_3 on the line, C_2C_3 (see figure)

(b). Find electric field at point B at a distance $\frac{R}{4}$

from C_2 on the line C_3C_2 (See figure)



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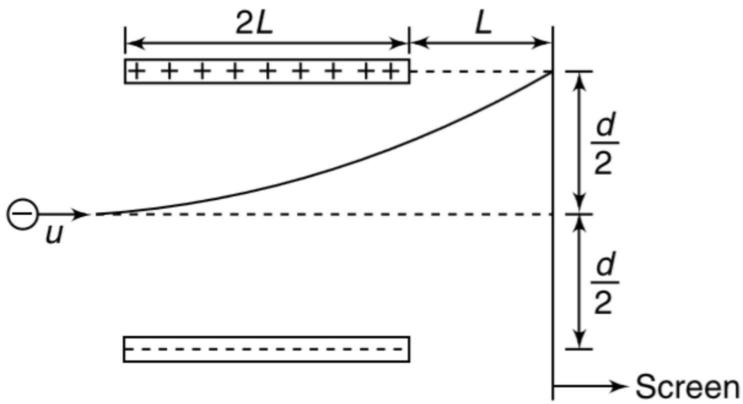
35. An electron (charge = e, mass = m) is projected horizontally into a uniform electric field produced between two oppositely charged parallel plates, as shown in figure. The charge density on both plates is $\pm \sigma C / m^2$ and separation between them is d. You have to assume that only electric force acts on the electron and there is no field outside the plates. Initial velocity of the electron is u, parallel to the plates along the line bisecting the gap between the plates. Length of plates is 2L and there is a screen perpendicular to them at a distance L. (i) Find s if the electron hits the screen at a point that is at same height as the upper plate.

(ii) Final the angle q that the velocity of the electron makes with the screen while it strikes it.



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36. A particle is projected at a speed of u = 40 m/s in vertically upward direction in a place where exists a horizontal uniform electric field E0. The specific charge of the particle is $\frac{4g}{3E_0}$. (a) Find the time after projection, when speed of the particle will be least. (b) Find the time (after projection) when displacement of the particle becomes perpendicular to its acceleration. (c) Assuming that the particle has been projected from a great height and the electric field is present in large region, what angle the velocity of the particle will make with horizontal after a long time?

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37. A charged particle having mass m I projected in a uniform electric field with a kinetic energy K_0.

After time t_0 it was observed that the kinetic enrgy of the particle was $\frac{K_0}{4}$ and its velocity was perpendicular to the field.

(a). (a) How much more time is required for the particle to regain its lost kinetic energy? (b) Write the impulse of the electric force acting on the particle between the two points where its kinetic energy is K_0. Neglect all other forces on the particle apart from the electrostatic force.

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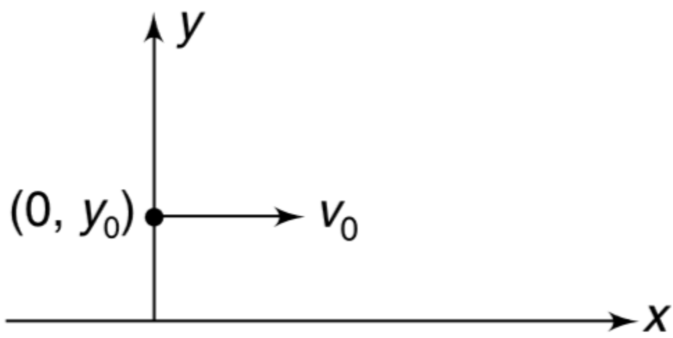
38. 

Electric field in xy plane is directed along positive y direction and its magnitude changes with y co-ordinate as $E = ay^2$

A particle having charge q and mass m is projected at point (0,y_0) with velocity

$\vec{v} = v_0\hat{i}$

Neglect all other forces o the particle apart from the electric force. Calculate the slope of the trajectory of the particle as a function of y.

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39. Two identical positive charges are placed at $x = -a$ and $x = a$. The correct variation of potential V along the x-axis is given by

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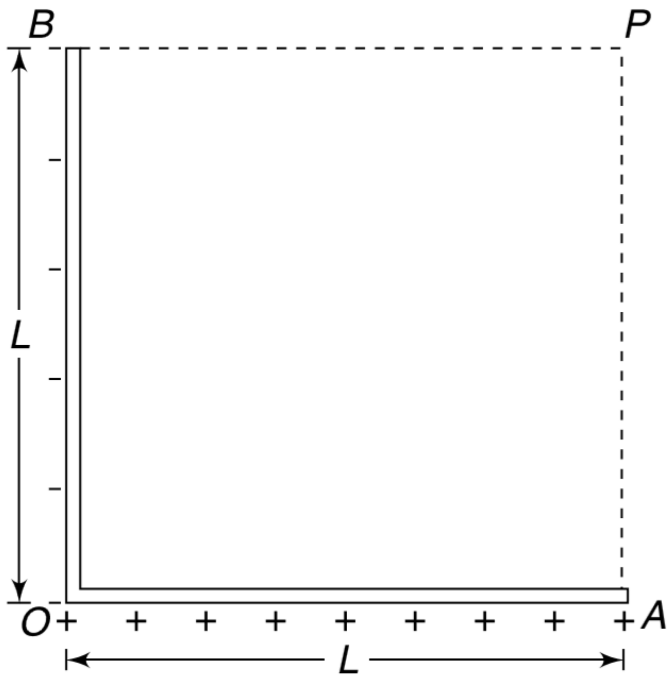
40. L shaped rod has equal and opposite charge $(\pm Q)$ spread along its both arms (see figure).

(a) What is direction of electric field at point P?

(b) Write electric potential at P.



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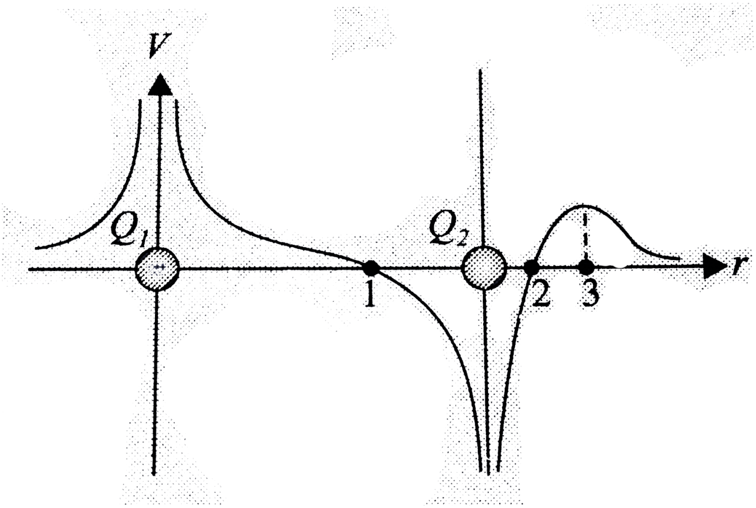
41. Two point charges Q_1 and Q_2 lie along a line at a distance from each other. Figure 3.7 shows the potential variation along the line of charges. At which of the points 1, 2, and 3 is the electric field zero ? What are the singns of the charges Q_1 and Q_2 and which of the two charges is greater in magnitude ?



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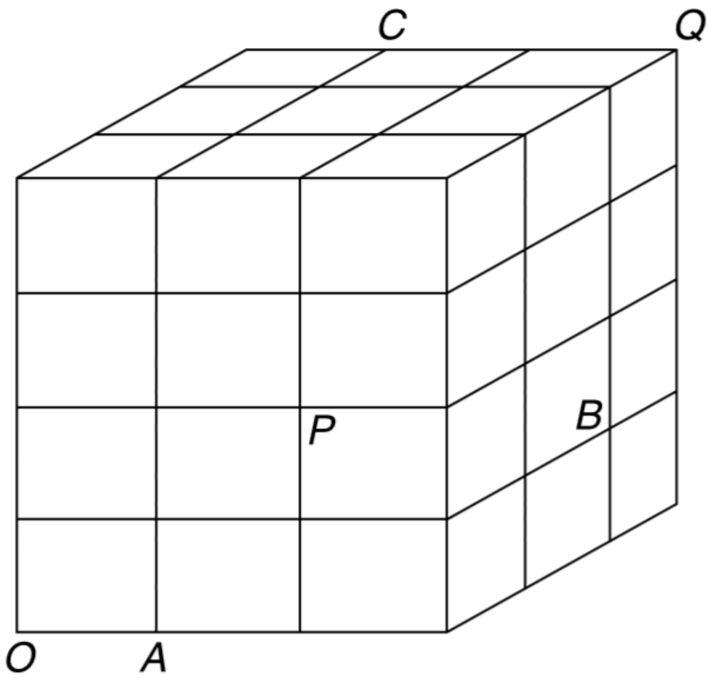
42. A uniform electric field exists in a region of space. Potential at potential O,A,B and C are $V_0 = 0$ and $V_A = -1V, V_B = -6V$ and $V_C = -3V$ respectively. Alll the cubes shown in fig have side length of 1m. ltbr. (a). Find $V_P - V_Q$ (b). Find the smallest distance of a point from O where the potential is $-2V$



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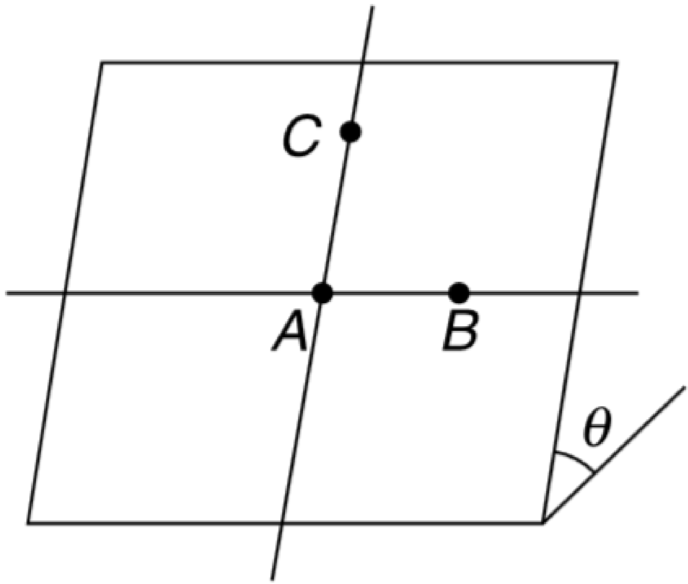
43. It is known that there exists a uniform electric field in a certain region. Imagine an incline plane (figure) in the region which is inclined at $\theta = 37^{\circ}$ to the horizontal when one moves horizontally along the incline from A to B (AB=1cm), the electric potential decreases by 10V. Similarly, potential at C(AC=1cm) is less than potential at A by 10 V where line AC lies on the incline and is perpendicualr to AB. When one moves vertically up from point A to a point D(AD=1cm), the potential drop by 10 V again. Find the magnitude of the electric field in the region and the angle that it makes with vertical [given $\sin 37^\circ = \frac{3}{5}$]



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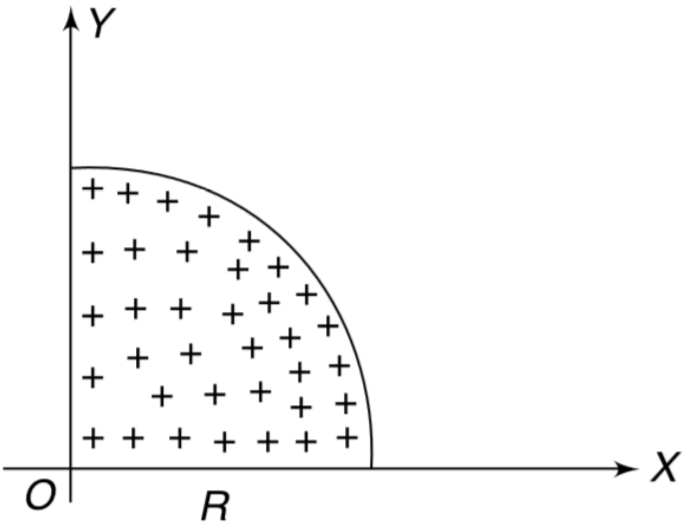
44. 

The quarter disc of radius R (see figure) has a uniform surface charge density σ.

(a) Find electric potential at a point (O,O,Z)

(b). Find the Z component of electrif field at (O,O,Z)

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45. Electric field in a three dimensional space is directed radially towards a fixed point and its magnitude varies with distance (r) from the fixed point as E = 4r V/m (a) Draw electric field lines to approximately represent such a field.

(b) Calculate the quantity of charge present inside a spherical volume of radius a centered at the fixed point.

(c). Find potentail difference $(V_A - V_B)$ between two points $A\left(1, 1, \sqrt{2}\right)$ m and $B(0, 3, 4)m$ take the fixed point to be the origin.

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46. When a conducting disc is made to rotate about its axis, the centrifugal force causes the free electrons to be pushed toward the edge. This causes a sort of polarization and an electric field is induced. The radial movement of free electrons stops when electric force on an electron balance the centrifugal force. Calculate the potential difference developed across the centre and the edge of a disc of radius R rotating with angular speed ω. [This potential difference is sometimes called as sedimentation potential]. Take mass and charge of an electron to be m and e respectively

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47. Consider a cube of uniform charge density ρ. The ratio of electrostatic potential at the centre of the cube to that at one of the corners of the cube is

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48. A metallic sphere of radius R has been charged to a potential of V = 100 volt. A thin hemispherical conducting shell has dimensions so that it can just fit on the half of the metallic sphere. The shell is originally grounded. Now, using an insulating handle, it is placed on top of the charged sphere so as to perfectly cover its top half. The shell is removed from the sphere and again grounded. After this the shell is again placed on the sphere, removed and then grounded. The process is continued till the potential of the sphere becomes V' = 6.25 volt. How many times the shell was placed on the sphere?

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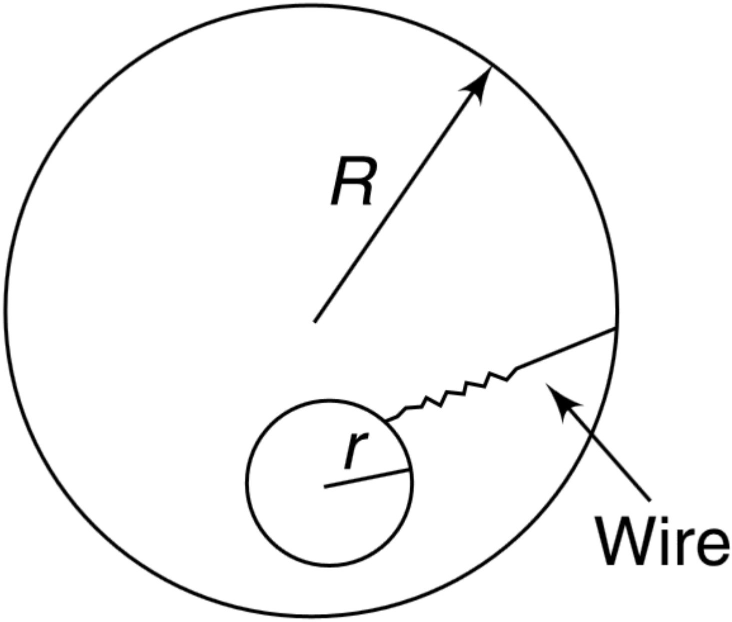

49.

A conducting ball of radius r is charged to a potential V_0. It is enveloped by a thin walled conducting sphere of radius R (gt r) and the two spheres are connected by a conducting wire. Find the potential of the outer sphere.

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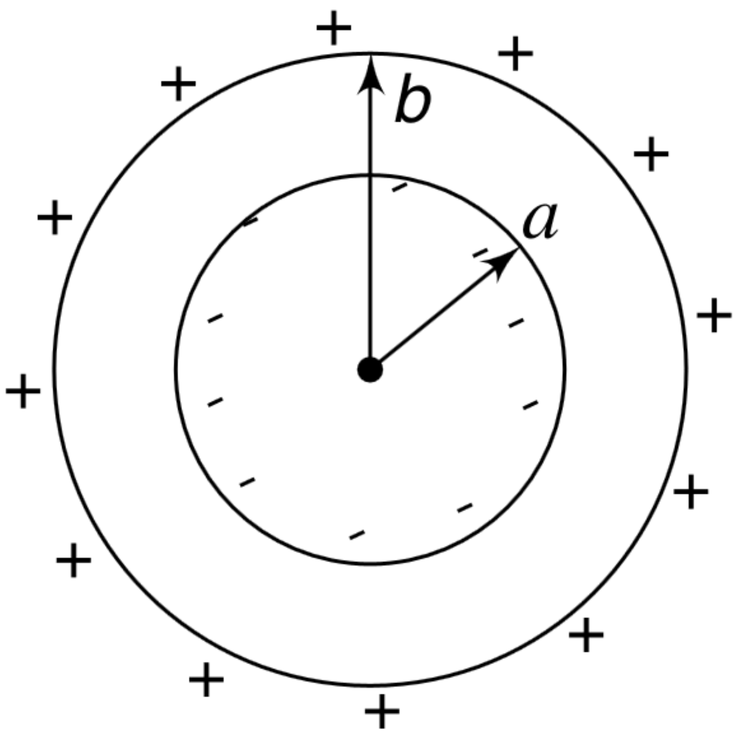
50.



A thick conducting spherical shell of inner radius a and outer radius b is shown in figure. It is observed that the inner face of the shell carries a uniform charge density $-\sigma$. The outer surface also carries a uniform surface charge density $+\sigma$.

(a) Can you confidently say that there must be a charge inside the shell? Find the net charge present on the shell. (b) Find the potential of the shell.

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51. A conducting liquid bubble of radius a and thickness $t(t < < a)$ is charged to potential V. If the bubble collapses to a droplet , find the potential on the droplet .

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52. A point charge q has been placed at a distance x from the centre of a neutral solid conducting sphere of radius R(x gt R). Find the potential of the sphere. How will your answer change if the sphere is not solid, rather it is a thin shell of conductor.

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53. There is a hemispherical shell having charge Q uniformly distributed on its surface. Radius of the shell is R. Find electric potential and field at the centre (of the sphere).

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54. There is a hemisphere of radius R having a uniform volume charge density ρ. Find the electric potential and field at the centre

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55. Find the potential φ at the edge of a thin disc of radius R carrying the uniformly distributed charge with surface density σ.

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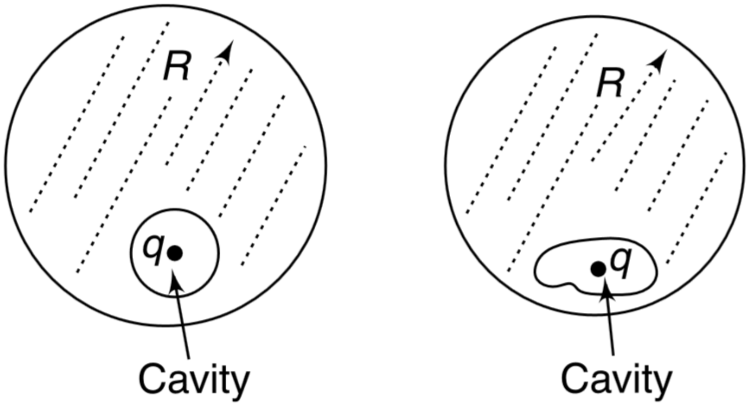
56. A solid spherical conductor of radius R has a spherical cavity inside it (see figure). A point charge q is placed at the centre of the cavity. (a) What is the potential of the conductor? (b) If the charge q is shifted inside the cavity by a distance Δx, how does the potential of the conductor change? (c) How does your answer to the question (a) and (b) change if the cavity is not spherical and the charge q is placed at any point inside it (see figure) (d) Draw electric field lines in entire space in each case. In which case all field lines are straight lines



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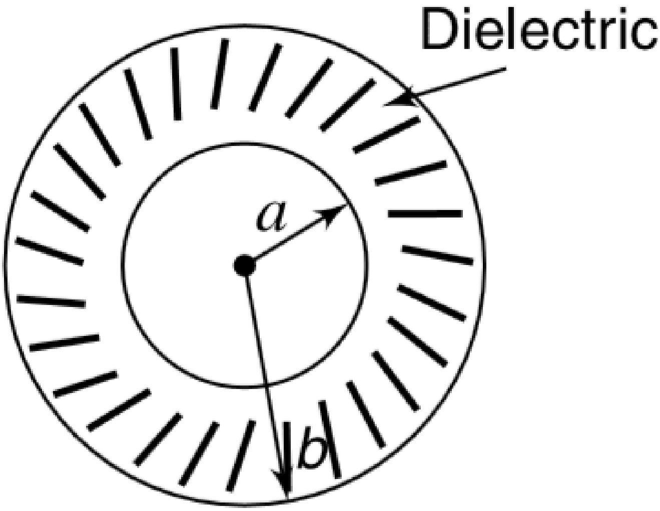
57. Conducting ball of radius a is surrounded by a layer of dielectric having inner radius a and outer radius b. The dielectric constant is K. The conducting ball is given a charge Q. Write the magnitude of electric field and electric potential at the outer surface of the dielectric.



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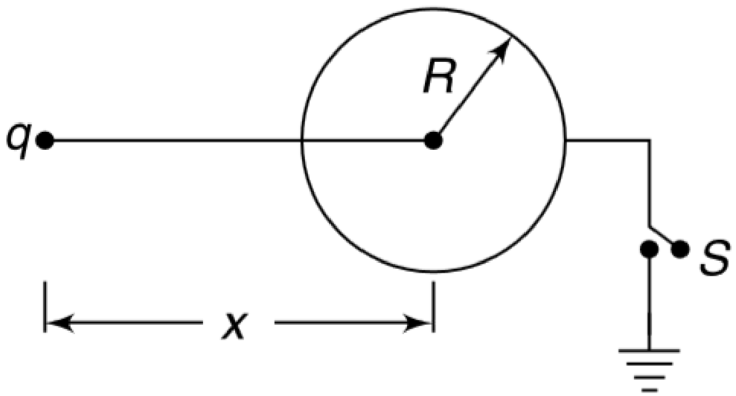
58. A point charge q is placed at a distance x from the centre of a conducting sphere of radius R(lt x). (a) How much charge will flow through the switch S when it is closed to ground the sphere? (b) Find the current through the switch S when charge ‘q’ is moved towards the sphere with velocity V.



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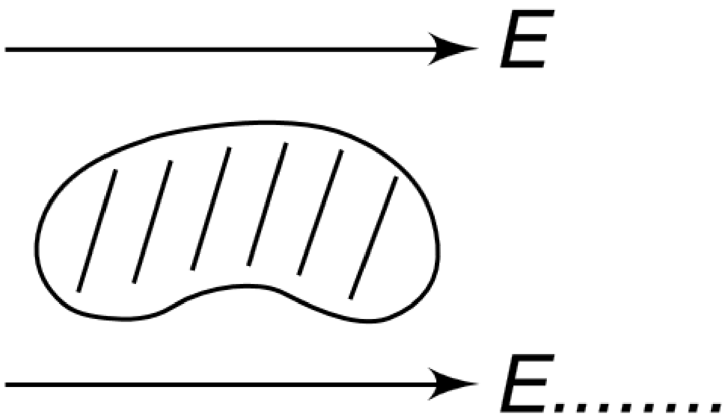
59. A conductor is placed in a uniform external electric field (see figure). Sketch the equipotential surfaces.



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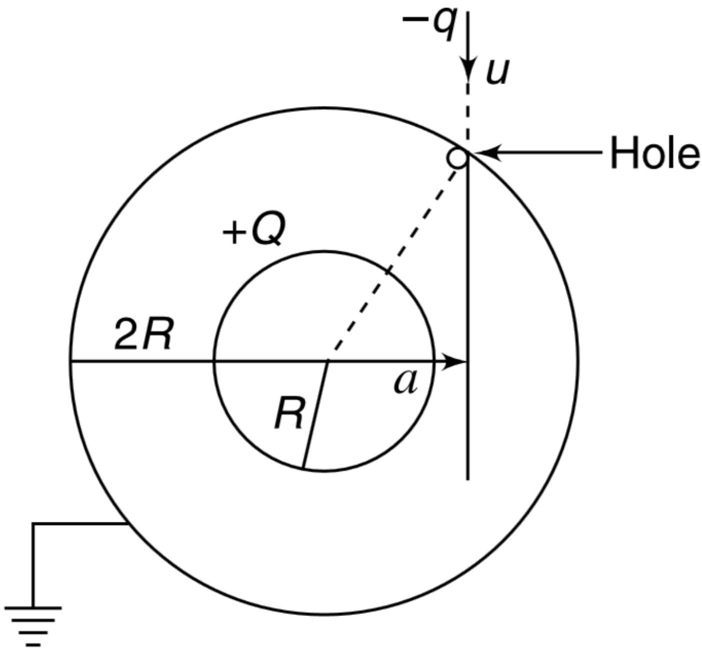
60. Two concentric spherical shells have radii R and 2R. The outer shell is grounded and the inner one is given a charge +Q. A small particle having mass m and charge – q enters the outer shell through a small hole in it. The speed of the charge entering the shell was u and its initial line of motion was at a distance $a = \sqrt{2}R$ from the centre. (a) Find the radius of curvature of the path of the particle immediately after it enters the shell. (b) Find the speed with which the particle will hit the inner sphere. Assume that distribution of charge on the spheres do not change due to presence of the charge particle



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61. There charges q, 3q and 12q are to be placed on a straight line AB having 12 cm length. Two of the charges must be placed at end points A and B and the third charge can be placed anywhere between A and B. Find the position of each charge if the potential energy of the system is to be minimum. In the position of minimum potential energy what is the force on the smallest charge?

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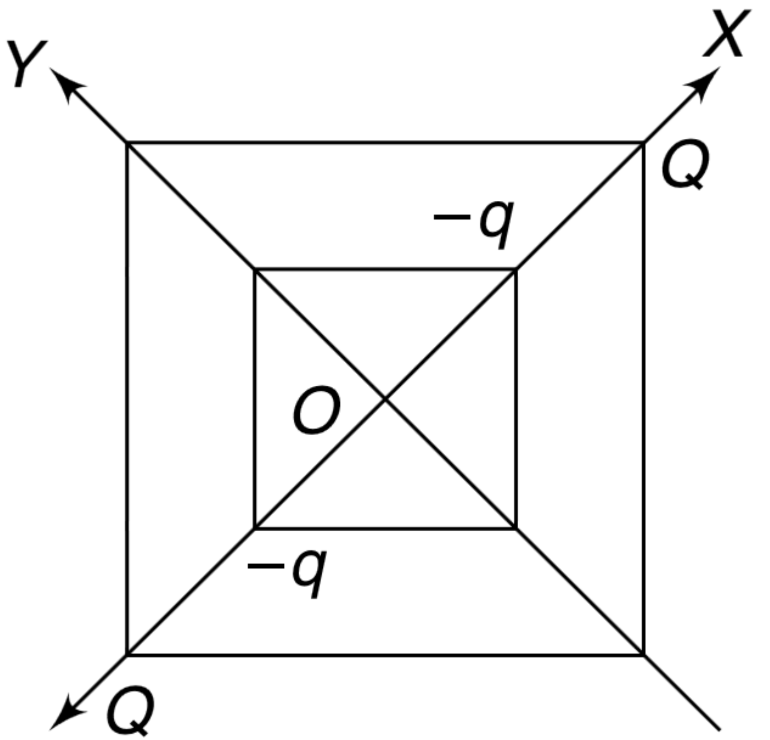
62. Two square of sides a and 2a are placed in xy plane with their centers at the origin. Two charges, – q each, are fixed at the vertices of smaller square (lying on X axis). Two charges, Q each, are fixed at the vertices of bigger square on the X axis (see figure). (a) Find work required to slowly move the larger square to infinity from the position shown. (b) Find work done by the external agent in slowly rotating the inner square by 90° about the Y axis followed by a rotation of 90° about the Z axis.



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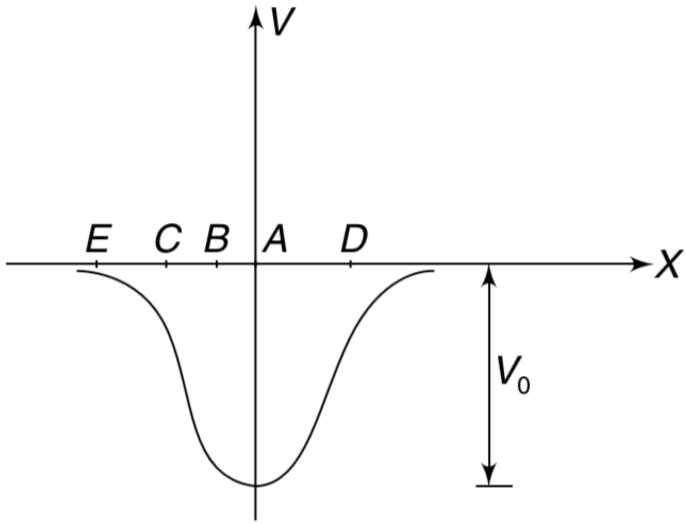
63. A certain charge distribution produces electric potential that varies along the X axis as shown in figure. [There is no field in y or z direction] (a) At which point (amongst A, B, C, D and E) does a negative charge feel the greatest force in positive X direction? (b) Find the upper limit of the speed that a proton can have, as it passes through the origin, and still remain bound near the origin. Mass and charge of a proton are m and e. How will your answer change for an electron?



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64. A simple pendulum of length l has a bob of mass m , with a charge q on it. A vertical sheet of charge , with the vertical . Its time period of oscillation is T in this position

(i) $\tan\theta = \dfrac{\sigma q}{2\varepsilon_0 mg}$

(ii) $\tan\theta = \dfrac{\sigma q}{\varepsilon_0 mg}$

(iii) $T < 2\pi\sqrt{\dfrac{l}{g}}$

(iv) $T > 2\pi\left(\dfrac{l}{g}\right)$

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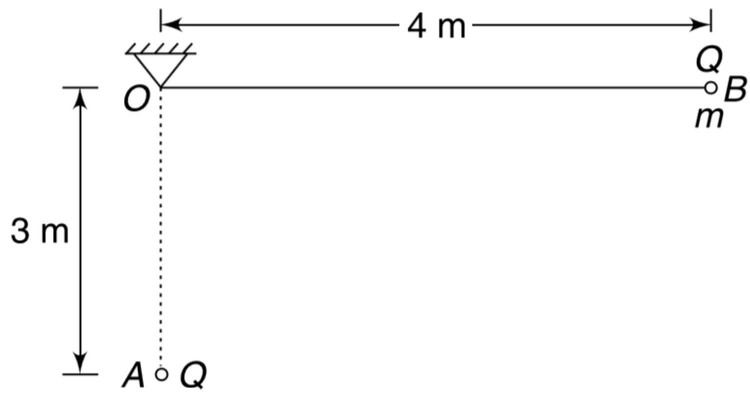
65. Below the fixed end O of the insulating horizontal thread OB, there is a fixed charge A of $Q = 20\mu c$. At the end B of the thread there is a small mass m carrying charge $Q = 20moc$. The mass is released from the position shown and it is found to come to rest when the thread becomes vertical. Assume that the thread does not hit the fixed charge at A. $\left[g = 10m/s^2\right]$ (a) Find mass m. (b) Find tension in the thread in the equilibrium position when the thread is vertical. (c) Is the equilibrium mentioned in (b) stable or unstable?



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66. A small positively charged ball of mass m is suspended by an insulating thread of length L. This ball remains in equilibrium with string horizontal when another small charged ball is placed exactly at a distance L below the point of suspension of the first ball. The second ball is slowly moved away from the first ball to a far away point. (The second ball is moved horizontally so that the first ball does not accelerate). As a result the first ball lowers down to the original position of the second ball and the string become vertical. Find the work done by the external agent in removing the second ball.

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67. A particle (A) having charge Q and mass m is at rest and is free to move. Another particle (B) having charge q and mass m is projected from a large distance towards the first particle with

speed u. (a) Calculate the least kinetic energy of the system during the subsequent motion. (b) Find the final velocity of both the particles. Consider coulomb force only.

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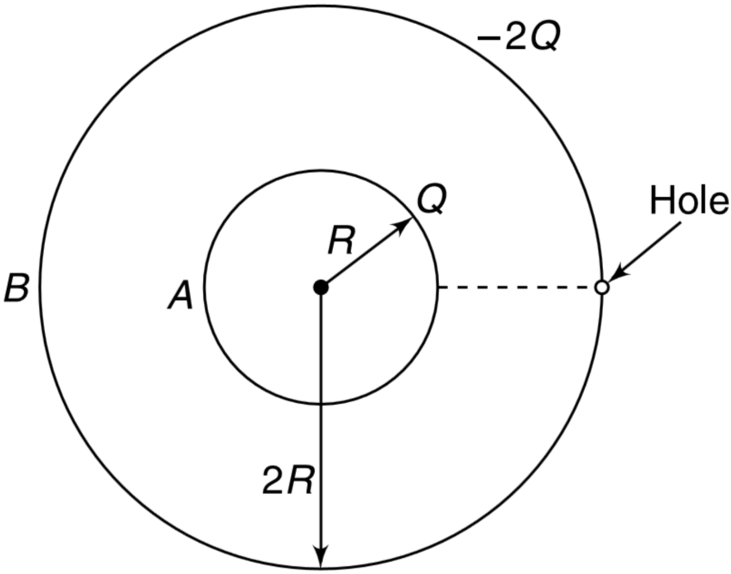
68. In the last question, the two particles A and B are initially held at a distance $r = \frac{qQ}{2\pi \in_0 mu^2}$ apart. Particle B is projected directly towards A with velocity u and particle A is released simultaneously. Find the velocity of particle A after a long time. Consider coulomb force only.

69. Two positively charged balls having mass m and 2 m are released simultaneously from a height h with horizontal separation between them equal to x_0. The ball with mass 2 m strikes the ground making an angle of 45° with the horizontal. (a) At what angle, with horizontal, the other ball hits the ground? (b) Find the work done by the electrostatic force during the course of fall of the two balls.

70. A and B are two concentric spherical shells made of conductor. Their radii are R and 2R respectively. The two shells have charge Q and – 2Q on them. An electron escapes from the surface of the inner shell A and moves towards a small hole in the outer shell B. (a) What shall be the minimum kinetic energy of the emitted electron so that it can escape to infinity through the small hole in outer shell? (b) What will be your answer if charge on both the shells were +Q? Charge on electron = e.



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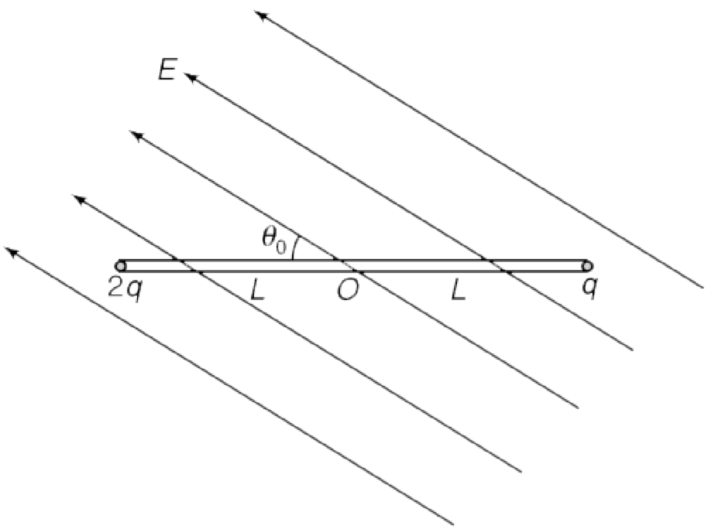
71. A thin uniform rod of mass M and length 2L is hinged at its centre O so that it can rotate freely in horizontal plane about the vertical axis

through O. at its ends the insulating rod has two point charges 2q and q (see figure). An electrif field E is switched on making and angle $\theta_0 = 60^\circ$ with the initial position of the rod. The field is uniform and horizontal. (a) Calculate the maximum angular velocity of the rod during subsequent motion. (b) Find the maximum angular acceleration of the rod.



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72. Two charge particles are moving such the distance between them remains constant. The ratio of their masses is 1 : 2 and they always have equal and opposite momentum. The particles interact only though electrostatic force and no other external force is acting on them. The electrostatic interaction energy for the pair of the particles is $-U_0$. Find the kinetic energy of the lighter particle. How does the kinetic energy change with time?

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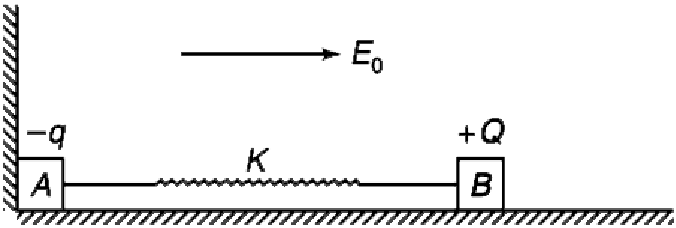
73. Two blocks A and B are connected by a spring made of a non conducting material. The blocks are placed on a non conducting smooth horizontal surface (see figure). The wall touching A is also non conducting. Block A carries a charge – q. There exists a uniform electric field of intensity E_0 in horizontal direction, in the entire region. Find the value of minimum positive charge Q that we must place on block B and release the system so that block A subsequently leaves contact with the wall. Force constant of the spring is k. Neglect interaction between charges on the blocks.



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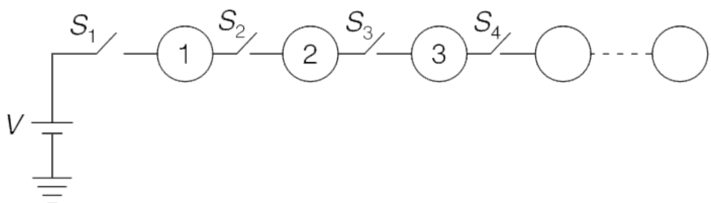
74. Large number of identical conducting spheres have been laid as shown in figure. Radius of each sphere is R and all of them are uncharged. Switch S_1 is closed to connect sphere 1 to the positive terminal of a V volt cell whose other terminal is grounded. After some time switch S_1 is opened and S_2 is closed. Thereafter, S_2 is opened and S_3 is closed, next S_3 is opened and S_4 is closed. The process is continued till the last switch is closed. Consider the cell and spheres to be your system and calculate the loss in energy of the system in the entire process.



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75. A short electric dipole has dipole moment p. Find the distance of farthest point from the dipole where (a) potential due to the dipole is V_0 (b) Electric field due to the dipole is E_0

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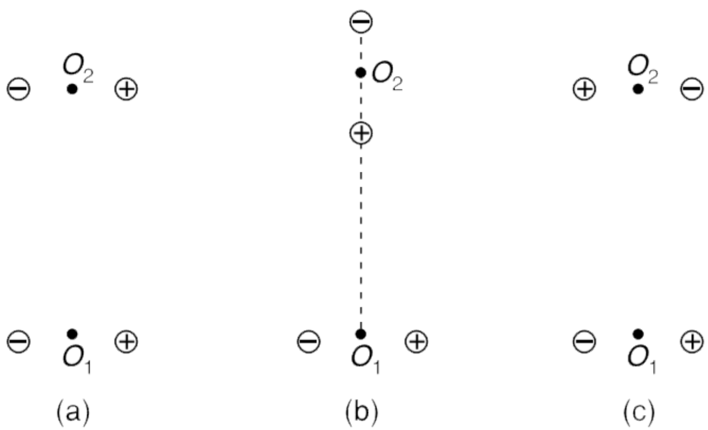
76. Two identical electric dipoles are arranged parallel to each other with separation between them large compared to the length of individual dipole. The electrostatic energy of interaction of the two dipoles in this position is U. (a) Find work done in slowly rotating one of the dipoles by 90° so as to bring it to position shown in Fig. (b). (b) Find work done in rotating one of the dipoles by 180° so as to bring it to the position shown in Fig. (c). O_1 and O_2 are centers of the dipoles.



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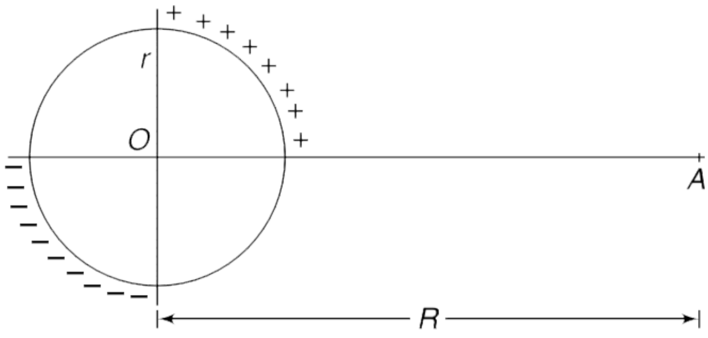
77. A ring of radius r has a uniformly spread charge + q on quarter of its circumference. The opposite quarter of the ring carries a charge – q uniformly spread over it. Find the electric potential at a point A shown in the figure. Point A is at a distance R(gtgt r) from the centre of the ring.



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Level 3

1. Three small equally charged identical conducting balls are suspended from identical insulating threads secured at one point. Length (L) of the threads is large compared to the equilibrium separation (a) between any two balls. (a) One of the balls is suddenly discharged. Find the separation between the charged balls when equilibrium is restored. Assume that the threads do not interfere and balls do not collide. (b) If two of the balls are suddenly discharged, how will the balls behave after this? Find the separation between the balls when equilibrium is restored. The threads do not interfere

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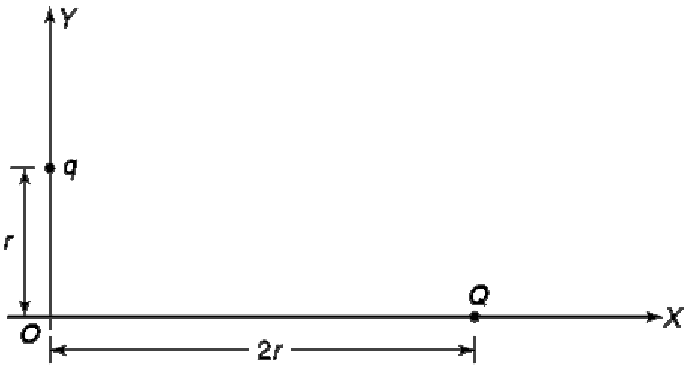
2. Two charged particle of equal mass are constrained to move along X and Y direction. The X – Y plane is horizontal and the tracks are smooth. The particles are released from rest when they were at positions shown in the figure. At the instant distance of q becomes 2r from the origin, find the location of charge Q.



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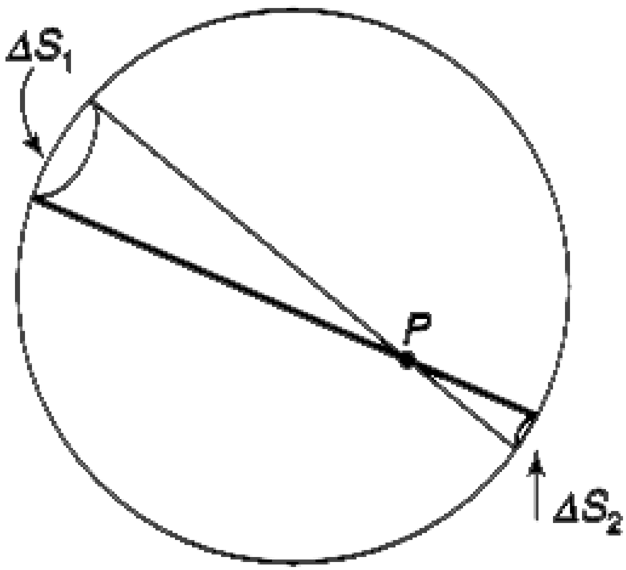
3. Consider a uniformly charged spherical shell. Two cones having same semi vertical angle, and their common apex at P, intercept the shell. The intercepts have area $\Delta S1$ and $\Delta S2$. For a cone of very small angle, $\Delta S1$ and $\Delta S2$ will be very small and charge on them can be regarded as point charge for the purpose of writing electric field at point P. Prove that the charge on $\Delta S1$ and $\Delta S2$ produce equal and opposite field at P. Hence, argue that field at all points inside the uniformly charged spherical shell is zero.



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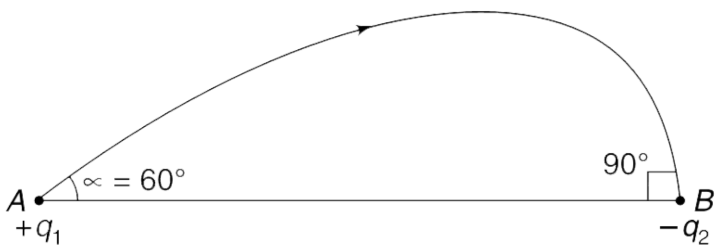
4. Two point charges $+q_1$ and $-q_2$ are placed at A and B respectvely. An electric line of force emerges from q_1 making an angle $\alpha = 60^\circ$ with line AB and terminates as $-q_2$ making an angle of 90° with line AB.

(a). Find $\left|\frac{q_1}{q_2}\right|$ ltbr. (b). Find the maximum value of angle α at which a line emitted from q_1 terminates on charge q_2.



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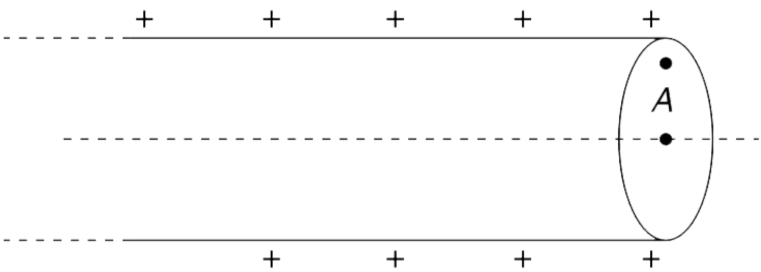
5. There is a semi-infinite hollow cylindrical pipe (i.e. one end extends to infinity) with uniform surface charge density. What is the direction of electric field at a point A on the circular end face?



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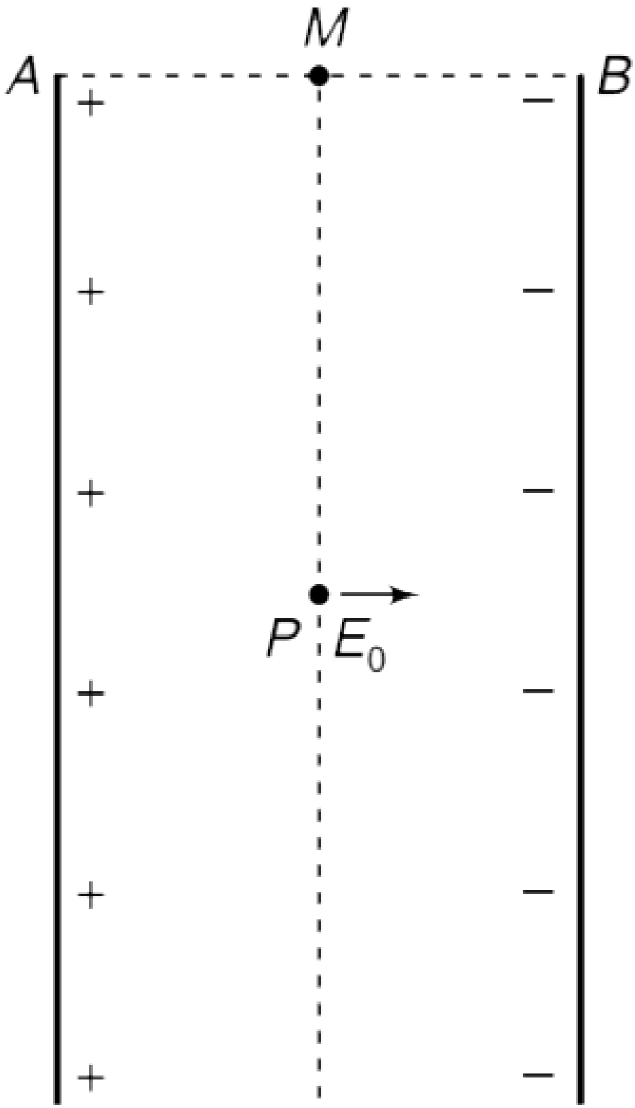
6. Two equal insulating threads are placed parallel to each other. Separation between the threads (= d) is much smaller than their length. Both the threads have equal and opposite linear charge density on them. The electric field at a point P, equidistant from the threads (in the plane of the threads) and located well within (see figure) is E_0.

Calculate the field at mid point (M) of line AB.



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7. If coulomb's law were $F = K\frac{qQ}{r^3}$, calculate the electric field due to a uniformly charged line charge at a distance d from it. The linear charge density on the line charge is λ C/m, and it is of infinite length.

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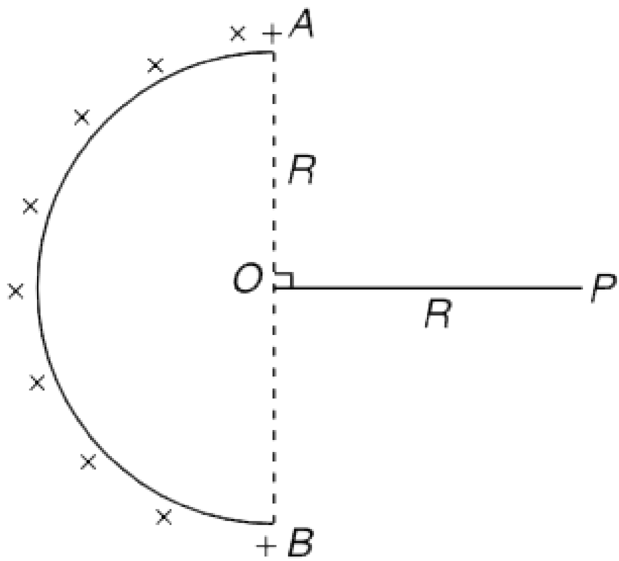
8. A sermicircular ring of radius R carries a uniform linear charge of λ. P is a point in the plane of the ring at a distance R from centre O. OP is perpendicular to AB. Find electric field intensity at point P.



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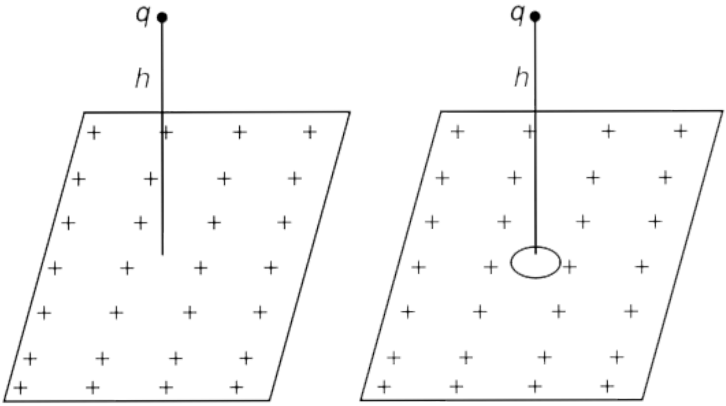
9. A small charged ball is in state of equilibrium at a height h above a large horizontal uniformly charged dielectric plate having surface charge

density of $\sigma C/m^2$. (a) Find the acceleration of the ball if a disc of radius r (ltlt h) is removed from the plate directly underneath the ball. (b) Find the terminal speed (V_0) acquired by the falling ball. Assume that mass of the ball is m, its radius is x and coefficient of viscosity of air is η. Neglect buoyancy and assume that the ball acquires terminal speed within a short distance of its fall.



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10. In a certain region of space the electrostatic field depends only on the coordinates x and y as follows.

$$E = 0 \qquad \text{for} \qquad \sqrt{x^2 + y^2} < r_0$$

$$E = a\left(x\hat{i} + y\hat{j}\right)\left(x^2 + y^2\right) \qquad \text{for} \qquad \sqrt{x^2 + y^2} > r_0$$

Where a is a positive constant and $\hat{i}$ and $\hat{j}$ are the unit vectors along the X-and Y-axes. find the charge within a sphere of radius $2r_0$ with the centre at the origin.

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11. A solid sphere of radius R has total charge Q. The charge is distributed in spherically symmetric manner in the sphere. The charge density is zero at the centre and increases linearly with distance from the centre. (a) Find the charge density at distance r from the centre of the sphere. (b) Find the magnitude of electric field at a point 'P' inside the sphere at distance r_1 from the centre.

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12. A ball of radius R carries a positive charge whose volume charge depends only on the distance r from the ball's centre as: $\rho = \rho_0\left(1 - \frac{r}{R}\right)$

Where r_0 is a constant. Take ε to be permittivit of the ball. Calculate the maximum electric field intensity at a point (inside or outside the ball) due to such a charge distribution.

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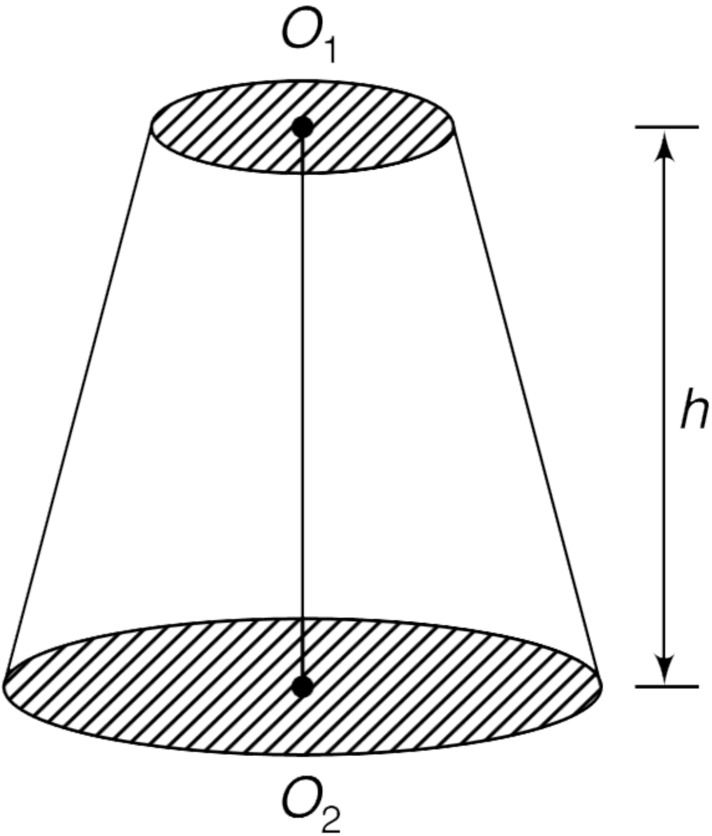
13. A frustum is cut from a right circular cone. The two circular faces have radii R and 2R and their centers are at O_1 and O_2 respectively. Height of the frustum is $h = 3R$. When a point charge Q is placed at O_1, the flux of electric field through the circular face of radius 2R is ϕ_1 and when the charge Q is placed at O_2, the flux through the other circular face is ϕ_2. find the ratio $\frac{ph_1}{\phi_2}$



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14. The electric field in a region of space varies as $E = \left(x\hat{i} + 2y\hat{j}\right) + 3z\hat{k}\right)$ V/m

(a). Consider an elemental cuboid whose one vertex is at (x,y,z) and the three sides are dx, dy and dz, sides being parallel to the three co-ordinate axes. Calculate the flux of electric field through the cube.

(b). Usig the expression obtained in (a) find the charge enclosed by a spherical surface of radius r, centred at the origin.

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15. A ball of radius R has a uniformly distributed charge Q. The surrounding space of the ball is filled with a volume charge density $\rho = \frac{b}{r}$, where b is a constant and r is the distance from the centre of the ball. It was found that the magnitude of electric field outside the ball is independent of distance r. (a) Find the value of Q. (b) Find the magnitude of electric field outside the ball.

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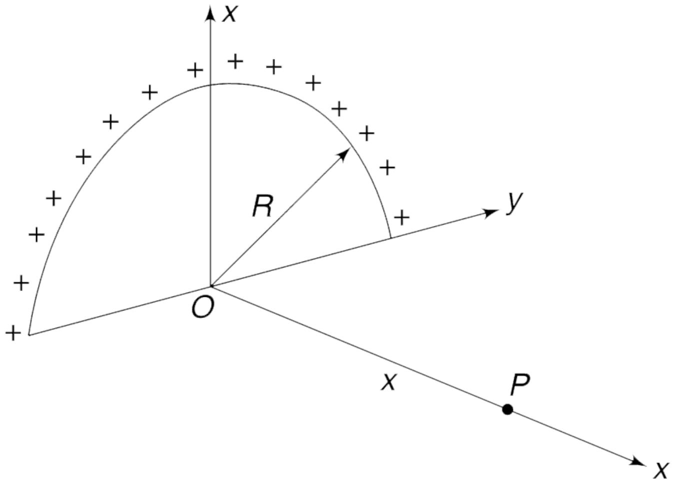
16. A uniform semicircular ring of radius R is in yz plane with its centre at the origin. The half ring carries a uniform linear charge density of λ.



(a) Find the x, y and z component of Electric field at a point P(x, 0, 0) on the axis of the ring. (b) Prove that the field at P is directed along a line joining the centre of mass of the half ring to the point P.

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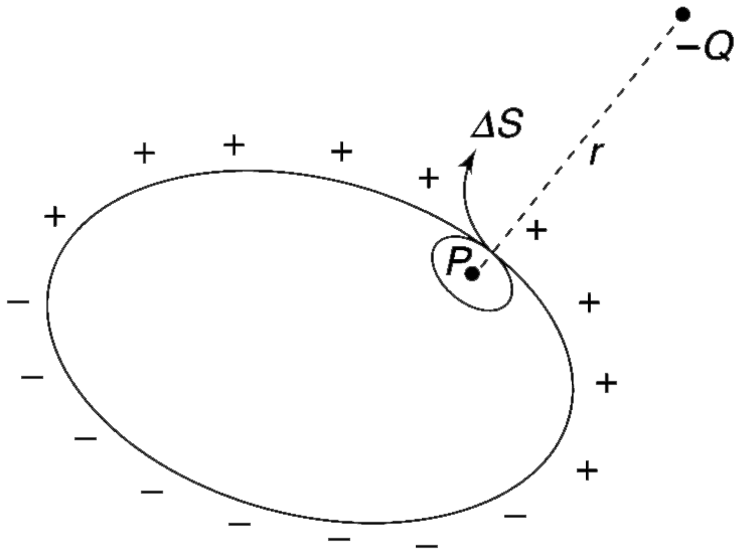
17. A charge – Q is placed at some distance from a neutral conductor. Charge is induced on its surface. In the neighbourhood of a point P on its surface, the charge density is $\sigma C / m^2$. Consider a small area ΔS on the surface of the conductor encircling point P. Find the resultant force experienced by the area ΔS due to charge present on the surface elsewhere and the charge

– Q.



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18. A soap bubble of radius R = 1 cm is charged with the maximum charge for which breakdown of air on its surface does not occur. Calculate the electrostatic pressure on the surface of the bubble. It is know that dielectric breakdown of air takes place when electric field becomes larger then $E_0 = 3 \times 10^6 W / m$

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19. A conducting sphere of radius R is cut into two equal halves which are held pressed together by a stiff spring inside the sphere. (a) Find the change in tension in the spring if the sphere is given a charge Q. (b) Find the change in tension in the spring corresponding to the maximum charge that can be placed on the sphere if dielectric breakdown strength of air surrounding the sphere is E_0.

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20. Surface tension of a soap solution is T. There is a soap bubble of radius r. Calculate the amount of charge that must be spread uniformly on its surface so that its radius becomes 2r. Atmospheric pressure is P_0. Assume that air temperature inside the bubble remains constant.

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21. A point charge Q has been placed at a point outside a neutral spherical conductor. The induced charge density at point P on the surface of the conductor is $-\sigma$ The distance of point P from the point charge Q is 2R (where R is radius of the conductor). Find the magnitude and direction of electric field at a point outside the conductor that is very close to its surface near P.

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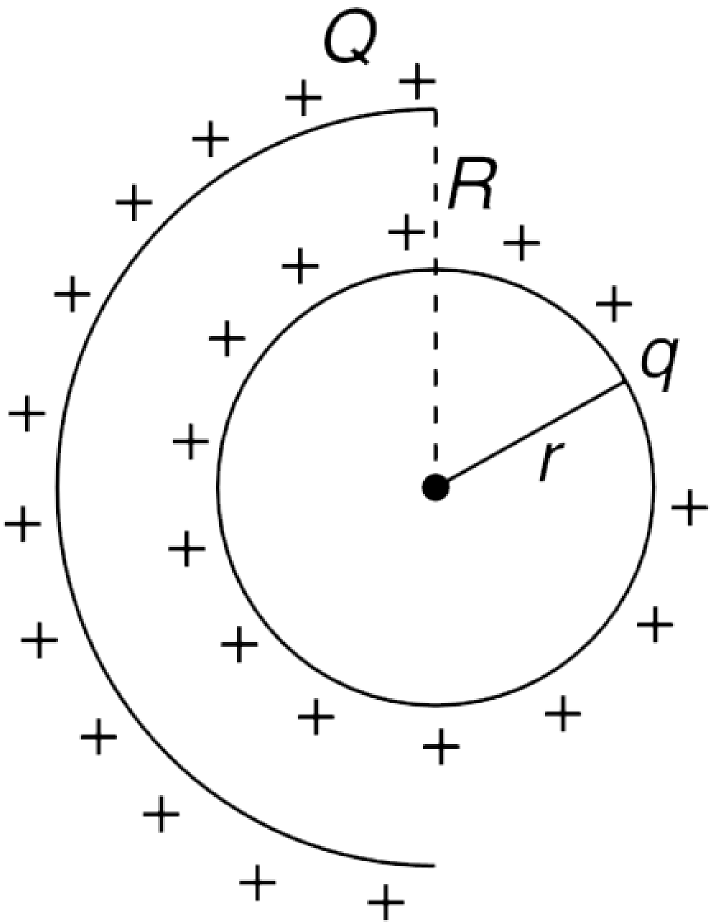
22. A spherical shell of radius r carries a uniformly distributed surface charge q on it. A hemispherical shell of radius R(gt r) is placed covering it with its centre coinciding with that of the sphere of radius r. The hemisphere has a uniform surface charge Q on it. The charge distribution on the sphere and the hemisphere is not affected due to each other. Calculate the force that the sphere will exert on the hemisphere.



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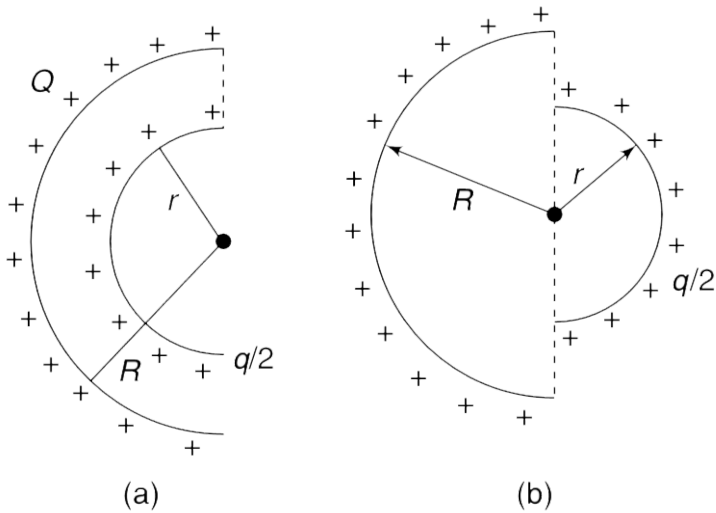
23. In the last question half of the inner sphere is removed along with its charge (i.e., the remaining half has charge $\frac{q}{2}$). Find the force between the bigger and smaller hemispheres in the two cases shown in figure (a) and figure (b).



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24. A charged ball with mass m and charge q is dropped from a height h over a non-conducting smooth horizontal plane. There exists a uniform electric field E_0 in vertically downward direction and the coefficient of restitution between the ball and the plane is e. Find the maximum height attained by the ball after n^{th} collision.

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25. In the last question, the electric field in vertical direction is switched off and a field of same strength(E_0) is switched on in horizontal direction. Find the horizontal velocity of the ball during the n^{th} collision. Also calculate the time interval between n^{th} and $(n+1)^{th}$ collision

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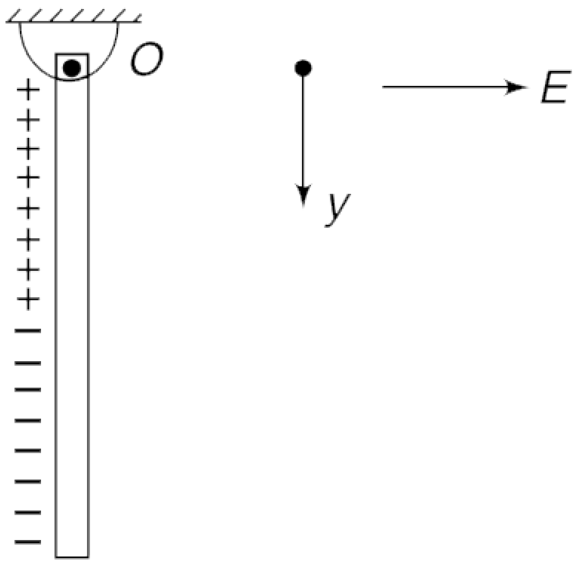
26. A thin insulating rod of mass m and length L is hinged at its upper end (O) so that it can freely rotate in vertical plane. The linear charge density on the rod varies with distance (y) measured from upper end as

$$\left.\begin{aligned}\lambda &= ay^2 \quad & 0 \le y \le \tfrac{L}{2} \\ &= -by^n \quad & \tfrac{L}{2} < y \le L\end{aligned}\right\}$$

Where a and b both are positive constants. whena horizontal electric field E is switched on the rod is found to remains stationary.

(a). find the value of constant b in terms of a. Also find n.

(b). Find the force applied by the hinge on the rod, if $EaL^3 = 45mg$.



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27. Two charges $-2Q$ abd Q are located at the points with coordinates $(-3a, 0)$ and $(+3a, 0)$ respectively in the x-y plane. (i) Show that all points in the x-y plane where the electric potential due to the charges is zero, on a circle. Find its radius and the location of its centre (ii) Give the expression V(x) at a general point on the x-axis and sketch the function V(x) on the whole x-axis. (iii) If a particle of charge +q starts from rest at the centre of the circle, shown by a short quantitative argument that the particle eventually crosses the circule. Find its speed when it does so.

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28. A metallic sphere of radius R has a small bulge of hemispherical shape on its surface. The radius of the bulge is r. If a charge Q is given to the sphere, calculate the quantity of charge on the surface of the bulge. Assume that charge is uniformly distributed on the surface of the bulge (though it is wrong !) and also on the remaining surface of the sphere.

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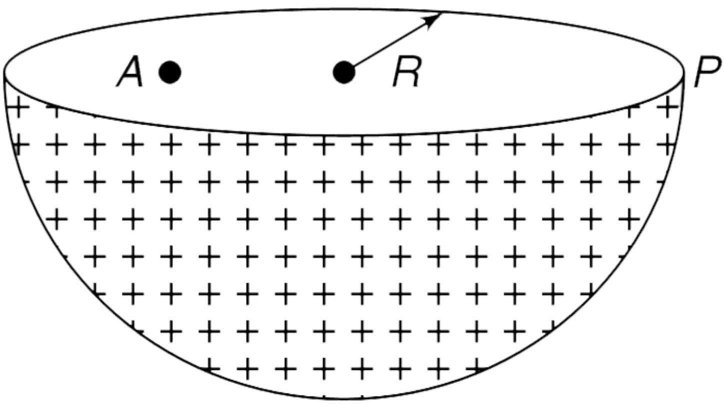
29. A hemispherical bowl of radius R carries a uniform surface charge density of σ. Find potential at a point P located just outside the rim of the bowl (see figure). Also calculate the potential at a point A located at a distance R/2 from the centre on the equatorial plane.



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30. Two infinite line have linear charge densities $-\lambda$ and $+\lambda$. They are parallel to z axis passing through x axis at point $x = -a$ and $x = a$ respectively. Show that the equipotential surface having potential $\frac{\lambda \ln(2)}{4\pi\varepsilon_0}$ is a cylinder haivng radius $2\sqrt{2}a$

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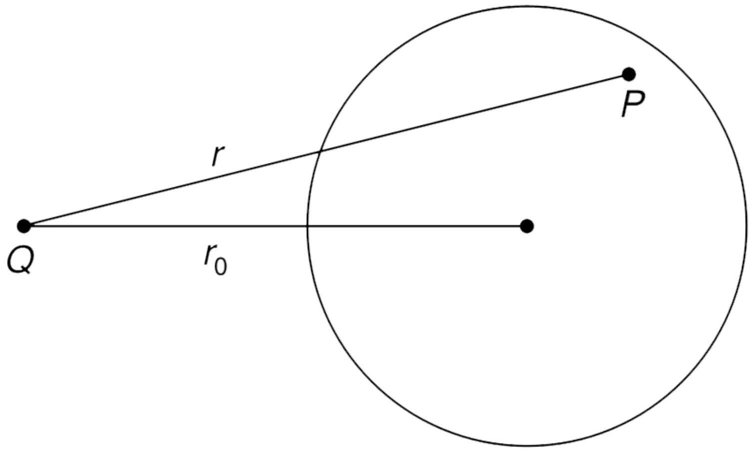
31. A conducting shell having no charge has radius R. A point charge Q is placed in front of it at a distance r_0 from its centre. Find potential due to charge induced on the surface of the shell at a point P inside the shell. Distance of point P from point charge Q is r.



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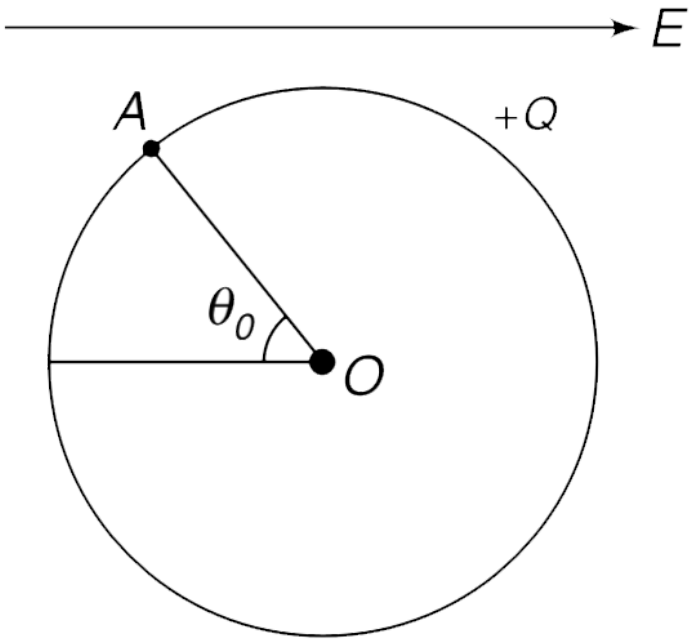
32. A conducting sphere of radius R having charge Q is placed in a uniform external field E. O is the centre of the sphere and A is a point on the sphere of the sphere such that AO makes an angle of $\theta_0 = 60^\circ$ with the opposite direction fo external field. calculate the potential at point A due to charge on the sphere only.



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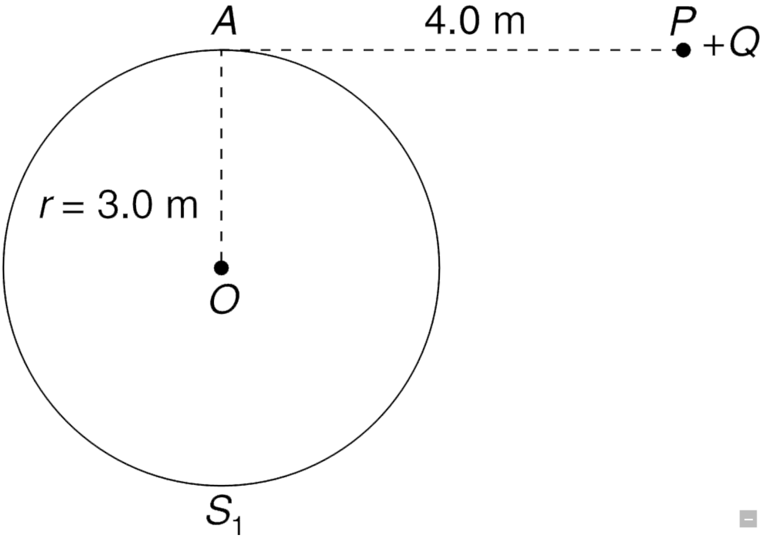
33. Consider a solid neutral conducting sphere S_1 of radius r=3.0m. A point charge $Q = +2\mu C$ s placed at point P such that AP=-4.0m (AP is tangent to the sphere). Charge Q' is induced on the surface of te conducting sphere S_1. Consider another non conducting sphere (S_2) of same radius r. Charge Q' is spread on the surfaec of S_2 in exactly the same way as it is present on the surface of conducting sphere S_1 [i.e., the distribution of charge on surface of S_2 is exact replica of the induced surface charge on S_1]. There is no other charge in vicinity of S_2. Find the smallest potential (at a point) on the surface of sphere S_2.



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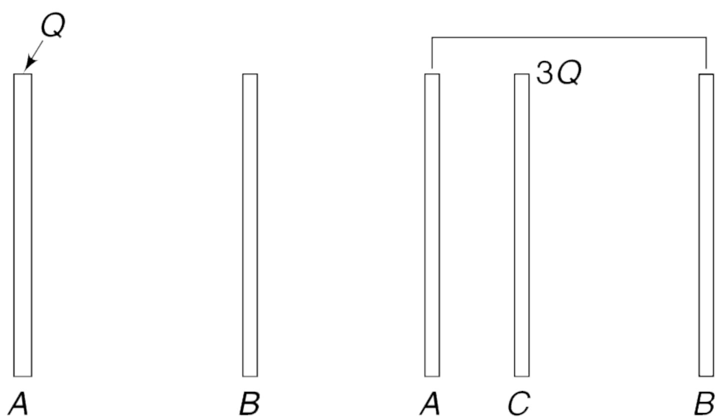
34. A and B are two large identical thin metal plates placed parallel to each other at a small separation. Plate A is given a charge Q. (i) Find the amount of charge on each of the two faces of A and B. (ii) Another identical plate C having charge 3Q is inserted between plate A and B such that distance of C from B is twice its distance from A. Plate A and B is shorted using a conducting wire. Find charge on all six faces of plates A, B and C. (iii) In the situation described in (ii) the plate A is grounded. Now write the charge on all six faces.



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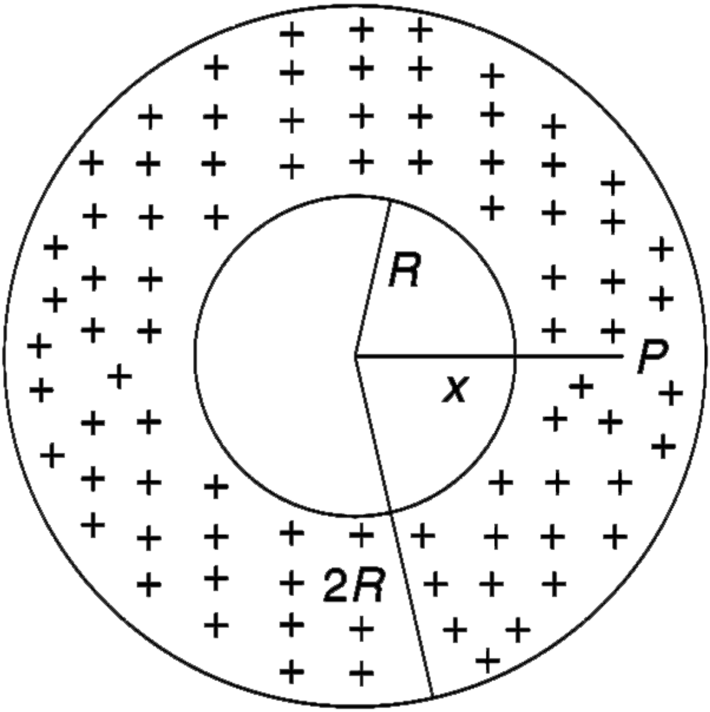
35. The figure shows equipotential surfaces due to two poit charges +3Q and -Q placed at a separation d.

(a) Will the shape of epuipotential surface be spherical very close to both the point charges? What shape of equipotentials will be seen at very far away points from the pair of charges. (b) Find the distance of point P from the negative charge. (c) Find the potential of the surface marked as S_1 is the figure. (d) Consider the surface having zero potential. Write the flux of electric field through this surface



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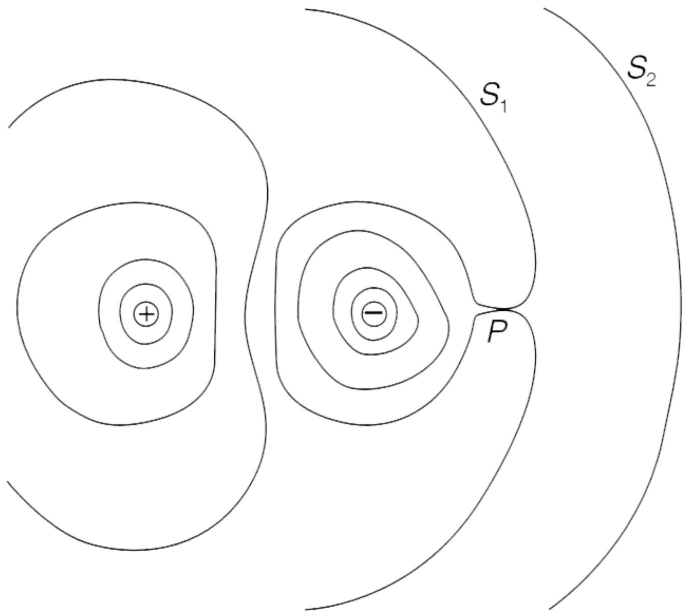
36. Three point charge have been placed along the x axis at points A, B and C. Distance AB = BC.

The field lines generated by the system is shown in figure. (a) Plot the variation of electric potential along x axis. Show potential on y axis of your graph. (b) Plot the variation of electric potential along y axis with B as origin. Shows potential on x axis in your graph.



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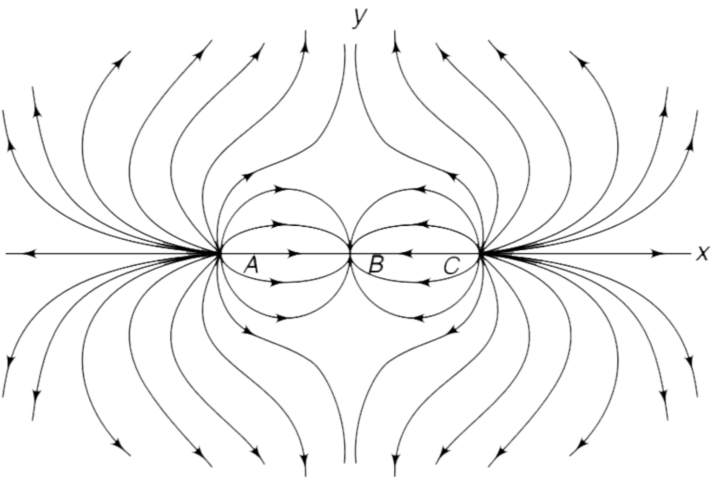
37. A conducting shell has inner radius R and outer radius 2R. A charge + q is given to the spherical shell. (a) Find the electric field at a point which is at a distance x from the centre of the shell. Give your answer for three cases (i) x lt R (ii) R lt x lt 2R (iii) x gt 2R (b) Find the electric potential in all the three cases mentioned in (a) (c) Find field and potential in all the three cases mentioned in (a) after a point charge – q is introduced at the centre of the shell. (d) Write the electrical potential energy of the system consisting of the shell and the point charge at its centre. (e) Find the electrostatic force that the shell exerts on the point charge. (f) Now, another point charge + q is placed at a distance 4R from the centre of the shell. Find electric field and potential in following cases. (i) x lt R (ii) R lt x lt 2R



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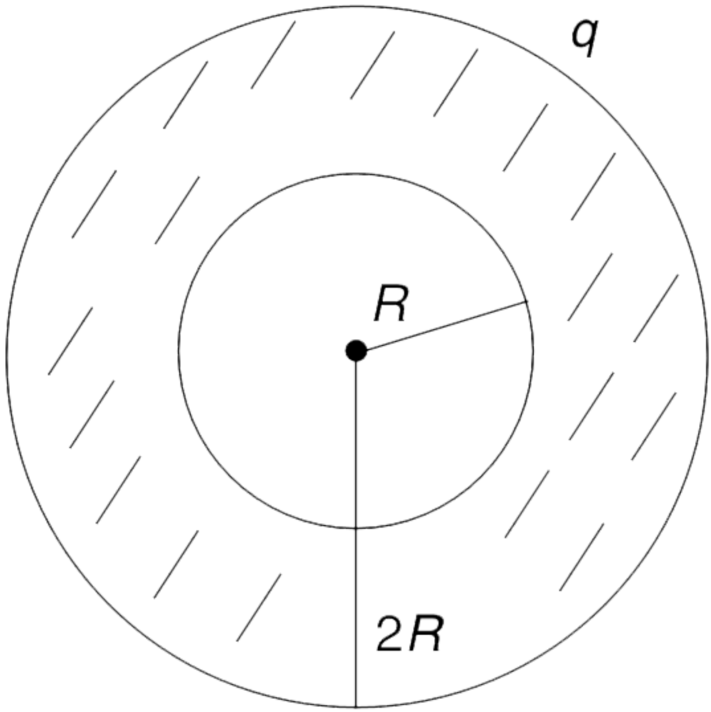
38. A solid conducting sphere of radius R is surrounded by a concentric metallic shell of inner radius 2R and outer radius 3R. The shell is earthed. The inner sphere is connected to a switch S by a thin conducting wire through a small hole in the shell. By closing the switch S, the inner sphere is connected to a distant conducting sphere of radius R having charge Q. Find the charge that flows to earth through wire AB.



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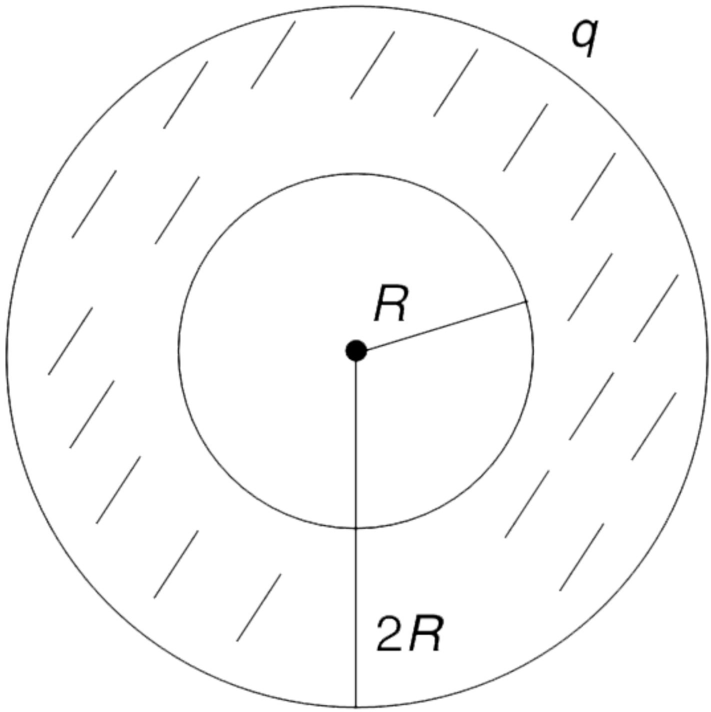

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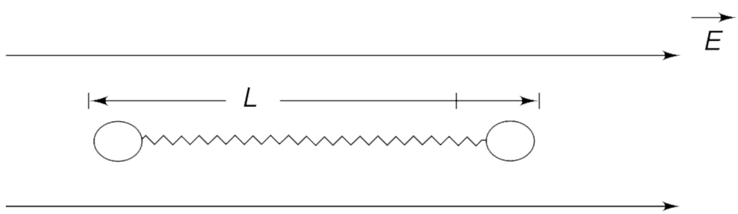
40. Two small identical conducting balls each of radius r and mass m are placed on a frictionless horizontal table, connected by a light conducting spring of force constant K and un-deformed length L (L gtgt r). A uniform electric field of strength E is switched on in horizontal direction parallel to the spring. (a) How much charge will appear on the two balls when they are at separation L. (b) The system fails to oscillate if K lt K_0. Find K_0. (c) Assuming $K = 2K_0$, find the time period of oscillation after the electric field is switched on.



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41. Four charges have equal magnitude. Two of them are positive and remaining two are negative. Charges have been placed on the vertices of a rectangle and the electrostatic potential energy of the system happens to be zero. (a) Show the arrangement of the charges on the vertices of the rectangle. (b) If the smaller side of the rectangle has a length of 1.0 m, show that length of larger side must be less than 2.0 m. [Actually you need to solve on algebraic polynomial to get the exact length of the larger side. Here I am not exactly interested in making you solve that equation]

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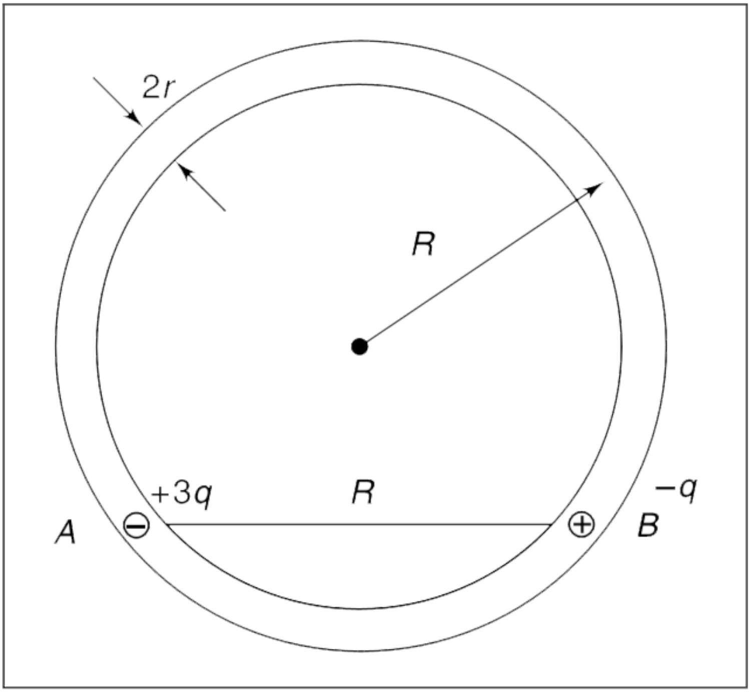
42. On a horizontal table, there is a smooth circular groove of mean radius R. The walls of the groove are non conducting. Two metal balls (each having mass m and radius r) are placed inside the groove with their centers R apart. The balls just fit inside the groove. The two balls are given charge + 3q and – q and released from state of rest. Ignore the non-uniformity in charge distribution as the balls come close together and collide. The collision is elastic. Find maximum speed acquired by each ball after they collide for the first time.



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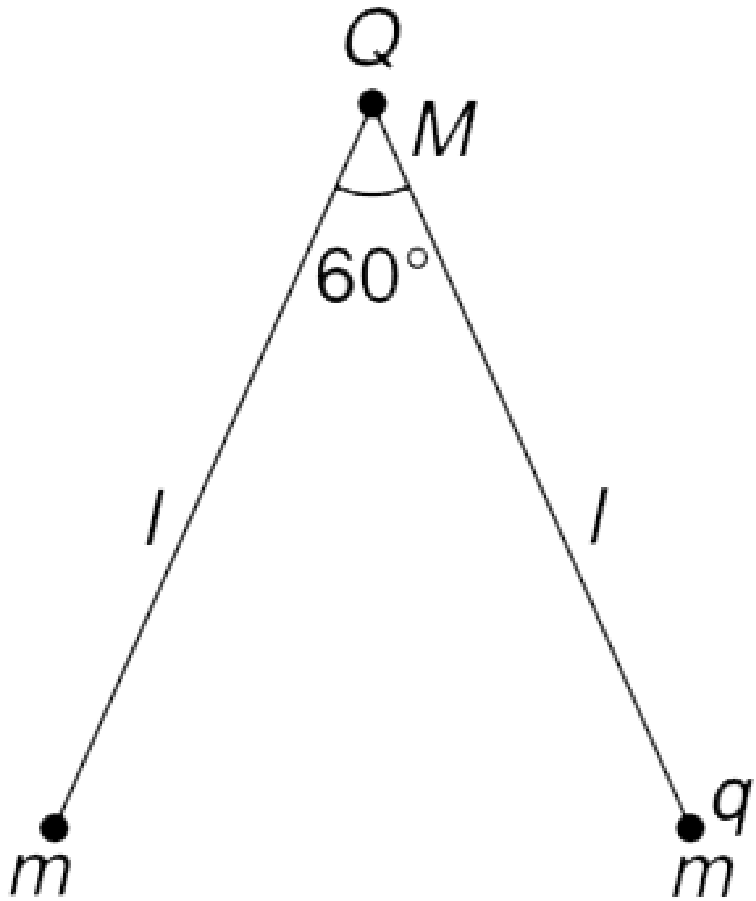
43. A particle having charge Q and mass M = 2 m is tied to two identical particles, each having mass m and charge q. The strings are of equal length, l each, and they are inextensible. The system is held at rest on a smooth horizontal surface (with string taut) in a position where the strings make an angle of 60° between them. From this position the system is released. (a) Find the amplitude of oscillation of M (b) Find maximum speed acquired by M (c) Find tension in the string when all the three particles get in one straight line.



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44. Four point charges $+8\mu C, -1\mu C, -1\mu C$ and , $+8\mu C$ are fixed at the points $-\sqrt{27/2}m, -\sqrt{3/2}m, +\sqrt{3/2}m$ and $+\sqrt{27/2}m$ respectively on the y-axis. A particle of mass $6 \times 10^{-4} kg$ and $+0.1\mu C$ moves along the x-direction. Its speed at $x = +\infty$ is v_0. find the least value of v_0 for which the particle will cross the origin. find also the kinetic energy of the particle at the origin in tyhis case. Assume that there is no force part from electrostatic force.

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45. A dielectric disc of radius R and uniform positive surface charge density σ is placed on the grup with its axis vertical. A particle of mass m and positive charge q is dropped, along the axis of the disc from a height H with dropped, along the axis of the disc from a height H with zero intial velocity. The charge -mass ratio of the particle is $\frac{q}{m} = \frac{4\varepsilon o n_0 g}{\sigma}$.

(i). Find the value of H if the particle just reaches the disc.

(ii). Sketch the potential energy of the particle as a function of its height and find its height in equilibrium position.

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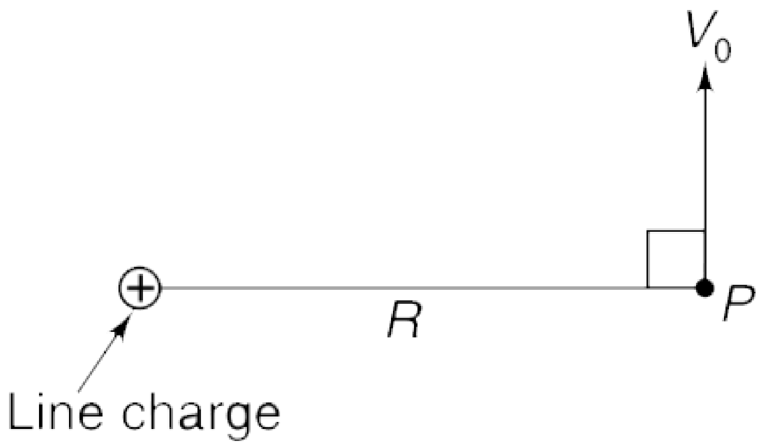
46. An infinite line cahrge is perpendicular to the plane of the figure having linear charge density λ, A partcle having charge Q and mass m is projected in the field of the line cahrge fromo point P. the point P is at a distance R from the line cahrge and velocity given tot he particle is perpendicular tot he radial line at P (see figure)

(i). Find the speed of the particle when its distance from the line cahrge grows the $\eta R(\eta > 1)$

(ii). Find the velocity component of the particle along the radial line (joining the line charge to the particle) at the instant its distance becomes ηR.



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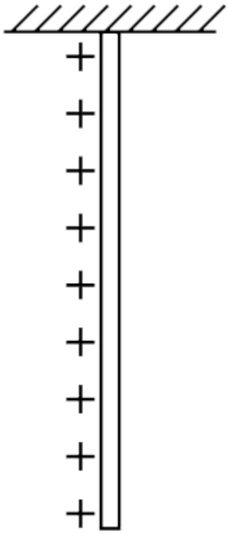
47. A uniformly charged non conducting rod is suspended vertically at its end. The rod can swing freely in the vertical plane without any friction. The linear charge density on the rod is $\lambda C/m$ and it has a uniformly distributed mass of M Length of the rod is L. A uniform horizontal electrif field (E) is switched on in the region.

(a). For what value of electric field (call it E_0) the rod just manages to make itself horizontal.?

(b). If eletrif field E_0 is switched on, what is the maximum angular speed acquired by the rod during its motion?



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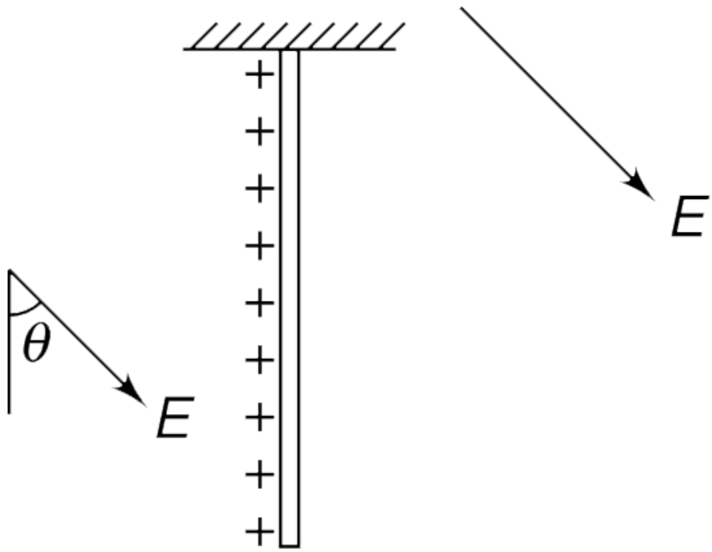
48. In the last question let us assume that the uniform electric field makes an angle θ with the vertical in downward direction. With the uniformly charged rod in vertical position the field is switched on. Mass of the rod, its length and charge per unit length is M, L and λ respectively. (a) Find the strength of field (E) such that the rod can reach the horizontal position if $\theta = 30^\circ$ (b) Find the minimum strength of field (E) such that the rod can reach the horizontal position if $\theta = 60^\circ$ (c) However high the field might be, the rod cannot become horizontal if

$\theta < \theta_0$ find θ_0



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49. A massless rod of length L has two equal charges (q) tied to its ends. The rod is free to rotate in horizontal plane about a vertical axis passing through a point at a distance $\frac{L}{4}$ from one of its ends. A uniform horizontal electric field (E) exists in the region. (a) Draw diagrams showing the stable and unstable equilibrium positions of the rod in the field. (b) Calculate the change in electric potential energy of the rod when it is rotated by an angle $\Delta\theta$ from its stable equilibrium position. (c) Calculate the time period of small oscillations of the rod about its stable equilibrium position. Take the mass of each charge to be m.

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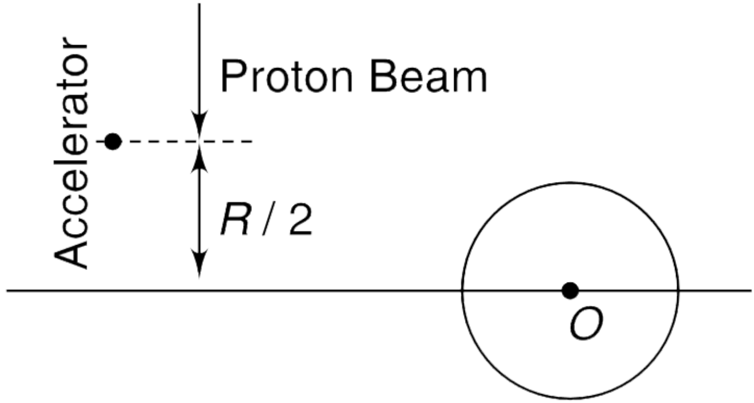
50.



A proton accelerator produces a narrow beam of protons, each having an initial speed of v_0. The beam is directed towards an initially uncharged distant metal sphere of radius R. The sphere is fixed and centered at point O. The initial path of the beam is at a distance of (R/2) from the centre, as indicated in the diagram. The protons in the beam that collide with the sphere get absorbed and cause it to become uniformly charged. The subsequent potential field at the accelerator due to the sphere can be neglected. Assume the mass of the proton as m_P and the charge on it as e.

(a) After a long time, when the potential of the sphere reaches a constant value, sketch the trajectory of proton in the beam. (b) Once the potential of the sphere has reached its final, constant value, find the minimum speed v of a proton along its trajectory path. (c) Find the limiting electric potential of the sphere.

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51. Consider a uniformly charged spherical shell of radius R having charge Q charge Q can be through to be made up of number of point charges $q_1, q_2, q_3...$ etc. the electrostatic energy of the charged shell is sum of interaction energies of all possible pairs of charges.

$$U = \sum \frac{q_i q_j}{4\pi\varepsilon_0 r_{ij}}$$

Where r_{ij} is distance between q_i and q_j. for continuous charg on the shell, the summation has to be carried through intergration.

(a). Calculate the electrostatic energy of the shell. We can term this energy as self energy of the shell.

(b). Calculate the work done in assembling a spherical shell of uniform charge Q and radius R by bringing charges in small installments from infinity and putting them of the shell. Do you ding the answers in (a) and (b) to be same?

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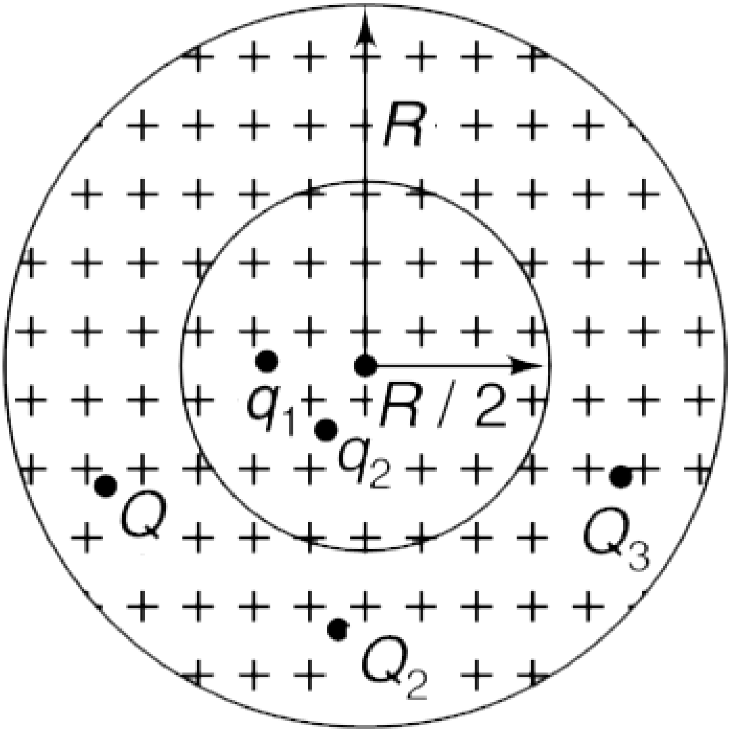

52.

(a). Use the method in part (b) of the previous problem of calculate the electrostatic self energy of a uniformly charegd sphere of radius R having charge Q.

(b). Divide the above sphere (mentally) into two regions-spherical concentric part having radius $\frac{R}{2}$ and the remaining annular part (between $\frac{R}{2}$ and R). Denote the point charges in sphere of radius $R/2$ by q_1, q_2, q_3 .. . .etc.

The charges in annular part be denoted by $Q_1, Q_2, Q_3 \ldots$ etc.

Calculate the electrostatic interaction energy for all pairs like $[(Q_i, Q_j) + (q_i + q_j)]$.

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53. A conducting sphere S_1 of radius r is attached to an insulating handle. Another conduction sphere S_2 of radius R is mounted on an insulating stand. S_2 is initially uncharged. S_1 is given a charge Q brought into contact with S_2 and removed. S_1 is recharge such that the charge on it is again Q and it is again brought into contact with S_2 and removed. This procedure is repeated n times.

a. Find the electrostatic energy of S_2 after n such contacts with S_1.

b. What is the limiting value of this energy as $n \to \infty$?

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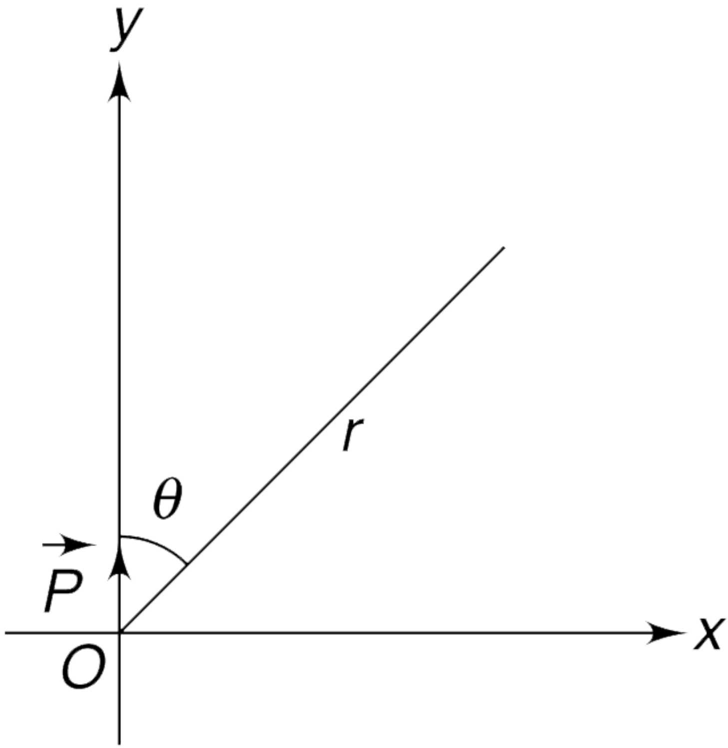
54.



A short electric dipole is placed at the origin of the Co-ordinate system with its dipole moment P along y direction. Give answer to following questions for points which are at large distance r from the origini in x-y plane.

[r is large compared to length of the dipole] (a). Find maximum value of x component of electric field at a piont that is at r_0 distance from the origin

(b). Prove that (for $0 < \theta < 90^\circ$) all the points, where electric field due to the di8pole is parallel to x-axis, fall on a straight line, find the slope of the line.

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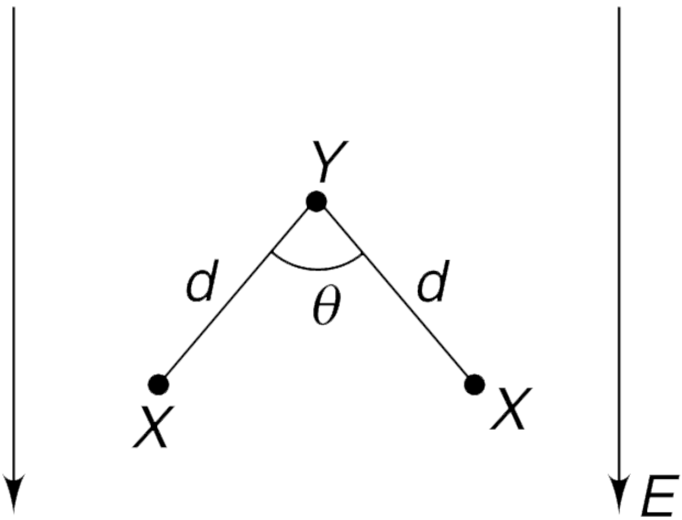
55. A tri atomic molecule X_2Y has plane structure as shown in figure. Due to difference in electronegativity, charge acquired by each X atom is q and charge on Y atom is – 2q. The bond length between Y and X is d, and angle between the two bonds is $\theta = 120^\circ$ mass of one atom of X and Y are m and 8m respectively. The molecule is placed in a uniform Electric field E and is making small oscillations about an axis perpendicular to the plane of figure and passing through the centre of mass of the molecule. Find the time period of oscillation.



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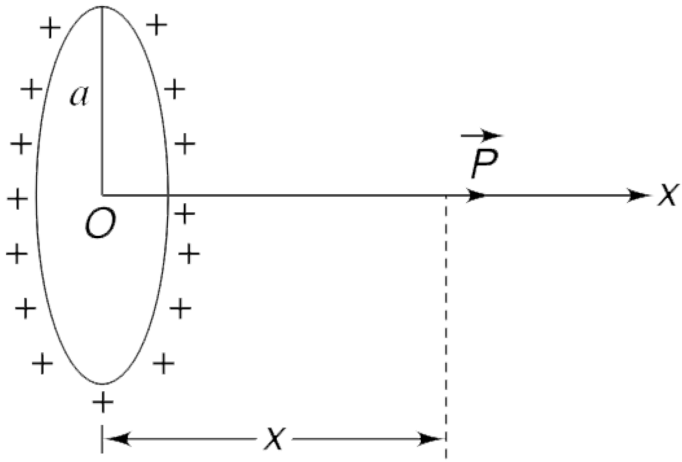
56. A short electric dipole (dipole moment P) is placed on the axis of a uniformly charged ring at a distance x from the centre as shown in figure. Radius of the ring is a and charge on it is Q.

Write the force on the dipole when $x = \frac{a}{2}$ and when $x = a$. why the direction of force at two points is different?

(ii) is the force ont he dipole zero if $x = 0$? if not where will you place the dipole so that force on it is zero.



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57. Consider two spheres of the same radius R having uniformly distributed volume charge density of same magnitude but opposite sign $(+\rho$ and $-\rho)$ the spheres overlap such that the vector joining the centre of the negative sphere to that of the positive sphere is $\vec{d}$. $(d << R)$. Find magnitude of electric field at a point outside the spheres at a distance r in a direction making an angle θ with $\vec{d}$. Distance r is measure with respect to the mid point of the line joining the centers of the two spheres.

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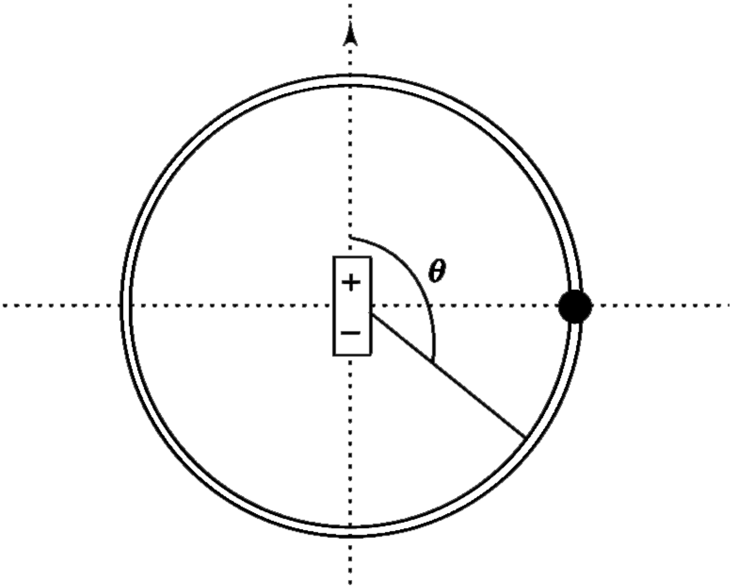
58. A small, electrically charged bead can slide on a circular, frictionless, thin, insulating ring. Charge on the bead is Q and its mass is m . A small electric dipole, having dipole moment P is fixed at the centre of the circle with the dipole's axis lying in the plane of the circle. Initially, the bead is held on the perpendicular bisector of the dipole (see fig.) Ignore gravity and answer the following questions.

(a) Write the speed of the bead when it reaches the position θ shown in the figure. (b) Find the normal force exerted by the ring on the bead at position θ. (c) How does the bead move after it is released? Where will the bead first stop after being released? (d) How would the bead move in the absence of the ring?



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59. A short electric dipole $\left(\overrightarrow{P}\right)$ has been placed in a uniform electric field $\left(\overrightarrow{E}\right)$ with the dipole mopment vector $\left(\overrightarrow{P}\right)$ parallel to $\overrightarrow{E}$. Show the field lines in the regio. Mark the null point (i.e., the points where the field is zero)

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