PHYSICS

BOOKS - HC VERMA

GAUSS LAW

Examples

1. A square frame of edge 10 cm is placed with its positive normal making on angle of 60^0 with a uniform electric field of $20Vm^{-1}$. Find the flux of the electric field through the surface bounded by the frame.

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2. A charge q is placed at the centre of a sphere. Taking outward normal as positive, find the flux of the electric field through the surface of the sphere due to the enclosed charge.

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3. A uniform electric field exists in space. Find the flux of this field through a cylindrical surface with the axis parallel to the field.

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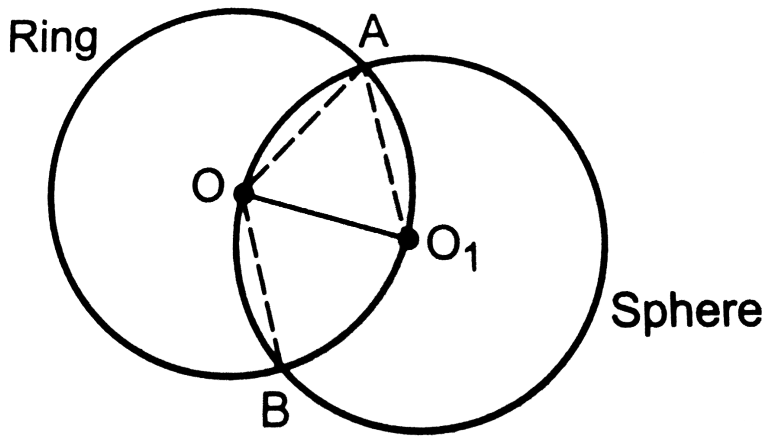
4. A Charge Q is distributed uniformly on a ring of radius r. A sphere of equal r is constructed with its centre at the periphery of the ring (figure 30.12) Find the flux of the electric field through the surface of the sphere.



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Worked Out Examples

1. A uniform electric field of magnitude $E = 100NC^{-1}$ exists in the space in x-direction. Calculate the flux of this field through a plane square of edga 10 cm placed in the y-z plane. Take the normal along the positive x-axis to be positive.

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2. A large plane charge sheet having surface xharge density $\sigma = 2.0 \times 10^{-6} Cm^{-2}$ lies in the x-y plane. Find the flux of the electric field through a circular area of radius 1 cm lying completely in the region where x, y, z are all positive and with its normal making an angle of 60^0 with the z-axis.

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3. A Charge of $4 \times 10^{-8} C$ is distrivuted uniformaly on the surface of a sphere of rasius 1 cm. It is covered by a concentric, hollow conducting sphere of radius 5 cm. (a) Find the electric field at a point 2 cm away from the centre. (b) A xharge of$6 \times 10^{-8} C$ is placed on the hollow spher. Find the surface charge density on the auter surface of the hollow sphere.

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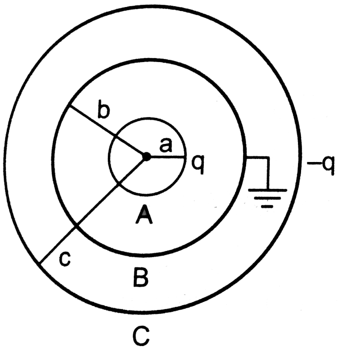
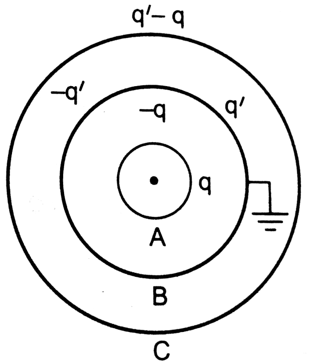
4. Figure shows three concentric thin spherical shells A, B and C of radii a, b and c respectively. The shells A and C are given charges q and -q respectively and the shell B is earthed. Find the charges appearing on the surfaces of B and C.





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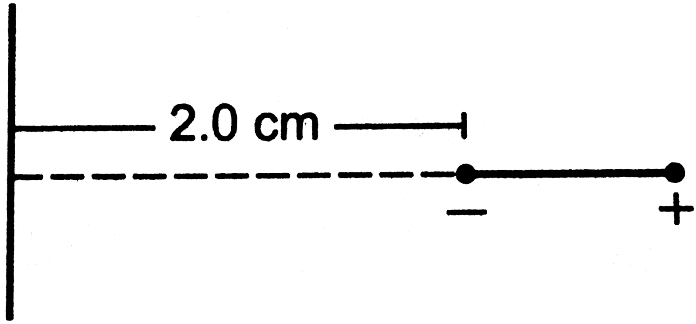
5. An electric dipole consists of charges $\pm 2.0 \times 10^{8} C$ separated by a distance of 2.0×10^{-3} m. It is placed near a long ilne charge of linear charge density $4.0 \times 10^{-4} Cm^{-1}$ as shown in figure (30-W4), Such thet the negative charge is at a distance of `2.0 cm from the line charge. Find the force acting on the dipole.



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6. The electric field in aregion is radially ourward with magnitude $E = Ar$. Find the charge contained in a sphere of radius a centred at the origin. Take $A = 100Vm^{-2}$ and $a = 20.0cm$.

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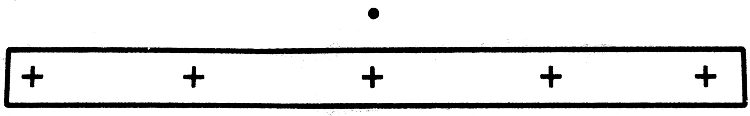
7. A particle of mass $5 \times 10^{-6}g$ is kept over a large horizantal sheet of charge of denisity $4.0 \times 10^{-6}Cm^{-2}$ (Figure 30-W5). What charge should be given to this partical so that if released, it does not fall down? How many electrons are to be removed to give this charge? How much mass is decreased due to the removal of these electrons?



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8. Two conducting plates A and B are placed parallel to each other. A is given a charge. Q_1 and B a charge Q_2. Find the distribution of charges on the four surface.

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Short Answer

1. A small plane area is rotated in an electric field. In which orientation of the area is the flux of electric field through the area maximum? In which orientation is it zero.?

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2. A circular ring of radius r made of a nonconducting material is placed with its axis parallel to a uniform electric field. The ring is rotated about a diameter through180^0. Does the flux of electric field change? If yes, does it decrease of increase?

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3. A charge Q is uniformly distributed on a thin spherical shell. What is the field at the centre of the shell? If a point charge is brought close to the shell, will the field at the centre change? Does your answer depend on whether the shell is conducting or nonconducting?

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4. A spherical shell made of plastic, contains a charge Q distributed uniformly over its surface. What is the electric field inside the shell? If the shell is hammered to deshape it without altering the charge. Will the field inside be changed? What happend if the shell is made of a metal?

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5. A point charge q is placed in a cavity in a metal block. If a charge Q is brought outside the metal, will the charge q feel an electric force?

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6. A rubber balloon is given a charge Q distributed uniformly over its surface. Then

A. electric field maybe there inside the balloon

B. electric field will be there inside the balloon

C. electric field may be constant inside the balloon

D. potential may be constant inside the balloon

Answer:

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7. It is said that any charge given to a conductor comes to its surface. Should all the protons come to the surface? Should all the electrons come to the surface? Should all the free electrons come to the surface?

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Objective 1

1. A charge Q is uniformly distributed over a large plastic plate. The electric field at a point P close to the centre of the plate is $10Vm^{-1}$. If the plastic plate is replaced by a copper plate of the same geometrical dimension and carryin the same charge Q_1 the electric field at the point P will become

A. zero

B. $5Vm^{-1}$

C. $10Vm^{-1}$

D. $20Vm^{-1}$.

Answer: C

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2. A metallic partical having no net charge is placed near a finite metal plate carrying a positive charge. The electric force on the particale will be

A. towards the plate

B. away from the plate

C. parallel to the plate

D. zero.

Answer: A

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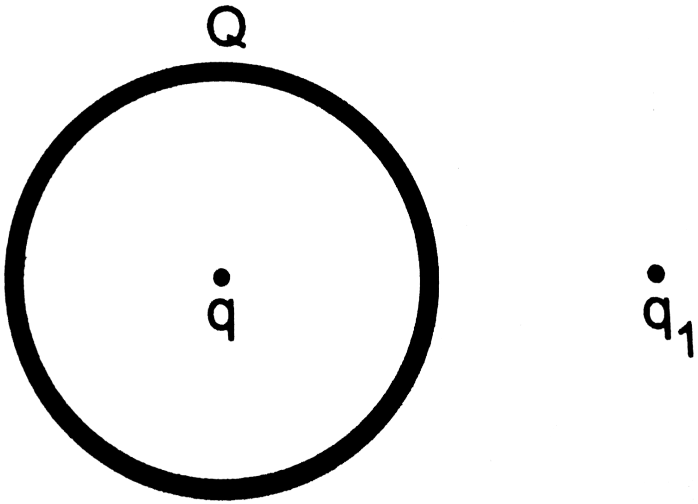
3. A thin. Metallic spherical shell contains s charge Q on it. A point charge q is placed at the centre of the shell and another charge q_1

is placed outside it as shown in figure (30-Q1). All the three charges are positive. The force on the charge at the centre is



A. towards left

B. towards right

C. upward

D. zero.

Answer: D

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4. Consider the situation of the previous problem. The force on the central charge due to the shell is

A. rowards left

B. towards right

C. upward

D. zero.

Answer: B

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5. Electric charge are distributed in a small vouume. The flux of the electric field through a spherical surface of rasius 10cm surrounding the total charge is 25 V m. The flux over a concentric sphere of radius 20 cm will be

A. 25 V m

B. 50 V m

C. 100 V m

D. 200 V m.

Answer: A

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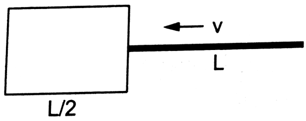
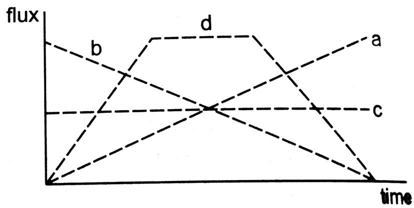
6. Figure shown an imaginary cube of edge L/2. A uniformly Charged rod of length L moves towards left at a small but constant speed v. At t=0, the left end just touches the centre of the cube opposite it. Which of the graphs shown in figure represents the flux of the electic field through the cube as the rod goes through it?





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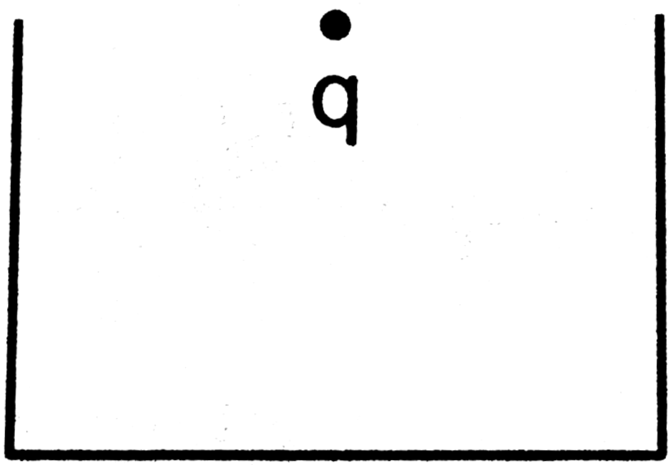
7. A charge q is placed at the centre of the open end of a cylindrical vessel . The flux of the electric field through the surface of the vessel is



A. zero

B. $\frac{q}{\varepsilon_0}$

C. $\frac{q}{2}\varepsilon_0$

D. $2\frac{q}{2}\varepsilon_0$.

Answer: C

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Objective 2

1. Mark the correct option:

A. gauss's law is valid only for symmetrical charge distributions.

B. gauss's law is valid only for charge placed in vacuum.

C. The electric field calculated by Gauss's law is the field due to the charges inside the Gaussian surface.

D. The flux of the electric field through a closed surface due to all the charges is equal to the flux due to the charges enclosed by the surface.

Answer: D

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2. A positive point charge Q is bruought mear an isolated metal cube.

A. The cube becomes negatively charged.

B. The cube becomes positively charged.

C. The interior becomes positively charged and the surface becomes negatively charged.

D. The interior remains charge free and the surface gets onouniform charge distribution.

Answer: D

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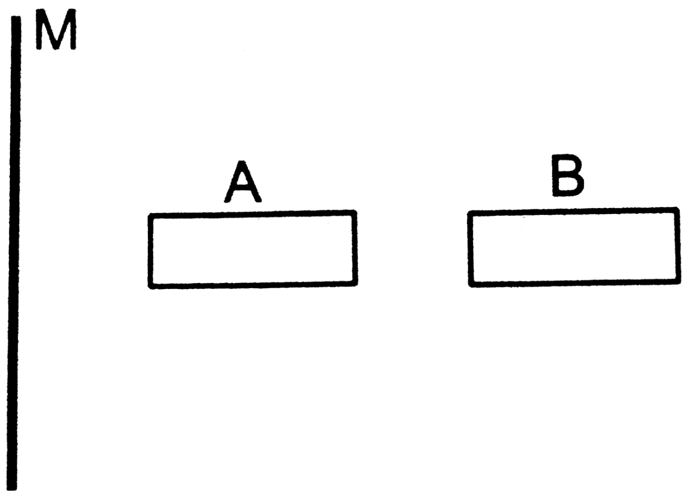
3. A large nonconducting sheet M is given a uniform charge density. Two unchared small metal rods A and B are placed near the sheet as shown in figure



A. M attracts A.

B. M attracts B.

C. A attracts B.

D. B attracts A.

Answer: A::B::C::D

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4. If the flux of the electric field through a closed surface is zero,

A. the electric field must be zero everywhere on the surface

B. the electric field may be zero everywhere on the surface

C. the charge inside the surface must be zero

D. the charge in the vicinity of the surface must be zero.

Answer: B::C

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5. An electric dipole is placed at the centre of a sphere. Mark the correct options:

A. The flux of the delectric field through the the sphere is zero.

B. The electric field is zero at every point of the sphere.

C. The electric field is not zero anywhere on the sphere.

D. The electric field is zero on a circle on the sphere.

Answer: A::C

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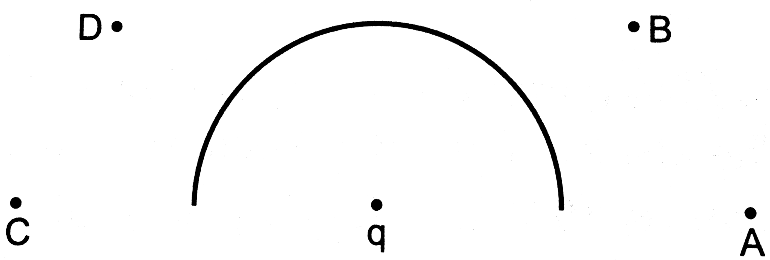
6. Figure shows a charge q placed at the centre of a hemisphere. A second charge Q is placed at one of the positions A, B, C and D. In which position(s) of this second charge, the flux of the electric field through the hemisphere remains unchanged?



A. A

B. B

C. C

D. D

Answer: A::C

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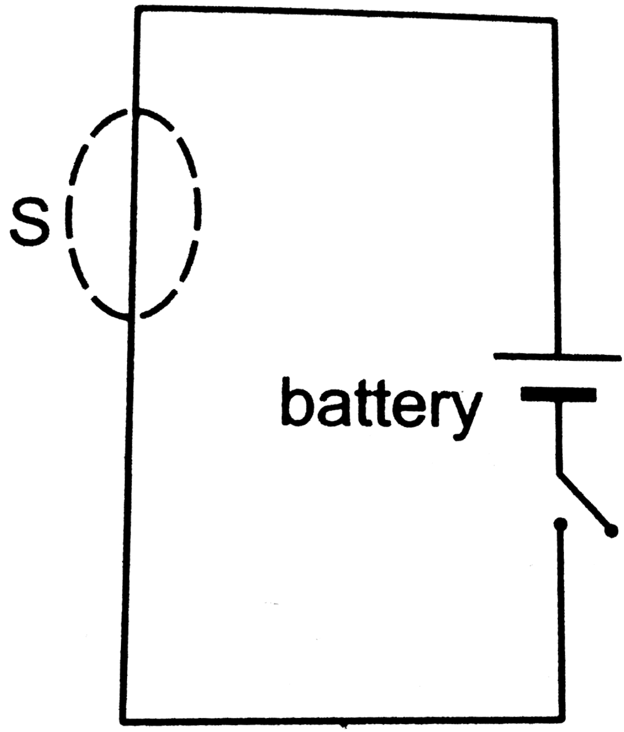
7. A closed surface S is condtructed sround a conducting wire connected to a battery and a switic (figure 30-Q6). As the switch is clsed, the free electrons in the wire start moving along the wire. In any time interval, the number of electrons entering the closed surface S is equal to the number of electrons leaving it. On closing the switch, the flux of the electic field hrough the closed surface



A. is increased

B. is decreased

C. remains unchanged

D. remains zero.

Answer: C::D

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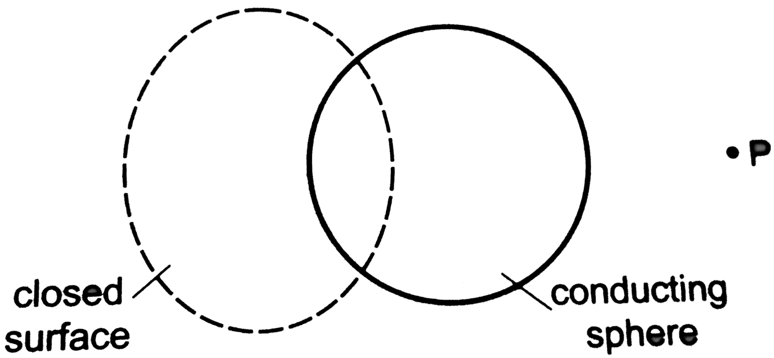
8. Figure shown a closed surfce which intersects a conducting sphere. If a positive charge is placed at the point P, the flux of the electric field through the closed surface



A. will remain zero

B. will become positive

C. will become negative

D. will become undefined.

Answer: B

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Exercises

1. The electric field in a region is given by $\overrightarrow{E} = \frac{3}{5}E_0\overrightarrow{i} + \frac{4}{5}E_0\overrightarrow{j}$ with $E_0 = 2.0 \times 10^3 NC^{-1}$. Find the flux of this field through a recatngular surface of area $0.2m^2$ parallel to the y-z plane.

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2. A charge Q is uniformly distributed over a rod of length l. Consider a hypothetical cube of edge l with the centre of the cube at one end of the rod. Find the minimum possible flux of the electric field through the entire surface of the cube.

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3. Show that there con be no net charge in a region in which the electric field is uniform at all points.

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4. The electric field in a region is given by $\overrightarrow{E} = \frac{E_0 x}{l} \hat{i}$. Find the charge contained inside a cubical volume bounded by the surface $x = 0, x = a, y = 0, z = 0$ and $z = a.$ $\left[\text{Take } E_0 = 5 \times 10^3 N/C, l = 2cm \text{ and } a = 1cm\right]$

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5. A charge Q is placed at the centre of a cub. Find the flux of the electric field through the six surfaced of the cube.

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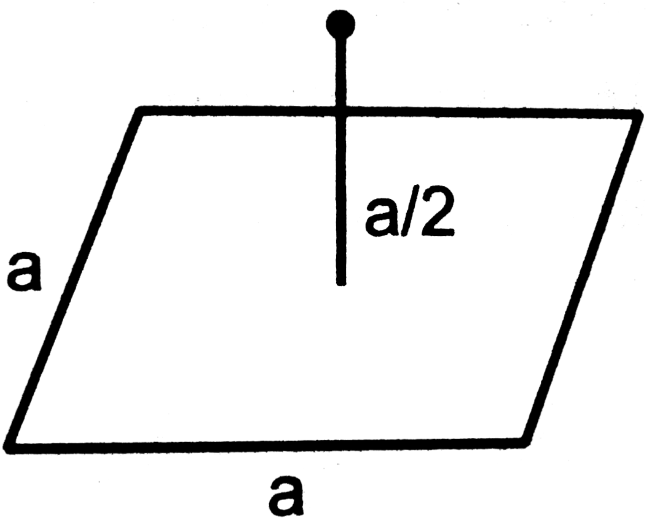
6. A charge Q is placed at a distance $\frac{\alpha}{2}$ above the centre of a horizontal, spuare surface of edge a as shown in figure (30-E1). Find the flux of the electric field through the square surface.



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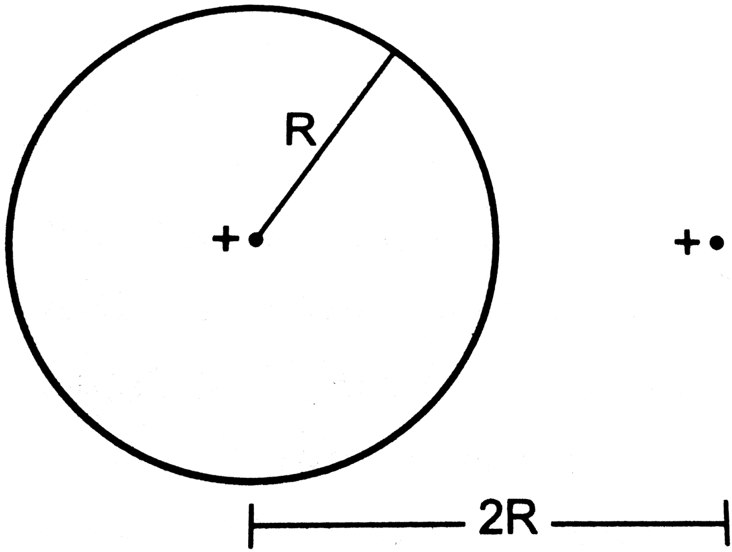
7. Find the fluz f the electric field through a spherical surface of radius R due to a charge of $10^{-7}C$ at the centre and another equal charge at a point 2R away from the centre (figure).



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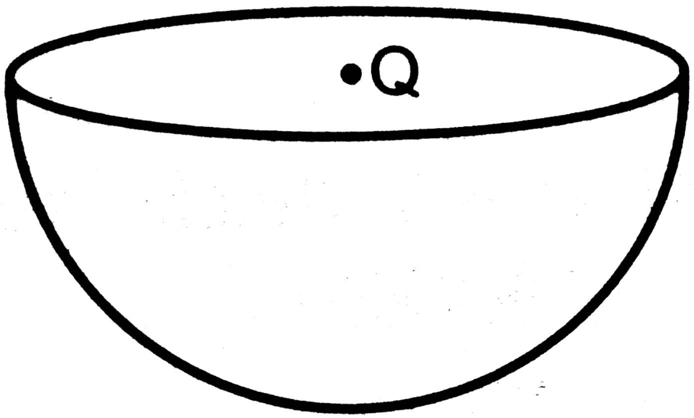
8. A charge Q is placed at the centre of an inaginary hemispherical surface. Using symmetry arguments and the Gauss's law, find the flux of the electric field due to this charge through the surface of the hemisphere (figure).



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9. A spherical volume contains a uniformaly distributed charge of density $2.0 \times 10^4 Cm^3$. Find the electric field at a piont inside the volume at a distance 4.0 cm from the centre.

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10. The radius of a gold nucleus (Z=79) is about $7.0 \times 10^9 - 15)m$. Assume that the positive charge is distributed uniformly throughout the the nuclear volume. Find the strength of the electric field at (a) the surface of the nucleus and (b) at the middle oint of a radius. Remembering that gold is a conductor, is it justifild to assume that the positive charge is uniformly distributed over the entire volume of the nucleus and does not come to the ourer surface?

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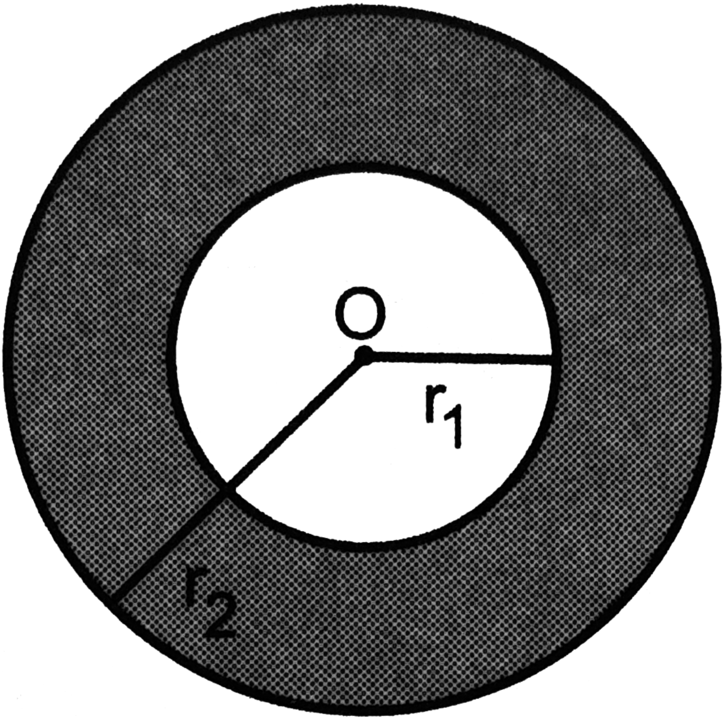
11. A Charge Q is distributed uniformly within the material of a hollow sphere of inner and outer radii r_1 and r_2 (figure 30-E4) $. F \in dthee \leq ctricfieldatap \oint Padis \tan cexawayomthecentref$ or r_1ltxltr_2

$. Drawaroughgraphshow \in gthee \leq ctricfieldasafunct \in oofx$

for 0ltx lt2r_2`. (figure).



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12. A charge Q is placed at the centre of an uncharged, hollow metallic sphere of radius of rasius alpha. (a) Find the surface charge density on the inner surface and on the outer surface. (b) If a charge q is pur on the sphege, what would be the surface charge dendities on the inner and the outer surface? (c) Find the electric field inside the sphere at a distance x from the centre in the situations (a) and (b).

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13. Consider the following very rough model of a beryllium atom. The nucleus has four protons and four neutrons confined to a small volume of radius $10^{-15}m$. The two 1s electrons make a spherical charge cloud at an average distance of 1.3×10^{-11} m from the nucleus, whereas the two 2s electrons make another spherical cloud at an average distance of 5.2×10^{-11} m from the nucleus. Find the electric field at (a) a point just inside the 1 s cloud and (b) a point just inside the 2s cloud.

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14. Find the magnitude of the electric field at a point 4 cm away from a line charge of density $2 \times 10^{-6} Cm^{-1}$.

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15. A long cylindrical wire carries a positive charge of linear density `2.0 x 10^(-8) C m^(-1). An electron revolves around it in a circular path under the influence of the attactive electrostatic force. Find the kinetic energy of the electron. Note that it is independent of the radius.

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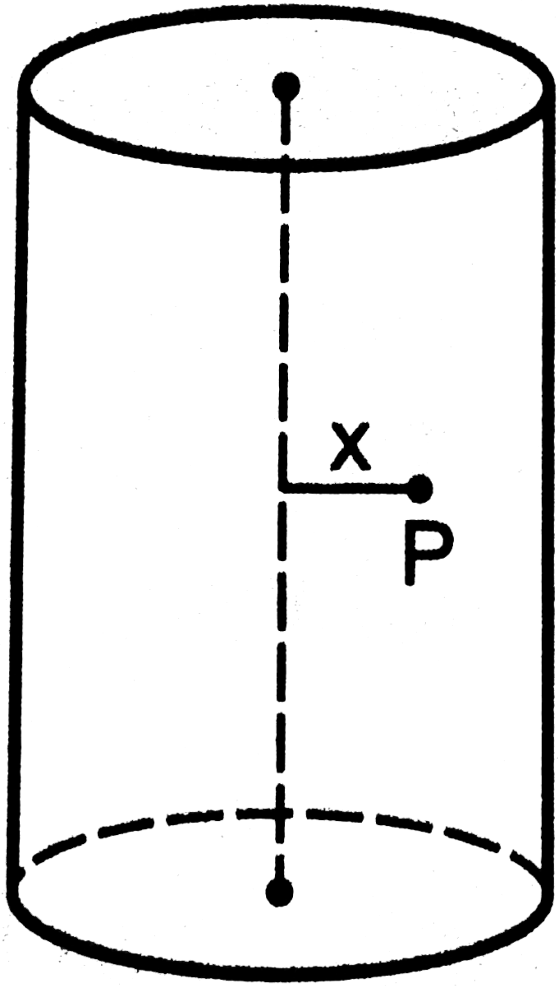
16. A long cylindrical volume contains a uniformly distributed charge of dendity ρ. Find the electric field at a point P inside the cylindrical volume at a distance x from its axis (figure 30-E5) ,



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17. 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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18. A charged partical having a charge of $-2.0 \times 10^{-6} C$ is placed close to a nonconducting plate having a surface charge density `4.0 xx 10^(6) C m^(-2). Fine the force of attraction between the particle and the plate.

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19. One end of a 10 cm long silk thread is fixed to a large vertical surface of a xharged nonconducting plate and the other end is fastened to a small ball having a mass of 10 g and charge of 4.0×10^{C}. In equilibrium, the thread make an angle of 60^{0} with the vertical. Find the surface charge dendity on the plate.

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20. Consider the situation of the previous problum. (a) Find the tension in the string in equilibrium. (b) Suppose the ball is slightly pushed aside and released. Find the time period of the small oscillations.

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21. Two large conducting plates are placed parallel to each other with a separation of 2.00 cm betweeen them. An electron starting from rest near one of the plates reaches the other plate in 2.00

microseconds. Find the surface charge density on the inner surfaces.

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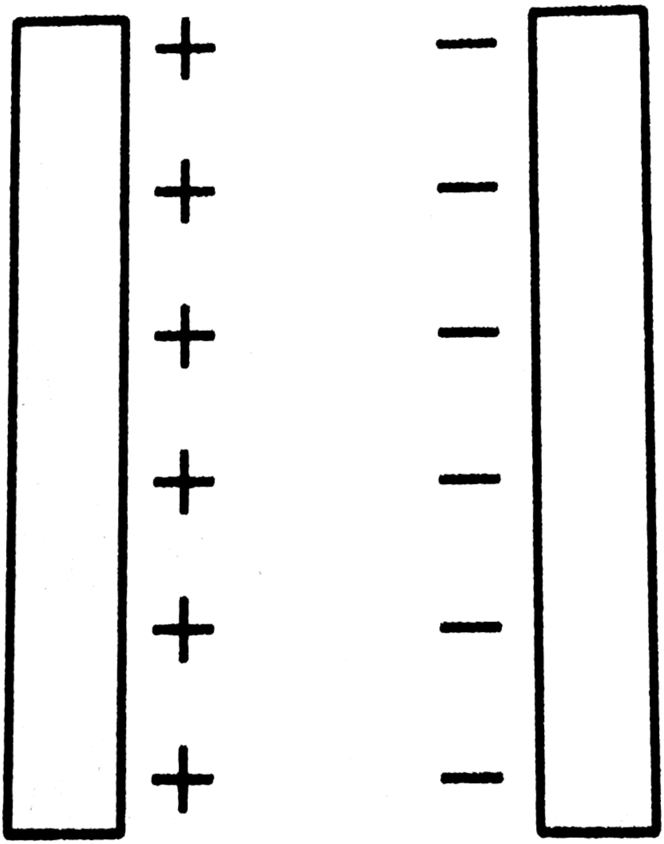
22. Two large conducting plates are placed parallel to each other nad they carry equal and opposite charges with surface density σ as shown in figure (30-E6). Find the electric field (a) at the left of the plates, (b) in between the plates and © at the right of the plates.



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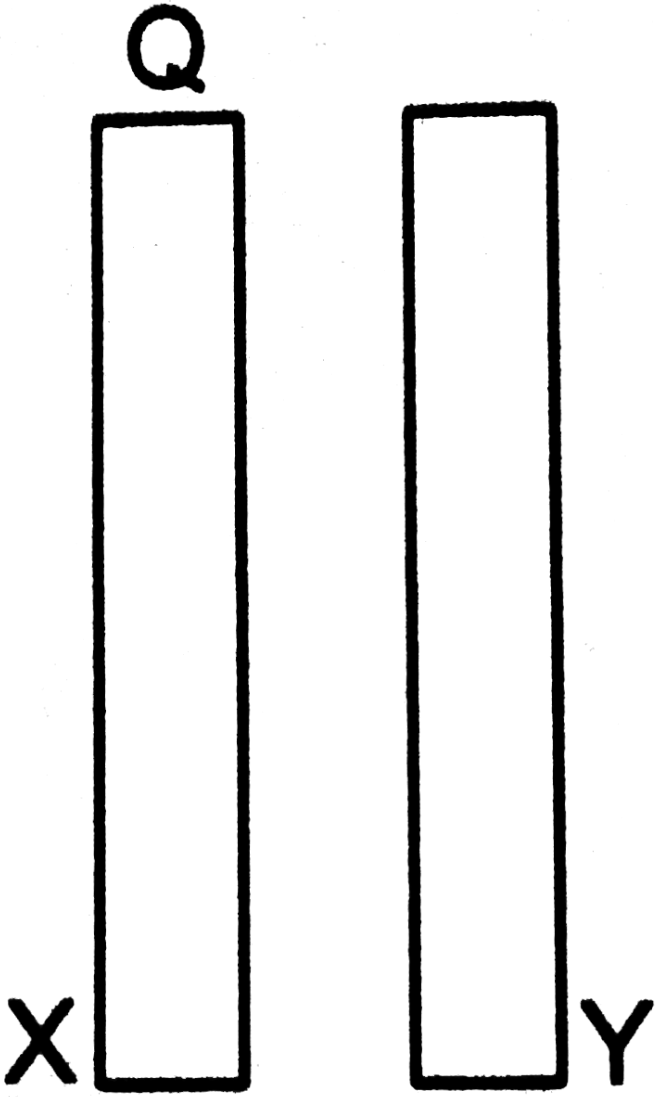
23. Two large conducting plates X and Y. each having large surface area A (on one side), are placed parallel to each other as shown in figure (30-E7). The plate X ia given a charge Q whereas the other is neutral. Find (a) the surface charge dendity at the inner surface of the plates X, (b) the electric field at a point to the left of the plates, (c) the electric field at a point in between the plates and (d) the electric field at a point to the right of the plates.



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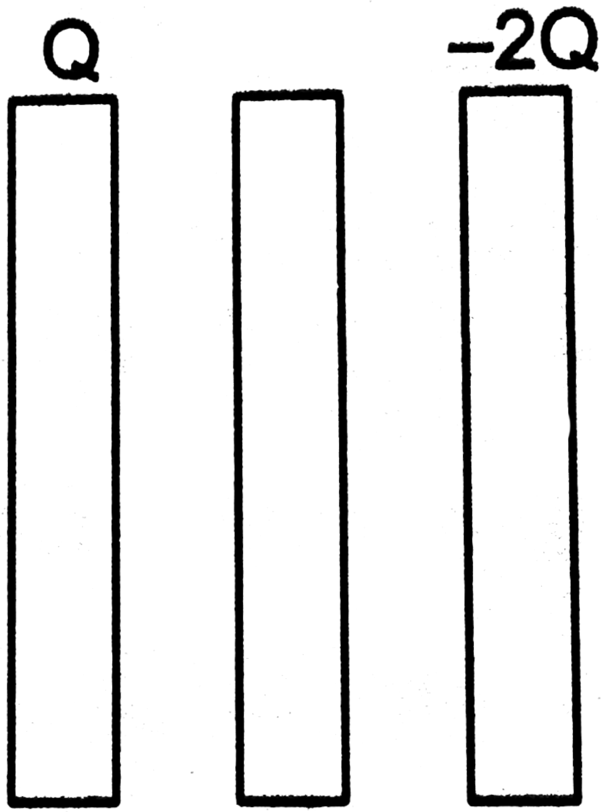
24. Three inentical metal plates with large surface areas are kept parallel to each as shown in figure (30-E8). The leftmost plate is given a charge Q, the rightmost a chrge _2Q and the middle one remains neutral. Finde the charge appearing on the outer surface of the rightmost plate.



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