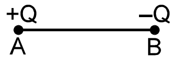
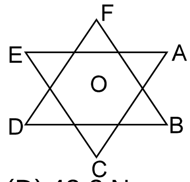
Electrostatics (Question Bank)

1. Two point charges of the same magnitude and opposite sign are fixed at points A and B. A third point charge is to be balanced at point P by the electrostatic force due to these two charges. The point P:



(A) lies on the perpendicular bisector of line AB (B) is at the mid point of line AB
(C) lies to the left of A (D) none of these.

2. The electric force on 2 μ c charge placed at the centre O of two equilateral triangles each of side 10 cm, as shown in figure is P. If charge A, B, C, D, E & F are 2 μ c, 2 μ c, 2 μ c, -2 μc, - 2 μ c, - 2 μ c respectively, then force acting on P is :



(A) 21.6 N (B) 64.8 N (C) 0 (D) 43.2 N

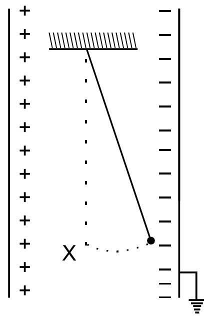
3. Ten positively charged particles are kept fixed on the X-axis at points x = 10 cm, 20 cm, 30 cm, ..., 100 cm. The first particle has a charge 1.0×1.0^{-8} C, the second 8×10^{-8} C, the third 27×10^{-8} C and so on. Find the magnitude of the electric force acting on a 1 C charge placed at the origin.

4. The distance between two fixed positive charges 4e and e is ℓ. How should a third charge 'q' be arranged for it to be in equilibrium? Under what condition will equilibrium of the charge 'q' be stable (for displacement on the line joining 4e and e) or will it be unstable?

5. A simple pendulum has a length ℓ, mass of bob m. The bob is given a charge q coulomb. The pendulum is suspended between the vertical plates of charged parallel plate capacitor. Which produces a uniform electric field of strength E between the plates, then assuming that it does not collide with the plate calculate the time period T =

(A) $2\pi\sqrt{\frac{\ell}{g}}$ (B) $2\pi\sqrt{\left\{\frac{\ell}{g+\frac{qE}{m}}\right\}}$

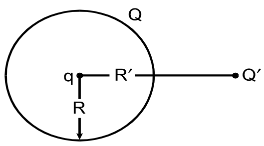
(C) $2\pi\sqrt{\left\{\frac{\ell}{g-\frac{qE}{m}}\right\}}$ (D) $2\pi\sqrt{\frac{\ell}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$

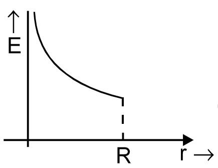


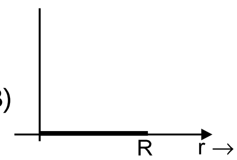
6. A charged particle of charge q and mass m is released from rest in an uniform electric field E. Neglecting the effect of gravity, the kinetic energy of the charged particle after time 't' seconds is

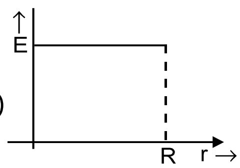
(A) $\frac{Eqm}{t}$ (B) $\frac{E^2q^2t^2}{2m}$ (C) $\frac{2E^2t^2}{mq}$ (D) $\frac{Eq^2m}{2t^2}$

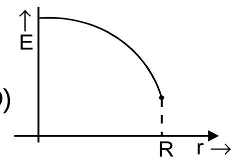
7. A charge ' q ' is placed at the centre of a conducting spherical shell of radius R, which is given a charge Q. An external charge Q′ is also present at distance R′ (R′ > R) from ' q '. Then the resultant field will be best represented for region r < R by:
[where r is the distance of the point from q]



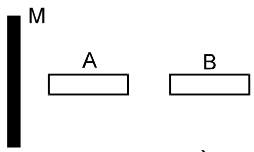
(A) 

(B) 

(C) 

(D) 

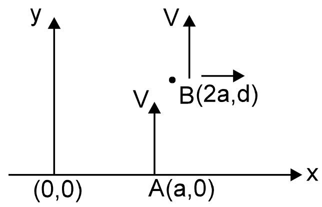
8* A large nonconducting sheet M is given a uniform charge density. Two uncharged small metal rods A and B are placed near the sheet as
shown in figure.



(A) M attracts A (B) M attracts B
(C) A attracts B (D) B attracts A

9* A uniform electric field of strength E exists in a region. An electron (charge –e, mass m) enters a points A perpendicularly with velocity V. It moves through the electric field & exits at point B.Then:

(A) $E = -\frac{2amv^2}{ed^2}\hat{i}$ → use S_x, $v = \frac{d}{t}$

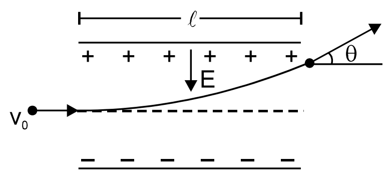


(B) Rate of work done by the electric field at B is $\frac{4ma^2v^3}{d^3}$

(C) Rate of work by the electric field at A is zero

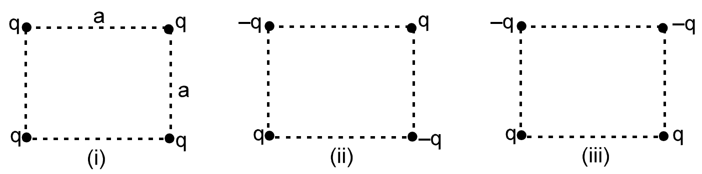
(D) Velocity at B is $\frac{2av}{d}\hat{i} + v\hat{j}$

10. A uniform electric field E is created between two parallel, charged plates as shown in figure. An electron enters the field symmetrically between the plates with a speed v_0. The length of each plate is l. Find the angle of deviation of the path of the electron as it comes out of the field.

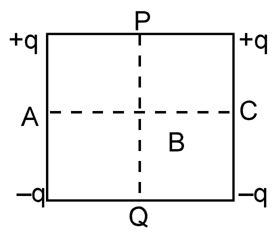


11. Ten charges are placed on a meter stick at regular interval starting from 10cm mark at an interval of 10cm. The magnitude of the charges are q, 4q, 9q,.........Find the field intensity at the zero mark of the stick.

12 In the following figures find the electric field at a point 'P' on the axis of the square. The distance of 'P' from the centre is 'x'.



13. Figure represents a square carrying charges +q, +q, –q, –q at its four corners as shown. Then the potential will be zero at points



(A) A, B, C, P and Q (B) A, B and C (C) A, P, C and Q (D) P, B and Q

14. Two equal positive charges are kept at points A and B. The electric potential at the points between A and B (excluding these points) is studied while moving from A to B. The potential
(A) continuously increases (B) continuosly decreases
(C) increases then decreases (D) decreases than increases

15. If a uniformly charged spherical shell of radius 10 cm has a potential V at a point distant 5 cm from its centre, then the potential at a point distant 15 cm from the centre will be :

(A) $\frac{V}{3}$ (B) $\frac{2V}{3}$ (C) $\frac{3}{2}V$ (D) 3V

16. A hollow uniformly charged sphere has radius r. If the potential difference between its surface and a point at distance 3r from the centre is V, then the electric field intensity at a distance 3r from the centre is:

(A) V/6r (B) V/4r (C) V/3r (D) V/2r

17. A hollow sphere of radius 5 cm is uniformly charged such that the potential on its surface is 10 volt then potential at centre of sphere will be :

(A) Zero (B) 10 volt

(C) Same as at a point 5 cm away from the surface

(D) Same as at a point 25 cm away from the centre

18. A 5 coulomb charge experiences a constant force of 2000 N when moved between two points separated by a distance of 2 cm in a uniform electric field. The potential difference between these two points is :

(A) 8 V (B) 200 V (C) 800 V (D) 20,000 V

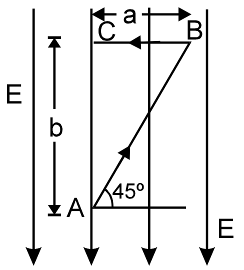
19. The potential difference between points A and B in the given uniform electric field is :

(A) Ea

(B) $E\sqrt{(a^2+b^2)}$

(C) Eb

(D) $(Eb/\sqrt{2})$



20. A particle of charge Q and mass m travels through a potential difference V from rest. The final momentum of the particle is :

(A) $\frac{mV}{Q}$ (B) $2Q\sqrt{mV}$ (C) $\sqrt{2m\ QV}$ (D) $\sqrt{\frac{2QV}{m}}$

21. A point charge 20 μC is shifted from infinity to a point P in an electric field with zero acceleration. If the potential of that point is 1000 volt, then

(i) find out work done by external agent against electric field?

(ii) what is the work done by electric field?

(iii) If the kinetic energy of charge particle is found increase by 10 mJ when it is brought from infinity to point P then what is the total work done by extenal agent?

(iv) what is the work done by electric field in the part (iii)

(v) If a point charge 30 μC is released at rest at point P, then find out its kinetic energy at a large distance?

22. What is the potential at origin if two equal point charges 'q' are placed at (a, 0) and (–a, 0)?

23. Six equal point charges 'q_0' are placed at six corners of a regular hexagon of side 'a'. Find out work required to take a point charge 'q'

(i) From infinity to the centre of hexagon. 6kq / a²

(ii) From infinity to a point on the axis which is at a distance '$\sqrt{3}$ a' from the centre 5kq / 3a²

(iii) Does your answer to part (i) and (ii) depends on the path followed by the charge. No

24. 12 J of work has to be done against an existing electric field to take a charge of 0.01 C from A to B. How much is the potential difference $V_B - V_A$?

25. An electric field of 30 N/C exists along the negative x-axis in space. Calculate the potential difference $V_B - V_A$ where the points A and B are given by,

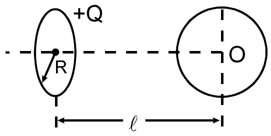
(a) A = (0, 0) ; B = (0, 2m) −60 (b) A = (4m, 2m) ; B = (6m, 5m) −30√13

26. A positive charge $Q = 50\ \mu C$ is located in the xy plane at a point having position vector $r_0 = (2\hat{i}+3\hat{j})m$ where $\hat{i}$ and $\hat{j}$ are unit vectors in the positive directions of X and Y axis respectively. Find:

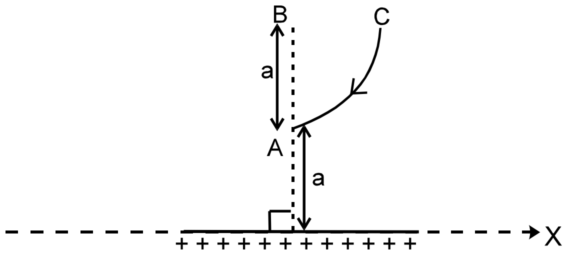
(a) The electric intensity vector and its magnitude at a point of coordinates (8 m, - 5 m).

(b) Work done by external agent in transporting a charge $q = 10\ \mu C$ from (8 m, 6 m) to the point (4 m, 3 m).

27. A thin ring of radius R has been non-uniformly charged with an amount of electric charges Q and placed in relation to a conducting sphere in such a way that the centre of the sphere O, lies on the axis at a distance of ℓ from the plane of the ring. Determine the potential of the sphere.



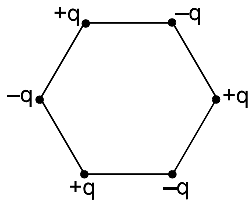
28. For an infinite line of charge having charge density λ lying along x-axis, the work required in moving charge from C to A along are CA is :



(A) $\frac{q\lambda}{\pi\varepsilon_0}\log_e\sqrt{2}$ (B) $\frac{q\lambda}{4\pi\varepsilon_0}\log_e\sqrt{2}$

(C) $\frac{q\lambda}{4\pi\varepsilon_0}\log_e 2$ (D) $\frac{q\lambda}{2\pi\varepsilon_0}\log_e\frac{1}{2}$

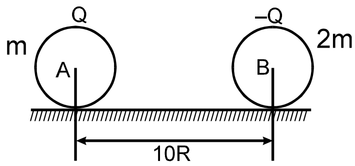
29. Six charges of magnitude + q and –q are fixed at the corners of a regular hexagon of edge length a as shown in the figure. The electrostatic interaction energy of the charged particles is :



(A) $\frac{q^2}{\pi\epsilon_0 a}\left[\frac{\sqrt{3}}{8}-\frac{15}{4}\right]$ (B) $\frac{q^2}{\pi\epsilon_0 a}\left[\frac{\sqrt{3}}{2}-\frac{9}{4}\right]$

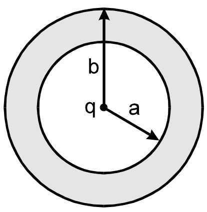
(C) $\frac{q^2}{\pi\epsilon_0 a}\left[\frac{\sqrt{3}}{4}-\frac{15}{2}\right]$ (D) $\frac{q^2}{\pi\epsilon_0 a}\left[\frac{\sqrt{3}}{2}-\frac{15}{8}\right]$

30. Two smooth spherical non conducting shells each of radius R having uniformly distributed charge Q & – Q on their surfaces are released on a smooth non-conducting surface when the distance between their centres is 10 R. The mass of A is m and that of B is 2 m. The speed of A just before A and B collide is: [Neglect gravitational interaction]



(A) $\sqrt{\frac{2kQ^2}{15\,mR}}$ (B) $\sqrt{\frac{4kQ^2}{15\,mR}}$ (C) $\sqrt{\frac{8kQ^2}{15\,mR}}$ (D) $\sqrt{\frac{16kQ^2}{15\,mR}}$

31. A point charge q is brought from infinity and is placed at the centre of a conducting neutral spherical shell of inner radius a and outer radius b, then work done by external agent is:

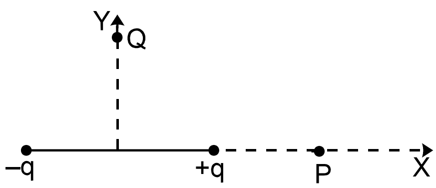


(A) 0 (B) $\frac{kq^2}{2b}$

(C) $\frac{kq^2}{2b}-\frac{kq^2}{2a}$ (D) $\frac{kq^2}{2a}-\frac{kq^2}{2b}$

32. Two positive point charges 15 μC and 10 μC are 30 cm apart. Calculate the work done in bringing them closer to each other by 15 cm.

33. Due to an electric dipole shown in fig., the electric field intensity is parallel to dipole axis :



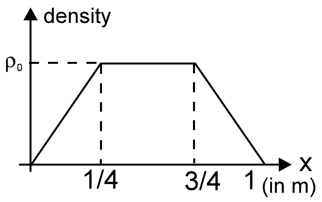
(A) at P only (B) at Q only (C) both at P and at Q (D) neither at P nor at Q

34. An electric dipole consists of two opposite charges each of magnitude 1.0 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 1.0×10^5 N/C. The maximum torque on the dipole is :
(A) 0.2×10^{-3} N-m (B) 1.0×10^{-3} N-m (C) 2.0×10^{-3} N-m (D) 4.0×10^{-3} N-m

35. A dipole of electric dipole moment P is placed in a uniform electric field of strength E. If θ is the angle between positive directions of P and E, then the potential energy of the electric dipole is largest when θ is :
(A) zero (B) $\pi/2$ (C) π (D) $\pi/4$

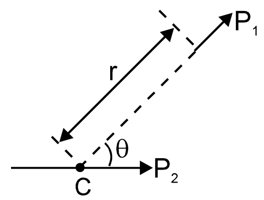
36. Two opposite and equal charges 4×10^{-8} coulomb when placed 2×10^{-2} cm apart form a dipole. If this dipole is placed in an external electric field 4×10^8 N/C, the value of maximum torque and the work done in rotating it through 180º from its initial orientation which is along electric field will be :
(A) 64×10^{-4} N-m and 44×10^{-4} J (B) 32×10^{-4} N-m and 32×10^{-4} J
(C) 64×10^{-4} N-m and 32×10^{-4} J (D) 32×10^{-4} N-m and 64×10^{-4} J

37. The volume charge density as a function of distance X from one face inside a unit cube is varying as shown in the figure. Then the total flux (in S.I. units) through the cube if $\rho_0 = 8.85 \times 10^{-12}$ C/m^3 is:



(A) 1/4 (B) 1/2 (C) 3/4 (D) 1

38. Two short electric dipoles are placed as shown (r is the distance between their centres). The energy of electric interaction between these dipoles will be:
(C is centre of dipole of moment P_2)

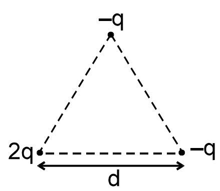


(A) $\dfrac{2k\,P_1P_2\cos\theta}{r^3}$ (B) $\dfrac{-2k\,P_1P_2\cos\theta}{r^3}$

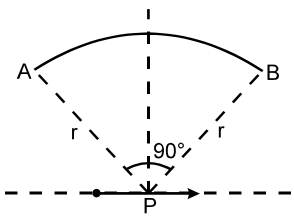
(C) $\dfrac{-\,2kP_1P_2\sin\theta}{r^3}$ (D) $\dfrac{-\,4kP_1P_2\cos\theta}{r^3}$

39* An electric dipole is kept in the electric field produced by a point charge.
(A) dipole will experience a force.
(B) dipole can experience a torque.
(C) dipole can be in stable equilibrium.
(D) it is possible to find a path in the field on which work required to move the dipole is zero.

40. Three charges are arranged on the vertices of an equilateral triangle as shown in figure. Find the dipole moment of the combination.

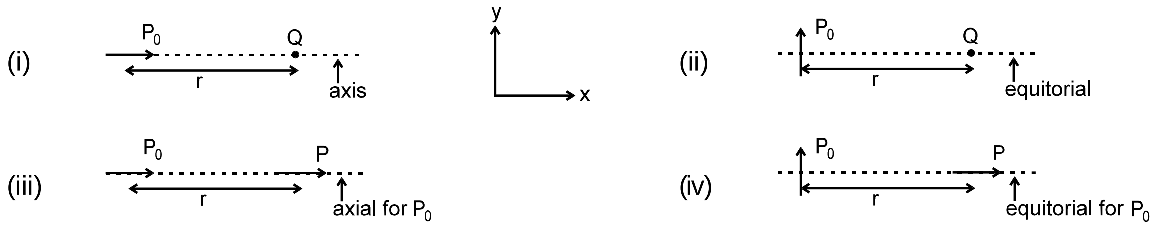


41. A charge ' q ' is carried from a point A (r, 135º) to point B (r, 45º) following a path which is a quadrant of circle of radius ' r '. If the dipole moment is $\vec{P}$, then find out the work done by external agent ?



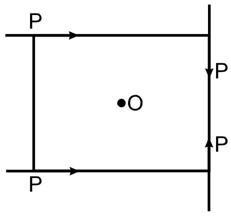
42. Find out force experienced by short dipole $\vec{P}_0$ in following different arragnement as shown in figures.

[Assume point charge is Q, $\vec{P}_0 = q_0(2a)$ and $\vec{P} = q(2a)$]

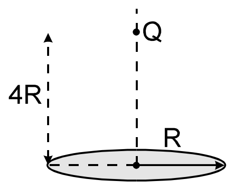


43. Find out the magnitude of electric field intensity at point (2, 0, 0) due to a dipole of dipole moment, $\vec{P} = \hat{i} + \sqrt{3}\,\hat{j}$ kept at origin? Also find out the potential at that point.

44. Four short dipoles each of dipole moment $\vec{P}$ are placed at the vertices of a square of side a. The direction of the dipole moments are shown in the figure. Find the electric field and potential at the centre 'O' of the square.



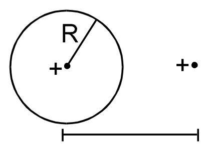
45. A charge Q is placed at a distance of 4R above the centre of a disc of radius R. The magnitude of flux through the disc is ϕ. Now a hemispherical shell of radius R is placed over the disc such that it forms a closed surface. The flux through the curved surface taking direction of area vector along outward normal as positive, is



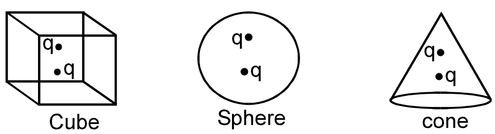
(A) zero (B) ϕ (C) $-\phi$ (D) 2ϕ

46. Find out the electric flux through an area 10 m^2 lying in XY plane due to an electric field $\vec{E} = 2\hat{i} - 10\hat{j} + 5\hat{k}$.

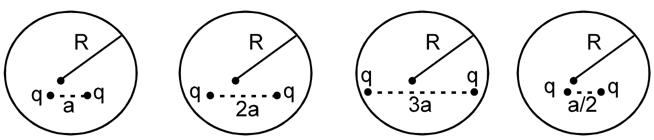
47. Find the flux of the electric field through a spherical surface of radius R due to a charge of 8.85 x 10^{-8}C at the centre and another equal charge at a point 2R away from the centre



48. Two point charges are placed at a certain ditance (as shown in figures) inside a cube , sphere and a cone. Arrange the order of flux through the closed surfaces.



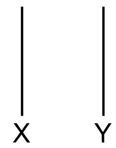
49. In which of the following case the flux is maximum through close spherical gaussian surface of radius R ?



50. What do you predict by the statement about the nature of charge in a close surface. "In a close surface lines which are leaving the surface are double then the lines which are entering in it".

51. The electric field in a region is given by $\vec{E} = \frac{E_0 x}{\ell}\vec{i}$. Find the charge contained inside a cubical volume bounded by the surface x = 0, x = a, y = 0, y = a, z = 0 and z = a. Take $E_0 = 5 \times 10^3$ N/C, $\ell = 2$ cm and a = 1 cm.

52. Two conducting plates X and Y, each having large surface area 'A' as shown in figure (on one side) are placed parallel to each other. The plate X is given a charge Q whereas the other is neutral. The electric
field at a point in between the plates is given by:

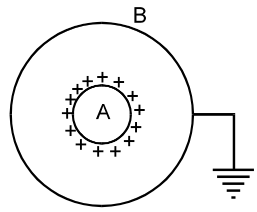


(A) $\frac{Q}{2A}$ (B) $\frac{Q}{2A\varepsilon_0}$ towards left

(C) $\frac{Q}{2A\varepsilon_0}$ towards right (D) $\frac{Q}{2\varepsilon_0}$ towards right

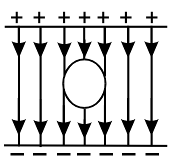
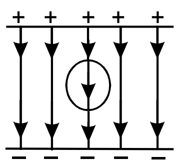
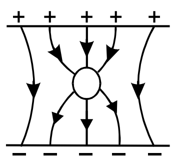
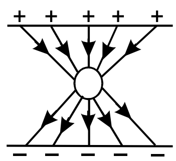
53. A charge Q is unifromly distributed over a large plastic plate. The electric field at a point P close to the centre of the plate is 10 V/m. If the plastic plate is replaced by a copper plate of the same geometrical dimensions and carriying the same charge Q, the electric field at the point P will become
(A) zero (B) 5 V/m (C) 10 V/m (D) 20 V/m

54* A and B are two concentric spherical shells. A is given a charge Q while B is uncharged. If now B is earthed as shown in Figure.Then:

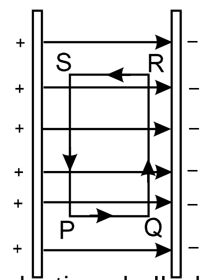


(A) The charge appearing on inner surface of B is -Q
(B) The field inside and outside A is zero
(C) The field between A and B is not zero
(D) The charge appearing on outer surface of B is zero

55. An uncharged sphere of metal is placed in a uniform electric field produced by two large conducting parallel plates having equal and opposite charges, then lines of force look like

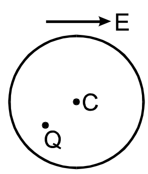
(A)  (B)  (C)  (D) 

56. The amount of work done in Joules in carrying a charge +q along the closed path PQRSP between the oppositely charged metal plates is (where E is electric field between the plates)



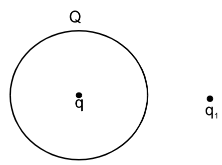
(A) zero (B) q
(C) qE (PQ + QR + SR + SP) (D) q/ε_0

57. A positive point charge Q is kept (as shown in the figure) inside a neutral conducting shell whose centre is at C. An external uniform electric field E is applied. Then



(A) force on Q due to E is zero
(B) net force on Q is zero
(C) net force acting on Q and conducting shell considered as a system is zero
(D) net force acting on the shell due to E is zero.

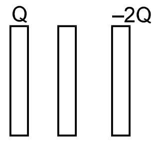
58. A thin, metallic spherical shell contains a chrage Q on it. A point charge q is placed at the centre of the shell and another charge q_1 is placed outside it as shown in fig. All the three charges are positive. The force on the charge at the centre is



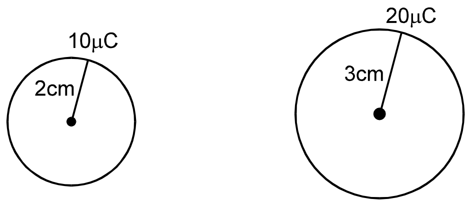
(A) towards left (B) towards right
(C) upward (D) zero

59. The net charge given to an isolated conducting solid sphere:
(A) must be distributed uniformly on the surface
(B) may be distributed uniformly on the surface
(C) must be distributed uniformly in the volume
(D) may be distributed uniformly in the volume.

60. Three identical metal plates with large equal surface areas are kept parallel to each other as shown in figure. The leftmost plate is given a charge Q, the rightmost a charge – 2Q and the middle one remains neutral. Find the charge appearing on the outer surface of the rightmost plate.

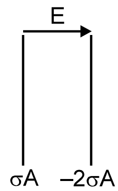


61. Figure shows two isolated conducting spheres of radius 2cm and 3cm containing charges 10μC and 20μC respectively. When the spheres are connected by a conducting wire then find out following :
(i) Ratio of the final charge. (ii) Final charge on each sphere.
(iii) Ratio of final charge densities. (iv) Heat loss during the process.

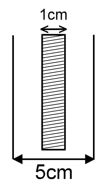


62. Two concentric hollow conducting spheres of radius a and b (b>a) contains charges Q_a and Q_b respectively. If they are connected by a conducting wire then find out following
(i) Final charges on inner and outer spheres.
(ii) Heat produced during the process.

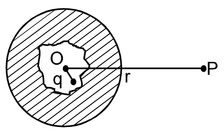
63. Two thin conducting plates (very large) parallel to each other carrying total charges σA and -2σA respectively (where A is the area of each plate), are placed in a uniform external electric field E as shown. Find the surface charge on each surface.



64. The distance between two large plates is d = 5 cm and the intensity of the field in it is E = 300 V/cm. An uncharged metal bar which is 1 cm thick, is inserted between the plates as shown. Determine the potential difference between the plates of the capacitor
before and after the bar is introduced.

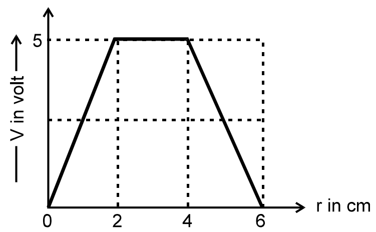


65. The point charge 'q' is within an electrically neutral conducting shell whose outer surface has spherical shape. Find potential V at point P lying outside shell at a distance 'r' from centre O of outer sphere.



66* The electric field intensity at a point in space is equal in magnitude to :
(A) The potential gradient there
(B) The electric charge there
(C) The force, a unit charge would experience there
(D) The force, an electron would experience there

67. The variation of potential with distance r from a fixed point is shown in Figure. The electric field at r = 5 cm, is :
(A) (2.5) V/cm (B) (–2.5) V/cm
(C) (–2/5) cm (D) (2/5) V/cm



68. The electric potential V as a function of distance x (in metre) is given by
$$V = (5x^2 + 10x - 9) \text{ volt}$$
The value of electric field at x = 1 m would be :
(A) – 20 volt/m (B) 6 volt/m (C) 11 volt/m (D) –23 volt/m

69. A uniform electric field having a magnitude E_0 and direction along positive X-axis exists. If the electric potential V is zero at x = 0, then its value at x = +x will be :
(A) $V_x = xE_0$ (B) $V_x = -xE_0$ (C) $V_x = x^2E_0$ (D) $V_x = -x^2 E_0$

70. The electric potential decreases uniformly from 120 V to 80 V as one moves on the X-axis from x = – 1 cm to x = + 1 cm. The electric field at the origin
(A) must be equal to 20V/cm (B) may be equal to 20V/cm
(C) may be greater than 20V/cm (D) may be less than 20V/cm

71. The electric field in a region is directed outward and is proportional to the distance r form the origin. Taking the electric potential at the origin to be zero, the electric potential at a distance r :
(A) is uniform in the region (B) is proportional to r
(C) is proportional to r^2 (D) increases as one goes away from the origin.

72. If $V = x^2y + y^2z$ then find $\vec{E}$ (x, y, z)

73. If $V = 2r^2$ then find out (i) $\vec{E}$ (1, 0, –2) (ii) $\vec{E}(r = 2)$

74. An electric field $\vec{E} = (20\hat{i} + 30\hat{j})$ N/C exists in the space. If the potential at the origin is taken to be zero, find the potential at (2m, 2m).

75. If $E = 2r^2$ then find V(r)

76. If $\vec{E} = 2y\hat{i} + 2x\hat{j}$ then find V (x, y, z)

ANSWER KEY

1. D **2.** D **3.** 4.95×10^5 N

4. $\frac{2\ell}{3}$ from charge 4 e (If q is positive stable, If q is negative unstable)

5 D **6.** B **7.** A **8.** C **9.** C,D **10.** A,B,C,D

11. The electron deviates by an angle $\theta = \tan^{-1}\frac{eEl}{mv_0^2}$

12. $\frac{10q}{4\pi\varepsilon_0 . r^2}$ where r = 10cm.

13. (i) $\frac{4Kqx}{\left(\frac{a^2}{2}+x^2\right)^{3/2}}$, along the axis, $\frac{4Kq}{x^2}$, The whole system behaves as a point charge

(ii) 0 (iii) $\frac{2Kqa}{\left(\frac{a^2}{2}+x^2\right)^{3/2}}$

14. B **15.** D **16.** B **17.** A **18.** B **19.** C **20.** C

21. (i) 20 mJ. (ii)– 20 mJ (iii) 30 mJ (iv) –20mJ (v) 30 mJ

22. $\frac{2Kq}{a}$. **23.** (i) $\frac{6Kqq_0}{a}$ (ii) $\frac{3Kqq_0}{a}$ (iii) No

24. 1200 volts **25.** (a) 0 (b) 60

26. (a) 450 $(6\hat{i} - 8\hat{j})$ V/m, 4.5 k V/m (b) 1.579 J **27.** $V = \frac{KQ}{\sqrt{R^2+\ell^2}}$ **28.** A

29. D **30.** C **31.** C **32.** 4.5 J **33.** C **34.** C
35. C **36.** D **37.** C **38.** B **39.** ABD

40. $qd\sqrt{3}$, along the bisector of the angle at 2q, away from the triangle

41. $\frac{\sqrt{2}\,qP}{4\pi\varepsilon_0 r^2}$ **42.** (i) $\frac{2KP_0Q}{r^3}(-\hat{i})$ (ii) $\frac{KP_0Q}{r^3}\hat{j}$ (iii) $\frac{6KP_0P}{r^4}\hat{i}$ (iv) $\frac{3KP_0P}{r^4}(-\hat{j})$

43. $|E| = \frac{\sqrt{7}K}{8}$, $V = \frac{K}{4}$ [where K = 1/4 $\pi \epsilon_0$] . **44.** $E = \frac{\sqrt{2}\,p}{\pi \epsilon_0 a^3}$, $V = \frac{\sqrt{2}\,p}{\pi \epsilon_0 a^2}$

45. C **46.** 50 Nm²/C. **47.** $10^4 \frac{N-m^2}{C}$ **48.** $\phi_{cube} = \phi_{sphere} = \phi_{cone} = \frac{2q}{\varepsilon_0}$.

49. Same in all cases . **50.** There is a positive charge in the close surface. **51.** 2.2×10^{-12} C

52. C **53.** C **54.** ACD **55.** C **56.** A **57.** D **58.** D

59. A **60.** $-\frac{Q}{2}$ **61.** (i) $\frac{Q'_1}{Q'_2} = \frac{2}{3}$ (ii) 12 mC, 18 mC (iii) $\frac{\sigma'_1}{\sigma'_2} = \frac{3}{2}$ (iv) 1.49 Joules.

62. **(i)** on inner shell = 0 , on outer shell = $Q_a + Q_b$ (ii) $\frac{KQ_a^2}{2}\left[\frac{1}{a} - \frac{1}{b}\right]$

63. $(\sigma - x)A$, xA, $-xA$, $(x - 2\sigma)A$ where $x = (2\varepsilon_0 E + 3\sigma)/2$

64. 1500 V, 1200 V **65.** $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

66. AC **67.** A **68.** A **69.** B **70.** BC **71.** C **72.** $-2xy\,\hat{i} - (x^2 + 2yz)\,\hat{j} - y^2\hat{k}$

73. (i) $-4(\hat{i} - 2\hat{k})$ (ii) $\vec{E} = -8\hat{r}$ **74.** –100 V **75.** $\frac{-2r^3}{3}$ + C **76.** – 2xy + C