Electromagnetism: Electric Field and Gauss's Law – Typical Questions

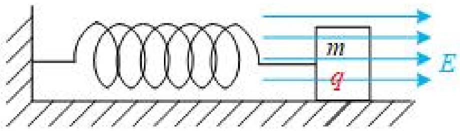
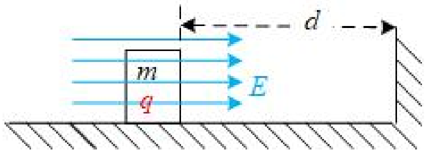
No of Questions: 72 **Time Allotted: 6 Hours (in 2 parts)**

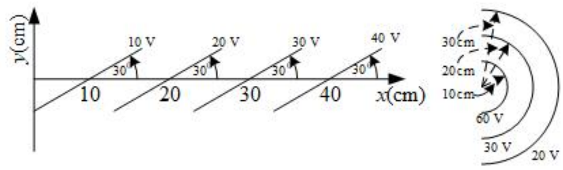
All questions are compulsory

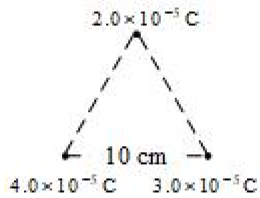
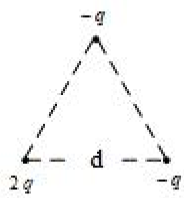
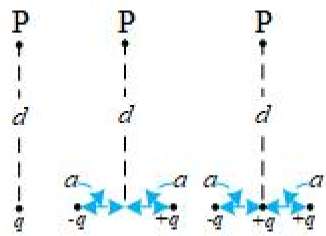
[Note: a. Figures are conceptual only and not to the scale**]**

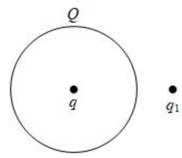
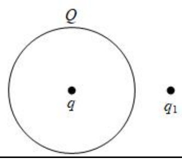
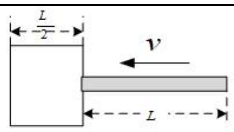
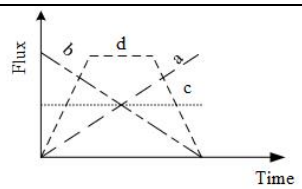
[b. Solutions may be taken up in Three parts as, Part I: 1 to 40 of Three Hours; Part II: 41 to 72 of Three Hours]

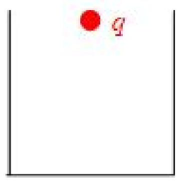
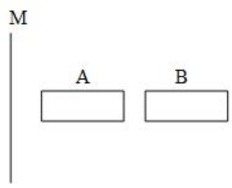
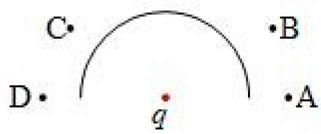
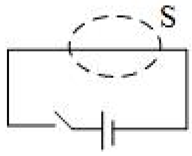
[c. It is advised to attempt question under examination conditions**]**

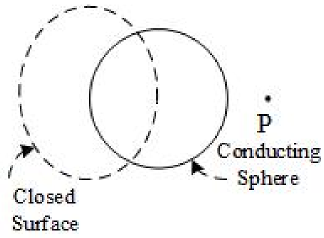
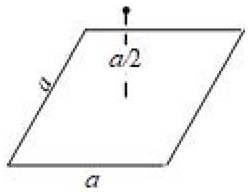
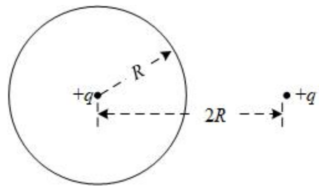
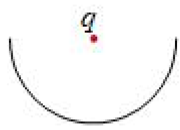
Q-1	The bob of a simple pendulum has a mass of 40 g and a positive charge 4.0×10^{-6}C. It makes 20 oscillations in 45 s a vertical field pointing upward and of magnitude 2.5×10^{4} NC^{-1} is switched on. How much time will it take to complete 20 oscillations?
Q-2	A block of mass m having a charge q is placed on a smooth horizontal able and is connected to a wall through an upstretched spring of spring constant k as shown in the figure. A horizontal electric field E parallel to the spring is switched on. Find the amplitude of the resulting SHM of the block. 
Q-3	A block of mass m containing a net positive charge q is placed on a smooth horizontal table which terminates in a vertical wall as shown in figure. The distance of the block from the wall is d. A horizontal electric field E towards right is switched on. Assuming elastic collisions (if any) find the time period of the resulting oscillatory motion. Is it a simple harmonic motion? 
Q-4	A uniform electric field of 10 NC^{-1} exists in the vertically downward direction. Find the increase in the electric potential as one goes up through a height of 50 cm.
Q-5	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 $V_B - V_A$?
Q-6	Two equal charges 2.0×10^{-7}C each are held fixed at a separation of 20 cm. A third charge of equal magnitude is placed midway between the two charges. It is now moved to a point 20 cm from both the charges. How much work is done by the electric field during the process?
Q-7	Q-56, HCV-II, Ch-29, Ex, pp. 123
Q-7	An electric field of 20 NC^{-1} exits along X-axis on space. Calculate the potential difference $V_B - V_A$, such that points A and B are given by (a) A = (0, 0); B = (4 m, 2 m) (b) A = (4 m, 2 m); B = (6 m, 5 m) (c) A = (0,0); B = (6 m, 5 m) Find relation between the answers of part (a), (b) and (c)

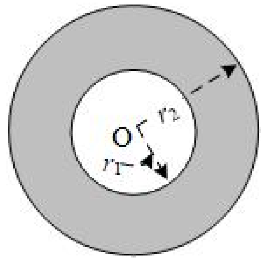
Q-8	An electric field of 20 NC^{-1} exits along X-axis on space. A charge of -2.0×10^{-4} C is moved from point A to the point B. Find change in potential energy $U_B - U_A$, such that points A and B are given by (a) A = (0, 0); B = (4 m, 2 m) (b) A = (4 m, 2 m); B = (6 m, 5 m) (c) A = (0,0); B = (6 m, 5 m)
Q-9	An electric field $\vec{E} = (20\hat{\imath} + 30\hat{\jmath})NC^{-1}$ exists in the space. If potential at the origin is taken to be zero, find the potential at (2m, 2m).
Q-10	An electric field $\vec{E} = Ax\hat{\imath}$ exists in space where $A = 10Vm^{-2}$. Take the potential at (10 m, 20 m) to be zero. Find the potential at the origin.
Q-11	The electric potential existing in space is $V(x, y, x) = A(xy + yz + zx)$. (a) Write the dimensional formula of A (b) Find expression for the electric field (c) If A is 10 SI units, find the magnitude of electric field at (1m, 1m, 1m).
Q-12	Two charged particles having equal charge 2.0×10^{-5} C each, are brought from infinity to within a separation of 10 cm. Find increase in potential energy in the process.
Q-13	Some equipotential surfaces are shown in figure. What can you say about the magnitude and the direction of the electric field? 
Q-14	Consider a circular ring of radius *R*, uniformly charged with linear charge λ. Find the electric potential at a point on the axis at a distance *x* from the center of the ring. Using this expression for the potential, find electric field at the point.
Q-15	An electric field magnitude 1000 NC^{-1} is produced between two parallel plates having a separation of 2.0 cm as shown in the figure.  (a) What is the potential difference between the plates? (b) With what minimum speed should an electron be projected from the lower plate in the direction of the field so that it may reach the upper plate? (c) Suppose the electron is projected from the lower plate with the speed calculated at (b), such that the direction of projection makes an angle of 60^0 with the field. Find the maximum height reached by the electron.
Q-16	A uniform electric field of 2.0 NC^{-1} exists in space in X-direction. (a) Taking the potential at the origin to be zero, write an expression for the potential at a general point (*x*, *y*, *z*). (b) At which points the potential is 25 V (c) If potential at origin is 100 V, what will be the expression for the potential at a general point? (d) What will be the potential at the origin if potential at infinity is taken to be zero? (e) Is it practical to choose the potential at infinity to be zero?

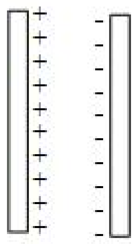
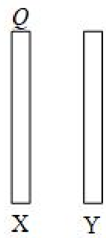
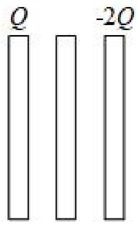
Q-17	How much work has to be done in assembling three charged particles at the vertices of an equilateral triangle as shown in the figure? 
Q-18	The kinetic energy of a charged particle decreases by 10 J as it moves from a point at potential 100 V to a point at potential 200 V. Find charge on the particle.
Q-19	Two identical particles each having a charge 2.0×10^{-4} C and mass of 10 g are kept at a separation of 10 cm and then released. What would be the speed of the particle when separation becomes large.
Q-20	Two particles have equal masses of 5.0 g each and opposite charges $+4.0 \times 10^{-5}$ C and -4.0×10^{-5}C. They are released from rest with a separation of 1.0 m between them. What would be the speed of the particles when separation is reduced to 50 cm?
Q-21	A sample of HCl gas is placed in an electric field of 2.5×10^{4} NC^{-1}. The dipole moment of each HCL molecule is 3.4×10^{-30} Cm. Find the maximum torque that can act on the molecule.
Q-22	Two particles A and B having opposite charges $+2.0 \times 10^{-6}$ C and -2.0×10^{-6}C are placed at a separation of 1.0 cm. (a) Write down the electric dipole moment of the pair (b) Calculate the electric field at a point on the axis of the dipole at 1.0 cm away from center. (c) Calculate the electric field at a point on the perpendicular bisector of the dipole and 1.0 m away from the center.
Q-23	Three charges are arranged on the vertices of an equilateral triangle as shown in the figure. Find the dipole moment of the combination. 
Q-24	Find the magnitude of the electric field at the point P in the configuration shown in the figure for $d \gg a$. Take $2qa = p$. 
Q-25	Two particles carrying charges $-q$ and $+q$ and having equal masses m each are fixed at the ends of a light rod of length a to form a dipole. The rod is clamped at an end and is placed in a uniform electric field E with the axis of the dipole along the electric field. The rod is slightly tilted and then released. Neglecting gravity, find time period of the oscillation.
Q-26	Assume that each atom in a copper wire contributes one free electron. Estimate the number of free electrons in a copper wire having a mass of 6.4 g (take the atomic weight of copper to be 64 $gm.mol^{-1}$).
Q-27	A small plane area is rotated in an electric field. In which orientation of the area is the flux of the electric field through the area maximum? In which orientation is it zero?

Q-28	A circular ring of radius r made of a non-conducting material is placed with its axis parallel to a uniform electric field. The ring is rotated about its diameter through 180^0. Does the flux of electric field change? If yes does it increase or decrease?
Q-29	A charge Q is uniformly distributed on a thin spherical shell. What is the field at the center of the shell? If a point charge is brought close to the shell, will the field at the center change? Does your answer depend on whether the shell is conducting or non-conducting?
Q-30	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 it change?
Q-31	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?
Q-32	A rubber balloon is given a charge Q distributed uniformly over its surface. Is the field inside the balloon zero everywhere, if the balloon does not have a spherical surface?
Q-33	It is said that any charge given to a conductor comes to its surface. Should all the protons come to surface? Should all the electrons come to the surface? Should all the free electrons come to the surface?
Q-34	A charge Q is uniformly distributed over a large plastic plate. The electric field at a point P close to the center of the plate is 10 V/m. If the plastic is replaced by a copper plate of the same geometrical dimensions and carrying the same charge Q, the electric field at the point will become (a) Zero (b) 5 V/m (c) 10 V/m (d) 20 V/m
Q-35	A metallic particle having no net charge near a finite metal plate carrying a positive charge. The electric force on the particle will be (a) Towards the plate (b) Away from the plate (c) Parallel to the plate (d) Zero
Q-36	A thin, metallic shell contains a charge Q on it. A point charge q is placed at the center of the shell and another charge q_1 is placed outside it as shown in the figure. All the three charges are positive. The force on the charge at the center is – (a) Towards left (b) Towards right (c) Upward (d) Zero 
Q-37	A thin, metallic shell contains a charge Q on it. A point charge q is placed at the center of the shell and another charge q_1 is placed outside it as shown in the figure. All the three charges are positive. The force on the central charge due to the shell is – (a) Towards left (b) Towards right (c) Upward (d) Zero 
Q-38	Electric charges are distributed in a small volume. The flux of the electric field through a spherical surface of radius 10 cm surrounding the total charge is 25 V.m. The flux over a centric sphere of radius 20 cm will be – (a) 25 V.m (b) 50 V.m (c) 100 V.m (d) 200 V.m
Q-39	Figure shows an imaginary cube of edge $\frac{L}{2}$. A uniformly charged rod of length L moves toward left at a small but constant speed v. At $t = 0$, the left end touches the center of the face of the cube opposite it. Which graph shown in the figure represents the flux of the electric field through the cube as the rod goes through it? 

Q-40	A charge q is placed at the center of the open end of a cylindrical vessel as shown in the figure. 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) $\frac{2q}{\varepsilon_0}$ 
Q-41	Mark the correct options: (a) Gauss's Law is valid for symmetrical charge distribution (b) Gauss's Law is valid only for charges placed in vacuum (c) The electric field calculated by Gauss's Law is the field due to the charge inside the Gaussian surface (d) The flux of the electric field through a closed surface due to all charges is equal to the flux due to the charges enclosed by the surface.
Q-42	A positive point charge Q is brought near 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 non-uniform charge distribution.
Q-43	A large non-conducting sheet M is given a uniform charge density. Two uncharged small metal rods A and B are placed near the sheet as shown in the figure – (a) M attracts A (b) M attracts B (c) A attracts B (d) B attracts A 
Q-44	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 vicinity of the surface must be zero
Q-45	An electric dipole is placed at the center of a sphere. Mark the correct options – (a) The flux of the electric field through the sphere is zero (b) The electric field is zero at every point on the sphere (c) The electric field is zero anywhere on the sphere (d) The electric field is zero on a circle on the sphere
Q-46	Figure shows a charge q placed at the center of a hemisphere. A second Q is placed at one of the positions A, B, C and D. In which position(s) of the second charge, the flux of the electric field through the hemisphere remains unchanged?  (a) A (b) B (c) C (d) D
Q-47	A closed surface S is constructed around a conducting wire connected to a battery and a switch as shown in the figure. As the switch is closed, the free electrons in the wire start moving along the wire. In any time, interval, the number of electrons entering the closed surface is equal to the number electrons leaving it. On closing the switch, the flux of the electric field through the closed surface  (a) Is increased (b) Is decreased (c) Remains unchanged (d) Remain zero

Q-48	Figure shows a closed surface 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
Q-49	The electric field in a region is given by $\vec{E} = \frac{3}{5}E_0\hat{\imath} + \frac{4}{5}E_0\hat{\jmath}$ with $E_0 = 2.0 \times 10^3$N/C. find the flux of this field through a rectangular surface of area 0.2 m^2 parallel to Y-Z plane.
Q-50	A charge Q is uniformly distributed over a rod of length l. Consider a hypothetical cube of edge l with the center 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.
Q-51	Show that there can be no net charge in a region in which the electric field is uniform at all points.
Q-52	The electric field in a region is given by $\vec{E} = \frac{E_0 x}{l}\hat{\imath}$. Find the charge contained inside a cubical volume bounded by surface $x = 0, x = a. y = a. z = 0$ and $z = a$. Take $E_0 = 5 \times 10^3$ N/C, $l = 2$ cm and $a = 1$ cm.
Q-53	A charge Q is placed at the center of a cube. Find the flux of the electric field through the six surfaces of the cube.
Q-54	A charge Q is placed at a distance $\frac{a}{2}$ above the center of a horizontal, square surface of edge a as shown in the figure. Find the flux of the electric field through the square surface. 
Q-55	Find the flux of the electric field through a spherical surface of Radius R due to a charge 10^{-7} C at the center and another equal charge at a point $2R$ away from the center as shown in the figure. 
Q-56	A charge Q is placed at the center of an imaginary hemispherical surface as shown in the figure. Using symmetry argument and the Gauss's Law, find the flux of the electric field due to this charge through the surface of the hemisphere. 
Q-57	A spherical volume contains a uniformly distributed charge density 2.0×10^{-4} C/m^3. Find the electric field at a point inside the volume at a distance 4.0 from the center.
Q-58	Q-10, HCV-II, Ch-30, Ex, pp. 141
Q-58	The radius of a gold nucleus ($Z = 79$) is about 2.0×10^{-15}m. Assume that the positive charge is distributed uniformly throughout the nuclear volume. Find the strength of the electric field at - (a) The surface of the nucleus (b) At the middle point of the radius. (c) Gold is a conductor, Is it justified to assume that the positive charge is uniformly distributed over the entire nuclear volume and does not come out of the nuclear surface?

Q-59	A charge Q is distributed uniformly within the material of a hollow sphere of inner and outer radii r_1 and r_2 as shown in the figure. Find the electric field at a point P distance x away from the center for $r_1 < x < r_2$. Draw a rough graph showing the electric field as a function of x for $0 < x < r_2$. 
Q-60	A charge Q is placed a the center of an uniformly uncharged, thin hollow metallic sphere of radius a- (a) Find the surface charge density on the inner sphere and on the outer sphere (b) If a charge q is put on the sphere, what would be the surface charge density on the inner and outer surfaces? (c) Find the electric field inside the sphere at a distance x from the center in the situation (a) and (b) above.
Q-61	Consider the following very rough model of a beryllium atom. The nucleus has four protons and four neutrons confined to a small volume of radium 10^{-15} m. The two 1s electrons make a spherical charge cloud at an average distance 1.3×10^{-11}m from the nucleus, whereas two 2s electrons make another spherical cloud at an average distance 5.2×10^{-11}m from the nucleus. Find the electric field at – (a) A point just inside 1s cloud (b) A point just inside 2s.
Q-62	Find the magnitude of the electric field at a appoint 4 cm away from a line charge of density 2×10^{-6} C/m.
Q-63	A long cylindrical wire carries a positive charge of linear density 2×10^{-8}C/m. An electron revolves around it in a circular path under the influence of the attractive electrostatic force. Find the kinetic energy of the electron. Note that it is independent of the radius.
Q-64	A long cylindrical volume, as shown in the figure, contains a uniformly distributed charge of density ρ. Find the electric field at a point P inside the cylindrical volume at a distance x from its axis. 
Q-65	A non-conducting sheet of large area and thickness d contains a uniform charge density ρ. Fin 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 $0 < x < d$.
Q-66	A charged particle having a charge -2.0×10^{-6}C is placed close to a non-conducting plate having a surface charge density 4.0×10^{-6} C/m^2. Find the force of attraction between the particle and the plate.
Q-67	One end of a 10 cm long silk thread is fixed to a large vertical surface of a charged non-conducting plate and other end is fastened to a small ball having a mass of 10 g and a charge of 4.0×10^{-6}C. In equilibrium, the thread makes an angle of 60^0 with the vertical. Find the surface charge density of the plate.
Q-68	One end of a 10 cm long silk thread is fixed to a large vertical surface of a charged non-conducting plate and other end is fastened to a small ball having a mass of 10 g and a charge of 4.0×10^{-6}C. In equilibrium, the thread makes an angle of 60^0 with the vertical. (a) Find the tension in the string in equilibrium (b) Suppose ball is slightly pushed aside and released. Fid time period of the small oscillation.
A-68	(a) 0.20 N (b) 0.45 s

Q-69	Two large conducting plates are placed parallel to each other with a separation 2.00 cm between 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.
Q-70	Two large conducting plates are placed parallel to each other and they carry equal and opposite charges with surface density σ as shown in the figure. Find the electric field – (a) At the left of the plate, (b) In between the plates (c) At the righto the plates 
Q-71	Two conducting plates X and Y each having large surface area A (on One Side) are placed parallel to each other as shown in the figure. The plate X is given a charge Q, whereas the other is neutral. Find – (a) The surface charge density at the inner surface of X (b) The electric field at a point to the left of the plates (c) Electric field at a point in between the plates (d) The electric field at a point to the right of the plates 
Q-72	Three identical metal plates with large surface area are kept parallel to each other as shown in the figure. The leftmost plate is given a charge Q, the rightmost a charge -2Q and the middle remains neutral. Find the charge appearing on the outer surface of the rightmost plate. 

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