Part I

1. When +3.0 C of charge moves from point A to point B in an electric field, the potential energy is decreased by 27 J. It can be concluded that point B is

   (a) 9.0 V lower in potential than point A.

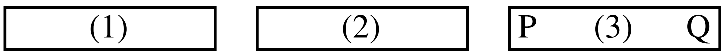
   (b) 9.0 V higher in potential than point A.

   (c) 81 V higher in potential than point A.

   (d) 81 V lower in potential than point A.

   Answer (a). It is lower since a positive charge has decreased its potential energy

2. A negatively charged rod (1) is placed near, but not touching two other initially uncharged metal rods.



   The charge distribution on rod (3) is such that

   (a) it carries a net negative charge.

   (b) it carries a net positive charge.

   (c) side P is positively charged and side Q is negatively charged.

   (d) side Q is positively charged and side P is negatively charged.

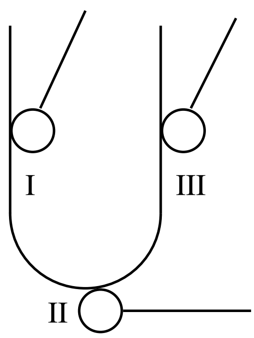
   Answer (c)

3. Two charges $q_1 = Q$ and $q_2 = -2Q$ are placed on the x-axis at $x = 0$ m and $x = 1$ m respectively. The value of x when the electric field is zero lies in the interval

   (a) $x < 0$ (b) $x > 0$ (c) $0 < x < 1$ (d) nowhere.

   Answer (a). Between the charges the electric fields point in the same direction and hence add up . Only on the left of q_1 can the magnitude of the electric field due to each charge be equal and opposite.

4. A small uncharged ball touches a positively charged Faraday Ice Pail in one of the positions I, II, III. The ball will be charged after touching



   (a) only at positions II and III.

   (b) only at position I

   (c) only at position II

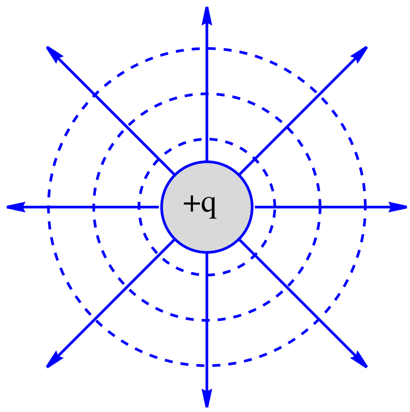
   (d) at positions I, II, III

   Answer (a). There is no charge on the inside surface of a conductor

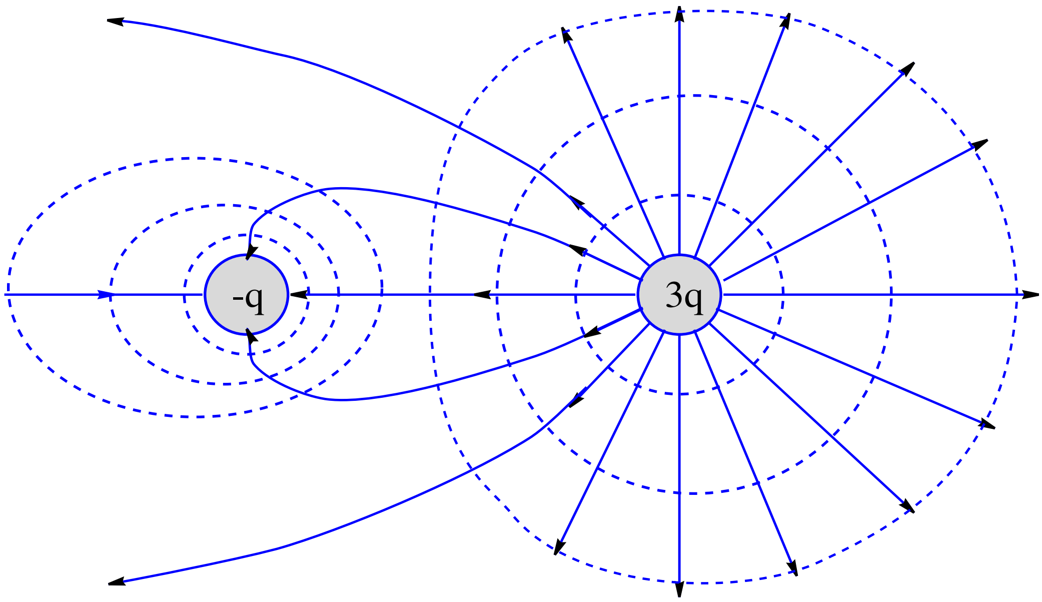
Part II

1. Illustrate how electric field lines and equipotential lines are drawn to represent the properties of the electric field and potential by drawing electric field lines and equipotential lines for the following charge configurations:

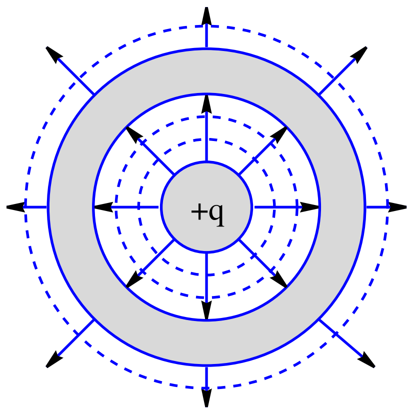
   (a) a small sphere with radius r and positive charge $+q$.



   (b) a small sphere with radius r and negative charge $-q$ a distance 8r from a sphere of radius r with a charge of $3q$.



   (c) a small sphere with radius r and positive charge $+q$ placed inside a larger electrically neutral conducting shell with inner radius $4r$ and outer radius $5r$.



2. Consider a uniformly charged insulating balloon.

   (a) If the balloon is spherical is the field inside the balloon zero. Explain.
   Yes the field is zero. On a spherical body with a uniform charge distribution on the surface the field is zero inside the body.

   (b) If the balloon is sausage shaped is the field inside zero? Explain.
   No the field is not zero inside the balloon. For zero field inside to be zero there would need to be a higher charge density near the ends of the balloon and this is not the case.

   (c) Do your answers change if the balloon is coated with conducting paint before being charged?
   The answer to (b) changes because the charges on the conducting surface are now free to redistribute themselves to make the field inside zero.

3. A gold nucleus has a radius of 3×10^{-15} m and carries a charge of $79e$?

   (a) What is the electric field strength at its surface?
   $E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2} = \frac{(9\times10^9)(79)(1.6\times10^{-19})}{(3\times10^{-15})^2} = 1.26\times10^{22}$ N/C directed away from the nucleus

   (b) What is the potential at its surface?
   $V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r} = \frac{(9\times10^9)(79)(1.6\times10^{-19})}{(3\times10^{-15})} = 3.79\times10^7$ Volts

   (c) How much energy in electron volts would be required to bring a proton from a large distance up to the surface of the gold nucleus.
   $\Delta u = q\Delta V = (1.6\times10^{-19})(3.79\times10^7) = 6.60\times10^{-12}$ J= 37.9 MeV.

   (d) What would the initial velocity of the proton need to be in order to come this close to the gold nucleus? (Assume the gold nucleus does not recoil.)
   $\Delta KE = -\Delta u \Rightarrow 0 - \frac{1}{2}mv^2 = -6.60\times10^{-12} \Rightarrow v = 8.5\times10^7$ m/s

4. A potential difference of 10,000 V exists between two parallel plates which are separated by 10 cm. An electron is released from the negative plate at the same instant a proton is released from the positive plate.

   (a) What is the kinetic energy of each particle as they reach the opposite sides? State your answer in units of Joules and electron volts.
   $\Delta KE = -\Delta u = -q\Delta V = -(-1.6\times10^{-19})(10,000) = 1.6\times10^{-15}$ J for both the electron and the proton. This is just 10 Kev.

   (b) With what velocity does each of the particles hit the opposite plates?
   Assuming non relativistic speeds we set $\Delta KE = \frac{1}{2}mv^2 = qV \;\Rightarrow\; v = \sqrt{2qV/m}$. For an electron this gives $v = \sqrt{2(1.6\times10^{-15})/(9.11\times10^{-31})} = 5.93\times10^{7}$ m/s and for the proton this is $v = \sqrt{2(1.6\times10^{-15})/(1.67\times10^{-27})} = 1.38\times10^{6}$ m/s.

   (c) What is the electric field strength between the plates?
   $E = V/d = 10,000/0.1 = 100,000$ V/m (or Joules/Coulomb).

   (d) What is the acceleration of each particle?
   $a = F_{\rm net}/m = qE/m$ assuming gravity is negligible compared with the electric force (it is!) so for the electron $a_e = (-1.6\times10^{-19})(100,000)/(9.11\times10^{-31}) = -1.75\times10^{16}$ m/s^2 and for the proton $a_p = (1.6\times10^{-19})(100,000)/(1.67\times10^{-27}) = 9.58\times10^{12}$ m/s^2

   (e) How far from the positive plate do the two particles pass each other?
   We set up the equations of uniformly accelerated motion for the electron and proton. Take the positive plate as the origin then for the electron, which starts at the negative plate, $x_e = d + \frac{1}{2}a_e t^2$, where is $d = 0.1$ m is the separation of the plate, and for proton, which starts at the positive plate, $x_p = \frac{1}{2}a_p t^2$. The particle pass each other when $x_p = x_e$ so $d + \frac{1}{2}a_e t^2 = \frac{1}{2}a_p t^2 \;\Rightarrow\; t^2 = 2d/(a_p - a_e) = 2(0.1)/(9.58\times10^{12} - (-1.75\times10^{16})) \;\Rightarrow$ $t = 3.34\times10^{-9}$ seconds. So $x_p = \frac{1}{2}a_p t^2 = \frac{1}{2}(9.58\times10^{12})(3.34\times10^{-9})^2 = 5.47\times10^{-5}$ m. The proton barely moves.