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.

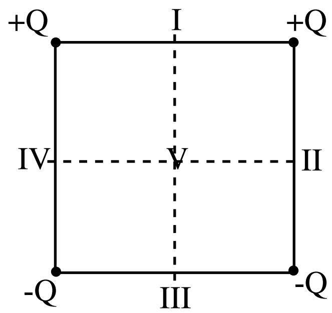
   (b) 9.0 V higher in potential than point A.

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

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

   Answer (a): Lower since a positive charge has decreased its potential energy

2. Four charges are arranged on the four corners of a square as shown in the diagram.
   If the electric potential is defined to be zero at infinity then it is also zero at

   (a) point V only.

   (b) points II and IV and V.

   (c) points I and III.

   (d) none of the labeled points.

   Answer (b) These points lie halfway between the positive and negative charges.

3. A small positive charge q is brought from far away to a distance r from a positive charge Q. In order to pass through the same potential difference a charge $2q$ should be brought how close to the charge Q. (Assume the initial charge q has been removed.)

   (a) a distance $r/2$.

   (b) a distance r.

   (c) a distance $2r$.

   (d) a distance $4r$.

   Answer (b): Electric potential difference depends only on the charge Q, not on the charge moving through it.

4. Consider two different charged spherical conductors, Sphere A with radius $r = a$ and Sphere B radius $r = b$ with $b > a$. If the conductors are brought into contact then which of the following statements are true:

   (a) Sphere A has more charge and higher charge density.

   (b) Sphere A has more charge but lower charge density.

   (c) Sphere A has less charge but higher charge density.

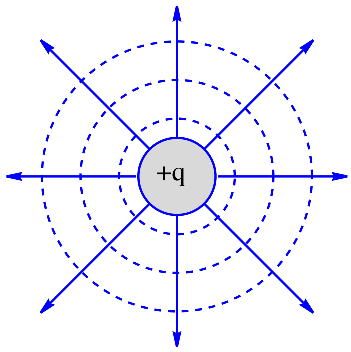
   (d) Sphere A has less charge and lower charge density.

Answer(c): In contact the two spheres will have the same potential, and thus the sphere with the smaller radius must have the smaller charge. ($V = kQ/R \Rightarrow Q \propto R$). However charge density is higher for objects with lower radius of curvature.

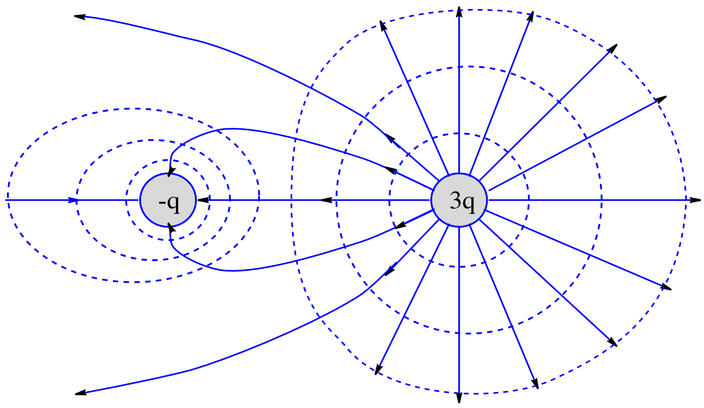
Part II

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

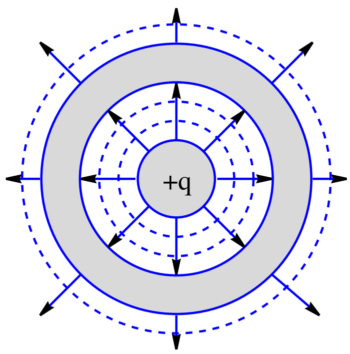
   (a) a small sphere with radius r and positive charge $+q$.



   (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. 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

3. 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?
   By conservation of energy 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?
   $a = F_{\text{net}}/m = qE/m$ 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