Part I

1. One Coulomb is defined as the amount of charge that

   (a) produces an electric field of 1 volt/metre at a distance of 1 metre.

   (b) produces a potential of 1 volt at a distance of 1 metre.

   (c) when placed at each of two points which are separated by 1 metre produces a force of 1 newton.

   (d) flows passed a point in a circuit in 1 second when the current is 1 Ampere.

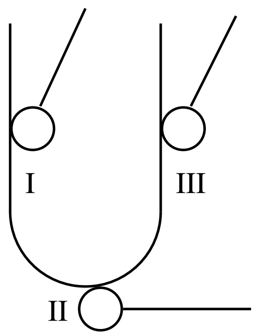
   Answer (d)

2. 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. On the left and right they point in opposite directions, but only on the left of q_1 can the magnitude of the electric field due to each charge be equal and hence cancel out.

3. A small uncharged ball touches a positively charged metal container 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

4. A point charge Q_1 exerts an electrostatic force F on a point charge Q_2 when they are 3.0 cm apart. If the charges are placed 6.0 cm apart, the magnitude of the electrostatic force Q_1 exerts on Q_2 will be

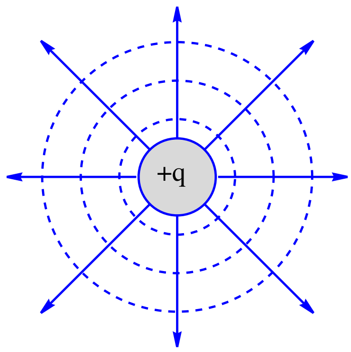
   (a) $4F$ (b) $2F$ (c) $F/2$ (d) $F/4$

   Answer (d): Force varies as one over distance squared.

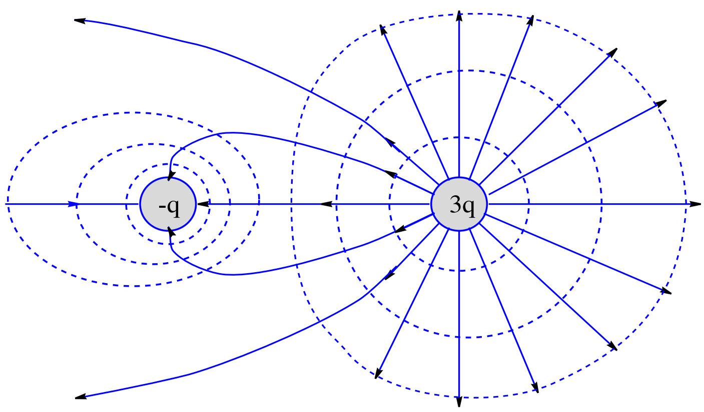
Part II

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

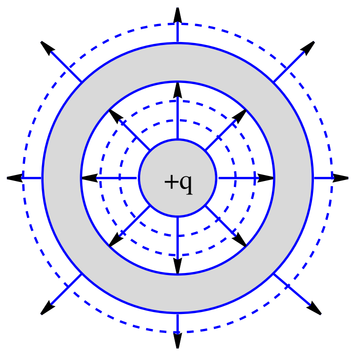
   (a) a small sphere with radius r and positive charge $+q$.



   (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 $5r$.



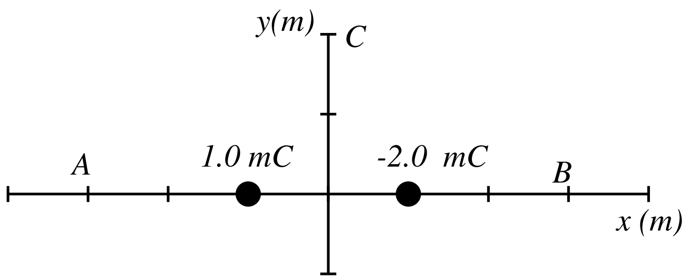
2. Consider a uniformly charged insulating balloon.

   (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. Two charges are placed in a line as shown below



   (a) Find the electric field strength at points A and B.
   At A the electric field due to the -2 mC charge points right (toward the negative charge) and has magnitude

$$E = (9 \times 10^9)(2 \times 10^{-3})/4^2 = 1.125 \times 10^6 \text{ N/C}$$

   and the electric field due to the 1 mC charge points left (away from the positive charge) and has magnitude

$$E = (9 \times 10^9)(1 \times 10^{-3})/2^2 = 2.25 \times 10^6 \text{ N/C}.$$

   So the total electric field is to the left with magnitude

$$E = (2.25 - 1.125 \times 10^6 = 1.125 \times 10^6 \text{ N/C}.$$

   Similarly at B the electric field due to the -2 mC charge points left (toward the negative charge) and has magnitude

$$E = (9 \times 10^9)(2 \times 10^{-3})/2^2 = 4.5 \times 10^6 \text{ N/C}$$

   and the electric field due to the 1 mC charge points right (away from the positive charge) and has magnitude

$$E = (9 \times 10^9)(1 \times 10^{-3})/4^2 = 0.5625 \times 10^6 \text{ N/C}.$$

So the total electric field is to the left with magnitude

$$E = (4.5 - .5625) \times 10^6 = 3.9 \times 10^6 \text{ N/C}.$$

(b) Find the location where the electric field is zero.
The electric field will be zero on the left of the 1 mC charge. Here the fields due to each charge are opposite in direction and will be equal in magnitude at one point. Let the point where the field is zero be d units to the left of the 1 mC charge. Then the field due to the 1 mC charge has magnitude $E = k(1mC)/d^2$ and the field due to the -2 mC charge has magnitude $E = k(2mC)/(2+d)^2$. Setting these two equal implies that $k/d^2 = 2k/(2+d)^2 \Rightarrow (2+d)^2 = 2d^2 \Rightarrow d+2 = \sqrt{2}d \Rightarrow d = 2/(\sqrt{2}-1) = 4.83$ m left of the 1 mC charge, or at position $x = -5.83$.

(c) Repeat your calculation for the case where both charges are positive.
If both charges where positive then the fields would cancel between the two charges because it is here where the fields point in opposite directions. Let the point where the field is zero be d units to the right of the 1 mC charge. Then the electric field is zero when $k/d^2 = 2k/(2-d)^2 \Rightarrow (2-d)^2 = 2d^2 \Rightarrow 2-d = \sqrt{2}d \Rightarrow d = 2/(\sqrt{2}+1) = 0.83$ m to the right of the 1 mC charge or at position $x = -0.17$.