Electric Fields Assignment ***SOLUTIONS***

1.

a) $E = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{d^2}$

b)

$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{d^2} \quad E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{(2d)^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{4d^2}$$

$$E_1 = E_2$$

$$\therefore \frac{1}{4\pi\varepsilon_0}\frac{q_1}{d^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{4d^2}$$

$$\therefore q_1 = \frac{q_2}{4} \quad \left\{\text{multiplying both sides by } d^2 4\pi\varepsilon_0\right\}$$

$$\therefore q_1 : q_2 = 1:4$$

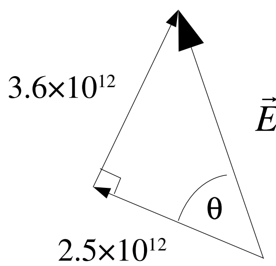
c)

$$q_1 = 1.0\text{ C} \quad \therefore q_2 = 4q_1 = 4.0\text{ C}$$

$$r_1 = 5.0\times10^{-2}\text{ m} \quad r_2 = 12.0\times10^{-2}\text{ m}$$

$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1^2} = 9.0\times10^9 \times \frac{1.0}{\left(5.0\times10^{-2}\right)^2} = 3.6\times10^{12}\text{ N C}^{-1}$$

$$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2^2} = 9.0\times10^9 \times \frac{4.0}{\left(12.0\times10^{-2}\right)^2} = 2.5\times10^{12}\text{ N C}^{-1}$$



$$\vec{E}_T = \vec{E}_1 + \vec{E}_2$$

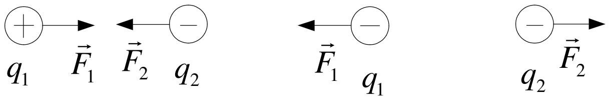
$$\vec{E}_1 + \vec{E}_2 = \sqrt{\left(3.6\times10^{12}\right)^2 + \left(2.5\times10^{12}\right)^2} = 4.4\times10^{12}\text{ N C}^{-1}\text{ (2 s.f.)}$$

$$\theta = \tan^{-1}\left(\frac{3.6\times10^{12}}{2.5\times10^{12}}\right) = 55°\text{ (2 s.f.)}$$

So the field strength at point P is 4.4×10^{12} N C^{-1} at an angle of 55° above the direction from q_2 to P

An alternative answer for the angle is 35° above (or to the left) of the direction from q_1 to P

2. Electric forces are consistent with Newton's third law because each body pulls (or pushes) the other in opposite directions with the same magnitude of force, meaning that the forces are equal and opposite.



3.

$$F = 462\text{N} \qquad q = 2.31\times10^{-3}\ \text{C}$$

$$F = Eq$$

$$E = \frac{F}{q} = \frac{462}{2.31\times10^{-3}} = 2.00\times10^{5}\ \text{N C}^{-1}\ \text{(3 s.f.)}$$

4.

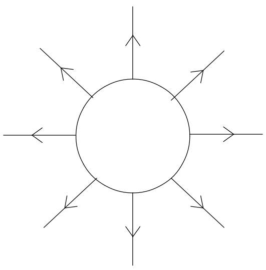
Starting with a test charge Q:

$$E = \frac{F}{Q} \quad \{\text{considering only magnitudes}\}$$

$$\therefore E = \frac{\frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}}{Q} \quad \left\{\text{inserting Coulomb's Law } F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\right\}$$

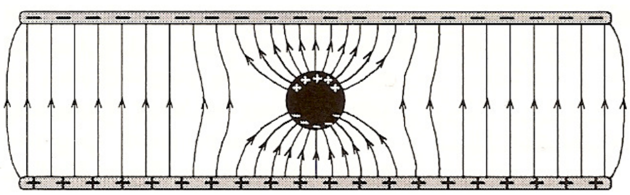
$$\therefore E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \quad \{\text{the magnitude of the test charge is irrelevant as it cancels out}\}$$

5. a)



b) The inside of conductor reaches electrostatic equilibrium, so no charges should be moving around inside. The charges must be experiencing no net force, so there must be no electric field.

6.



7. Electric fields and charges concentrate at sharp points on conductors. If the field is high enough at this point, the air molecules polarise and are attracted close enough to the point for charges to be transferred, ionising the air.

8. The charges on the outside surface of a conductor reach electrostatic equilibrium, so they should not be accelerating along the surface. For this to be the case they must be experiencing no force, so there must be no field parallel to the surface.