Raffles Institution
Year 5-6 Physics Department

2024 Year 6 H2 Physics Remedial
Chapter 13: Electric Fields

Suggested Solutions

1 **(a)**

$$E_A = \frac{4.8\times10^{-19}}{4\pi(8.85\times10^{-12})(3.00\times10^{-3})^2} = 4.796 \times 10^{-4}\ \text{N C}^{-1}$$

$$E_B = \frac{1.60\times10^{-19}}{4\pi(8.85\times10^{-12})(4.00\times10^{-3})^2} = 8.992 \times 10^{-5}\ \text{N C}^{-1}$$

Resultant electric field = $\sqrt{(4.796\times10^{-4})^2+(8.992\times10^{-5})^2}$

$= 4.88 \times 10^{-4}\ \text{N C}^{-1}$

(b)

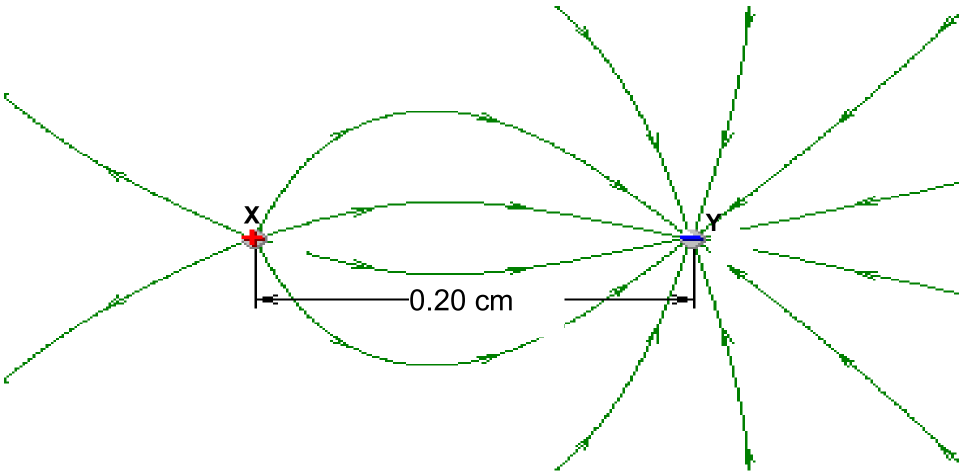
$$V_A = \frac{(-4.8\times10^{-19})}{4\pi\varepsilon_o(3.00\times10^{-3})} = -1.439 \times 10^{-6}\ \text{V}$$

$$V_B = \frac{(1.6\times10^{-19})}{4\pi\varepsilon_o(4.00\times10^{-3})} = 3.597 \times 10^{-7}\ \text{V}$$

$V = V_A + V_B = -1.439 \times 10^{-6} + 3.597 \times 10^{-7} = -1.08 \times 10^{-6}\ \text{V}$

2 **(a)** The electric field strength at a point is defined as the electric force exerted per unit positive charge placed at that point.

(b)



Main features of drawing:
1. Arrows point from positive charge X to negative charge Y.
2. More field lines (nearly double) point towards the negative charge compared to the positive charge.
3. Asymmetry of the field lines between the two charges, with the 'hump' closer to the positive charge. Symmetry about the horizontal line joining the two charges.

(c) **(i)** Distance TY = $\sqrt{0.20^2-0.10^2} = \sqrt{0.03} = 0.173$ cm

Force on T due to charge at Y,

$$F_Y = \frac{q_Y q_T}{4\pi\varepsilon_o r^2} = \frac{(6.2\times10^{-10})(1.2\times10^{-10})}{4\pi\varepsilon_o\left(\sqrt{0.03}\times10^{-2}\right)^2} = 2.23\times10^{-4}\ \text{N}$$

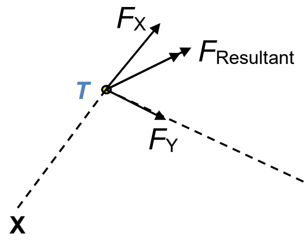
Force on T due to charge at X,

$$F_X = \frac{q_X q_T}{4\pi\varepsilon_o r^2} = \frac{(3.2\times10^{-10})(1.2\times10^{-10})}{4\pi\varepsilon_o(0.10\times10^{-2})^2} = 3.45\times10^{-4}\text{ N}$$

Magnitude of the net force acting on T,

$$F = (\sqrt{3.45^2+2.23^2})\times10^{-4} = 4.11\times10^{-4}\text{ N}$$

(ii) Direction of the net force on T is acting towards the top right hand corner.



3 (a) (i) The electric field strength at a point is defined as the electric force exerted per unit positive charge placed at that point.

(ii) **1.** Electric field strength inside both spheres is zero

2. There is a point between the spheres, where electric field strength is zero and the electric field strength of sphere A is positive at its surface (which means that the direction of the electric field is away from sphere A).

(iii) The particle will move towards sphere B and oscillate about x = 8.0 cm

4 (a) (i) The electric field strength at a point is defined as the electric force exerted per unit positive charge placed at that point.

(ii)

$$E = \frac{\Delta V}{\Delta d} = \frac{0-(-600)}{3.20\times10^{-2}} = 18750 = 1.88\times10^4\text{ N C}^{-1}$$

(iii)

$$F_{net} = F_E$$

$$ma = qE$$

$$a = \frac{qE}{m} = \frac{(1.60\times10^{-19})(18750)}{9.11\times10^{-31}} = 3.293\times10^{15} = 3.29\times10^{15}\text{ m s}^{-2}$$

Assuming constant acceleration and using kinematics equation in the horizontal direction,

$$s = ut + \frac{1}{2}at^2$$

$$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2(3.20\times10^{-2})}{3.293\times10^{15}}} = 4.41\times10^{-9}\text{ s}$$

5 **(c)** **(i)** Shows arrows from + to – plates on all the given lines

(ii) Surface of constant potential.
OR No work done in moving a charge on the surface.
OR All points on the surface have the same potential.
OR No potential difference between any two points on the surface.

(iii) 3 vertical lines between plates, equally spaced. 0 V line is right in the middle between the plates, +12.5 kV line at ¼ way from the left. –12.5 kV line at ¾ way from the left.

(iv) **1.** Electric force, $F = qE$ where E is the electric field strength given by $E = -\mathrm{d}V/\mathrm{d}x$

Taking the magnitude of the electric force,

$$F = qE = q\left|-\frac{dV}{dx}\right|$$

$$= \left(5.5\times10^{-9}\right)\left|\frac{25\times10^{3} - \left(-25\times10^{3}\right)}{4.0}\right|$$

$$= 0.0688 \text{ mN}$$

$$= 0.07 \text{ mN (shown)}$$

2. Since electric force F is the only force acting on the particle, by Newton's 2nd Law
$F_{net} = F = ma$ where a is the acceleration and m is the mass of the particle.

$$a = \frac{F}{m} = \frac{0.0688\times10^{-3}}{1.2\times10^{-4}} = 0.573 \text{ m s}^{-2}$$

In the horizontal direction:
Using kinematics equation, since a is constant, $s = ut + \frac{1}{2} at^2$

The initial speed in the horizontal direction is zero. Hence $u = 0$.

$s = 0.t + \frac{1}{2} a t^2$
$2.0 = \frac{1}{2} (0.573)t^2$
$t = 2.64$ s

In the vertical direction:
Length of plate = vertical constant speed x time
= 0.80 x 2.64
= 2.11 m

6 **(a)** The electric field strength at a point is defined as the electric force exerted per unit positive charge placed at that point.

(b) **(i)** Positive

(ii) $\sum F = 0$

$\Rightarrow kx = qE$

$$\Rightarrow k = \frac{qE}{x} = \frac{qV}{xd} = \frac{(41\times10^{-9})(5000)}{(18\times10^{-3})(0.048)} = 0.237 \text{ N m}^{-1}$$

(c) (i) The electrons/charges flow from one plate to the other until there is no potential difference between the plates. (discharge)
Electric field between the plates is zero.

(ii) Only weight and tension in the spring acts on the sphere as electric force is now zero. The net force on the sphere is the difference between the tension and its weight.

At equilibrium position, the tension is equal to the weight of the sphere and thus net force is zero.

When the sphere is not at its equilibrium position, the net force acting on the sphere is the difference in the tension in the spring from that at the equilibrium position, which always acts towards the equilibrium position.

Hence net force, $-kx = ma$ where x is the displacement from the equilibrium position. This gives us $a = (-k/m)x$, where acceleration is proportional to the displacement of the sphere from the equilibrium position and is always directed opposite to its displacement.

This is the defining equation for simple harmonic motion. Sphere oscillates in simple harmonic motion.