2020 Sec 4 AP2 Superposition

Answers to EX2

1 **(a)** Since the product of the charges remain constant, then:

$$F_1 r_1^2 = F_2 r_2^2$$
$$(100)(d^2) = (25)(d + 5.0)^2$$
$$4d^2 = d^2 + 10d + 25$$
$$0 = 3d^2 - 10d - 25$$
$$0 = (x - 5)(3d + 5)$$

→ x = 5.0 mm

(b)
$$F = |kQq/r^2|$$
$$100 \times 10^{-6} = (8.99 \times 10^9)\ Q^2 / (5.0 \times 10^{-3})^2$$
$$Q = 5.273 \times 10^{-10}$$
$$= 5.3 \times 10^{-10}\ C\ (2\ sf)$$

2 Let the length of the wire be L and the magnetic flux density be B

$$F_B = \text{difference in reading}$$
$$BIL = \text{difference in reading}$$
$$B(2.0)L = (144.6 - 142.0)(10^{-3})(10)$$
$$BL = 0.013\ T\ m$$

New reading = W − F_B
$$= mg - BIL$$
$$= [(142.0)(10^{-3})(10) - (0.013)(3.0)] / 10$$
$$= 0.1381\ kg$$
$$= 138.1\ g$$

3
$$v^2 - u^2 = 2as$$
$$-(2.5 \times 10^6)^2 = 2a(60 - 30)(10^{-2})$$
$$a = -1.0416 \times 10^{13}\ m\ s^{-2}$$

$$ma = Eq$$
$$E = ma / q$$
$$= (1.67 \times 10^{-27})(-1.0416 \times 10^{13}) / (1.60 \times 10^{-19})$$
$$= -108723$$
$$= -1.1 \times 10^5\ N\ C^{-1}\ (2\ sf)$$

4   **(a)**   Consider horizontal motion:

$$s = ut + 0.5at^2$$
$$1.27 \times 10^{-3} = (9.55 \times 10^3 \cos\theta)\, t \text{ ------- (1)}$$

$$ma = Eq$$
$$a = Eq/m$$
$$= (720)(1.60 \times 10^{-19}) / (1.67 \times 10^{-27})$$
$$= 6.898 \times 10^{10} \text{ m s}^{-2}$$

Consider vertical motion (take downwards as positive):

$$v = u + at$$
$$v_i \sin\theta = -v_i \sin\theta + at$$
$$2(9.55 \times 10^3) \sin\theta = (6.898 \times 10^{10})\, t \text{ ------- (2)}$$

Equate (1) and (2) together:
$$1.27 \times 10^{-3} / (9.55 \times 10^3 \cos\theta) = 2(9.55 \times 10^3) \sin\theta / (6.898 \times 10^{10})$$
$$\sin 2\theta = 0.9605$$
$$2\theta = 73.85 \text{ or } 106.1$$
$$\theta = 36.92 \text{ or } 53.07$$
$$\theta = 36.9° \text{ or } 53.1° \text{ (3 sf)}$$

(b) $$1.27 \times 10^{-3} = (9.55 \times 10^3 \cos 36.92)\, t$$
$$t = 1.663 \times 10^{-7} \text{ s}$$
$$= 166 \text{ ns (3 sf)}$$

$$1.27 \times 10^{-3} = (9.55 \times 10^3 \cos 53.07)\, t$$
$$t = 2.213 \times 10^{-7} \text{ s}$$
$$= 221 \text{ ns (3 sf)}$$

5   **(a)**   Apply Flemming's left hand rule: upwards

(b) $$F_C = F_B$$
$$mv^2 / r = Bqv$$
$$r = mv / Bq$$
$$= (1.67 \times 10^{-27})(4.5 \times 10^6) / (0.12)(1.60 \times 10^{-19})$$
$$= 0.3914$$
$$= 0.39 \text{ m (2 sf)}$$

(c)   **(i)**   As magnetic force is downwards, electric force must be downwards. Therefore, direction of electric field is upwards.

(i) $$F_E = F_B$$
$$Eq = Bqv$$
$$E = Bv$$
$$= (0.12)(4.5 \times 10^6)$$
$$= 5.4 \times 10^5 \text{ N C}^{-1}$$