4.8

a) $V_{AB} = \frac{W_{AB}}{q} \Rightarrow W_{AB} = q\, V_{AB} = -q \int_A^B \vec{E} \cdot \vec{dl}$

$$\therefore W_{AB} = -4 \times 10^{-9} \int_{\rho=1}^{4} (z+1) \sin\phi \, d\rho \Big|_{\substack{\phi=0 \\ z=0}} = 0$$

b) $$W_{BC} = -4 \times 10^{-9} \int_{\phi=0}^{\pi/6} (z+1)\rho \cos\phi \, (\rho\, d\phi) \Big|_{\rho=4,\ z=0}$$

$$= -64 \times 10^{-9} (\sin\phi) \Big|_0^{\pi/6} = -32\, nJ$$

c) $$W_{CD} = -4 \times 10^{-9} \int_{z=0}^{-2} \rho \sin\phi \, dz \Big|_{\rho=4,\ \phi=\pi/6}$$

$$= -4 \times 10^{-9} \times 4 \times \frac{1}{2} \times (-2) = 16\, nJ$$

d) $$W_{AD} = 0 - 32n + 16n = -16\, nJ$$

4.9

a) Work done on the particle = change in its kenitic energy

$$\therefore \quad W_{AB} = q V_{AB} = \tfrac{1}{2} m v_f^2$$

$$\therefore \quad v_f^2 = \frac{2q}{m} V_{AB} \implies v_f = \underbrace{\sqrt{\frac{2q}{m}}}_{\text{constant}} V_{AB}^{1/2}$$

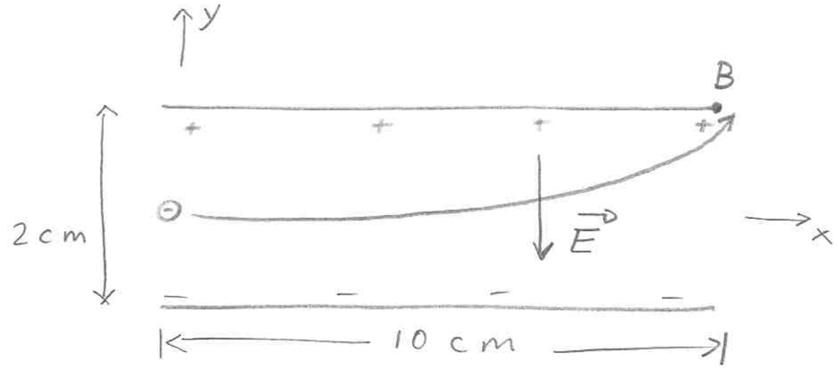
$$\therefore \quad v_f \propto V_{AB}^{1/2}$$

b) $$\sqrt{\frac{2q}{m}} = \sqrt{\frac{2 \times 1.602 \times 10^{-19} C}{9.109 \times 10^{-31} kg}} = 5.931 \times 10^5 \left(\frac{C}{kg}\right)^{1/2}$$

c) $$v_f = \frac{c}{10} = \frac{3 \times 10^8}{10} = 5.931 \times 10^5 \sqrt{V_{AB}}$$

$$\therefore \quad V_{AB} = 2.559 \ KV$$

4.10 a)



Time it takes to reach B:

$$t = \frac{10cm}{10^7 m/s} = \frac{0.1 m}{10^7 m/s}$$

$$t = 10^{-8} s$$

During this time, the particle moved vertically a distance of 1 cm (0.01 m). The electron is obviously accelerated in the vertical direction. It has a zero initial vertical velocity, and it travels 0.01 m vertically in 10^{-8} s. Let us then find its vertical acceleration.

From Newton's laws:

$$y_f - y_i = V_i t + \frac{1}{2} a t^2$$

$$0.01 = 0 + \frac{1}{2} a (10^{-8})^2 \Rightarrow a = 2 \times 10^{14} \frac{m}{s^2}$$

Since $F = qE = ma \Rightarrow E = \frac{m}{q} a$

$$\therefore E = \frac{9.109 \times 10^{-31}}{1.602 \times 10^{-19}} \times 2 \times 10^{14} = 1.137 \times 10^3 \text{ V/m}.$$

4.10 b) There are two ways to calculate the vertical velocity of the electron at point B.

First method (Using Newton's laws):

$$V_{fy} - V_{iy} = at$$

$$V_{fy} - 0 = 2 \times 10^{14} \times 10^{-8} = 2 \times 10^{6} \text{ m/s}.$$

2nd method (Using the result of problem 4.9)

$$V_{AB} = Ed = 1.137 \times 10^{3} \times 0.01 = 11.37 \text{ V}$$

$$\therefore v_{fy} = 5.931 \times 10^{5} \sqrt{V_{AB}} = 5.931 \times 10^{5} \sqrt{11.37}$$

$$= 2 \times 10^{6} \text{ m/s}$$

The magnitude of the velocity at (B):

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(10^7)^2 + (2 \times 10^6)^2}$$

$$= 1.02 \times 10^{7} \text{ m/s}.$$