Proposed solutions to H1 Physics Prelim Paper 2

1 (a) (i)

Average speed = 0.200 / 0.06428 = 3.11139 m s^{-1}
[C1 for value of v]

Max = 0.202 / 0.06427 = 3.14299 m s^{-1}
Min = 0.198 / 0.06429 = 3.07979 m s^{-1}
Δv = (3.14299−3.07979) / 2 = 0.0316 m s^{-1} [C1 for value of Δv]

OR:

$$\frac{\Delta v}{v} = \frac{\Delta d}{d} + \frac{\Delta t}{t} = \frac{0.002}{0.200} + \frac{0.00001}{0.06428} = 0.01016$$

Δv = 0.01016 × 3.11139 = 0.0316 m s^{-1} [C1 for value of Δv]

Final answer = (3.11 ± 0.03) m s^{-1}
[A1 for Δv expressed to 1 s.f., v expressed to 2 d.p. (same number of d.p. as Δv]

(ii)

Idea 1: "Average" vs "instantaneous" [B1]
There is an increase in speed as the card is falling through the light gate, so the measured speed is only an average value (based on total distance / total time) and this is not equal to the instantaneous value.

Idea 2: "Speed" vs "velocity" [B1]
The light gate only detects the duration of the obstruction, and thus cannot detect direction of travel (which direction the card is moving).

(iii)

Card does not fall straight (e.g. rotates) and this affects the effective length of the card that obstructs the infrared beam.

(b) (i)

Obtain acceleration from gradient of graph

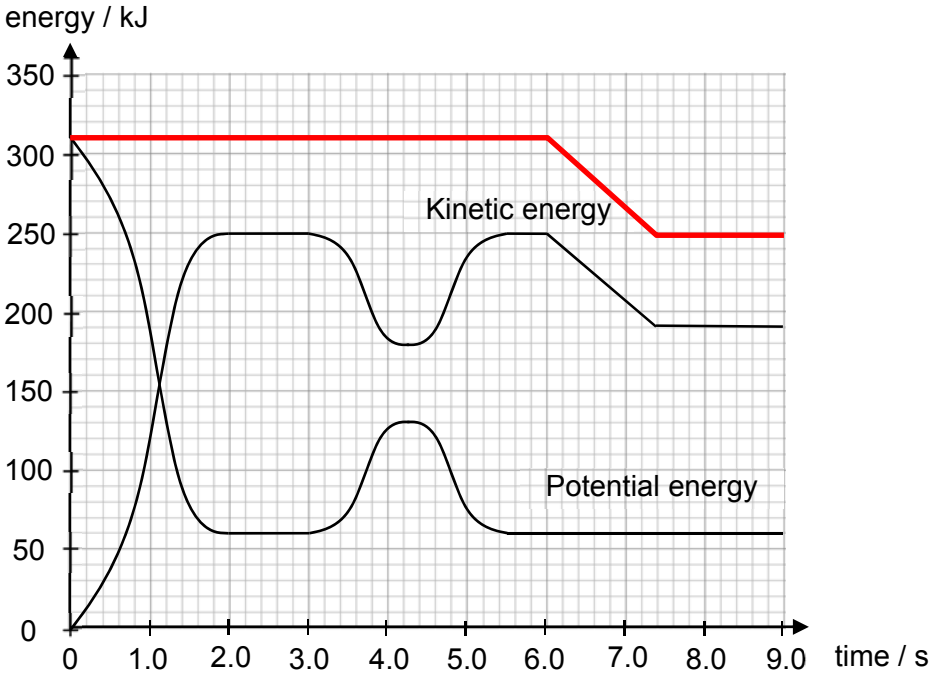
$$= \frac{0.33 - 0.10}{0.025} = 9.2$$ [M1,A1]

(ii)

The <u>gradient</u> [A1] of the graph gives a value for acceleration that is <u>lower than the expected (accepted) value</u> for acceleration. [M1]

(Y-intercept of the graph is <u>not</u> a systematic error, because it just shows that the initial speed of the light gate is 0.10 m s^{-1} when it first crosses / triggers the light gate. Does not have to be corrected as the y-intercept is not required to obtain the value of acceleration.)

2



(a)

Horizontal line from t = 0 s to t = 6.0 s, at 310 kJ [B1]
Diagonal line from (6.0 , 310) to (7.4, 250) followed by horizontal line to the t = 9.0 s [B1]

(b)

From the Fig 2.2, t = 3.0 s to t = 4.2 s, the increase in gravitational potential energy is

$\Delta GPE = 130 - 60 = 70$ kJ

$mgh = 70000$

$h = \dfrac{70000}{300 \times 9.81}$ [M1]

$= 23.785 \approx 23.8$ m [A1]

The height, and therefore the diameter, is 23.8 m

(c) (i)

time start: 6.0s time end: 7.4 s [B1 – both must be correct]
Due to the dissipative force of friction, kinetic energy is lost [B1]
However, gravitational potential energy is constant [B1] since height remains the same.

(ii)

$$\text{rate of KE dissipation} = \frac{\text{loss of KE}}{\text{duration in zone A}}$$
$$= \frac{(250-190)\times 10^3}{1.4} \quad [M1]$$
$$= 42\ 857 \approx 42.9 \text{ kW or kJ s}^{-1} \quad [A1]$$

(iii)

From the Fig 2.2, the carriage enters zone A with a velocity of 250 kJ

$$\frac{1}{2}mv^2 = 250\ 000$$
$$v = \sqrt{\frac{2(250\ 000)}{300}} \quad [M1]$$
$$= 40.824 \approx 40.8 \text{ m s}^{-1}$$

(iv)

Taking the rate of kinetic energy dissipation as the "power" of friction

$$P = Fv$$
$$F = \frac{P}{v}$$
$$= \frac{42\ 857}{40.824} \quad [M1]$$
$$= 1049.7 \approx 1050 \text{ N} \quad [A1]$$

3 (a)

$$R_{XY} = R + \left(\frac{1}{R}+\frac{1}{R}+\frac{1}{R}\right)^{-1} = R + \frac{R}{3} = 10 + \frac{10}{3} \quad [M1]$$
$$= 13.3\ \Omega \quad [A1]$$

(b) (i)

$$I = \frac{V}{R_{total}} = \frac{3.0}{13.3 + 0.40} \quad [M1]$$
$$= 0.219 \text{ A} \quad [A1]$$

(ii)

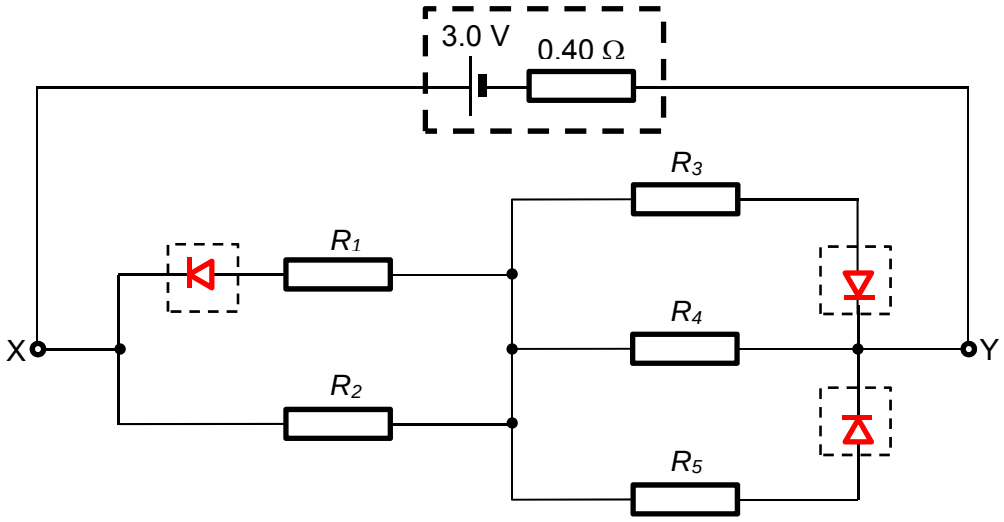
Since the resistors R_3, R_4 and R_5 are identical and in parallel,

Current through $R_3 = \frac{0.219}{3} = 0.073$ [C1]

$$P = I^2R_3 = (0.073)^2(10)$$
$$= 0.0532 \text{ W} \quad [A1]$$

Alternatively; use potential divider to find p.d. across R_3; use $P = \frac{V^2}{R}$

(c)



[M1] Correct orientation (Not accepting just arrows, students should at least draw the triangle to indicate direction of allowed current flow)
[A1] Correct symbol (, circle optional, with lines to connect to the rest of the circuit)

4 (a)

Emission line spectrum consists of discrete bright coloured lines on a dark background. [B1]
Absorption spectrum consists of dark lines against a continuous white light spectrum. [B1]

(b)

Summary of key marking points:
Thermal excitation / electrical discharge (B1)
Photons emitted due to de-excitation of atoms (B1)
Each line corresponds to one particular photon energy of specific frequencies/ wavelengths. (B1)

Extended version:
Gases such as hydrogen or neon can be placed in a discharge tube at low pressure. A voltage (several kilo-volts) is applied between metal electrodes in the tube which is large enough to produce an electric current in the gas. The gas becomes excited by the collisions with the electrons passing through the tube, from cathode to anode of the discharge tube. [B1]

The excited gas atoms are unstable. When the gas atoms undergoes a transition to a lower energy level, the excess energy is emitted as electromagnetic radiation (photon) with a specific frequency. [B1]

The frequency *f* of the emission line is dependent on the difference between the high and low energy levels, $\Delta E = hf$. Due to the discrete energy levels, only certain high-to-low energy level transitions are possible within the atom, therefore only certain frequency lines are present in the spectrum. [B1]

(c)

No two gases give the same exact line spectrum. [B1]
Hence by comparing the line spectrum of the given sample with that of known elements, we can identify the elements in that sample. [B1]

(d) (i)

13.6 eV [B1]

(ii)

Kinetic energy of electrons = $2.00 \times 10^{-18} / 1.60 \times 10^{-19}$ = 12.5 eV
hence the highest state that the atom can be excited to n=3. [B1]
Note: The typical excitation processes that we would expect would be:
From n=1 to n=2,
From n=1 to n=3.

When the atom de-excites, the following transitions may be observed
From n =3 to n=2
From n =2 to n=1
From n =3 to n=1
[B1 for all three correct transitions – the second B1 mark will not be given if excitation instead of de-excitations were mentioned.]

5 (a) (i)

1.

Magnitude = 40.0 N
Angle = 0°

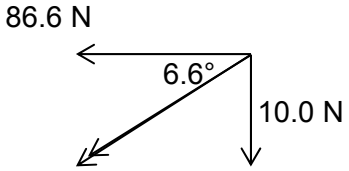
2.

Horizontal, assuming Y_{hor} pointing to left:
$100 \sin 60° - Y_{hor} = 0$ or $100 \sin 60° = Y_{hor}$

Vertical, assuming Y_{vert} pointing upward:
$100 \cos 60° + Y_{vert} - 40.0 = 0$ or $100 \cos 60° + Y_{vert} = 40.0$

Y_{hor} = 86.6 N (i.e. 86.6 N in leftward direction)
Y_{vert} = −10.0 N (i.e. 10.0 N in the downward direction)

[M1 for horizontal forces & vertical forces]



Solving, $\theta = 90° + 6.6° = 96.6°$ [A1 for angle]
Using Pythagoras' Theorem, Y = 87.2 N [A1 for magnitude]
[Alternative methods using vector triangles are also acceptable.]

(ii)

Horizontal component of *X* is not zero. [M1] To keep forces in equilibrium, there must be a (non-zero) horizontal component of Y [A1]. Thus rope B cannot be parallel to the weight of S.

(b) (i)

The initial total momentum of the two carts is zero because the two carts have the same mass and have the same speed but travel in opposite directions.

[For learning only:]
In equation form (let mass of each cart be M):
$M(10) + M(-10) = Mv_1 + Mv_2$
$0 = v_1 + v_2$

This means that after the collision, the total momentum of the carts must be zero. Since the two carts have the same mass, the velocities of the two carts will be equal in magnitude but in opposite directions. [B1]

(ii)

Since the mass, initial speeds, final speeds, of the two carts are the same, the two carts must have lost the same amount of kinetic energy. [B1, for appropriate comparison of masses]

We can focus on just one cart.

Initial speed = 10 m s^{-1}
Initial KE = ½ m $(10)^2$

Let final speed be v.
Final KE = ½ m v^2 = 0.8 (½ m $(10)^2$)
[M1 for correct comparison of KE]
$v^2 = 80$
v = 8.87 = 8.9 m s^{-1}

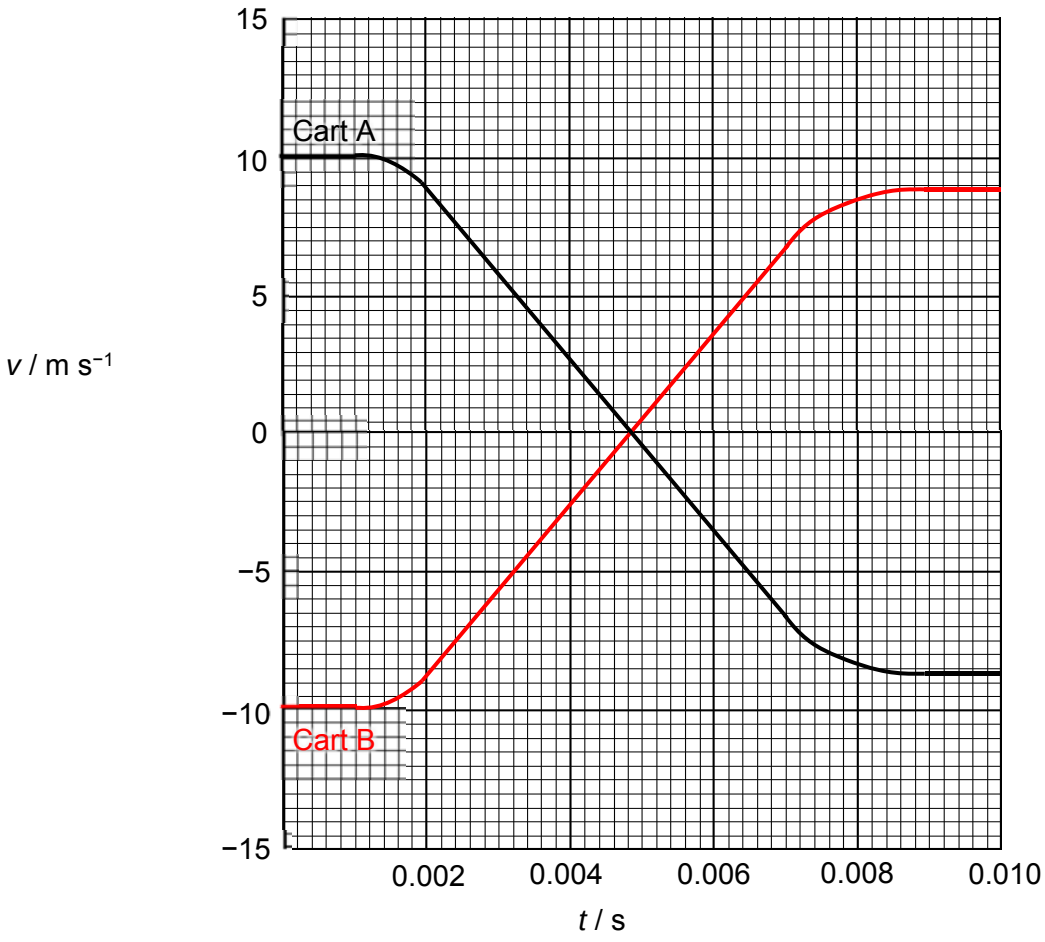
(iii)

Area under graph:
Impulse = ½ (440)(0.001) + (440)(0.005) + ½ (440)(0.002) = 2.86 N s
[M1 method, A1 answer]
Acceptable units:
N s OR kg m s^{-1} [B1]

(iv)

Impulse on cart A = change in momentum = 2.86 Ns
(can ecf from earlier part)
Magnitude of change in velocity of cart A = 10 – (–8.9) = 18.9 m s^{-1}.
[C1]
Mass = change in momentum / change in velocity = 2.86 / 18.9 = 0.151 kg
(or 0.152 kg using value of 8.87 instead of 8.9)

(v)



Initial and Final values [B1]
Shape: straight segments & curved segments [B1]
Intersection at v = 0 [B1]

(vi)

The gradient of the two graphs, which represents the acceleration of each cart, are equal but opposite in sign at every point in time. [M1]
This shows that the forces acting on the identical carts (due to each other) are equal and opposite in direction, since the masses of the carts are the same. [A1 for correct statement or application of Newton's third law]

(Setter's comment: Note that for a situation that does not have identical masses, the acceleration of the two bodies will be different, and the explanation would have to be more elaborate.)

6 (a) (i)

In polarised transverse wave, the wave oscillates in only one plane that is perpendicular to the direction of wave propagation. [B1]
In unpolarised transverse wave, the wave oscillates in all possible planes perpendicular to direction of wave propagation. [B1]

(ii)

While shining the laser beam through the polariser perpendicularly, rotate the polariser through an axis parallel to the beam. [B1]
The intensity of the laser light exiting the polariser should vary as the polariser is rotated.

(b) (i)

1.

2.80 cm [A1]

2.

Taking two points (1.6, 2.8) and (7, 0),

$\lambda = \dfrac{(7-1.6)}{1.25}$ [M1]

= 4.32 m [A1]

(ii)

Since the speed of light can be determined from $v = f\lambda$, [M1]
the period / frequency of the wave has to be known. [A1]

(c) (i)

Principle of Superposition states that when two or more waves of the same kind meet at a point, the resultant displacement at any point at any instant is the vector sum of the displacements that the individual waves would have separately produced at that point and at that instant.

(ii)

A laser source ensures that the waves from the two slits are coherent, i.e. there is a constant phase difference between the two waves emerging from the slits.

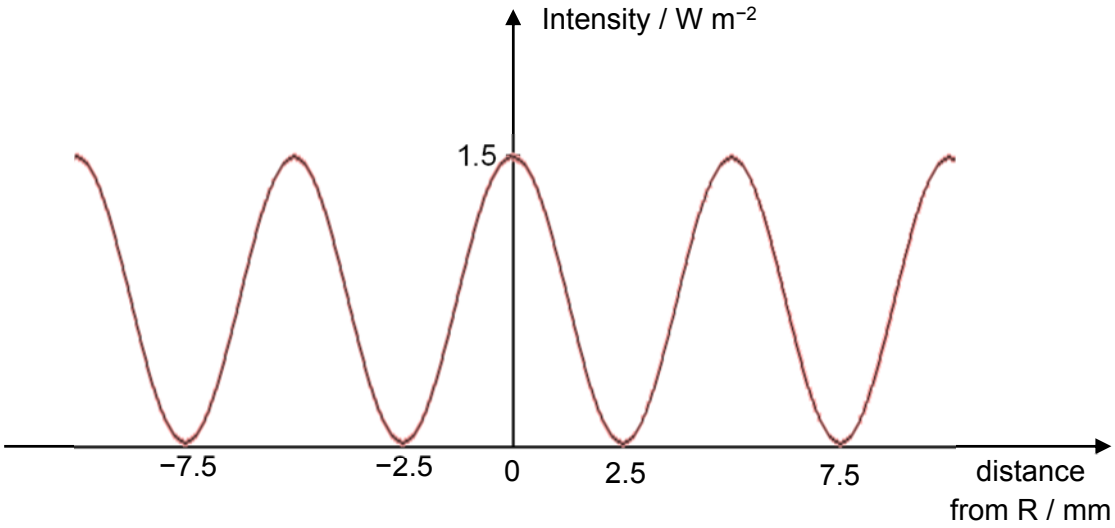
(iii)

$$X = \frac{D\lambda}{a}$$

$$5.0 \times 10^{-3} = \frac{6.2\lambda}{0.80 \times 10^{-3}} \quad \text{[M1]}$$

$$\lambda = 6.45 \times 10^{-7}\,\text{m or } 645\text{ nm} \quad \text{[A1]}$$

(iv)



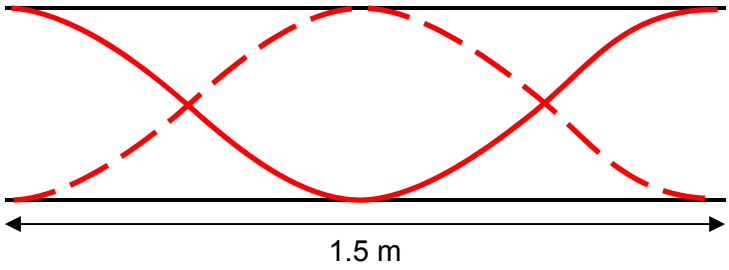
(v)

Since intensity of wave propagating away from a point source is inversely proportional to the square of the distance from the point source, [M1]
Since the region above point R is further from the double slits, the Intensity of wave reaching the region and hence intensity of the bright fringes are lower than the region below point R. [A1]

(vi)

Using $X = \frac{D\lambda}{a}$, fringe separation increases when distance from screen increases. [M1]
For bright fringes above point R, the fringe separation is larger due to further distance from the screen.
For bright fringes below point R, the fringe separation is smaller than that above point R due to smaller distance from the screen. [A1]

(d)



[B1]

$f = \frac{v}{\lambda} = \frac{330}{1.5} = 220 \text{ Hz}$ [B1]

7 (a) (i)

The ***resistance*** of a device is defined as the *ratio* of the *potential difference* across it to the *current* flowing through it.

(ii)

A resistor has a *resistance* of one *ohm* if there is a *current of one ampere* through it when the *potential difference* across it is *one volt*.

(b)

$R = \frac{\rho \ell}{A} = \frac{1.1 \times 10^{-6} \times 4.5}{6.8 \times 10^{-8}}$ [B1]

$= 73\ \Omega$

(c) (i)

$V = IR$

$I = \frac{Q}{t} = \frac{Nq}{t}$

$N = \frac{Vt}{Rq} = \frac{240 \times 10 \times 60}{73 \times 1.6 \times 10^{-19}}$ [M1]

$= 1.23 \times 10^{22}$ electrons [A1]

(ii)

$P = \frac{V^2}{R} = \frac{240^2}{73}$ [M1]

$= 789$ W [A1]

(iii)

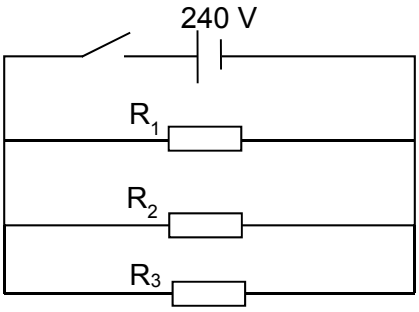
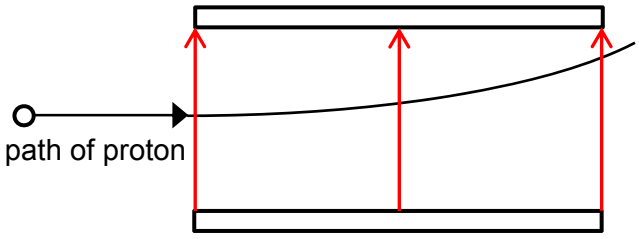


Diagram [B1]
p.d. across each heating element is maximum of 240 V, maximum power output is obtained for each element since $P = \frac{V^2}{R}$ [B1]

(iv)

Current is flowing in the same direction (e.g. upwards) [M1] for adjacent turns of the coil. Using right-hand grip rule, current in the adjacent turn creates a magnetic field that interacts with the current in that turn. By Fleming's left hand rule, the magnetic force forms an attractive force [A1] between two adjacent turns.

(d) (i)



Correct direction of field lines (upwards), uniform spacing [A1]

(ii)

$$F = ma$$
$$6.7\times10^{-10} = 1.67\times10^{-27}a$$
$$a = 4.01\times10^{17}\ \text{m s}^{-2} \quad \text{[M1]}$$

Using kinematics equation,

$$v_y = u_y + a_y t$$
$$v_y = 0 + 4.01\times10^{17}\times2.4\times10^{-13} \quad \text{[M1]}$$
$$v_y = 96.2\times10^{3}\ \text{m s}^{-1}$$

Hence, final speed

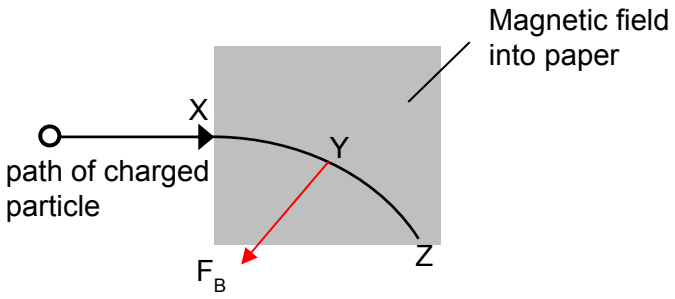
$$v = \sqrt{v_x^{\,2} + v_y^{\,2}} = \sqrt{(2.8\times10^{5})^2 + (96.2\times10^{3})^2} \quad \text{[M1]}$$
$$= 2.96\times10^{5}\,\text{m s}^{-1} \quad \text{[A1]}$$

(e) (i)

1.

Negatively charged

2.



[B1] – correct direction of force

(ii)

The magnetic force on the charged particle is always acting perpendicular to its displacement / velocity. [M1]
There is no work done by the magnetic field [A1], hence the speed of the electron remains the same.