VCE® PHYSICS

Unit 3 and 4 Practice Written Examination

SOLUTIONS

Solution Pathway

Section A: Multiple-Choice Questions (20 marks)

Question	Correct Answer	Explanation
1	B	$Ft = m(v-u) = \Delta p - 4.32 = 0.18(v-13)$ $v = -11\,m\,s^{-1} = 11\,m\,s^{-1}$ ¿ *the* ¿
2	D	$a = \frac{v^2}{r} = \frac{0.83^2}{1 \sin 15} = 2.66\,m\,s^{-2}$
3	A	Block is travelling up the slope, so friction is acting down the slope. The normal is perpendicular to the surface and the force due to gravity is straight down.
4	B	$u = 1.4, a = -1.8\, t = ?\, v = 0$ $v = u + at\ 0 = 1.4 - (1.8)t\ t = 0.78$ *seconds*
5	A	$W = qEd = (1.6 \times 10^{-19})(350)(0.1) = 5.6 \times 10^{-18}\,J$
6	C	$E = \frac{kQ}{r^2} = \frac{(8.99 \times 10^9)(2.8 \times 10^{-6})}{(0.15)^2} = 1.1 \times 10^6\,N\,C^{-1}$
7	D	$F = \frac{k\,Q_1 Q_2}{r^2} = Eq = (1.12 \times 10^6)(3 \times 10^{-6}) = 3.36\,N$
8	D	An inverter converts DC (from a PV cell) to AC.
9	B	$\frac{N_1}{N_2} = \frac{I_2}{I_1} \frac{8}{40} = \frac{I_2}{1.4}\ I_2 = 0.28\,A$
10	B	$\frac{N_1}{N_2} = \frac{I_2}{I_1} \frac{8}{40} = \frac{I_2}{1.4}\ I_2 = 0.28\,A$
11	D	$\lambda = \frac{h}{mv}$. Electron has smaller mass, longer wavelength.
12	D	$E = hf = \frac{hc}{\lambda}$ *Smallest* λ *, largest* E *, therefore transition* Z and X. Absorption so Z to X.
13	C	$\Delta x = \frac{\lambda L}{d}$. Increasing ‘d’ would decrease $'\Delta x'$.

14	**A**	Einstein's second postulate.
15	**B**	$L=\frac{L_0}{\gamma}=\frac{25}{1.3}=19.2\,m$
16	**B**	Diffraction is a property of waves.
17	**C**	Resolution is the smallest change in a quantity that is measurable. The ruler has 1 cm markings, so this is the resolution.
18	**B**	Systematic errors affect the accuracy by a consistent amount each time it is read. This example is a parallel error, which is considered a systematic error.
19	**A**	Julius' results are closest to the known value of 9.8 $m\,s^{-2}$.
20	**B**	Maximus' values have the smallest range, indicating the most precise.

Section B: Short-Answer Questions (100 marks)

Below are sample answers. Please consider the merit of alternative responses.

Question 1 (3 marks)

a. Show that the energy stored in the bow is 56 J. **1 mark**

$$E_s = \frac{1}{2} k x^2 = \frac{1}{2}(200)\left(0.75^2\right) = 56\,J$$

- **1 mark** is awarded for subbing the correct values into the correct equation.

b. Calculate the velocity of the arrow immediately after release. **2 marks**

$All\ E_s\ converted \therefore E_k$

$$\frac{1}{2} k x^2 = \frac{1}{2} m v^2$$

$$56 = \left(\frac{1}{2}\right)(0.05)\left(v^2\right)$$

$$v = 47.3\,m\,s^{-1} \approx 47\,m\,s^{-1}$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

Question 2 (6 marks)

a. Calculate the centripetal force acting on the car moving around path A. **2 marks**

$$F = \frac{m v^2}{r}$$

$$F = \frac{\left(1.5 \times 10^3\right)(18)^2}{80}$$

$$F = 6.1 \times 10^3\,N$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. The car now moves to path B, travelling at the same speed it did in part A. Compare the new values for centripetal force and period, giving reasons for each choice. 4 marks

Centripetal force: ***Greater than A*** *Less than A* *The same as A*

Radius decreases, force will increase as per $F = \frac{mv^2}{r}$

Period: *Greater than A* ***Less than A*** *The same as A*

$$F = \frac{4\pi^2 rm}{T^2} = \frac{mv^2}{r}$$

$$\frac{4\pi^2 r^2}{v^2} = T^2$$

radius decreases , T decreases

- **1 mark** is awarded for correctly circling **Greater than A** for centripetal force.
- **1 mark** is awarded for appropriate reasoning for centripetal force.
- **1 mark** is awarded for correctly circling **Less than A** for period.
- **1 mark** is awarded for appropriate reasoning for period.

Question 3 (3 marks)

Min speed at top ¿ $\sqrt{gr} = \sqrt{(9.8)(0.7)} = 2.6\ m\ s^{-1}$

$$E_{bottom} = E_{top}$$

$$\frac{1}{2}mv_{botton}^2 = \frac{1}{2}mv_{top}^2 + mgh$$

$$\frac{1}{2}v^2 = \left(\frac{1}{2}\right)(2.6^2) + (9.8)(1.4)$$

$$v = 5.8 m\ s^{-1}$$

- **1 mark** is awarded for correct calculation of the minimum speed at the top of the loop.
- **1 mark** is awarded for correct working using conservation of energy.
- **1 mark** is awarded for correct answer.

Question 4 (5 marks)

a. Show that the initial vertical velocity is 5.9 m s^{-1}. **1 mark**

$u_y = u\sin\theta$

$u_y = 14\sin 25$

$u_y = 5.92 \approx 5.9\, m\, s^{-1}$

- **1 mark** is awarded for correct working.

b. Calculate the acceleration due to gravity on this unknown planet. **2 marks**

$When\ s = -120, s = ut + \frac{1}{2}at^2$

$-120 = (5.9)(7.4) + \left(\frac{1}{2}\right)(a)(7.4^2)$

$a = -6.0\, m\, s^{-2}$

$g = 6.0\, m s^{-2}$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

c. If the planet has a radius of 2500 km, calculate the mass of the planet. **2 marks**

$g = \frac{GM}{r^2}$

$6.0 = \frac{(6.67 \times 10^{-11})(M)}{(2500000)^2}$

$M = 5.6 \times 10^{23} kg$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

Question 5 (7 marks)

a. Calculate the combined momentum of the car and truck before the collision. Include a direction. 3 marks

$mu+mu=(2000)(18)+(10000)(-14)$

$p=-104000\,kg\,m\,s^{-1}$

$p=1.04\times10^{5}\,kg\,m\,s^{-1}\,West$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.
- **1 mark** is awarded for correct direction.

b. Calculate the velocity of the car and truck after the collision. 2 marks

$p_{before}=p_{after}$

$1.04\times10^{5}=(12000)v$

$v=8.7\,m\,s^{-1}$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

c. Compare and contrast the forces acting on the car and the force on the truck, referring to appropriate physics principles in your response. 2 marks

Force acting in the car = force acting on the truck as per Newton's third law $F_{AonB}=F_{BonA}$

- **1 mark** is awarded for correct showing the forces are equal.
- **1 mark** is awarded for linking to Newton's third law.

Question 6 (6marks)

a. Label the direction of the magnetic field around the wire on Figure 9 above. 1 mark

Dots above the wire, crosses below:

- **1 mark** is awarded for correct labels on diagram.

b. Which of the following word(s) could be used to describe the magnetic field around the wire. Circle all those that are appropriate. 1 mark

Static and non-uniform.

- **1 mark** is awarded for correctly identifying both *static* and *non-uniform.*

c. i. Identify the direction of the force on the wire from the magnetic field. Circle your choice below. 1 mark

Up

- **1 mark** is awarded for correct identifying *up.*

ii. Calculate the magnitude of the force on the wire. Give your answer to two significant figures. 3 marks

$F = nBIL$

$F = (1)(0.062)(0.85)(0.15)$

$F = 7.905 \times 10^{-3} N = 7.9 \times 10^{-3} N$ (2 sig fig)

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.
- **1 mark** is awarded for correct significant figures.

Question 7 (3 marks)

	Point mass only	**Point charge only**	**Both point charge and point mass**
Creates a gravitational field	✓		
Field around it can attract only	✓		
Creates an electric field		✓	
Creates a radial non-uniform field			✓
Strength weakens as per the inverse square law the further you get away			✓
Field around it can attract or repel		✓	

- **1 mark** is awarded for 2 or more ticks correct.
- **1 mark** is awarded for 4 or more ticks correct.
- **1 mark** is awarded for all ticks correct.

Question 8 (4 marks)

a. Compare the masses of A and B. Justify your response. 2 marks

The null point (the point at which the combined gravitational field = 0) is closer to the B mass. Therefore, mass A must have a greater mass to be producing a stronger field.

- **1 mark** is awarded for identifying that mass A is greater than mass B.
- **1 mark** is awarded for identifying that the point where the two gravitational fields cancel out is closer to B.

b. Annotate Figure 1 to show the direction of the field at point labelled X. 2 marks

Arrow tangential to the line in the general direction towards the mass.

- **1 mark** is awarded for arrow tangential to the line.
- **1 mark** is awarded for correct direction.

Question 9 (3 marks)

a. Calculate the orbital radius for an Earth satellite having a period of 1.00 hour. 2 marks

$$r^3 = \frac{GMT^2}{4\pi^2} = \frac{\left(6.67 \times 10^{-11}\right)\left(5.98 \times 10^{24}\right)\left(1 \times 60 \times 60\right)^2}{\left(4\right)\left(\pi\right)^2}$$

$$r = 5.1 \times 10^6 m$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. Give a reason why this result could be considered unreasonable. 1 mark

Radius of the earth is $6.37 \times 10^6 m$ *which is larger than the orbital radius. This is not possible.*

- **1 mark** is awarded for correctly identifying the radius is smaller than the Earth.

Question 10 (3 marks)

When closed, the current starts flowing.

The magnetic field around coil A increases to a maximum.

While the B field changes, coil B experiences a change in flux (from zero to maximum).

A changing flux will induce a current as per Faraday's law ($\epsilon = -N\left(\frac{\Delta\phi}{\Delta t}\right)$

When the field reaches maximum, it is no longer changing and so no longer induces an emf in coil B.

- **1 mark** is awarded for correctly identifying changing flux when switch first closed.
- **1 mark** is awarded for correctly linking changing flux to induced emf as per Faraday's law.
- **1 mark** is awarded for correctly identifying no changing flux when current left on (and so no induced emf).

Question 11 (9 marks)

a. Calculate the maximum flux through the coil. Include an appropriate unit. 3 marks

$\phi = BA = (0.3)¿$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.
- **1 mark** is awarded for correct unit.

b. Calculate the induced emf as the coil moves from point A to point B. 3 marks

$$\epsilon = \frac{-N(\Delta\phi)}{\Delta t}$$

$$\frac{4\,cm}{s} = 16\,cm \in 4\,seconds$$

$$\epsilon = \frac{-N(\Delta\phi)}{\Delta t} = \frac{(1)\left(6.0\times10^{-3}\right)}{4}$$

$$\epsilon = 1.5\times10^{-3}V$$

- **1 mark** is awarded for correctly calculating the time to transit into the field.
- **1 mark** is awarded for correct working.

- **1 mark** is awarded for correct answer.

c. Determine and label the direction of the current through the coil as it enters the field. Explain how you determined this direction, including appropriate laws of physics. 3 marks

Lenz's law: induced emf will produce a magnetic field that acts to oppose the original change in flux.

As the coil enters the field, flux into the page increases. Opposite is out of the page. Using RHR, current flows anticlockwise.

- **1 mark** is awarded for correct direction of current.
- **1 mark** is awarded for correct link to Lenz's law.
- **1 mark** is awarded for correct showing how Lenz's law was used to determine the direction.

Question 12 (3 marks)

Light hits to top layer (n-type semiconductor), excites electrons. Electrons are attracted to the bottom layer (p-type semiconductor) but must travel through external circuit. Electrons travelling through external circuit provides the current.

- **1 mark** is awarded for correctly identifying freeing of electrons when light hits the PV cell (top or n-type semiconductor layer).
- **1 mark** is awarded for correctly identifying the flow of electrons through the external circuit to the bottom layer.
- **1 mark** is awarded for an appropriate diagram relevant to the explanation.

Question 13 (4 marks)

a. Calculate the power that reaches town 2 as a percentage of the original power produced.

2 marks

$P_{loss} = I^2 R = (300^2)(80) = 7.2 \times 10^6 W$

$P_{town} = (20 \times 10^6) - (7.2 \times 10^6) = 12.8 \times 10^6 W$

As a percentage $\frac{Power\ reaching}{Power\ supplied} \times 100 = \frac{12.8 \times 10^6}{20 \times 10^6} = 64\%$

- **1 mark** is awarded for correctly calculating power loss in Watts.
- **1 mark** is awarded for correctly calculating power loss as a percentage.

b. Explain how transformers could be used to increase the power supplied to Town 2.

2 marks

Step-up transformer to reduce the current.

Which will reduce the power loss as per $P_{loss} = I^2 R$.

Step down transformer at the town.

- **1 mark** is awarded for correctly including a step up transformer at the start and step down transformer at the end.
- **1 mark** is awarded for correctly linking lower current to decreased power loss.

Question 14 (8 marks)

a. Calculate the wavelength of light used to produce the fringe separation of 0.14 mm. Give your answer in nm. **3 marks**

$$\Delta x = \frac{\lambda L}{d}$$

$$0.14 \times 10^{-3} = \frac{\lambda(0.8)}{2.5 \times 10^{-3}}$$

$$\lambda = 4.38 \times 10^{-7}\, m = 438\, nm$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.
- **1 mark** is awarded for correct answer in nm.

b. Explain why there is a light band rather than a dark band at point X. **2 marks**

Constructive interference meaning that the path difference between the two slits must be a whole number of wavelengths so that the two waves reach the point in phase and undergo constructive interference and creating a light band.

- **1 mark** is awarded for correctly identifying that constructive interference is occurring at that point.
- **1 mark** is awarded for correctly identifying that constructive interference is occurring due to a path difference that is a whole number of wavelengths.

c. At the time at which Young's double slit experiment was conducted, there were two competing models of the nature of light. Explain how Young's experiment supported one of these models. **3 marks**

Supports the wave model.

The light passing through the slits diffracts and produces an interference pattern.

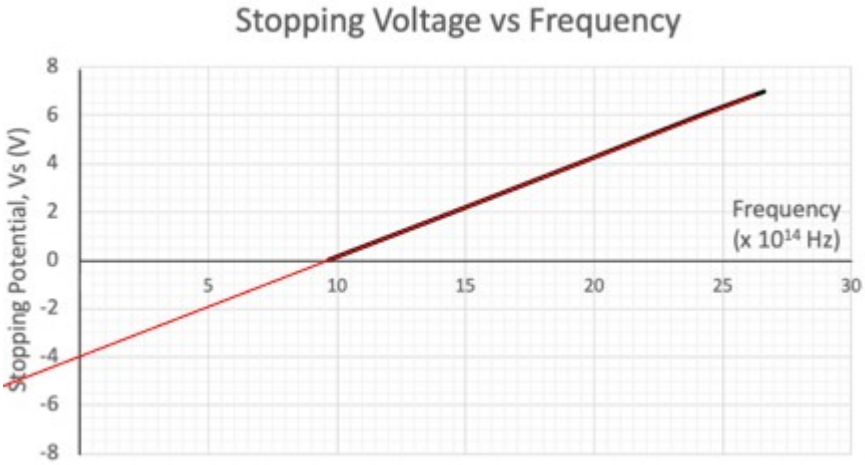
Interference is a property of waves but not of particles.

- **1 mark** is awarded for correctly identifying 'wave model.
- **1 mark** is awarded for referring to interference pattern produced.
- **1 mark** is awarded for identifying that interference is a property of waves.

Question 15 (8 marks)

a. Use the graph to determine the work function for zirconium.
Include an appropriate unit. **2 marks**

Crosses the y axis at approximately 4 V*, which means the stopping voltage is 4 eV.*



- **1 mark** is awarded for correct value.
- **1 mark** is awarded for correct units.

b. Explain why the stopping voltage increases as the frequency increases. **3 marks**

As the frequency increases, the photons are carrying more energy and so pass on more energy to the electrons. The more energy the electrons have, the more energy is required to stop them and so the greater the stopping voltage.

- **1 mark** is awarded for correctly linking increased frequency to increased energy of photons.
- **1 mark** is awarded for correctly identifying all of the photon energy is passed onto electrons.
- **1 mark** is awarded for correctly linking increased energy of electrons to increased voltage required to stop them.

c. Light of wavelength 290 nm is incident on zirconium in a vacuum. Electrons are emitted. Calculate the shortest de Broglie wavelength of the emitted electrons. 3 marks

Max kinetic energy of the electrons

$$E_k = \frac{hc}{\lambda} - \phi = \frac{\left(6.63 \times 10^{-34}\right)\left(3 \times 10^{8}\right)}{290 \times 10^{-9}} - (4)\left(1.6 \times 10^{-19}\right) = 4.59 \times 10^{-20}\, J$$

From this you can work out the greatest velocity electrons emitted.

$$E_k = \frac{1}{2} m v^2 = \left(\frac{1}{2}\right)\left(9.1 \times 10^{-31}\right)\left(v^2\right) = 4.59 \times 10^{-20}\, v = 3.17 \times 10^{5}\, m s^{-1}$$

Using the velocity, you can work out the wavelength $\lambda = \frac{h}{mv}$*. Highest velocity has the lowest wavelength.*

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{\left(9.1 \times 10^{-31}\right)\left(3.17 \times 10^{5}\right)} = 2.3 \times 10^{-9}\, m$$

- **1 mark** is awarded for correct calculation of the maximum kinetic energy of the electrons.
- **1 mark** is awarded for correct calculation of the greatest velocity of the electrons ejected.
- **1 mark** is awarded for correct calculation of the de Broglie wavelength.

Question 16 (3 marks)

Light interferometer, which involves splitting light off into two perpendicular paths and measuring the time difference to travel the two different paths. The difference in time would be used to measure the movement of the Earth through the ether. No difference in time so a null result.

- **1 mark** is awarded for correct description of experiment.
- **1 mark** is awarded for correct identification of results (no difference in speed).
- **1 mark** is awarded for correct reference to a null result.

Question 17 (4 marks)

a. Calculate the relativistic kinetic energy of the proton. 3 marks

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{v^2}{c^2}\right)}} = \frac{1}{\sqrt{\left(1-\frac{\left(2.75\times10^8\right)^2}{\left(3\times10^8\right)^2}\right)}} = 2.5$$

Relativistic $E_k = (\gamma - 1)mc^2 = (2.5-1)\left(1.67\times10^{-27}\right)\left(3\times10^8\right)^2 = 2.25\times10^{-10}\,J$

- **1 mark** is awarded for correct calculation of γ.
- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer.

b. Explain how a proton colliding with another proton in a particle accelerator can produce a particle with a mass much greater than that of two protons. 2 marks

$E = mc^2$. *The protons are accelerated to high speeds, so they have a large amount of energy. The energy can be converted into matter.*

- **1 mark** is awarded for correctly identifying the relationship between energy and mass.
- **1 mark** is awarded for correctly linking to high kinetic energy at large speeds and conversion to mass.

Question 18 (11 marks)

a. Write a hypothesis for this experiment. Include a reason for your prediction. 3 marks

If the velocity is increased, then the radius of the path will also increase because the relationship between the variables is $r = \frac{mv}{qB}$ and all the other variables are kept constant.

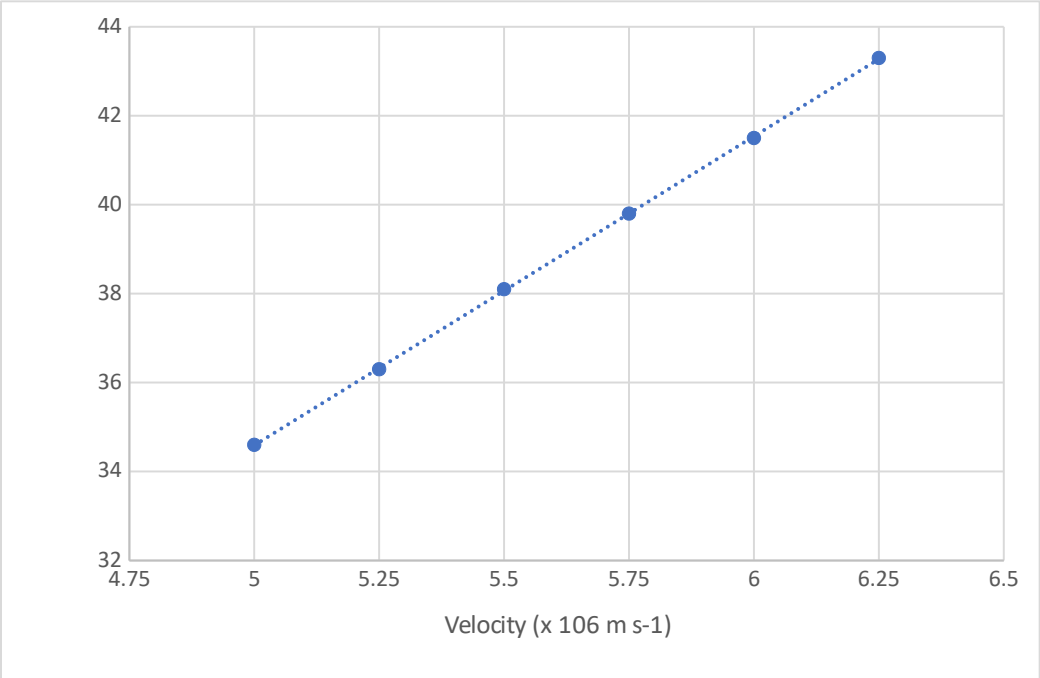
- **1 mark** is awarded for mentioning both independent variable and dependent variable.
- **1 mark** is awarded for correct prediction.
- **1 mark** is awarded for appropriate reason.

b. Complete the table to identify the independent variable, the dependent variable and two controlled variables for this experiment. 4 marks

Independent Variable	Dependent Variable	Controlled Variables
Speed	*Radius*	*Mass*
		Magnetic field strength

- **1 mark** is awarded for correct independent variable.
- **1 mark** is awarded for correct dependent variable.
- **1 mark** is awarded for each correct controlled variable.

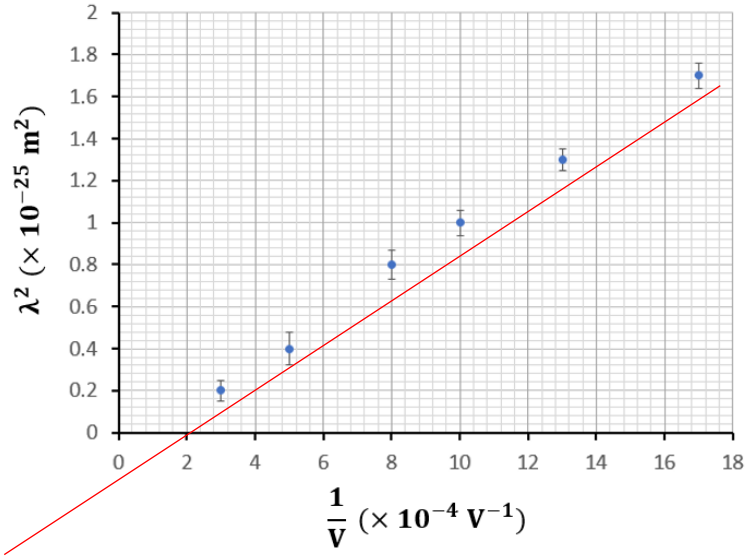
c. Graph the data. Include a straight line of best fit. 4 marks



- **1 mark** is awarded for correct scales.
- **1 mark** is awarded for correct axis labels with units.
- **1 mark** is awarded for each correctly plotted point.
- **1 mark** is awarded for an appropriate straight line of best fit.

Question 19 (5 marks)

a. Draw a straight line of best fit through the data. **1 mark**



- **1 mark** is awarded for correct trendline that goes through all uncertainty bars.

b. Calculate the gradient of the line of best fit. Show your working. **2 marks**

$$Gradient = \frac{Rise}{Run} = \frac{(1.7-0.2)\times 10^{-25}}{(17-2.8)\times 10^{-4}} = \frac{1.5\times 10^{-25}}{14.2\times 10^{-4}} = 1.06\times 10^{-22}$$

- **1 mark** is awarded for correct calculation of a gradient using points on the line of best fit.
- **1 mark** is awarded for correct answer (within acceptable range).

c. The charge on the particle is 2e (where e is the elementary charge). Use your gradient of your line of best fit to calculate the mass of the particle. **2 marks**

$$gradient = \frac{h^2}{2qm}$$

$$1.06\times 10^{-22} = \frac{h^2}{2qm}$$

$$m = \frac{h^2}{(2)(1.06\times 10^{-22})(2\times 1.6\times 10^{-19})}$$

$$= 6.5\times 10^{-27} kg$$

- **1 mark** is awarded for correct working.
- **1 mark** is awarded for correct answer (within acceptable range as per individual gradient).