



Rossmoyne Senior High School

ATAR course examination, 2022

Question/Answer booklet

Physics Unit 3 and 4

Student number:

In figures

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In words

Time allowed for this paper

Reading time before commencing work:

ten minutes

Working time:

three hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet

Formulae and Data Booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: Scientific calculator

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of Questions	Questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One Short Response	10	10	50	54	30
Section Two Problem Solving	6	6	90	90	50
Section Three Comprehension	2	2	40	36	20
Total				180	100

Instructions to candidates

- The rules for the conduct of Western Australian external examinations are detailed in the *Year 11 Information Handbook 2022: Part II Examinations*. Sitting this examination implies that you agree to abide by these rules.
- Write your answers in this Question/Answer booklet preferably using a black/blue pen. Do not use erasable or gel pens.
- You must be careful to confine your answers to the specific questions asked and follow any instructions that are specific to a particular question.
- When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

In calculations, give final answers to three significant figures and include appropriate units where applicable.

In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

- Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate in the original answer where the answer is continued, ie – give the page number.
- The Formulae and Data booklet is not to be handed in with your Question/Answer booklet.

Section One: Short Response**30% (54 marks)**

This section has ten (10) questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 50 minutes.

Question 1**(5 marks)**

One particular kaon meson consists of a down quark and an anti-strange quark. Its quark composition is below:

$$d\bar{s}$$

- a) Calculate the mass of this kaon, in kilograms, if its mass was due only to its constituent quarks. (3 marks)

_____ kg

- b) Calculate the electric charge of this kaon meson. (2 marks)

_____ C

Question 2

(6 marks)

A person on Earth sees three (3) spacecraft travelling as shown in the diagram below.



As can be seen, spaceship 'X' is travelling to the right with a velocity of $0.800c$ relative to the Earth observer. Spaceship 'Y' and spaceship 'Z' are both travelling to the left with a velocity of $0.700c$ relative to the Earth observer. According to the observer on Earth, spaceship Y has a length of 10.0 metres.

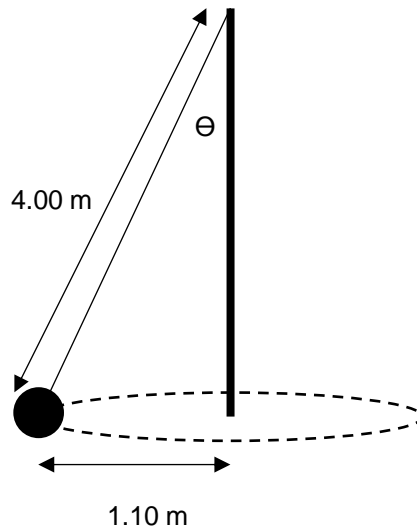
- a) Calculate the velocity of spaceship 'X' relative to 'Y' and 'Z'. (3 marks)

_____ c

- b) State and explain which observer or spaceship will view the length of Spaceship 'Y' as the longest **and** which will view the length as the shortest. (3 marks)

Question 3**(6 marks)**

An object of mass of 2.40 kg is being swung in a horizontal circular path of radius 1.10 m. The object is attached to a wire 4.00 m in length. See below.



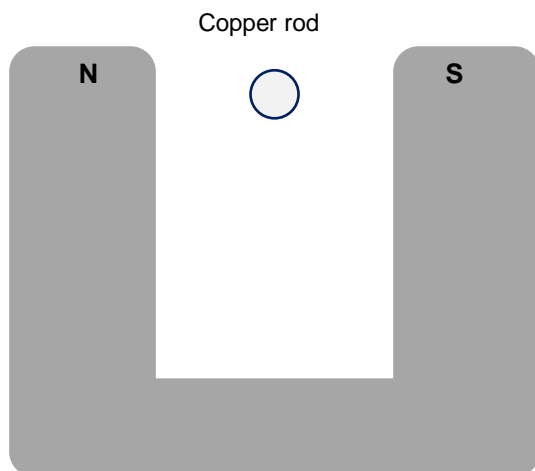
Calculate ' θ ' and, hence, the period (T) of the object's circular motion. Show all working.

$$\theta = \underline{\hspace{2cm}}^\circ$$

$$T = \underline{\hspace{2cm}} \text{ s}$$

Question 4**(5 marks)**

During a Physics demonstration, a teacher suspends a thin copper rod of mass 23.3 g and length 5.10 cm between the poles of a horseshoe magnet as shown below (the entire length of the copper rod is contained between the poles of the magnet):



The copper rod is suspended by two electric leads that can be connected to a power supply. In this way, a current can be made to flow through the copper rod.

After switching the current on in a particular trial, the copper rod is observed to accelerate upwards with an acceleration of 0.520 m s^{-2} .

- a) State the direction in which conventional current must be flowing in the copper rod. (1 mark)

- b) Calculate the strength of the magnetic field (B) between the poles of the horseshoe magnet if a current of 1.30 A is flowing in the copper rod. (4 marks)

_____ T

Question 5**(7 marks)**

An electron in an electron microscope is accelerated by an electric potential to 15.0% of the speed of light.

- a) Calculate the de Broglie wavelength for this electron. As part of your answer, calculate the **relativistic** momentum of the electron at this speed.

(4 marks)

_____ m

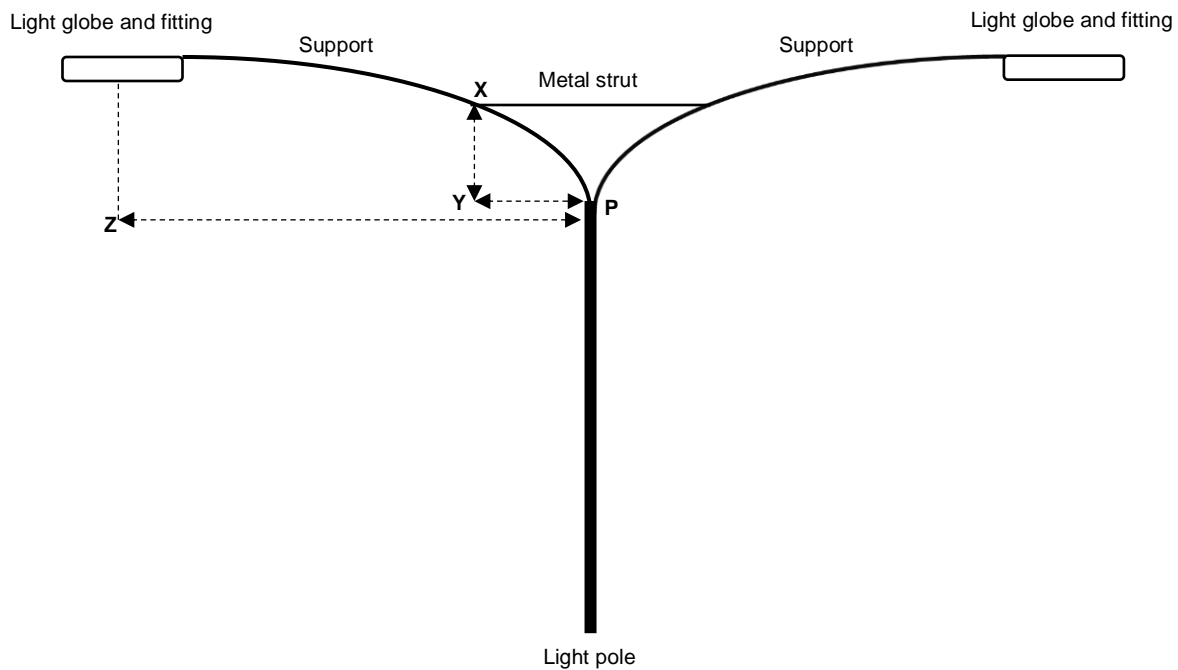
When viewing very small objects under the electron microscope, the best resolution is achieved when the de Broglie wavelength of the electron beam is comparable to the object's size.

- b) Atoms have a size that is on a scale of 10^{-10} metres. Explain how the electron beam in part a) would need to be changed to achieve maximum resolution of objects at this scale.

(3 marks)

Question 6**(4 marks)**

A light pole has the structure shown below.



The light pole has the following dimensions and specifications:

- Mass of the light globe and fitting = 55.0 kg
- Mass of support = 25.0 kg
- Distance PZ = 2.30 m
- Distance PY = 0.350 m
- Distance XY = 0.320 m

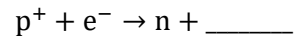
The centre of mass of the left support is at point X (the point where the metal strut connects with the support).

Calculate the magnitude of the tension in the metal strut.

_____ N

Question 7**(4 marks)**

A particle interaction called 'electron capture' can be represented by the following incomplete equation:



- a) Write the name and symbol of the unidentified particle in the spaces provided below. (2 marks)

NAME: _____

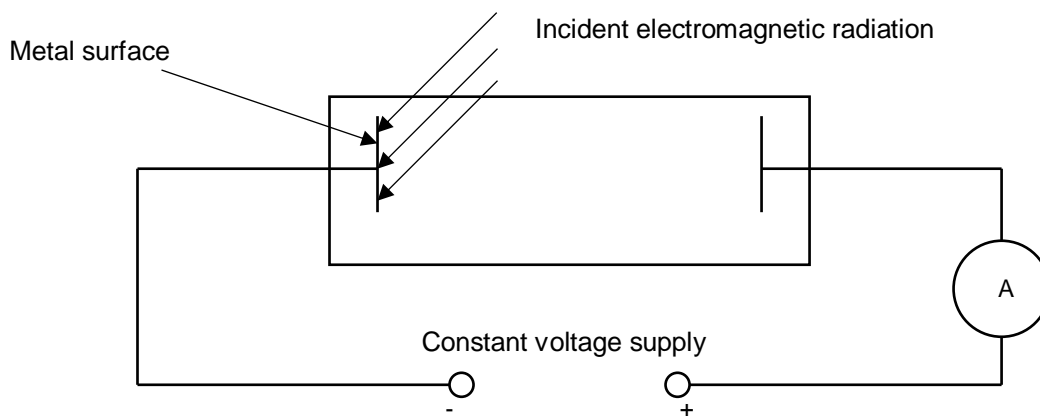
SYMBOL: _____

- b) Using relevant conservation laws, explain how you determined the unidentified particle in part a). (2 marks)

Question 8

(5 marks)

The apparatus below is used to investigate photoelectric emission when electromagnetic radiation is shone onto a metal surface. The intensity and wavelength of the incident radiation can be varied; the type of metal is unchanged. The ammeter measures the photoelectric current in the circuit.



Electromagnetic radiation of a particular wavelength is shone onto some sodium metal and a small current reading is measured by the ammeter.

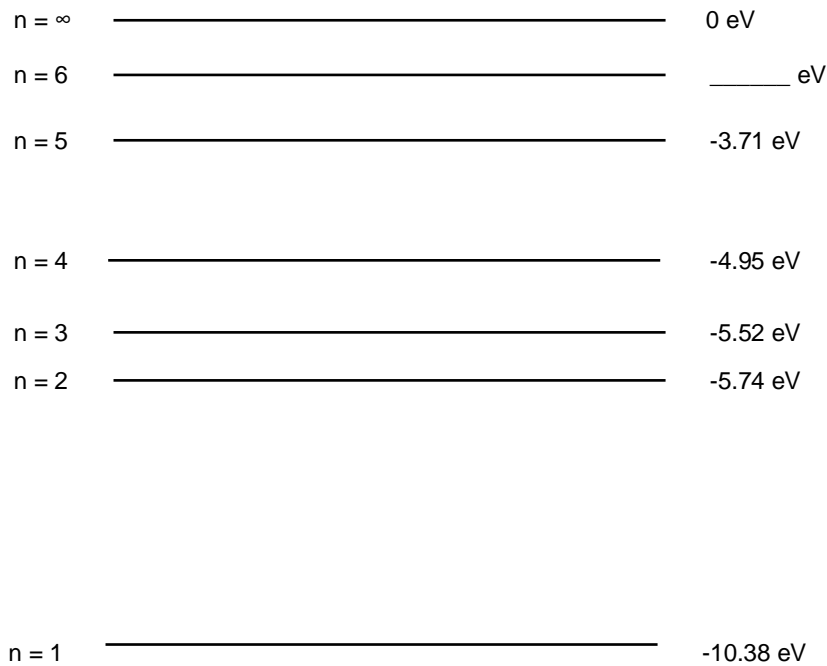
- a) The intensity of the incident electromagnetic radiation is slowly increased whilst the wavelength remains constant. Describe and explain what happens to the current measured by the ammeter. (2 marks)

- b) The intensity of the incident electromagnetic radiation is returned to its original value and its wavelength is continually increased. Describe and explain what would be observed in the ammeter over time. (3 marks)

Question 9

(6 marks)

The energy level diagram for a mercury atom is shown below (not to scale).



- a) An electron undergoes a downward transition between $n = 6$ and $n = 4$. As a result, a photon of wavelength 548 nm is emitted. Calculate the value (in eV) of energy level $n = 6$. (3 marks)

_____ eV

- b) If an electron of energy 5.00 eV bombards a mercury atom in ground state, calculate **all** the possible energies of the electrons after they have been scattered. (3 marks)

_____ eV, _____ eV, _____ eV

Question 10**(6 marks)**

As part of their preparation for operating in a 'weightless' environment whilst in orbit in the International Space Station (ISS), astronauts undergo training in a specially adapted reduced-gravity airplane (called the 'Vomit Comet!').

To create this reduced gravity environment, the airplane undertakes a vertical circular path of radius 4.13 kilometres. If the airplane travels at an exact speed at the top of the vertical circle, a completely weightless environment can be simulated.



- a) Explain how the airplane can create a 'weightless' environment at the top of the vertical circle. Include a diagram showing the force(s) acting on the airplane at this point, including the resultant force.

(3 marks)

- b) Calculate the speed 'v' at which this airplane would need to be travelling to simulate a weightless environment at the top of the vertical circle.

(3 marks)

_____ m s⁻¹**END OF SECTION ONE****See Next Page**

Section Two: Problem Solving**50% (90 marks)**

This section contains six (6) questions. Answer **all** questions. Answer the questions in the space provided.

Suggested working time is 90 minutes.

Question 11**(16 marks)**

Bobsled tracks are made of ice and, hence, are virtually frictionless. They have high speed bends which allow the bobsleds to travel at high speeds around banked turns. Typically, these tracks are banked at an angle ' θ ' of 20.0° and have an inner radius of about 180 metres. This is the minimum radius of the circular path a bobsled can take around this turn.

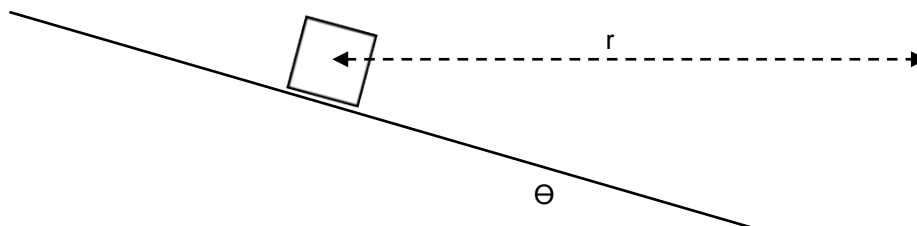


Some race officials decide to collect some data to investigate the relationship between the speed ' v ' of a bobsled and the radius ' r ' of its path on one of these banked turns.

The officials know that the relationship between ' v ', ' r ' and ' θ ' is given by:

$$\tan \theta = \frac{v^2}{gr}$$

The situation can be represented by the diagram below:



- a) Explain, referring to the relevant forces, why the path taken by a bobsled changes on the banked turn as its speed 'v' increases.

(3 marks)

Using appropriate equipment, the officials gathered the following data.

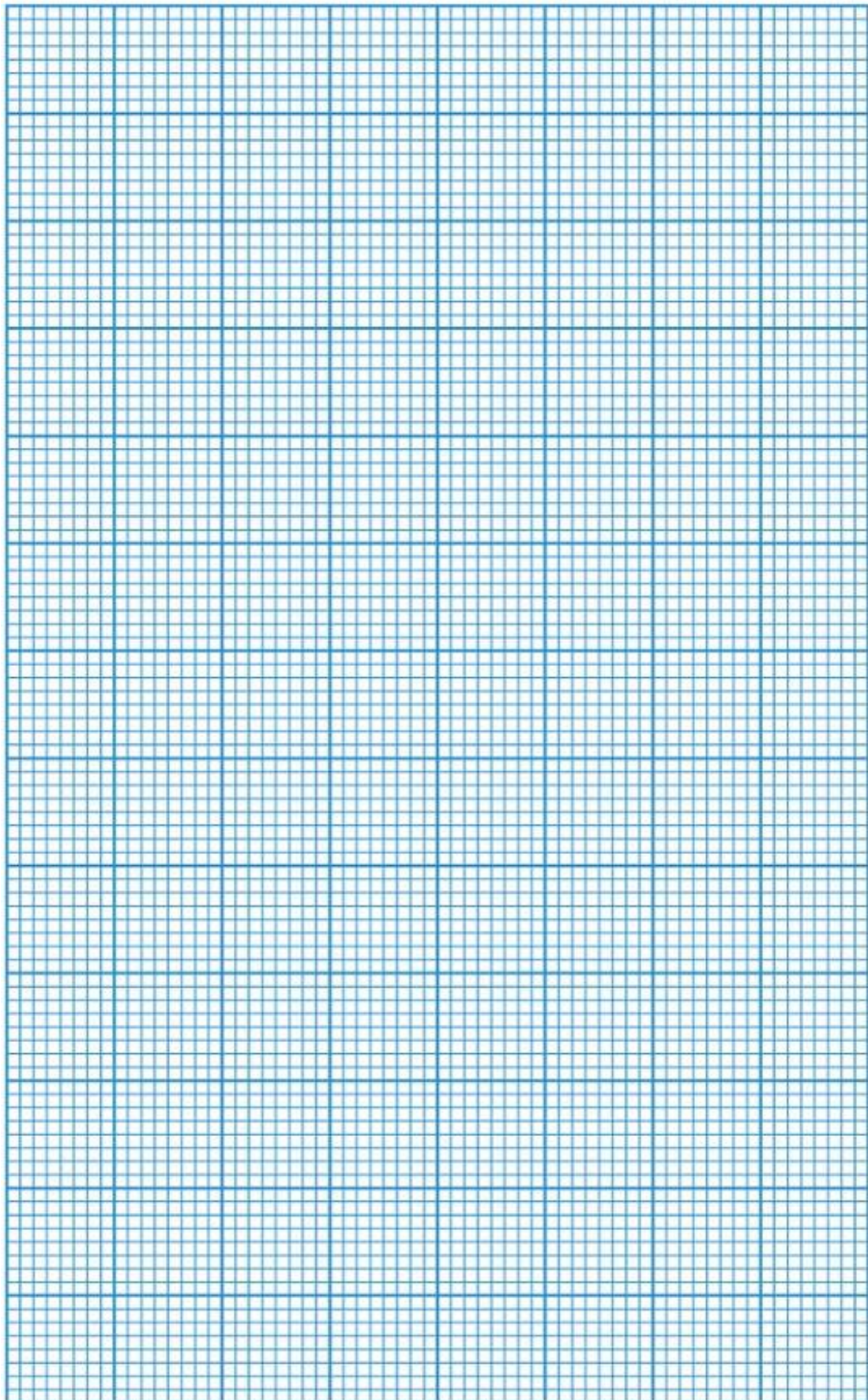
v (km h ⁻¹)	v (m s ⁻¹)	v ² (m ² s ⁻²)	r (m)
95	26.4	697	193
100			215
105	29.2	853	238
110	30.6	936	264
115	31.9	1020	285
120	33.3	1110	312

- b) Complete the table by calculating the missing values in the table above. Show any calculations in the space below.

(2 marks)

- c) On the grid on the next page, plot a graph of 'r' against 'v²'. Place 'r' on the y-axis. Draw a line of best fit

(4 marks)



-
- d) Calculate the gradient of the line of best fit. Show clearly how you did this. Include units in your answer.

(4 marks)

Gradient = _____

Units: _____

- e) Use the gradient from part d) to calculate an experimental value for 'g' (acceleration due to gravity on the Earth's surface).

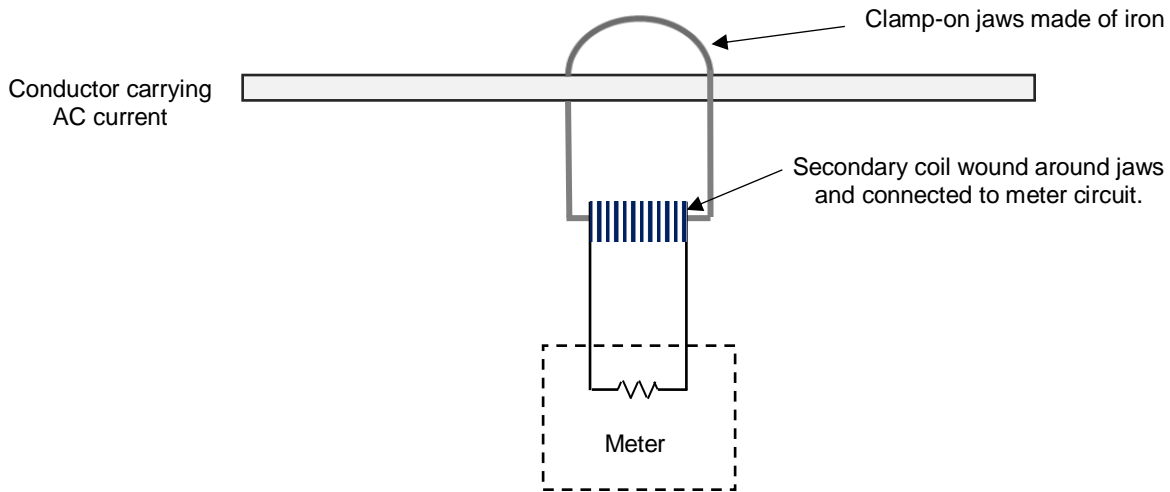
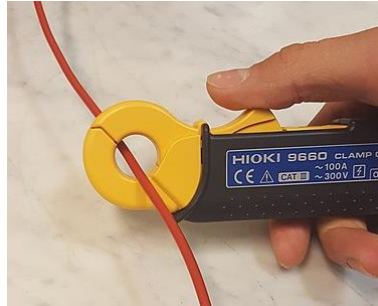
(3 marks)

g = _____

Question 12

(18 marks)

An AC ‘clamp meter’ is a device that is used to measure the alternating current in a circuit without contacting or touching the circuit itself. Whenever the meter is ‘clamped’ around a conductor carrying an AC current, a root-mean square current (RMS) reading is displayed by the meter. The picture and diagram below shows how the clamp works.



a) Explain how the current in the circuit can be measured by the clamp meter.

(4 marks)

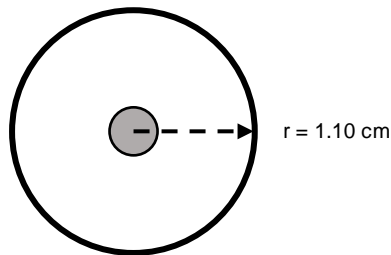
The clamp measures a root-mean square current of 5.00 A from a 240 V, 50 Hz AC mains power supply.

- b) Calculate the peak current (I_{PEAK}) in the conductor.

(2 marks)

_____ A

The average distance of the clamp-on jaws to the conductor is 1.10 cm. See below.



- c) Calculate the maximum magnitude of the magnetic field strength at the distance where the clamp is positioned. You may assume the clamp does not affect the magnetic field strength.

(2 marks)

_____ T

The flux change experienced by the iron clamp is completely passed through the secondary coil.

- d) Calculate the maximum **change** in flux experienced by the coil if its cross-sectional area is 4.00 cm². [If you were unable to calculate an answer for part c), use a value of 1.30×10^{-4} T]

(4 marks)

_____ Wb

e) Hence, calculate the average EMF (\mathcal{E}) generated in the secondary coil during the maximum change in flux if it consists of 250 turns.

(3 marks)

_____ V

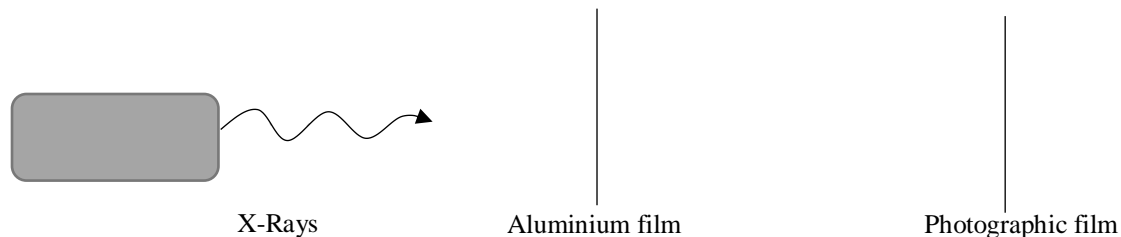
f) Would this particular type of circuit clamp work for a DC circuit? Explain.

(3 marks)

Question 13

(13 marks)

A beam of X-rays of wavelength 2.50×10^{-10} m is directed onto a thin aluminium foil as shown in the diagram below. The X-rays scatter from the foil and strike the photographic film.

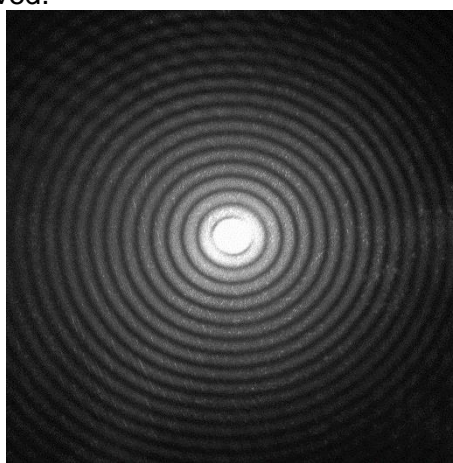


a) Calculate the energy, in keV of these X-rays.

(4 marks)

_____ keV

After the X-rays pass through the foil, a pattern of circular fringes forms on the photographic film, as shown in the diagram below. In further experiments, the source was replaced with a beam of energetic electrons. Again, a similar pattern was observed.



b) Explain how electrons and X-rays produce these diffraction patterns.

(4 marks)

-
- c) Assuming the diffraction patterns have identical fringe spacing, (i.e. the wavelength of the electrons is the same as the X-ray photons) calculate the momentum of the electron beam.

(2 marks)

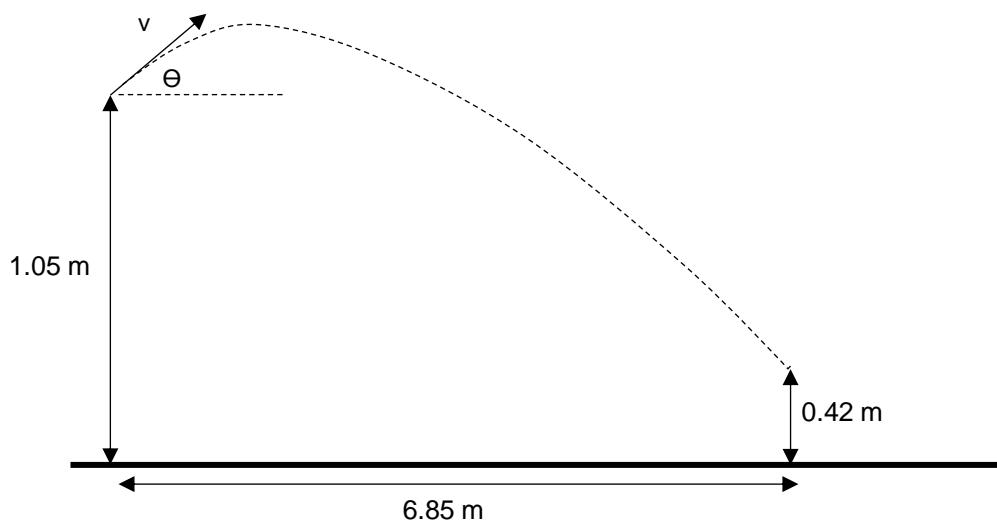
_____ kg m s⁻¹

- d) The voltage that accelerates the electron beam is gradually increased, providing a higher electrical potential to the electrons. Explain how the wavelength of the electrons are impacted.

(3 marks)

Question 14**(13 marks)**

An athlete completes a long jump which has the dimension shown in the diagram below. The curve represents the path taken by the athlete's centre of mass. The athlete's flight time during this jump is equal to 0.847 seconds. Air resistance can be ignored in parts a), b) and c) of this question.



- a) Calculate the horizontal component (u_h) of the athlete's launch velocity ' v '.

(2 marks)

_____ m s^{-1}

- b) Using the vertical displacements shown, calculate the vertical component (u_v) of the athlete's launch velocity ' v '.

(4 marks)

_____ m s^{-1}

-
- c) Hence, calculate the magnitude of the launch velocity ' v ' and the launch angle ' θ '. [If you were unable to calculate answers for parts a) and b), use values of 8.00 m s^{-1} and 3.40 m s^{-1} respectively]
- (4 marks)

_____ m s^{-1}

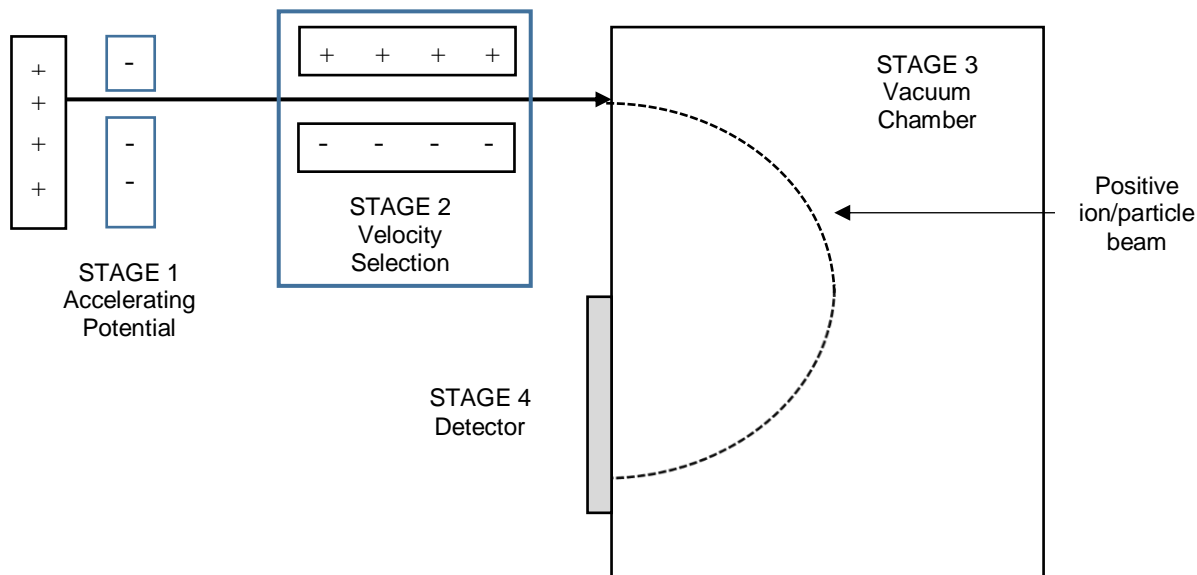
_____ $^{\circ}$

This athlete's jump can be assumed to have taken place at sea level. In 1968, a world record jump was set in Mexico City that stood for over 20 years before it was broken. Apart from the excellent speed and technique of the athlete, experts also thought the fact that Mexico City has an altitude of 2240 metres above sea level assisted.

- d) Argue how the high altitude of Mexico City could have contributed to a world record in the long jump event.
- (3 marks)

Question 15**(17 marks)**

Mass spectrometers are used to analyse data related to the mass of atomic and sub-atomic particles. The structure of a Bainbridge mass spectrometer is shown below. It accelerates positively charged gas ions/particles into a magnetic field contained in a vacuum chamber.



In STAGE 1, positively charged gas ions/particles are accelerated by an accelerating potential to a maximum speed. A particular ion beam consists of deuterium ions (${}^2_1\text{H}^+$). Deuterium ions consist of one proton and neutron; and have a positive charge equal to that of one proton.

- a) Each ${}^2_1\text{H}^+$ ion achieves a speed of $6.19 \times 10^5 \text{ m s}^{-1}$. Calculate the magnitude of the accelerating potential (in volts). The mass of a ${}^2_1\text{H}^+$ ion is $3.34 \times 10^{-27} \text{ kg}$.

(4 marks)

_____ V

- b) In STAGE 2 (Velocity Selection), the effects of an electric field and a magnetic field combine to ensure the velocity of the ${}^2_1\text{H}^+$ ions are constant and in a straight line.
- (i) Using the diagram as a guide, state the direction of the magnetic field of the STAGE 2 velocity selector by circling the correct option. (1 mark)

INTO THE PAGE

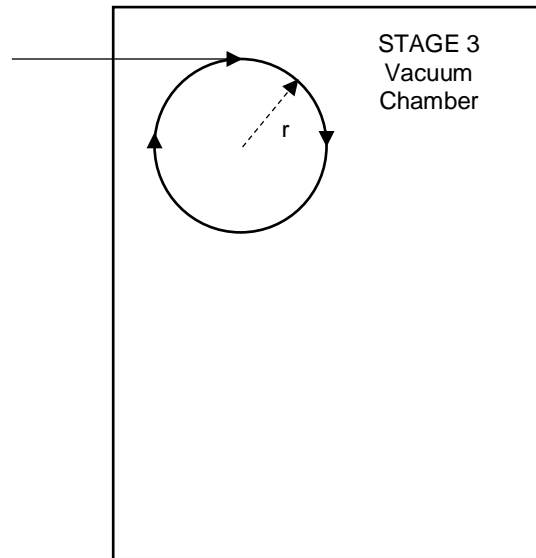
OUT OF THE PAGE

- (ii) Derive an expression showing the relationship between the electric field strength 'E'; the magnetic field strength 'B', and the speed of the ${}^2_1\text{H}^+$ ions 'v'. (2 marks)

- c) In STAGE 3, the beam of ${}^2_1\text{H}^+$ ions are bent into a circular path by a magnetic field in a vacuum chamber.
- (i) Based on the diagram, state the direction of the magnetic field in the chamber. (1 mark)

- (ii) Explain why the chamber is a vacuum. As part of your answer, describe how the radius of the beam of ${}^2_1\text{H}^+$ ions would change if the chamber was filled with a low-pressure gas. (3 marks)

If the magnetic field in the vacuum chamber is increased to a high enough strength, the ${}^2_1\text{H}^+$ ions will undergo a perfect circular path (see below).



- d) Use the appropriate formulae in your data booklet to derive the following expression for the frequency 'f' of the charged particle's rotation in the field:

$$f = \frac{Bq}{2\pi m}$$

where B = magnetic field strength (T);
q = electric charge on the particle (C); and
m = mass of the particle (kg).

(4 marks)

- e) Hence, calculate the frequency of circular rotation of the ${}^2_1\text{H}^+$ ions if the magnetic field strength in the vacuum chamber is 1.20 T.

(2 marks)

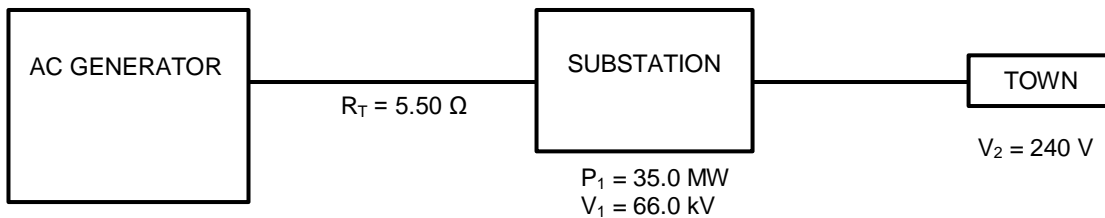
_____ Hz

Question 16

(13 marks)

A remote town has its electric power generated by a standalone AC generator situated on its outskirts. Transmission lines with a total resistance (R_T) of 5.50Ω run between the generator and a substation. The power generated in the primary coil of the transformer (P_1) at this substation is 35.0 MW (RMS); the voltage delivered to the primary coil (V_1) is 66.0 kV (RMS).

The transformer at the substation steps the transmission voltage (V_2) down to 240 V (RMS) for electric power transmission to the houses and factories in the town. See diagram below.



- a) Calculate the transmission current (RMS) in the line between the AC generator and the substation.

(2 marks)

_____ A

- b) Hence, calculate the power lost in the transmission line between the AC generator and the substation.

(2 marks)

_____ W

- c) Calculate the electric power generated at the AC generator.

(2 marks)

_____ W

-
- d) Determine the voltage at which electric power is generated at the AC generator. (2 marks)

_____ V

- e) Calculate the ideal turns ratio in the transformer at the substation. (2 marks)

The transformer at the substation is NOT ideal. Some energy in a transformer is lost because of eddy currents forming in the iron cores of the transformer.

In Australia, electric power is generated at an AC frequency of 50 Hz; in the United States, it is generated at an AC frequency of 60 Hz.

- f) If all other factors were kept equal, would an increase in AC frequency from 50 Hz to 60 Hz increase or decrease the power loss in a transformer due to eddy currents? Explain. (3 marks)

END OF SECTION TWO

See Next Page

Section Three: Comprehension**20% (36 marks)**

This section has two (2) questions. Answer **both** questions. Answer the questions in the spaces provided.

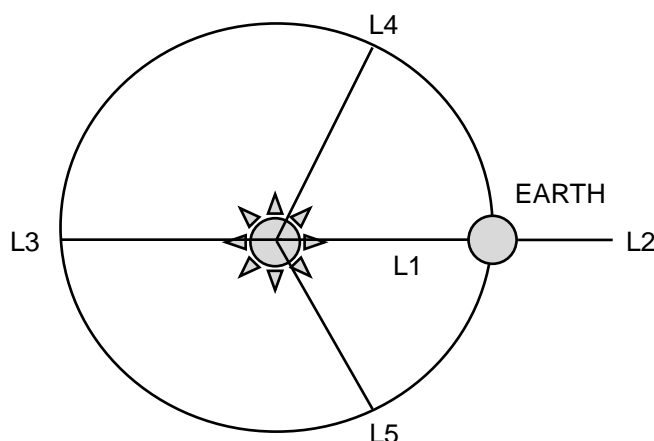
Suggested working time: 40 minutes.

Question 17**(18 marks)****James Webb Space Telescope**

Xmas Day, 2021, saw the launch of the most ambitious astronomy experiment ever undertaken by humans – the James Webb Space Telescope. Its mission is to reach back in time to examine the Universe as it was almost back to the instant of the Big Bang.

It took thirty days for the 6200 kg payload to travel 1.5 million kilometres to reach its permanent 'parking space' – a place called the L2 La Grange Point which is a gravitationally stable location in space. This has already been the home for some other telescopes – including the WMAP spacecraft and the Planck telescope.

La Grange Points are created by the gravitational pull of two bodies - in this case, the Earth and our Sun. There are five such points (see below). James Webb arrived at L2 on January 24, 2022.



At L2, the Sun, Earth and James Webb are all located on a line, with the Earth always located between the telescope and the Sun. This helps the telescope maintain a cool operating temperature of 50K.

At L2, the combined gravitational pull of the Sun and the Earth exactly provides the centripetal force required for James Webb to synchronise its orbit around the Sun with the Earth. Despite the overall stability of L2, NASA will continually need to make minor corrections to its position to account for any small deviations.

The James Webb Telescope will conduct its observations of the distant Universe in the infrared region of the electromagnetic spectrum. Its four instruments will collect radiation in the 0.5 to 28 micron (micrometre) range. This will allow astronomers to view the Universe as it was 100 million to 250 million years after the Big Bang (which scientists agree occurred about 13.6 billion years ago).

This mission contrasts with the missions of the COBE and WMAP satellites which operate in the microwave region of the electromagnetic spectrum. These telescopes detected the cosmic microwave background radiation – the first light emitted in the Universe 380 000 years after the Big Bang.

The James Webb Telescope has the potential to unlock even more secrets about our early Universe and provide images of the first stars, galaxies - and even planets - that formed 100 million years after the Big Bang – some of which will not even exist anymore.

- a) Using information from the article - and data from your Formulae and Data Booklet – calculate the centripetal force acting on the James Webb Telescope while it is in orbit at L2 La Grange Point. [Note, the distance between the Earth's centre of mass and L2 is 1.5 million kilometres].
(3 marks)

_____ N

- b) (i) State the orbital period (T) of the James Webb Telescope around the Sun in seconds.
(2 marks)

_____ s

- (ii) Hence (or otherwise) calculate the average orbital speed of the James Webb Telescope around the Sun.
(3 marks)

_____ m s⁻¹

-
- c) The James Webb Telescope is tuned to infrared radiation that is emitted by extremely distant luminous objects (e.g. – galaxies). To be able to detect this faint IR radiation, the telescope needs to be cooled to a very low operating temperature of 50 K. Suggest a reason for this. (3 marks)

- d) The James Webb Telescope's four instruments collect radiation in the 0.5 to 28 micron range. Calculate the corresponding frequency range for these instruments. (2 marks)

_____ Hz to _____ Hz

Question 18**(18 marks)****Einstein's Theory of Special Relativity**

Prior to 1905, scientists understood the Universe in terms of Newton's Three Laws of Motion. These Laws – established by Isaac Newton in 1686 – explain nearly all observations in the Universe. They formed our understanding of mechanics and gravity.

There were, however, some phenomena that could not be adequately explained by these Laws. The behaviour of light was chief amongst them.

In 1887, the Michelson-Morley experiment hypothesised that the speed of light from a source such as our Sun would be affected by the Earth's motion. In one of the most famous null hypotheses in history, this experiment proved the exact opposite. The speed of light was measured to be constant in all frames of reference, no matter the motion of the Earth. A Newtonian Universe could not explain this, and new thinking was required.

Einstein claimed to have started thinking about this 'light problem' as a sixteen-year-old in a 'thought experiment' where he chased a beam of light. As Einstein caught up to the beam, the relative speed between him and the light wave would become zero: this electromagnetic wave and its alternating fields would become 'frozen'. Einstein already knew that this contradicted the work of James Maxwell whose equations required an electromagnetic wave to travel at 'c' – the speed of light in a vacuum ($300\,000\text{ km s}^{-1}$) - in ALL frames of reference.

Einstein took these ideas further by examining the concept of 'simultaneity'. In his famous 'Train Experiment', Einstein illustrated that events that are observed to occur simultaneously in one frame of reference will NOT appear to occur simultaneously in another. At low speeds, this effect is not noticeable; as the train approaches the speed of light, it becomes more significant. It led Einstein to a conclusion that time itself is relative and is measured differently by observers in different frames of reference.

These thought experiments developed into the Theory of Special Relativity - which is based on two important 'postulates'. In his paper, published in 1905, Einstein changed our view of the Universe forever. This theory is 'special' because it accurately explains extreme contexts: events that require huge energies; objects that are travelling at speeds that are significant proportions of the speed of light; events that occur over large astronomical distances. Special relativity does not, however, consider the effect of gravity; Einstein would later develop his Theory of General Relativity which includes the effects of this fundamental force.

The implications of this Theory were profound. For example, Einstein showed that it is impossible for any object to travel at the speed of light. Further, he showed that time is relative and, while this 'time dilation' effect is insignificant at everyday speeds, it is very significant as the speed of objects and observers approaches the speed of light.

For example, an astronaut on board the International Space Station is moving much faster relative to observers on the Earth's surface. Einstein's Theory showed that the Earth-bound observer would age a little faster than the astronaut. In fact, over the course of one year, the individual on the Earth would have aged about five milliseconds more than the astronaut. This time dilation is, of course, negligible due to the comparatively low speeds that an astronaut is travelling at whilst in orbit.

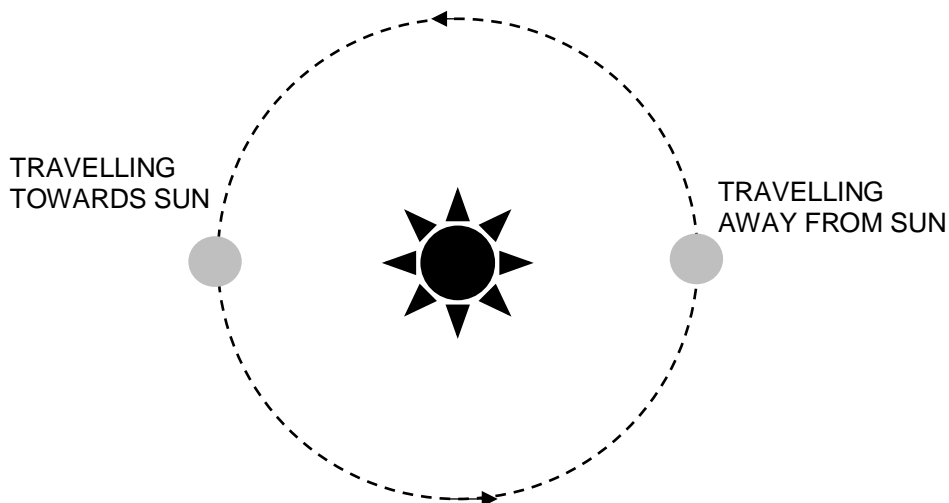
However, at speeds approaching the speed of light, the effects of time dilation become very significant. If an astronaut leaves the Earth and travels around the galaxy at 99.5% of the speed of light for five years, when they return to the Earth, they would have aged those five years they spent travelling. Inhabitants of the Earth, however, would be much older - many more years would have passed on our planet in that time.

While humans don't currently have the ability to travel anywhere near the speed of light, time dilation does actually affect precision instruments and has to be factored into their operation.

GPS devices are used to calculate the positions of objects on the Earth's surface to a high degree of accuracy. At least three satellites in distant Earth orbits are used to do this and they use atomic clocks to keep track of the incredibly precise times needed to pinpoint an object's location on the planet's surface. These atomic clocks are on board satellites that are orbiting at very high speeds relative to the Earth's surface. The Theory of Special Relativity calculates that these clocks tick an extra seven (7) microseconds each day compared to stationary clocks on Earth. In order to maintain pace with Earth clocks, and calculate accurate locations, the atomic clocks on GPS satellites need to subtract these seven microseconds each day.

- a) In their famous experiment, Michelson and Morley used the rotation of the Earth on its axis and its revolution around the Sun to measure the speed of sunlight. They took measurements of the speed of sunlight six (6) months part.

One measurement was taken when the observers were travelling AWAY from the Sun. The next measurement was taken so that they were travelling TOWARDS the Sun (see below).



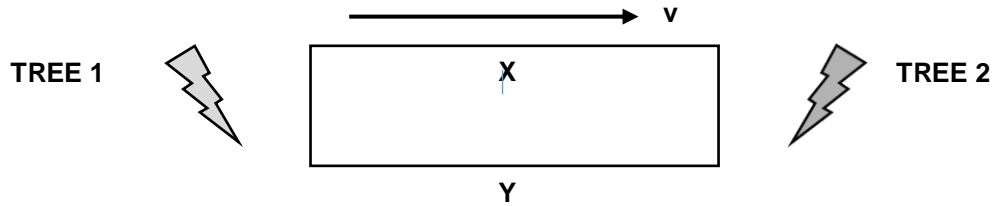
In accordance with Newton's Laws, Michelson and Morley incorrectly hypothesised that the speed of light should be measured to be different values at these two locations. State their hypothesis and explain why they made this prediction.

[4 marks]

b) In his famous train experiment, Einstein imagined a train travelling at speed 'v' that was a significant proportion of the speed of light 'c'. At particular instant of time, the train was situated equidistant between two trees – an observer (X) on the moving train was also positioned at the midpoint between the two trees (see below).

Another observer (Y) is standing in a stationary position on the side of the tracks directly opposite the train. At the same instant, this stationary observer is standing directly opposite the observer in the train and is also equidistant between the two trees (see below).

At this instant in time, the stationary observer sees two bolts of lightning strike the two trees at exactly the same time.



State the order in which the observer on the train (X) sees the lightning bolts. Explain your answer.

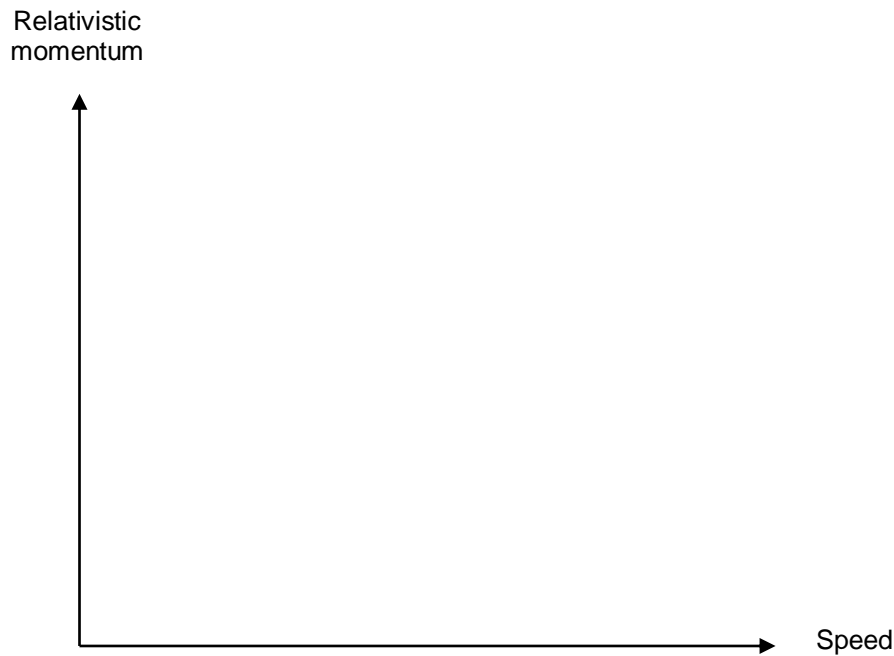
(3 marks)

c) (i) Using appropriate formulae from your Data Booklet, explain why objects cannot travel at the speed of light, 'c'.

(3 marks)

- (ii) On the axes below, sketch a graph showing how the relativistic momentum of an object changes as its speed approaches 'c'.

(3 marks)



- d) The following questions relate to the examples of time dilation mentioned in the article. Consider only the effects of **special** relativity

- (i) A spaceship travels from Earth to a distant galaxy at 99.5% of the speed of light. The astronaut ages 5.00 years by the time they arrive. Calculate the duration of the astronaut's journey from Earth's reference frame.

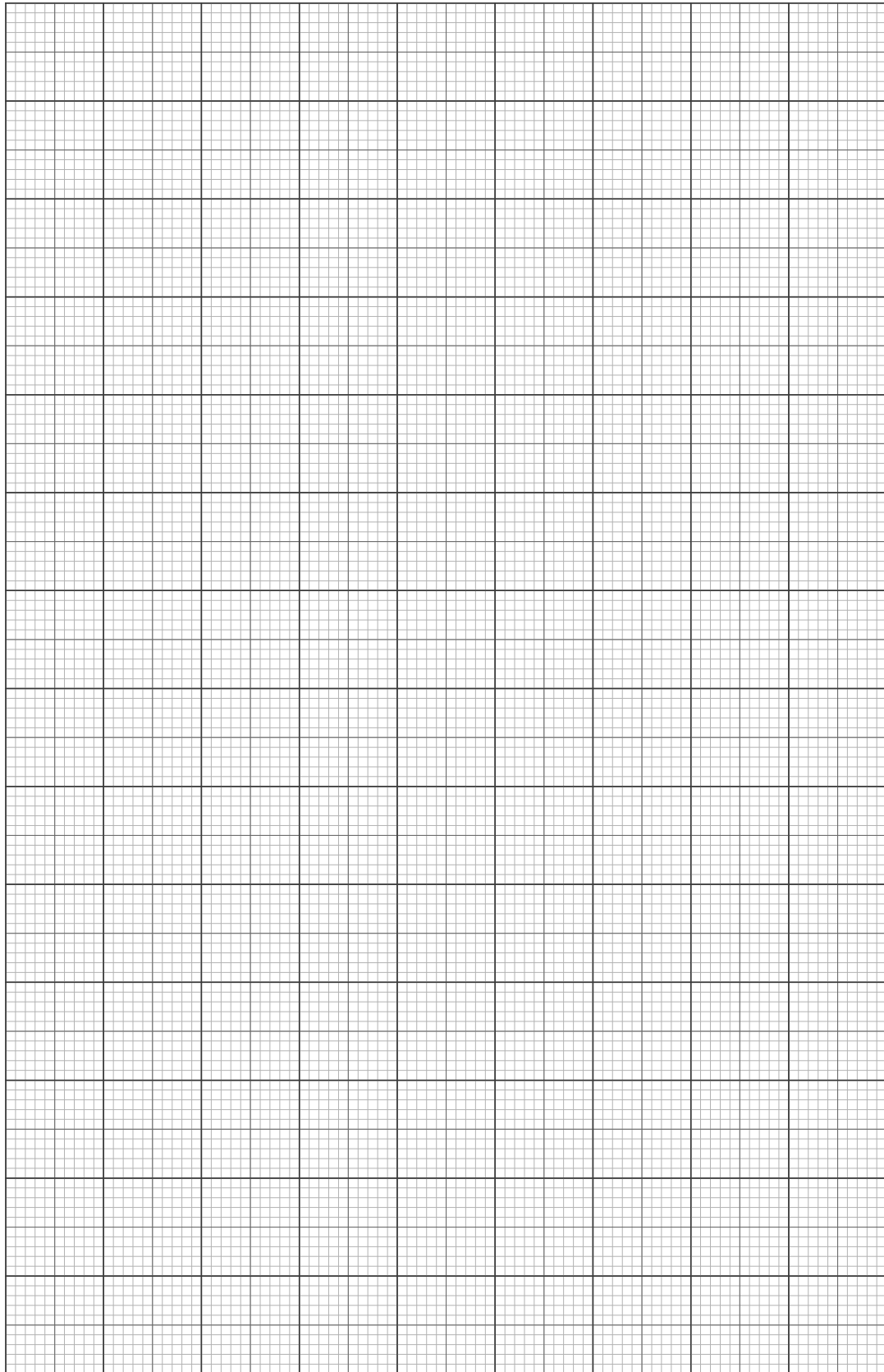
(2 marks)

_____ years

- (ii) Calculate the average orbital speed of a GPS satellite if it ticks seven (7) microseconds longer in the course of one day than a stationary clock on earth.
- (3 marks)

_____ ms^{-1}

END OF EXAMINATION

Spare grid for graph

Teacher Marking Allocation.