Please paste the barcoded label here	TOTAL MARKS

INTERNATIONAL SECONDARY CERTIFICATE EXAMINATION
NOVEMBER 2022

FURTHER STUDIES PHYSICS

EXAMINATION NUMBER													

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 32 pages and a Data Sheet of 2 pages (i–ii). Please check that your question paper is complete.
2. Answer ALL the questions on the question paper and hand it in at the end of the examination. Remember to write your examination number in the space provided above.
3. Use the data and formulae whenever necessary.
4. Clearly show ALL calculations, diagrams, graphs, equations etc. that you have used in determining your answers. Final answers only will NOT necessarily be awarded full marks.
5. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
6. Answers must be expressed using the correct significant figures.
7. It is in your own interest to read the questions carefully, write legibly and to present your work neatly.
8. ONE blank page (page 32) is included. If you run out of space for a question, use this page. Clearly indicate the number of your answer should you use this extra space.

FOR OFFICE USE ONLY: MARKER TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total
Mark										
Marker Initial										
Moderated Mark										
Moderator Initial										
Question Total	**20**	**28**	**26**	**20**	**30**	**14**	**22**	**18**	**22**	**200**
Re-mark										
Initial										
Code										

QUESTION 1 MULTIPLE CHOICE

Answer these questions on the multiple-choice answer grid below. Make a clear cross (X) in the box corresponding to the letter that you consider to be correct.

1.1	**A**	**B**	**C**	**D**
1.2	**A**	**B**	**C**	**D**
1.3	**A**	**B**	**C**	**D**
1.4	**A**	**B**	**C**	**D**
1.5	**A**	**B**	**C**	**D**
1.6	**A**	**B**	**C**	**D**
1.7	**A**	**B**	**C**	**D**
1.8	**A**	**B**	**C**	**D**
1.9	**A**	**B**	**C**	**D**
1.10	**A**	**B**	**C**	**D**

1.1 James and Sannie each perform an investigation to determine the acceleration due to gravity. Their results for g in $m \cdot s^{-2}$ are shown below.

James	9,22	10,56	9,81	10,40	9,06
Sannie	8,73	8,75	8,71	8,73	8,74

Which one of the following rows describes the results obtained by the two students as well as the possible error made, the best?

	Description of results		**Possible error made**	
	James	**Sannie**	**James**	**Sannie**
A	precise	accurate	systematic	random
B	accurate	precise	random	systematic
C	precise	accurate	random	systematic
D	accurate	precise	systematic	random

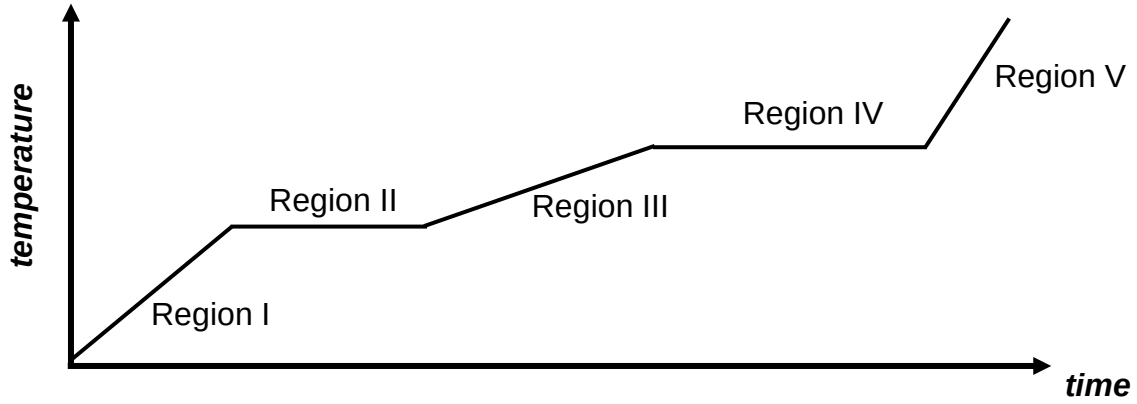
(2)

1.2 Which of the following correctly gives the SI derived unit and the base units for energy?

	Derived unit	**Base unit**
A	J	$kg \cdot m^2 \cdot s^{-2}$
B	W	$kg \cdot m \cdot s^{-2}$
C	J	$kg \cdot m^{-2} \cdot s^{-2}$
D	W	$kg \cdot m^2 \cdot s^2$

(2)

1.3 A substance is heated by supplying heat energy at a constant rate. A graph of the temperature vs time for the substance is shown below.



In which region(s) will the substance exist as a mixture of two phases and have particles with the highest average kinetic energy?

A Region I, III and V
B Region IV
C Region II and IV
D Region V (2)

1.4 During a series of nuclear decays, a uranium-238 nucleus forms uranium-234. Which one of the following series of decays could give this result? (Note: The atomic number of uranium is 92)

Adjusted from CIE 2021

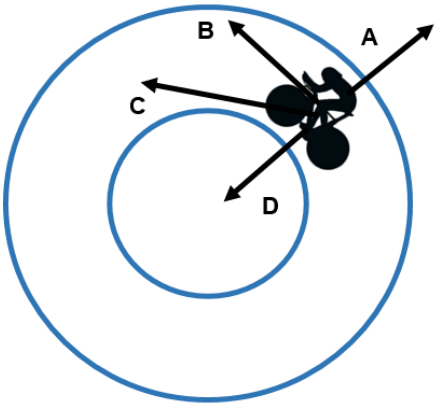
A Emission of two alpha particles and eight beta particles.
B Emission of one alpha particle and two beta particles.
C Emission of four gamma rays.
D Emission of four beta particles. (2)

1.5 An arrow is shot at an angle to the horizontal so that it follows a parabolic path. Points PQRST are the positions of the arrow after successive equal time intervals.

The displacements PQ, QR, RS and ST…

A decrease at a constant rate.
B increase at a constant rate.
C have equal horizontal components.
D have equal vertical components. (2)

1.6 The diagram below shows a bicycle going around a circular tar track at a constant speed. Which arrow shows the direction of the net force on the bicycle?



(2)

1.7 A star of mass M and radius r rotates so that star dust at the equator only just remains on the surface of the star. What would the period of rotation of the star be?

A $2\pi\sqrt{\frac{r^3}{MG}}$

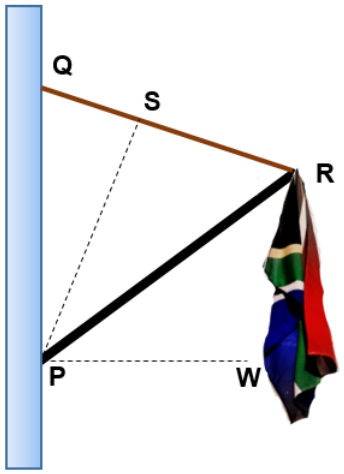
B $2\pi\sqrt{\frac{MG}{r^3}}$

C $2\pi\sqrt{\frac{r}{MG}}$

D $2\pi\sqrt{\frac{G}{r}}$

(2)

1.8 A flagpole is hinged on a vertical wall at position P and held by a wire connected at point Q. The mass of the flag is negligible.

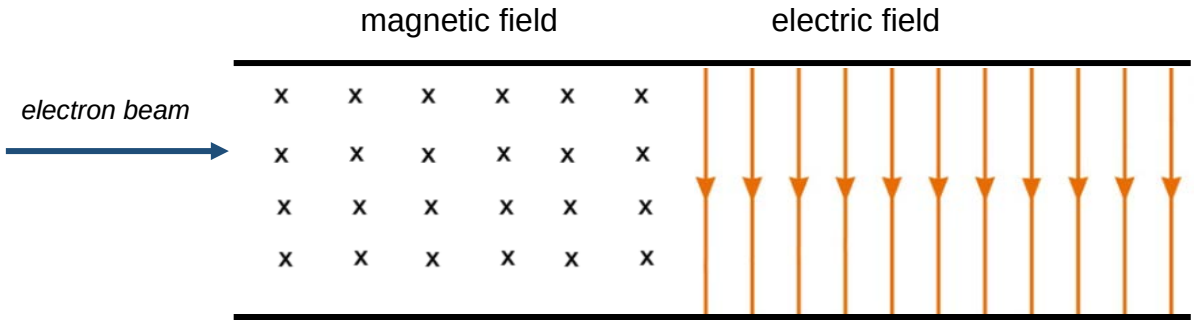


What is the direction of the resultant force exerted by the wall on the flagpole?

A PR
B PW
C QR
D PS

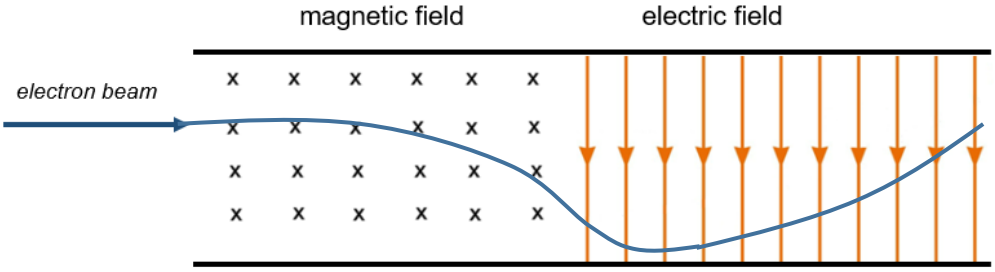
(2)

1.9 In a cathode ray tube, electrons move through adjacent electric and magnetic fields as shown below.

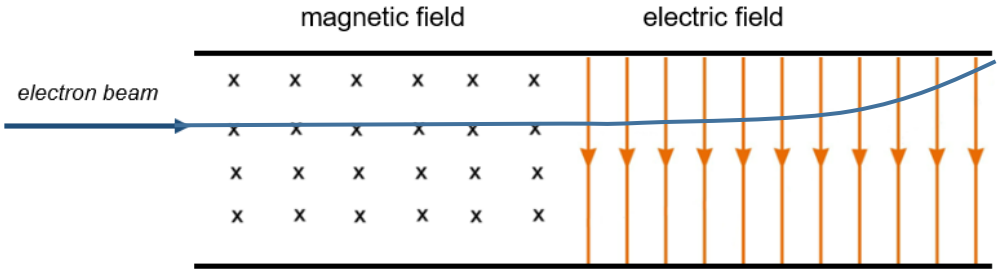


Which of the options below is the most likely path to be followed by the beam of electrons?

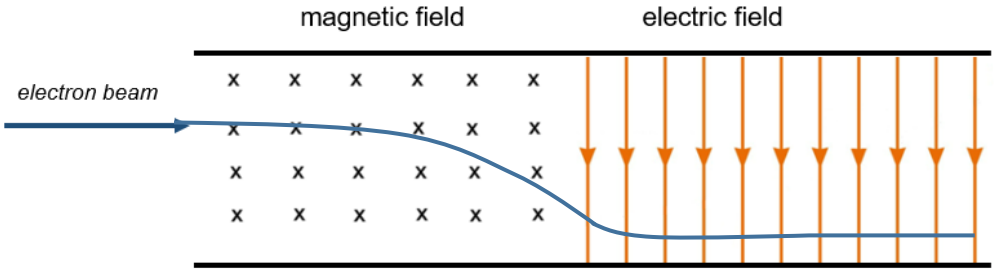
A



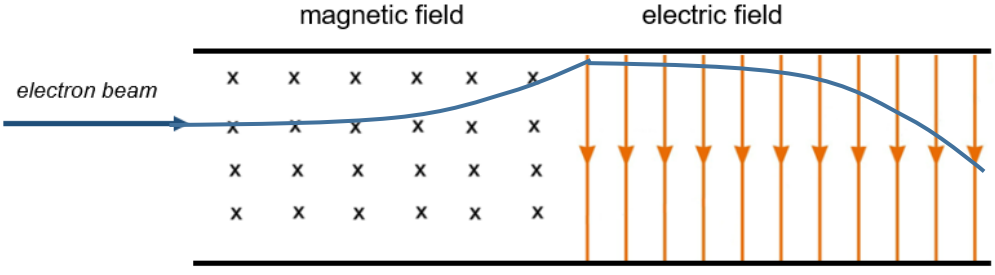
B



C

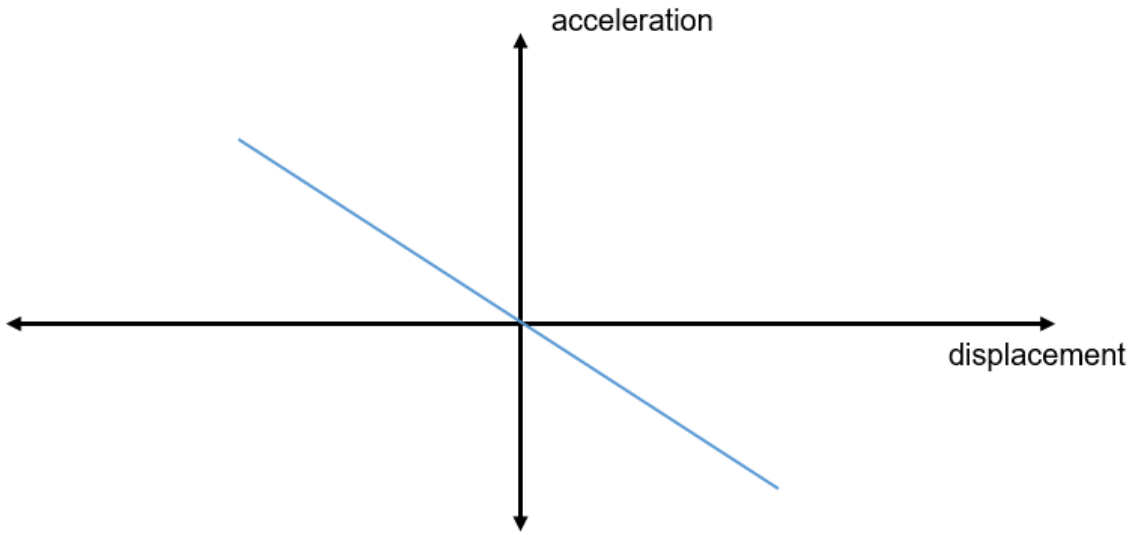


D



(2)

1.10 A trolley oscillates horizontally on a frictionless surface. The sketch graph below shows the variation of the acceleration of the trolley with the displacement from the equilibrium position.



Consider the following features of the line above:

I: Straight line passing through the origin
II: Line ending with negative acceleration
III: Line with a negative gradient

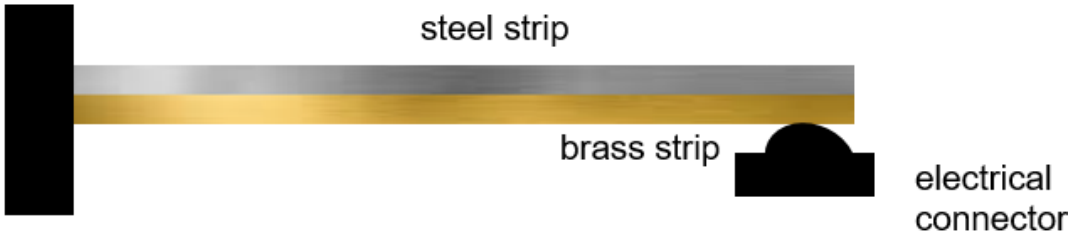
Which of the features demonstrate that the motion of the trolley is simple harmonic?

A I only
B I and II
C I and III
D I, II and III (2)

[20]

QUESTION 2 THERMAL PHYSICS

2.1 A bimetal thermometer in a heat detector alarm is made by bonding two thin strips of steel and brass together as shown below. The alarm is not activated provided the electrical contact is maintained as shown.



2.1.1 Use your ruler to determine the length of the strips.
State your answer in mm to the correct number of significant figures and add an appropriate uncertainty in your measurement. (2)

_____

2.1.2 When a brass strip is heated from 20,0 ± 0,1 °C to 127,0 ± 0,1 °C it expands from 150,00 cm to 150,30 cm.

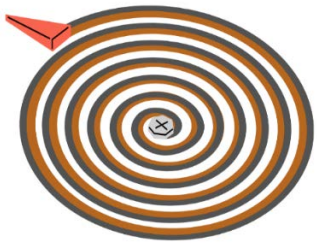
(a) Show by calculation that the coefficient of linear expansion for brass is $19 \times 10^{-6}\ K^{-1}$. (3)

The coefficient of linear expansion of the steel is $11 \times 10^{-6}\ K^{-1}$.

(b) Explain, with the aid of a diagram, how the alarm will be triggered when the strips are heated. (4)

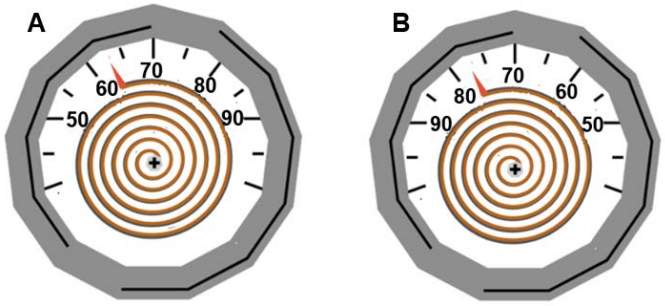
(c) Calculate the difference in the length of the strips when they are heated from 20,0 ± 0,1 °C to 127,0 ± 0,1 °C. The uncertainty in the length is 0,01 cm.
Include the absolute uncertainty in your answer. (5)

2.1.3 Instead of using alcohol or mercury thermometers, bimetallic strips are used in thermostats all over the world to monitor and maintain temperatures. Recall that these strips contain layers of steel and brass, which have relatively low and high thermal expansion coefficients, respectively, as shown in the diagram below:



[Adapted from: <https://brilliant.org/courses/puzzle-science>]

The diagrams below show possible scales that could transform this strip into a thermometer. In each case the steel is on the outside of the spiral and the brass is on the inside.



Which one of the diagrams correctly shows the scale that could transform this strip into a thermometer? Only write A or B. (3)

_____

Explain your choice above.

_____

_____

2.2 A mom living in an igloo needs to warm a baby's bottle to the ideal temperature of 38 °C.

Her only source of water is the ice around her house. She places a lump of ice at –7,0 °C in a pot on the stove, the ice melts and reaches the ideal temperature.

2.2.1 Compare the volume of the ice and the volume of the water. Explain your answer by refering to the anomalous behaviour of water. (3)

2.2.2 Define *specific latent heat of a material.* (2)

2.2.3 Determine the amount of heat energy required to melt 320 g of ice at –7,0 °C and reach the ideal temperature of 38 °C.

(c_{water} = 4 180 J·kg^{-1}·K^{-1}; c_{ice} = 2 090 J·kg^{-1}·K^{-1}; L_f = 33,6 kJ·kg^{-1}) (6)

[28]

QUESTION 3 MATTER AND NUCLEAR PHYSICS

Oceanographers learn about climate changes by studying the age of coral.
They use carbon-14 dating to determine the ages of living and fossil coral.

3.1 A nucleus of a carbon-14 atom consists of 6 protons and 8 neutrons.

3.1.1 Are protons and neutrons considered to be elementary particles? (1)

3.1.2 Give a reason for your answer in Question 3.1.1. (2)

3.2 The mass defect of carbon-14 is 0,113 u.

3.2.1 Define *mass defect.* (2)

3.2.2 Determine the binding energy per nucleon for a carbon-14 nucleus. (5)

3.3 Carbon-14 decays to become nitrogen-14 as a consequence of the weak nuclear force.

3.3.1 State the quark composition of a proton. (2)

3.3.2 Which exchange particle(s) can be associated with the weak nuclear force? (2)

3.3.3 Name 3 properties of the weak nuclear force. (3)

3.4 A piece of dead coral retrieved from the ocean contains 760 g of carbon and has an activity of 16,0 decays per second. In living coral, the decay of carbon-14 produces 15,3 disintegrations·min^{-1}·g^{-1}. The half-life of carbon-14 is 5730 years. ($x = x_0 e^{-\lambda t}$)

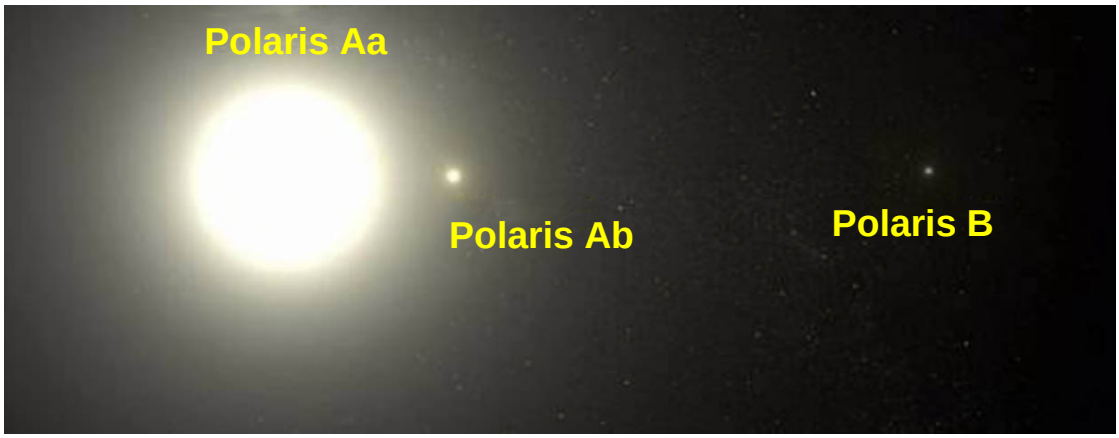
3.4.1 Define the term *half-life*. (2)

3.4.2 Determine the age of the dead coral. (7)

[26]

QUESTION 4 ASTROPHYSICS AND COSMOLOGY

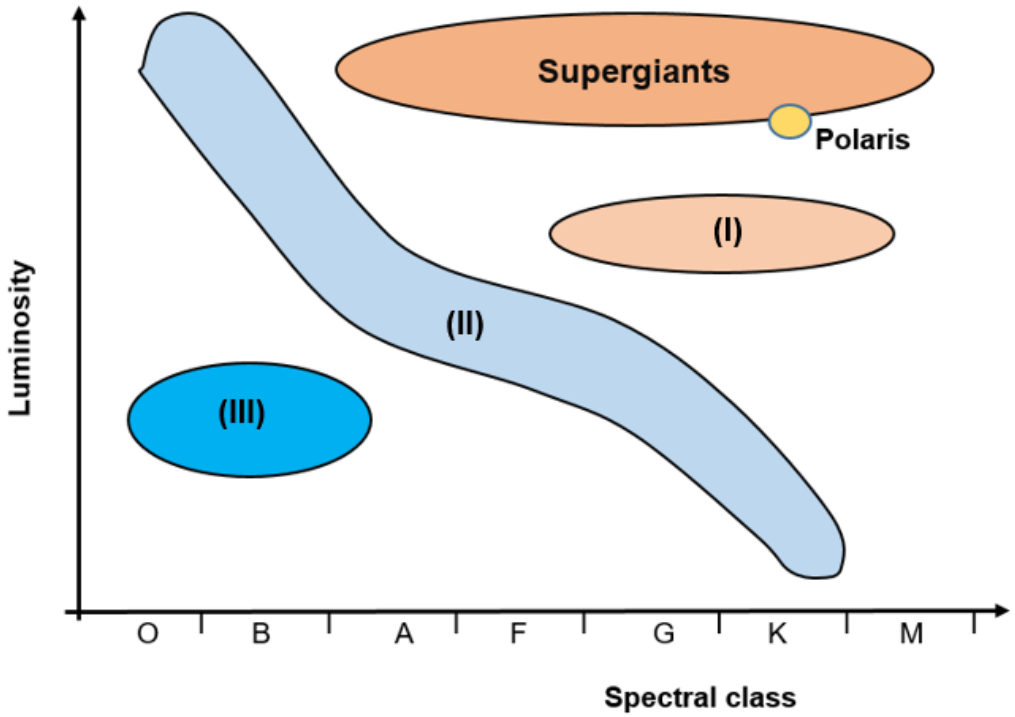
Polaris (the north star) is the only star in the night sky that appears to be stationary. It is a three-star system consisting of a supergiant, *Aa* and two smaller yellow-white dwarfs, *Ab* and *B*.



[Source: <nineplanets.org>]

4.1 Describe two features of a supergiant star. (2)

4.2 The diagram below shows a basic Hertzsprung-Russell (HR) diagram indicating the position of the supergiant stars as well as the approximate position of Polaris.



4.2.1 Explain what is meant by the term *luminosity*. (2)

_____

_____

_____

4.2.2 Label the regions (I), (II), and (III) indicated on the HR diagram above. (3)

(I) _____

(II) _____

(III) _____

4.3 Polaris B is the hottest of the three-star system with an estimated peak temperature of about 7 500 K and a luminosity 3,9 times larger than that of the Sun (mass of the Sun = $1,99 \times 10^{30}$ kg, a = 4,2).

4.3.1 Use Wien's displacement law to determine the peak wavelength emitted from this star. (3)

4.3.2 Determine the mass of Polaris B. (3)

4.3.3 Use your answer to Question 4.3.2 to explain how the Chandrasekhar and Oppenheimer-Volkoff limits predict that Polaris B would probably end up as a white dwarf rather than a neutron star. (4)

4.4 When we look up at the night sky, we are viewing a part of only 5% of the universe. Dark matter makes up 26% of the universe while dark energy accounts for the other 69%. Discuss how gravitational lensing provides evidence for the existence of dark matter. (3)

[20]

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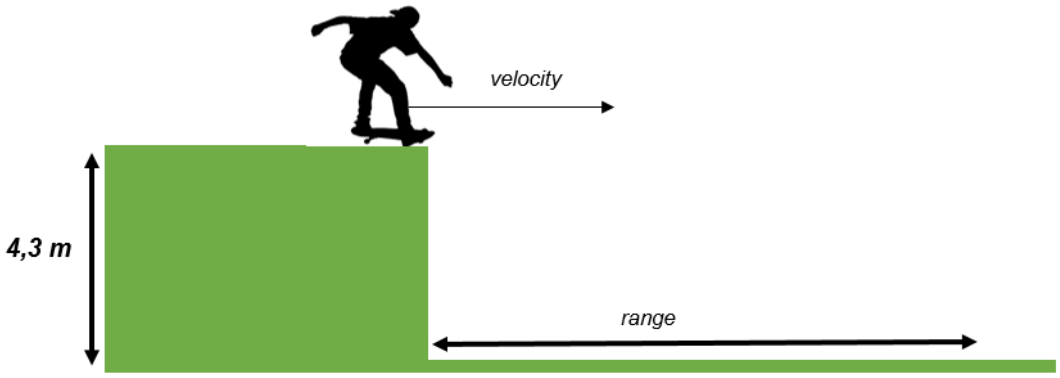
QUESTION 5 PROJECTILE MOTION AND DATA ANALYSIS

After a skateboarding competition, Akhil decides to investigate how the velocity with which the skater leaves a 4,3 m high horizontal platform, affects the landing range of the skater.



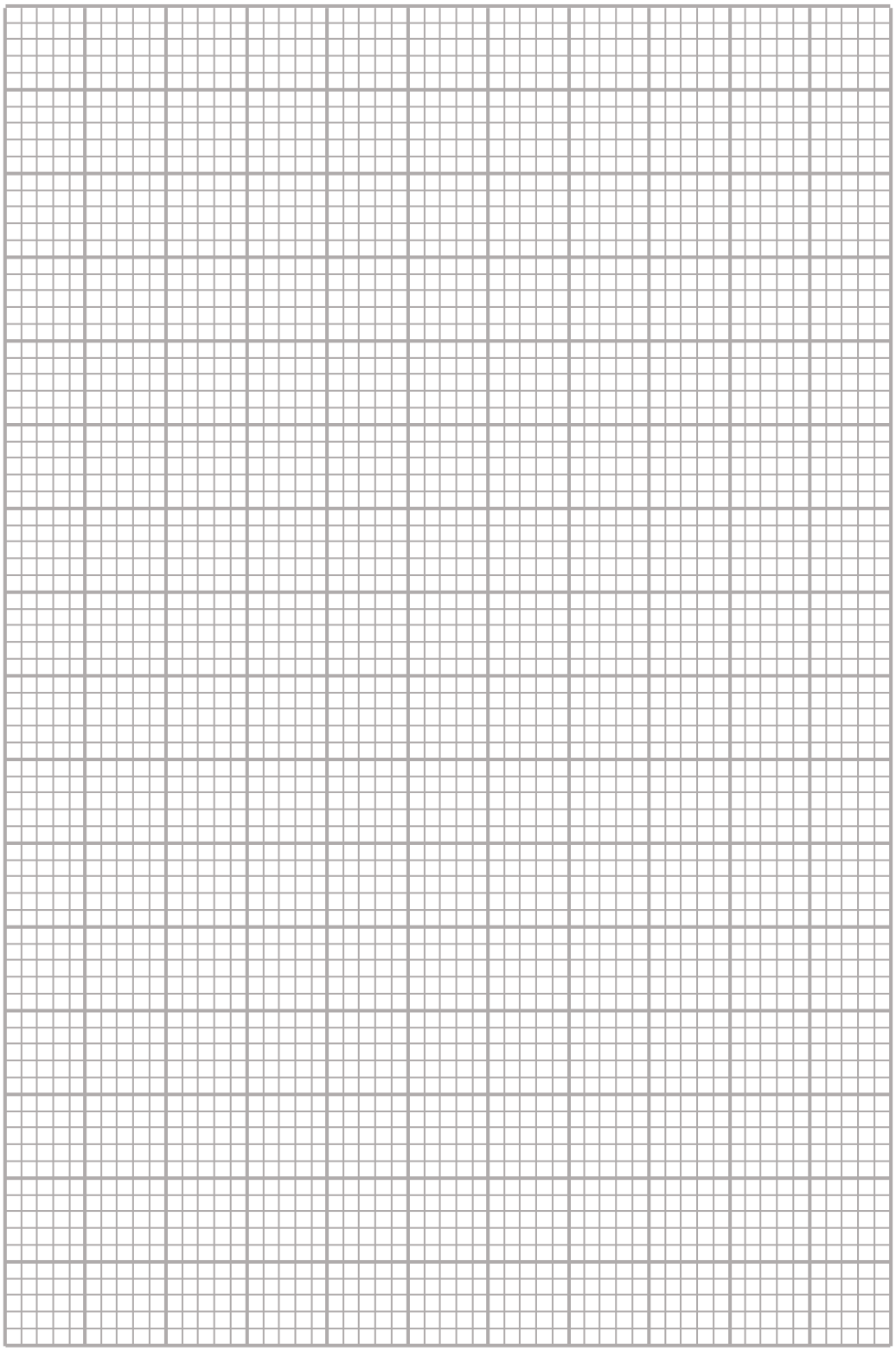
They do not have a measuring tape and measure the time it takes to land. They calculate the range for each velocity.
The table below shows their results. The uncertainty in the time measured is 0,2 s.

velocity / $m \cdot s^{-1}$	time / s	range / m
1,6	1,06 ± 0,20	1,70 ± 0,32
3,7	0,95 ± 0,20	3,52 ± 0,74
5,5	0,90 ± 0,20	4,95 ± 1,12
9,5	0,93 ± 0,20	9,12 ± 1,96
12,0	0,91 ± 0,20	10,92 ± 2,40
13,4	0,93 ± 0,20	12,46 ± 2,70

5.1 Explain why the time remained relatively constant although the velocity increased. (2)

5.2 Comment on the number of significant figures used in the calculated values for the range reached. (2)

Graph grid for Question 5.3



5.3 On the graph grid on page 19, plot a graph of the range vs the velocity at which the skater leaves the ramp. (4)

5.4 Include error bars for the range on your graph. (2)

5.5 Draw the line of best fit as well as one worst acceptable line of fit on your graph. Label these lines clearly. (2)

5.6 Use your graph to determine:

5.6.1 The gradient of your line of best fit. Include an appropriate unit. (4)

5.6.2 The absolute uncertainty in the gradient. (3)

5.6.3 The quantity represented by the gradient. (2)

5.7 Keila suggests to Akhil that a slight increase in the angle of the ramp can affect the range significantly.

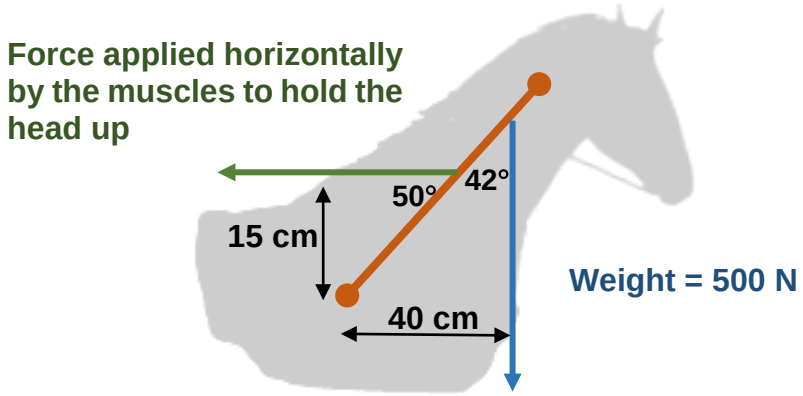
5.7.1 Calculate the range for a starting velocity of 11,0 $m \cdot s^{-1}$ when the ramp is placed at an angle of 10° to the horizontal. (6)

5.7.2 Calculate the absolute uncertainty in your answer for Question 5.7.1 using any given uncertainties in the investigation. (3)

[30]

QUESTION 6 TORQUE AND FIELDS

The diagram (not to scale) shows the forces acting on different parts around the horse's head and neck (weight 500 N). (All distances indicated are either horizontal or vertical.)



6.1 Define *torque*. (2)

6.2 Determine the magnitude of the force that the muscles need to apply to hold the head in a stationary position. (4)

6.3 While jumping the horse over an obstacle, the rider (mass 62 kg) lifts out of her saddle and for a moment she seems to be floating and not to be affected by any forces.

6.3.1 Define *gravitational field*. (2)

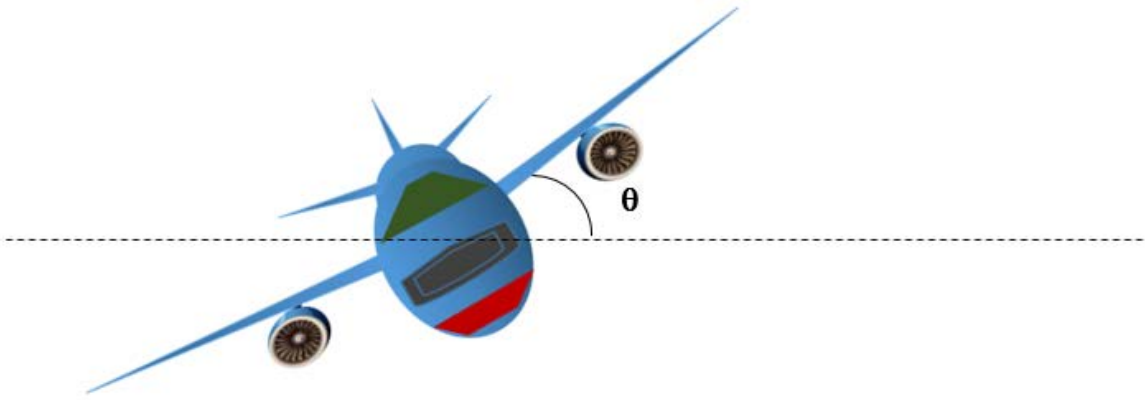
6.3.2 Determine the magnitude of the gravitational force that the rider exerts on the Earth. (radius of Earth = $6{,}4 \times 10^6$ m, mass of Earth = $6{,}0 \times 10^{24}$ kg) (4)

6.3.3 Comment on the statement that the rider is attracting the Earth towards her. (2)

[14]

QUESTION 7 CIRCULAR MOTION

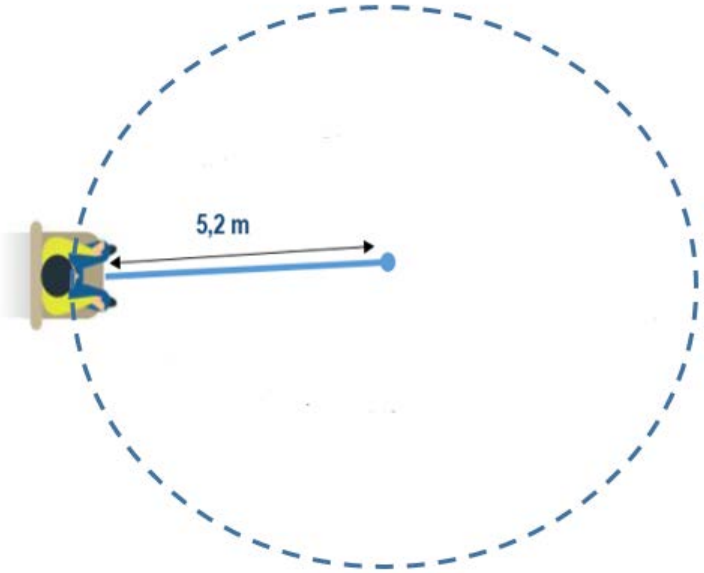
7.1 The diagram below shows an aeroplane banking to make a horizontal turn while traveling at a speed of 83 $m \cdot s^{-1}$. The radius of the turning circle is 900 m.



7.1.1 Draw a labelled free body diagram showing all the forces acting on the aeroplane. (2)

7.1.2 Calculate the angle θ that the aeroplane wings make with the horizontal. (4)

7.2 During training, a pilot (mass 84 kg) is tested by being spun around at high speed in a seat at the end of a beam as shown in the simplified diagram below.



7.2.1 Define *centripetal force*. (2)

7.2.2 Describe what the pilot will feel and relate this to centripetal force. (2)

7.2.3 When the system reaches its top speed, the pilot experiences a force equivalent to 5 times their own weight. For this top speed, calculate the following:

(a) The speed of the pilot. (3)

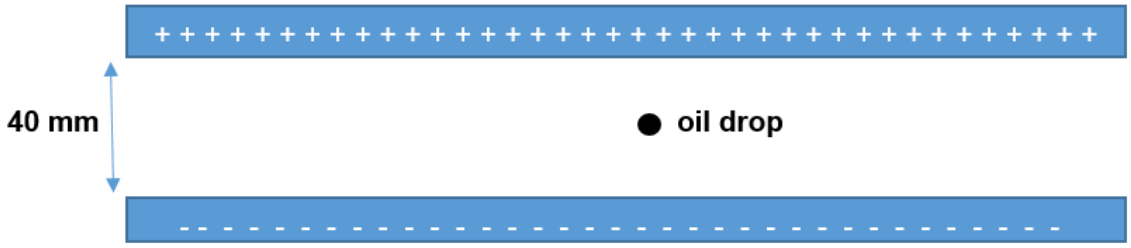
(b) The number of revolutions of the pilot per minute. (5)

7.3 Planets orbit the sun in a similar way. Use Newton's law of gravitation to derive Kepler's Law showing the relationship between the period and the radius of circular orbits. (4)

[22]

QUESTION 8 CHARGED PARTICLES IN ELECTRIC AND MAGNETIC FIELDS

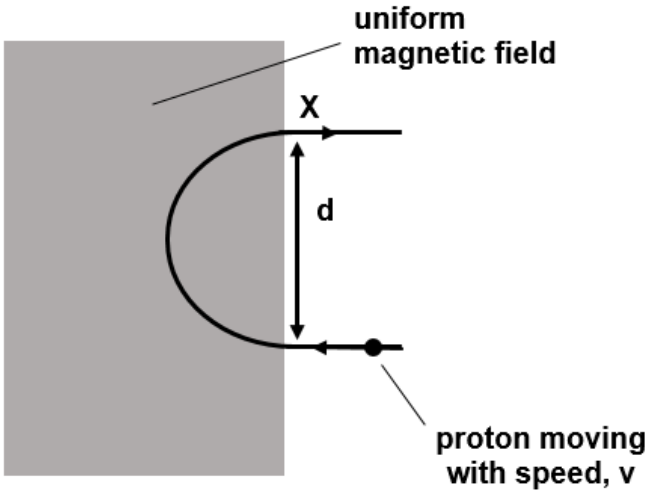
8.1 Robert Millikan devised an ingenious way to determine the charge on an electron by suspending tiny, charged droplets of oil in a uniform electric field as shown in the simplified diagram below.



8.1.1 On the diagram above, draw in the electric field. (2)

8.1.2 The oil drop of mass $5{,}60 \times 10^{-15}$ kg, is kept stationary between plates 40,0 mm apart by applying a potential difference of 490,0 V.
Determine the number of excess electrons present in the oil drop. (6)

8.2 A proton is travelling in a vacuum with speed of $4{,}1 \times 10^4$ m·s^{-1}. The proton enters a uniform magnetic field of flux density 8,7 mT at right angles as shown below and leaves the field at point X.



8.2.1 State the direction of the magnetic field. Only state into the page or out of the page. (2)

8.2.2 Explain why the proton follows a circular path when inside the region of the magnetic field. (2)

8.2.3 Explain why the speed of the proton is not affected by the magnetic field. (2)

8.2.4 Determine the diameter of the semi-circular path. (4)

[18]

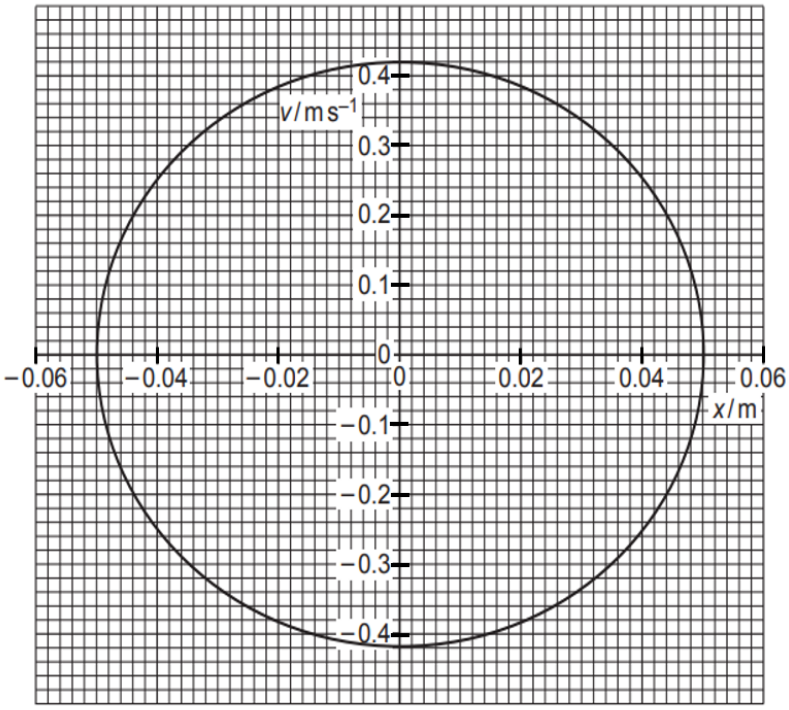
QUESTION 9 OSCILLATIONS

A pendulum bob of mass 120 g oscillates with simple harmonic motion with an angular velocity of 8,4 rad·s^{-1}.

9.1 When can motion be described as simple harmonic motion? (2)

9.2 Find the period at which the pendulum oscillates. (3)

9.3 The graph below shows the velocity vs the displacement for this oscillation.



9.3.1 Explain why there are two values of velocity for zero displacement. (2)

9.3.2 Calculate the acceleration of the mass at a displacement of 30 mm. (4)

9.4 Draw a sketch graph to show the corresponding acceleration vs time for the simple harmonic motion of the pendulum. The pendulum has a maximum displacement of + 0,05 m at t = 0 s. Indicate the equilibrium positions on the graph. (3)

9.5 The energy of this system is conserved.

9.5.1 Use a clear cross to indicate on the graph (on page 29) the position(s) where the potential energy of the mass is a maximum. (2)

9.5.2 Calculate the maximum kinetic energy of the mass. (4)

9.5.3 Draw a sketch graph of the kinetic energy vs displacement. No values need to be shown. (2)

[22]

Total: 200 marks

ADDITIONAL SPACE (ALL QUESTIONS)

REMEMBER TO CLEARLY INDICATE AT THE QUESTION THAT YOU USED THE ADDITIONAL SPACE TO ENSURE THAT ALL ANSWERS ARE MARKED.