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TOTAL MARKS

GRADE 12 EXAMINATION
NOVEMBER 2021

ADVANCED PROGRAMME PHYSICS

EXAMINATION NUMBER

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 34 pages and a Data Sheet of 2 pages (i–ii). Please check that your question paper is complete.
2. Read the questions carefully.
3. Use the data and formulae whenever necessary.
4. 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.
5. Diagrams are not necessarily drawn to scale.
6. You may use an approved non-programmable and non-graphical calculator.
7. 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.
8. Answers must be expressed using the correct significant figures.
9. Units need not be included in the working of the calculations, but appropriate units and significant figures should be shown in the final answer.
10. It is in your own interest to write legibly and to present your work neatly.
11. Two blank pages (page 33 and 34) are included at the end of the paper. If you run out of space for a question, use these pages. Clearly indicate the number of your answer should you use this extra space.

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 The volume of a liquid is 28,3 ml. Which of the following sets of readings represents the results with a good degree of accuracy but bad precision?

	Reading 1/ml	**Reading 2/ml**	**Reading 3/ml**	**Reading 4/ml**
A	28,3	28,5	28,1	28,4
B	29,0	28,3	27,3	28,6
C	24,3	24,5	24,2	24,1
D	28,3	14,6	28,3	14,6

1.2 To determine the intensity of light we need to determine the energy transferred to a unit area per unit time. What would the unit be for light intensity in SI base units?

A $kg \cdot m^{-2} \cdot s^{-1}$
B $kg \cdot s^{-2}$
C $kg \cdot m^{2} \cdot s^{-3}$
D $kg \cdot s^{-3}$

1.3 Which of the following best describes latent heat of fusion?

A The kinetic energy that particles acquire during melting.
B The potential energy that particles acquire during melting.
C The kinetic and potential energy that particles acquire during melting.
D The kinetic energy that particles lose during melting.

1.4 Which one of the following combinations correctly lists only elementary particles?

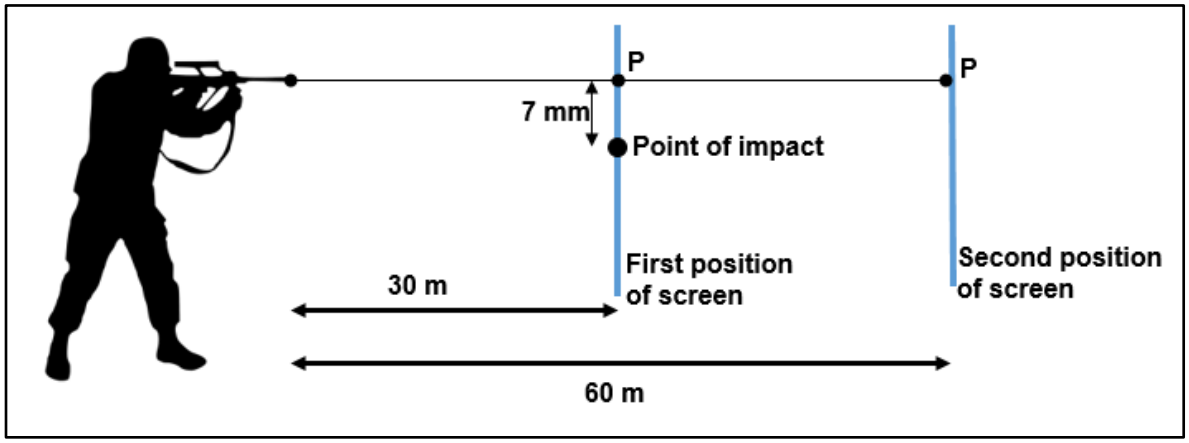
A electron, charm quark, tau neutrino
B top quark, proton, muon
C tau, down quark, neutron
D proton, neutron, electron

1.5 The half-life of a particular radioactive material is 10 days. What fraction of the sample will decay in 30 days?

A $\frac{7}{8}$
B $\frac{1}{8}$
C $\frac{1}{7}$
D $\frac{1}{3}$

1.6 At a shooting range, a rifle is fired horizontally towards a target, point P, on a screen. The screen is placed 30 m away from the rifle and the bullet strikes the screen at a point 7 mm below point P.

The screen is moved to a distance of 60 m away from the rifle and the rifle is fired for a second time.



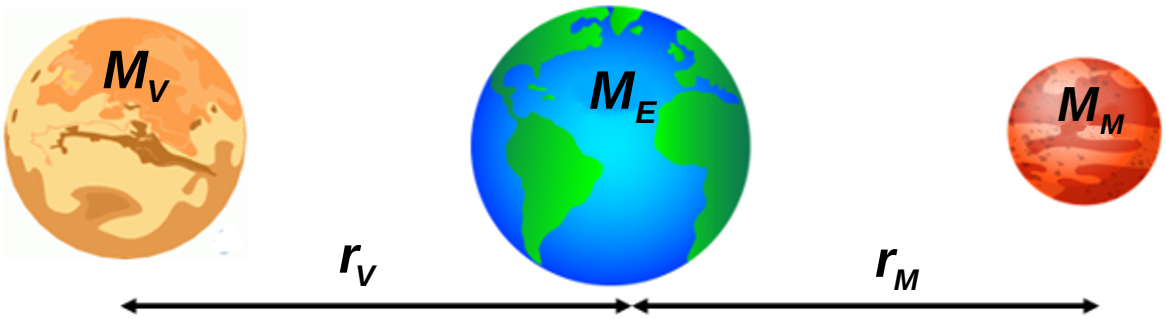
[Source: Adjusted from CIE 1982]

How far below point P will the bullet strike the screen when the bullet is fired the second time? (Air resistance can be ignored.)

A $7\sqrt{2}$ mm
B 14 mm
C 49 mm
D 28 mm

1.7 The Earth experiences a gravitational force (F_V) due to Venus as well as a gravitational force (F_M) due to Mars. Venus has a mass M_V and is a distance r_V from Earth. Mars has a mass M_M and is a distance r_M from Earth as shown in the diagram.

(The diagram is not to scale.)



Determine the ratio $\frac{F_V}{F_M}$

A $\frac{M_V}{M_M}\left(\frac{r_V}{r_M}\right)^2$

B $\frac{M_V}{M_M}\left(\frac{r_V}{r_M}\right)$

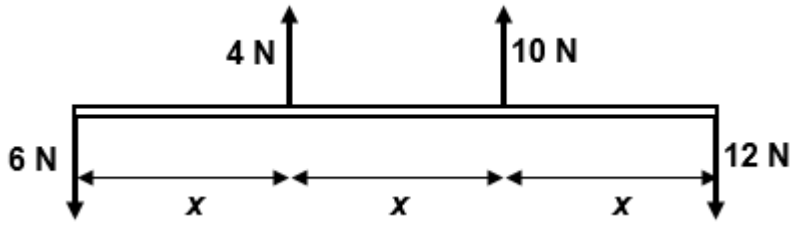
C $\frac{M_V}{M_M}\left(\frac{r_M}{r_V}\right)^2$

D $\frac{M_V}{M_M}\left(\frac{r_M}{r_V}\right)$

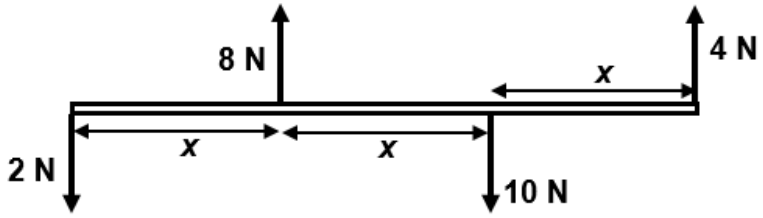
1.8 Four different forces act on a uniform beam of length 3***x***.

Which of the force diagrams below shows a system that causes rotational motion without any linear motion?

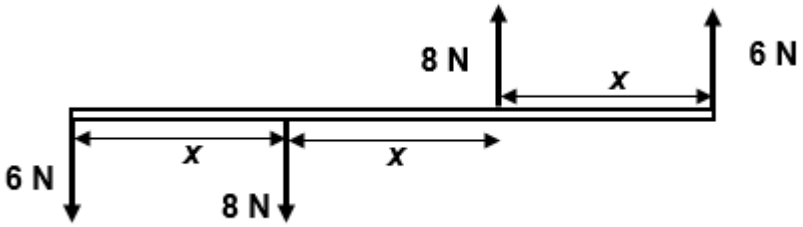
A



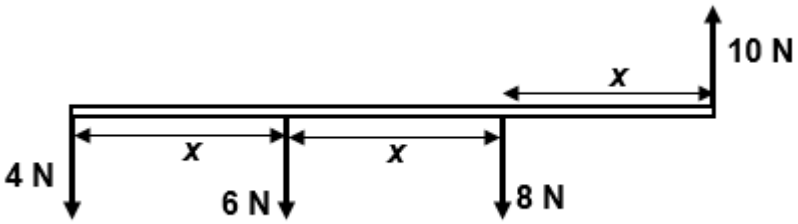
B



C



D



1.9 A negatively charged sphere with mass is kept at a constant height by placing it in a uniform electric field.

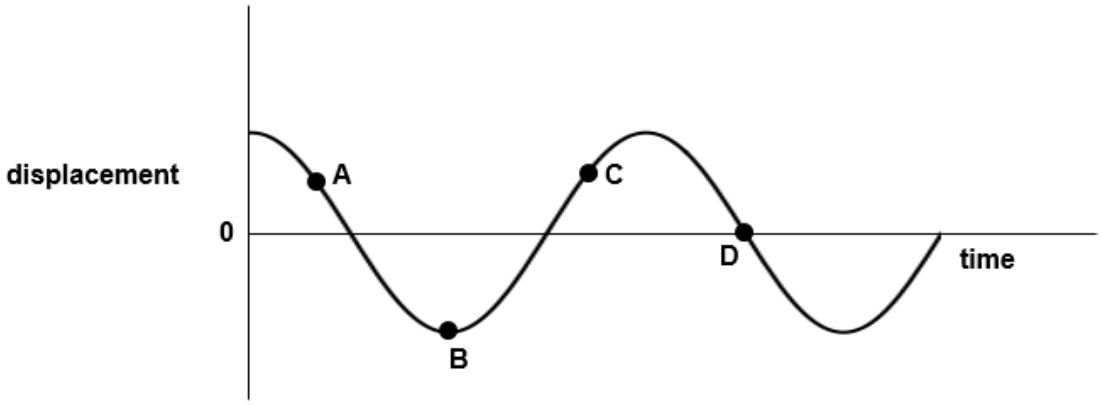
A uniform magnetic field is applied in the same direction as the electric field.

Which of the following combinations describes the direction of the fields and the motion of the sphere correctly?

	Direction of the fields	**Motion of the sphere**
A	Downwards	Remain stationary
B	Downwards	Move in a horizontal circle
C	Upwards	Move upwards in a spiral path
D	Upwards	Move downwards in a spiral path

1.10 A body performs simple harmonic motion as shown in the diagram below.

Which of the points indicated on the diagram shows a point where the velocity and the acceleration of the body are in opposite directions?



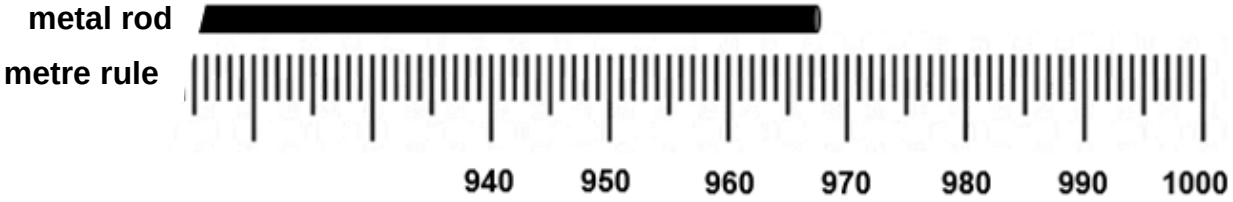
[20]

QUESTION 2 THERMAL PHYSICS

2.1 Determine the change in length of a metal rod before and after being heated from 25 °C to 78 °C. A metre rule is used to take the measurements.

State all readings and answers to the correct number of significant figures and include the uncertainties in all answers.

2.1.1 Measurement A at 25 ± 1 °C = _____ mm



2.1.2 Measurement B at 78 ± 1 °C = _____ mm

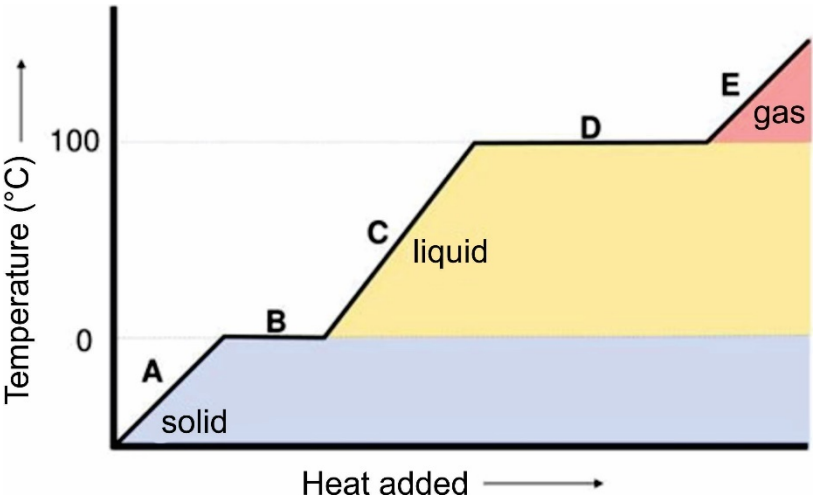
2.1.3 Determine ΔL.

(4)

2.2 Determine the coefficient of linear expansion for this metal. Include the absolute uncertainty in your final answer.

(6)

2.3 The diagram below shows a heating curve for water.



[Source: Chemistry connections to our changing world]

Explain why there is no increase in temperature during sections B and D.

(3)

2.4 Five ice cubes at –2,00 °C, each of mass 0,010 kg, are added to 200,0 g coffee in a paper cup.

(Useful information: L_f for water = 334 kJ·kg^{-1}; melting point of water is 0,00 °C; specific heat capacity for water and coffee is 4 190 J·kg^{-1}·K^{-1} and that of ice is 2 050 J·kg^{-1}·K^{-1}).

2.4.1 Define *specific heat capacity of a material.*

(2)

2.4.2 The initial temperature of the ice blocks is –2,00 °C. State this temperature in Kelvin.

(1)

2.4.3 Determine the amount of heat energy required to melt the five ice blocks.

(5)

2.4.4 Determine the final temperature of the coffee (initially at 75,0 °C) after the five blocks of ice have melted.

(5)

2.4.5 The final temperature of the coffee is measured, and the actual temperature is lower than that calculated in Question 2.4.4. Explain the reason for this lower temperature.

(3)
[29]

QUESTION 3 MATTER AND NUCLEAR PHYSICS

3.1 Plutonium-239 $\left(\begin{matrix}239\\94\end{matrix}Pu\right)$ is one of the main isotopes used in nuclear reactors. This isotope decays by the emission of an alpha-particle (α) to an isotope of uranium.

3.1.1 How many **down** quarks are in the nucleus of this isotope?

(4)

3.1.2 Complete the equation for this decay. Include all the nucleon numbers and proton numbers.

(2)

3.1.3 The strong nuclear force is responsible for nuclear stability.

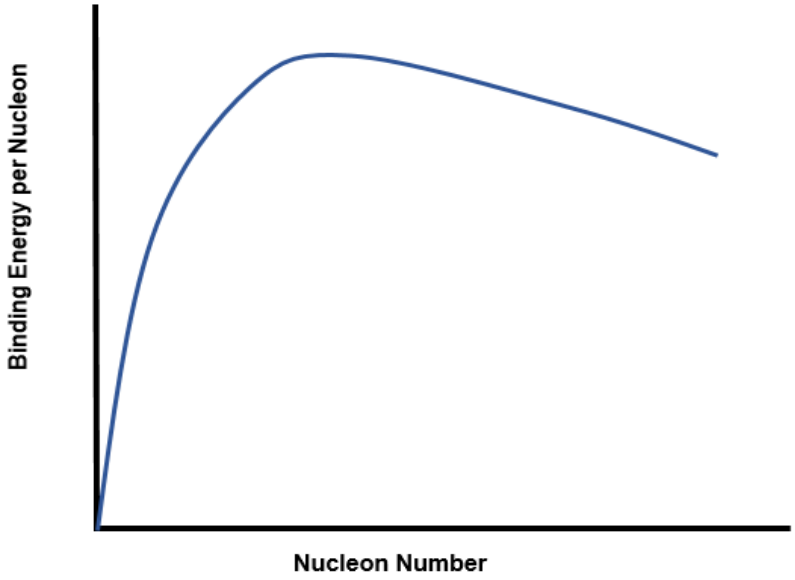
(a) Discuss the nature of this force by listing TWO features of the strong nuclear force.

(2)

(b) Name the exchange particles associated with this force.

(2)

3.2 The diagram below shows the binding energy per nucleon vs the nucleon number for atomic nuclei.



3.2.1 Define the term *binding energy per nucleon*.

(2)

3.2.2 On the diagram above, indicate the following clearly:

(a) Region in which nuclear fission takes place (mark as A).
(b) Region in which nuclear fusion takes place (mark as B).
(c) Region of greatest stability (mark as C).

(3)

3.3 Somewhere in the future scientists discover a nuclear warhead manufactured in 2021. They find that the warhead material contains a mixture of the radioactive plutonium *Pu*-239 and stable uranium *U*-235.

3.3.1 Explain why some nuclei are stable while others are unstable.

(2)

3.3.2 The half-life of the plutonium is 25 000 years. Determine the decay constant, λ.

(3)

3.3.3 The scientists analysed a sample taken from the warhead and determined the following:

Mass of $^{239}_{94}Pu$ present = $3{,}0 \times 10^{-6}$ kg

Mass of $^{235}_{92}U$ present = $9{,}0 \times 10^{-6}$ kg

Activity of the $^{239}_{94}Pu$ in the sample = $4{,}4 \times 10^{6}$ Bq

(a) What is meant by the term *activity*?

(2)

The scientists correctly assumed that the uranium was a by-product of the decay of the plutonium.

(Remember $n = \frac{N}{N_A} = \frac{m}{M}$)

(b) What fraction of the original plutonium atoms remains undecayed?

(5)

(c) How far into the future will the scientist discover this warhead?

$(x = x_0 e^{-\lambda t})$

(3)
[30]

QUESTION 4 ASTROPHYSICS AND COSMOLOGY

Although our Sun is an average-sized star, it is the most important source of energy on Earth.

4.1 What is the main energy source of stars?

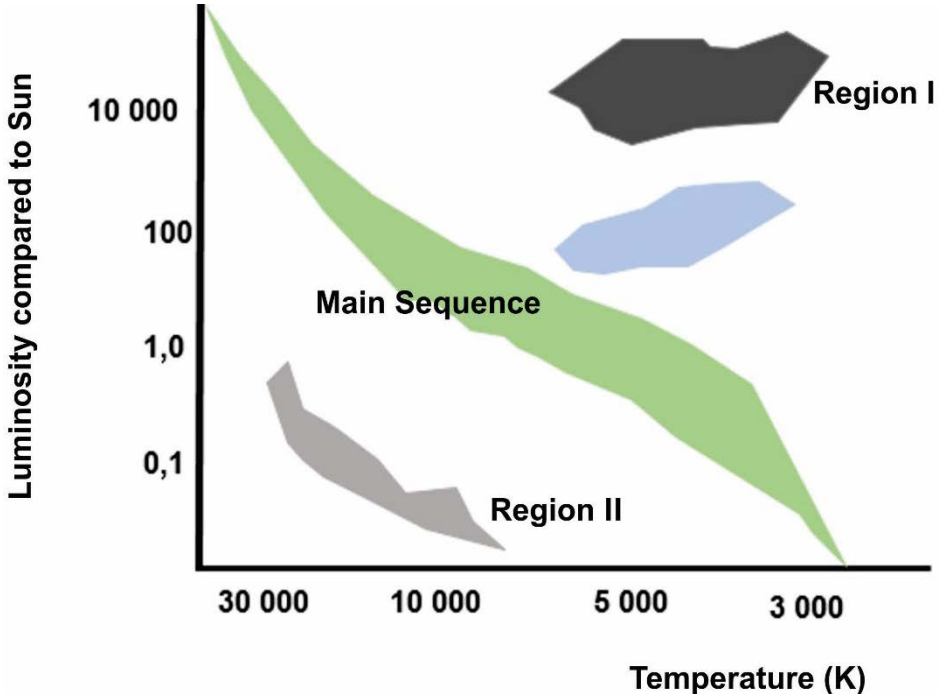
(2)

4.2 The surface temperature of the Sun is approximately 5 800 K. This is only a fraction, $\left(\frac{3}{20}\right)$ of the surface temperature of one of the hottest stars, Eta Carinae.

Use Wien's displacement law to calculate the maximum wavelength at which energy is radiated from Eta Carinae.

(4)

4.3 The figure below shows an HR-diagram representing the general regions of star types.



4.3.1 Identify the general star types that can be found in the regions indicated on the diagram.

(a) Region I

_____

(b) Region II

_____

(2)

4.3.2 Use a large cross to show the position of our Sun on the HR-diagram above.

(1)

4.3.3 From this cross, draw the evolutionary path of a star like our Sun on the HR-diagram above.

(2)

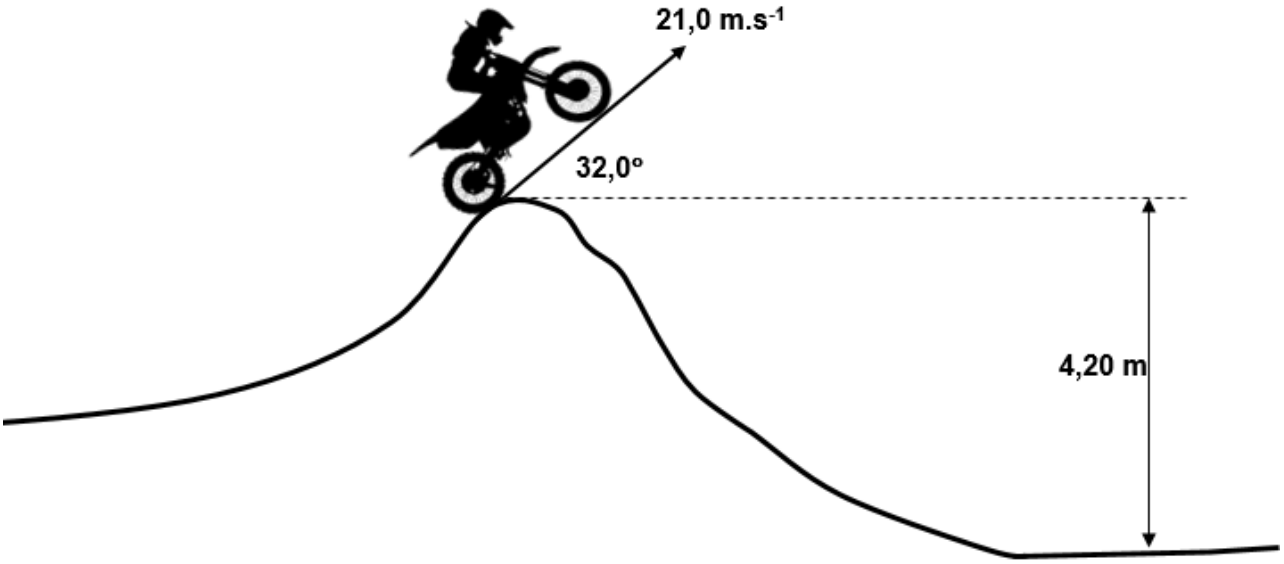
4.4 Only 5% of the universe consists of ordinary matter. Briefly discuss how galaxy rotation curves give evidence for dark matter. (You can use sketch graphs to aid your discussion.)

(3)
[14]

QUESTION 5 PROJECTILE MOTION

Robbie Maddison, the world record holder for the longest motorcycle jump, trains on rough terrain.

The diagram below shows his bike leave a hill at an angle of 32,0° to the horizontal at a velocity of 21,0 $m \cdot s^{-1}$. The landing platform is 4,20 m lower than the starting point.



5.1 Calculate the maximum height reached by the bike above the landing platform.

(5)

5.2 Determine the range of the bike.

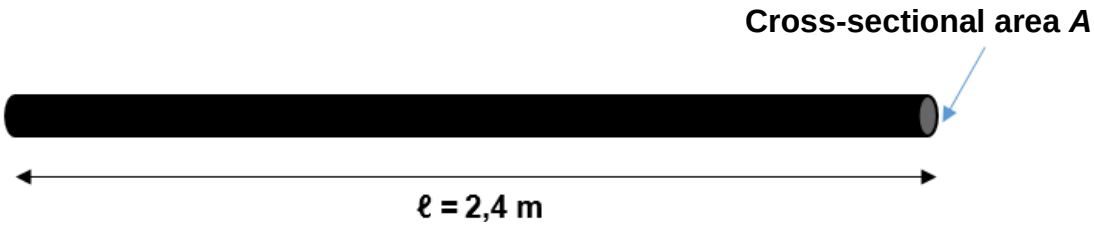
(6)

5.3 Calculate the velocity of the bike just as it reaches the landing platform.

(7)
[18]

QUESTION 6 FISHING AND TORQUE

6.1 A uniform rigid rod of length ℓ is shown below. The rod has a length of 2,4 m.



[Source: CIE 2020]

The rod has a weight W of 5,6 N and is made of wood of density $\rho = 780\ kg{\cdot}m^{-3}$. To determine the cross-sectional area of the rod, Amy uses the following equation:

$$W = \rho Vg$$

6.1.1 Use base units to prove that the equation is homogeneous.

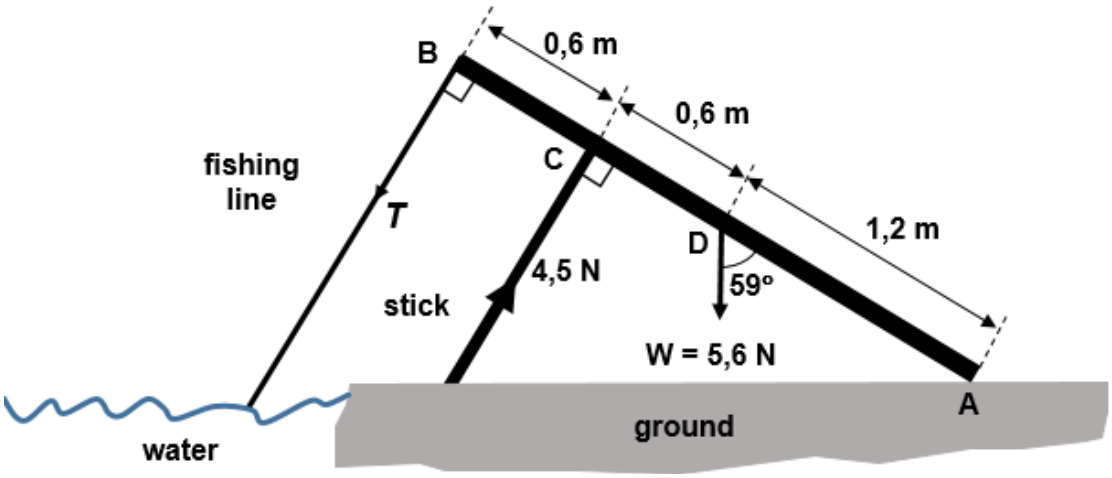
(3)

6.1.2 Calculate the cross-sectional area of the rod in mm^2.

(3)

6.2 The rod is used for fishing. End A of the rod rests on the ground and a fishing line is attached to the other end, B. To support the rod, a stick is placed perpendicular to the rod at point C. The weight of the rod acts at point D.

All forces and distances are shown in the diagram below.



[Source: CIE 2020]

The tension, *T*, in the fishing line is perpendicular to the rod and the rod is stationary at an angle of 59° to the vertical.

6.2.1 Explain why this system can be considered to be in equilibrium.

_____

_____

_____

(2)

6.2.2 Show that the component of the weight that is perpendicular to the rod is 4,8 N.

_____

_____

(1)

6.2.3 Use torque to calculate the magnitude of the tension, *T*, in the fishing line.

_____

_____

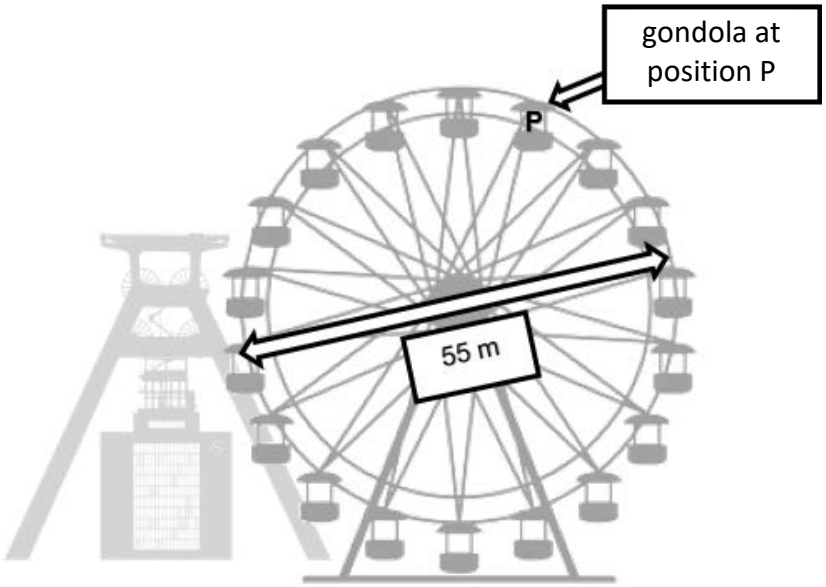
_____

_____

(3)
[12]

QUESTION 7 CIRCULAR MOTION AND DATA ANALYSIS

7.1 Gold Reef City is home to the largest Ferris wheel in South Africa. The big wheel at Gold Reef City has a diameter of 55 m and it takes 8 minutes for a gondola to complete a full rotation.



7.1.1 Calculate the distance that a gondola moves when it rotates through 0,60 radians.

(2)

7.1.2 Explain why the gondola is accelerating even though the wheel is turning at a constant speed.

(2)

7.1.3 Sketch an arrow (on the diagram above) to represent the resultant force acting on the gondola when it is at position P as shown.

(1)

7.1.4 Calculate the centripetal acceleration of a gondola.

(5)

7.2 Communication satellites are placed at 36×10^3 m away from the Earth's equator in geostationary orbits.

7.2.1 State two conditions required for a satellite to be in a geostationary orbit?

(2)

7.2.2 Use the relevant forces acting on a satellite to show that the speed v of a satellite in a circular orbit of radius r about a planet of mass M is given by the equation:

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

(3)

An investigation is carried out using a number of satellites at different distances r from the centre of the Earth and measuring the velocity v of each satellite at each distance.

The results obtained for $\frac{1}{r}$ and v^2 are shown in the table below. The uncertainties in v^2 were calculated based on the uncertainties obtained in the period and are included in the table.

$\frac{1}{r}$ / × 10^{-7} m^{-1}	v^2 / × 10^7 m^2·s^{-2}
1,52	6,2 ± 0,7
1,40	5,7 ± 0,7
1,10	4,4 ± 0,6
0,94	3,8 ± 0,6
0,52	2,1 ± 0,5
0,32	1,3 ± 0,3

7.2.3 On the graph paper provided on page 25:

(a) plot a graph of v^2 vs $\frac{1}{r}$.

(4)

(b) Include the error bars for v^2 on your graph.

(4)

(c) Draw the line of best fit as well as the steepest, least acceptable line on your graph. Label these lines clearly.

(3)

(d) State the relationship indicated by your graph. Motivate your answer by referring to your graph.

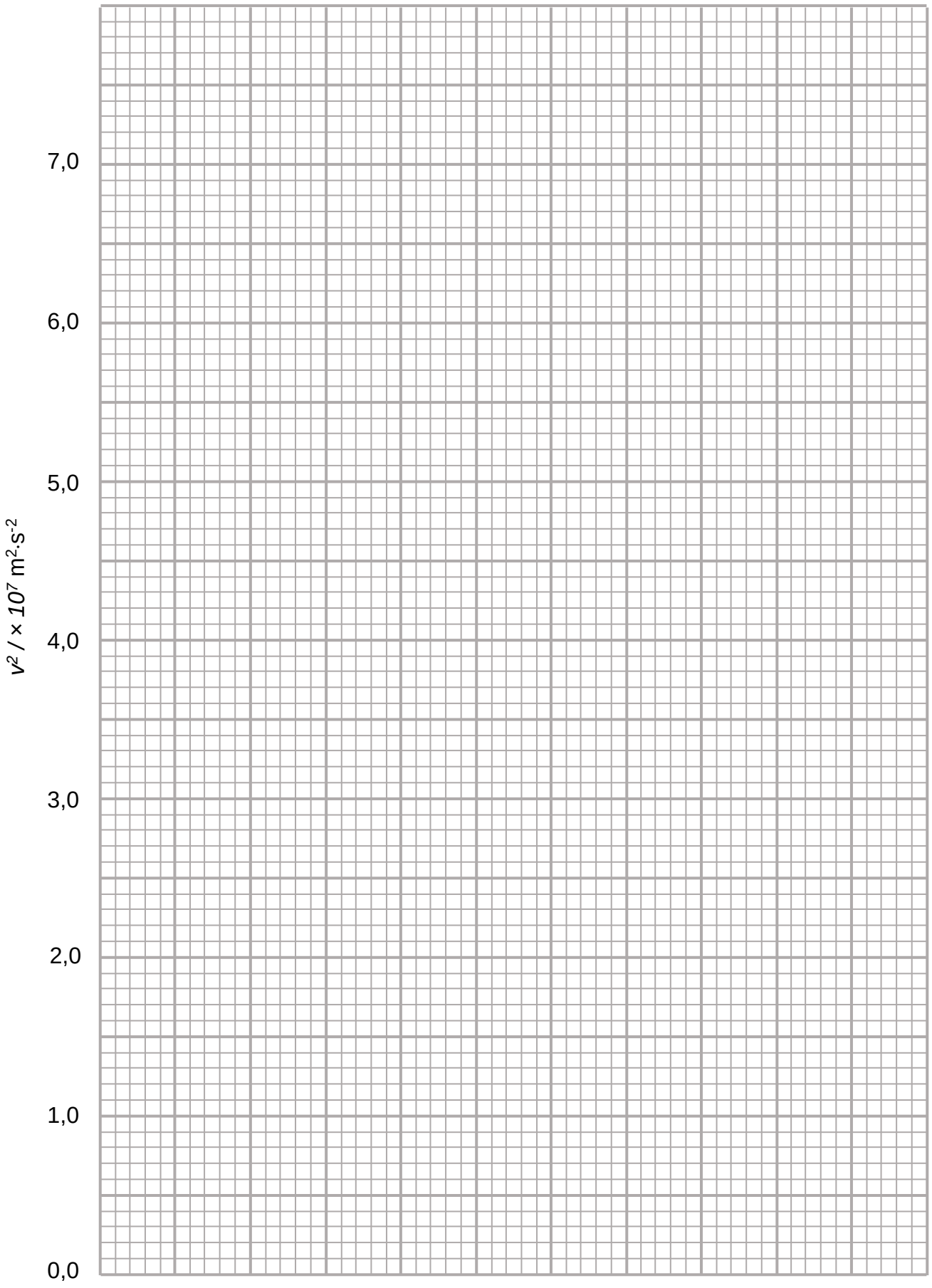
_____

_____

_____

_____

(3)



7.2.4 Determine the gradient of your line of best fit. Show clearly how you obtained values from your graph and include an absolute uncertainty in your answer.

(8)

7.2.5 Use the equation $v^2 = \frac{GM}{r}$ as well as the gradient calculated in Question 7.2.4 to determine the value of G. (Mass of the Earth = $5{,}98 \times 10^{24}$ kg.)

(3)
[40]

QUESTION 8 CHARGED PARTICLES IN ELECTRIC AND MAGNETIC FIELDS

8.1 The figure below shows two parallel plates placed a distance of 35 mm apart in a vacuum. A particle with a charge of –6 μC enters the uniform electric field of 400 $N \cdot C^{-1}$ with a velocity *v* of 500 $m \cdot s^{-1}$, as shown in the diagram below.

8.1.1 State the direction of the electric force acting on the charged particle. State only upwards (towards the negative plate), downwards (towards the positive plate), to the left, to the right, out of the page or into the page.

_____

(2)

8.1.2 A magnetic field is turned on between the plates to ensure the charged particle continues with a constant velocity.

(a) Calculate the magnitude of the magnetic field required to ensure that the charge has a constant velocity between the plates.

_____

_____

_____

_____

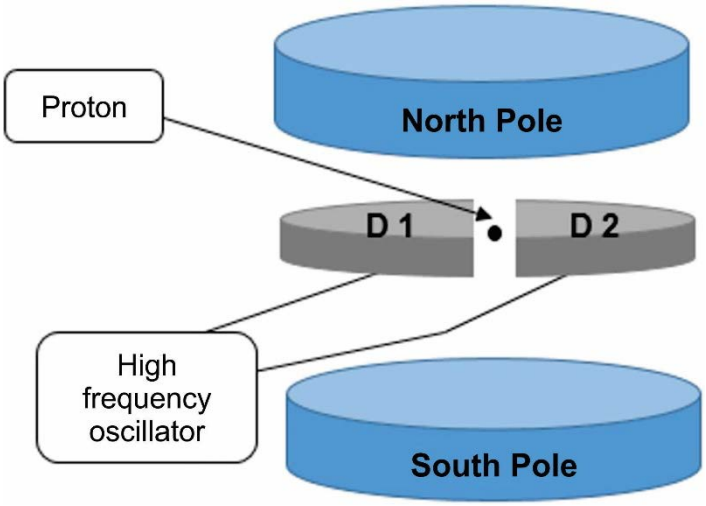
(3)

(b) State the required direction of the magnetic field.

_____

(2)

8.2 Cyclotrons are used worldwide to produce radionuclides for nuclear medicine. The diagram below is a schematic representation of the structure of a cyclotron. D1 and D2 are placed perpendicular to the magnetic field *B* of 1,3 T.



8.2.1 Name the main function of the following:

(a) The magnetic field

(2)

(b) D1 and D2

(2)

8.2.2 The proton reaches D2 with a speed of $7,5 \times 10^5$ $m \cdot s^{-1}$. Determine the radius of the circular path the proton follows across D2.

(5)

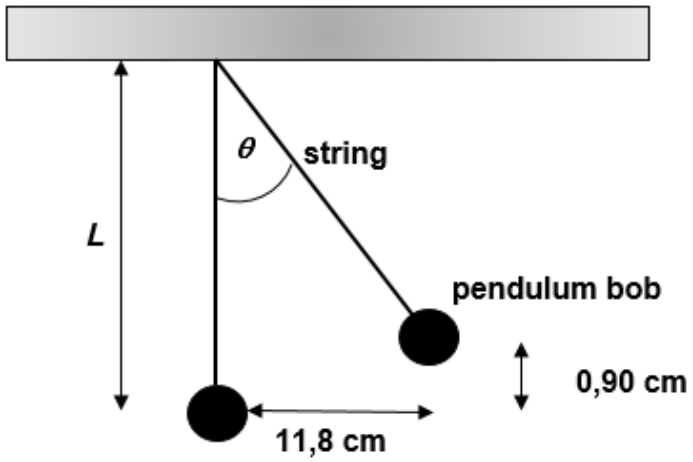
There are only about 70 synchrotrons in the world compared to over 1 500 cyclotrons.

8.2.3 Name two advantages of a synchrotron over a cyclotron.

(2)
[18]

QUESTION 9 OSCILLATIONS

A simple pendulum consists of a metal pendulum bob suspended from a string of length *L*.



The bob of mass 88,0 g is displaced to the right through a horizontal distance of 11,8 cm and a vertical distance of 0,90 cm. The bob is released so that it oscillates with simple harmonic motion.

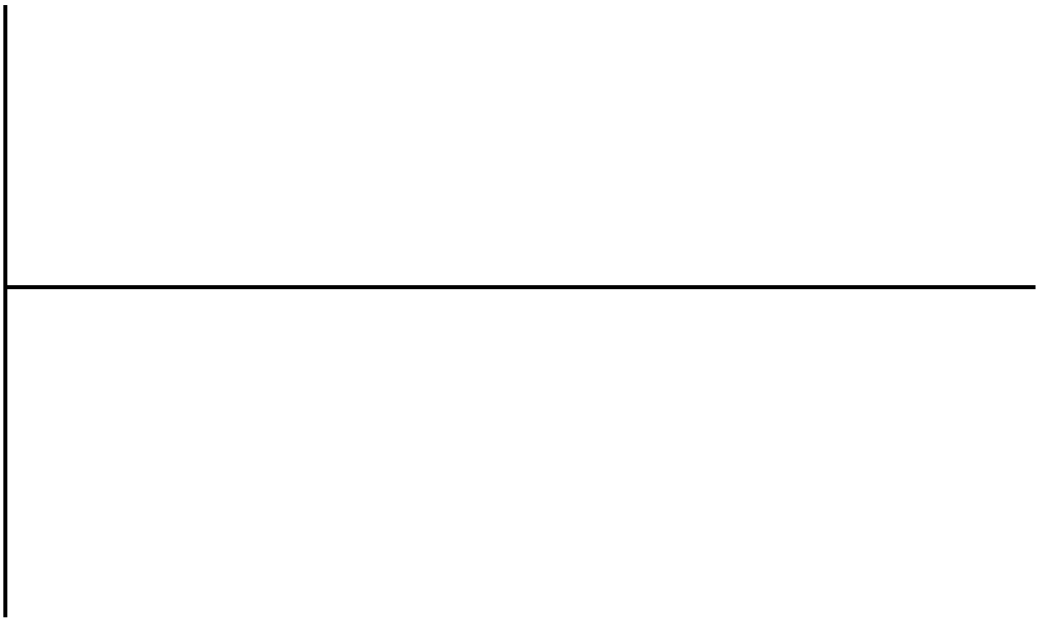
9.1 What is meant by *simple harmonic motion*?

(2)

9.2 Determine the **total** energy of the system.

(3)

9.3 Sketch a graph of the potential energy vs time for 2 complete oscillations of the bob. Only show already calculated values.



(4)

9.4 9.4.1 Draw a labelled free body diagram of the pendulum bob when the string is at an angle θ. Include θ in your diagram.

(3)

9.4.2 Determine an expression for the restoring force acting on the bob for a small angle, θ.

(2)

9.4.3 Use your answers to Questions 9.4.1 and 9.4.2 to derive the expression for the acceleration of a simple pendulum for a small angle, θ.

(3)

9.4.4 Hence, show that for a simple pendulum, $T = 2\pi\sqrt{\frac{L}{g}}$.

(2)
[19]

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.

