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TOTAL MARKS

INTERNATIONAL SECONDARY CERTIFICATE EXAMINATION
NOVEMBER 2023

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. THREE blank pages (pages 11, 30 and 31) and an extra graph grid (page 32) are included in 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.

FOR OFFICE USE ONLY: MARKER TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total
Mark									
Marker Initial									
Moderated Mark									
Moderator Initial									
Question Total	**20**	**21**	**28**	**34**	**21**	**35**	**23**	**18**	**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 The frequency of an object oscillating is 8,6 MHz. What is the frequency when expressed in kilohertz? (2)

A 0,0086 kHz
B 8,60 kHz
C $8{,}6 \times 10^{-3}$ kHz
D $8{,}6 \times 10^{3}$ kHz

1.2 Which of the following correctly gives the base units for kinetic energy? (2)

A $m \cdot a \cdot \Delta x$
B N·m
C $kg \cdot m^{2} \cdot s^{-2}$
D $kg \cdot m^{-2} \cdot s^{-2}$

1.3 Which one of the following statements about the specific latent heat of vaporisation (L_v) and the specific latent heat of fusion (L_f) of a material is true? (2)

A $L_v > L_f$
B $L_v < L_f$
C $L_v = L_f$
D $L_v \geq L_f$

1.4 How many hadrons, baryons and mesons are there in a nucleus of $^{58}_{28}Ni$? (2)

	hadrons	baryons	mesons
A	58	28	30
B	28	28	0
C	86	30	28
D	58	58	0

1.5 The nucleus of a radioactive nuclide undergoes beta-minus decay, then alpha decay and then beta-minus decay again. (2)

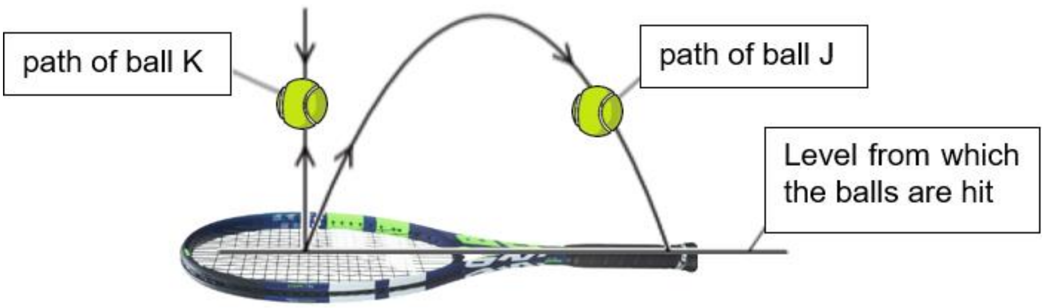
Which one of the statements below is true for the daughter nuclide formed?

A It now belongs to a different element and has a higher proton number.
B It now belongs to a different element and has a lower proton number.
C It is an isotope of the original element.
D It still belongs to the same element but has a different proton number.

1.6 Which one of the statements about dark matter and dark energy below is NOT true? (2)

A Ordinary matter accounts for 5% of the universe while dark matter makes up 26% and dark energy 69%.
B The fact that the velocity of stars decreases as we move from the centre of the galaxy to the outer edges, provides evidence for the existence of dark matter.
C Dark energy makes the universe expand.
D We can detect dark matter by observing gravitational lensing, which shows shifts in light when passing objects with mass.

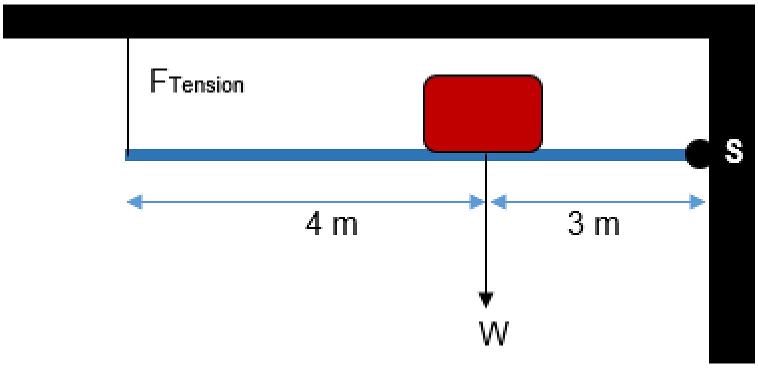
1.7 A tennis player hits two identical tennis balls, K and J into the air from the same height above the ground and they reach the same maximum height, as shown.



Ball K is hit vertically upwards and ball J is hit at an angle to the horizontal. Which one of the following quantities will be equal for ball K and J?

A Their velocity at the maximum height.
B Their initial velocity.
C The time they take to return to the ground.
D The distance they travelled by the time they reach the ground. (2)

1.8 A uniform beam of weight, W is pivoted against a wall at point S. A block of weight, W is supported by the beam as shown in the diagram below. What must the force, $F_{Tension}$ be to keep the beam in place? (2)



A $\frac{3}{7}$ W

B $\frac{13}{14}$ W

C $\frac{14}{13}$ W

D $\frac{7}{3}$ W

1.9 A particle of mass m undergoes simple harmonic motion with amplitude A and frequency f. Which one of the following expressions represents the total energy of the particle? (2)

A $2\pi^2 m f^2 A^2$
B $2\pi^2 m f A^2$
C $4\pi^2 m^2 f^2 A$
D $4\pi^2 m f^2 A^2$

1.10 In a cyclotron, particles are accelerated using a force field.

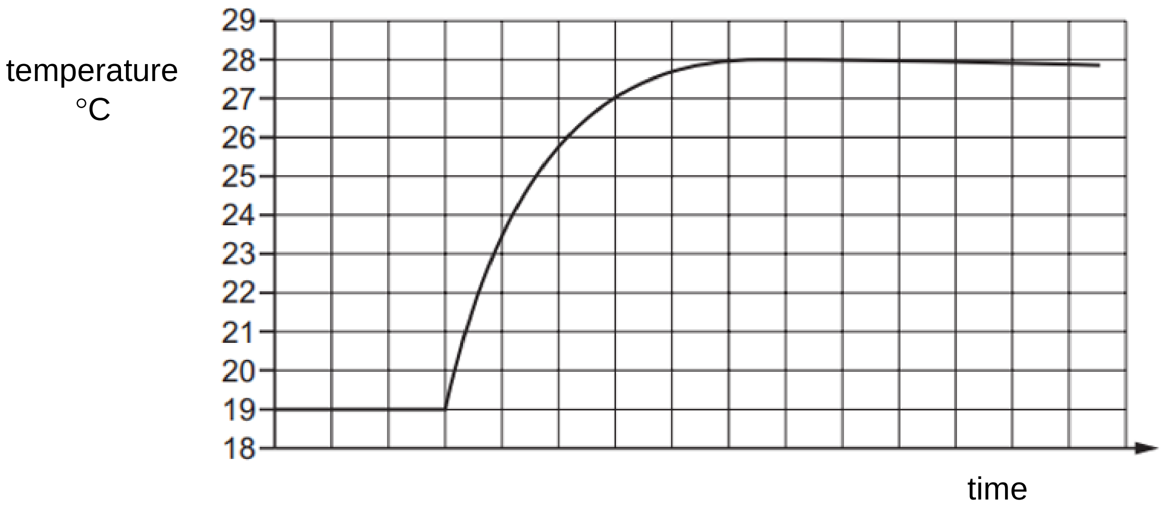
Which one of the following combinations of particle and field(s) will only cause an increase in the speed of the particle? (2)

	particle	**field**
A	electron	magnetic and electric field
B	neutron	magnetic and electric field
C	neutron	magnetic field only
D	proton	electric field only

[20]

QUESTION 2 THERMAL PHYSICS

An aluminium ball of 330 g at a temperature of 112 °C is dropped into 670 g (670 cm^3) of water at 19 °C in a measuring cylinder. A temperature sensor is used to record the variation of the temperature of the water with time. The results are shown below.



2.1 State the change in temperature in Kelvin. (1)

___

The coefficient of thermal expansion of the water is 207×10^{-6} K^{-1}.

2.2 Explain why the volume of the water increases. (3)

___

___

___

___

2.3 Calculate the change in the volume of the water. (3)

2.4 The coefficient of thermal expansion of aluminium is $23 \times 10^{-6}\ K^{-1}$.

2.4.1 Compare your answer in Question 2.3 with the level of water **actually** measured on the measuring cylinder from when the ball is first placed in the water to the level of water measured when an equilibrium between the ball and the water is reached at 28 °C. Only write LESS THAN, MORE THAN, or EQUAL TO. (1)

2.4.2 Explain your answer in Question 2.4.1. (2)

The specific heat capacity of water is $4\,200\ J{\cdot}kg^{-1}{\cdot}K^{-1}$

2.5 Define the specific heat capacity of a substance. (2)

2.6 Determine the specific heat capacity of the aluminium. (4)

The container is left for 2 days, and the level of the water reduced significantly.

2.7 Did the water evaporate or boil? (1)

2.8 Explain the difference between boiling and evaporation. (4)

[21]

QUESTION 3 MATTER AND NUCLEAR PHYSICS

3.1 Many nuclear reactors use uranium-235 $\left({}^{235}_{92}U\right)$ as a fuel.

The mass of a nucleus of uranium-235 is 235,04395 *u*.

3.1.1 Define *binding energy per nucleon.* (2)

3.1.2 Calculate the binding energy per nucleon for uranium-235 in joules. (5)

In nuclear reactors, a neutron is absorbed by the nucleus of *U*-235 to produce a nucleus of *U*-236.

The *U*-236 splits into *Zr*-94, *Te*-139 $\left({}^{139}_{52}Te\right)$ and some neutrons.

3.1.3 State the following: (2)

Number of neutrons produced: ______

Atomic number of *Zr*: ______

3.1.4 State if this process can be described as fission or fusion and explain why a reaction like this releases energy. (3)

3.1.5 This process involves two fundamental forces. Name each force according to the description given below.

(a) The force to overcome before the large nucleus can be split into smaller ones. (1)

___

(b) The force allowing the two smaller nuclei to separate from each other. (1)

___

3.2 Collisions between protons can provide a neutron to be absorbed by the nucleus of uranium.

However, all particle reactions must obey the conservation laws. The reaction below is **not** possible.

$$p + p \rightarrow p + e^{+} + v$$

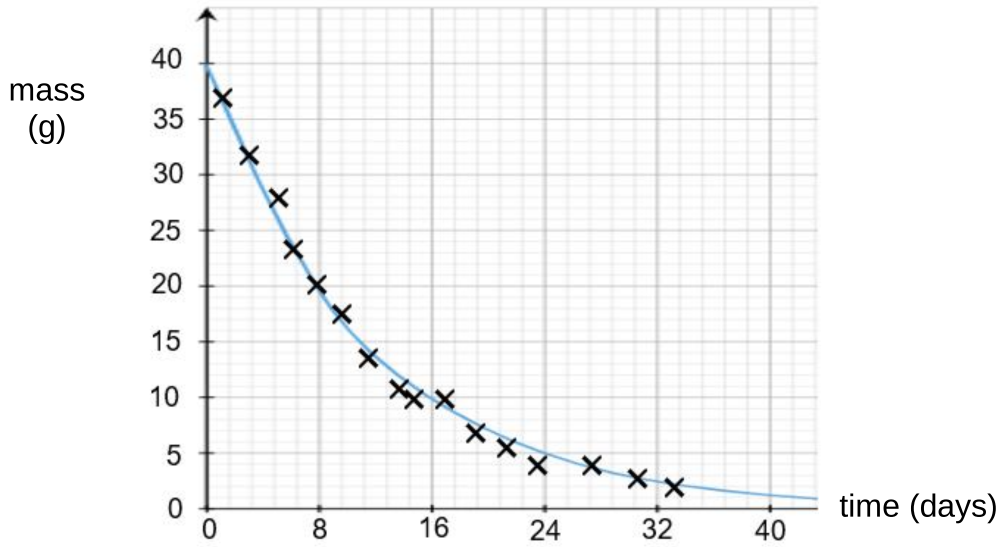
3.2.1 Name two fundamental particles represented in the reaction above. (2)

___

3.2.2 Name a conservation law that would be violated by this reaction. (1)

___

3.3 The graph below shows the mass vs time for a radioactive sample.



3.3.1 Refer to the nature of radioactive decay to explain why many of the points do not lie on the line of best fit. (2)

3.3.2 Define the *decay constant.* (2)

3.3.3 Determine the decay constant for this radioactive nuclide. (3)

3.3.4 Calculate how many days it will take for the sample to decrease to 10% of the original sample. (4)

[28]

ADDITIONAL SPACE (ALL QUESTIONS)

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

QUESTION 4 ASTROPHYSICS AND COSMOLOGY

Stars mainly emit light in a specific region of the electromagnetic spectrum. The peak wavelength emitted by stars depends on the average surface temperature of the star.

The table below gives a range of stars with their effective surface temperature, T and peak wavelengths, λ. The absolute uncertainties in λ and $1/\lambda$ are given in the table.

Name of star	Effective temperature, T (K)	Peak wavelength, λ (nm)	$1/\lambda$ ($\times 10^5$ m^{-1})
Altair	8100	400 ± 50	25 ± 3
Polaris A	7200	450 ± 50	22 ± 2
Alpha Centauri	5790	560 ± 50	18 ± 2
Arcturus	4590	670 ± 50	15 ± 1
Betelgeuse	3650	850 ± 50	
V1426 Cygni	2800	1100 ± 50	$9,1 \pm 0,4$

4.1 Name the main energy source in all the stars above. (1)

____

4.2 Complete the table by adding in the missing value for Betelgeuse with the absolute uncertainty.

Show the calculation you used to calculate the absolute uncertainty in the answer for Betelgeuse below. (4)

4.3 Justify the number of significant figures used in the values given for $1/\lambda$. (2)

____

____

4.4 On the grid on Page 13, plot a graph of T vs $1/\lambda$.
(Use the grid in landscape as given.) (4)

4.5 Include error bars for $1/\lambda$ on your graph. (2)

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

GRAPH GRID FOR QUESTIONS 4.4–4.6

4.7 Determine the gradient of the line of best fit. Include the absolute uncertainty and units in your answer. (7)

4.8 Wien's displacement law is given by $\lambda_{max}T = k$, where k is a constant. Using the gradient of your graph and this law, determine the predicted value of the constant in Wien's displacement law. (2)

4.9 Determine the percentage uncertainty in the proportionality constant given by your graph. (3)

4.10 The mass of Betelgeuse is $2{,}19 \times 10^{31}$ kg and that of Rigel is $3{,}58 \times 10^{31}$ kg.

How many times more luminous is Rigel than the Betelgeuse?

(mass of the Sun = $1{,}99 \times 10^{30}$ kg, a = 3,8) (4)

4.11 Explain why a black hole will be the most probable fate of Rigel.

Motivate your answer with a calculation. (3)

[34]

QUESTION 5 PROJECTILE MOTION AND LEVERS

5.1 A rugby ball is kicked from the ground towards the posts at a velocity of 19,5 $m{\cdot}s^{-1}$ at an angle of 42° to the horizontal as shown below. The horizontal bar of the post is 3,4 m above the ground. Air resistance can be ignored. The diagram is not drawn to scale.

5.1.1 Calculate the maximum height reached by the rugby ball. (3)

5.1.2 Show that the minimum speed of the ball travelling towards the post is 14,5 $m{\cdot}s^{-1}$. (2)

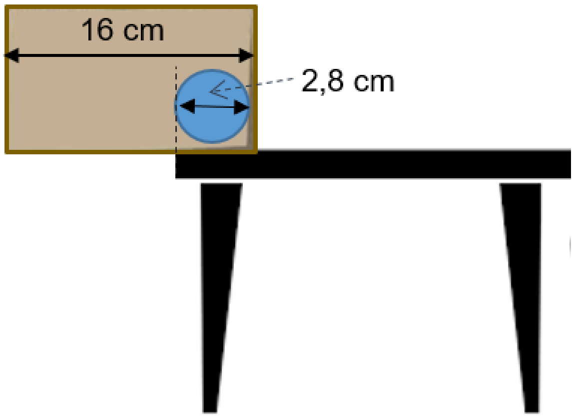
5.1.3 Explain your answer to Question 5.1.2. (2)

5.1.4 The ball just passes over the crossbar on its downward trajectory. Determine the time that it takes for the ball to reach the crossbar. (4)

5.1.5 How far from the post is the player positioned to get the ball to just pass over the crossbar? (2)

5.2 Students place a box on the edge of the table with the greater part of its length overhanging the edge of the table. A sphere is placed against the one side inside the box, as shown.

The length and the weight of the box is 16 cm and 0,56 N respectively. The sphere has a diameter of 2,8 cm.



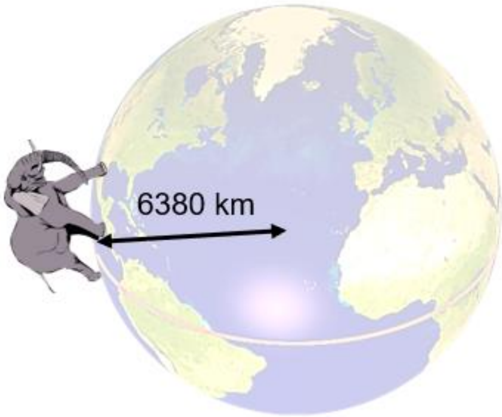
5.2.1 State the conditions for translational and rotational equilibrium of a rigid body and explain why the box does not topple off the table. (3)

5.2.2 Calculate what the mass of the sphere should be to just keep the box from falling off the table. (5)

[21]

QUESTION 6 CIRCULAR ORBITS

6.1 An elephant stands on the equator of the Earth. The radius of Earth at the equator is 6 380 km and the mass of the Earth is $5,97 \times 10^{24}$ kg. The Earth rotates about its axis with a period of 24 hours.



not to scale

6.1.1 Calculate the linear displacement of the elephant that corresponds with an angular displacement of 1,55° of the Earth. (3)

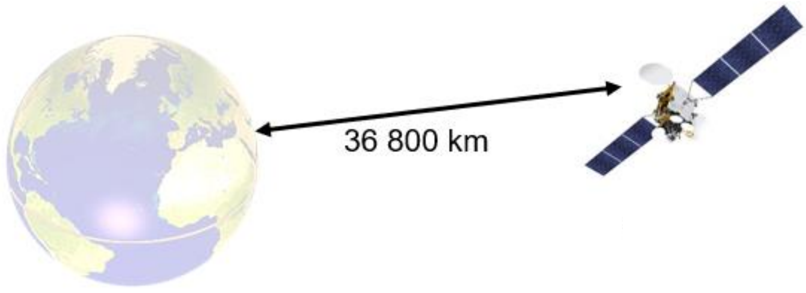
6.1.2 Draw a free body diagram showing all the forces acting on the elephant while the Earth is rotating. (2)

6.1.3 Calculate the centripetal acceleration of the elephant. (5)

6.1.4 At what speed must the Earth spin for the elephant to be weightless? (4)

6.1.5 Hence, calculate the hypothetical length of a day (in hours) for the speed calculated in Question 6.1.4. (4)

6.2 The Inmarsat-4 F3 orbits the Earth at 36 800 km above the surface.



[<satelliteprome.com>]

6.2.1 Derive Kepler's law that shows the relationship between the period of the rotation of a satellite and the distance from the centre of the Earth. Hence, use this law to calculate the period of the satellite. (5)

6.2.2 Calculate the orbital speed of the satellite. (4)

6.2.3 Determine if Inmarsat-4 F3 is a geostationary satellite. (4)

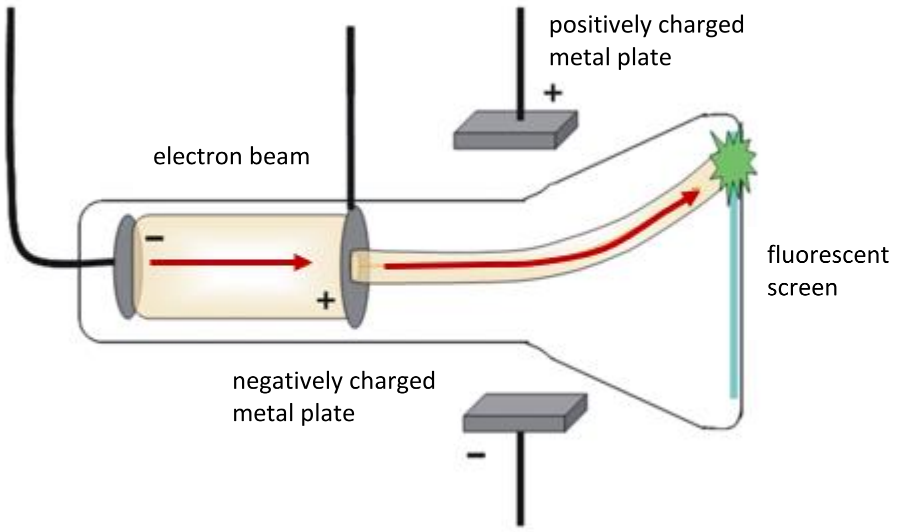
6.2.4 The satellite uses its boosters to move further from the Earth. What must happen to the satellite's speed to remain in a stable orbit? (2)

6.2.5 State one reason why communications satellites should be in geostationary orbits. (2)

[35]

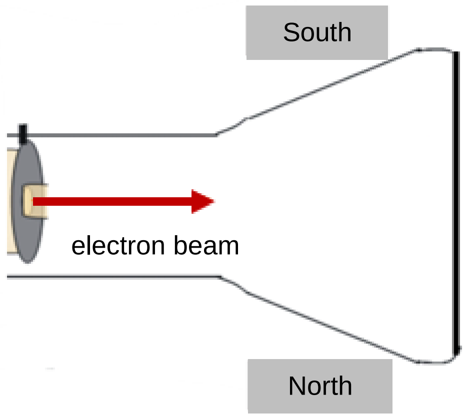
QUESTION 7 CHARGED PARTICLES IN ELECTRIC AND MAGNETIC FIELDS

7.1 The figure below shows a cathode ray tube in which a high-speed electron beam strikes a fluorescent screen.



7.1.1 The beam of electrons gets deflected by two metal plates with a potential difference of 32 V applied across them. The distance between the metal plates is 5,0 cm. Calculate the strength of the electric field between the plates. (3)

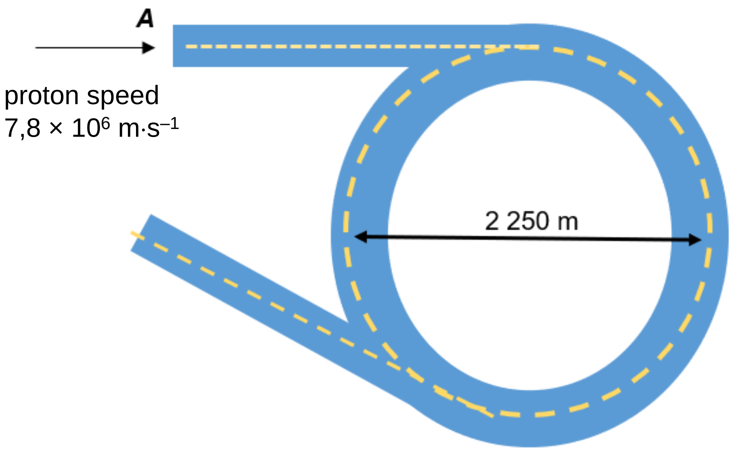
7.1.2 State the direction of motion of the electron if the electric field was replaced by a magnetic field as shown. (2)



7.1.3 An electron enters the magnetic field of $1{,}5 \times 10^{-4}$ T with a velocity of $7{,}5 \times 10^{7}$ m·s^{-1}.

Calculate the magnitude of the force acting on the electron. (3)

7.2 The diagram below shows a schematic diagram of a proton synchrotron used to accelerate protons to high speeds in a horizontal circular path.



7.2.1 Although the main function of a synchrotron is to accelerate charged particles, it is also a source of useful radiation. Name the radiation produced by a synchrotron and state one function of this radiation. (2)

7.2.2 Protons are injected at point A with a speed of $7{,}8 \times 10^{6}$ m·s^{-1}. The diameter of the synchrotron is 2 250 m. Calculate the magnetic flux density needed to keep the proton in the circular path. (4)

7.2.3 Protons enter at A with a specific speed. A combination of electric and magnetic fields is used in the selection of a specific speed. Explain how this is achieved and derive an expression for the speed in terms of the fields. (4)

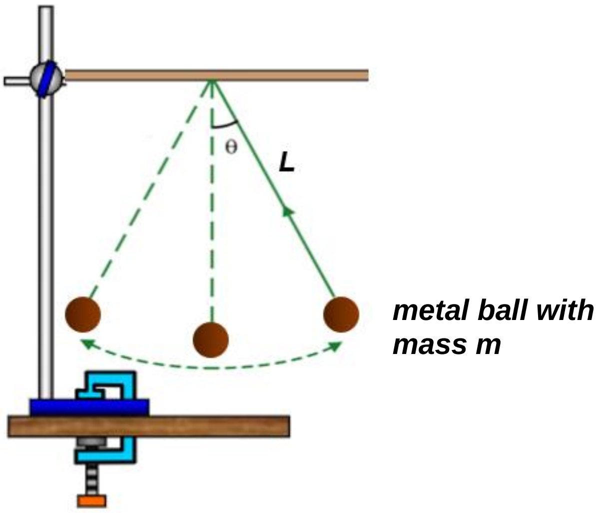
7.2.4 The proton is replaced by an electron. State two ways in which the magnetic field must be adjusted for the electron to follow the same path as the proton. (3)

7.2.5 Other charged particles can be injected into the synchrotron to cause collisions. Explain how high-energy collisions produce other subatomic particles of large mass. (2)

[23]

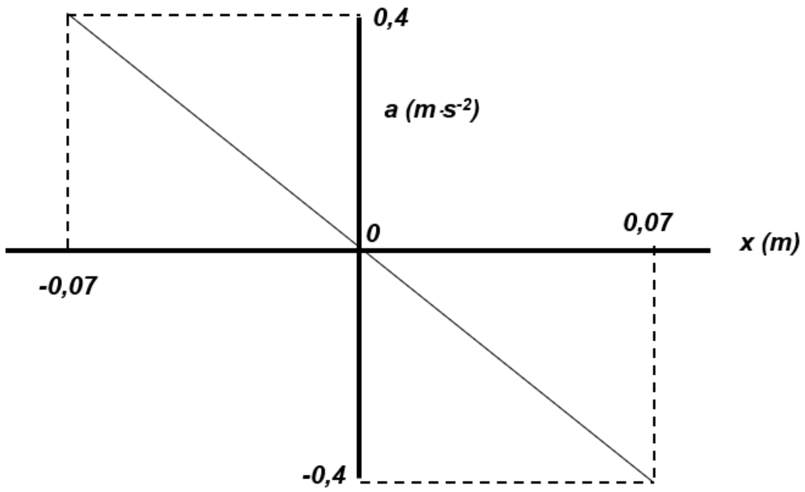
QUESTION 8 OSCILLATIONS

A simple pendulum is constructed by suspending a metal ball from a fixed point using an inextensible string of length *L*. When the pendulum is displaced at an initial angle θ and released, it swings back and forth with simple harmonic motion.



The length L of the pendulum is measured from the fixed point to the centre of the metal ball.

The sketch graph below shows how the acceleration (a) of the metal ball varies with the displacement (x) from the equilibrium position.



8.1 What features of the graph show that the pendulum undergoes simple harmonic motion? (2)

___

___

___

8.2 Use the graph to determine the angular frequency of the oscillations. (3)

8.3 Calculate the period of the oscillations of the pendulum. (3)

8.4 Use the conservation of mechanical energy to show that the maximum speed of the pendulum is given by the equation below. The angle, θ, is shown in the diagram on Page 27. (3)

$$v = \sqrt{2gL(1 - \cos\theta)}$$

8.5 A longer string was used for the same mass and the same angle of release. State how the following variables will be affected. Only write **increase**, **decrease** or **remains the same**.

(a) Period: ____ (1)

(b) Velocity: ____ (1)

8.6 Explain your answer given in Question 8.5 (b). (2)

____

____

8.7 Draw a sketch graph showing the displacement vs time when the oscillations are damped. (3)

[18]

Total: 200 marks

ADDITIONAL SPACE (ALL QUESTIONS)

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ADDITIONAL SPACE (ALL QUESTIONS)

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

ADDITIONAL GRAPH GRID: QUESTIONS 4.4–4.6

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