CSSA

Centre Number

Student Number

Physics

Afternoon Session
Tuesday, 9 August 2022

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Use the Multiple-Choice Answer Sheet provided
- NESA-approved calculators may be used
- A data sheet, formulae sheet and Periodic Table are provided SEPARATELY
- Write your Centre Number and Student Number on the top of this page

Total marks:
100

Section I – 20 marks (pages 2 – 12)
- Attempt Questions 1 – 20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 13 – 29)
- Attempt Questions 21 – 33
- Allow about 2 hours and 25 minutes for this section

Section I
20 marks

Attempt Questions 1 – 20
Allow about 35 minutes for this part

Use the Multiple-Choice Answer Sheet for Questions 1 – 20.

1   Both U^{235} and O^{16} can be used in nuclear reactions to produce energy. They are shown on the binding energy per nucleon graph below.
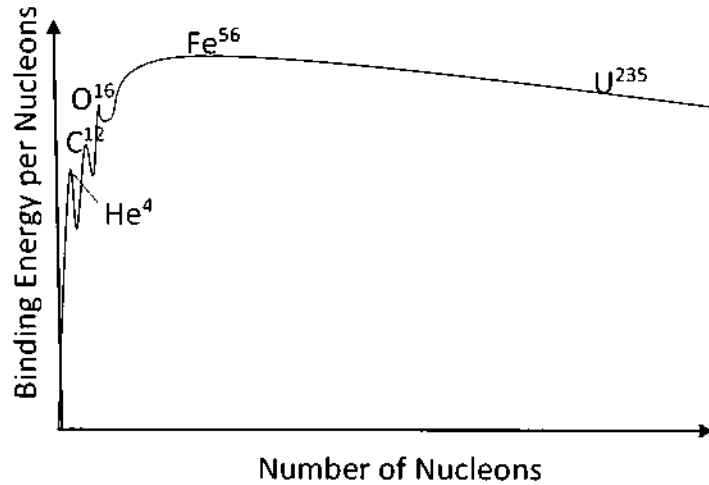
Which row of the table below correctly identifies the type of energy-producing nuclear reaction that applies to these nuclides?

	U^{235}	O^{16}
A.	fission	fusion
B.	fission	fission
C.	fusion	fission
D.	fusion	fusion

2 Ultrasound has a range of uses including medical imaging, industrial scanning, and echolocation.

Which of the following wave properties is not employed when using ultrasound waves?

A. Diffraction

B. Interference

C. Polarisation

D. Reflection

3 In an early thought experiment, Newton imagined a projectile fired horizontally with different initial speeds from the top of a very high mountain. The diagram below charts the hypothesised path of three cannon balls X, Y and Z launched with different initial speeds.
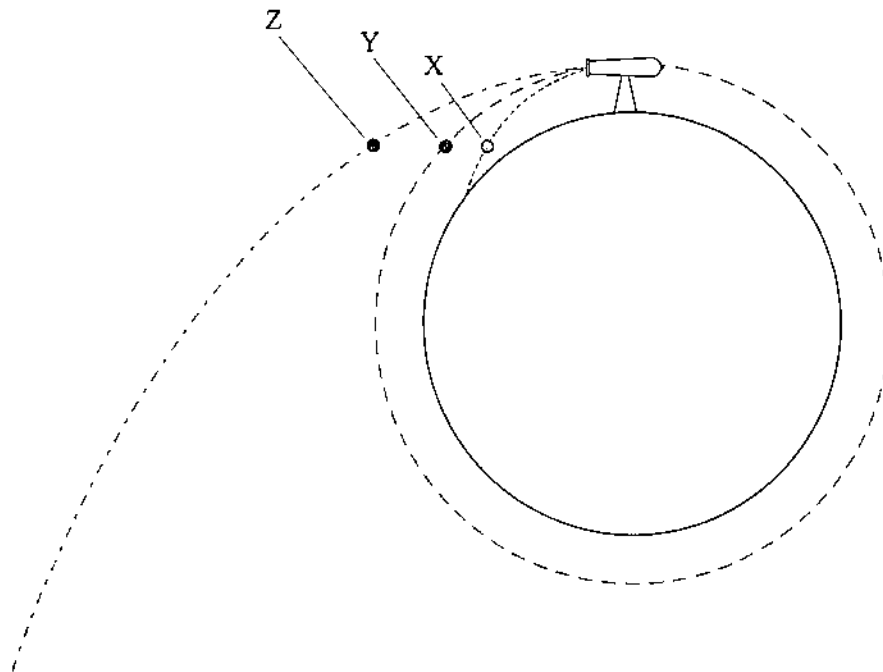
Which of the following is correct about the initial speed of the cannon balls?

A. Ball X has a launch speed greater than ball Z.

B. Ball X has a launch speed equivalent to the orbital velocity.

C. Ball Y has a launch speed that is less than the escape velocity.

D. Ball Y has a launch speed that is greater than the escape velocity.

4 Which row of the table correctly lists the six types of quarks with their main force carrier?

	Types of quarks	Main force carrier
A.	Right, left, up, down, charm, strange	W and Z bosons
B.	Right, left, up, down, charm, strange	gluon
C.	Up, down, charm, strange, top, bottom	W and Z bosons
D.	Up, down, charm, strange, top, bottom	gluon

5 An exoplanet is a planet orbiting a star in a solar system other than our own. In a Physics Depth Study, a student collected and organised astronomical data for stars and exoplanets in several known solar systems in the Milky Way galaxy. She plans a spreadsheet with the column headings shown below.

solar system name	central star name	central star mass (kg)	exoplanet name	exoplanet mass (kg)	exoplanet orbital radius (km)	exoplanet orbital period (Earth years)

To calculate the mass of the central star in each solar system, she needs to know

A.   the total mass of the exoplanets in that system.

B.   the mass and orbital period of at least one exoplanet in that system.

C.   the mass and orbital radius of at least one exoplanet in that system.

D.   the orbital radius and orbital period of at least one exoplanet in that system.

6 A projectile is released three times with the same velocity at different launch angles.

Which of the following statements is correct if the launch angles are 30°, 45° and 60°?

A.   The range and maximum height will be the same for each launch angle.

B.   The projectiles launched at 30° and 60° will have different maximum heights.

C.   The projectiles launched at 30° and 60° will have the same maximum height.

D.   The projectile launched at 45° will have both the greatest range and maximum height.

7   Which of the following postulates is true in BOTH Galilean and Special Relativity?

   A.   Velocities of objects can be infinite.

   B.   The mechanical laws of physics are the same for all inertial observers.

   C.   The mechanical laws of physics change depending on how fast the object is travelling.

   D.   The relative velocity between two objects is equal to the difference between their two velocities.

8   Parallel metal plates are separated by distance d. They are connected to a DC power supply, with voltage V. A positively charged particle, q, is placed a distance x from the positive plate as shown.
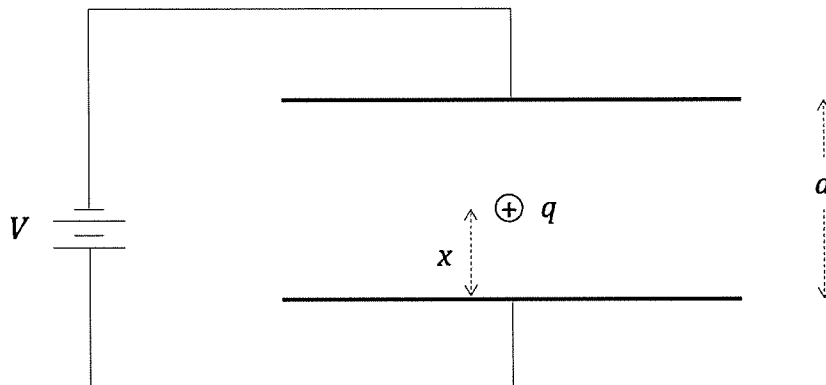
The electric force experienced by q is dependent on the size of V, x, and d.

Which row in the table correctly identifies how these factors affect the size of the electric force experienced by the charge q?

	Increases force on q	Reduces force on q
A.	increasing V	increasing x
B.	increasing d	increasing V
C.	decreasing x	decreasing d
D.	decreasing d	decreasing V

9   An electron in a hydrogen atom moves from energy level 3 to 1.

     What wavelength will the emitted photon have?

     A. 1.03×10^2 nm

     B. 1.37×10^2 nm

     C. 3.03×10^2 nm

     D. 3.25×10^7 nm

10. The graph below shows the current in the secondary coil of a transformer as the current in
     the primary coil is varied.
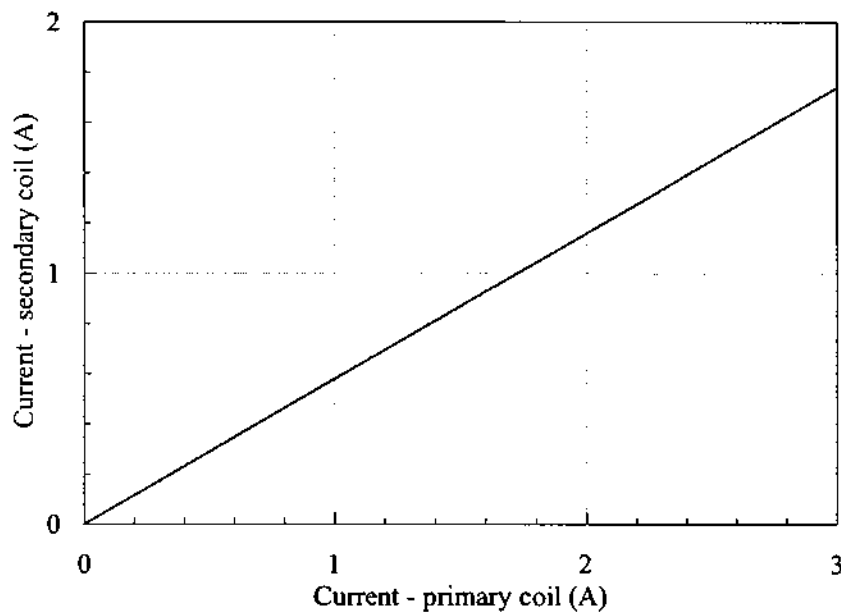
     If there are 580 turns in the primary coil, the number of turns in the secondary coil is closest
     to

     A.   330

     B.   350

     C.   660

     D.   1000

11 Two exoplanets, X and Y, are in circular orbits around their central star in a remote solar system. Their masses are identical, and their orbital radii are R and 9R, respectively.

What is the ratio of their orbital periods, $T_X : T_Y$?

A.   1 : 3

B.   1 : 9

C.   1 : 27

D.   1 : 54

12 The graph shows the frequency of radiation being produced by a hot body.
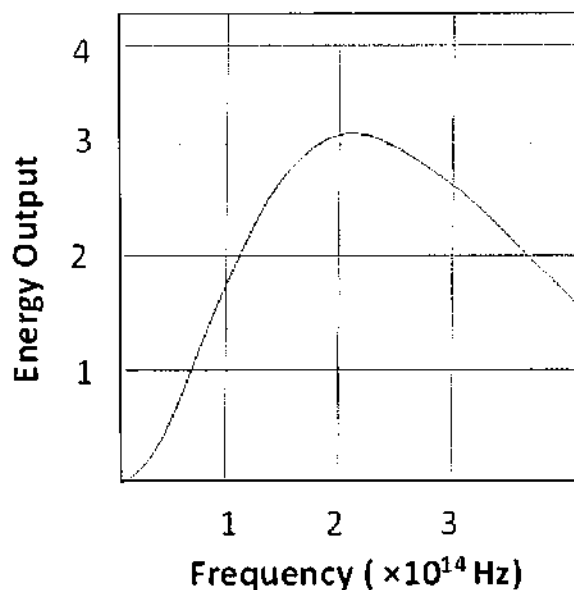
Determine the temperature of the body using the energy output graph above.

A. 1.32×10^{-17} K

B. 1.45×10^{-3} K

C. 2.03×10^{3} K

D. 2.42×10^{3} K

13 A particle enters a 0.2 T magnetic field with a velocity of 5.74×10^5 m s^{-1}. The particle exits the field 0.06 m above where it entered the field, as shown below.

0.06 m

$v = 5.74 \times 10^5$ m s^{-1}

B = 0.2 T
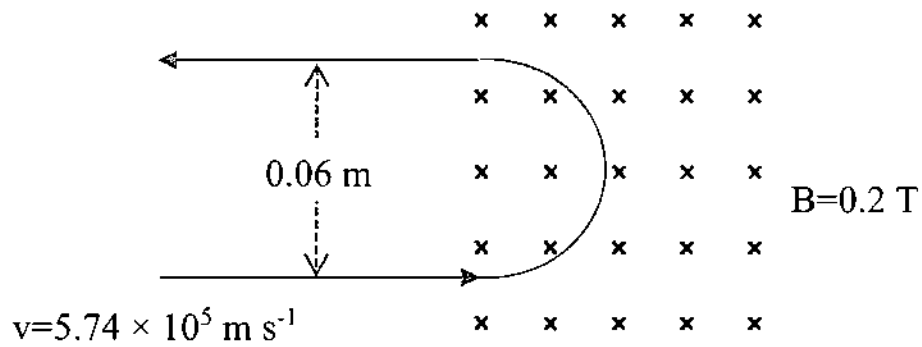
The particle is most likely

A.   a proton.

B.   a neutron.

C.   an electron.

D.   an alpha particle.

14 What is the primary type of nuclear fusion happening in the stars X, Y and Z respectively shown on the Hertzsprung-Russell diagram below?

Surface Temperature (K)
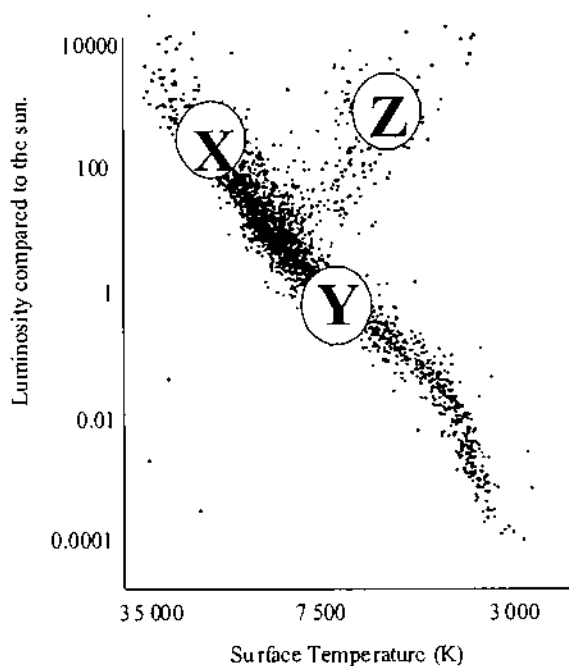
	X	Y	Z
A.	CNO Cycle	Proton-proton chain	Helium fusion (triple alpha process)
B.	Proton-proton chain	CNO Cycle	Helium fusion (triple alpha process)
C.	Helium fusion (triple alpha process)	Proton-proton chain	CNO Cycle
D.	Helium fusion (triple alpha process)	CNO Cycle	Proton-proton chain

15 In a low-energy collision, an electron and positron annihilate each other to produce two photons. What is the combined energy of the two photons?

A. 8.198×10^{-14} MeV

B. 1.639×10^{-13} MeV

C. 0.511 MeV

D. 1.023 MeV

16 The magnetic flux in a circuit is changed with time, as shown in the following graph.
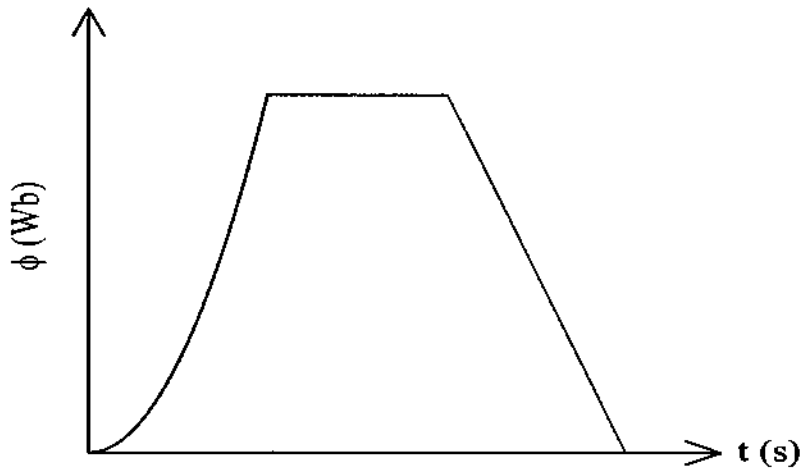
Which of the following graphs best represents the induced emf in the circuit?

A.

B.

C.

D.
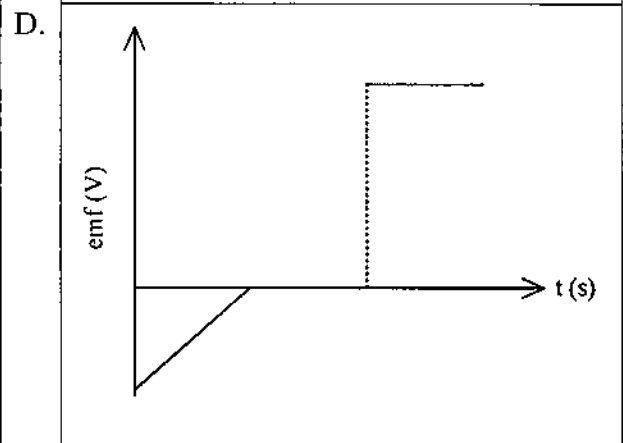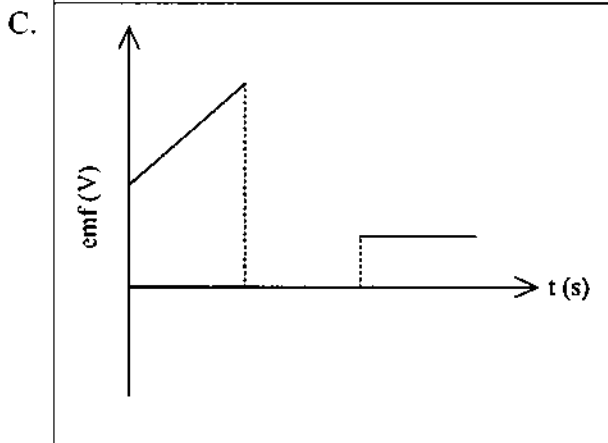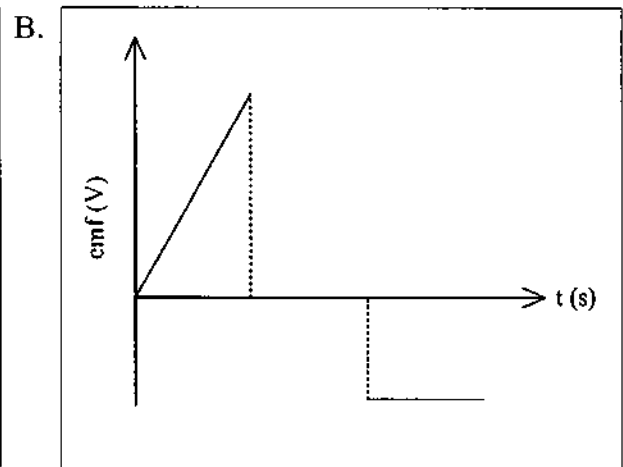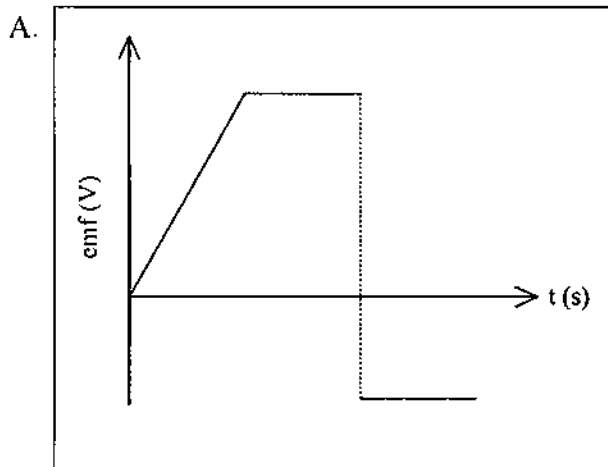
17 A distant moon is found to be orbiting a planet. The radius of orbit of the moon is 4.46×10^8 m and the period of orbit is 1.5×10^8 s.

If the planet has a radius of 4500 km, what is the escape velocity from the planet?

A. 1.48×10^2 m s^{-1}

B. 2.63×10^2 m s^{-1}

C. 6.92×10^4 m s^{-1}

D. 5.88×10^5 m s^{-1}

18 A 900kg racing car is driving on a frictionless banked corner with an angle of 20° and radius of curvature of 35m. The car is travelling at a velocity of 30 m s^{-1}
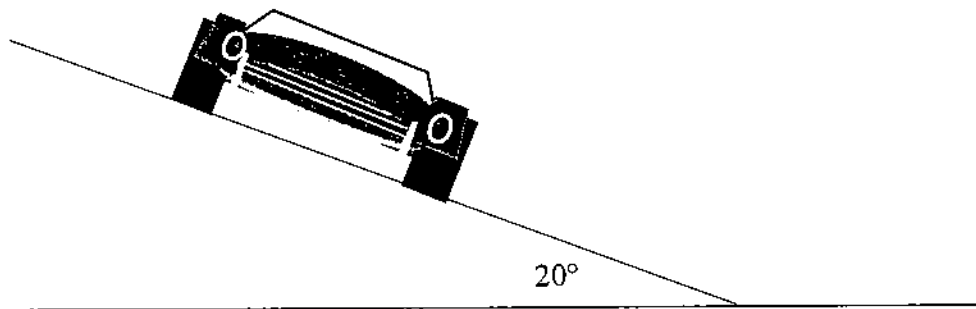
Which of the following statements correctly predicts the car's motion?

A.   The car will slide up the slope due to lack of friction.

B.   The car will slide down the slope due to lack of friction.

C.   The car will remain moving at the same height on the ramp.

D.   The car will tip over due to the excessive angle of the banked corner.

19 A solenoid is held in a fixed position near a magnet that is suspended by a string.

The magnet is displaced and allowed to swing back and forth. A motion sensor measures the position of the magnet and a sensitive ammeter measures the induced current in the solenoid as a result of the motion of the magnet. Both the motion sensor and the ammeter are connected to a data logger.
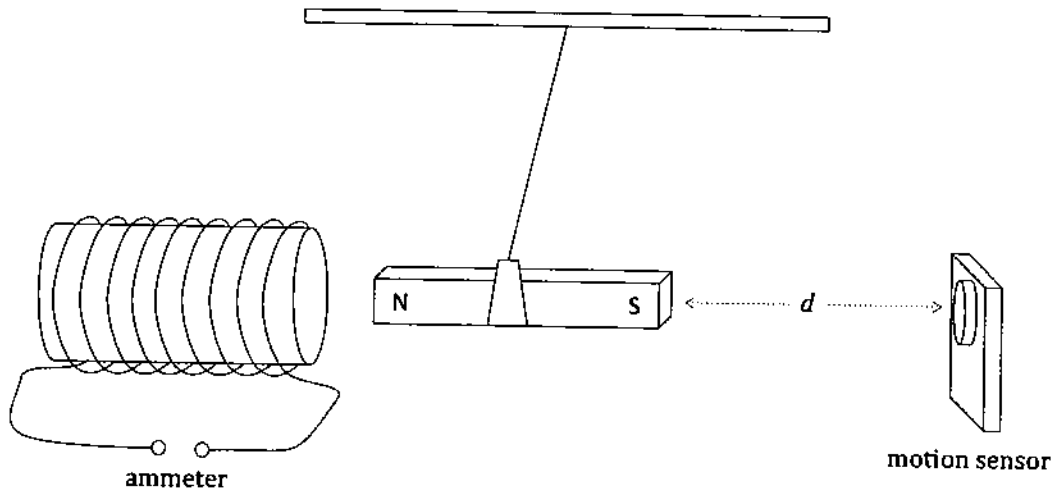
Which of the following best represents the output of the data logger?
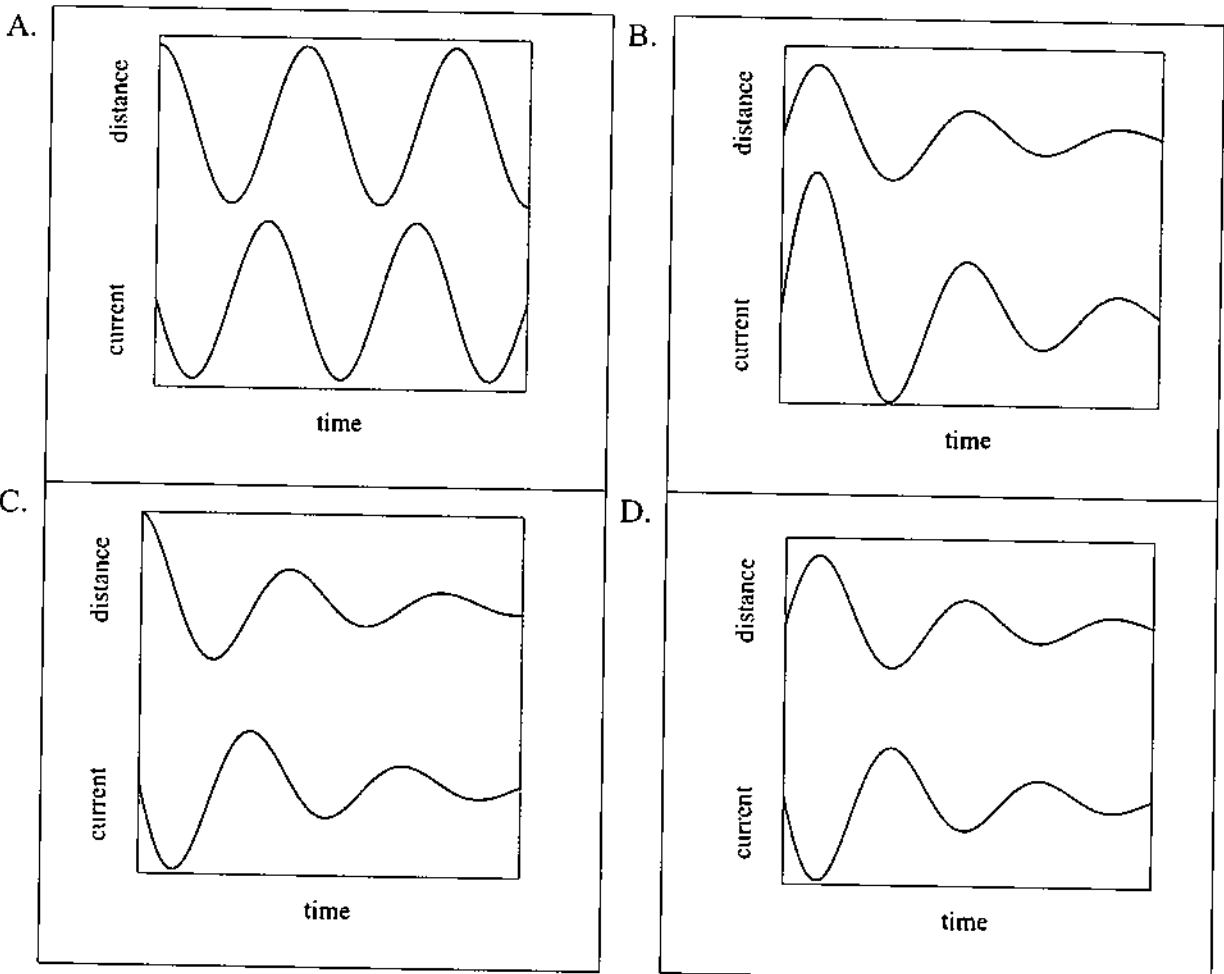
20 The launch of the James Webb Space Telescope (JWST) has highlighted the position of Lagrange points in the Earth-Sun System. At these points, small satellites can naturally orbit the Sun with the same period as the Earth (365.25 days), even though their radii of orbit are not what Kepler's third law would predict. This is because the gravitational force from the Earth is a significant factor. Three Lagrange points are shown in the diagram below. The circles show their orbits around the sun.

NOT TO SCALE
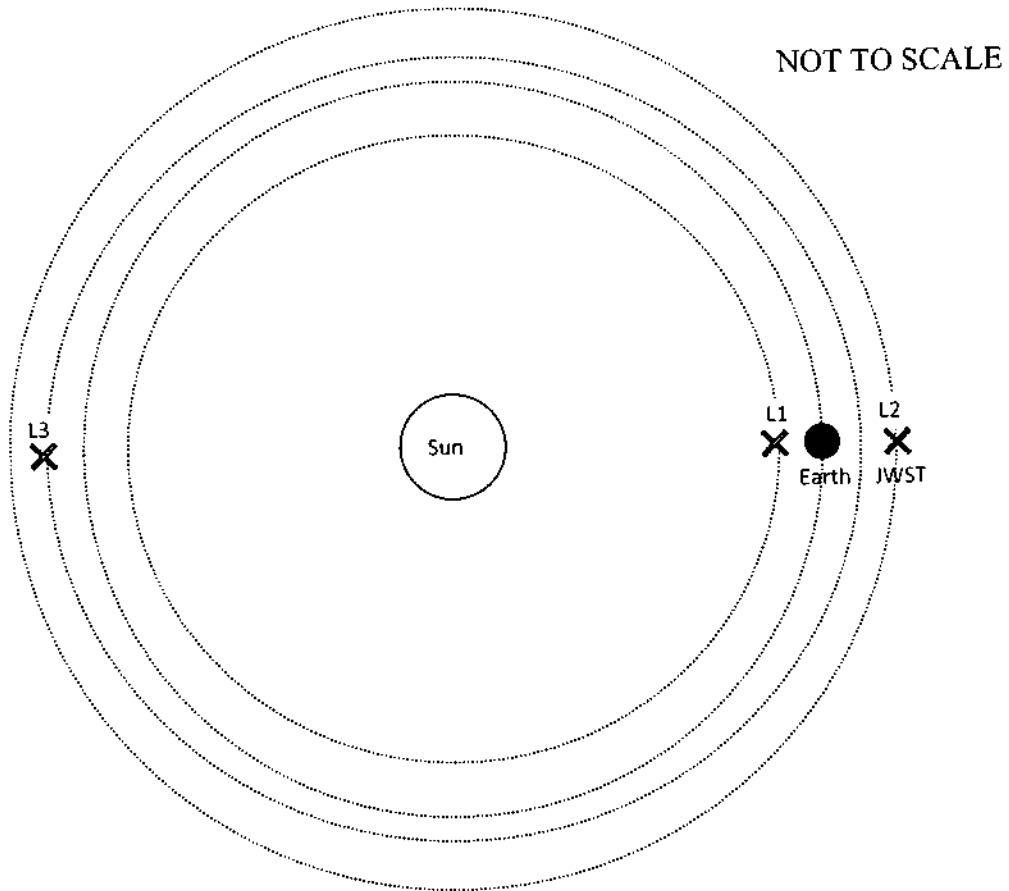
Imagine three identical satellites are in orbit at the three Lagrange points shown above.

Which of the following statements would be true?

	Greatest centripetal force	Greatest linear velocity
A.	L1	L1
B.	L2	L2
C.	L2	L1
D.	L3	L2

- 13 -

Section II
80 marks

Attempt Questions 21 – 34
Allow about 2 hours and 25 minutes for this section

- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.
- SEPARATE writing booklets are available if required. If you use a SEPARATE writing booklet, clearly indicate which question you are answering by writing the question number before beginning the response.

Question 21 (5 marks)

(a) Calculate the binding energy of a neutral atom of ^7_3Li in MeV, given that its rest mass is $6.941u$.   **3**

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(b) The isotope ^5_3Li can undergo alpha decay. Write a nuclear equation to show the products of this decay process.   **2**

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Question 22 (5 marks)

A student builds a simple DC motor. It has been set up to lift a mass using string around the drive shaft as shown. The power supply is connected using a split ring commutator.

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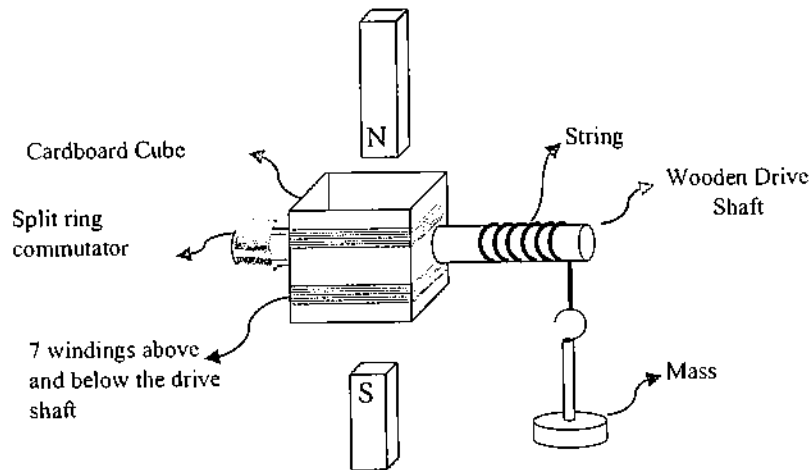
The student is disappointed to see that, although the motor rotates with no frictional effects, it cannot lift a mass of more than 20 g even on the highest power setting.

Identify 5 things that can be done to the motor design to increase the mass that this motor can lift.

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Question 23 (5 marks)

(a) In many science fiction movies, travellers are seen wearing magnetic boots inside spacecraft when in deep space.

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Assuming the spacecraft is made of steel, why would the occupants of spacecraft in deep space need to wear magnetic boots?

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(b) A space station in deep space is designed to rotate on an axis as shown below.

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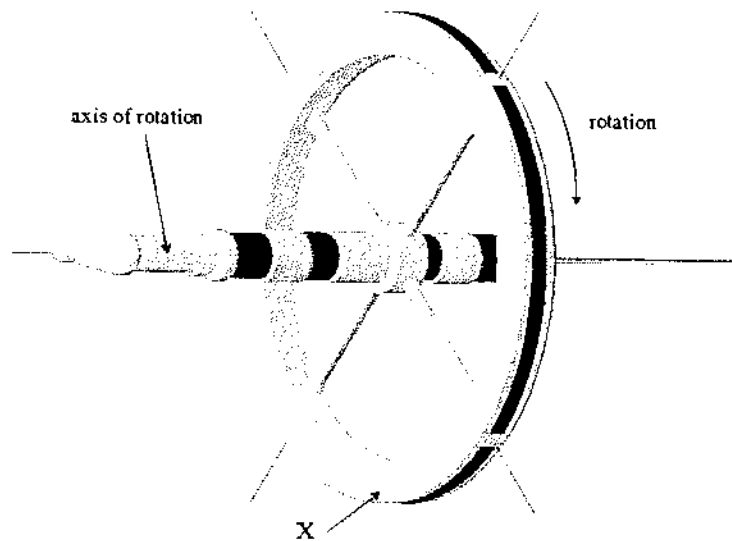
An occupant inside the space station is standing on the outside rim at a point X that is 500 m from the axis of rotation. The rotation of the space station produces an acceleration equivalent to the gravitational acceleration on the surface of the Earth.

What is the period of rotation of the space station?

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Question 24 (3 marks)

Two current-carrying conductors, A and B, are placed in magnetic fields with the same width, *d*, and magnetic flux density as shown below.
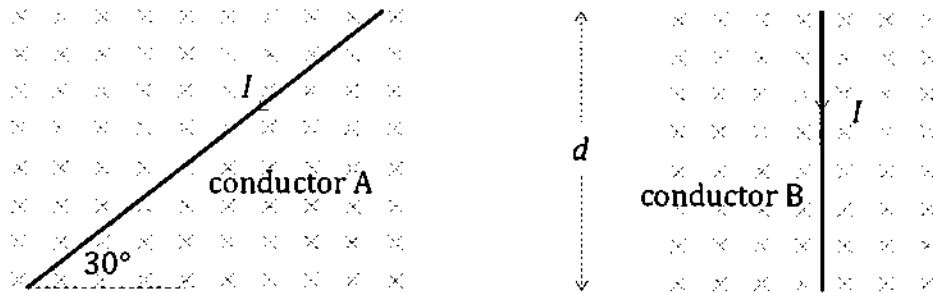
The same current, *I*, passes through A and B.

Compare the size of the magnetic forces on A and B.

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Question 25 (4 marks)

In a forensic investigation, a ballistics expert was trying to determine the type of gun from which a bullet was fired. From footprint analysis, it was known that the gun was fired 23.5 m from the base of a wall where it was stopped and lodged in a thick layer of dense plaster 8.05 m above the floor. From the stopping distance in the plaster and the change in momentum, it was calculated that the bullet entered the wall with a velocity of 119 m s^{-1} at an angle of 15.6° above the horizontal as shown.

4

NOT TO SCALE

119 m s^{-1}

15.6°

8.05 m

h

23.5 m
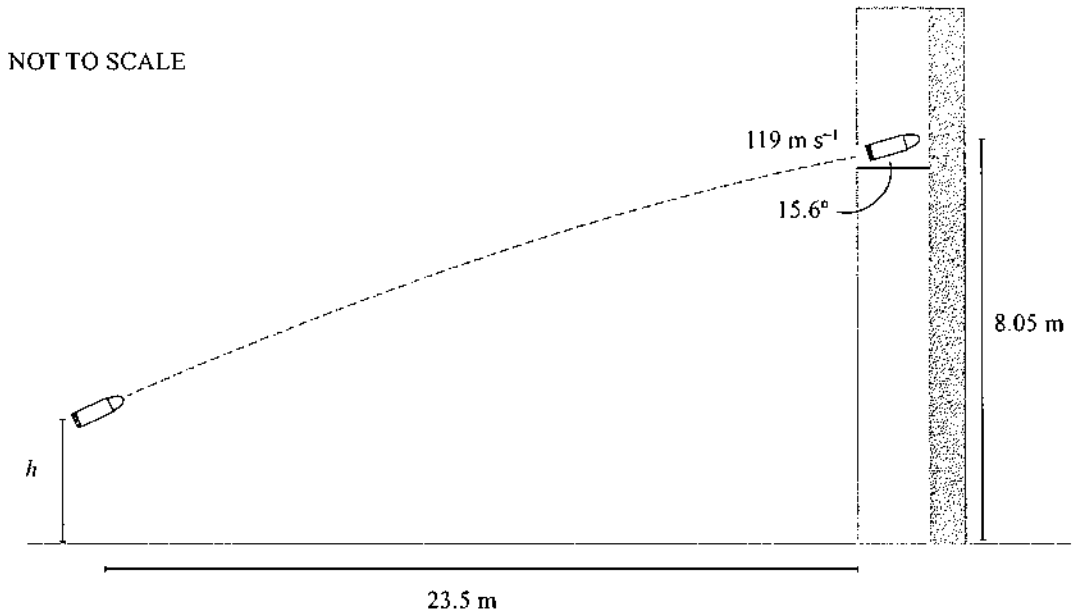
Determine the initial speed and angle at which the bullet left the gun.

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Question 26 (7 marks)

Two metal plates are placed horizontally 0.10 m apart in a vacuum. The potential difference between the plates can be varied. Negatively charged drops of oil are released from rest through a small hole in the top of charged parallel plates.

(a) A drop with a mass of 8.0×10^{-6} kg was recorded to take 1.0 seconds to fall between   **2**
     the plates when there was a potential difference of 10 V between the plates.

     Calculate the acceleration of the drop.

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(b) Using a labelled vector addition diagram show how the two forces on the drop combine   **2**
     to form the net force.

(c) Find the charge on the drop.   **3**

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Question 27 (4 marks)

Students are investigating the photoelectric effect using the apparatus below.

With no applied voltage, when the UV light is switched on they observe a reading on the ammeter. They vary the voltage until the ammeter reads zero, finding the stopping voltage to be 2.70 V.
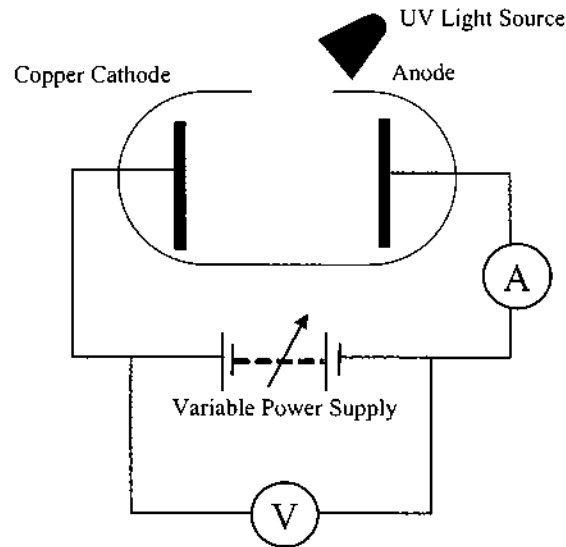
(a) What is the maximum kinetic energy of the photoelectrons ejected from the copper surface? State your answer in electron volts.   **1**

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(b) The work function of the copper surface is 4.70 eV. Calculate the wavelength of the radiation incident on the copper.   **3**

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Question 28 (9 marks)

A physicist is performing an experiment to determine the effects of time dilation on the decay of a radioisotope, Lithium-8. The physicist places one sample of the radioisotope in their frame of reference and one sample on a fast-moving spaceship above the Earth. The physicist can measure number of Lithium-8 atoms remaining in each sample using 3 different detectors.

	Detector 1	Detector 2	Detector 3
Motion of detector	Stationary relative to Earth	Stationary relative to Earth	Moving on spaceship
Measurement made by detector	Measuring decay of stationary radioisotope	Measuring decay of moving radioisotope	Measuring decay of moving radioisotope

The physicist obtained the following results from Detectors 1 and 2.
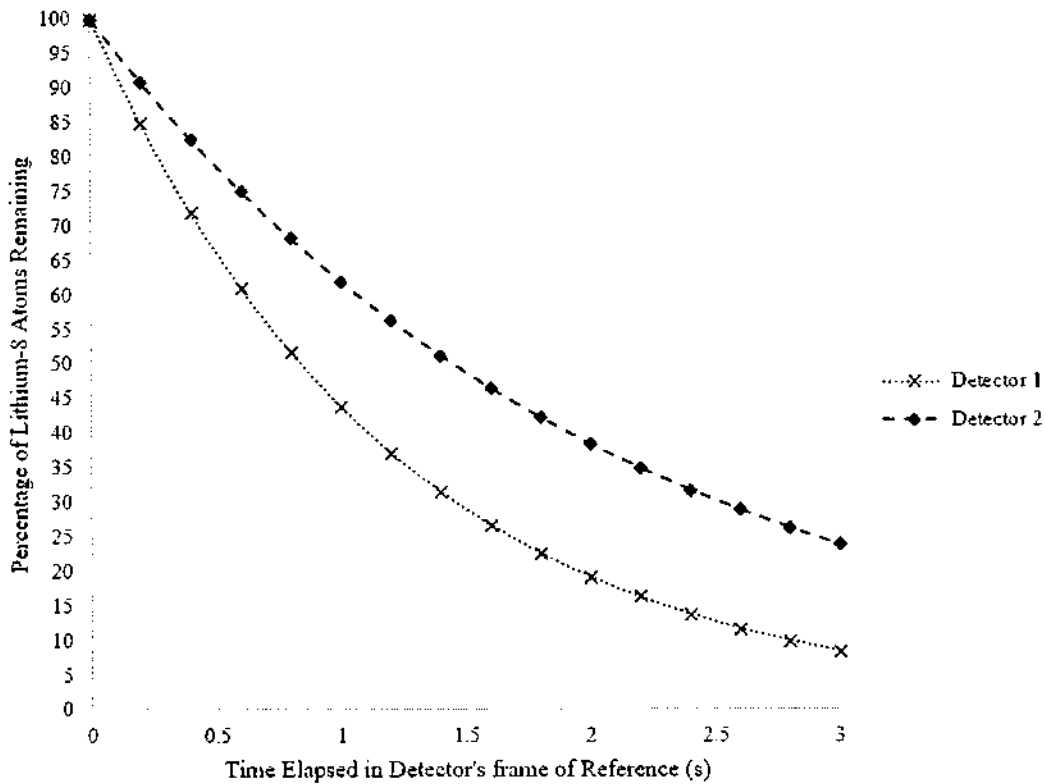
Question 28 continues on page 22

Question 28 (continued)

(a) Using the graph, calculate the decay constant of Lithium-8 when at rest.   **2**

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(b) Detector 3 was returned from the spaceship. Explain the results of Detector 3 using the   **2**
    results of Detectors 1 and 2.

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(c) Calculate the velocity of the spaceship.   **3**

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(d) Explain how the principle behind this experiment was used to validate Einstein's   **2**
    Special Theory of Relativity.

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Question 29 (8 marks)

Students investigating the interference of light are asked by their teacher to determine the slit separation in the double slit experiment. To practise their skills and analysis, they are asked to use 4 different wavelengths of light.

    Student A proposes the use of 4 lasers of different wavelengths that the teacher has made available.

    Student B argues that using a hydrogen lamp, with 4 distinct wavelengths in the visible spectrum, would save time.

(a)   Compare the two student propositions giving the advantages and disadvantages of each.   **4**

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(b)   The students' results can be seen in the table on the next page. The fringe separation d between central maxima and first order maxima were measured.

Using the small angle approximation, the formula for the slit separation d is found using

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

Where L = distance to screen, x = distance between maxima and λ is the wavelength of light used.

Their teacher suggests that the students plot a graph of λL against x.

Wavelength, λ (nm)	Distance to screen, L (m)	λL (m^2)	Distance between maxima on screen, x (mm)	Calculated slit separation, d (mm)
410	3	1.23×10^{-6}	4.2	0.293
434	3	1.30×10^{-6}	4.3	0.303
486	3	1.46×10^{-6}	4.9	0.298
656	3	1.97×10^{-6}	6.5	0.303

Question 29 continues on page 24

Graph this data on the axes provided. Include a line of best fit, and use it to calculate the slit separation using this graphical method. **3**

Distance between maxima (mm)

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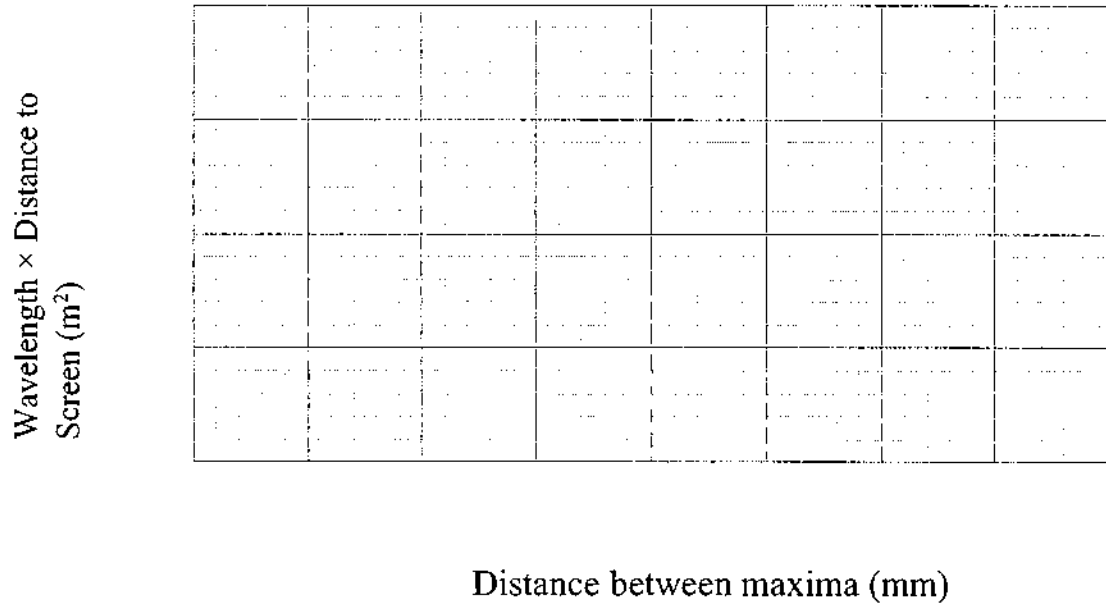
(c) Why is the graphical method of finding the slit separation preferred by the teacher? **1**

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Question 30 (5 marks)

A bicycle is fitted with a DC electric motor in the rear wheel hub. It is powered by a battery   **5**
connected to the frame.

The battery is the only source of power for the bicycle.
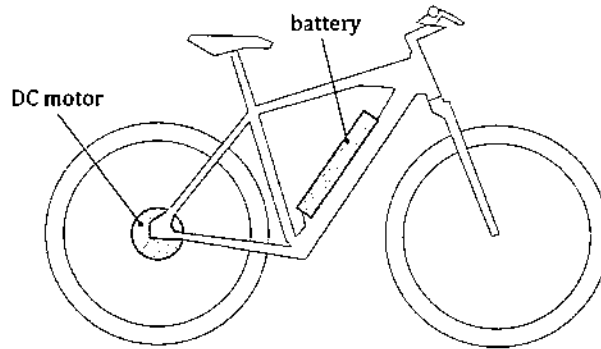
Two observations are made when the bicycle starts heading up a hill after travelling on flat ground:

   i.   the bicycle moves at a slower speed; and

   ii.   the current drawn by the motor from the battery increases.

Explain these two observations.

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Question 31 (6 marks)

A 920 kg satellite intended for a geostationary orbit was mistakenly placed at an orbital radius of 44,428 km from the centre of the Earth.

(a) Find the total mechanical energy of this satellite.   **3**

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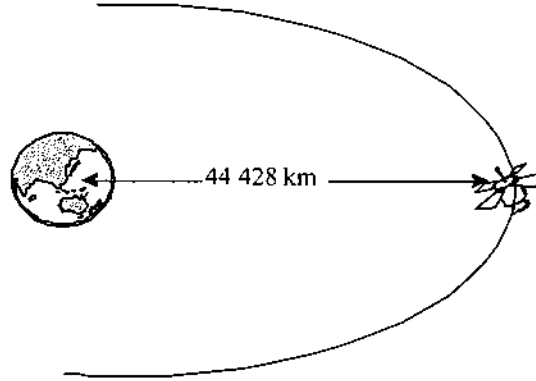..

(b) How much work must be done to change the satellite's orbital radius to the required   **2**
42,164 km?

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(c) Justify whether the satellite gained or lost energy in the transition to the geostationary   **1**
orbit.

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Question 32 (10 marks)

A Helmholtz Apparatus consists of a glass sphere containing low pressure helium gas with an electron gun inside, directed to the right. In front and behind the sphere, large coils carrying DC currents are positioned. The electrons from the gun are deflected by the magnetic field into an anticlockwise circular path within the sphere. Occasional collisions of the electrons with helium atoms result in the emission of light, allowing the path of the electrons to be seen. A ruler at the back of the apparatus can be used to measure the radius of this circular path. The apparatus has two controls; one to alter the magnetic field strength within the sphere and the other to adjust the accelerating voltage within the electron gun between 0 and 500 volts, thus altering the kinetic energies of the electrons. An enlarged diagram of the Electron Gun is also shown in the diagram below.
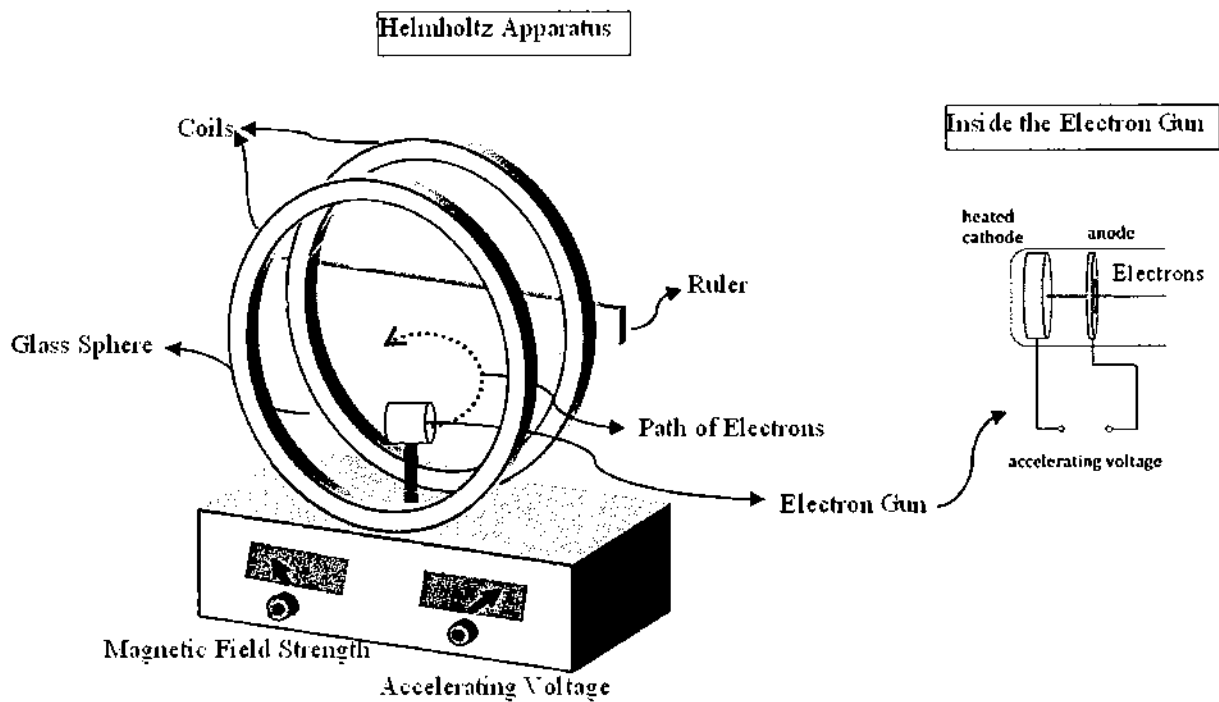
(a) Clearly show the direction of current in both the front coil and the back coil on the diagram above.

1

Question 32 (continued)

(b) The Helmholtz Apparatus is used in universities to confirm the charge to mass ratio of an electron (q_e/m_e).   6

Outline the method the students should use to collect measurements and then calculate the q_e/m_e value. Include steps the students should take to ensure the experiment is safe, reliable, and accurate.

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(c) Derive the equation to find the charge to mass ratio of the electrons (q_e/m_e) using this equipment. Include the terms V for accelerating voltage, B for magnetic field strength and r for radius.   3
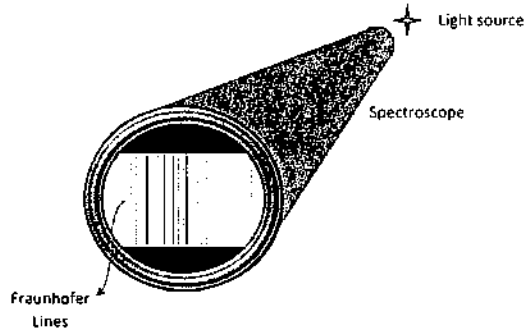
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Question 33 (9 marks)

In the 1800s, Fraunhofer and Kirchhoff discovered that the spectra of the Sun and other stars contained dark lines.

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Since this discovery, spectroscopy has led to dramatic changes in our understanding of atoms, stars and the universe.

Outline how spectroscopy led to some of the most significant advances in our understanding of these three areas of science.

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Question 33 (continued)

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End of Examination

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Question 33	Diagram created by the 2022 CSSA Trial HSC Examination Committee - Physics. Used with permission.

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