CSSA

2022
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

DO NOT REMOVE PAPER FROM EXAMINATION ROOM

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.

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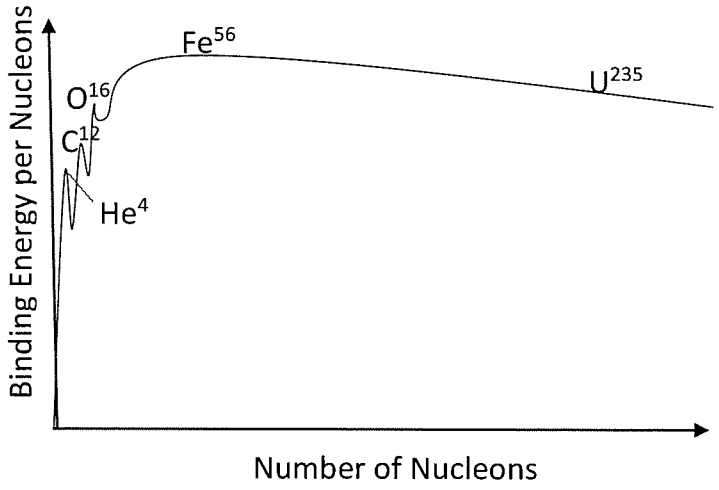
1 Both U^{235} and O^{16} can be used in nuclear reactions to produce energy. They are shown on the binding energy per nucleon graph below.



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?

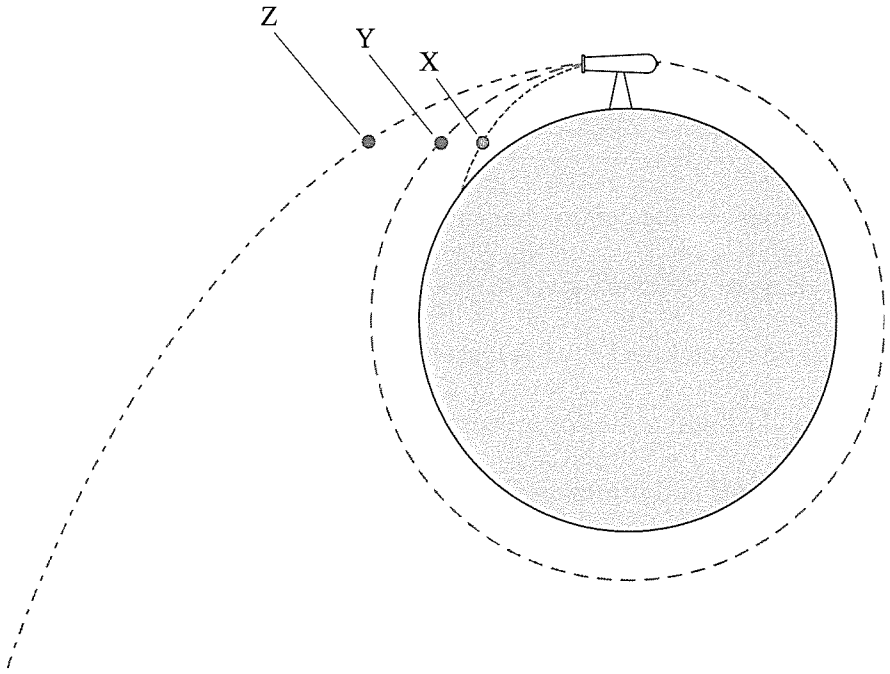
A. Diffraction

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?

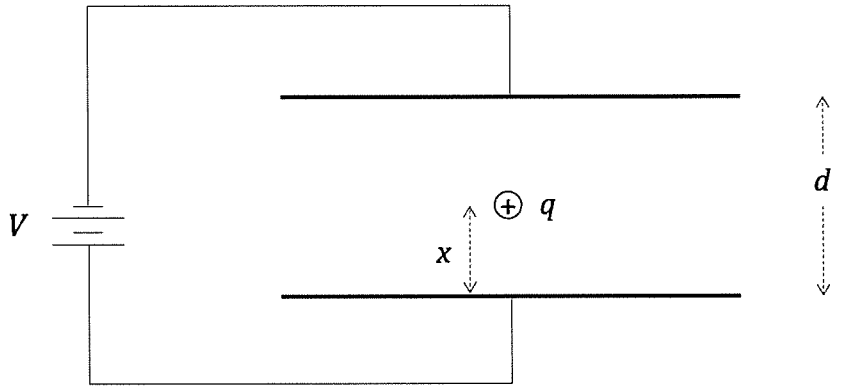
A. Velocities of objects can be infinite.

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?

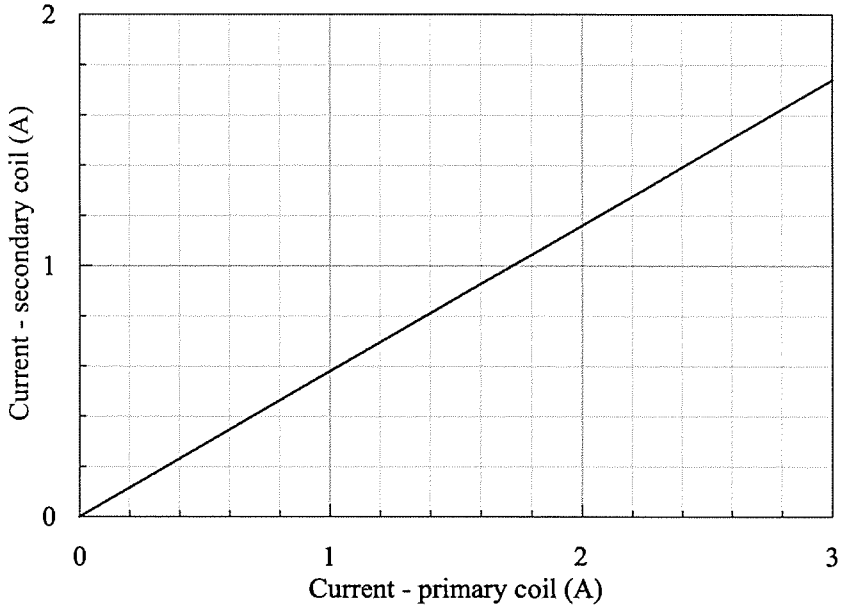
A. 1.03×10^2 nm

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, $T_X : T_Y$?

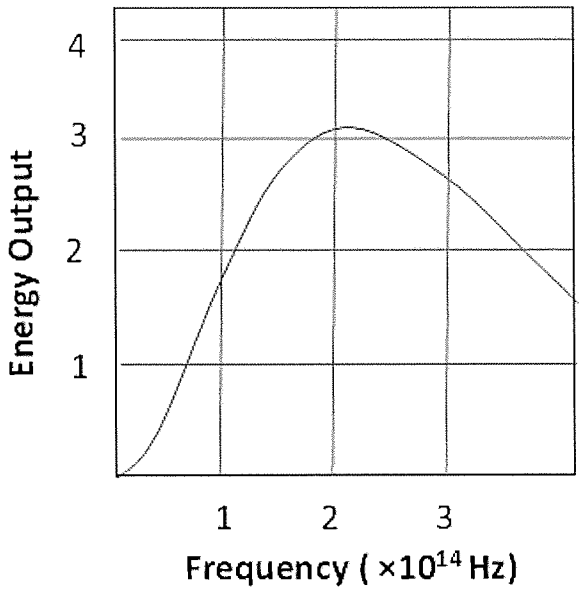
A. 1 : 3

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.

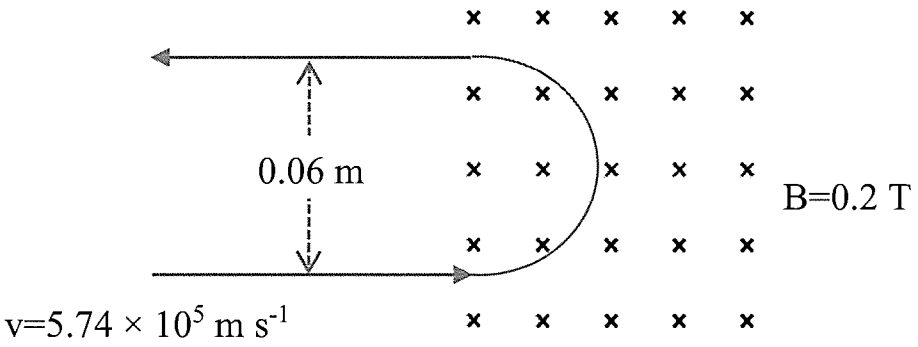
A. 1.32×10^{-17} K

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.



The particle is most likely

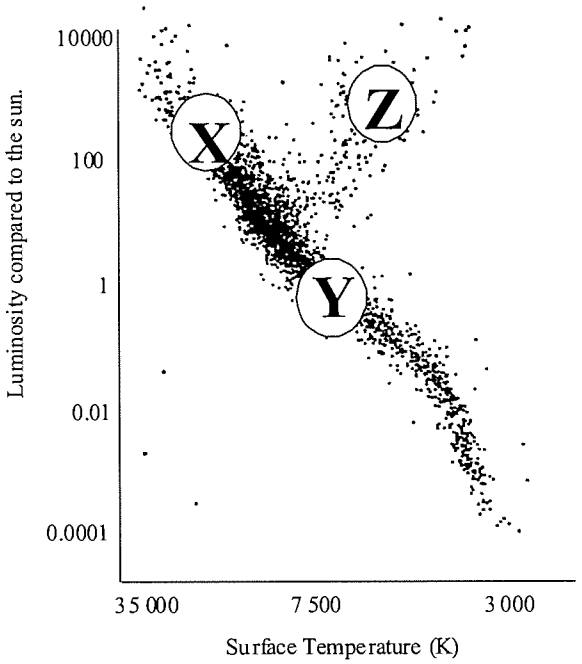
A. a proton.

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?



	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?

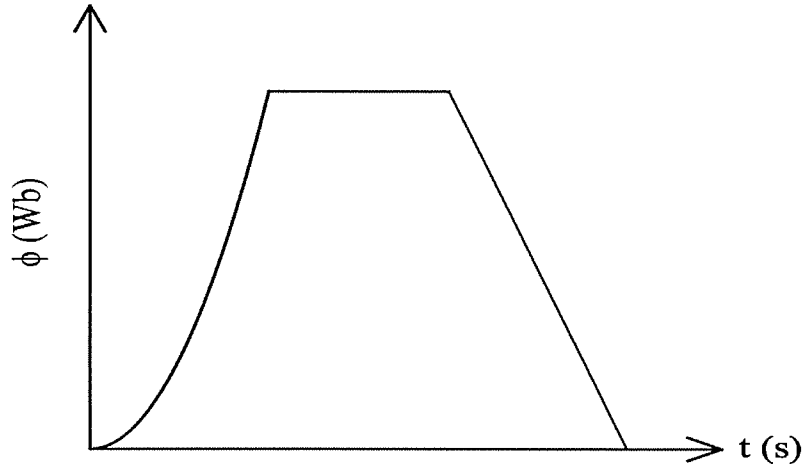
A. 8.198×10^{-14} MeV

B. 1.639×10^{-13} MeV

C. 0.511 MeV

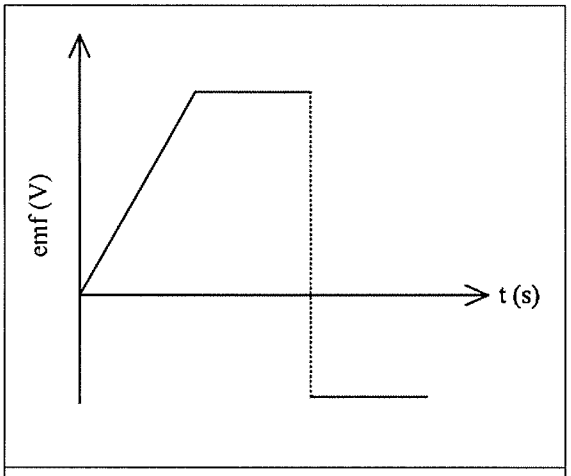
D. 1.023 MeV

16 The magnetic flux in a circuit is changed with time, as shown in the following graph.

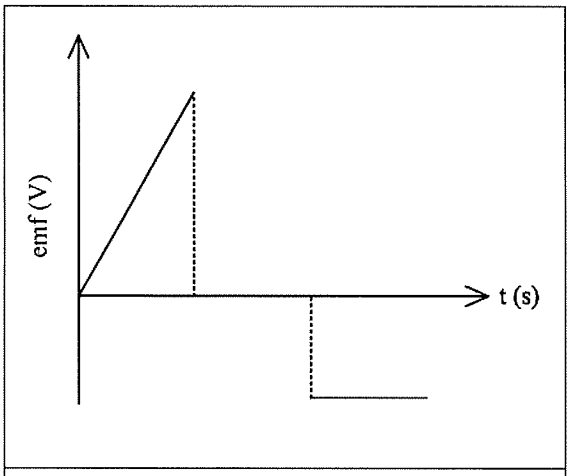


Which of the following graphs best represents the induced emf in the circuit?

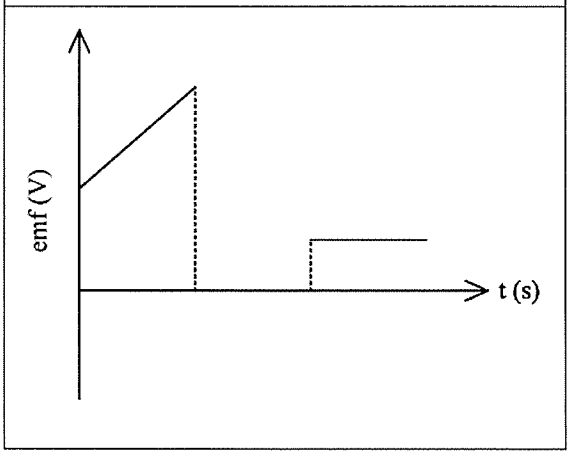
A.



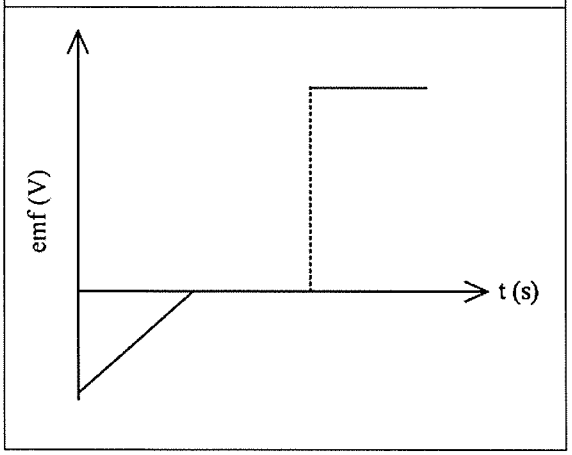
B.



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?

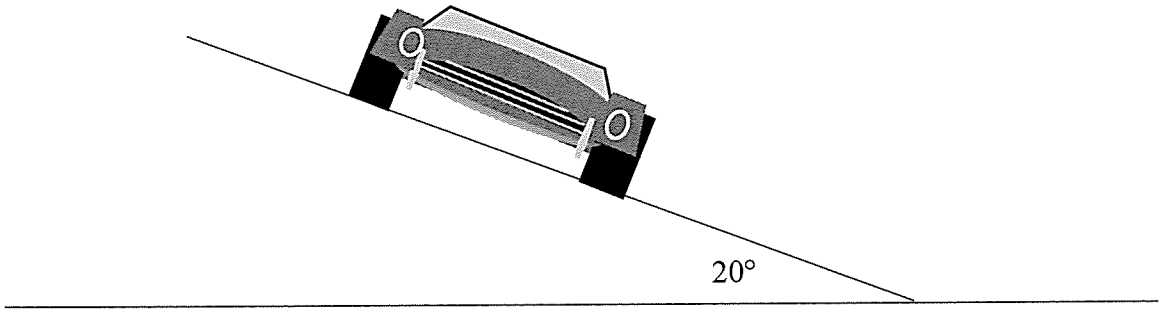
A. 1.48×10^2 m s^{-1}

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.

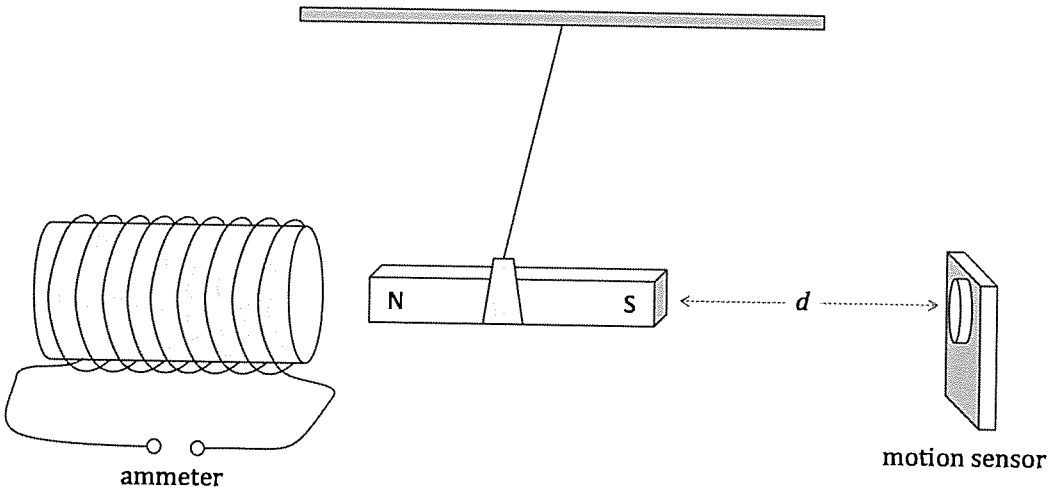
B. The car will slide down the slope due to lack of friction.

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.

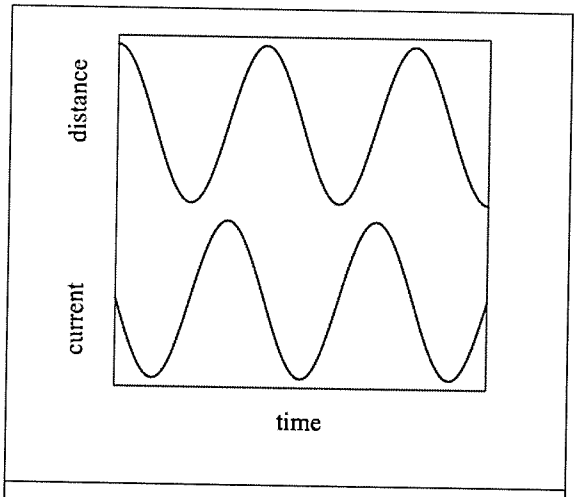
19 A solenoid is held in a fixed position near a magnet that is suspended by a string.

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.

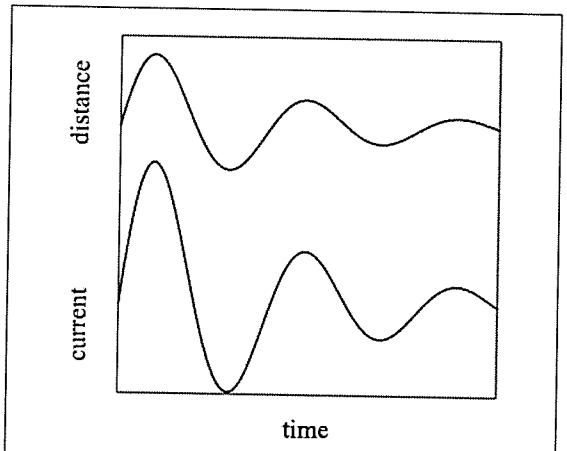


Which of the following best represents the output of the data logger?

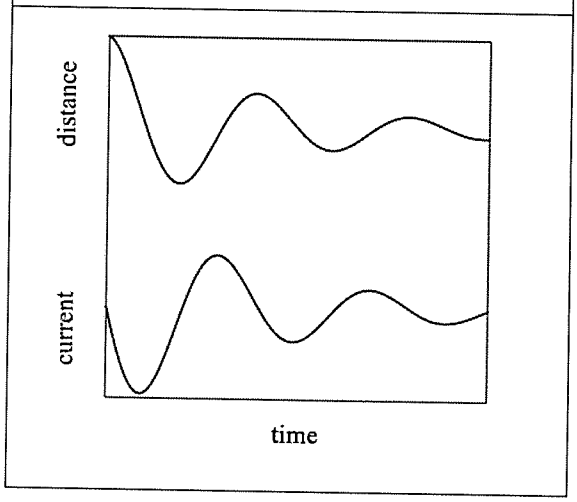
A.



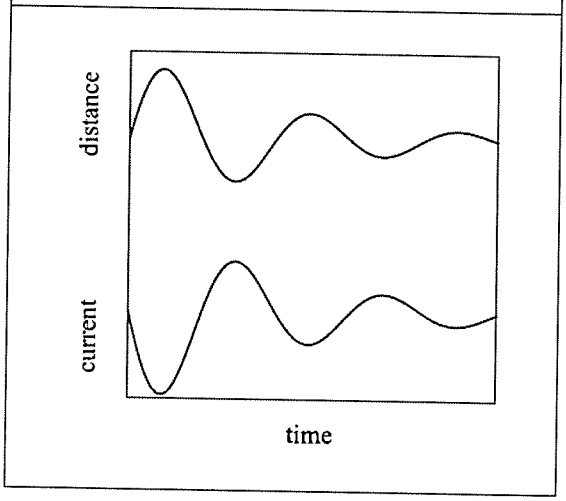
B.



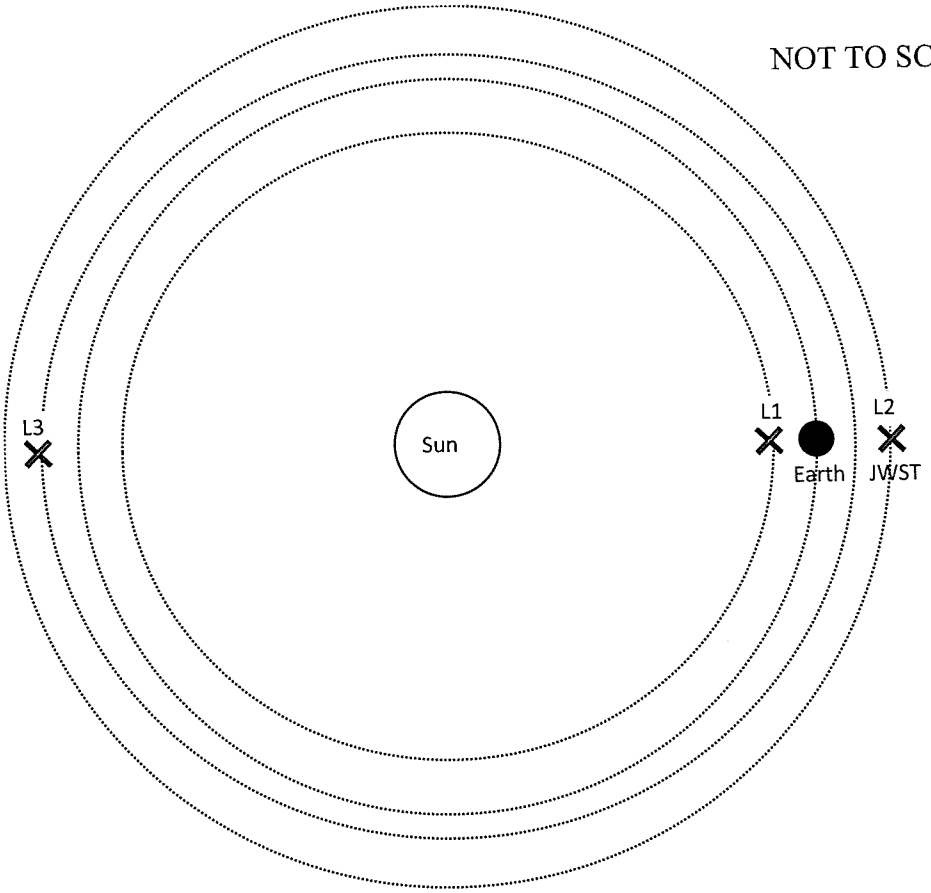
C.



D.



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.



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

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 $^{7}_{3}Li$ in MeV, given that its rest mass is $6.941u$. **3**

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(b) The isotope $^{5}_{3}Li$ can undergo alpha decay. Write a nuclear equation to show the products of this decay process. **2**

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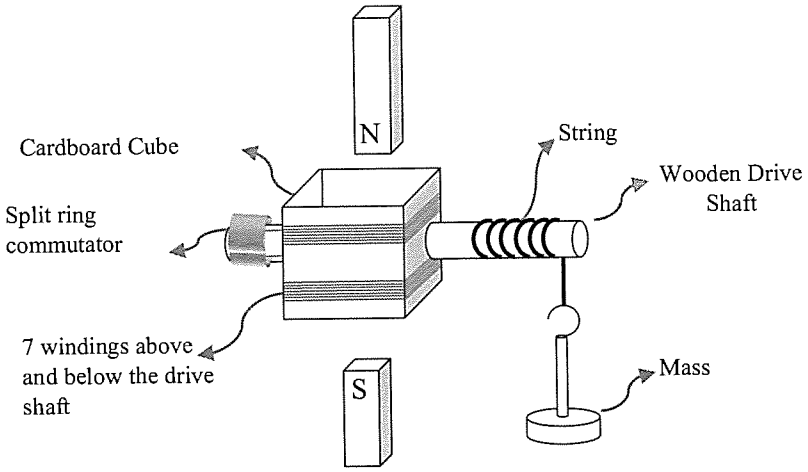
Question 22 (5 marks)

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. **5**



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. **2**

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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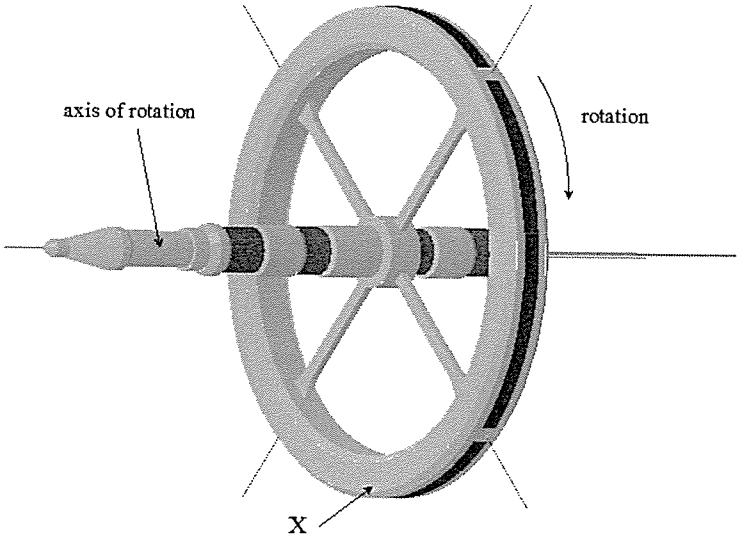
(b) A space station in deep space is designed to rotate on an axis as shown below. **3**



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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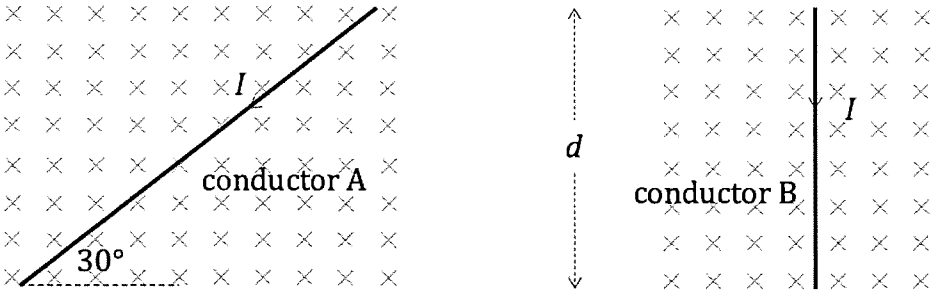
Question 24 (3 marks)

Two current-carrying conductors, A and B, are placed in magnetic fields with the same width, *d*, and magnetic flux density as shown below. **3**



The same current, *I*, passes through A and B.

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

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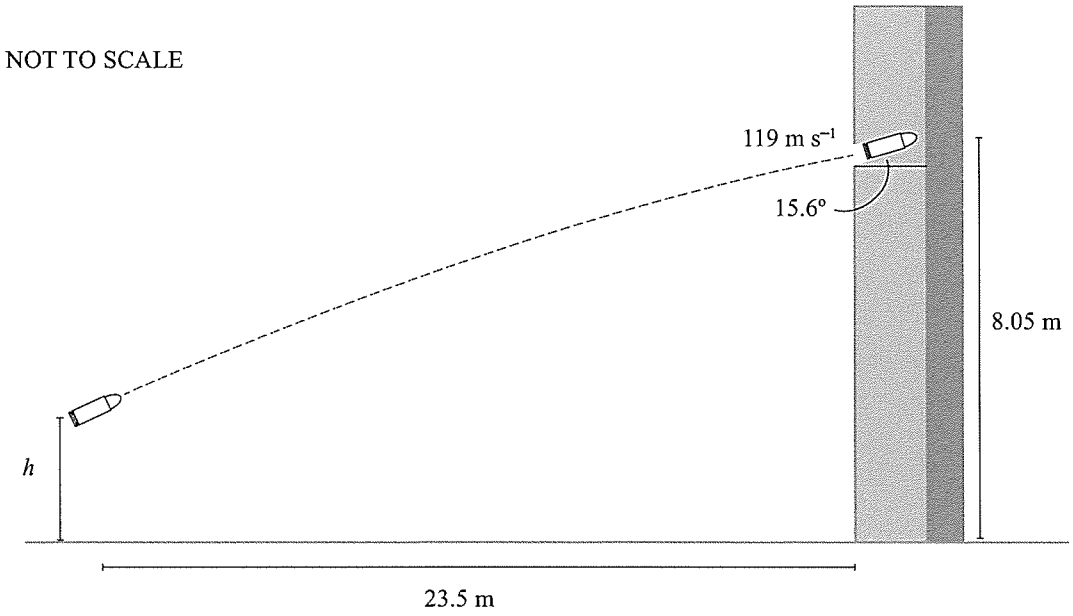
Question 25 (4 marks)

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**



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 the plates when there was a potential difference of 10 V between the plates. **2**

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 to form the net force. **2**

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

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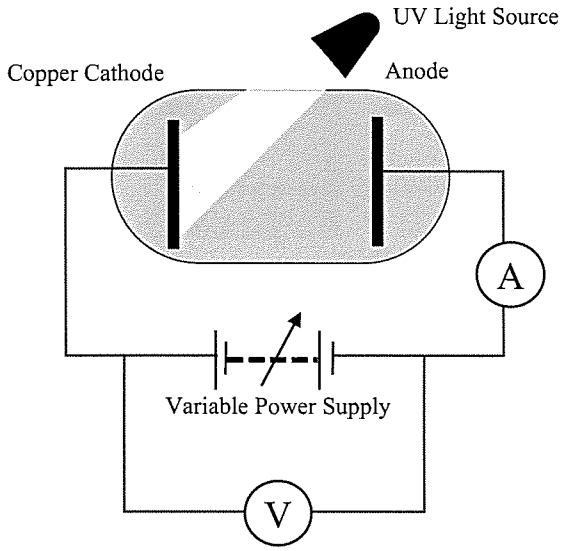
Question 27 (4 marks)

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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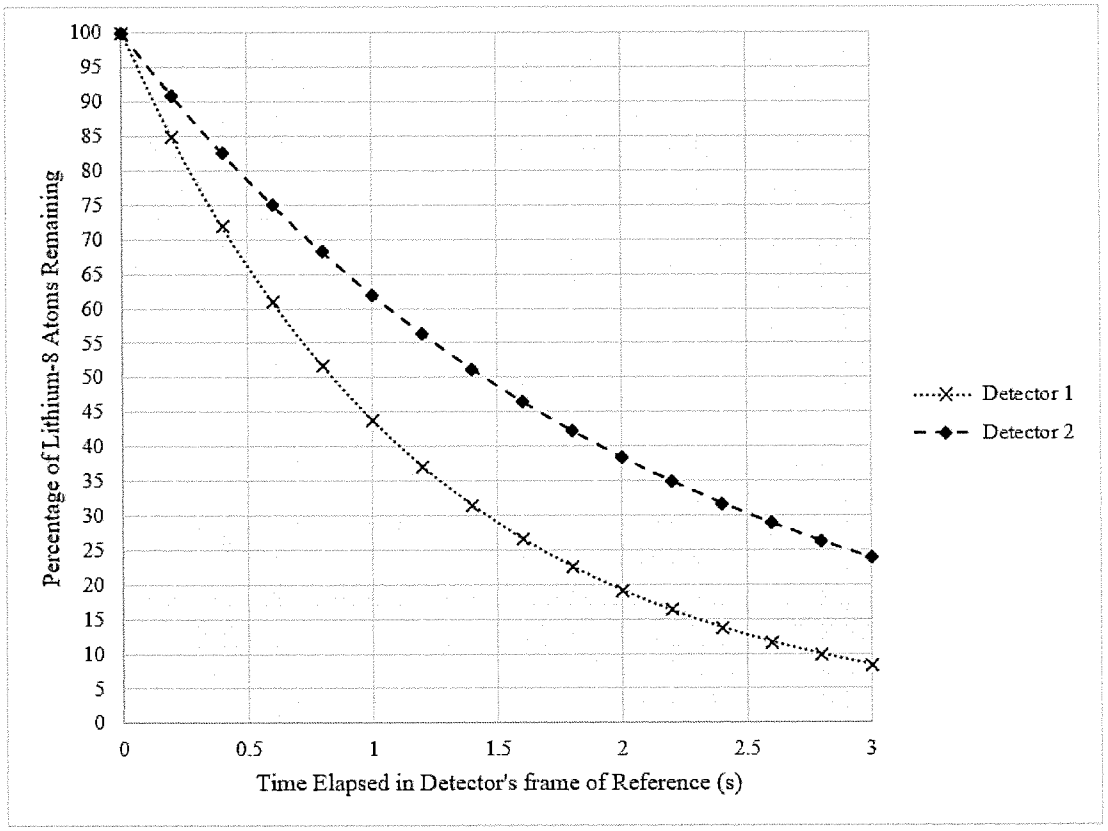
Question 28 (9 marks)

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 results of Detectors 1 and 2. **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 Special Theory of Relativity. **2**

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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.

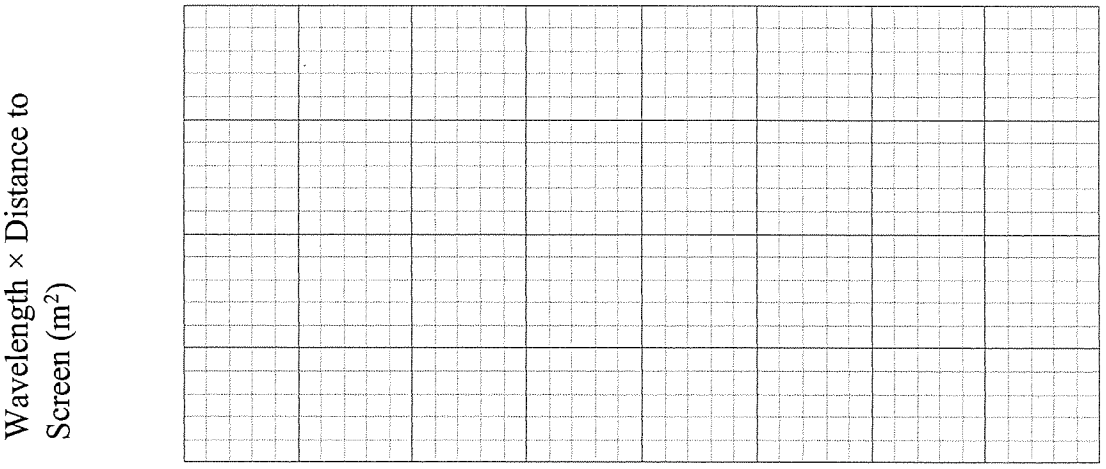
Their teacher suggests that the students plot a graph of λL against x.

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

Question 29 (continued)

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**



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

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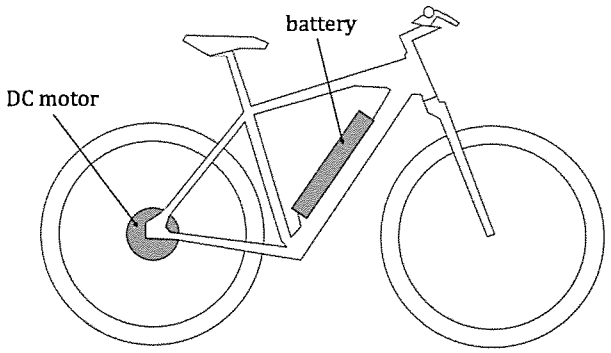
Question 30 (5 marks)

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

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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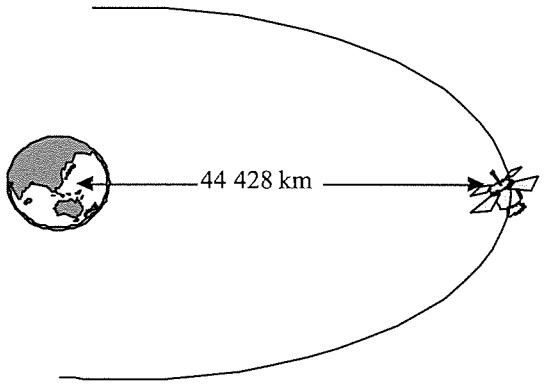
Question 31 (6 marks)

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 42,164 km? **2**

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

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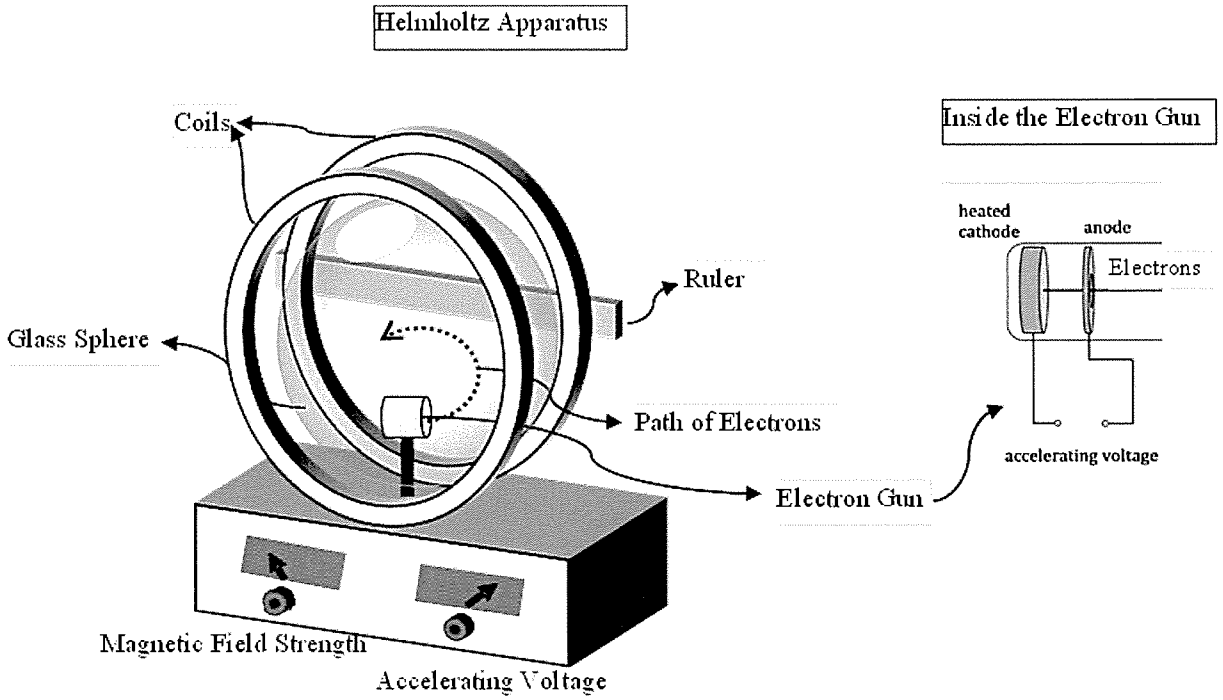
Question 32 (10 marks)

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 continues on page 28

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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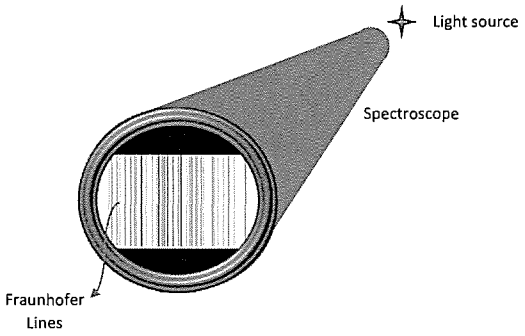
Question 33 (9 marks)

In the 1800s, Fraunhofer and Kirchhoff discovered that the spectra of the Sun and other stars contained dark lines. **9**



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 continues on page 30

Question 33 (continued)

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End of Examination

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EXAMINERS

Janet Pemberton (Convenor)	Education Consultant
Alex Connolly	Santa Sabina College, Strathfield
Toby Duncan	MLC School, Burwood
Andrew Latham	Stella Maris College, Manly
Lily Okati	Christian Brothers' High School, Lewisham
Jonathan Saurine	Our Lady of Mercy College, Parramatta

CSSA

2022
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

MARKING GUIDELINES

Physics

Section I
20 marks

Questions 1-20 (1 mark each)

Question	Answer	Outcomes Assessed	Targeted Performance Band
1	A	12-15	2-3
2	C	12-14	2-3
3	C	12-12	2-3
4	D	12-15	2-3
5	D	12-12	3-4
6	B	12-12	3-4
7	B	12-14	3-4
8	D	12-13	3-4
9	A	12-15	3-4
10	D	12-13	4-5
11	C	12-12	3-4
12	C	12-14	3-4
13	A	12-12/13	4-5
14	A	12-15	3-4
15	D	12-14	4-5
16	B	12-13	4-5
17	B	12-12	5-6
18	A	12-12	5-6
19	C	12-12/13	5-6
20	B	12-12	5-6

Section II
80 marks

Question 21 (4 marks)

21 (a) (2 mark)

Outcomes Assessed: 12-15

Targeted Performance Bands: 1-4

Criteria	Mark
• Correctly calculates the binding energy in MeV.	2
• Correctly calculates mass defect OR correctly calculates binding energy from incorrect mass defect.	1

Sample answer:

Mass defect= [(3 × mass of proton)+ (4 × mass of neutron)+(3 × mass of electrons)]- mass of the lithium atom.

$= [(3 \times \frac{1.673\ x\ 10^{-27}}{1.661\ x\ 10^{-27}}) + (4 \times \frac{1.675\ x\ 10^{-27}}{1.661\ x\ 10^{-27}}) + (3 \times \frac{9.109\ x\ 10^{-31}}{1.661\ x\ 10^{-27}})]$- 6.941=0.116 u

$E = 0.116 \times 931.5 = 1.081 \times 10^{2}$ MeV

21 (b) (2 marks)

Outcomes Assessed: PH11/12-6; PH12-15

Targeted Performance Bands: 2-3

Criteria	Marks
• Correct format for the equation and correct products shown	2
• Correctly identifies the formula for either alpha particle or hydrogen particle.	1

Sample Answer:

$$^{5}_{3}Li \rightarrow {}^{4}_{2}He + {}^{1}_{1}H$$

Question 22 (5 marks)

22 (a) (5 marks)
Outcomes Assessed: 12-13
Targeted Performance Bands: 2-5

Criteria	Marks
• 5 useful suggestions	5
• 4 useful suggestions	4
• 3 useful suggestions	3
• 2 useful suggestions	2
• 1 useful suggestion	1

Sample Answer:
Increasing the strength of the magnetic field by using stronger magnets.
Placing a laminated core (or nails) into the centre of the cardboard cube.
Place more windings above and below the drive shaft.
Decrease the radius of the drive shaft to decrease the torque required to lift the mass.
Make the cube of cardboard taller so that the windings have a greater torque.

Also
Use windings with less resistance
Increase the area of the windings.

Question 23 (5 marks)

23 (a) (2 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands: 2-4

Criteria	Marks
• Identifies that there is negligible gravity in deep space. • Explains that magnetic boots will create a downward force simulating weight.	2
• Identifies that the boots will create a magnetic force downward on the travellers.	1

Sample Answer:

In deep space, far from the centre of any massive body, the force of gravity is negligible and astronauts are literally weightless. Walking around the interior of a large spacecraft would be difficult without magnetic boots that simulate the attractive force of gravity between the boots and the floor.

23 (b) (3 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands: 4-5

Criteria	Marks
• Correct result from correct substitutions	3
• Combines 9.8 m/s^2 with centripetal acceleration.	2
• Correct formula for centripetal acceleration OR Using 9.8m/s^2	1

Sample Answer:

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

$$v = \frac{2\pi r}{T}$$

$$a = \frac{\left(\frac{2\pi r}{T}\right)^2}{r}$$

$$= \frac{4\pi^2 r}{T^2}$$

$$9.8 = \frac{(4\pi^2 \times 500)}{T^2}$$

$$T = \sqrt{\frac{(4\pi^2 \times 500)}{9.8}}$$

$$= 45 \text{ s}$$

Question 24 (3 marks)

24 (a) (3 marks)
Outcomes Assessed: 12-13
Targeted Performance Bands: 3-5

Criteria	Marks
• Correct answer for size comparison	3
• Uses the correct equation F=IlB sinθ with θ=90 • Attempts to find Length in terms of the angle and d	2
• Uses or implies the use of the correct equation F=IlB sinθ OR • Realises that they are both at right angles to the magnetic field	1

Sample Answer:

For A $F = ILBsin\theta \quad where\ \theta = 90^{\circ}\ and\ L = \frac{d}{sin30} = 2d \qquad \therefore F = 2IdB$

For B $F = ILBsin\theta \quad where\ \theta = 90^{\circ}\ and\ L = d \qquad \therefore F = IdB$

So the force on A is twice that of the force on B

Question 25 (4 marks)

Outcomes Assessed: 12-12
Targeted Performance Bands: 3-5

Criteria	Marks
• Correct value for speed and angle.	4
• Correct value for angle based on wrong value for speed • Combines horizontal and vertical values to find speed.	3
• Combines horizontal and vertical values to find speed • Attempt to find initial speed values	2
• Attempt to use vertical and horizontal value to find speed or angle	1

Sample Answer:

$$v_x = \frac{s_x}{t}$$
$$= u\cos\theta$$
$$= 119 \times \cos 15.6$$
$$= 115 \text{ m s}^{-1}$$
$$t = \frac{s_x}{u_x}$$
$$= \frac{23.5}{119\cos 15.6}$$
$$= 0.205 \text{ s}$$
$$v_y = u_y + at$$
$$u_y = v_y - at$$
$$= 119\sin 15.6 - (-9.8 \times 0.205)$$
$$= 34.0 \text{ m s}^{-1}$$
$$u = \sqrt{u_x^2 + u_y^2}$$
$$= \sqrt{115^2 + 34.0^2}$$
$$= 120 \text{ m s}^{-1}$$
$$\theta = \tan^{-1}\left(\frac{34.0}{115}\right)$$
$$= 16.5°$$

Question 26 (7 marks)

26 (a) (2 marks)

Outcomes Assessed: 12-12

Targeted Performance Bands: 2-3

Criteria	Marks
• Correct acceleration.	2
• Attempt to use constant acceleration formula or formulae.	1

Sample Answer:

$s_y = u_y t + 1/2 a_y t^2$

$-0.1 = 0 + \frac{1}{2} a_y 1^2$

$a_y = -0.2$ ms^{-2} or 0.2 ms^{-2}downwards

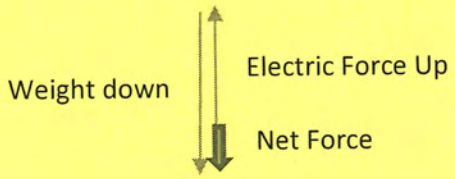
26 (b) (2 marks)

Outcomes Assessed: 12-12/13

Targeted Performance Bands: 4-5

Criteria	Marks
• Shows the two force vectors -electric up and gravity down. • Gravity is bigger than electric	2
• Shows the two force vectors-electric up and gravity down	1

Sample Answer:



26 (c) (3 marks)

Outcomes Assessed: 12-13
Targeted Performance Bands: 4-5

Criteria	Marks
• Correct answer for q	3
• Correct calculation of two of the following ○ Net Force ○ Electric Field ○ Gravitational Force ○ Combining forces using correct directions	2
• Correct calculation of one of the above points.	1

$F_{net}=ma=8 \times 10^{-6} \times(-0.2)= -1.6 \times 10^{-6}$ *or* 1.6×10^{-6} *downwards*

$$E = \frac{V}{d} = \frac{10}{0.1} = 100\ Vm^{-1}$$

$F_{net}\downarrow=mg\downarrow+Eq\uparrow$

$-1.6 \times 10^{-6}=8 \times 10^{-6} \times(-9.8)+ 100 \times q$

$q=-7.68 \times 10^{-7}\ C$

Question 27 (5 marks)

27 (a) (2 marks)

Outcomes Assessed: 12-14

Targeted Performance Bands: 3-5

Criteria	Marks
• Correct answer using W=qV formula and answer in Joules OR answer in eV	2
• Attempts to use Work equation OR recognises that KE = work done	1

Sample Answer:

$KE_{max}=W=qV=1.602 \times 10^{-19} \times 2.7= 4.3254 \times 10^{-19}$ J $= 4.3254 \times 10^{-19}/1.602 \times 10^{-19}=2.7$eV
OR 2.7V of work on an electron is 2.7 eV.

27 (b) (3 marks)

Outcomes Assessed: 12-14

Targeted Performance Bands: 3-5

Criteria	Marks
• Correct answer including ○ Correct conversion from eV to Joules ○ Correct use of $K_{max} = hf-\phi$ ○ Correct use of $c=f\lambda$	3
• Two of the above points correctly completed	2
• One of the above points correctly completed	1

Sample Answer:

$K_{max} = hf-\phi$
$4.3254 \times 10^{-19} = 6.626 \times 10^{-34}f - 4.7 \times 1.602 \times 10^{-19}$
$f= 1.789 \times 10^{15}$ Hz
$c=f\lambda$
$\lambda=3 \times 10^{8}/1.789 \times 10^{15}=1.6768 \times 10^{-7}m = 167nm$
OR
$K_{max} = hf-\phi$
$2.70=hf-4.70$
$hf=7.4$ eV $=7.4 \times 1.602 \times 10^{-19} =1.185 \times 10^{-16}$J
$6.626 \times 10^{-34}f=1.185 \times 10^{-16}$
$f=1.789 \times 10^{15}$ Hz
$c=f\lambda$ so $\lambda=3 \times 10^{8}/1.789 \times 10^{15}=1.6768 \times 10^{-7}m = 167nm$

Question 28 (9 marks)
28 (a) (2 marks)
Outcomes Assessed: 12-15
Targeted Performance Bands: 3-4

Criteria	Marks
• Correct estimate of half life from graph (0.83-0.85) • Correct value for decay constant using formula	2
• One of the points above	1

Sample Answer:
Finding Half Life from the graph. 100 to 50 is about 0.84 s 40 to 20 is 0.85 s.
$\lambda = \frac{ln2}{t_{1/2}} = \frac{ln2}{0.84} = 0.8251 = 0.83s^{-1}$

28 (b) (2 mark)
Outcomes Assessed: 12.15
Targeted Performance Bands: 4-5

Criteria	Marks
• Same as detector 1 established • Justified using clear explanation of frames of reference in Special relativity (Einstein's First Postulate)	2
• Correct statement about same physics in all inertial frames of reference	1

Sample Answer:

Detector 3 will show the same results as detector 1. This is because the detector 1 & 3 are both moving at the same speed as the experiments they are measuring. Thus we will not see any difference in the physics for the two detectors as they are each in the same inertial frames of reference as the experiment they are detecting. (Detector 2 will see time dilation as the experiment is moving relative to the detector.)

Einstein's First postulate stated that the laws of physics are the same in all inertial frames of reference. So the half life measurements should have the same results as the first detector which was in the same frame of reference as the stationary radioisotope.

28 (c) (3 marks)
Outcomes Assessed: 12-14
Targeted Performance Bands: 4-5

Criteria	Marks
• Correct readings for both half-life graphs • Substituted correctly into formula • Correct calculation	3
• Two of the points above	2
• One of the points above	1

Sample Answer:

Using the half lives from the two graphs
T_0=0.84s T=1.45s

$$T = \frac{T_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

1

$$1.45 = \frac{0.84}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\frac{v}{c} = 0.8151 = 0.82c \;\; OR \;\; 2.45 \times 10^8 \; m/s$$

28 (d) (2 marks)
Outcomes Assessed: 12-14
Targeted Performance Bands: 4-6

Criteria	Marks
• Proposed an experiment that validated special relativity • Explained how it worked	2
• Proposed an experiment that validated special relativity	1

Sample Answer:

Comparing regularly timed events at different speeds relative to the detectors can be seen in the Hafele Keating experiment.
In atomic clocks the regular oscillation of electrons in atoms is a physical process that happens at a precise rate. In 1971 The Hafele Keating experiment had four atomic clocks taken on airliners flying directly east and then directly west. The clocks were found to disagree with clocks left behind the US. Their differences were explainable using special relativity. Thus the clock processes were happening more slowly in some reference frames compared to others. The principle of Time Dilation was supported.
Note: Muon decay experiment would also be a good example for students to use.

Question 29 (8 marks)

29 (a) (4 mark)
Outcomes Assessed: 12-14
Targeted Performance Bands: 3-5

Criteria	Mark

• Comparison of the two experiments showed a thorough knowledge of
  • Safety aspects of lasers and hydrogen lamps.
  • Advantage of using each equipment
  • Disadvantage of using each method
  • Equipment and measurements required
	4

• Demonstrating a knowledge of the experimental methods students achieved 3 points from the above list.	3
• Demonstrating a knowledge of the equipment required students fulfilled 2 of the criteria above	2
• Students demonstrated some knowledge of the equipment.	1

Sample Answer:

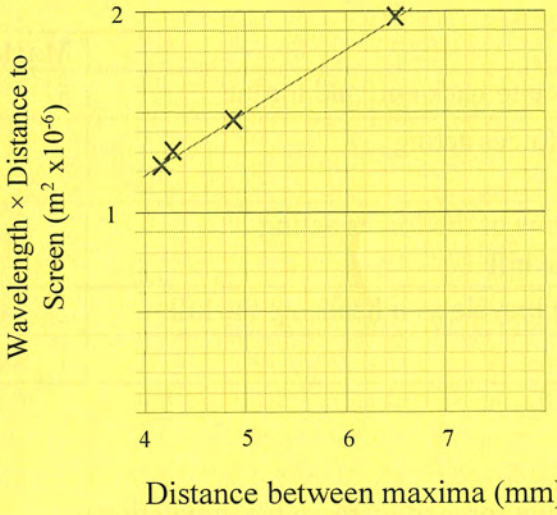
Student A uses lasers that do not use high voltages but are dangerous to the eyes. The double slit experiment will produce precise dots on a distant screen. No single slit would be required before the double slit. It is achievable in a room that is not totally dark.
Student B uses a hydrogen lamp which runs at high voltages and so must be used with great care not to touch. The light needed to be sent through a single slit first before going through a double slit. All the bands of four colours will be displayed at once. So time will be saved the room must be very dark.

Both experiments would work and need a distant screen to be able to measure the small angle of diffractions.
The lasers would be easier to set up as the light source is coherent and no single slit would be needed.

29 (b) (3 marks)
Outcomes Assessed: 12-5
Targeted Performance Bands: 3-5

Criteria	Marks
• Accurate plotting of all four points with axes drawn with correct scale and correct units included on labels. • Line of best fit is straight, is close to all points and points are scattered evenly above and below the line. • Calculation of slope is clear and correct.	3
• Two correct from above	2
• One correct from above	1

Sample Answer:



Slope =rise/run=$(2\times10^{-6}-1.2\times10^{-6})/(6.6\times10^{-3}-4.05\times10^{-3})=3.14\times10^{-4}$ or 0.314 mm

29 (c) (1 mark)
Outcomes Assessed: 12-5
Targeted Performance Bands: 4-5

Criteria	Marks
• A suitable explanation is given.	1

Sample Answer:

In the mathematical method each measurement is given equal importance for the calculation. However, one measurement might be an outlier. The graphical method enables the scientist to spot outliers and hence ignore them.

Question 30 (5 marks)
Outcomes Assessed: 12-13
***Targeted Performance Bands*: 3-5**

Criteria	Mark
• Provides thorough explanation incorporating reference to back emf and torque	5
• Explains both the slowing of the bicycle in terms of forces acting • Relates the increase of current to the back emf	4
• Adequately explains the slowing of the bicycle in terms of the forces acting • Adequately explains the increase in the current on the hill	3
• Reference to the net force and the acceleration of the bicycle as it heads up the hill.	2
• Some relevant reference to the weight force	1

Sample Answer:

To head up the hill, the motor must work against the weight force to increase the gravitational potential energy of the bicycle. This is in addition to the frictional forces already acting against the motion. As a result, there will initially be a net force acting down the hill and the bicycle will slow down.

As the rate at which the motor spins decreases, the back emf reduces. The current passing through the motor therefore increases. This results in an increasing torque on the motor. The rotation and back emf continues to decrease until the torque produced by the motor balances the increased forces on the wheels. The bicycle continues up the hill at a constant (but lower) speed.

Question 31 (6 marks)

31 (a) (3 marks)
Outcomes Assessed: 12-12
Targeted Performance Bands: 4-5

Criteria	Marks
• Correct formulae using both Kinetic and Gravitational Energy • Correct formula substitution • Correct use of the -ve sign in the working	3
• 2 correct from above list	2
• 1 correct from above list	1

Sample Answer:
K=-1/2U U=-GMm/r
Total Energy=U+K=U-1/2U=U/2
Total Energy=-GMm/2r= $-\frac{6.67\times10^{-11}\times6.0\times10^{24}\times920}{2\times44428000}$ =4143603133=4.14×10^{9} J

31 (b) (2 marks)
Outcomes Assessed: 12-12
Targeted Performance Bands: 4-6

Criteria	Marks
• Correct subtraction of the two energy values	2
• Correct process but incorrect substitution or incorrect use of the -ve sign.	1

Sample Answer:
At the initial orbital radius of 44,428 km: -4.14 GJ

At the final orbital radius of 42, 164km

$$T = -\frac{GMm}{2r}$$

$$= -\frac{(6.67\times10^{-11})\times(6.00\times10^{24})\times920}{(2\times42164000)}$$

$$= -4.37 \text{ GJ}$$

To calculate work:

$$\Delta E = E_f - E_i$$
$$= -4.37 - (-4.14)$$
$$= -4.37 + 4.14$$
$$= -0.230 \text{ GJ}$$

31 (c) (1 marks)
Outcomes Assessed: 12-12
Targeted Performance Bands: 5-6

Criteria	Marks
• States that the energy is lower. Justified by the mathematics in part b of the two energies.	1

Sample Answer:
The satellite's total energy has decreased from –4.14 to –4.37 GJ so it has lost energy equivalent to the work done. This is shown by the fact that the change in energy has a negative sign. (The way that gravitational energy is defined, with energy at infinity being zero, means that a more negative number means less energy)

Question 32 (10 marks)

32 (a) (1 marks)
Outcomes Assessed: 12-13
Targeted Performance Bands: 3-4

Criteria	Marks
• Arrows clearly show current going in anticlockwise direction in both coils	1

Sample Answer

Current in both coils goes in the anticlockwise direction

32 (b) (6 marks)
Outcomes Assessed: 11/12-4, 12-13
Targeted Performance Bands: 2-6

Criteria	Marks
• Mentions sensible safety protocols and the need to avoid parallax error on ruler. • Includes changing one quantity (B or V) systematically to get a spread of values • Includes the measurement of radius using the ruler. • Includes repetition of each value to check reliability. • Demonstrates understanding of why the path is circular. ($qvB=mv^2/r$) • Suggests altering B (or V) to get a circular path and hence a good value for r.	5-6
• Includes 3-4 points from the above list	3-4
• Includes1-2 points from the above list	1-2

Sample Answer:

Safety: Establish protocols for using high voltage equipment. Eg do not work alone, have one hand in your pocket and don't touch the equipment when it is switched on.

Method:
1 Stand directly in front of the equipment (to avoid parallax error when reading the ruler) and switch on the current in the coil and electron gun voltage.
2 Starting from zero voltage increase the voltage until a clear curve of electron beam can be seen in the flask. Alter the magnetic field until the beam hits the left side of the electron gun. (ie is perfectly circular)
3 Read the diameter of the circle and divide by two to obtain the radius.
4 Record the values for r, B and V
5 Take 10 more readings spreading the voltage evenly up to 500 Volts.
6 Repeat the same readings to see if the radius values are coming out reliably.
7 Calculate the value for q/m using the equations.

32 (c) (2 marks)
Outcomes Assessed: 11/12-2,3 12-13
Targeted Performance Bands: 5-6

Criteria	Marks
• Gets the correct relationship.	3
• Attempts to use W=qV, F=mv^2/r and F=qvB • Some logical working	2
• Works with some formulae	1

Sample Answer

Formulae: for settings of Accelerating Voltage (V) on the electron gun the electrons will travel at different speeds (v). The speeds are determined by the formula
W=qV= ½ mv^2

$$\therefore v = \sqrt{\frac{2qV}{m}}$$

Using the equipment for each setting of the Voltage alter the Magnetic field (B) until a complete circle is obtained in the flask. For this circle measure the diameter of the circle using the ruler. Halve the diameter to find r. The magnetic force acts as the centripetal force therefore

$$\frac{mv^2}{r} = qvB$$

$$\therefore v = \text{qBr/m}$$

$$\therefore \sqrt{\frac{2qV}{m}} = \frac{qBr}{m}$$

$$\frac{2qV}{m} = \frac{q^2B^2r^2}{m^2}$$

$$\frac{q}{m} = \frac{2V}{B^2r^2}$$

Question 33 (9 marks)
Outcomes Assessed: 12-14/15
Targeted Performance Bands: 3-6

Criteria	Marks
• Clearly outlines at a wide variety of discoveries related to atoms, stars and universe • Indicates a clear understanding of what spectroscopy is. • Discoveries range from work of Hubble to work of Bohr and beyond. • Demonstrates extensive knowledge on this subject.	8-9
• Outlines a variety of discoveries that are related to spectroscopy. • Relates them to change in view of atom or universe. • Indicates an understanding of what spectroscopy is. • Covers both universe and atom examples.	6-7
• Outlines some discoveries that are related to spectroscopy. • Relates them to change in view of atom, stars or universe.	4-5
• Outlines at some examples of discoveries that are related to spectroscopy	2-3
• Gives some examples of spectroscopy usage.	1

Sample Answer:

Spectroscopy is taking the light from star or gaseous element and splitting that light into the individual colours using a prism or diffraction grating. This results in spectra including spectral lines which can be bright if emitted from atoms or dark lines if absorbed by atoms.

Changes in our view of the stars and universe

1 It was the study of galaxy spectra that enabled Hubble to discover a Doppler shift in the spectra establishing the theory that the universe is expanding according to Hubble's Law. This led to the idea of a beginning to the universe (the Big Bang Theory)

2 Stella spectra establish that there is plenty of Helium in stars which indicates that Helium was present before the formation of stars. This helps establish the idea that the universe was once very dense and very hot. This is part of the steps in the Big Bang theory.

3 Comparing the Sun's spectra to other stars enabled scientists to establish that the sun is the same as other stars. Thus the universal laws apply to our solar system and beyond. This has led to scientists confidently studying the universe using the laws of physics we have established on Earth.

4 Stella spectra also enabled scientists to know the elements present in stars by comparing spectral lines in stars with emission spectra of elements in evacuated flasks in the laboratory,

5 The density of stars outer layers and the surface temperature of stars was found by studying the thickness of the spectral lines. Thick lines meant denser atmospheres.

6 The surface temperature of stars was found by studying the darkness of the hydrogen lines and other clues including the presence of lines from molecules rather than just elements. Suggesting cooler star surfaces.

7 From this the nuclear reactions within stars have been found AND the life cycle of stars has been established. We now know for example that our Sun will not last forever and in fact has about 5 billion years to go before it becomes unstable.

8 Spectroscopy also confirms that Stars in the center of the galaxy are rotating about an invisible giant mass (a black hole) and that the galaxy is rotating.

Changes in our view of the atom

The study of the spectra of the elements has also changed our view of the structure of the atom.
9 Balmer used the spectrum of hydrogen to establish the Rydberg equation which shows a mathematical relationship between the wavelengths of the spectral lines of Hydrogen. This led Bohr to develop his idea of the quantum nature of the electron orbits. This led to quantum physics as a whole.
10 The electron orbits led to the study of standing waves of matter by de Broglie AND the Heisenberg uncertainty principle. Changing our entire view on matter vs waves.
Hence the study of spectroscopy has totally changed our view of the universe and the atom.