CSSA

2024
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

DO NOT REMOVE PAPER FROM EXAMINATION ROOM

Centre Number

Student Number

Physics

Morning Session
Friday, 9 August 2024

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA-approved calculators may be used
- Use the Multiple-Choice Answer Sheet provided
- 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 2–15)
- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 16–37)
- Attempt Questions 21–36
- 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 A ball is thrown at 45° above the horizontal so that it follows a parabolic trajectory. What ONE change to the initial conditions would make the ball's maximum height greater?

A. Increasing the horizontal component of its initial velocity

B. Decreasing the vertical component of its initial velocity

C. Increasing the angle of launch to the horizontal

D. Decreasing the angle of launch to the horizontal

2 An object is undergoing uniform circular motion. The magnitude of the centripetal force required to maintain its motion is F.

Which of the following best represents the new centripetal force if the mass of the object is doubled, the radius halved, and the speed tripled?

A. 3F

B. 9F

C. 12F

D. 36F

3 The Bohr model of atoms suggests that a hydrogen atom consists of an electron orbiting a proton.

Which of the following forces keeps the electron in its orbit?

A. Centripetal

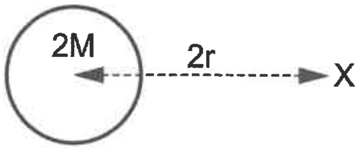
B. Electrostatic

C. Gravitational

D. Strong Nuclear

4 Each of the diagrams below shows a point X in space, located at a given distance from the centre of a planet.

Which diagram represents the weakest gravitational field strength at point X?

A.


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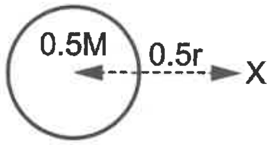

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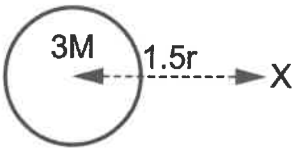

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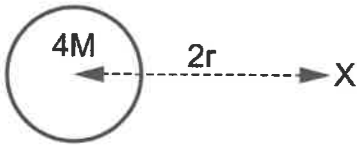


5 An engineer is tasked with designing a stepdown transformer to meet the specifications of a new smart device. The new device can accept up to 12 W of power at a current of 1.2 A. The primary coil is supplied with a 240 V AC power supply.

What is the ratio of turns in the primary coil to the secondary coil?

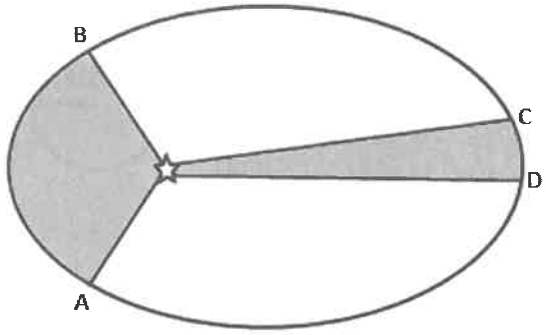
A. 1:24

B. 12:1.2

C. 20:1

D. 24:1

6 Johannes Kepler deduced three Laws of Planetary Motion. The diagram below shows a planet's orbital path as an ellipse as it orbits a star in a clockwise direction. The shaded sections are of equal area.



Which of the following statements is true?

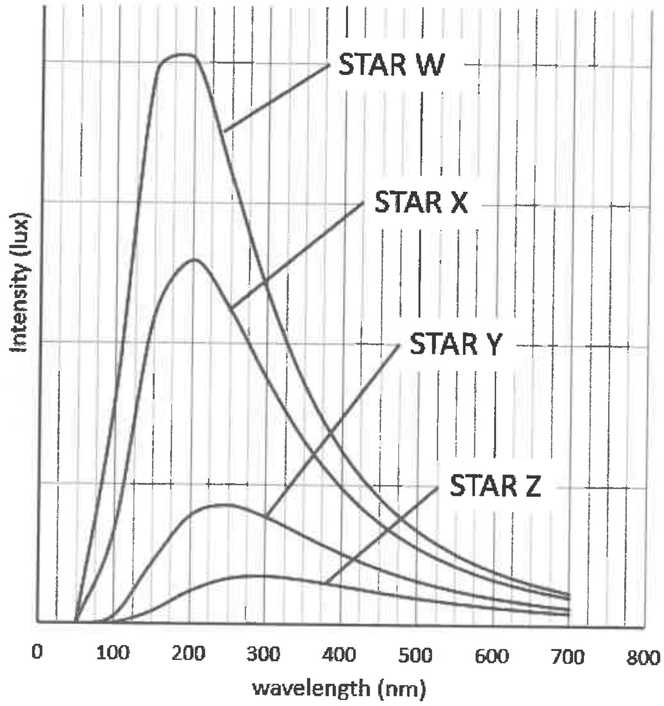
A. The planet will have the greatest velocity at point D.

B. The planet will have equal velocity between A and B and between C and D.

C. The time taken for the planet to travel from point A to point B is more than the time taken between point C and point D.

D. The time taken for the planet to travel from point A to point B is equal to the time taken between point C and point D.

7 The following data shows the intensity of electromagnetic radiation as a function of wavelength for four different stars W, X, Y and Z.



Which conclusion can be correctly deduced from this data?

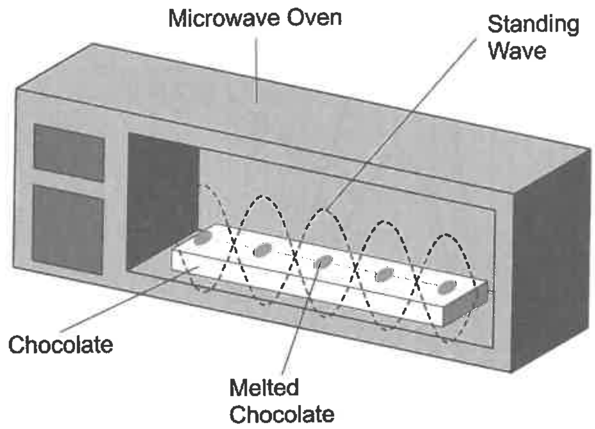
A. Star W is closer to Earth than Star Z.

B. Star Y has a higher surface temperature than Star X.

C. Star X has a surface temperature of about 15000 K and Star Y has a surface temperature of about 12000 K.

D. Star W has a surface temperature of about 15000 K and Star Z has a surface temperature of about 5000 K.

8 A microwave oven creates standing waves, which causes water in food to vibrate and cook the food. The microwaves have a frequency of 2450 MHz. The turntable inside the microwave moves the food through the hot spots to evenly cook it. If the turntable is removed and a large block of chocolate is placed in the microwave it will melt in some areas and not in others.



If the distance between the melted areas in the chocolate is 6.00 cm, what is the speed of the microwaves in the oven?

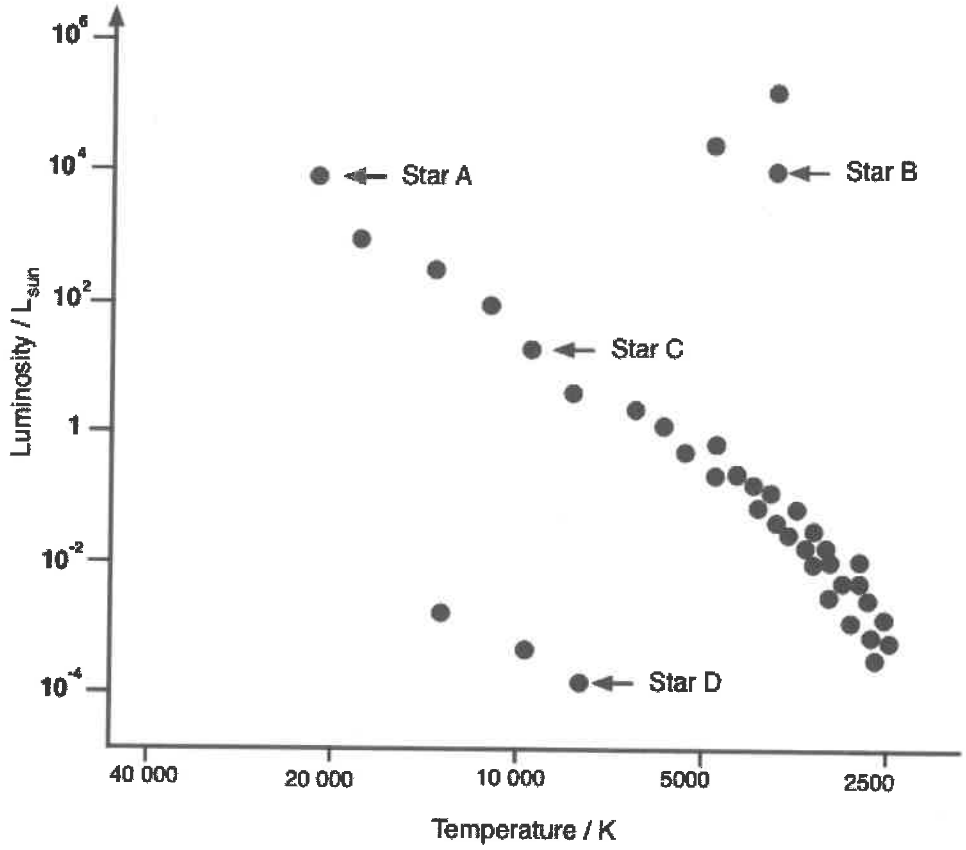
A. $1.47 \times 10^{2}\ ms^{-1}$

B. $1.47 \times 10^{8}\ ms^{-1}$

C. $2.94 \times 10^{8}\ ms^{-1}$

D. $2.96 \times 10^{8}\ ms^{-1}$

9 The diagram below shows the HR-diagram for a particular stellar cluster. Four of the cluster's stars are labelled on the diagram.



Which of the labelled stars would have the greatest surface area?

A. Star A

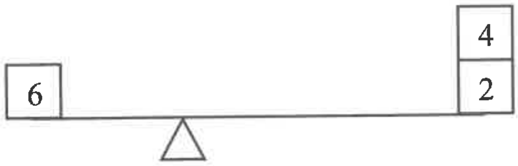
B. Star B

C. Star C

D. Star D

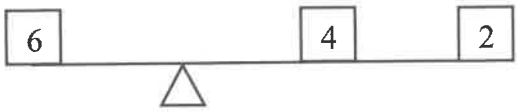
10 Which of the diagrams below shows the greatest net torque around the fulcrum? All drawings are to scale. All masses are in kilograms.

A.

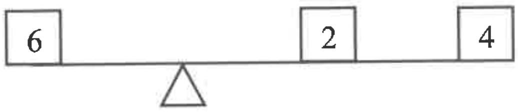


B.

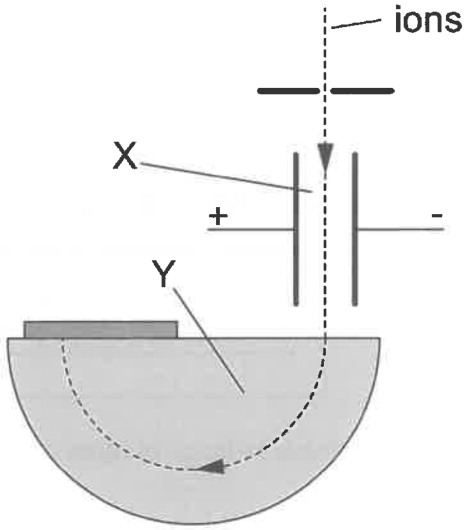
C.



D.



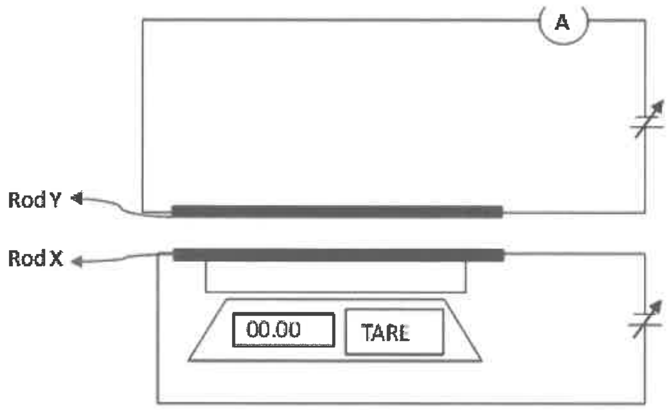
11 Below is a model of a particle accelerator being used as a mass spectrometer to determine the relative abundance of isotopes within a sample of material. The atoms in the sample are ionised and passed through the accelerator as shown in the diagram.



Which row of the table correctly identifies the fields present in Region X and in Region Y?

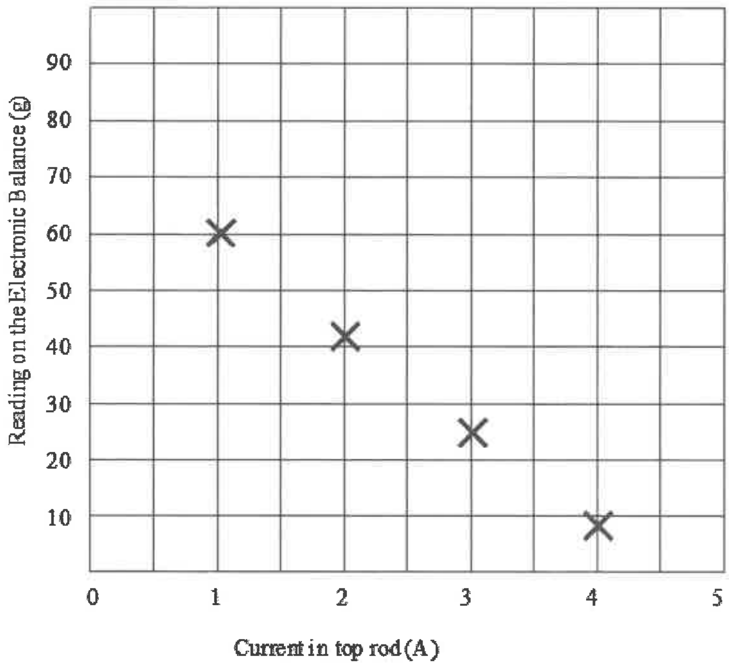
	Region X	*Region Y*
A.	electric only	magnetic only
B.	electric only	electric and magnetic
C.	electric and magnetic	electric only
D.	electric and magnetic	magnetic only

12 A metal Rod X is placed on an electronic balance. It is connected to a power supply with wires that can be considered weightless. Fixed above the rod is an identical Rod Y which is attached to an ammeter and power supply.



A student graphs data on the electronic balance reading as the current in Rod Y is altered.

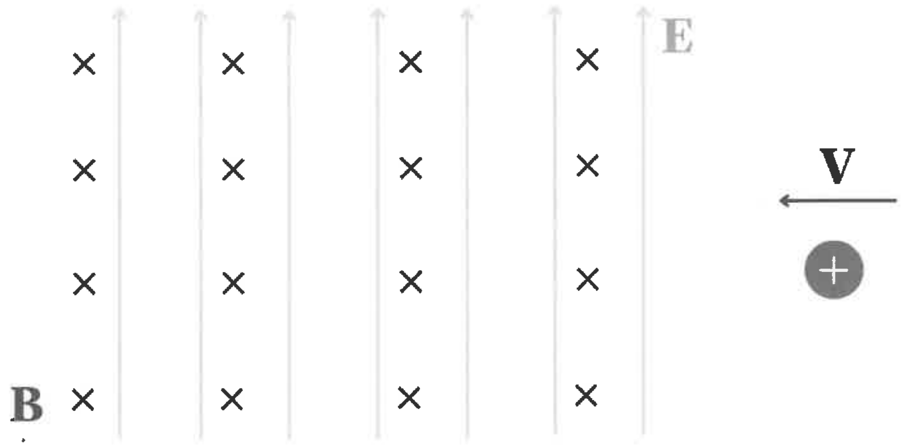
The graph is shown below.



From the graph determine the mass of Rod X and predict the minimum current in Rod Y that will lift Rod A off the electronic balance.

	Mass of Rod X (g)	*Current in Y that will lift Rod X (A)*
A.	78	1.0
B.	60	4.4
C.	78	4.4
D.	60	4.9

13 A mass with a 1.00 millicoulomb positive charge is moving in a straight line at the speed of 6.50×10^{3} ms^{-1} through an electric field of strength 1.20×10^{-3} NC^{-1} and a magnetic field as shown. The mass of the charge is insignificant.



What is the magnitude of the magnetic field required to maintain the straight-line motion?

A. 1.20 T

B. 1.85×10^{-7} T

C. 7.81×10^{-5} T

D. 7.81×10^{-7} T

14 Current theories and models of the Big Bang indicate the very early Universe underwent several key stages in its early evolution. Four of these key stages are:

I: formation of atomic nuclei

II: rapid Inflation of the Universe

III: formation of particles and antiparticles in large numbers

IV: electromagnetic radiation decouples from matter and can travel through the Universe

Which of the below options lists the most correct order in which these stages occurred?

A. II → III → I → IV

B. II → IV → I → III

C. III → II → IV → I

D. IV → I → III → II

15 The minimum frequency required to eject photoelectrons from the surface of a metal's surface is f. A monochromatic radiation with frequency of 3f is shone on the metal surface and the kinetic energy of a photoelectron is measured to be K.

What is the kinetic energy of the photoelectron if the frequency of radiation is 5f?

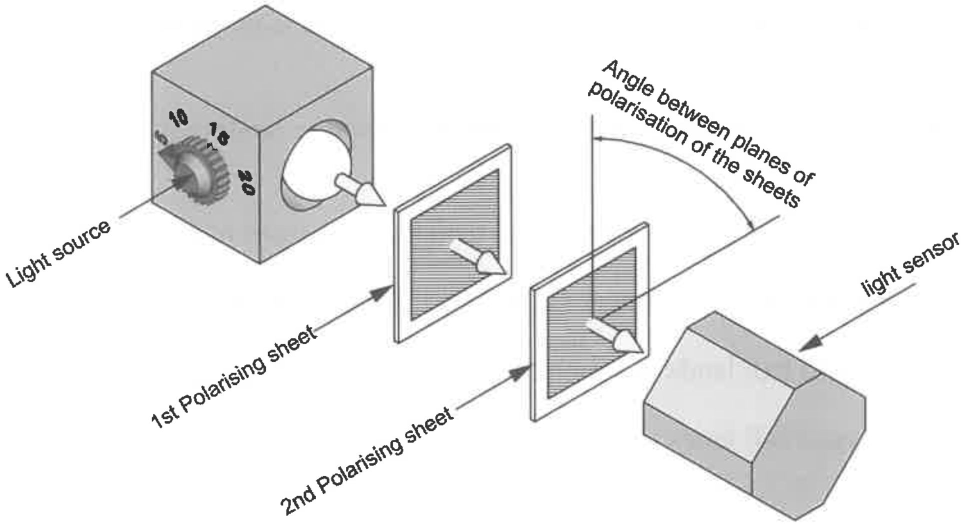
A. 4.0 K

B. 2.0 K

C. 1.7 K

D. 0.6 K

16 The following apparatus was set up to investigate how changing variables affect the measured intensity of light.



Which row of the table shows the best configuration that results in the greatest value in the intensity of light measured at the light sensor?

	Luminosity of light source	*Angle between planes of polarisation of the sheets (°)*
A.	5	20
B.	10	40
C.	15	60
D.	20	80

17 Which row of the table correctly describes the spectra produced from discharge tubes, reflected sunlight and incandescent filaments?

	Discharge tubes	*Reflected sunlight*	*Incandescent filaments*
A.	Continuous	Absorption	Continuous
B.	Emission	Continuous	Emission
C.	Emission	Absorption	Continuous
D.	Continuous	Emission	Emission

18 Two identical balls are fired with the same device, East to West along the equator of Earth. One ball carries a large positive electric charge, the other ball has no net electric charge. The balls are both aimed 45 degrees above the horizontal. The trajectory of the balls is perpendicular to the magnetic field of the Earth, which is directed northwards at the equator.

Which of the following statements correctly describes the landing position of the charged ball?

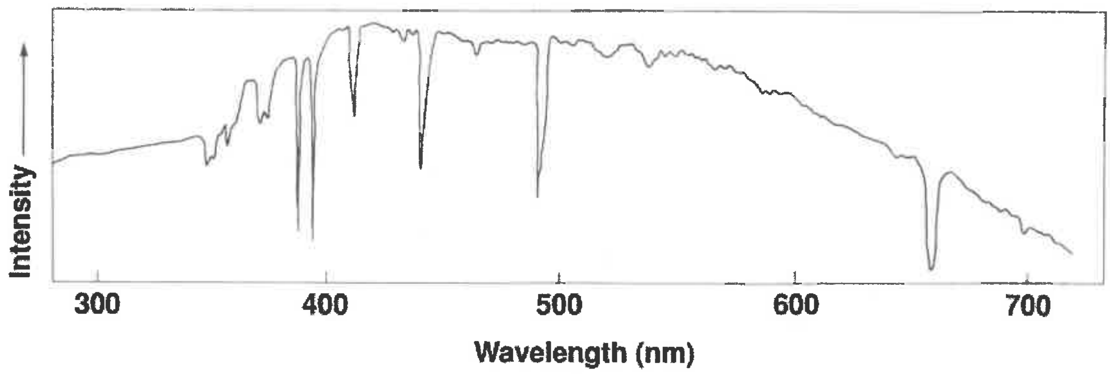
A. The charged ball has a shorter range than the uncharged ball.

B. The charged ball has a longer range than the uncharged ball.

C. The charged ball lands in a more northerly location than the uncharged ball.

D. The charged ball lands in a more southerly location than the uncharged ball.

19 The diagram below demonstrates a star's spectrum. The spectrum shows a number of absorption lines and its black body spectrum.



Which of the following features would be predominantly used to determine the spectral class of the star?

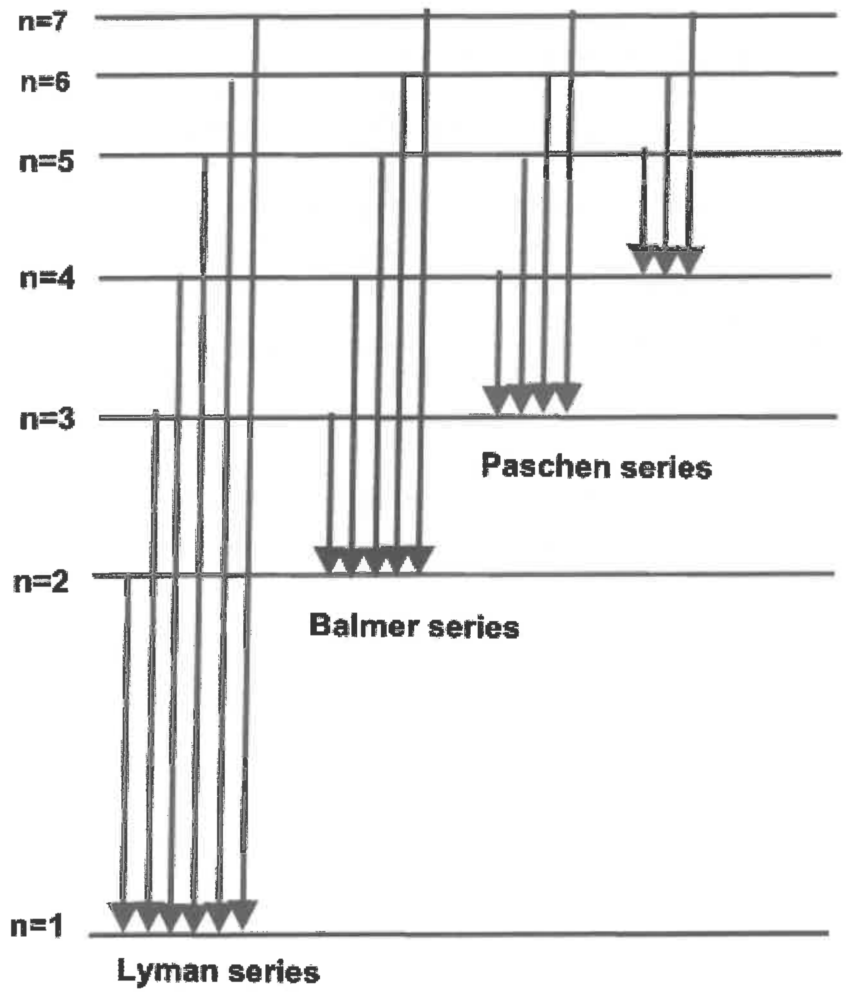
A. The longest wavelength absorption line in the spectrum

B. The maximum intensity from black body radiation curve

C. The relative depths of different absorption lines in the spectrum

D. The relative widths of different absorption lines in the spectrum

20 The diagram below shows some of the transitions for three series of emission spectra for hydrogen.



An electron in the n=6 energy level of a hydrogen atom relaxed to a lower energy level. In the process, a single photon with energy 3.025 eV was emitted.

Which of the following energy levels did the electron relax to?

A. n = 2

B. n = 3

C. n = 4

D. n = 5

Section II

80 marks
Attempt Questions 21–33
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 (2 marks)

A spaceship with a rest mass of 35000 kg is moving with a velocity of 0.8 C relative to an observer. Calculate the relativistic momentum of the spaceship, relative to the observer. **2**

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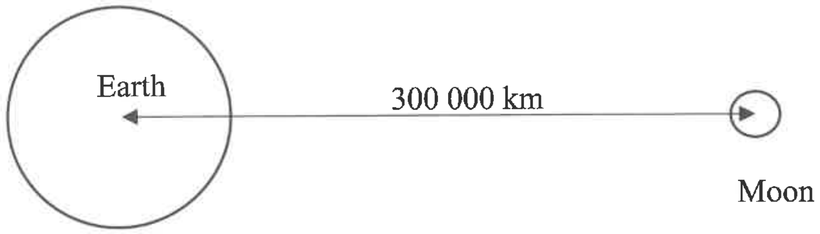
Question 22 (4 marks)

The moon orbits the earth every 27.3 days at an orbital radius of 300 000 km. The radius of the moon is 1737 km and the acceleration due to gravity on its surface is 1.6 ms^{-2}.



(a) Calculate the total mechanical energy of the moon as it orbits the earth. **2**

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(b) Calculate the escape velocity from the surface of the moon. **2**

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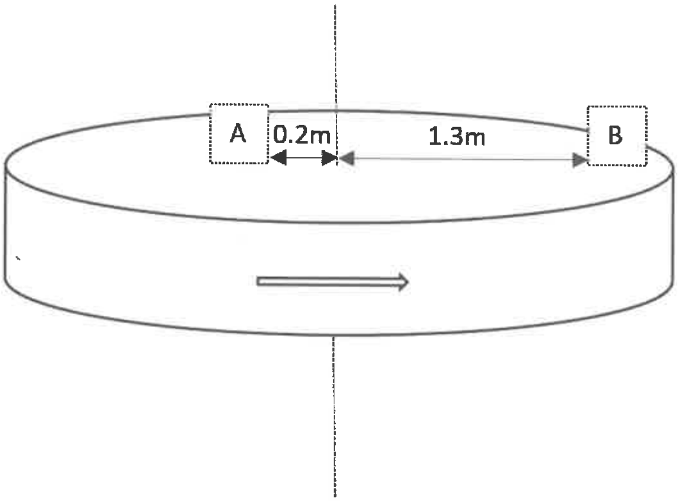
Question 23 (4 marks)

Two objects sit on top of a rotating disc. Object A has a mass of 2 kg and object B a mass of 5 kg. Both objects are undergoing uniform circular motion.

A frictional force of 160 N is required to keep object A in uniform circular motion.



(a) Calculate the magnitude of angular velocity of the disc. **2**

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(b) Calculate the magnitude of the centripetal force required to keep object B remaining in uniform circular motion. **2**

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Question 24 (3 marks)

Two planets X and Y are orbiting a distant star. X is observed to have an orbital radius of 1.9×10^{11} m and an orbital period of 326 days. Y has an orbital period of 516 days. **3**

Determine the mass of the distant star and the orbital radius of Y.

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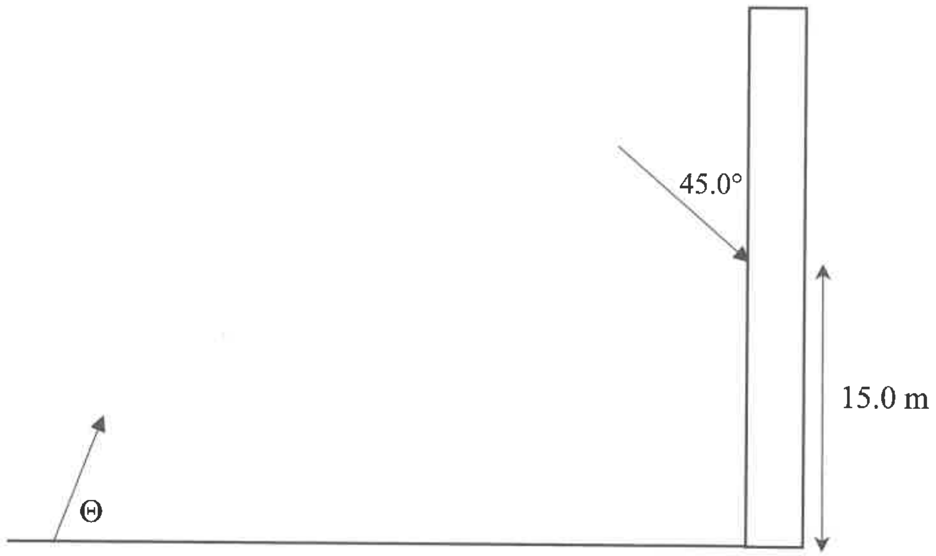
Question 25 (4 marks)

A projectile is launched against a vertical wall. As shown below, the projectile strikes the wall at an angle of 45.0 degrees and 15.0 m above the height at which it was launched. The final horizontal velocity of the projectile is 13.0 ms^{-1}. **4**



How far is the launch site from the wall?

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Question 26 (4 marks)

Discuss how the wave model of light cannot explain a number of features of the photoelectric effect. **4**

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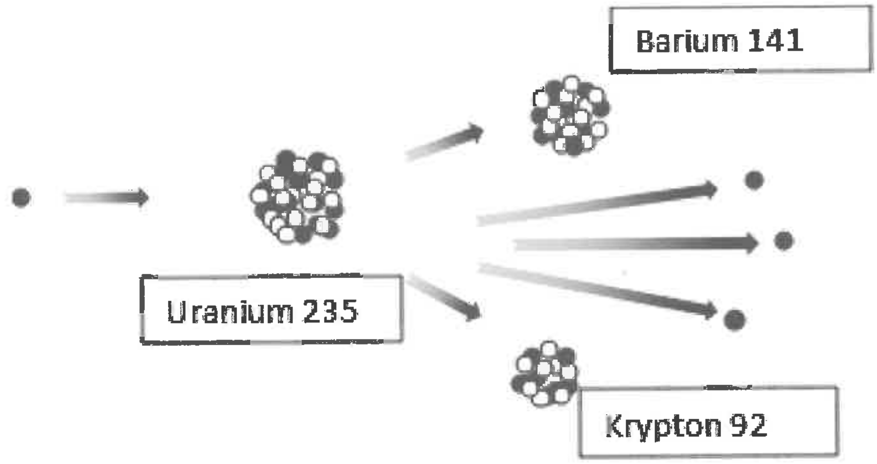
Question 27 (6 marks)

The diagram below shows one possible fission reaction involving Uranium 235. **6**



Explain, using a nuclear equation, how this reaction could lead to an uncontrolled chain reaction <u>and</u> how the reaction rate can be controlled in nuclear reactors.

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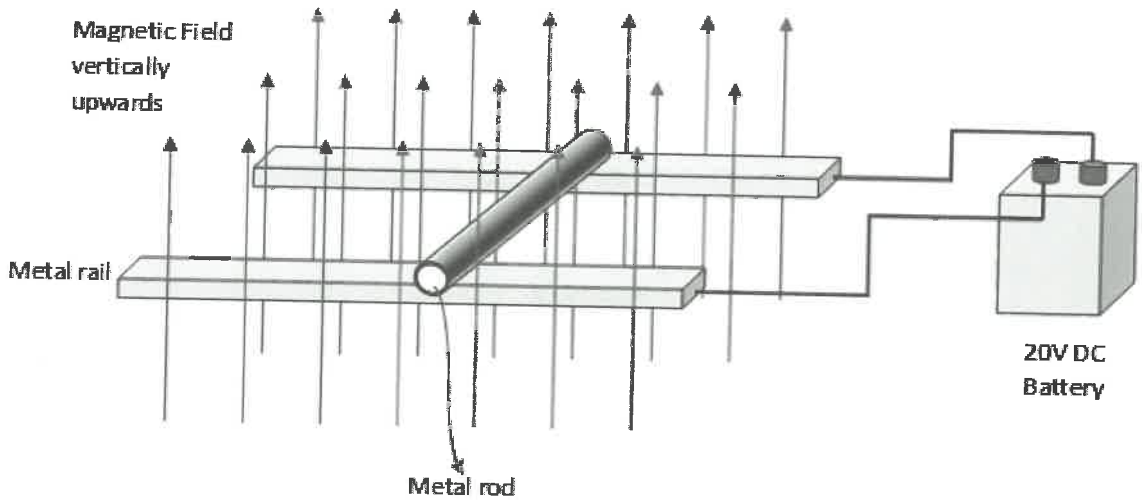
Question 28 (4 marks)

Two metal rails which are fixed in place, horizontally and parallel to each other, are connected to a 20 V battery. The rails are 8 cm apart. A light metal rod of length 8 cm is balanced on the two rails. A current flows along one rail, through the rod and back along the other rail.

A magnetic field of 0.005 T is directed vertically upwards around the rod. The rod begins to move to the right.



(a) On the diagram above, show the direction of current flow through the rails and rod. Explain your answer. **2**

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(b) The metal rails have no resistance and the rod in this situation has a resistance of 0.02 Ω. Calculate the electromagnetic force acting on the rod. **2**

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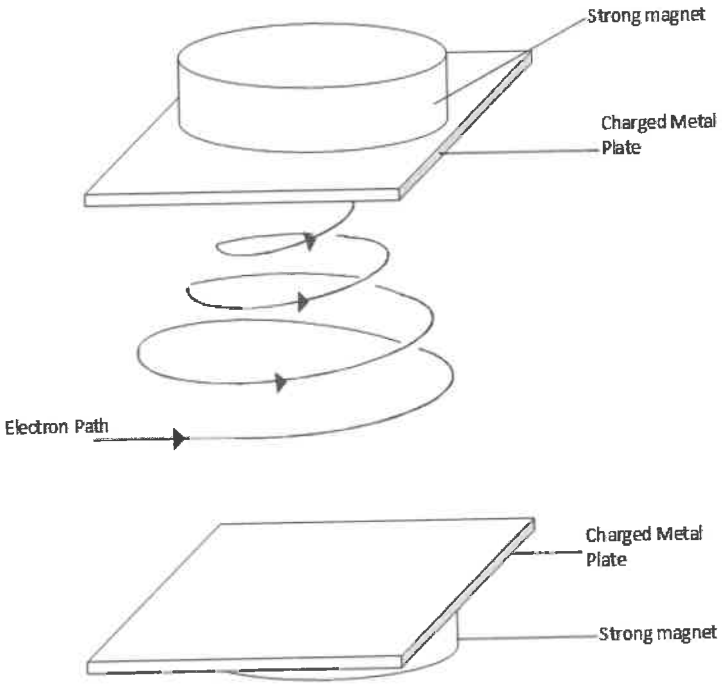
Question 29 (5 marks)

In a computer simulation, the gravitational effects are turned off. An electron is moving into a field chamber at speed v to the right.

The electron moves in an upward spiral, moving in an anti-clockwise direction when viewed from above.



(a) What directions are the electric and magnetic fields in this chamber? **2**

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Question 29 continues on page 25

Question 29 (continued)

(b) The electron was removed from the chamber and a proton was sent into this chamber with the same initial speed and direction. Compare the path of the proton to that of the electron. **3**

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End of Question 29

Question 30 (7 marks)

When 50.0 g of hydrogen gas undergoes combustion, the energy released is 7145 kJ.

(a) Calculate the mass of hydrogen required for the same amount of energy to be produced via direct mass-energy transformation. **1**

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(b) Account for the difference in mass required to release the same amount of energy, with respect to the two processes of combustion, and mass-energy transformation. **3**

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Question 30 continues on page 27

Question 30 (continued)

(c) The overall reaction of the proton-proton chain can be summarised by the following nuclear equation. **3**

$$4\ {}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\ {}^{0}_{0}v_{e} + 2\ {}^{0}_{1}e + 2\ \gamma$$

The masses of the particles in this process are shown in the table below.

Particle	*Atomic Mass (u)*
${}^{1}_{1}H$	1.00784
${}^{4}_{2}He$	4.00260
${}^{0}_{1}e$	0.00055

Calculate the energy released, in Joules, for one proton-proton chain reaction.

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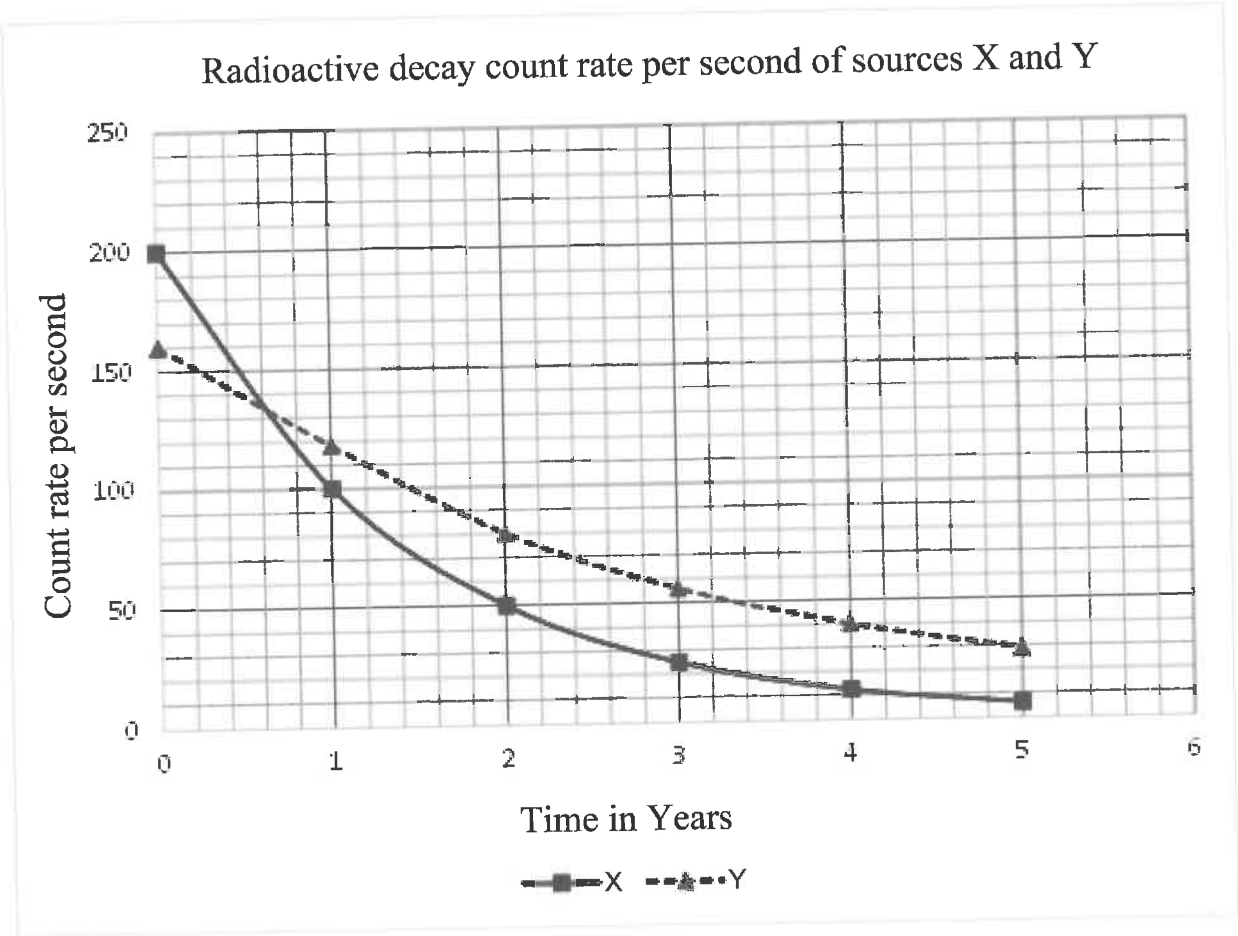
End of Question 30

Question 31 (4 marks)

A scientist is measuring the radioactive decay of sources X and Y over a number of years.



(a) Compare numerically the half-life and decay constant of sources X and Y. **3**

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(b) Each year the masses of the sources were measured, and there was no observable change. Account for this statement. **1**

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Question 32 (5 marks)

Many experiments were conducted that contributed to the development and understanding of the basic nuclear model of the atom.

(a) Outline how the results of the Geiger-Marsden gold-foil experiment provided evidence for Rutherford's nuclear model of the atom. **3**

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(b) In other experiments, beryllium was found to emit a stream of radiation when bombarded with alpha particles. These were called *beryllium rays* and were thought to be a form of electromagnetic radiation. Paraffin wax exposed to beryllium rays was found to eject protons. **2**

Describe how Chadwick verified that beryllium rays were in fact small neutral particles rather than electromagnetic radiation.

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Question 33 (6 marks)

A group of students performed an experiment to investigate the diffraction patterns caused by shining monochromatic light through a double slit. Their data is summarised below.

Maxima number, (m)	*Angle of deflection, Θ (°)*	*sin θ*
2	7.8	0.136
3	11.5	0.199
4	15.5	0.267
5	19.3	0.331

The distance between slits, d, was 1×10^{-5} m.

Construct an appropriate graph of the data **and** use it to determine the wavelength of the laser light. **6**

Question 33 continues on page 31

Question 33 (continued)

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End of Question 33

Question 34 (4 marks)

There are two balls: one black and one grey. Each ball has a mass of 0.50 kg. The two balls are rolled within a frictionless tube. The tube is bent into a circular curve which lays horizontally.

The two balls are each rolled at a different velocity.

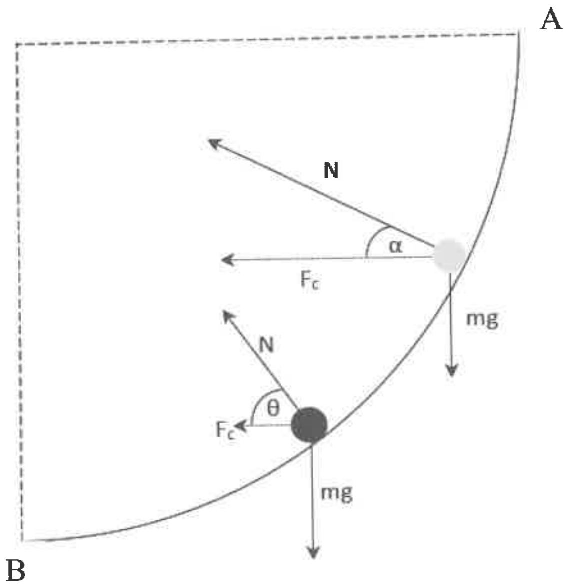

Fig 1. A section of the tube showing forces acting on the black and grey balls.

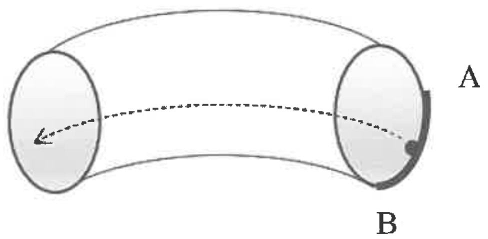

Fig 2. A view of the path of the black ball through the tube bent into a corner.

(a) Identify which ball has the greater velocity. **1**

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(b) Calculate the velocity of the grey ball if $\alpha = 25°$ and the radius of its path is 6.0 m. **3**

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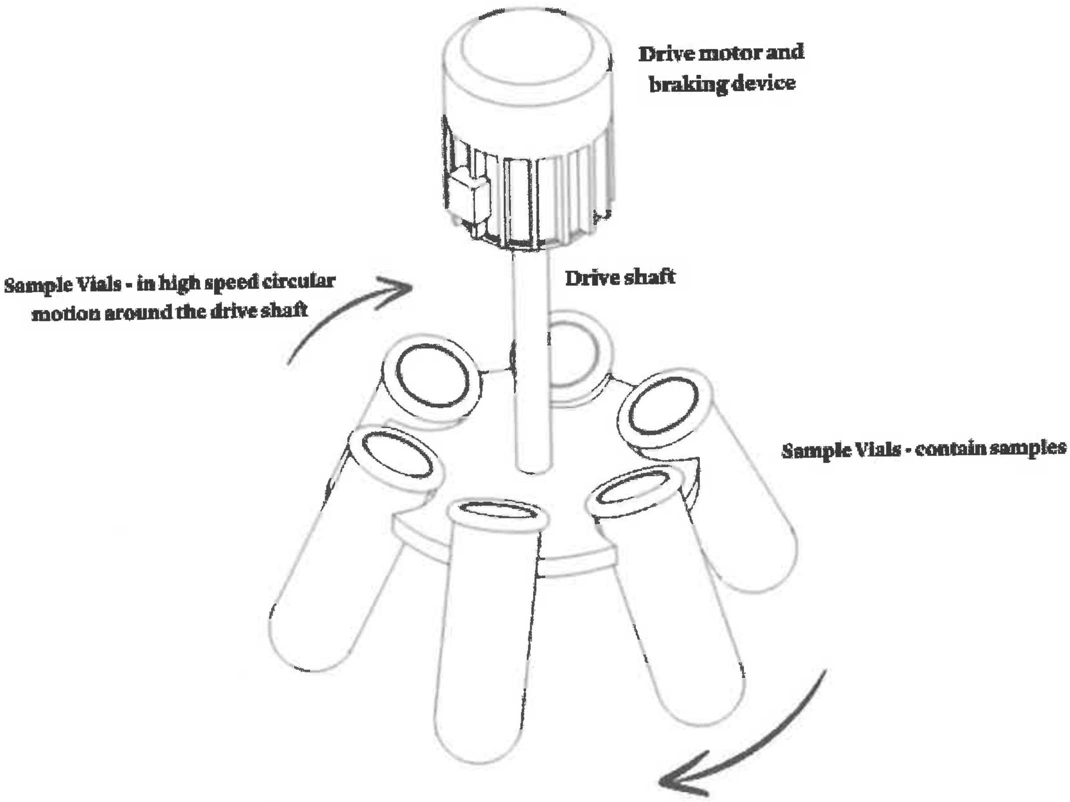
Please turn over

Question 35 (9 marks)

A laboratory centrifuge (functional parts are shown in the figure below) is used to separate components of delicate samples by rapidly spinning them. **9**



Magnetic braking is used to slow the device down after separation. Braking effect utilises an aluminium disc, which rotates with the drive shaft, and lies between a pair of electromagnets. It has been found that slowing the centrifuge down too suddenly is dangerous to the sample. However, making it slow down too gently wastes valuable time.

Question 35 continues on page 35

Question 35 (continued)

Explain how electromagnetic braking occurs and why it is necessary to vary the current supply to the electromagnets of the braking system to provide a safer deceleration for the samples without wasting too much time.

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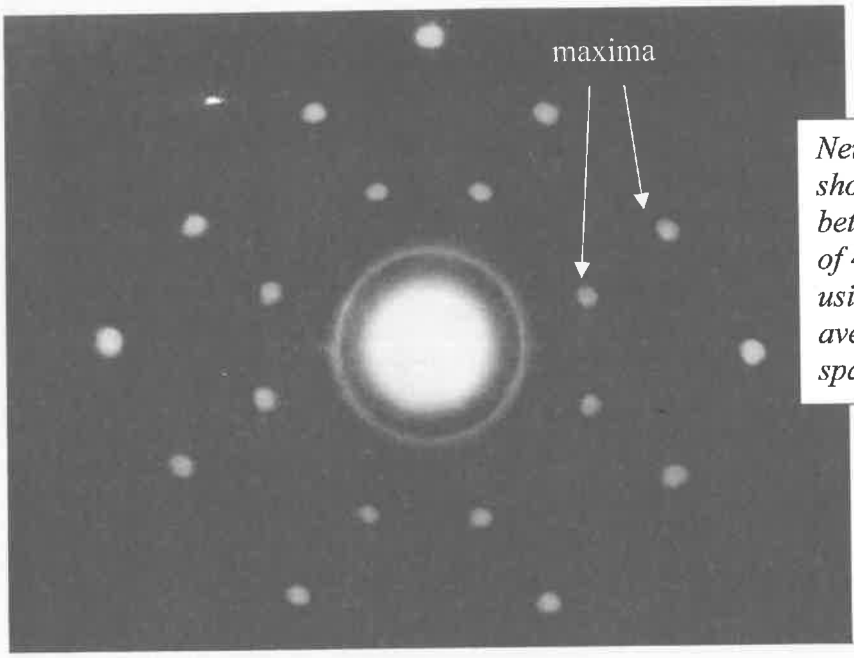
End of Question 35

Question 36 (9 marks)

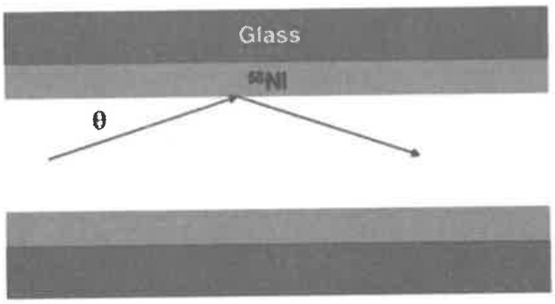
The image below shows one of the first ever diffraction patterns made using neutrons. It was produced by directing neutrons through a crystal of sodium chloride (table salt), where the inter-atomic average spacings of $d = 0.282\ nm$ act as small slits, producing a diffraction pattern. 9



Neutron diffraction image showing angular separation between successive maxima of 4° which was produced using a crystal of NaCl with average inter-atomic spacing of 0.282 nm

The neutrons are created in nuclear reactors designed to produce large numbers of neutrons, across a range of energies, some of which may enter the openings of *neutron guides,* which direct the neutrons to diffraction instruments.

Neutrons that enter *neutron guides* and interact with the internal walls of the guide at an angle less than the *specific angle,* θ_s, will stay within, and travel along, the guide (as shown below). Those that interact at a greater angle than θ_s will pass through the walls of the guide, to be absorbed by shielding materials.



A neutron will stay inside the guide provided: $\theta < \theta_s$

Note that in neutron guides, angles are measured to the boundaries, rather than to the normal.

Question 36 continues on page 37

Question 36 (continued)

Incorporate the information provided on page 36 and what you have learned during your physics course to describe the production of neutrons from reactor fuel through to their use in probing the structures of crystals, highlighting all the processes involved and properties of neutrons that are utilised.

Your response should include the following:

- an example of a nuclear reaction.
- evidence for neutrons travelling as matter waves.
- calculations to determine the velocity of the neutrons used to produce the diffraction pattern shown.
- the benefit of using neutrons to probe atomic and molecular structures of materials.

End of Examination

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Question 36	Shull, C. G. (1976). *Physics with early neutrons*, presented at the conference on Neutron scattering, Gatlinburg, Tennessee, June 6–10, 1976. Used with permission.

EXAMINERS

Lily Okati (Convenor)	Santa Sabina College, Strathfield
Matthew Bentley	St Ignatius College Riverview, Riverview
Tracy Getts	Trinity Grammar School, Summer Hill
Andrew Latham	Stella Maris College, Manly
Janet Pemberton	Education Consultant
Peter Robson	William Clarke College, Kellyville

2024

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

CSSA

MARKING GUIDELINES

Physics

Section I

20 marks
Questions 1–20 (1 mark each)

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

Section II

80 marks
Question 21 (2 marks)
Outcomes Assessed: PH 12-14
Targeted Performance Bands: 2–3

Criteria	Mark
• Calculates the relativistic momentum of the spaceship	2
• Provides some relevant information	1

Sample Answer:

$$\rho_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$\rho_v = \frac{(35000)(0.8)(8 \times 10^8)}{\sqrt{(1 - (0.8)^2)}}$$

$\rho_v = 1.4 \times 10^{13}$ kgms^{-1}

Question 22 (4 marks)
Question 22 (a) (2 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly calculates the total energy of the moon	2
• Provides some relevant steps	1

Sample Answer:

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

$$1.6 = \frac{6.67 \times 10^{-11} \times M_m}{1737000^2}$$

$$M_m = \frac{1.6 \times 1737000^2}{6.67 \times 10^{-11}}$$

$$M_m = 7.24 \times 10^{22}\ kg$$

$$Total\ Energy = -\frac{GM_E M_m}{2r}$$

$$Total\ Energy = -\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 7.24 \times 10^{22}}{2 \times 300\,000\,000}$$

$$Total\ Energy = -4.83 \times 10^{28} J$$

Question 22 (b) (2 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly calculates escape velocity from the moon	2
• Any relevant information	1

Sample Answer:

$$v_{escape} = \sqrt{\frac{2GM_m}{r}}$$

$$v_{escape} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 7.24 \times 10^{22}}{1737000}}$$

$$v_{escape} = 2358\, ms^{-1}$$

Question 23 (4 marks)
Question 23 (a) (2 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly calculates the magnitude of angular velocity of the disc	2
• Provides some relevant steps	1

Sample Answer:

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

$$v = \sqrt{\frac{Fr}{m}}$$

$$v = \sqrt{\frac{160 \times 0.2}{2}}$$

$$v = 4\ ms^{-1}$$

$$\omega = \frac{v}{r}$$

$$\omega = \frac{4}{0.2}$$

$$\omega = 20\ rad.s^{-1}$$

Question 23 (b) (2 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly calculates the magnitude of centripetal force required for object B	2
• Provides some relevant steps	1

Sample Answer:

Length of arc of circle = $\Delta s = r\Delta\theta$

$$\frac{\Delta s}{\Delta t} = r \times \frac{\Delta\theta}{\Delta t}$$

$$v = r\omega$$

$v = 1.3 \times 20$

$v = 26\,ms^{-1}$

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

$$F = \frac{5 \times 26^2}{1.3}$$

$F = 2600N$

Question 24 (3 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2–5

Criteria	Marks
• Correct answer for radius of Y AND Mass of star	3
• Correct answer for radius of Y OR Mass of star	2
• Attempts to use Kepler's equation for at least one calculation	1

Sample Answer:

Radius of Orbit of Y

$$\frac{r_x^3}{T_x^2} = \frac{r_y^3}{T_y^2}$$

$$\frac{(1.9 \times 10^{11})^3}{326^2} = \frac{r_y^3}{516^2}$$

$R_y = 2.58 \times 10^{11}$ m = $2.6 \times 10^{11}\,m$

Mass of Central Star

$$\frac{r_x^3}{T_x^2} = \frac{GM}{4\pi^2}$$

$$\frac{(1.9 \times 10^{11})^3}{(326 \times 24 \times 60 \times 60)^2} = \frac{6.67 \times 10^{-11} M}{4\pi^2}$$

$M = 5.1 \times 10^{30} kg$

Question 25 (4 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 3–5

Criteria	Marks
• Correctly calculates the horizontal displacement	4
• Correctly calculates the time of flight	3
• Attempts some relevant substitutions	2
• Provides some relevant information	1

Sample Answer:

Upwards direction is considered as positive.

$v_y = vsin45$

$v_x = vcos45$

$v_y = v_x = 13ms^{-1}$

$v^2 = u^2 + 2as$

$(-13)^2 = u_y^2 + 2(-9.8)15$

$u_y = 21.52\, ms^{-1}$

$v_y = u_y + gt$

$-13 = 21.52 + (-9.8)t$

$t = 3.5\, s$

$s_x = u_x t$

$s_x = 13\, x\, 3.5 = 45.8\, m$

Question 26 (4 marks)
Outcomes Assessed: PH 12-14; PH 12-7
***Targeted Performance Bands*: 2–5**

Criteria	Marks
• Discusses THREE features of the photoelectric effect and how they cannot be explained using the wave model of light	4
• Discusses TWO features of the photoelectric effect and how they cannot be explained using the wave model of light	3
• Discusses ONE feature of the photoelectric effect and how it cannot be explained using the wave model of light	2
• Identifies some features of the photoelectric effect that cannot be explained using the wave model of light	1

Sample Answer:

According to the wave model, light travels as a continuous wave, and its properties are described by wavelength (λ) and frequency (f), related by the equation $c = \lambda f$ (where c is the speed of light). The amplitude of the wave determines its intensity.
The photoelectric effect, however, posed a significant challenge to the wave model. In this phenomenon, light shining on a metal surface ejects electrons.
The kinetic energy of emitted electrons: Classical wave theory predicts that increasing the intensity of light should increase the kinetic energy of emitted electrons. Contrary to this prediction, experimental observations revealed that the kinetic energy of emitted electrons depended on the frequency of light, not its intensity.
Instantaneous emission: Additionally, electrons were ejected instantaneously upon light exposure. Classical waves would require a buildup of energy before electron ejection, contrary to observations.
Threshold Frequency: Classical wave theory predicts that the intensity of light governs the amount of energy available, however experimental observations revealed that changing the frequency of light greatly impacted on the ejection of electrons. Only when a threshold frequency and above was supplied the ejection of electrons will happen. The intensity of light affects the size of photocurrent.

Question 27 (6 marks)
Outcomes Assessed: PH 12-15; PH 12-7
Targeted Performance Bands: 2–5

Criteria	Marks
• Complete reaction written with correct formatting and identifying neutrons • Links neutrons to the possibility of further reactions and showing how exponential increase could occur • Outlines how the absorption of neutrons by the control rods keeps the reaction rate steady	5–6
• Covers two points from above OR fails to give detail in explanation	3–4
• Covers one point from above	2
• Any relevant information	1

Sample Answer:

$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$$

The reaction is started by a slow neutron colliding with a uranium nucleus. The reaction produces three more neutrons. If each of them is absorbed by other uranium nuclei that would produce 9 neutrons which could then produce 27. The result is an exponential increase in the reaction rate which would be uncontrolled.

To increase the reaction rate:

- the neutrons are slowed down by a moderator like heavy water so they are more likely to be absorbed by a uranium nucleus.
- the fuel rods are placed near to each other
- neutron absorbing control rods are lifted away.

To decrease the reaction rate:

- The control rods are lowered between the fuel rods

Careful adjustment of the above parameters enables the reaction rate to stay constant.

Question 28 (4 marks)
Question 28 (a) (2 marks)
Outcomes Assessed: PH 12-13
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly shows the direction of current and explained their answer	2
• Correctly shows the direction of current	1

Sample Answer:

Rod moves to the right. Using the Right Hand Palm rule. The field is up, the push is to the right so the current must be flowing into the page (towards the back). So current must flow to the left on the front rail and to the right on the back rail.

Question 28 (b) (2 marks)
Outcomes Assessed: PH 12-13
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly calculates the electromagnetic force acting on the rod	2
• Correctly calculates the magnitude of the current	1

Sample Answer:

$V=IR$
$20=I\times0.02$
$I=1000A$
$F=lIB\sin\theta$
$F=1000\times0.08\times0.005=0.4$ N to the right

Question 29 (5 marks)
Question 29 (a) (2 marks)
Outcomes Assessed: PH 12-14
Targeted Performance Bands: 2–5

Criteria	Mark
• Correct electric and magnetic field directions	2
• Correct electric or magnetic field direction	1

Sample Answer:

Electric field is down the page and magnetic field is up the page.

Question 29 (b) (3 marks)
Outcomes Assessed: PH 12-14
Targeted Performance Bands: 2–5

Criteria	Marks
• States proton moving downward due to electric field AND • Clockwise due to magnetic field AND • Spiralling with a bigger radius	3
• Two of the points above	2
• One of the points above	1

Sample Answer:

- The proton will spiral downwards due to electric field instead of upwards.
- Spiral in the opposite direction to the electron (clockwise when seen from above) due to magnetic field.
- The spiral will have larger radius because the mass is greater.

Question 30 (7 marks)
Question 30 (a) (1 mark)
Outcomes Assessed: PH 12-14
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly calculates the mass of hydrogen needed	1

Sample Answer:

$$E = mc^2$$

$$7145000 = m(3 \times 10^8)^2$$

$$m = \frac{7145000}{(3 \times 10^8)^2}$$

$$m = 7.94 \times 10^{-11} \text{ kg}$$

Question 30 (b) (3 marks)
Outcomes Assessed: PH 12-14; PH 12-7
Targeted Performance Bands: 3–6

Criteria	Marks
• Correctly compares the mass values of the two processes with respect to their relevant energy output • Demonstrates an understanding of the source of the energy in the two processes to account for this difference	3
• Correctly compares the mass values of the two processes with respect to their relevant energy output	2
• Gives some reasoning to account for the difference	1

Sample Answer:

Direct mass-energy transformation accounts for 100% of the rest mass released as energy, whereas during combustion, only a miniscule proportion of the mass is released as energy. 50 g of hydrogen can produce 7145 kJ of energy through this process.
To produce 7145 kJ of energy through mass-energy transformation only 7.94×10^{-11} kg of hydrogen is required. The energy release from this process can be enormous, as it is governed by $E=mc^2$, and releases more energy compared to chemical reactions like combustion.

Question 30 (c) (3 marks)
Outcomes Assessed: PH 12-14
Targeted Performance Bands: 3–6

Criteria	Marks
• Correctly uses the nuclear equation, including electrons • Calculates mass defect in amu or kg • Calculates energy output in Joules	3
• Two steps above	2
• One step above	1

Sample Answer:

Mass defect $= (4)(1.00784) - [4.00260 + (2)(0.00055)]$

$= 0.02766 \text{ u}$

Mass defect $= (0.02766)(1.661 \times 10^{-27})$

$= 4.59433 \times 10^{-29} \text{ kg}$

$E = (4.59433 \times 10^{-29})(3 \times 10^{8})^{2}$

$E = 4.13 \times 10^{-12} \text{ J}$

Question 31 (4 marks)
Question 31 (a) (3 marks)
Outcomes Assessed: PH 12-15; PH 12-5
Targeted Performance Bands: 2–5

Criteria	Marks
• Finds the half-life for both sources • Finds the decay constant for both sources • Compares them clearly	3
• Finds the half-life for one source correctly and finds decay constants OR • Finds the half-life for both sources	2
• Finds the half- life for one source	1

Sample Answer:

X half- life 1 year. Y half- life of 2 years.

$\lambda = \frac{ln2}{t_{1/2}}$

X decay constant of 0.693. Y decay constant of 0.347
So Y has double the half- life and half the decay constant.

Question 31 (b) (1 mark)
Outcomes Assessed: PH 12-15
Targeted Performance Bands: 3–6

Criteria	Marks
• Demonstrates understanding that the majority of the nucleons are still present in the daughter nuclei	1

Sample Answer:

The daughter nucleus is still part of the source. Also, the number of atoms in a source is incredibly high even after a few years the number of undecayed atoms will be high.

Question 32 (5 marks)
Question 32 (a) (3 marks)
Outcomes Assessed: PH 12-15; PH 12-7
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly states 2 key experimental results AND • Correctly relates both results to the corresponding feature of Rutherford's atomic model	3
• Correctly states 2 key experimental results AND • Correctly relates 1 result to its corresponding feature of Rutherford's atomic model	2
• Correctly relates 1 experimental result to a feature of Rutherford's atomic model OR • Provides relevant information regarding 2 or more experimental results OR • Provides relevant information for 2 or more features of Rutherford's atomic model	1

Sample Answer:

Any 2 of:

Experimental Result	Evidence for
Most alpha particles passed straight through foil	Empty spaces inside the atoms of the foil, big enough to cause such large numbers to pass straight through undeflected, and so the atom was mostly empty space.
Some particle showed deflection through small angles	Some sort of repulsive electrostatic interaction between the positively charged alpha particles and a small region of the atoms, implying that there is a concentrated area of positive charge in the atom.
A small number of particles (~1 in 8000) were deflected through large angles	Implies some sort of collision between masses or extremely close interaction of electrostatic repulsion and since the deflections were so rare, further implies a high concentration of mass and charge in a small part of the atom (probably at the centre)

Question 32 (b) (2 marks)
Outcomes Assessed: PH 12-15; PH 12-7
Targeted Performance Bands: 2–5

Criteria	Marks
• Correctly relates the experimental evidence to both conservation laws	2
• Correctly relates the experimental evidence to one of the conservation laws	1

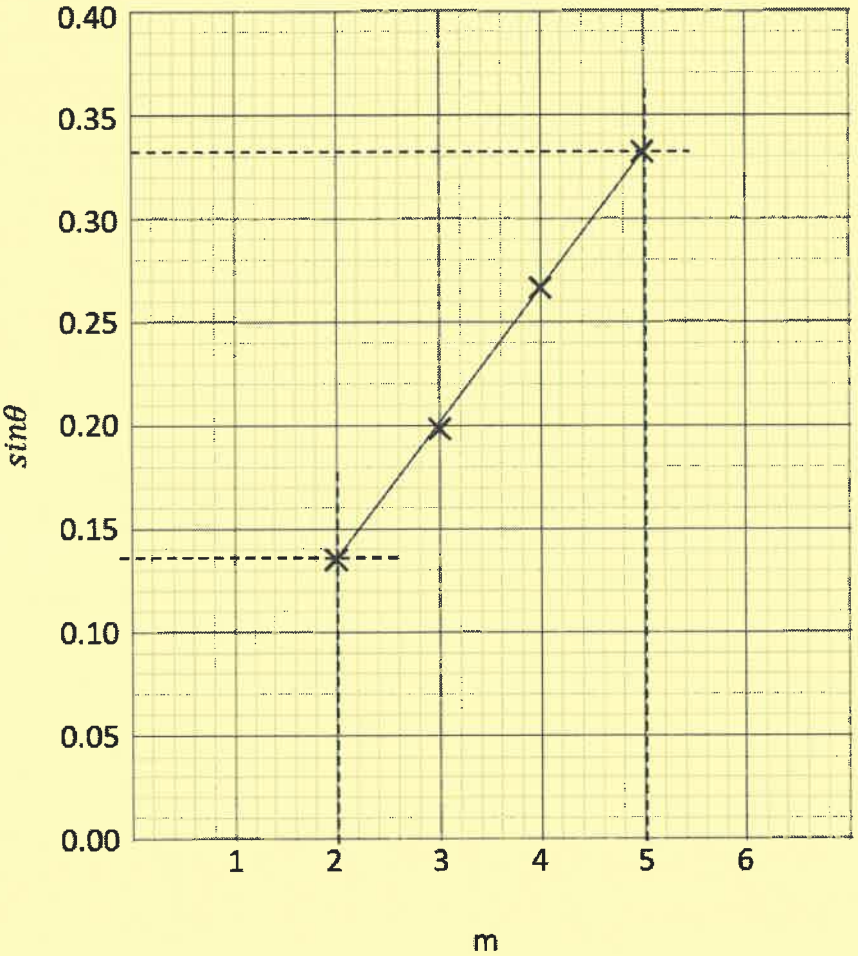
Sample Answer:

Chadwick observed the conservation of atomic mass and atomic numbers, and measured the momentum and kinetic energy of the ejected protons. He deduced that electromagnetic radiation would not provide enough energy to eject the protons and only a particle would be capable of such a collision and satisfy the laws of conservation of momentum and conservation of energy.

Question 33 (6 marks)
Outcomes Assessed: PH 12-14; PH 12-5; PH 12-6
Targeted Performance Bands: 3–6

Criteria	Marks
• Correctly chooses the axes as dsinθ or sinθ versus m • Correctly formats the scale for axes • Correctly plots points • Correctly draws a line of best fit • Correctly uses the line of best fit to calculate the gradient • Correctly calculates the wavelength of light using the gradient	6
• Achieves any five of the above criteria	5
• Achieves any four of the above criteria	4
• Achieves any three of the above criteria	3
• Achieves any two of the above criteria	2
• Correctly plots at least one point or identifies the correct equation. OR • Attempts to calculate the wavelength of light	1

Sample Answer:



$d \sin\theta = m\lambda$

$\lambda = d\dfrac{\sin\theta}{m}$

$\frac{\sin\theta}{m}$ is the gradient of the graphed data.

$\lambda = (1 \times 10^{-5})\,\frac{(0.331-0.136)}{(5-2)}$

$\lambda = 6.50 \times 10^{-7}$ m

OR

$\lambda = 650$ nm

Question 34 (4 marks)
Question 34 (a) (1 mark)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2–6

Criteria	Marks
• States the grey ball	1

Sample Answer:

The grey ball has a greater velocity than the black ball.

Question 34 (b) (3 marks)
Outcomes Assessed: PH 12-12
Targeted Performance Bands: 2–6

Criteria	Marks
• Correctly calculates the velocity of the grey ball	3
• Attempts some relevant calculations	2
• Provides some relevant information	1

Sample Answer:

$N\sin\theta = mg$
$N\cos\theta = F_c$
$N = \dfrac{mg}{\sin\theta}$
$\dfrac{mg}{\tan\theta} = F_c$
$\dfrac{mg}{\tan\theta} = \dfrac{mv^2}{r}$
$v = \sqrt{\dfrac{rg}{\tan\theta}}$
$v = \sqrt{\dfrac{9.8 \times 6}{tan25}}$

$v = 11.2\ ms^{-1}$

Question 35 (9 marks)
Outcomes Assessed: PH 12-12; PH 12-13; PH12-7
Targeted Performance Bands: 2–6

Criteria	Marks
• Explains how eddy currents are produced as the centrifuge rotates near the solenoids (Faraday's law) • Explains how the eddy currents create a magnetic force in the opposite direction as they cut field lines (Lenz's Law) • Recognises that increasing the current in the solenoids is necessary as the centrifuge slows down • Relates the current in the solenoid to the size of the brake force with a clear explanation as to why this is the case • Demonstrates understanding of how increasing the magnetic field around the centrifuge at slower speeds will allow the centrifuge to slow down at a steady rate (rather than at a decreasing rate if the magnetic field was kept constant)	8–9
• Covers four points above	6–7
• Covers three points above	4–5
• Covers two points above	2–3
• Identifies features of magnetic braking	1

Sample Answer:

Magnetic Braking is the result of relative motion between a conducting surface and a magnetic field. This motion induces an emf in the conductor (Faraday's law) and the emf will induce eddy current. As a result, a force is exerted on the eddy current which opposes the motion of charges through the field, in keeping with the Law of Conservation of Energy (Lenz's law).
At the beginning of the slowing down phase the eddy currents will be large as the conductor is moving quickly through the magnetic field. This could create a large deceleration. Which could damage the sample.
Therefore, setting the magnetic field to low is desirable. A low current setting would let the deceleration be less.
However, if the current was kept constant and the conductor slows down the eddy currents would reduce and this would mean the centrifuge would slow down at a much lower rate. This would be good for the sample but could result in very long time to slow down.
To keep the rate of deceleration constant increasing the magnetic field in the solenoids would be ideal. Thus, increasing the current towards the end of the slowing down phase would be best.

Question 36 (9 marks)
Outcomes Assessed: PH 12-14; PH 12-15; PH12-7
Targeted Performance Bands: 2–6

Criteria	Marks
• Provides a comprehensive analysis, relating features of the experimental facilities, instruments and processes to the experimental evidence for matter-waves • Incorporates a correct and balanced fission reaction equation • Includes relevant calculations • Correctly determines the velocity of the neutron	9
• Provides a thorough analysis, relating features of the experimental facilities and processes to the experimental evidence for matter-waves • Includes a fission reaction equation, calculation and detailed diagram	8
• Relates features of the facilities and processes to the experimental evidence • Includes a fission reaction equation or description, and a relevant calculation	6–7
• Identifies some links between the facility and/or processes to the experimental evidence for matter-waves, and/or a calculation	4–5
• Provides details of some experimental evidence	2–3
• Provides some relevant information	1

Sample Answer:

Neutrons are produced in nuclear reactors via fission reactions. Fission reactions are usually stimulated by a single neutron, yet produce 2 or 3 free neutrons per reaction. An example fission reaction is:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3^{1}_{0}n$$

If neutrons hit the opening of a neutron guide they can enter and travel through the guide if they satisfy the specific angle requirements of the material for that guide. Since neutrons have to satisfy some angle condition to avoid passing through the material, this implies there is (total internal) reflection at the walls/boundaries of the guide, thus neutrons could be travelling in a wave-like manner.

Since diffraction patterns are produced when neutrons are passed through materials, this further implies that the spaces between particles/atoms/molecules in the material act as slits for diffraction in the same way as for electromagnetic radiation, with the resulting images produced via interference of the waves from each spacing. This is further evidence of the wavelike behaviour of neutrons. and supports the de Broglie hypothesis of matter waves.

The de Broglie wavelength is given by $\lambda = \frac{h}{mv}$ where h is Planck's constant, m is the mass of the neutron, and v is the velocity of the neutron. This further implies that neutrons of different energies will have different de Broglie wavelengths. Since diffraction works best when the wavelength is the same order of magnitude as the slit size, different energy neutrons could be used to probe materials with different inter-particle spacings.

For the material shown:

$d = 2.82 \times 10^{-10}$ m $\quad \theta = 4°$, $\quad m = 1$

$d \sin\theta = m\lambda$

$\lambda = 2.82 \times 10^{-10} \times \sin 4 \quad = 1.967 \times 10^{-11}$ m

also, $\lambda = \dfrac{h}{mv}$

$$1.967 \times 10^{-11} = \frac{6.626 \times 10^{-34}}{1.675 \times 10^{-27} \times v}$$

$$v = \frac{h}{m\lambda} = \frac{6.626 \times 10^{-34}}{1.675 \times 10^{-27} \times 1.967 \times 10^{-11}} = 20110\ m\, s^{-1} = 20100\ m\, s^{-1} \text{ (to 3 sig. fig)}$$

The advantage of using neutrons in this manner, is that neutrons predominantly interact via the strong force and there are no electro-static interactions between the diffracting particles and the particles in the material, so it is a more accurate probe of the atomic structure of materials.

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