NSW GOVERNMENT

NSW Education Standards Authority

2022 **HIGHER SCHOOL CERTIFICATE EXAMINATION**

Physics

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks (pages 2–14)

- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – 80 marks (pages 17–39)

- Attempt Questions 21–35
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1–20.

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1 An ideal transformer has 20 turns on the primary coil and an input voltage of 100 V.

How many turns are there on the secondary coil if the output voltage is 400 V?

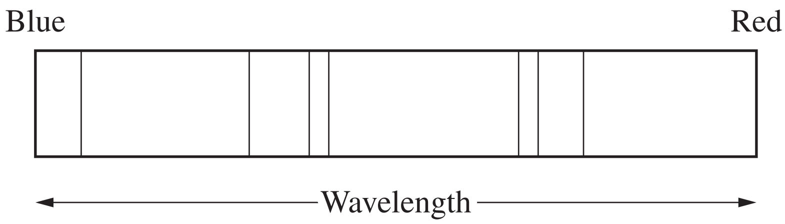
A. 4

B. 5

C. 80

D. 400

2 The absorption lines in a star's spectrum are shown.



What feature of the star is directly responsible for these absorption lines?

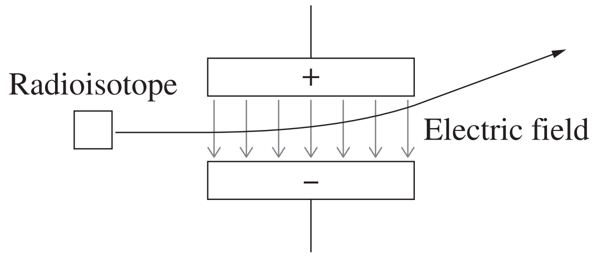
A. Size

B. Colour

C. Distance from Earth

D. Chemical composition

3 A radioisotope emits radiation which is deflected by an electric field, as shown.



What type of radiation is this?

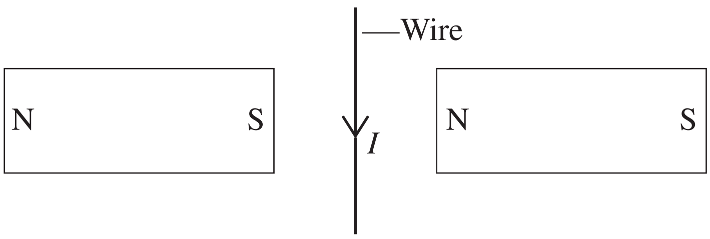
A. Alpha

B. Gamma

C. Beta positive (positron)

D. Beta negative (electron)

4 A current-carrying wire is in a magnetic field, as shown.



What is the direction of the force on the wire?

A. Left

B. Right

C. Into the page

D. Out of the page

5 Protons and neutrons are made up of quarks. The table shows the charges of these quarks.

Quark	*Charge*
Up	$+\frac{2}{3}$
Down	$-\frac{1}{3}$

What combination of quarks forms a neutron?

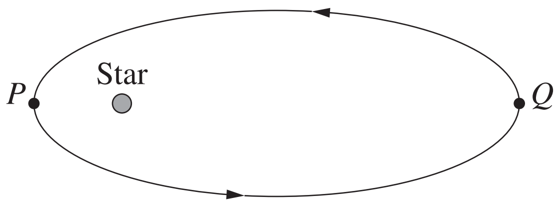
A. 1 up, 1 down

B. 1 up, 2 down

C. 2 up, 1 down

D. 2 up, 2 down

6 The elliptical orbit of a planet around a star is shown.



Which type of energy is greater at position *P* than at *Q*?

A. Kinetic

B. Nuclear

C. Potential

D. Total

7 A photon has an energy of 9.0×10^{-24} J.

What is the frequency of this radiation?

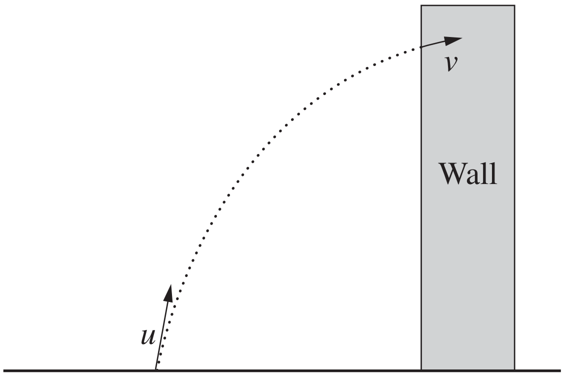
A. 1.00×10^{-40} Hz

B. 7.36×10^{-11} Hz

C. 1.36×10^{10} Hz

D. 5.97×10^{11} Hz

8 An object is launched with an initial velocity, *u*, and hits a wall with a final velocity, *v*.



Which statement correctly compares components of *u* and *v*?

A. The vertical component of *v* is less than the vertical component of *u*.

B. The vertical component of *v* is greater than the vertical component of *u*.

C. The horizontal component of *v* is less than the horizontal component of *u*.

D. The horizontal component of *v* is greater than the horizontal component of *u*.

9 The radiation emitted by a black body has a peak wavelength of 5.8×10^{-7} m.

What is its temperature?

A. 3000 K

B. 4500 K

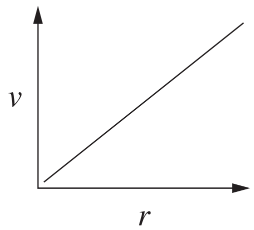
C. 5000 K

D. 5500 K

10 The orbital velocity, v, of a satellite around a planet is given by $v = \sqrt{\frac{GM}{r}}$.

Which graph is consistent with this relationship?

A.



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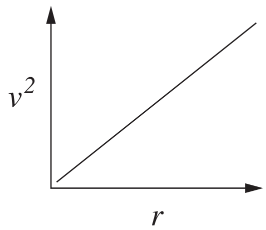

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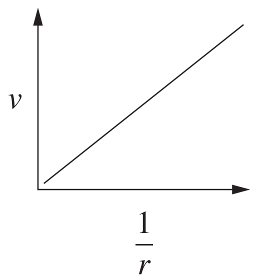
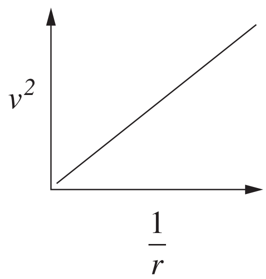
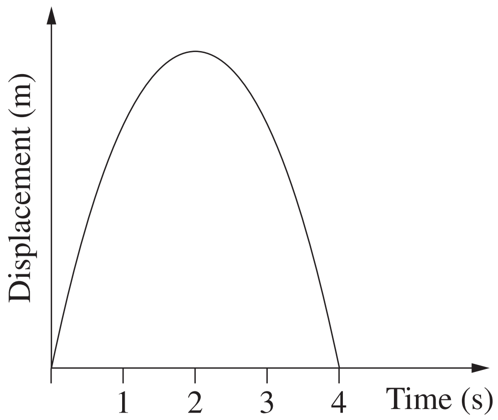


D.

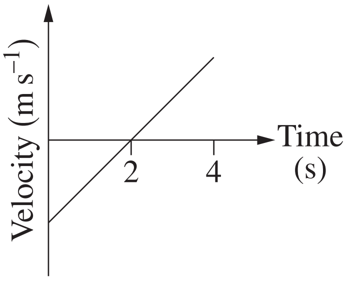


11 A projectile is launched vertically upwards. The displacement of the projectile as a function of time is shown.

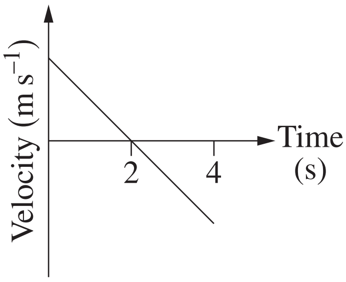


Which velocity–time graph corresponds to this motion?

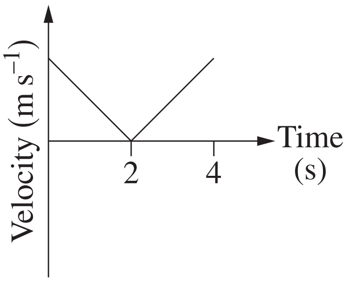
A.



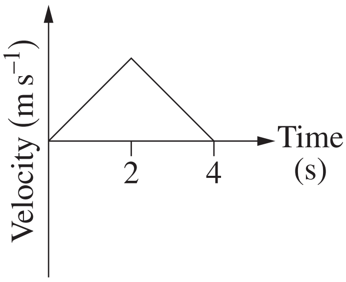
B.



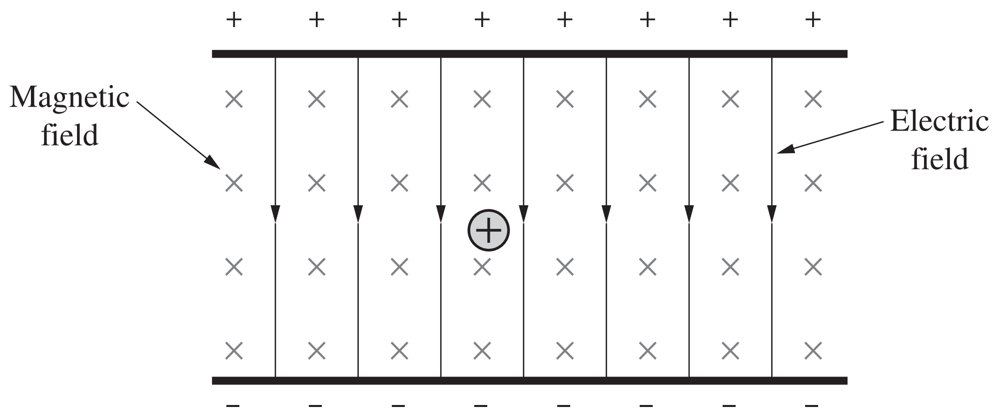
C.



D.



12 The diagram shows a region in which there are uniform electric and magnetic fields. A positively charged particle moves in the region at constant velocity.



What is the direction of the particle's velocity?

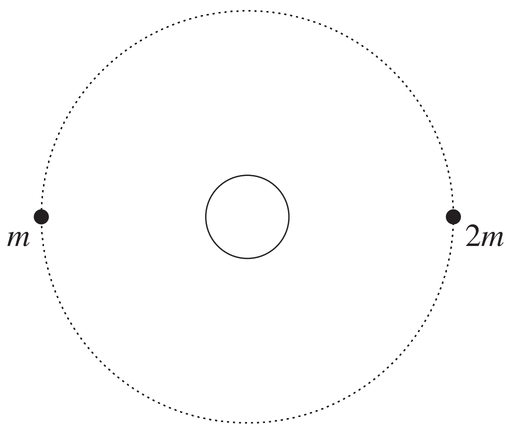
A. Up the page

B. Down the page

C. To the left

D. To the right

13 Two satellites share an orbit around a planet. One satellite has twice the mass of the other.



Which quantity would be different for the two satellites?

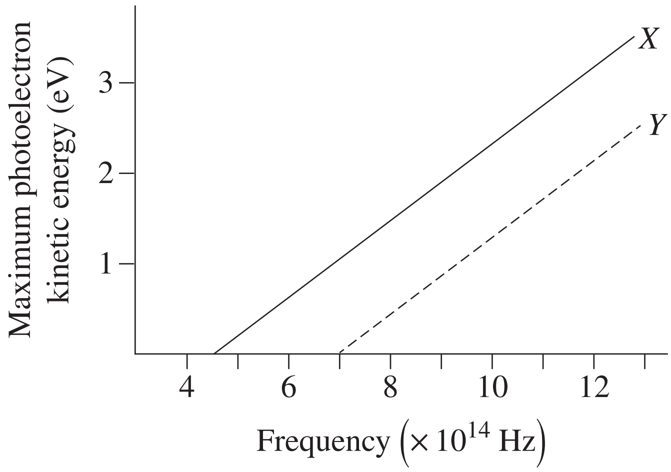
A. Speed

B. Momentum

C. Orbital period

D. Centripetal acceleration

14 Line X shows the results of an experiment carried out to investigate the photoelectric effect.



What change to this experiment would produce the results shown by line Y?

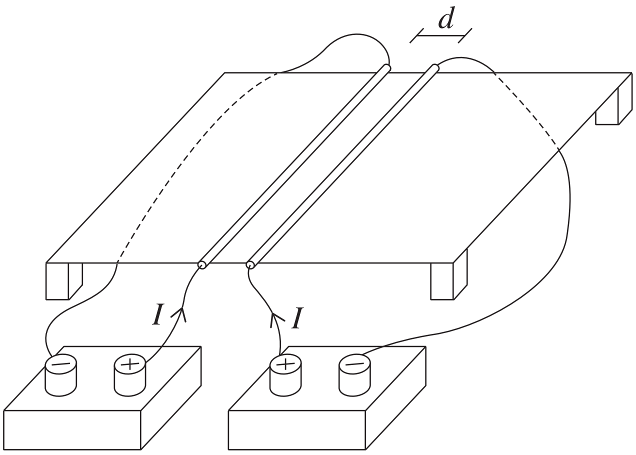
A. Increasing the frequency of the radiation

B. Using a metal that has a greater work function

C. Decreasing the intensity of the incident radiation

D. Decreasing the maximum energy of photoelectrons

15 Two wires separated by a distance, *d*, carry equal electric currents producing a magnetic force between them.



The separation between the wires is increased to $4d$ and the current in each wire is doubled.

What happens to the magnetic force between the wires, compared to the original force?

A. It does not change.

B. It increases by a factor of 4.

C. It decreases by a factor of 4.

D. It decreases by a factor of 8.

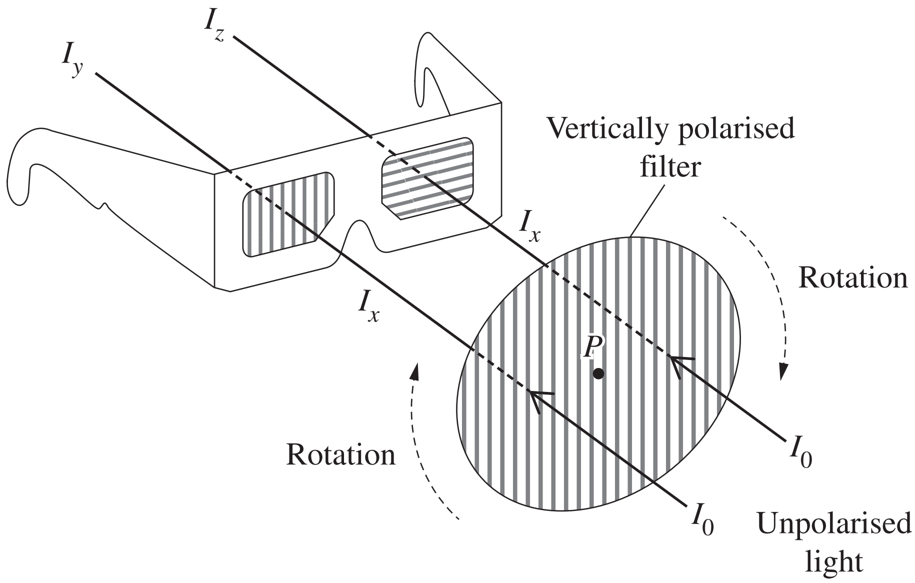
16 The binding energy of helium-4 (He-4) is 28.3 MeV and the binding energy of beryllium-6 (Be-6) is 26.9 MeV.

Which of the following rows in the table is correct?

A.	He-4 requires more energy to separate into individual protons and neutrons	He-4 is less massive than Be-6
B.	He-4 requires less energy to separate into individual protons and neutrons	He-4 is less massive than Be-6
C.	He-4 requires more energy to separate into individual protons and neutrons	He-4 is more massive than Be-6
D.	He-4 requires less energy to separate into individual protons and neutrons	He-4 is more massive than Be-6

17 Unpolarised light of intensity I_0 is incident upon a vertically polarised filter. The filtered light then passes through a pair of glasses. The glass have polarising filters, with one side polarised vertically and the other horizontally.

The filter undergoes one complete 360° rotation around point P, as shown.



Which of the following correctly compares I_y to the intensity at other positions?

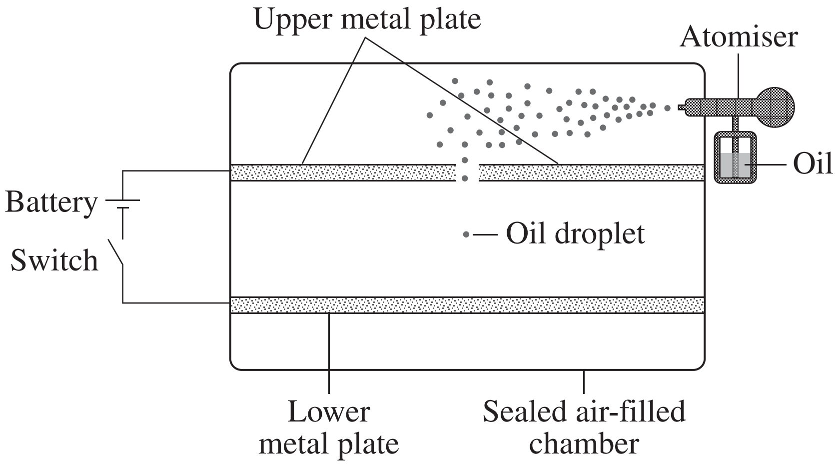
A. I_y never equals I_x

B. I_y never equals I_z

C. I_y sometimes equals I_z

D. I_y sometimes equals I_0

18 A charged oil droplet was observed between metal plates, as shown.



While the switch was open, the oil droplet moved downwards at a constant speed. After the switch was closed, the oil droplet moved upwards at the same constant speed.

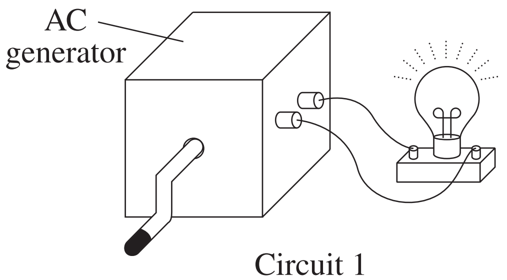
Assume that the only three forces that may act on the oil droplet are the force of gravity, the force due to the electric field and the frictional force between the air and the oil droplet. The magnitudes of these forces are F_G (due to gravity), F_E (due to the electric field) and F_F (due to the frictional force).

Which row of the table shows all the forces affecting the motion of the oil droplet in the direction indicated, and the relationship between these forces?

	Downwards motion	*Upwards motion*
A.	$F_G > F_F$	$F_E > F_F$
B.	$F_G > F_F$	$F_E > F_G + F_F$
C.	$F_G = F_F$	$F_G = F_E$
D.	$F_G = F_F$	$F_E = F_G + F_F$

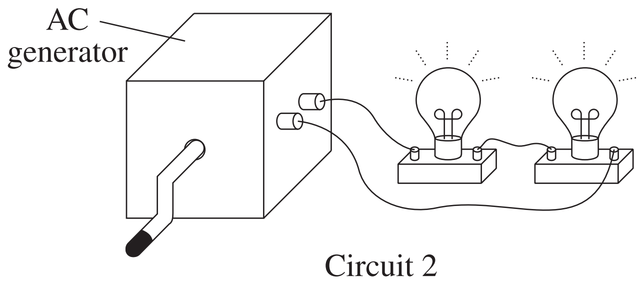
19 An AC generator is operated by turning a handle, which rotates a coil in a magnetic field.

The handle is turned at a constant speed and the AC voltage output of the generator causes a light globe connected to it to light up, as shown in Circuit 1.



Circuit 1

A second identical light globe is then connected in series to the generator output, as shown in Circuit 2. The handle is turned at the same constant speed.



Circuit 2

Which statement describes and explains the effort required to turn the handle in Circuit 2, compared to Circuit 1?

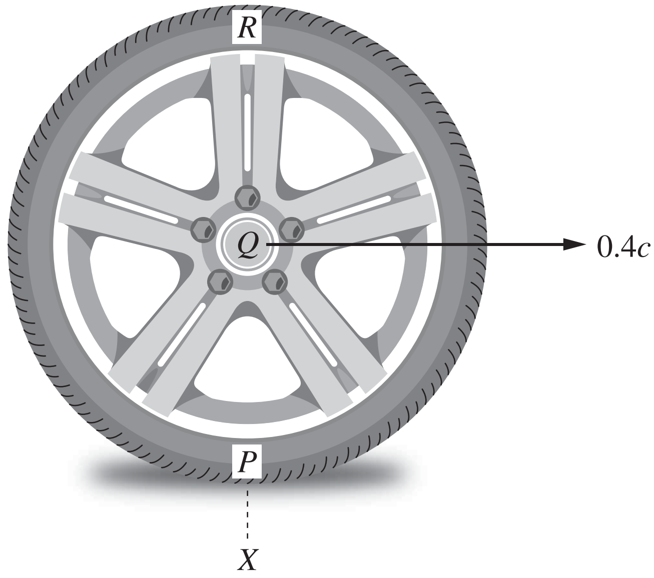
A. The handle in Circuit 2 is easier to turn because the smaller current in Circuit 2 produces less opposing torque.

B. The handle in Circuit 2 is easier to turn because the voltage output is shared equally across the two identical light globes.

C. The handle in Circuit 2 is more difficult to turn because the larger current in Circuit 2 produces more opposing torque.

D. The handle in Circuit 2 is more difficult to turn because it takes more power to operate the two identical globes than it does to operate the single globe.

20 In a thought experiment, a car is travelling at a uniform velocity of $0.4c$. The diagram shows one of the car's wheels as it rolls past a stationary observer at X.



Consider the instantaneous velocity of different points on the car's wheel relative to the ground. Assume that there is no slippage of the tyre on the road.

At the instant the centre of the wheel, Q, passes X, how would the observer describe the relativistic length contraction at points P, Q and R?

A. It is the same at P, Q and R.

B. It is zero at P and greatest at R.

C. It is equal at P and R, and least at Q.

D. It is zero at P and the same value at Q and R.

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2022 HIGHER SCHOOL CERTIFICATE EXAMINATION

Centre Number

Physics

Student Number

Section II Answer Booklet

80 marks
Attempt Questions 21–35
Allow about 2 hours and 25 minutes for this section

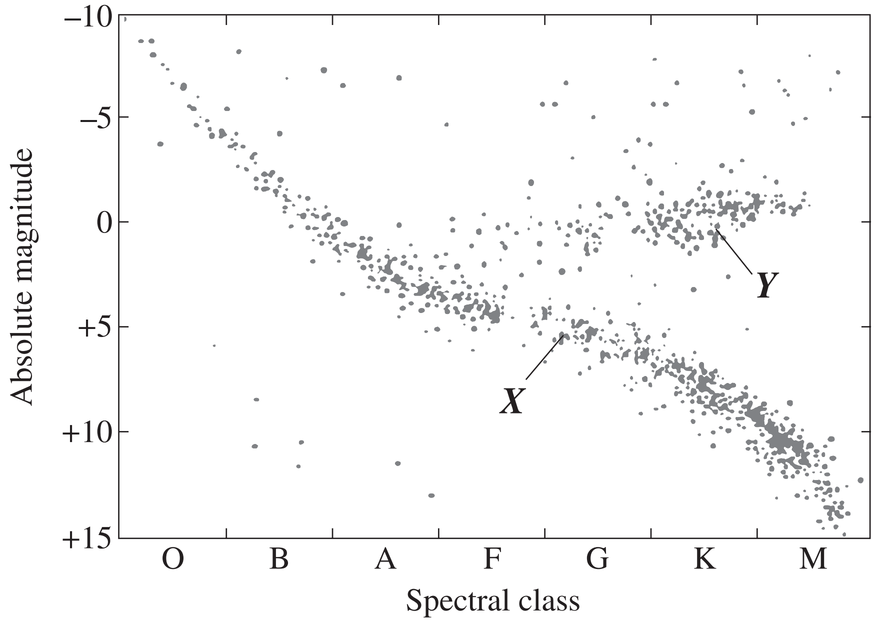
Instructions

- Write your Centre Number and Student Number at the top of this page.
- 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.
- Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Please turn over

Question 21 (4 marks)

The positions of two stars, *X* and *Y*, are shown in the Hertzsprung–Russell diagram.



(a) Compare qualitatively the surface temperature and luminosity of *X* and *Y*. **2**

Surface temperature: ....

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Luminosity: ....

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(b) Identify the elements undergoing fusion in the core of each star, *X* and *Y*. **2**

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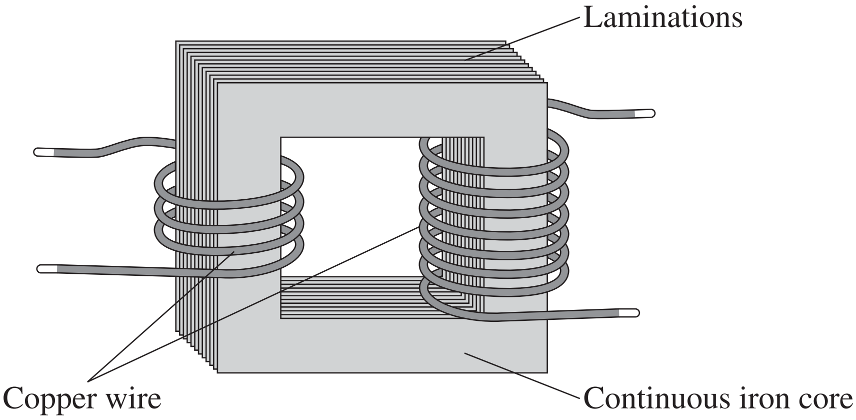
Question 22 (4 marks)

The diagram shows features of a transformer. **4**



For TWO features of the transformer, describe how each contributes to the transformer's efficiency.

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Question 23 (4 marks)

Outline a method that could be used to determine a value for the speed of light. In your answer, identify ONE factor that would limit the accuracy of the experimental data. **4**

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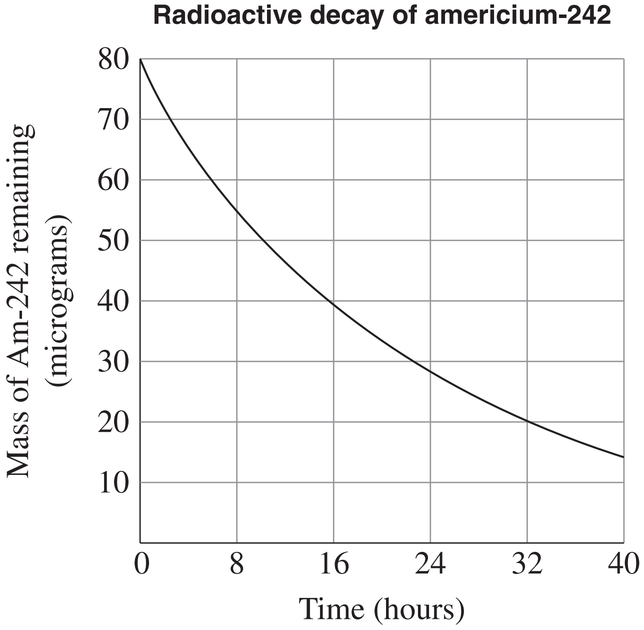
Question 24 (4 marks)

The radioactive decay curve for americium-242 is shown.



(a) Use the graph to find the half-life of Am-242 and hence show that the decay constant, λ, is 0.043 h^{-1}. **2**

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(b) Calculate how long it takes until the mass of Am-242 is 8 micrograms. **2**

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Question 25 (5 marks)

A rocket is launched vertically from a planet of mass M. After it leaves the atmosphere, the rocket's engine is turned off and it continues to move away from the planet. From this time the rocket's mass is 200 kg. The rocket's speed, v, at two different distances from the planet's centre, R, is shown.

Point	R (m)	v ($m\,s^{-1}$)
1	4.3×10^6	5500
2	2.5×10^7	2900

(a) Show that the magnitude of the change in kinetic energy from point 1 to point 2 is 2.2×10^9 J. **2**

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(b) Determine the mass M of the planet using the law of conservation of energy. **3**

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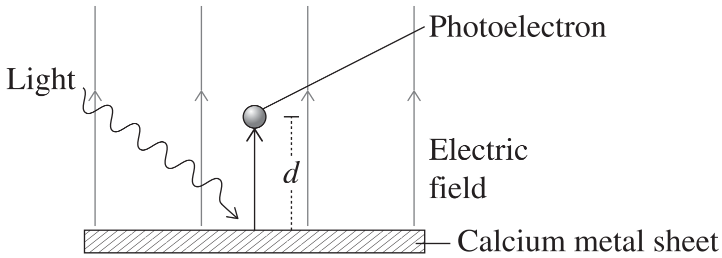
Question 26 (6 marks)

Light of frequency 7.5×10^{14} Hz is incident on a calcium metal sheet which has a work function of 2.9 eV. Photoelectrons are emitted.

The metal is in a uniform electric field of $5.2\ \text{NC}^{-1}$, perpendicular to the surface of the metal, as shown.



(a) Show that the maximum kinetic energy of an emitted photoelectron is 3.2×10^{-20} J. **3**

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(b) Calculate the maximum distance, *d*, an emitted photoelectron can travel from the surface of the metal. **3**

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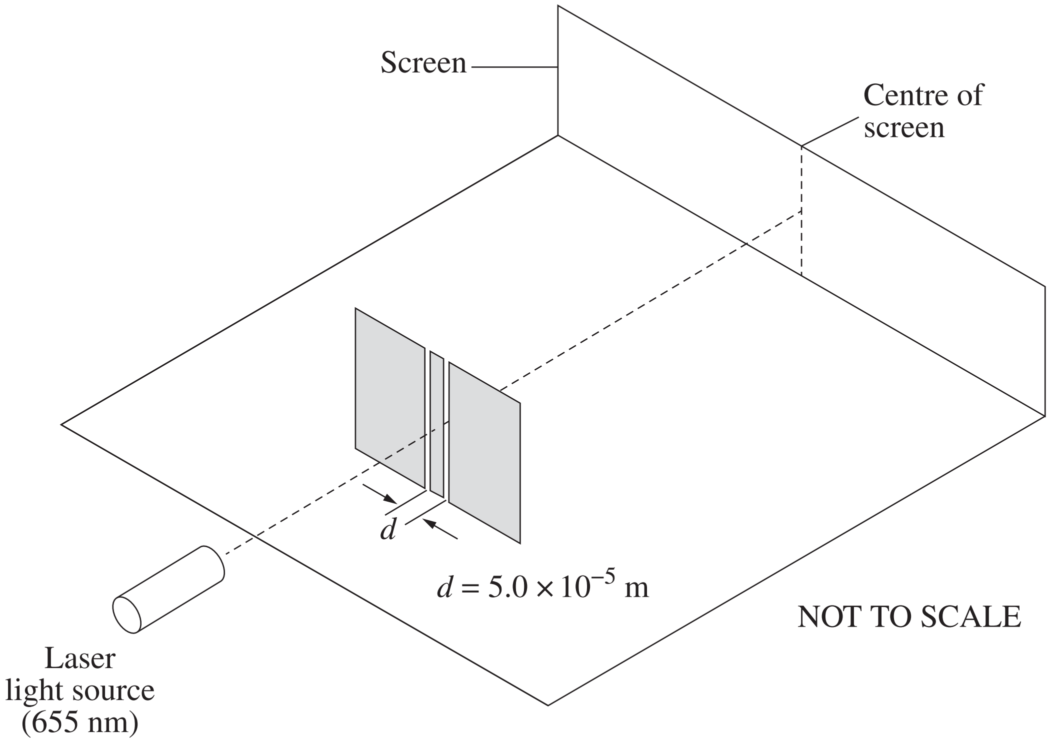
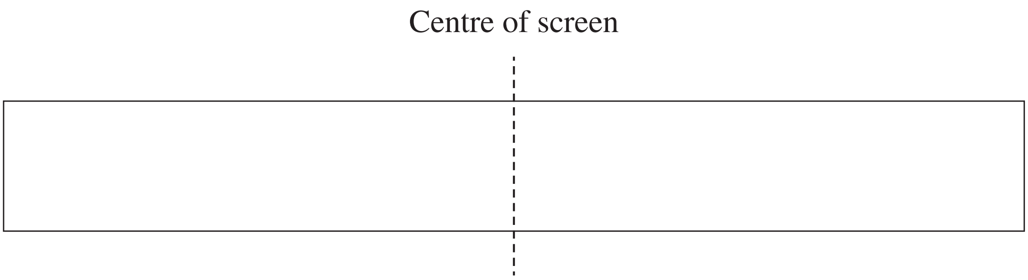
Question 27 (7 marks)

A laser producing red light of wavelength 655 nm is directed onto double slits separated by a distance, $d = 5.0 \times 10^{-5}$ m. A screen is placed behind the double slits.



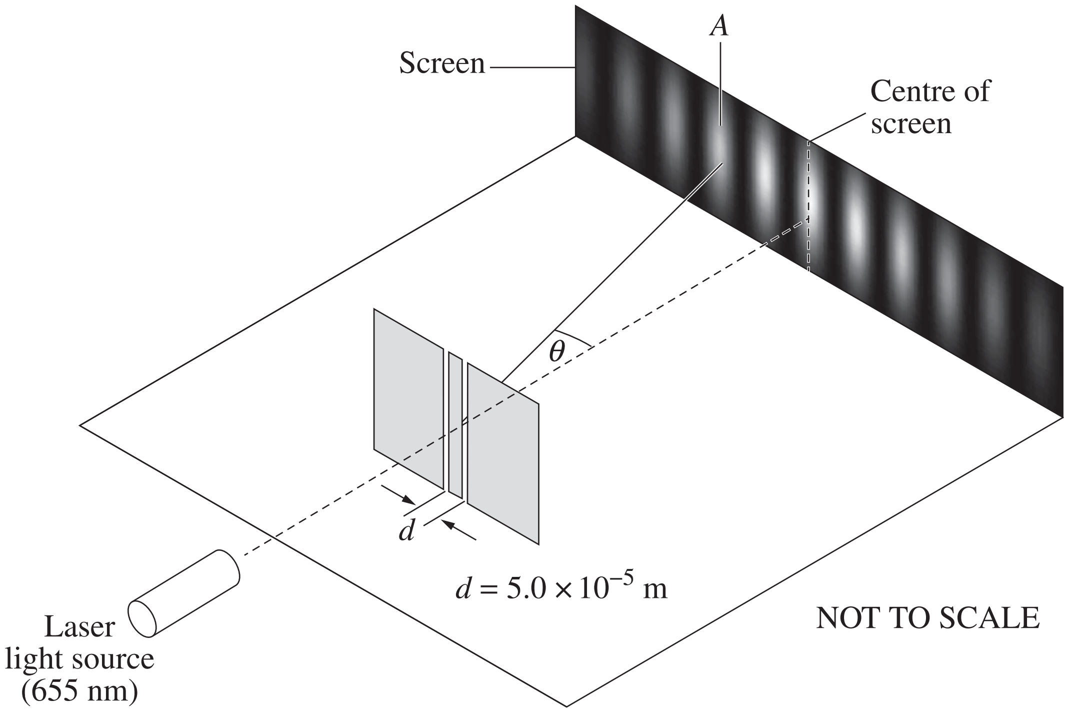
(a) Newton proposed a model of light. Use a labelled sketch to show the pattern on the screen that would be expected from Newton's proposed model. **2**



Question 27 continues on page 25

Question 27 (continued)

When the laser light is turned on, a series of vertical bright lines are seen on the screen.



(b) Calculate the angle, θ, between the centre line and the bright line at A. **3**

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(c) The laser is replaced with one producing green light of wavelength 520 nm. **2**

Explain the difference in the pattern that would be produced.

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End of Question 27

Question 28 (3 marks)

Two steps in the CNO cycle of nuclear fusion are shown. **3**

Step *X*	$^{13}N \longrightarrow {}^{13}C + e^{+} + \nu$
Step *Y*	$^{13}C + {}^{1}H \longrightarrow {}^{14}N$

Step *X* releases 1.20 MeV.

The masses in Step *Y* are shown in the table.

Isotope	*Mass* (*u*)
Carbon-13	13.003
Proton	1.007
Nitrogen-14	14.003

Propose a reason why Step *Y* releases more energy than Step *X*. Support your answer with calculations.

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Question 29 (4 marks)

An apple was thrown horizontally to the east from the window of a car which was moving with a uniform velocity to the north. **4**

Explain the horizontal and vertical components of the apple's motion during its flight.

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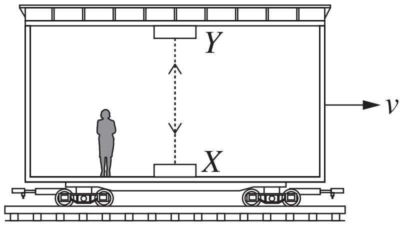
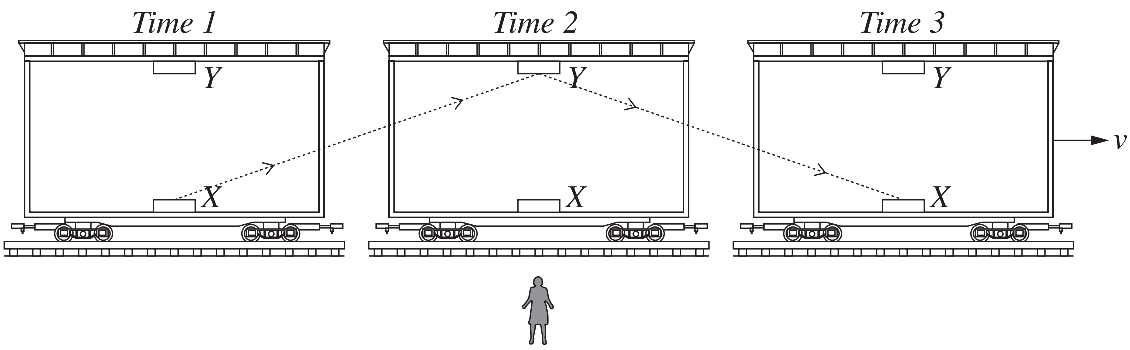
Please turn over

Question 30 (6 marks)

In a thought experiment, light travels from X to a mirror Y and back to X on a moving train carriage. The path of the light relative to an observer on the train is shown.



Relative to an observer outside the train, the path of the light is shown below, at three consecutive times as the train carriage moves along the track.



(a) Describe qualitatively how the constancy of the speed of light and the thought experiment above led Einstein to predict time dilation. **3**

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Question 30 continues on page 29

Question 30 (continued)

(b) The train is travelling with a velocity $v = 0.96c$. To the observer inside the train, the return journey for the light between X and Y takes 15 nanoseconds. **3**

How long would this return journey take according to the observer outside the train?

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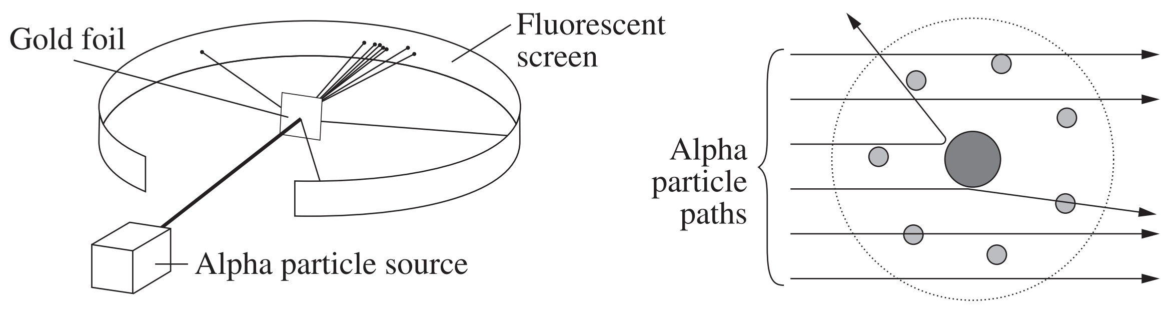
End of Question 30

Please turn over

Question 31 (9 marks)

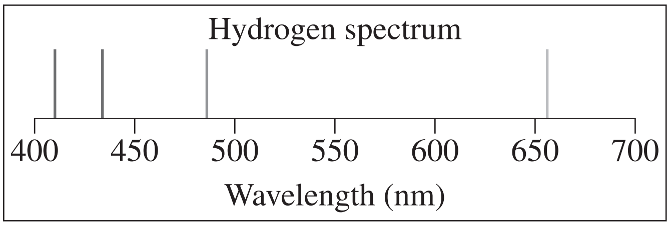
Following the Geiger–Marsden experiment, Rutherford proposed a model of the atom. **9**



The Geiger–Marsden experiment

Rutherford's model of the experimental results

Bohr modified this model to explain the spectrum of hydrogen observed in experiments.



The Balmer series

The Bohr–Rutherford model of the atom consists of electrons in energy levels around a positive nucleus.

How do features of this model account for all the experimental evidence above? Support your answer with a sample calculation and a diagram, and refer to energy, forces and photons.

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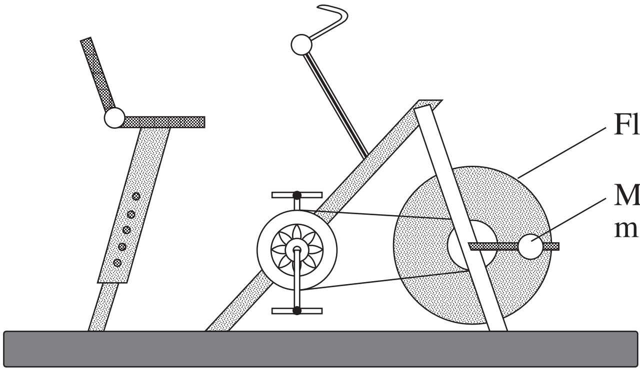
Question 31 continues on page 31

Question 31 (continued)

End of Question 31

Question 32 (6 marks)

One type of stationary exercise bike uses a pair of strong, movable magnets placed on opposite sides of a thick, aluminium flywheel to provide a torque to make it harder to pedal.



(a) Explain the principle by which these magnets make it harder to pedal. **3**

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(b) The bike rider wants to increase the opposing torque on the flywheel. Justify an adjustment that could be made to the magnets to achieve this. **3**

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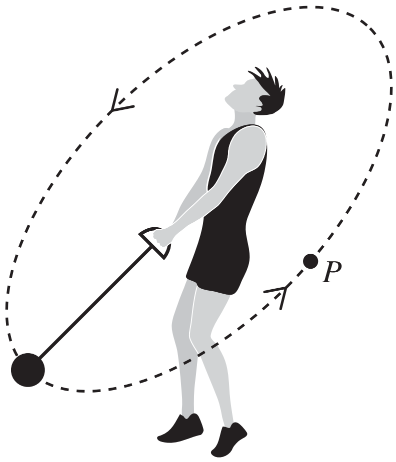
Question 33 (6 marks)

In a hammer throw sport event, a 7.0 kg projectile rotates in a circle of radius 1.6 m, with a period of 0.50 s. It is released at point *P*, which is 1.2 m above the ground, where its velocity is at 45° to the horizontal.



(a) Show that the vertical component of the projectile's velocity at *P* is 14.2 $\mathrm{m\,s^{-1}}$. **2**

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(b) Calculate the horizontal range of the projectile from point *P*. **4**

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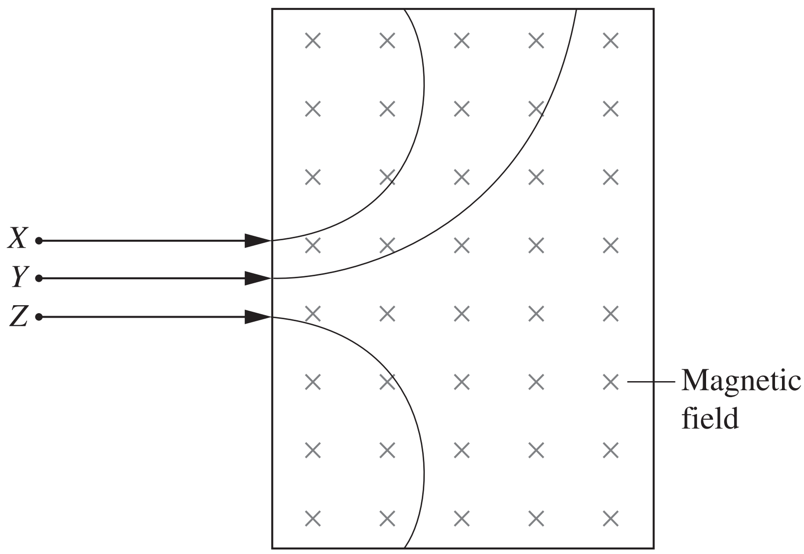
Question 34 (7 marks)

Three charged particles, X, Y and Z, travelling along straight, parallel trajectories at the same speed, enter a region in which there is a uniform magnetic field which causes them to follow the paths shown. Assume that the particles do not exert any significant force on each other. **7**



Explain the different paths that the particles follow through the magnetic field.

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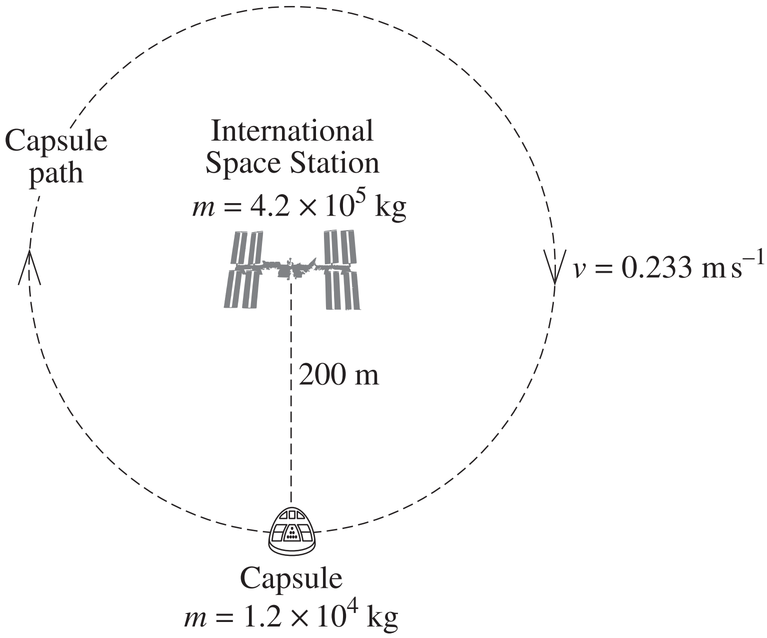
Question 35 (5 marks)

A capsule travels around the International Space Station (ISS) in a circular path of radius 200 m as shown. **5**



Analyse this system to test the hypothesis below.

> *The uniform circular motion of the capsule around the ISS can be accounted for in terms of the gravitational force between the capsule and the ISS.*

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Physics

DATA SHEET

Charge on electron, q_e	-1.602×10^{-19} C
Mass of electron, m_e	9.109×10^{-31} kg
Mass of neutron, m_n	1.675×10^{-27} kg
Mass of proton, m_p	1.673×10^{-27} kg
Speed of sound in air	$340\ \mathrm{m\,s^{-1}}$
Earth's gravitational acceleration, g	$9.8\ \mathrm{m\,s^{-2}}$
Speed of light, c	$3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
Electric permittivity constant, ε_0	$8.854 \times 10^{-12}\ \mathrm{A^2\,s^4\,kg^{-1}\,m^{-3}}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}\ \mathrm{N\,A^{-2}}$
Universal gravitational constant, G	$6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$
Mass of Earth, M_E	6.0×10^{24} kg
Radius of Earth, r_E	6.371×10^{6} m
Planck constant, h	6.626×10^{-34} J s
Rydberg constant, R (hydrogen)	$1.097 \times 10^{7}\ \mathrm{m^{-1}}$
Atomic mass unit, u	1.661×10^{-27} kg $931.5\ \mathrm{MeV}/c^2$
1 eV	1.602×10^{-19} J
Density of water, ρ	$1.00 \times 10^{3}\ \mathrm{kg\,m^{-3}}$
Specific heat capacity of water	$4.18 \times 10^{3}\ \mathrm{J\,kg^{-1}\,K^{-1}}$
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

$$s = ut + \frac{1}{2}at^2$$

$$v = u + at$$

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

$$\vec{F}_{\text{net}} = m\vec{a}$$

$$\Delta U = mg\Delta h$$

$$W = F_{||}s = Fs\cos\theta$$

$$P = \frac{\Delta E}{\Delta t}$$

$$K = \frac{1}{2}mv^2$$

$$P = F_{||}v = Fv\cos\theta$$

$$\sum \frac{1}{2}mv^2_{\text{before}} = \sum \frac{1}{2}mv^2_{\text{after}}$$

$$\sum m\vec{v}_{\text{before}} = \sum m\vec{v}_{\text{after}}$$

$$\Delta\vec{p} = \vec{F}_{\text{net}}\Delta t$$

$$a_{\text{c}} = \frac{v^2}{r}$$

$$\omega = \frac{\Delta\theta}{t}$$

$$F_{\text{c}} = \frac{mv^2}{r}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

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

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

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$U = -\frac{GMm}{r}$$

Waves and thermodynamics

$$v = f\lambda$$

$$f_{\text{beat}} = \left| f_2 - f_1 \right|$$

$$f = \frac{1}{T}$$

$$f' = f\,\frac{\left(v_{\text{wave}} + v_{\text{observer}}\right)}{\left(v_{\text{wave}} - v_{\text{source}}\right)}$$

$$d\sin\theta = m\lambda$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$n_{\text{x}} = \frac{c}{v_{\text{x}}}$$

$$\sin\theta_{\text{c}} = \frac{n_2}{n_1}$$

$$I = I_{\text{max}}\cos^2\theta$$

$$I_1 r_1^2 = I_2 r_2^2$$

$$Q = mc\Delta T$$

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

Electricity and magnetism

$$E = \frac{V}{d}$$

$$V = \frac{\Delta U}{q}$$

$$W = qV$$

$$W = qEd$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \frac{\mu_0 NI}{L}$$

$$\Phi = B_{\parallel}A = BA\cos\theta$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$\frac{V_{\mathrm{p}}}{V_{\mathrm{s}}} = \frac{N_{\mathrm{p}}}{N_{\mathrm{s}}}$$

$$\vec{F} = q\vec{E}$$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

$$I = \frac{q}{t}$$

$$V = IR$$

$$P = VI$$

$$F = qv_{\perp}B = qvB\sin\theta$$

$$F = lI_{\perp}B = lIB\sin\theta$$

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1I_2}{r}$$

$$\tau = nIA_{\perp}B = nIAB\sin\theta$$

$$V_{\mathrm{p}}I_{\mathrm{p}} = V_{\mathrm{s}}I_{\mathrm{s}}$$

Quantum, special relativity and nuclear

$$\lambda = \frac{h}{mv}$$

$$K_{\mathrm{max}} = hf - \phi$$

$$\lambda_{\mathrm{max}} = \frac{b}{T}$$

$$E = mc^2$$

$$E = hf$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_{\mathrm{f}}^2} - \frac{1}{n_{\mathrm{i}}^2}\right)$$

$$t = \frac{t_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$$

$$l = l_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}$$

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

$$N_{\mathrm{t}} = N_0 e^{-\lambda t}$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

2022 HSC Physics
Marking Guidelines

Section I

Multiple-choice Answer Key

Question	Answer
1	C
2	D
3	D
4	C
5	B
6	A
7	C
8	A
9	C
10	D
11	B
12	D
13	B
14	B
15	A
16	A
17	C
18	D
19	A
20	B

Section II

Question 21 (a)

Criteria	Marks
• Correctly compares the surface temperatures and luminosities of *X* and *Y*	2
• Correctly compares the surface temperatures or luminosities of *X* and *Y*	1

Sample answer:

The surface temperature of *X* is greater than the surface temperature of *Y*.
The luminosity of *X* is less than the luminosity of *Y*.

Question 21 (b)

Criteria	Marks
• Identifies the elements undergoing fusion in *X* and *Y*	2
• Identifies an element undergoing fusion in *X* or *Y*	1

Sample answer:

In star *X* fusion of hydrogen is taking place and in star *Y* helium is fusing.

Question 22

Criteria	Marks
• Describes effects of TWO features that contribute to efficiency	4
• Describes effect of ONE feature that contributes to efficiency and identifies an effect of another feature	3
• Identifies effect of ONE feature that contributes to efficiency	2
• Provides some relevant information	1

Sample answer:

The laminations in the core minimise the production of eddy currents that would heat the core, reducing efficiency. The fact that the iron core is continuous enables maximum transfer of flux from the primary to the secondary coil, increasing efficiency.

Answers could include:

The high conductivity/low resistance of copper wire reduces heating loss.

Question 23

Criteria	Marks
• Outlines the steps necessary to conduct measurements in a relevant experiment • Outlines how measurements are used to determine the speed of light • Identifies a limiting factor	4
• Outlines some steps necessary to conduct measurements in a relevant experiment • Outlines how measurements are used to determine the speed of light or identifies a limiting factor	3
• Provides some details about a relevant experiment or calculation or limiting factor	2
• Provides some relevant information	1

Sample answer:

A light source is directed at a mirror a large distance away. The light and a stopwatch are turned on at the same instant.

The stopwatch is stopped when the reflected light is observed.

The total distance to the mirror and back is measured and the speed of light can be determined by dividing the distance travelled by the time taken.

A limitation to the accuracy of the experiment could be the reaction time in stopping the stopwatch when the reflected light is observed.

Answers could include:

- The passing of light through the teeth of a rotating cog and using the speed of rotation and the flickering of the reflected light in making the calculation of the speed of the light
- Other experimental setups involving lasers, retro reflectors, interferometers and resonant cavities etc
- Rømer's experiment involving light from Jupiter.

Question 24 (a)

Criteria	Marks
• Correctly uses half-life to calculate the decay constant	2
• Provides one correct step in calculation	1

Sample answer:

$t_{\frac{1}{2}}$ = 16 hours

So $\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

$\lambda = \dfrac{\ln 2}{16} = 0.043\ \text{h}^{-1}$

Question 24 (b)

Criteria	Marks
• Correctly calculates time taken	2
• Provides one correct step in calculation	1

Sample answer:

$N_t = N_0 e^{-\lambda t}$

$8 = 80\ e^{-0.043t}$

$\ln\left(\dfrac{8}{80}\right) = -0.043t$

$t = 54$ hours

Answers could include:

53 hours if using unrounded value from part (a).

Question 25 (a)

Criteria	Marks
• Correctly calculates the change in kinetic energy	2
• Provides a substitution into a relevant equation	1

Sample answer:

Change in kinetic energy = $\dfrac{mv^2}{2} - \dfrac{mu^2}{2} = \dfrac{200}{2}(8\ 410\ 000 - 30\ 250\ 000) = 2.2 \times 10^9$ J

Question 25 (b)

Criteria	Marks
• Correctly calculates mass of the planet	3
• Applies the law of conservation of energy OR • Shows steps in calculating the mass of the planet	2
• Provides a step in the calculation of the mass of the planet	1

Sample answer:

Change of kinetic energy = change in potential energy

$$2.2 \times 10^9 = \mathrm{GMm}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\mathrm{M} = \frac{2.2 \times 10^9}{6.67 \times 10^{-11} \times 200\left(\frac{1}{4.3 \times 10^6} - \frac{1}{2.5 \times 10^7}\right)}$$

$\mathrm{M} = 8.6 \times 10^{23}$ kg

Answers could include:

$\mathrm{M} = 8.5 \times 10^{23}$ kg depending on rounding.

Question 26 (a)

Criteria	Marks
• Correctly calculates *K*	3
• Provides substantial working for calculating *K*	2
• Provides one correct step in calculation	1

Sample answer:

$$K = hf - \phi = 6.626 \times 10^{-34} \times 7.5 \times 10^{14} - 2.9 \times 1.602 \times 10^{-19}$$

$$= 4.9695 \times 10^{-19} - 4.6458 \times 10^{-19} = 3.2 \times 10^{-20} \text{ J}$$

Question 26 (b)

Criteria	Marks
• Correctly calculates *d*	3
• Provides some working for calculating *d*	2
• Provides one correct step in calculation	1

Sample answer:

Photoelectron stops when work done by field = kinetic energy at surface

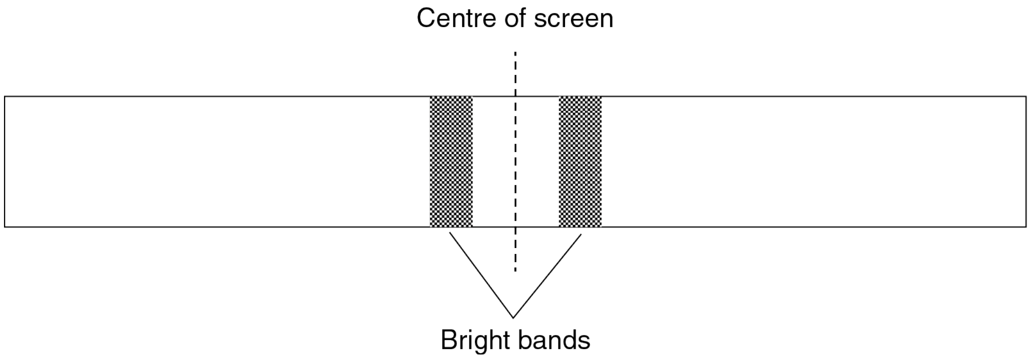
$$\text{Work} = Vq = qEd = 1.602 \times 10^{-19} \times 5.2 \times d = 3.2 \times 10^{-20}$$

$$d = \frac{3.2 \times 10^{-20}}{8.33 \times 10^{-19}} = 0.038 \text{ m} = 3.8 \text{ cm}$$

Question 27 (a)

Criteria	Marks
• Correctly sketches and labels the expected pattern	2
• Shows two bands of light OR • Identifies a feature of Newton's model	1

Sample answer:



Question 27 (b)

Criteria	Marks
• Calculates the angle θ	3
• Provides substantial working to calculate the angle θ	2
• Provides one correct step in calculation	1

Sample answer:

$$d\sin\theta = m\lambda$$

$$5.0\times10^{-5}\sin\theta = 2\left(655\times10^{-9}\right)$$

$$\theta = \sin^{-1}\frac{\left(2\left(655\times10^{-9}\right)\right)}{5.0\times10^{-5}}$$

$$\theta = 1.5 \text{ degrees}$$

Question 27 (c)

Criteria	Marks
• Describes and clearly explains the difference in the pattern	2
• Describes the difference in the pattern	1

Sample answer:

The bright lines would be closer together, because θ is smaller if λ is smaller.

Question 28

Criteria	Marks
• Correctly calculates energy released and suggests why it is greater than *X*	3
• Correctly calculates energy released or identifies that more mass is lost in Step *Y*	2
• Provides some relevant information	1

Sample answer:

Change of mass in Step $Y = \Delta m = 13.003 + 1.007 - 14.003 = 0.007u$

Energy released $E = 0.007 \times 931.5 = 6.52\ MeV$

This is more energy than was released in Step *X*, so more mass must have been lost.

Question 29

Criteria	Marks
• Describes and explains the horizontal component of the apple's motion • Describes and explains the vertical component of the apple's motion	4
• Relates features of the apple's horizontal and vertical motion to a force acting on it	3
• Describes features of the apple's motion OR • Relates a feature of the apple's motion to the forces acting on it	2
• Provides some relevant information	1

Sample answer:

The horizontal component of the motion of the apple remains constant because there is no net force acting on it in the horizontal direction. The initial horizontal velocity of the apple is the vector sum of the car's velocity relative to the ground plus the apple's initial velocity relative to the car.

The vertical motion of the apple is accelerated uniformly vertically downward from rest by the gravitational force acting on it.

Question 30 (a)

Criteria	Marks
• Describes the process that led to the prediction of time dilation	3
• Outlines parts of the process	2
• Provides some relevant information	1

Sample answer:

The distance travelled by the light, *X* to *Y* to *X*, appears to be greater to the observer outside the train than to the observer in the train. Since both observe the same speed of light, then the return trip must have taken longer for the observer outside the train, since $t = \frac{d}{c}$. This is what Einstein called time dilation.

Question 30 (b)

Criteria	Marks
• Calculates the outside observer's time, includes relevant unit	3
• Provides substantial working to calculate outside observer's time	2
• Provides a correct step in calculation	1

Sample answer:

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

So $$t = \frac{1.5 \times 10^{-8}}{\sqrt{\left(\frac{1 - (0.96)^2 c^2}{c^2}\right)}}$$

$$= \frac{1.5 \times 10^{-8}}{0.28}$$

$$= 5.4 \times 10^{-8} s$$

Answers could include:

= 54 ns

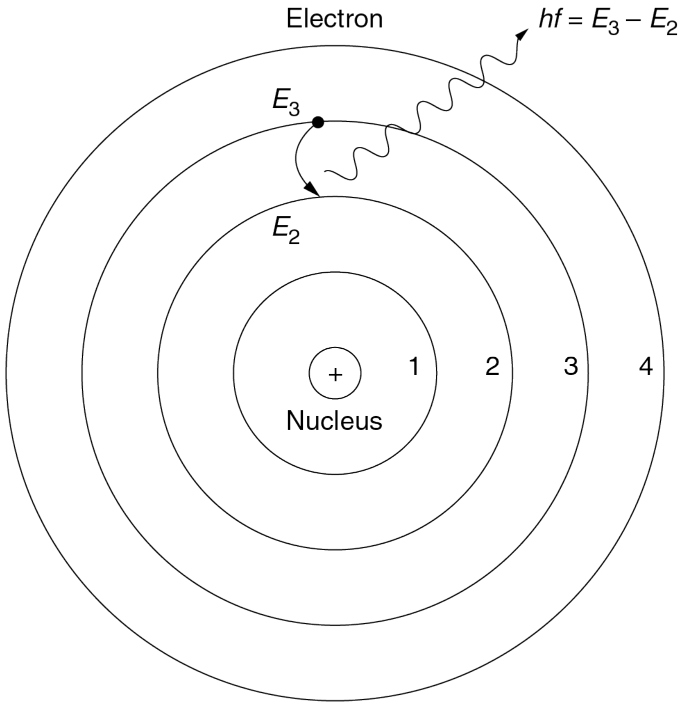
Question 31

Criteria	Marks
• Provides a comprehensive analysis, relating features of the model to the experimental evidence • Incorporates a relevant calculation and detailed diagram in analysis	9
• Provides a thorough analysis, relating features of the model to the experimental evidence • Includes a relevant calculation and detailed diagram	8
• Relates features of the model to the experimental evidence • Includes a relevant calculation and/or a diagram	6–7
• Identifies some links between the model and the experimental evidence and/or a calculation	4–5
• Provides details of the model and/or the experimental evidence	2–3
• Provides some relevant information	1

Sample answer:

In the Geiger–Marsden experiment, the fact that most alpha particles went straight through the gold atom was accounted for by the atom being mostly empty space in the model. The small fraction of alpha particles that were deflected through large angles were accounted for by the dense positive nucleus that exerted a repulsive electrostatic force on the alpha particles headed towards it. The large mass of the nucleus relative to the alpha particles made them bounce back while the nucleus remained stationary. Alpha particles passing near the nucleus were deflected by smaller amounts due to a smaller electrostatic force.

The model was able to account for experimental results of the spectrum of hydrogen using the postulates that electrons exist in stable energy states around the nucleus. If an electron moves from a higher-energy state to a lower one, it emits a photon with energy given by $E_p = hf = E_f - E_i$.



The four visible spectral lines of the Balmer series have wavelengths that were accounted for in the model using the equation:

$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2 - n_i^2}\right]$, where n_f is 2 and n_i is 3, 4, 5 and 6.

For $n_i = 3$, this gives $\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{4} - \frac{1}{9}\right]$, so λ=656 nm, which is shown in the diagram as the line furthest to the right.

Question 32 (a)

Criteria	Marks
• Explains how the magnets make it harder to pedal	3
• Relates magnetic effects to induced currents	2
• Outlines magnetic effects	1

Sample answer:

Relative motion between the magnets and the moving flywheel induce eddy currents in the flywheel. These produce magnetic fields and a subsequent force on the wheel that opposes the changing flux. This produces a torque that opposes the pedalling action of the person, making it harder for them to pedal.

Question 32 (b)

Criteria	Marks
• Justifies a method for increasing torque	3
• Outlines a method that would increase torque	2
• Links torque to parts of the bike OR • Identifies a related method	1

Sample answer:

The magnets could be moved closer to the wheel causing the induced eddy currents to be larger due to the greater flux change. The stronger field produced by these currents thus exerts a greater force and greater opposing torque on the flywheel.

Answers could include:

Moving the magnets further away from the flywheel's axis.

Question 33 (a)

Criteria	Marks
• Correctly calculates vertical component of velocity	2
• Provides one correct step in calculation	1

Sample answer:

Speed of hammer in circular motion is $v = \frac{2\pi r}{t} = \frac{2 \times \pi \times 1.6}{0.5} = 20.1 \text{ ms}^{-1}$

Vertical component $v_y = 20.1 \times \sin 45° = 14.2 \text{ ms}^{-1}$

Question 33 (b)

Criteria	Marks
• Correctly calculates range	4
• Provides substantial working to calculate range	3
• Calculates one relevant quantity	2
• Provides one correct step in calculation	1

Sample answer:

At top of trajectory, $v_y = 0$

$$0 = 14.2 - 9.8t, \text{ so } t_{up} = 1.45 \text{ s}$$

$$\text{Distance risen} = s = ut + \frac{1}{2}at^2$$

$$= 14.2 \times 1.45 - 4.9 \times 1.45^2$$

$$= 10.3 \text{ m}$$

At top, distance from ground $= 10.3 + 1.2 = 11.5$ m

$$\text{Distance fallen} = s = ut + \frac{1}{2}at^2$$

$$11.5 = 4.9t^2, \text{ so } t_{down} = 1.53 \text{ s}$$

$$t_{total} = 1.45 + 1.53 = 2.98 \text{ s}$$

$$\text{Range } x = v_x t = 14.2 \times 2.98 = 42.3 \text{ m}$$

Question 34

Criteria	Marks
• Comprehensively explains the different paths of each particle *X*, *Y* and *Z* through the magnetic field	7
• Explains the paths of particles *X*, *Y* and *Z*	6
• Explains some aspects of the paths of particles *X*, *Y* and *Z*	4–5
• Provides details of particle properties and/or paths in the field	2–3
• Provides some relevant information	1

Sample answer:

X and *Y* are both positive since they are deflected towards the top of the page when they initially enter the magnetic field which exerts a force on the charges, initially up the page. As they travel through the magnetic field, the force is applied perpendicular to their velocity, causing them to curve in the arc of a circle as shown, with the magnetic force providing the centripetal force.

This allows the curvature of each charge's circular path to be expressed as $r = \dfrac{mv}{qB}$.

X has a smaller radius of arc which indicates it has a smaller mass or greater charge than *Y*.

Z must have the same charge to mass ratio as *X*, but an opposite sign charge. This would explain the identical curvature of the path through the magnetic field in the opposite direction.

Question 35

Criteria	Marks
• Provides correct calculations to reject the hypothesis	5
• Provides calculations which analyse the system	4
• Makes some calculations using appropriate formulae OR • Provides a correct calculation or evidence and makes a relevant conclusion	3
• Substitutes into a relevant formula	2
• Provides some relevant information	1

Sample answer:

$$F_c = \frac{mv^2}{r} = 1.2 \times 10^4 \times \frac{(0.233)^2}{200}$$

$$= 3.26 \text{ N}$$

$$F_G = \frac{GMm}{r^2} = \frac{6.67 \times 10^{-11} \times 4.2 \times 10^5 \times 1.2 \times 10^4}{200^2}$$

$$= 8.4 \times 10^{-6} \text{ N}$$

Hence the centripetal force required to accelerate the capsule around the ISS is much greater than the gravitational force of attraction between the two space vehicles. The hypothesis is rejected.

2022 HSC Physics
Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Mod 6 Electromagnetic Induction	12-13
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3	1	Mod 8 Properties of the Nucleus	12-15
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