Neap

Trial Examination 2022

HSC Year 12 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 2–10)

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

SECTION II – 80 marks (pages 11–30)

- Attempt Questions 21– 33
- Allow about 2 hours and 25 minutes for this section

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2022 HSC Year 12 Physics examination.

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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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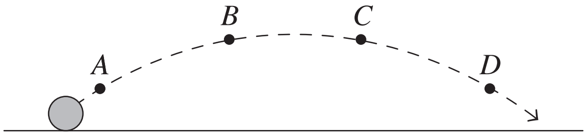
1 A field hockey player scoops the ball up and over opposing players to pass to their teammate further up the field. The ball moves from position *A* to position *D*, as shown in the diagram.



At which position(s) would the acceleration of the ball be vertically downward?

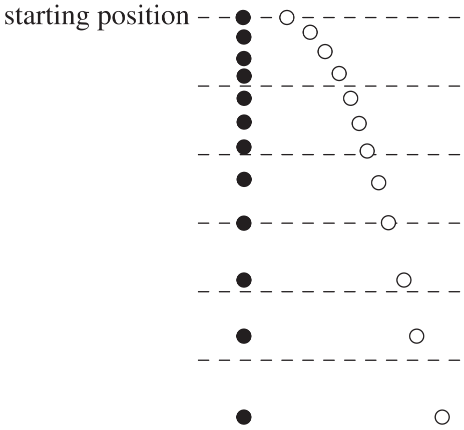
A. *D* only

B. *C* and *D* only

C. *B*, *C* and *D* only

D. *A*, *B*, *C* and *D*

2 Two balls were simultaneously released from the same starting position. The black ball was dropped from rest and the white ball was projected horizontally, as shown in the diagram. The dashed lines represent equal distance intervals.



Which row of the table identifies the relative motions of the balls?

	X position of the balls	*Y position of the balls*	*Y velocities of the balls*	*X velocities of the balls*	*Y acceleration of the balls*
A.	different	same	same	different	same
B.	same	same	same	same	same
C.	different	different	different	different	different
D.	different	same	same	different	different

3 A National Aeronautics and Space Administration (NASA) scientist uses a simulator to model the surface gravity of four different bodies in the Solar System. The surface gravity of each body is shown in the table.

Body	*Surface gravity (m s^{-2})*
Ceres	5.55
Icarus	0.38
Hermes	4.97
Pallas	2.49

In the first simulation, the scientist throws a small cube with a mass of 450 g upwards. The cube initially travels at a speed of 6.5 m s^{-1} and reaches a maximum height of 8.5 m.

Which body is the scientist simulating?

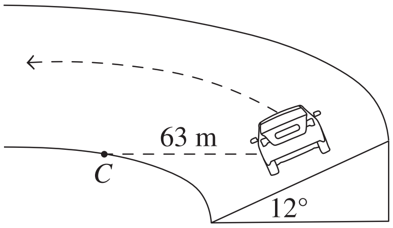
A. Ceres

B. Icarus

C. Hermes

D. Pallas

4 A road has a curve of radius 63 m and is banked at an angle of 12°. The diagram shows a car approaching the curve in wet, slippery conditions.



Assuming that there is no friction, calculate the maximum speed at which the car can safely make the turn.

A. 6.07 km h^{-1}

B. 11.5 km h^{-1}

C. 36.5 km h^{-1}

D. 41.2 km h^{-1}

5 What will be produced when white light is passed through a gaseous sample of an element and examined with a spectrometer?

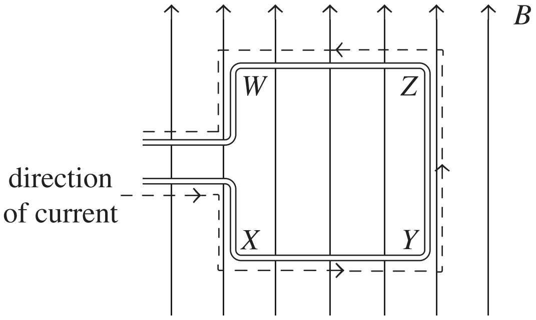
A. an absorption spectrum that is shown as a series of dark lines on a coloured background

B. an emission spectrum that is shown as a series of coloured lines on a dark background

C. an absorption spectrum that is shown as a series of coloured lines on a dark background

D. an emission spectrum that is shown as a series of dark lines on a coloured background

6 Consider the current-carrying loop.



How is torque created in the current-carrying loop?

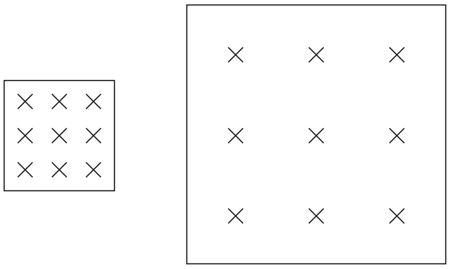
A. There is a force on *WZ* out of the page and a force on *XY* into the page.

B. There is a force on *WZ* into the page and a force on *XY* out of the page.

C. There is a force on *WZ* out of the page and a force on *XY* out of the page.

D. There is a force on *WZ* into the page and a force on *XY* into the page.

7 A Physics teacher drew two magnetic fields and asked their students to explain the difference between the magnetic flux of each field. The two magnetic fields are shown in the diagram.



Which of the following statements is correct?

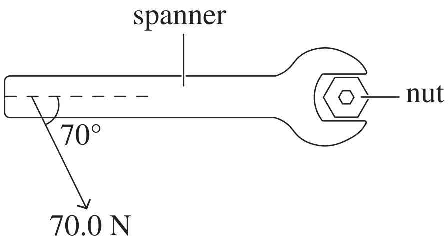
A. The two magnetic fields show the same amount of flux, and the smaller magnetic field shows less flux density.

B. The two magnetic fields show different amounts of flux, and the smaller magnetic field shows less flux density.

C. The two magnetic fields show different amounts of flux, and the smaller magnetic field shows greater flux density.

D. The two magnetic fields show the same amount of flux, and the smaller magnetic field shows greater flux density.

8 In cycling, it is important for the nuts on bike seats to be tightened appropriately so they do not come loose during a race. Before a race, a cyclist tightened the nuts with a 50.0 cm spanner and applied a force of 70.0 N at an angle of 70° to the spanner, as shown in the diagram.



What magnitude of torque has the cyclist applied to the nut?

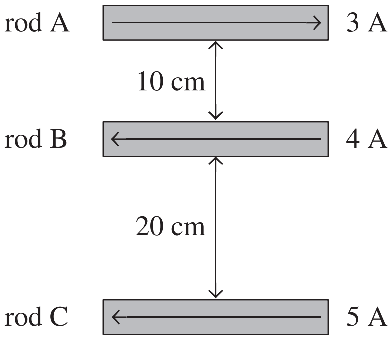
A. 11.97 N m

B. 32.89 N m

C. 1197.07 N m

D. 3289.92 N m

9 The diagram shows a set-up that uses three rods (A–C), each carrying a current in the direction indicated by the arrows.



What is the magnitude and direction of the force per unit length on rod C?

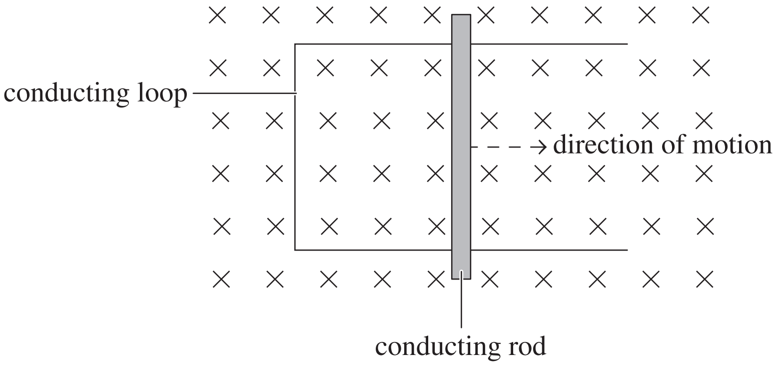
A. 1×10^{-5} N m^{-1} down

B. 1×10^{-5} N m^{-1} up

C. 3×10^{-5} N m^{-1} up

D. 3×10^{-5} N m^{-1} down

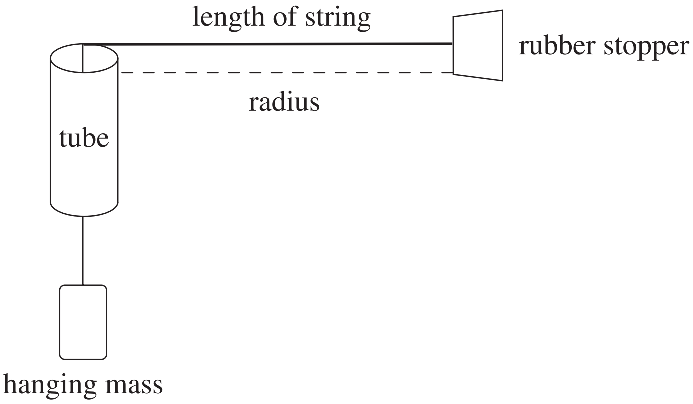
10 A conducting rod slides along a metal conducting loop, as shown in the diagram.



Which row of the table is correct?

	Direction of force on the conducting rod	*Direction of induced current in the rod*	*Direction of current around the conducting loop*
A.	to the left	up the rod	anticlockwise
B.	to the left	down the rod	clockwise
C.	to the right	up the rod	anticlockwise
D.	to the right	down the rod	clockwise

11 A student carries out an investigation to find the relationship between the centripetal force, rotational speed and radius of an object moving in a uniform, circular motion. The student attaches a rubber stopper to a hanging mass using a string that passes through a tube and swings the rubber stopper around the tube, as shown in the diagram. As the rubber stopper is swung, the hanging mass rises and falls depending on the rotational speed of the stopper. When the hanging mass neither rises nor falls, the radius of the stopper is measured.



Which row of the table identifies the variables for this investigation?

	Independent variable	*Dependent variable*	*Controlled variables*
A.	hanging mass	length of string	mass of rubber stopper, rotational speed
B.	rotational speed	length of string	hanging mass, rotational speed
C.	mass of rubber stopper	rotational speed	hanging mass, length of string
D.	rotational speed	radius	mass of rubber stopper, length of string

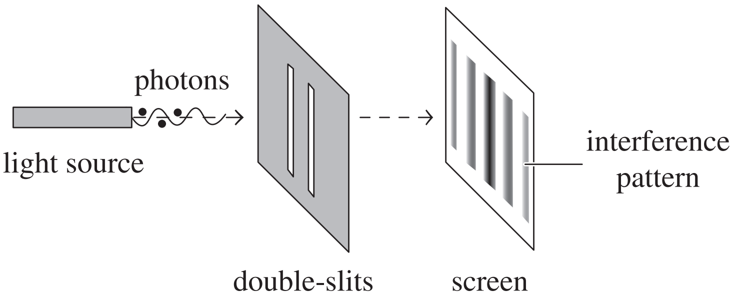
12 As a star rotates, the observed atomic absorption bands change. Consider the statement about this relationship.

> When a star is rotating away from an observer, light is ______*X*______. When the star is rotating towards the observer, light is ______*Y*______. The ______*Z*______ it rotates, the wider the absorption band will appear in its spectrum.

Which row of the table completes the statement?

	X	*Y*	*Z*
A.	blue-shifted	red-shifted	faster
B.	red-shifted	blue-shifted	faster
C.	blue-shifted	red-shifted	slower
D.	red-shifted	blue-shifted	slower

13 Young performed an experiment where photons were beamed through a double-slit onto a screen, as shown in the diagram.



The following changes were made one at a time.

Change 1: The slit separation is changed.

Change 2: The distance between the double-slit and the screen is increased.

Which row of the table identifies what will occur after each change?

	Change 1	*Change 2*
A.	If the slit separation increases, the spacing between the bright bands decreases.	The spacing between the bright bands decreases.
B.	If the slit separation increases, the spacing between the bright bands decreases.	The spacing between the bright bands increases.
C.	If the slit separation increases, the spacing between the bright bands increases.	The spacing between the bright bands increases.
D.	If the slit separation decreases, the spacing between the bright bands increases.	The spacing between the bright bands decreases.

14 Light passes through a diffraction grating with a slit separation of 0.07 mm. An interference pattern is shown on a screen placed 105 cm from the grating. Six of the bright bands have a separation of 50 mm.

What is the wavelength of the light?

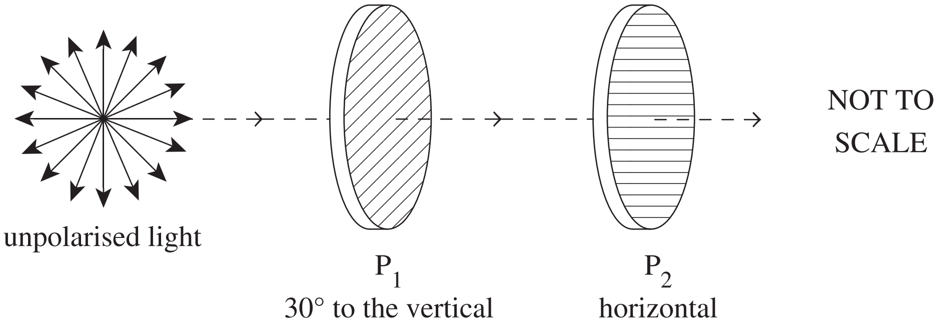
A. 5.55 nm

B. 6.66 nm

C. 555 nm

D. 666 nm

15 A light meter measures 150 Wm^{-2} of unpolarised light at a fixed position from a light source. A polarising sheet, P_1, is placed at this position with an axis of polarisation 30° to the vertical. A second polarising sheet, P_2, is placed so that any light that passes through P_1 also passes through the P_2. P_2 has an axis of polarisation oriented horizontally. The diagram shows the set-up.



What intensity of light is transmitted through P_2?

A. 9.38 Wm^{-2}

B. 18.75 Wm^{-2}

C. 37.5 Wm^{-2}

D. 75 Wm^{-2}

16 Most stars have at least one planet orbiting them. Two planets, Psi and Tri, have been observed to orbit a star. Psi has an orbital path with a radius that is four times smaller than the radius of Tri's orbital path.

Which of the following statements about Psi and Tri is correct?

A. Tri would take 8 times longer than Psi to make a full orbit of the star.

B. Psi would take 8 times longer than Tri to make a full orbit of the star.

C. Tri would take 64 times longer than Psi to make a full orbit of the star.

D. Psi would take 64 times longer than Tri to make a full orbit of the star.

17 A Geiger–Muller counter is an instrument that emits a beep every time a beta particle is detected. A radioactive sample that emits beta radiation, *X*, gives a reading of 2.3 counts per minute on the Geiger–Muller counter. Sample *Y* is taken from the same element as sample *X*, but has a more recent origin. Sample *Y* gives a reading of 18.4 counts per minute.

If the half-life of the element is 356 years, how much older than sample *Y* is sample *X*?

A. 25 years

B. 119 years

C. 1068 years

D. 15 065 years

18 Stars go through a lifecycle.

Which of the following lists the stages of a star's lifecycle in chronological order?

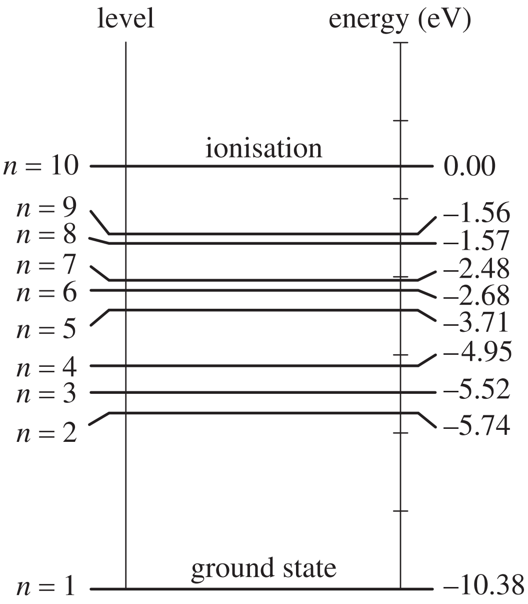
A. protostar, nebula, main sequence star, neutron star, red giant

B. nebula, protostar, main sequence star, red giant, black hole

C. protostar, nebula, main sequence star, red supergiant, white dwarf

D. nebula, protostar, main sequence star, red giant, neutron star

19 The energy level diagram for mercury is shown.



What frequency of light would be emitted as an electron falls from the $n = 5$ state to the $n = 3$ state?

A. 1.81 eV

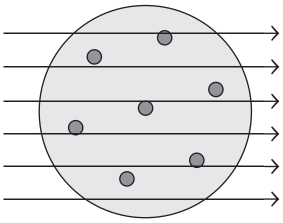
B. 2.89×10^{-19} J

C. 4.4×10^{14} Hz

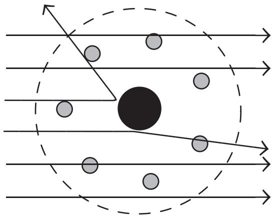
D. 7.4×10^{14} Hz

20 The following schematic diagrams represent two models of the atom, one of which was proposed by Ernest Rutherford and the other by Joseph Thomson.

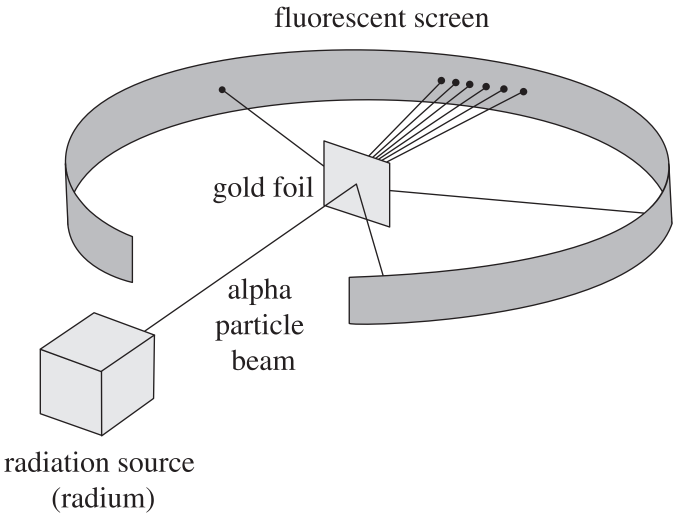
Model 1



Model 2



Geiger and Marsden were asked by Rutherford to test Thomson's model of the atom. The experiment shown in the diagram below was carried out in a vacuum.



Which row of the table identifies the atomic model of each scientist and explains the results obtained by Geiger and Marsden?

	Thomson's model and explanation	*Rutherford's model and explanation*
A.	Model 1 Some alpha particles go through the gold foil undeflected as they are attracted to the positive particles scattered throughout the atom.	Model 2 Most alpha particles are deflected as they hit the positively charged nucleus inside the mostly empty atom.
B.	Model 1 Most alpha particles go through the gold foil undeflected as they are attracted to the negative particles scattered throughout the atom.	Model 2 Some alpha particles are deflected as they hit the positively charged nucleus inside the mostly empty atom.
C.	Model 2 Most alpha particles are deflected as they hit the positively charged nucleus inside the mostly empty atom.	Model 1 Some alpha particles go through the gold foil undeflected as they are attracted to the positive particles scattered throughout the atom.
D.	Model 2 Some alpha particles are deflected as they hit the positively charged nucleus inside the mostly empty atom.	Model 1 Most alpha particles go through the gold foil undeflected as they are attracted to the negative particles scattered throughout the atom.

HSC Year 12 Physics

Section II Answer Booklet

Section II

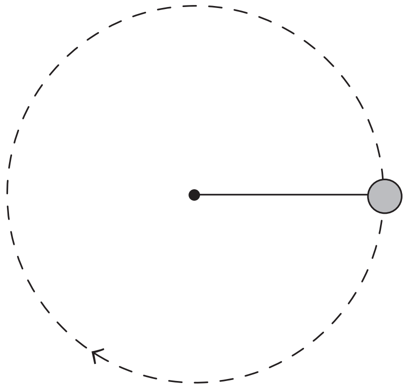
80 marks
Attempt Questions 21–33
Allow about 2 hours and 25 minutes for this section

Instructions
- 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 (5 marks)

The diagram shows a totem tennis set-up, as viewed from above. A tennis ball is tied to a pole with a cord so that it moves in a clockwise, circular motion around the centre pole.



(a) Label the velocity of the ball and the forces acting on it at the point shown in the diagram above. Explain your answer. **2**

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(b) The ball has a mass of 60.0 g and the cord is 1.80 m long. The ball rotates around the centre pole at an angle of 45° to the pole. **1**

Calculate the radius of the ball's circular path.

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Question 21 continues on page 13

Question 21 (continued)

(c) Determine the magnitude of the net force acting on the ball at the point shown. **2**

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End of Question 21

Question 22 (3 marks)

A student kicks a ball at a speed of 8.3 m s^{-1} at an angle of 35° above the ground. **3**

What is the range of the ball?

Question 23 (4 marks)

A communications company launched a satellite of mass 250 kg. The satellite is in an orbit with a uniform circular radius of 33 500 km around Earth. **4**

Calculate the gravitational potential energy of the satellite and its escape velocity. In your response, explain what the term ‘escape velocity’ means.

Question 24 (8 marks)

(a) Supertankers are large cargo ships that often transport oil. The supertankers *TI Europe* and *TI Oceania* are two of the largest man-made objects. They float with their centres 100.00 m apart and each has mass of 5.00×10^8 kg. **2**

Calculate the gravitational force between the two supertankers.

The centre of a planet of mass 1.00×10^{24} kg is a distance, *d*, from the centre of one of its moons. The table shows the gravitational force of attraction between the planet and this moon.

$F\ (\times 10^3\ N)$	37	32	23	17	11	6
$d\ (\times 10^6\ m)$	3.43	3.70	4.34	5.06	6.32	8.45
$\frac{1}{d^2}\ (\times 10^{-14}\ m^{-2})$	8.5	7.3	5.3	3.9	2.5	1.4

(b) Plot the graph of F versus $\frac{1}{d^2}$. **3**

Question 24 continues on page 16

Question 24 (continued)

(c) Find the gradient of the graph drawn in part (b) and use the relationship $F = \frac{k}{d^2}$ to determine the mass of the moon. **3**

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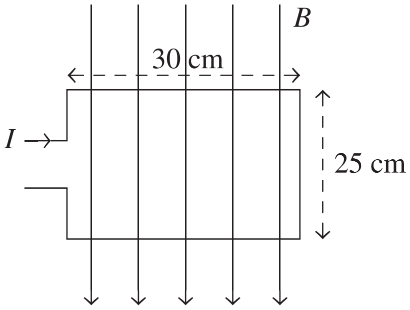
End of Question 24

Question 25 (9 marks)

The diagram shows the wire loop of a motor in a magnetic field. The loop carries a current of 8 A and the magnetic field intensity is 0.025 T.



(a) Compare the structural features and physics principles that are involved in DC motors and AC induction motors to explain how the motor effect is used in both motors. **5**

(b) Calculate the magnitude of the torque experienced by the wire loop. **2**

Question 25 continues on page 18

Question 25 (continued)

(c) Identify TWO modifications to the wire loop that would make the motor run faster. Explain your answer. **2**

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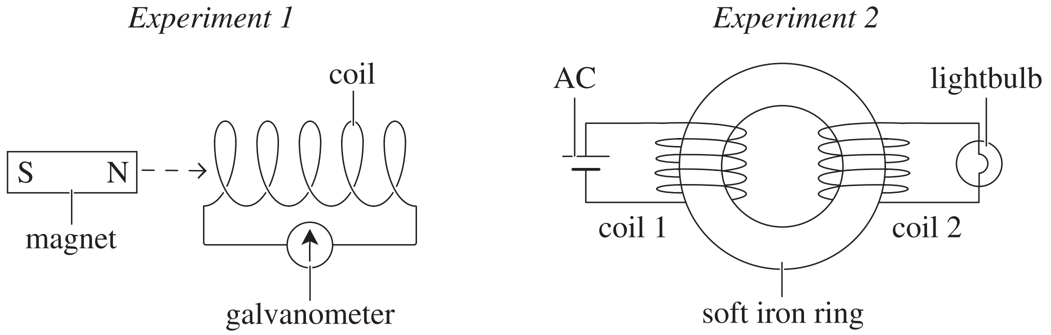
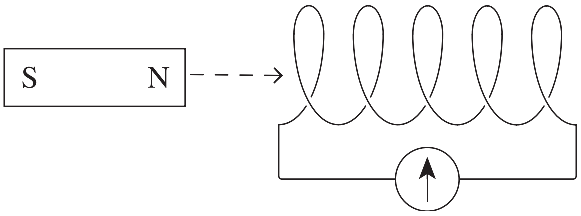
End of Question 25

Question 26 (5 marks)

Scientists including Faraday and Lenz investigated the relationship between electricity and magnetism through a series of experiments. The diagram shows the set-up of Faraday's first and second experiments.



(a) Label the diagram below to show the direction of current and induced magnetic field in experiment 1. **1**



(b) Assess the contribution of Faraday and Lenz to our understanding of how electric and magnetic fields are related in terms of the Law of Conservation of Energy. Refer to the diagrams in your response. **4**

Question 27 (3 marks)

For electricity to be transmitted over the large distances between generators and households, transformers are used. Two transmissions take place over the same transmission lines. **3**

- In transmission A, energy is transmitted at 28 kV AC.
- In transmission B, the same amount of energy is transmitted at 280 kV AC.

Compare the power losses that occur in transmissions A and B. Include relevant equations and calculations in your response.

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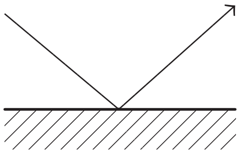
Question 28 (9 marks)

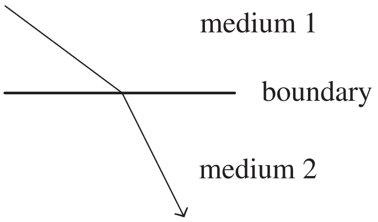
‘Prior to the twentieth century, physicists developed theories and models under the banner of classical physics that were able to make predictions. However, developments in the twentieth century saw these models and theories being challenged by quantum physics.’ **9**

Analyse this statement with reference to the photoelectric effect and the work of Bohr, de Broglie and Schrödinger.

Question 29 (4 marks)

Two theories of light were proposed by Newton and Huygens in in the seventeenth century: **4**
the corpuscular theory and the wave theory. Two properties of light are depicted in the diagrams.





Analyse the evidence, including the determination of the speed of light, that supported the two models. In your response, make reference to the properties shown in the diagrams.

Question 30 (6 marks)

Einstein used thought experiments to explain how the behaviour of light affects the concepts of time, space and matter.

(a) The rest life, or proper lifetime, of a meson is 2.5×10^{-8} s. An observer measures the distance travelled by a meson moving at 2.95×10^{8} m s^{-1} in the laboratory. **3**

Compare the expected distance travelled by the meson in the absence of time dilation with the distance that would be measured by the observer.

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(b) A spacecraft of mass 79 000 kg is moving at 0.3*c*. **3**

Compare the mass of the spacecraft measured by the spacecraft's pilot with the mass measured by an external observer, and explain why objects cannot accelerate to the speed of light.

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Question 31 (8 marks)

In science, there is a close link between developments in technology and developments in knowledge and understanding. **8**

Evaluate how the invention of particle accelerators has advanced our understanding of atoms and provided evidence that supports the Standard Model of matter.

Question 32 (10 marks)

(a) As part of the Physics course, you have modelled the process of nuclear fission. **4**

Explain the difference between a controlled and uncontrolled fission chain reaction. In your response, refer to the model you studied.

(b) Information about an oxygen-18 atom is given in the table. **3**

Mass of atom	17.99916 amu
Mass of proton	1.007276 amu
Mass of neutron	1.008664 amu

Calculate the mass defect of the nucleus of an oxygen-18 atom and provide its binding energy in joules AND electron volts.

Question 32 continues on page 26

Question 32 (continued)

(c) Identify and describe a balanced nucleosynthesis reaction that can be used to explain how energy is released by nuclear fusion in cooler main sequence stars. **3**

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End of Question 32

Question 33 (6 marks)

Experimental evidence was gathered by scientists to support the existence of the electron.

(a) As part of the Physics course, you have investigated the early experiments examining the nature of cathode rays. **2**

Complete the table below by describing TWO observations from these experiments and explaining how the observed behaviour of the cathode rays supported the existence and properties of the electron. Your response may include diagrams.

Observation	*Explanation*

Question 33 continues on page 28

Question 33 (continued)

(b) In an experiment involving an evacuated gas tube, electrons were accelerated from rest through a voltage of 2400 V. They entered a uniform magnetic field strength of 1.8×10^{-3} T at right angles to the electron beam. **2**

Calculate the speed of these electrons upon entering the magnetic field.

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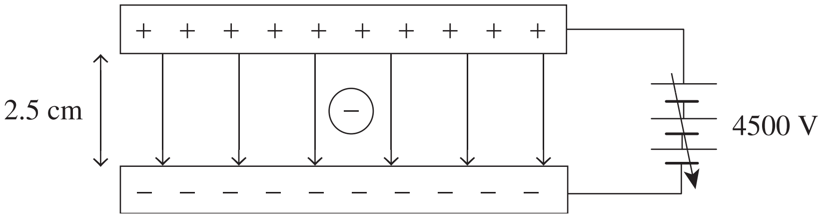
(c) In science, observations lead to hypotheses and further experimentation. **2**

Robert Millikan conducted experiments to determine the charge on an electron.
One of these experiments is shown in the diagram.



Explain the observations Millikan made that led to his determination of the charge of an electron.

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If you use this space, clearly indicate which question you are answering.

Section II extra writing space

If you use this space, clearly indicate which question you are answering.

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 ms^{-1}
Earth's gravitational acceleration, g	9.8 ms^{-2}
Speed of light, c	3.00×10^{8} ms^{-1}
Electric permittivity constant, ε_0	8.854×10^{-12} $\text{A}^2\ \text{s}^4\ \text{kg}^{-1}\ \text{m}^{-3}$
Magnetic permeability constant, μ_0	$4\pi \times 10^{-7}$ N A^{-2}
Universal gravitational constant, G	6.67×10^{-11} $\text{N m}^2\ \text{kg}^{-2}$
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)	1.097×10^{7} m^{-1}
Atomic mass unit, u	1.661×10^{-27} kg 931.5 MeV/c^2
1 eV	1.602×10^{-19} J
Density of water, ρ	1.00×10^{3} kg m^{-3}
Specific heat capacity of water	4.18×10^{3} $\text{J kg}^{-1}\ \text{K}^{-1}$
Wien's displacement constant, b	2.898×10^{-3} m K

FORMULAE SHEET

Motion, forces and gravity

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

$v = u + at$

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

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

$\Delta U = mg\Delta h$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Waves and thermodynamics

$v = f\lambda$

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

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

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

$d\sin\theta = m\lambda$

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

$n_x = \frac{c}{v_x}$

$\sin\theta_c = \frac{n_2}{n_1}$

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

$I_1r_1^2 = I_2r_2^2$

$Q = mc\Delta T$

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

FORMULAE SHEET (continued)

Electricity and magnetism

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

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

$$W = qV$$

$$W = qEd$$

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

$$B = \frac{\mu_0 N I}{L}$$

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

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

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

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

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

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

$$V = IR$$

$$P = VI$$

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

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

$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

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

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

Quantum, special relativity and nuclear

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

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

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

$$E = mc^2$$

$$E = hf$$

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

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

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

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

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

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

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 moybdenum	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	111 **Cn** copernicium	113 **Nh** nihonium	114 **Fl** flerovium	115 **Mc** moscovium	116 **Lv** livermorium	117 **Ts** tennessine	118 **Og** oganesson

Lathanoids

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.

Neap

Trial Examination 2022

HSC Year 12 Physics

Solutions and Marking Guidelines

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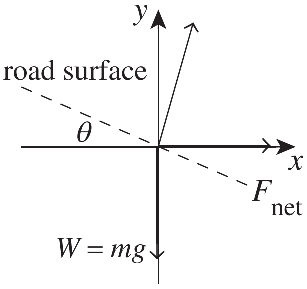
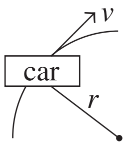
SECTION I

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 1 **D** **D** is correct. Gravity always acts downwards, so the acceleration on the ball is vertically downward at every position in the ball's journey. **A** is incorrect. This option may be reached by only accounting for the force of gravity when the ball is close to the surface of the Earth again. **B** is incorrect. This option may be reached by assuming that gravity acts downwards as the ball is travelling back to the surface of the Earth. **C** is incorrect. This option may be reached by assuming that, as it is rising, the ball has no downwards acceleration due to gravity.	Mod 5 Advanced Mechanics PH12–5 Band 3
Question 2 **A** **A** is correct. Projectile motion can be analysed as a combination of horizontal motion with constant velocity and vertical motion with constant acceleration. The two balls have different *x* motions, as the black ball was dropped from rest and the white ball was projected horizontally, but identical *y* motions, as they both fall the same distance at the same time. **B** is incorrect. This option identifies that the two balls have identical *x* positions, but the black ball was projected horizontally. **C** is incorrect. This option identifies that the *y* positions and *y* acceleration are different for the two balls when they are the same. **D** is incorrect. This option identifies that the *y* acceleration is different for the two balls when it is the same.	Mod 5 Advanced Mechanics PH12–4, 12–5, 12–12 Band 4
Question 3 **D** At the maximum height, vertical velocity is 0. $v^2 = u^2 + 2as$ $0 = (6.5)^2 + 2 \times a \times 8.5$ $a = \frac{6.5^2}{2 \times 8.5}$ $= 2.49 \text{ m s}^{-2}$ From the table, this equates to the surface gravity of Pallas.	Mod 5 Advanced Mechanics PH12–4, 12–5, 12–12 Bands 4–5

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 4 **D**   $r = 63$ m $\theta = 12°$ There is no net force in the vertical direction. $N\cos\theta - mg = 0 \quad \left(N = \frac{mg}{\cos\theta}\right)$ There is a net force provided by the normal force, which is the centripetal force. $F_{\text{net}} = N\sin\theta = \frac{mv^2}{r}$ $v^2 = mg\cos\theta \times \sin\theta \times \frac{r}{m}$ $= rg\tan\theta$ $v = \sqrt{(rg\tan\theta)}$ $= \sqrt{(63 \times 9.8\tan 12°)}$ $= 11.46 \text{ m s}^{-1}$ $= 41.24 \text{ km h}^{-1}$ $\approx 41.2 \text{ km h}^{-1}$ (to three significant figures)	Mod 5 Advanced Mechanics PH12–4, 12–5, 12–6, 12–12 Bands 5–6
Question 5 **A** **A** is correct. The electrons in the vaporised element will absorb energy at a characteristic wavelength and, as they are excited, they will go to a higher energy state before dropping back to ground state. The wavelengths absorbed are distinctive of the element as each element has a unique arrangement of electrons. The wavelengths absorbed will appear as dark lines on a coloured background. **B** and **D** are incorrect. Energy is absorbed by the gaseous atoms, which will result in an absorption spectrum. **C** is incorrect. An emission spectrum is shown as coloured lines on a dark background. The lines on emission and absorption spectra are complementary, meaning that they appear at the same values.	Mod 7 The Nature of Light PH12–14 Bands 3–4

Answer and explanation	**Syllabus content, outcomes and targeted performance bands**
Question 6 B **B** is correct. Using the right-hand palm rule, where *B* is up the page and the direction of the current (*I*) is to the left, the loop would experience a force into the page at *WZ*. At *XY*, *B* is up the page and *I* is to the right. Thus, it experiences a force out of the page. **A** is incorrect. This option may be reached by using the right-hand palm rule incorrectly. **C** and **D** are incorrect. When a loop experiences torque, it rotates. Thus, if the two forces were acting in the same direction, there would be no torque.	Mod 6 Electromagnetism PH12–3 Band 4
Question 7 D **D** is correct. Magnetic flux is represented by the total number of lines of force in any given area. Thus, both magnetic fields have the same amount of flux. As the smaller field has more lines of force in a smaller area, its magnetic flux density/ magnetic field strength is greater than the larger field. **A** is incorrect. Both fields show the same number of force lines (9), but the smaller field has more lines in a smaller area. Thus, its flux density is greater. **B** and **C** are incorrect. Both fields show the same number of force lines.	Mod 6 Electromagnetism PH12–13 Band 4
Question 8 B $\tau = rF\sin\theta$ $= 0.5 \times 70\sin(70°)$ $= 32.8892\ldots$ ≈ 32.89 N m	Mod 5 Advanced Mechanics PH12–4, 12–6, 12–12 Band 4

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 9 **B** **B** is correct. Finding the magnitude and direction of the force from rod A to rod C gives: $\frac{F}{l} = \frac{k \times 5 \times 3}{0.3}$ $= 0.00001 \text{ Nm}^{-1}$ down Finding the magnitude and direction of the force from rod B to rod C gives: $\frac{F}{l} = \frac{k \times 5 \times 4}{0.2}$ $= 0.00002 \text{ Nm}^{-1}$ up Finding the magnitude and direction of the force on rod C gives: $\frac{F}{l} = 0.00002 - 0.00001$ $= 0.00001 \text{ Nm}^{-1}$ up **A** is incorrect. This option gives the wrong direction. **C** and **D** are incorrect. These options use incorrect calculations.	Mod 6 Electromagnetism PH12–5, 12–13 Band 5
Question 10 **A** As the rod moves to the right, the area to the left of the rod increases, increasing the flux down through the area. Hence, a current is induced upwards in the rod, whose own magnetic field opposes the flux increase, producing a force to the left to oppose the motion. The increasing area on the left will induce a current in an anticlockwise direction around the loop.	Mod 6 Electromagnetism PH12–4, 12–13 Bands 5–6
Question 11 **D** **D** is correct. In the investigation, the student is changing the rotational speed, causing the hanging mass to rise and fall; therefore, the rotational speed is the independent variable. The student then measures the radius of the string, which will change depending on the rotational speed used by the student; therefore, the radius is the dependent variable. They keep the mass of the rubber stopper and length of string the same; therefore, they are the controlled variables. **A** is incorrect. The rotation period is what the student is trying to determine (the dependent variable) and the length of string is a controlled variable. **B** and **C** are incorrect. The mass of the rubber stopper should not change; it is a controlled variable.	Mod 5 Advanced Mechanics PH12–4, 12–5, 12–12 Band 4

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 12 **B** **B** is correct. As a star rotates away from the observer, the light observed shifts towards the red end (longer frequency) of the spectrum. When the star is rotating towards the observer, the light observed shifts to the blue end (shorter frequency). The faster it rotates, the wider the absorption band will appear. This is the Doppler effect. **A** and **C** are incorrect. Light will shift towards the red end of the spectrum as the star rotates away from the observer and towards the blue end of the spectrum as it rotates towards the observer. **D** is incorrect. A wider absorption band occurs as the star rotates faster, not slower.	Mod 7 The Nature of Light PH12–14 Bands 4–5
Question 13 **C** Increasing the slit separation increases the distance between the bright bands. As the slit separation increases, interference decreases as interference is caused by individual photons passing through both slits. Therefore, widening the slits decreases the interference, which increases the distance between the bright bands. Increasing the distance between the double slits and the screen increases the spacing between the bright bands.	Mod 7 The Nature of Light PH12–2, 12–14 Band 5
Question 14 **D** **D** is correct. $d\sin\theta = m\lambda = \frac{dx}{L}$ For the six bright bands: $x = \frac{50 \text{ mm}}{5}$ $= 10\times10^{-3}$ m $\lambda = 10\times10^{-3}\times\frac{0.07\times10^{-3}}{1.05}$ $= 6.66\times10^{-7}$ m $= 666$ nm **A** is incorrect. This option may be reached by incorrectly converting to nanometres and dividing the 50 mm separation by 6 rather than 5. **B** is incorrect. This option may be reached by incorrectly converting to nanometres. **C** is incorrect. This option may be reached by incorrectly dividing the 50 mm separation by 6 rather than 5.	Mod 7 The Nature of Light PH12–4, 12–14 Band 4

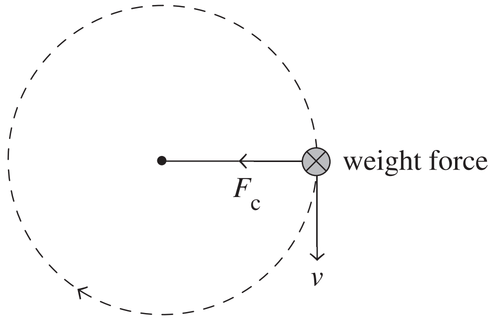
Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 15 **B** $I_1 = I_0 \times \frac{1}{2}$ $= 150 \times \frac{1}{2}$ $= 75\ \text{Wm}^{-2}$ change in angle = 60° $I_2 = I_1 \times \cos^2(60°)$ $= 75 \times \cos^2(60°)$ $= 18.75\ \text{Wm}^{-2}$	Mod 7 The Nature of Light PH12–14 Band 5
Question 16 **A** $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ As Psi and Tri orbit the same star, $\frac{r^3}{T^2}(\text{Psi}) = \frac{r^3}{T^2}(\text{Tri})$. $\frac{{r_{\text{Tri}}}^3}{{r_{\text{Psi}}}^3} = \frac{(4r_{\text{Psi}})^3}{{r_{\text{Psi}}}^3}$ $= 4^3$ $= 64$ $\frac{{T_{\text{Tri}}}^2}{{T_{\text{Psi}}}^2} = \sqrt{64}$ $= 8$ Thus, Tri would take eight times longer to orbit the star than Psi.	Mod 5 Advanced Mechanics PH12–6, 12–12 Band 5
Question 17 **C** $\left(\frac{1}{2}\right)^2 \times 18.4 = 2.3$ $2^n = \frac{18.4}{2.3}$ $= 8$ $n = 3$ $t_{\frac{1}{2}} = 356 \times 3$ $= 1068\ \text{years}$	Mod 8 From the Universe to the Atom PH12–5, 12–6, 12–15 Bands 5–6

Answer and explanation	**Syllabus content, outcomes and targeted performance bands**
Question 18 D **D** is correct. A nebula is a cloud of dust and gas. Gravity pulls the nebula into a point and a protostar forms. Hydrogen then fuses into helium and a main sequence star is formed. Stars spend most of their lives as main sequence stars. A larger main sequence star has stronger gravitational forces, which results in a denser and hotter star. Depending on its mass, the star may form a red supergiant, which then collapses into a black hole or a red giant. A neutron star is the collapsed core of a massive star. They form when a massive star runs out of fuel. **A** and **C** are incorrect. The nebula is what forms the protostar. Red supergiants also collapse into black holes; red giants collapse into white dwarfs. **B** is incorrect. The red giant would form a white dwarf. Stars spend most of their life as main sequence stars, then, depending on their mass, they form either red supergiants or red giants. It is the red supergiants that form black holes. Red giants, which are smaller, form white dwarfs, pulsars or neutron stars.	Mod 8 From the Universe to the Atom PH12–15 Bands 3–4
Question 19 C $DE = 3.71 - 5.52$ $= 1.81$ eV emitted $= 2.895 \times 10^{-19}$ J $E = hf$ $f = \dfrac{2.896 \times 10^{-19}}{6.626 \times 10^{-34}}$ $= 4.4 \times 10^{14}$ Hz	Mod 8 From the Universe to the Atom PH12–6, 12–15 Bands 5–6
Question 20 B **B** is correct. Model 1 represents the plum pudding model proposed by Thomson. The alpha particles travel through the atom as they are not significantly affected by the scattered charged particles in the atom. Model 2 represents Rutherford's model with the positive nucleus and negative electrons around the nucleus. Most of this atom is empty space, so most alpha particles can travel through the gold foil; only some collide with the small nucleus and are, thus, deflected. **A** is incorrect. Most, not a few, of the alpha particles would travel through the foil when using Thomson's model. When using Rutherford's model, only a few of the alpha particles are deflected by such a degree of scattering. Most travel through the foil undeflected with some deflected a narrow angle. **C** and **D** are incorrect. These options incorrectly identify the models.	Mod 8 From the Universe to the Atom PH12–5, 12–6, 12–15 Band 5

SECTION II

<table>
<tr><th>Sample answer</th><th>Syllabus content, outcomes, targeted performance bands and marking guide</th></tr>
<tr><td>Question 21</td><td></td></tr>
<tr><td>

(a)



The ball is accelerating towards the centre of the circle. This net force is the centripetal force. Gravity is acting downwards, but the tension in the cord (the horizontal component) pulls the ball inward, keeping it moving in a circle around the pole. The velocity is a tangent to the circle in the direction of the motion of the ball.

</td><td>

Mod 5 Advanced Mechanics
PH12–4, 12–6, 12–12 Bands 4–5

- Labels the velocity and forces.

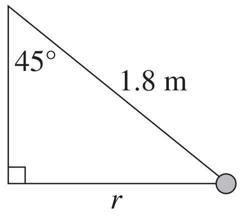
AND

- Explains the unbalanced force and the direction of velocity 2

- Any ONE of the above points 1

</td></tr>
<tr><td>

(b)



$$\sin 45° = \frac{r}{1.80}$$
$$r = 1.80 \sin 45°$$
$$= 1.27 \text{ m} \quad \text{(to three significant figures)}$$

Note: A diagram is not required for the response but may be used as part of the working.

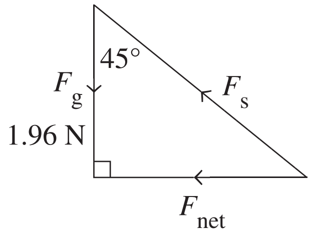
</td><td>

Mod 5 Advanced Mechanics
PH12–4, 12–6, 12–12 Band 4

- Provides the correct solution 1

</td></tr>
<tr><td>

(c)



$$F_{net} = 0.588 \tan 45°$$
$$= 0.59 \text{ N}$$

Note: A diagram is not required for the response but may be used as part of the working.

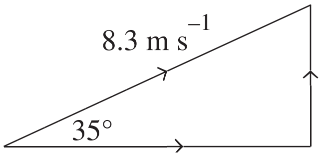
</td><td>

Mod 5 Advanced Mechanics
PH12–4, 12–6, 12–12 Band 4

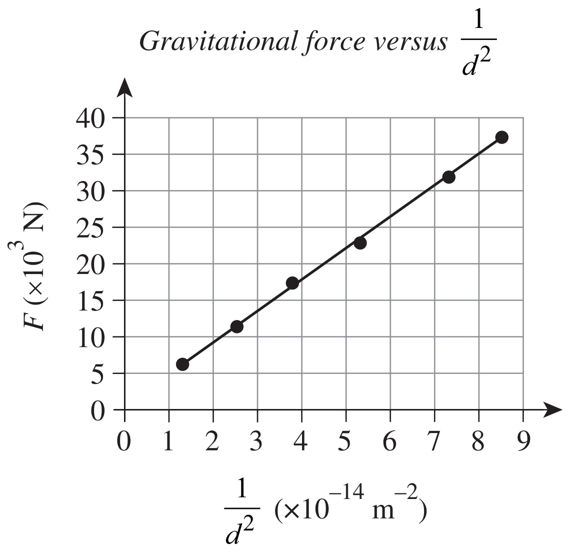
- Calculates the magnitude of the net force using appropriate units 2

- Calculates the magnitude of the net force without using appropriate units. 1

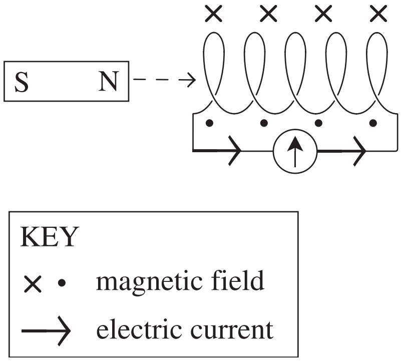
</td></tr>
</table>

Sample answer	**Syllabus content, outcomes, targeted performance bands and marking guide**
Question 22	
 vertical component $= 8.3\sin 35^\circ$ $= 4.76 \text{ m s}^{-1}$ horizontal component $= 8.3\cos 35^\circ$ $= 6.80 \text{ m s}^{-1}$ Calculating the time of flight gives: $u = 4.76 \text{ m s}^{-1}$ (upwards) $v = -4.76 \text{ m s}^{-1}$ (downwards) $a = -9.8 \text{ m s}^{-1}$ $v = u + at$ $-4.76 = 4.76 + -9.8 \times t$ $\frac{-4.76 - 4.76}{-9.8} = 0.971 \text{ s}$ Calculating the range gives: $v = 6.80 \text{ m s}^{-1}$ $t = 0.971 \text{ s}$ $d = v \times t$ $= 6.80 \times 0.971$ $= 6.60 \text{ m}$ *Note: A diagram is not required for the response but may be used as part of the working.*	Mod 5 Advanced Mechanics PH12–6, 12–12 Band 5 • Calculates the horizontal and vertical components. AND • Calculates the time of flight. AND • Calculates the range using appropriate units . . . . 3 • Any TWO of the above points. OR • All THREE of the above points without using appropriate units . . . . 2 • Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 23	
Calculating the gravitational potential energy gives: $U = -\frac{GMm}{r}$ $= \frac{-6.67\times10^{-11}\times6.0\times10^{24}\times250}{3.35\times10^{7}}$ $= -2.99\times10^{9}$ J Calculating the escape velocity gives: $-\frac{1}{2}mv^{2} = \left\|E_{p}\right\|$ $= -2.99\times10^{9}$ J $v = \sqrt{\frac{2GM}{r}}$ $= 4888$ m s^{-1} The escape velocity is the minimum speed that the satellite requires to escape Earth's gravitational field; this occurs when the satellite's kinetic energy is equal to magnitude of the gravitational potential energy.	Mod 5 Advanced Mechanics PH12–6, 12–7, 12–12 Band 5 • Calculates the gravitational potential energy using appropriate units. AND • Calculates the escape velocity using appropriate units. AND • Explains escape velocity . . . . 4 • Calculates the gravitational potential energy using appropriate units. AND • Calculates the escape velocity using appropriate units. AND • Outlines escape velocity . . . . 3 • Any TWO of the above points. OR • Provides the correct solution with no explanation of escape velocity . . . . 2 • Any ONE of the above points 1
Question 24	
(a) $m_{1} = m_{2} = 5.0\times10^{8}$ kg $R = 100$ m $G = 6.67\times10^{-11}$ Nm^{2} kg^{-2} $F = \frac{Gm_{1}m_{2}}{r^{2}}$ $= \frac{6.67\times10^{-11}\times5\times10^{8}\times5\times10^{8}}{100^{2}}$ $= 1668$ N	Mod 5 Advanced Mechanics PH12–6, 12–12 Band 5 • Identifies the appropriate data and formulae to use. AND • Calculates the force of attraction . . . . 2 • Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) 	Mod 5 Advanced Mechanics PH12–6, 12–12 Band 4 • Provides the title, axes labels and units. AND • Uses the x-axis for $\frac{1}{d^2}$ and the y-axis for F. AND • Clearly plots the data. AND • Draws a neat, smooth line of best fit . . . . 3 • Any THREE of the above points. . . 2 • Any TWO of the above points. 1
(c) $k = \frac{(37-6)\times 10^3}{(8.5-1.4)\times 10^{-14}}$ $= \frac{31\times 10^3}{7.1\times 10^{-17}}$ $= 4.366\times 10^{17}$ Nm $k = GM_1M_2$ $4.366\times 10^{17}\ \text{Nm}^2 = 6.67\times 10^{-11}\ \text{m}^3\ \text{kg}^{-1}\ \text{s}^{-2} \times 1.00\times 10^{24}\ \text{kg} \times \text{mass of moon}$ $\text{mass of moon} = \frac{4.366\times 10^{17}}{6.67\times 10^{-11}\times 1.00\times 10^{24}}$ $= 6546$ kg	Mod 5 Advanced Mechanics PH12–6, 12–12 Bands 5–6 • Uses the graph to determine the gradient. AND • Uses the data to find the mass of the moon. AND • Provides the correct calculations using appropriate units. . . . . 3 • Any TWO of the above points. . . . . 2 • Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 25	
(a) In DC motors, a DC current runs through a coil in a magnetic field. Thus, it experiences a force known as the motor effect and it spins. A split ring commutator is used to switch the direction of the current in the coil every half rotation, or 180°, to ensure that the torque stays in the same direction. In DC motors, electric energy produces kinetic energy. The DC motor has an input voltage into the leads, which allows current to run through the motor. It also has brushes that connect the external circuit to the coil, which spins. The coil, known as the armature, spins inside the magnets or the stator. In an AC induction motor, there are no connected leads, brushes or split ring commutator. AC induction motors have a rotor, squirrel cage and a stator, which is a pair of electromagnets. As AC current is supplied to the electromagnets, an oscillating magnetic field is produced, causing a change in flux. By Faraday's Law, a coil experiencing a change of flux produces an electromotive force. By Lenz's Law, the emf causes a current, which creates a magnetic field that opposes the original change of flux. The squirrel cage experiences a change of flux, and a current is induced in the rotor. The induced current in a magnetic field experiences a force that makes it turn (the motor effect).	Mod 6 Electromagnetism PH12–13 Band 5 • Provides a detailed description of the structures of DC and AC motors. AND • Explains the physics principles involved in DC and AC motors. AND • Identifies the similarities and differences between DC and AC motors . . . . 5 • Provides a description of the structures of DC and AC motors. AND • Outlines the physics principles involved in DC and AC motors. AND • Identifies the similarities and differences between DC and AC motors . . . . 4 • Outlines the structures of DC and AC motors. AND • Identifies the physics principles involved in DC and AC motors. AND • Identifies the similarities and differences between DC and AC motors . . . . 3 • Identifies the structures of DC and AC motors. AND • Identifies the physics principles involved in DC and AC motors. OR • Identifies the similarities and differences between DC and AC motors . . . . 2 • Identifies the structures OR physics principles of DC and AC motors 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) $\tau = nBIA\sin\theta$ $= 1\times 0.025\times 8\times(0.30\times 0.25)\times\sin 0^\circ$ $= 0.015$ Nm	Mod 6 Electromagnetism PH12–4, 12–13 Band 4 • Identifies the appropriate data, formulae and units. AND • Calculates the magnitude of the torque. . . . . 2 • Any ONE of the above points 1
(c) Using more coils would incrementally increase the size of the torque. As seen in the formulae, torque is multiplied by n (number of coils). Increasing the area of the loop would make the motor run faster. As $\tau \propto A$, increasing the area will allow the motor to attain a higher rotational speed.	Mod 6 Electromagnetism PH12–4, 12–13 Band 5 • Provides TWO appropriate modifications. AND • Explains why the modifications would make the motor run faster . . . . 2 • Any ONE of the above points. OR • Names and explains ONE appropriate modification 1
Question 26	
(a) 	Mod 6 Electromagnetism PH12–4, 12–13 Band 5 • Labels the direction of current and the induced magnetic field on the diagram 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) Faraday found that a current was induced in one direction as the magnet was pushed into a coil and in the opposite direction when the magnet is removed from the coil. When the magnet was kept still in the coil, there was no current. Faraday identified the relationship between a changing magnetic field, brought about by moving the magnet, and the creation of an induced current. He confirmed this when he wrapped two separate coils of wire around opposite sides of an iron ring and showed that, when one was supplied with current that was switched on and off continuously, a current was induced in the second coil. Faraday's Law states that the induced emf is proportional to the rate of change of flux through the coil. Lenz's Law explains that 'whenever there is an induced emf, its direction will be such that there is opposition to the change in flux that created it'. As the magnet approaches the coil, the flux density increases and an emf is generated in the coil. Thus, induced current flows in a direction that creates a magnetic field to oppose the motion of the magnet. This supports the Law of Conservation of Energy. If the induced emf did not oppose the motion of the magnet, then the magnet would speed up, creating a greater change in flux and greater emf. This is not possible as it violates the Law of Conservation of Energy. The work of Faraday and Lenz is significant as it gave rise to the development of transformers, which have many applications in society including the transport of electricity. *Note: This response is more comprehensive than a student would be required to give.*	Mod 6 Electromagnetism PH12–13 Bands 5–6 • Provides a concise and coherent response. AND • Provides a detailed explanation of Faraday and Lenz's laws. AND • Links to the Law of Conservation of Energy. AND • Makes a summative judgement about the contributions of Faraday and Lenz .... 4 • Provides a detailed explanation of Faraday and Lenz's laws. AND • Links to the Law of Conservation of Energy. AND • Makes a summative judgement about the contributions of Faraday and Lenz .... 3 • Provides an outline of Faraday and Lenz's laws AND a summative judgement about the contributions of Faraday and Lenz. OR • Provides a description of Faraday and Lenz's laws .... 2 • Provides an outline of Faraday and Lenz's laws. OR • Makes a summative judgement about the contributions of Faraday and Lenz 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 27	
Given that voltage is equal to *IR*, power can equal *VI*. If power remains constant, an increase in voltage must result in a decreased current to uphold the Law of Conservation of Energy. This reduced current results in a reduced overall transformation of electrical energy into heat energy. This means that the transmission lines will retain more of the original electrical energy, resulting in an overall decrease in the percentage of energy lost. Therefore, the power loss in each system can be significantly less when transferring energy at a much higher voltage. Both voltages travel along the same line; hence, *R* is constant. Voltage in transmission A: 28×10^3 kV Voltage in transmission B: 280×10^3 kV The voltage in transmission B is 10 times greater than in transmission A. The current in transmission A must be a tenth of the system in transmission B. $P_{\text{loss}} = I^2R$ $= \left(\frac{1}{10}\right)^2 \times R$ As the P_{loss} of transmission B is 1 : 100, it loses 100 times less energy than transmission A. *Note: An explanation of the difference in the transmissions is not required but may be included to develop the response.*	Mod 6 Electromagnetism PH12–5, 12–13 Band 5 • Compares the energy losses mathematically. AND • Includes $P = VI$ and $P = I^2R$. AND • Provides an overall comparison about energy and power loss in each transmission 3
	• Any TWO of the above points. 2
	• Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 28	
Classical physics is based on Newton's Laws of Motion and attempts to explain the movement of objects as being defined. Quantum physics aligns the dual nature of energy and matter as waves and particles. Classical physics cannot do this. The photoelectric effect needs quantum theory to be understood. The initial energy of a photon of light is hf. When the photon hits the metal surface, the energy is passed to the electron. For the electron to be released from the surface of the metal, it possesses kinetic energy (K_{max}) and the work function (ϕ). As $hf = K_{\text{max}} + \phi$, so $K_{\text{max}} = hf - \phi$. In the experiments conducted by Lenard, light was fired at a metal plate, causing electrons to be ejected from it, and then travelled through a circuit to a collecting plate. The current produced was measured by an ammeter. A voltage was applied to the collector plate to stop current flowing; this was known as the stopping voltage. The ammeter read zero as no electrons were reaching the collecting plate. The energy of the photoelectrons could be measured by the size of this voltage. For photoelectrons to be emitted, there was a particular frequency of light that had to be reached, which is the threshold frequency. If the frequency of the incident light was increased, the energy of the photoelectrons increased but there was no increase seen on the ammeter. Even when the voltage was increased, the current reaches a maximum value. If the intensity of the incident light increased, the kinetic energy of the photoelectrons remained constant. However, as the number of photoelectrons released increased, the reading on the ammeter increased. These observations cannot be explained by classical physics, which would instead predict that the frequency of the light would not determine whether photoelectrons were emitted. In classical physics, energy from a wave builds up over time. Thus, even low frequency light should build up enough energy for electrons to be ejected over time. The wave model would also predict a delay between the waves striking the metal and the photoelectrons being emitted. (continues on next page)	Mod 8 From the Universe to the Atom PH12–6, 12–7, 12–15 Band 6 • Provides a well-structured and succinct analysis. AND • Assesses what classical physics cannot explain. AND • Assesses what quantum physics can explain. AND • Provides a detailed description of the photoelectric effect. AND • Provides an equation for the photelectric effect. AND • Describes the work of Bohr, De Broglie and Schrodinger. . . . . 8–9 • Assesses what classical physics cannot explain. AND • Assesses what quantum physics can explain. AND • Provides a description of the photoelectric effect. AND • Provides an equation for the photelectric effect. AND • Describes the work of Bohr, De Broglie and Schrodinger . . . . 6–7 • Defines classical and quantum physics. AND • Outlines the photoelectric effect. AND • Describes the work of Bohr, de Broglie AND Schrödinger 5

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(continued) Similarly, questions about the structure of the atom that arose from observations of spectra of gases could not be explained by classical physics. Bohr explained the emission spectrum of hydrogen by using quantum physics. He proposed that the hydrogen atom was only capable of absorbing a limited range of frequencies of light; this absorbed energy was quantised. The emission spectra produced by hydrogen was complementary to the energy absorbed by the atom. Bohr labelled the electron orbits of the hydrogen atom with principal quantum numbers and was able to calculate the energy of each. Electrons could only exist in one discrete level; they gained a quantum of energy to be excited to a higher level and would release the fixed amount of energy as they returned to the lower or ground state energy level. Bohr's model worked well for hydrogen, but not so well for larger atoms with more electrons. De Broglie's work used standing waves to explain the stable orbits of Bohr's model. He developed the wave-particle theory by explaining the orbiting electrons in the hydrogen atom as matter waves. They were only stable because they established standing waves. The path they travelled (circumference) is equal to a whole number of wavelengths. Classical physics cannot explain the dual nature of energy and matter. Schrödinger's work on the probability of finding an electron by developing a mathematical equation calculates the region of space that an electron occupies, the orbital. Classical physics provides the underlying assumption that all particles, large and small, have a defined place and defined movement. Only knowing the probability of particles being in a three-dimensional space is the realm of quantum physics. *Note: This response is more comprehensive than a student would be required to give.*	• Defines classical OR quantum physics. AND • Outlines the photoelectric effect. AND • Describes the work of Bohr, de Broglie AND Schrödinger . . . . . 4 • Outlines the photoelectric effect. AND • Describes the work of Bohr, de Broglie AND Schrödinger . . . . . 3 • Outlines the photoelectric effect. OR • Describes the work of Bohr, de Broglie AND Schrödinger . . . . . 2 • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 29	
Newton’s corpuscular model proposed that light was made of spherical particles. The wave theory proposed by Huygens described light as a longitudinal wave, where light waves spreading out from a point source were overlapping secondary semicircular waves. Every point on any wavefront represented a new point source of secondary waves. This model considered wavefronts as a superposition of secondary wavelets. When a particle of light hits a plane surface like a mirror, energy is conserved. Thus, the incident light hits the surface (incident angle) and the angle that it reflects (angle of reflection) is equal. This is known as the law of reflection, which Newton was able to prove experimentally. In Huygens’ model, the law of reflection was also supported as the angle of incidence for a wavefront is equal to the angle of reflection for a wavefront. Refraction of light is where the models differed. Newton’s theory predicted that light would speed up as it travelled from air to a solid material. We know now that the ratio of $\frac{\sin i}{\sin r}$ is equal to the refractive index of the material. This constant being greater than one suggested that the light speeds up as it enters a denser material. However, we know now that light slows down when it enters a denser material. As the speed of light was not known at the time, Newton’s theory could not be verified. Huygens’ theory described the speed of light slowing down in the denser material, which we know now is correct, though it was not able to be verified at the time. *Note: This response is more comprehensive than a student would be required to give.*	Mod 7 The Nature of Light PH12–4, 12–7, 12–14 Bands 4–5 • Describes the corpuscular and wave models of light. AND • Describes in detail Newton’s theory with reference to the diagrams. AND • Describes in detail Huygens’ theory with reference to the diagrams. . . . . 4 • Describes the corpuscular and wave models of light. AND • Outlines Newton’s theory with reference to the diagrams. AND • Outlines Huygens’ theory with reference to the diagrams. . . . . 3 • Describes the corpuscular OR wave model of light. AND • Outlines Newton’s OR Huygens’ theory . . . . 2 • Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 30	
(a) $t = \frac{t_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$ $= \frac{2.5\times10^{-8}}{\sqrt{1-\frac{\left(2.95\times10^8\right)^2}{\left(3.0\times10^8\right)^2}}}$ $=1.37\times10^{-7}$ s In this time, travelling at 2.95×10^8 m s^{-1}, the observer would measure the meson travelling at: $s = vt$ $= 2.95\times10^8 \times 1.37\times10^{-7}$ $= 40.4$ m (with time dilation) If time dilation did not exist, the meson would travel for 2.5×10^{-8} s. Therefore, the expected distance it would travel is: $s = vt$ $= 2.95\times10^8 \times 2.5\times10^{-8}$ $= 7.38$ m (without time dilation)	Mod 7 The Nature of Light PH12–4, 12–14 Bands 5–6 • Calculates the distance travelled in the observer's timeframe. AND • Calculates the distance travelled in the meson's timeframe. AND • Provides the correct significant figures for each solution . . . . 3 • Any TWO of the above points. . . . . 2 • Any ONE of the above points 1
(b) The pilot is inside the spacecraft, so they would measure a mass of 79 000 kg. Calculating the mass measured by an observer gives: $p_v = \frac{m_0 v}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$ $= \frac{7.9\times10^4}{\sqrt{1-\left(\frac{(0.3c)^2}{c^2}\right)}}$ $=8.28\times10^4$ kg Because the total energy of a mass is $E = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$, the energy requirement approaches infinity as the velocity approaches the speed of light. Hence, an object with mass cannot accelerate to the speed of light.	Mod 7 The Nature of Light PH12–4, 12–14 Band 5 • Identifies the mass for pilot AND observer. AND • Calculates the mass. AND • Explains why objects cannot exceed the speed of light . . . . 3 • Any TWO of the above points. . . . . 2 • Any ONE of the above points 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 31	
The invention of particle accelerators led to the discovery of more particles and allowed scientists to gain a better understanding of the model of the atom through the experiments that were made possible. Particle accelerators use electric fields to accelerate charged particles to very high speeds (close to the speed of light) and, consequently, very high energies. Magnetic fields are used to direct their travel. They are aimed at targets and, as they bombard them, new particles are created from the collisions. When the particles smash into each other, they break apart into their constituent particles: quarks, bosons and other fundamental particles. These particles do not last long, so new technology was needed to even detect them. The Standard Model was developed to describe the structure of atoms and the forces or interactions holding them together. It divides fundamental particles into two main groups: fermions (particles that make up matter) and bosons (particles that impart force). Fermions include two types of particles: quarks and leptons. There are six quarks: up, down, charm, strange, top and bottom. Quarks also have antimatter equivalents, with their charges being equal and opposite. They do not exist on their own and usually combine with each other. These combinations are hadrons. Three-quark combinations are baryons, and two-quark combinations are mesons; they have one quark and one antiquark. Neutrons made of are one up quark and two down quarks (udd). Protons are made of two up quarks and one down quark (uud). For mesons, the positive kaon is the up and anti-strange combination, while the negative kaon is the strange and anti-up combination. Leptons include the electron, muon and neutrino. The muon is a heavier form of the electron. The neutrino is neutral, has very little interaction with matter and has a very small mass. In the Standard Model, there are four fundamental forces. For each force, there is an exchange particle called a boson. The gravitational force is a long-range force that acts on all particles with mass. It is believed to be carried by gravitons that have not yet been discovered. This is an area of study in which particle accelerators continue to be important. The electromagnetic force acts on all electrically charged particles and holds atoms and molecules together; it is carried by the photon. The strong nuclear force is a short acting force that joins quarks together to form neutrons and protons; it is carried by gluons. (continues on next page)	Mod 8 From the Universe to the Atom PH12–7, 12–15 Band 6 • Provides a well-organised and succinct response. AND • Describes in detail ALL particles and forces of the Standard Model. AND • Explains in detail the role of particle accelerators in enhancing understanding of atoms . . . . 7–8 • Describes in detail ALL particles and forces of the Standard Model. AND • Explains the role of particle accelerators in enhancing understanding of atoms . . . . 6 • Describes most of the particles and forces of the Standard Model. AND • Describes the role of particle accelerators in enhancing understanding of atoms . . . . 5 • Outlines most of the particles and forces of the Standard Model. AND • Outlines the role of particle accelerators in enhancing understanding of atoms . . . . 4 • Identifies most of the particles and forces of the Standard Model. AND • Identifies the role of particle accelerators in enhancing understanding of atoms 3

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(continued) The weak nuclear force is a short-range force that interacts with some particles to form other particles; it is carried by W and Z bosons. Therefore, the invention of particle accelerators has not only allowed the discovery of new particles but, by studying their interactions, it has enabled physicists to understand more about the fundamental forces of nature holding atoms together. Without particle accelerators, particles could not reach the speeds necessary to conduct these experiments. *Note: This response is more comprehensive than a student would be required to give.*	• Identifies most of the particles OR forces of the Standard Model. AND • Identifies the role of technology in enhancing understanding of atoms . . . . 2 • Identifies most of the particles OR forces of the Standard Model. OR • Identifies the role of technology in enhancing understanding of atoms 1
Question 32	
(a) *For example:* A computer simulation was used where unstable atoms were hit with neutrons, which caused them to split into smaller atoms. Each atom produced neutrons, which then caused other atoms to split in a chain reaction. After a few seconds, the chain reaction had increased to the point of an explosion. In the simulation, it was possible to include control rods made of a metal that absorbed neutrons. When these were used, the reaction was controlled as not all neutron collisions caused fission. For every two or three neutrons released, only one hit an atom and caused fission. The model was very effective. It was a clear visual representation of fission that demonstrated the chain reaction. It showed that if it was not controlled, the chain reaction became explosive. It also showed the effect of introducing the neutron-absorbing material to control the chain reaction.	Mod 8 From the Universe to the Atom PH12–7, 12–15 Bands 4–5 • Describes the model. AND • Explains how the model showed fission. AND • Explains how the model shows controlled versus uncontrolled fission. AND • Provides a concise judgment about the effectiveness of the model . . . . 4 • Any THREE of the above points . . . 3 • Any TWO of the above points . . . . . 2 • Any ONE of the above points 1

<table>
<tr><th colspan="2">Sample answer</th><th>Syllabus content, outcomes, targeted performance bands and marking guide</th></tr>
<tr><td>(b)</td><td>Oxygen has 8 protons and 10 neutrons.
$1.007276 \text{ amu} \times 8 = 8.058208$
$1.008664 \text{ amu} \times 10 = 10.08664$
$= 18.144848 \text{ amu}$
Calculating the mass defect gives:
$18.144848 - 17.99916 = 0.145688 \text{ amu}$
$0.145688 \text{ amu} \times 1.661 \times 10^{-27} \text{ kg} = 2.42 \times 10^{-28} \text{ kg}$
Calculating the binding energy gives:
$E = mc^2$
$= 2.42 \times 10^{-28} \times \left(3.00 \times 10^8\right)$
$= 2.18 \times 10^{-11} \text{ J}$
$= 135.9 \times 10^8 \text{ eV}$</td><td>Mod 8 From the Universe to the Atom
PH12–6, 12–15 Bands 4–5
• Calculates the mass defect.
AND
• Calculates the binding energy in joules.
AND
• Calculates the binding energy in electron volts 3
• Any TWO of the above points. 2
• Any ONE of the above points . . . . . 1</td></tr>
<tr><td>(c)</td><td>Cooler main sequence stars, including the sun, undergo nucleosynthesis via the proton–proton (PP) chain. This fusion reaction involves four hydrogen nuclei fusing into a helium nucleus, which releases energy.
The PP chain involves three steps. The overall reaction is $4\,{}^{1}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + 2\,{}^{0}_{+1}e + 2\nu + 2\gamma$.
In this process, four protons join and produce a helium nucleus along with two positrons, two neutrinos and two high-energy gamma rays.</td><td>Mod 8 From the Universe to the Atom
PH12–7, 12–15 Band 5
• Identifies that main sequence stars undergo the PP chain.
AND
• Provides an overall equation for the fusion of four hydrogen nuclei into one helium nuclei.
AND
• Describes the PP chain 3
• Any TWO of the above points. 2
• Any ONE of the above points . . . . . 1</td></tr>
<tr><td colspan="2">Question 33</td><td></td></tr>
<tr><td>(a)</td><td><table><tr><th><i>Observation</i></th><th><i>Explanation</i></th></tr><tr><td>The cathode rays cast a shadow with the sharp edges of the maltese cross.</td><td>The shadow demonstrates that the cathode rays travel in straight lines. This portrays both the particle nature and wave nature of the cathode rays.</td></tr><tr><td>A paddle wheel rotates from the cathode to the anode.</td><td>This shows that they possessed momentum. Thus, they must have mass and are, therefore, particles.</td></tr></table></td><td>Mod 8 From the Universe to the Atom
PH12–5, 12–6, 12–7, 12–15 Band 5
• Describes in detail the observations.
AND
• Explains the observations by linking to the properties of cathode rays. 2
• Outlines the observations. . . . . 1</td></tr>
</table>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) $eV = \frac{1}{2}mv^2$ $1.6\times10^{-19}\times2400 = \frac{1}{2}\times9.1\times10^{-31}\times v^2$ $v^2 = \frac{1.6\times10^{-19}\times2400}{\frac{1}{2}\times9.1\times10^{-31}}$ $v = 2.9\times10^{7}\ \text{m s}^{-1}$	Mod 8 From the Universe to the Atom PH12–6, 12–15 Bands 4–5 • Identifies the appropriate formula to use. AND • Provides the correct solution using appropriate units. . . . . 2 • Any ONE of the above points 1
(c) Millikan observed the oil drops that fell through the small gap between the plates. When the electric force was equal to the opposing gravitational force, the drop remained in static equilibrium. Therefore, $Mg = qE$, where $E = \frac{V}{d}$. He found that the charge on the oil droplet was always a multiple of 1.6×10^{-19} C, which is the charge on an electron.	Mod 8 From the Universe to the Atom PH12–7, 12–15 Bands 5–6 • Provides a concise description of observations. AND • Links to the charge always being a multiple of 1.6×10^{-19} C . . . . 2 • Any ONE of the above points 1