**Victorian Certificate of Education
2020**

Letter

STUDENT NUMBER

PHYSICS
Written examination

Tuesday 24 November 2020

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	Number of questions	Number of questions to be answered	Number of marks
A	20	20	20
B	18	18	110
			Total 130

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape) and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 38 pages
- Formula sheet
- Answer sheet for multiple-choice questions

Instructions
- Write your student number in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the formula sheet.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

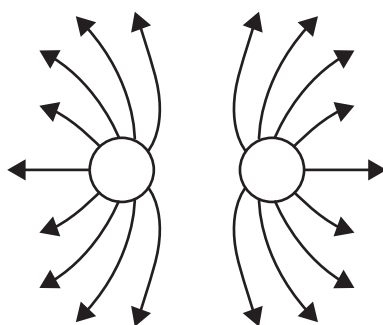Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Take the value of g to be 9.8 m s^{-2}.

Question 1

The diagram below shows the electric field lines between two charges of equal magnitude.

The best description of the two charges is that the

A.   charges are both positive.

B.   charges are both negative.

C.   charges can be either both positive or both negative.

D.   left-hand charge is positive and the right-hand charge is negative.

Question 2

Jupiter's moon Ganymede is its largest satellite.

Ganymede has a mass of 1.5×10^{23} kg and a radius of 2.6×10^6 m.

Which one of the following is closest to the magnitude of Ganymede's surface gravity?

A.   0.8 m s^{-2}

B.   1.5 m s^{-2}

C.   3.8 m s^{-2}

D.   9.8 m s^{-2}

Use the following information to answer Questions 3 and 4.

A positron with a velocity of 1.4×10^6 m s^{-1} is injected into a uniform magnetic field of 4.0×10^{-2} T, directed into the page, as shown in the diagram below. It moves in a vacuum in a semicircle of radius r. The mass of the positron is 9.1×10^{-31} kg and the charge on the positron is 1.6×10^{-19} C. Ignore relativistic effects.
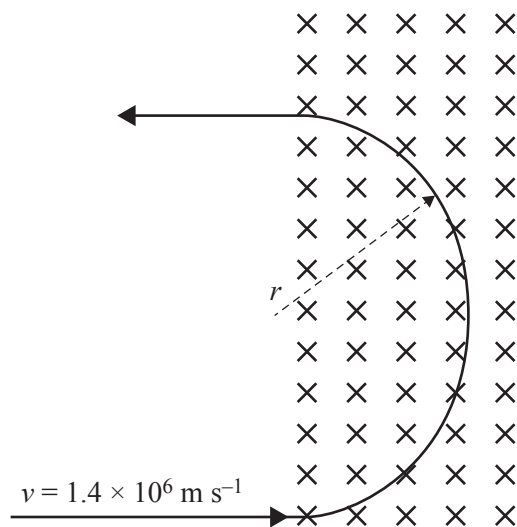
$v = 1.4 \times 10^6$ m s^{-1}

Question 3

Which one of the following best gives the speed of the positron as it exits the magnetic field?

A. 0 m s^{-1}

B.   much less than 1.4×10^6 m s^{-1}

C. 1.4×10^6 m s^{-1}

D.   greater than 1.4×10^6 m s^{-1}

Question 4

The speed of the positron is changed to 7.0×10^5 m s^{-1}.
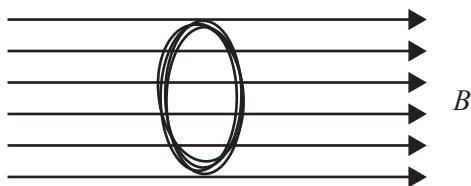
Which one of the following best gives the value of the radius r for this speed?

A. $\dfrac{r}{4}$

B. $\dfrac{r}{2}$

C. r

D. $2r$

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Question 5

A coil consisting of 20 loops with an area of 10 cm^2 is placed in a uniform magnetic field B of strength 0.03 T so that the plane of the coil is perpendicular to the field direction, as shown in the diagram below.
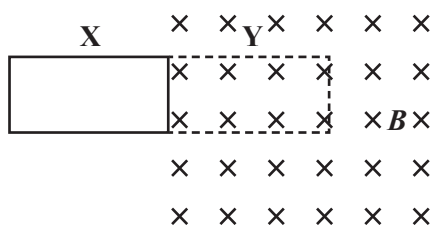

The magnetic flux through the coil is closest to

A. 0 Wb

B. 3.0×10^{-5} Wb

C. 6.0×10^{-4} Wb

D. 3.0×10^{-1} Wb

Question 6

A single loop of wire moves into a uniform magnetic field B of strength 3.5×10^{-4} T over time $t = 0.20$ s from point X to point Y, as shown in the diagram below. The area A of the loop is 0.05 m^2.

The magnitude of the average induced EMF in the loop is closest to

A. 0 V

B. 3.5×10^{-6} V

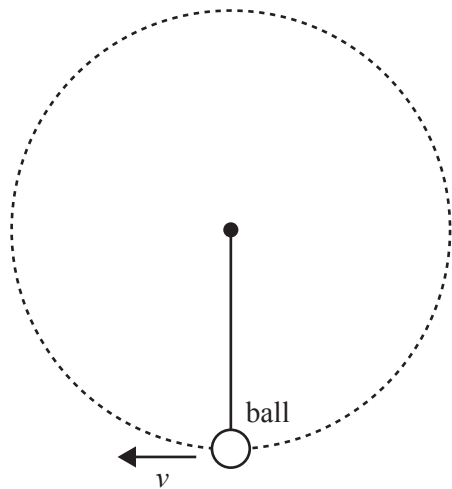C. 8.8×10^{-5} V

D. 8.8×10^3 V

Question 7

An ideal transformer has an input DC voltage of 240 V, 2000 turns in the primary coil and 80 turns in the secondary coil.

The output voltage is closest to

A. 0 V

B. 9.6 V

C. 6.0×10^3 V

D. 3.8×10^7 V

Question 8

A ball is attached to the end of a string and rotated in a circle at a constant speed in a vertical plane, as shown in the diagram below.
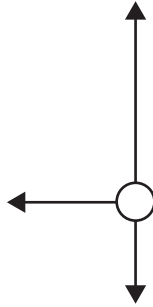
The arrows in options A. to D. below indicate the direction and the size of the forces acting on the ball.

Ignoring air resistance, which one of the following best represents the forces acting on the ball when it is at the bottom of the circular path and moving to the left?
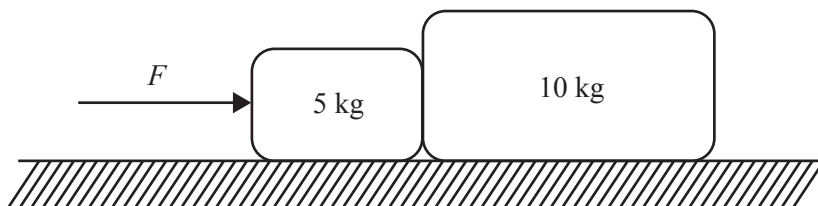
A.

B.

C.

D.
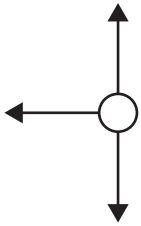
Use the following information to answer Questions 9 and 10.

Two blocks of mass 5 kg and 10 kg are placed in contact on a frictionless horizontal surface, as shown in the diagram below. A constant horizontal force, F, is applied to the 5 kg block.

Question 9

Which one of the following statements is correct?

A.   The net force on each block is the same.

B.   The acceleration experienced by the 5 kg block is twice the acceleration experienced by the 10 kg block.

C.   The magnitude of the net force on the 5 kg block is half the magnitude of the net force on the 10 kg block.

D.   The magnitude of the net force on the 5 kg block is twice the magnitude of the net force on the 10 kg block.
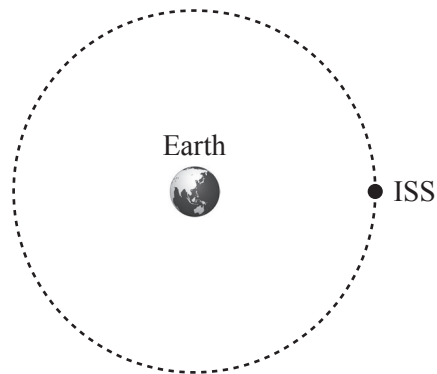
Question 10

If the force F has a magnitude of 250 N, what is the work done by the force in moving the blocks in a straight line for a distance of 20 m?

A.   5 kJ

B.   25 kJ

C.   50 kJ

D.   500 kJ

Question 11

The International Space Station (ISS) is travelling around Earth in a stable circular orbit, as shown in the diagram below.

Which one of the following statements concerning the momentum and the kinetic energy of the ISS is correct?

A.   Both the momentum and the kinetic energy vary along the orbital path.

B.   Both the momentum and the kinetic energy are constant along the orbital path.

C.   The momentum is constant, but the kinetic energy changes throughout the orbital path.

D.   The momentum changes, but the kinetic energy remains constant throughout the orbital path.

Question 12

A high-energy proton is travelling through space at a constant velocity of 2.50×10^8 m s^{-1}.

The Lorentz factor, γ, for this proton would be closest to

A.   1.81

B.   2.44

C.   3.27

D.   3.39

Question 13

Matter is converted to energy by nuclear fusion in stars.
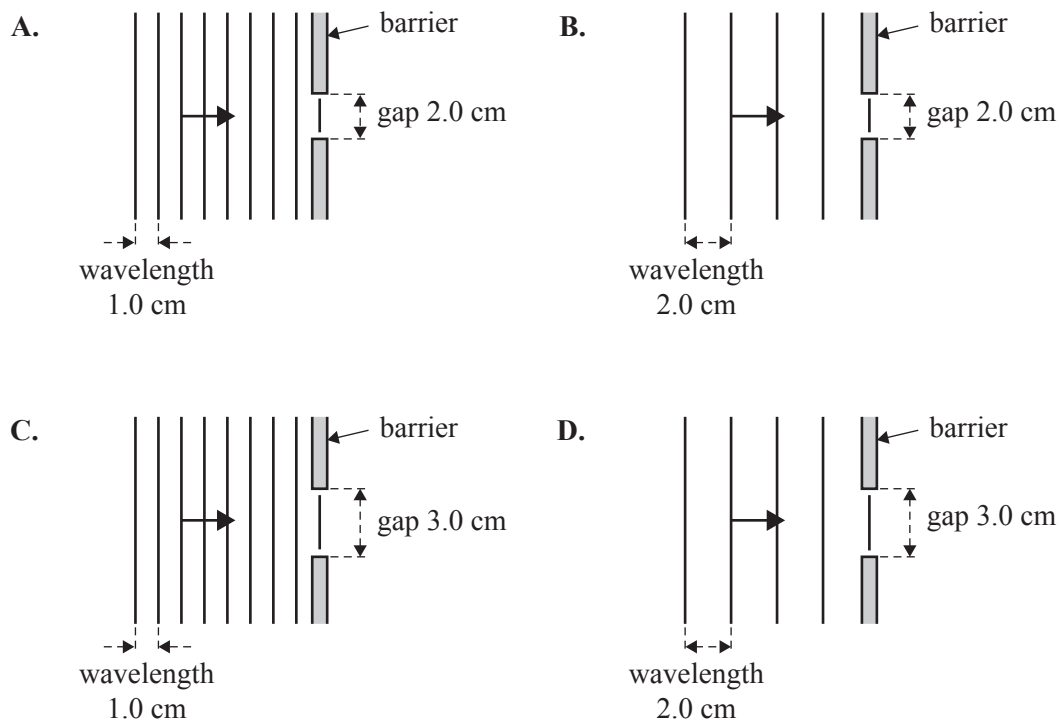
If the star Alpha Centauri converts mass to energy at the rate of 6.6×10^9 kg s^{-1}, then the power generated is closest to

A. 2.0×10^{18} W

B. 2.0×10^{18} J

C. 6.0×10^{26} W

D. 6.0×10^{26} J

Question 14

Students are investigating the diffraction of waves using a ripple tank. Water waves are directed towards barriers with gaps of different sizes, as shown below.

In which one of the following would the greatest diffraction effects be observed?

A.

barrier

gap 2.0 cm

wavelength
1.0 cm

B.

barrier

gap 2.0 cm

wavelength
2.0 cm

C.

barrier

gap 3.0 cm

wavelength
1.0 cm

D.

barrier

gap 3.0 cm

wavelength
2.0 cm

Question 15

I   The energy of a light wave increases with increasing amplitude.

II   The energy of a light wave increases with increasing frequency.

III   The energy of a light wave increases with decreasing wavelength.

Which of the statements above about the energy of light waves is correct?

A.   III only

B.   I and II only

C.   I and III only

D.   all of the statements are correct

Question 16

The diagram below shows a plot of maximum kinetic energy, $E_{k\,max}$, versus frequency, f, for various metals capable of emitting photoelectrons.
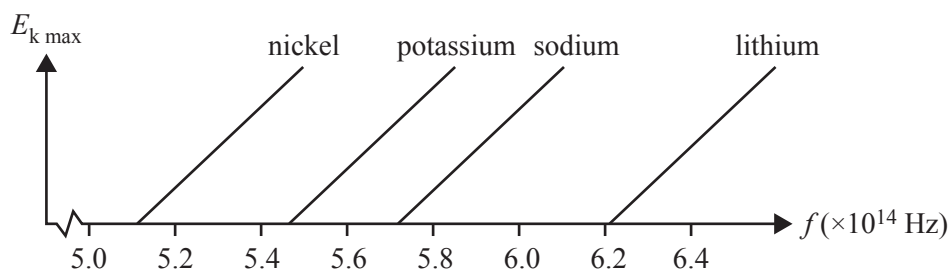

Which one of the following correctly ranks these metals in terms of their work function, from highest to lowest in numerical value?

A. sodium, potassium, lithium, nickel

B. nickel, potassium, sodium, lithium

C. potassium, nickel, lithium, sodium

D. lithium, sodium, potassium, nickel

Question 17

The diagram below shows some of the energy levels for the electrons within an atom. The arrows labelled A, B, C and D indicate transitions between the energy levels and their lengths indicate the relative size of the energy change.
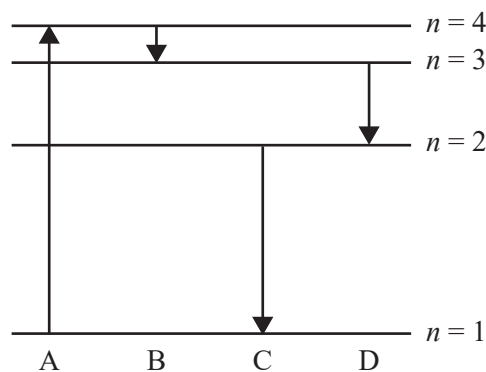
Which transition results in the emission of a photon with the most energy?

A. A

B. B

C. C

D. D

Question 18

Quantised energy levels within atoms can best be explained by

A. electrons behaving as individual particles with different energies.

B. electrons behaving as waves, with each energy level representing a diffraction pattern.

C. protons behaving as waves, with only standing waves at particular wavelengths allowed.

D. electrons behaving as waves, with only standing waves at particular wavelengths allowed.

Question 19

Which one of the following best describes a hypothesis?

A. a testable scientific explanation

B. a well-tested scientific explanation

C. a scientific explanation by a famous scientist

D. a widely believed and highly plausible explanation

Question 20

When photons with energy E strike a metal surface, electrons may be emitted.

The maximum kinetic energy, $E_{k\ max}$, of the emitted electrons is given by $E_{k\ max} = E - W$, where W is the work function of the metal.

Which one of the following graphs best shows the relationship between the maximum kinetic energy of these electrons, $E_{k\ max}$, and the wavelength of the photons, λ?

A.

B.

C.

D.
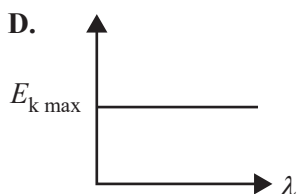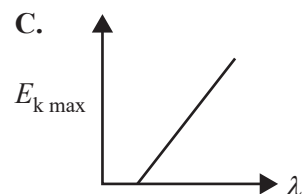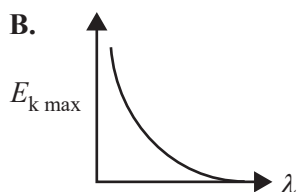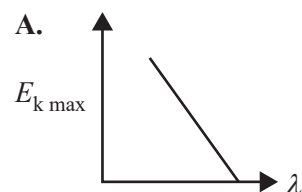
END OF SECTION A

CONTINUES OVER PAGE

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.

Where an answer box is provided, write your final answer in the box.

If an answer box has a unit printed in it, give your answer in that unit.

In questions where more than one mark is available, appropriate working **must** be shown.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Take the value of g to be 9.8 m s^{-2}.

Question 1 (2 marks)

Two bar magnets are placed close to each other, as shown in Figure 1.

Sketch the shape and the direction of **at least four** magnetic field lines between the two poles within the dashed border shown in Figure 1.
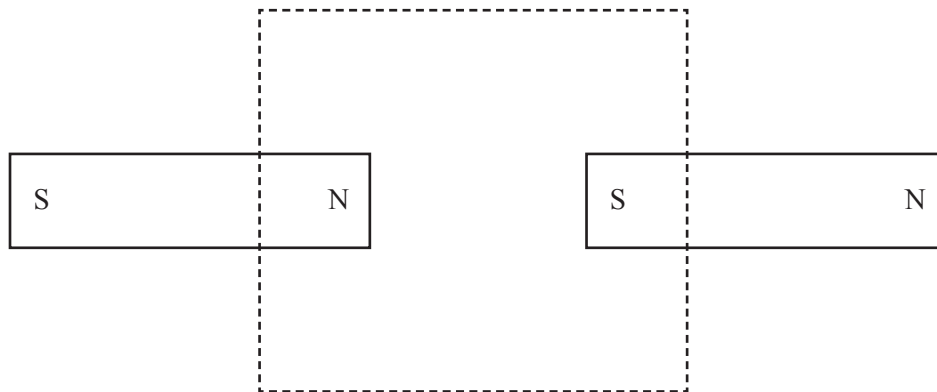
Figure 1

Question 2 (3 marks)

Gravitation, magnetism and electricity can be explained using a field model. According to our understanding of physics and current experimental evidence, these three field types can be associated with only monopoles, only dipoles or both monopoles and dipoles.

In the table below, indicate whether each field type can be associated with only monopoles, only dipoles or both monopoles and dipoles by ticking (✓) the appropriate box.

Field type	Only monopoles	Only dipoles	Both monopoles and dipoles
gravitation			
magnetism			
electricity			

Question 3 (6 marks)

Electron microscopes use a high-precision electron velocity selector consisting of an electric field, E, perpendicular to a magnetic field, B.

Electrons travelling at the required velocity, v_0, exit the aperture at point Y, while electrons travelling slower or faster than the required velocity, v_0, hit the aperture plate, as shown in Figure 2.
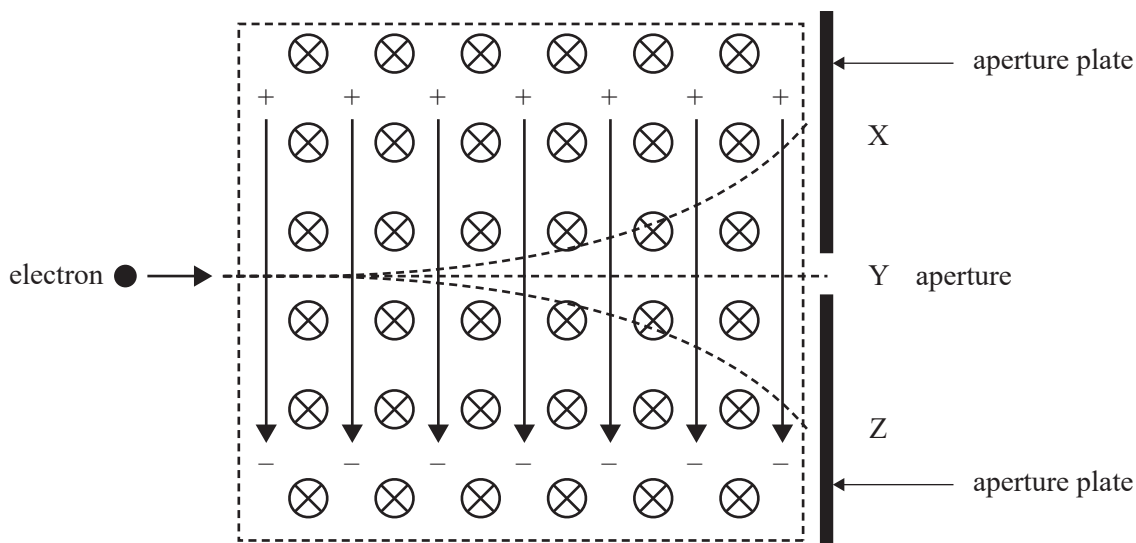
Figure 2

a. Show that the velocity of an electron that travels straight through the aperture to point Y is given by
$v_0 = \dfrac{E}{B}$.

1 mark

_____

_____

b. Calculate the magnitude of the velocity, v_0, of an electron that travels straight through the aperture to point Y if $E = 500$ kV m^{-1} and $B = 0.25$ T. Show your working.

2 marks

_____

_____

_____

m s^{-1}

c.   **i.**   At which of the points – X, Y or Z – in Figure 2 could electrons travelling faster than v_0 arrive?   1 mark

ii.   Explain your answer to **part c.i.**   2 marks

Question 4 (10 marks)

The Ionospheric Connection Explorer (ICON) space weather satellite, constructed to study Earth's ionosphere, was launched in October 2019. ICON will study the link between space weather and Earth's weather at its orbital altitude of 600 km above Earth's surface. Assume that ICON's orbit is a circular orbit. Use $R_E = 6.37 \times 10^6$ m.

a. Calculate the orbital radius of the ICON satellite. 1 mark

	m

b. Calculate the orbital period of the ICON satellite correct to three significant figures. Show your working. 4 marks

	s

c. Explain how the ICON satellite maintains a stable circular orbit without the use of propulsion engines. 2 marks

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d. Figure 3 shows the strength of Earth's gravitational field, g, as a function of orbital altitude, h, above the surface of Earth.
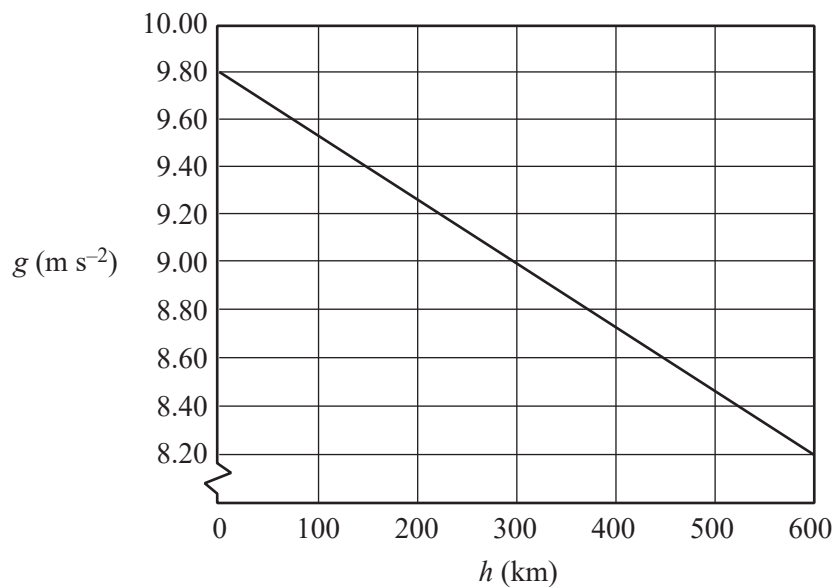

Figure 3

Determine the change in gravitational potential energy of the ICON satellite as it travels from Earth's surface to its orbital altitude of 600 km above Earth's surface. The mass of the ICON satellite is 288 kg.

3 marks

_____

_____

_____

_____

_____

J

Question 5 (9 marks)

A rectangular wire loop with dimensions 0.050 m × 0.035 m is placed between two magnets that create a uniform magnetic field of strength 0.2 mT. The loop is rotated with a frequency of 50 Hz in the direction shown in Figure 4. The ends of the loop are connected to a split-ring commutator to create a DC generator. The loop is initially in the position shown in Figure 4.
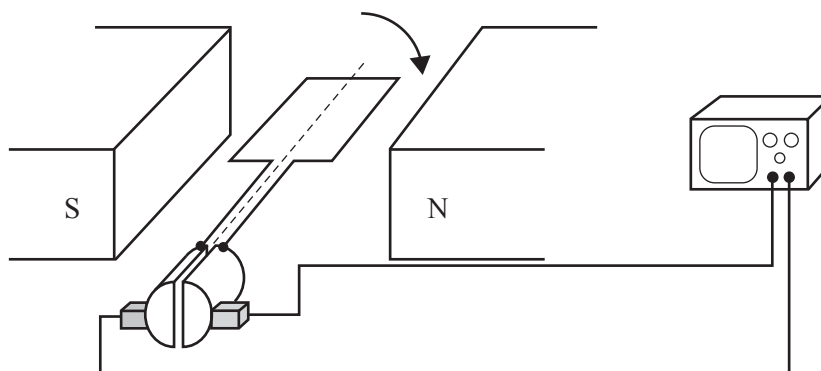
Figure 4

a. In which direction – clockwise or anticlockwise – will the induced current travel through the loop for the first quarter turn as seen from above? 1 mark

b. Calculate the average EMF measured in the loop for the first quarter turn. 3 marks

_____

_____

_____

_____

_____

V

c. On the axes provided below, sketch the output EMF versus time, t, for the first two rotations. Include a
scale on the horizontal axis. 3 marks

EMF

t
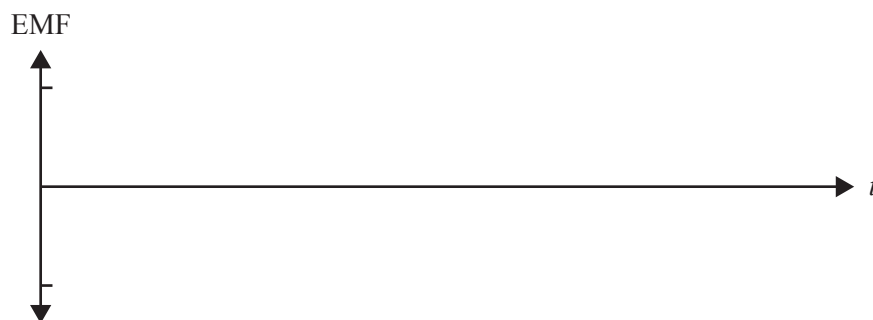
d. Suggest **two** modifications that could be made to the apparatus shown in Figure 4 that would increase
the output EMF of the DC generator. 2 marks

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Question 6 (6 marks)

Two Physics students hold a coil of wire in a constant uniform magnetic field, as shown in Figure 5a. The ends of the wire are connected to a sensitive ammeter. The students then change the shape of the coil by pulling each side of the coil in the horizontal direction, as shown in Figure 5b. They notice a current register on the ammeter.
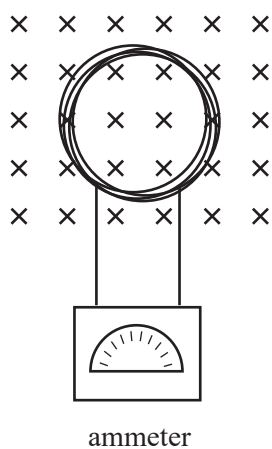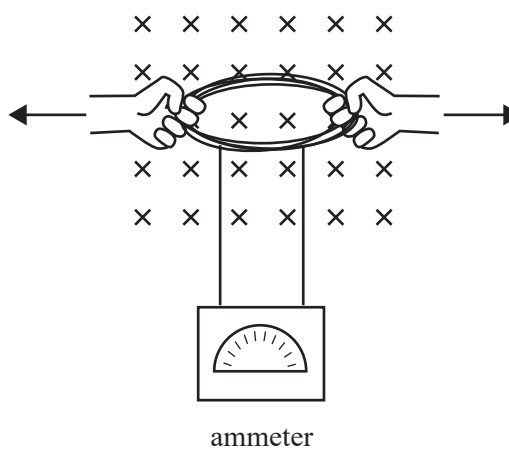
Figure 5a   **Figure 5b**

a. Will the magnetic flux through the coil increase, decrease or stay the same as the students change the shape of the coil?   1 mark

b. Explain, using physics principles, why the ammeter registered a current in the coil and determine the direction of the induced current.   3 marks

c. The students then push each side of the coil together, as shown in Figure 6a, so that the coil returns to its original circular shape, as shown in Figure 6b, and then changes to the shape shown in Figure 6c.
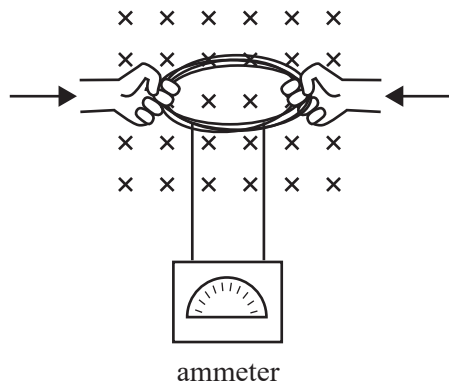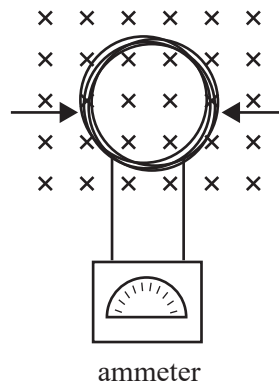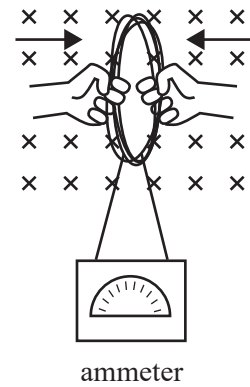
| Figure 6a | Figure 6b | Figure 6c |

Describe the direction of any induced currents in the coil during these changes. Give your reasoning.   2 marks

Question 7 (5 marks)

A rechargeable electric toothbrush uses a transformer circuit, as shown in Figure 7. A secondary coil inside the toothbrush is connected, via an iron core, to a primary coil that is connected to the mains power supply. The mains power is 240 V_{RMS} and the toothbrush recharges at 12 V_{RMS}. The average power delivered by the transformer to the toothbrush is 0.90 W. Assume that the transformer is ideal.
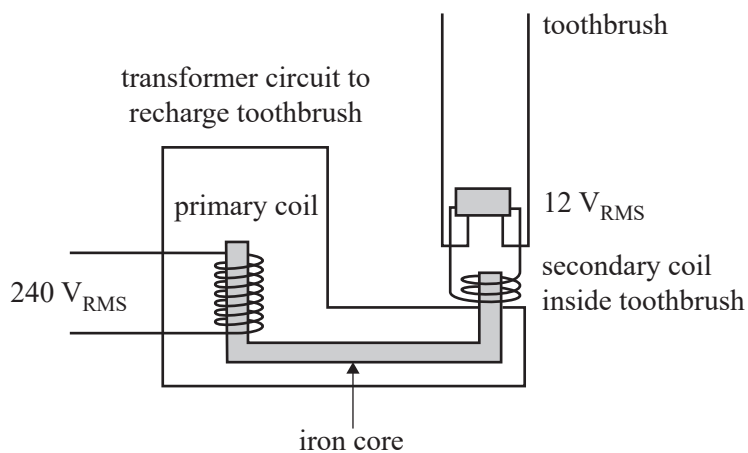
Figure 7

a. Calculate the peak voltage in the secondary coil. Show your working. 2 marks

_____

_____

_____

V

b. Determine the ratio of the number of turns $\dfrac{N_p}{N_s}$. 1 mark

_____

_____

_____

c. Calculate the RMS current in the primary coil while the toothbrush is charging. Show your working.   2 marks

_____

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mA

Question 8 (6 marks)

Figure 8 shows a small ball of mass 1.8 kg travelling in a horizontal circular path at a constant speed while suspended from the ceiling by a 0.75 m long string.
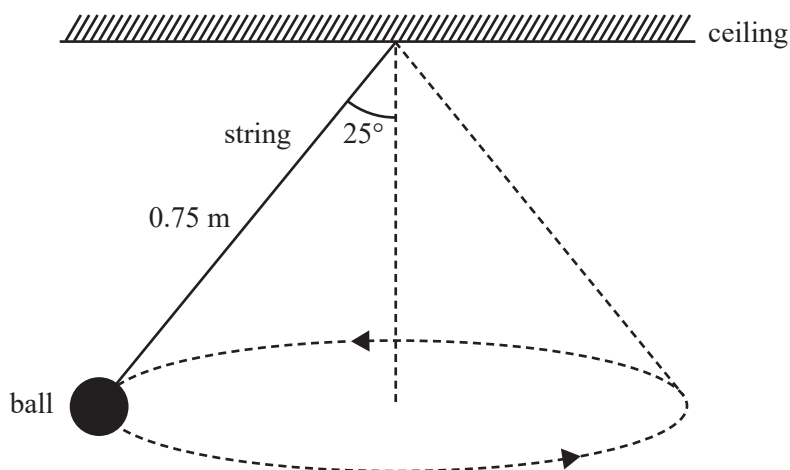
Figure 8

a. Use labelled arrows to indicate on Figure 8 the two physical forces acting on the ball. 2 marks

b. Calculate the speed of the ball. Show your working. 4 marks

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m s^{-1}

Question 9 (5 marks)

An ideal spring is compressed by 0.15 m. A ball of mass 0.20 kg is placed in contact with the compressed spring. The spring is then released, causing the ball to move horizontally, with a velocity of v, across a smooth surface, as shown in Figure 9.
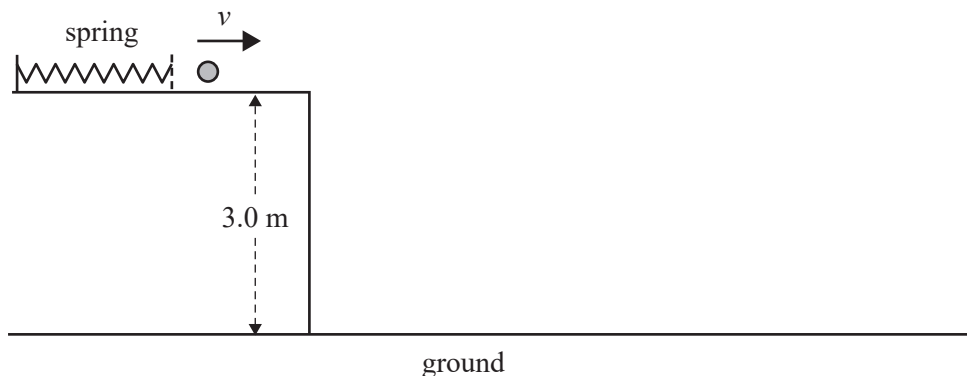
Figure 9

a. If the spring constant is 1250 N m^{-1}, show that the magnitude of the initial velocity, v, of the ball is 12 m s^{-1}, correct to two significant figures. Show your working.   2 marks

b. Calculate the speed of the ball after it has fallen a vertical distance of 2.5 m. Show your working.   3 marks

m s^{-1}

Question 10 (12 marks)

Jacinda designs a computer simulation program as part of her practical investigation into the physics of vehicle collisions. She simulates colliding a car of mass 1200 kg, moving at 10 m s^{-1}, into a stationary van of mass 2200 kg. After the collision, the van moves to the right at 6.5 m s^{-1}. This situation is shown in Figure 10.

Before collision

$\longrightarrow$ 10 m s^{-1}

1200 kg   2200 kg

car   van

After collision

$v?$ $\longrightarrow$ 6.5 m s^{-1}

1200 kg   2200 kg

car   van
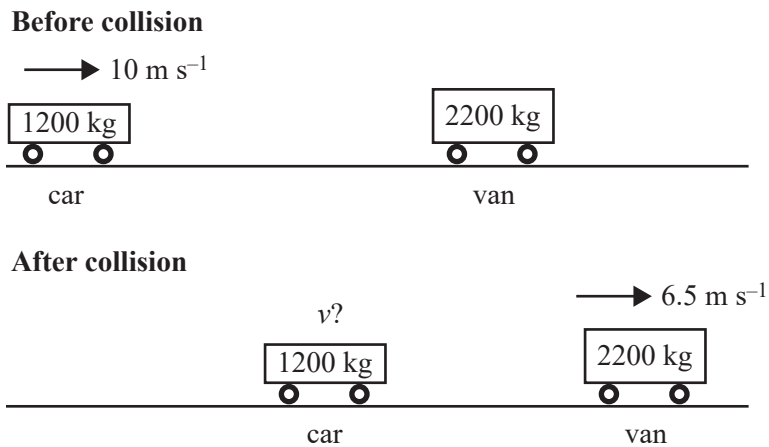
Figure 10

a. Calculate the speed of the car after the collision and indicate the direction it would be travelling in. Show your working.   4 marks

_____

_____

_____

_____

_____

_____

| m s^{-1} | |

b. Explain, using appropriate physics, why this collision represents an example of either an elastic or an inelastic collision. 3 marks

_____

_____

_____

_____

_____

_____

_____

c. The collision between the car and the van takes 40 ms.

   i. Calculate the magnitude and indicate the direction of the average force on the van by the car. 3 marks

_____

_____

_____

_____

_____

kN	

   ii. Calculate the magnitude and indicate the direction of the average force on the car by the van. 2 marks

_____

_____

_____

_____

kN	

Question 11 (4 marks)

An astronaut has left Earth and is travelling on a spaceship at $0.800c$ ($\gamma = 1.67$) directly towards the star known as Sirius, which is located 8.61 light-years away from Earth, as measured by observers on Earth.

a. How long will the trip take according to a clock that the astronaut is carrying on his spaceship? Show your working. 2 marks

_____

_____

_____

years

b. Is the trip time measured by the astronaut in **part a.** a proper time? Explain your reasoning. 2 marks

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_____

Question 12 (5 marks)

In a Young's double-slit interference experiment, laser light is incident on two slits, S_1 and S_2, that are 4.0×10^{-4} m apart, as shown in Figure 11a.

Rays from the slits meet on a screen 2.00 m from the slits to produce an interference pattern. Point C is at the centre of the pattern. Figure 11b shows the pattern obtained on the screen.
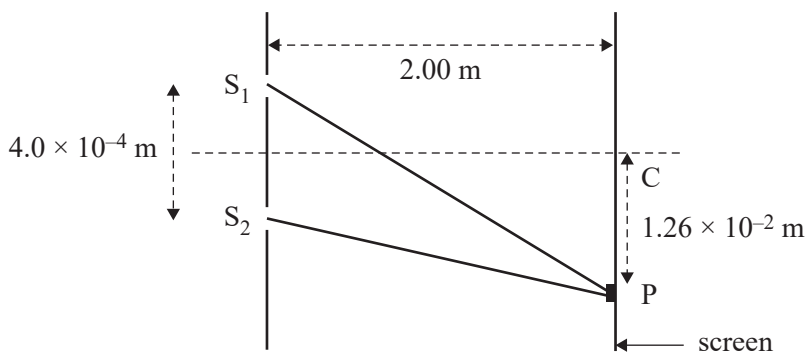
Figure 11a

Figure 11b

a. There is a bright fringe at point P on the screen.

Explain how this bright fringe is formed.   2 marks

_____

_____

_____

_____

b. The distance from the central bright fringe at point C to the bright fringe at point P is 1.26×10^{-2} m.

Calculate the wavelength of the laser light. Show your working.   3 marks

_____

_____

_____

_____

nm	

Question 13 (4 marks)

A 0.8 m long guitar string is set vibrating at a frequency of 250 Hz. The standing wave envelope created in the guitar string is shown in Figure 12.

0.8 m
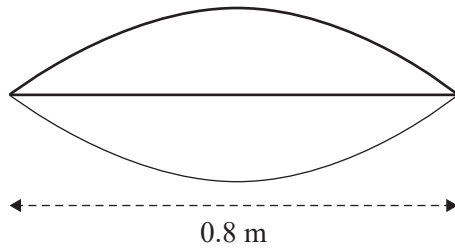
Figure 12

a. Calculate the speed of the wave in the guitar string. 2 marks

_____

_____

_____

| m s^{-1} |

b. The frequency of the vibration in the guitar string is tripled to 750 Hz.

On the guitar string below, draw the shape of the standing wave envelope now created. 2 marks

_____

Question 14 (3 marks)

Figure 13 shows a representation of an electromagnetic wave.

Correctly label Figure 13 using the following symbols.

E – electric field B – magnetic field c – speed of light λ – wavelength
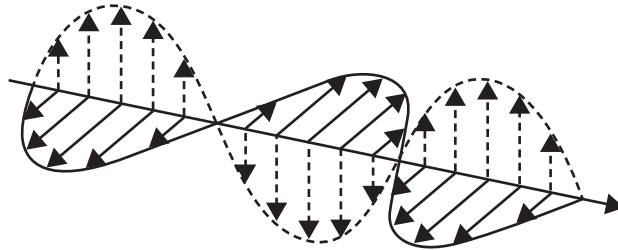
Figure 13

Question 15 (4 marks)

The metal surface in a photoelectric cell is exposed to light of a single frequency and intensity in the apparatus shown in Figure 14.

The voltage of the battery can be varied in value and reversed in direction.
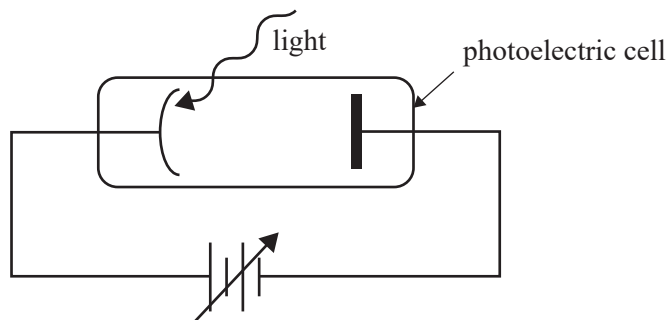
Figure 14

a. A graph of photocurrent versus voltage for one particular experiment is shown in Figure 15.

On Figure 15, draw the trace that would result for another experiment using light of the same frequency but with triple the intensity. 2 marks
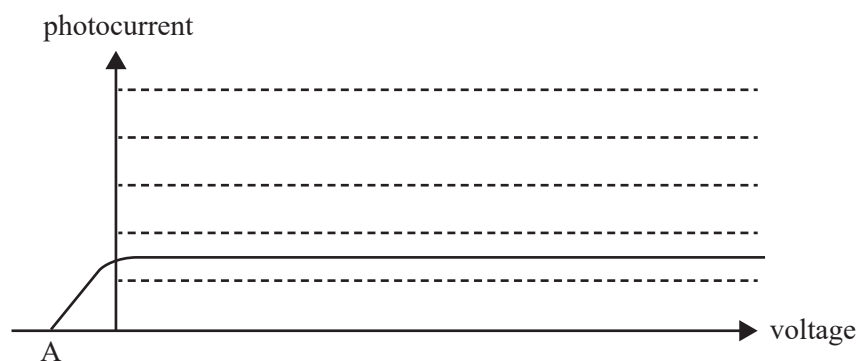
Figure 15

b. What is a name given to the point labelled A on Figure 15? 1 mark

_____

c. Why does the photocurrent fall to zero at the point labelled A on Figure 15? 1 mark

_____

_____

Question 16 (5 marks)

A beam of electrons travelling at 1.72×10^5 m s^{-1} illuminates a crystal, producing a diffraction pattern as shown in Figure 16. Take the mass of an electron to be 9.1×10^{-31} kg. Ignore relativistic effects.
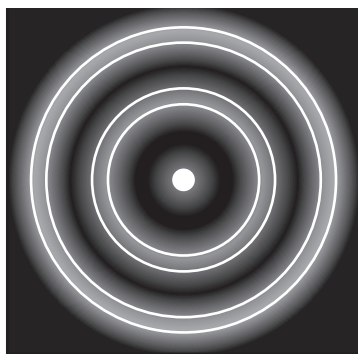
Figure 16

a.   Calculate the kinetic energy of one of the electrons. Show your working.   2 marks

eV

b.   The electron beam is now replaced by an X-ray beam. The resulting diffraction pattern has the same spacing as that produced by the electron beam.

Calculate the energy of one X-ray photon. Show your working.   3 marks

eV

Question 17 (5 marks)

Figure 17 shows the emission spectrum for helium gas.

502   492
668   588   471 447   403

700   600   500   400
wavelength (nm)
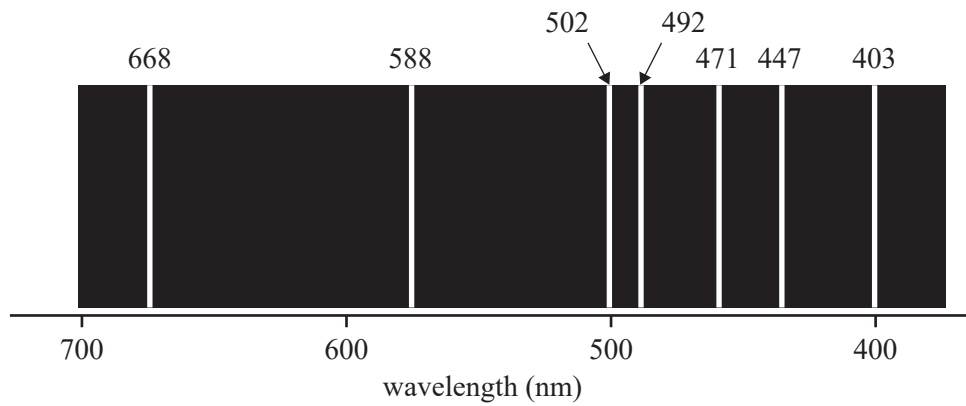
Figure 17

a. Which spectral line indicates the photon with the lowest energy? 1 mark

nm

b. Calculate the frequency of the photon emitted at the 588 nm line. Show your working. 2 marks

Hz

DO NOT WRITE IN THIS AREA

c. Explain why only certain wavelengths and, therefore, certain energies are present in the helium
spectrum.   2 marks

_____

_____

_____

_____

DO NOT WRITE IN THIS AREA

Question 18 (16 marks)

Students are modelling the effect of the resistance of electrical cables, r, on the transmission of electrical power. They model the cables using the circuit shown in Figure 18.

resistance of electrical cables, r

A

24 V_{DC} power supply (modelling mains power)

constant resistance globe, R
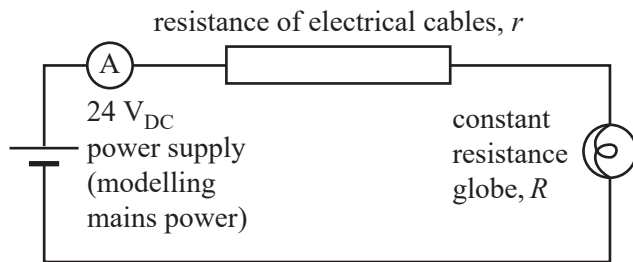
Figure 18

a. The 24 V_{DC} power supply models the mains power.

Describe the effect of increasing the resistance of the electrical cables, r, on the brightness of the constant resistance globe, R.

2 marks

The students investigate the effect of changing r by measuring the current in the electrical cables for a range of values. Their results are shown in Table 1 below.

Table 1

Resistance of cables, r (Ω)	Current in cables, i (A)	$\dfrac{1}{i}$ (A^{-1})
2.4	2.4	
3.6	2.0	
6.4	1.7	
7.6	1.5	
10.4	1.3	

b. Identify the dependent and the independent variables in this experiment. Give your reasoning.   2 marks

_____

_____

c. To analyse the data, the students use the following equation to calculate the resistance of the cables for the circuit.

$$r = \frac{24}{i} - R$$

Show that this equation is true for the circuit shown in Figure 18. Show your working.   2 marks

_____

_____

d. Calculate the values of $\dfrac{1}{i}$ and write them in the spaces provided in the last column of Table 1.   2 marks

TURN OVER

e. Plot a graph of r on the y-axis against $\dfrac{1}{i}$ on the x-axis on the grid provided below. On your graph:

- choose an appropriate scale and numbers for the x-axis
- draw a straight line of best fit through the plotted points
- include uncertainty bars ($\pm$ x-direction only) of $\pm 0.02\ \text{A}^{-1}$.
 (Uncertainty bars in the y-direction are not required.)   6 marks
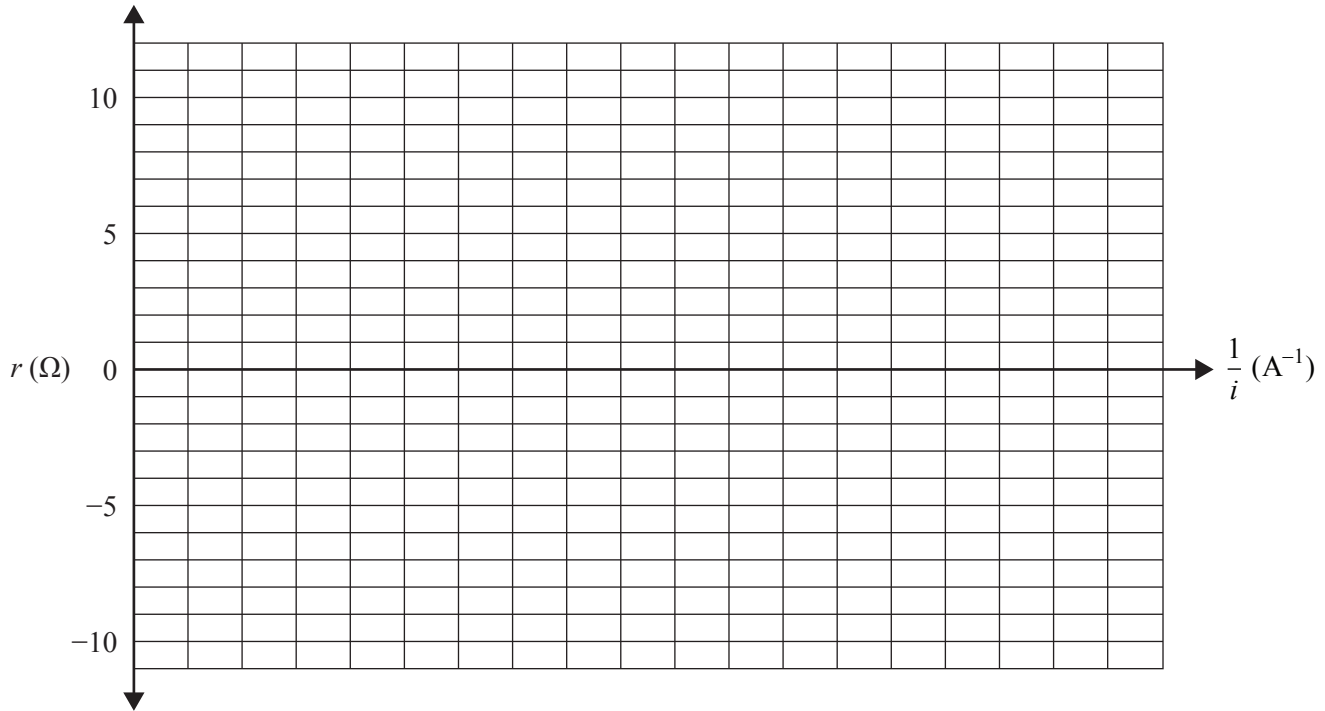
f. Use the straight line of best fit to find the value of the constant resistance globe, R. Give your reasoning.   2 marks

_____

_____

_____

_____

	Ω

END OF QUESTION AND ANSWER BOOK

PHYSICS

Written examination

FORMULA SHEET

Instructions

This formula sheet is provided for your reference.
A question and answer book is provided with this formula sheet.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

Physics formulas

Motion and related energy transformations

velocity; acceleration	$v = \dfrac{\Delta s}{\Delta t}; \quad a = \dfrac{\Delta v}{\Delta t}$
equations for constant acceleration	$v = u + at$ $s = ut + \dfrac{1}{2}at^2$ $s = vt - \dfrac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \dfrac{1}{2}(v + u)t$
Newton's second law	$\Sigma F = ma$
circular motion	$a = \dfrac{v^2}{r} = \dfrac{4\pi^2 r}{T^2}$
Hooke's law	$F = -k\Delta x$
elastic potential energy	$\dfrac{1}{2}k(\Delta x)^2$
gravitational potential energy near the surface of Earth	$mg\Delta h$
kinetic energy	$\dfrac{1}{2}mv^2$
Newton's law of universal gravitation	$F = G\dfrac{m_1 m_2}{r^2}$
gravitational field	$g = G\dfrac{M}{r^2}$
impulse	$F\Delta t$
momentum	mv
Lorentz factor	$\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$
time dilation	$t = t_0 \gamma$
length contraction	$L = \dfrac{L_0}{\gamma}$
rest energy	$E_{\text{rest}} = mc^2$
relativistic total energy	$E_{\text{total}} = \gamma mc^2$
relativistic kinetic energy	$E_k = (\gamma - 1)mc^2$

Fields and application of field concepts

electric field between charged plates	$E = \dfrac{V}{d}$
energy transformations of charges in an electric field	$\dfrac{1}{2}mv^2 = qV$
field of a point charge	$E = \dfrac{kq}{r^2}$
force on an electric charge	$F = qE$
Coulomb's law	$F = \dfrac{kq_1 q_2}{r^2}$
magnetic force on a moving charge	$F = qvB$
magnetic force on a current carrying conductor	$F = nIlB$
radius of a charged particle in a magnetic field	$r = \dfrac{mv}{qB}$

Generation and transmission of electricity

voltage; power	$V = RI; \quad P = VI = I^2 R$
resistors in series	$R_T = R_1 + R_2$
resistors in parallel	$\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$
ideal transformer action	$\dfrac{V_1}{V_2} = \dfrac{N_1}{N_2} = \dfrac{I_2}{I_1}$
AC voltage and current	$V_{RMS} = \dfrac{1}{\sqrt{2}} V_{peak} \qquad I_{RMS} = \dfrac{1}{\sqrt{2}} I_{peak}$
electromagnetic induction	EMF: $\varepsilon = -N\dfrac{\Delta \Phi_B}{\Delta t} \qquad$ flux: $\Phi_B = B_\perp A$
transmission losses	$V_{drop} = I_{line} R_{line} \qquad P_{loss} = I^2_{line} R_{line}$

Wave concepts

wave equation	$v = f\lambda$
constructive interference	path difference $= n\lambda$
destructive interference	path difference $= \left(n - \dfrac{1}{2} \right)\lambda$
fringe spacing	$\Delta x = \dfrac{\lambda L}{d}$

TURN OVER

The nature of light and matter

photoelectric effect	$E_{k\,max} = hf - \phi$
photon energy	$E = hf$
photon momentum	$p = \dfrac{h}{\lambda}$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$

Data

acceleration due to gravity at Earth's surface	$g = 9.8 \text{ m s}^{-2}$
mass of the electron	$m_e = 9.1 \times 10^{-31} \text{ kg}$
magnitude of the charge of the electron	$e = 1.6 \times 10^{-19} \text{ C}$
Planck's constant	$h = 6.63 \times 10^{-34} \text{ J s} \qquad h = 4.14 \times 10^{-15} \text{ eV s}$
speed of light in a vacuum	$c = 3.0 \times 10^{8} \text{ m s}^{-1}$
universal gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
mass of Earth	$M_E = 5.98 \times 10^{24} \text{ kg}$
radius of Earth	$R_E = 6.37 \times 10^{6} \text{ m}$
Coulomb constant	$k = 8.99 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$

Prefixes/Units

p = pico = 10^{-12}	n = nano = 10^{-9}	μ = micro = 10^{-6}	m = milli = 10^{-3}
k = kilo = 10^{3}	M = mega = 10^{6}	G = giga = 10^{9}	t = tonne = 10^{3} kg

END OF FORMULA SHEET