VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2023

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Letter

STUDENT NUMBER

PHYSICS
Written examination

Monday 29 May 2023

Reading time: 10.30 am to 10.45 am (15 minutes)
Writing time: 10.45 am to 1.15 pm (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	21	21	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.

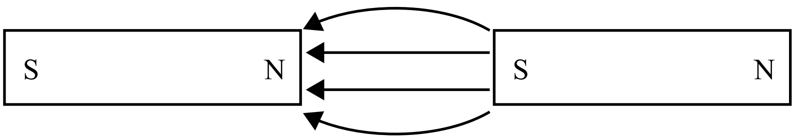
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

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

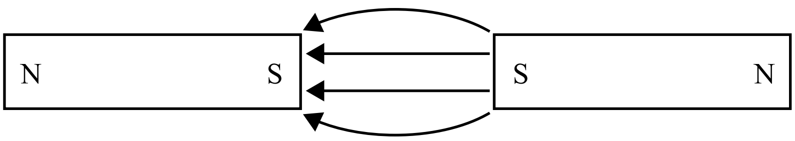
Question 1

Which one of the following diagrams best represents the magnetic field between two magnets?

A.



B.



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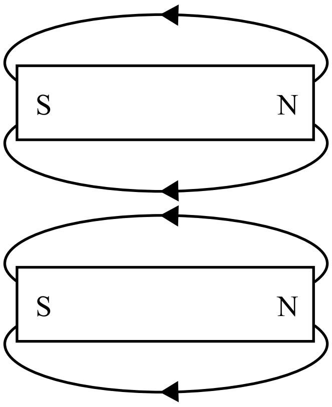

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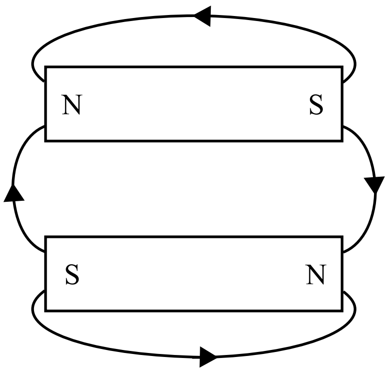
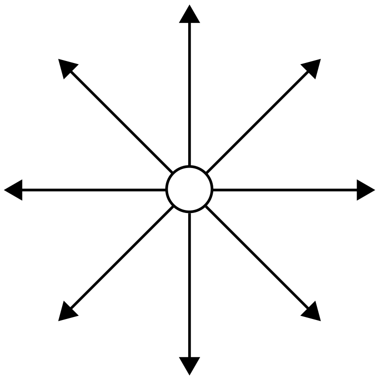


Question 2

Consider the diagram below, which shows a stationary object with field lines that extend outwards from the object.



The field shown is most likely to be identified as an example of

A. an electric field that is uniform.

B. an electric field that is non-uniform.

C. a gravitational field that is uniform.

D. a gravitational field that is non-uniform.

Question 3

Two identical satellites, S_1 and S_2, each of mass m, are placed into two circular orbits around Earth. Satellite S_1 has an orbital radius of $5R$. Satellite S_2 has an orbital radius of R.

Which one of the following best gives the value of $\dfrac{\text{gravitational force exerted on } S_1 \text{ by Earth}}{\text{gravitational force exerted on } S_2 \text{ by Earth}}$?

A. $\dfrac{1}{25}$

B. $\dfrac{1}{10}$

C. 10

D. 25

Question 4

Which one of the following statements about the polarisation of waves is correct?

A. Transverse waves can be polarised.

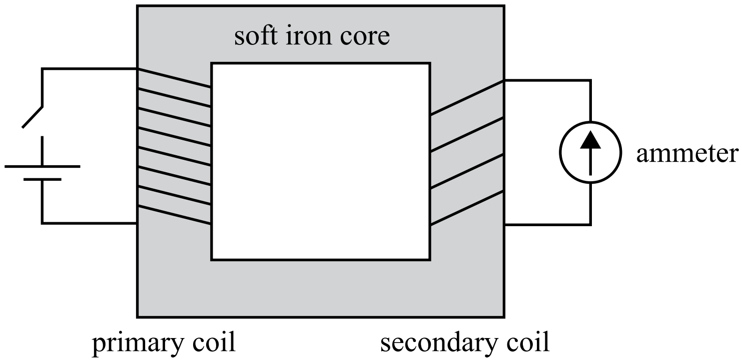
B. Longitudinal waves can be polarised.

C. Both longitudinal and transverse waves can be polarised.

D. Neither longitudinal nor transverse waves can be polarised.

Question 5

The diagram below shows an ideal transformer in which the primary coil is connected to a battery and a switch. An ammeter is connected to the secondary coil.



When the switch is closed, the pointer on the ammeter momentarily deflects.

How could the deflection on the ammeter be made larger?

A. decrease the number of primary coils

B. decrease the number of secondary coils

C. increase the number of secondary coils

D. place a resistor in series with the ammeter

Question 6

An RMS current of 15.6 A is equivalent to a peak-to-peak current of

A. 11.0 A

B. 22.1 A

C. 44.1 A

D. 55.2 A

Question 7

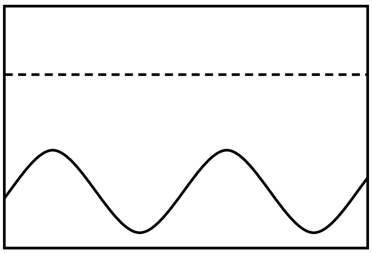
Electrical generators may use slip rings or split-ring commutators when generating electricity. When operating at equal frequencies, the output voltages of these two types of generators can be displayed together on an oscilloscope screen.

The output of the split-ring commutator is displayed as a dotted line.

The output of the slip rings is displayed as a solid line.

Which one of the following diagrams best represents the two outputs?

A.



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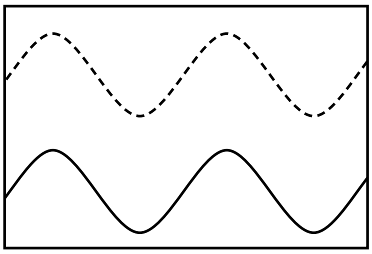

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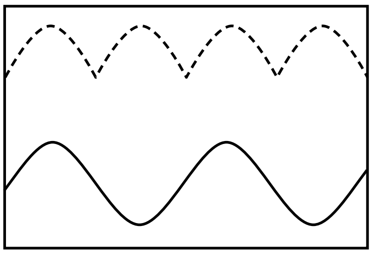
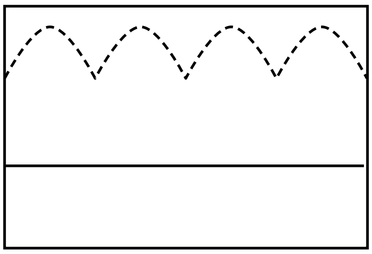


D.



Question 8

Saturn has 83 moons. One of them, Enceladus, has a mass 1.08×10^{20} kg and a circular orbit of radius 2.38×10^{8} m.

The mass of Saturn is 5.68×10^{26} kg.

Which one of the following is closest to the gravitational force of attraction between Enceladus and Saturn?

A. 0 N

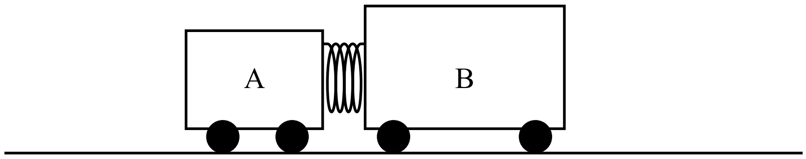
B. 1300 N

C. 4.9×10^{8} N

D. 7.2×10^{19} N

Use the following information to answer Questions 9 and 10.

The diagram below shows two stationary trolleys on a smooth surface, with an ideal spring compressed between them. Trolley A has mass of 1.0 kg and Trolley B has mass of 2.5 kg. The spring is released and the trolleys move off in opposite directions. The spring falls straight down.



Question 9

In the first experiment, Trolley A moves to the left at 0.80 m s^{-1}.

Which one of the following is closest to the speed of Trolley B?

A. 0.32 m s^{-1}

B. 0.80 m s^{-1}

C. 2.0 m s^{-1}

D. 3.1 m s^{-1}

Question 10

The experiment is repeated with a different spring. The spring is compressed 2.8 cm and released. Now Trolley A moves to the left at 1.0 m s^{-1} and Trolley B moves to the right at 0.4 m s^{-1}.

Which one of the following is closest to the spring constant of this spring?

A. 710 N m^{-1}

B. 1100 N m^{-1}

C. 1800 N m^{-1}

D. 6300 N m^{-1}

Question 11

Which one of the following best describes a hypothesis?

A. an explanation that is correct

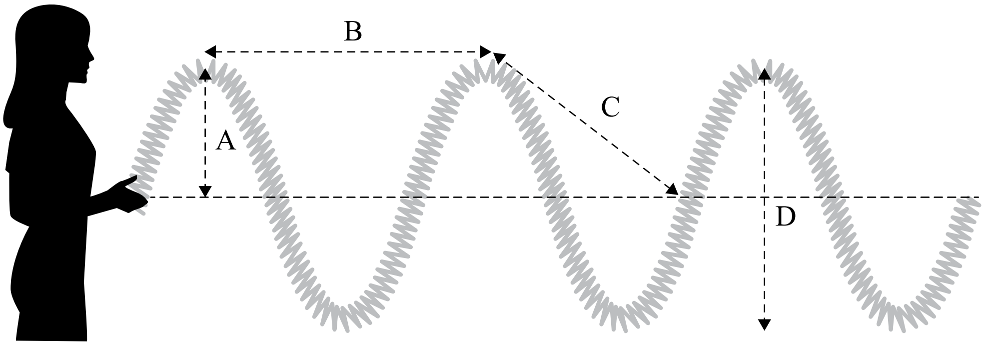
B. a statement that is widely accepted by physicists

C. an explanation that has been supported by experimental evidence

D. a possible explanation that needs to be tested by experimental evidence

Question 12

Sophia is moving the end of a Slinky spring up and down, creating a transverse wave.



Which of the lines labelled with arrows best represents the amplitude of the wave?

A. line A

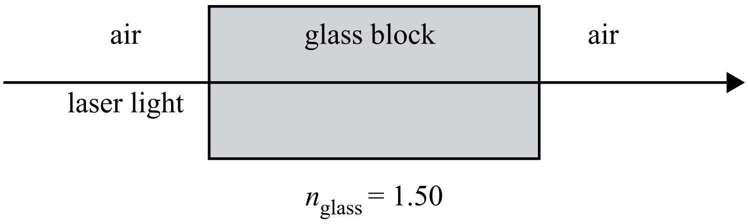
B. line B

C. line C

D. line D

Question 13

A ray of monochromatic laser light travels from air, straight through a glass block of refractive index 1.50, as shown below.

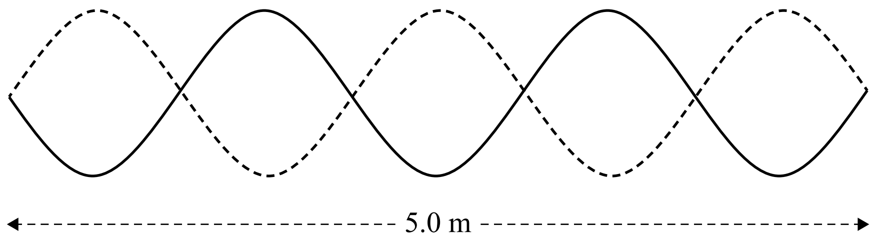


Which one of the following best describes what happens to the speed, the wavelength and the frequency of the light ray when it is travelling through the glass block, compared to when it is travelling through air?

	Speed	Wavelength	Frequency
A.	decreases	same	same
B.	decreases	decreases	same
C.	decreases	same	decreases
D.	increases	same	same

Question 14

A standing wave is produced on a flexible string, as shown in the diagram below. The diagram shows the wave at two different times – the solid line represents what the wave looks like at a particular time and the dotted line represents what the wave looks like exactly half a cycle later.



Which one of the following is closest to the wavelength of the standing wave?

A. 0.5 m
B. 1.0 m
C. 1.5 m
D. 2.0 m

Question 15

Violet light shines on a metal surface and electrons are emitted. The maximum kinetic energy of electrons emitted is measured to be 0.120 eV.

This energy, when expressed in joules, is closest to

A. 1.33×10^{-20} J
B. 1.92×10^{-20} J
C. 1.33×10^{-18} J
D. 1.92×10^{-18} J

Question 16

A proton of mass 1.67×10^{-27} kg is accelerated until its de Broglie wavelength is 5.00×10^{-9} m. The speed of the proton is then closest to

A. 1.33×10^{-18} m s^{-1}
B. 1.26×10^{-2} m s^{-1}
C. 79.4 m s^{-1}
D. 5.04×10^{4} m s^{-1}

Question 17

Which one of the following light sources produces a full continuous spectrum of visible light?

A. He–Ne laser
B. infra-red heat lamp
C. incandescent globe
D. mercury vapour lamp

Question 18

Light of wavelength 300 nm is just able to cause the photoelectric emission of electrons from a lead surface.

If light of twice this wavelength were incident on a lead surface

A. no photoelectric emission would occur.

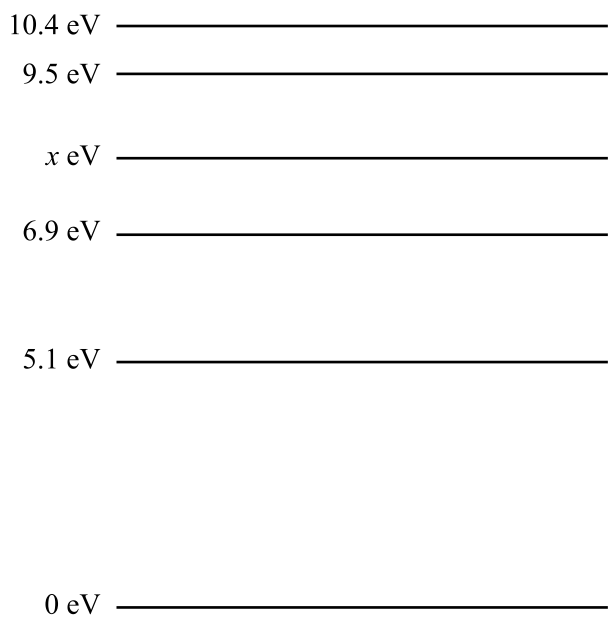
B. half as many electrons would be ejected per second.

C. the same number of electrons would be ejected per second, with twice the energy.

D. the same number of electrons would be ejected per second, with more energy but not necessarily twice as much energy.

Question 19

Some of the energy levels for an unknown atom are shown in the diagram below, with one of the lines labelled x eV. These energy levels are not drawn to scale.



A part of the emission spectrum of the atom shows lines at 1.0 eV, 1.6 eV and 1.9 eV.

The value of x is closest to

A. 7.7

B. 7.9

C. 8.0

D. 8.5

Question 20

A pion and its antiparticle, each at rest, annihilate and produce only two photons with a total energy of 4.5×10^{-11} J. The masses of the pion and its antiparticle are the same.

The rest mass of the pion is closest to

A. 1.3×10^{-28} kg

B. 2.5×10^{-28} kg

C. 5.0×10^{-28} kg

D. 7.5×10^{-20} kg

END OF SECTION A
TURN OVER

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 (3 marks)

Two small charges, A and B, are placed 6.0 cm apart in a straight line, as shown in Figure 1.

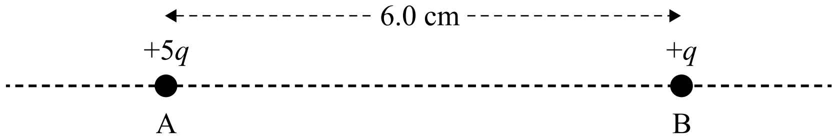


Figure 1

Charge A has a magnitude of $+5q$ coulombs and charge B has a magnitude of $+q$ coulombs.

If the force exerted by charge A on charge B is 5.1×10^{-24} N to the right, determine the value of q.

C

SECTION B – continued

Question 2 (3 marks)

A positively charged particle carrying a charge of $+1.5 \times 10^{-8}$ C enters a region between two large, charged plates with opposite charges, as shown in Figure 2.

The potential difference between the plates is 2.0 kV, and the kinetic energy of the charged particle as it enters the hole is 2.8×10^{-5} J. Ignore gravitational effects and air resistance.

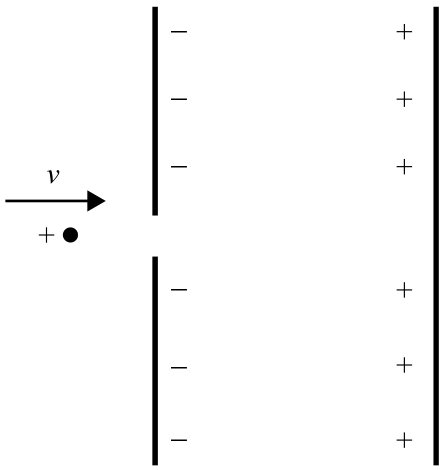


Figure 2

Ariel and Jamie discuss what they think will happen to the particle after it enters the region between the two equally but oppositely charged plates.

Ariel says that the particle has insufficient kinetic energy to reach the positively charged plate and will travel part of the way before returning towards the negatively charged plate.

Jamie says that the particle will collide with the positively charged plate and then head back towards the negatively charged plate.

Evaluate Ariel and Jamie's statements, giving clear reasons for your answer.

Question 3 (3 marks)

Two thin, light aluminium tubes, A and B, are supported in a vertical wooden rack, as shown in Figure 3. Both of the aluminium tubes rest horizontally on wooden pegs.

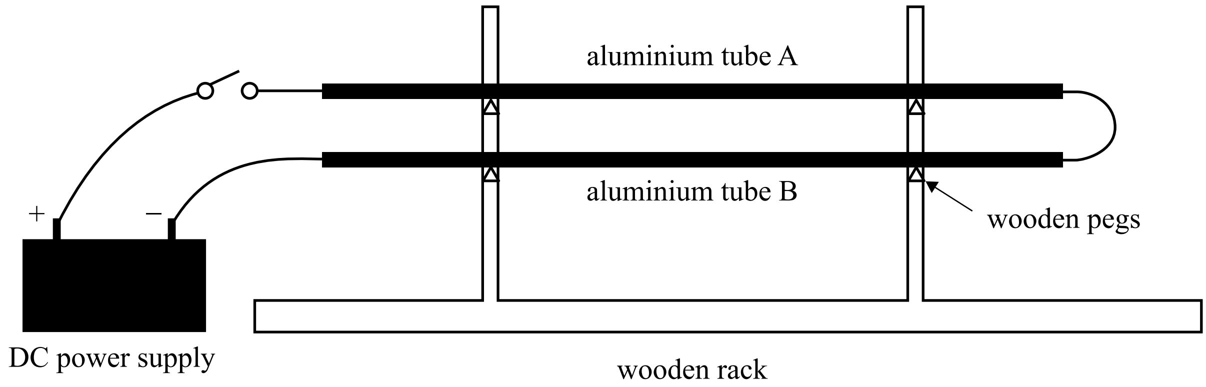


Figure 3

The two thin, light aluminium tubes form a series circuit with a DC power supply. It was observed that one of the tubes jumped upwards when the DC power supply was switched on.

Identify which tube jumped upwards and explain why this occurred.

Aluminium tube

Question 4 (4 marks)

Two electrons, e_1 and e_2, are emitted, one after the other, from point P in a uniform magnetic field, as shown in Figure 4.

Both electrons travel perpendicular to the magnetic field, but in opposite directions. Throughout their journey, both electrons remain within the magnetic field.

Electron e_1 travels at twice the speed of e_2. Relativistic effects can be ignored as both electrons are travelling at low speeds. Electrostatic effects at point P can be ignored as the two electrons are emitted at different times.

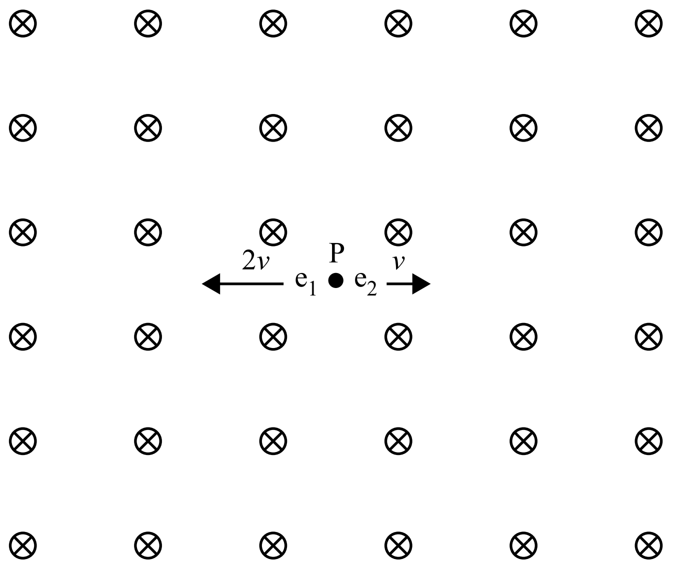


Figure 4

Which one of the following three outcomes occurs?

- Outcome 1 – Electron e_1 returns to point P in the shortest time.
- Outcome 2 – Electron e_2 returns to point P in the shortest time.
- Outcome 3 – Both electrons take the same time to return to point P.

Outcome

Explain your answer.

Question 5 (3 marks)

Figure 5 shows the sun, the moon and Earth.

The mass of the sun is approximately 3.3×10^5 times the mass of Earth.

The distance from the sun to the moon is approximately 390 times the distance from Earth to the moon.

Figure 5

Calculate $\dfrac{\text{magnitude of the sun's gravitational force on the moon}}{\text{magnitude of Earth's gravitational force on the moon}}$.

Question 6 (5 marks)

Measuring very small changes in Earth's surface mass, the 600 kg satellite GRACE-FO1 is in a circular orbit around Earth at an altitude of 500 km. The radius of Earth is 6.37×10^6 m.

a. Calculate the magnitude and direction of the satellite's centripetal acceleration. Give your answer correct to three significant figures. 3 marks

m s^{-2}

b. Figure 6 shows a graph of the gravitational force that would act on GRACE-FO1 for a range of altitudes.

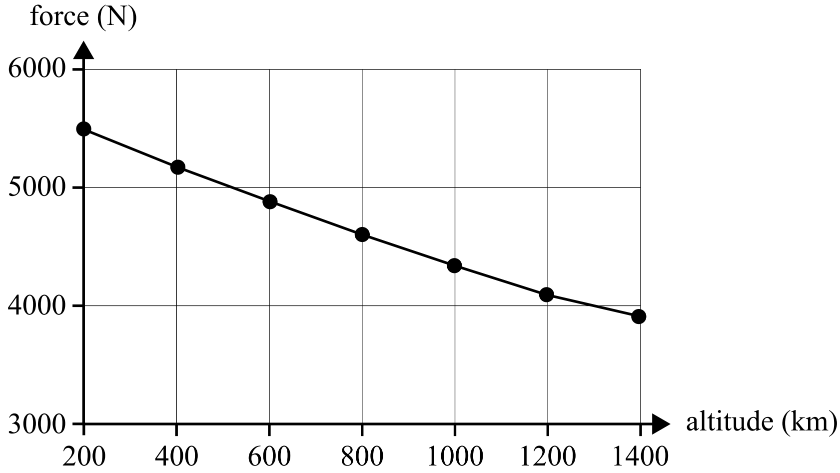


Figure 6

Estimate the energy required to lift the satellite from its present orbit at an altitude of 500 km to a new orbit at an altitude of 1400 km. 2 marks

J

Question 7 (3 marks)

Figure 7 shows a schematic diagram of a simple DC motor, powered by a battery.

The motor has a rectangular coil, WXYZ, consisting of 45 turns. The side WX has a length of 6.0 cm and the side XY has a length of 4.0 cm. The coil is connected to a split-ring commutator. Two permanent magnets provide a uniform magnetic field of 80 mT. Both the coil and the commutator are free to turn.

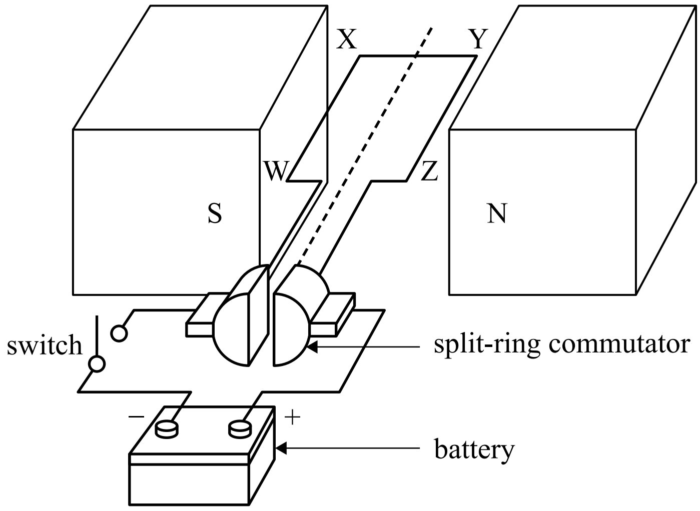


Figure 7

The switch is now closed.

a. Will the motor spin clockwise, spin anticlockwise or remain stationary when viewed from the battery side? 1 mark

b. Calculate the magnitude of the force on the side YZ if a current of 3.2 A flows through the coil. Show your working. 2 marks

N

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Question 8 (7 marks)

Sarah and Raminda construct a simple alternator, as shown in Figure 8.

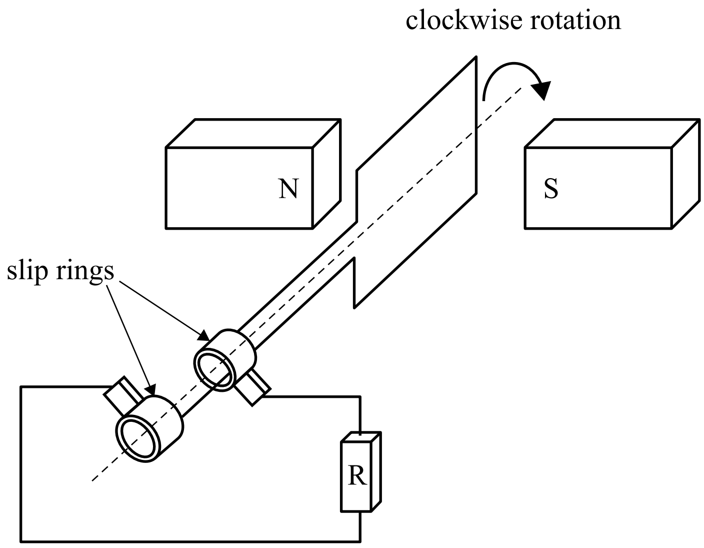

Figure 8

When the coil is rotating steadily, it takes 50.0 ms to complete one revolution and the peak EMF generated is 4.30 V.

a. Calculate the frequency of the alternator. 1 mark

Hz

b. Calculate the EMF, V_{RMS}, generated. Show your working and give your answer correct to three significant figures. 2 marks

V

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c. To increase the magnitude of the EMF produced by the alternator, Raminda suggests making a number of changes to the alternator.

Sarah insists that each change be investigated one at a time.

In the spaces provided, indicate whether each suggestion will increase, decrease or have no effect on the EMF produced by the alternator. 4 marks

Suggested change	**Effect on EMF (increases, decreases or has no effect)**
reduce the resistance of resistor R	
increase the strength of the permanent magnets	
reduce the period of rotation of the coil to 25 ms	
increase the number of turns of the rotating coil	

Question 9 (7 marks)

A local community wishes to power its town hall using hydro-electricity. A waterfall drives an AC generator, with power delivered to the hall via transmission lines, as shown in Figure 9. The generator has an RMS power output of 4.2 kW when operating normally.

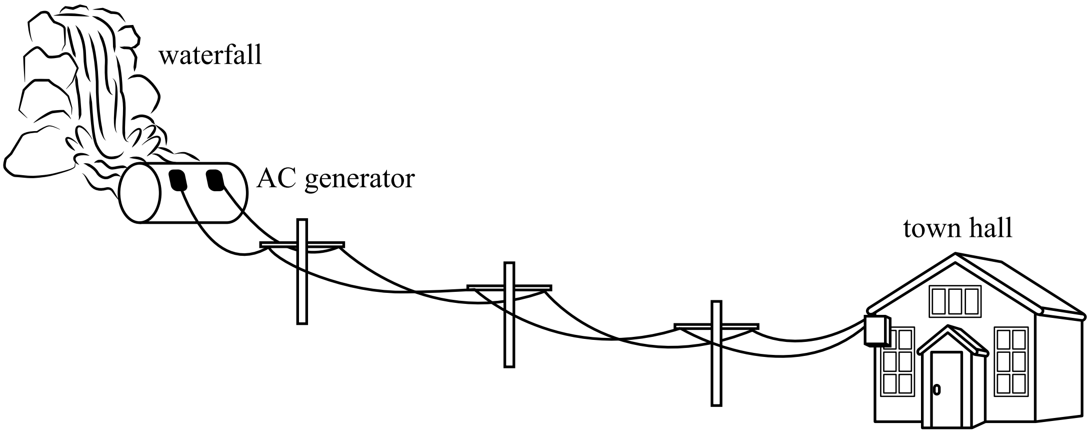

Figure 9

The town hall's electrical loads have a total resistance of 20 Ω and require 2.6 kW of RMS power when operating normally.

a. Calculate the RMS voltage at the town hall under these conditions. Show your working. 2 marks

V

b. Calculate the resistance of the transmission lines. 3 marks

Ω

c. Suggest two changes the community could make to the system that would reduce power losses without changing the output of the AC generator or the load at the town hall. 2 marks

1. ____

2. ____

Question 10 (6 marks)

A single rectangular loop of wire containing a cut out section labelled EF moves to the right at a constant speed of 2.4 m s^{-1}, as shown in Figure 10a. At time $t = 0$, the right-hand edge of the loop enters a constant magnetic field into the page.

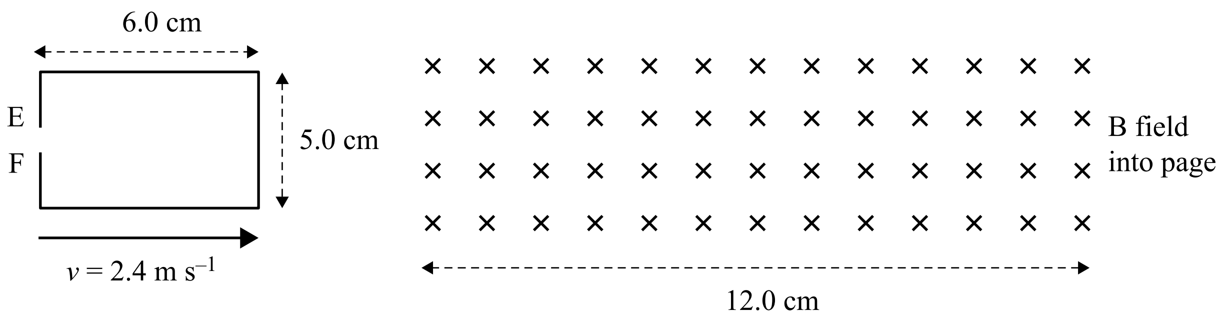

Figure 10a

The induced EMF produced as a function of time is shown in the graph in Figure 10b.

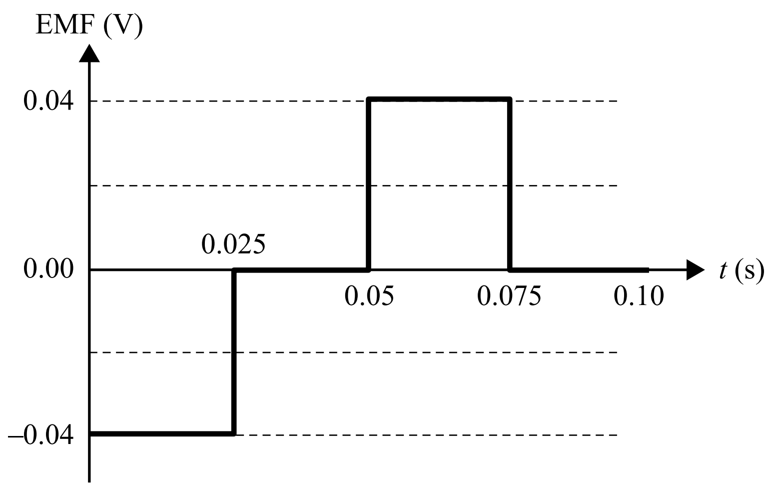

Figure 10b

While the loop enters, and is partially within, the field, an EMF is generated between points E and F.

a. Which point, E or F, is positive? 1 mark

b. Explain why the induced EMF is constant during the time period 0.00 s to 0.025 s. 2 marks

c. Calculate the strength of the magnetic field through which the rectangular loop travels. 3 marks

T

Question 11 (9 marks)

Lee ties a small ball of mass 100 g to a string and rotates it in a vertical circle, as shown in Figure 11a. Assume that the ball is rotated at a constant speed of 3.0 m s^{-1}. The radius, r, of the circle is 0.60 m. Figure 11b shows a side view.

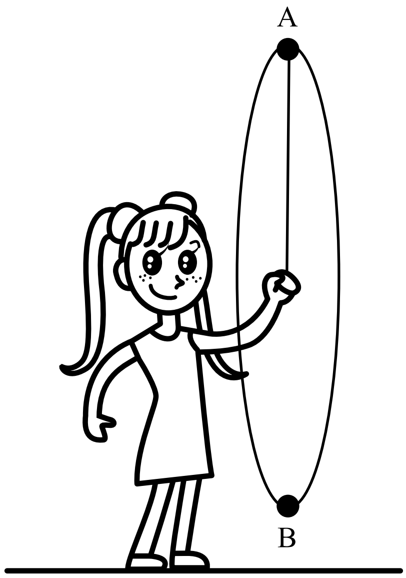

Figure 11a

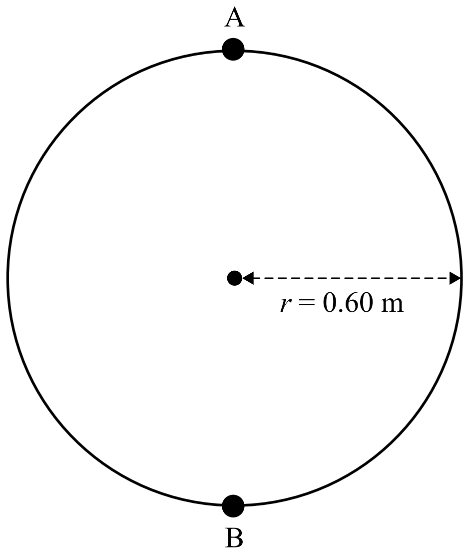

Figure 11b

a. On Figure 11b, draw arrows to represent each of the forces acting on the small ball at position A, at the top of the circle, and at position B, at the bottom of the circle. Label each arrow clearly and use the lengths of the arrows to show the relative approximate magnitudes of the forces. No calculations are required. 4 marks

b. Calculate the tension force in the string when the ball is at position B. Use g = 10 m s^{-2}. 2 marks

N

c. Lee now increases the speed of the ball to a new constant speed, which is greater than 3.0 m s^{-1}, and notices that the string breaks when the ball is at position B.

Explain why the string is more likely to break at position B than at position A. 3 marks

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Question 12 (8 marks)

Two students investigate the physics of long jumps. They analyse a video of their friend Jemina as she runs along a track and then jumps. She lands in a sand pit that is level with the track.

Jemina's horizontal speed at the moment she jumps is 8.0 m s^{-1}. She is in the air for 0.6 s before landing in the sand pit. The students use $g = 10$ m s^{-2} for their calculations. The motion is modelled as that of a point mass, as shown in Figure 12.

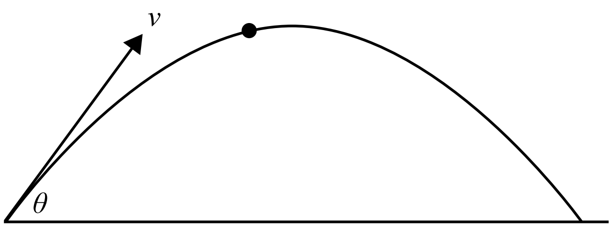


Figure 12

a. Calculate the horizontal distance that Jemina would be expected to travel if her motion were modelled as a projectile with point mass as shown in Figure 12. Show your working. 2 marks

m

b. Calculate Jemina's vertical speed as she takes off from the track. Show your working. 2 marks

m s^{-1}

c. Calculate Jemina's velocity as she launches. Include both the magnitude and the angle from the horizontal of her velocity at take-off. 3 marks

$\mathrm{m\ s^{-1}}$	°

d. The students use a tape measure to check the horizontal distance that Jemina actually jumps, and find that it is less than the distance they calculated in **part a.**

Suggest **one** possible reason for this. 1 mark

Question 13 (13 marks)

As part of their practical investigations, two Physics students, Chris and Arya, investigate changes in gravitational potential energy and elastic potential energy for a 2.0 kg mass initially hanging on a spring.

The spring has an unstretched length of 1.0 m, as shown at position P in Figure 13a.

The 2.0 kg mass is placed by Arya on the unstretched spring and it hangs stationary at position Q in Figure 13b.

Their Physics teacher tells them that they can use $g = 10$ m s^{-2} for their calculations.

a. Show that the spring constant of the spring, k, is 20 N m^{-1}. 1 mark

Chris then pulls the mass down a further 1.0 m below position Q, to position R, and releases it so that it oscillates between positions R and P, as shown in Figure 13c.

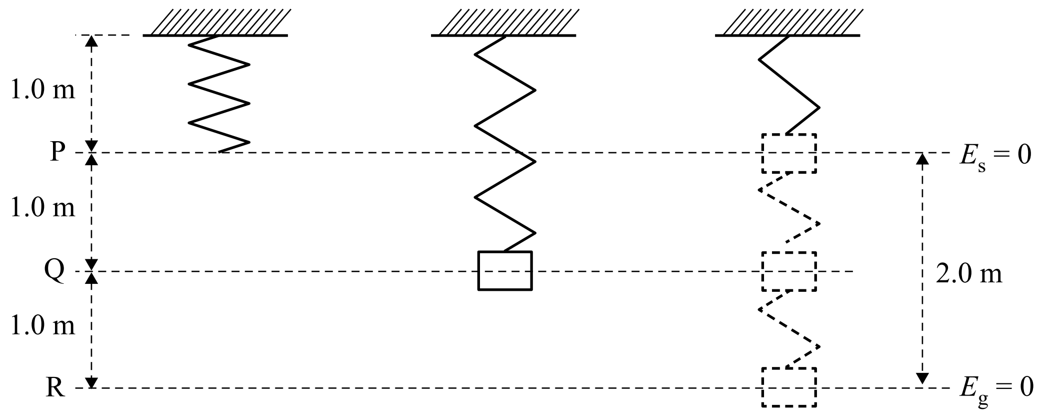


Figure 13a **Figure 13b** **Figure 13c**

The students decide that the gravitational potential energy, E_g, is zero at position R, and that they can use the formula for gravitational potential energy, $E_g = mg\Delta h$, where Δh is the height above position R.

The students also decide that the elastic potential energy is zero at the top position P, and that they can use the elastic potential energy formula $E_s = \frac{1}{2}k(\Delta x)^2$, where Δx is the extension of the spring beyond its unstretched length.

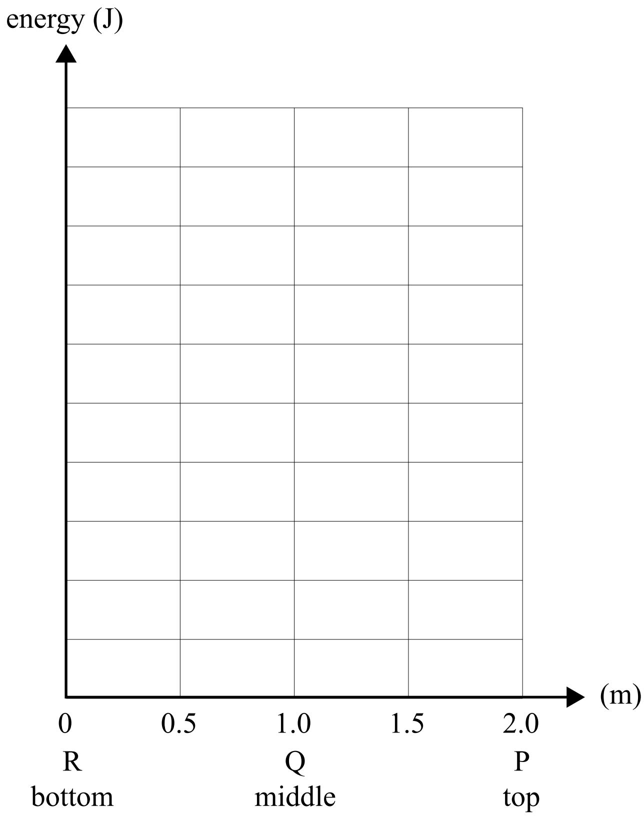
Arya enters the following information into a table.

Position	h (m)	E_g (J)	Δx (m)	E_s (J)
P	2.0	40.0	0	0
	1.5	30.0	0.5	2.5
Q	1.0		1.0	10.0
	0.5	10.0	1.5	
R	0	0	2.0	40.0

b. Using the formulas for E_g and E_s, verify that Arya's $E_s = 10$ J at position Q is correct and fill in the missing data points in the table. Show your working for each calculation. 3 marks

c. On the axes below, plot the E_g and E_s versus position data for the oscillating mass. On your graph:

- choose an appropriate scale and numbers for the *y*-axis
- use small circles for the E_g data and small triangles for the E_s data
- draw a line/curve of best fit through the plotted points for the E_g data
- draw a line/curve of best fit through the plotted points for the E_s data. 4 marks



d. Determine the speed of the mass as it goes through position Q. Show your working. 3 marks

m s^{-1}

e. Arya and Chris discuss the graphs that they have drawn. Chris says that their calculation must be wrong because the graphs should add up to a constant amount – the total energy of the system. However, Arya says that the graphs are correct.

Explain why Chris is incorrect. 2 marks

Question 14 (4 marks)

A spaceship of length 71 m, measured when stationary on Earth, is travelling horizontally past an observer on Earth at a speed of 0.80c.

a. The spaceship emits a beam of light towards the observer.

State the speed of the light as measured by the observer on Earth. Justify your answer. 2 marks

b. Calculate the length of the spaceship as measured by the observer on Earth. 2 marks

Question 15 (6 marks)

Nialle is standing between two loudspeakers on the school oval, as shown in Figure 14. Sound of a single frequency of 200 Hz is being emitted equally from both speakers. The distance between the speakers is 7.2 m.

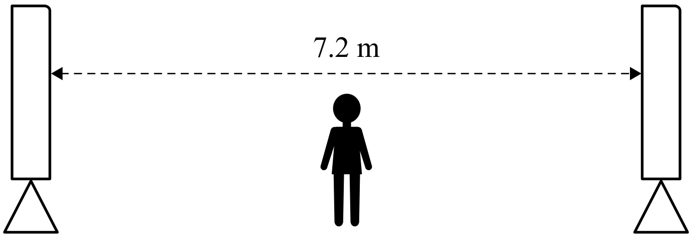


Figure 14

When Nialle stands exactly halfway between the speakers, the sound is quite loud. Nialle begins to walk towards one speaker and notices that the sound gets quieter and then louder.

a. Calculate the wavelength of the 200 Hz sound, taking the speed of sound to be 360 m s^{-1}. 1 mark

m

b. Nialle decides that this observation must be due to interference.

Explain how interference accounts for the loud and quiet points. 3 marks

c. Calculate the spacing between two adjacent quiet points. 2 marks

m

Question 16 (3 marks)

Priya and Dan are playing music in a soundproof recording room. Priya leaves the room while Dan is still playing. She notices that when she is standing at point X with the door open, as shown in Figure 15, she can still hear the music. The music is not only softer, but some of the frequencies also seem to be relatively much softer. The door to the recording room is 1 m wide.

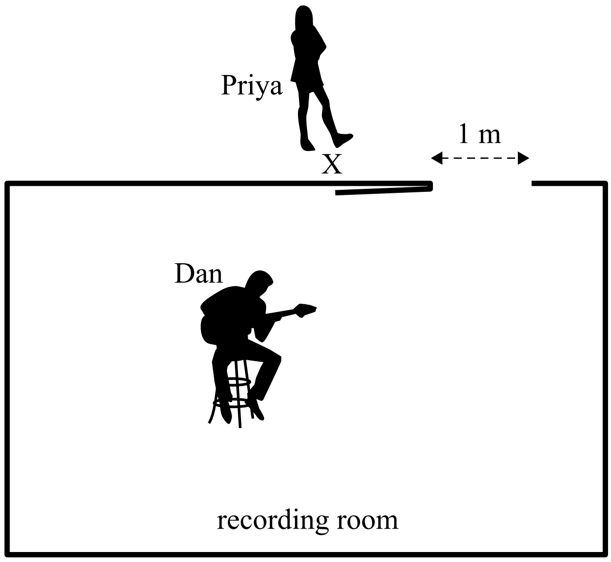


Figure 15

Outline in what way the music sounds different to Priya and explain why.

Question 17 (5 marks)

An optical fibre consists of a transparent cylindrical glass core surrounded by transparent glass cladding. A ray of monochromatic light is incident on an optical fibre at an angle θ_1. It refracts to an angle θ_2 inside the fibre. It then travels in the core until it reflects at the critical angle at the interface between the core and the cladding, as shown in Figure 16.

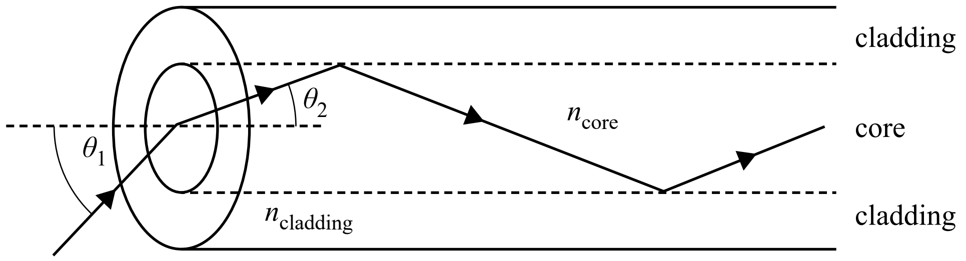


Figure 16

The refractive index of the core, n_{core}, is 1.55 and the angle θ_2 is 31°.

a. Calculate the value of θ_1. Take the refractive index of air to be 1.00 — 2 marks

°

b. Calculate the refractive index of the cladding. — 3 marks

Question 18 (6 marks)

Students carry out a Young's double-slit experiment using the experimental set-up shown in Figure 17. Laser light passes through two closely spaced narrow slits and forms a pattern of light and dark bands on a screen. The bands are numbered – the even numbers are bright bands and the odd numbers are dark bands. The band spacing is X. Band 6 is equidistant from each of the two slits.

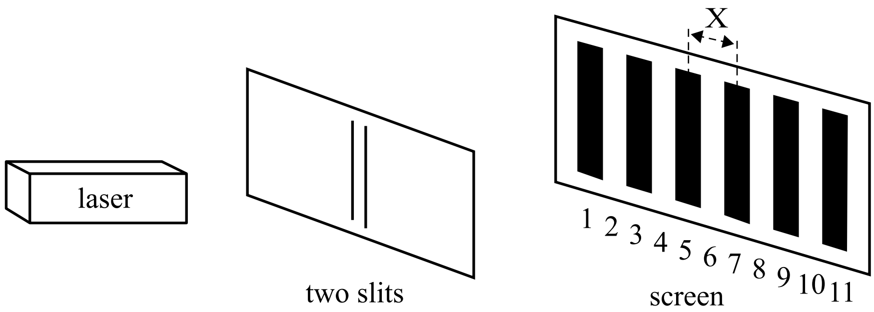


Figure 17

a. Using a wave model of light, explain why Band 3 is dark. 2 marks

DO NOT WRITE IN THIS AREA

b. The two slits are 1.00 m from the screen. The wavelength of the laser is 600 nm. The spacing between the two slits is 0.100 mm.

Calculate the band spacing, X, in millimetres. 2 marks

mm

c. The whole apparatus is now immersed in an insulating liquid of refractive index 1.2. The spacing of the bands changes.

Explain why the spacing of the bands changes and include a calculation of the new band spacing. 2 marks

Question 19 (4 marks)

In an experiment on the photoelectric effect, Sam shines ultraviolet light onto a zinc plate and ejects photoelectrons, as shown in Figure 18.

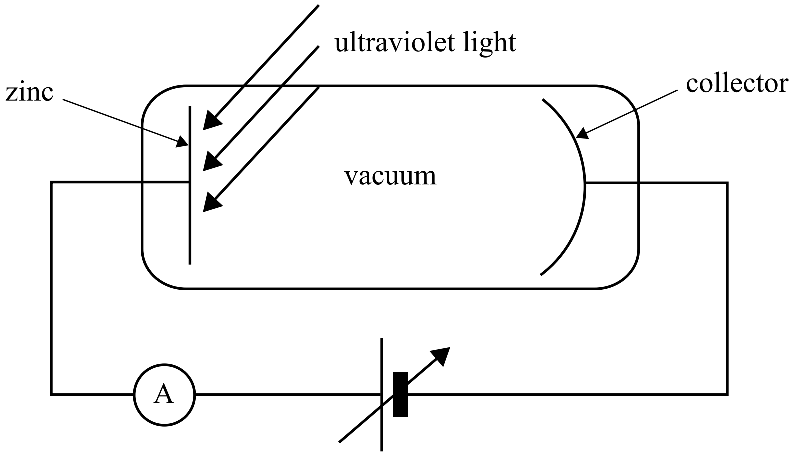


Figure 18

a. The work function of zinc is 4.30 eV.

Calculate the minimum frequency of the ultraviolet light that could eject a photoelectron. 2 marks

Hz

b. Sam wants to produce a greater photocurrent – that is, to emit more photoelectrons. He considers using a much brighter red light instead of the original ultraviolet light source used in **part a.**

Is Sam's idea likely to produce a greater photocurrent? Explain your answer. 2 marks

Question 20 (5 marks)

A beam of electrons, each with a momentum 4.60×10^{-24} kg m s^{-1}, is passed through a salt crystal to produce a diffraction pattern, as shown in Figure 19.

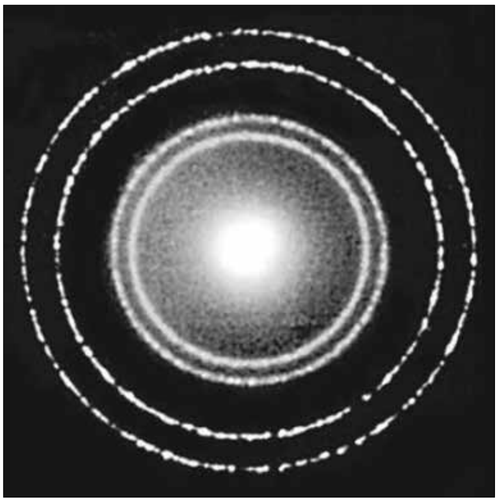


Figure 19

a. Calculate the de Broglie wavelength of the electrons. Show your working. 2 marks

m

b. Explain why electron diffraction patterns from salt crystals provide evidence for the wavelike nature of matter. 3 marks

Question 21 (3 marks)

The energy levels of the hydrogen atom are discrete (quantised) and there are no levels between them.

Explain, in terms of the properties of the electron in the hydrogen atom, why only certain energy levels are allowed.

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM
AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2023

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	$v = \frac{\Delta s}{\Delta t}; \quad a = \frac{\Delta v}{\Delta t}$
equations for constant acceleration	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $s = vt - \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(v + u)t$
Newton's second law	$\Sigma F = ma$
circular motion	$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
Hooke's law	$F = -k\Delta x$
elastic potential energy	$\frac{1}{2}k(\Delta x)^2$
gravitational potential energy near the surface of Earth	$mg\Delta h$
kinetic energy	$\frac{1}{2}mv^2$
Newton's law of universal gravitation	$F = G\frac{m_1 m_2}{r^2}$
gravitational field	$g = G\frac{M}{r^2}$
impulse	$F\Delta t$
momentum	mv
Lorentz factor	$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$
time dilation	$t = t_o\gamma$
length contraction	$L = \frac{L_o}{\gamma}$
rest energy	$E_{rest} = mc^2$
relativistic total energy	$E_{total} = \gamma mc^2$
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	$F = \dfrac{kq_1q_2}{r^2}$
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	$V = RI; \quad P = VI = I^2R$
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: $\varepsilon = -N\dfrac{\Delta\Phi_B}{\Delta t}$ 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	$\Delta x = \dfrac{\lambda L}{d}$
Snell's law	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
refractive index and wave speed	$n_1 v_1 = n_2 v_2$

The nature of light and matter

photoelectric effect	$E_{\text{k max}} = hf - \phi$
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	$h = 6.63 \times 10^{-34} \text{ J s}$ $h = 4.14 \times 10^{-15} \text{ eV s}$
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