VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2023

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER Letter

PHYSICS
Written examination

Thursday 9 November 2023

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	17	17	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 44 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.

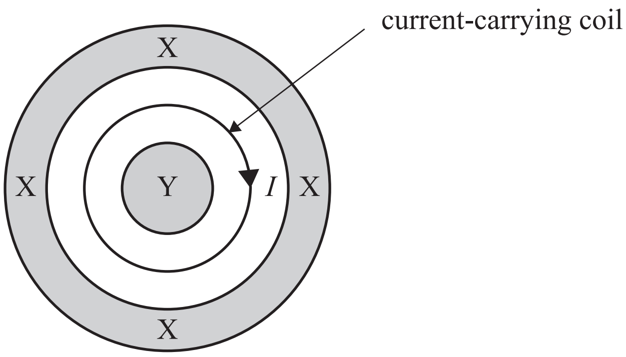
No marks will be given if more than one answer is completed for any question.

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

One type of loudspeaker consists of a current-carrying coil within a radial magnetic field, as shown in the diagram below. X and Y are magnetic poles, and the direction of the current, I, in the coil is clockwise as shown.



The force, F, acting on the current-carrying coil is directed into the page.

Which one of the following statements correctly identifies the magnetic polarities of X and Y?

A. X is a north pole and Y is a south pole.

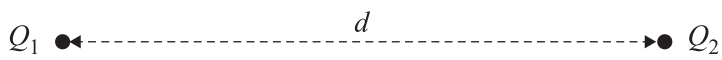
B. X is a south pole and Y is a north pole.

C. Both X and Y are north poles.

D. Both X and Y are south poles.

Question 2

The diagram below shows two charges, Q_1 and Q_2, separated by a distance, d.



There is a force, F, acting between the two charges.

Which one of the following is closest to the magnitude of the force acting between the two charges if both d and the charge on Q_1 are halved?

A. $\frac{F}{4}$

B. F

C. $2F$

D. $4F$

Question 3

Space scientists want to place a satellite into a circular orbit where the gravitational field strength of Earth is half of its value at Earth's surface.

Which one of the following expressions best represents the altitude of this orbit above Earth's surface, where R is the radius of Earth?

A. $\frac{\sqrt{2}R}{2} - R$

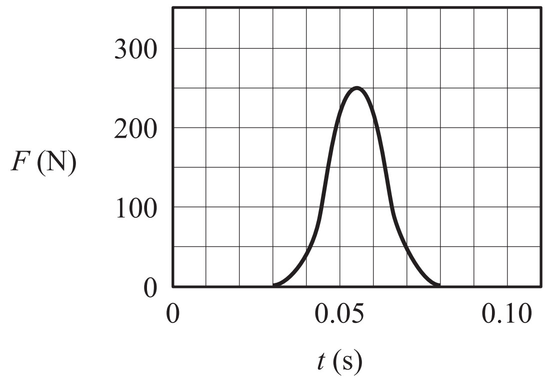
B. $\sqrt{2}R$

C. $\left(\sqrt{2}R\right) - R$

D. $2R - \sqrt{2}R$

Question 4

The diagram below shows the force versus time graph of the force on a tennis ball when it is hit by a tennis racquet. The tennis ball is stationary when the tennis racquet first comes into contact with the ball.



Which one of the following is closest to the impulse experienced by the tennis ball as it is hit by the tennis racquet?

A. 0.50 N s

B. 5.0 N s

C. 10 N s

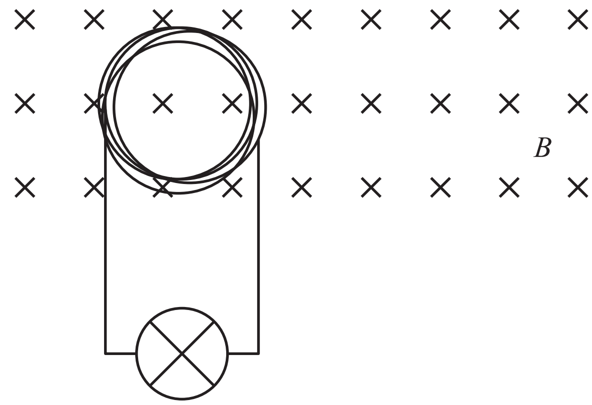
D. 50 N s

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Use the following information to answer Questions 5 and 6.

The diagram below shows a stationary circular coil of conducting wire connected to a low-resistance globe in a uniform, constant magnetic field, *B*.



Question 5

The magnetic field is switched off.

Which one of the following best describes the globe in the circuit **before** the magnetic field is switched off, **during** the time the magnetic field is being switched off and **after** the magnetic field is switched off?

	Before	During	After
A.	Off	On	Off
B.	On	On	Off
C.	On	Off	Off
D.	Off	On	On

Question 6

The radius of the coil is 5 cm and the magnetic field strength is 0.2 T. The coil has 100 loops. Assume that the magnetic field is perpendicular to the area of the coil.

Which one of the following is closest to the magnitude of the magnetic flux through the coil of wire when the magnetic field is switched on?

A. 0.0016 Wb

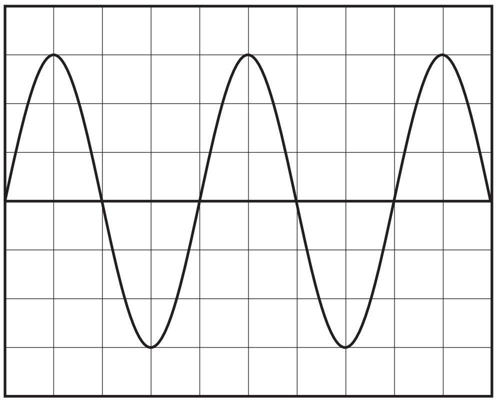
B. 0.16 Wb

C. 16 Wb

D. 1600 Wb

Question 7

An oscilloscope is connected to a sinusoidal AC voltage source. The resulting trace on the oscilloscope screen is shown below. One vertical division on the oscilloscope screen represents a potential difference of 20 V, and one horizontal division represents a time interval of 10 ms.



Which one of the following is closest to both the peak-to-peak voltage and the frequency of the signal shown in the diagram?

A. 42 V and 10 Hz

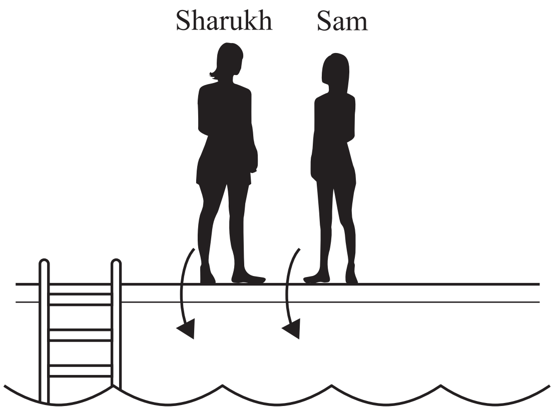
B. 60 V and 25 Hz

C. 120 V and 10 Hz

D. 120 V and 25 Hz

Question 8

At a swimming pool, Sharukh and Sam, shown below, step off the low diving board at the same time. Over the small distance they fall, air resistance may be ignored. Sharukh and Sam have masses of 80 kg and 60 kg respectively.



Which one of the following best explains what happens to Sharukh and Sam as they drop straight down into the water?

A. Sharukh reaches the surface first because she has a larger mass.

B. The net force on Sharukh is larger than that on Sam, so Sharukh reaches the surface first.

C. They both reach the surface together because they both experience the same downward force.

D. They both reach the surface together because they both experience the same downward acceleration.

DO NOT WRITE IN THIS AREA

Question 9

An engineer is designing a banked circular curve of radius 25 m in a new bicycle velodrome.

Diagram A shows the bicycle approaching the banked section, and diagram B shows the front view of a bicycle moving out of the page as it rounds the banked bend.

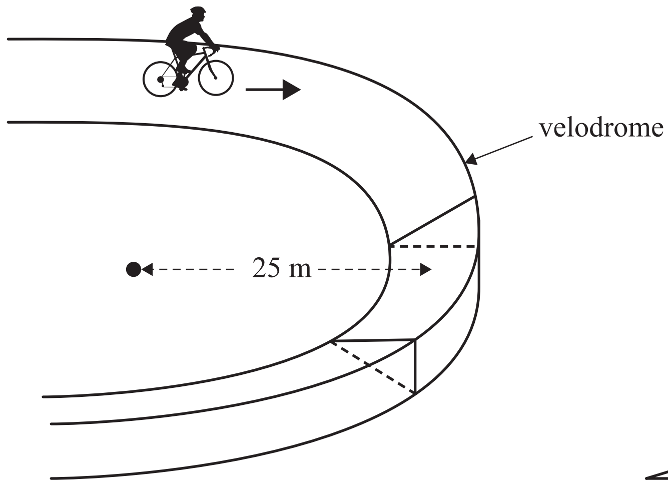


Diagram A

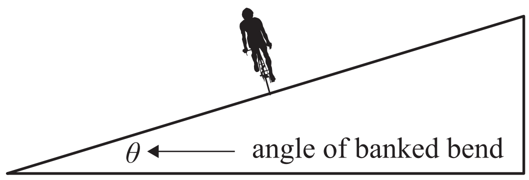


Diagram B

The bicycle is travelling at 11 m s^{-1} on the banked section. At this speed there are no sideways frictional forces between the wheels and the road surface.

Which one of the following is closest to the angle of the banked bend?

A. 2.6°

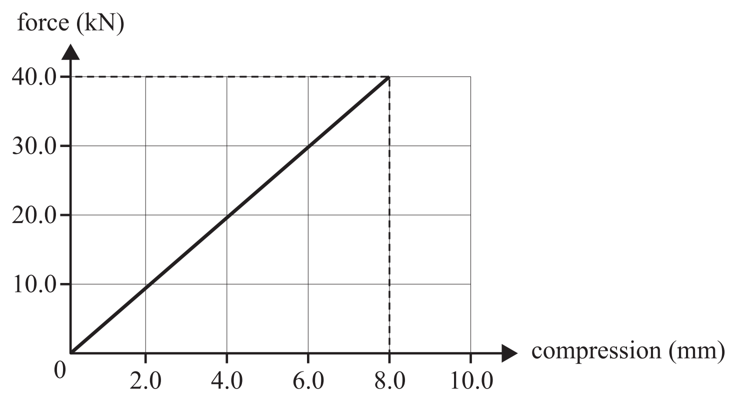
B. 10°

C. 26°

D. 30°

Use the following information to answer Questions 10 and 11.

A force versus compression graph for a car spring is shown below.



Question 10

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

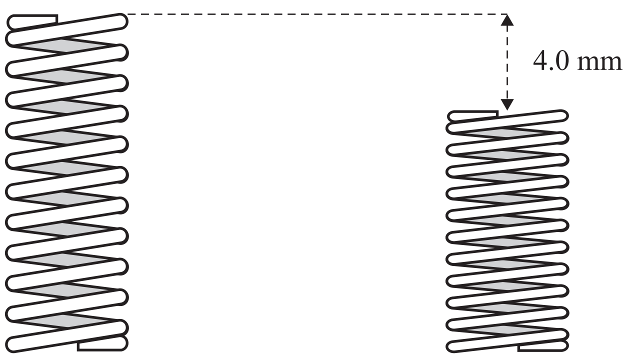
A. 5.0 N m^{-1}

B. 5.0×10^3 N m^{-1}

C. 5.0×10^5 N m^{-1}

D. 5.0×10^6 N m^{-1}

When the car is sitting on a level surface, the car spring is compressed by 4.0 mm from its natural length, as shown below.



natural length of car spring **car spring compressed by 4.0 mm**

As the car goes over a bump in the road, the car spring compresses an additional 4.0 mm from the initial compression of 4.0 mm, to a total compression of 8.0 mm.

Question 11

Which one of the following is closest to the additional potential energy stored in the car spring when the car goes over the bump?

A. 4.0×10^1 J

B. 1.2×10^2 J

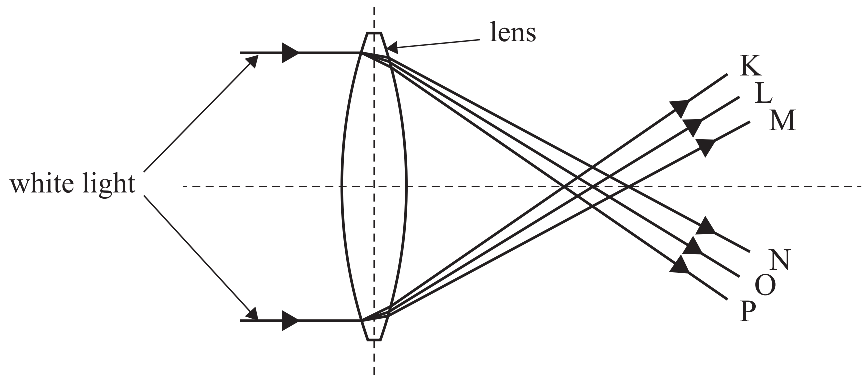
C. 1.6×10^2 J

D. 3.2×10^2 J

SECTION A – continued

Question 12

A physics class is investigating the dispersion of white light using a lens, as shown in the diagram below.



The students observe the rays K–P that have been refracted by the lens.

Which one of the following correctly identifies the colour, red (R), green (G) or violet (V), of the rays K–P?

	K	L	M	N	O	P
A.	R	G	V	V	G	R
B.	V	G	R	R	G	V
C.	V	G	R	V	G	R
D.	V	R	G	G	R	V

Question 13

A physics student hears a clap of thunder shortly after observing a flash of lightning.

Which one of the following statements best describes the sound associated with the clap of thunder and the visible light associated with the flash of lightning?

A. Both the sound and the visible light are examples of transverse waves.

B. Both the sound and the visible light are examples of longitudinal waves.

C. Sound is an example of a transverse wave and visible light is an example of a longitudinal wave.

D. Sound is an example of a longitudinal wave and visible light is an example of a transverse wave.

Question 14

Polarisation of visible light provides evidence that electromagnetic radiation can be explained using a

A. standing wave model for light.

B. transverse wave model for light.

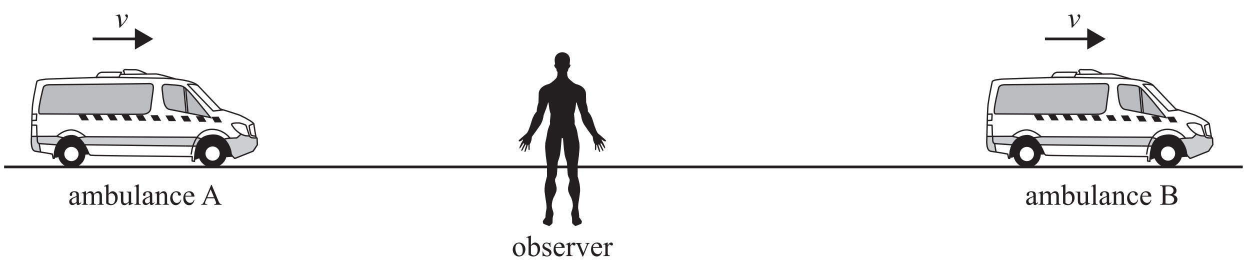
C. mechanical wave model for light.

D. longitudinal wave model for light.

Question 15

Two ambulances, A and B, are travelling along a straight road, both with the same constant velocity, *v*. Both ambulances have their sirens on and the sounds produced are identical and have a constant frequency.

Ambulance A is travelling directly towards a stationary observer, while ambulance B is travelling directly away from the stationary observer, as shown in the diagram below.



Which one of the following best describes the frequency of each siren as measured by the stationary observer, compared to the frequency the observer would measure if the ambulances were stationary?

A. The observer measures each siren's frequency to be lower.

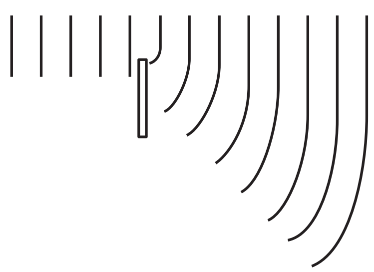
B. The observer measures each siren's frequency to be higher.

C. The observer measures the frequency of ambulance A's siren to be lower and the frequency of ambulance B's siren to be higher.

D. The observer measures the frequency of ambulance A's siren to be higher and the frequency of ambulance B's siren to be lower.

Question 16

Water waves travelling at constant speed and hitting a barrier can change direction, as shown in the diagram below.



Which one of the following best identifies this phenomenon?

A. diffraction

B. dispersion

C. refraction

D. resonance

Question 17

Which one of the following statements best explains why it is possible to compare X-ray and electron diffraction patterns?

A. X-rays can exhibit particle-like properties.

B. Electrons can exhibit wave-like properties.

C. Electrons are a form of high-energy X-rays.

D. Both electrons and X-rays can ionise matter.

Question 18

Which one of the following statements best describes the type of light produced from different types of light sources?

A. Light from a laser is coherent and has a very narrow range of wavelengths.

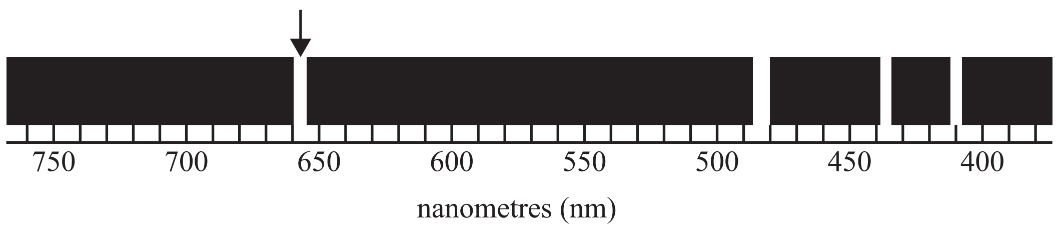
B. Light from an incandescent lamp is coherent and has a range of wavelengths.

C. Light from an incandescent lamp is incoherent and has a very narrow range of wavelengths.

D. Light from a single-colour light-emitting diode (LED) is coherent and contains a very wide range of wavelengths.

Question 19

The diagram below shows the spectrum of light emitted by a hydrogen vapour lamp. The spectral line indicated by the arrow on the diagram is in the visible region of the spectrum.



Which one of the following is closest to the frequency of the light corresponding to the spectral line indicated by the arrow?

A. 6.5×10^{2} Hz

B. 4.6×10^{14} Hz

C. 6.5×10^{14} Hz

D. 4.6×10^{16} Hz

Question 20

Heisenberg's uncertainty principle can be used to explain the results of single-slit diffraction experiments for electrons.

This is because Heisenberg's uncertainty principle

A. fixes the size range of the slit to be used.

B. states that each electron's exact position was predictable after passing through the slit.

C. states that each electron's actual position after passing though the slit was only known within a wide range.

D. states that if the electron's momentum was known, its position after passing through the slit was also known.

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 (7 marks)

Some physics students are conducting an experiment investigating both electrostatic and gravitational forces. They suspend two equally charged balls, each of mass 4.0 g, from light, non-conducting strings suspended from a low ceiling.

The charged balls repel each other with the strings at an angle of 60°, as shown in Figure 1.

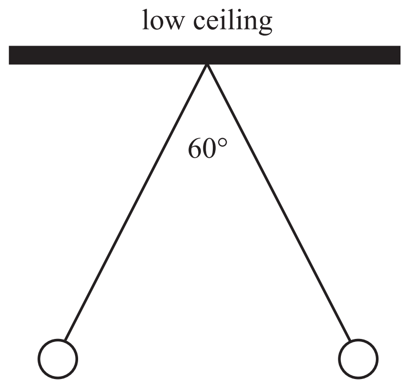


Figure 1

There are three forces acting on each ball:

- a tension force, T
- a gravitational force, F_g
- an electrostatic force, F_E.

a. On Figure 1, using the labels T, F_g and F_E, draw each of the three forces acting on each of the charged balls. 3 marks

b. Show that the tension force, T, in each string is 4.5×10^{-2} N. Use $g = 9.8\ \text{N kg}^{-1}$.
Show your working. 2 marks

c. Calculate the magnitude of the electrostatic force, F_E. Show your working. 2 marks

N

DO NOT WRITE IN THIS AREA

Question 2 (7 marks)

Phobos is a small moon in a circular orbit around Mars at an altitude of 6000 km above the surface of Mars. The gravitational field strength of Mars at its surface is 3.72 N kg^{-1}. The radius of Mars is 3390 km.

a. Show that the gravitational field strength 6000 km above the surface of Mars is 0.48 N kg^{-1}. 2 marks

b. Calculate the orbital period of Phobos. Give your answer in seconds. 3 marks

s

c. Phobos is very slowly getting closer to Mars as it orbits.

Will the orbital period of Phobos become shorter, stay the same or become longer as it orbits closer to Mars? Explain your reasoning. 2 marks

DO NOT WRITE IN THIS AREA

Question 3 (5 marks)

Two long, straight current-carrying wires, P and Q, are parallel, as shown in Figure 2a. The current in the wires is the same in magnitude and opposite in direction.

Figure 2b shows the wires as viewed from above.

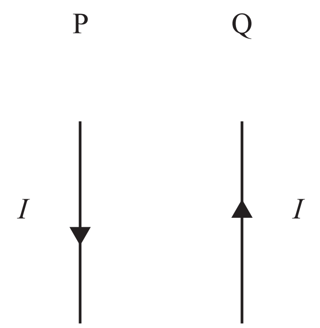


Figure 2a – Front view

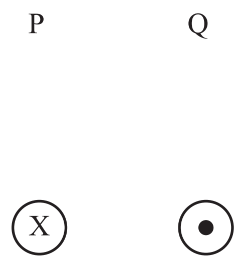


Figure 2b – Top view

a. On Figure 2b, sketch the magnetic field around the wires, showing the direction of the magnetic field. Use at least five field lines. 3 marks

b. Do the two wires, P and Q, attract or repel each other? Explain your reasoning. 2 marks

Question 4 (5 marks)

A transformer is used to provide a low-voltage supply for six outdoor garden globes. The circuit is shown in Figure 3. Assume there is no power loss in the connecting wires. All voltage values are RMS values.

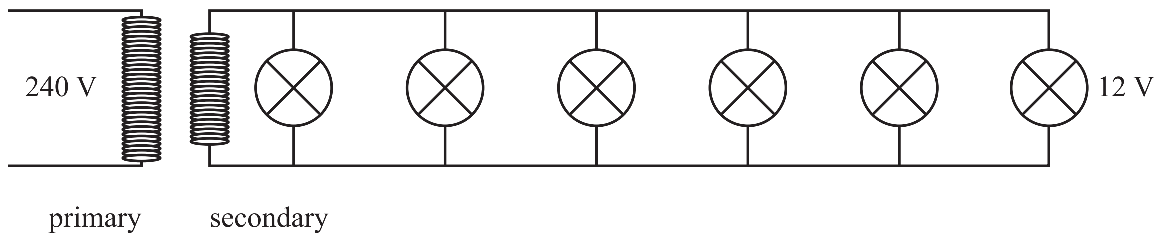


Figure 3

The input of the transformer is connected to a power supply that provides an AC voltage of 240 V. The globes in the circuit are designed to operate with an AC voltage of 12 V. Each globe is designed to operate with a power of 20 W.

a. Assuming that the transformer is ideal, calculate the ratio of primary turns to secondary turns of the transformer. 1 mark

The globes are turned on.

b. Calculate the current in the primary coil of the transformer. 2 marks

A

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

c. Explain why the input current to the primary coil of the transformer must be AC rather than constant DC for the globes to shine. 2 marks

Question 5 (3 marks)

Figure 4a shows a single square loop of conducting wire placed just outside a constant uniform magnetic field, *B*. The length of each side of the loop is 0.040 m. The magnetic field has a magnitude of 0.30 T and is directed out of the page.

Over a time period of 0.50 s, the loop is moved at a constant speed, *v*, from completely outside the magnetic field, Figure 4a, to completely inside the magnetic field, Figure 4b.

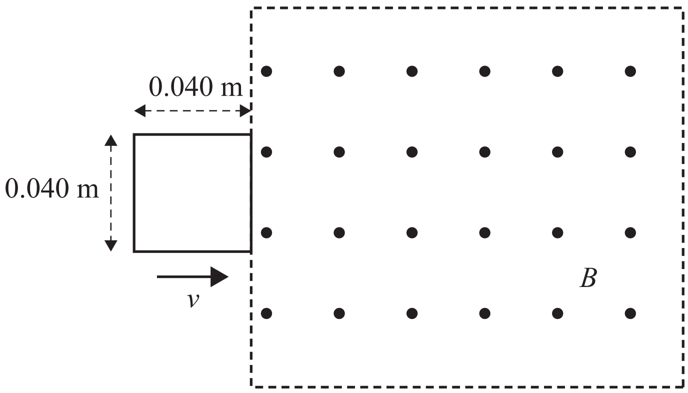


Figure 4a

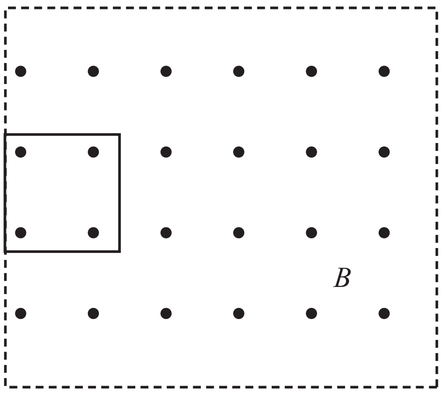


Figure 4b

a. Calculate the average EMF produced in the loop as it moves from the position just outside the region of the field, Figure 4a, to the position completely within the area of the magnetic field, Figure 4b. Show your working. 2 marks

V

DO NOT WRITE IN THIS AREA

b. On the small square loop in Figure 5, show the direction of the induced current as the loop moves into the area of the magnetic field. 1 mark

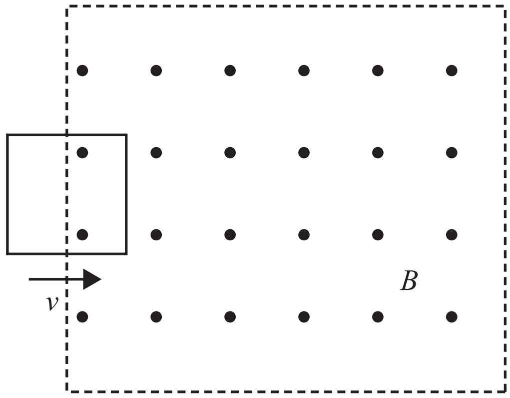


Figure 5

Question 6 (3 marks)

Kim and Charlie are attempting to create a DC generator and have arranged the magnets along the axis of rotation of the wire loop, J, K, L and M, as shown in Figure 6. They are having some trouble getting it to work. They rotate the loop in the direction of the arrow, as shown in Figure 6.

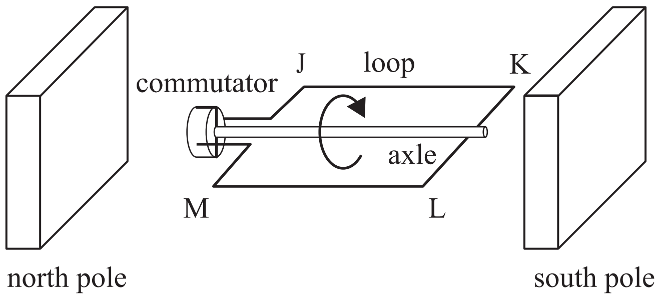


Figure 6

a. Using physics concepts, explain why this orientation of the magnets will not generate an EMF. 2 marks

b. Kim and Charlie decide to move the magnets so that an EMF is generated. On Figure 6, draw the positions of the magnets to ensure that an EMF is generated. 1 mark

DO NOT WRITE IN THIS AREA

CONTINUES OVER PAGE

Question 7 (7 marks)

Two high-voltage transmission lines span a distance of 260 km between Power Plant A and Town B, as shown in Figure 7. Power Plant A provides 350 MW of power. The potential difference at Power Plant A is 500 kV. The current in the transmission lines has an RMS value of 700 A and the power loss in the transmission lines is 20 MW.

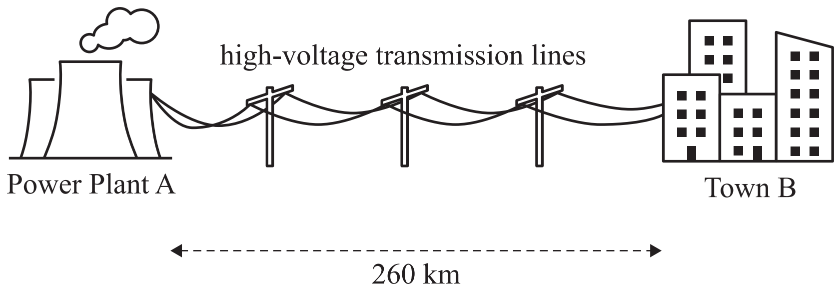


Figure 7

a. Show, using calculations, that the total resistance of the two transmission lines is 41 Ω. 2 marks

DO NOT WRITE IN THIS AREA

b. Town B needs a minimum of 480 kV.

Determine whether 480 kV will be available to Town B. Show your working. 3 marks

c. Explain what would happen if the electricity between Power Plant A and Town B were to be transmitted at 50 kV instead of 500 kV. Assume that the resistance of the transmission lines is still 41 Ω. 2 marks

Question 8 (7 marks)

Maia is at a skatepark. She stands on her skateboard as it rolls in a straight line down a gentle slope at a constant speed of 3.0 m s^{-1}, as shown in Figure 8. The slope is 5° to the horizontal.

The combined mass of Maia and the skateboard is 65 kg.

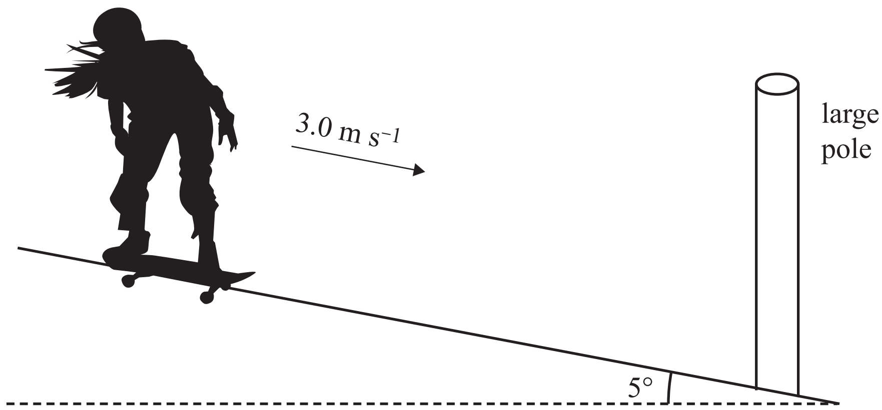


Figure 8

a. In Figure 9, the combined system of Maia and the skateboard is modelled as a small box with point M at the centre of mass.

Draw and label arrows to represent each of the forces acting on the system – that is, Maia and skateboard, as they roll down the slope. 3 marks

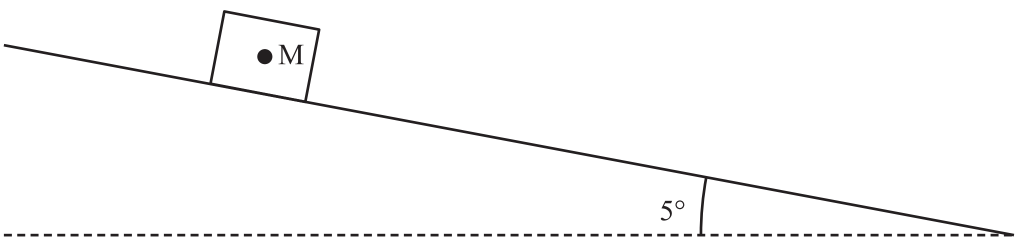


Figure 9

b. Calculate the magnitude of the total frictional forces acting on Maia and the skateboard. 2 marks

N

DO NOT WRITE IN THIS AREA

Near the bottom of the ramp, Maia takes hold of a large pole and comes to a complete rest while still standing on the skateboard. Maia and the skateboard now have no momentum or kinetic energy.

c. Explain what happened to both the momentum and the kinetic energy of Maia and the skateboard. No calculations are required. 2 marks

Question 9 (7 marks)

Giorgos is practising his tennis serve using a tennis ball of mass 56 g.

a. Giorgos practises throwing the ball vertically upwards from point A to point B, as shown in Figure 10. His daughter Eka, a physics student, models the throw, assuming that the ball is at the level of Giorgos's shoulder, point A, both when it leaves his hand and also when he catches it again. Point A is 1.8 m from the ground. The ball reaches a maximum height, point B, 1.8 m above Giorgos's shoulder.

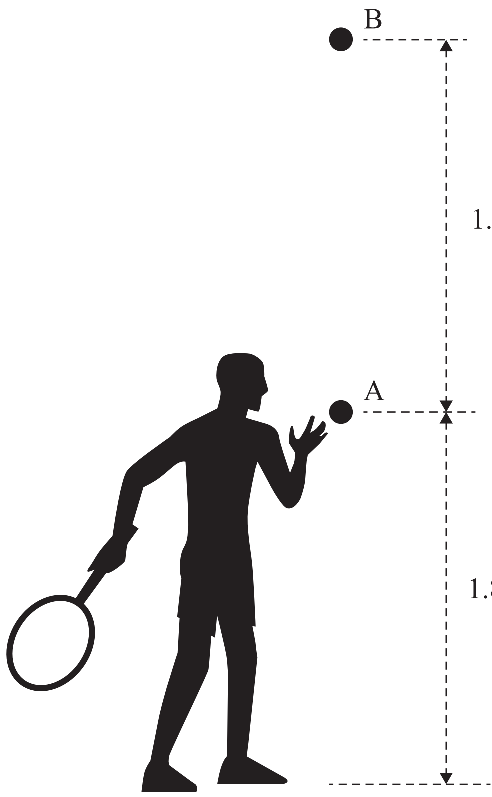


Figure 10

Show that the ball is in the air for 1.2 s from the time it leaves Giorgos's hand, which is level with his shoulder, until he catches it again at the same height. 2 marks

b. Giorgos swings his racquet from point D through point C, which is horizontally behind him at shoulder height, as shown in Figure 11, to point B. Eka models this swing as circular motion of the racquet head. The centre of the racquet head moves with constant speed in a circular arc of radius 1.8 m from point C to point B.

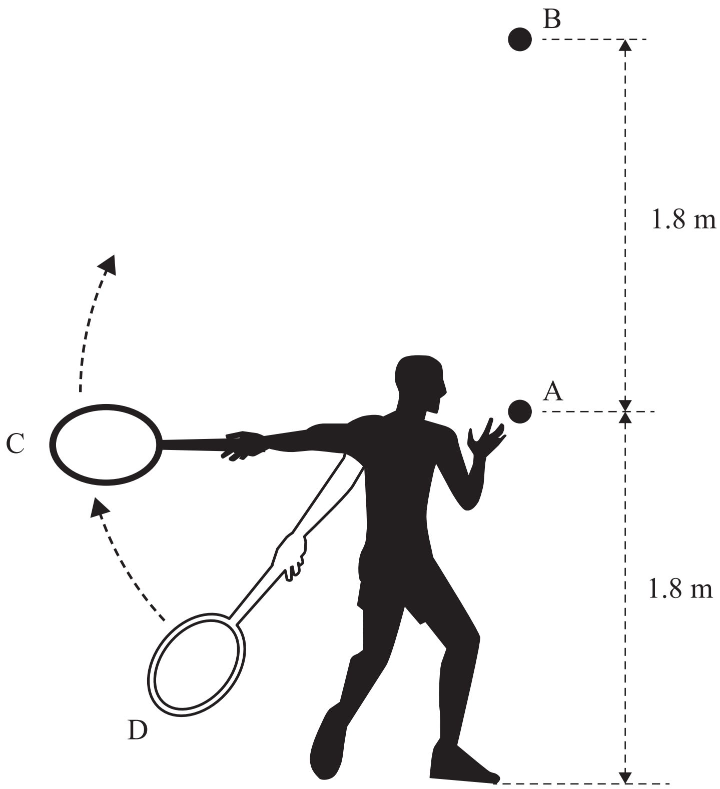


Figure 11

The racquet passes point C at the same time that the ball is released at point A and then the racquet hits the ball at point B.

Calculate the speed of the racquet at point C. 2 marks

m s^{-1}

c. The ball leaves Giorgos's racquet with an initial speed of 24 m s^{-1} in a horizontal direction, as shown in Figure 12. A tennis net is located 12 m in front of Giorgos and has a height of 0.90 m.

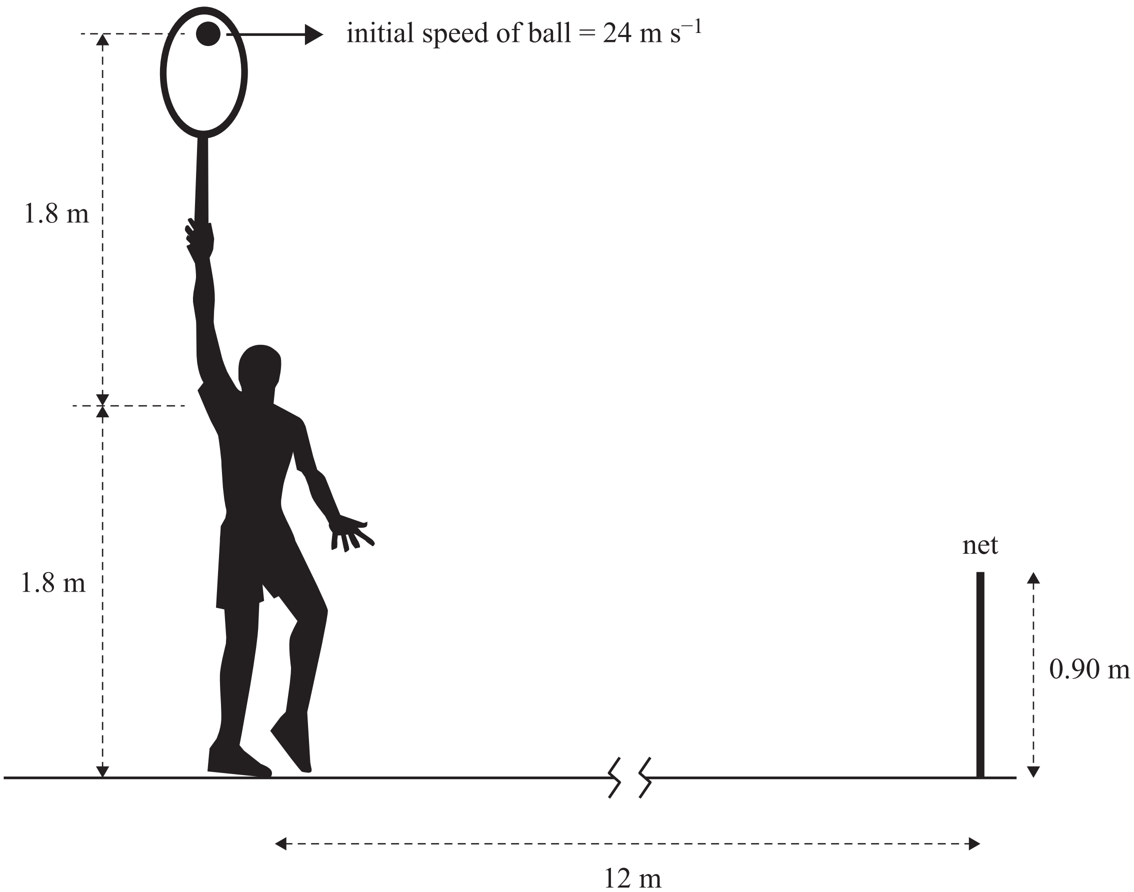


Figure 12

How far above the net will the ball be when it passes above the net? Assume that there is no air resistance. Show your working. 3 marks

m

DO NOT WRITE IN THIS AREA

Question 10 (6 marks)

A proton in an accelerator beamline of proper length 4.80 km has a Lorentz factor, γ, of 2.00.

a. Calculate the speed of the proton relative to the beamline in terms of *c*, the speed of light in a vacuum. Give your answer to three significant figures. 3 marks

b. Calculate the length of the beamline in the reference frame of the proton. 1 mark

km

c. Calculate the kinetic energy of the proton in joules. Show your working.

Mass of proton = 1.67×10^{-27} kg. 2 marks

J

Question 11 (3 marks)

A guitar string of length 0.75 m and fixed at both ends is plucked and a standing wave is produced.

The envelope of the standing wave is shown in Figure 13.

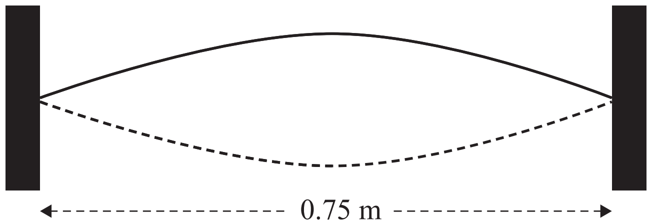


Figure 13

The speed of the wave along the string is 393 m s^{-1}.

a. What is the frequency of the wave? 1 mark

Hz

b. Describe how the standing wave is produced on the string fixed at both ends. 2 marks

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question 12 (4 marks)

A ray of monochromatic light is incident on a triangular glass prism with a refractive index of 1.52. The ray is perpendicular to the side AB of the glass prism, as shown in Figure 14.

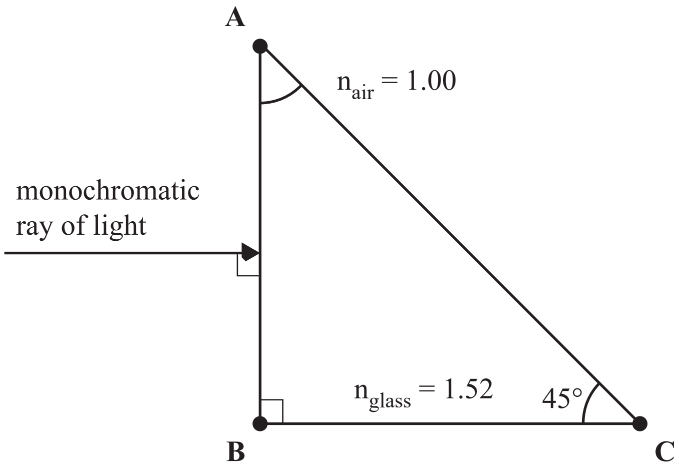


Figure 14

The ray of light travels through the glass prism before reaching side AC.

a. Calculate the critical angle for the glass prism at the glass–air interface. 2 marks

°

b. Will the ray of light undergo total internal reflection at side AC of the glass prism? Justify your answer. 2 marks

Question 13 (6 marks)

A group of physics students undertake a Young's double-slit experiment using the apparatus shown in Figure 15. They use a green laser that produces light with a wavelength of 510 nm. The light is incident on two narrow slits, S_1 and S_2. The distance between the two slits is 100 μm.

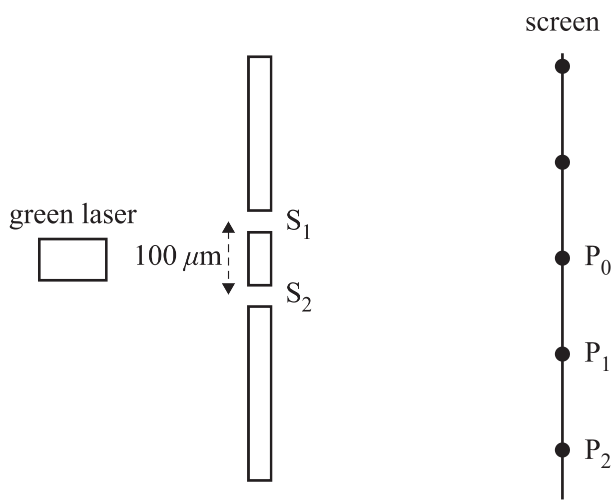


Figure 15

An interference pattern is observed on a screen with points P_0, P_1 and P_2 being the locations of adjacent bright bands, shown in Figure 15. Point P_0 is the central bright band.

a. Calculate the path difference between S_1P_2 and S_2P_2. Give your answer in metres. Show your working. 2 marks

m

b. The green laser is replaced by a red laser.

Describe the effect of this change on the spacing between adjacent bright bands. 1 mark

DO NOT WRITE IN THIS AREA

c. Explain how Young's double-slit experiment provides evidence for the wave-like nature of light and not the particle-like nature of light. 3 marks

Question 14 (6 marks)

Neutrons are subatomic particles and, like electrons, they can exhibit both particle-like and wave-like behaviour. Ignore any relativistic effects.

A beam of neutrons that can be used for scientific experiments is produced by a nuclear research reactor.

The mass of a neutron is 1.67×10^{-27} kg.

The de Broglie wavelength of the neutrons produced by the nuclear reactor is 3.02×10^{-10} m.

a. Calculate the speed of the neutrons. 2 marks

m s^{-1}

b. The neutron beam is sent through a crystal with an interatomic spacing of 3.62×10^{-10} m.

Would you expect to observe a diffraction pattern? Justify your answer. 2 marks

c. Consider an electron beam with the same de Broglie wavelength as the neutron beam, 3.02×10^{-10} m.

Which will have the greater speed: an electron in the electron beam or a neutron in the neutron beam? Justify your answer. 2 marks

DO NOT WRITE IN THIS AREA

Question 15 (8 marks)

In a photoelectric effect experiment, a team of physics students investigated the relationship between the maximum kinetic energy of ejected electrons and the frequency of the light incident on calcium metal. Their results are shown in Figure 16.

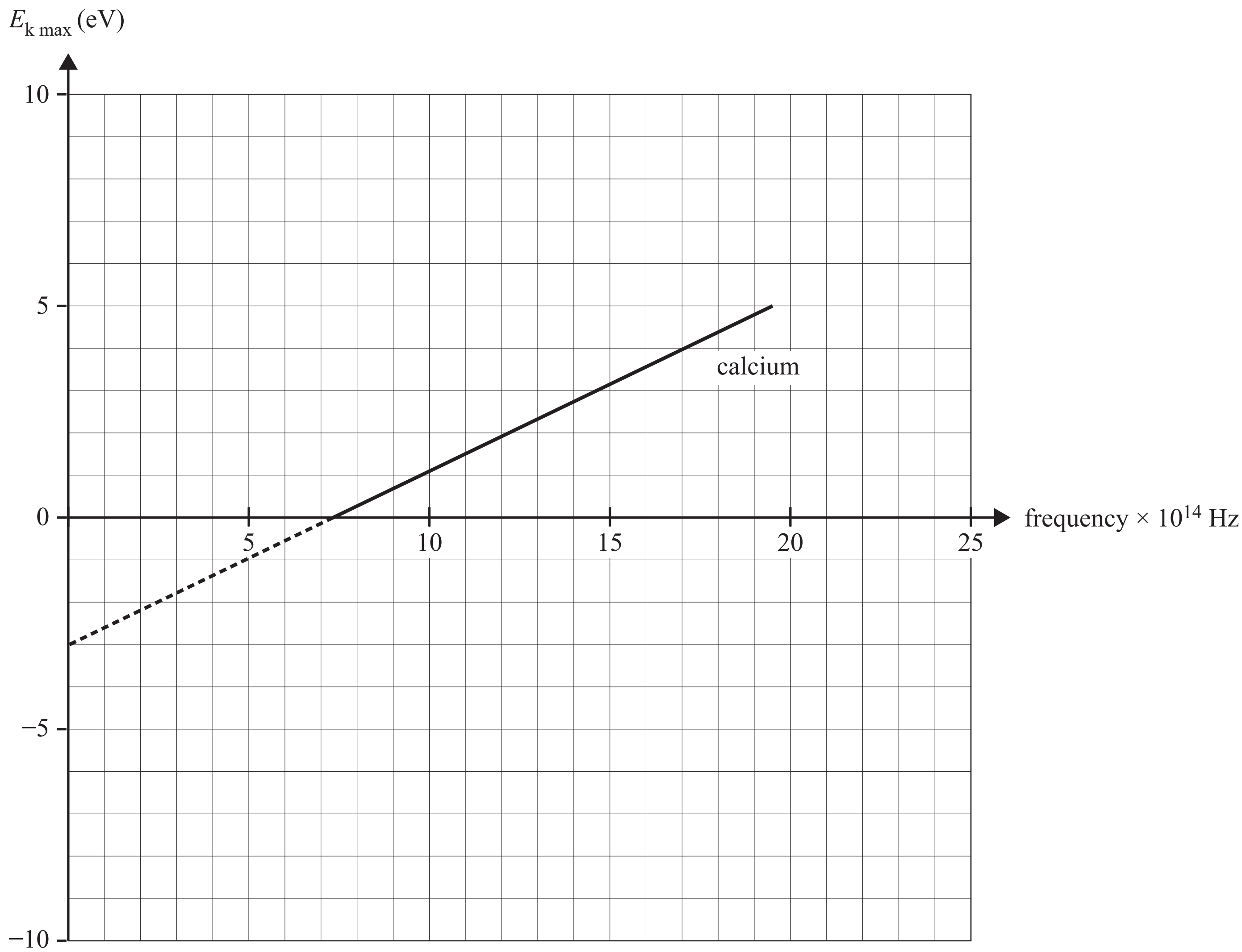


Figure 16

a. Using data from the graph in Figure 16, estimate the work function for calcium. 1 mark

____

eV

b. Using data from the graph in Figure 16, determine the maximum wavelength of the light that can emit photoelectrons from the calcium surface. 2 marks

m

The calcium metal was replaced with copper metal with a work function of 4.70 eV.

c. On the grid in Figure 16, draw the graph that would result when the calcium metal was replaced with copper metal. 2 marks

d. The copper metal is illuminated by photons of wavelength 380 nm.

Will photoelectrons be ejected? Justify your answer using a calculation and any relevant data from the graph in Figure 16. 3 marks

DO NOT WRITE IN THIS AREA

Question 16 (6 marks)

Fluorescent lights, when operating, contain gaseous mercury atoms, as shown in Figure 17.

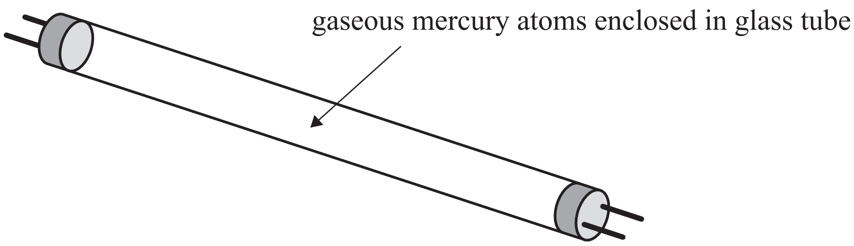


Figure 17

Analysis of the light produced by fluorescent lights shows a number of emission spectral lines, including a prominent line representing a wavelength of 436.6 nm.

a. Calculate the energy of the photons represented by the emission spectral line representing a wavelength of 436.6 nm. 2 marks

eV

DO NOT WRITE IN THIS AREA

Figure 18 shows the lowest five energy levels for mercury.

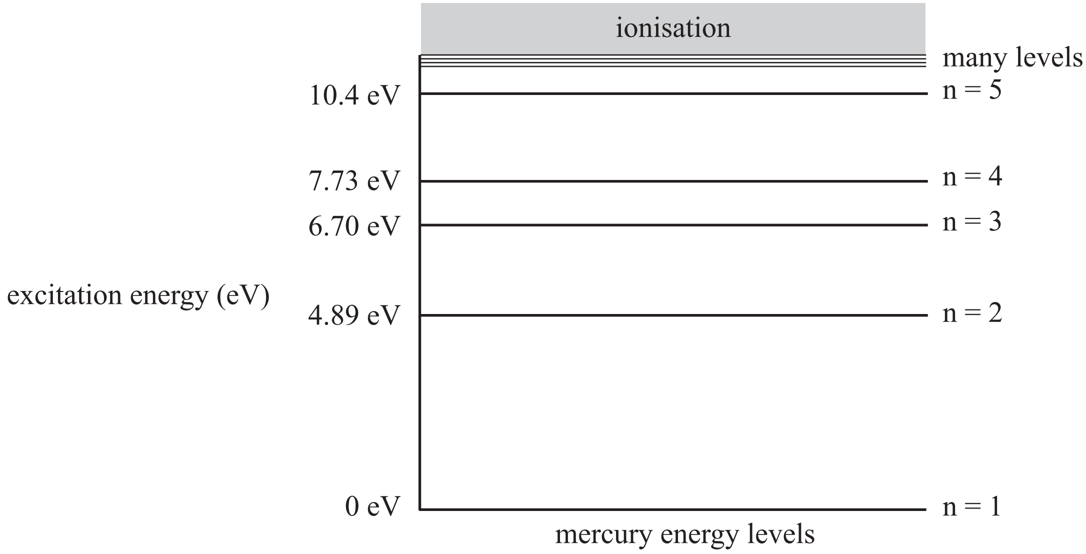


Figure 18

b. On the energy level diagram in Figure 18, draw an arrow showing the energy level transition that corresponds to the production of the spectral line representing a wavelength of 436.6 nm. 1 mark

c. A 6.7 eV photon is absorbed by a mercury atom in the ground state and then the atom transitions back to the ground state.

Identify the energies, in eV, of all the possible photons that could be produced. 3 marks

Question 17 (20 marks)

JJ Thomson discovered electrons in 1897. He used evacuated cathode ray tubes to determine the ratio of electric charge to mass of these rays, which we now know were electrons.

Modern-day physics students plan an experiment to measure the ratio of the charge, *e*, to the mass, *m*, of electrons. This can be written as *e/m.* The apparatus they use is shown schematically in Figure 19.

An electron gun ejects a beam of electrons horizontally from the left side of the apparatus through the evacuated glass tube. A fluorescent screen displays the path the electrons take.

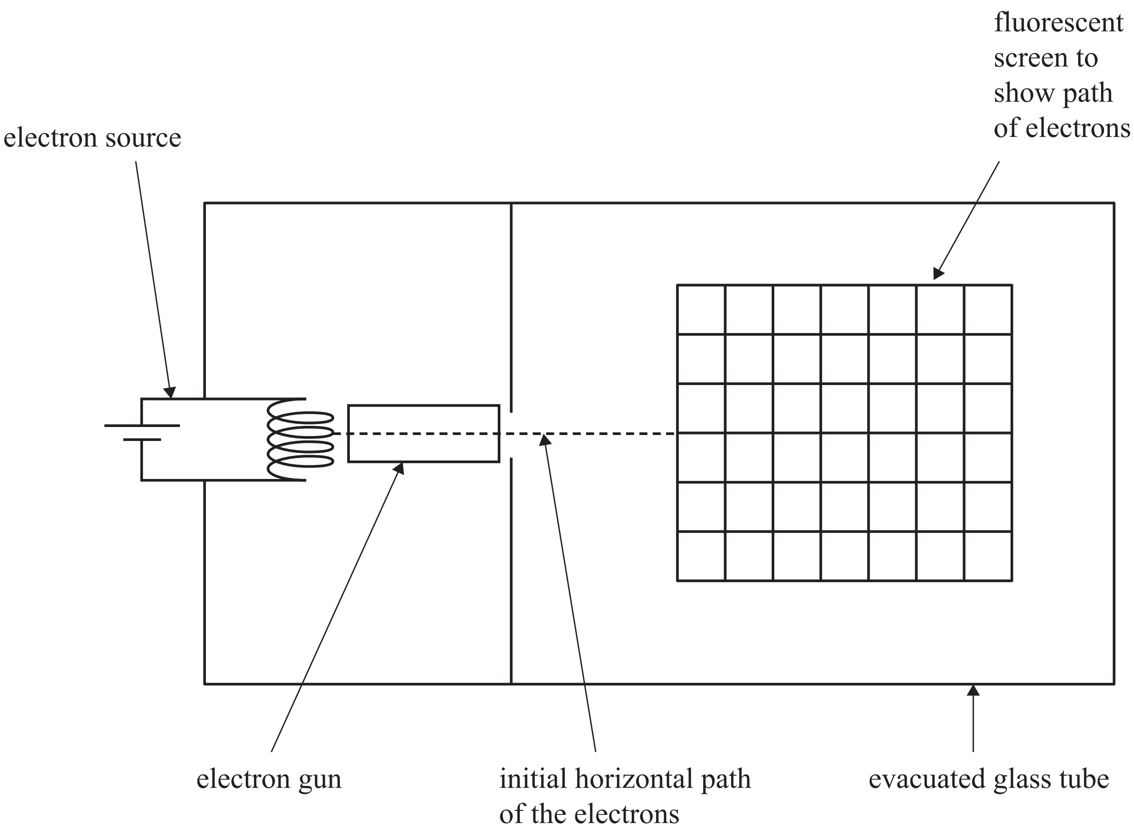


Figure 19

The electron gun can be modelled as shown in Figure 20. Electrons are produced at the electron source and accelerated between plate A and plate B.

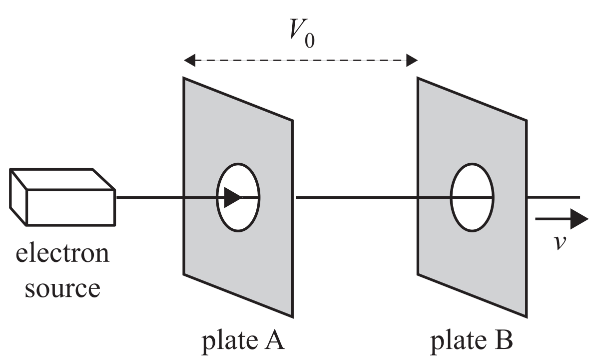


Figure 20

Electrons reach plate A with negligible speed and are accelerated by the potential difference between the plates, V_0, emerging from plate B with speed, v.

a. Write an equation that gives the speed, v, in terms of potential difference, V_0, the electron mass, m, and the electron charge, e. Assume that v is much less than the speed of light, c. 1 mark

b. A uniform magnetic field, B, directed into the page, is applied to the region of the fluorescent screen and the electrons follow a circular arc of radius, r; as shown in Figure 21.

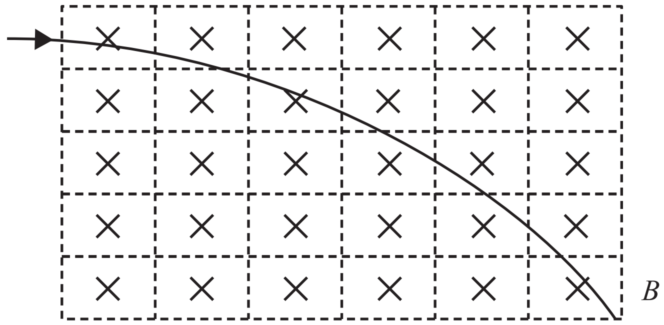


Figure 21

Explain why the path followed by the electrons is a circular arc. 2 marks

c. Write an equation that represents the relationship between the electron mass, m, the electron charge, e, the electron speed, v, the magnetic field, B, and the radius, r, of the circular arc. 1 mark

The equations in **part a.** and **part c.** can be combined to show that

$$V_0 = \frac{eB^2}{2m} r^2$$

(Do not attempt to derive this equation.)

The physics students planning the experiment keep the uniform magnetic field constant at 2.0 mT. They vary the voltage, V_0, and measure the resulting radius, r, of the circular path of the electrons.

d. Identify the independent variable, the dependent variable and one controlled variable. 2 marks

independent variable:

dependent variable:

controlled variable:

e. The table below shows the values of V_0 and r measured by the students. Complete the missing values of r^2 in the table. 2 marks

V_0 (volts)	r (m)	r^2 (m^2)
500	0.036	0.0013
1000	0.052	
1500	0.059	
2000	0.072	

f. On the grid below:

- Plot the values of V_0 on the y-axis and the corresponding value of r^2 on the x-axis. Include a point for $V_0 = 0$.
- Label the axes correctly.
- Add an uncertainty of +/– 0.0002 to the r^2 values.
- Draw a straight line of best fit through the plotted points. 7 marks

g. Using the graph produced in **part f.**, calculate the gradient of the line of best fit. Show your working. 2 marks

$\mathrm{V\ m^{-2}}$

h. Use the value of the gradient found in **part g.** to find a value for *e/m*. Show your working. 3 marks

$\mathrm{C\ kg^{-1}}$

DO NOT WRITE IN THIS AREA

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	$v = \dfrac{\Delta s}{\Delta t}; \quad a = \dfrac{\Delta v}{\Delta t}$
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	$t = t_o\gamma$
length contraction	$L = \dfrac{L_o}{\gamma}$
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	$E = \frac{V}{d}$
energy transformations of charges in an electric field	$\frac{1}{2}mv^2 = qV$
field of a point charge	$E = \frac{kq}{r^2}$
force on an electric charge	$F = qE$
Coulomb's law	$F = \frac{kq_1q_2}{r^2}$
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	$r = \frac{mv}{qB}$

Generation and transmission of electricity

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

Wave concepts

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