2024 NHT

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

Write your **student number** in the boxes above. **Letter**

Physics

Question and Answer Book

VCE (NHT) Examination – Monday 27 May 2024

- Reading time is **15 minutes**: 10.30 am to 10.45 am
- Writing time is **2 hours 30 minutes**: 10.45 am to 1.15 pm

Approved materials

- One scientific calculator
- Pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape)

Materials supplied

- Question and Answer Book of 52 pages
- Formula Sheet
- Multiple-Choice Answer Sheet

Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.

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

Contents

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Section A – Multiple-choice questions

Instructions

- Answer **all** questions in pencil on the Multiple-Choice Answer Sheet.
- 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

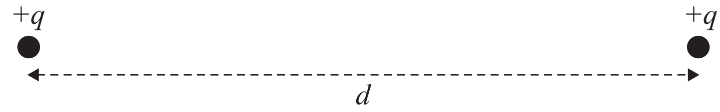
Electric and gravitational forces have a variety of properties.

Which one of the following best describes the attraction and repulsion properties of electric and gravitational forces?

	Electric forces	Gravitational forces
A.	either attract or repel	only attract
B.	only repel	neither attract nor repel
C.	only attract	only attract
D.	either attract or repel	either attract or repel

Question 2

Two positive isolated electric charges, each carrying a charge of $+q$, are separated by a distance, d, and exert an electrical force, F, on each other.



To decrease the electrical force to $\frac{F}{5}$, the separation of the charges would have to change to

A. $\frac{d}{5}$

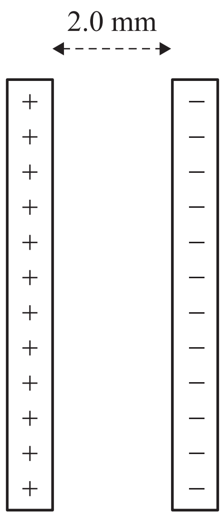
B. $\frac{d}{\sqrt{5}}$

C. $\sqrt{5}d$

D. $5d$

Question 3

Two large charged plates with equal and opposite charges are placed close together, as shown in the diagram below. A distance of 2.0 mm separates the plates. The potential difference between the plates is 6.0 V.



Which one of the following is closest to the electric field between the plates?

A. $3.0\ \mathrm{N\,C^{-1}}$

B. $12\ \mathrm{N\,C^{-1}}$

C. $3.0 \times 10^{2}\ \mathrm{N\,C^{-1}}$

D. $3.0 \times 10^{3}\ \mathrm{N\,C^{-1}}$

Question 4

Two satellites in circular orbits around Earth have the same mass but are travelling at different speeds.
This means that

A. they orbit Earth at different radii.

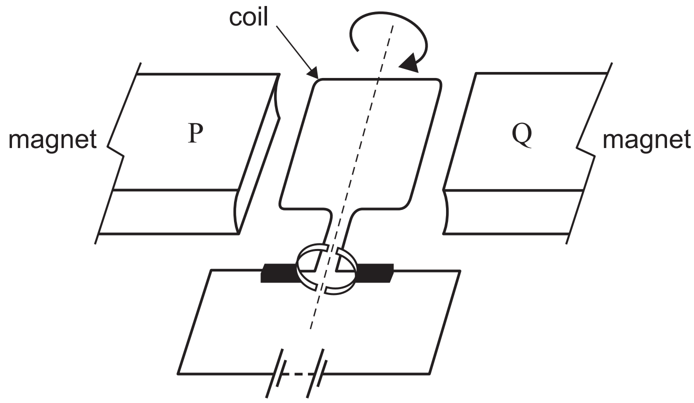
B. they will have the same kinetic energy.

C. they orbit Earth with the same period.

D. the gravitational force exerted on them by Earth will be the same.

Question 5

Students construct a simple DC motor using two magnets, a single coil of wire, a split-ring commutator and a battery, as shown in the diagram below. The coil turns clockwise, as seen from the battery end of the DC motor.

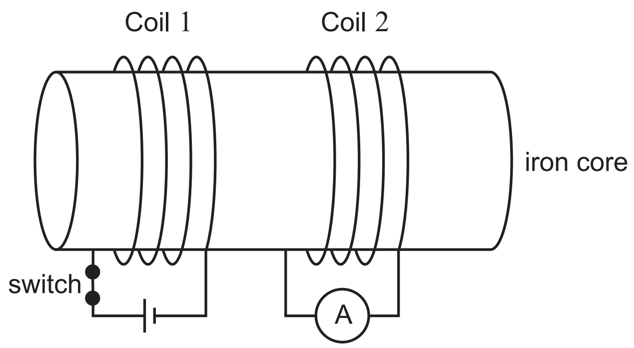


Which of the following pairs best represents the polarity of the magnetic poles P and Q?

	Polarity of P	Polarity of Q
A.	south	south
B.	south	north
C.	north	south
D.	north	north

Question 6

The diagram below shows two coils of conducting wire wound around an iron core. Coil 1 is connected to a battery and a switch. Initially, the switch is closed and current flows through Coil 1. There is an ammeter connected to Coil 2.



The switch is now opened.

Which one of the following statements best describes what happens to the reading on the ammeter?

A. It remains at a constant non-zero reading.

B. It moves from a non-zero reading to a zero reading.

C. It moves from a zero reading to a non-zero reading, then back to a zero reading.

D. It moves from a zero reading to a non-zero reading and remains at a non-zero reading.

Question 7

An ideal step-down transformer has a primary-to-secondary turns ratio of 6:1.

The input power at the primary is 40 W, and the input voltage is AC and has an RMS value of 240 V.

Which one of the following is closest to the output current of the transformer?

A. 0.17 A

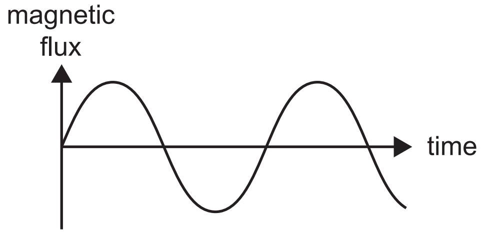
B. 1.0 A

C. 6.0 A

D. 10 A

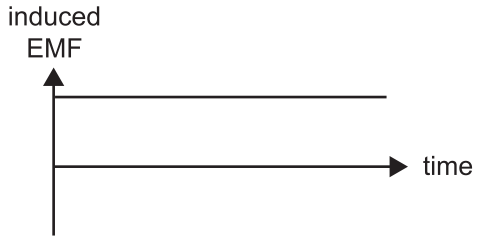
Question 8

The graph below shows the variation in magnetic flux through a coil as a function of time.



Which one of the following graphs best represents the induced EMF in the coil as a function of time?

A.



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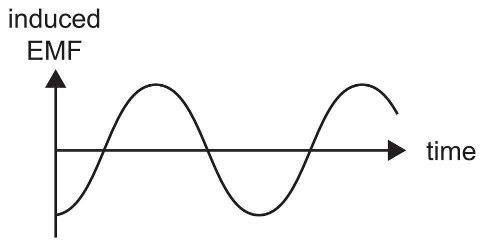

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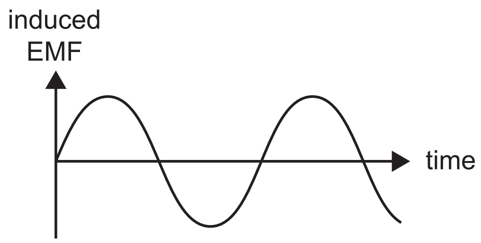

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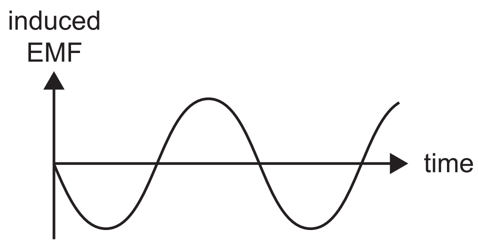
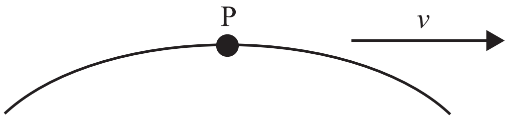


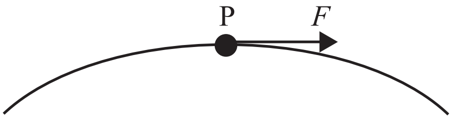
Question 9

A soccer ball is kicked and it moves through the air from left to right, as shown in the diagram below. Point P is the highest point of its flight. Air resistance is **not** negligible.



Which one of the following diagrams best shows the direction of the resultant force on the ball at point P, at maximum height?

A.



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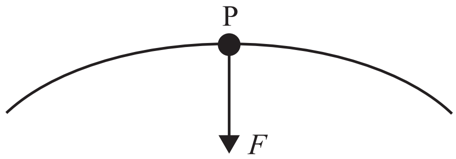

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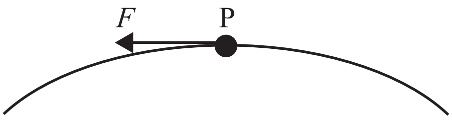
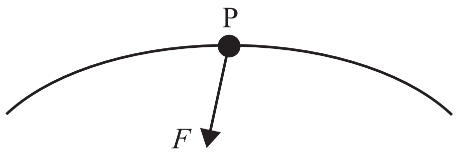
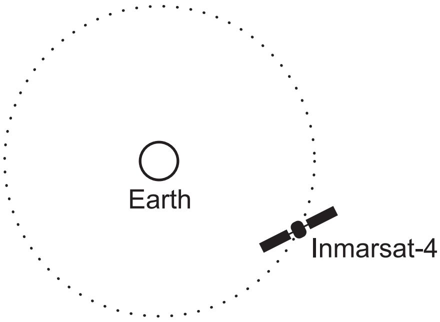


D.



Question 10

The global positioning system (GPS) satellite Inmarsat-4 orbits Earth at an altitude of $35\,786\ \mathrm{km}$. Assume that its orbit is circular.



Which one of the following statements is correct concerning the momentum and the kinetic energy of Inmarsat-4 as it moves around its orbit?

A. Both the kinetic energy and the momentum are constant.

B. Both the kinetic energy and the momentum vary.

C. The kinetic energy is constant and the momentum varies.

D. The kinetic energy varies and the momentum is constant.

Question 11

Which one of the following is **not** a version of a postulate of Einstein's special theory of relativity?

A. The speed of light does not depend on the motion of the source.

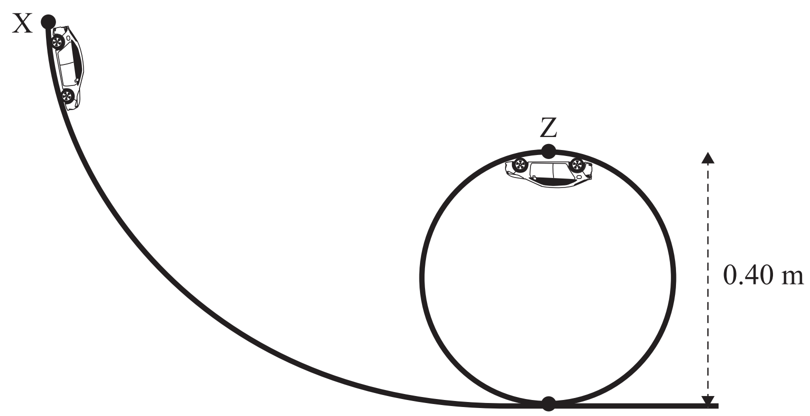
B. The laws of physics are the same in all inertial reference frames.

C. The speed of light does not depend on the motion of the observer.

D. The speed of light is the same at Earth's surface as it is in all transparent materials.

Question 12

A small toy car travels on a track with a vertical circular loop, starting at point X, as shown in the diagram below. The diameter of the loop is $0.40\ \text{m}$.



The minimum speed at which the car must be travelling at point Z (at the top of the loop) in order to continue to touch the track is closest to

A. $0.20\ \text{m s}^{-1}$

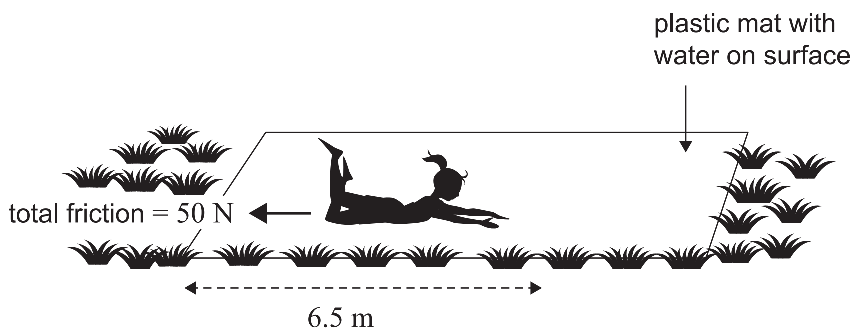
B. $0.40\ \text{m s}^{-1}$

C. $1.4\ \text{m s}^{-1}$

D. $2.0\ \text{m s}^{-1}$

Question 13

Belinda is a child with a mass of $30\ \mathrm{kg}$. She runs along grass and then slides on a horizontal plastic water mat. She comes to rest after sliding $6.5\ \mathrm{m}$. The frictional force between Belinda and the mat is constant and has a value of $50\ \mathrm{N}$.



Which one of the following is closest to the work done by the plastic surface on Belinda, causing her to stop?

A. 325 J

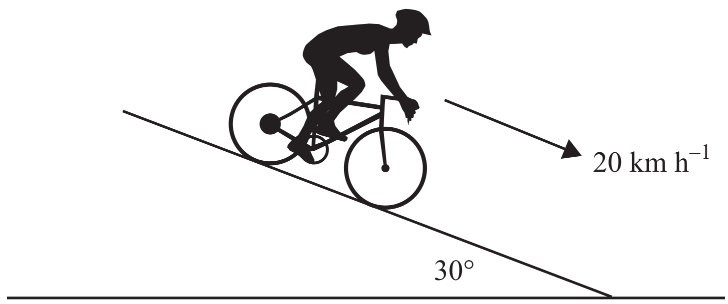
B. 195 J

C. 150 J

D. 32.5 J

Question 14

Helena is riding down a hill on her bicycle. It is a very steep hill, and she has the brakes of her bicycle partially on so that she travels down at a constant speed of $20\ \mathrm{km\ h^{-1}}$. The combined mass of Helena and the bicycle is $60\ \mathrm{kg}$.



Which one of the following is closest to the frictional force acting on the bicycle due to Helena's braking as it moves down the hill?

A. 30 N

B. 300 N

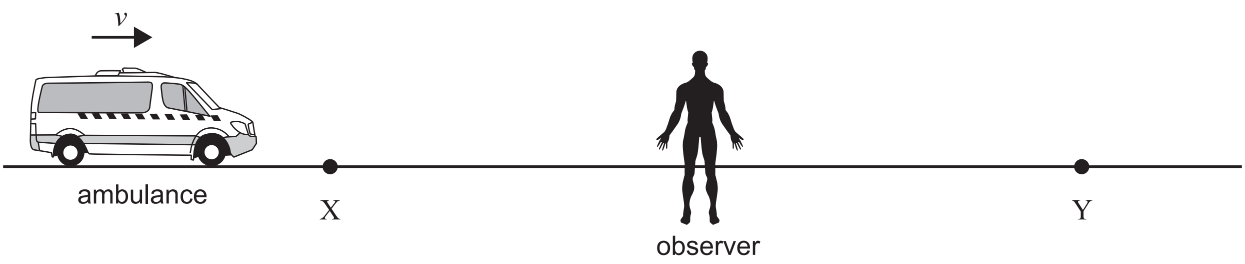
C. 510 N

D. 600 N

Question 15

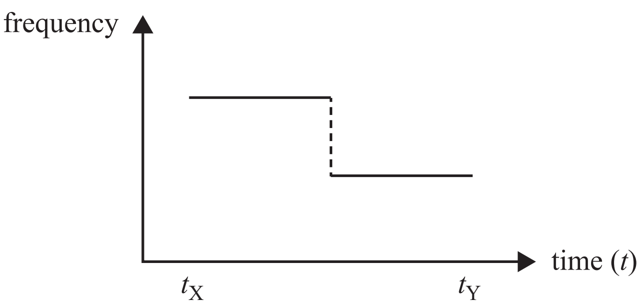
An ambulance, with its siren sounding, is travelling with a constant velocity, v, along a straight road.

Initially the ambulance passes a marker, X, then a stationary observer, and finally a marker, Y, as shown in the diagram below. The observer is located midway between the two markers, X and Y.

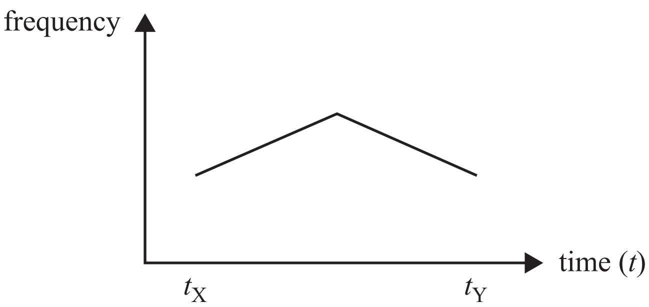


If the siren emits sound with a constant frequency, which one of the following graphs best represents the frequency of the siren as measured by the stationary observer?

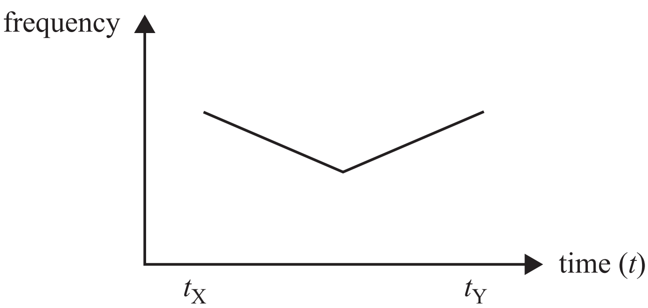
A.



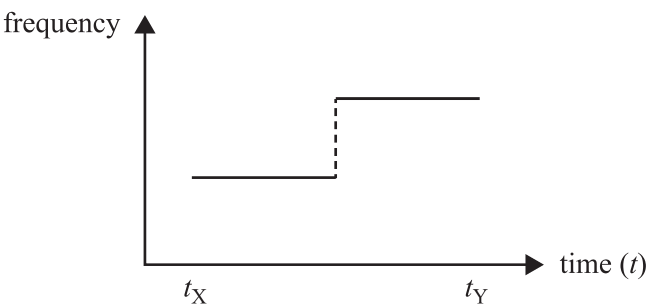
B.



C.



D.



Question 16

Which one of the following correctly lists the different regions of the electromagnetic spectrum in order from longest wavelength to shortest wavelength?

A. X-ray, ultraviolet, visible, infrared, radio, microwave

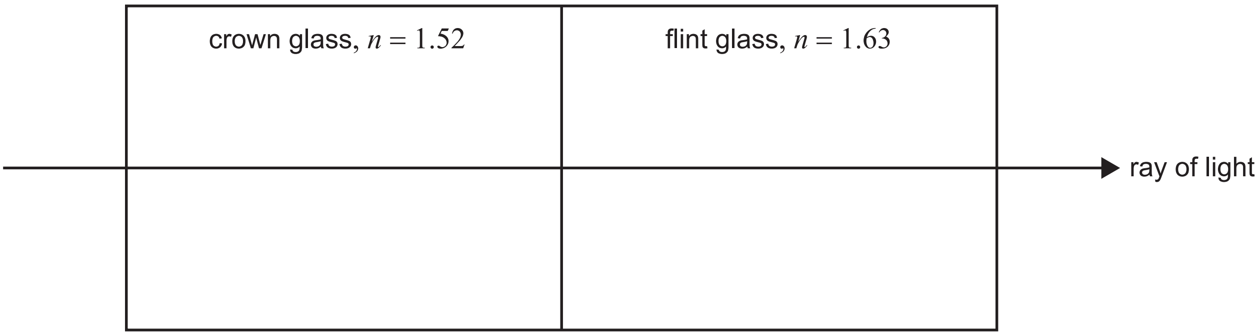
B. X-ray, ultraviolet, visible, infrared, microwave, radio

C. radio, microwave, visible, infrared, ultraviolet, X-ray

D. radio, microwave, infrared, visible, ultraviolet, X-ray

Question 17

A ray of light passes from a block of crown glass with a refractive index of 1.52, and then through a block of flint glass with a refractive index of 1.63, as shown in the diagram below.



While travelling within the flint glass, the speed of the ray of light is closest to

A. $1.63 \times 10^8 \text{ m s}^{-1}$

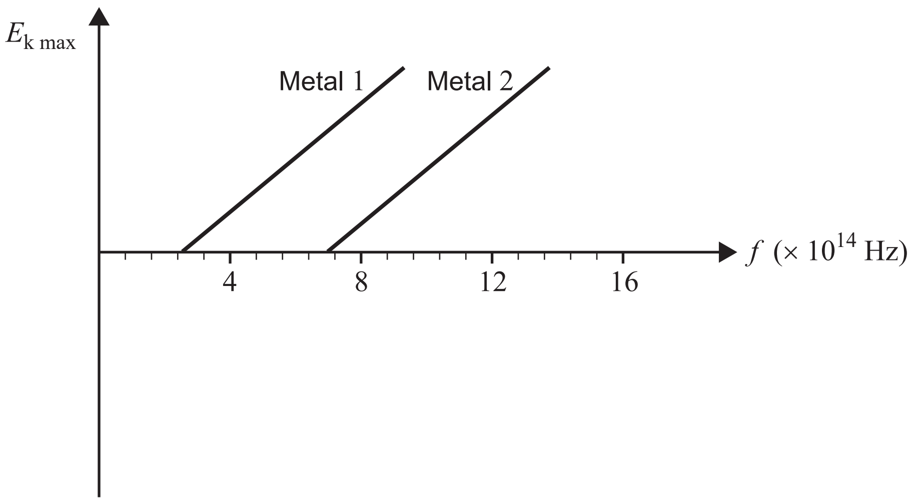
B. $1.84 \times 10^8 \text{ m s}^{-1}$

C. $1.97 \times 10^8 \text{ m s}^{-1}$

D. $3.00 \times 10^8 \text{ m s}^{-1}$

Question 18

The graph below shows the relation between the maximum kinetic energy of ejected photoelectrons, $E_{k\,max}$, and the frequency of the light, f, used to irradiate two different metal surfaces.



Light of frequency of 8.0×10^{14} Hz is incident on both metals.

Compared with the fastest photoelectrons emitted from Metal 1, the fastest photoelectrons emitted from Metal 2 will

A. have a lower velocity.

B. have a higher velocity.

C. take a longer time to gain enough energy to be ejected.

D. take a shorter time to gain enough energy to be ejected.

Question 19

A laser has a power output of $30\ \text{mW}$ and emits light with a wavelength of $650\ \text{nm}$.

How many photons does this laser emit per second?

A. 4.6×10^{14}

B. 9.8×10^{15}

C. 9.8×10^{16}

D. 9.8×10^{19}

Question 20

The electron double-slit experiment provides evidence for

A. atomic energy levels.

B. the photoelectric effect.

C. the wave nature of light.

D. the wave nature of matter.

End of Section A

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Section B

Instructions

- Answer **all** questions in the spaces provided.
- Write your responses in English.
- 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 (6 marks)

The speed, v, of charged particles can be measured by passing them through a combination of electric and magnetic fields that are perpendicular to each other.
An electron enters the space between two parallel charged plates, P and Q, where there is a magnetic field, B, directed into the page, as shown in Figure 1.
Ignore gravitational forces.

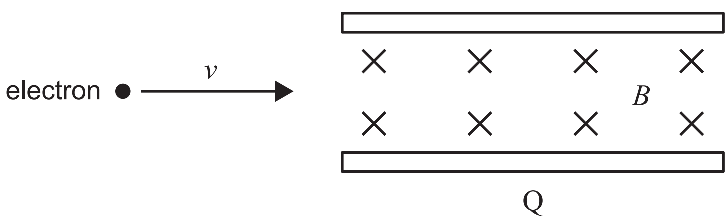

Figure 1

a. The electron passes between the charged plates and is undeflected.

Determine the polarity of the charges on P and Q. Justify your answer. 2 marks

b. When the electron has a speed of $1.2 \times 10^5 \text{ m s}^{-1}$ and the electric field strength is $2.4 \times 10^4 \text{ N C}^{-1}$, the electron is undeflected as it travels between the charged plates.

i. Calculate the magnitude of the magnetic field strength if the electron is undeflected. 2 marks

T

ii. The electron is now replaced by a proton travelling at the same speed.

What changes, if any, are required so that the proton is also undeflected as it travels between the charged plates? Explain your reasoning. 2 marks

Question 2 (7 marks)

Himawari-8 is an equatorial weather satellite.

It orbits Earth at a constant speed at a radius of 4.22×10^7 m from the centre of Earth, as shown in Figure 2. The mass of Himawari-8 is 1300 kg. Assume that the orbit is circular.

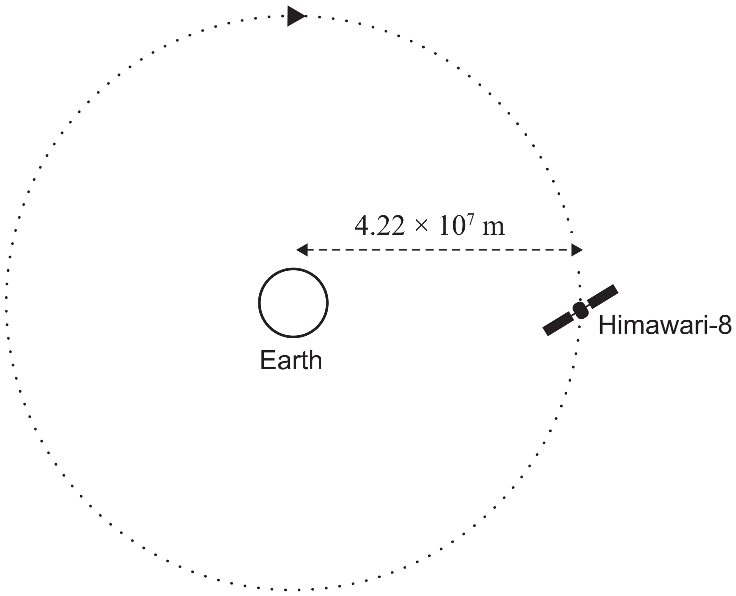

Figure 2

a. Calculate the magnitude of Earth's gravitational field at the orbital radius of Himawari-8. Give your answer to three significant figures. Show your working. 3 marks

N kg^{-1}

b. Show that the period of Himawari-8 is 24 hours. Show your working. 2 marks

c. Juan calculates the gravitational potential energy, E_g, of the Himawari-8 satellite in orbit and uses the working:

$$E_g = mgh = (1300 \text{ kg})(9.81 \text{ m s}^{-2})(4.22 \times 10^7 \text{ m})$$

Analyse Juan's use of the gravitational potential energy formula for the Himawari-8 satellite in orbit. 2 marks

Question 3 (6 marks)

A $4.0\ \mathrm{m}$ long vertical copper pole acts as a lightning conductor on top of a skyscraper, as shown in Figure 3. The lightning conductor is located where Earth's magnetic field, B, is horizontal and points directly north. The magnitude of Earth's magnetic field at the location of the lightning conductor is $5.0 \times 10^{-5}\ \mathrm{T}$.

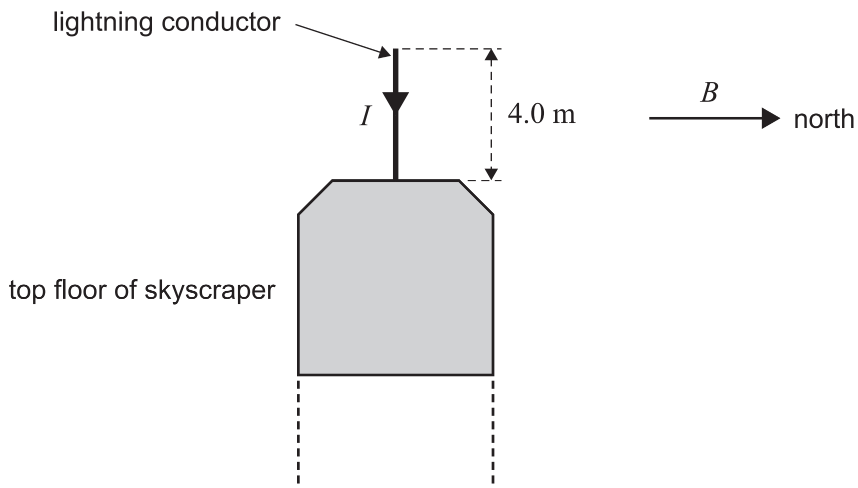

Figure 3

During an electrical thunderstorm, a lightning bolt produces a current, I, of $4.0 \times 10^{3}\ \mathrm{A}$ downwards in the lightning conductor.

a. Calculate the magnitude of the force acting on the lightning conductor while there is current in the lightning conductor. 2 marks

N

b. The vertical copper pole is increased in length and is again hit by a lightning bolt that produces a current of 4.0×10^3 A downwards in the lightning conductor.

Describe what effect, if any, this increase in length will have on the magnitude of the force acting on the lightning conductor while the current is present. Justify your answer. 2 marks

c. Another flash of lightning is measured to have a voltage of 500 kV between the ends of the pole and a current of 8.0×10^4 A in the pole for a duration of 120 μs.

Calculate the total energy transferred from this lightning bolt to the pole during the lightning strike. 2 marks

J

Question 4 (5 marks)

A simple electricity generator is shown in Figure 4, below. When the coil is rotated with a frequency of $10\ \mathrm{Hz}$, the output voltage across the slip rings is measured.

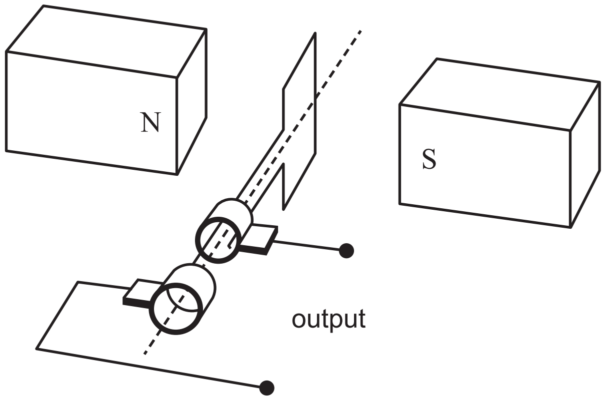

Figure 4

The graph in Figure 5 below shows how the output voltage varies over time for two cycles.

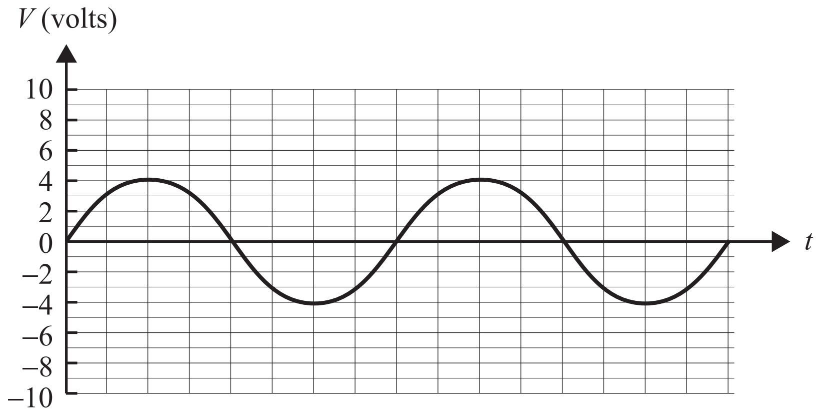

Figure 5

a. Calculate the period of the generator. 1 mark

s

b. The frequency of the generator is now halved to $5.0\ \text{Hz}$. The coil commences rotating from the same position, as shown in Figure 4.

On Figure 6 below, sketch the new output voltage. The original waveform is shown as a dashed line for reference. 2 marks

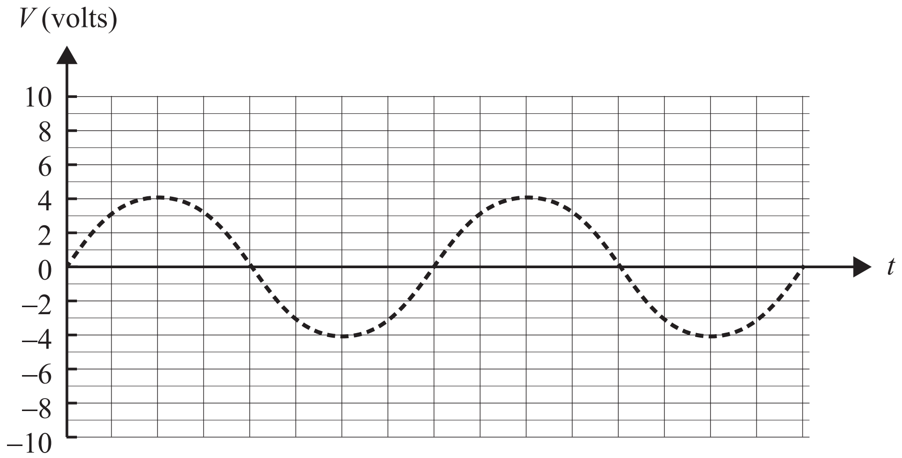

Figure 6

c. The frequency, f, is now returned to the original $10\ \text{Hz}$. The slip rings are replaced with a split-ring commutator.

Sketch the new output voltage on Figure 7 below. Assume that the coil commences rotating from the same position as shown in Figure 4. The original waveform is shown as a dashed line for reference. 2 marks

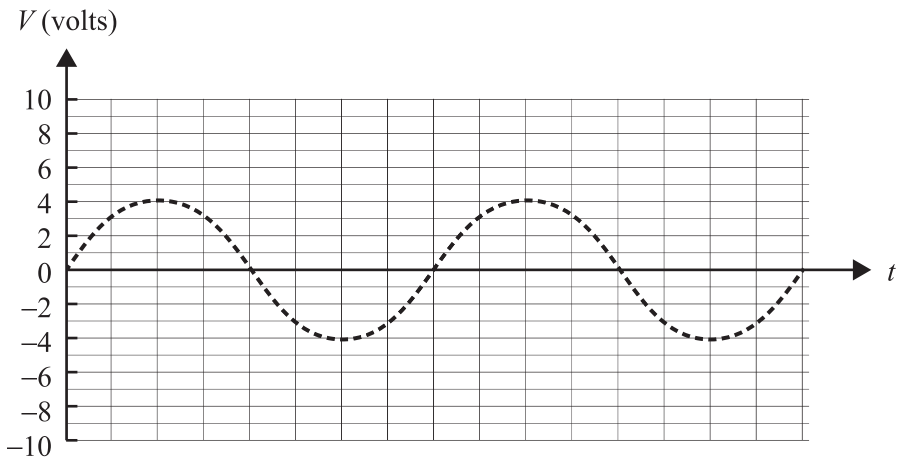

Figure 7

Question 5 (5 marks)

Mass spectrometers are used to separate charged particles of different mass.

Two particles, P and Q, have identical charges but different masses.

Both particles enter the uniform magnetic field, B, inside the mass spectrometer at the same point and at a speed of $2.50 \times 10^4 \text{ m s}^{-1}$. The particles travel in circular arcs that have different radii and strike a detector at different places. The paths of particles P and Q are shown in Figure 8.

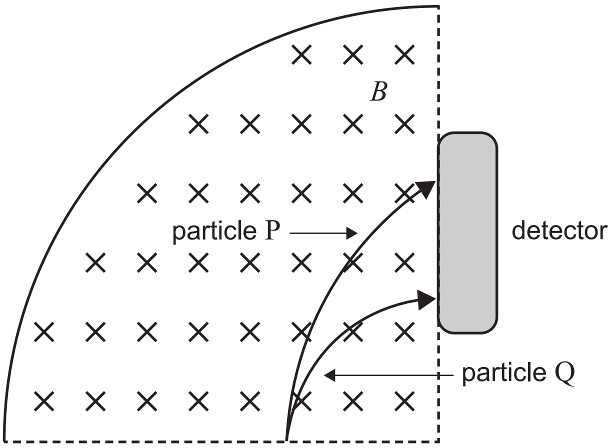

Figure 8

a. Which particle, P or Q, has the greater mass? Justify your answer. 2 marks

b. The strength of the magnetic field, B, inside the spectrometer is $0.010\ \mathrm{T}$. Particle P has a charge of $3.2 \times 10^{-19}\ \mathrm{C}$ and moves in a circular path of radius $0.64\ \mathrm{m}$.

Calculate the mass of particle P. 3 marks

kg

Question 6 (6 marks)

A small bar magnet is moved at constant speed, v, through the middle of a circular wire loop, as shown in Figure 9. An EMF is generated in the wire loop. The wire loop is connected to two terminals, A and B.

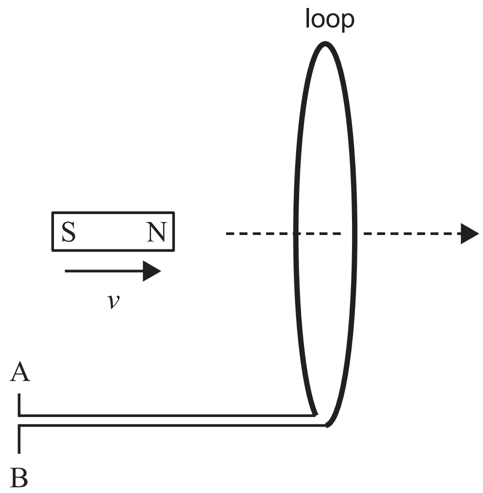

Figure 9

a. Explain why an EMF is generated in the wire loop. 1 mark

b. As the magnet approaches the loop, current flows in the loop. As viewed from the left in Figure 9, does the current flow clockwise or anticlockwise?

Explain your answer. 3 marks

c. On the graph below, sketch the EMF generated in the loop as a function of time, from when the magnet begins to the left of the loop, as it goes through the loop, to when it is to the right of the loop. 2 marks

Question 7 (7 marks)

Aisha is learning to play table tennis. She throws the ball vertically upwards and, when it is at its highest point, and stationary, she hits it with the table tennis bat.

The bat hits the ball horizontally, as shown in Figure 10. At the moment of collision, the bat has a speed of 2.5 m s^{-1}. The mass of the table tennis bat is 0.20 kg and the mass of the table tennis ball is $3.0 \times 10^{-3} \text{ kg}$.

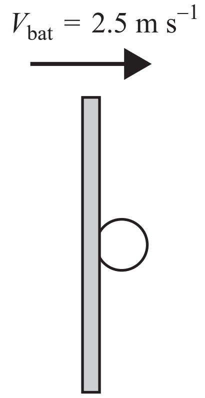

Figure 10

a. On Figure 10, draw vectors to show the force(s) acting on the ball at the moment it collides with the bat. Include labels to show the cause of each force. 2 marks

b. On Figure 10, draw and label the normal force (according to Newton's third law), resulting from the force of the bat on the ball. 1 mark

c. The bat slows down to 2.4 m s^{-1} immediately after the collision.

Calculate the speed of the ball immediately after it leaves the bat. 2 marks

m s^{-1}

Do not write in this area.

d. Explain why the gravitational force acting on the table tennis ball can be neglected in this collision. 2 marks

Question 8 (6 marks)

Many dog owners use ball-throwers to throw tennis balls a long way, which their dogs can then retrieve.

A student, Olaf, uses a ball-thrower to investigate projectile motion.

Olaf launches a tennis ball with a speed of $30.0\ \mathrm{m\ s^{-1}}$ at an angle of $15.0°$ above the horizontal, and from a height of $2.10\ \mathrm{m}$, as shown in Figure 11.

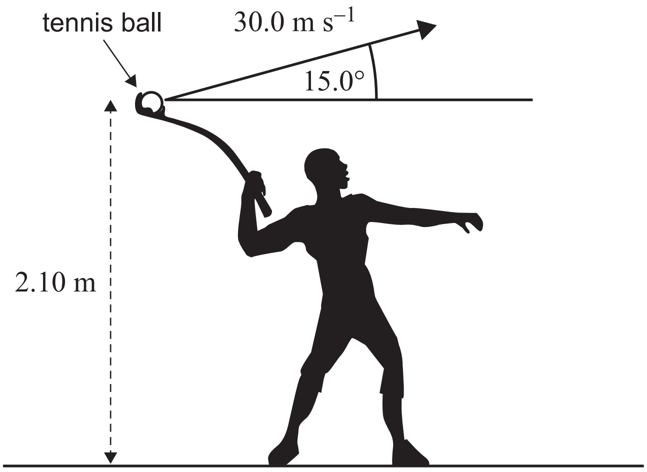

Figure 11

Ignore air resistance for **part a**, **part b** and **part c**.

a. Show that the initial horizontal speed of the ball is $29.0\ \mathrm{m\ s^{-1}}$. 1 mark

b. Show that the initial vertical speed of the ball is $7.76\ \mathrm{m\ s^{-1}}$. 1 mark

c. Calculate the maximum height of the ball above the ground. 2 marks

m

d. Explain the effect that air resistance would have on the maximum height reached by the tennis ball, as calculated in **part c**. 2 marks

Question 9 (4 marks)

In a thought experiment, a very fast train of proper length 700 m passes through a tunnel, MN, while travelling at speed of $0.9000\,c$. Adina, a train spotter, watches from nearby. Adina can see both ends of the tunnel, as shown in Figure 12.

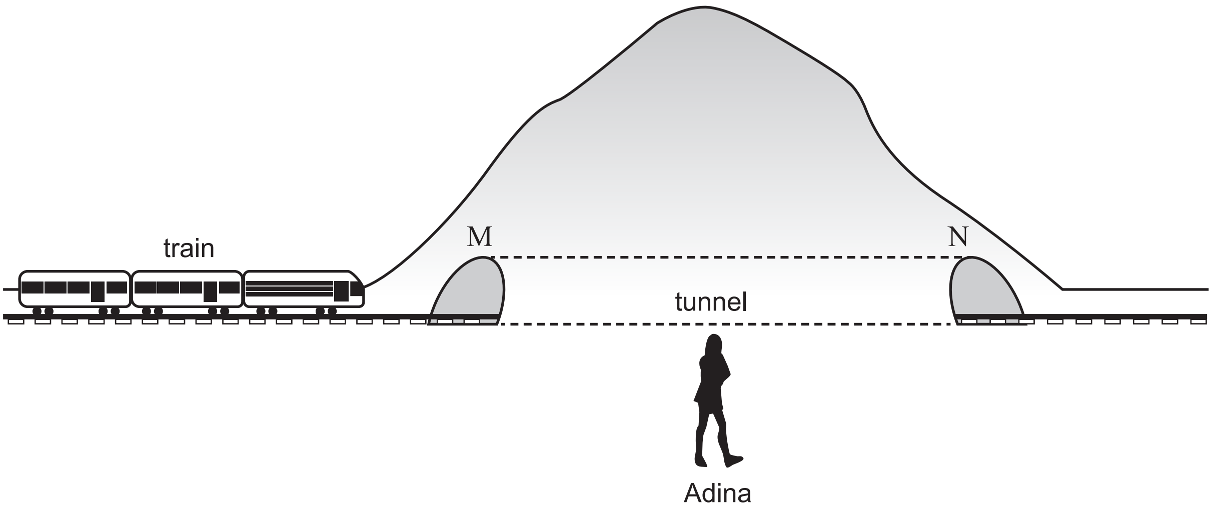

Figure 12

a. Show that the Lorentz factor for the train at this speed is 2.294 1 mark

b. Adina sees the train enter the tunnel, MN, of proper length 700 m, as measured by an observer who is stationary with respect to the tunnel.

Will Adina see both ends of the train when the front of the train emerges from position N of the tunnel? Justify your answer. 3 marks

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Question 10 (7 marks)

A $0.50\ \mathrm{kg}$ ball swings in a horizontal circle on the end of a $1.6\ \mathrm{m}$ cord attached to a pole, as shown in Figure 13. The cord makes an angle of $30°$ with the vertical pole.

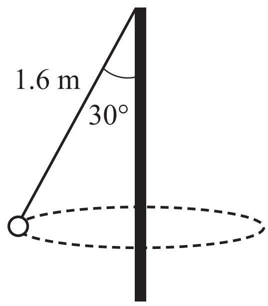

Figure 13

a. Show that the magnitude of the tension in the cord is $5.7\ \mathrm{N}$. 2 marks

b. Calculate the magnitude of the acceleration of the ball. 2 marks

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

c. Calculate the speed of the ball. 3 marks

$\boxed{\quad\quad\quad\quad \text{m s}^{-1}}$

Question 11 (4 marks)

Two wave pulses, P and Q, each with the same wavelength but with different amplitudes, are travelling in opposite directions at speed v, as shown in Figure 14. The amplitude of pulse P is double the amplitude of pulse Q.

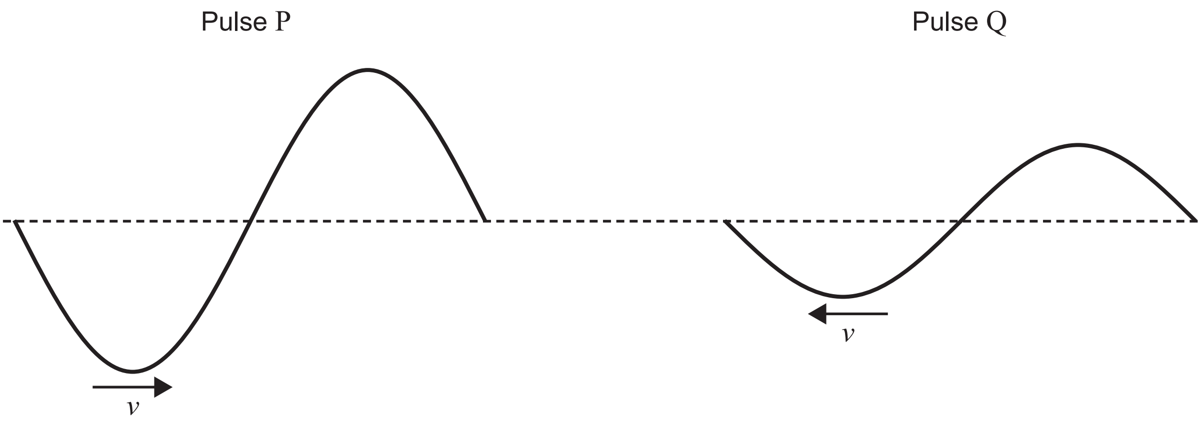

Figure 14

A short time later, the two wave pulses are at the positions shown in Figure 15 below.

a. In the box shown in Figure 15, sketch the wave pulse resulting from the combination of the wave pulses P and Q. 2 marks

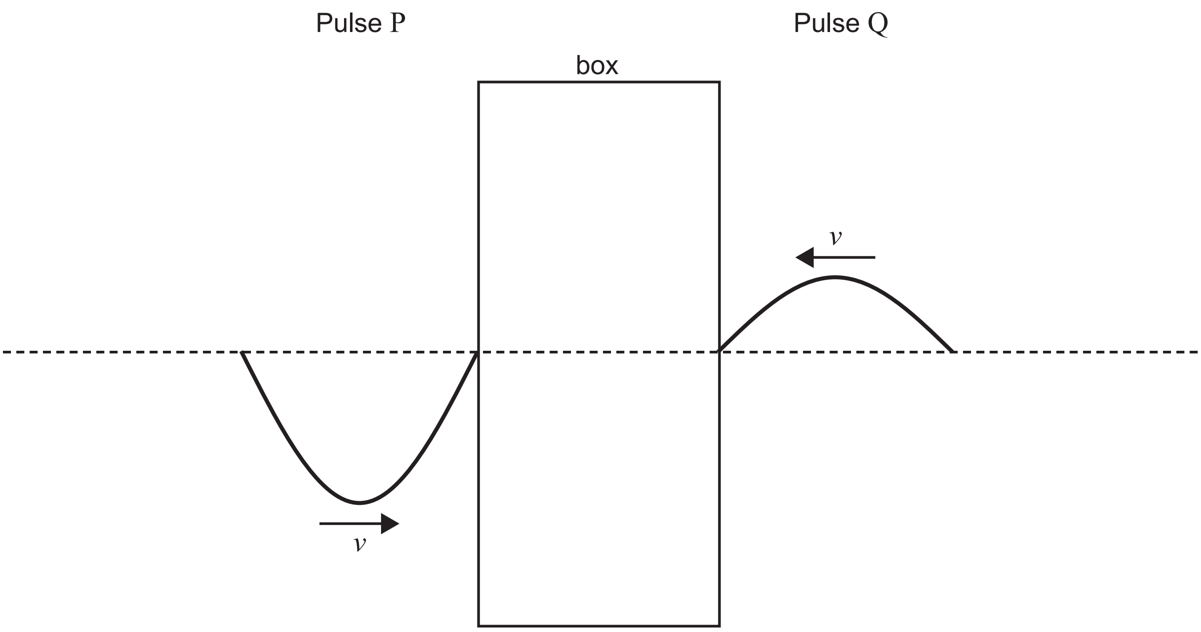

Figure 15

b. Explain the production of the wave form you have sketched in **part a**. State the physics principle involved. 2 marks

Question 12 (4 marks)

Figure 16 below shows a ray of light entering from air ($n_{air} = 1.00$) into an optical fibre that consists of two transparent materials, the core and the surrounding cladding. The core and cladding have refractive indices of 1.50 and 1.47 respectively.

The ray is incident on the air–core interface at an angle of incidence of $24°$.

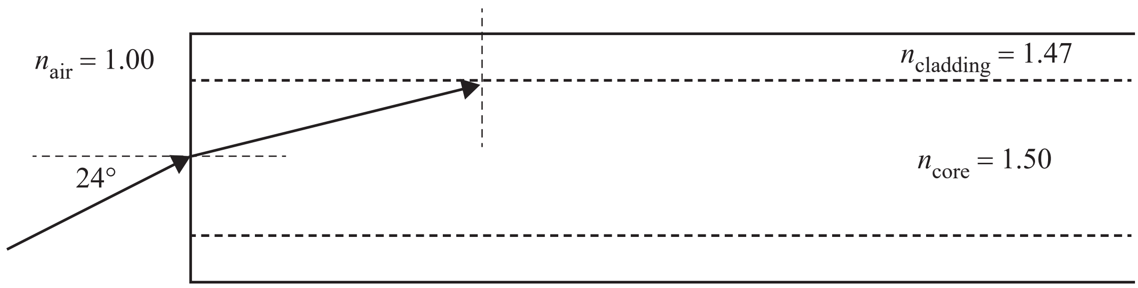

Figure 16

a. Show that the critical angle for the core–cladding boundary is $78.5°$ 1 mark

b. Will total internal reflection occur at the core–cladding boundary for this incoming ray? Support your answer with calculations. 3 marks

Question 13 (3 marks)

A double slit is illuminated by light from a dual laser, which produces light of two distinct wavelengths. This arrangement is shown in Figure 17a. One of the wavelengths produced by the laser is known to be 650 nm, the other is unknown.

The interference pattern on a screen shows that the second bright band for the light of known wavelength coincides with the third dark band for the unknown wavelength, as shown in Figure 17b.

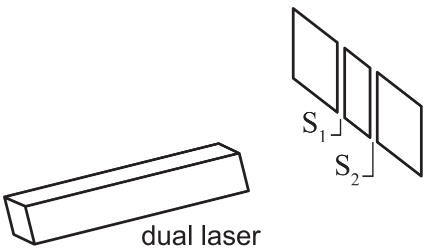

Figure 17a

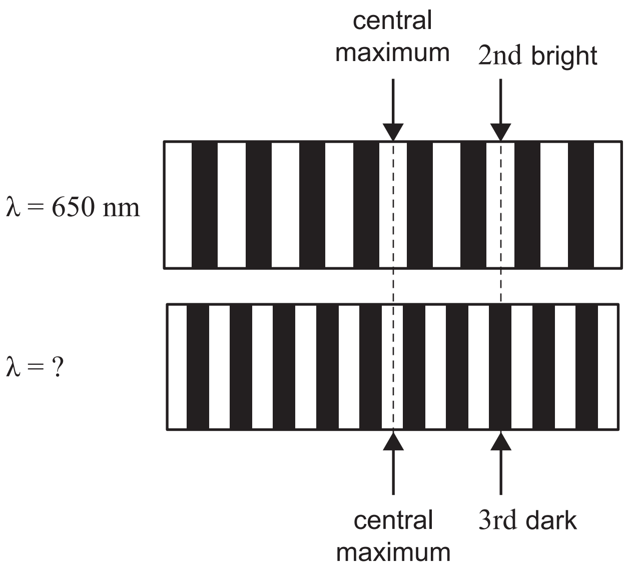

Figure 17b

Determine the value of the unknown wavelength of light. Show your reasoning.

nm

Question 14 (4 marks)

A ray of white light is incident on a triangular glass prism, as shown in Figure 18.
The glass prism has a refractive index of 1.50 and is completely surrounded by air. Air has a refractive index of 1.00

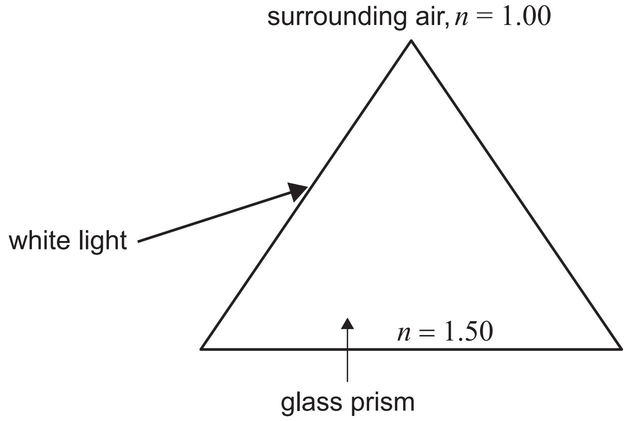

Figure 18

a. The white light disperses as it passes through the prism. On Figure 18, draw the path of the light as it passes through the triangular prism and into the air. Show and label two rays, red and violet, the colours at opposite ends of the visible spectrum. No calculations are necessary. 2 marks

b. The glass prism is now completely immersed into a surrounding clear liquid that has the exact same refractive index as the glass prism. This is shown in Figure 19.

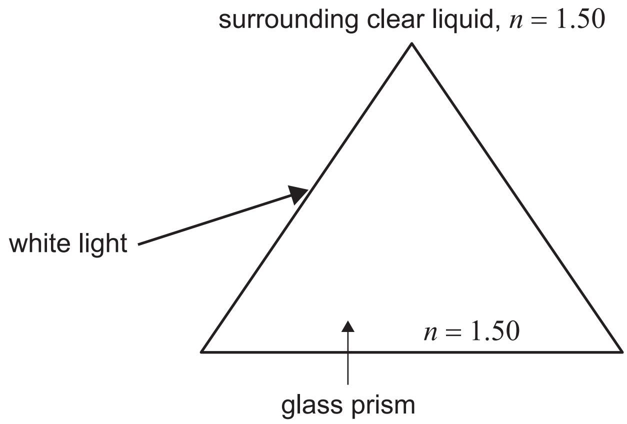

Figure 19

On Figure 19, draw the path of the light as it passes through the triangular prism and exits into the surrounding clear liquid. 2 marks

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Question 15 (2 marks)

A series of regular straight water waves are incident on a barrier with a small opening. The water waves emerge on the other side, as shown in Figure 20.

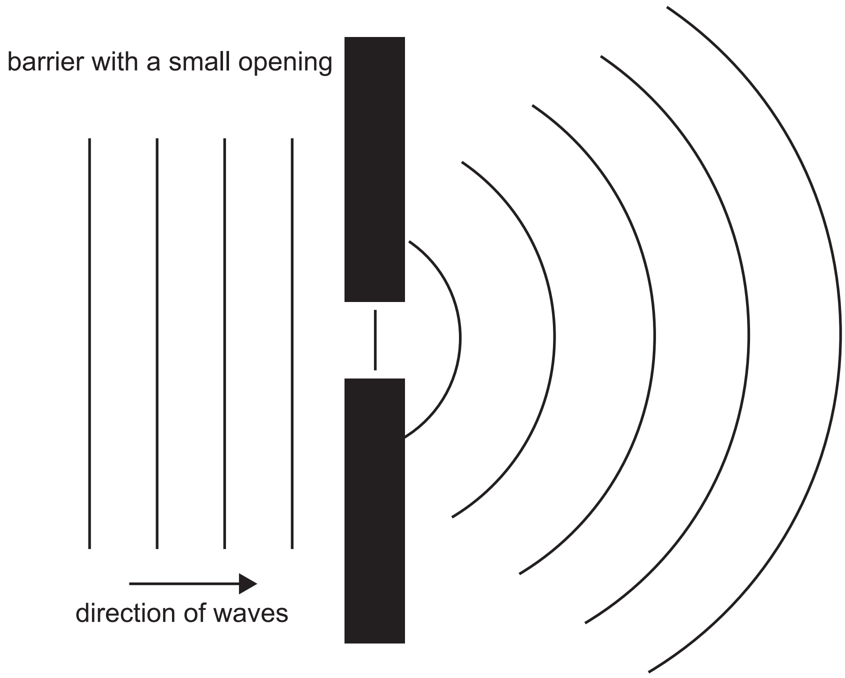


Figure 20

Li and Chang are discussing their observations of the water waves as they emerge beyond the barrier.

Li says that the waves diffract only if the wavelength is smaller than the gap width.

Chang says that the extent of diffraction is independent of the wavelength.

Evaluate the statements made by Li and Chang.

Question 16 (7 marks)

Two Physics students are investigating the photoelectric effect by shining monochromatic light with a frequency of 1.00×10^{15} Hz onto a calcium plate. Their equipment is shown in Figure 21.

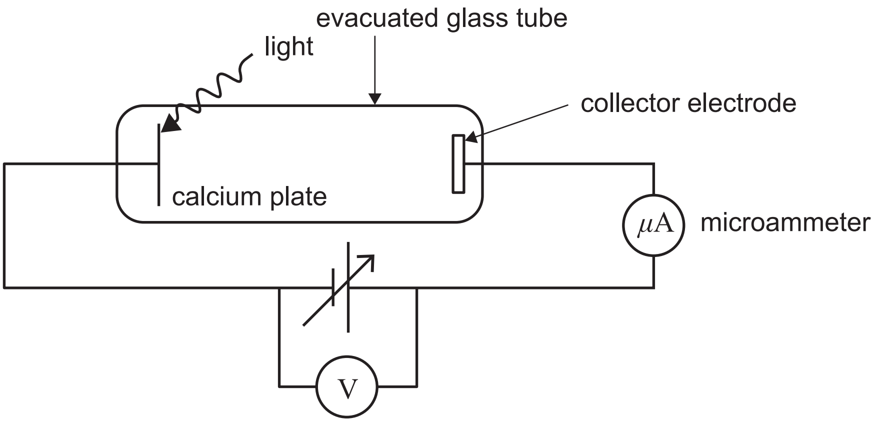


Figure 21

Figure 22 shows a graph of the relationship between the photocurrent and the reading on the voltmeter.

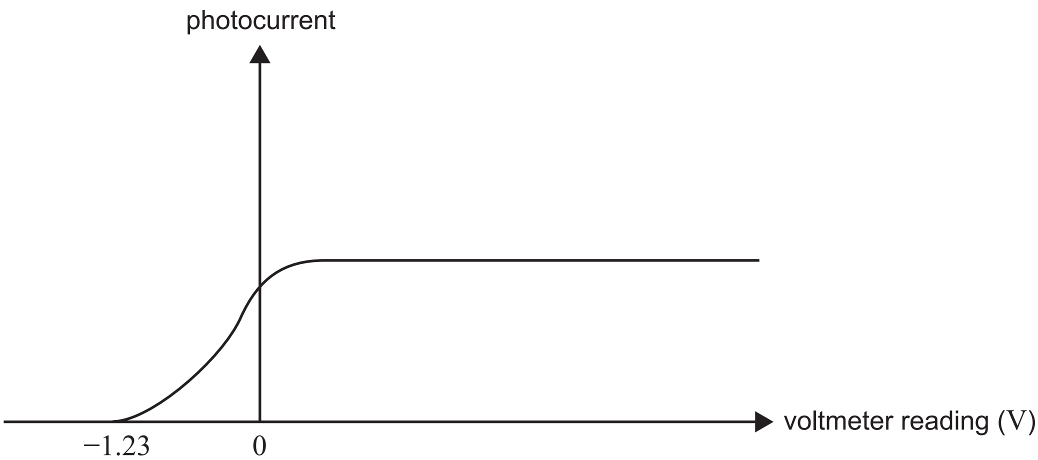


Figure 22

a. Use the information in Figure 22 to determine the maximum kinetic energy, in eV, of the photoelectrons. 1 mark

eV

b. Calculate the work function, in eV, of calcium. 2 marks

eV

c. The intensity of the light is now reduced to 50% of the original light intensity and the experiment is repeated using light of the same frequency on the calcium plate. The students obtain a new graph of photocurrent against voltage.

Sketch the graph of photocurrent and voltage for the reduced light intensity on Figure 23. The original graph is shown as a dashed line for reference. 2 marks

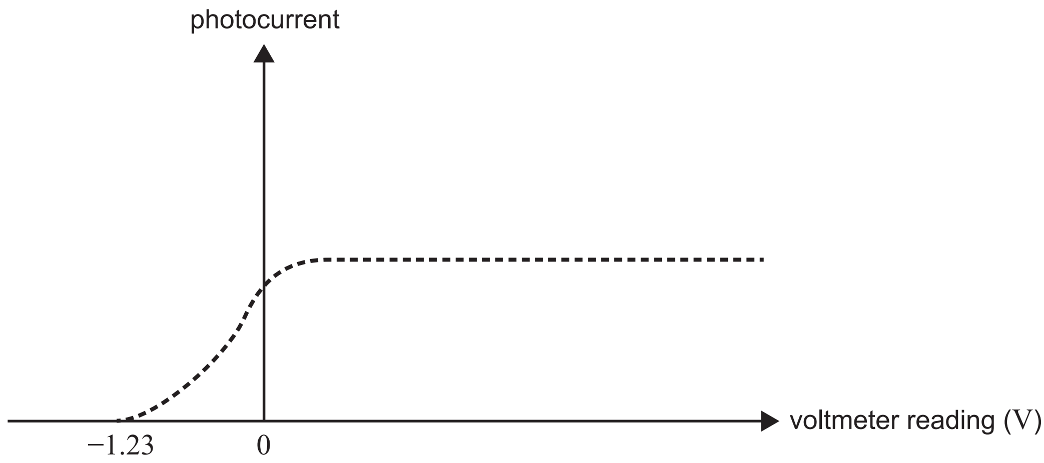


Figure 23

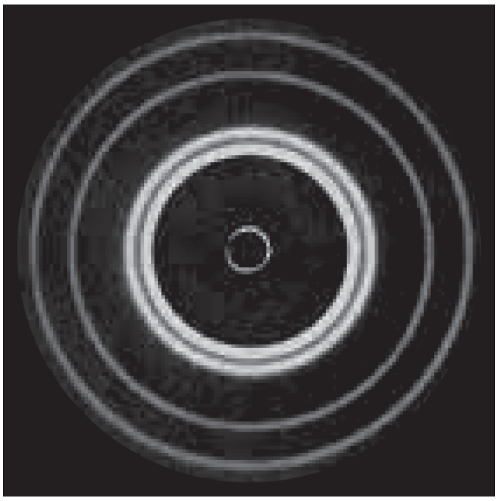
d. The students change the light source to one with a different frequency. They observe that the photocurrent is zero and remains zero regardless of the size or the polarity of the voltage.

Explain this observation. 2 marks

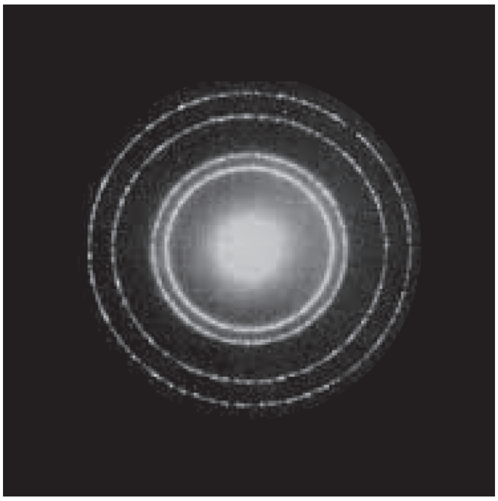
Question 17 (6 marks)

Scientists carried out an experiment comparing X-ray diffraction with electron diffraction by analysing the patterns produced by passing an X-ray beam and an electron beam through a thin polycrystalline aluminium foil. The X-ray photon energy and the electron kinetic energy are the same.

The patterns produced have the same general appearance, but different spacings, as shown in Figures 24a and 24b.



X-ray diffraction
Figure 24a



Electron diffraction
Figure 24b

The X-rays have energy of 137 eV.

a. Calculate the wavelength of the X-ray beam. Show your working. 2 marks

m

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

m

c. Explain why the patterns have different spacings when both beams have the same energy. 2 marks

Question 18 (4 marks)

Sodium-vapour lamps have often been used for night-time street illumination, because the yellow light they produce penetrates mist and fog particularly well.

When switched on, the sodium-vapour lamp emits a characteristic yellow light of wavelength 589 nm.

Figure 25 below shows a schematic energy-level diagram for a sodium atom.

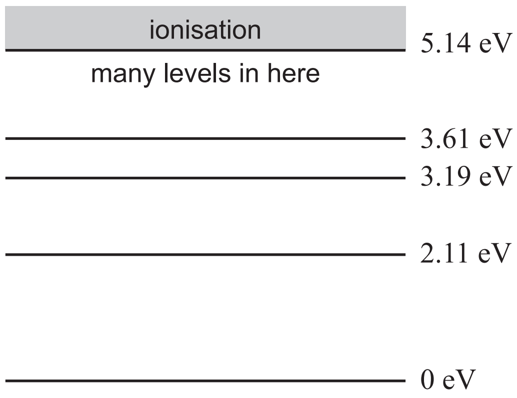


Figure 25

a. Calculate the photon energy, in eV, for yellow light of wavelength 589 nm.
Use $c = 3.00 \times 10^{8}$ m s^{-1} 2 marks

eV

b. Draw an arrow on Figure 25 to show the energy level transition that takes place to produce the characteristic sodium yellow light of wavelength 589 nm. 1 mark

c. The ionisation level for sodium is 5.14 eV.

A sodium atom in the ground state absorbs a photon that ionises the atom. Draw an arrow on Figure 26 to show this transition. 1 mark

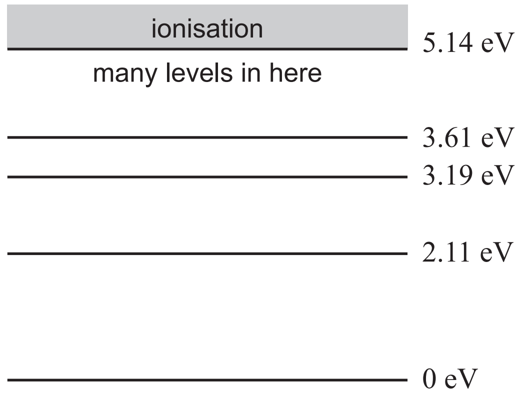


Figure 26

Question 19 (17 marks)

Students are building a model of part of a children's game. It consists of a spring that fires a block of mass m along a frictionless track. The track curves upwards and the block stops for an instant at height h above its original position. It then slides back down the track. The experimental setup is shown below in Figure 27, with the spring shown in an uncompressed state where L is the natural length of the spring. The spring constant is k.

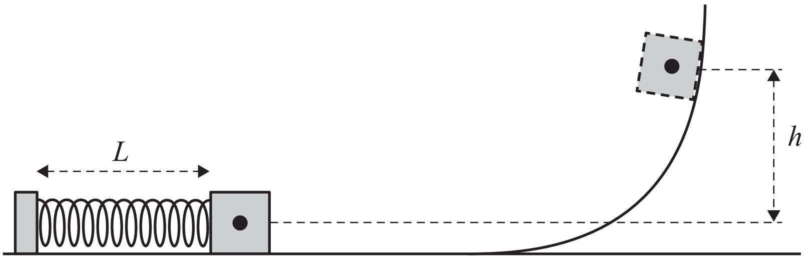


Figure 27

a. The spring is compressed a distance x and then released.

Model the block as a small point mass, the surface as frictionless and the spring as both massless and ideal. Show that $h = \frac{kx^2}{2mg}$. Outline the steps of your reasoning. 2 marks

b. If the spring were **not** massless, what would be the effect on the height, h? Calculations are not necessary. Give your reasoning. 2 marks

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Do not write in this area.

c. The students know that the value of m is 150 g, but they do not have a value for k. They set up an experiment to find a value for k, by varying the compression of the spring and observing the resulting height, h.

Identify the independent and dependent variables of their experiment. 2 marks

Independent variable

Dependent variable

d. The measurements that the students record are tabulated below.

x (m)	h (m)
0.110 ± 0.005	0.21 ± 0.01
0.095 ± 0.005	0.14 ± 0.01
0.077 ± 0.005	0.11 ± 0.01
0.055 ± 0.005	0.040 ± 0.01

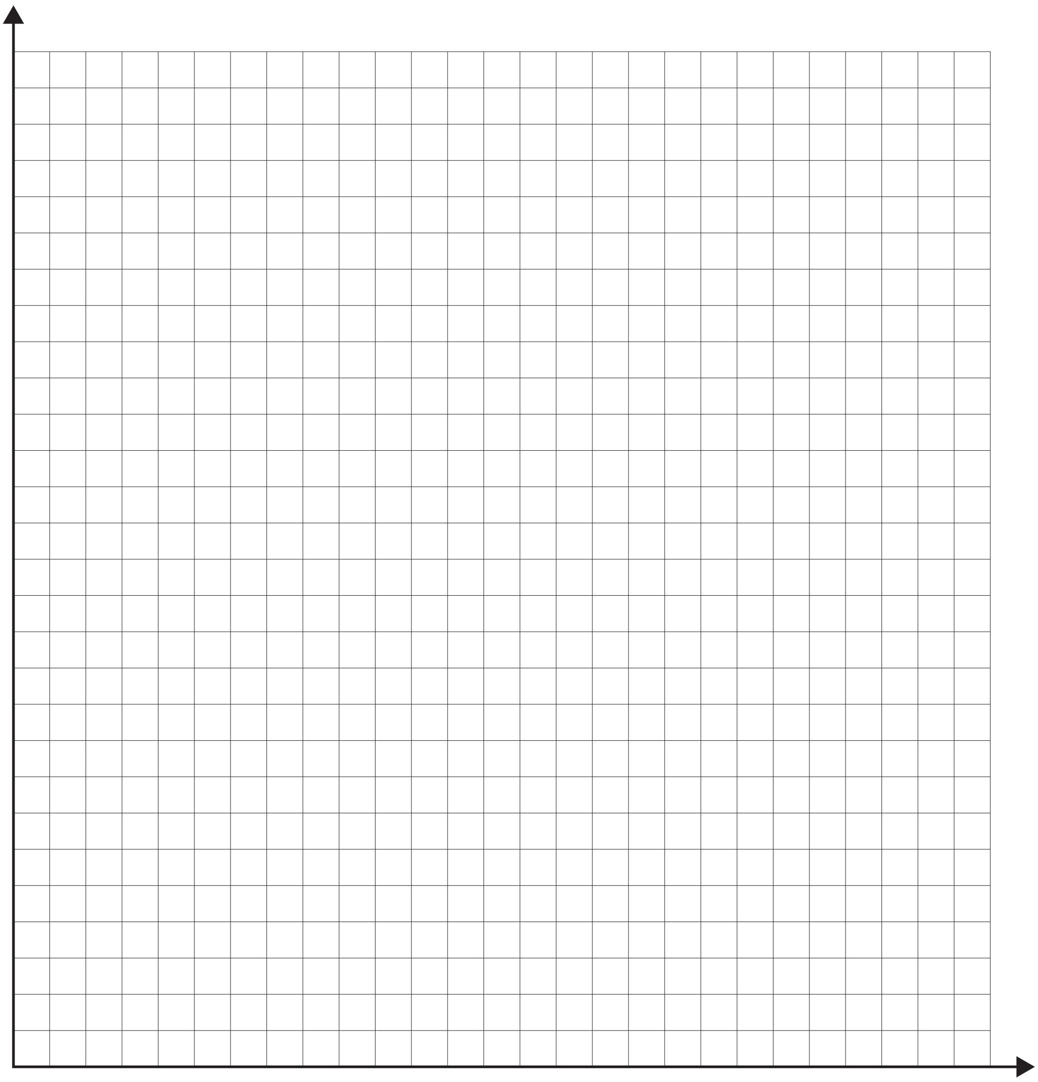
Their teacher suggests that they plot values of h on the y-axis against x^2 on the x-axis.

Give a reason why it would be better to plot values of x^2 rather than x on the x-axis. 1 mark

Question 19 continues on the next page.

e. Using the values in the table below, construct a graph with h on the y-axis and x^2 on the x-axis. Include error bars and a line of best fit. 6 marks

x^2 (m^2)	h (m)
0.0120 ± 0.001	0.21 ± 0.01
0.0090 ± 0.001	0.14 ± 0.01
0.0059 ± 0.001	0.11 ± 0.01
0.0030 ± 0.001	0.040 ± 0.01



f. Measure the gradient of the graph from the line of best fit. 2 marks

$\boxed{\qquad\qquad \text{m}^{-1}}$

g. Use your result in **part f** to calculate the value of the spring constant k. 2 marks

$\boxed{\qquad\qquad \text{N m}^{-1}}$

End of examination questions

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Physics

Formula Sheet

You may keep this Formula Sheet.

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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	$E = \frac{V}{d}$
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	$V = RI; \quad P = VI = I^2R$
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	$V_{RMS} = \frac{1}{\sqrt{2}}V_{peak} \qquad I_{RMS} = \frac{1}{\sqrt{2}}I_{peak}$
electromagnetic induction	EMF: $\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$ flux: $\Phi_B = B_\perp A$
transmission losses	$V_{drop} = I_{line}R_{line} \qquad P_{loss} = I^2_{line}R_{line}$

Wave concepts

wave equation	$v = f\lambda$
constructive interference	path difference $= n\lambda$
destructive interference	path difference $= \left(n + \frac{1}{2}\right)\lambda$
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	$p = \frac{h}{\lambda}$
de Broglie wavelength	$\lambda = \frac{h}{p}$

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	$M_E = 5.98 \times 10^{24}$ 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 Physics Formula Sheet