VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2005

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures										Letter
Words										

PHYSICS

Written examination 2

Wednesday 9 November 2005

Reading time: 11.45 am to 12.00 noon (15 minutes)
Writing time: 12.00 noon to 1.30 pm (1 hour 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A – Core – Areas of study			
1. Electric power	17	17	40
2. Interactions of light and matter	11	11	25
B – Detailed studies			
1. Synchrotron and its applications	11	11	25
OR			
2. Photonics	10	10	25
OR			
3. Sound	11	11	25
			Total 90

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, up to two pages (one A4 sheet) of pre-written notes (typed or handwritten) and an approved graphics calculator (memory cleared) and/or one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied
- Question and answer book of 38 pages, with a detachable data sheet in the centrefold.

Instructions
- Detach the data sheet from the centre of this book during reading time.
- Write your **student number** in the space provided above on this page.
- Answer all questions in the spaces provided.
- **Always** show your working where space is provided because marks may be awarded for this working.
- All written responses must be in English.

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

SECTION A – Core

Instructions for Section A

Answer **all** questions **for both** Areas of study in this section of the paper.

Area of study 1 – Electric power

A vertical wire carrying a current I is placed opposite the centre of a permanent bar magnet as shown in Figure 1.

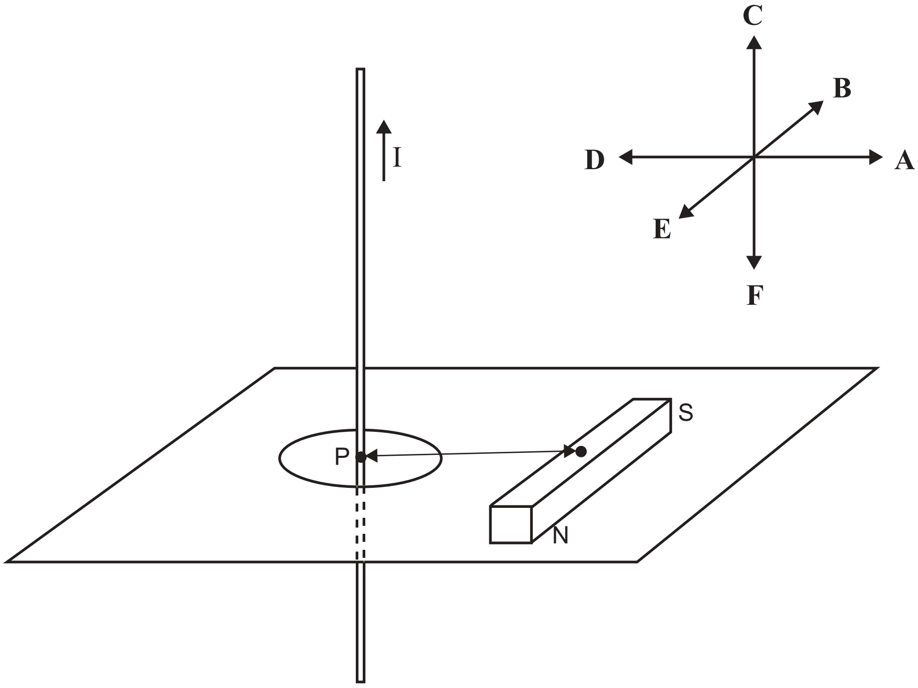


Figure 1

Question 1

Which of the arrows **(A–F)** best shows the direction of the magnetic force on the wire at the point P?

2 marks

Some students are studying the emf induced by a magnetic field in a coil of wire. Their experimental apparatus consists of a coil of 100 turns of wire in a magnetic field of 2.0×10^{-2} T as shown in Figure 2 below.

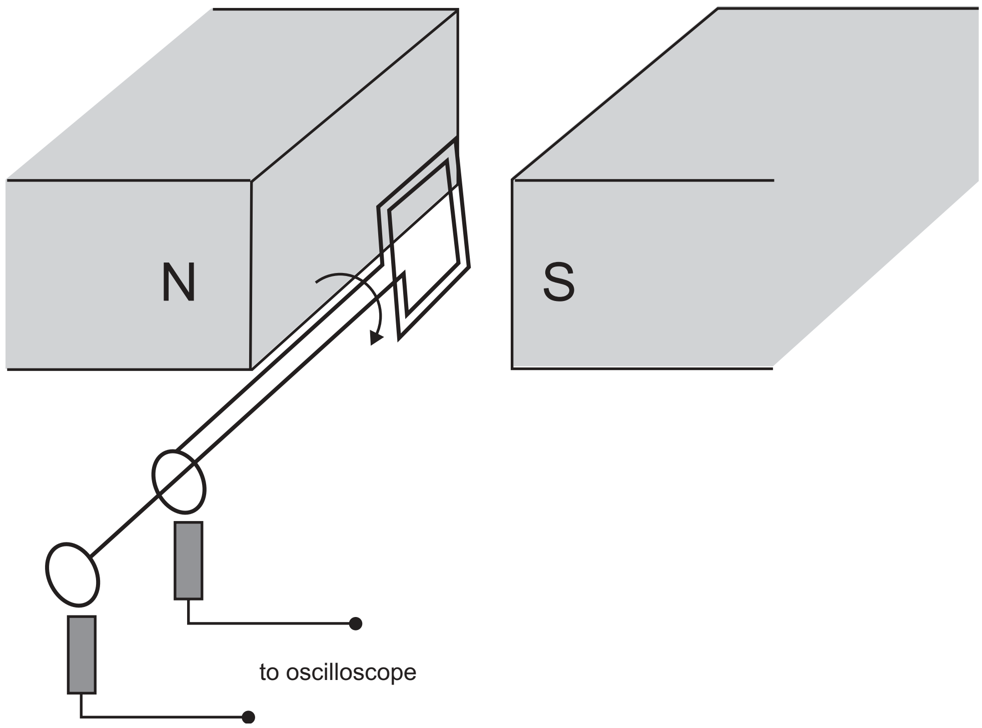


Figure 2

Question 2

With the coil vertical as shown in Figure 2, the flux through the coil is 8×10^{-6} Wb. What is the area of the coil?

m^2

2 marks

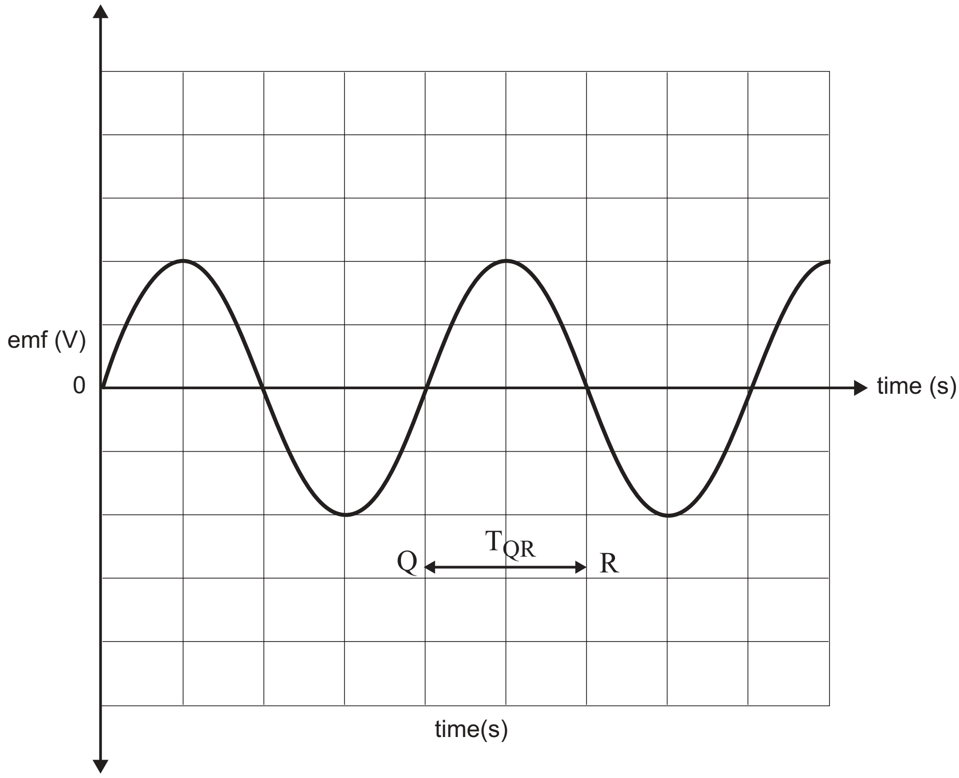


Figure 3

The coil (in Figure 2) is rotated at a rate of 10 revolutions per second, and the output is observed on an oscilloscope (CRO), as shown in Figure 3 above.

Question 3

What is the time interval, T_{QR}, between Q and R?

s

2 marks

Question 4

Calculate the **average** emf observed over the time interval T_{QR}.

V

3 marks

The rotation speed of the coil is increased to 20 revolutions per second.

Question 5

On Figure 3, sketch the output from the oscilloscope that would be observed now.

3 marks

Pat and Kris are discussing **DC generators**. Pat says that slip rings are used in a DC generator. Kris disagrees, and says that DC generators cannot use slip rings because they must produce DC, and therefore a commutator is essential.

Question 6

Who is correct? (Write Kris or Pat in the box below.)

1 mark

Question 7

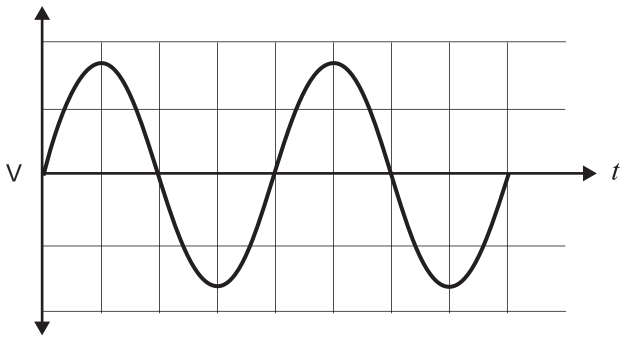
Explain the operation of a commutator.

2 marks

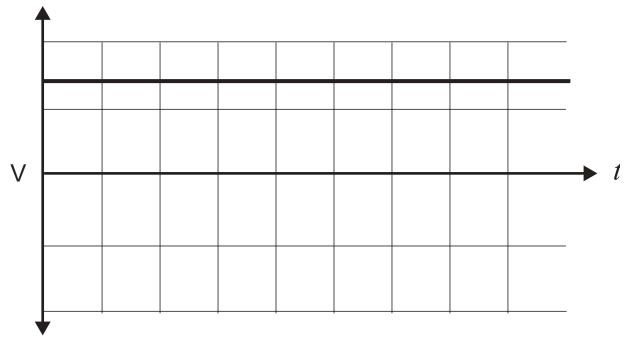
Question 8

Which one of the following diagrams **(A.–D.)** best describes the output of a DC generator?

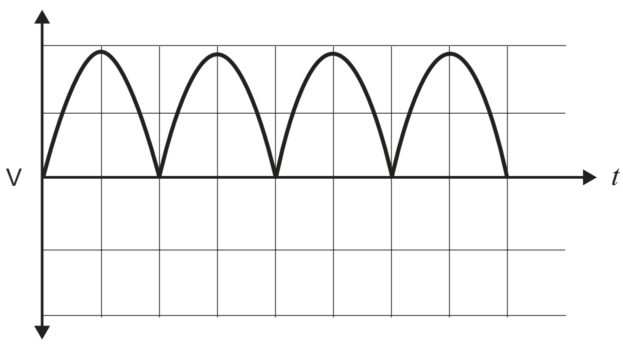
A.



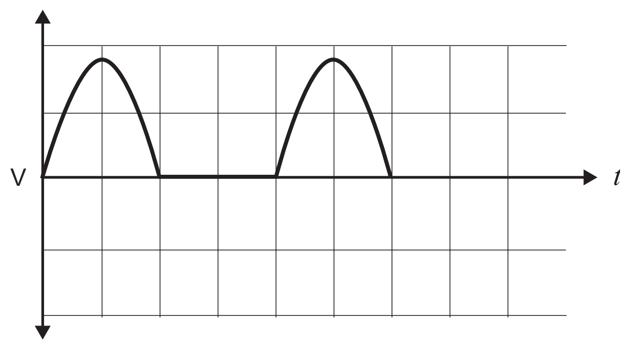
B.



C.



D.



2 marks

An electrician is planning a new power supply to a farm house. The house is 1.0 km from the existing supply. At this supply point there is a choice of either a high voltage 11 000 V_{RMS} AC or a lower voltage 240 V_{RMS} AC supply. All of the appliances in the house require 240 V_{RMS} AC and the expected maximum power demand (load) is 12 000 W. The owner is keen to avoid the cost of a transformer, and so initially plans to use a 1.0 km supply line to the house from the 240 V_{RMS} supply.

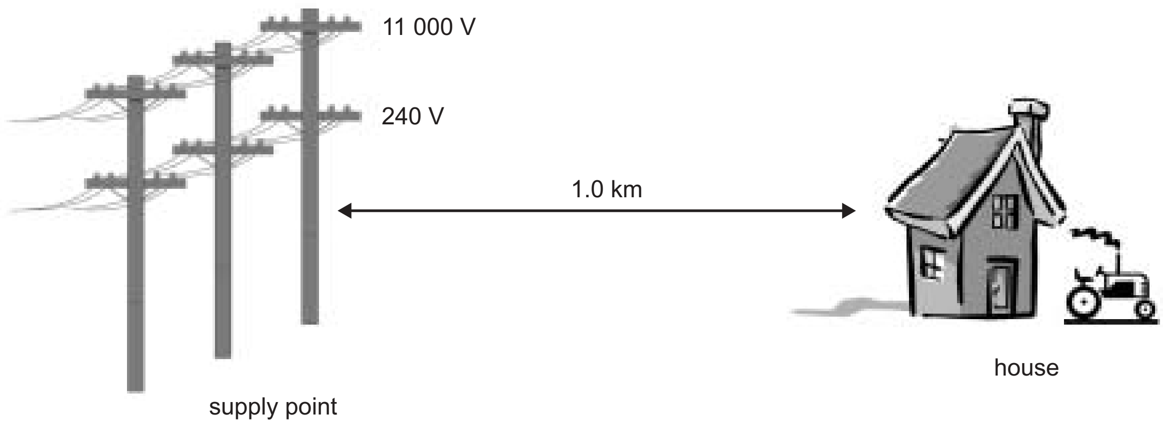


Figure 4

Question 9

A heater in the house is rated at 1200 W.

Calculate the current flowing through the heater when it is connected to a 240 V_{RMS} supply.

A

2 marks

The electrician connects the house to the 240 V_{RMS} supply using lines with a **total** resistance of 2.0 Ω. Some of the appliances in the house are turned on to test the new supply. Measurements reveal that, under these test conditions, the current flowing is 30 A.

Question 10

Calculate the power loss in the supply lines from the road to the house when the current flowing is 30 A.

W

2 marks

Question 11

What would be the voltage measured at the house when the current is 30 A?

V

4 marks

The electrician suggests that using the 11 000 V_{RMS} supply with a step-down transformer at the house could deliver the same amount of power to the house, with a significant reduction in the power loss in the supply lines.

Question 12

Explain why using an 11 000 V_{RMS} rather than the 240 V_{RMS} supply would reduce the power loss in the lines.

3 marks

Question 13

What is $V_{peak\text{-}peak}$ at the 11 000 V_{RMS} supply point?

V

2 marks

Joan found an old transformer in her grandfather's shed and performed some simple tests to see if it was still working using the circuit shown in Figure 5. These tests included voltage and current measurements, and the data obtained is summarised below in Table 1. Joan's conclusion was that the transformer still worked, but for safety reasons she chose not to measure the current in the primary coil and assumed the voltage to be 240 V_{RMS}.

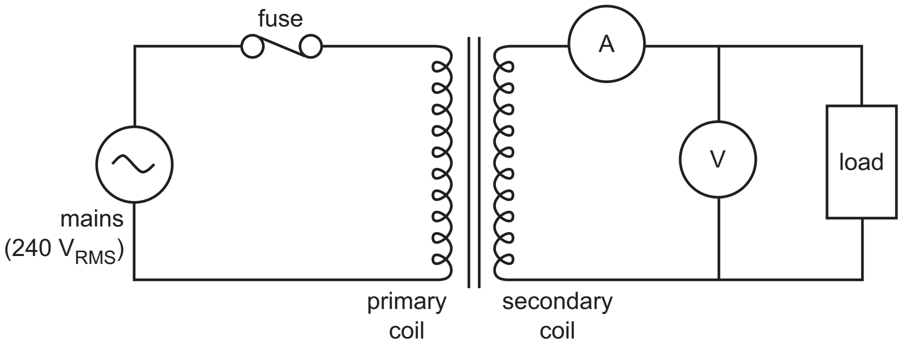


Figure 5

Table 1

Primary coil		**Secondary coil**	
$I_{p\ RMS}$	$V_{p\ RMS}$	$I_{s\ RMS}$	$V_{s\ RMS}$
	240 V_{RMS}	2.2 A_{RMS}	11.3 V_{RMS}

Question 14

Assuming the transformer is ideal, calculate the RMS current in the primary coil.

A

2 marks

Question 15

Joan and her grandfather were discussing how a transformer works and this led to a discussion about Faraday's and Lenz's laws. Joan's grandfather stated that the two laws were essentially the same, but Joan disagreed.

Compare and contrast Faraday's law and Lenz's law.

3 marks

As a final test of the transformer, Joan increases the load on the secondary side of the transformer. Suddenly, it stops working. She suspects that the fuse in the primary circuit has blown and intends to replace it.

Question 16

In order to replace the fuse as safely as possible, which of the following is the **best** precaution for Joan to take?

A. stand on a rubber mat

B. switch off the mains supply

C. disconnect the transformer from the mains supply

D. remove the load from the transformer

2 marks

The left side of Figure 6 shows three sources of magnetic fields.
The right side of Figure 6 shows three possible magnetic field patterns of the shaded planes.

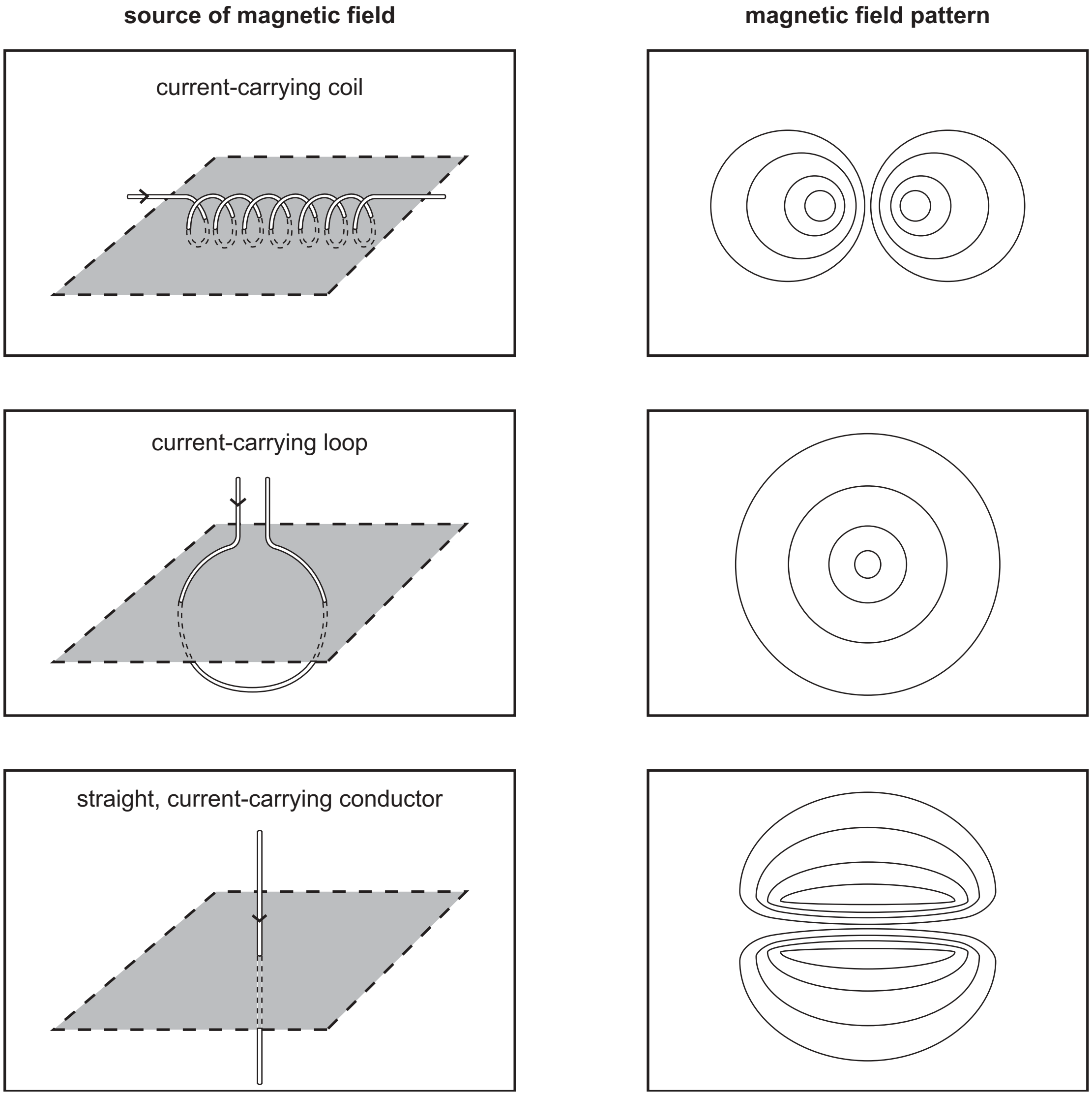


Figure 6

Question 17

For each of the three sources, draw a line linking the source to the magnetic field pattern it produces in the shaded region.

3 marks

END OF AREA OF STUDY 1

Area of study 2 – Interactions of light and matter

The spectrum of wavelengths produced by a particular incandescent light globe is shown in Figure 1 below.

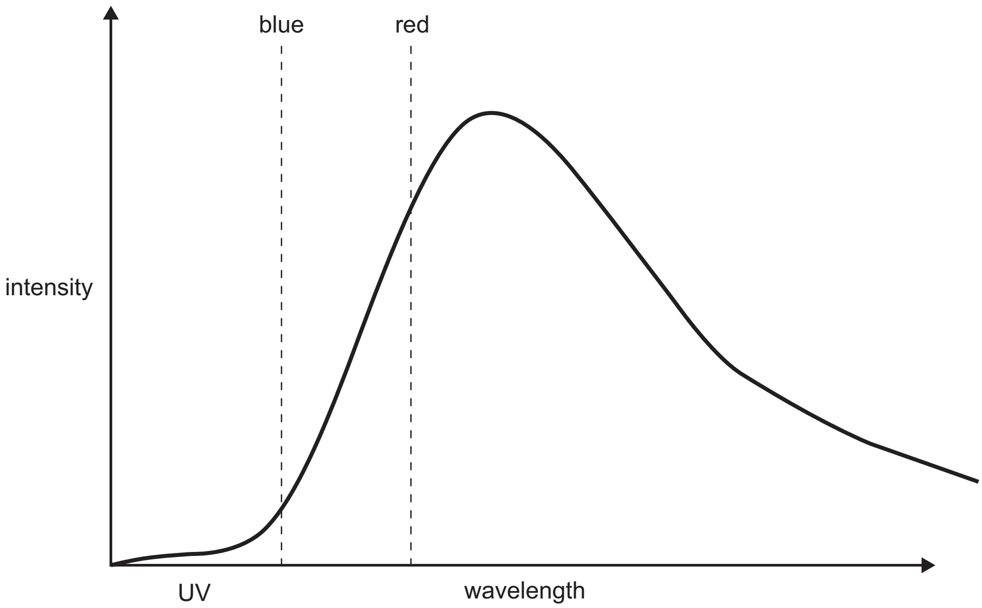


Figure 1

Question 1

Describe the mechanism by which light is produced in an incandescent light globe.

2 marks

Question 2

The light produced by an incandescent light globe can best be described as

A. coherent.

B. incoherent.

C. monochromatic.

D. in phase.

2 marks

Susan and Peter conducted a photo-electric experiment in which they used a light source and various filters to allow light of different frequencies to fall on the metal plate of a photo-electric cell. The maximum kinetic energy of any emitted photo-electrons was determined by measuring the voltage required, V_S (stopping voltage), to just stop them reaching the collector electrode. The apparatus is shown in Figure 2.

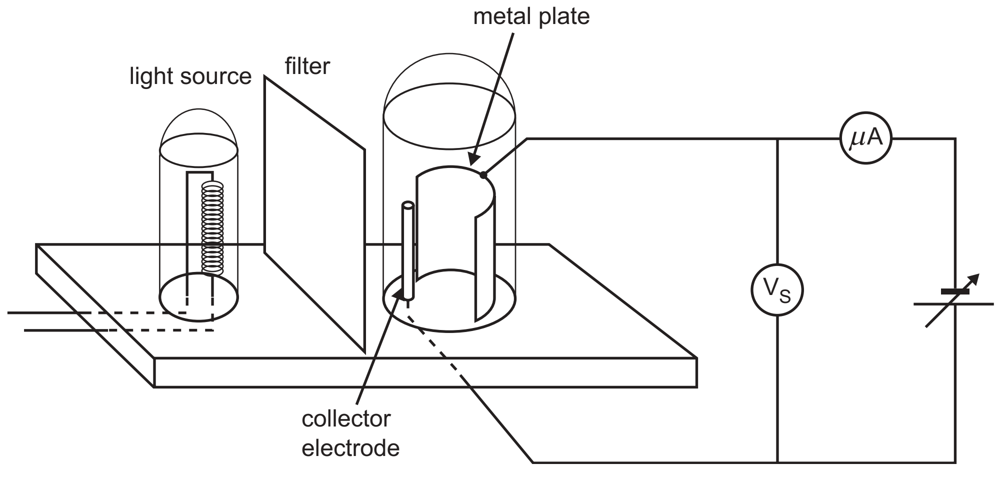


Figure 2

Figure 3 shows the stopping voltage, V_S, as a function of the frequency (f) of the light falling on the plate.

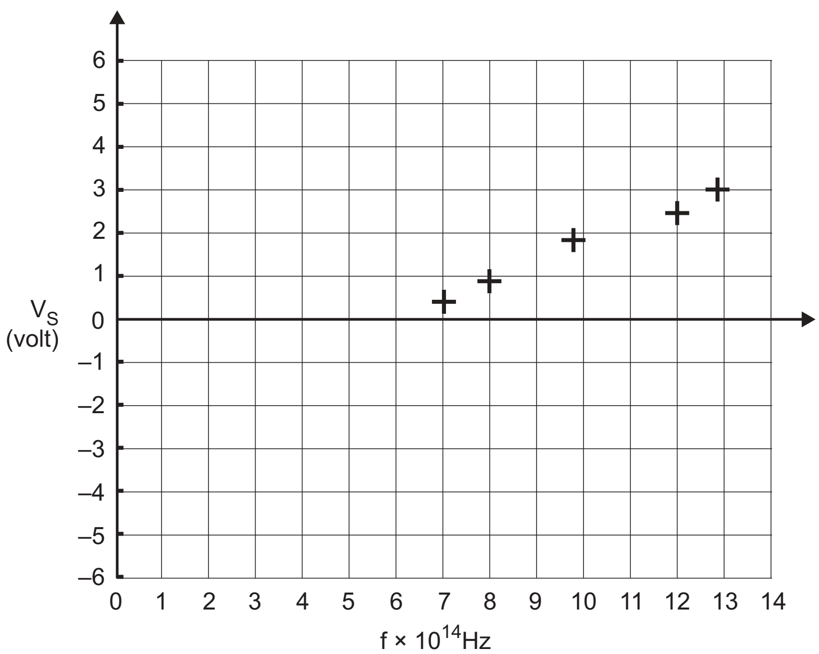


Figure 3

Table 1 shows the work functions for a series of metals.

Table 1

Metal	Work function
selenium	1.90 eV
sodium	2.75 eV
copper	4.70 eV
gold	5.30 eV

Question 3

Use the information above to identify the metal surface used in Susan and Peter's experiment.

metal

2 marks

Question 4

Use the results in Figure 3 to calculate the value for Planck's constant that Susan and Peter would have obtained from the data.

You must show your working.

eV s

3 marks

A physics teacher has apparatus to show Young's double slit experiment. The apparatus is shown in Figure 4. The pattern of bright and dark bands is observed on the screen.

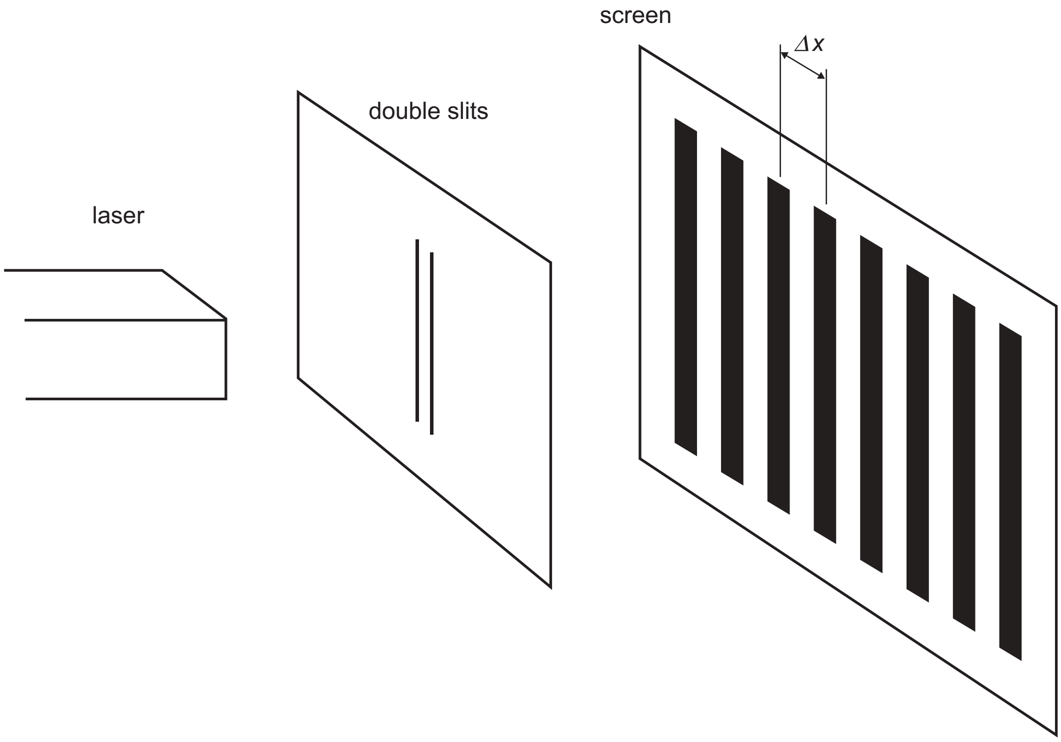


Figure 4

Question 5

Which one of the following actions will **increase** the distance, Δx, between dark bands in this double slit interference pattern?

A. decrease the slit width

B. decrease the slit separation

C. decrease the slit–screen distance

D. decrease the wavelength of the light

2 marks

Working space

A sketch of a cathode ray tube (CRT) is shown in Figure 5. In this device, electrons of mass 9.10×10^{-31} kg are accelerated to a velocity of 2.0×10^{7} m s^{-1}. A fine wire mesh in which the gap between the wires is $\Delta w = 0.50$ mm has been placed in the path of the electrons, and the pattern produced is observed on the fluorescent screen.

Planck's constant: $h = 6.63 \times 10^{-34}$ J s

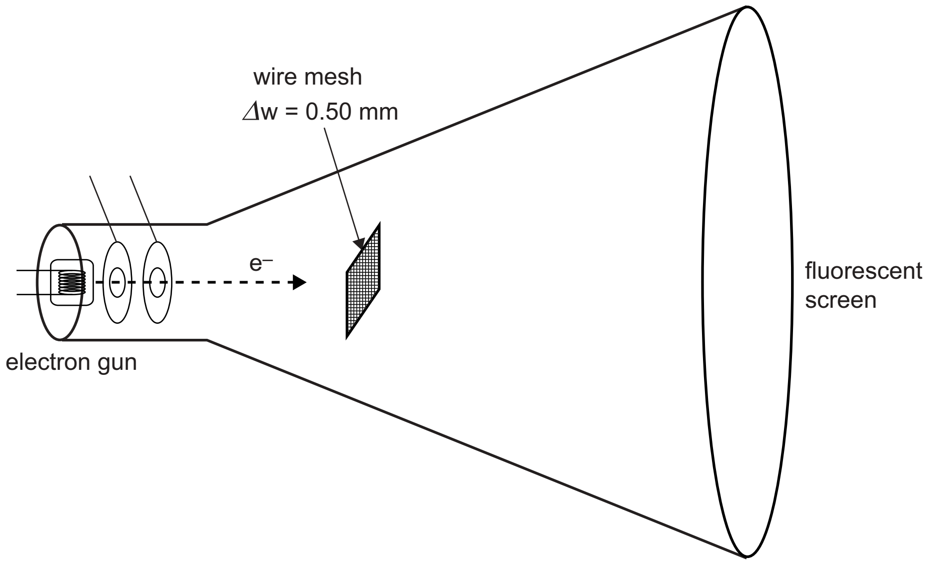


Figure 5

Question 6

Calculate the de Broglie wavelength of the electrons. You must show your working.

m

3 marks

Question 7

Explain, with reasons, whether or not the students would observe an electron diffraction pattern on the fluorescent screen due to the presence of the mesh.

2 marks

Question 8

Light sometimes behaves as a particle and sometimes as a wave. Which **one or more** of the following properties does light sometimes show?

A. mass

B. momentum

C. charge

D. energy

2 marks

The spectrum of photons emitted by excited atoms is being investigated. Shown in Figure 6 is the atomic energy level diagram of the particular atom being studied. Although most of the atoms are in the ground state, some atoms are known to be in n = 2 and n = 3 excited states.

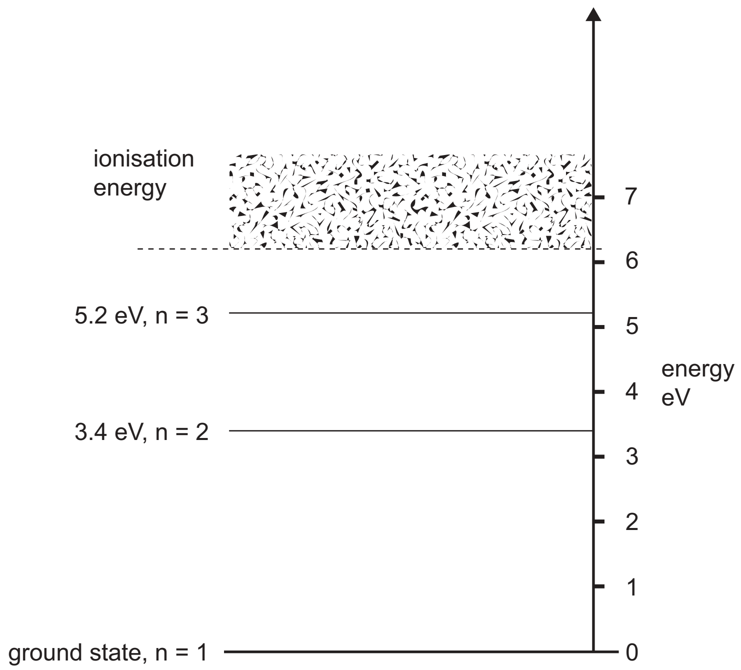


Figure 6

Question 9

What is the lowest energy photon that could be emitted from the excited atoms?

eV

2 marks

Question 10

Calculate the wavelength of the photon emitted when the atom changes from the n = 2 state to the ground state (n = 1).

Data: $h = 4.14 \times 10^{-15}$ eV s , $c = 3.0 \times 10^{8}$ m s^{-1}

m

2 marks

Question 11

In the space below describe how the wave-particle duality of electrons can be used to explain the quantised energy levels of the atom.

3 marks

Working space

END OF SECTION A

TURN OVER

SECTION B – Detailed studies

Instructions for Section B

Choose **one** of the following **Detailed studies**. Answer **all** the questions on the Detailed study you have chosen.

Detailed study 1 – Synchrotron and its applications

Question 1

In the sentences below, options are given within the brackets. Only **one** of the options will be correct. Circle the best option.

In a synchrotron, the circulating electrons are produced in

[*an electron gun / a linac / a storage ring*]. Ultimately the electrons are

accelerated to a speed of approximately **[*50% / 90% / 99.99%*]** of the speed of

light by **[*a linac / a storage ring / an undulator*]**.

3 marks

One section of a storage ring is shown in Figure 1. Electrons travelling through this section of the storage ring have a momentum of approximately 1.2×10^{-18} kg m s^{-1} and are bent through an arc of radius 7.7 m as shown. The charge on the electron is -1.6×10^{-19} C.

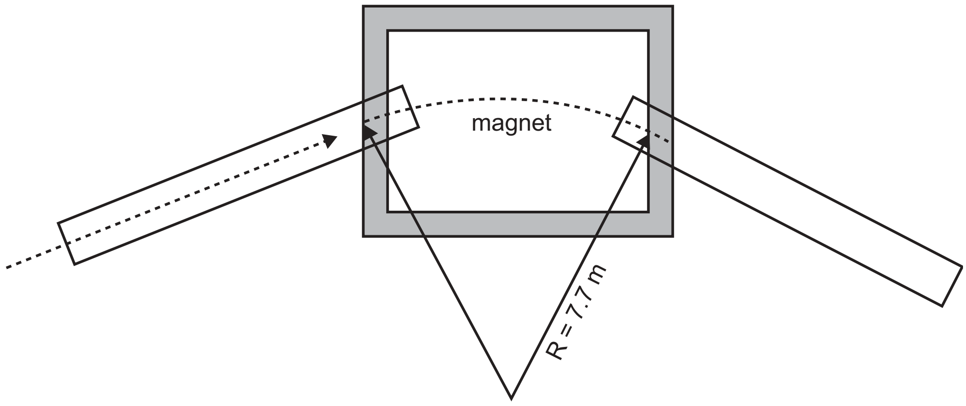


Figure 1

Question 2

Calculate the strength of the magnetic field required to keep the electrons on this arc.

T

2 marks

One of the uses for synchrotron radiation is to produce monochromatic x-rays that will be used to measure crystal structure. One technique is to use Bragg diffraction of x-rays from planes of atoms within the crystal. Figure 2a shows an experimental arrangement, and Figure 2b shows an enlarged view of the crystal planes, that are a distance *d* apart, that cause the diffraction.

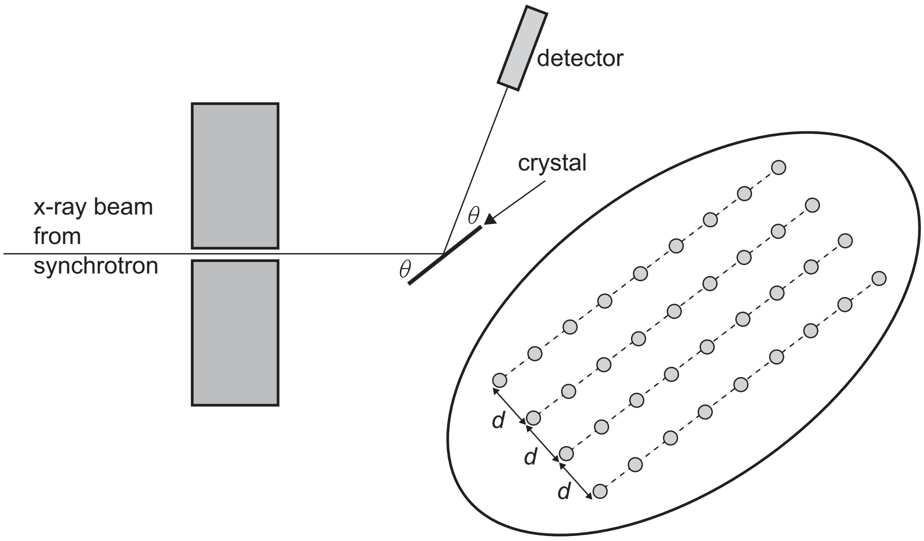


Figure 2a **Figure 2b**

A narrow beam of x-rays with a wavelength of 0.115 nm is incident on the crystal.

Question 3

What is the energy of these x-rays?

keV

2 marks

In the experiment, the angle, θ, between the crystal and the detector, was increased from zero while recording the number of x-rays detected. A sharp peak was observed at $\theta = 9.6°$ as shown in Figure 3.

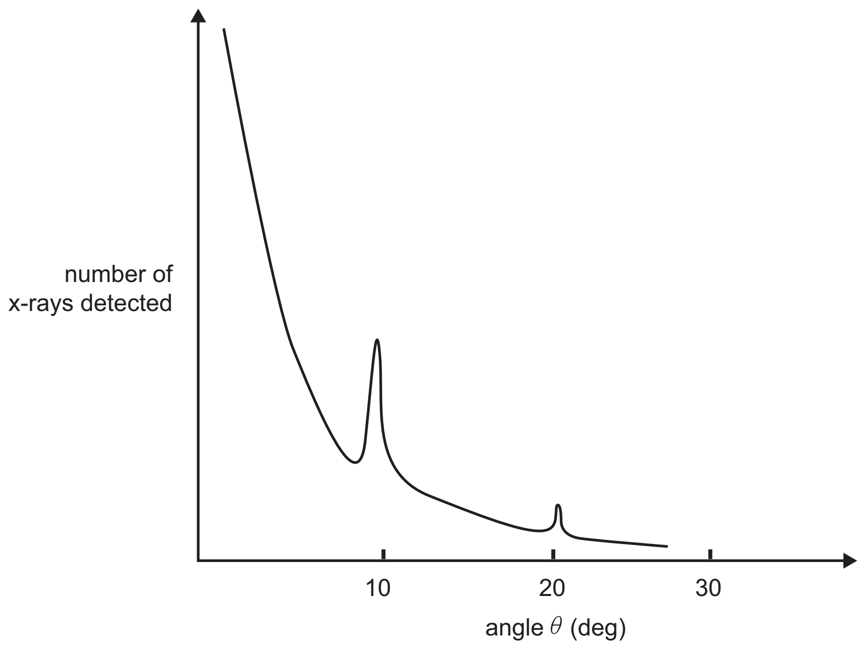


Figure 3

Question 4

What is the spacing, d, between the layers in the crystal?

nm

3 marks

As the angle was increased further, it was found that at $\theta = 20.2°$ another increase in the number of x-rays was detected as shown in Figure 3.

Question 5

From your understanding of Bragg's law ($n\lambda = 2d\sin\ \theta$) explain why this second maximum appears.

2 marks

Question 6

Choose **one** of the following options to complete the sentence.

Radiation generated by a synchrotron occurs because electrons

A. have high energies.

B. accelerate when they change direction.

C. collide with other electrons.

D. collide with residual air particles.

2 marks

A typical cathode ray tube is shown in Figure 4 below. It consists of an electron gun, a deflecting system and a fluorescent screen that emits light when struck by electrons.

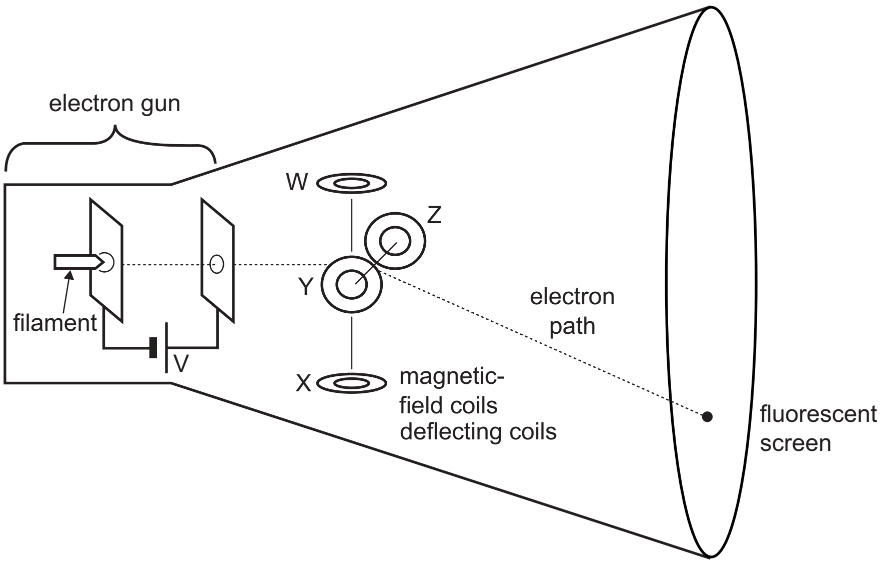


Figure 4

The electron gun consists of a filament that emits electrons with very small kinetic energy into an electric field created by a high voltage, V, applied between a pair of parallel plates. In a particular case the electrons emerge from the gun with an energy of 8.0×10^{-16} J.

Charge on the electron: $e = -1.6 \times 10^{-19}$ C

Question 7

Calculate the voltage, V, between the plates, used to accelerate the electrons.

V

2 marks

After acceleration, the electrons enter the magnetic-deflecting system which consists of two pairs of mutually perpendicular magnetic-field coils (W and X), (Y and Z) aligned as shown in Figure 4.

The electrons are deflected **downwards**, as shown.

Question 8

Choose one of the following options to complete the sentence.

The downward deflection can be achieved by the coils

A. WX producing a magnetic field in direction W to X.

B. WX producing a magnetic field in direction X to W.

C. YZ producing a magnetic field in direction Y to Z.

D. YZ producing a magnetic field in direction Z to Y.

2 marks

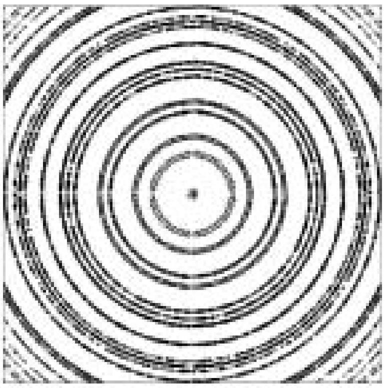


Figure 5a

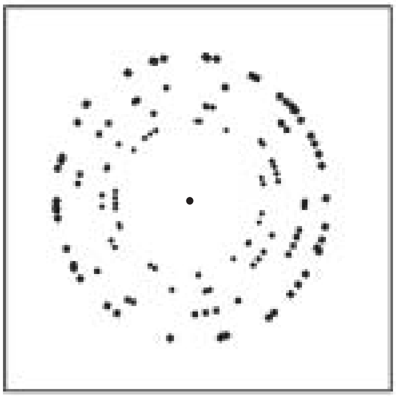


Figure 5b

The diffraction images in Figures 5a and 5b are experimental results obtained by scattering x-rays from a powder crystal sample for the same exposure time. Figure 5a was obtained using x-rays from a synchrotron, and Figure 5b was obtained using x-rays from a conventional x-ray tube. Apart from this difference, both experiments utilised identical procedures, equipment and recording times.

Question 9

Explain why the image obtained with the synchrotron appears clearer than the other image.

3 marks

A beam of x-rays with energy 10 keV is scattered by a thin metallic foil.

Question 10

Which of the following is the best estimate for the wavelength of the incident x-rays?

A. 1.2×10^{-8} m

B. 1.2×10^{-10} m

C. 1.2×10^{-12} m

D. 1.2×10^{-14} m

2 marks

Question 11

Which of the following is the best estimate for the energy of x-rays that have undergone Thomson (elastic) scattering?

A. 0 keV

B. 5 keV

C. 10 keV

D. 20 keV

2 marks

END OF DETAILED STUDY 1

Detailed study 2 – Photonics

Question 1

In the sentences below, options are given within the brackets. Only **one** of the options will be correct. Circle the best option.

A laser produces **[*coherent / multi-modal / wide spectrum*]** light. The input power to the laser produces **[*coherence / a population inversion / ionisation*]** in the electron energies of the gas atoms. The atoms are stimulated to release their energy by interacting with **[*electrons of the same / photons of the same / photons of higher*]** energy.

3 marks

The spectra of wavelengths produced by three different light sources are shown in Figure 1.

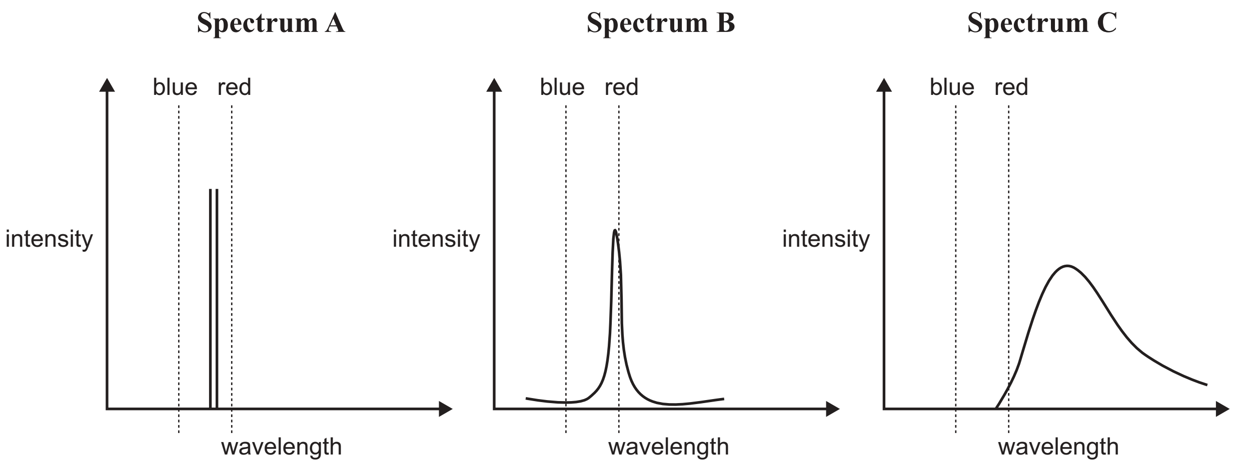


Figure 1

A selection of light sources is listed below.

- sodium vapour lamp
- incandescent globe
- blue laser
- red hot slab of iron
- red LED
- candle

Question 2

For each spectrum (**A–C**), identify the most likely light source. Write the corresponding light source in the appropriate box below.

Spectrum A	
Spectrum B	
Spectrum C	

3 marks

Question 3

Explain how light is produced in a LED (Light Emitting Diode). Your explanation should include reference to the band gap.

2 marks

Question 4

The band gap in a LED is 2.1 eV. Calculate the average wavelength of light emitted by this LED.

m

3 marks

The structural composition of a commercially available optical fibre is shown in Figure 2 below. The core has a refractive index of 1.62 and a diameter of 50 μm. The cladding material is 2.3 μm thick.

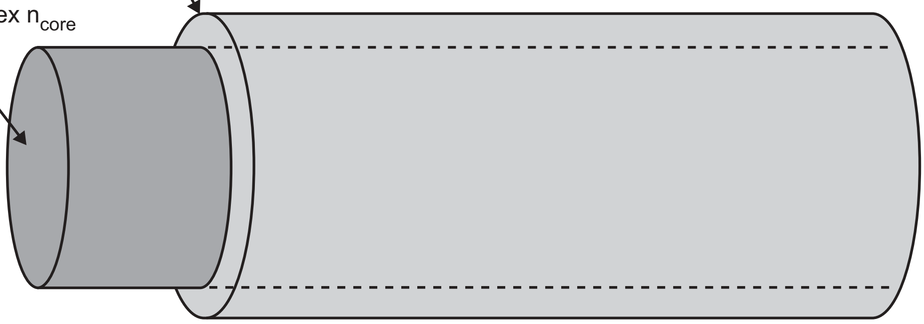


Figure 2

Question 5

Assuming proper modes of propagation, which of the following relative values of refractive indices is correct?

A. $n_{air} < n_{core} < n_{cladding}$

B. $n_{air} < n_{cladding} < n_{core}$

C. $n_{core} < n_{air} < n_{cladding}$

D. $n_{cladding} < n_{core} < n_{air}$

2 marks

The beam from a laser is incident onto the hemispherical end face of a plastic rod as shown in Figure 3.

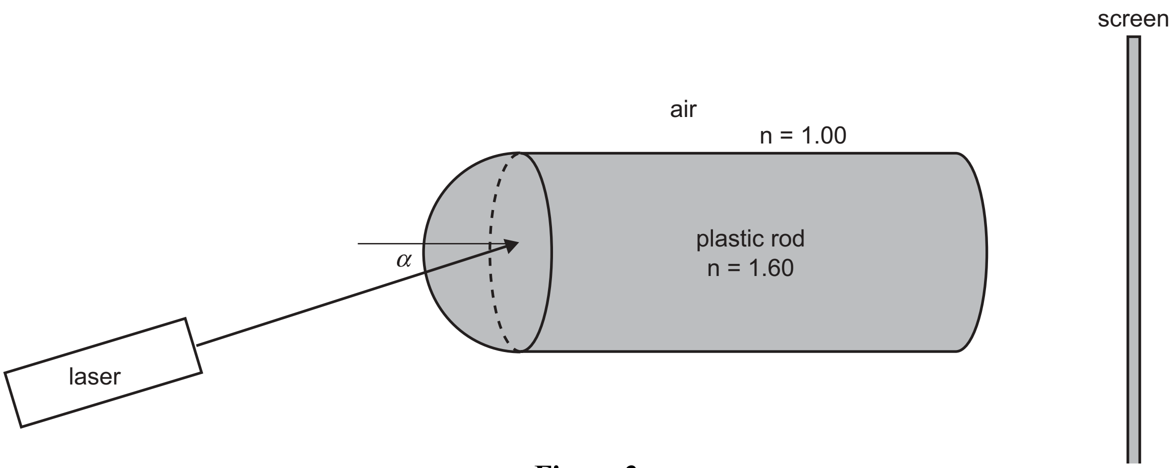


Figure 3

Question 6

What is the maximum acceptance angle, α, that will allow the beam from the laser to reach the screen?

2 marks

Question 7

Which **one** of the following changes would reduce modal dispersion of a fibre optic cable?

A. use a larger diameter fibre

B. use a smaller diameter fibre

C. use a thicker cladding

D. use a thinner cladding

2 marks

A single mode fibre optic cable is intended to be used to transmit a data signal over a long distance. A series of repeater-stations will be placed at regular intervals to amplify the signal. The transmission characteristics of the fibre optic cable are shown in Figure 4.

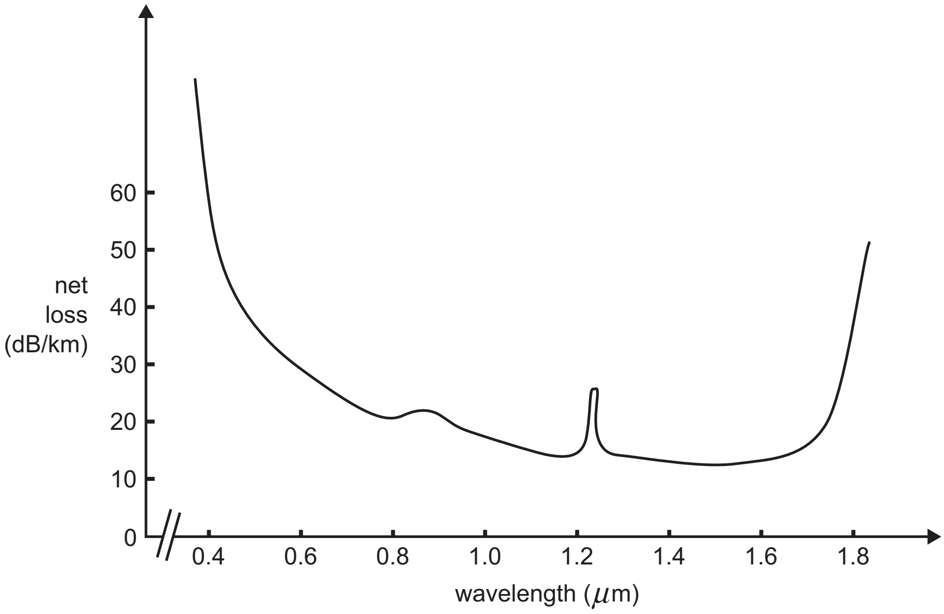


Figure 4

Red laser diodes ($\lambda = 0.6\ \mu$m) are commonly available and when used with this cable they perform adequately over distances less than 1 km, but the performance is degraded considerably for much larger distances.

Question 8

Which of the following is the most likely cause of this signal degradation?

A. modal dispersion

B. Rayleigh scattering

C. demodulation

D. multiplexing

2 marks

Question 9

The attenuation characteristics of the fibre optic cable in Figure 4 show high losses for wavelengths less than 0.7 μm and greater than 1.7 μm. Identify **one** likely cause of each of these losses, and explain the physical process that leads to the loss.

i. Cause for wavelengths less than 0.7 μm ______________________________

Explanation of physical process ______________________________

____

____

____

ii. Cause for wavelengths greater than 1.7 μm ______________________________

Explanation of physical process ______________________________

____

____

____

4 marks

Question 10

Which of the following arrangements would be suitable for long distance transmissions (hundreds of kilometres)?

A. multimode fibre with a LED as the light source

B. multimode fibre with a laser diode as the light source

C. single mode fibre with a LED as the light source

D. single mode fibre with a laser diode as the light source

2 marks

Detailed study 3 – Sound

Question 1

In the sentences below, options are given within the brackets. Only **one** of the options will be correct. Circle the best option.

A sound wave is a **[*torsional / transverse / longitudinal*]** wave in which the air

particles move **[*at right angles to / parallel to / by spiralling around*]** the

direction of propagation of the wave. The wave transmits

[*energy / air particles / wave maxima*] from the source to the receiver.

3 marks

Listed below are three types of microphones.

- crystal
- dynamic
- electret-condenser

Question 2

Complete the following table by choosing, from the choices above, the type of microphone that matches the physical effect on which its operation depends.

Microphone type	**Principle of operation**
	electromagnetic induction
	piezoelectric effect
	capacitance

3 marks

A high fidelity loudspeaker system comprising individual speakers mounted on a baffle board is shown in the diagram in Figure 1.

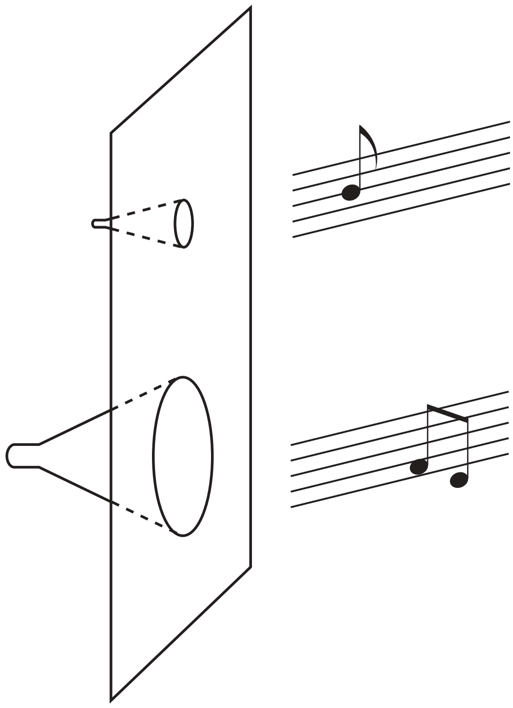


Figure 1

Question 3

Explain the role of the baffle board in improving the performance of the loudspeaker **system** above.

2 marks

The frequency response curve for one of the speakers in shown in Figure 2 below.

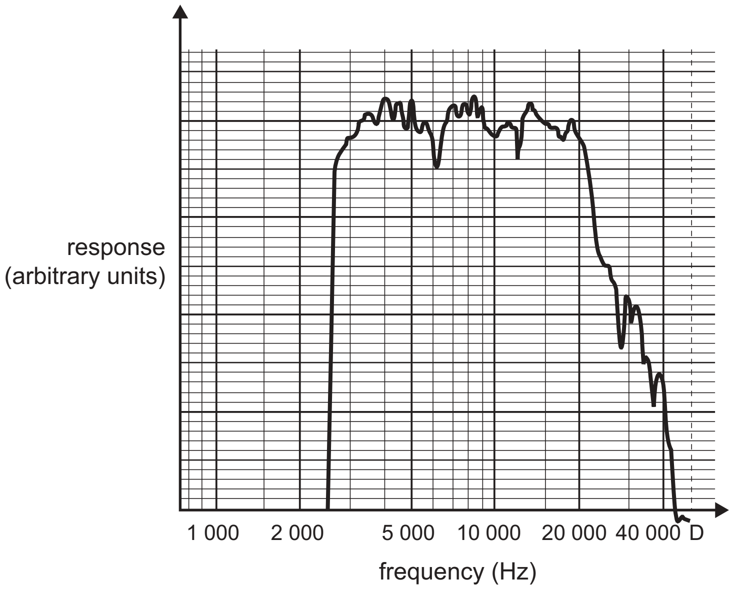


Figure 2

Question 4

Which type of speaker is most likely to have a response curve similar to that shown in Figure 2?

A. sub-woofer

B. woofer

C. mid-range speaker

D. tweeter

2 marks

Question 5

A system uses a single, wide-frequency response speaker. Explain why the quality (fidelity) will deteriorate as the listener moves off the centreline. Hence explain why a multiple-loudspeaker system, as shown in Figure 1, would be more satisfactory.

3 marks

Lee and Chris are constructing their own pipe organ. It consists of a number of plastic pipes, each of which has been cut to a specific length. Their design is such that each pipe can be considered to be an air column **closed at one end**. The organ is to have a range of 4 octaves, where the highest note has a fundamental resonance of approximately 2000 Hz.

The speed of sound may be taken as 320 ms^{-1}.

Question 6

One particular pipe is designed to resonate at a fundamental frequency of 160 Hz.

Which of the choices below is the best estimate of the length of this pipe?

A. 0.25 m

B. 0.5 m

C. 1.0 m

D. 2.0 m

2 marks

Question 7

List two other frequencies below 1000 Hz at which this pipe could resonate.

Hz	Hz

2 marks

Chris intends to record the sounds being produced by the pipe organ. He argues that since the frequency of the top note is about 2000 Hz, for good reproduction they need a microphone with a good frequency response only up to about 2000 Hz. Lee, however, knows that a microphone with a much higher frequency response is needed to reproduce the organ sound with good fidelity.

Question 8

Outline, with reasons, why Lee is correct.

2 marks

It is a cold, windless morning and three hot-air balloons hover above a park. Each balloon is stationary and in direct line of sight, with no obstacles near them, as shown in Figure 3. Balloon A is equipped with a 100 W siren, which emits a 2000 Hz tone uniformally in all directions. On board balloons B and C are students with sound measuring equipment.

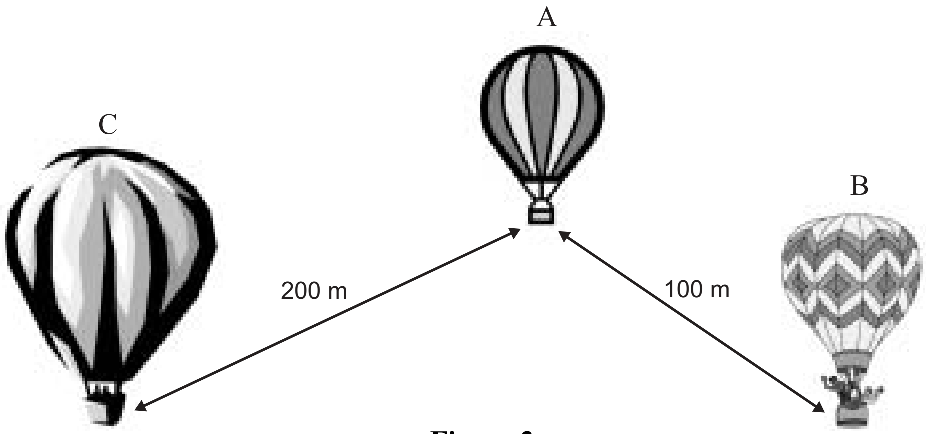


Figure 3

Question 9

Which of the following is the best estimate of the sound **intensity** of the siren as measured at balloon B?

A. 0.5 W m^{-2}

B. 2.5×10^{-2} W m^{-2}

C. 8.0×10^{-4} W m^{-2}

D. 2.5×10^{-5} W m^{-2}

2 marks

Question 10

By how many decibels will the sound intensity level at balloon C be lower than at balloon B?

dB

2 marks

Question 11

Balloons B and C move so that they are at equal distances from balloon A.

The sound intensity at balloon C is now measured as 1.0×10^{-2} W m^{-2}.

What is the sound intensity level (dB) at balloon B?

dB

2 marks

END OF QUESTION AND ANSWER BOOK

PHYSICS

Written examination 2

DATA SHEET

Directions to students

Detach this data sheet before commencing the examination. This data sheet is provided for your reference.

1	photoelectric effect	$E_{k\max} = hf - W$
2	photon energy	$E = hf$
3	photon momentum	$p = \frac{h}{\lambda}$
4	de Broglie wavelength	$\lambda = \frac{h}{p}$
5	resistors in series	$R_T = R_1 + R_2$
6	resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$
7	magnetic force	$F = I\,l\,B$
8	electromagnetic induction	emf : $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ flux: $\Phi = BA$
9	transformer action	$\frac{V_1}{V_2} = \frac{N_1}{N_2}$
10	AC voltage and current	$V_{RMS} = \frac{1}{\sqrt{2}}V_{peak}$ $I_{RMS} = \frac{1}{\sqrt{2}}I_{peak}$
11	voltage; power	$V = RI$ $P = VI$
12	transmission losses	$V_{drop} = I_{line} R_{line}$ $P_{loss} = I^2_{line} R_{line}$
13	mass of the electron	$m_e = 9.1 \times 10^{-31}$ kg
14	charge on the electron	$e = -1.6 \times 10^{-19}$ C
15	Planck's constant	$h = 6.63 \times 10^{-34}$ J s $h = 4.14 \times 10^{-15}$ eV s
16	speed of light	$c = 3.0 \times 10^8$ m s^{-1}

Detailed study 3.1 – Synchrotron and applications

17	energy transformations for electrons in an electron gun (<100 keV)	$\frac{1}{2}mv^2 = eV$
18	radius of electron beam	$r = p/eB$
19	force applied to an electron beam	$F = evB$
20	Bragg's law	$n\lambda = 2d\sin\theta$
21	electric field between charged plates	$E = \frac{V}{d}$

Detailed study 3.2 – Photonics

22	band gap energy	$E = \frac{hc}{\lambda}$
23	Snell's law	$n_1 \sin i = n_2 \sin r$

Detailed study 3.3 – Sound

24	speed, frequency and wavelength	$v = f\lambda$
25	intensity and levels	sound intensity level (in dB) $= 10\log_{10}\left(\frac{I}{I_0}\right)$ where $I_0 = 1.0 \times 10^{-12}$ W m^{-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 DATA SHEET