VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2004

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures										Letter
Words										

PHYSICS – PILOT STUDY

Written examination 2

? ? ? 2004

Reading time: ? to ? (15 minutes)
Writing time: ? to ? (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. Interactions of light and matter	11	11	25
2. Electric power	17	17	40
B – Detailed studies			
1. Synchroton and applications	9	9	25
OR			
2. Photonics	10	10	25
OR			
3. Recording and reproducing 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 35 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 electronic communication 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 – Interactions of light and matter

Question 1

In 1801, Thomas Young performed his now-famous interference experiment. In this experiment the wave nature of light was demonstrated. Figure 1 below is a drawing similar to the original sketch recorded by Young at the time. The dark circles represent wave crests, and the troughs are midway between these.

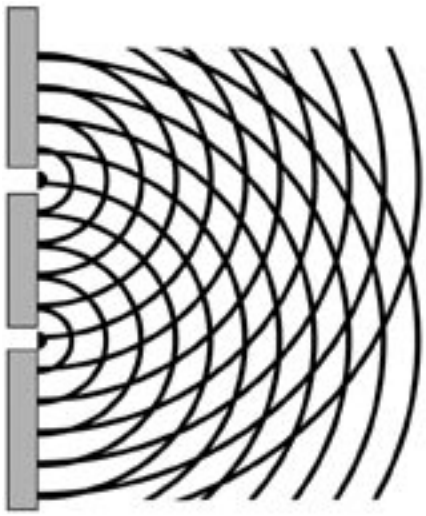


Figure 1

Which **one** or **more** of the following statements is true.

Constructive interference occurs where

A. crests overlap crests.

B. crests overlap troughs.

C. troughs overlap crests.

D. troughs overlap troughs.

2 marks

A group of students are attempting a modern version of this old experiment and plan to investigate the use of different light sources. Figure 2 below represents their intended setup together with their prediction of the observed interference pattern on the screen.

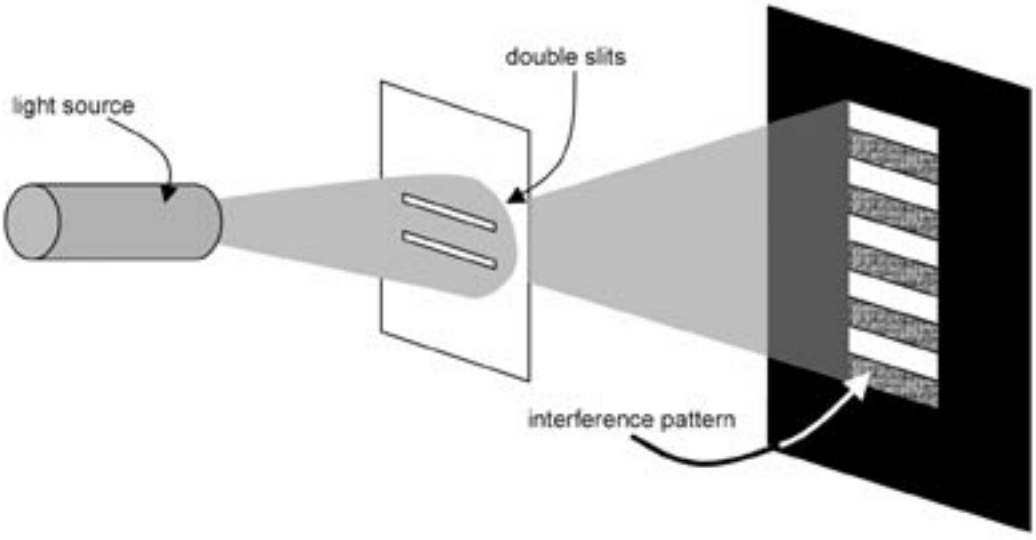


Figure 2

- Hermione is keen to use a bright torchlight aimed at both slits simultaneously.
- Harry disagrees, he comments that we now have lasers in the 21st century and suggests that two laser pointers, each aimed at one of the slits, would be preferable.
- Neville disagrees with both of them. Neville plans to cover Hermione's torch with a pinhole and use this as a source.

Each suggestion is tried and only Neville's idea resulted in the formation of bright and dark lines on the screen.

Question 2

Briefly explain why Harry's plan did not work.

3 marks

Question 3

Figure 3 is a side view of the experimental setup, where AB indicates the separation of the two slits. Note that the diagram is not to scale, and that AC is approximately 1000 mm and AB 5 mm.

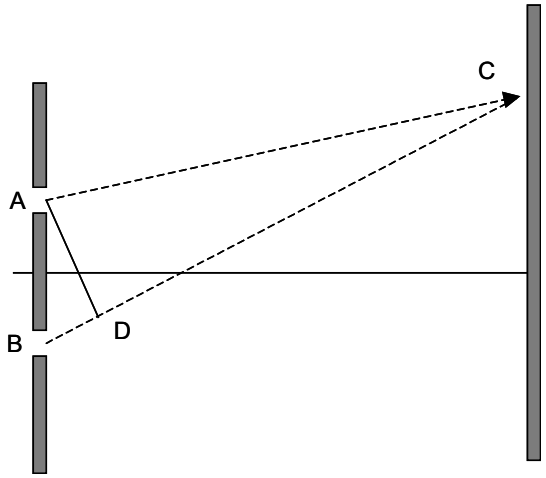


Figure 3

Write down, in terms of the lengths AD, a formula for the path difference.

2 marks

Question 4

What is the significance of the path difference with respect to the pattern formed?

2 marks

Some students are performing an experiment to determine the work function of Na (sodium) metal. The apparatus used is shown in Figure 4. Their method involved exposing a sheet of metal to a variety of light sources and measuring the current of ejected photoelectrons and the potential required to stop the electrons. As part of the experiment, the students have identified a calibration table for the light source.

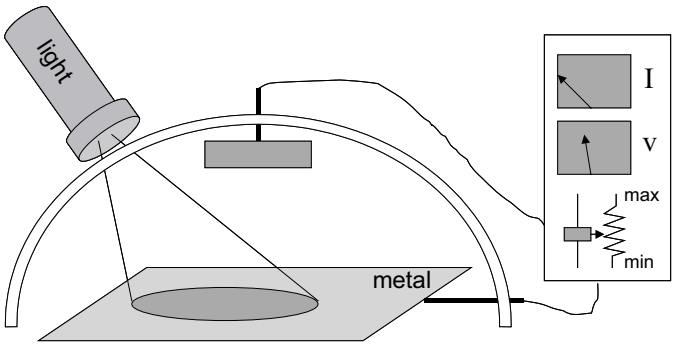


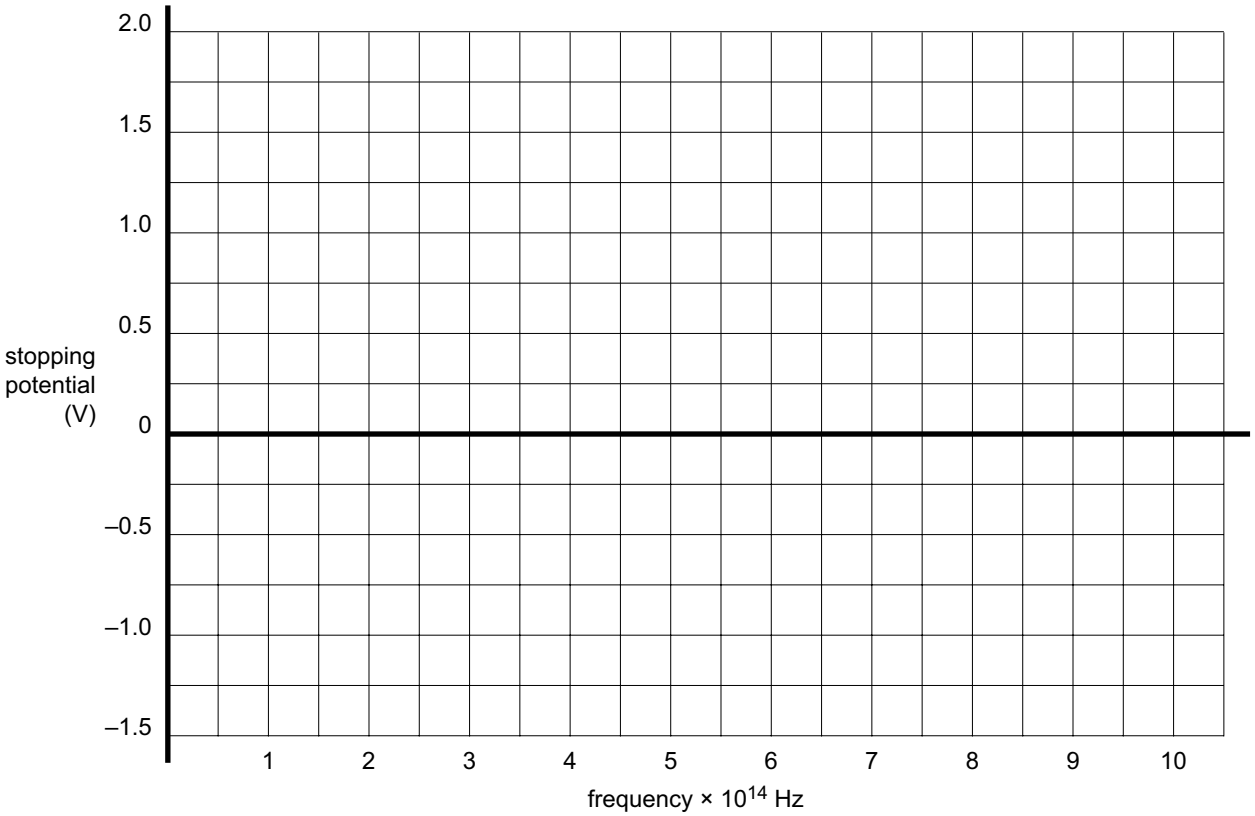
Figure 4

Here is a copy of the experimental results they have obtained.

Colour	**Wavelength nm**	**Frequency × 10^{14} Hz**	**Stopping potential (V)**	**I_{max} (mA)**
Red	630	4.8	0	0
Yellow	570	5.3	0	0
Green	520	5.8	0.1	.023
Blue	480	6.3	0.3	.032
Violet	430	7.0	0.6	.051
Ultra violet	295	10.0	1.9	.021

Question 5

Use the experimental results to construct a plot of stopping potential versus frequency.



3 marks

Question 6

Use the graph from Question 5 to determine an experimental value of Plank's constant. Make sure that you outline your method and/or reasoning.

J s

3 marks

Figures 5a and 5b below are two images that have been obtained by scattering electrons and x-rays off a collection of many small crystals with random orientations. The pictures are all to the same scale, and the x-rays have a wavelength of 35×10^{-12} m.

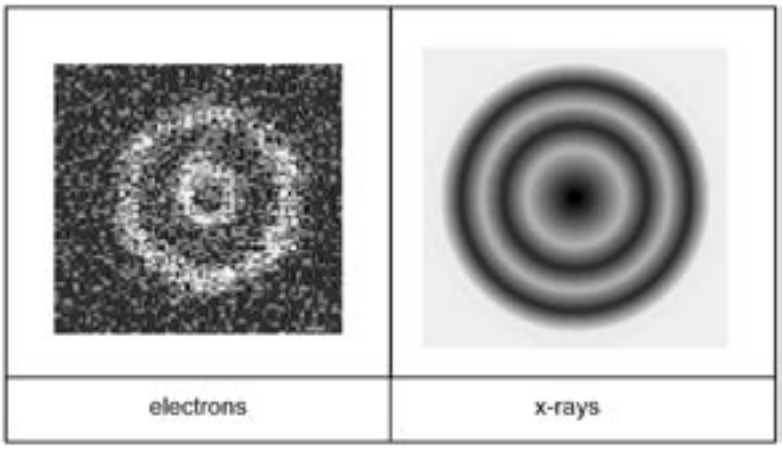


Figure 5a **Figure 5b**

Question 7

Why do the patterns observed appear so similar?

2 marks

Question 8

Calculate the energy of the x-rays in keV.

keV

2 marks

Question 9

Provide an estimate for the de Broglie wavelength of the electrons.

pm

2 marks

The basic hydrogen energy level structure is in agreement with the Bohr model. Common pictures are those of a shell structure.

Each shell is associated with a value of the principal quantum number n, as shown in Figure 6.

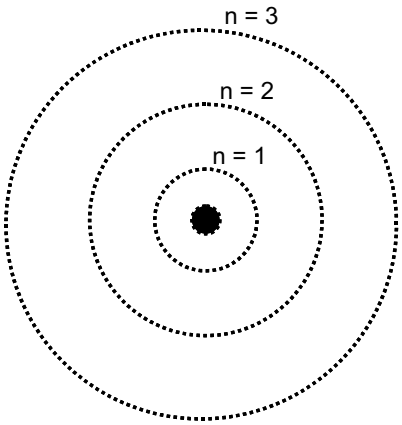


Figure 6

Question 10

What are the consequences of this model for the energy states in the hydrogen atom?

2 marks

Question 11

The pattern below (Figure 7) is meant to represent the 'standing wavestate' of an electron in a hydrogen atom. Which value of 'n' would best describe this pattern?

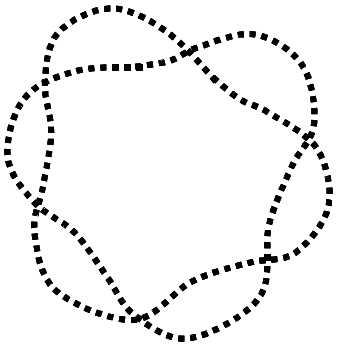


Figure 7

n =

2 marks

END OF AREA OF STUDY 1
SECTION A – continued

Area of study 2 – Electric power

Many science books contain experiments where a battery, coil and nail can be used to create an electromagnet, as is shown in Figure 1.

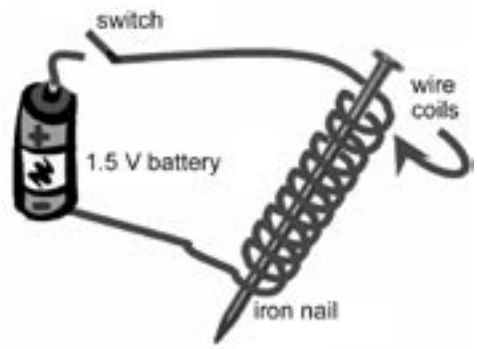


Figure 1

Question 1

Briefly describe the process by which the 'magnetism' is made when the switch is closed.

3 marks

Question 2

On Figure 1 indicate the following.

i. the north pole of the magnet with a 'N'

ii. six field lines

2 marks

Two separate but similar coils are mounted closely to each other as shown in Figure 2. The second coil is connected to a battery and switch. The switch is initially open and no current is flowing. An ammeter is connected to the second coil and initially shows no deflection. When the switch is **first** closed, the ammeter needle is deflected to the left.

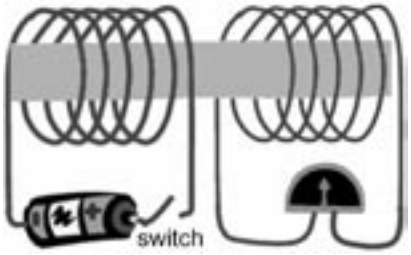


Figure 2

Question 3

Complete the table below by describing how the ammeter responds to the following sequential actions. Write your answer in the two empty entries of the column in the table.

Action	Ammeter
Switch is open	No deflection
Switch is closed for the first time	Meter deflects to LEFT
Switch is left closed for a few seconds	
Switch is returned to open position	

2 marks

Chee-lin has a small portable sound system that requires 24 V AC for operation. She would like to use the transformer in Figure 3a below to provide this power. This transformer has two secondary outputs, which when combined correctly provide 24 V AC. All voltages are RMS and the coils are each wound in the same direction.

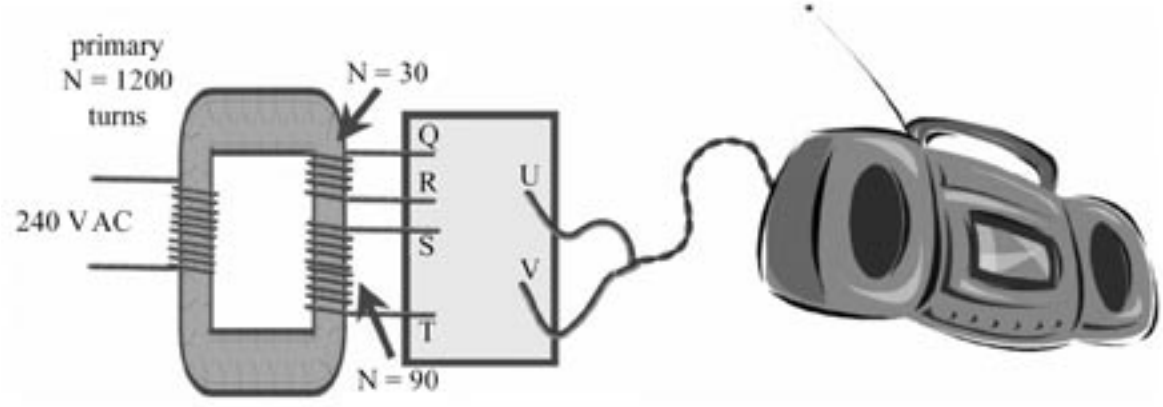


Figure 3a

Question 4

Calculate the output voltage between Q and R.

V

2 marks

Question 5

Complete the circuit diagram (Figure 3b) below by correctly connecting the points Q, R, S, T, U and V to provide 24 V AC to the device.

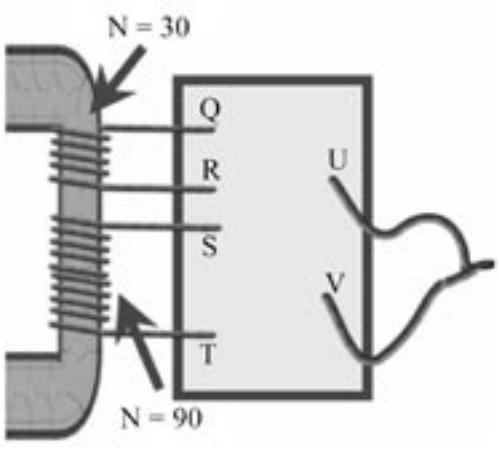


Figure 3b

3 marks

A conducting wire is placed in a uniform magnetic field of 0.1 T, as shown in Figure 4. When a DC voltage is applied between A and B, the wire experiences a constant force as indicated on the diagram.

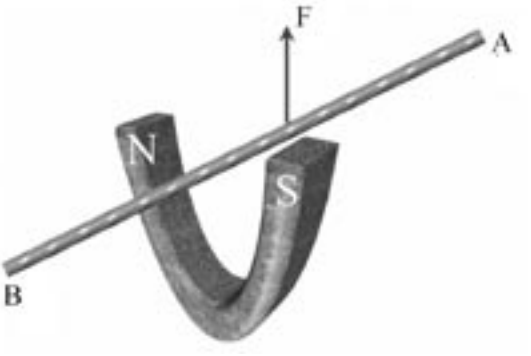
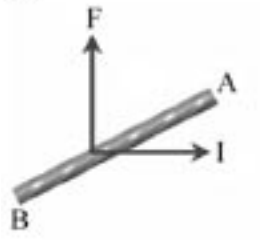


Figure 4

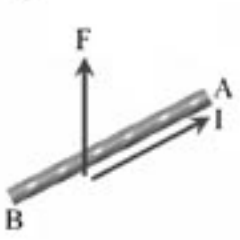
Question 6

Choose one of the following options (**A–D**) that correctly indicates the direction in which the current must flow for the wire to experience the force as indicated.

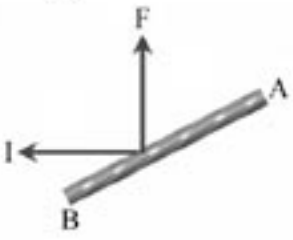
A.



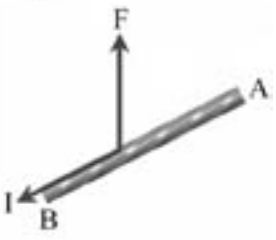
B.



C.



D.



2 marks

Question 7

Assume that the magnetic field exists only between the poles of the magnet, and is uniform. What current must flow for the wire to experience a force of 0.02 N?

N

2 marks

Question 8

Briefly describe what would happen to the wire if instead of a DC source, the wire was connected to an AC power source of the same voltage and frequency 50 Hz.

2 marks

Payel is investigating the operation of a simple **alternator**, as shown in Figure 5a below. She has found that if the coil is rotated anticlockwise as shown, the light glows dimly.

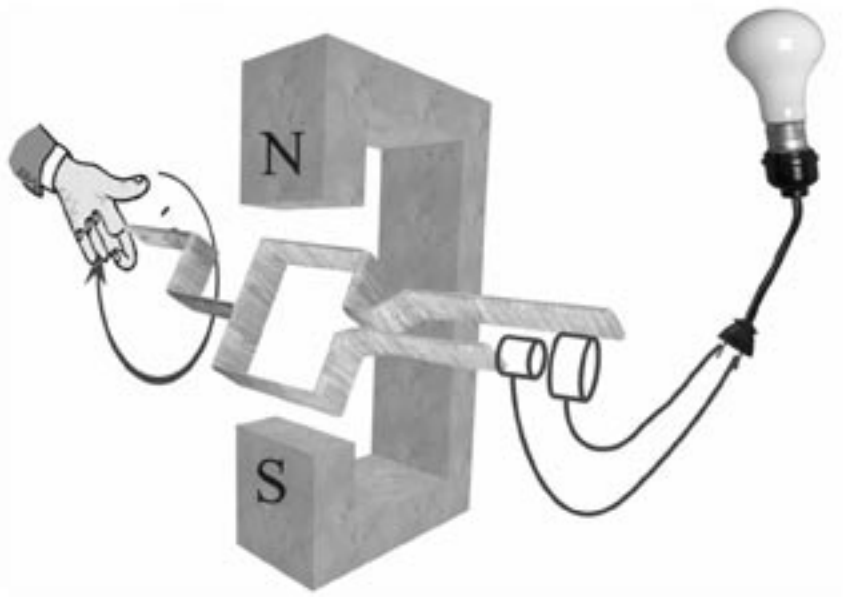


Figure 5a

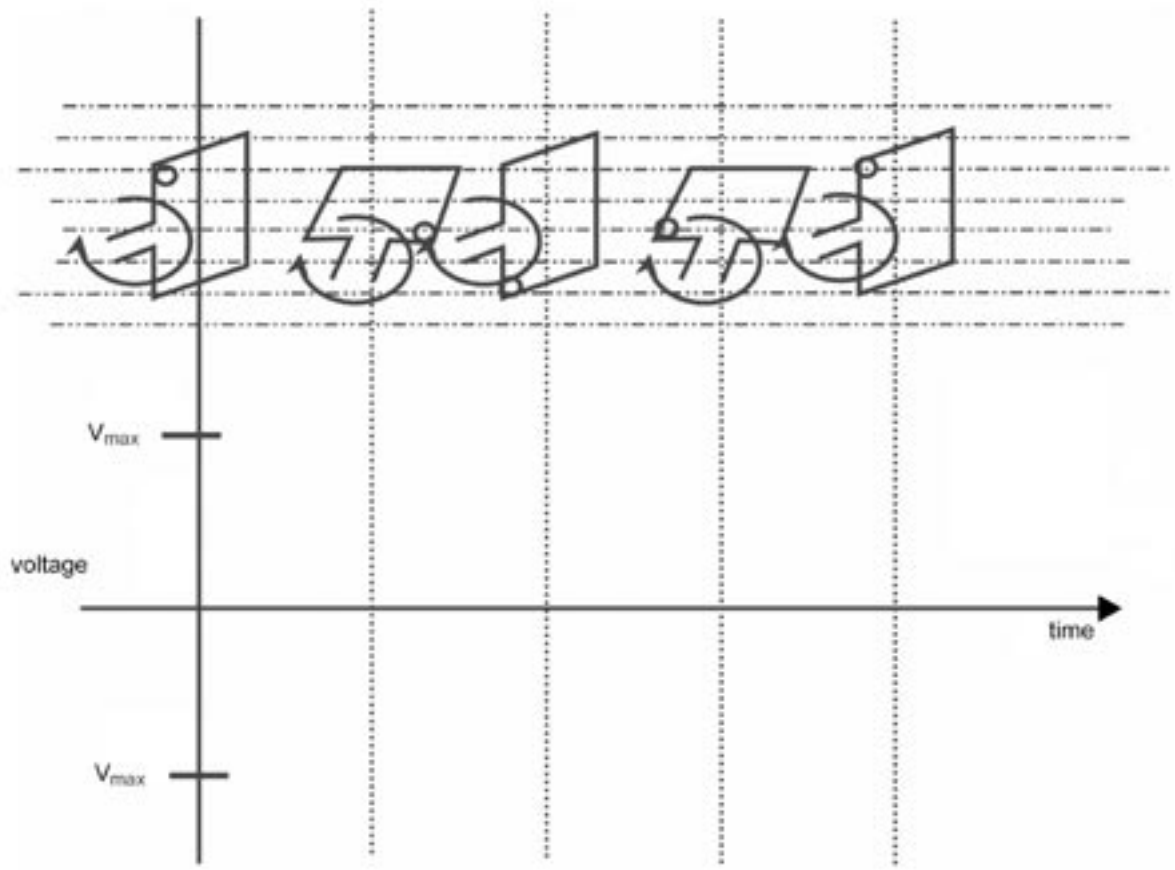


Figure 5b

Question 9

Sketch the **voltage** produced in the coil on Figure 5b above. Note that initially the coil is positioned to intercept the maximum number of field lines.

2 marks

Question 10

Does the voltage output of the alternator **increase** or **decrease** when it is spun faster?

2 marks

Question 11

i. State Lenz's law.

Lenz's law:

ii. Use Lenz's law to explain your answer to Question 10.

1 + 2 = 3 marks

Jo is a farmer, who has agreed to address the local community on the topic of power transmission. This topic has been chosen because the community is concerned about high-voltage power lines and is considering removing all of them and replacing them with low-voltage alternatives. Jo has sketched out a speech below aimed at convincing them that there is a good reason for high-voltage power lines. One minor issue is that Jo needs your help to eliminate a few incorrect words.

Below is Jo's speech. Go through it carefully and choose the correct word to ensure that the speech is scientifically correct.

Question 12

Identify your choice by **circling** the correct choice.

Almost all electricity sold today is in the form of [**DC / AC**],

mainly because of the ease with which it can be [**TRANSFORMED / RECTIFIED**] from one [**CURRENT / VOLTAGE**] to another.

Large [**VOLTAGES / CURRENTS**] in wires produce heat and therefore energy loss because of the resistance in the wires. To overcome this loss, power is transmitted over large distances at [**LOW / HIGH**] voltages and correspondingly [**LOW / HIGH**] currents.

As an example, if the transmission voltage was reduced to one-tenth (1/10) of the original voltage, and the power consumption maintained, the line losses would [**INCREASE / DECREASE**] by a factor of [**1 / 10 / 100 / 1000**].

<end of Jo's speech>

4 marks

Three groups of students are out camping. Part of their camping equipment includes a set of 12 V camping lamps, each rated at 12 W. The students do not want to run the lamps off torch batteries. Instead they intend to power the lamps from their campervan, which has two 12 V outputs. Realising that their tents could be some distance away from the car, they have brought three 18 m extension leads. Each lamp has a switch and is connected as shown in Figure 6.

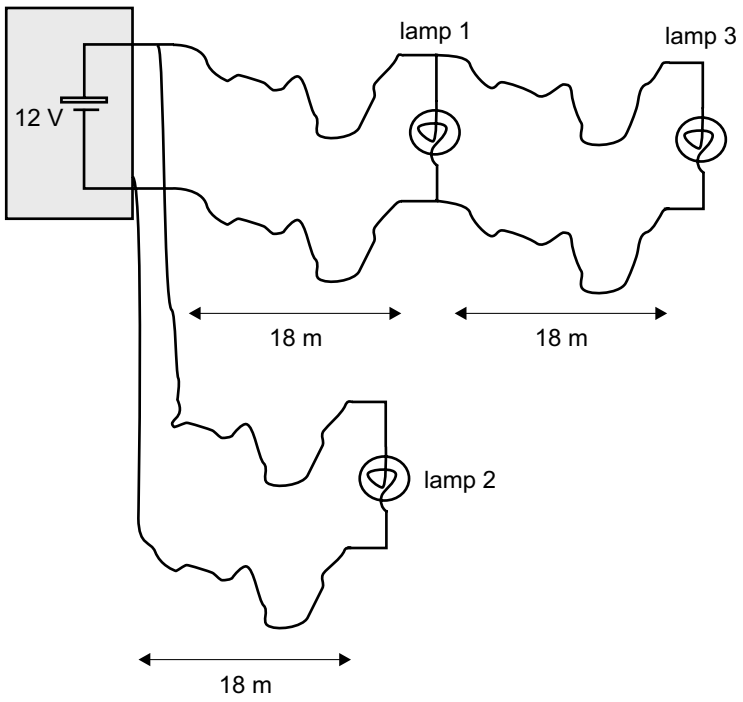


Figure 6

As each lamp is turned on one at a time, the students notice that the lights do not seem as bright as when they were first tested. One of the enterprising students measures the voltage on lamp 2 and notices it is only 11 V, whereas the voltage at the campervan is 12 V. All three lights are now turned on and left on.

Question 13

Which **one** of the following statements (**A–D**) best describes the relative brightness of the three lamps?

A. Lamp 1 is the brightest of all.

B. Lamp 1 is the same brightness as lamp 2.

C. Lamp 1 is brighter than lamp 3.

D. Lamps 1, 2 and 3 are equally bright.

2 marks

Question 14

Calculate the resistance of the 18 m extension lead connecting lamp 2.

Ω

3 marks

Question 15

Calculate the voltage at lamp 3.

V

2 marks

An oscilloscope is used to observe the output of an AC power adapter, which delivers 12 V_{RMS} when connected to a 240 V_{RMS}, 50 Hz power source. The oscilloscope has been calibrated and the position marked 'O' is at 0 V.

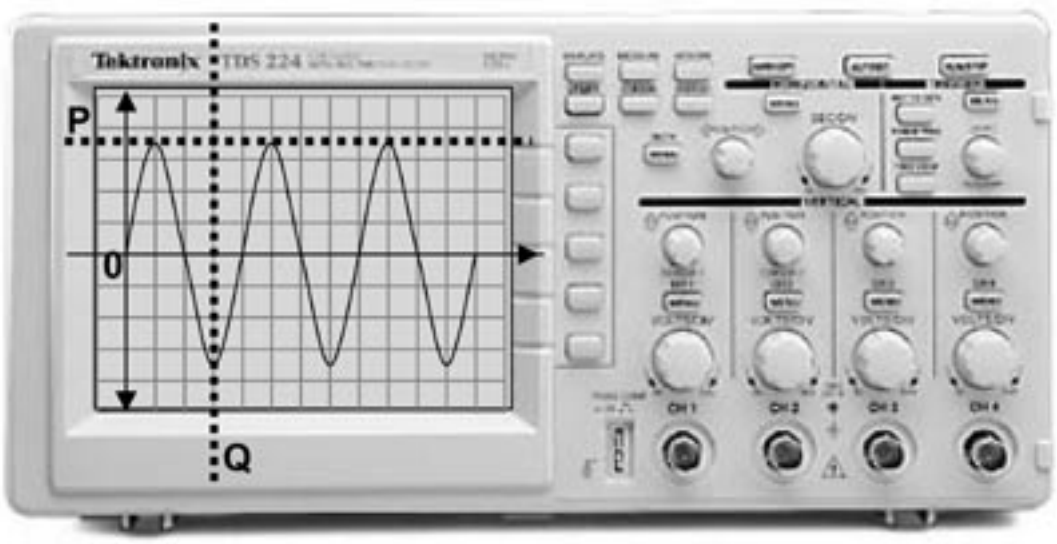


Figure 7

Question 16

Calculate the voltage reading of the dashed line P.

V

2 marks

Question 17

What is the time difference between O and Q?

ms

2 marks

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 applications

X-rays are an important noninvasive diagnostic tool. Since their discovery, x-rays have had wide application in medicine and science. For most of this time, x-rays have been produced with small electron accelerators. In recent times, synchrotron radiation has emerged as a viable and superior alternative for the production of x-rays.

Question 1

Describe the characteristics of synchrotron radiation which make it superior to conventional x-rays.

3 marks

Question 2

Consider a beam of x-rays incident on a very thin metal foil. Figure 1 below lists some possible interactions for the x-rays. Complete the diagram by providing a possible value for the final energy of the incident x-ray **after** it has interacted.

Choose from the following options and write you answer in the boxes provided.

A. Equal to **B.** less than **C.** more than **D.** zero

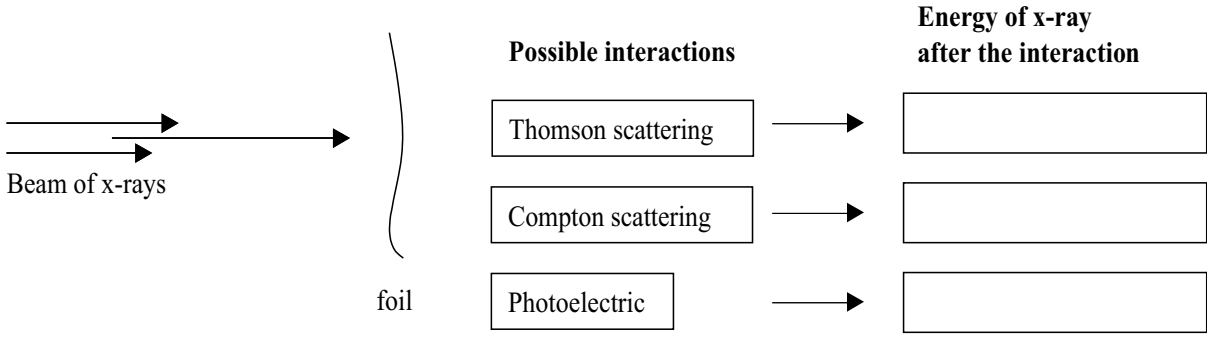
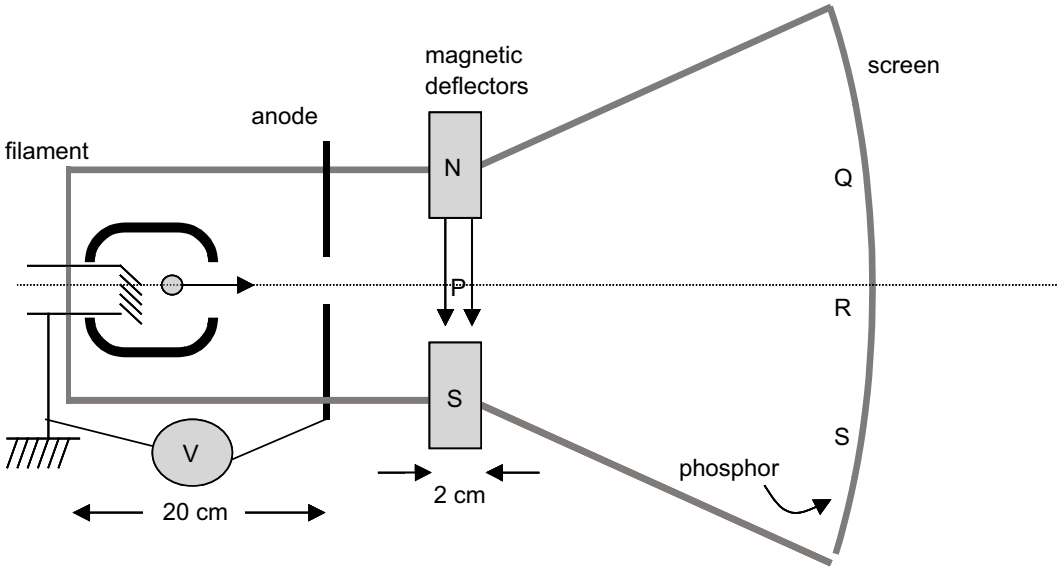


Figure 1

3 marks

A schematic diagram of a cathode ray oscilloscope (CRO) is shown below (Figure 2). It consists of an electron gun (filament) that boils off electrons into an evacuated space. The electrons are then accelerated to a positively charged anode. The anode contains a hole for the electrons to pass through.

The electron has a charge of 1.6×10^{-19} C and a mass of 9.1×10^{-31} kg.



cathode ray tube (side view)

Figure 2

Question 3

Calculate the anode voltage (V) required to accelerate the electrons to a velocity of 5×10^{7} m s^{-1}.

V

3 marks

Figure 3 is a section of a typical linear accelerator (linac). The linac consists of an electron injector (gun) attached to a series of accelerating chambers. Electrons which emerge from the injector with kinetic energy of 120 keV are accelerated to very high energies, 300 MeV in this particular example.

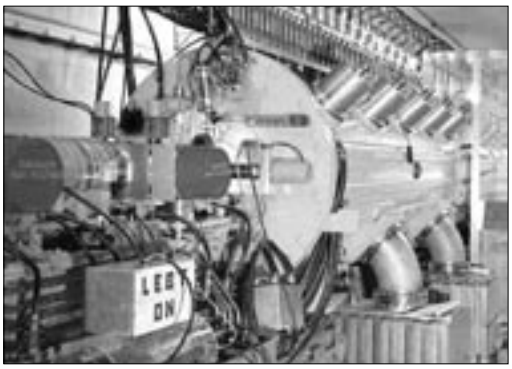


Figure 3

Question 4

Briefly explain how the electrons in a linac are accelerated to these high energies. Make sure that you highlight in your answer what provides the high-potentials required for acceleration.

3 marks

The diagram below, Figure 4, is a prototype design for a high-energy electron synchrotron ring. A linac is used to accelerate the electrons which are then stored in the large ring. The storage ring is constructed from eight dipole bending magnets, each of magnetic field strength 1.5 T. Between each dipole magnet there is a straight section as indicated on the diagram. One of these sections contains a small RF power source. Pumps are used to maintain the ring under vacuum.

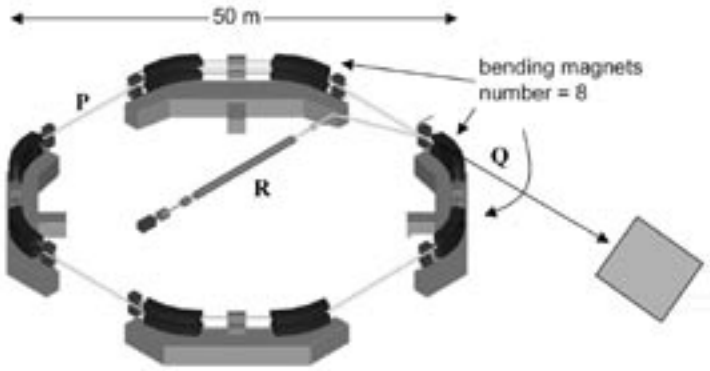


Figure 4

Question 5

Which one of the following statements (**A–D**) best describes why there is additional RF acceleration in the straight sections of a synchrotron ring?

A. The vacuum is not completely zero and so electrons lose energy as they travel through the ring.

B. The bending and focusing magnets consume energy.

C. Electrons collide with each other and lose energy.

D. Electrons lose energy because of synchrotron radiation.

2 marks

Question 6

At each of the bending magnets, the electrons are bent through an arc of radius 10 m. Use this information, together with the characteristics of the magnet, to calculate the momentum of the electrons in the ring.

kg m s^{-1}

3 marks

A beam of monochromatic x-rays is incident on a single crystal, as shown in Figure 5. Some of the x-rays pass through without interacting, whereas others are deflected as shown.

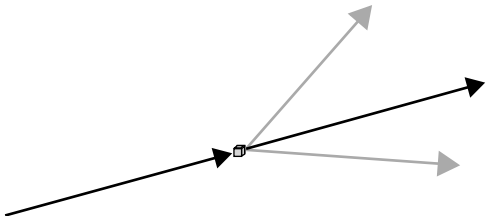


Figure 5

Question 7

Use Bragg's law to explain the conditions under which x-rays will be diffracted by a crystal.

3 marks

The powder diffraction pattern in Figure 6 below has been generated from the detection of x-rays that have scattered from a mixture of two crystalline substances. Each sample contains thousands of each crystal. A circle of film has been used to record the diffraction pattern as shown. A section of the film, together with the intensity profile, is also shown.

The smaller peak at about 27° has been assigned to substance 'A', which has an inter-atomic spacing of 40×10^{-12} m. The other peak belongs to substance 'B'.

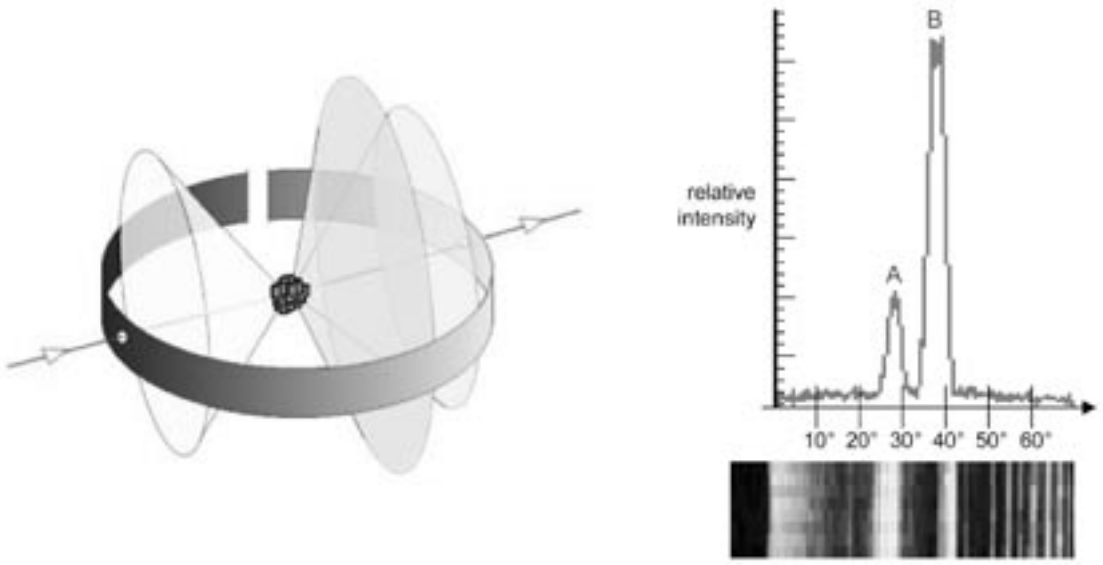


Figure 6

Question 8

Calculate the wavelength of the incident x-rays.

m

3 marks

Question 9

Which **one** of the following statements (**A–C**) is **true**.

A. The interatomic spacing of substance B is greater than that of A.

B. The interatomic spacing of substance B is less than that of A.

C. The interatomic spacing of substance B is equal to that of A.

2 marks

END OF DETAILED STUDY 1

SECTION B – continued

Detailed study 2 – Photonics

Question 1

One way of producing an intense narrow beam of red light is to use a Helium-Neon (HeNe) laser. Alternatively, an incandescent lamp coupled with a **red** filter and a series of lenses arranged to focus the beam can also produce an intense beam of light. Compare the characteristics of the red light in these two cases by describing how the light is produced. Use **each** of the following keywords in your answer.

i. Wavelength **ii.** Coherence **iii.** Phase

3 marks

Question 2

The spectrum for sunlight is shown in Figure 1 below. Use this as a reference to identify which of the spectra (**A–C**) best matches the following sources of light.

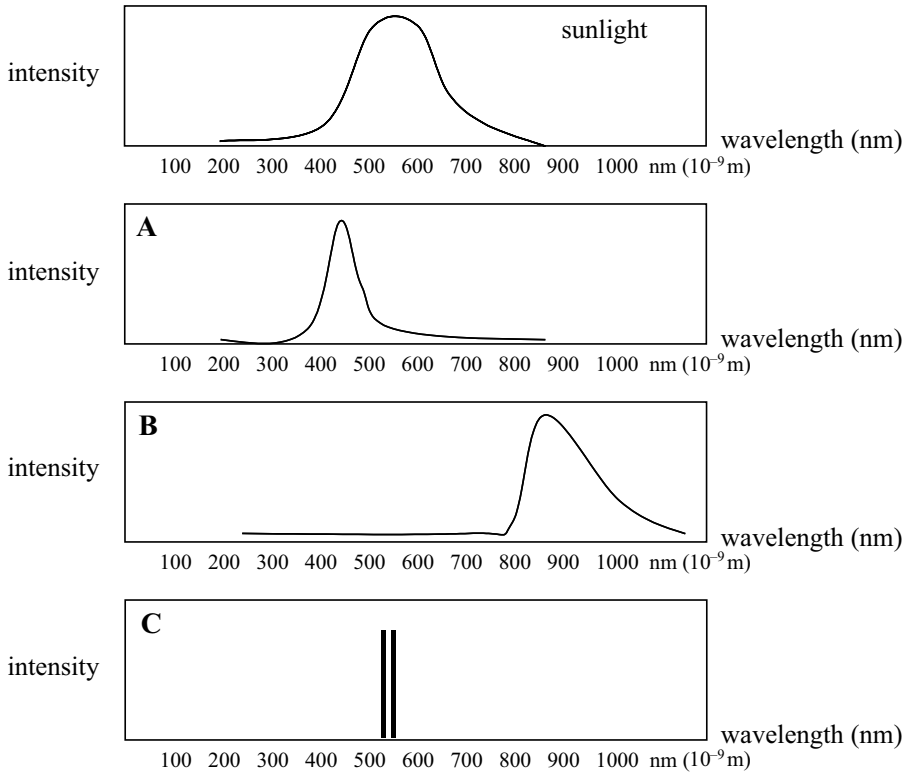


Figure 1

Electric stove element	**Blue theatre light**	**Sodium vapour lamp (yellow)**

3 marks

Question 3

Briefly, with a diagram, describe how the light is produced in a LED.

4 marks

A recent invention is that of the super-bright indium-gallium-aluminum-phosphide (IGAP) Light Emitting Diode (LED). These LEDs are now finding wide application in many devices.

Question 4

The IGAP LED glows predominantly red, with wavelengths in the range 610–620 nm. Use this information to estimate the band-gap energy in the LED.

($h = 4.14 \times 10^{-15}$ eV s)

eV

2 marks

A beam of red laser light of wavelength 632 nm is incident on a fibre optic cable of refractive index n_1 as shown in Figure 2. The light enters the cable and proceeds as shown to the point P where it meets the cladding of refractive index n_2, reflects and proceeds to point Q. (Note that the diagram is not to scale.)

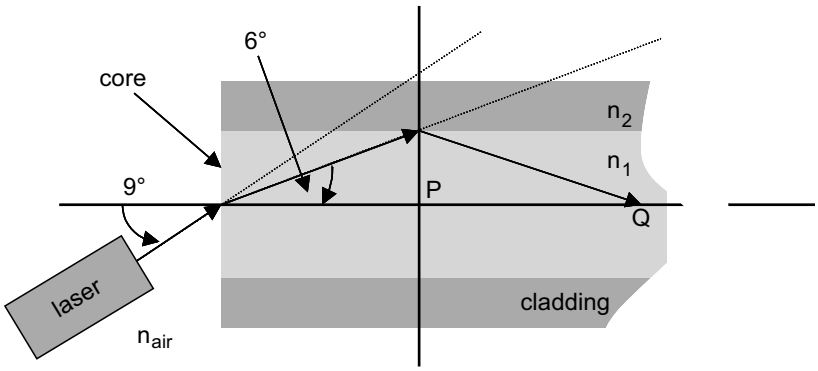


Figure 2

Question 5

Which **one** of the following statements (**A–D**) best describes the relative refractive indices of the material involved?

A. $n_{air} > n_1 > n_2$

B. $n_{air} < n_1 < n_2$

C. $n_{air} > n_1 < n_2$

D. $n_{air} < n_1 > n_2$

2 marks

Question 6

Calculate the refractive index of the core.

2 marks

Question 7

The red laser is now **replaced** with a green laser of wavelength 510 nm. Which of the following statements best describes the path of the green laser beam as it enters the fibre optic cable?

A. The beam does not enter the cable as it totally internally reflects.

B. The beam enters the cable and meets the cladding at point P.

C. The beam enters the cable and meets the cladding to the left of point P.

D. The beam enters the cable and meets the cladding to the right of point P.

2 marks

Figure 3 is a cross-sectional cut of a typical optical-communications cable. For proper operation, the transmitted light must remain within the core.

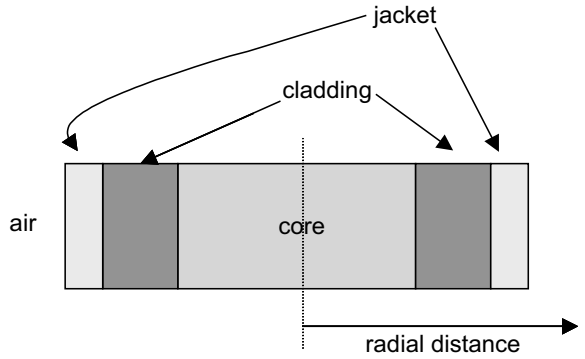
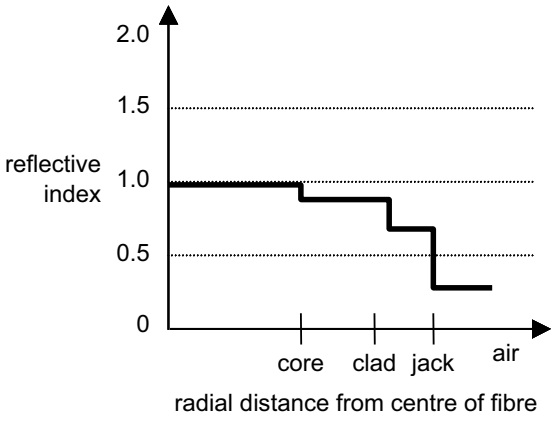


Figure 3

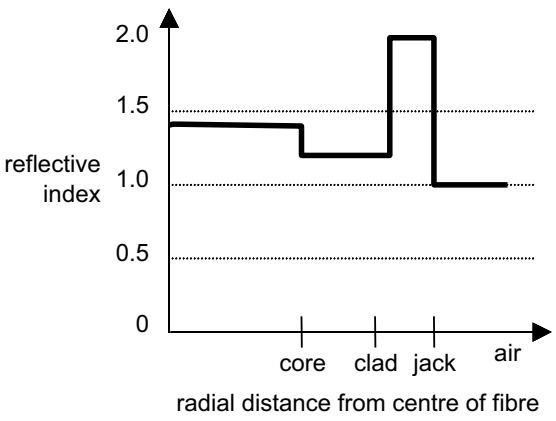
Question 8

Which **one** of the following refractive-index profiles (**A–D**) will allow the light to propagate through the fibre?

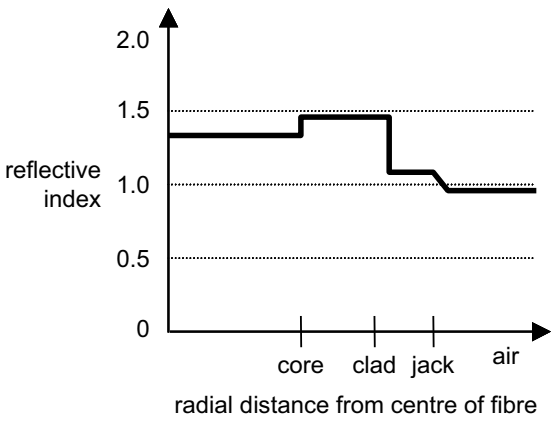
A.



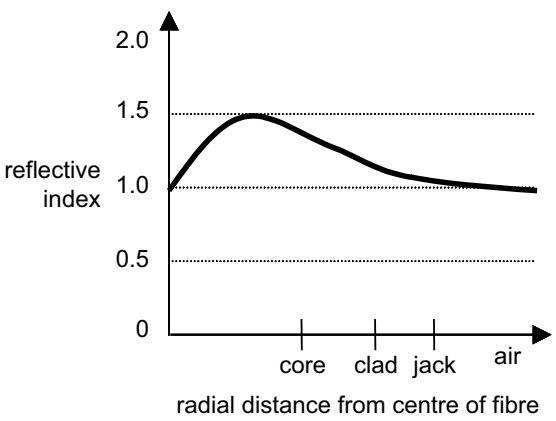
B.



C.



D.



2 marks

Figure 4, is a typical attenuation loss graph for a fibre optic cable. The dashed line represents the 'Rayleigh' scattering component of the total absorption.

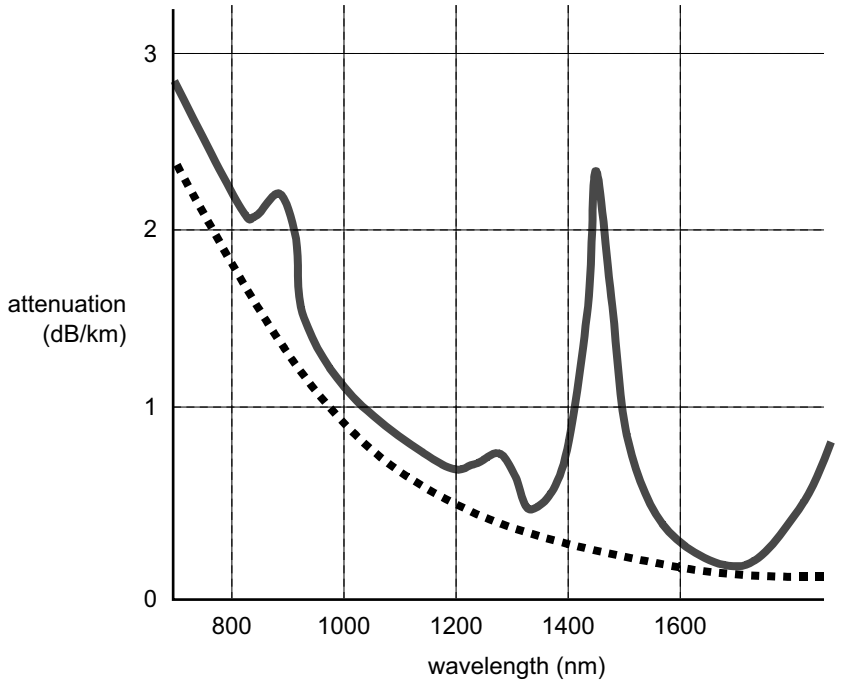


Figure 4

Question 9

Analyse the mechanism behind the majority of signal losses which occur at 1000 nm.

3 marks

Question 10

Which **one** of the following (**A–D**) is the most likely cause for the sharp peak in the top curve near 1450 nm?

A. total internal reflection

B. numerical aperture

C. dispersion

D. absorption

2 marks

END OF DETAILED STUDY 2
SECTION B – continued

Detailed study 3 – Recording and reproducing sound

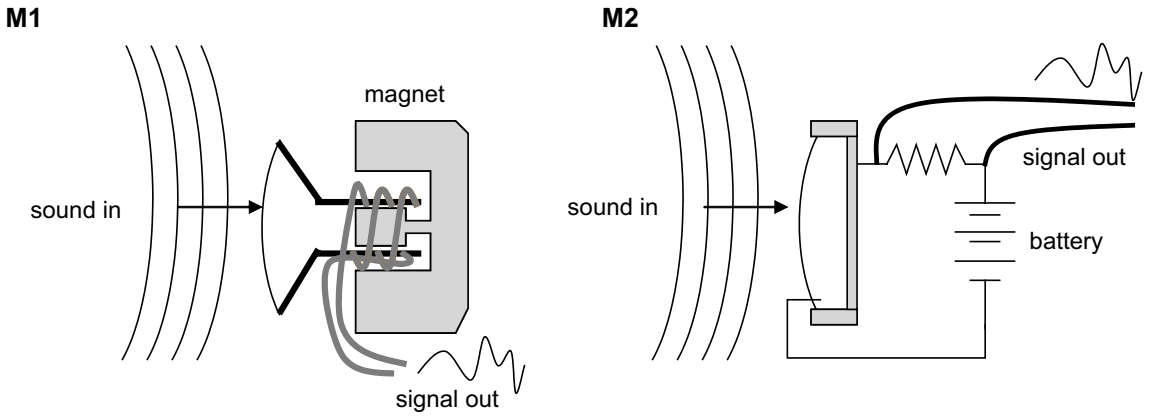


Figure 1

Choose **one** of the microphones labelled M1 **or** M2 in Figure 1 above and write your choice in the box provided.

Using the microphone of your choice, answer Questions 1 and 2.

Question 1

Identify the type of microphone which you have chosen.

A. electret condensor

B. crystal

C. velocity

D. dynamic

2 marks

Question 2

A sound pressure wave is incident on the microphone. Describe how the microphone of your choice detects the wave and produces the signal output.

4 marks

One of the world's most popular microphones is the Shure SM58. The microphone is shown in Figure 2, together with a graph detailing its frequency response.

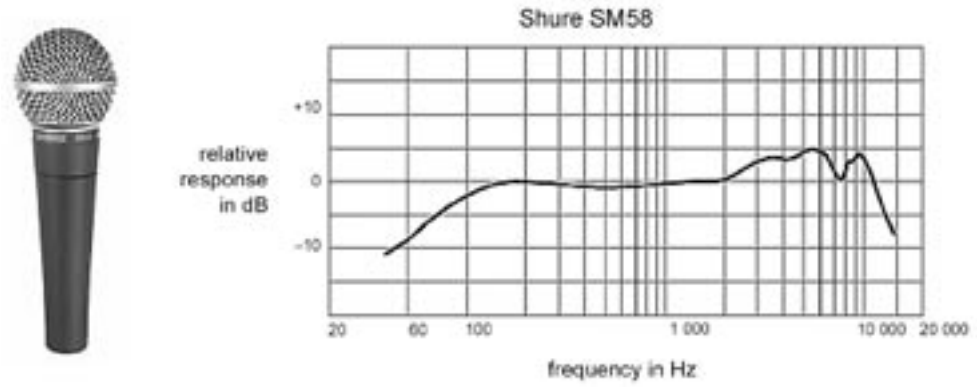


Figure 2

Question 3

Which **one** of the following (**A–D**) **best** describes the range of frequencies that can be reliably detected by this microphone?

A. frequencies below 200 Hz

B. frequencies above 10 000 Hz

C. frequencies below 200 Hz and above 10 000 Hz

D. frequencies between 200 Hz and 10 000 Hz

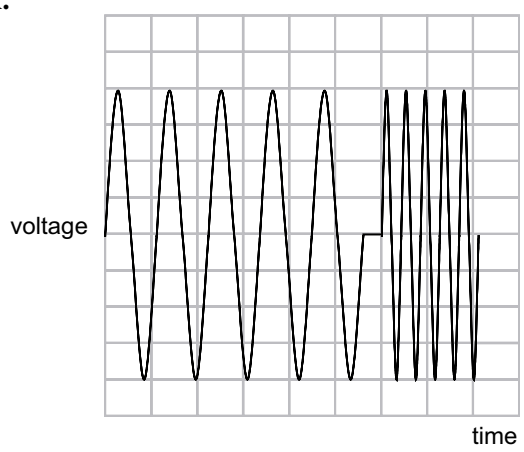
2 marks

A synthesiser produces two pure sine tones, one at a frequency of about 1000 Hz, and another at a higher frequency of 4000 Hz. The SM58 microphone is used to capture these sounds. The synthesiser has been adjusted to ensure both tones have the same amplitude at the microphone. An oscilloscope is used to observe the signal output of the microphone.

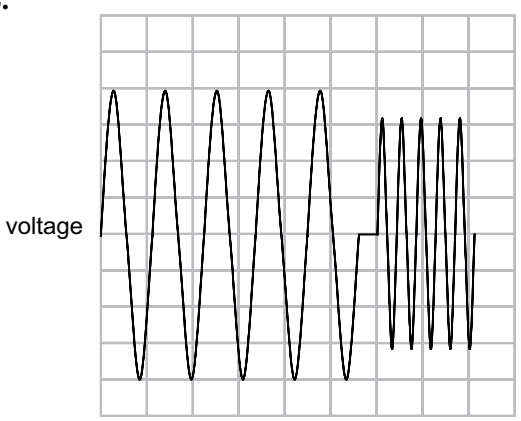
Question 4

Which **one** of the following diagrams (**A–D**) best represents the waveform observed.

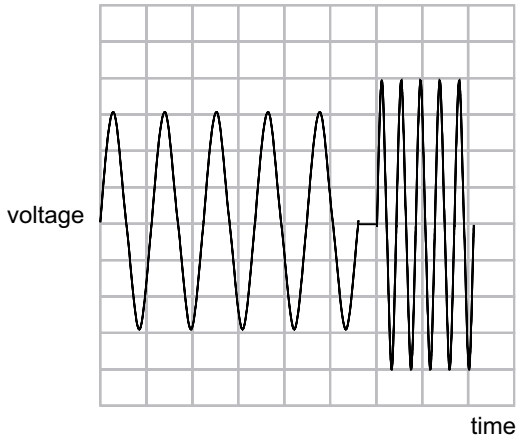
A.



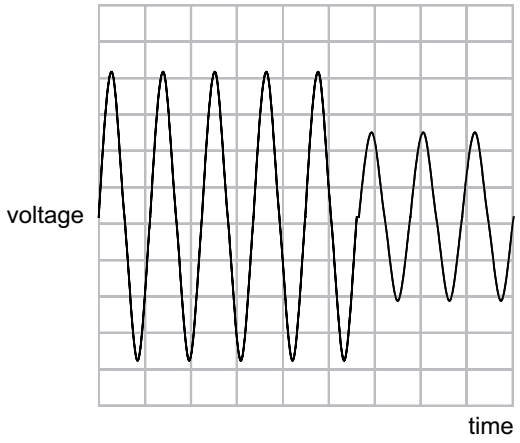
B.



C.



D.



2 marks

In the air are fine dust particles, which are floating at rest. After the loudspeaker is turned on, the particles will be forced to move by the pressure variations associated with the sound wave.

Figure 3

Question 5

For the dust particle at point P, directly in front of the loudspeaker, which of the following statements (**A–D**) best describes its motion?

A. lt vibrates vertically up and down at the frequency of the sound wave.

B. It vibrates horizontally back and forwards at the frequency of the sound wave.

C. It moves horizontally forwards, travelling with the sound wave.

D. It remains at rest.

2 marks

Question 6

Explain the reason for your answer to Question 5.

2 marks

Louise and Leo like to listen to music while working. They have a new enclosure for their loudspeaker. Louise has chosen to orient the enclosure as shown in Figure 4, pointing mainly towards her desk as she is further away from the speakers than Leo.

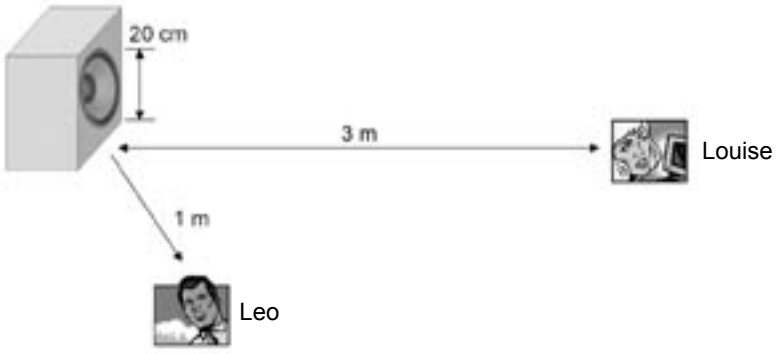


Figure 4

Louise comments that the music sounds great through the new speaker, but Leo complains that the higher frequency sounds seem very soft.

Question 7

Which of the wave phenomena (**A–D**) best explains their differing observations?

A. reflection

B. refraction

C. resonance

D. diffraction

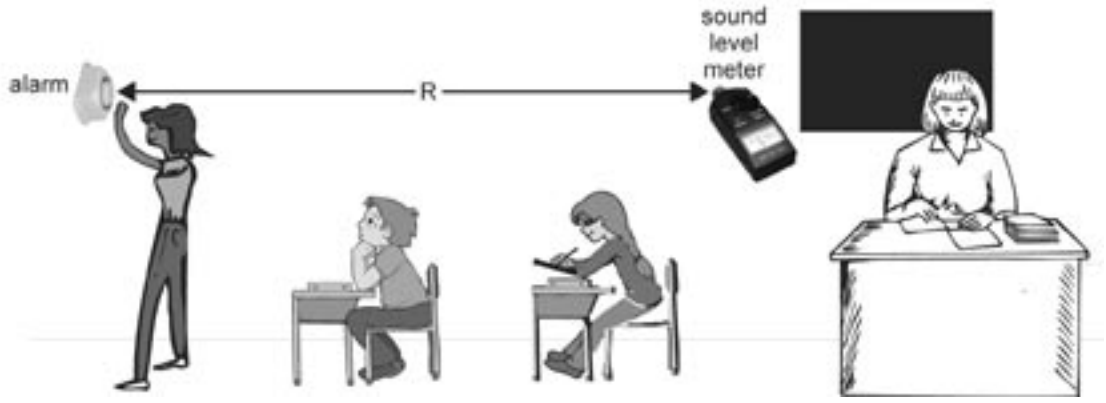
2 marks

Question 8

Explain why Louise and Leo hear the sounds differently.

3 marks

Jenny is conducting some experiments to investigate the loudness of a fire alarm. Her tests are aimed at verifying that the alarm will be heard above background noise and that it will not endanger anyone in the classroom, including the teacher. The alarm produces a high-pitched sound which the manufacturers claim is at least 120 dB.



Here is a copy of the relevant page from Jenny's logbook. Notice that two entries are missing.

NAME: JENNY JENNINGS
EXPERIMENT: ALARM SAFETY

DISTANCE (cm)	INTENSITY LEVEL (dB)	INTENSITY (W/m^2)
10	117.0	5.0 E-01
20	111.0	1.25 E-01
40	105.0	3.2 E-02
60	101.5	1.4 E-02
100		5.0 E-03
200	91.0	1.25 E-03
	87.5	5.6 E-04
500	83.0	2.0 E-04

Question 9

Calculate the missing entry in the logbook for the 100 cm measurement.

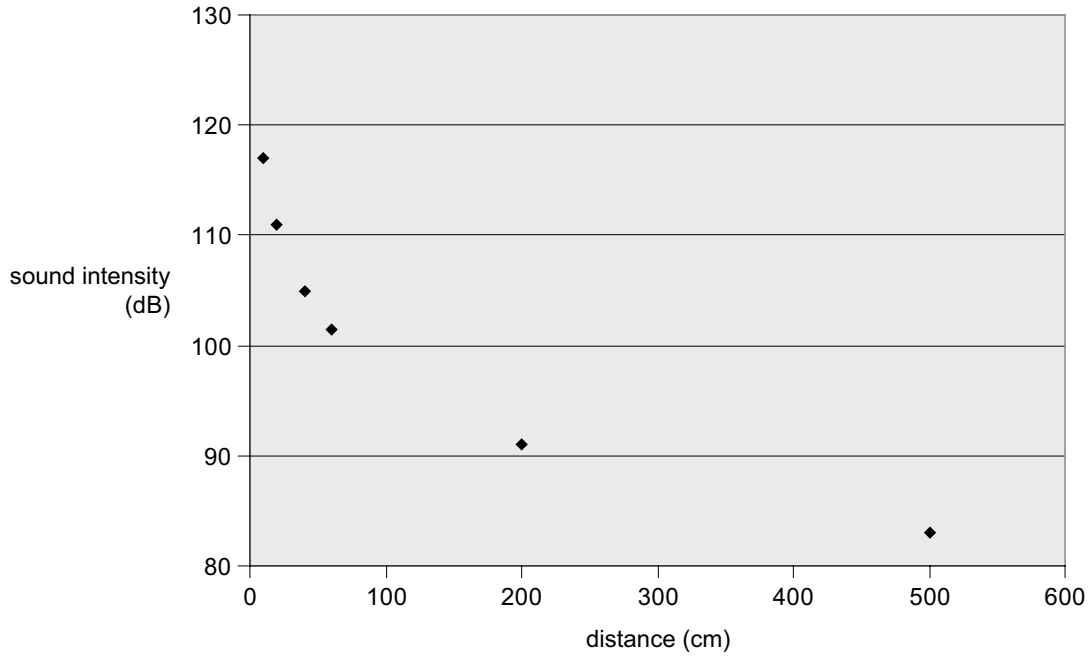
dB

2 marks

Jenny has plotted the data using a spreadsheet program.

Question 10

Draw a 'best fit' to the data below and use the fit to estimate the distance at which the 87.5 dB measurement was made. Write your estimate of the value in the box provided.



cm

2 marks

Question 11

Use the trend in Jenny's logbook or the graph to estimate the distance at which the sound intensity level is 120 dB.

cm

2 marks

END OF QUESTION AND ANSWER BOOK