Neap:

Trial Examination 2007

VCE Physics Unit 4

Written Examination

Question and Answer Booklet

Reading time: 15 minutes
Writing time: 1 hour 30 minutes

Student's Name: ______________________________

Teacher's Name: ______________________________

Structure of Booklet

Section	Number of questions	Number of questions to be answered	Number of marks
A Core – Areas of study			
1. Electric power	21	21	40
2. Interactions of light and matter	11	11	25
B Detailed studies			
1. Synchrotron and its applications **OR**	10	10	25
2. Photonics **OR**	11	11	25
3. Sound	10	10	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 one scientific calculator. Students are NOT permitted to bring into the examination room: blank pieces of paper and/or white out liquid/tape.

Materials supplied

Question and answer booklet of 24 pages with a detachable data sheet in the centrefold.

Instructions

Detach the data sheet from the centre of this booklet during reading time.

Write your **name** and your **teacher's name** in the space provided 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.

Where an answer box has a unit printed in it, give your answer in that unit.

All written responses must be in English.

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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

Figure 1 shows a circular magnet used in a loudspeaker. The arrows indicate the direction of the magnetic field.

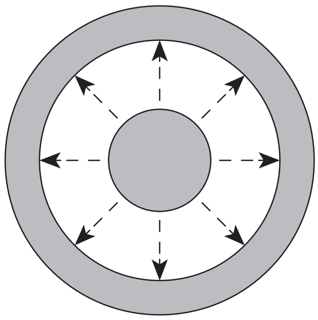

Figure 1

Question 1

Using the symbol N for north and S for south, correctly label the north and south pole areas of the circular magnet shown in Figure 1.

2 marks

A current-carrying wire with the current going in a clockwise direction is inserted between the poles of the circular magnet as shown in Figure 2.

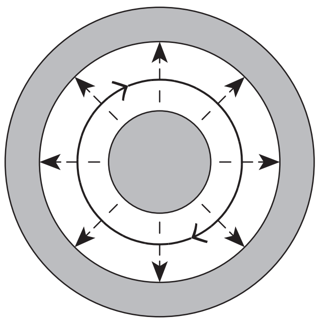

Figure 2

Question 2

Select which one of the following (**A**–**G**) best indicates the direction of the force acting on the current-carrying wire in the magnetic field.

A. up
B. down
C. left
D. right
E. into the page
F. out of the page
G. no force

2 marks

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Sam is boiling water with an 1800 W kettle running on 240 V AC mains electricity.

Question 3

Determine the peak-to-peak voltage for the kettle.

V

1 mark

Question 4

Calculate the RMS current being drawn by the kettle.

A

2 marks

Adela, a senior physics student, is doing some simple practicals in electromagnetic induction. One experiment involves pushing the north end of a magnet into a circular conducting loop of wire as show in Figure 3.

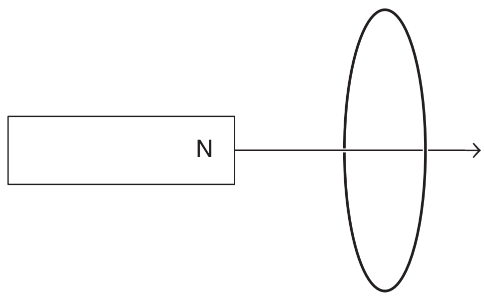

Figure 3

Question 5

Draw in the induced magnetic field on Figure 3.

2 marks

Question 6

Draw in on Figure 3 the direction of the induced current in the circular conducting loop of wire.

1 mark

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Figure 4 shows a simplified diagram of a small working model of a DC motor. It is built using two permanent magnets, a split-ring commutator and twenty coils of wire connected to a 12 V DC power supply. The resistance of the twenty coils of wire is 2.0 Ω. The length of side *AB* is 10 cm and the length of side *BC* is 6.0 cm.

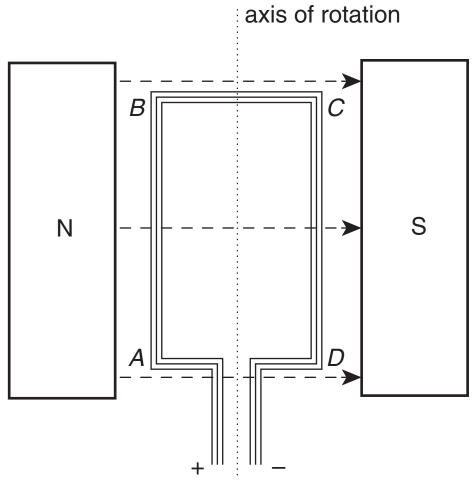

Figure 4

Question 7

Calculate the current through the twenty coils of wire.

A

2 marks

The strength of the magnetic field is 0.6 T.

Question 8

Calculate the magnitude of the force acting on side *CD*.

N

2 marks

Question 9

Which one of the following (**A**–**G**) best indicates the direction of the force acting on side *CD*?

A. up
B. down
C. left
D. right
E. into the page
F. out of the page
G. no force

2 marks

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Question 10

Determine the magnitude of the force acting on side *BC*.

N

2 marks

Question 11

Which one of the following (**A**–**G**) best indicates the direction of the force acting on side *BC*?

A. up
B. down
C. left
D. right
E. into the page
F. out of the page
G. no force

1 mark

Question 12

Explain the purpose of the split-ring commutator in the DC motor.

3 marks

Figure 5 shows a simplified diagram of one type of electrical generator. It consists of a single loop that rotates within a magnetic field produced by two permanent magnets.

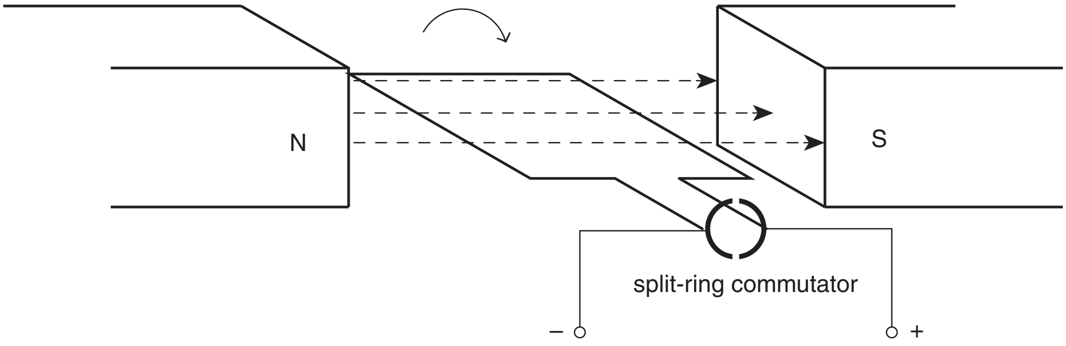

Figure 5

The strength of the magnetic field is 0.5 T, the area of the loop is 0.020 m^2, and the rate of rotation is 5.0 Hz.

Question 13

Determine the magnetic flux through the loop at the instant shown in Figure 5.

Wb

1 mark

Question 14

Calculate the magnitude of the average emf produced as the loop turns from the instant shown in Figure 5 to a point one quarter of a period later.

V

2 marks

Question 15

On the axes below, sketch the output voltage of the split-ring commutator for a whole cycle. Indicate the period on the time axis.

3 marks

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A generator at an electrical power station generates 1000 MW of power at 10 kV. Using transformer T_1, the voltage is stepped up to 500 kV for transmission through wires with a total resistance of 4.0 Ω. At the substation, the voltage is then stepped down to 50 kV using transformer T_2. Figure 6 shows a schematic diagram of this process.

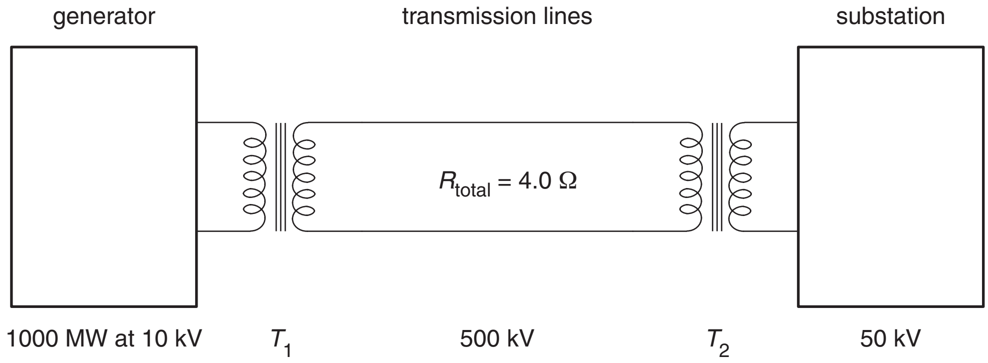

Figure 6

Question 16

Calculate the RMS current (in kA) in the primary windings of transformer T_1.

kA

2 marks

Question 17

Calculate the ratio of the number of turns of the primary windings to the number of turns of the secondary windings for transformer T_1.

2 marks

Question 18

Calculate the total electrical power loss (in MW) in the transmission wires when the electricity is transmitted at 500 kV.

MW

2 marks

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Question 19

Explain why the power is not transmitted through the transmission lines at the generator voltage of 10 kV. Support your argument with appropriate estimations.

3 marks

Question 20

Two VCE Unit 4 Physics students are undertaking practical work related to the Area of study on Electric Power when they notice that the electrical equipment they are using seems to have an electrical fault. The options below (**A**–**C**) list actions the students should take. Choose the correct order (e.g. **C**, **A**, **B**) of the actions for a safe and responsible approach to handling electrical safety issues in the physics laboratory.

A. Get up, leave the equipment and walk over to tell the teacher that there may be an electrical fault.

B. Turn off the electrical equipment at the switch on the electrical power outlet.

C. Pull out the power cord from the electrical power outlet.

2 marks

Question 21

Figure 7 shows the safety warning on a transformer used in an AC adapter for a notebook computer that converts 240 V AC into 20 V AC.

FOR INDOOR USE ONLY
RISK OF ELECTRIC SHOCK
DRY LOCATION USE ONLY
SHOCK HAZARD – DO NOT OPEN

Figure 7

Explain the safety warning in terms of the risks associated with using this transformer in a manner contrary to the safety warning instructions.

2 marks

END OF AREA OF STUDY 1

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Area of study 2 – Interactions of light and matter

Question 1

The light produced by the Sun is said to be **incoherent**. Explain how light is produced by the Sun and why it is incoherent.

2 marks

In an experiment to investigate the photoelectric effect, light of varying frequencies is shone onto potassium metal using the apparatus shown in Figure 1.

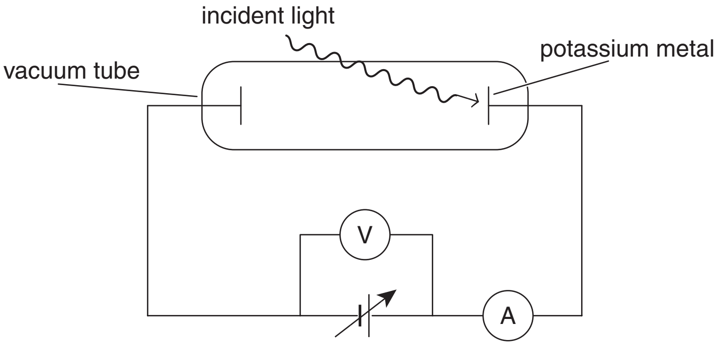

Figure 1

It is found that when light of frequency 7.0×10^{14} Hz is shone onto the potassium metal, photoelectrons are ejected. However, if the variable voltage V approaches 0.70 V, no photocurrent is measured on the ammeter.

Question 2

Calculate the energy of a photon of light of frequency 7.0×10^{14} Hz. ($h = 4.14 \times 10^{-15}$ eV s)

eV

2 marks

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Question 3

Use the information provided to calculate the work function of potassium. You must show your working.

eV

2 marks

Question 4

If the frequency of the light remains the same, but the intensity of the light is halved,

A. the voltage required to stop the photocurrent will be twice the original value.
B. the voltage required to stop the photocurrent will be half the original value.
C. the voltage required to stop the photocurrent will remain the same.
D. no photoelectrons will be ejected from the potassium.

2 marks

When the frequency of light incident on the potassium is lower than the threshold frequency, no photoelectrons are ejected from the metal, even if the intensity of the light is very high.

Question 5

Explain why this observation is best explained by the particle model of light rather than the wave model. You must refer to both models in your answer.

3 marks

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In order to investigate interference of light, students shone light of wavelength 650 nm through two slits as shown in Figure 2.

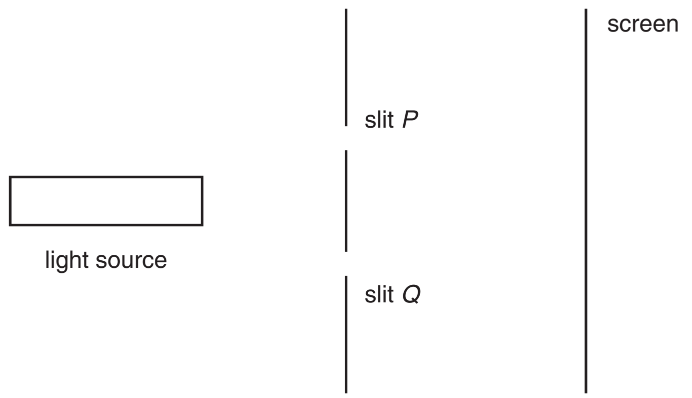

Figure 2

The resulting interference pattern of light and dark bands observed on the screen is shown in Figure 3.

Figure 3

Question 6

Explain how the dark bands on the screen are produced.

2 marks

Question 7

In order to **increase** the amount of space between the dark bands, the students could (choose one or more answers)

A. decrease the wavelength of the light source.
B. move the screen further away from the slits.
C. decrease the distance between the slits.
D. increase the intensity of the light.

2 marks

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When X-rays of wavelength 2.0×10^{-10} m are passed through a crystal, a diffraction pattern is produced, as shown in Figure 4. When electrons of a particular energy are passed through the crystal, a similar diffraction pattern is produced, as shown in Figure 5.

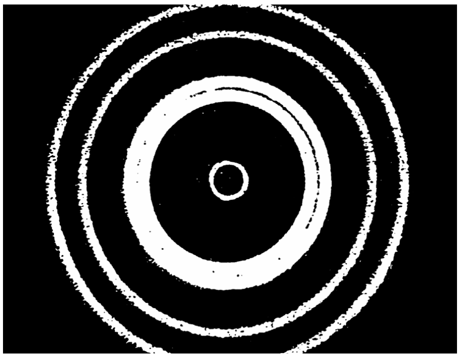
Figure 4

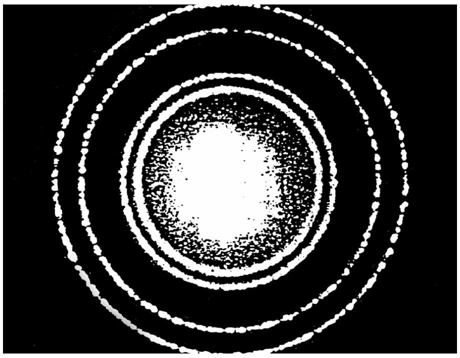
Figure 5

Question 8

Calculate the momentum of the X-rays used to produce the diffraction pattern shown in Figure 4.
($h = 6.63 \times 10^{-34}$ J s)

kg m s^{-1}

2 marks

Question 9

Calculate the kinetic energy of the electrons that would produce the diffraction pattern shown in Figure 5.
($m_e = 9.11 \times 10^{-31}$ kg, $h = 6.63 \times 10^{-34}$ J s)

J

3 marks

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Trial Examination 2007

VCE Physics Unit 4

Written Examination

Data Sheet

Directions to students

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

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Physics Unit 4 Data Sheet

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	$F = IlB$
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	$V_{drop} = I_{line}R_{line}$ $P_{loss} = I_{line}^2R_{line}$
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 1 – Synchrotron and its applications

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

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Detailed study 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 – 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

The energy levels of atomic mercury are shown in Figure 6.

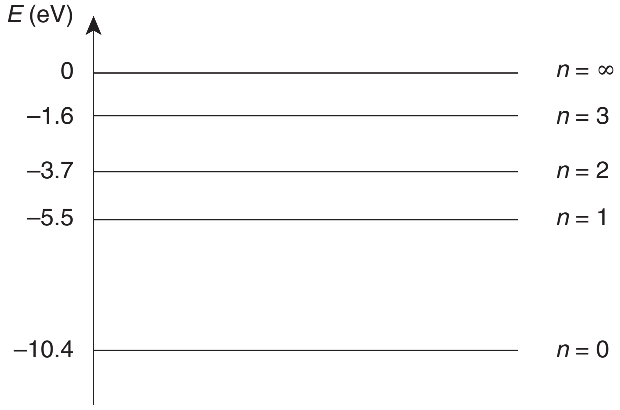

Figure 6

A particular electron is initially in the **ground state**.

Question 10

Which **one or more** of the following photons could the electron absorb?

A. 4.7 eV
B. 6.7 eV
C. 8.7 eV
D. 10.7 eV

2 marks

Question 11

How does the wave–particle duality of electrons explain how an electron can only occupy the energy levels shown in Figure 6?

3 marks

END OF AREA OF STUDY 2

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.

The beamline in a synchrotron is the path travelled by **[electrons / light]**.

The beamline is located between the storage ring and the **[experimental station / booster ring]**.

2 marks

An electron gun is used to accelerate electrons from rest to a speed of 7.5×10^6 m s^{-1}.

Question 2

Calculate the potential difference required to accelerate the electrons to this speed.

($m_e = 9.1 \times 10^{-31}$ kg, $q_e = 1.6 \times 10^{-19}$ C)

V

3 marks

Question 3

After being emitted by an electron gun, electrons in the Australian synchrotron will enter the

A. booster ring
B. linac
C. storage ring
D. cathode

2 marks

Question 4

In the storage ring, synchrotron radiation is produced when electrons travelling at close to the speed of light

A. collide with other electrons.
B. collide with gas molecules injected into the storage ring.
C. travel in a curved path.
D. travel in a straight line without colliding with any matter.

2 marks

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An electron with momentum 6.4×10^{-23} kg m s^{-1} passes through a magnetic field of strength 0.7 T, as shown in Figure 1.

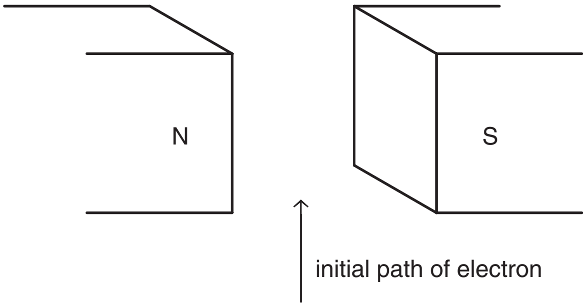

Figure 1

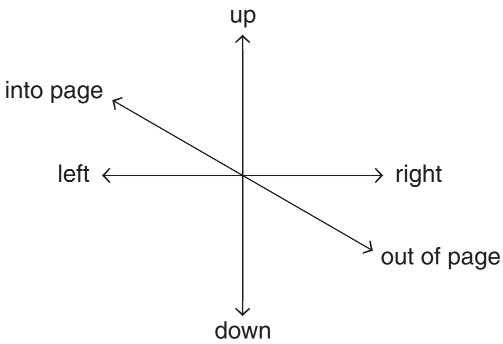

Figure 2

Question 5

Calculate the radius of the arc that the electron will be deflected through as it enters the magnetic field. ($q_e = 1.6 \times 10^{-19}$ C)

m

2 marks

Question 6

Calculate the magnitude and determine the direction of the force exerted on the electron when it enters the magnetic field (ignoring relativistic effects). Use the key shown in Figure 2 to indicate the direction of the force. ($m_e = 9.1 \times 10^{-31}$ kg, $q_e = 1.6 \times 10^{-19}$ C)

N	Direction:

4 marks

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Question 7

One of the advantages of synchrotron radiation over other sources is that it is highly **collimated**. Explain what is meant by the term 'collimated' in relation to synchrotron radiation and why it is an advantage.

2 marks

Collimated X-rays produced by a synchrotron are used to investigate the spacing of atoms on a crystal, using the model of Bragg diffraction. X-rays of wavelength 2.4×10^{-10} m are incident on the crystal as shown in Figure 3.

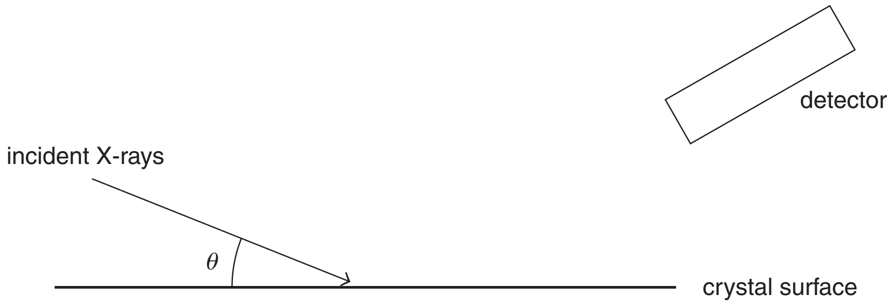

Figure 3

Question 8

If the spacing between atoms in the crystal is 2.9×10^{-10} m, find the smallest value of the angle θ shown in Figure 3 that will result in a maximum being detected by the detector.

°

3 marks

Question 9

Explain why Bragg diffraction would not result if visible light of wavelength 680 nm were incident on this crystal, whereas it does when 2.4×10^{-10} m X-rays are incident on the crystal.

2 marks

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When X-ray photons collide with electrons, the photons can undergo either Thomson scattering or Compton scattering.

Question 10

Each description in the table below applies to Thomson scattering, to Compton scattering, or to both. If the description applies to Thomson scattering, place a **T** in the box next to it. If the description applies to Compton scattering, place a **C** in the box next to it. If the description applies to both Thomson and Compton scattering, place a **T** and a **C** in the box next to it.

Description	Type of scattering
The collision between electrons and photons is elastic	
The scattered photons have larger wavelengths than the incident photons.	
Momentum is conserved in the collision between the electrons and the photons.	

3 marks

END OF DETAILED STUDY 1

Detailed study 2 – Photonics

Light-emitting diodes (LEDs) are used for various display applications. For example, green (for ON) and red (for OFF) LED displays are often used to indicate whether various electronic appliances are on or off.

Question 1

Explain how an LED produces light.

___

___

___

___

2 marks

Question 2

Explain the difference between the band-gap energies in green and red LEDs.

___

___

___

___

2 marks

A red LED is manufactured to produce light of wavelength 660 nm.

Question 3

Calculate the energy gap for this LED.

eV

2 marks

Lasers are used for photonics experiments in senior physics classes.

Question 4

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

Laser light is **[monochromatic / polychromatic]**.

Laser light is **[coherent / incoherent]** and all of the light produced is **[in phase / out of phase]**.

3 marks

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Question 5

Explain why special precautions need to be taken when using lasers in photonics experiments in senior physics classes. You must refer to the properties of laser light in your answer.

___

___

___

2 marks

Optical fibres are used as waveguides in telecommunications networks.

Question 6

Which one of the following terms (**A**–**D**) best describes the physical phenomenon that underpins the working of an optical fibre?

A. constructive interference
B. diffraction
C. reflection
D. total internal reflection
E. refraction
F. dispersion

[ ]

2 marks

A single-step step-index multimode optical fibre has a core of silica glass with a refractive index of 1.51 and a cladding with a refractive index of 1.48.

Question 7

Explain what is meant by the term 'multimode' as it applies to an optical fibre.

___

___

___

2 marks

Question 8

Calculate the critical angle for light incident on the silica–cladding interface in this single-step step-index multimode optical fibre.

[°]

2 marks

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Question 9

Explain what the acceptance angle is for such an optical fibre.

2 marks

Question 10

Explain what Rayleigh scattering is and why it is a problem when sending laser signals of different frequencies down an optical fibre.

3 marks

When optical fibres are used for some medical imaging purposes, the optical fibre bundle needs to be a coherent bundle.

Question 11

Explain what is meant by a coherent optical fibre bundle and explain why this is important for medical imaging purposes.

3 marks

END OF DETAILED STUDY 2

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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.

When sound waves travel through air, they travel as **[longitudinal / transverse]** waves.

This means that the direction of vibration of the air particles is **[at right angles to / parallel to]**

the direction of wave propagation.

2 marks

Lachlan, a physics student, plays a note on a clarinet. The wavelength of the sound wave produced is 1.20 m.

Question 2

What is the frequency of the note produced by the clarinet? The speed of sound in air is equal to 340 m s^{-1}.

Hz

2 marks

Lachlan knows that a clarinet can be modelled as an air column of length *l* that is open at one end and closed at the other, as shown in Figure 1.

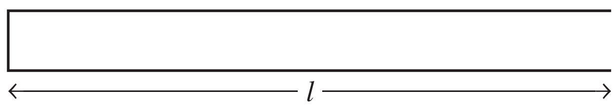

Figure 1

Question 3

Calculate the length of the air column closed at one end, *l*, that would resonate with a fundamental frequency the same as that of the note played by Lachlan.

m

2 marks

Question 4

Which of the following length air columns closed at one end would also resonate at the same frequency as the note played by Lachlan?

A. 0.15 m
B. 0.60 m
C. 1.20 m
D. 1.50 m

2 marks

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Lachlan's classmate Ben measures the intensity of the note played by Lachlan at a distance of 2.0 m from the clarinet. The intensity is found to be 1.8×10^{-7} W m^{-2}.

Question 5

What sound intensity level (in dB) is this intensity equivalent to?

dB

2 marks

Ben now moves further away from Lachlan, until the sound intensity is reduced to 2.0×10^{-8} W m^{-2}.

Question 6

How far is Ben from the clarinet when he measures the sound intensity as 2.0×10^{-8} W m^{-2}?

m

3 marks

Lachlan and Ben now repeat their experiments using a flute that produces a note of frequency 880 Hz. The clarinet still produces a sound of wavelength 1.2 m. The intensity of the sound produced by each instrument is the same.

Merryn, another physics student, notices that when she stands near the doorway of the classroom at *A* in Figure 2, the flute sounds louder than the clarinet, but when she walks down the corridor to *B* the clarinet sounds louder than the flute.

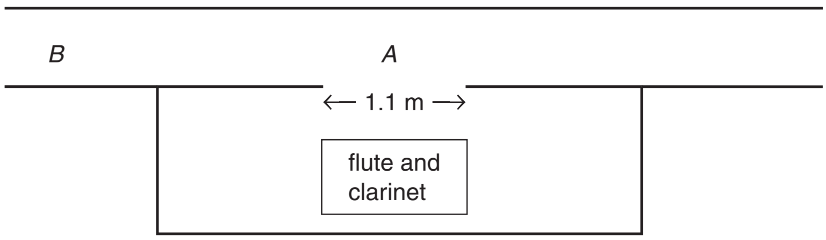

Figure 2

Question 7

Explain Merryn's observations, using calculations to support your answer.

4 marks

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The frequency response of Merryn's ear is shown in Figure 3.

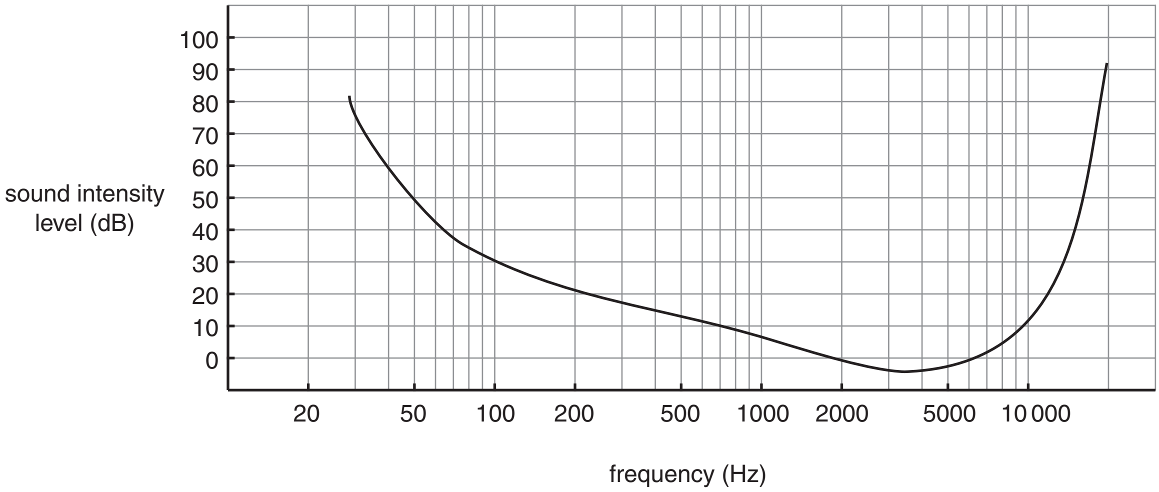

Figure 3

Ben connects a loudspeaker to a signal generator producing a sound of frequency 50 Hz. Merryn stands at position *A* and measures the sound intensity to be 30 dB, although she cannot hear the sound. Ben then connects a second loudspeaker to the signal generator so that both loudspeakers are producing a sound of frequency 50 Hz.
With the two loudspeakers connected, the sound intensity (in W m^{-2}) is double the intensity produced by the single speaker.

Question 8

Will Merryn be able to hear the 50 Hz sound at position *A* when the two speakers are operating? Explain your answer.

3 marks

Question 9

Baffles are used with loudspeakers in order to

A. improve the fidelity of the speaker system by preventing air pressure changes due to large speakers affecting the movement of smaller speakers in the same enclosure.

B. increase the frequency response of the loudspeaker by enabling the enclosure to resonate at a larger range of frequencies.

C. increase the volume of sound produced by the loudspeaker by reducing the interaction of waves produced by the front and back surfaces of the speaker cone.

D. increase the volume of the sound produced by the loudspeaker by ensuring that the waves produced by the front and back of the speaker cone are in phase so that they can interfere constructively.

2 marks

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Figure 4 shows the basic components of both the dynamic loudspeaker and the dynamic microphone. A lightweight cone is attached to a magnet, around which is wound a coil of metal wire.

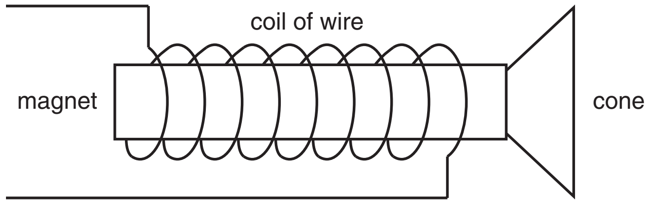

Figure 4

Question 10

Compare and contrast the operation of a dynamic loudspeaker and a dynamic microphone.

3 marks

END OF QUESTION AND ANSWER BOOKLET

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