Student Name: ______________________________

PHYSICS

Unit 4 – Written examination 2

2007 Trial Examination

Reading Time: 15 minutes
Writing Time: 1 hour and 30 minutes

QUESTION AND ANSWER BOOK

Structure of Book

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

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, and rulers, up to 2 pages of pre written notes and an approved 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.

Instructions
- Print your name in the space provided on the top of this page.
- 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

Ben and Akshay are experimenting with a solenoid. Ben connects a battery to either end of the solenoid and Akshay places a small compass near one end of the solenoid as shown in **Figure 1**.

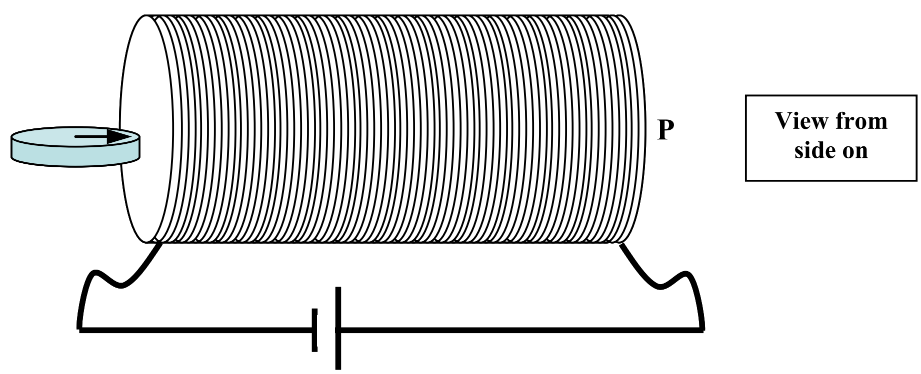

Figure 1

Question 1

Based on the direction of the small compass in Figure 1, which of the following best describes the direction of the magnetic field at Point P **when viewed from above**?

A	B	C	D	E
→	↑	←	↓	↔

2 marks

SECTION A- AREA OF STUDY 1- continued

Ben now places a length of wire above the solenoid at **Point Q**, as shown in **Figure 2.** The magnetic field strength at **Point Q** is known to be 0.05 T and the length of the wire is 4 cm. The wire experiences a force of 1.4 x 10^{-3} N, directed upwards in relation to the solenoid.

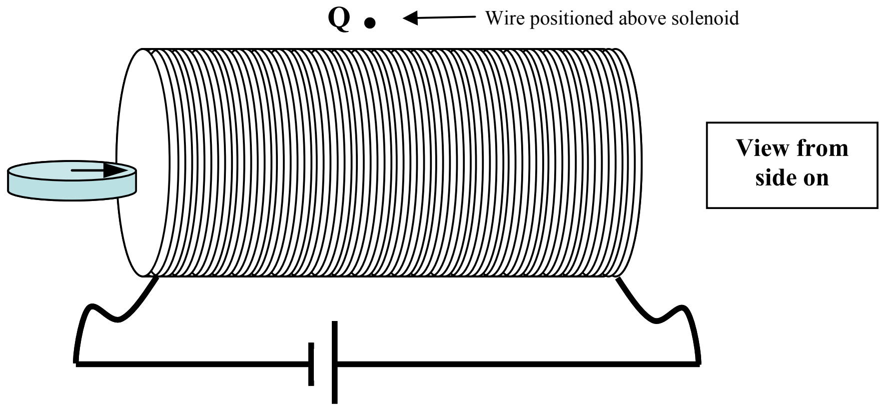

Figure 2

Question 2

Determine the magnitude and direction of the current that is flowing through the wire.

A

Direction: Into page / out of page (circle correct direction)

3 marks

SECTION A- AREA OF STUDY 1- continued
TURN OVER

Kelvin has constructed a rudimentary DC motor, as shown in **Figure 3**. When he connects the power supply, the coil of 25 turns begins to turn clockwise within the magnetic field.

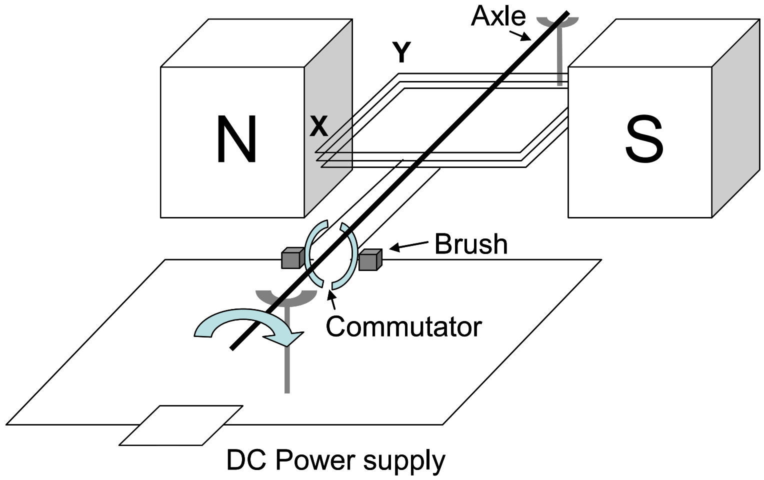

Figure 3

Question 3
With respect to points **X** and **Y** on the coil, determine which direction the current must flow to produce clockwise rotation.

2 marks

Question 4
Explain how the commutator and the brushes are able to reverse the direction of the current in the coil AND at which point in the rotation this must occur.

3 marks

SECTION A- AREA OF STUDY 1- continued

Kelvin now disconnects the battery, commutator and brushes, then connects a small handle to the end of the axle, creating a basic device as shown in **Figure 4.**

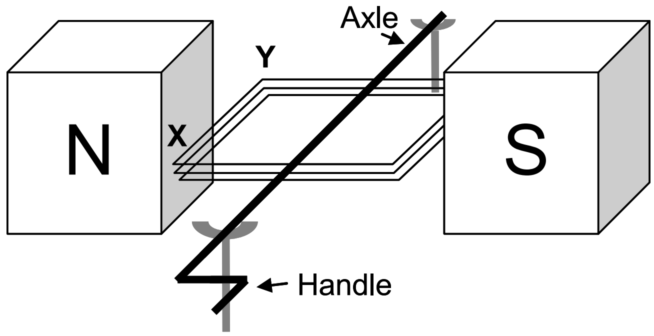

Figure 4

Question 5
Kelvin wants to **INITIALLY** induce current to flow from **X** to **Y**. Which direction should he rotate the coil? Explain your answer.

Direction: Anticlockwise / Clockwise (circle correct)

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3 marks

SECTION A- AREA OF STUDY 1- continued
TURN OVER

Excited by his ability to generate current, Kelvin reconnects the commutator and brushes in combination with a CRO to analyse the induced current. He spins the coil at four cycles per second. He has measured the magnetic field to be 0.2 T. Under these conditions, a quarter turn generates an average emf of 0.3 V in the coil.

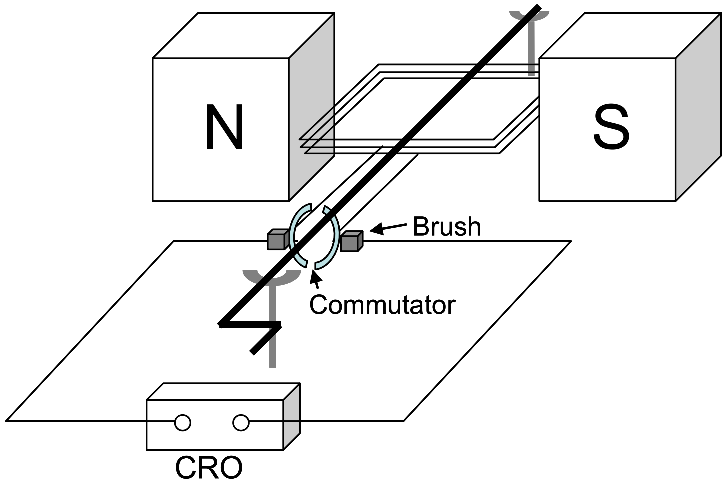


Figure 5

Question 6

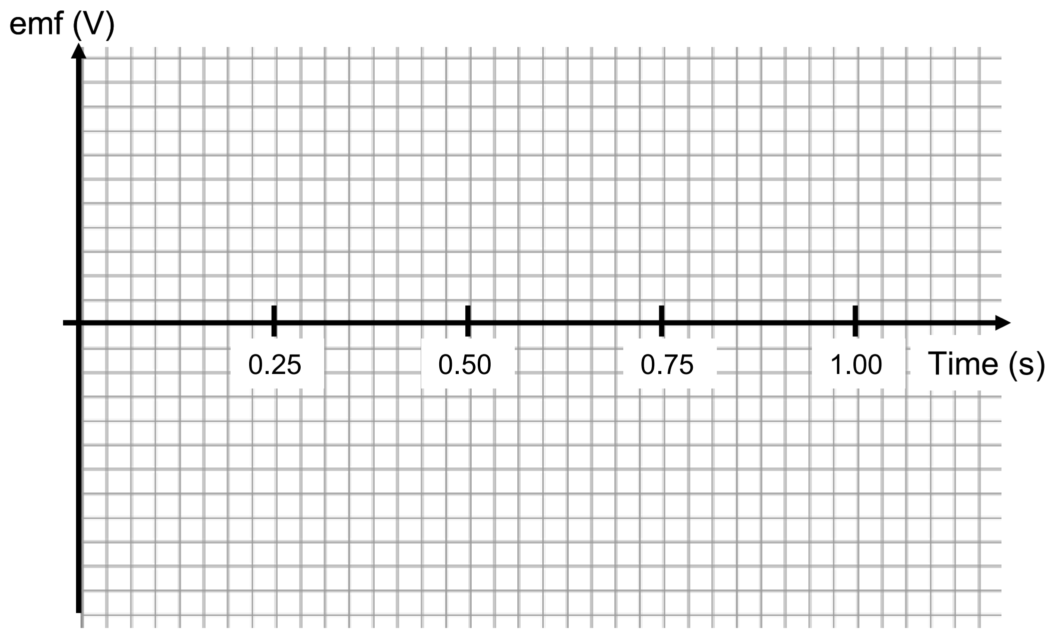
Determine the area of the coil in square metres.

m^2

2 marks

SECTION A- AREA OF STUDY 1- continued

Question 7
Sketch the voltage output that Kelvin would expect to see on the CRO. You must show an accurate horizontal scale, but no vertical scale is required.



2 marks

After some time, Kelvin becomes tired and is forced to make some adjustments. He replaces the magnets with a new pair that provides double the field strength and conserves energy by rotating the coil at two cycles per second.

Question 8
On the same graph as **Question 7**, sketch the CRO output that Kelvin would now expect to see. Be sure to carefully label each plot.

3 marks

Sara enters Kelvin's workshop and the two students immediately become engaged in an argument about whether Kelvin's device is in fact a generator or an alternator. Sara asserts that **if she were to replace the commutator with a set of slip rings**, the device would become an **alternator**. Kelvin disagrees, saying that with slip rings or a commutator, his device remains a **generator**.

Question 9
Who is correct? Justify your answer.

Kelvin / Sara (circle correct)

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1 + 2 = 3 marks

Lachlan is demonstrating electromagnetic induction to a group of younger students. He takes a loop of copper wire and places it within the magnetic field of a horseshoe magnet. The field can be modelled as uniform in the vicinity of the loop, as shown in **Figure 6**. Current flows **anti-clockwise** around the loop as Lachlan removes it from the magnetic field.

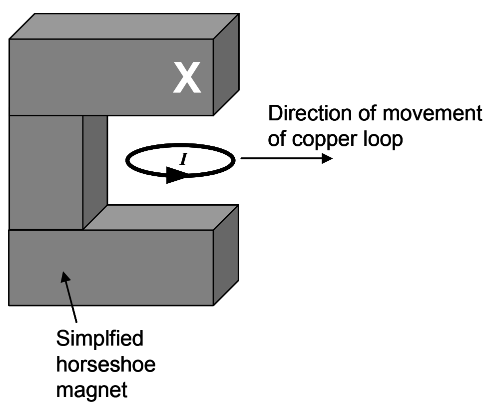

Figure 6

SECTION A- AREA OF STUDY 1- continued

Question 10
Determine the polarity of the magnet at X and justify your answer

Polarity of X:

___

___

___

1+ 2 = 3 marks

Christina is investigating the operation of a simple transformer that she has found in an old Physics lab. She connects an AC input supply to the primary side of the transformer and uses two CROs to observe the voltage characteristics on the primary and secondary sides, as shown in **Figure 7**.

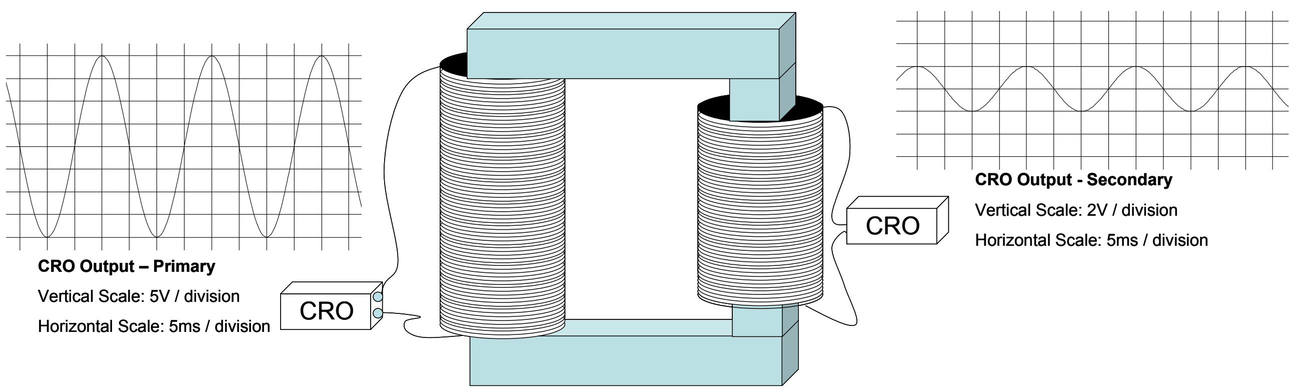

Figure 7

Question 11
What is the Peak to Peak voltage in the primary coil of the transformer?

V

1 mark

SECTION A- AREA OF STUDY 1- continued
TURN OVER

Question 12
Determine the RMS voltage in the primary coil.

V

1 mark

Christina counts the number of turns on the primary coil to be 150.

Question 13
Determine the number of turns in the secondary coil

turns

2 marks

Christina's apprentice, Liz, states that given that the iron core is laminar, this transformer can be modelled as "**ideal**".

Question 14
Referring to the construction of the iron core, explain what is meant by an **ideal** transformer.

2 marks

SECTION A- AREA OF STUDY 1- continued

Mana has moved to a remote highland shack which is not reachable by mains power. Instead, he installs a small generator, but to maintain the serenity, he keeps it 1 km from shack so that the noise is less intrusive. The generator provides a 1200 V RMS output and is connected by cables to the shack. A step down transformer located at the shack site, with a turns ratio of 5:1, as shown in **Figure 8.**

When all the appliances in the shack are switched on, the current drawn is 15 A but Mana is disappointed to find that the voltage only measures 236 V RMS on his multimeter, after it is stepped down by the transformer.

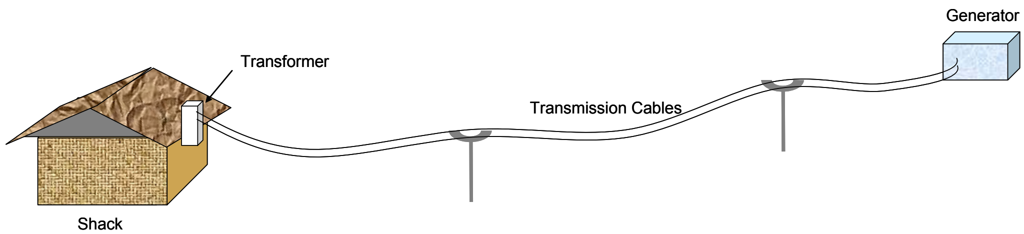

Figure 8

Question 15
Determine the current that must be flowing in the cables.

A

2 marks

Question 16
Determine the **total** resistance in the cables.

Ω

3 marks

SECTION A- AREA OF STUDY 1- continued
TURN OVER

Question 17
Mana notices that as he switches off some of the appliances, the voltage at the shack increases. Explain why this occurs.

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3 marks

END OF AREA OF STUDY 1
SECTION A-continued

Area of Study 2 – Interactions of light and matter

George is conducting an experiment with a basic photocell. Using a light source, various filters and miscellaneous electronic equipment, he has constructed a test circuit which is shown in **Figure 1**. George directs blue light of wavelength 450 nm onto the metal plate and observes photocurrent on the milliammeter. Using a voltmeter, he also measures the potential difference between the metal and collector plate.

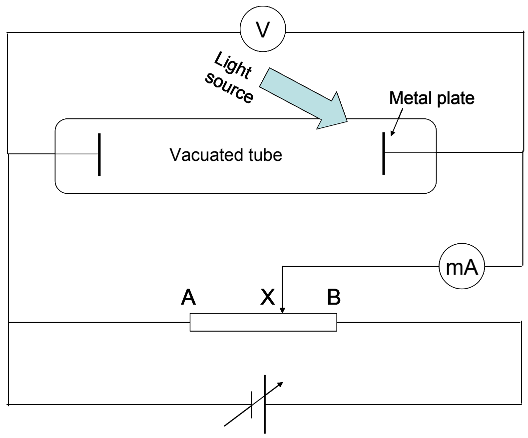


Figure 1

George adjusts the slider at Point X, moving it left and right to record a range of voltage and current readings, which he plots as shown in **Figure 2**.

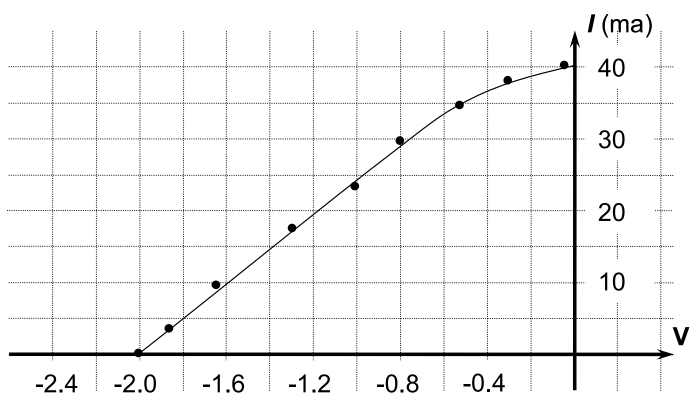


Figure 2

Question 1

Calculate the energy of a photon of the blue light source used by George.

J

2 marks

SECTION A- AREA OF STUDY 2- continued
TURN OVER

Question 2
Determine the size of the work function for the metal used in the photocell. Give your answer in electron volts.

eV

3 marks

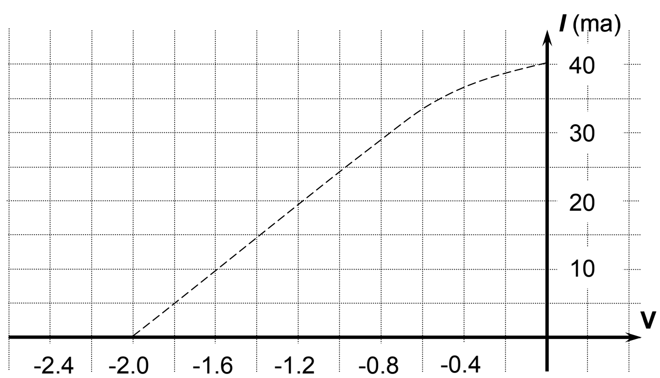
Question 3
George now adjusts the slider towards **Point A**. Which **one or more** of the following statements would result?

A. Increase in photocurrent
B. Decrease in photocurrent
C. No change in photocurrent
D. Decrease in kinetic energy of electrons reaching the collector plate
E. Increase in kinetic energy of electrons reaching the collector plate
F. No change in kinetic energy of electrons reaching the collector plate

2 marks

George now replaces the 450 nm filter with one of **shorter** wavelength. He also reduces the intensity of the light source.

Question 4
On **Figure 3** provided below, sketch an **estimate** of the curve that you would expect George to plot for this revised scenario. (The dashed line represents the curve for the 450 nm source)



2 marks

Figure 3

SECTION A- AREA OF STUDY 2- continued

Chinh has constructed a basic version of Young's double slit experiment. He has a monochromatic laser source which he directs through a pair of narrow slits. Chinh notes the distinctive interference pattern that forms on the nearby screen. A simplified version of the setup is shown in **Figure 4**. Point C represents a point equidistant from slit A and B. The pattern formed on the screen is shown in **Figure 5**.
Point P is the centre of a dark band and the path difference: PB – PA = 1.70 μm.

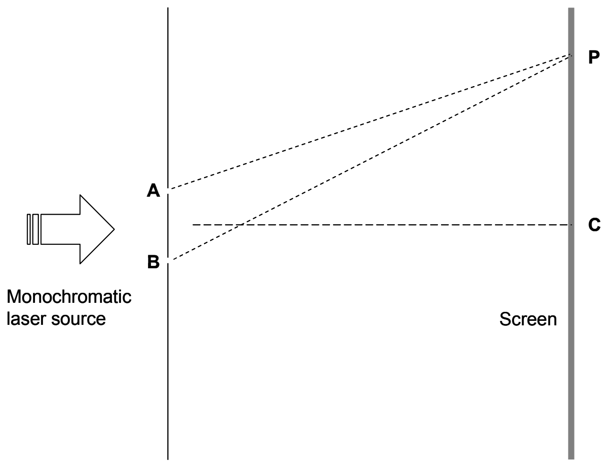


Figure 4

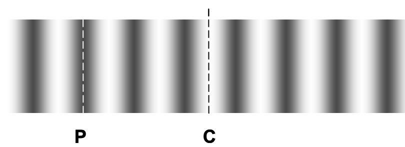


Figure 5

Question 5

Determine the wavelength of the laser that Chinh is using.

nm

3 marks

SECTION A- AREA OF STUDY 2- continued
TURN OVER

Chinh now wants to make the interference pattern narrower, so that the dark bands are closer together.

Question 6
Choose a set of actions that would lead to the **NARROWEST** pattern.

A. Change the light to a higher frequency source.
B. Change the light to a lower frequency source.
C. Reduce the gap between slits A & B.
D. Increase the gap between slits A & B.
E. Move the screen further away from the source.
F. Move the screen closer to the source.

2 marks

Dharvin is investigating the patterns formed when he directs X-Rays and high speed electrons through a crystal lattice. He is able to generate similar diffraction patterns, as shown in **Figure 6**. The X-Rays used have a wavelength of 0.15nm.

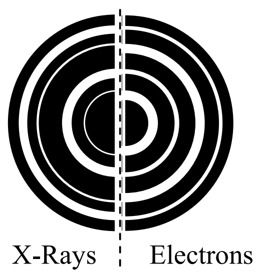


Figure 6

Question 7
Determine the speed of the electrons required for the diffraction patterns to match.

ms^{-1}

2 marks

SECTION A- AREA OF STUDY 2- continued

Dharvin now switches to a crystal lattice with a **narrower** spacing.

Question 8
Which of the following changes to the X-Ray and Electron beams could Dharvin make if he wanted to achieve a pattern with the same spacing as **Figure 6**?

A. Increase the intensity of the X-Ray source.
B. Increase the accelerating voltage driving the electrons.
C. Increase the frequency of the X-Ray source.
D. Increase the wavelength of the X-Ray source.
E. Decrease the accelerating voltage driving the electrons.

2 marks

Martin is analysing the emission spectrum for an unknown gas. He constructs a test rig that allows him to pass high energy electrons through the sample and views the resultant photon emission through a spectroscope. A simplified version of the setup is shown in **Figure 7.** The diffraction grating in the spectroscope reveals a series of discrete wavelengths, as shown in **Figure 8**.

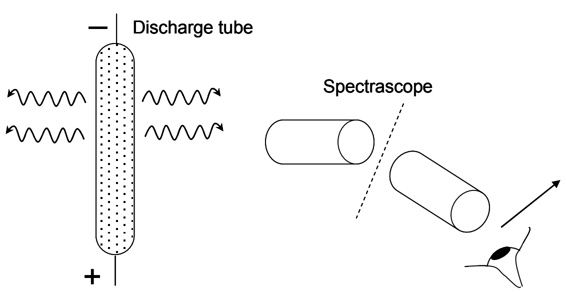


Figure 7

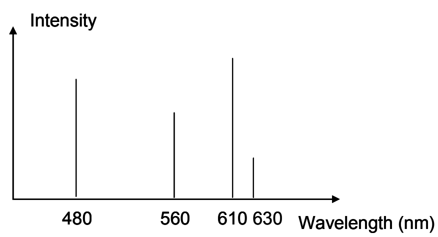


Figure 8

Question 9
Assuming the gaseous atoms are all initially in their ground state, calculate the **minimum** energy of the electrons that Martin must use to generate the pattern shown.

eV

2 marks

SECTION A- AREA OF STUDY 2- continued
TURN OVER

Meanwhile, Calvin is reviewing the results from a similar test, this time involving mercury vapour excited by UV light. The physicist performing the experiment has produced an energy level diagram for the mercury as shown in **Figure 9**.

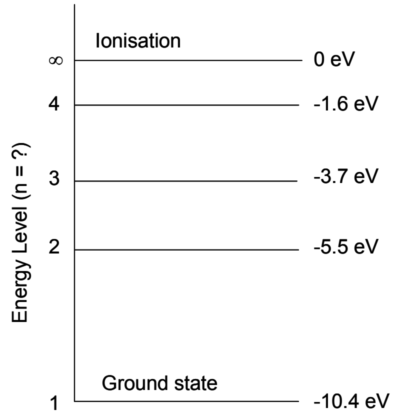


Figure 9

Question 10
Which of the following UV photons would be likely be absorbed by the gaseous mercury? **(may be more than one answer)**
A. 6.0 eV
B. 4.9 eV
C. 8.4 eV
D. 5.5 eV
E. 11.2 eV

2 marks

Question 11
Explain why the emission spectrum for mercury supports the idea that electrons are best modelled as waves.

3 marks

END OF SECTION A

SECTION B- Detailed Studies

Instructions for Section B
Choose **one** of the following **Detailed Studies**. Answer **all** questions on the Detailed Study you have chosen.

Detailed Study 1 – Synchrotron and its applications

Question 1
Match the following components of the Australian Synchrotron with the correct description

The electron linac ☐

Storage ring ☐

Booster ring ☐

A measures the energy of electrons in the electron beam **B** measures the speed of electrons in the electron beam **C** uses a magnetic field to deflect electrons into a circular path **D** uses a overall voltage of 100 million volts to accelerate electrons **E** further increase the energy of already accelerated electrons	**F** increase the speed of electrons beyond the speed of light **G** transform the energy of electrons into photon energy **H** reduces the energy of the accelerated electrons before injecting them into the storage ring **I** a single piece of silicon cut with high precision to allow only specific wavelengths to pass	**J** location where electrons, at maximum speed, produce radiation for use in beamlines **K** a row of magnets with alternating polarity that produce brighter synchrotron radiation at a specific frequency **L** thin tungsten wire, or a filament, heated by a current to 1000^{o}C

3 marks

Question 2
Briefly explain the **difference** between the purpose of the **undulators** and the **wigglers** used in the Australian Synchrotron, in terms of the synchrotron light produced.

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2 marks

SECTION B- DETAILED STUDY 1- continued
TURN OVER

Question 3
Complete the following table, comparing synchrotron light with light from a torch globe. Also list an advantage that this provides.

Characteristic	Comparison of synchrotron light compared to torch globe	Practical advantage of synchrotron light
Spectrum		
Divergence		
Brightness		

3 marks

A photon interacts with an electron and is detected afterwards with a slightly longer wavelength as per the data in **Figure 1**.

	Wavelength (nm)
Photon before interaction	0.46
Photon after interaction	8.5

Figure 1

SECTION B- DETAILED STUDY 1- continued

Question 4
Determine the change in momentum of the electron. Include a unit in your answer.

3 marks

Peta is experimenting with a simple electron gun. It is assumed that the electrons are emitted from the heated element with no kinetic energy, but are then accelerated by a potential difference of 10 kV within a vacuum chamber. Peta has also placed a pair of strong permanent magnets within the chamber as indicated in **Figure 2**. The magnetic field between the magnets can be assumed to be a uniform 20 mT

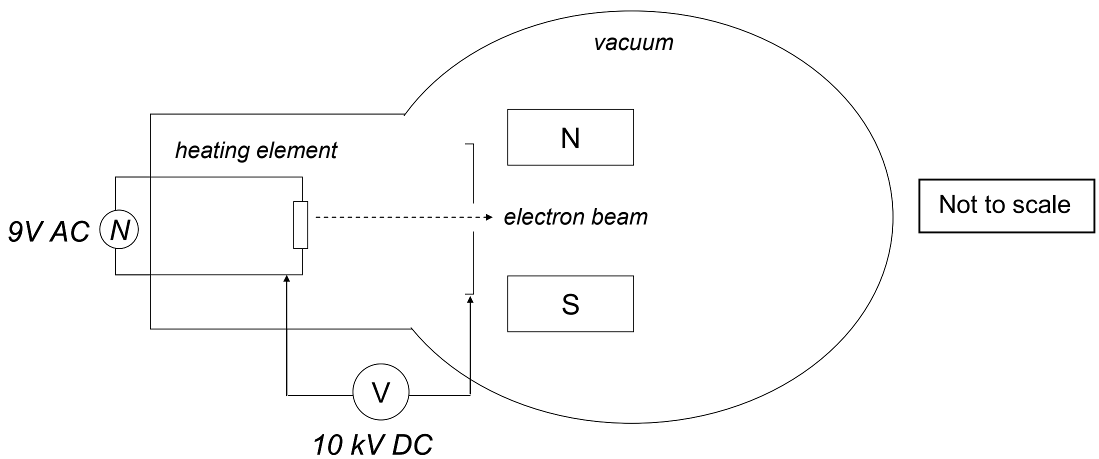

Figure 2

Question 5
Calculate the kinetic energy of an electron after it leaves the accelerating potential.

J

2 marks

SECTION B- DETAILED STUDY 1- continued

Question 6
Determine the radius of curvature and the circle the correct direction of the path of the electron as it passes through the permanent magnets.

m	**Direction**: up / down / left / right / into-page / out-of-page

3 marks

Question 7
Explain why synchrotron radiation can be termed **tuneable**, with particular reference to frequency, monochrometer and beamlines.

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3 marks

Physicists at a university laboratory are investigating the spacing between layers of atoms in a bunsenite (NiO) crystal. In a particular experiment, they use X-rays of 9.5 keV

Question 8

Show that the wavelength of the X-rays used in the experiment is 0.13nm

2 marks

The experimenters direct the X-Rays towards a bunsenite crystal, and record high intensity X-rays reflected at various angles of incidence. The experiment setup is shown in **Figure 3** and the data from the experiment has been converted to graphical form in **Figure 4**.

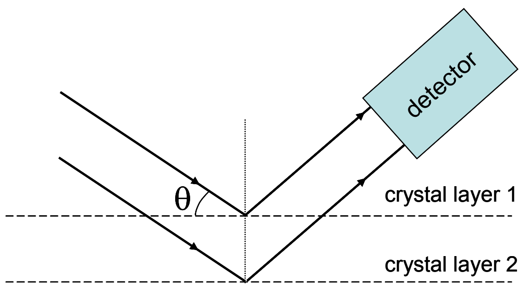

Figure 3

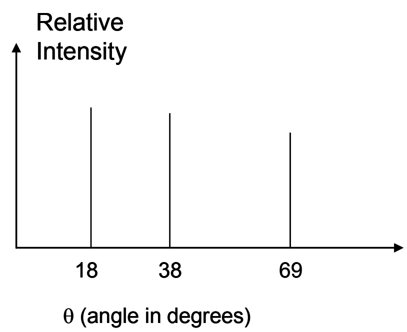

Figure 4

SECTION B- DETAILED STUDY 1- continued

Question 9
Use the data from **Figure 3 & 4** to calculate the spacing between the crystal layers in NiO.

m

2 marks

Question 10
Explain why there are no more than three high intensity peaks recorded in this experiment. Use a calculation to support your answer.

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2 marks

END OF DETAILED STUDY 1
TURN OVER

Detailed Study 2 – Photonics

Julian is using an LED made using Gallium Arsenide, for which the band gap energy is known to be 3.4×10^{-19} J

Question 1
Determine the wavelength of light emitted by the LED. Give your answer in nanometres.

nm

2 marks

Question 2
LASER is an acronym Light Amplification by Stimulated Emission of Radiation. Use a diagram to demonstrate your understanding of **Stimulated Emission**.

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3 marks

SECTION B- DETAILED STUDY 2- continued

Jane is comparing input and output pulse signals for three different types of optical fibre. He sends a pulse down each fibre and plots the data as per the graphs shown below in **Figure 1.**

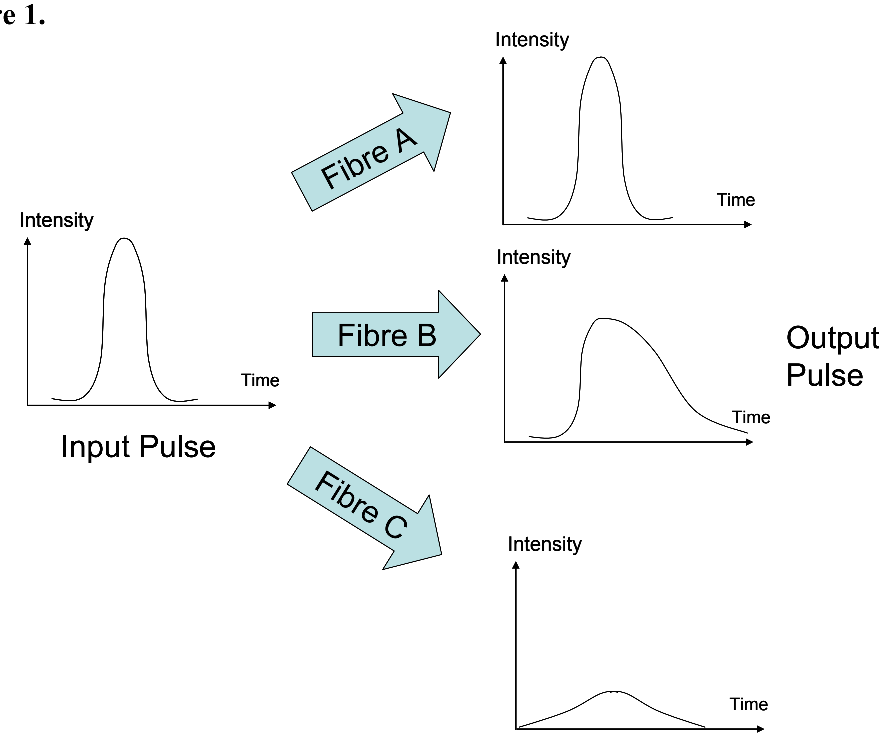

Figure 1

Question 3
Considering **modal dispersion only**, match the graphs in Figure 1 with the correct type of fibre

Single-mode step-index [ ]

Multimode step-index [ ]

Multimode graded-index [ ]

3 marks

SECTION B- DETAILED STUDY 2- continued
TURN OVER

Question 4
Explain the difference between **modal** and **material** dispersion, clearly indicating which is more significant for multi-mode fibres.

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3 marks

Paulette is testing her new optical fibre, as shown in **Figure 2**. She knows the refractive index of the cladding is 1.49, but is unsure of the index of the core. Initial tests indicate that the minimum angle required for total internal reflection is 82.1 ^{o}.

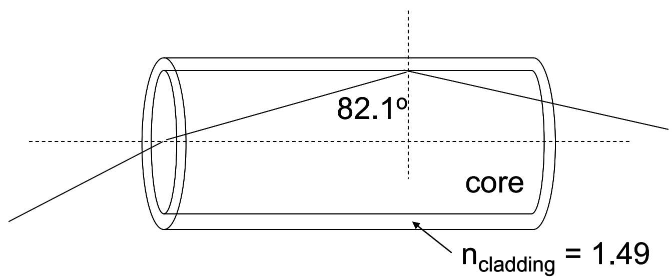

Figure 2

Question 5
Determine the refractive index of the core material.

2 marks

Question 6
Calculate the numerical aperture for Paulette's fibre

2 marks

SECTION B- DETAILED STUDY 2- continued

Test of Paulette's fibre reveals an attenuation pattern, shown below in **Figure 3**.

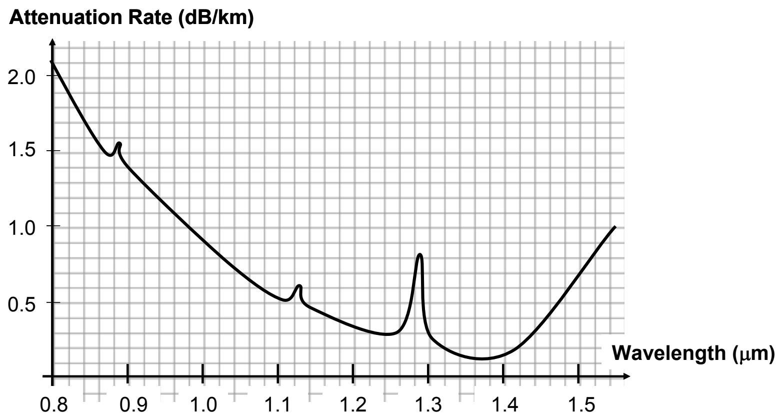

Figure 3

Question 7
Determine the total loss in decibels for a 3 km length of fibre operating with a signal of 1.0 μm

dB

2 marks

Two primary modes of optical loss drive the attenuation curve shown in Figure 3.

Question 8
Briefly describe each mode and state which is most significant at a wavelength of 1.0μm

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3 marks

SECTION B- DETAILED STUDY 2- continued
TURN OVER

Fibre optic bundles are now widely used, particularly for internal surgical procedures.

Question 9
Explain why surgeons require **coherent** bundles for internal cameras, but can use **non-coherent** bundles for basic light sources.

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2 marks

Fibre optic sensing systems are now widely used in civil engineering structures to provide real time, ongoing information about stress and strain in materials. Composite materials such as carbon fibre can be cast with multiple strands of optical fibre, which are fed back to a central monitoring system.
The sensors often use intensity based approach, with variations in attenuation along the fibre calibrated to stress and strain states.

Question 10
Briefly outline three advantages that optical based sensing systems have over more traditional copper wiring circuits.

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____

____

3 marks

END OF DETAILED STUDY 2

Detailed Study 3 – Sound

Andrew is analysing the output of a small speaker. He measures the pressure variation over time at a point 2.0 m from the speaker. A graph of pressure variation vs. time is shown in **Figure 1**. Assume the speed of sound is 330 ms^{-1} in the room where Andrew is measuring the sound.

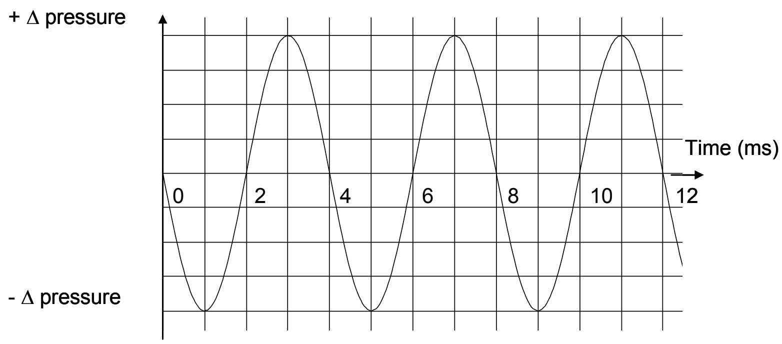

Figure 1

Question 1
Determine the wavelength of the sound source depicted in **Figure 1**.

m

2 marks

Alex parks her new car in the centre of an outdoor carpark and selects one of her favourite loud tracks to play on the stereo. She moves to one side of the carpark at a distance of 12m from the vehicle.
Meanwhile, her friend Joel stands on the other side of the carpark, a distance of 8 m from the source. Both students have a sound intensity level meter. The setup is shown below in **Figure 2.**

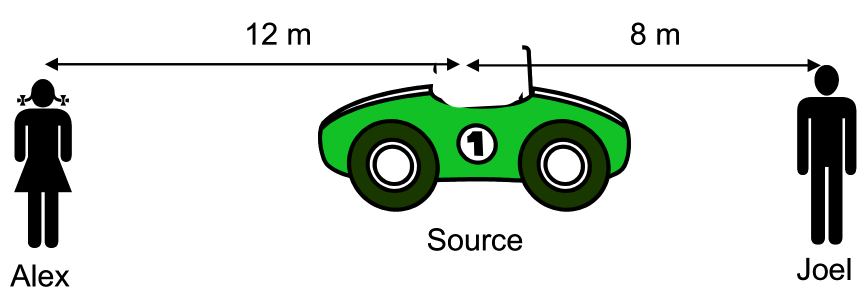

Figure 2.

SECTION B- DETAILED STUDY 3- continued
TURN OVER

Question 2
Alex records the music at an average of 96 dB. Determine the sound intensity level that Joel would record. (You can assume the stereo broadcasts evenly in all directions. Ignore any reflection effects.)

dB

3 marks

Satisfied with their measurements, Alex and Joel jump back into the car.
Alex is singing along to one of her favourite songs. In one chorus, she sustains a particularly gruesome note of 3330 Hz. Alex's vocal system can be modelled as a air column open at both ends, with length of 15 cm. Alex is singing quite hard, so assume the note is the third harmonic.

Question 3
Determine the speed of sound in the air at the time

ms^{-1}

3 marks

Question 4
Which of the following notes are **harmonics** that Alex could achieve?
A. 833 Hz
B. 1110 Hz
C. 1665 Hz
D. 2220 Hz

2 marks

SECTION B- DETAILED STUDY 3- continued

Question 5

To improve the quality of Alex's singing, Joel hands her a balloon filled with helium and convinces her to inhale a lungful of the gas. If sound travels through helium at 1005 m/s, explain the effect this would have on Alex singing. Use a calculation to support your answer

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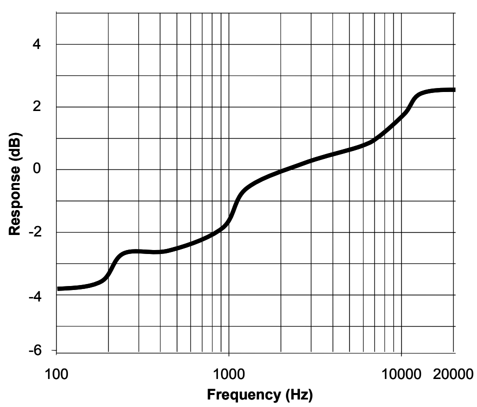
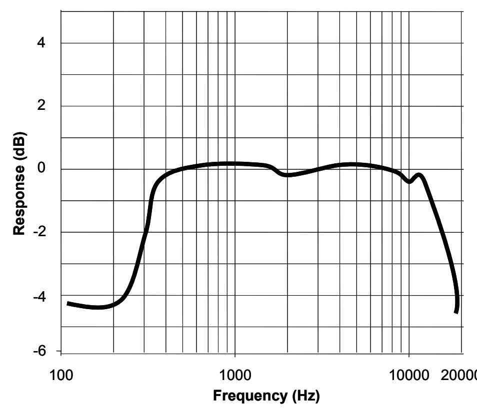
3 marks

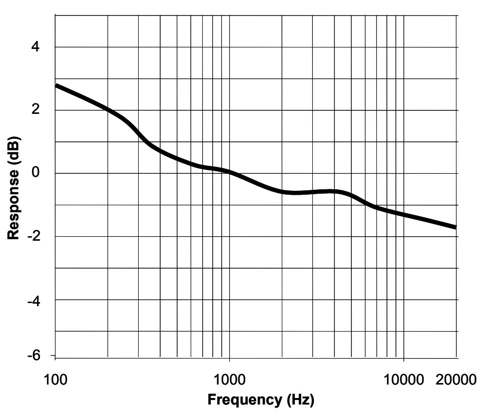
Encouraged by the response to her singing, Alex goes shopping for a microphone and karaoke system. There are several microphones on sale and being a keen physics student, Alex is determined to check the specifications of each. The response curves for three microphones are shown below.



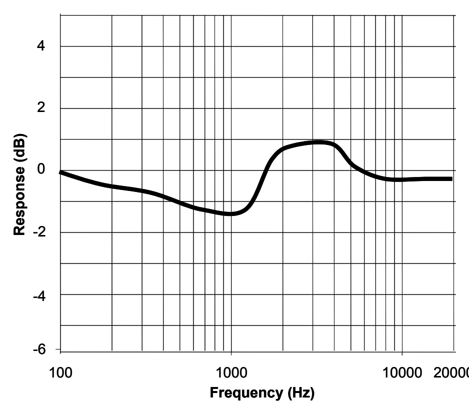
Microphone A



Microphone B



Microphone C



Microphone D

Question 6
Based on highest fidelity over a typical human vocal range, which microphone should Alex choose? Explain your answer.

2 marks

Question 7
Alex also notices that there is a range of types of microphones on sale. Ignoring any secondary transformers used in the microphone circuits, which of the following are **NOT** true about the various microphones available? (May be more than one answer)

A. Carbon microphones use pressure induced variations in the resistance of carbon dust to alter the current in a secondary circuit. The higher the pressure on the dust, the higher it's resistance.

B. Ribbon, dynamic coil and electret condenser microphones all utilise principles of electromagnetic induction, whereas crystal and carbon microphones do not.

C. Electret condenser microphones use a thin diaphragm of mylar or plastic which is permanently positively charged on both sides. Sound causes the diaphragm to vibrate above a capacitor, with the permanent static charge producing a corresponding voltage signal.

D. Ribbon (or velocity) microphones use a piece of corrugated aluminium ribbon, which is vibrated by moving air. The thicker and more rigid the ribbon, the better it responds to sound signals.

2 marks

SECTION B- DETAILED STUDY 3- continued

After too much loud music, Alex decides she should consult a specialist. Susan, the friendly audiologist, performs a series of tests, one of which determines a threshold of hearing and phon curves for Alex's left ear, as shown in **Figure 4**.

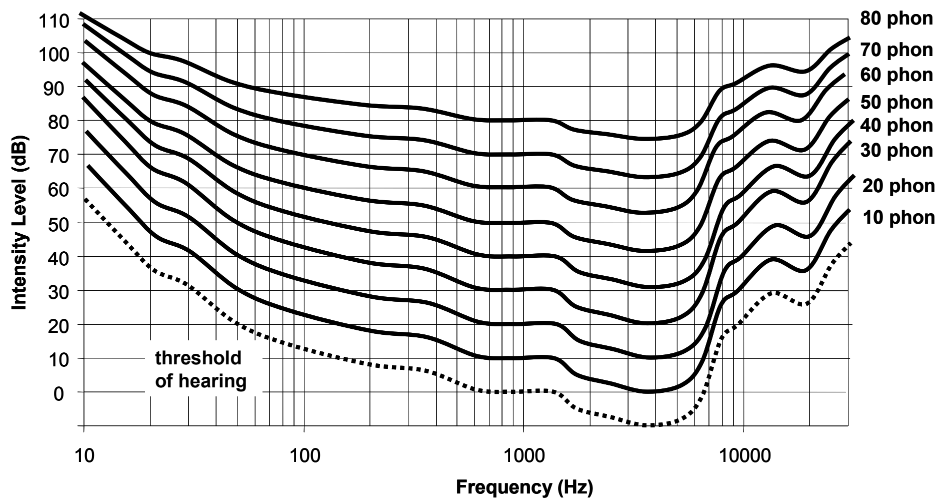


Figure 4

Question 8

Estimate from the graph any frequency at which a 70 dB signal sound as loud to Alex as 50 dB at 1000 Hz signal (give all possible answers as per **Figure 4**.)

2 marks

After several tests, Susan is satisfied that Alex's hearing is normal. However, after they establish that she is a Year 12 Physics student, she has one final demonstration for him.
Sitting blindfolded in the especially sound-proofed consulting room, where sound reflections can be assumed to be zero, Alex is asked to locate the source of a test sound at various frequencies. Alex's head measurements are shown below in **Figure 5**:

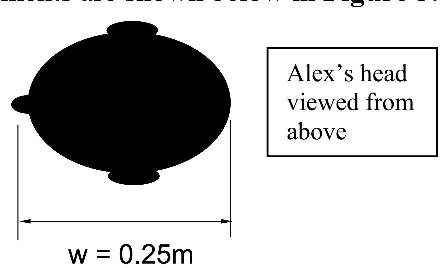


Figure 5

SECTION B- DETAILED STUDY 3- continued
TURN OVER

The following table summarises the result of the demonstration:

Test Frequency	Correct Identification	Incorrect Identification
250Hz	2	8
3000Hz	9	1

Question 9
Explain why, even with satisfactorily functioning ears, Alex was able to locate some sounds more accurately than others. Use a calculation to support your answer. (Assume speed of sound = 340 ms^{-1})

3 marks

Question 10
Referring specifically to the physics principles of **interference** and **baffles**, explain the purpose of building an airtight box around the large, low range speaker. Use a clearly labelled diagram to support your answer.

3 marks

END OF QUESTION AND ANSWER BOOK