THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 4 PHYSICS 2008

WRITTEN EXAMINATION 2

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

QUESTION AND ANSWER BOOKLET

Structure of Booklet

Section		*Number of Questions*	*Number of Questions to be Answered*	*Number of Marks*	*Suggested Times (minutes)*
A	**Core Studies**				
	Electric Power	20	20	37	37
	Interactions of Light and Matter	12	12	27	27
B	**Detailed Studies**				
	1. Synchrotron **OR**	13	13	26	26
	2. Photonics **OR**	13	13	26	26
	3. Sound	13	13	26	26
				Total 90	Total 90

Students are permitted to bring into the examination rooms: 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 sheets of paper and/or white out liquid/tape.

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

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SECTION A – CORE STUDIES

Instructions For Section A

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

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

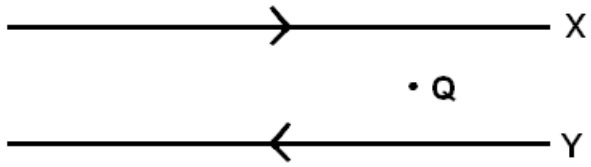
Where an answer box has a unit printed in it, give your answer in that unit.

You should take the value of g to be $10\ ms^{-2}$.

AREA OF STUDY 1 – ELECTRIC POWER

The following information refers to Questions 1 and 2.

Two wires carry current in opposite directions as shown in the diagram below. The current in wire Y is twice the current in wire X. Point Q is midway between wires X and Y.



Use the following key for your answers:

A. To the right
B. To the left
C. Up
D. Down
E. Into the page
F. Out of the page
G. Zero

QUESTION 1
Which of the following best describes the direction of the resultant magnetic field at point Q

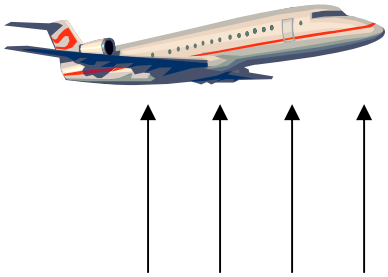
1 mark

QUESTION 2
The current in wire X is reversed. Both conductors now have current passing from right to left. Which alternative would now represent the resultant magnetic field?

1 mark

The following information refers to Questions 3 and 4.

An aeroplane with a wing span of 25 metres is flying over the south magnetic pole located within the Antarctic, at 540 $kmhr^{-1}$. The magnetic field within this region is vertically orientated and the magnetic field strength is 6.0×10^{-5}T.



$B = 6.0 \times 10^{-5}$ T

QUESTION 3
What is the magnitude of the emf induced across the wing tips?

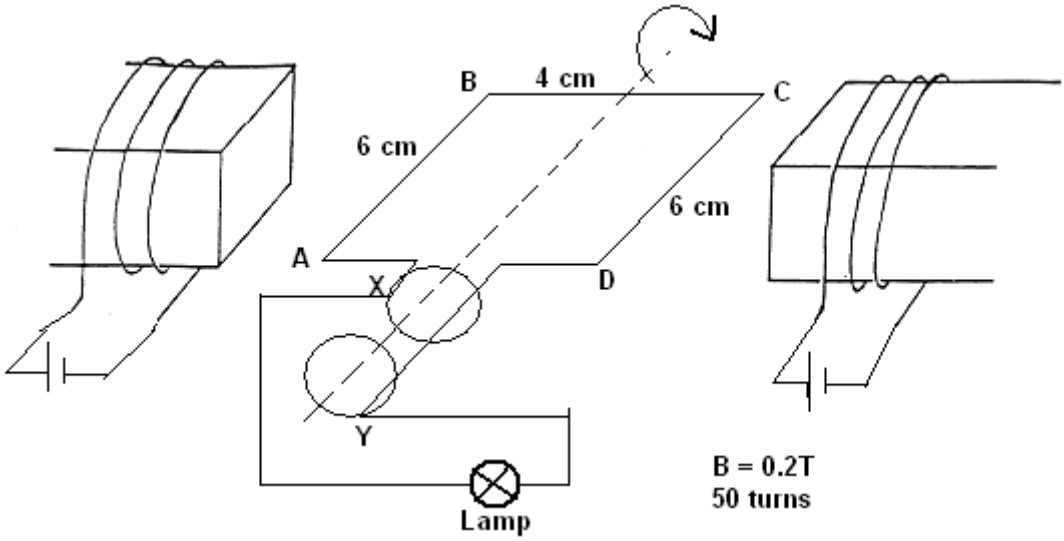
2 marks

QUESTION 4
Which wing is positive? The left or the right?

2 marks

The following information refers to Questions 5 to 12.

A student decided to make an AC generator. He winds a rectangular coil of **50 turns**, each of length **6cm** and width **4cm**. It rotates about the axis represented by the dotted line at a frequency of **4 Hz**. To test the generator he connects a small lamp across the output XY.



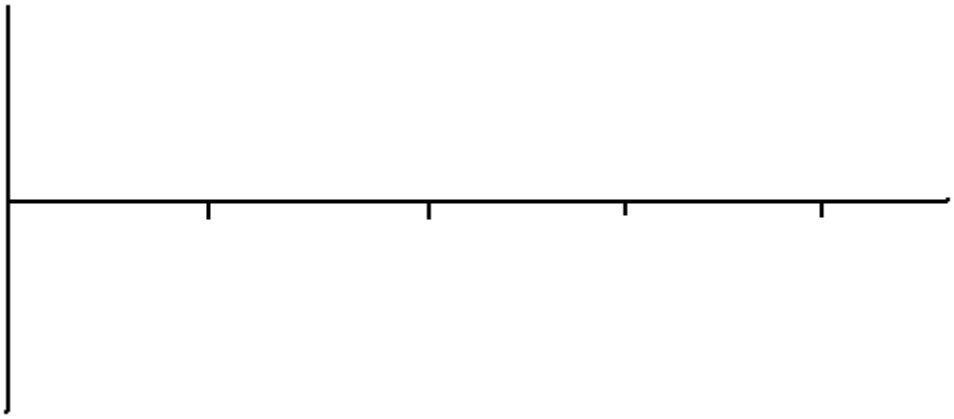
A uniform magnetic field of **0.2T** is produced by a pair of DC electromagnets (stator coils) located each side of the rotating loops.

QUESTION 5
For each electromagnet (stator coil), label the pole that is adjacent to the rotating coils with N (north) or S (south).

2 marks

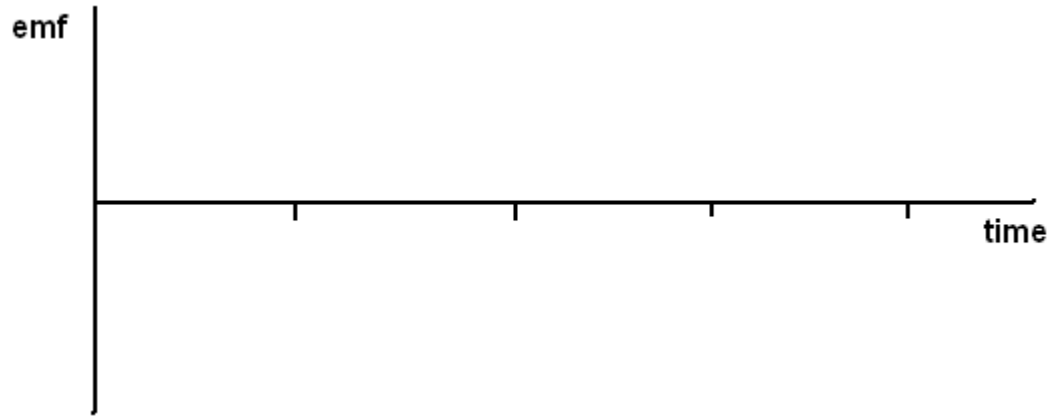
The loop is rotated such that $\overline{AB}$ is initially moving upwards. It continues to rotate at 4.0 Hz in a clockwise direction.

QUESTION 6
Draw a graph on the set of axes provided below to represent the magnetic flux passing through the loop for one complete revolution. Label the axes and include values.



3 marks

QUESTION 7
Draw the corresponding emf-time graph (no need to include values here).



2 marks

QUESTION 8
What is the average emf generated across XY during a quarter turn?

2 marks

QUESTION 9
When the loop is rotating, at the instant shown in the diagram, is position **X** positive or negative?

2 marks

QUESTION 10
The student notices that the lamp flickers. Why is this?

2 marks

QUESTION 11
What is the frequency of the 'flicker'?

2 marks

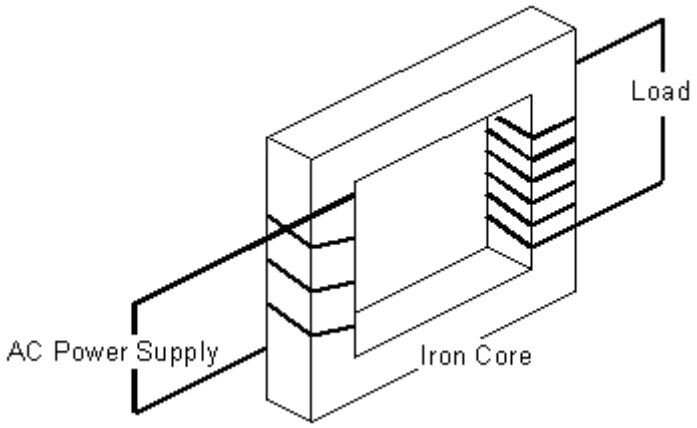
Hz

QUESTION 12
A cathode ray oscilloscope was connected across the terminals of the lamp. A peak voltage of 4.8V was recorded. What is the rms voltage?

2 marks

V

The following information refers to Questions 13 to 16.



QUESTION 13
Is the transformer illustrated a step-up or a step-down transformer?

1 mark

QUESTION 14

Primary coils = 200
Secondary coils = 800
Primary voltage = 24V

What is the secondary voltage?

2 marks

V

QUESTION 15
If the 'ideal' transformer was replaced with a 'real' transformer, which of the following would be true?

A. The secondary voltage would be less but the secondary current would remain the same.
B. The output power from the transformer would be less than the input power.
C. The frequency of the secondary coil would be less than the primary coil.
D. The secondary current would increase.

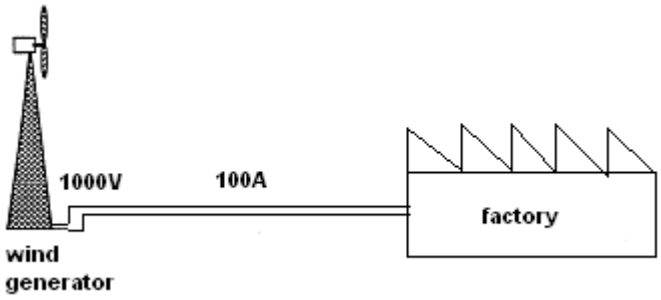
2 marks

QUESTION 16
It is generally accepted that the metal copper is a better conductor than iron.
If the iron core of the transformer was replaced with a copper core, what would be the effect on the brightness of the globe operating? Explain your answer.

3 marks

The following information refers to Questions 17 to 20.

.A factory acquires electricity from a wind generator located 2km away. The generator supplies a constant 1000V and 100A when there is a moderate wind blowing. The resistance of the transmission system is 2 ohms.



QUESTION 17
What power is supplied by the generator?

W

1 mark

QUESTION 18
How much power is lost in the transmission system?

1 mark

W

QUESTION 19
What voltage is supplied to the factory?

V

2 marks

QUESTION 20
Describe one method for reducing the power lost through the transmission system?

2 marks

End of Section on Electric Power

AREA OF STUDY 2
INTERACTIONS OF LIGHT AND MATTER

Questions 1 to 3 refer to the following information.

George and Peta have set up the apparatus for a double slit experiment. The light source produces a monochromatic, coherent light of wavelength 580 nm. A diagram of their apparatus and interference pattern (not to scale) is shown in Figure 1.

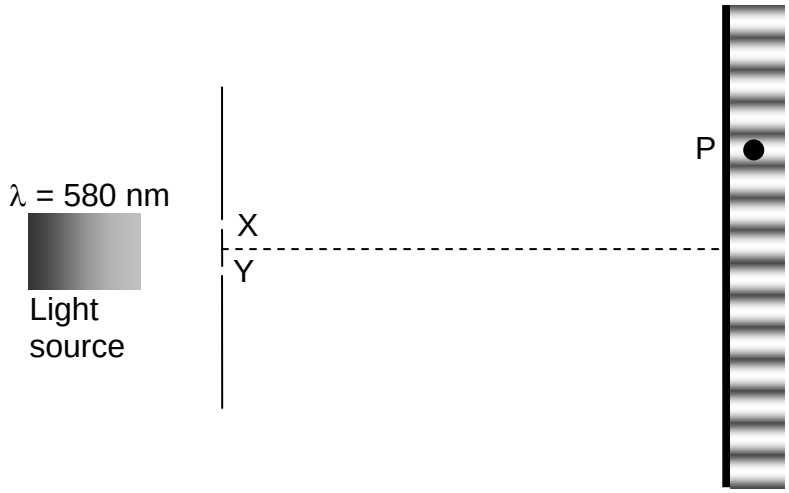


Figure 1

QUESTION 1
Which of the following light sources is most likely being used in this experiment?

A. Sun light
B. LED
C. Light globe with filter
D. LASER

[ ]

2 marks

QUESTION 2
Determine the path difference between PX and PY

_____

_____

_____

_____

2 marks

[ ] m

QUESTION 3
Which *one or more* of the following changes to the experiment will **increase** the spacing between maxima in George and Peta's interference pattern?

A. Increase wavelength of the light source.
B. Decrease wavelength of the light source.
C. Increase slit separation.
D. Decrease slit separation.

2 marks

Questions 4 and 5 refer to the following information.

The equipment for the photoelectric effect was set up as shown in Figure 2. Light was shone through various coloured filters onto a metal electrode P housed in a vacuum sealed chamber. The photocurrent was measured by an ammeter for a varying voltage measured by the voltmeter.

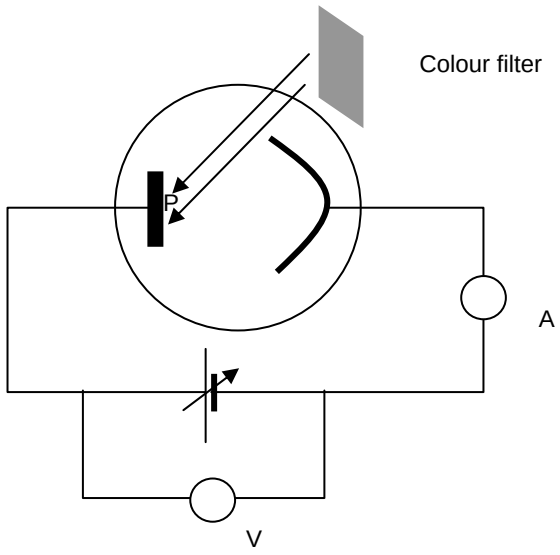
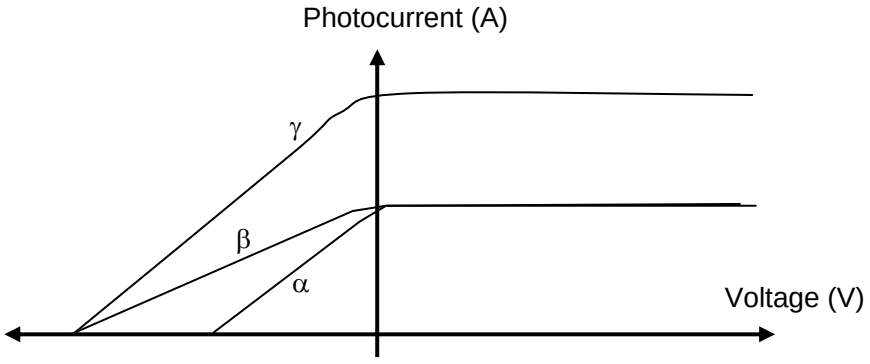


Figure 2

Three experiments (α,β,γ) were conducted. For each experiment the intensity, frequency or electrode metal were varied. The resulting photocurrent versus voltage graphs are shown in Figure 3 below.



QUESTION 4
Which one of the following statements about the experiments in Figure 3 is true?

A. Light intensity for α and γ are the same.
B. The electrodes at P for β and γ are the same.
C. The light filters for α and β are the same.
D. It is impossible to determine from the information given.

2 marks

QUESTION 5
During the α experiment, the recorded stopping voltage was found to be 1.13 V for a wavelength of 384 nm. When only the filter was changed, a stopping voltage of 0.36 V was recorded for a wavelength of 492 nm. Show that the **experimental** value for Plank's constant was 4.5×10^{-15} eVs. (*Students are required to show all working)*

4 marks

QUESTION 6
Complete the table below by placing examples of when photons and electrons exhibit wave and particle properties from the given list.

Photoelectric effect, gas discharge tube, Young's double slit experiment , orbiting atoms

	Photons	**Electrons**
Wave		
Particle		

2 marks

Questions 7 to 10 refer to the following information.

Charley and Alex are investigating whether taking an image of a bacterium of size 1 μm would be better using an electron microscope or a light microscope.

QUESTION 7
What is the momentum of a photon with a wavelength of 490 nm?

Ns

2 marks

QUESTION 8
What is the de Broglie wavelength of an electron with a momentum of 8.7×10^{-27} Ns?

m

2 marks

QUESTION 9
Determine the voltage required to accelerate the electrons to achieve a momentum of 8.7×10^{-27} Ns.

V

3 marks

QUESTION 10
Will the electrons or the photons produce a clearer image? Explain your answer.

_____

_____

_____

_____

_____

_____

3 marks

Questions 11 and 12 refer to the following information.

The energy level diagram of a particular metal atom is shown in Figure 4. As the atom is excited the emission spectra from the emitted photons is studied.

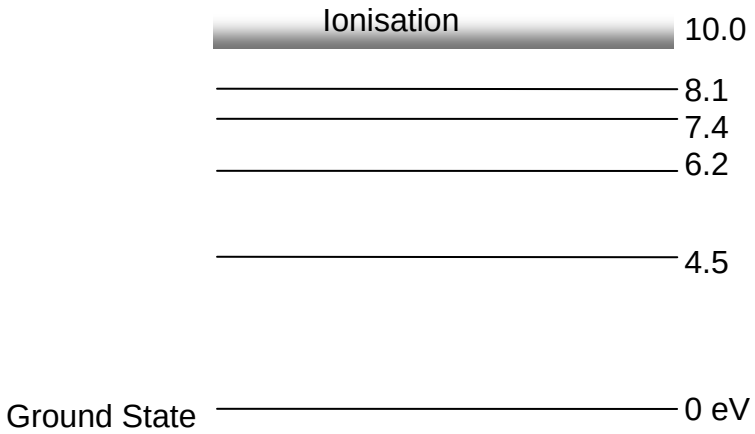


Figure 4

QUESTION 11
Atoms are excited to the n = 4 energy state. How many emission lines will be observed as the electrons fall back to the ground state?

1 mark

QUESTION 12
Determine the maximum wavelength of the photon required to ionize an atom.

m

2 marks

End of Section on Interactions of Light and Matter

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.

Choose the response that is **correct** for the question.

A correct answer scores 2, an incorrect answer scores 0.

Marks will not be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

You should take the value of g to be $10\ ms^{-2}$.

DETAILED STUDY 1

SYNCHROTRON AND ITS APPLICATIONS

Questions 1 and 2 refer to the following information.

Free electrons are created with a heat filament and accelerated between two parallel plates connected to power supply as shown in Figure 1.

($m_e = 9.1\times10^{-31}$ kg, $e = 1.6\times10^{-19}$ C)

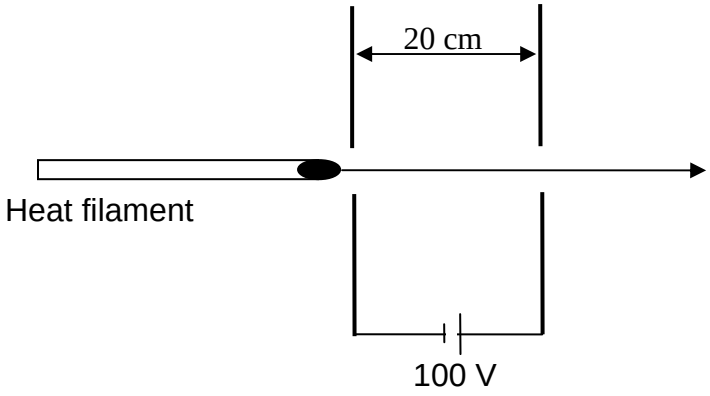


Figure 1

The plates are separated by a distance of 20 cm and have a potential difference of 100 V.

QUESTION 1
Which of the following values (A-D) best estimates the electric field experienced by an electron passing between the plates?

A. 5 V m^{-1}
B. 50 V m^{-1}
C. 500 V m^{-1}
D. 5000 V m^{-1}

2 marks

QUESTION 2
Which of the following kinetic energies in Joules (A-D) is gained by an electron passing through the positive plate?

A. 1.6×10^{-19} J
B. 1.6×10^{-17} J
C. 10 J
D. 100 J

2 marks

QUESTION 3
The electrons then pass into a linear accelerator (linac) such that they are travelling at speeds close to the speed of light by the time they exit.

A simple linac is shown in Figure 2.

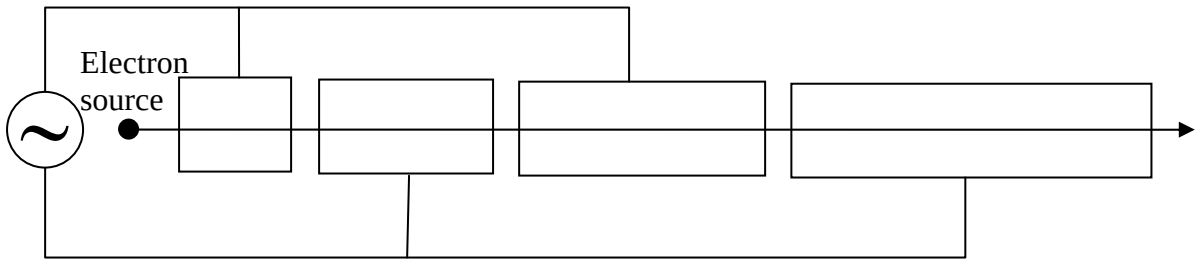


Figure 2

Which of the following statements (A-D) provides the reason why the linac tubes are of different lengths?

A. The electrons are accelerating.
B. The number of electrons increases.
C. The voltage of the tubes needs to increase.
D. The voltage of the tubes needs to decrease.

2 marks

QUESTION 4
Which of the following A-D best describes the order of the components in a synchrotron?

A. Booster Ring then Storage Ring.
B. Beam-line then Booster Ring.
C. Storage Ring then Linac.
D. Storage Ring then Booster Ring.

2 marks

QUESTION 5
Electrons of a given momentum, p, travelling in a magnetic field, B, undergo circular motion with radius r. Which of the following A-D represents the radius of the electron's circular motion if the magnetic field is doubled?

A. 4 r
B. 2 r
C. r
D. ½ r

2 marks

QUESTION 6
Figure 3 shows an electron passing between the opposing poles of an electromagnet.

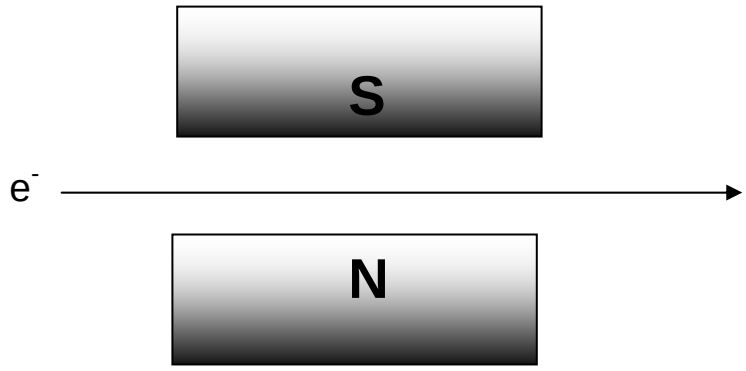


Figure 3

Which of the following directions (A-D) best describes the magnetic force acting on the electrons as they pass between the magnet poles?

A. Up
B. Down
C. Into Page
D. Out of page

2 marks

QUESTION 7
Which of the following statements (A-D) about the brightness of various x-ray sources is true?

A. The X-ray tube is brighter than the sun.
B. The sun is brighter than a synchrotron undulator.
C. An undulator is brighter than a bending magnet.
D. A bending magnet is brighter than a synchrotron undulator.

2 marks

Questions 8 to11 refer to the following information.

X-rays of wavelength 0.105 nm are incident on a crystal sample which has a spacing between the planes of 0.350 nm. The crystal is rotated and a detector records the diffracted x-rays at a glancing angle as shown in Figure 4.

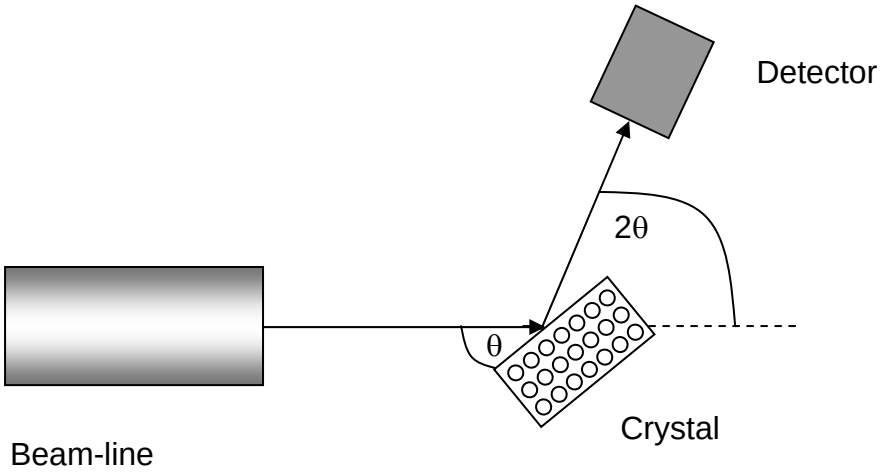


Figure 4

QUESTION 8
Which of the following angles, θ, (A-D) will be the **first** diffracted ray found?

A. 0.3^o
B. 0.15^o
C. 8.6^o
D. 17.5^o

2 marks

QUESTION 9
What is the greatest order of diffracted rays that will be observed from this experiment?

A. 5
B. 6
C. 7
D. 8

2 marks

A new crystal sample is placed at the end of the beam-line with the same incident x-rays. Figure 5 shows the intensity results recorded by the detector as the crystal was rotated.

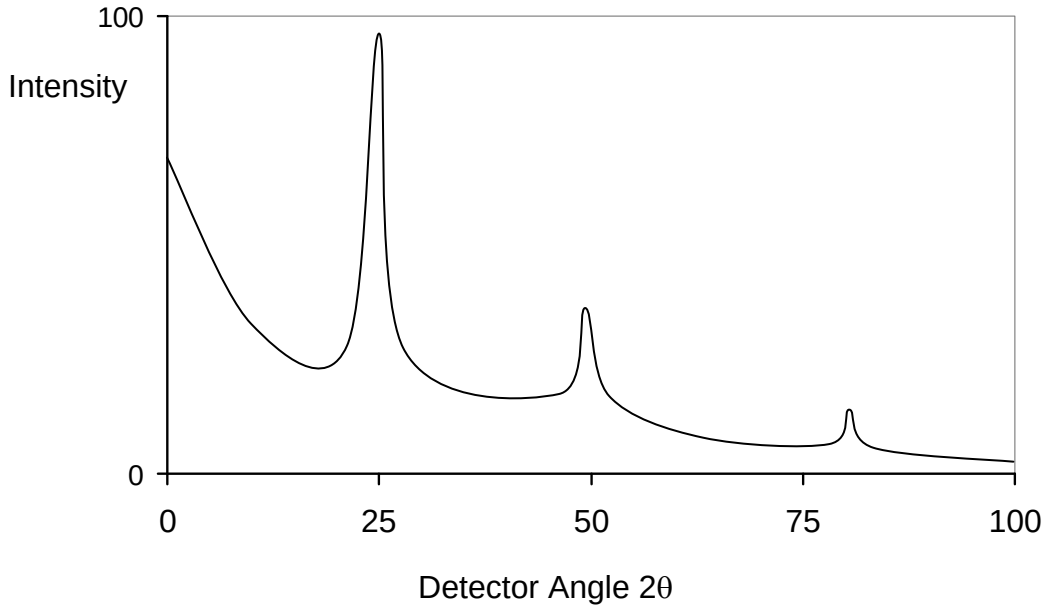


Figure 5

QUESTION 10
From the graph in Figure 5, which statement about the new crystal (A-D) is true.

A. The new crystal has three different plane spacings.
B. The crystal has at least three reflected rays due to diffraction.
C. The new crystal has a larger distance between planes.
D. The new crystal is in powder form.

2 marks

QUESTION 11
What is the best estimate (A-D) for the distance between planes for the new crystal?

A. 0.1 nm
B. 0.3 nm
C. 0.5 nm
D. 1.0 nm

2 marks

QUESTION 12
Which of the following statements (A-D) is true about the scattering of electrons and photons?

A. Compton scattering is an elastic collision between electrons.
B. Compton scattering is an elastic collision between electrons and photons.
C. Thomson scattering is an elastic collision between electrons.
D. Thomson scattering is an elastic collision between electrons and photons.

2 marks

QUESTION 13
Which of the following (A-D) causes the diffuse scattering of x-rays?

A. Increased brightness.
B. Increased frequency.
C. Increased wavelength.
D. Increased temperatures.

2 marks

End of Section on Synchrotron and its Applications

DETAILED STUDY 2 - PHOTONICS

QUESTION 1
Which one of the following statements is INCORRECT?

A. LEDs are semiconductor devices that produce coherent light in a process called electroluminescence, as electrons drop from the conduction band to the valence band.
B. Incandescent light sources emit incoherent light because of their temperature.
C. A LASER is a device that generates a beam of coherent light as excited atoms drop to a lower energy level.
D. In a gas discharge tube, atoms excited by collisions with electrons, may produce incoherent light of specific wavelengths.

2 marks

QUESTION 2
An LED is made with the material gallium phosphide (GaP). It has an energy gap of 2.24 eV when placed in forward bias in a circuit. The wavelength of the light it emits is likely to be:

A. 888 nm
B. 672 nm
C. 554 nm
D. 350 nm

2 marks

QUESTION 3
Changing the gallium phosphide LED (energy gap = 2.24 eV) to an indium phosphide LED (energy gap = 1.34 eV) is likely to:

A. Decrease the frequency of the emitted light.
B. Decrease the wavelength of the emitted light.
C. Emit light of the same wavelength but of lower intensity.
D. Have no effect on the frequency of emitted light.

2 marks

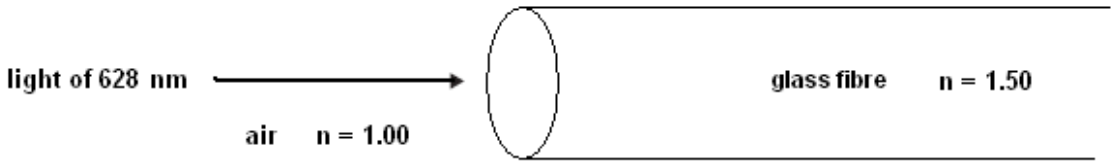
QUESTION 4
Pulses of light sent through a particular optical fibre are spread out over 40 nanoseconds as they travel the length of the fibre. What is the maximum frequency (bandwidth) that could be used to transmit this information?

A. 20 MHz
B. 25MHz
C. 40 MHz
D. 25 GHz

2 marks

The following information refers to Questions 5 and 6.

A one microsecond pulse from a LASER with a power rating of 1.0mW is directed into the end of a glass fibre of refractive index n = 1.50. The pulse consists of a single wavelength of 628nm. For the purpose of this exercise the beam will be considered to be a single line of photons.



QUESTION 5
What is the length of the one microsecond pulse of light as it passes through the glass fibre?

A. 200 m
B. 300 m
C. 2.0×10^5 m
D. 3.0×10^5 m

2 marks

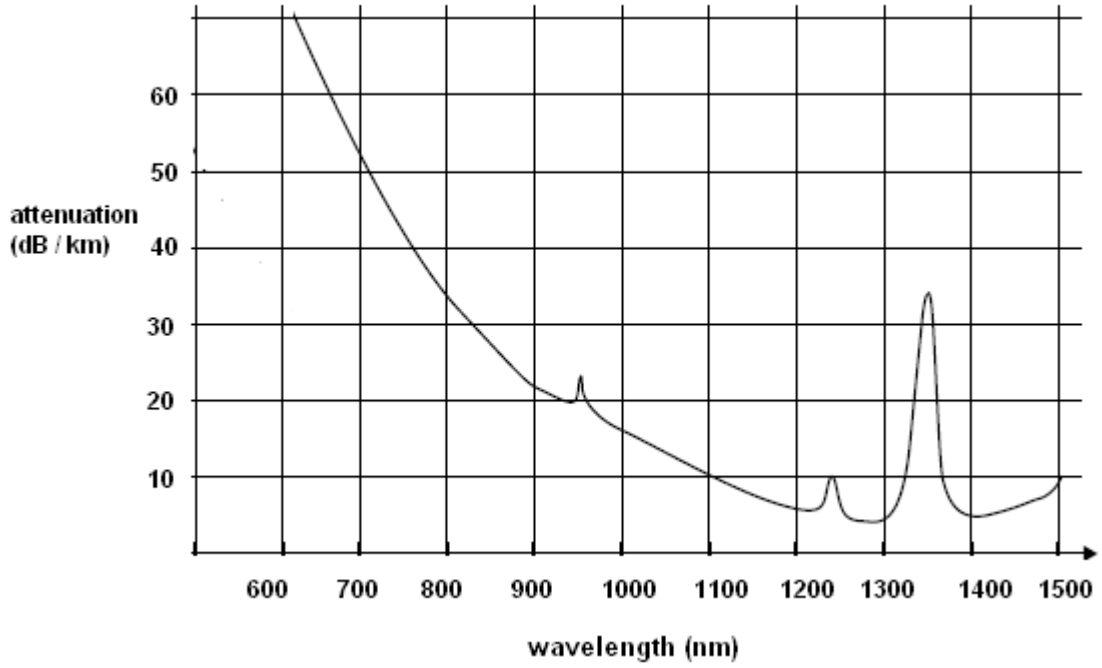
QUESTION 6
What is the average distance between adjacent photons

A. 3.1 nm
B. 42 nm
C. 65 nm
D. 97 nm

2 marks

The following information refers to Questions 7 and 8.

The transmission characteristics of a long distance single mode fibre optic cable are shown below:



QUESTION 7
Which of the following would clearly apply to the cable:

A. Increasing the wavelength from 660nm to 830nm approximately halves the total amount of signal loss.
B. Light of wavelength1400nm transmits more efficiently through the optical fibre than red light of wavelength 620nm.
C. Blue light is likely to transmit more efficiently than red light.
D. The peak at 1350nm suggests this would be a suitable wavelength for signal transmission through the particular cable.

2 marks

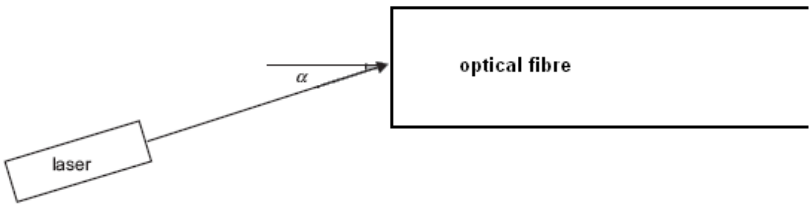
QUESTION 8
Which of the following would be the major cause of attenuation for a red laser which produces a 635nm wavelength.

A. Absorption by the material.
B. Rayleigh scattering.
C. Material dispersion.
D. Small imperfections in the glass fibre.

2 marks

The following information refers to Questions 9 and 10

The light-gathering ability of an optical fibre is an indication of the range of angles (α) at which light can enter the end of the core of an optical fibre and be propagated along the fibre.



The bigger the range of angles for light entering the fibre, the greater the light-gathering ability.

QUESTION 9
The light-gathering ability of an optical fibre can be improved by:

A. Decreasing the diameter of the fibre.
B. Increasing the difference in refractive indices between the core and cladding.
C. Immersing the light gathering end of the fibre in water.
D. Using a light source with a shorter wavelength.

2 marks

QUESTION 10
The optical fibre is a step index fibre with a glass core of refractive index 1.48 and a surrounding cladding of refractive index 1.46. The maximum value for angle α, that would enable light to be passed through the core is:

A. 12 degrees
B. 13 degrees
C. 14 degrees
D. 15 degrees

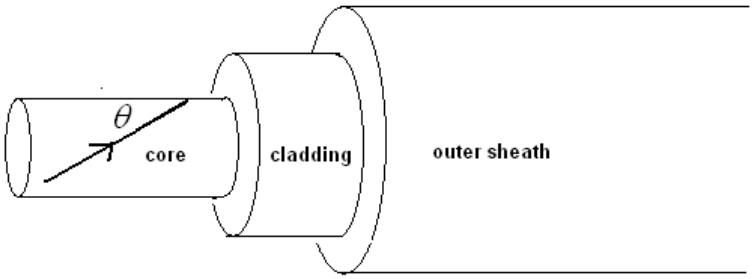
2 marks

QUESTION 11
Which of the following best describes material dispersion?

A. The spreading of pulses due to the different paths that light can follow through the medium.
B. The spreading of pulses due to different wavelengths making up the beam travelling at different speeds.
C. The spreading of pulses due to trace impurities in the medium making up the optical fibre.
D. The spreading of pulses due to variations in the intensity of the light transmitted.

2 marks

QUESTION 12
The following diagram represents a glass optical fibre.



n_{core} = 1.50
$n_{cladding}$ = 1.45

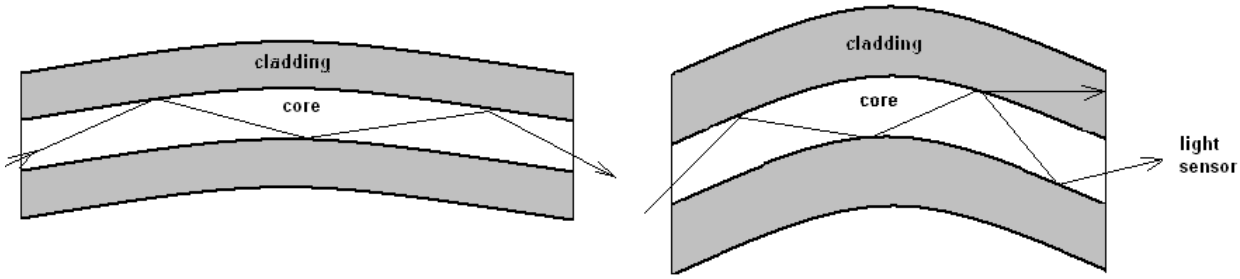
Determine the minimum value of θ that would enable pulses of light to remain within the core.

A. 15^o
B. 42^o
C. 48^o
D. 75^o

2 marks

QUESTION 13

Some types of fibre optic sensors rely on direct modification of the light signal which gives a measure of the amount of bending that occurs. As bending increases a greater proportion of the transmitted light escapes into the cladding.



Which of the following are true (one or more answers):

A. The optical properties of this sensor would be more effective if $n_{core} > n_{cladding}$
B. The optical properties of this sensor would be more effective if $n_{cladding} > n_{core}$
C. The intensity of the signal received at the light sensor will increase with the amount of bending.
D. As bending increases, the incident angle at that point increases resulting in more of the signal entering the cladding layer.

2 marks

End of Section on Photonics

DETAILED STUDY 3 - SOUND

Questions 1 and 2 refer to the following information.

A loudspeaker is turned on at time t = 0 s, and is driven back and forth such that its position as a function of time is shown in Figure 1.

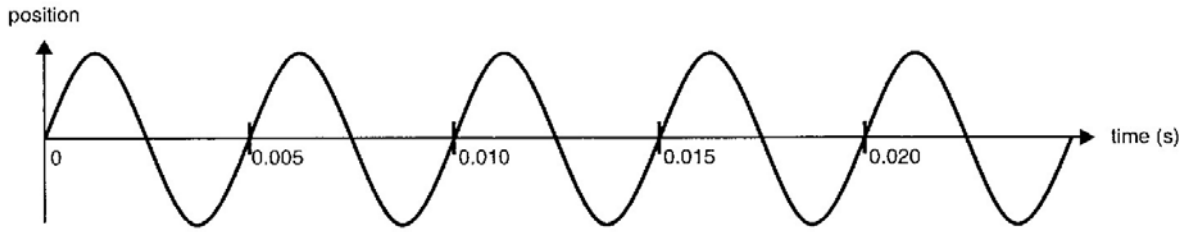


Figure 1

QUESTION 1
What is the wavelength of the sound transmitted through the air by the loud speaker if the speed of sound in air is 350 ms^{-1}

A. 0.005 m
B. 0.175 m
C. 1.75 m
D. 7.0×10^4 m

2 marks

QUESTION 2
Which of the following statements would be true if the same sound (of the same frequency) was produced under water?

A. Its speed of propagation would be greater and its wavelength shorter than in air.
B. Its speed of propagation would be greater and its wavelength longer than in air.
C. Its speed of propagation would be less and its wavelength longer than in air.
D. Its speed of propagation would be less and its wavelength shorter than in air.

2 marks

QUESTION 3
One electric fan operates at 12 dB. Which of the following is closest to the Sound Intensity Level when 8 such fans are operating together?

A. 21 dB
B. 24 dB
C. 48 dB
D. 96 dB

2 marks

Questions 4 & 5 refer to the following information.

QUESTION 4

Two people hear a loud buzz coming from a hair dryer. The sound intensity is measured as 2×10^{-6} W/m^2 for Mary, 20 cm from the hair dryer. John is 1.6 m away from the hair dryer. What would be the intensity of the sound where John is?

A. 1.28×10^{-4} W.m^{-2}
B. 1.60×10^{-5} W.m^{-2}
C. 2.50×10^{-7} W.m^{-2}
D. 3.13×10^{-8} W.m^{-2}

2 marks

QUESTION 5
What would the respective Sound Intensity Levels be for Mary and John?

A. 63 dB and 45 dB
B. 63 dB and 54 dB
C. 63 dB and 72 dB
D. 63 dB and 81 dB

2 marks

Questions 6 and 7 refer to the following information.

A tuba is playing a musical note of frequency 64 Hz while a trombone plays a note of 256 Hz. Both are playing with exactly the same volume and sound intensity.

Some distance away Peter stands behind a small building and finds that one instrument can be clearly heard while the other is not as audible.

QUESTION 6
Which of the following statements best describes these phenomena?

A. The trombone can be heard louder than the tuba due to the diffraction of the two sounds.
B. The trombone can be heard louder than the tuba due to the refraction of the two sounds.
C. The tuba can be heard louder than the trombone due to the diffraction of the two sounds.
D. The tuba can be heard louder than the trombone due to the refraction of the two sounds.

2 marks

QUESTION 7
Given that the instruments were played outside on a very, very cold night (5 ^{0}C), which of the following was the **most likely** wavelength of the sound from the tuba?

A. 5.22 m
B. 5.34 m
C. 5.47 m
D. 5.59 m

2 marks

Question 8 refers to the following graph (Figure 2) for the threshold of Ryan's hearing.

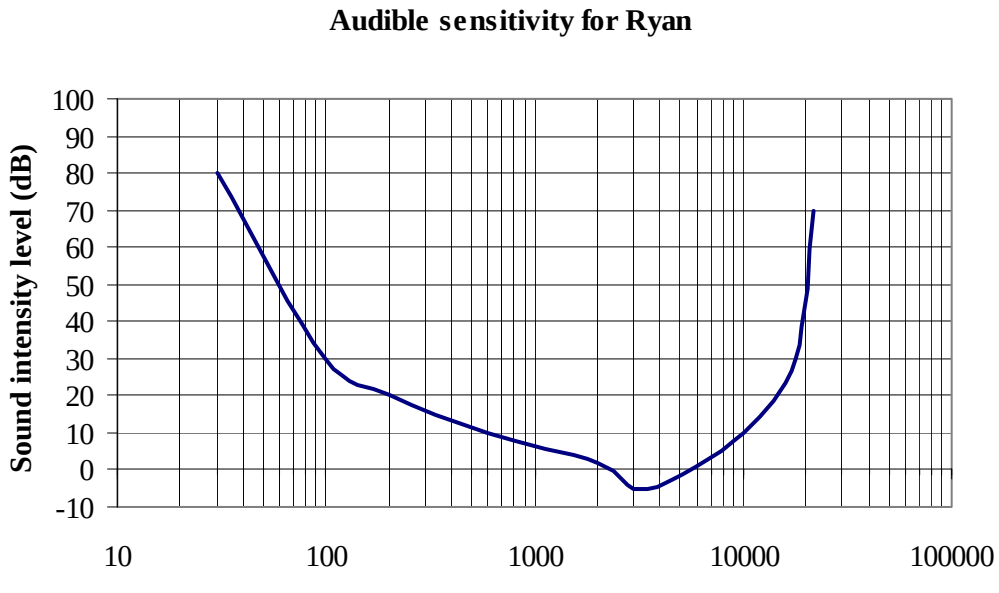


Figure 2

Figure 2 is a chart showing the threshold of hearing for a boy named Ryan, indicating the sound intensity level required as the frequency of the sound is varied.

QUESTION 8

The sound from an audio oscillator is set at a sound intensity level of 30 dB and the frequency is decreased from an initial 20,000 Hz until Ryan first begins to hear the sound at a frequency of approximately 18,000 Hz. The frequency is further decreased. At what frequency will Ryan again not be able to hear the sound?

A. 30 Hz
B. 100 Hz
C. 200 Hz
D. 600 Hz

2 marks

QUESTION 9
Which type of microphone is most likely to require a source of voltage and responds via variations in capacitance?

A. Condenser
B. Crystal
C. Dynamic
D. Ribbon

2 marks

Questions 10 and 11 refer to the following information.

Caleb finds he can play a musical note by blowing in a vacuum cleaner pipe, which can be modelled as a simple open pipe with one part able to slide over the other to alter the total length of the pipe. (see Figure 3)

His musical knowledge enables him to recognise a fundamental frequency of 256 Hz when the tube is 0.64 m long

Figure 3

QUESTION 10
How long should the tubing be to attain a fundamental frequency of 64 Hz?

A. 0.08 m
B. 0.16 m
C. 1.28 m
D. 2.56 m

2 marks

QUESTION 11
What was the speed of sound for the tube?

A. 328 ms^{-1}
B. 332 ms^{-1}
C. 336 ms^{-1}
D. 340 ms^{-1}

2 marks

QUESTION 12
Which of the following is the best description of why the tube has a fundamental frequency of 256 Hz?

A. At this speed of sound (Question 11) an open tube of length 0.64 metre will have established in it a wavelength equal to the length of the tube which results in a sound of 256 Hz.
B. At this speed of sound (Question 11) an open tube of length 0.64 metre will have established in it a wavelength equal to the half the length of the tube which results in a sound of 256 Hz.
C. It has been tuned to play the musical note “middle C”.
D. At any particular length of open tube only certain sound wavelengths can exist due to the presence of pressure nodes at the end of the tube and resonance gives rise to only some of these wavelengths being maintained.

2 marks

Figure 4 shows the response of a typical dynamic microphone to a range of input frequencies.

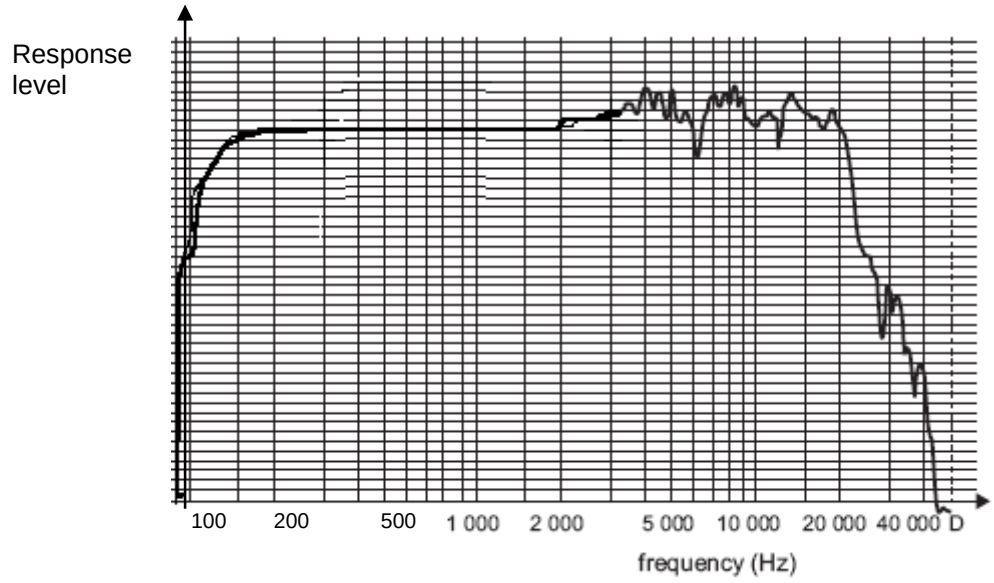


Figure 4

QUESTION 13
Many newsreaders, announcers and speakers prefer dynamic microphones over other types because they:

A. provide a consistent, faithful reproduction across all frequencies.
B. provide an increased response to higher resonant frequencies which “sharpens” letters such as “s”, “t”, “c”.
C. amplify the lower frequencies more than the higher frequencies; adding tone to the speech.
D. rapidly decrease in response beyond the range of audible frequencies meaning no “squeaks or squawks” are heard.

2 marks

End of Section on Sound