THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 4 PHYSICS 2010

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	19	19	36	36
	Interactions of Light and Matter	12	12	28	28
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

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SECTION A – CORE STUDIES

Instructions For Section A

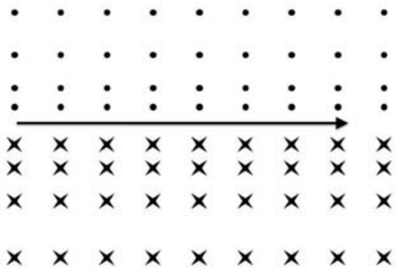
Answer **all** questions for **both** Areas of Study in this section of the paper.

AREA OF STUDY 1 – ELECTRIC POWER

QUESTION 1

Which of the following best represents the magnetic field above and below a current carrying wire, with the current travelling from left to right?

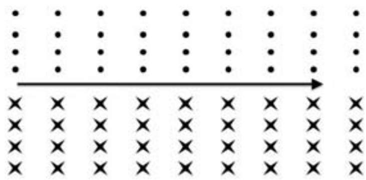
A.



B.

C.

D.



2 marks

QUESTION 2
A coil of wire is shown in Figure 1. A current is passed through the coil from left to right in a clockwise direction. In the boxes provided place N (North) and S (South) to indicate the magnetic pole at each end of the coil.

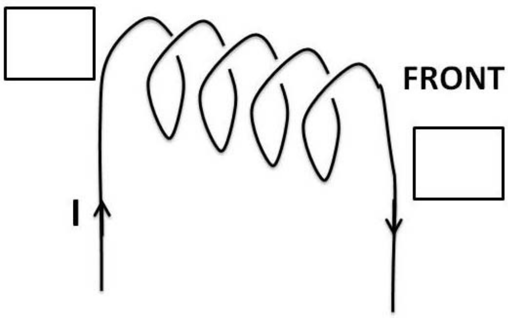


Figure 1

1 mark

The following information refers to Questions 3 to 5.

A current carrying wire is placed between two opposing magnetic poles as shown in Figure 2. The current in the wire is 0.5 A and the magnetic field strength is 0.1 T. The width of the magnets is 10 cm and the height is 5 cm.

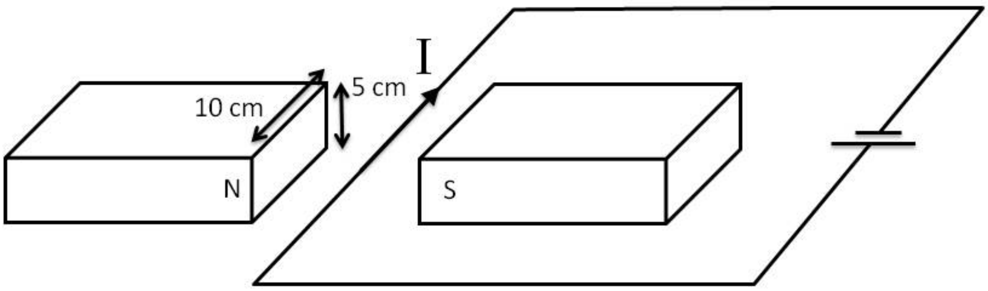


Figure 2

QUESTION 3
In which direction will the wire move?

1 mark

QUESTION 4
Calculate the strength of the force experienced by the wire.

N

2 marks

The wire is now rotated 90°, so that the current is travelling upwards. Describe the effects this will have on the force acting on the wire.

____

____

____

____

____

2 marks

The following information refers to Questions 6 to 10.

Jane and Paul construct a simple DC motor in their laboratory by making a square copper coil with length 3 cm and 100 turns. The coil is placed between two magnets providing a magnetic field strength of 0.4 T. A direct current of 0.5 A is placed through the wire as shown in Figure 3.

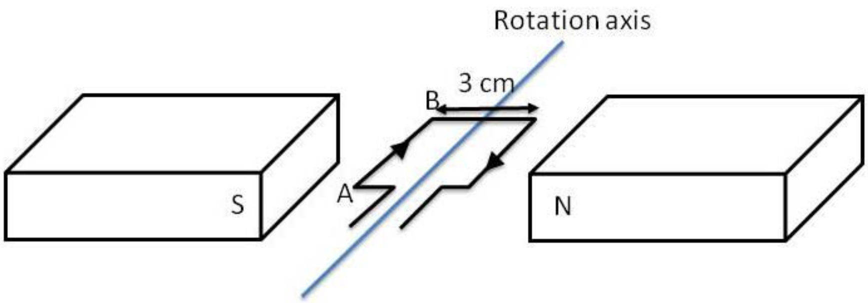


Figure 3

QUESTION 6
What is the direction for the rotation of the coil in Figure 3 when viewed from the front? (Circle the correct response.)

CLOCKWISE ***ANTICLOCKWISE***

1 mark

QUESTION 7
Determine the magnetic flux through the loop in the position shown.

1 mark

Wb

QUESTION 8

Determine the **maximum** magnetic flux through the coil.

Wb

2 marks

QUESTION 9

Determine the magnitude of the force acting on the coil length **AB**.

N

2 marks

Jane and Paul now attach a load to their motor. They find that the load is too heavy and the coil stops after rotating only 90^o.

QUESTION 10

Suggest *one* improvement they can make to their motor and *how* this improvement will ensure the coil keeps turning.

2 marks

The following information refers to Questions 11 and 12.

A closed wire loop is pulled through a uniform magnetic field as shown in Figure 4.

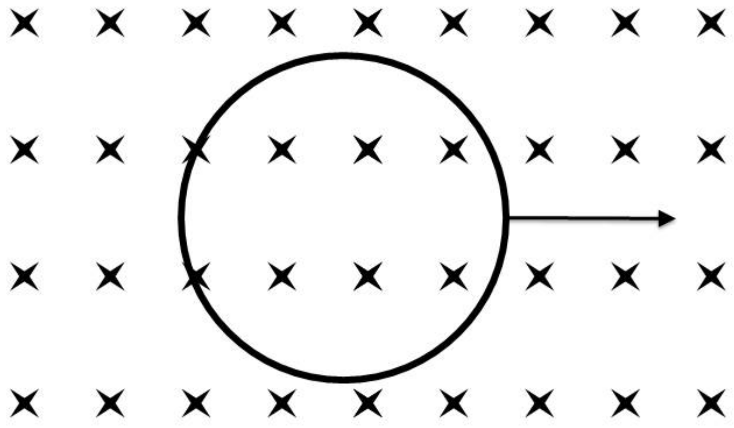


Figure 4

QUESTION 11
Which of the following best describes the direction of the current induced in the loop?

A. Clockwise
B. Anticlockwise
C. None
D. Not enough information to determine the direction

2 marks

QUESTION 12
Which one or more of the following will produce an **anticlockwise** current through the loop?

A. Reverse the direction of the magnetic field.

B. Rotate to the right.

C. Increase the magnetic field.

D. Stretch loop by pulling out sides.

2 marks

The following information refers to Questions 13 to 16.

A model AC generator is used to power a 1.5 V torch light. The generator consists of a 150 turn copper coil inside a uniform magnetic field of 0.2 T. The coil is rotated in a clockwise manner as shown in Figure 5.

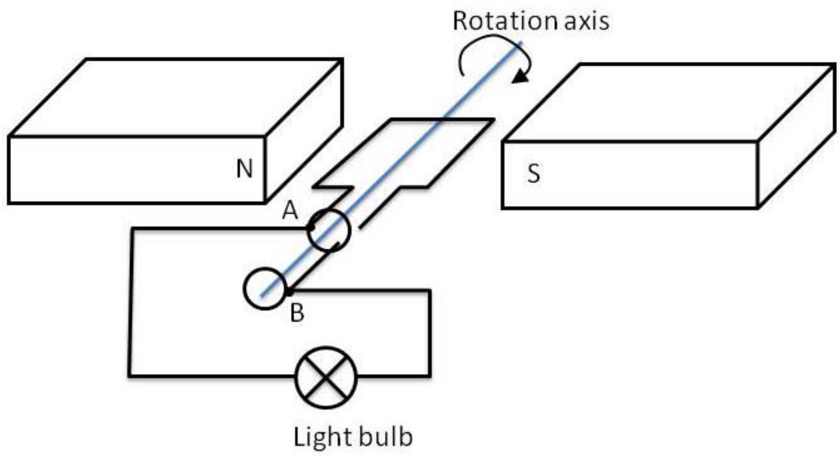


Figure 5

QUESTION 13
The *purpose* of the AC generator is to:

A. Use alternating current rather than direct current.
B. Use slip ring rather than split ring commutators.
C. Convert electrical energy to mechanical energy.
D. Convert mechanical energy to electrical energy.

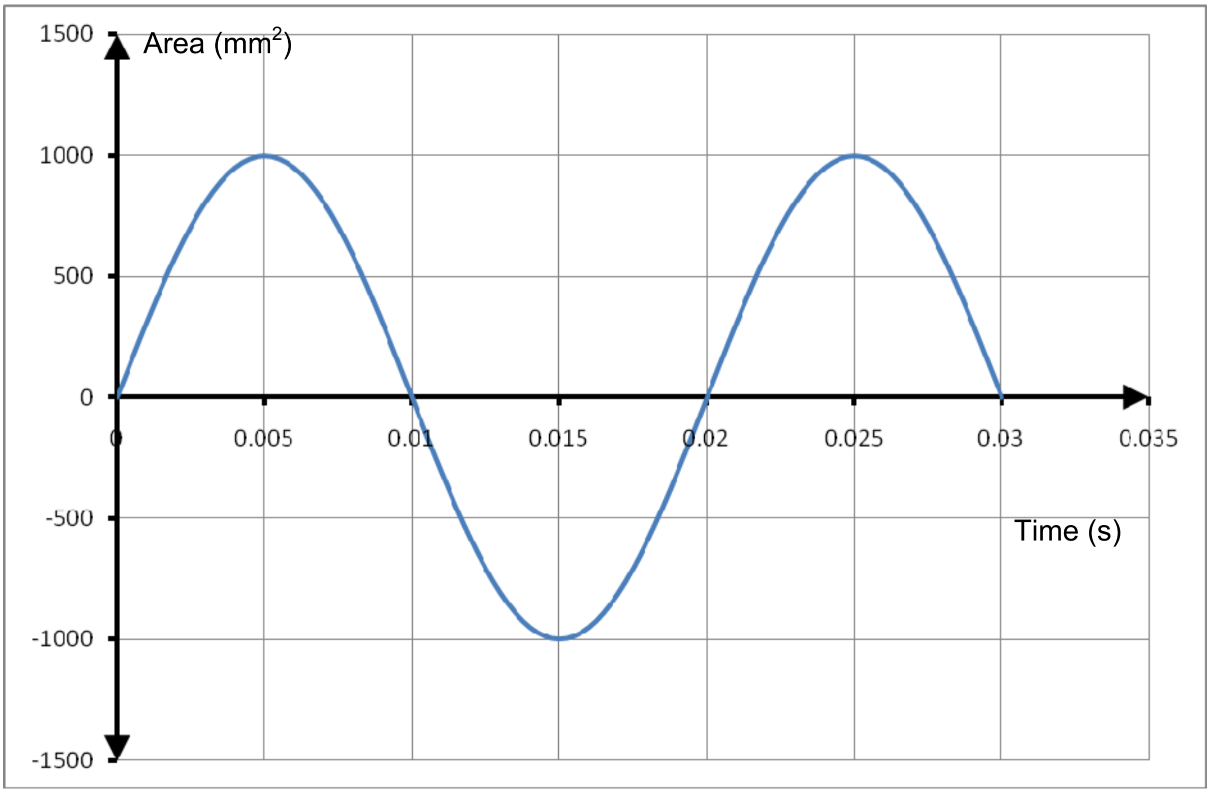
2 marks

QUESTION 14
What is the direction of the current through the loop when viewed from above AND which is the negative terminal (**A** or **B**) of the generator?
(Circle the correct response.)

Direction of current		Negative terminal	
CLOCKWISE	**ANTICLOCKWISE**	**A**	**B**

2 marks

The following graph represents the Area vs Time for the coil in Figure 5.

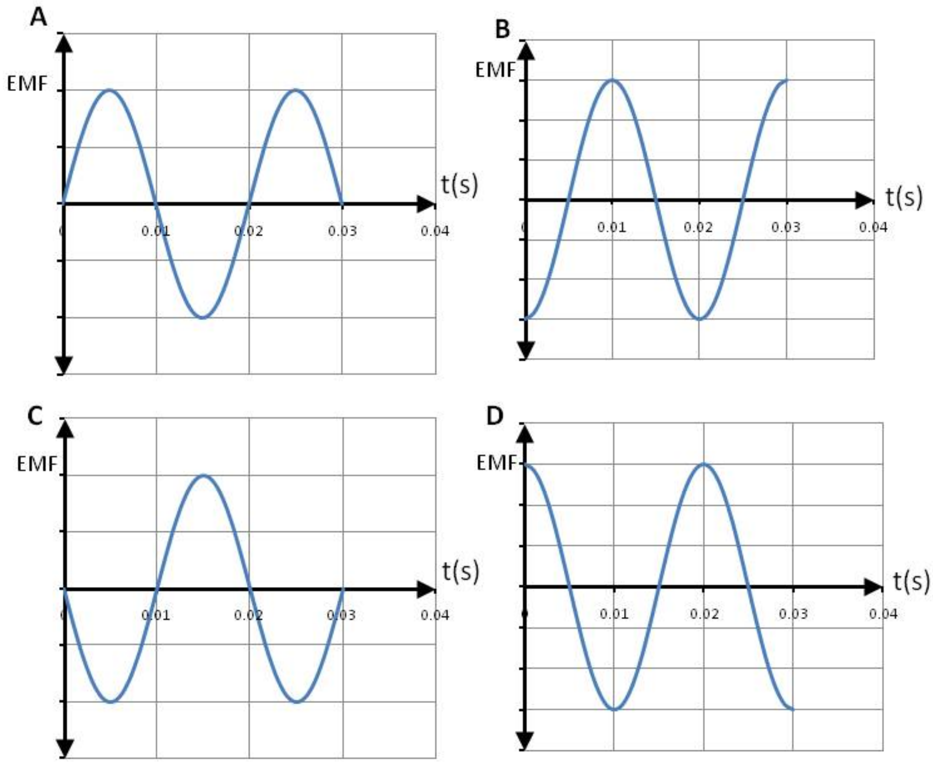


QUESTION 15
Determine the **average** EMF generated by the coil.

V

3 marks

QUESTION 16
Which of the following best describes the EMF vs Time graph for the coil in Figure 5?



2 marks

The following information refers to Questions 17 to 19.

A hotel wishes to install bud lights in its surrounding trees. Under normal operation, the lights require 24 V_{RMS} and the hotel's supply voltage is 240 V_{RMS}. The lights have their own transformer which has a primary coil of 1000 turns. (Assume the transformer is ideal.)

QUESTION 17
Calculate the number of coils in the secondary coil.

turns

1 mark

QUESTION 18
The power required for the lights to operate normally is 18 W. Under these conditions, calculate the RMS current drawn from the hotel power outlet.

A

2 marks

The hotel electrician installing the lights found that one tree was too far away and required an extension lead measuring 100 m. The extension lead has a total resistance of 0.4 Ω.

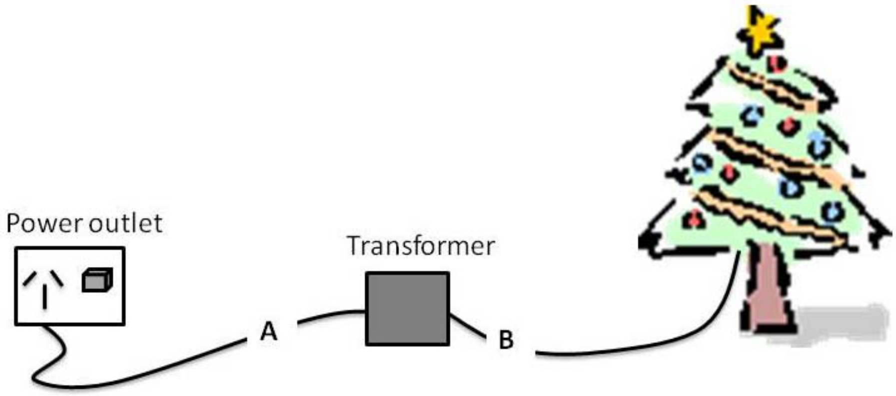


Figure 6

QUESTION 19
Would it be more energy efficient to use an extension lead between the power outlet and the transformer (**A**) *or* between the transformer and the lights (**B**) as shown in Figure 6? Support your answer.

A	**B**

4 marks

End of Section on Electric Power

AREA OF STUDY 2 – INTERACTIONS OF LIGHT AND MATTER

The following information refers to Questions 1 to 4.

In a reproduction of the photoelectric effect experiment, the graphs in Figure 1 were drawn showing the relationship between photoelectric current and potential difference between the cathode and anode in the apparatus when the incident light was blue light and independently; ultraviolet light.

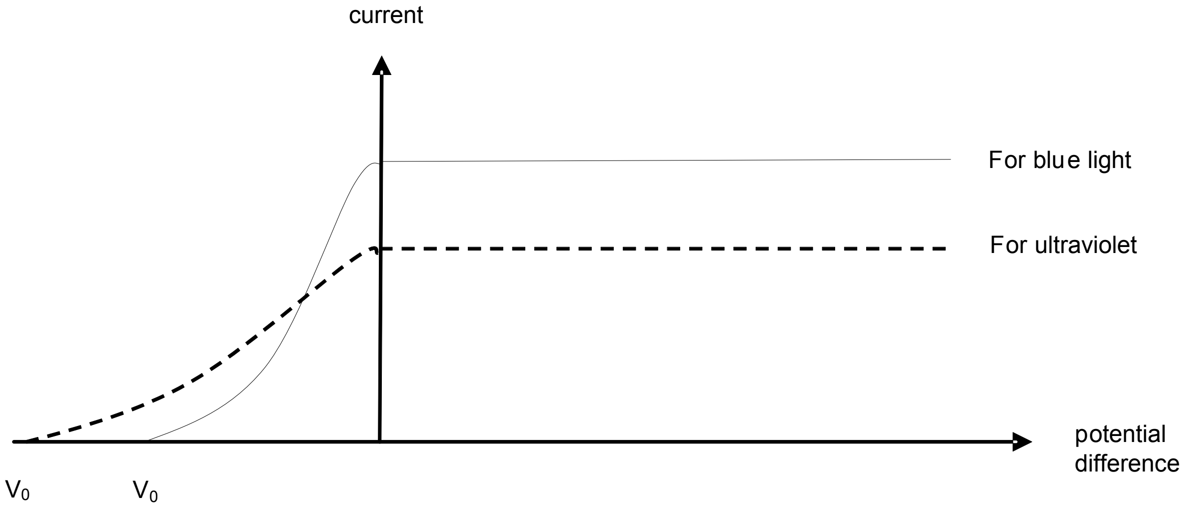


Figure 1

QUESTION 1
Which of the lights results in the use of a stopping voltage of greater magnitude? (Circle one)

BLUE **ULTRAVIOLET** **UNABLE TO DETERMINE**

1 mark

QUESTION 2
Which of the lights had the greater frequency? (Circle one)

BLUE **ULTRAVIOLET** **UNABLE TO DETERMINE**

1 mark

QUESTION 3
Which of the lights had the greater intensity? (Circle one)

BLUE **ULTRAVIOLET** **UNABLE TO DETERMINE**

1 mark

QUESTION 4
Which of the following statements correctly relates the maximum kinetic energy of the photoelectrons to the nature of the light?

A. The blue light results in photoelectrons of greater kinetic energy due to the greater intensity of the blue light when compared with the ultraviolet light.

B. The blue light results in photoelectrons of greater kinetic energy due to the greater frequency of the blue light when compared with the ultraviolet light.

C. The ultraviolet light results in photoelectrons of greater kinetic energy due to the greater intensity of the ultraviolet light when compared with the blue light.

D. The ultraviolet light results in photoelectrons of greater kinetic energy due to the greater frequency of the ultraviolet light when compared with the blue light.

2 marks

The following information refers to Questions 5 to 8.

The energy levels for atomic mercury are depicted in Figure 2 below.

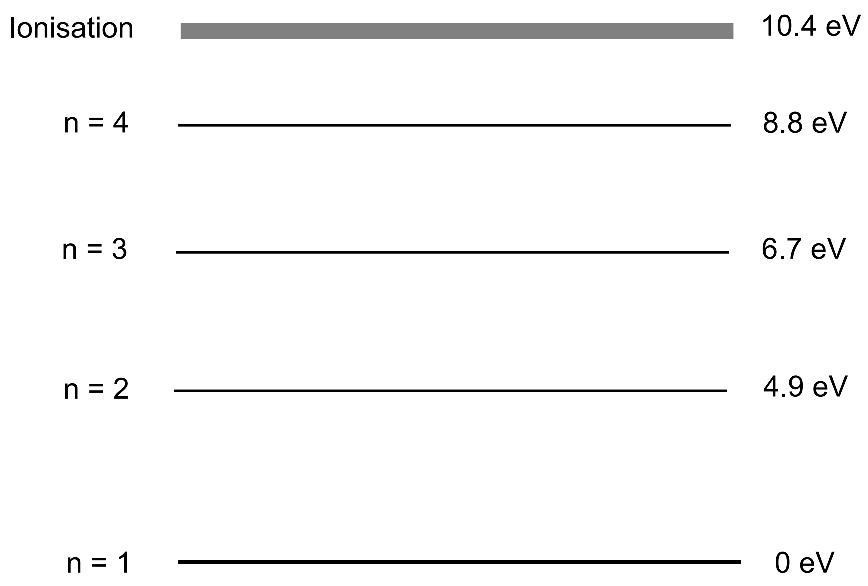


Figure 2

QUESTION 5
If a mercury atom returns to its ground state from the n = 4 state, photons of a range of wavelengths may be emitted. How many different wavelengths may result?

A. 3
B. 4
C. 5
D. 6

2 marks

QUESTION 6
What is the lowest frequency of light that can be emitted when a mercury atom drops from the n = 3 energy level?

Hz

3 marks

QUESTION 7
What will be the maximum speed of an emitted electron if an “ultraviolet photon” of wavelength 100 nm is incident on an atom of mercury in its ground state?

m/s

4 marks

QUESTION 8
How does the presence of quantized energy states in an atom (as depicted for mercury) support the wave model for electrons?

____

____

____

____

____

3 marks

The following information refers to Questions 9 and 10.

In reproducing Young's famous experiment, Tom directs a DPSS green (λ = 532 nm) laser at a pair of thin slits, producing a pattern of bands on a screen, as depicted in Figure 3.

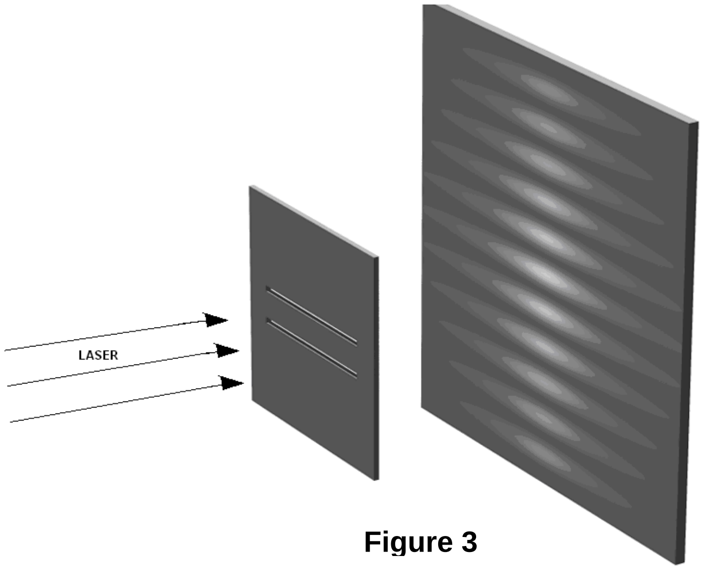


Figure 3

QUESTION 9

Which of the following would result in the bands on the screen becoming closer together when compared to Tom's original situation?

A. The screen is moved further away from the slits.
B. The green laser is replaced with a red one.
C. A new pair of slits is used in which the slits are closer to each other.
D. A new pair of slits is used in which the slits are further apart.
E. The green laser is replaced by a blue laser.
F. The screen is moved towards the slits.

3 marks

QUESTION 10

Circle the correct option (from each pair of **bold** options) to complete the following explanation of the presence of a **bright** band.

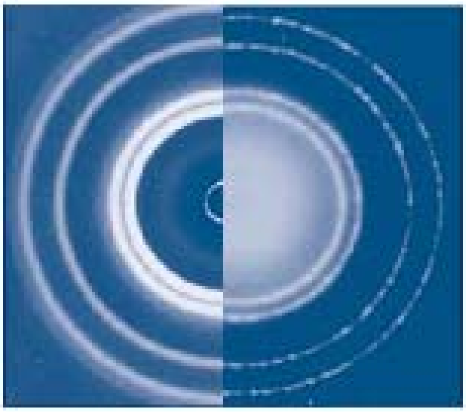
*The principle of **diffraction/superposition** describes how the two waves will combine together. In the case of the bright bands, this resulted in **constructive/destructive** interference due to the light from each slit differing in the distance travelled to the screen by an integer multiple of the wavelength of the **coherent/monochromatic** light used. This phenomenon supports the **wave/particle** model for light.*

4 marks

The following information refers to Questions 11 and 12.

To provide support for matter waves, Thomson fired a beam of electrons through a very thin metal foil onto a photographic plate. The pattern formed by the transmitted electrons was very similar to the diffraction pattern obtained when the exercise was repeated with a beam of X-rays.

The left hand side of the diagram is a diffraction pattern using 10 keV X-rays. On the right is the diffraction pattern obtained using electrons.



QUESTION 11
What would be the wavelength of the 10 keV X-rays?

m

2 marks

QUESTION 12
Which property is similar for these X-rays and these electrons given the similarity in the diffraction patterns?

A. Mass
B. Energy
C. Speed
D. Wavelength

2 marks

End of Section on Interactions of Light and Matter

SECTION B – DETAILED STUDIES

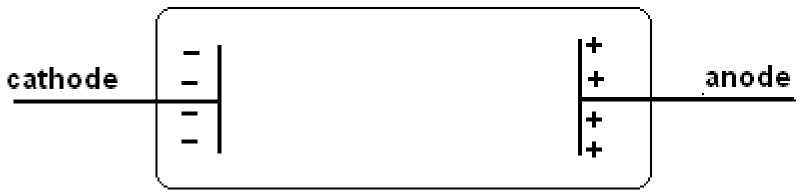
Instructions For Section B

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

DETAILED STUDY 1 – SYNCHROTRON AND ITS APPLICATIONS

Mass of electron is 9.11×10^{-31}kg
$c = 3.0 \times 10^{8}$ ms^{-1}
$e = 1.6 \times 10^{-19}$ C

QUESTION 1
In the following device, electrons accelerate across an evacuated chamber from the cathode to the anode as a result of an applied potential difference.



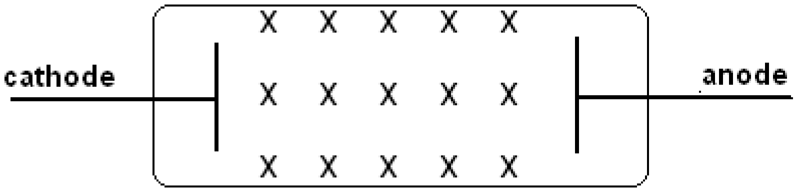
The direction of the electric field between the charged plates is:

A. Vertically down the page
B. Vertically up the page
C. To the left of the page
D. To the right of the page

QUESTION 2
A potential difference between the cathode and the anode of a cathode ray tube accelerates electrons to a speed of 6.0×10^{7}ms^{-1}. The potential difference is closest to:

A. 0.01 V
B. 1.0 V
C. 1000 V
D. 10 kV

QUESTION 3
A magnetic field is now applied to the chamber as shown in the diagram below. Which one of the following best describes the direction of the force applied by the magnetic field on the electrons as they travel across the chamber?



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

QUESTION 4
Which one of the following sequences best gives the order in which electrons pass through the synchrotron?

A.	Electron gun	Booster ring	Storage ring	Beamline
B.	Electron gun	Linac	Booster ring	Storage ring
C.	Booster ring	Linac	Electron gun	Storage ring
D.	Beamline	Linac	Booster ring	Storage ring

QUESTION 5
Which of the following best describes how synchrotron radiation is produced?

A. The acceleration of the electron's path due to the magnetic field produces a changing electric field, which in turn produces a changing magnetic field.

B. The electrons in the synchrotron path are in high frequency bursts which generates high frequency synchrotron light.

C. Electric fields within the linear accelerator cause electrons to accelerate and emit synchrotron radiation.

D. Oscillating electric fields cause an electron's path to change, producing a changing electric field, which in turn produces a changing magnetic field.

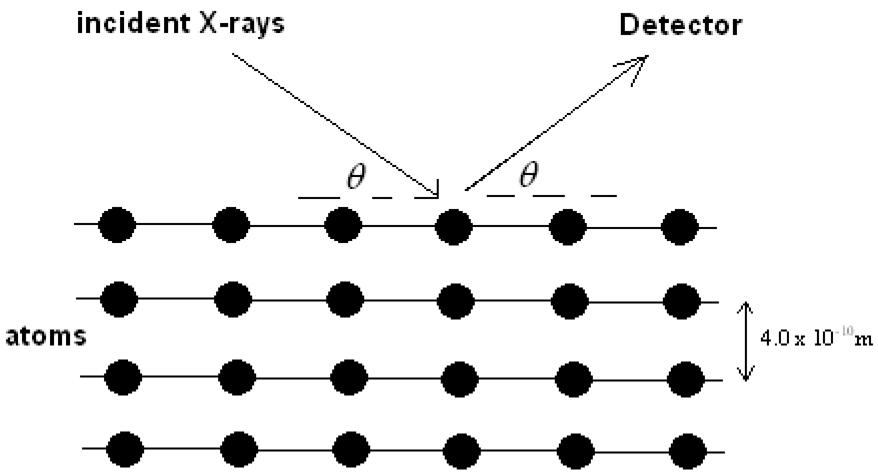
QUESTION 6
In a section of the synchrotron, electrons travelling at $2.9 \times 10^{8}\ ms^{-1}$ are maintained in a circular path by a perpendicular magnetic field of 100 mT.

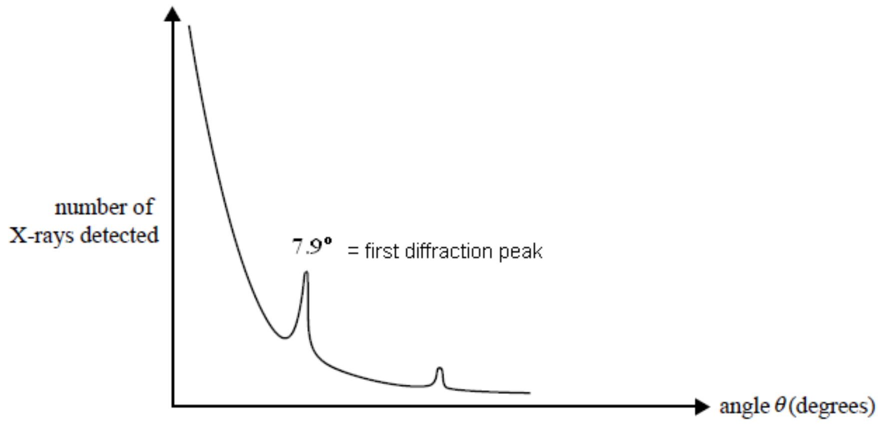
Which one of the following best gives the net force experienced by an electron?

A. 2.9×10^{-13}N
B. 4.6×10^{-12}N
C. 4.6×10^{-9}N
D. 2.9×10^{-9}N

The following information refers to Questions 7 to 9.

The crystal lattice shown below is rotated to enable the angle θ of incident X-rays to vary from zero to 90°. A number of diffraction peaks are received at a detector. The first Bragg diffraction peak is observed at 7.9°. The wavelength of the coherent X-rays is 0.11 nm and the atomic spacing is 4.0×10^{-10} nm.





QUESTION 7
Which one of the following values gives the best estimate of the energy of the X-rays?

A. 8.7 keV
B. 11.3 keV
C. 12.6 keV
D. 120 keV

QUESTION 8
Which of the following is the best estimate of the second diffraction peak?

A. 16.5°
B. 16.0°
C. 15.8°
D. 15.5°

QUESTION 9
The total number of diffraction peaks is:

A. 3
B. 5
C. 7
D. 9

QUESTION 10
In Thomson scattering the photons being scattered have:

A. An identical amount of energy as the incident photons.
B. Less energy than the incident photons.
C. More energy than the incident photons.
D. Zero energy.

QUESTION 11
The monochromator is a very important feature of the synchrotron beamline. Its function is to select specific wavelengths from the synchrotron light. Which one of the following statements is true of monochromators?

A. It increases the intensity of the synchrotron light.
B. It involves the process of Compton scattering.
C. Scattered photons constructively interfere with incident photons.
D. Focuses the light beam.

QUESTION 12
Incident X-rays are scattered from a sample of material by inelastic (Compton) scattering. Which one of the following statements best describes the scattered X-rays?

A. The scattered X-rays have the same momentum as the incident X-rays.
B. The scattered X-rays have a shorter wavelength than the incident X-rays.
C. The scattered X-rays have the same wavelength as the incident X-rays.
D. The scattered X-rays have a longer wavelength than the incident X-rays.

QUESTION 13
Multipole wigglers and undulators are included in synchrotron design in order to enhance certain characteristics. Which of the following statements best explains the difference in synchrotron radiation produced by these devices?

A. The undulator produces radiation that is more highly polarised and less coherent than multipole wiggler radiation.

B. The undulator produces radiation that is more intense for specific wavelengths, whereas the multipole wiggler produces a broader spectrum of radiation that is less intense.

C. Radiation from the multipole wiggler is brighter but less coherent than the undulator.

D. The undulator produces a continuous spectrum of radiation that has a much greater intensity than the multipole wiggler.

End of Section on Synchrotron and its Applications

DETAILED STUDY 2 – PHOTONICS

QUESTION 1
Which one of the following statements best explains how an LED produces light?

A. Stimulated emission of photons.
B. Spontaneous emission of photons.
C. Spontaneous absorption of photons.
D. Thermal emission of photons.

QUESTION 2
The energy gap for an LED is 2.46 eV. The average wavelength of the emitted light is:

A. 490 nm
B. 505 nm
C. 550 nm
D. 590 nm

QUESTION 3
Which of the following combinations would be best for long distance telecommunications?

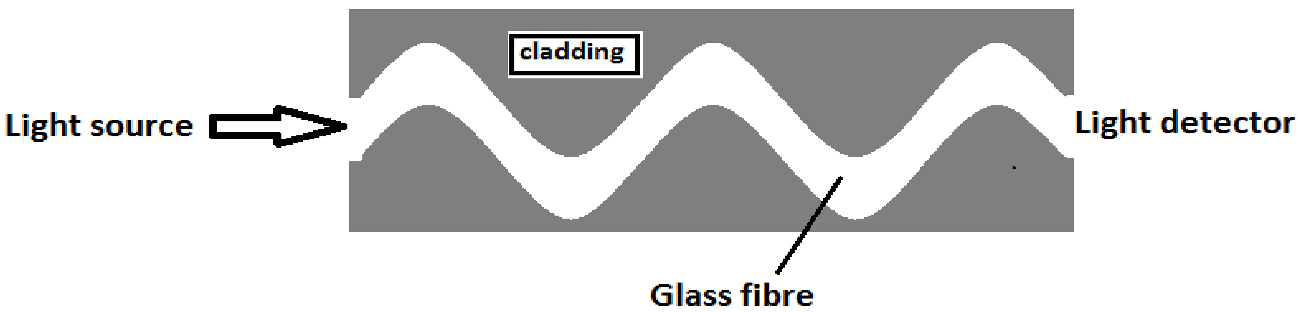
A. Multimode fibre using a laser diode light source.
B. Multimode fibre using a light emitting diode.
C. Single mode using a laser diode light source.
D. Single mode using a light emitting diode.

The following information refers to Questions 4 to 8.

A stepped index optical fibre embedded into the wing of an aeroplane is designed to provide information on the amount the wing flexes under particular flying conditions. The optical fibre is formed in a wave pattern and encased in a cladding material with a lower refractive index than the actual glass core. As the wing bends during manoeuvres the amount of light received by the light detector varies according to the following relationship:

$$\text{Light level at end of fibre} \propto \frac{1}{\text{Amount of bend in wing}}$$

The core has a refractive index of n = 1.46, and the cladding n = 1.41



QUESTION 4
Which one of the following best gives the critical angle for total internal reflection in the core of the fibre?

A. 18^o
B. 67^o
C. 75^o
D. 78^o

QUESTION 5
The ability of an optical fibre to transmit information using light is based on:

A. Total internal reflection
B. Attenuation
C. Diffraction
D. Interference

QUESTION 6
Which of the following statements most accurately describes the conditions necessary for the extent of bending of the wing to be measured?

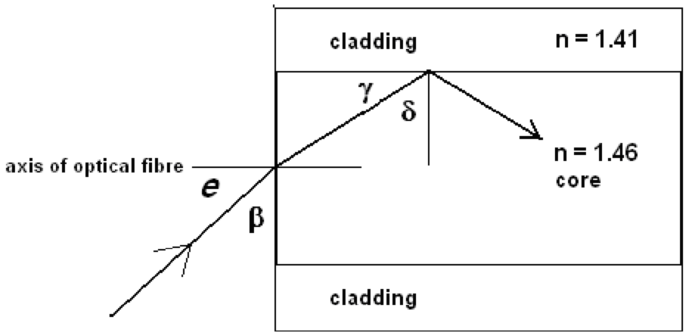
A. As the wing bends some light strikes the cladding interface at an angle greater than critical angle.

B. It is important that the incident angle of the light striking the cladding interface is always greater than the critical angle.

C. It is important that the incident angle of the light striking the cladding interface is always less than the critical angle.

D. Only light striking the interface at the critical angle is able to pass through the fibre.

The entry of light into the fibre is illustrated by the diagram below:



QUESTION 7
Which angle represents the acceptance angle?

A. ***e***
B. β
C. γ
D. δ

QUESTION 8
What is the numerical aperture for this optical fibre?

A. 0.030
B. 0.30
C. 0.32
D. 0.38

The following information refers to Questions 9 and 10.

The graph below represents the total attenuation with wavelength for a particular optical fibre.

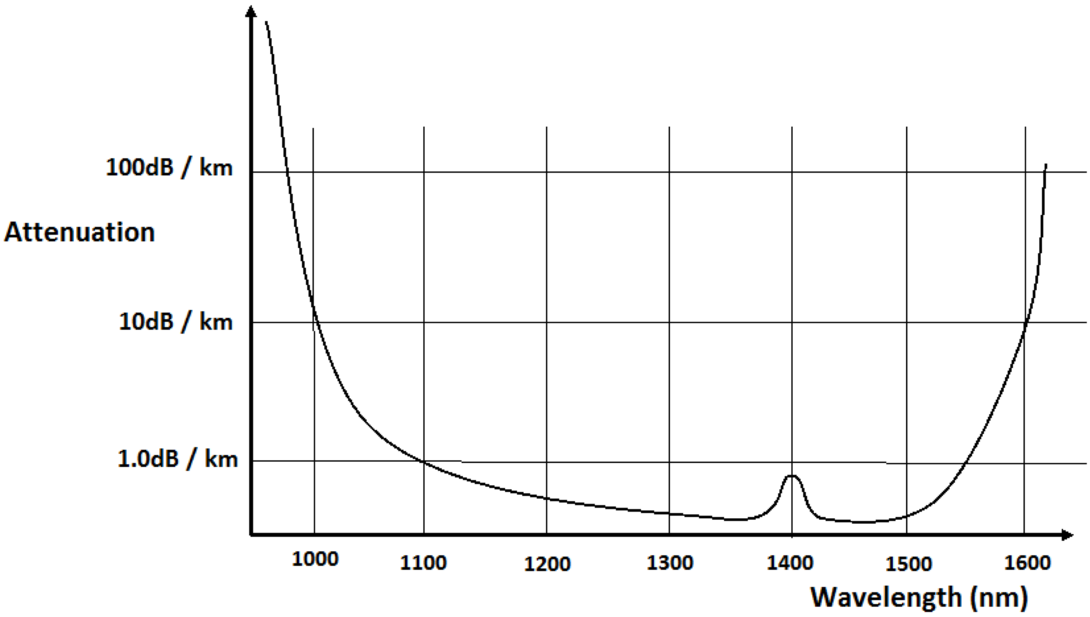


Figure 3

QUESTION 9

Which one of the following best represents the attenuation of a 1550 nm signal over a 20 kilometre optical fibre?

A. 0.5 dB
B. 1.0 dB
C. 5.0 dB
D. 20 dB

QUESTION 10

The steep increase in attenuation around 1600 nm best demonstrates:

A. Raleigh scattering.
B. Absorption by hydroxide ion impurities.
C. The infrared absorption edge.
D. The ultraviolet absorption edge.

QUESTION 11
Which one of the following statements gives the best benefit for optical fibres over copper wires in telecommunications?

A. Easy to join the fibres because they don't need soldering.

B. Signals are not affected by electromagnetic fields.

C. The glass has almost no electrical resistance allowing signals to be transmitted efficiently.

D. The high bandwidth of optical fibres enables transmission of much larger quantities of data.

QUESTION 12
Two beams of light of identical wavelength are sent down a fibre simultaneously, but are received at the other end slightly out of phase. This type of signal dispersion is most likely:

A. Rayleigh
B. Modal
C. Material
D. Fresnel

QUESTION 13
An optical fibre bundle is used by the Environmental Protection Agency (EPA) in order to investigate the condition of the inside of drain pipes. The bundle consists of imaging fibres which are used to transmit the vision from the pipe to the operator, as well as fibres used to send light to the drain pipe so it is well illuminated.

Which one of the following is the best account for a feature of the optical bundle?

A. The light source should emit coherent light.

B. Important that all fibres be arranged so that they are in the same relative position at each end of the bundle.

C. Only important that the imaging fibres are in the same relative position at each end of the bundle.

D. The imaging bundle needs a minimum of two fibres for a reasonable image.

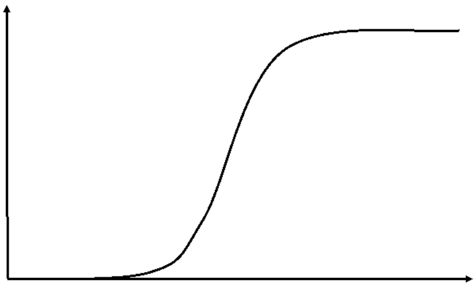
End of Section on Photonics

DETAILED STUDY 3 – SOUND

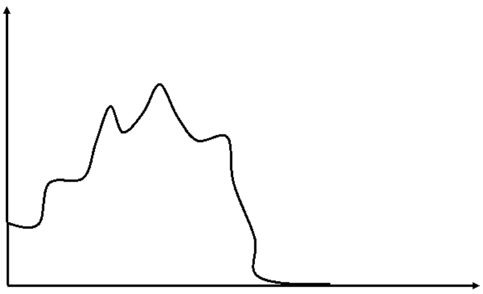
QUESTION 1
Ahmat is dismantling a microphone and finds a small metal ribbon inside. Which of the following names best suits this type of microphone?

A. Dynamic
B. Crystal
C. Electret-Condenser
D. Velocity

QUESTION 2
Helen wishes to buy a new high fidelity **bass** speaker for her Hi-Fi system. Below are four **frequency response curves** for frequencies across the audible range for the speakers she looked at. In each case the vertical axis represents **Sound Intensity Level** and the horizontal axis represents **frequency**. Which speaker best suits her needs?



A.



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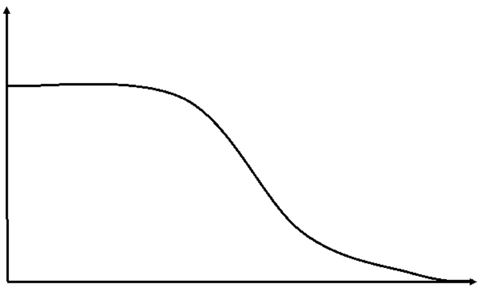

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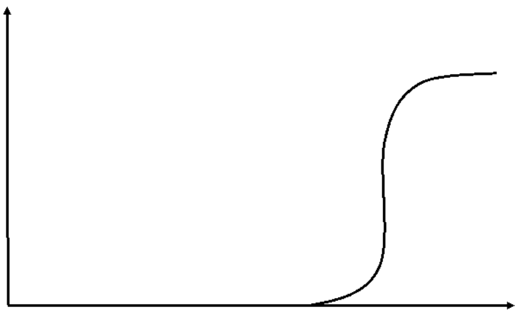


D.

QUESTION 3
Sound waves are best described as…..

A. Transverse pressure waves
B. Transverse displacement waves
C. Longitudinal pressure waves
D. Torsion displacement waves

The following frequency response curve resulted from a wide range of frequencies being supplied to a speaker box.

QUESTION 4
Which of the following is **not** a reason for the three thin peaks?

A. The dimensions of the box.
B. Diffraction within the box.
C. Resonances within the box.
D. Fundamental frequencies.

The following information refers to Questions 5 to 7.

One stationary F1 racing car is creating a sound of intensity level 140 dB as measured by a Physics student standing 15 metres away from the car.

QUESTION 5
What is the sound intensity of this car at this time?

A. 1.0×10^{2} W m^{-2}
B. 1.2×10^{2} W m^{-2}
C. 1.4×10^{2} W m^{-2}
D. 1.6×10^{2} W m^{-2}

An adjacent identical car is then started and operates at the same level.

QUESTION 6
What is the combined sound intensity level of the two cars?

A. 143 dB
B. 146 dB
C. 150 dB
D. 280 dB

The second car is turned off but the first car continues as before. The student now moves to a new position 30 metres away from the car.

QUESTION 7
What will be the **change** in the Sound Intensity Level at this new position (30 m away) as compared to the initial position (15 m away)?

A. -2 dB
B. -3 dB
C. -4 dB
D. -6 dB

The following information refers to Questions 8 to 10.

A particular Spanish guitar has a string of length 90 cm and has a fundamental frequency of 270 Hz. It is played on a particularly hot Spanish day with the temperature at 37ºC.

QUESTION 8
Which of the following speeds best represents the speed of the wave passing through the string?

A. 150 ms^{-1}
B. 243 ms^{-1}
C. 300 ms^{-1}
D. 486 ms^{-1}

QUESTION 9
What is the best approximation of the speed of the sound through the air?

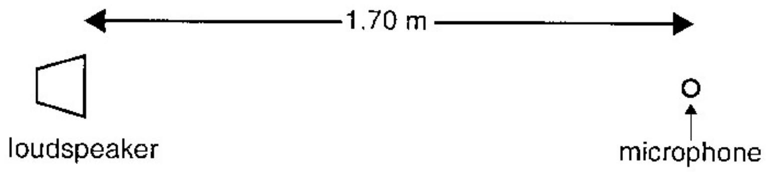
A. 290 ms^{-1}
B. 310 ms^{-1}
C. 330 ms^{-1}
D. 350 ms^{-1}

The guitarist then moves his hand along the string to produce its 5th harmonic.

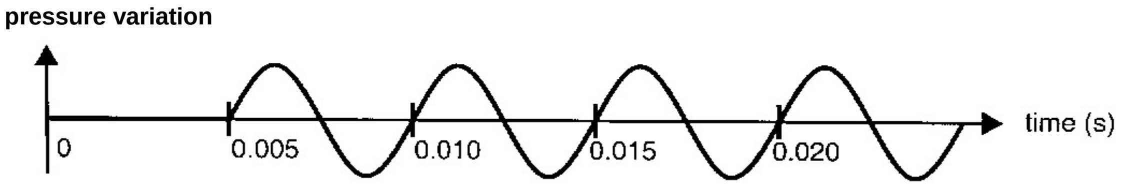
QUESTION 10
For this harmonic to be produced, what is the length of string vibrating?

A. 2.8 cm
B. 10 cm
C. 18 cm
D. 30 cm

QUESTION 11
A microphone is placed 1.70 m from the loudspeaker and the pressure at this point is measured as a function of time. The loudspeaker produces a sound of a constant 200 Hz in a region where the speed of sound is 340 m/s.



Which of the diagrams best represents the pressure variation at the microphone as a function of time? The time scales each start at t = 0 (when the speaker commenced to oscillate).

A.


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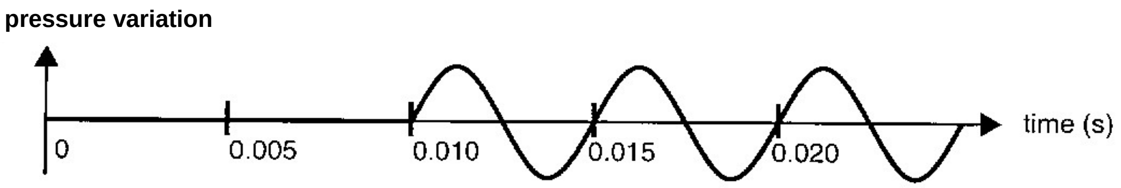

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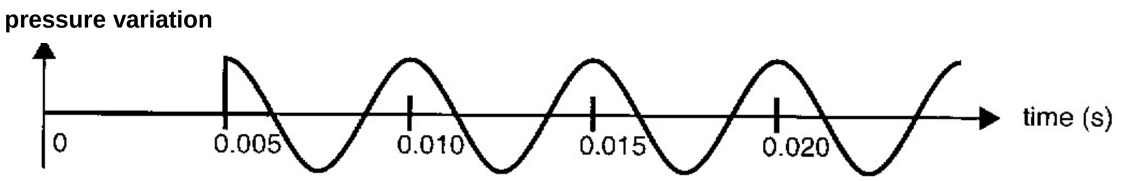

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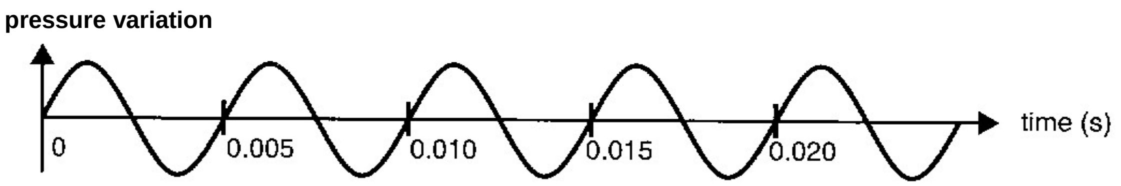

QUESTION 12
Two students are investigating the sound intensity level of the sound generated from a signal generator over a range of frequencies. Both students notice that even though the sound intensity level meter measures 60 dB at both 120 Hz and 2000 Hz, the higher frequency sounds louder. Which of the following statements provides the best explanation?

A. 120 Hz is below the frequency threshold for human hearing.
B. Higher frequency sounds diffract less.
C. The student's hearing is subject to the response of their ears to different frequencies.
D. The sound is more likely to destructively interfere at lower frequencies.

QUESTION 13

Which of the following is **incorrect** in explaining why a high frequency speaker (a tweeter) should be small and a low frequency speaker (a woofer) larger?

A. Lower frequency sounds have shorter wavelengths so they need a larger aperture to create more diffraction for the sounds to spread more evenly.

B. Low frequency speakers vibrate more slowly but need to move bigger masses of air to create the same sound levels as higher frequencies.

C. High frequency sounds have shorter wavelengths so they need smaller apertures to create diffraction of sound to reach all parts of the listening space more evenly.

D. High frequency speakers need to vibrate at a greater rate so the mass and size of the speaker cone needs to be smaller.

End of Section on Sound