THE SCHOOL FOR EXCELLENCE (TSFX)

UNIT 4 PHYSICS 2007

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	35	35
	Interactions of Light and Matter	14	14	30	30
B	**Detailed Studies**				
	1. Synchrotron **OR**	11	11	25	25
	2. Photonics **OR**	11	11	25	25
	3. Sound	11	11	25	25
				Total 90	Total 90

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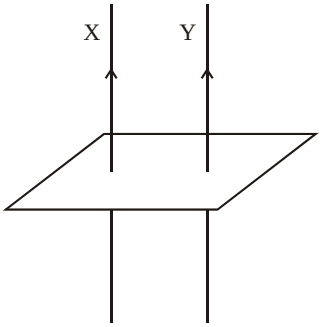
SECTION A – CORE STUDIES

Instructions For Section A

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

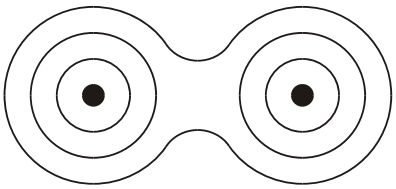
AREA OF STUDY 1 – ELECTRIC POWER

QUESTION 1
Two vertical wires X and Y carry current in the same direction and pass through horizontal sheet of paper.



Iron filings are scattered on the paper. Which **one** of the following diagrams best shows the pattern formed by the iron filings? *(The dots show where the wires X and Y enter the card).*

A.



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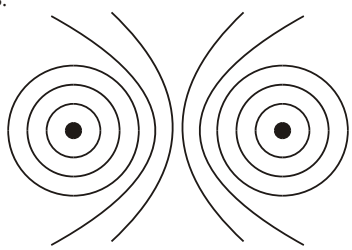
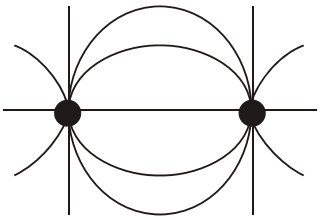


C.



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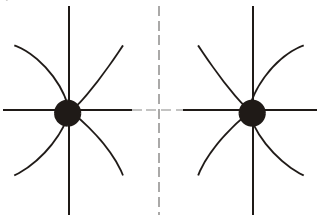
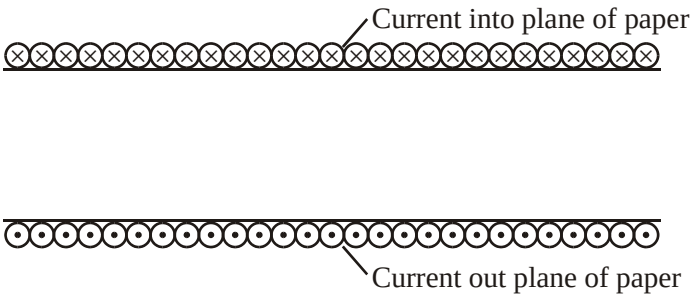


2 marks

The following information refers to Questions 2 and 3.

The diagram below shows a cross-section through a current-carrying solenoid. The current is moving into the plane of the paper at the upper edge of the solenoid and out of the plane of the paper at the lower edge. There is a vacuum in the solenoid.



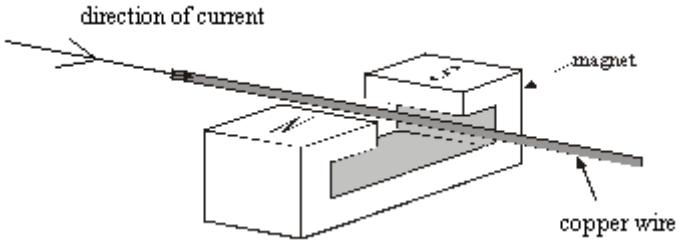
QUESTION 2
Sketch lines to represent the magnetic field inside the solenoid.

2 marks

QUESTION 3
An alpha particle (He^{2+}) enters the solenoid along its axis from the right. On the diagram, show the path of the particle in the solenoid.

1 mark

QUESTION 4
A strip of copper wire is positioned between the poles of a strong magnet, as shown below.



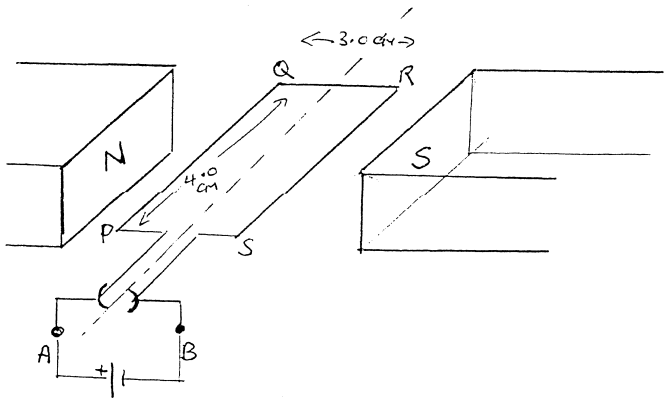
When a current is passed through the copper wire in the direction shown, the wire is deflected. In which direction is this deflection?

A. Vertically downwards
B. Vertically upwards
C. Towards the North pole of the magnet
D. Towards the South pole of the magnet

2 marks

The following information refers to Questions 5 to 7.

The diagram shows a rectangular coil of wire that can rotate between the poles of a magnet of field strength 80 mT. The loop consists of 40 turns of wire, sides PQ and RS are 4.0 cm, and QR and PS are 3.0 cm. Terminal A is positive and a current of 1.5 A flows in the coil.



QUESTION 5
Calculate the magnitude of the force on side RS

2 marks

N

QUESTION 6
What is the direction of the force experienced by side RS at the position shown?

1 mark

QUESTION 7
When the loop has rotated through 180^{o}, what is the net force on the coil?

_____

_____

_____

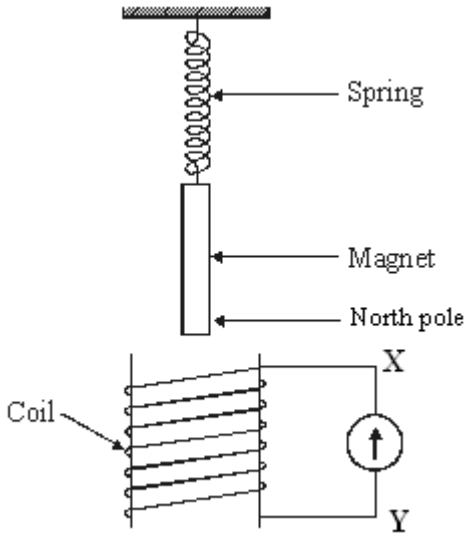
_____

2 marks

N

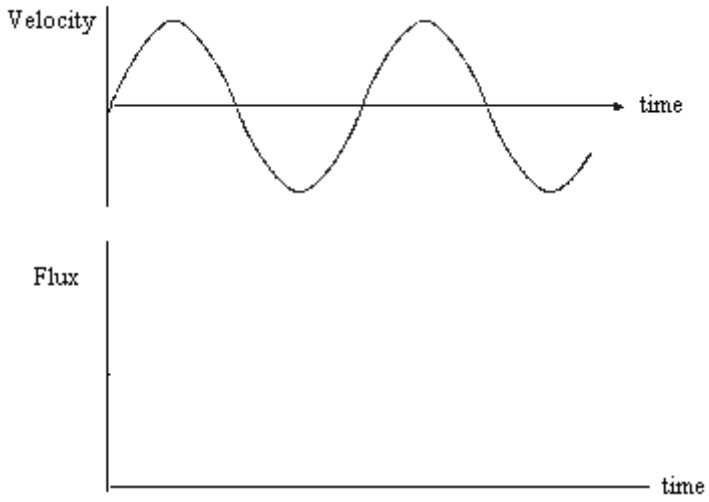
The following information refers to Questions 8 and 9.

A bar magnet is suspended above a coil of wire by means of a spring, as shown below. The end of the bar magnet closest to the solenoid is **a north pole.**



The ends of the coil are connected to a sensitive galvanometer. The bar magnet is pulled down so that its north pole is level with the top of the coil. The magnet is released and the variation with time *t* of the velocity *v* of the magnet is shown below.

QUESTION 8
On the axes provided, draw a flux – time graph corresponding to the movement of the magnet.



3 marks

QUESTION 9
When the magnet is initially released, does current flow from X to Y through the galvanometer, or from Y to X? Justify your choice.

_____

_____

_____

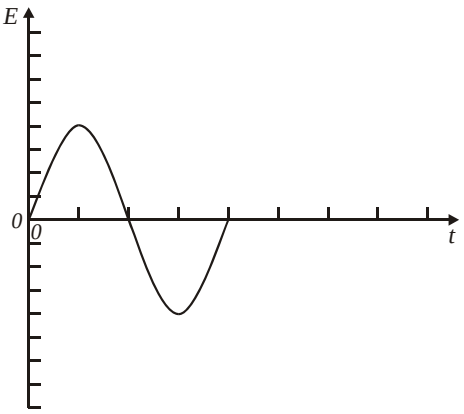
_____

_____

_____

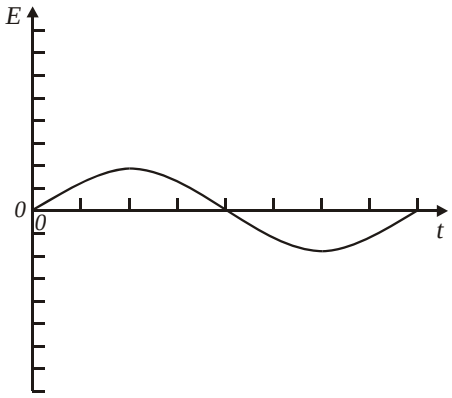
2 marks

QUESTION 10
When a coil is rotated in a uniform magnetic field at a certain frequency, the variation with time *t* of the induced e.m.f. *E* is as shown below.



The frequency of rotation of the coil is reduced to **one half** of its initial value. Which **one** of the following graphs correctly shows the new variation with time *t* of the induced e.m.f. *E*?

A.



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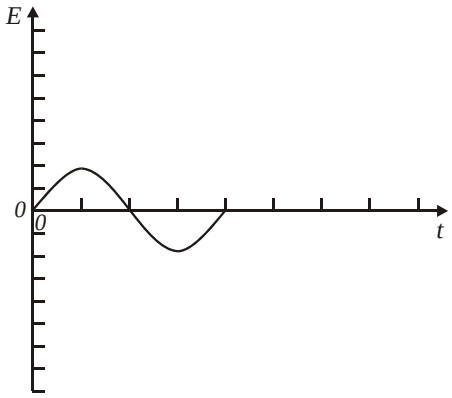

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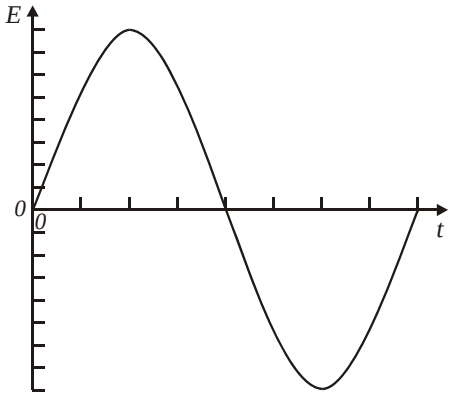

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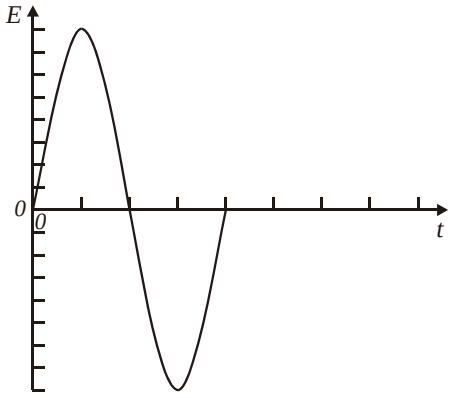


2 marks

Electrical power is delivered to a city through a 4.0 ohm resistance cable at 500 kV.

QUESTION 11
If 40 MW is transmitted, what current must be flowing through the cable?

_____

_____

_____

_____

2 marks

A

QUESTION 12
Calculate the percentage power loss

_____

_____

_____

_____

2 marks

%

QUESTION 13
What is the voltage drop across the transmission system?

_____

_____

_____

_____

2 marks

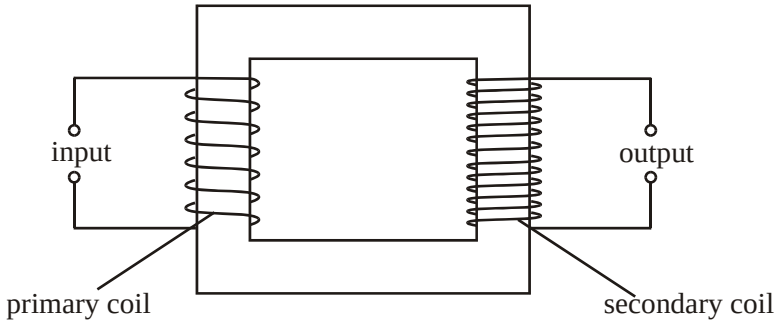
V

QUESTION 14
Explain why it is advantageous to transmit at a very high voltage

2 marks

The following information refers to Questions 15 to 16.

The diagram below shows an ideal transformer.



QUESTION 15
Is this a step-up or a step-down transformer?

1 mark

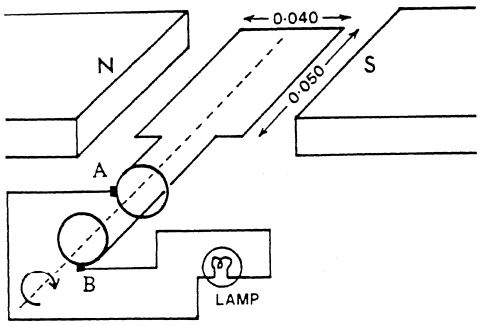
QUESTION 16
The transformer has 100 turns on the primary coil and 400 turns on the secondary coil, and the input to the primary coil is **24V AC rms**. What is the rms output voltage?

2 marks

V

The following information refers to Questions 17 to 19.

A student makes a model AC electric generator by winding a rectangular coil of 100 turns, each of length 0.05m and width 0.04m. The field strength in the region between the poles of the magnet is 0.4T. The coil is rotated clockwise at a rate of 2.0 revs/sec.



QUESTION 17
At the instant shown, is the positive terminal A or B?

1 mark

QUESTION 18
What is the average emf generated across AB during this quarter turn?

2 marks

V

QUESTION 19
Why does the lamp flicker as the generator rotates?

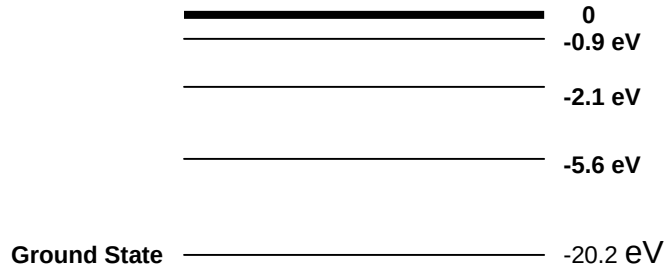
2 marks

End of Section on Electric Power

AREA OF STUDY 2 – INTERACTIONS OF LIGHT AND MATTER

Questions 1 to 3 refer to the following information.

The energy levels for a particular atom are shown in Figure 1 below.



QUESTION 1
Which of the following is **not** a possible energy value for photons released from this atom?

A. 14.6 eV
B. 16.4 eV
C. 18.1 eV
D. 19.3 eV
E. none of the above

2 marks

QUESTION 2
Calculate the energy (in Joules) of the photon emitted when an electron returns from the second excited state to the ground state.

2 marks

J

QUESTION 3
What is the wavelength of this photon?

_____

_____

_____

_____

2 marks

m

Questions 4 to 6 refer to the following information.

A student carries out an experiment to investigate the photoelectric effect. She shines a monochromatic light onto a metal plate (P) inside a sealed glass chamber as shown in Figure 2.

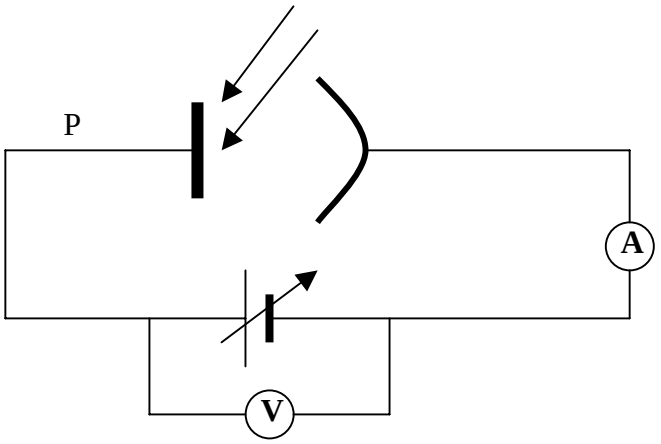


Figure 2

The current in the circuit changes as the voltage is varied as shown in Figure 3.

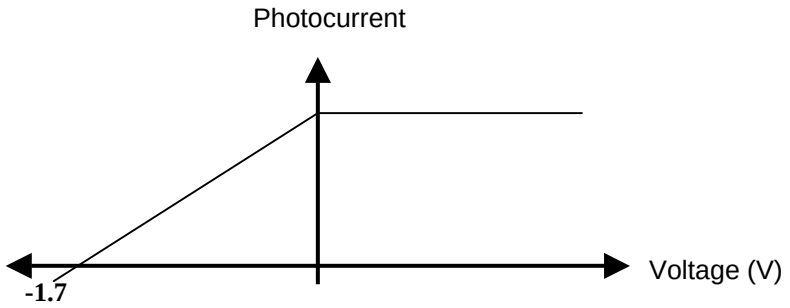


Figure 3

QUESTION 4
What is the maximum kinetic energy (in electron Volts) of the electrons ejected from the plate P?

2 marks

eV

QUESTION 5
What is the subsequent maximum speed of these electrons ejected from plate P?

2 marks

m/s

The student now replaces the monochromatic light source with one that emits light of a higher frequency.

QUESTION 6
How does this change affect the voltage at which the current becomes zero?
Justify your answer using appropriate principles of Physics.

3 marks

Questions 7 to 9 refer to the following information.

Thomas Young's double slit experiment has been replicated in the experimental arrangement shown in Figure 4.

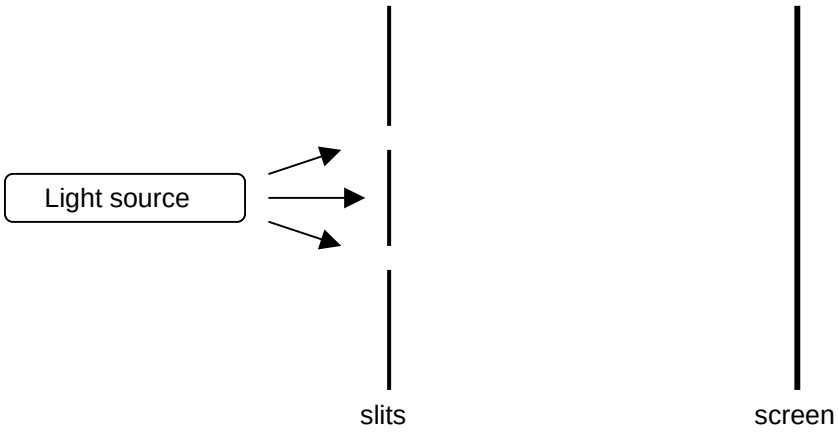


Figure 4

QUESTION 7
Explain using the wave theory of light why a series of bright and dark bars are observed on the screen.

3 marks

The slits are now moved further from the screen.

QUESTION 8
What effect would this have on the pattern observed on the screen?

1 mark

The light source is replaced by a beam of electrons, which pass through two very thin slits (approximately 10^{-10} m) and are detected on a electron detector screen as shown in Figure 5.

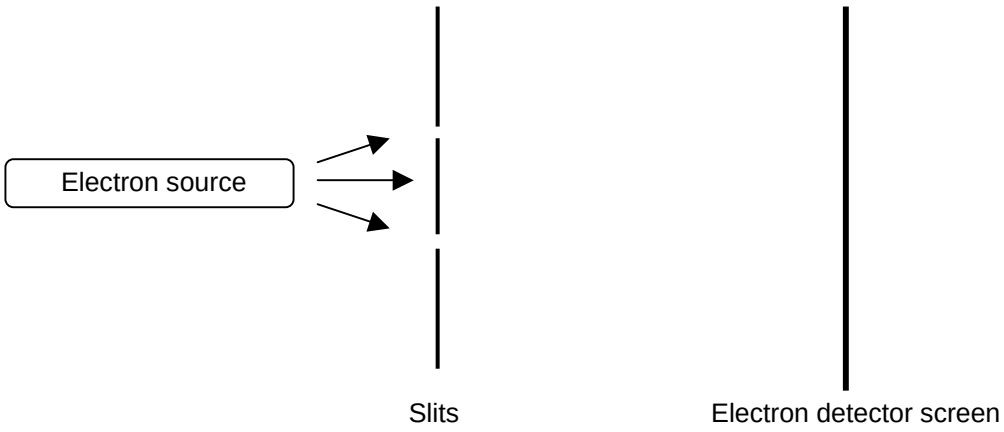


Figure 5

QUESTION 9
Explain whether the **particle model** or the **wave model** best explains the expected observations from this experiment.

3 marks

Questions 10 and 11 refer to the following information.

A monochromatic violet light of wavelength 390 nm is emitted by a light source with a power of 200 Watt.

QUESTION 10
How many photons leave this light source in a 10 second interval?

_____

_____

_____

_____

2 marks

QUESTION 11
What is the momentum of each of these photons?

_____

_____

_____

_____

2 marks

kgm/s

Questions 12 to 14 refer to the following information.

In a game of baseball a 145 gram ball is pitched at 162 km/h.

QUESTION 12
Calculate the de Broglie wavelength of the baseball.

2 marks

m

QUESTION 13
Calculate the de Broglie wavelength of an electron traveling at 4.50×10^6 m/s.

2 marks

m

QUESTION 14
Explain with an appropriate reference to a wave phenomenon, why it is possible to observe the wave nature of these such electrons but not the baseball.

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

A simplified electron gun is shown in Figure 1 below. The plates are separated by a distance of 10 cm and a voltage of 500V is applied across the plates. The electron is released from the filament and travels from point A to B.

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

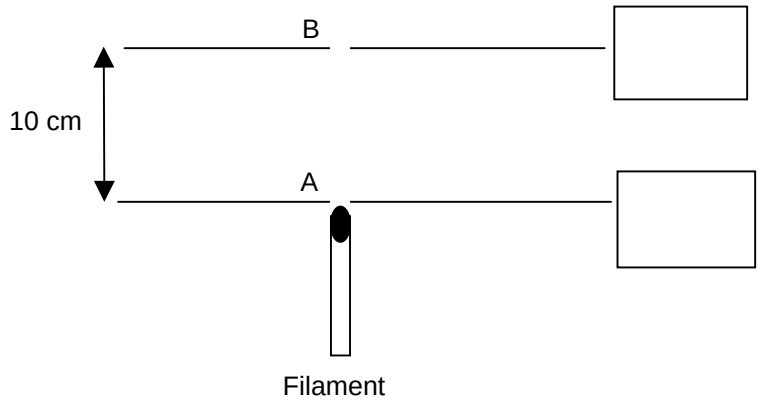


Figure 1

QUESTION 1
Place the charge of each plate, positive (+) and negative (-), in the appropriate box in Figure 1.

QUESTION 2
Determine the electric field between the plates.

_____

_____

_____

1 mark

Vm^{-1}

QUESTION 3

Show that the speed of the electron at position B is $1.3\times10^{7}\ m\ s^{-1}$.

(You must show all working out)

3 marks

QUESTION 4

A linac accelerates the electrons through a series of tubes with alternating polarities. In the design of the linac, which ONE OR MORE of the following changes (A-D) will increase the final speed of the electrons?

A. Increase the length of the tubes.
B. Decrease the length of the tubes.
C. Increase the voltage.
D. Decrease the voltage.

2 marks

QUESTION 5

Determine the magnetic field strength required to force an electron of momentum 1.0×10^{-18} kg m s^{-1} to travel in a circle of radius 34.5 m.

2 marks

T

QUESTION 6
Which of the following (A-D) best describes the purpose of the storage ring?

A. Accelerates electrons
B. Creates synchrotron radiation
C. Makes electrons move in a circle
D. Stores electrons

2 marks

The X-rays emitted from the synchrotron are incident on a crystal sample for a particular solid state diffraction experiment. The X-rays have a wavelength of 1.25 nm. The crystal is orientated in a planar direction.

QUESTION 7
Explain how the ***path difference*** between adjacent X-rays incident on a crystal causes a diffraction pattern. Include a **diagram** in your explanation.

4 marks

QUESTION 8
The diffraction pattern is observed and it is noted that the second order reflected ray occurs at an angle of 32.5^{o}. Determine the spacing between the planes in m.

3 marks

m

QUESTION 9
There are two types of diffraction techniques commonly used with X-rays, single crystal and powder diffraction. Provide ONE advantage for using each technique.

Single Crystal Diffraction

_____

_____

Powder Diffraction

_____

_____

2 marks

QUESTION 10
X-rays and electrons may undergo a number of different interactions. Which one of the following interactions (A-D) best describes the diagram in Figure 2?

Figure 2

A. Thomson scattering
B. Compton scattering
C. Diffuse scattering
D. Elastic scattering

2 marks

QUESTION 11
X-rays can be created from a large number of sources. Which one of the following sources (A-D) of X-rays is the brightest?

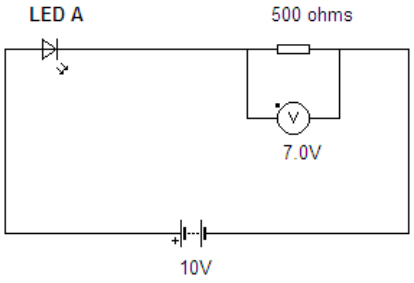
A. Bending magnets in a synchrotron
B. Light bulb
C. Sun
D. Undulators in a synchrotron

2 marks

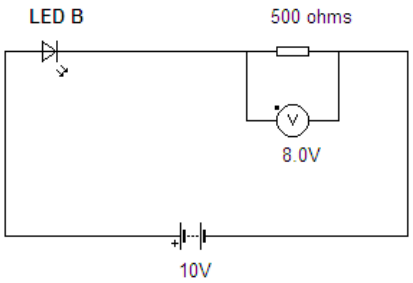
End of Section on Synchrotron and its Applications

DETAILED STUDY 2 - PHOTONICS

QUESTION 1
The following question involves two separate circuits, circuit 1 and circuit 2. Each circuit has a light emitting diode (LED) connected in series with a 500 ohm resistor and a 10V DC power supply. The LED in one circuit emits orange light while the LED in the other circuits emits violet light.



Circuit 1



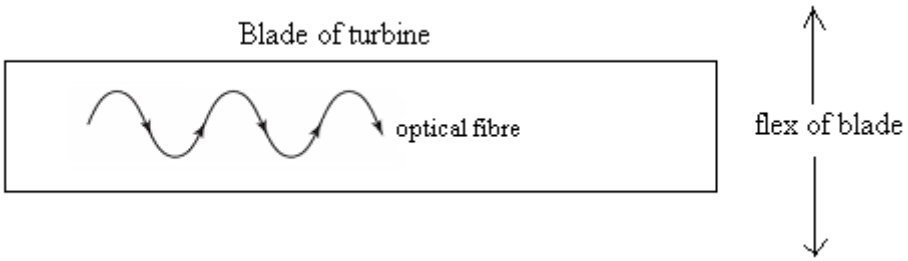
Circuit 2

Which LED, A or B, is likely to emit the violet light? Justify your choice.

3 marks

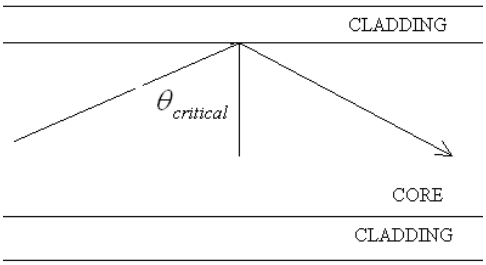
QUESTION 2

A wind turbine contains a fibre optic sensing system that is able to measure the amount of flex in the blades of the turbine in strong wind conditions. The system consists of a single mode step index glass fibre stretched along the inside of the blade in a wave pattern.



In the unflexed position of the blade, the radius of curvature of the fibre produces an incident angle that approaches but doesn't equal or become less than the critical angle (as measured from the normal).

A laser diode sends light into the fibre and a photodiode at the opposite end measures the transmitted light through the fibre As the blades flex under strong wind conditions bending losses occur and the amount of light detected by the photodiode decreases.



In order for small angular changes in the blades to result in bending losses, it is important that:

(one or more answers)

A. The refractive index of the cladding layer is less than the core.
B. The refractive index of the cladding is more than the core.
C. The refractive index of the cladding is equal to the core.
D. Bending causes the incident angle to exceed the critical angle.
E. Bending causes the incident angle to become less than the critical angle.

2 marks

QUESTION 3
Modal dispersion occurs significantly in multimode fibres. It happens because parts of a light pulse follow different paths (called modes) through the fibre. This means they arrive at different times at the other end of the fibre.

Suggest two methods for reducing the effects of modal dispersion

_____

_____

_____

_____

_____

_____

2 marks

QUESTION 4
A helium-neon laser emits light with a wavelength of 633 nm.
(h= 4.14 x 10^{-15} eVs = 6.63 x 10^{-34} Js, q = 1.6 x 10^{-19} C).
Calculate the energy of a single photon.

_____

_____

_____

_____

2 marks

J

QUESTION 5
If the laser had a power rating of 0.5 mW, how many photons would be emitted per second.

_____

_____

_____

_____

_____

_____

3 marks

QUESTION 6
Suggest three advantages with using optical fibres for modern communication over electrical methods.

3 marks

The following information refers to Questions 7 to 9.

The numerical aperture of an optical fibre is a measure of how readily it will capture light. A particular step-index fibre has a doped glass core of refractive index 1.52 and a surrounding cladding of refractive index 1.50.

QUESTION 7
Calculate the critical angle for the core / cladding interface.

2 marks

QUESTION 8
Calculate the numerical aperture for this fibre.

2 marks

QUESTION 9
What is the acceptance angle for this fibre in air?

2 marks

QUESTION 10
Describe the arrangement of optical imaging fibres in a coherent bundle.

3 marks

QUESTION 11
Suggest an application for such a bundle.

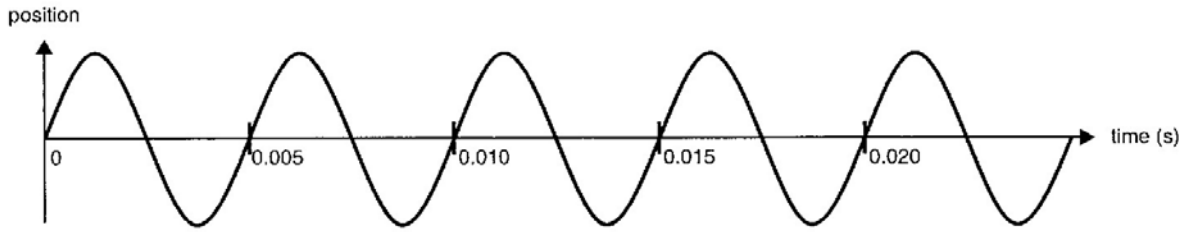
1 mark

End of Section on Photonics

DETAILED STUDY 3 - SOUND

Questions 1 to 3 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.



QUESTION 1
What is the frequency of oscillation of the speaker cone?

2 marks

Hz

QUESTION 2
What is the wavelength of the sound transmitted through the air by the loud speaker? (take the speed of sound in air as 340 ms^{-1}).

2 marks

m

A microphone is placed 1.70 m from the loudspeaker and the pressure at this point is measured as a function of time as shown in Figure 2.

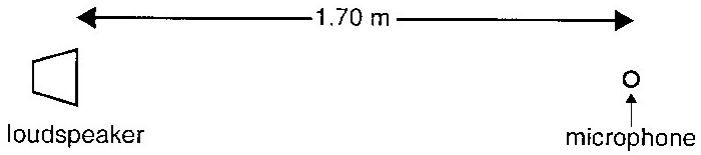
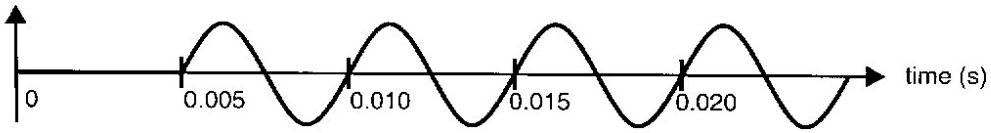


Figure 2

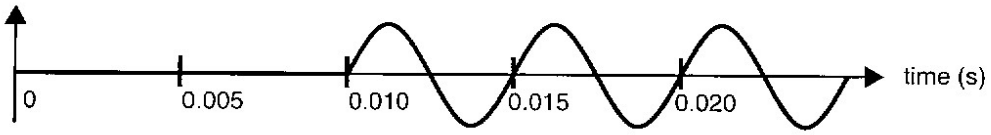
QUESTION 3

Which **one** of the diagrams below (A – D) best represents the pressure variation at the microphone, as a function of time? Each scale begins at t = 0 (when the speaker commenced to oscillate).

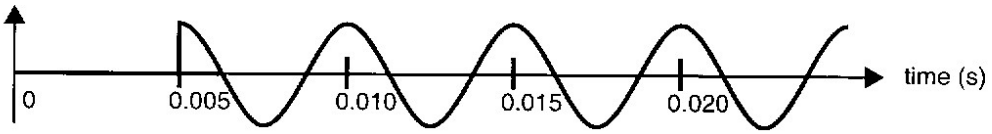
A.



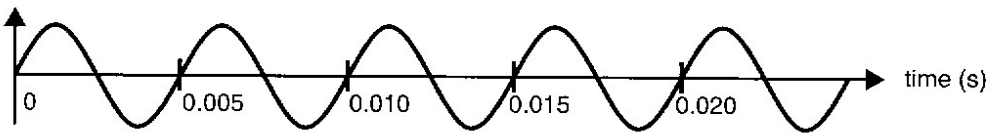
B.



C.



D.



2 marks

QUESTION 4

Two people hear a loud buzz coming from a computer. The sound intensity is measured as 2×10^{-7} W/m^2 for Mary, 40 cm from the computer's speaker. John is 1.6 m away from the speaker. What would be the intensity of the sound where John is?

_____

_____

_____

_____

2 marks

Wm^{-2}

QUESTION 5

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

_____

_____

_____

_____

_____

2 marks

Mary:	dB

John:	dB

QUESTION 6
A child is screaming at 90 dB. Another child from a similar distance decides to join in and also screams at 90 dB. Which of the following would be closest to the new "combined" sound level?

A. 90 dB
B. 90.4 dB
C. 93 dB
D. 95 dB
E. 180 dB

2 marks

QUESTION 7
Which of the above options would be most correct if the 2nd child was screaming at 80 dB?

A. 90.0 dB
B. 90.4 dB
C. 93.0 dB
D. 95.0 dB
E. 170 dB

2 marks

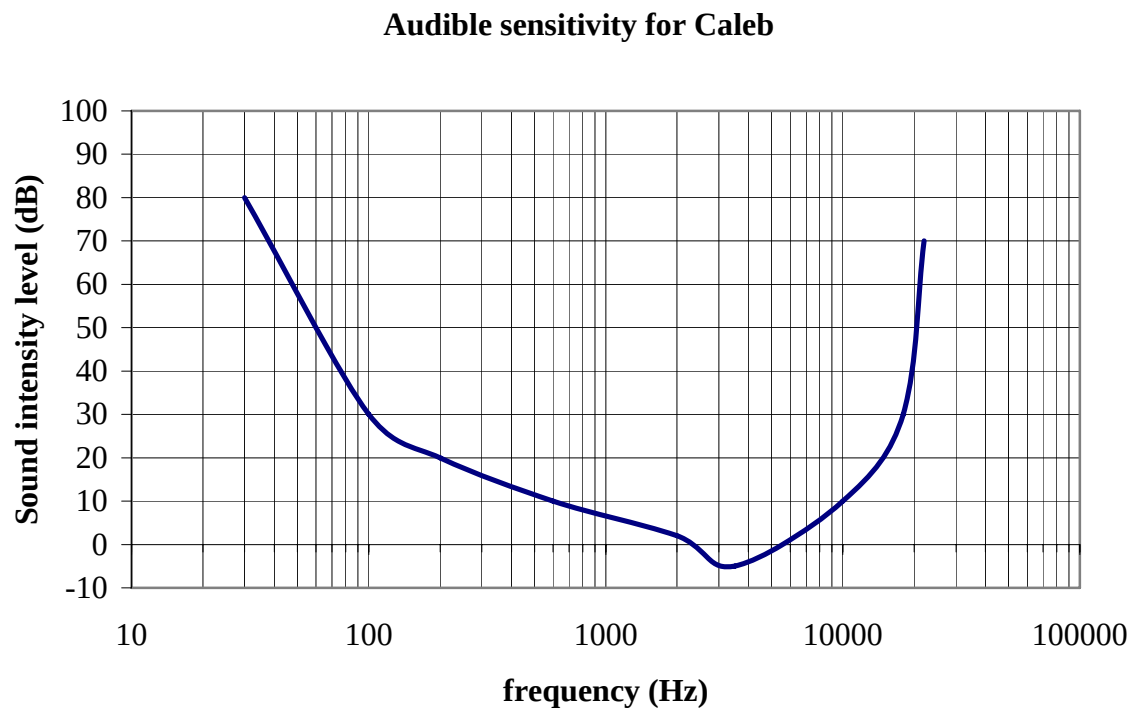


Figure 3

QUESTION 8

The sound from an audio oscillator is set at a sound intensity level of 20 dB and the frequency is decreased from an initial 20,000 Hz until Caleb first begins to hear the sound at a frequency of approximately 13,000 Hz. The frequency is further decreased. At what frequency will Caleb again not be able to hear the sound?

_____

_____

_____

_____

2 marks

Hz

Questions 9 and 10 refer to the following information.

Emily is studying standing waves that are set up in a narrow glass tube. She has an audio signal generator and a small speaker that is near one end of the tube, and adjusts the frequency to set up the resonances. The tube is filled with fine dust so that when a resonance is formed the dust indicates the positions of the pressure nodes and antinodes. Although s**he can see the entire tube**, shields prevent her from seeing whether the end of the tube is open or closed.

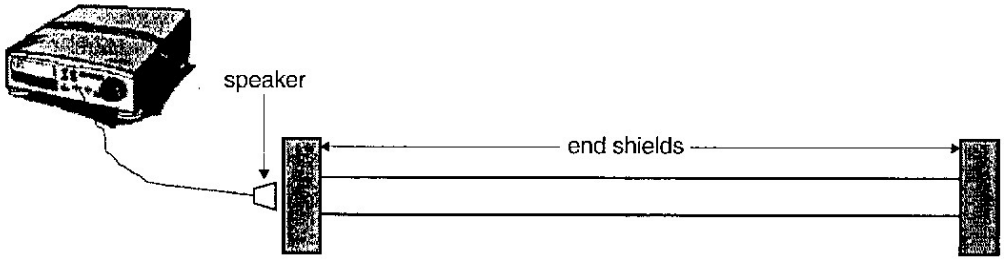


Figure 4

At a particular frequency of 680 Hz, he observes that there are 5 nodes and 5 antinodes.

QUESTION 9
How many open ends does the tube have? Please circle one number: **0 1 2**
Include a diagram to justify your answer.

3 marks

QUESTION 10
What is the length of the tube? Take the speed of sound to be 340 ms^{-1}.

_____

_____

_____

_____

2 marks

m

Question 11 refers to the following information.

Jung and Maxine are discussing how we determine the direction from which a sound comes. They are considering Figure 5 below.

Jung says that we can tell the direction of the sound from the speaker because the brain can detect the time difference between the arrival times of the peaks of a wave at each ear (see Figure 6).

Maxine says this cannot be so: we tell the direction of a sound because diffraction causes the intensity at the more distant ear to be lower, and the brain can detect this (see Figure 7).

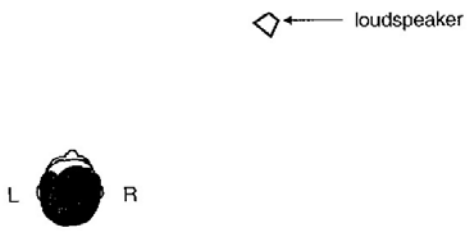


Figure 5

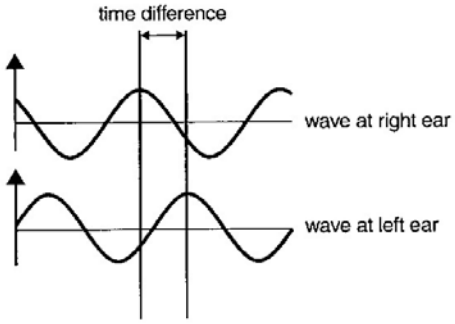


Figure 6

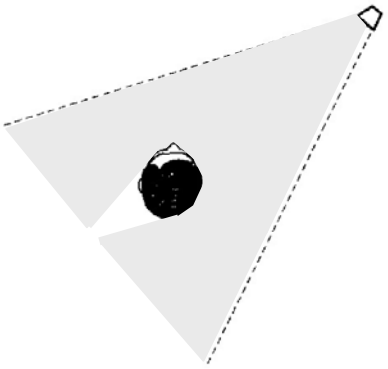


Figure 7

QUESTION 11

Discuss to what extent, and under what conditions, their explanations are correct. You may use diagrams to explain your answer.

4 marks

End of Section on Sound