UNIT 4 PHYSICS 2005

WRITTEN EXAMINATION 2

TRIAL EXAMINATION PAPER

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

QUESTION AND ANSWER BOOK

Structure of Book

Section		*Number of Questions*	*Number of Questions to be Answered*	*Number of Marks*	*Suggested Times (minutes)*
A	**Core Studies**				
	Electric Power	8	8	35	35
	Interactions of Light and Matter	5	5	30	30
B	**Detailed Studies**				
	1. Synchrotron **OR**	6	6	25	25
	2. Photonics **OR**	5	5	25	25
	3. Sound	7	7	25	25
				Total 90	Total 90

COMPLIMENTS OF THE SCHOOL FOR EXCELLENCE

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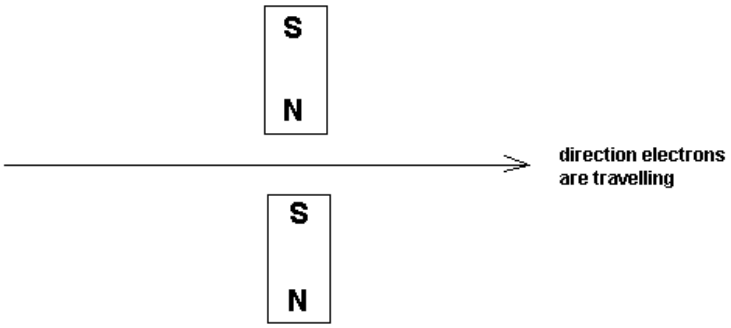
The following constants are relevant to this paper:

Mass of an electron = 9.1×10^{-31} kg
Charge on an electron = -1.6×10^{-19} C
Planck's constant = 4.14×10^{-15} eVs = 6.63×10^{-34} Js

SECTION A – CORE STUDIES

AREA OF STUDY 1 – ELECTRIC POWER

QUESTION 1



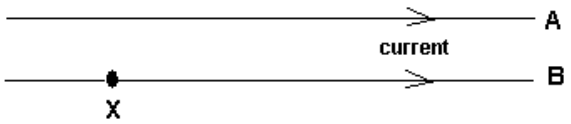
Which of the following best describes the path of an electron as it passes through the magnetic field?

A The electron is deflected up
B The electron is deflected down
C The electron is deflected into the page
D The electron is deflected out of the page

2 marks

QUESTION 2

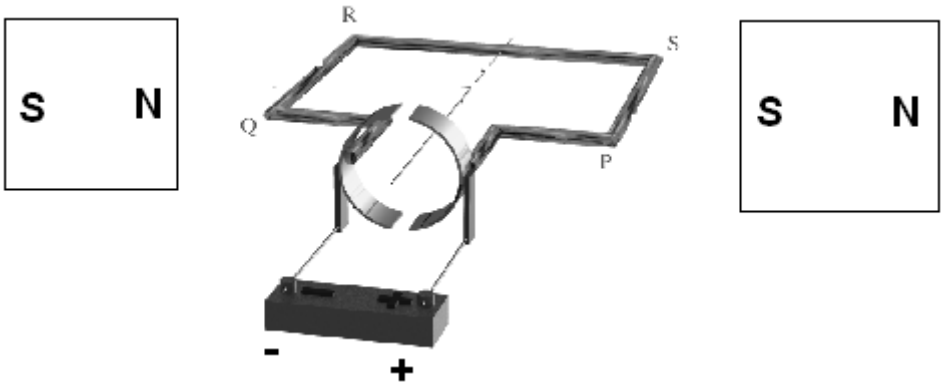
Two current carrying conductors are placed parallel as shown. What is the direction of the net force exerted on point X?



A Up
B Down
C Left
D Right
E Into page
F Out of page

2 marks

QUESTION 3
An electric motor contains an armature of 40 turns in a magnetic field of 0.10 T.
PS = RQ = 2 cm; RS = PQ = 4 cm.



A constant current of 1.5 A flows from P to S.

(a) Calculate the size and direction of the magnetic force on side PS.

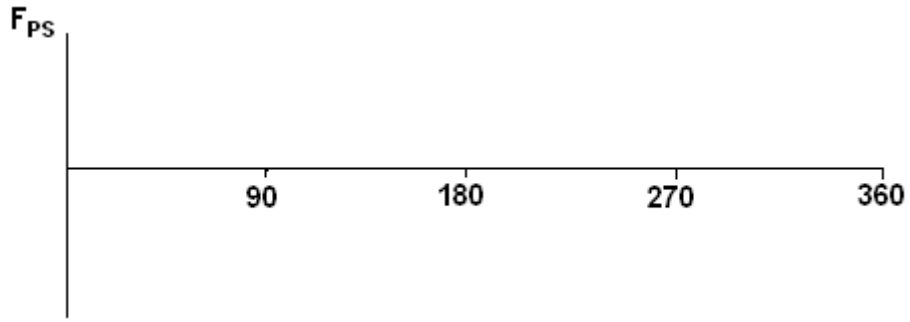
Direction =

1 mark

Magnitude = N

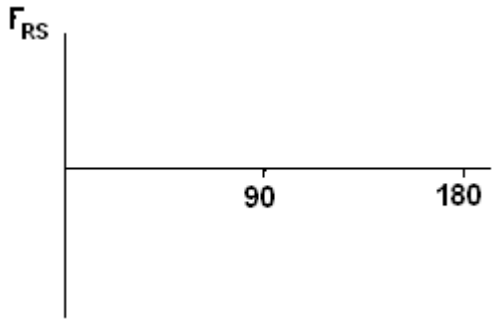
2 marks

(b) Sketch a graph on the axes below showing the net force on side PS for 360^{o} of rotation.



2 marks

(c) Sketch a graph on the axes below showing the net force on side RS for 180^{o} of rotation.



2 marks

(d) Explain how the action of the commutator and using a D.C. keeps the coil rotating in the same direction.

_____

_____

_____

_____

_____

_____

_____

_____

_____

3 marks

QUESTION 4
An aeroplane with a wing span of 40 m flies over the north magnetic pole at 120 ms^{-1}. The magnetic field at that position is 5 x 10^{-4} T.

(a) What is the emf induced across the wing tips?

_____

_____

_____

_____

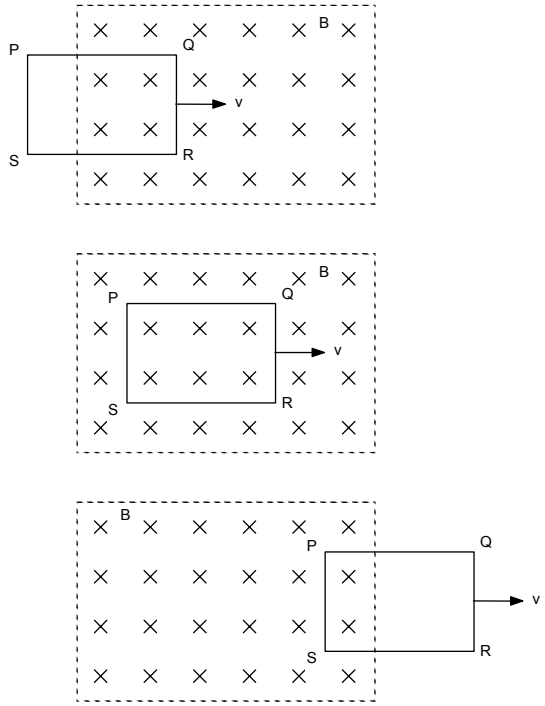
2 marks

V

(b) Which wing tip is positive?

1 mark

QUESTION 5
A small coil is passed through a perpendicular magnetic field and the induced emf is monitored on an oscilloscope.

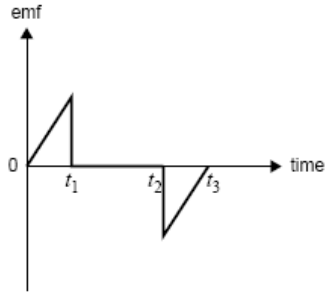


(a) On the following axes, show how the magnetic flux threading the loop varies with time, as the loop first enters the field and passes completely through.

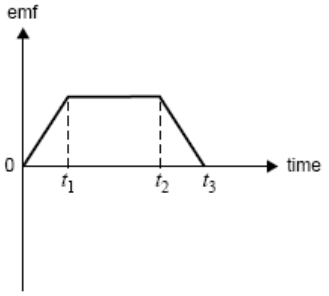
2 marks

(b) Which of the following best shows the variation of emf with time?

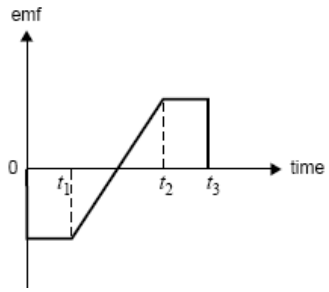
A.



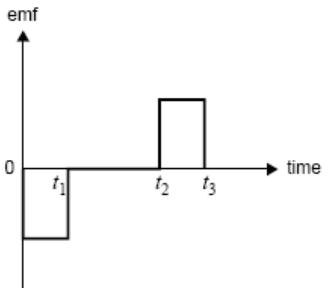
B.



C.

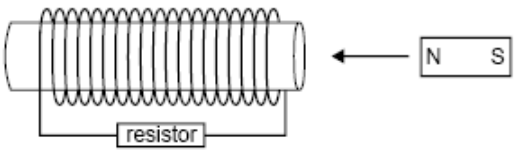


D.



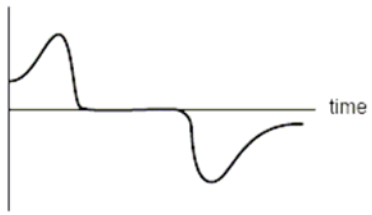
2 marks

QUESTION 6
A magnet is moved through a coil at constant speed and out the other side.

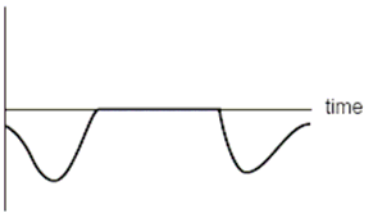


Which one of the diagrams (A – D) best shows how the current through the coil varies with time?

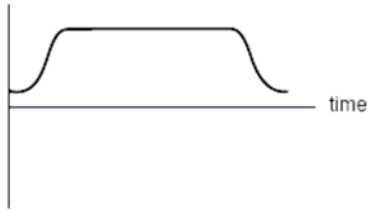
A.



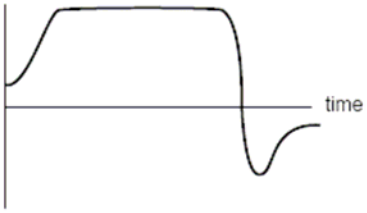
B.



C.



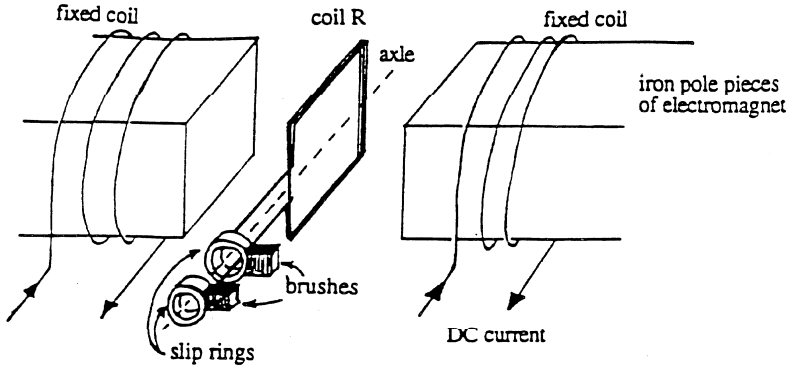
D.



2 marks

QUESTION 7

The following diagram shows a simple generator, which consists of coil R that can be rotated in a magnetic field. Electric contact is made with the coil through a pair of slip rings. The magnetic field is produced by passing a DC current through two fixed coils wound on two iron pole pieces to form an electromagnet. The magnetic field strength is 0.1 T. The rotating coil R has an area of $4.0 \times 10^{-3} m^2$. It consists of 40 turns of wire.



(a) What is the direction of the magnetic field passing through coil R?

A To the left
B To the right
C Up
D Down

2 marks

(b) What magnetic flux threads coil R as shown in the diagram?

2 marks

Wb

(c) If the coil is rotated at 5 Hz, what is the average emf induced during the first quarter turn?

_____

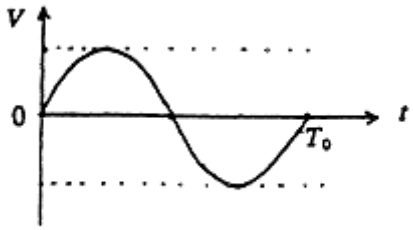
_____

_____

2 marks

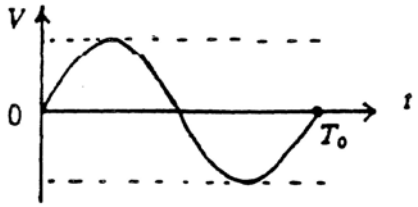
V

As the coil is rotated the voltage measured between the slip rings varies with time as shown in the graph below.

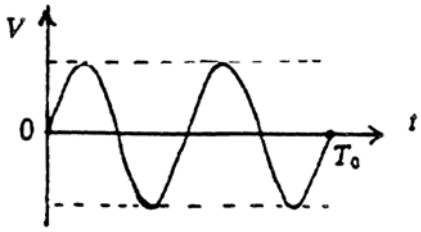


If the frequency of rotation is doubled, which of the graphs below best shows how the voltage now varies with time? Explain your reasoning.

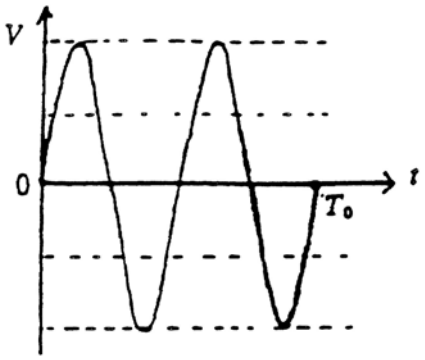
A



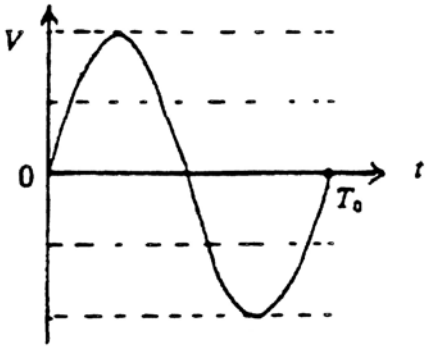
B



C



D



_____

_____

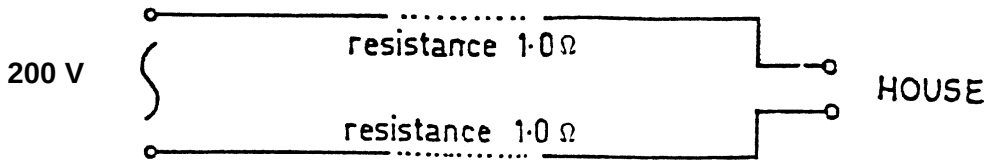
_____

_____

2 marks

QUESTION 8

A windmill drives a 200 V generator which produces electrical energy at the rate of 2000 W. This energy is supplied to a distant house through cables of total resistance 2.0 Ω.



(a) At what rate is energy dissipated in the cables?

_____

_____

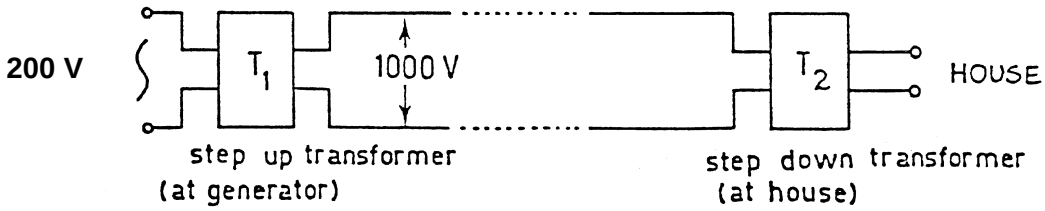
_____

_____

W

2 marks

T_1 *and* T_2 are two transformers of 100 per cent efficiency used to step up and step down the voltage (Assume the resistance of the cables remains unchanged).



(b) At what rate is energy now dissipated in the cables?

_____

_____

_____

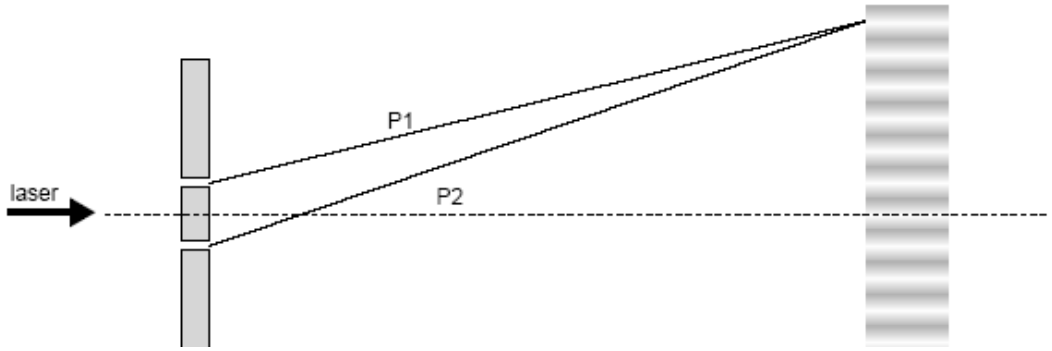
_____

W

2 marks

AREA OF STUDY 2 – INTERACTIONS OF LIGHT AND MATTER

QUESTION 1
In the following diagram, laser light of wavelength 600 nm is shone onto a pair of parallel slits and a pattern of alternating light/dark bands is projected onto a wall.



(a) Explain how the observed pattern on the wall supports a wave model for light.

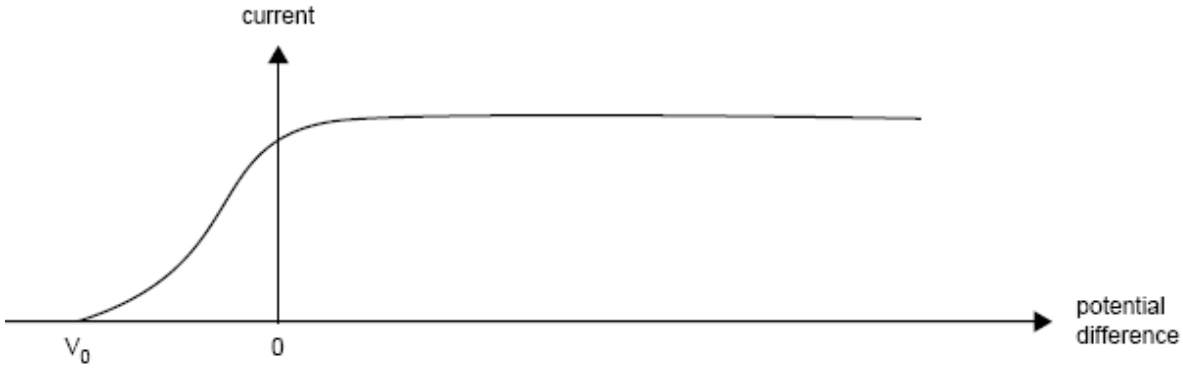
2 marks

(b) Estimate the difference in length between P1 and P2.

2 marks

m

QUESTION 2
When yellow light of frequency 6.0×10^{14} Hz is shone onto the photocathode of a photocell, the following relationship between photoelectric current and potential difference is obtained.



(a) On the previous diagram, sketch the curve expected if the light is changed to **blue** with a **higher intensity** than the original.

2 marks

(b) The threshold frequency for the metal chosen is 5.2×10^{14} Hz. What is the work function for this metal?

2 marks

eV

(c) What is the energy of a photon of frequency 6.0×10^{14} Hz?

2 marks

eV

(d) What is the cut-off potential, V_o, when light of frequency 6.0×10^{14} Hz is shone onto the photocathode of this photocell?

_____

_____

_____

_____

2 marks

eV

(e) What is the wavelength of light of frequency 6.0×10^{14} Hz?

_____

_____

_____

_____

2 marks

nm

(f) The wavelength of the incident light is now increased by 20%. What effect will this have on the photocurrent? Explain your reasoning.

_____

_____

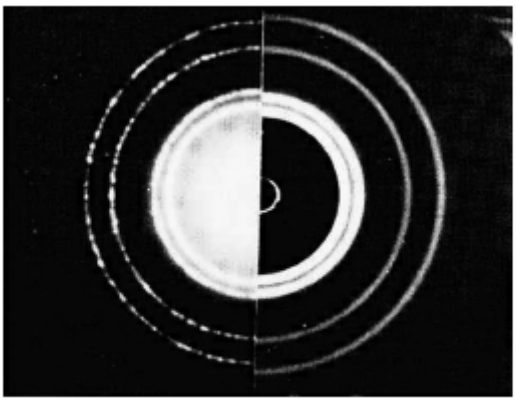
_____

_____

2 marks

QUESTION 3

In 1927, G.I. Thomson fired a beam of electrons through a very thin metal foil and the emerging electrons formed circular patterns, similar to the pattern obtained when the exercise was repeated with a beam of X-rays. The following diagram shows a comparison of the patterns obtained.



electrons X-rays

(a) How does this evidence support the concept of matter waves?

_____

_____

_____

_____

2 marks

(b) If the X-rays have frequency of 1.5×10^{19} Hz, what is the wavelength of the electrons?

_____

_____

_____

_____

2 marks

m

(c) What is the momentum of an X-ray photon?

_____

_____

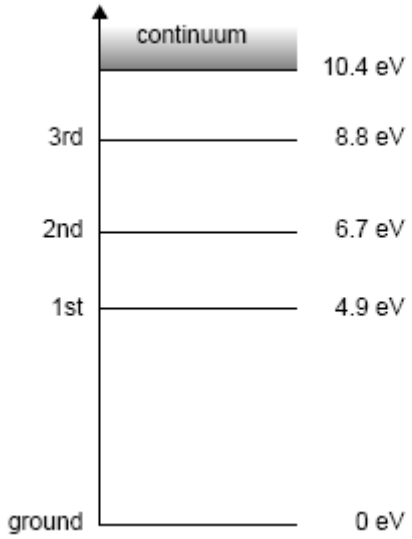
_____

_____

2 marks

$kgms^{-1}$

QUESTION 4
The following diagram shows the energy levels of a mercury atom.



(a) If the atom has been excited to the third excitation state, which of the following photon energies could be emitted? (one or more answers).

A 8.8 eV
B 6.7 eV
C 3.9 eV
D 1.8 eV

2 marks

(b) The mercury vapour is bombarded by photons of varying energies.
Which energy photons could be absorbed by the vapour? (one or more answers)

A 4.0 eV
B 6.7 eV
C 6.8 eV
D 8.7 eV
E 12.0 eV

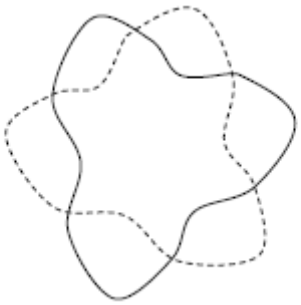
2 marks

(c) The mercury vapour is now bombarded with 10.2 eV electrons.
What possible energies could the emerging electrons have? (one or more answers).

A 0.4 eV
B 1.4 eV
C 3.5 eV
D 5.3 eV
E 10.2 eV
F All of the above

2 marks

QUESTION 5
Which excitation level for hydrogen does the following 'standing wave' state represent?



A 1st excitation state
B 2nd excitation state
C 3rd excitation state
D 6th excitation state

2 marks

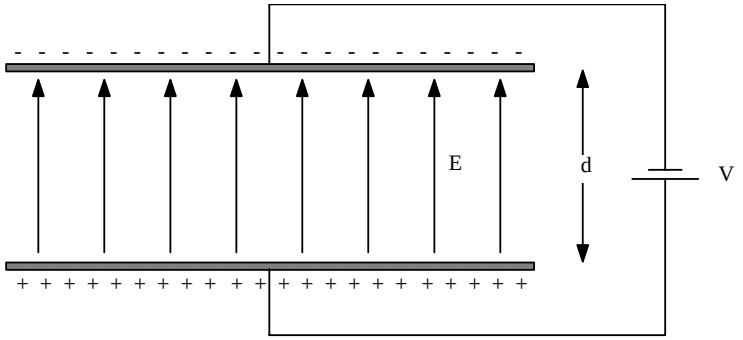
SECTION B – DETAILED STUDIES

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

QUESTION 1
An electron is accelerated from one plate to another across a potential difference of 2.0 kV. The separation of the plates, d, is 5.0 cm.



(a) What is the strength of the electric field between the plates?

_____

_____

_____

_____

2 marks

Vm^{-1}

(b) How much energy does the electron gain as it moves to the positive plate?

_____

_____

_____

_____

J

2 marks

(c) How fast will the electron be travelling when it hits the positive plate if it left the negative plate with zero velocity?

_____

_____

_____

_____

ms^{-1}

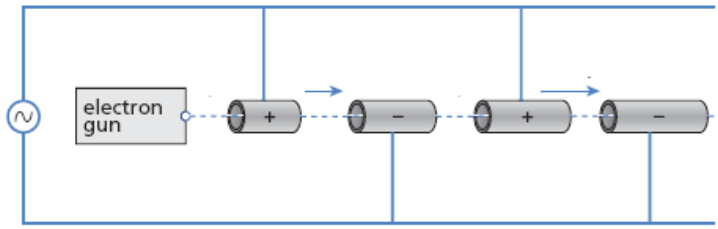
2 marks

(d) The separation between the two plates is increased to 2d. Compared to when the separation was d, which alternative represents the amount of kinetic energy of the electron as it reaches the positive plate?

A Less kinetic energy
B More kinetic energy
C The same amount of kinetic energy

2 marks

QUESTION 2
A linear accelerator (Linac) consists of a series of RF cavities of progressively increasing length.



Explain why each cavity is longer than the cavity before it.

2 marks

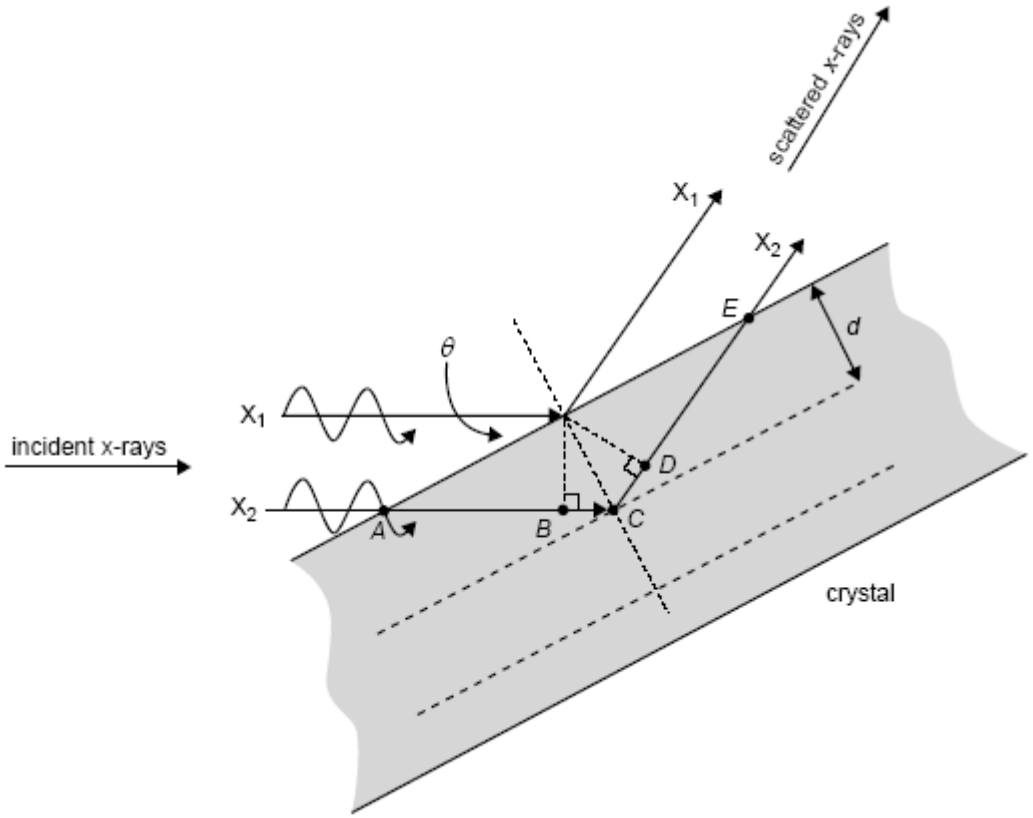
QUESTION 3
An electron enters a 0.2 T magnetic field at 2.99×10^8 ms^{-1}. What is the radius of the electron's resulting circular motion?

2 marks

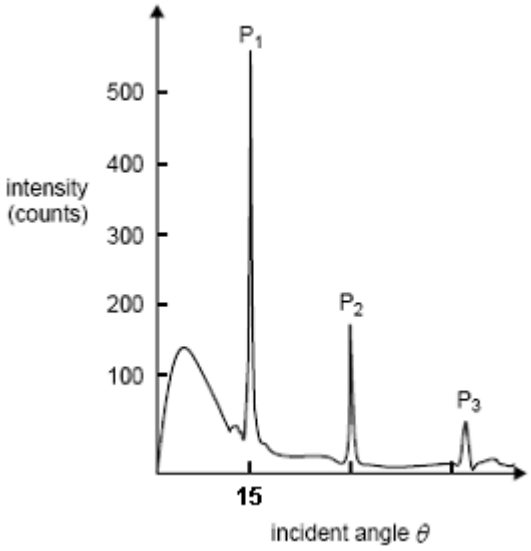
m

QUESTION 4

A beam of electrons initially in phase is scattered by a crystal as shown below. Beams X_1 and X_2 are rays that reflect from adjacent crystal planes separated by distance d.



Measurements of the intensity of the scattered beam were made at varying incident angles and the data obtained is shown below. The spacing between crystal planes is d = 0.18 nm.



(a) Explain the cause of the intensity peak at 15 degrees.

2 marks

(b) Calculate the wavelength of the incident rays.

2 marks

m

(c) Calculate the angle of the third peak. Show your working.

2 marks

$\theta =$

(d) If a slightly higher energy X-ray was used in the experiment, which of the following best describes what may happen to the peak P_2?

A The incident angle at which P_2 occurs increases
B The incident angle at which P_2 occurs decreases
C The peak remains unchanged

2 marks

QUESTION 5
In a Compton scattering experiment, the incoming X-rays had a wavelength of 1.45×10^{-10} metres. A portion of the outgoing X-rays were observed to have a wavelength of 2.25×10^{-10} m. How much energy is transferred from each X-ray to the electron as kinetic energy?

2 marks

J

QUESTION 6
Describe the basic difference between Compton scattering and Thomson scattering.

2 marks

DETAILED STUDY 2 - PHOTONICS

QUESTION 1
Find the wavelength of the light emitted from an atom for which the energy gap between levels is 2.1 eV.

nm

2 marks

A particular laser emits light of wavelength 600 nm.

QUESTION 2

(a) What is the frequency of this light?

Hz

1 mark

(b) Calculate the energy of a single photon.

J

2 marks

(c) If the laser had a power rating of 3.0 mW, how many photons would be emitted each second?

photons

2 marks

(d) If the laser was aimed at the sky and turned on for just one hundredth of a second, how long (in m) would the resultant laser pulse be?

m

1 mark

(e) If the photons from the laser beam formed a single line, what would be the approximate spacing between adjacent photons?

nm

2 marks

QUESTION 3
What is the critical angle for light passing from glass of index of refraction of 1.52 to water with an index of refraction 1.33?

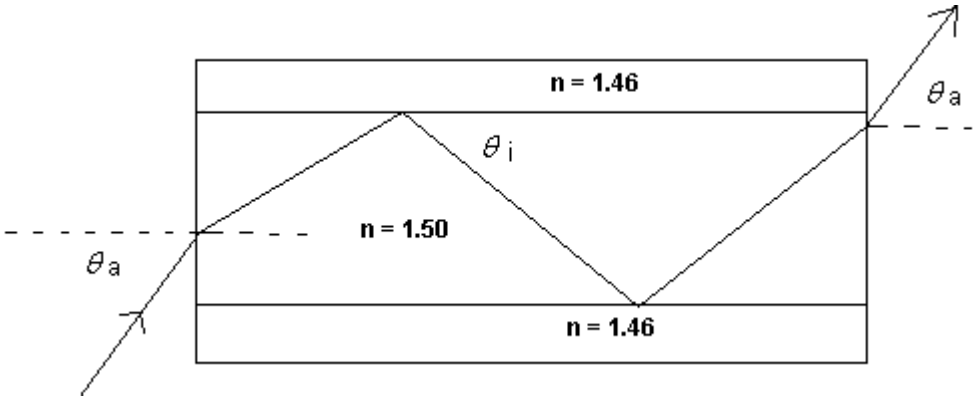
_____

_____

1 mark

$\theta_C =$

QUESTION 4
A step-index optical fibre has a glass core of refractive index 1.500 and a surrounding cladding of refractive index 1.460.



(a) Calculate the maximum angle θi for which the light will be totally reflected.

_____

_____

_____

_____

2 marks

$\theta =$

(b) Proportionately, how much further will light travel if it zig-zags down the length of the pipe at this angle than if it travels straight down the centre?

2 marks

% more

(c) What is the numerical aperture for this fibre?

2 marks

NA =

(d) What is the acceptance angle θa for this fibre if the fibre is in air (n = 1.000)?

2 marks

$\theta =$

(e) Discuss the problems associated with using this fibre for long distance broadband transmission.

_____

_____

_____

_____

2 marks

QUESTION 5

The input signal for a length of fibre is 3.0 mW. The attenuation of the optical fibre is 1.2 dB km^{-1}. A photo-detector will respond to a signal with a minimum power of $50\,\mu W$.

(a) What is the attenuation of a length of this fibre when the output signal has a power of $50\,\mu W$?

_____

_____

_____

_____

2 marks

dB

(b) What is the maximum length of fibre that can produce a detectable signal?

_____

_____

_____

_____

2 marks

km

DETAILED STUDY 3 - SOUND

QUESTION 1
At a distance of 4.0 m from a loudspeaker, a sound intensity of 1.25×10^{-4} Wm^{-2} is detected.

(a) What sound intensity would be detected at 1.0 m from the source?

_____

_____

_____

_____

2 marks

Wm^{-2}

(b) What sound level would be detected at 1.0 m from the source?

_____

_____

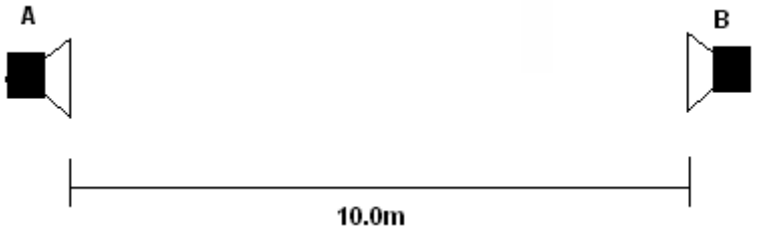
_____

_____

2 marks

dB

QUESTION 2
Two speakers facing each other are connected to the same signal generator/amplifier and are producing 340 Hz. Assume the speed of sound is 340 ms^{-1}.



Mary stands in the centre, equidistant to speakers A and B. She then moves towards speaker B and experiences a sequence of loud and quiet regions. She stops at the second region of quietness experienced. How far is she from speaker B? Explain your reasoning.

_____

_____

_____

_____

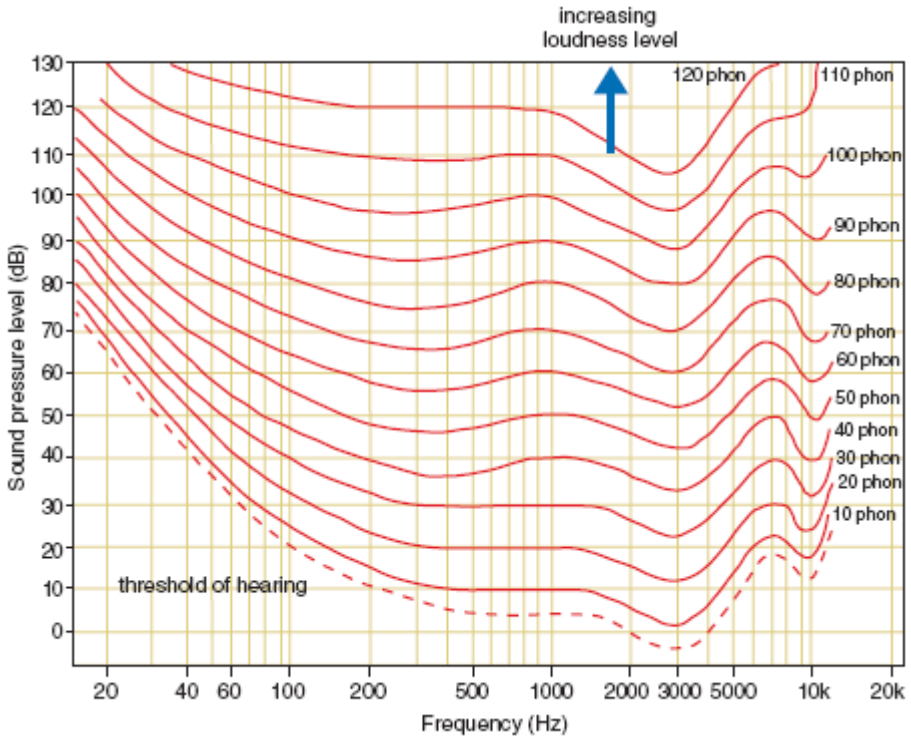
_____

_____

3 marks

m

QUESTION 3
The following data demonstrates hearing responses across the range of human hearing.



(a) What frequency would be heard most easily?

Hz

1 mark

(b) What sound level at 50 Hz would seem to be the same loudness as 70dB at 1000 Hz?

_____

_____

_____

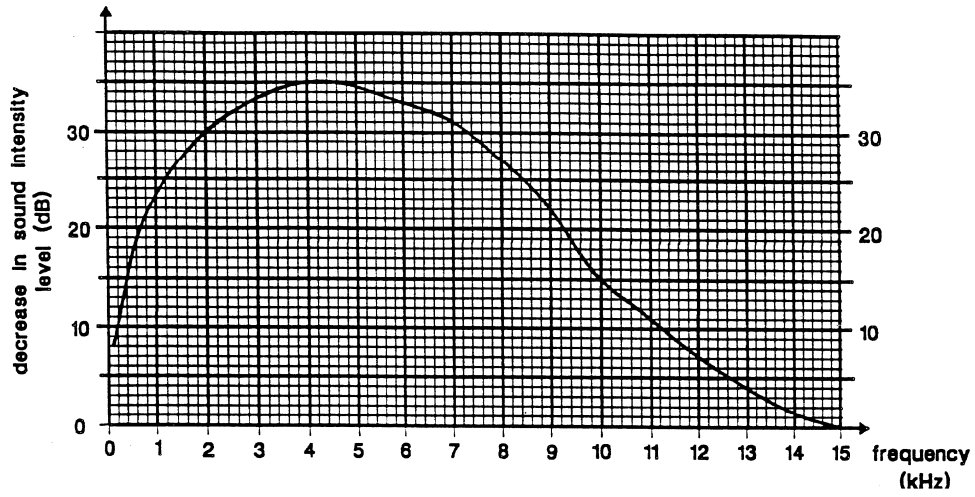
_____

2 marks

dB

QUESTION 4

The amount by which a pair of earmuffs decreases the sound intensity level is shown in the graph below:



The faintest 4.0 kHz tone Harry can hear without earmuffs reads 5.0 dB on the meter beside him. He then puts the earmuffs on, and increases the level of the 4.0 kHz tone until he can just hear it again.

Using the data in the graph above, what is the sound intensity level reading on the meter (in dB) now?

_____

_____

_____

_____

2 marks

dB

QUESTION 5

(a) Calculate the lowest resonant frequency that can be obtained with an 80 cm pipe open at both ends. Assume the speed of sound is 340 ms^{-1}.

_____

_____

_____

_____

2 marks

Hz

(b) The temperature of the room is raised, which increases the speed of the sound wave from 340 ms^{-1} to 352 ms^{-1}. The lowest resonant frequency at the higher temperature is now:

A Higher
B Lower
C Not affected by temperature

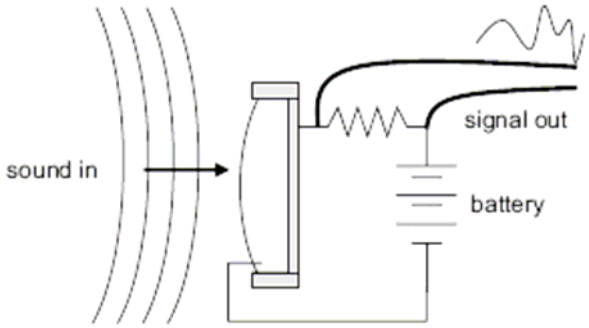
2 marks

(c) The wavelength of the lowest resonant frequency at the higher temperature is:

A Higher
B Lower
C Not affected by temperature

2 marks

QUESTION 6
The following diagram represents a particular microphone.



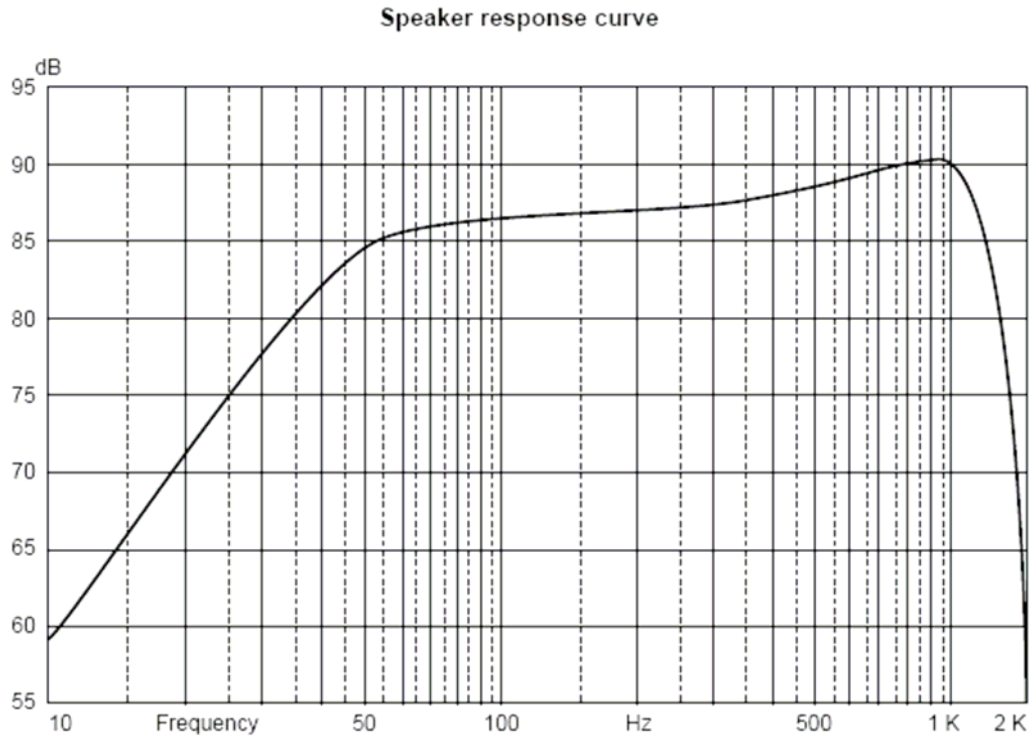
(a) Identify the type of microphone this diagram represents.

1 mark

(b) Describe how this microphone detects the wave and produces the signal output.

3 marks

QUESTION 7
The response curve for a loudspeaker is shown below:



(a) State the frequency range where the speaker performs well.

1 mark

(b) The speaker is used in a speaker box with crossover circuits to supply separate speakers within the box. What specific application would this speaker perform within the system?

2 marks

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