INSIGHT

Trial Exam Paper

2011

PHYSICS

Written examination 2

STUDENT NAME:

QUESTION AND ANSWER BOOK

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

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A – Core – Areas of Study			
1. Electric power	15	15	35
2. Interactions of light and matter	13	13	29
B – Detailed Studies			
1. Synchrotron and its applications	13	13	26
OR			
2. Photonics	13	13	26
OR			
3. Sound	13	13	26
Total			142

- Students are permitted to bring the following items into the examination: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring sheets of paper or white out liquid/tape into the examination.

Materials provided
- The question and answer book of 37 pages, with a separate data sheet.

Instructions
- Write your **name** in the box provided.
- Remove the data sheet during reading time.
- Answer all the questions in the space provided and always show your working where space is provided.
- You must answer all questions in English.

Students are NOT permitted to bring mobile phones or any other electronic device into the examination.

SECTION A – Core

Instructions for Section A

Answer **all** questions for **both** Areas of study in this section of the paper.
When answer boxes are provided, write your final answer in the box.
If a unit is printed in an answer box, give your final answer in that unit.

Area of study 1 – Electric power

Use the following information to answer Questions 1 and 2.

A solenoid, which is a coil of wire, is connected to a variable DC power supply, as shown in Figure 1.

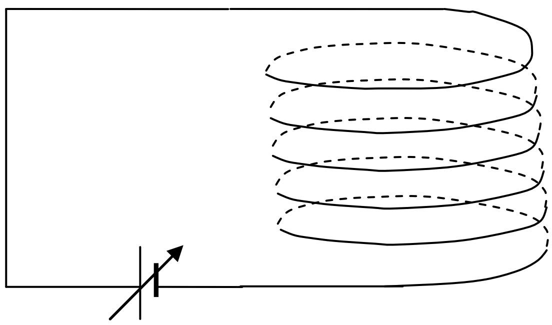


Figure 1

Question 1
Complete the diagram by sketching five magnetic field lines, with appropriate arrows, which illustrate the magnetic field inside and around the coils. Create your sketch over the diagram shown above.

2 marks

Question 2
Describe what changes will occur to the density of the magnetic field lines when a bar made of iron is placed inside the solenoid and the voltage of the battery is increased.

2 marks

Use the following information to answer Questions 3 and 4.
The following apparatus in Figure 2 shows a metal rod placed between two magnets. The pole pieces of the magnet are 20 cm long and 5 cm high and the uniform magnetic field between them is 3 mT. A current of 1.2 A flows in the rod from *P* to *Q* and a force is experienced by the rod pushing it in one of the directions *A*, *B*, *C* or *D*.

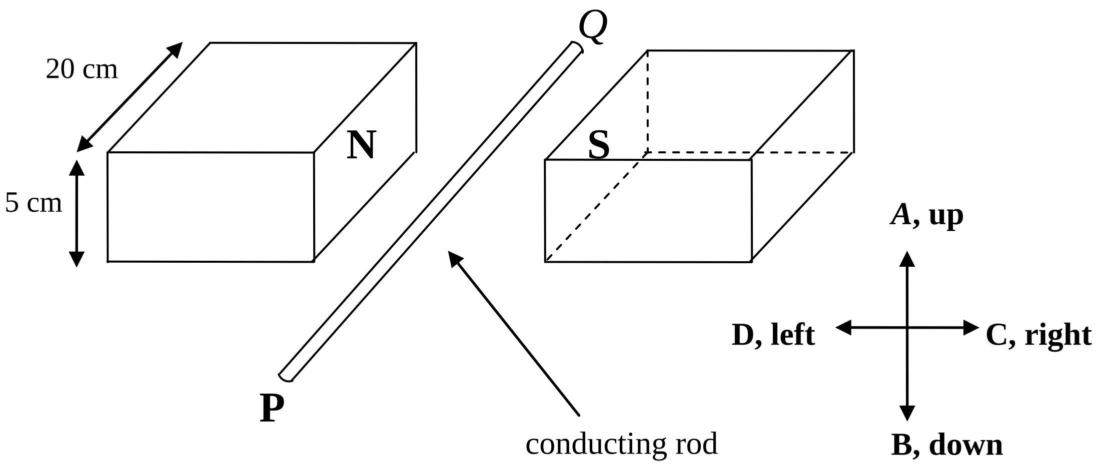


Figure 2

Question 3
Estimate the magnitude and direction of the force on the rod, the direction being stated as A, B, C or D.

3 marks

Question 4
Explain the primary cause of the force experienced by the rod. In your explanation you must refer to the magnetic field generated by the current.

2 marks

Use the following information to answer Questions 5 to 7.

A square coil, *ABCD*, with sides of 3 cm and consisting of a single turn, is moved at a uniform speed of 3 cm s^{-1} into a region of constant magnetic field and continues to move through it to the other side. The magnetic region is 12 cm long. For simplicity of analysis, assume the magnetic field drops from a uniform magnitude of 0.25 T to zero at the end of the field.

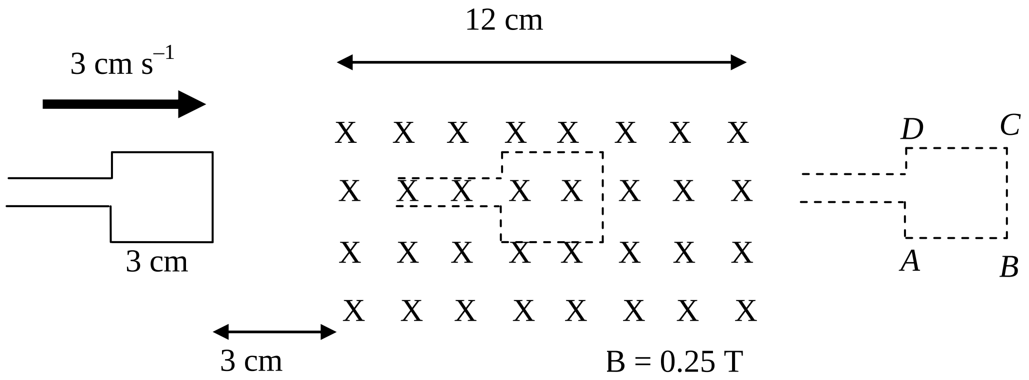
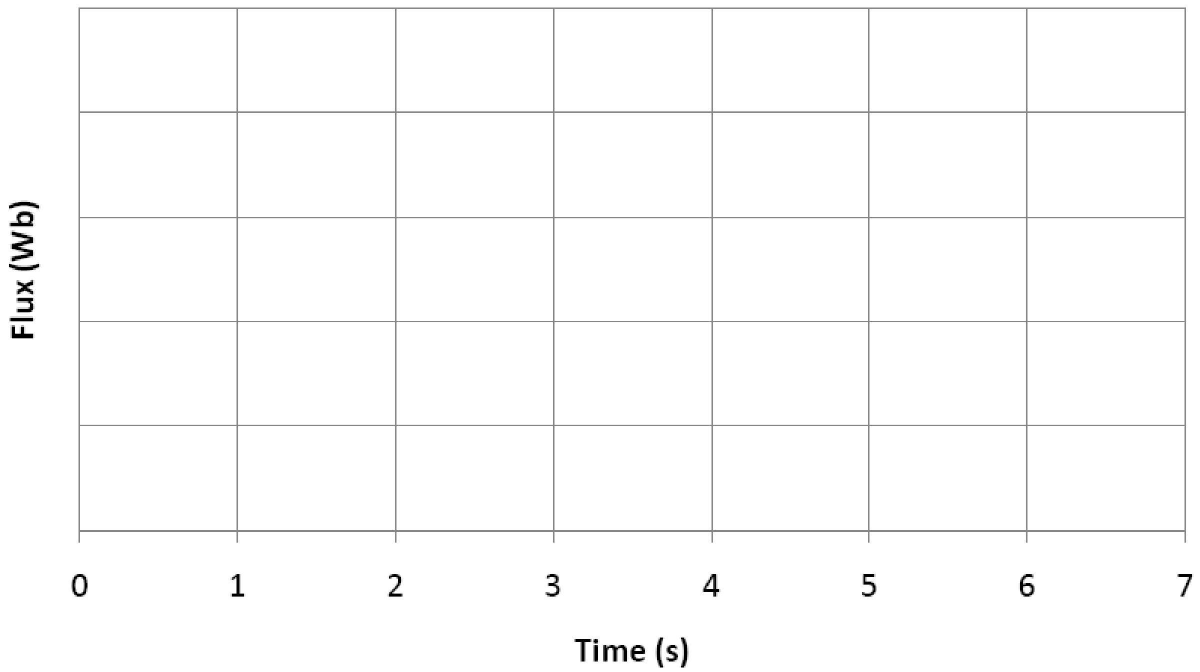


Figure 3

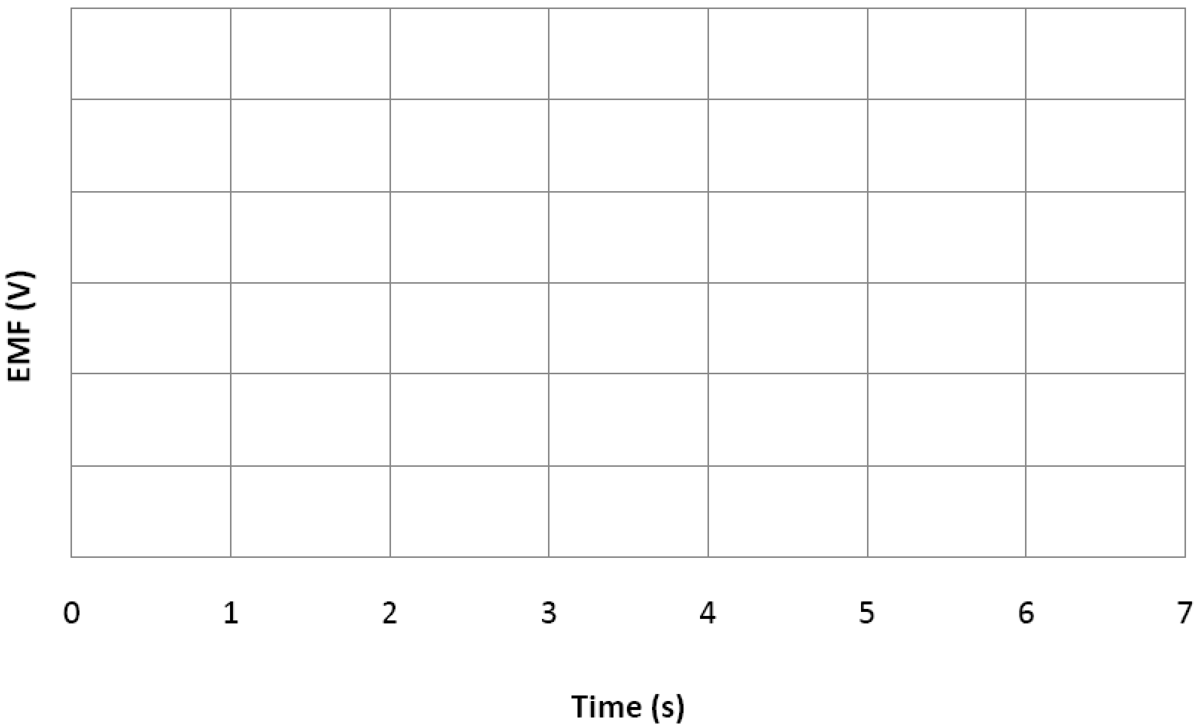
Question 5

On the axes below, draw a graph showing the flux through the coil as a function of time for the first 7 seconds of its motion, from the time it starts at the initial location (shown on the left side of the figure) and continues through the magnetic field emerging from the other side (shown on the right).



3 marks

Question 6
The coil is now replaced with another coil of the same size but consisting of six turns instead of one. Again, the coil is moved with the same constant speed through the magnetic region. On the axes below, draw the induced EMF in the coil for the first 7 seconds of its motion.



3 marks

Question 7
When the coil first enters the magnetic field, will the direction of induced current be from *A* to *B* or from *D* to *C*? Explain your reasoning clearly.

2 marks

Use the following information to answer Questions 8 and 9.

A simple DC motor has a square coil with sides of 5 cm. It has 50 turns and carries a current of 1.5 A in a uniform magnetic field of strength 5 mT, which is provided between two poles of a permanent magnet. Initially, it is positioned as shown in Figure 4 below.

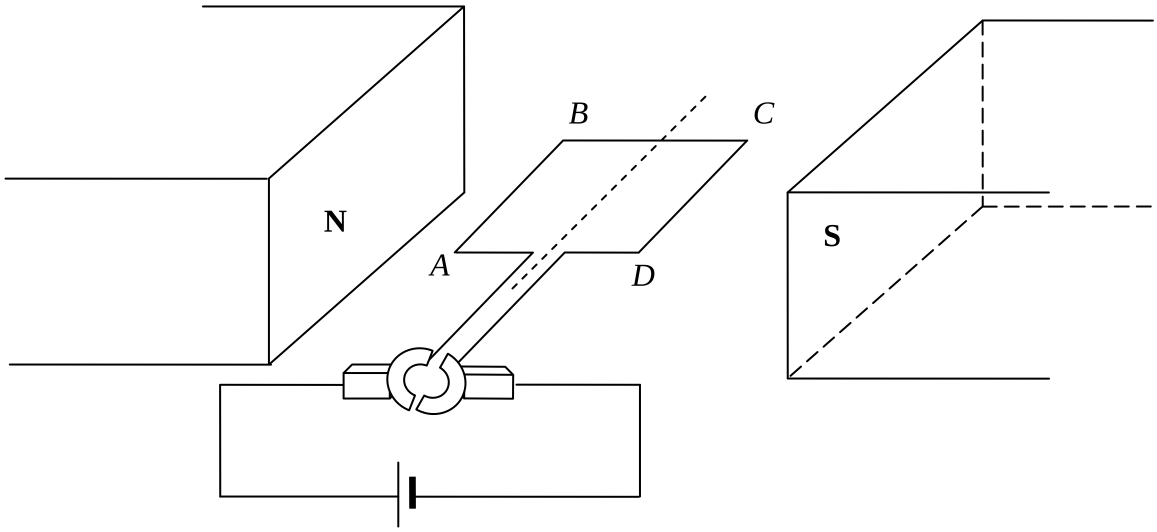


Figure 4

Question 8

What is the magnitude and direction of force on the side *AB* when the coil is in the position shown?

2 marks

Question 9

Which one of the graphs **A** to **D** best illustrates the magnitude of force on the side *AB* as the coil rotates through a cycle? Explain your reasoning.

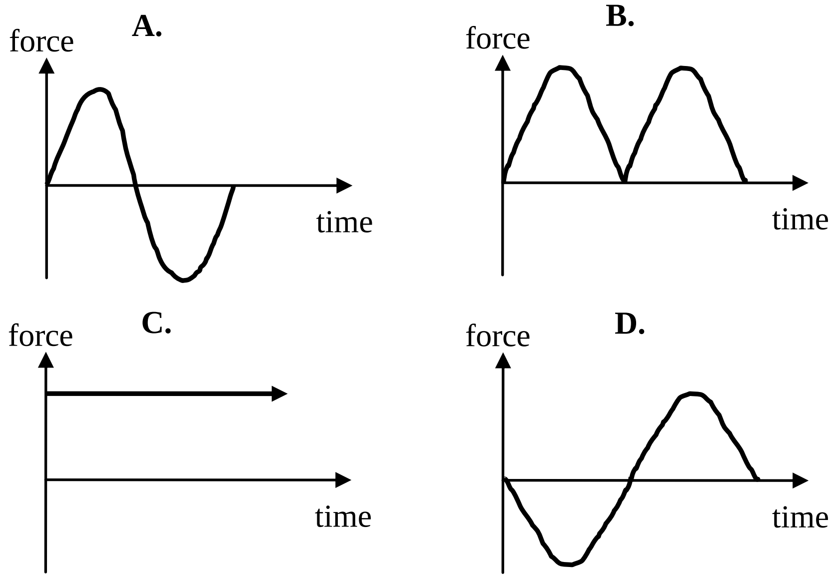


Figure 5

2 marks

Use the following information to answer Questions 10 to 13.

A power station generates AC power of 500 MW at 25 000 V to power a village 80 km away. Two ideal transformers, T1 and T2, are used to assist with power transmission. Transformer T1 has a turn ratio of 1 : 100. The total resistance of the power lines between the two transformers is a total of 5 Ω.

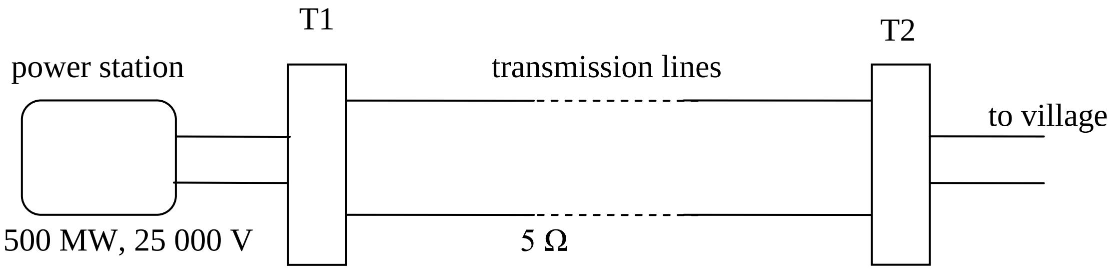


Figure 6

Question 10

What is the current in the transmission lines?

2 marks

Question 11

Calculate the power loss in the transmission lines.

2 marks

Question 12
What is the voltage in the primary coil of transformer T2? Show your working.

2 marks

Question 13
Suggest two ways to reduce power loss in the transmission lines, explaining clearly why the amount of power lost will be reduced.

3 marks

Use the following information to answer Questions 14 and 15.
A coil of wire is connected to a DC power supply, as shown in Figure 7 below.

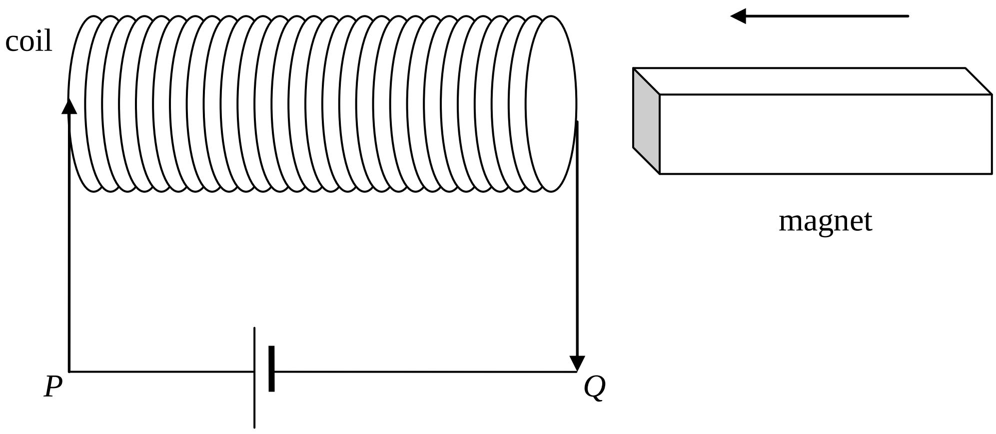


Figure 7

Question 14
In the first instance, a DC current flows in the coil. To determine the direction of the current, a magnet is brought to the coil and is found to be repelled. Is it a north or a south pole of the magnet that is inserted into the coil? Explain your answer.

2 marks

Question 15

With the current now switched off and the power supply replaced by an ammeter, a current is found to be induced when the magnet is re-inserted with the north pole facing towards the coils. See Figure 8.

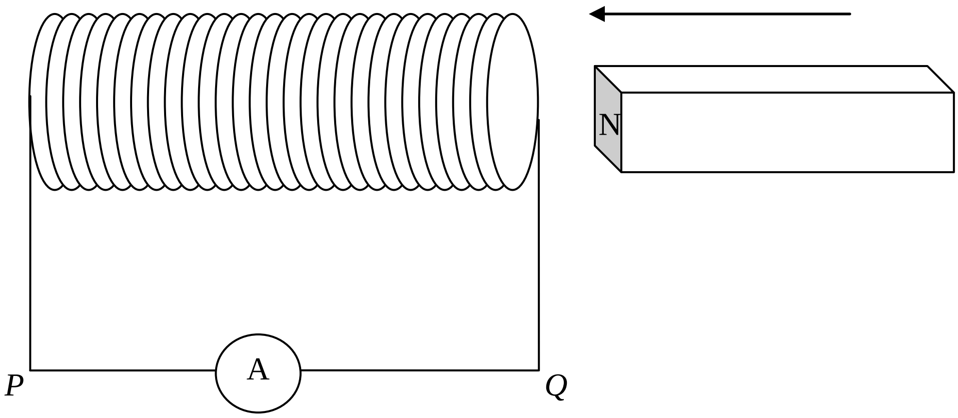


Figure 8

Will the current now flow from *P* to *Q* or from *Q* to *P* through the ammeter? Explain your answer.

3 marks

END OF AREA OF STUDY 1

Area of study 2 – Interactions of light and matter

Use the following information to answer Questions 1 to 5.

A photoelectric experiment is carried out using the equipment shown in Figure 1 below, in which a powerful light source of variable frequency is shone on a metal electrode enclosed in an evacuated glass tube. By changing the voltage of the variable battery, the photocurrent can be reduced to zero.

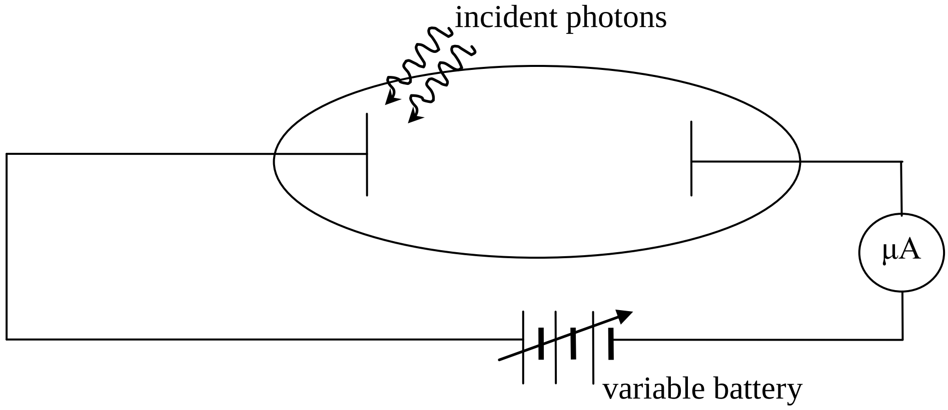


Figure 1

As the frequency and/or intensity of the incident light is changed, the voltage required to make the photocurrent zero is recorded. A graph is then plotted showing the measured photocurrent against the voltage of the variable battery that just reduces the current to zero. The shape of the graph is shown in Figure 2.

At a frequency of 5×10^{14} Hz, a cut-off voltage of –1.1 V is recorded. The work function of the metal is 1.5 eV.

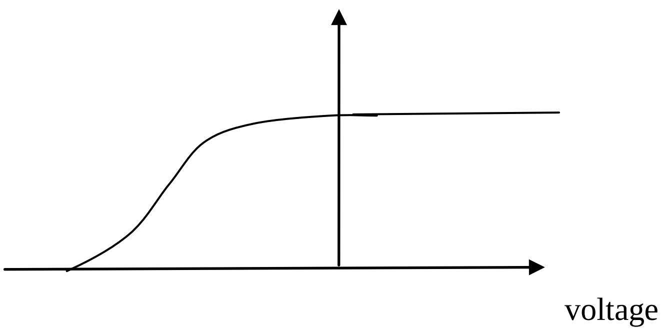


Figure 2

Question 1
What is the energy, in J, of one photon of the light beam of frequency 5×10^{14} Hz?

2 marks

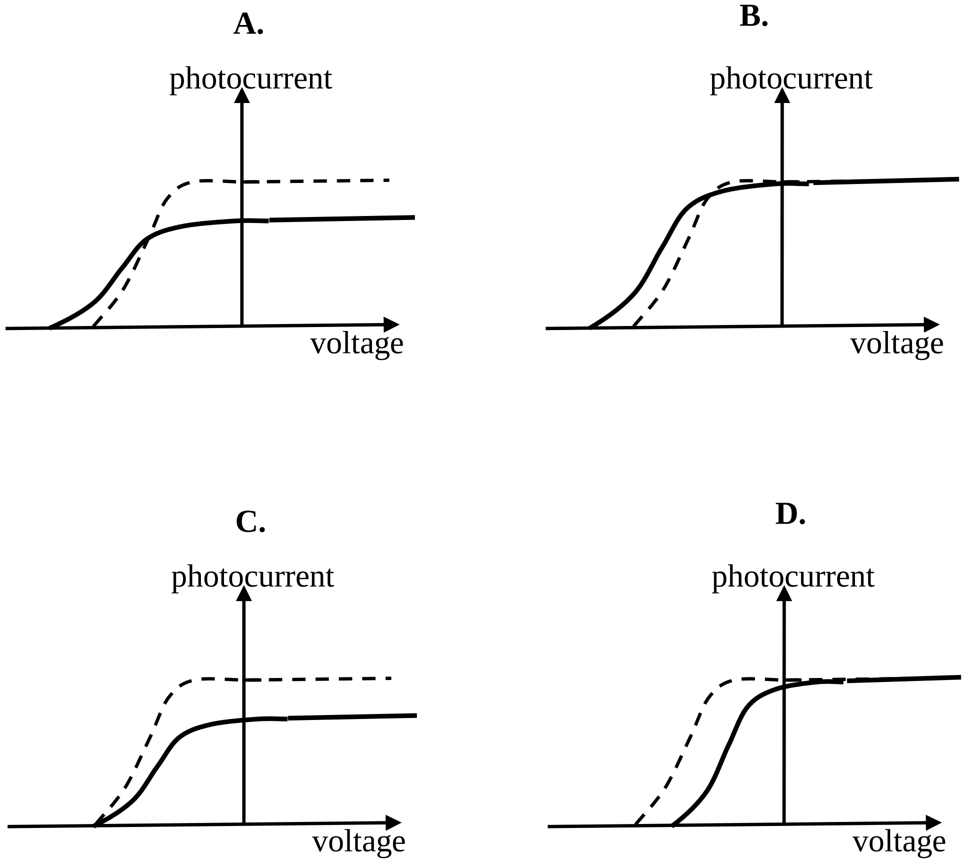
Question 2
What is the speed of the fastest moving photoelectron that required a cut-off voltage of –1.1 eV?

3 marks

Question 3
Using the data collected in this experiment, estimate the value of Planck's constant, in eV s.

2 marks

Question 4
In a subsequent experiment, the frequency of the light source is now increased and the intensity is reduced. When compared to the original graph (shown for comparison as the dashed line), which one of the graphs **A** to **D** (showing a solid line) is most likely to be observed now? Explain your answer.



3 marks

Question 5
Does this experiment better demonstrate the wave-like or particle-like nature of light? Explain your reasoning.

2 marks

Use the following information to answer Questions 6 to 8.

In an experiment to study diffraction, a beam of electrons with energy 450 eV strikes a crystal with inter-atomic distance 1.1×10^{-10} m.

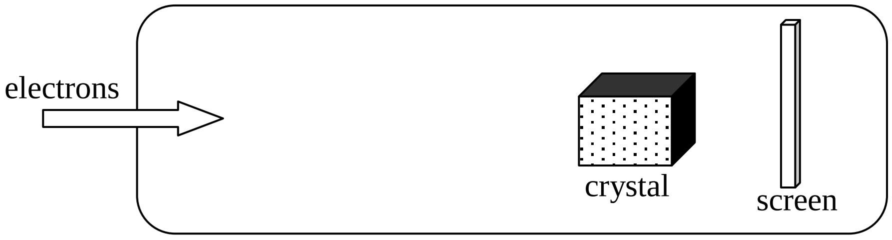


Figure 3

Question 6

Will the extent of diffraction be **significant**? Use suitable calculations to determine your answer.

3 marks

Question 7

What is the frequency of an electromagnetic wave that will produce the same wavelength as a 450 eV electron?

2 marks

Question 8

Calculate the momentum of a photon of energy 450 eV.

2 marks

Use the following information to answer Questions 9 and 10.

Figure 4 below represents Young's double slit experiment, which is used here to find the wavelength of a laser light source. When the laser light is shone through the double slits S_1 and S_2, a pattern of fringes is observed on the screen. A point, *P*, on the third dark band is being considered. The distance from S_1 to *P* is greater by 1150 nm when compared to the distance from *P* to S_2.

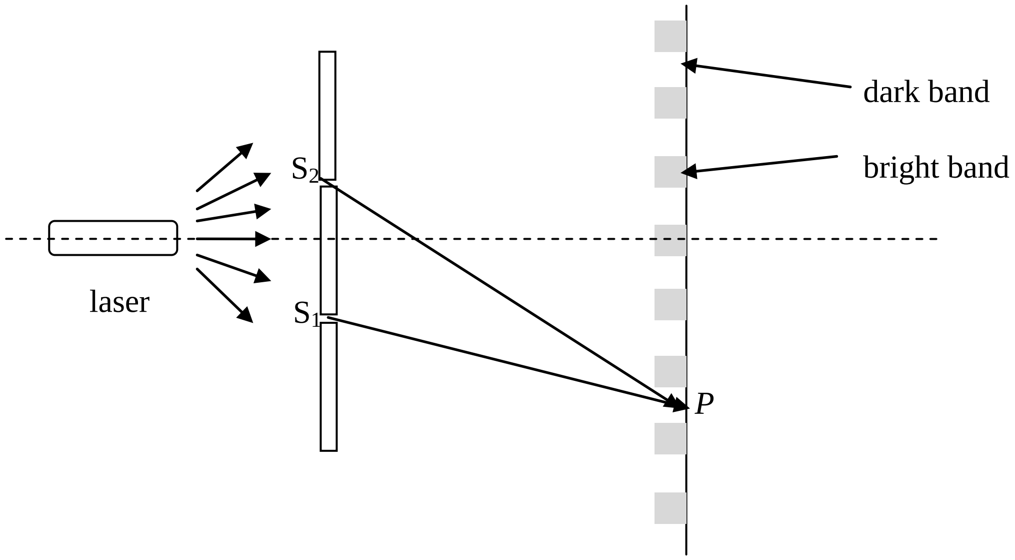


Figure 4

Question 9

Calculate the wavelength of the light emitted by the laser.

2 marks

Question 10

The laser is then exchanged for one with a higher wavelength. Which one of the following statements best describes the change that will now occur in the pattern of dark and bright bands?

A. The bands will move closer together.
B. The bands will become more intense.
C. The bands will become less intense.
D. The bands will move farther apart.

2 marks

Use the following information to answer Questions 11 to 13.

Figure 5 represents part of the energy level spectrum of a gas at room temperature. A sample of the gas is enclosed in a partially evacuated tube, upon which a beam of photons is shone.

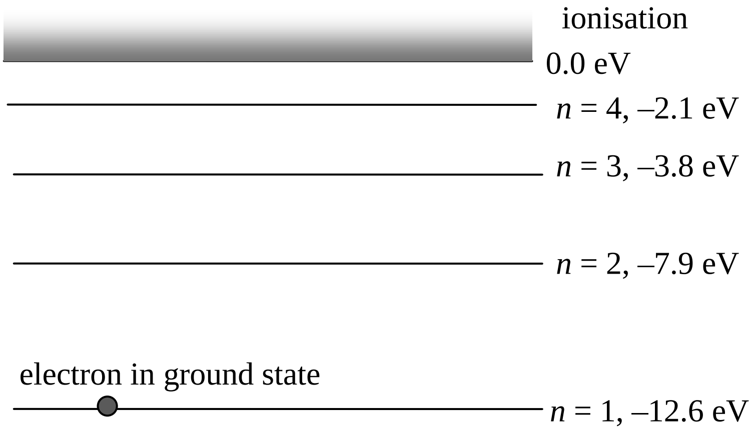


Figure 5

Question 11

Calculate the wavelengths of all of the emitted radiation when photons of 8.8 eV are shone onto the gas that is at room temperature. Express your answer in nm.

3 marks

Question 12

Explain, using suitable calculations, what the effect will be on an electron at ground level when photons of energy 14.2 eV are shone onto the gas at room temperature.

2 marks

Question 13

Determine the energy of the incident photons which will result in just one spectral line in the emission spectrum.

1 mark

END OF AREA OF STUDY 2

END OF SECTION A
TURN OVER

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 in the boxes provided.
A correct response scores 2 marks, an incorrect response scores 0.
Marks are not deducted for incorrect answers.

Detailed study 1 – Synchrotron and its application

Use the following information to answer Questions 1 to 3.

Two parallel metal electrodes are 4 cm apart and are enclosed in a partially evacuated tube. When powered by a 9.0 V DC battery, a uniform electric field is created between the electrodes. An electron is placed upon one electrode, as shown in Figure 1, and experiences a force as a result of the electric field.

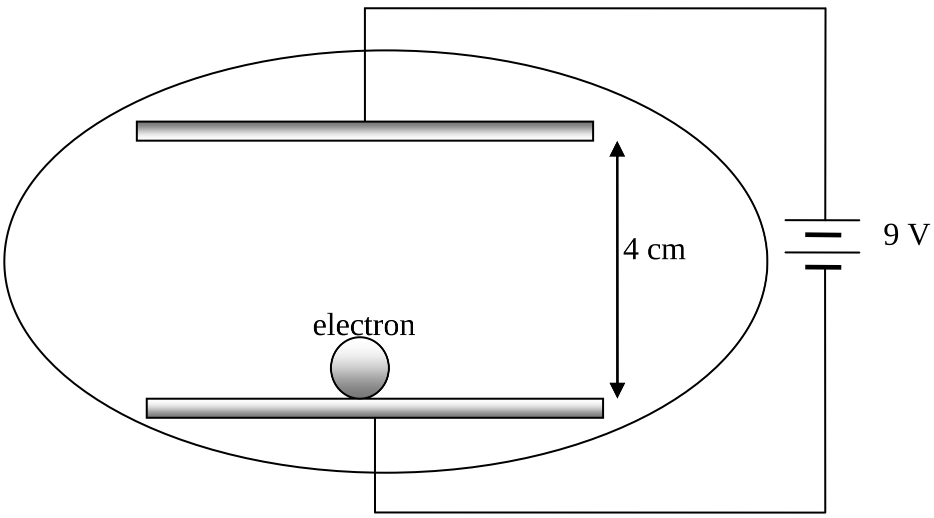


Figure 1

Question 1
The magnitude of the electric field created by the parallel plates is closest to

A. 0.36 V m^{-1}
B. 2.25 V m^{-1}
C. 36 V m^{-1}
D. 225 V m^{-1}

Question 2
The speed with which the electron will strike the positive plate as a result of the electric field is nearest in magnitude to
A. 1.8×10^6 m s^{-1}
B. 3.6×10^6 m s^{-1}
C. 1.8×10^7 m s^{-1}
D. 3.6×10^7 m s^{-1}

Question 3
If the voltage across the plates is increased 10 times, the speed of the electron will
A. decrease by a factor of about 3.2.
B. increase by a factor of 10.
C. increase by a factor of about 3.2.
D. decrease by a factor of 10.

Use the following information to answer Questions 4 and 5.

In a synchrotron, a beam of electrons, travelling at constant speed, enter a uniform magnetic field of 35 mT at right angles to the field. As a result of the magnetic field, the electrons experience a force that causes them to bend in a radius of 0.4 m.

Question 4

The energy of the electrons entering the field is closest to

A. 10.3 MeV
B. 17.2 MeV
C. 21.4 MeV
D. 1.1 MeV

Question 5

The magnetic field is now doubled and the speed of the electrons is halved. The radius of the beam in the magnetic field will now be

A. half of the original radius.
B. double the original radius.
C. one-quarter of the original radius.
D. four times the original radius.

Questions 6 to 9 relate to the Australian Synchrotron.

Question 6

In the Australian Synchrotron, electrons are generated in the

A. linac.
B. wiggler.
C. electron gun.
D. booster ring.

Question 7

The electrons achieve a speed of about 99.99% of the speed of light in the

A. linac.
B. wiggler.
C. undulator.
D. storage ring.

Question 8

Synchrotron radiation is best described as an intense

A. beam of electrons of synchronised energy.
B. beam of photons of synchronised energy.
C. beam of photons produced by the synchronised use of magnetic fields.
D. pulse of photons of coherent and synchronised radiation.

Question 9

Which one of the following best describes the advantages of using synchrotron radiation over a conventional X-ray beam?

A. Synchrotron radiation is polarised and coherent.
B. Synchrotron radiation has high intensity, has a range of tuneable energies and can be pulsed for time-resolved studies.
C. Synchrotron radiation consists of high-intensity radiation, containing the entire electromagnetic spectrum.
D. Synchrotron radiation is intense and can be filtered for time-resolved studies

Use the following information to answer Questions 10 and 11.

A beam of X-rays of wavelength 0.15 nm is fired at an unknown crystal in a diffractometer. The crystal is rotated to vary the incident angle, θ, between the X-rays and the crystal planes. A diffraction pattern is obtained which gives a number of peaks at various incident angles.

Question 10

The $n = 1$ peak is obtained at an incident angle of 14.1°. The corresponding d spacing between the crystal planes is closest to

A. 0.3 nm
B. 0.6 nm
C. 1.2 nm
D. 1.8 nm

Question 11

A crystal is now placed in the diffractometer with a known d spacing of 0.8 nm. Which one of the following statements best lists the incident angles, θ, at which a Bragg diffraction peak would be observed?

A. 5.38°, 10.81°, 16.33°.
B. 5.37°, 21.62°, 32.66°.
C. 10.74°, 10.81°, 16.33°.
D. 5.37°, 10.74°, 16.11°.

Use the following information to answer questions 12 and 13.

A beam of X-ray photons of frequency 4.2×10^{18} Hz are scattered by a thin metal foil. Both Thomson and Compton scattering are observed. The frequency of the scattered photons and/or electrons are also measured.

Question 12

Which is the closest in value to the frequency of the scattered X-rays upon undergoing Thomson scattering?

A. 4.2×10^{18} Hz
B. 2.1×10^{18} Hz
C. 8.4×10^{18} Hz
D. 1.0×10^{18} Hz

Question 13

Upon undergoing Compton scattering by the X-ray photon, an electron is emitted at a speed of 1.8×10^{7} m s^{-1}. The energy of the scattered X-ray photon is closest in magnitude to

A. 1650 eV
B. 2480 eV
C. 15000 eV
D. 16500 eV

END OF DETAILED STUDY 1

SECTION B – END OF DETAILED STUDY 1
TURN OVER

Detailed study 2 – Photonics

Use the following information to answer Questions 1 and 2.

A light-emitting diode (LED) emits light when it is connected in forward bias and a current flows through it. A band diagram of a LED and its *I–V* characteristic are shown in Figure 1.

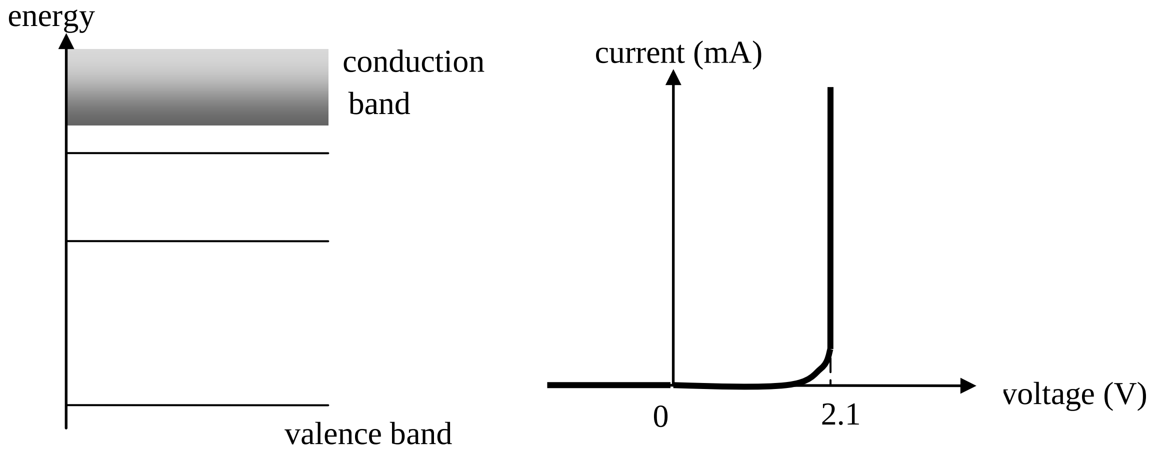


Figure 1

Question 1

The magnitude of energy between the valence band and conduction band is

A. 2.1 J
B. 1.31×10^{-19} J
C. 3.36×10^{19} J
D. 3.36×10^{-19} J

Question 2

In the spectrum of the LED, the wavelength corresponding to the highest intensity will be closest to

A. 450 nm
B. 510 nm
C. 590 nm
D. 700 nm

Use the following information to answer Questions 3 and 4.

Figure 2 below shows a laser that has a discharge cavity and two mirrors, one of which is partially reflecting. Laser light is emitted through the partially reflecting mirror.

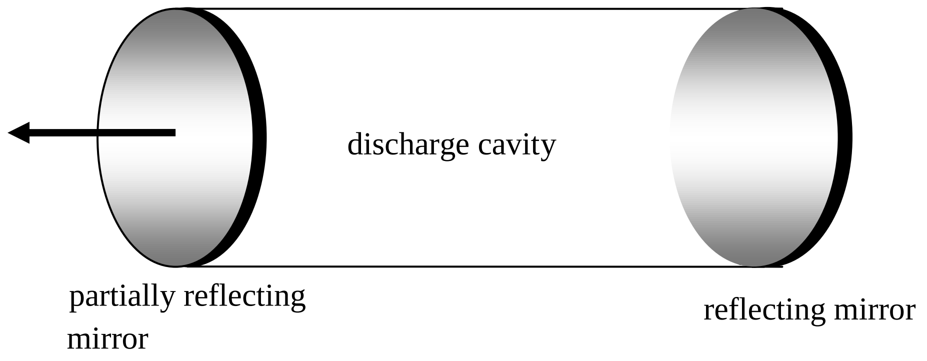


Figure 2

Question 3

Laser light is best described as

A. intense, incoherent and collimated.
B. intense, coherent and monochromatic.
C. in phase, single wavelength and very intense.
D. the amplified light of a single wavelength and in phase.

Question 4

Which one of the following best describes the important purpose performed by the mirrors?

A. The mirrors reflect photons back and forth in the chamber to amplify light by the stimulation of photons.
B. The mirrors trap photons for a longer time in the cavity so that they gain more energy.
C. The mirrors reflect photons in the chamber so that they can all get in phase.
D. The mirrors ensure that laser light emerges from only one end.

Use the following information to answer Questions 5 to 8.

Figure 3 shows an optical fibre that is constructed from a core, cladding and a jacket. The refractive index of the core and cladding material is 1.48 and 1.51, although not necessarily in this sequence.

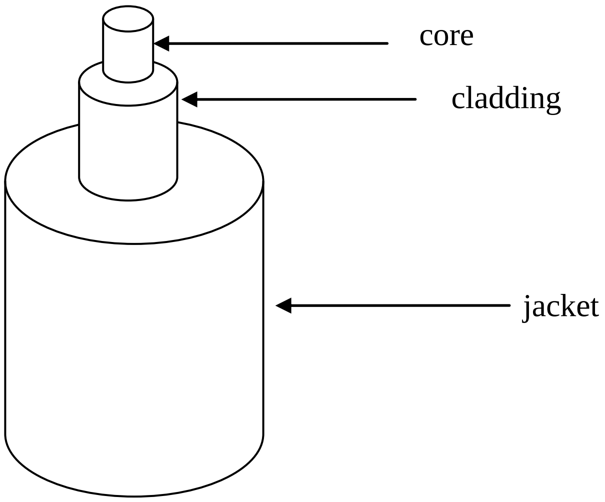
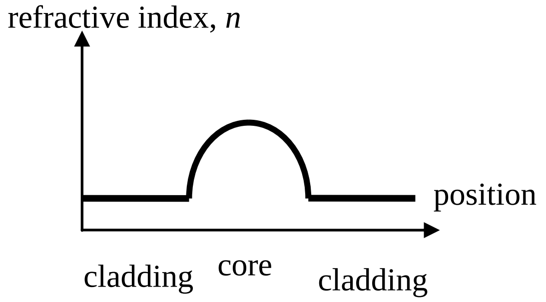


Figure 3

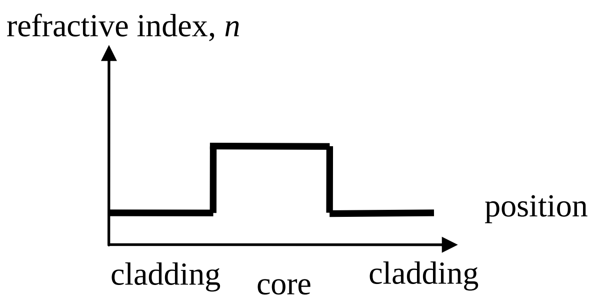
Question 5

Which one of the following best represents the refractive index of the core and cladding as a function of cross-section for a graded-index multimode (GIMM) fibre?

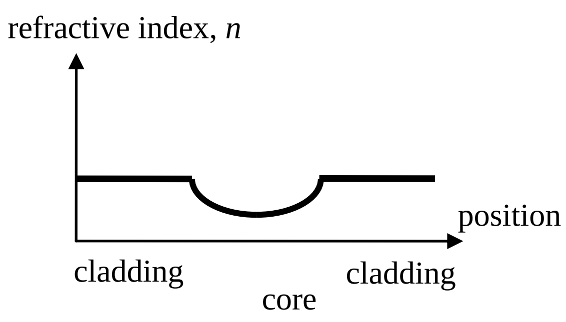
A.



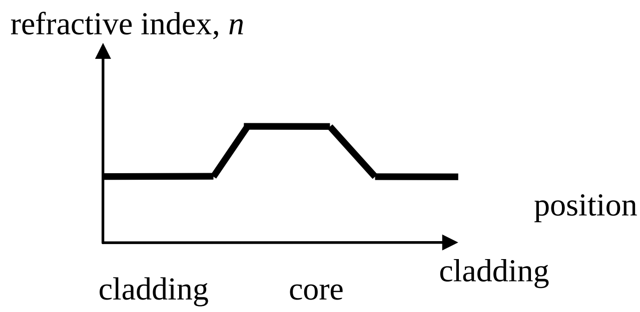
B.



C.



D.



Question 6
For a light beam entering the core and reflecting off the cladding, the critical angle is closest to

A. 64.9°
B. 72.6°
C. 78.6°
D. 83.2°

Question 7
The numerical aperture for the optical fibre is closest in value to

A. 0.3
B. 0.25
C. 0.2
D. 0.15

Question 8
The attenuation of this optical fibre is 0.4 dB km^{-1}. A signal of 3.5 mW is sent through a 6 km fibre. The output signal will be closest to

A. 3.0 mW
B. 2.5 mW
C. 2.0 mW
D. 1.5 mW

Use the following information to answer Questions 9 to 13.

Optical fibres are of different types, such as step index and single mode, single mode or multimode. Their application depends on factors such as cost, distance of communication and amount of dispersion.

Question 9

Modal dispersion is most significant in

A. single-mode fibre.
B. multimode, step-index fibre.
C. multimode, graded-index fibre.
D. single-mode, graded-index fibre.

Question 10

Modal dispersion can be minimised best using

A. multimode fibre.
B. multimode, graded-index fibre.
C. multimode, step-index fibre.
D. single-mode fibre.

Question 11

Material dispersion is most significant in

A. single-mode fibre.
B. multimode, step-index fibre.
C. multimode, graded-index fibre.
D. multimode, single-index fibre.

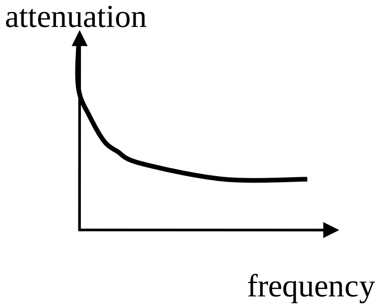
Question 12

Multimode fibres often have a graded index. The principal reason for this is to

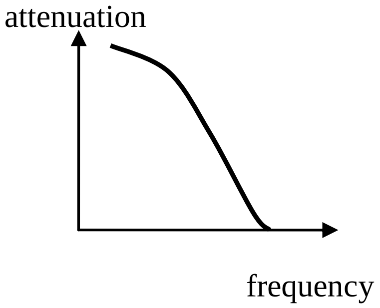
A. reduce material dispersion.
B. increase material dispersion.
C. increase modal dispersion.
D. reduce modal dispersion.

Question 13
Rayleigh scattering is best represented by which of the following attenuation graphs, all of which are drawn on the same scale?

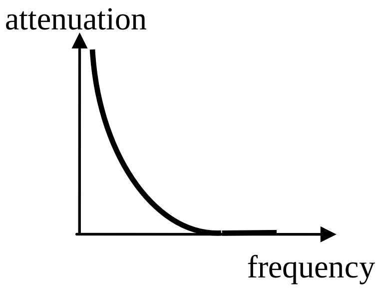
A.



B.



C.



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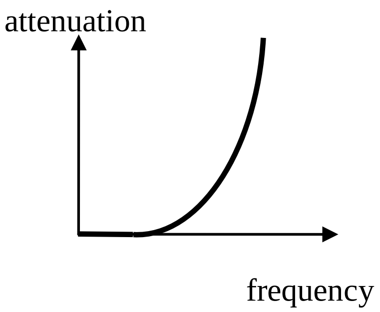


END OF DETAILED STUDY 2

SECTION B – END OF DETAILED STUDY 2
TURN OVER

Detailed Study 3 – Sound

Use the following information to answer Questions 1 to 4.

A flute can be considered to act as a pipe that is open at both ends. When the length of the air column in a particular flute is 1.5 m, the fundamental note detected is 120 Hz.

Question 1

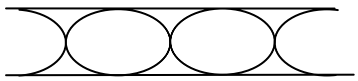
Under these conditions, the speed of sound in the air column of the flute is closest to

A. 340 m s^{-1}
B. 350 m s^{-1}
C. 360 m s^{-1}
D. 370 m s^{-1}

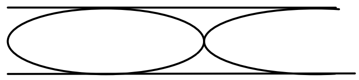
Question 2

When the air column in the flute is resonating so as to set up the third harmonic, which one of the following diagrams best shows the variation of air pressure along the distance of the pipe?

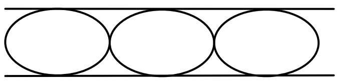
A.



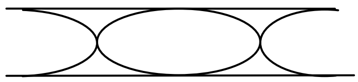
B.



C.



D.



Question 3
Which statement best describes the other frequencies that will also resonate in the flute?

A. 240 Hz but not 360 Hz.
B. 240 and 360 Hz but not 480 Hz.
C. 240 Hz, 360 Hz and 480 Hz.
D. 360 Hz but not 240 Hz.

Question 4
A clarinet is an example of a pipe closed at one end. In another experiment, one end of the flute is closed so that it models a clarinet. The length of the flute is now reduced to 0.81 m and the speed of sound is measured to be 340 m s^{-1}. Under these conditions, which one of the following values is closest to the fundamental frequency?

A. 209.9 Hz
B. 52.5 Hz
C. 184 Hz
D. 104.9 Hz

Use the following information to answer Questions 5 to 7.
In order to study the inverse square law and the addition of two sound waves, an experiment is carried out using two loudspeakers. The two loudspeakers, labelled L_1 and L_2, emit a frequency of 1000 Hz. A detector is placed at a position, *P*, which is 5.0 m equidistant from the two loudspeakers (see Figure 1).

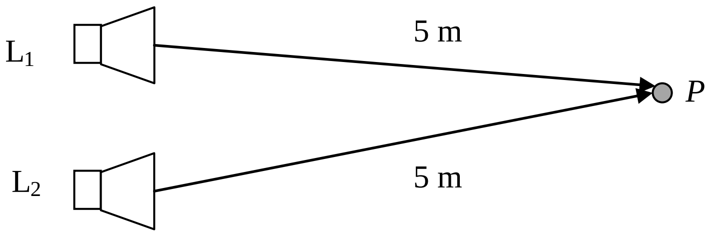


Figure 1

Question 5
The loudspeaker L_1 is switched on first and a loudness of 65 dB is recorded at *P*. A moment later, the second loudspeaker L_2 is turned on and L_1 is turned off. The loudness is then recorded as 70 dB at *P*. The ratio of the intensity from L_2 to that of the intensity from L_1 at *P* is closest to

A. 1 : 1.1
B. 5 : 16
C. 16 : 5
D. 1.1 : 1

Question 6
With loudspeaker L_2 still turned off, the volume of loudspeaker L_1 is adjusted such that the intensity at *P* is now 4.2×10^{-5} W m^{-2}. How far will the detector need to be placed from L_1 to record an intensity of 8.6×10^{-6} W m^{-2}? Select the answer that is closest to your calculations.

A. 9 m
B. 11 m
C. 13 m
D. 15 m

Question 7
In a different experiment, the two loudspeakers are both switched on and the sound waves of 65 dB and 70 dB from the two loudspeakers add on constructively at point *P*. The sound intensity level of the combined L_1 and L_2 speakers at point *P* is closest to

A. 71 dB
B. 73 dB
C. 75 dB
D. 77 dB

Use the following information to answer Questions 8 to 11.

In order to study the response of a particular loudspeaker to sounds of different frequencies, the loudspeaker, a dynamic microphone and a frequency synthesizer are connected, as shown in Figure 2.

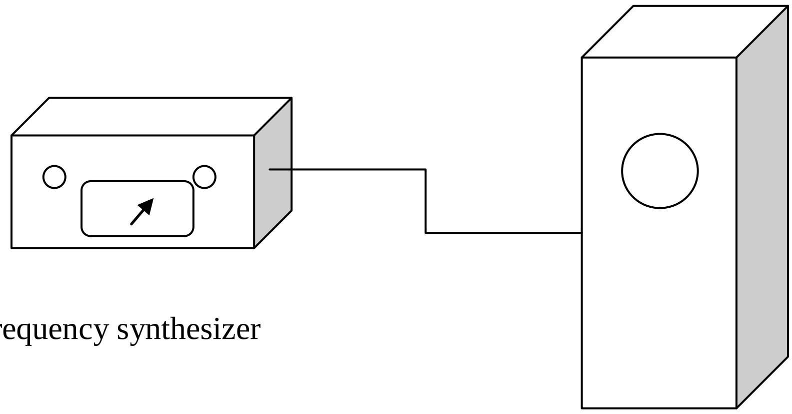


Figure 2

Question 8

A sound wave emitted from the loudspeaker has a power of 3×10^{-7} W. The sound wave is incident on a detector over an area of 5×10^{-5} m^2. Assuming that all output is directed at the detector, the loudness, *L*, measured by the detector will be closest to

A. 97.8 dB
B. 87.9 dB
C. 79.8 dB
D. 76.9 dB

Question 9

At a certain frequency, the diaphragm of the loudspeaker is seen to move forward and backward in an oscillating cycle. Ten such oscillations are observed in 0.1 s and in a range of frequencies around this, the loudspeaker has high fidelity. This loudspeaker is most likely to be

A. a woofer.
B. mid-range.
C. a tweeter.
D. an ultrasound.

Question 10
In another experiment, the frequency synthesizer generates a sound wave, whose shape is shown in Figure 3 below.

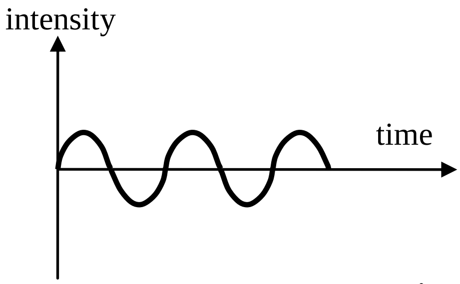
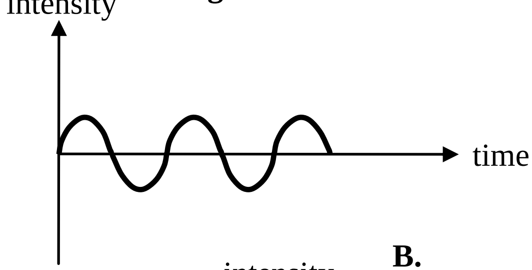


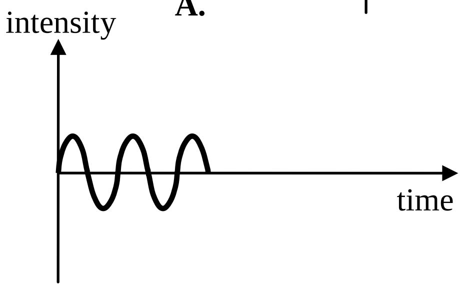
Figure 3

The following four waves are drawn on the same scale as the original wave. For ease of comparison, the original wave is also reproduced. Which one of the following (**A**–**D**) best represents a sound wave having half the frequency and double the amplitude of the original wave?

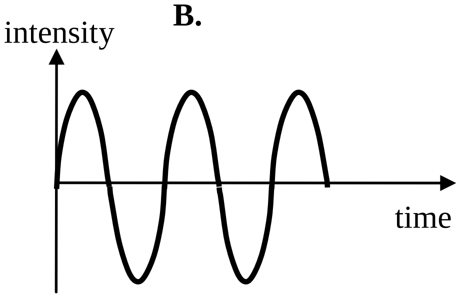
Original wave



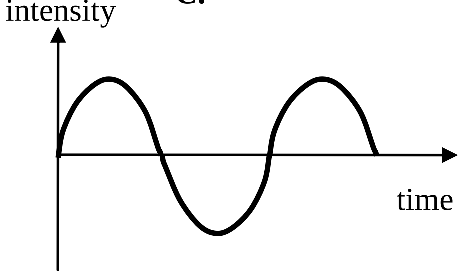
A.



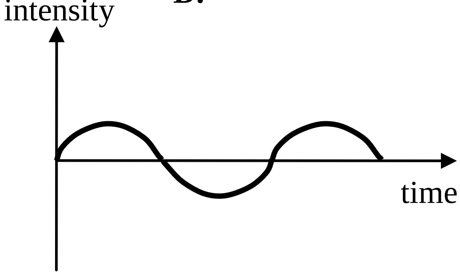
B.



C.



D.



Question 11
The frequency response of the speaker at a constant power is shown in Figure 4 below.

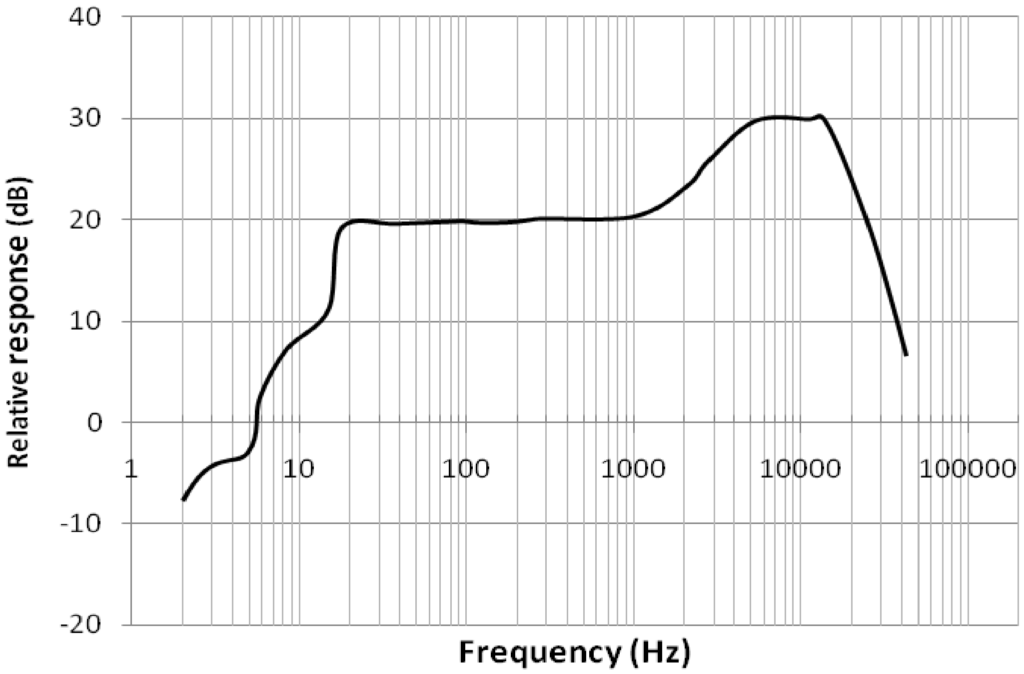


Figure 4

The **difference** in intensity between the response at 500 Hz and 5000 Hz is closest to

A. 9×10^{-10} W m^{-2}.
B. 9×10^{-9} W m^{-2}.
C. 1×10^{-10} W m^{-2}.
D. 1×10^{-9} W m^{-2}.

Use the following information to answer Questions 12 and 13.

Figure 5 below indicates lines of equal perceived loudness, as measured for Tony. The perceived loudness (phon) is based on 1000 Hz intensity and the threshold of hearing as 10^{-12} W m^{-2} at 1000 Hz.

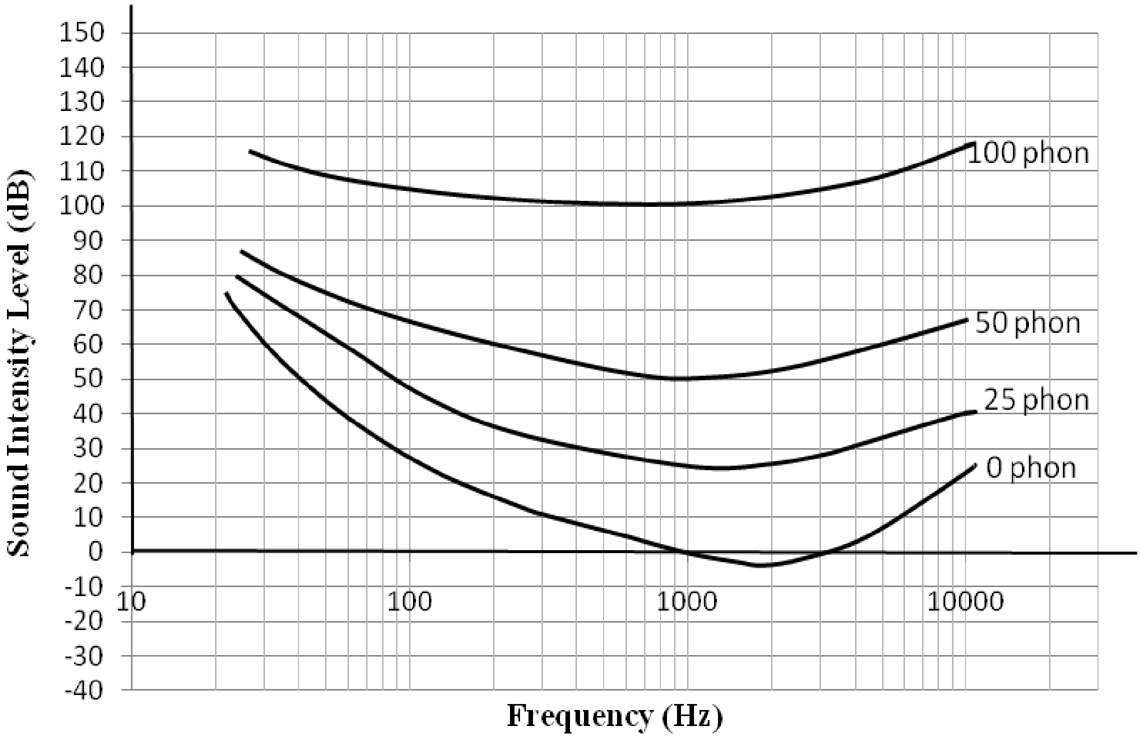


Figure 5

Question 12

Which one of the following statements is **not** true?

A. For the same power emitted by a loudspeaker, as the frequency increases from 100 Hz to 1000 Hz, Tony will perceive an increase in loudness.

B. Tony can hear a 20 dB sound at 300 Hz but not at 100 Hz.

C. A 50 dB sound at 90 Hz appears to Tony to be as equally loud as 30 dB at 400 Hz.

D. Tony can clearly hear a 60 dB sound at 60 Hz but not at 1000 Hz.

Question 13

A constant 40 dB sound is produced by the loudspeaker. At this sound intensity level, which one of the following frequencies would Tony **not** be able to hear clearly?

A. 9000 Hz

B. 2000 Hz

C. 100 Hz

D. 50 Hz

END OF DETAILED STUDY 3

END OF QUESTION AND ANSWER BOOK