THE SCHOOL FOR EXCELLENCE (TSFX)
UNIT 4 PHYSICS 2006

WRITTEN EXAMINATION 2

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

QUESTION AND ANSWER BOOKLET

Structure of Booklet

Section		*Number of Questions*	*Number of Questions to be Answered*	*Number of Marks*	*Suggested Times (minutes)*
A	**Core Studies**				
	Electric Power	20	20	40	40
	Interactions of Light and Matter	12	12	25	25
B	**Detailed Studies**				
	1. Synchrotron **OR**	14	14	25	25
	2. Photonics **OR**	13	13	25	25
	3. Sound	12	12	25	25
				Total 90	Total 90

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SECTION A – CORE STUDIES

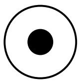
Instructions For Section A

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

AREA OF STUDY 1 – ELECTRIC POWER

QUESTION 1
Draw the lines representing the magnetic field resulting from the straight current-carrying conductor in Figure 1. A cross-section of the conductor is shown with the current direction indicated by a dot. You should show give an indication of field shape, direction & relative field strength.

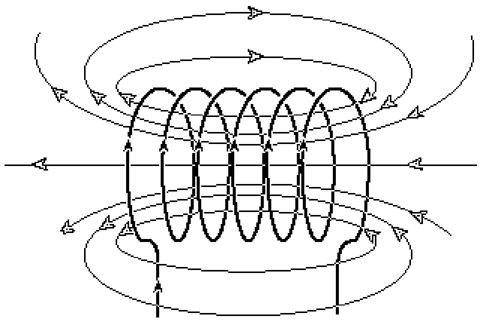
Figure 1



3 marks

The solenoid in Figure 2 is merely a series of coils lined up parallel to each other so that each of the individual coil's magnetic fields add together to produce a stronger magnetic field.

Figure 2



QUESTION 2
Describe two ways that we could further increase the magnetic field strength within the solenoid?

____

____

____

____

2 marks

Questions 3 to 8 refer to the following information.

Two students examine a D.C. motor. They find that it has an armature consisting of a rectangular coil with 50 turns, which is shown in Figure 3.

They observe that the armature can rotate within a magnetic field of 0.10 T produced by the currents flowing through two field coils as shown in Figure 4.

An enlarged diagram of one field coil is shown in Figure 5.

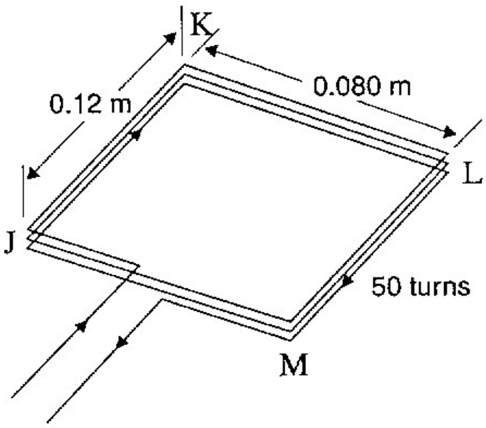
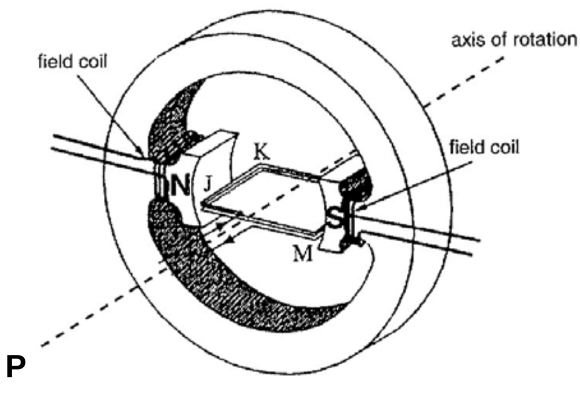


Figure 3

The armature coil and field coils are connected in series, so that the same current flows through all 3 coils. The current through the armature coil flows through a commutator (not shown) and in the direction JKLM. When the motor is operating, the current flowing is 1.5 A.



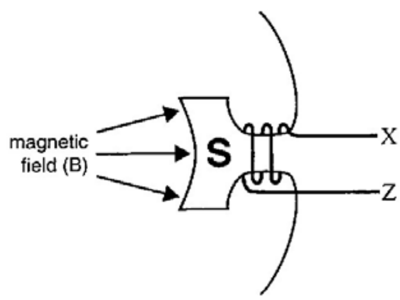


Figure 4 **Figure 5**

QUESTION 3
What is the magnitude of the force on the side **KL** of the armature when positioned as in Figure 4?

1 mark

N

QUESTION 4
What is the magnitude of the force on the side **JK** of the armature when positioned as in Figure 4?

2 marks

N

QUESTION 5
Which one of the following statements best describes the initial motion of the armature as viewed from position P in Figure 4?

A It will start to rotate anticlockwise.
B It will start to rotate clockwise.
C It will start to rotate but the direction cannot be predicted.
D It will oscillate rapidly about the position shown in Figure 4.

2 marks

QUESTION 6
In which direction must the current flow through the field coil to produce the field and South pole as indicated by the arrows in Figure 5.

A Into the coil at X and out of the coil at Z.
B Into the coil at Z and out of the coil at X
C It is an AC current, so the direction is always changing.
D In either direction, the field direction does not depend on the current direction.

2 marks

QUESTION 7
How much magnetic flux passes through the armature coil when positioned **parallel** to the magnetic field as in Figure 4?

____

____

1 mark

Wb

QUESTION 8
How much magnetic flux passes through the armature coil when positioned **perpendicular** to as in Figure 4 such that the flux is at a maximum?

____

____

____

2 marks

Wb

Questions 9 and 10 refer to the diagram of a D.C. generator in Figure 6.

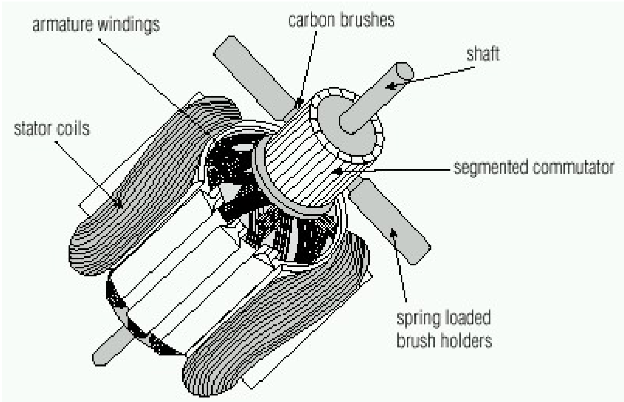


Figure 6

QUESTION 9

In the following description of a D.C. generator circle the most correct option each time alternative words are presented in **bold** font.

*"As the armature rotates the **commutator / carbon brushes / stator coils** reverse the direction of the current leaving the generator every half a cycle resulting in **Alternating / Direct / Conventional** Current being fed to the external circuit."*

2 marks

QUESTION 10

Which of the following will **not** enable more electrical power to be provided by a generator?

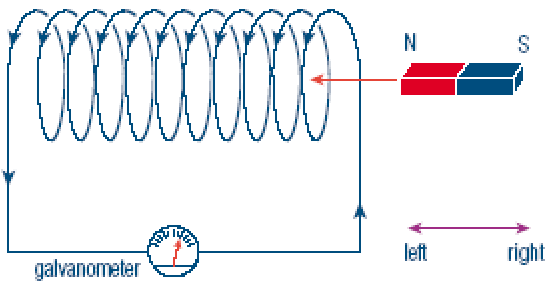
A Increasing the diameter of the segmented commutator.
B Increasing the number of loops in the armature windings.
C Increasing the area of the loops in the armature windings.
D Increasing the magnetic field strength by using electromagnets.
E Increasing the rate of rotation of the armature windings.

2 marks

QUESTION 11

A coil of wire connected to a galvanometer forms a circuit, as shown in the Figure 7. When a bar magnet is placed near the coil and moved to the left as illustrated, the galvanometer indicates a current to the **right** through the galvanometer.

Figure 7



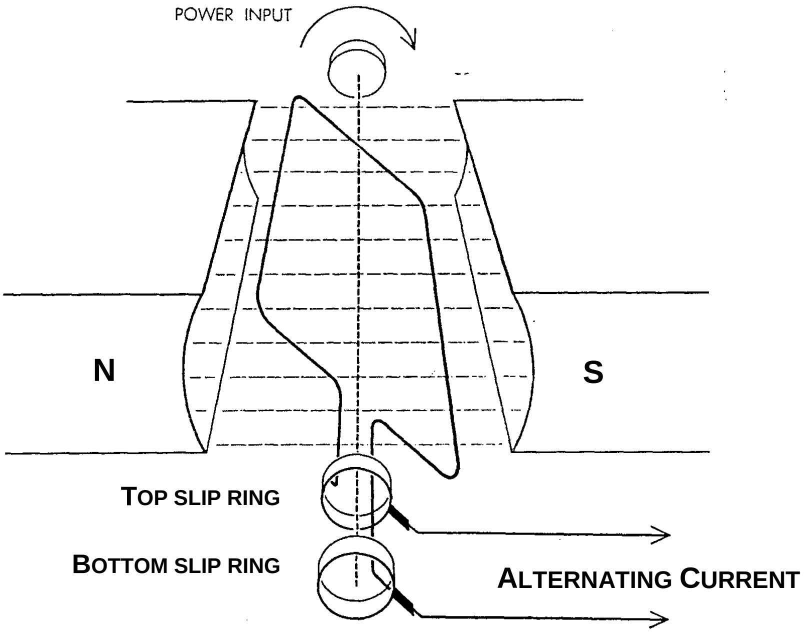
For each of the following situations state whether the current through the galvanometer will be **zero,** to the **left** or to the **right**.

	Current
a. The coil is stationary and the magnet is stationary.	
b. The coil is stationary and the magnet is moved to the right.	
c. The coil is moved to the right and the magnet is stationary.	
d. The coil is moved to the left and the magnet is stationary.	

4 marks

Questions 12 and 13 refer to the instant in time for the generator shown in Figure 8.

Figure 8



QUESTION 12

Is the magnitude of the magnetic flux through the loop **increasing** or **decreasing**?

____

____

1 mark

QUESTION 13

Does the induced current **leave** the generator through the **top** slip ring or the **bottom** one?

____

____

1 mark

Questions 14 to 20 refer to the following information.

It is common for the wires in the cables associated with garden lights to carry only low voltages (often 12 V_{RMS}). However it is more efficient to use 240 volt globes in the lights. In order to achieve this, the circuit shown in Figure 9 is used. At the 240 V supply, the voltage is stepped down using a 240 V to 12 V transformer, and at the light it is stepped up using a 12 V to 240 V transformer. The connecting wires joining the transformers are quite long. The transformers can be assumed to be ideal.

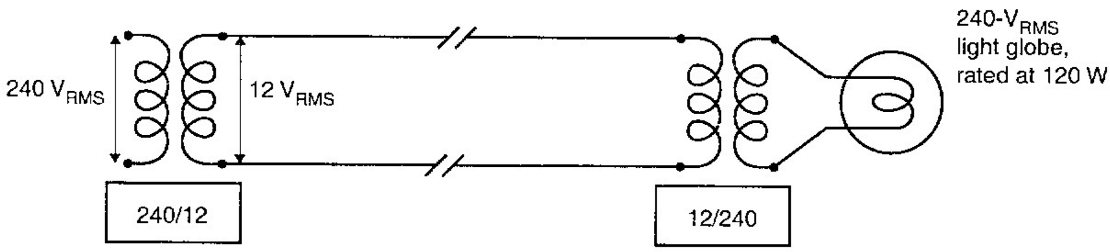


Figure 9

QUESTION 14
The light globe is rated at 120 W when connected to a 240 V_{RMS} supply. What current should flow through the light globe under this condition?

2 marks

A

QUESTION 15
Given these operating conditions for the globe calculate the electrical resistance of the globe.

2 marks

Ω

When the system in Figure 9 was tested it was clear that the globe was not operating at the rated 120 W.

QUESTION 16
Explain the reason for this.

____

____

____

____

2 marks

When the garden light is operating, the voltage across the input to the transformer at the globe is 10 V_{RMS}.

QUESTION 17
What is the RMS voltage across the globe?

____

____

____

| V |

2 marks

QUESTION 18
What current is subsequently flowing through the globe?

____

____

____

| A |

2 marks

QUESTION 19
What current is flowing through the long connecting wires?

3 marks

A

QUESTION 20
What is the total resistance of the long connecting wires between the transformers?

2 marks

Ω

AREA OF STUDY 2 – INTERACTIONS OF LIGHT AND MATTER

Two students set up the Young's double slit experiment as shown in Figure 1 below. The slit separation, d, and the slit-screen distance, L, are also shown. A green argon laser with a wavelength of 515 nm was used to illuminate the slits. The resulting interference pattern is shown in Figure 2, the arrow indicating the central maximum.

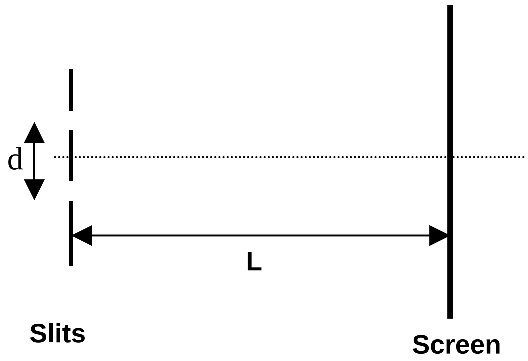


Figure 1

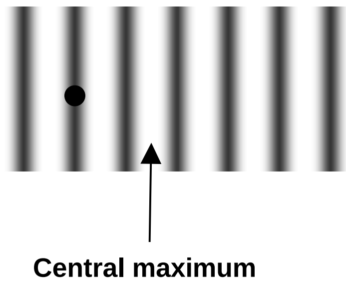


Figure 2

QUESTION 1
Place a **cross (x)** on Figure 2 to show the position of the *third* local maximum.

1 mark

QUESTION 2
Determine the path difference in nanometres for the dark band indicated by the **circle (•)** on Figure 2. Show all working.

____

____

____

2 marks

nm

Using the same experimental setup, the light source was changed to a red HeNe laser with a wavelength of 633 nm.

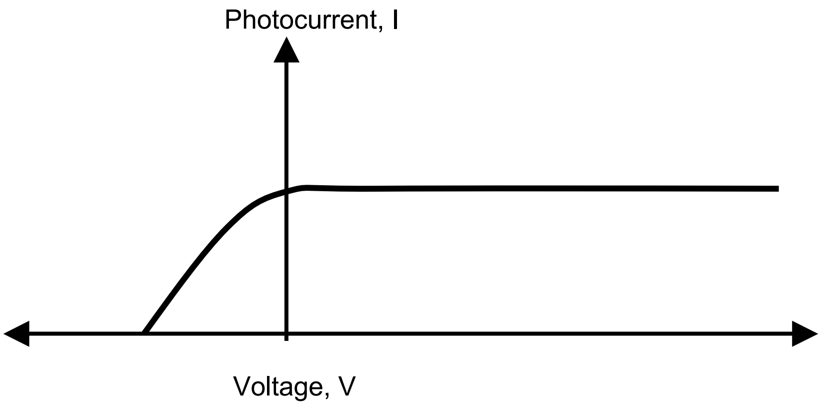
QUESTION 3
Which *one or more* of the following changes (A-D) occur to the interference pattern?

A Dark bands are further apart.
B Dark bands are closer together.
C The pattern will be brighter.
D No changes will occur.

2 marks

Blue light of wavelength 360 nm was incident on a potassium metal plate. The photo electrons emitted from the potassium plate were collected by a cathode and anode at varying voltages to obtain the curve in Figure 3. Potassium has a work function of 2.3 eV.

Figure 3



QUESTION 4
Determine the threshold frequency of potassium.

Hz

2 marks

QUESTION 5
Determine the retarding voltage for the blue light indicated by the intercept with the voltage axis.

3 marks

V

QUESTION 6
UV light of 200 nm was now shone onto the potassium plate at the same number of photons per second striking the cathode. Sketch the resulting curve on the graph in Figure 3 above.

2 marks

QUESTION 7
Which of the following (A-D) would occur if the frequency was decreased to less than the threshold frequency?

A Increased photocurrent
B Decreased photocurrent
C Lower stopping potential
D No signal.

2 marks

The atomic energy levels for hydrogen are shown in Figure 4. A photon is absorbed by the hydrogen atom which is excited to the 4th excited state.

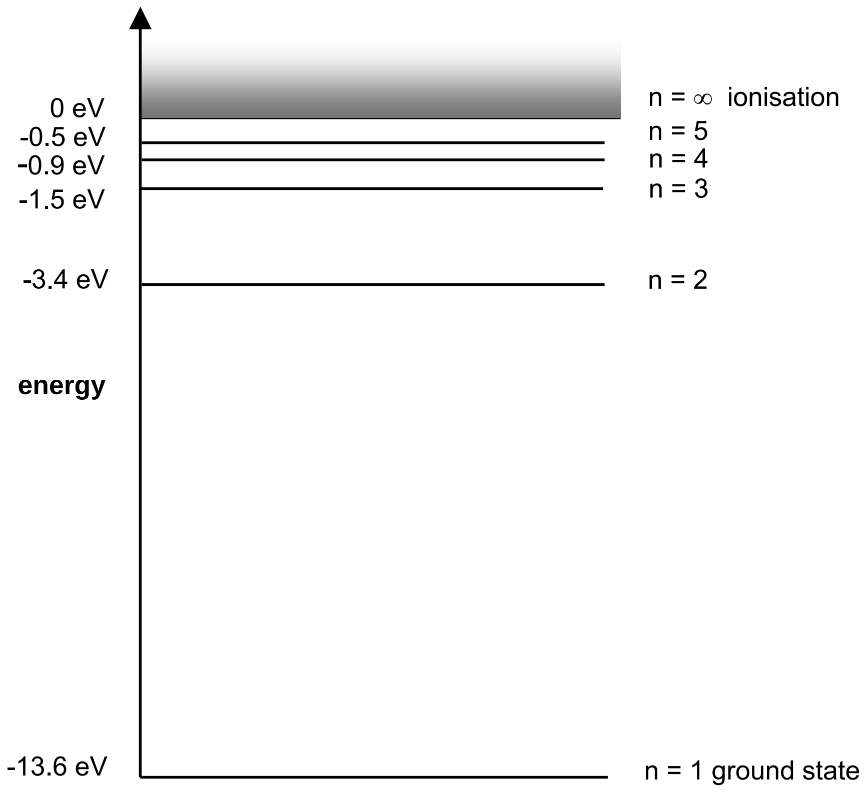


Figure 4

QUESTION 8

Determine the frequency of the photon absorbed by the hydrogen atom.

____

____

____

Hz

2 marks

QUESTION 9
Determine **all** the possible photon energies that can be emitted by the hydrogen atom in the $n = 3$ excited state?

3 marks

eV

QUESTION 10
To release an energetic electron from a hydrogen atom in the ground state, the absorbed photon would need to be

A 0 eV
B Less than 13.6 eV
C 13.6 eV
D More than 13.6 eV

2 marks

QUESTION 11
Explain why the standing wave model of orbiting electrons in an atom is more successful than Bohr's model.

2 marks

QUESTION 12

A microbiologist wishes to produce an image of a single large virus which is about 100 nm in size. As a physicist, you are asked to suggest appropriate imaging equipment to produce the clearest image. Which one of the following apparatus (A-D) would you recommend? Justify your answer.

A Electron microscope using keV electrons ($\lambda < 10^{-11}$ m).
B High energy ultraviolet light source ($\lambda \approx 100$ nm).
C Optical microscope using visible light ($\lambda \approx 500$ nm).
D Microwave transmitter using microwaves ($\lambda \approx 10$ cm).

3 marks

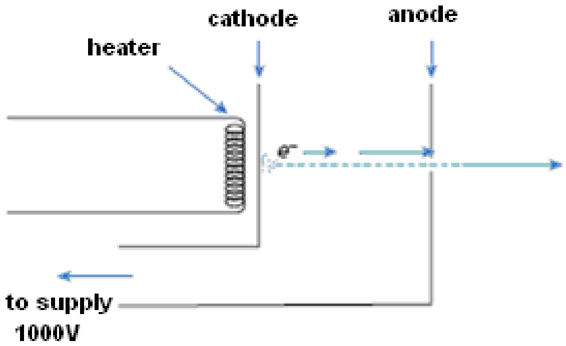
SECTION B – DETAILED STUDIES

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 AND ITS APPLICATIONS

The following diagram is the basic layout of an electron gun. The heating element causes electrons to be released which are then accelerated across a distance of 20 mm by a voltage of 1000V. A small number of electrons pass through a hole in the anode to form a narrow beam.



QUESTION 1
Is the anode positively or negatively charged?

1 mark

QUESTION 2
What is the strength of the electric field between the plates?

Vm^{-1}

1 mark

QUESTION 3
How much energy is transferred to a single electron as it reaches the anode?

2 marks

J

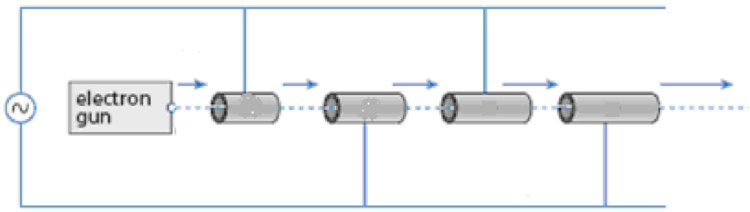
QUESTION 4
What speed does the electron attain as it passes through the anode?

2 marks

ms^{-1}

The LINAC (linear accelerator) consists of a series of RF cavities or drift tubes, of increasing length as shown below.

LINAC



QUESTION 5
Explain why the RF cavities have increasing length along the electron beam.

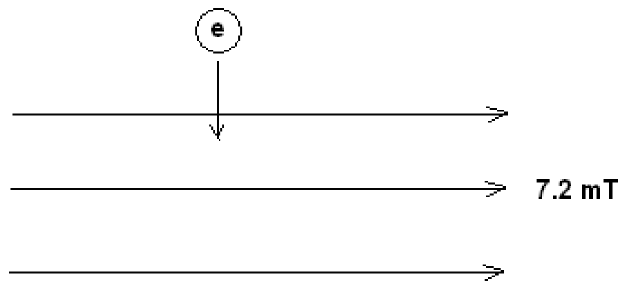
2 marks

QUESTION 6
Which parts of a synchrotron utilize RF cavities to accelerate the electrons? (one or more answers).

A Electron gun
B Linear accelerator
C Booster ring
D Storage ring
E Beamline

2 marks

An electron travelling at 6.0×10^7 ms^{-1} enters a magnetic field of strength 7.2 mT at right angles as shown.



QUESTION 7
What is the size of the force acting on the electron?

N

2 marks

QUESTION 8
In what direction does the force first act on the electron as it enters the magnetic field?

A To the right
B To the left
C Up
D Out of the page
E Into the page

1 mark

QUESTION 9
The electron's path will be circular as it passes through the field. Calculate the radius of the electron's motion.

m

2 marks

QUESTION 10
How do X-rays from synchrotrons compare to those produced by conventional X-ray tubes?

2 marks

An X-ray diffraction experiment has a first order grazing angle (or Bragg angle) of 17.5^{o}.
The spacing between crystal layers is 0.22 nm.

QUESTION 11
Calculate the wavelength of the X-rays used.

m

2 marks

QUESTION 12
What would be the second order Bragg angle?

2 marks

QUESTION 13
What is the most likely reason why this second peak occurs?

2 marks

QUESTION 14
Explain the difference between Thomson scattering and Compton scattering.

2 marks

DETAILED STUDY 2 - PHOTONICS

For Questions 1 and 2 select from the following:

A Incandescent globe
B Neon LASER
C Mercury vapour lamp
D Light emitting diode
E Bunsen burner flame

QUESTION 1
Which of the light sources above would be classed as coherent? (one or more answers).

2 marks

QUESTION 2
Which produces a line emission spectrum? (one or more answers)

2 marks

QUESTION 3
Calculate the energy band gap in electron volts for an indium phosphide LED that emits light with a wavelength of 930 nm.

eV

2 marks

The input of optical power into a 20 km communications fibre is 6.4 mW. Light of 1.6 mW emerges from the end of the fibre.

QUESTION 4
What is the attenuation of the fibre?

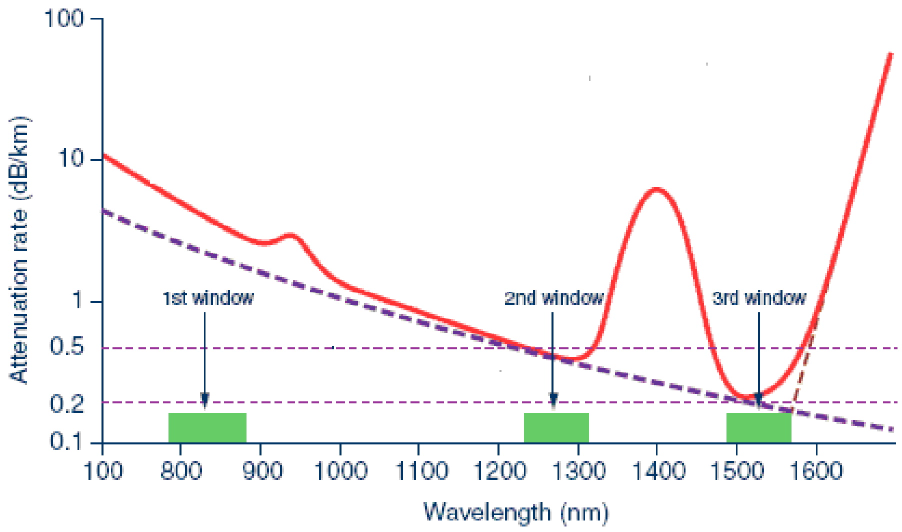
2 marks

dB

QUESTION 5
What is the attenuation rate of the fibre?

2 marks

$dBkm^{-1}$



QUESTION 6
What wavelength experiences an attenuation of 0.2 $dBkm^{-1}$ due to Rayleigh scattering?

nm

1 mark

QUESTION 7
What is the likely cause of the major attenuation peak at 1400 nm?

2 marks

QUESTION 8
What causes the attenuation to significantly increase beyond 1600 nm?

2 marks

A computer network uses a step-index fibre with an absolute refractive index for the core of 1.5 and 1.4 for the cladding. Light from a laser diode is projected a few millimeters through air before entering the glass fibre.

QUESTION 9
Calculate the numerical aperture for the fibre.

2 marks

QUESTION 10
Calculate the acceptance angle for the fibre.

2 marks

QUESTION 11
Suggest how modal dispersion can be reduced for this fibre.

2 marks

QUESTION 12
A single pulse of light from a LASER diode travelling through 6 km of this fibre is spread over 40 nanoseconds . What is the maximum bandwidth that can be used? Explain your answer.

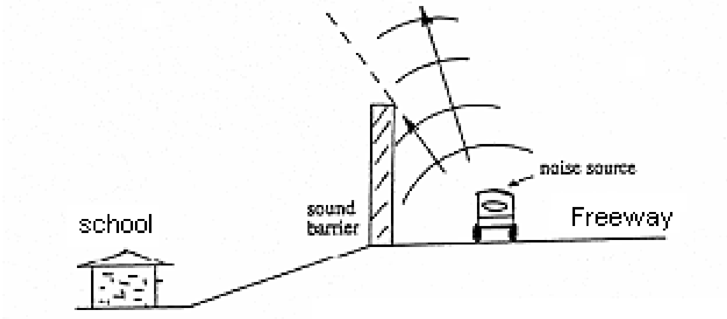
2 marks

QUESTION 13
Suggest two reasons why optical fibres can be superior to copper wire conductors for modern telecommunications

2 marks

DETAILED STUDY 3 - SOUND

As a result of noise from an adjoining freeway, soundproof barriers were installed opposite a school. Prior to the barriers being erected, two physics students measured the average sound level at the school during peak hour to be 76 dB. After the barriers were installed, the sound level was found to be only 70 dB during peak hour.



QUESTION 1

What is the value of the ratio of the $\dfrac{\textit{Sound intensity with barrier}}{\textit{Sound intensity without barrier}}$ at the school?

2 marks

In discussing the effectiveness of the barriers, one student noted that there was still a quite loud low frequency rumble that could be heard from the school.

QUESTION 2

The possible explanation for this is that the low frequency notes:

A Have longer wavelengths which diffract more.
B Have longer wavelengths which refract more.
C Have shorter wavelengths which diffract more.
D Have shorter wavelengths which refract more.

1 mark

Questions 3 and 4 refer to the following information.

An emergency vehicle is travelling to the scene of an accident on a major country highway. The vehicle travels with its siren on and the sound produces a series of compressions that are separated by 6.0×10^{-4} seconds. The speed of the waves travelling through the air is $340\ ms^{-1}$.

QUESTION 3
Calculate the wavelength of the sound waves leaving the siren?

____

____

____

m

2 marks

When the emergency vehicle is 400m from the accident scene the sound intensity level due to the siren is $1.0 \times 10^{-7}\ Wm^{-2}$. After a short time, the sound intensity level of the siren rises to $4.0 \times 10^{-7}\ Wm^{-2}$.

QUESTION 4
How far from the accident scene is the emergency vehicle now?

A $400\ m$

B $\frac{400}{\sqrt{2}}\ m$

C $\frac{400}{3}\ m$

D $200\ m$

E $\frac{2 \times 400}{3}\ m$

F $\frac{400}{\sqrt{3}}\ m$

2 marks

Tania stands in an open outside area, midway along a line between two speakers facing each other. The speakers are separated by 9.0m and are operated from the same amplifier, producing a single 170 Hz frequency. As she moves directly towards one of the speakers she experiences a series of loud and quiet regions

QUESTION 5

Is Tania's starting position likely to be a loud or a quiet region?

1 mark

QUESTION 6

If Tania stops at the second quiet region, how far is she from the closest speaker? Ignore any effects from reflection. The speed of sound in air is $340\ ms^{-1}$.

2 marks

m

QUESTION 7

The fundamental of a bugle is 88 Hz. Other notes easily produced by a bugle have frequencies of 264 Hz, 352 Hz and 440 Hz. Should the bugle be modelled as an open or a closed pipe? Justify your answer. Take the speed of sound in air as $340\ ms^{-1}$.

2 marks

QUESTION 8
Calculate the length of the air column in the bugle. You may neglect any end correction.

____

____

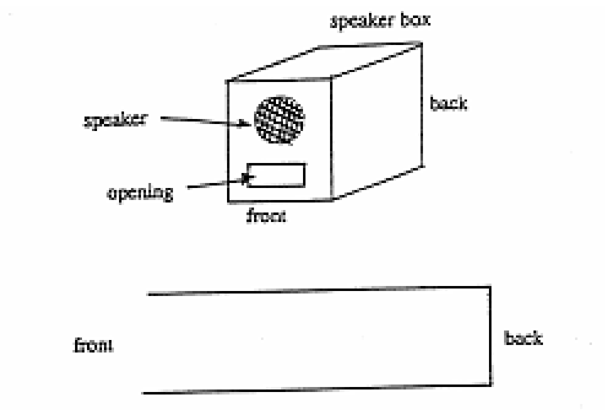
____

m

2 marks

In a speaker box the speaker cone generates sound both forwards (into the room) and backwards (towards the back of the speaker box). Speaker boxes are made so that they can reinforce the sounds that are reflected from the back of the speaker box. This enables a greater use of the energy from the speaker. The speaker box maybe thought of as a pipe that is closed at one end (the back of the box) and open at the other (a hole at the front).

The speed of sound in air is $340\ ms^{-1}$.



QUESTION 9
What must be the length from front to back of a speaker box so that the lowest frequency of sound reinforced within the speaker box is 500 Hz?

____

____

____

m

2 marks

QUESTION 10
At a position directly in front of the speaker box will sound emerging from the front opening constructively or destructively interfere with sound coming directly from the speaker? Explain your answer.

____

____

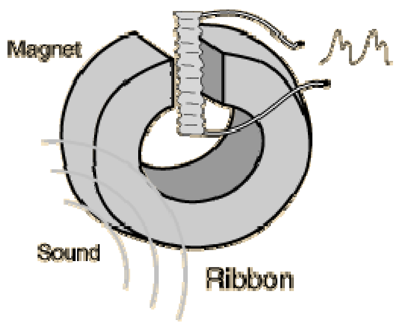
____

____

____

3 marks

QUESTION 11
The following diagram is a representation of a ribbon or velocity microphone.



Explain the operating principles of this microphone.

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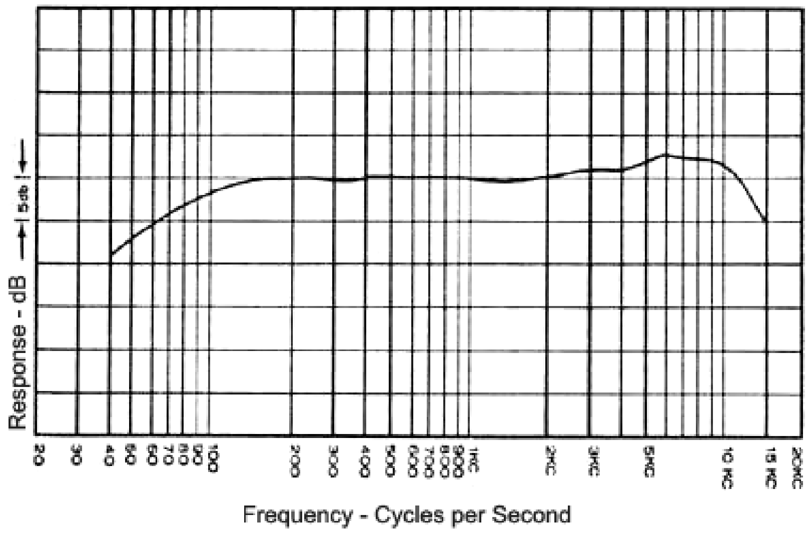
3 marks

QUESTION 12

The following is a frequency response curve for a particular microphone.



For a high fidelity microphone, what would be the 'ideal' features of its frequency response curve?

3 marks