CHEMOLOGY EDUCATION SERVICES

Name:______________________

2008 PHYSICS UNIT 4 TRIAL EXAM

Time allowed: 1 hour 30 minutes

QUESTION AND ANSWER BOOKLET

Structure of booklet

Area of study	*Number of questions*	*Marks available*	*Suggested time (minutes)*
1. Electric Power	18	40	40
2. Interactions of Light and Matter	12	30	30
3.1 Synchrotron and its applications	10	20	20
3.2 Photonics	10	20	20
3.3 Sound	10	20	20

Directions to students

This booklet is 24 pages long.
You should answer all questions in Areas of Study 1 and 2.
You should answer all questions in your selected Detailed Study in Area of Study 3.
(Note: You should choose only **ONE** Detailed Study and answer **only** questions from that Study)
You may use an A4 page of notes annotated on both sides.
There is a total of 90 marks available.
It is suggested that you spend about 1 minute per mark.

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AREA 1 – ELECTRIC POWER

Specific Instructions for Area 1
Area 1 consists of **18 questions.** A total of **40 marks** is available for Area 1.

Chris, a car enthusiast whose nickname is "Speed Racer", decides to investigate how the electric power supplied by his car battery varies over time.
Figure 1 shows the graph obtained by Chris of power supplied by the 12V battery as a function of time.

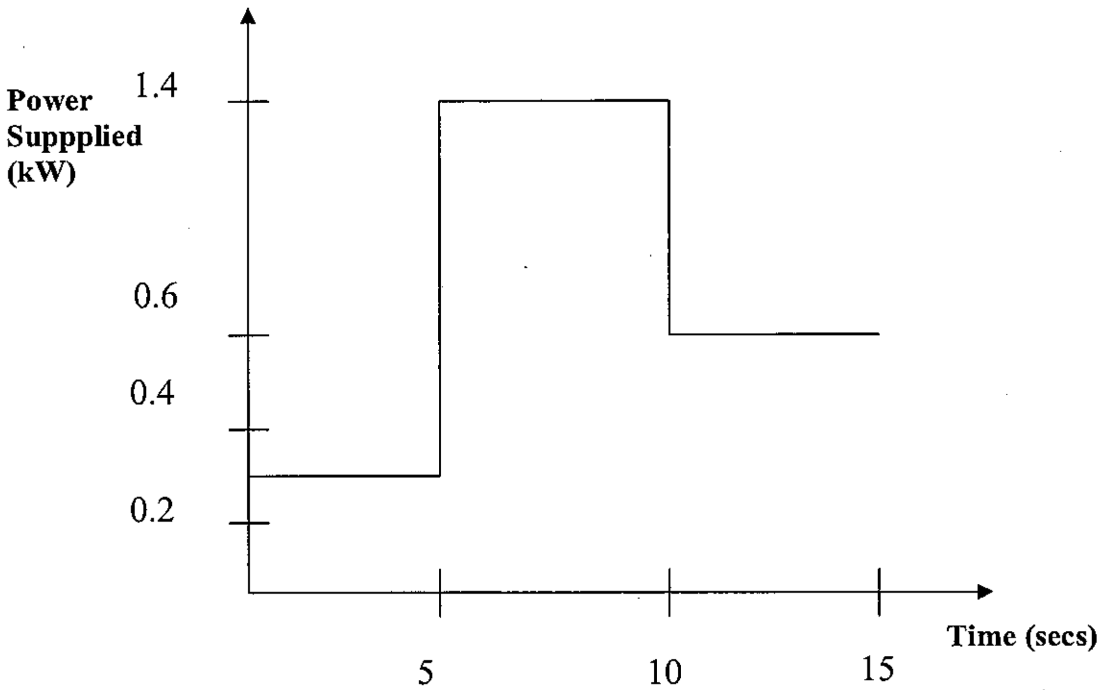


Figure 1

Question 1

How much electrical energy does the battery supply to each coulomb of charge?

[J]

2 marks

Question 2

How much electrical energy is drawn from the battery between t=5secs and t=10secs?

[J]

2 mark

Question 3

What current is drawn at t=7 secs?

A

2 marks

Question 4

How many coulomb of charge pass through the battery between t=5 and t=10 secs?

C

2 marks

Extending his investigation, Chris discovers that electricity is supplied to his house by a substation via a local area transformer with an input voltage of 9kV RMS, as shown in Figure 2. The electricity is supplied to the house at 240V RMS, at a rate of 350kW. The connecting wires between the substation and transformer have a total resistance of 50Ω.

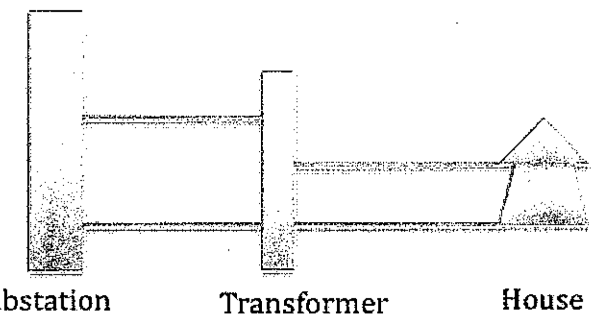


Figure 2

Question 5

The primary winding of the transformer consists of 2000 turns. How many turns are there on the secondary winding?

turns

2 marks

Question 6

What is the RMS current flowing in the wires from the substation to the transformer?

A

2 marks

Area 1 - continued

Question 7

What is the power loss in the wires between the substation and the transformer?

W

2 marks

Question 8

Explain why voltages are "stepped up" to high values for transmission, rather than just transmitting at the voltage required by the household.

3 marks

Caz is creating a spectacular moving art installation at her art gallery. She places numerous coils of wire in a dark room and directs brightly coloured lights at them, then moves the coils in various ways to reflect the light and create a spectacular effect.
One of these coils of wire happens to be positioned in an area that has a magnetic field strength of 0.5T, as shown in Figure 3.

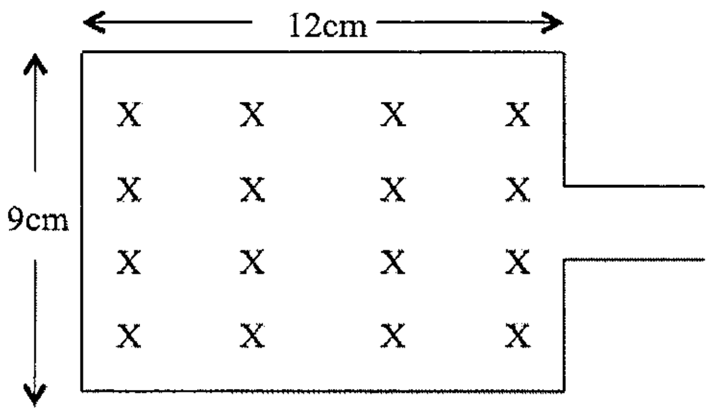


Figure 3

Question 9

Calculate the magnetic flux through the coil in the position shown in Figure 3.

Wb

2 marks

The coil begins to rotate at a frequency of 12Hz about a horizontal axis, as show by the dotted line in Figure 4 below.

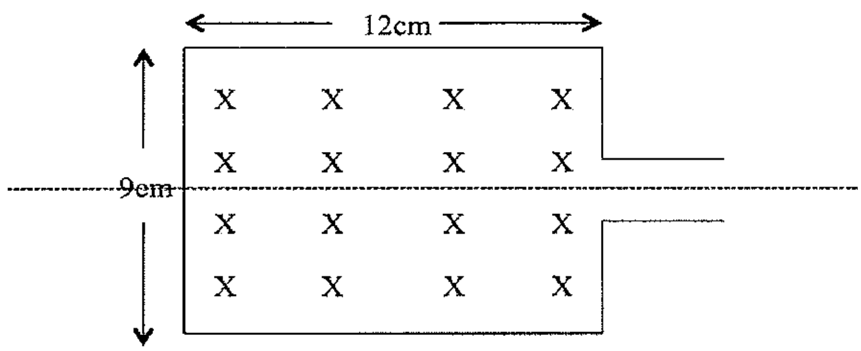


Figure 4

Question 10

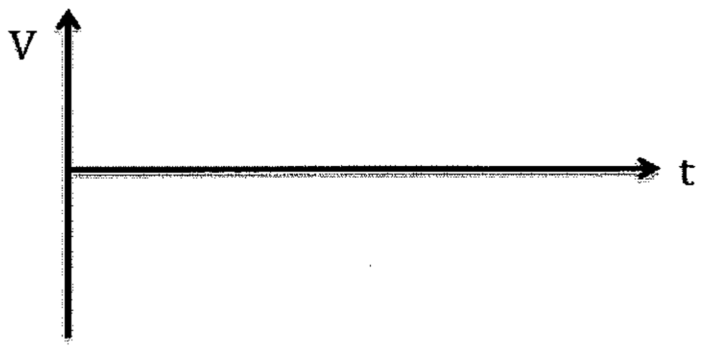
Calculate the magnitude of the average emf generated when the coil is rotated as shown in Figure 4.

V

2 marks

Question 11

Sketch the voltage-time graph for the coil as it rotates in the magnetic field.



3 marks

Area 1 – continued

The coil stops rotating and now begins to move to the right at a speed of 1.2m/s, which moves it out of the region of magnetic field.

Question 12

What is the magnitude of the emf induced as the coil is moved to the right?

V

2 marks

Question 13

What is the direction of the current induced in the coil as it is moved to the right?

V

2 marks

Question 14

Sketch the voltage-time graph for the coil as it completes its movement to the right and out of the magnetic field.

3 marks

Being a keen Physics student as well as a brilliant artist, Caz decides to investigate the possibility of using the force produced on a current-carrying wire in a magnetic field to produce new moving artworks. She sets up the apparatus shown in Figure 5, placing a 30mm piece of wire in a uniform magnetic field.

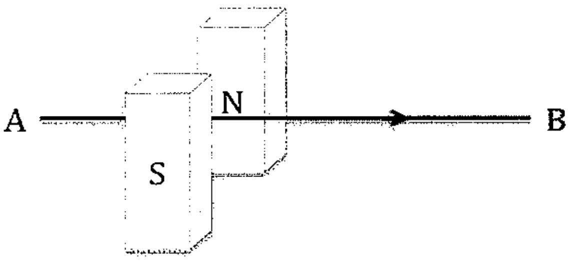


Figure 5

Area 1 - continued

Caz passes a DC current of 1.2A through the wire, producing a force of 0.03N.

Question 15

Calculate the strength of the magnetic field.

T

2 marks

Question 16

What is the direction of the resulting force on the wire?

2 marks

The DC power supply is now replaced with an ac power source with a frequency of 100Hz that produces an RMS voltage equal to that of the DC supply.

Question 17

Describe what happens to the wire when this new power supply is connected.

3 marks

Question 18

Explain the major difference between a DC generator and a DC alternator.

2 marks

AREA 2 – Interactions of light and matter

Specific Instructions for Area 2
Area 2 consists of 12 questions. There are 30 marks available for Area 2.

Specific data for Area 2:
Planck's constant = 6.63 x 10^{-34} Js
Charge on an electron = 1.6 x 10^{-19} C
Speed of light = 3.0 x 10^{8} m/s
Mass of an electron = 9.1 x 10^{-31} kg

Michael is investigating the photoelectric effect and sets up the apparatus shown in Figure 1, where light of a single wavelength is directed onto a metal plate, P, inside an evacuated chamber. Q is a second plate on the other side of the chamber and the DC voltage source provides an adjustable voltage V between P and Q.
Negative (retarding) voltages can be produced by reversing the voltage source, which is currently set at 0.6V.
The ammeter measures the photocurrent flowing through the circuit.

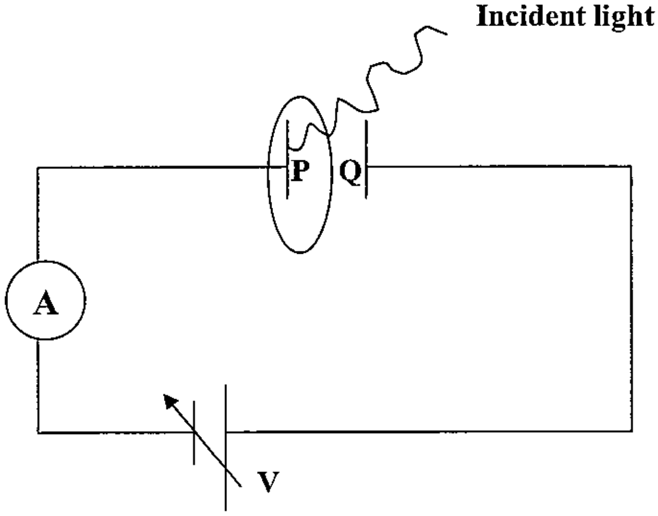


Figure 1

In a particular trial, light of frequency 1 x 10^{15} Hz is directed at the plate, and the number of photoelectrons striking the metal plate P is measured as 3.2 x 10^{14} s^{-1}.

Question 1

Calculate the energy (in joules) arriving each second at P.

J/s

2 marks
Area 2 - continued

Michael now varies the voltage V and observes the effect on the photocurrent.
The results for **red** light are shown below in Figure 2.

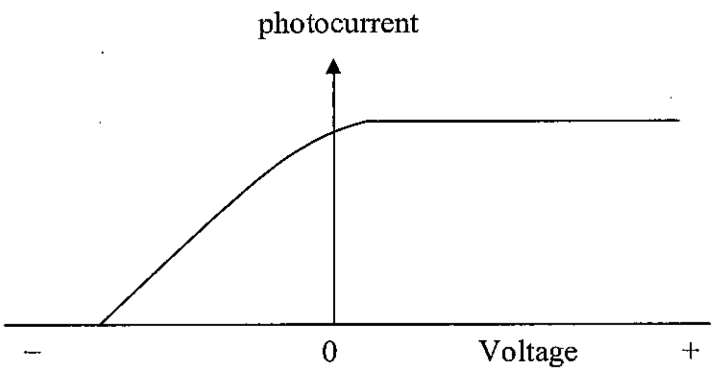
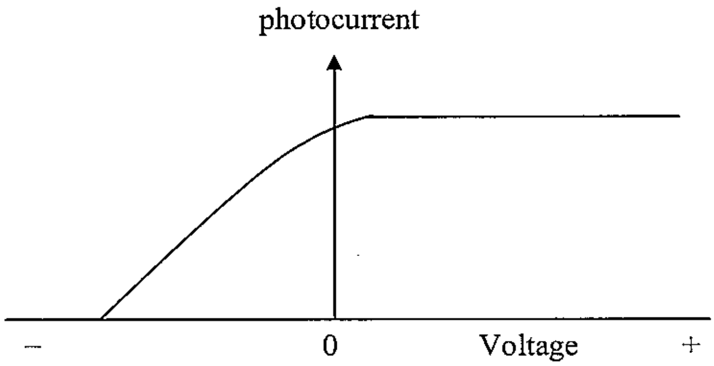


Figure 2

Question 2

On the copy of Figure 2 below, sketch a possible photocurrent vs voltage curve for an incident light which is **blue** rather than red.
(Assume the maximum photocurrent is unchanged)



3 marks

Michael now measures the maximum kinetic energy of electrons ejected for a range of different frequencies of light. A graph of his results is shown in Figure 3 below.

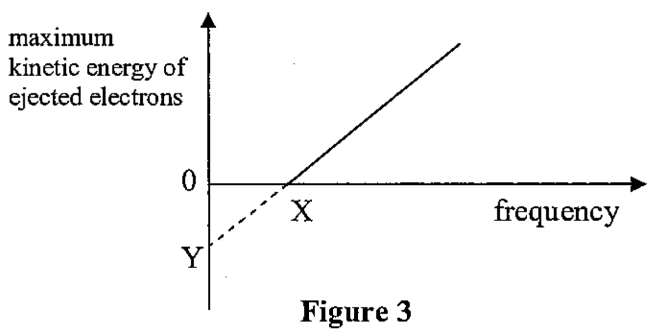


Figure 3

Area 2 – continued

The following answer key should be used for the next several questions:

A. The point X where the line intersects the horizontal axis.
B. The point Y where the dotted line intersects the vertical axis.
C. The slope of the line.
D. None of the above

Question 3

Which of the above would alter significantly if Michael replaced the metal plate with one made of a different metal?

2 marks

Question 4

Which of the above would alter significantly if Michael used the original metal plate but light of double the intensity?

2 marks

Question 5

Give 2 examples of situations in which the **particle** model of light is unable to satisfactorily explain the observed behaviour of light.

2 marks

Question 6

Describe the effect on the maximum energy of the electrons ejected if light of a different frequency is shone on the plate.

3 marks

Area 2 - continued

Michael often uses an electron microscope in his investigations. These microscopes accelerate electrons from rest across a potential difference of 10kV.

Question 7

Calculate the kinetic energy of these electrons.

J

2 marks

Question 8

Calculate the de Broglie wavelength of these electrons.

m

3 marks

Question 9

Explain why an electron microscope would give a clearer image than an optical microscope.

____

____

____

____

3 marks

Michael's friend Tom turns up and starts talking very excitedly about Young's double slit experiment. The two friends decide to investigate the phenomenon further and set up the apparatus shown in Figure 4. They shine a beam of light of frequency 5.2×10^{14} Hz onto a piece of cardboard from which they have cut two slits, each of width 1.2cm, which are 2.5cm apart, and observe the resulting pattern on a screen.

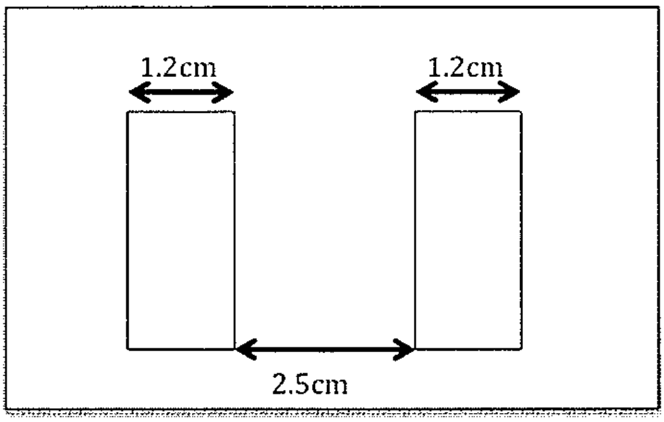


Figure 4

Area 2 - continued

Question 10

Describe what Michael and Tom are likely to observe on the screen.

2 marks

Question 11

Explain how Michael and Tom could adjust their apparatus in order to observe Young's pattern of dark and light bands.

3 marks

Question 12

Explain how the pattern of dark and light bands is created by the double slits.

3 marks

Area 2 - continued

AREA 3.1 – Synchrotron and its applications

Specific Instructions for Area 3.1

Area 3.1 consists of **10 questions. Answer all questions on the multiple choice answer sheet provided.** Marks are indicated at the end of each question. A total of **20 marks** is available for Area 3.1.

Specific data for Area 3.1:
Charge on an electron = 1.6×10^{-19} C
Mass of an electron = 9.1×10^{-31} C

Josh is tinkering around with X-rays of wavelength 0.12nm and decides to direct them onto a sample he has in his lab. He observes an angle of reflection of 15^0 for N=1.

Question 1

What is the atomic plane spacing of the material?

A. 1.9 Å
B. 19 Å
C. 2.3 Å
D. 23 Å

2 marks

Question 2

What is the next angle of reflection for the material in the sample?

A. 32^0
B. 47^0
C. 68^0
D. 12^0

2 marks

Josh is enjoying investigating X-rays and decides to look at different types of X-ray scattering.
In his first experiment, he finds that X-rays are scattered **elastically** from layers of atoms.

Question 3

This type of elastic scattering is known as:

A. Diffuse scattering
B. Compton scattering
C. Thompson scattering
D. Campbell scattering

2 marks

Area 3.1 - continued

In Josh's next experiment, the X-ray photons were found to interact in an **inelastic** manner with electrons, resulting in the X-ray photon emerging with a longer wavelength.

Question 4

This type of inelastic scattering is known as:

A. Diffuse scattering
B. Compton scattering
C. Thompson scattering
D. Campbell scattering **2 marks**

In a final experiment, Josh finds that the scattering produces a pattern of circular rings on the detector.

Question 5

Which type of scattering would most likely cause this result?

A. Diffuse scattering
B. Compton scattering
C. Thompson scattering
D. Campbell scattering **2 marks**

Josh now pops over to the synchrotron and bombards a material of work function 3.2eV with X-rays of wavelength 1.4Å. An electron is ejected from the material with kinetic energy 76eV.

Question 6

Assuming that all energy transferred to the electron comes from the incident photon, calculate the total amount of energy lost by the incident photon.

A. 76eV
B. 79.2eV
C. 72.8eV
D. 77.4eV **2 marks**

Question 7

What is the wavelength of the scattered photon?

A. 1.4nm
B. 7.6nm
C. 0.4nm
D. 14nm **2 marks**

Area 3.1 - continued

Question 8

Which of the following is true of the experiment described above?

A. It supports the wave model of light
B. It supports the particle model of light
C. It supports both the wave and particle models of light
D. It supports neither the wave nor the particle model of light **2 marks**

Question 9

In a synchrotron, electrons are produced in:

A. an electron gun
B. a booster ring
C. a storage ring
D. a linac **2 marks**

Question 10

Electrons are accelerated to speeds close to the speed of light by:

A. the beamline
B. the storage ring
C. the linac
D. the zanther **2 marks**

Area 3.1 - continued

AREA 3.2 – Photonics

Specific Instructions for Area 3.2

Area 3.2 consists of 10 questions. **Answer all questions on the multiple choice answer sheet provided.** There are 20 marks available for Area 3.2.

Specific data for Area 3.2:
Planck's constant = 6.63×10^{-34} Js
Speed of light in a vacuum = 3.0×10^{8} m/s
Charge on an electron = 1.6×10^{-19} C

Dot and Clare produce a brilliant and informative TV chat show called Doctor Dot, where viewers can ask Doctor Dot all of their questions on air.
At the start of the show, as Dot walks onto the set, an LED light display flashes "The Doctor is in!" in red and blue letters and Clare works the audience up into a frenzy of clapping.

Question 1

If the wavelength of the red light produced by the LED is 640nm, what is the energy gap of the material from which the LED is made?

A. 6.1×10^{-19} J
B. 3.1×10^{-19} J
C. 3.5×10^{-18} J
D. 6.2×10^{-18} J

2 marks

Question 2

Comparing the LED emitting red light with the LED emitting blue light, which of the following is true?

A. The blue LED material has a smaller band gap energy than the red LED material.
B. The red LED material has a smaller band gap energy than the blue LED material.
C. The red and blue materials have equal band gap energies, as they are both LEDs.
D. There is not enough information to conclude which material has a larger band gap energy.

2 marks

Question 3

Which of the following are advantages of LEDs as a light source (one or more answers)?

A. LEDs are very efficient at converting electricity into light energy
B. A single LED can produce light in a wide range of colours
C. LEDs are very cheap to buy compared to incandescent lights
D. LED have much longer life spans than incandescent bulbs

2 marks

Area 3.2 - continued

Clare uses a step-index multimode optical fibre for a short-distance telecommunication link when she is on the set. The fibre has a core with a refractive index of 1.47.

Question 4

If the cladding has refractive index 1.44, what is the critical angle of the core-cladding boundary of this fibre?

A. 11.6^0
B. 73^0
C. 13.5^0
D. 78.4^0 **2 marks**

Question 5

What would be the acceptance angle for this fibre in water (n=1.33)?

A. 73^0
B. 78.4^0
C. 12.8^0
D. 14.6^0 **2 marks**

Question 6

Why would a multimode fibre have been chosen for this application rather than a single-mode fibre (one or more answers)?

A. Multimode fibre has superior bandwidth capabilities
B. Single-mode fibre is more expensive
C. Pulse spreading is minimal over short distances
D. Multimode fibre has superior pulse dispersion qualities **2 marks**

Question 7

Which of the following changes would reduce modal dispersion of a fibre optic cable?

A. Use a thicker cladding
B. Use a thinner cladding
C. Use a smaller diameter fibre
D. Use a larger diameter fibre **2 marks**

Question 8

Which of the following would you choose for a transmission over a distance of 800km?

A. Multimode fibre with a laser diode light source
B. Single-mode fibre with a laser diode light source
C. Multimode fibre with LED light source
D. Single-mode fibre with LED light source **2 marks**

Area 3.2 - continued

Question 9

Choose the **best** description of the way in which a laser produces light.

A. Electrons emit photons as they drop from higher to lower energy levels
B. Atoms are stimulated to release their energies by interacting with photons of the same energy
C. Atoms are heated to produce light energy
D. Electrons are forced into higher energy levels within the atom, emitting photons of light as a result

2 marks

Question 10

Which **one or more** of the following is a correct statement about the light produced by a red LED light as compared to that produced by a red laser light?

A. The red laser light is less coherent than the red LED light
B. The red laser light is more intense than the red LED light
C. The red LED light has more divergence than the red laser light
D. The red LED light is more monochromatic than the red laser light

2 marks

Area 3.2 - continued

AREA 3.3 – Sound

Specific Instructions for Area 3.3

Area 3.3 consists of **10 questions. Answer all questions on the multiple choice answer sheet provided.**
A total of **20 marks** is available for Area 3.3.

Specific data for Area 4:
Speed of sound in air = 330m/s
Area of a sphere is $4\pi r^2$

Emilia plays French Horn in the Australian Opera and Ballet Orchestra (AOBO) and is having a hearing test, as is required of all players on a regular basis due to their exposure to loud volumes in the orchestra pit.
The graph shown in Figure 1 represents the intensity at Emilia's ear for which certain frequencies of sound can just be heard.

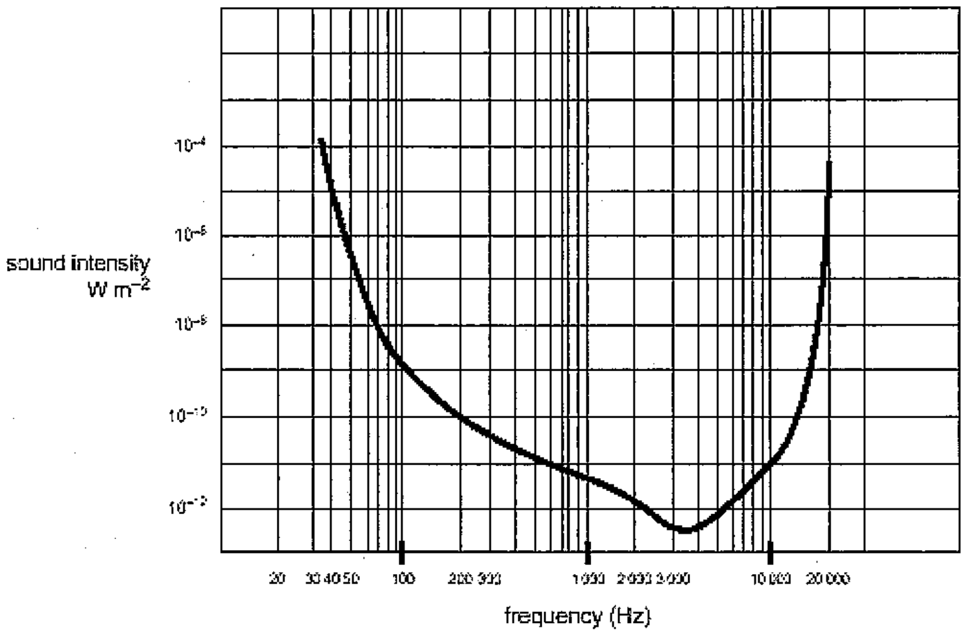


Figure 1

Question 1

If the sound intensity at Emilia's position is 10^{-5} Wm^{-2}, what are the lowest and highest frequencies she can hear?

A. 20Hz, 40Hz
B. 40Hz, 20kHz
C. 80Hz, 10kHz
D. 100Hz, 80kHz

2 marks
Area 3.3 - continued

Question 2

What is the value, in dB, of the ratio
intensity that can just be heard at 20 000 Hz / intensity that can just be heard at 200 Hz?

A. 40
B. 20
C. 80
D. 100

2 marks

Question 3

At what frequency is Emilia's ear most sensitive?

A. 20Hz
B. 40kHz
C. 40Hz
D. 5kHz

2 marks

Question 4

Which of the following best describes "resonance"?

A. A frequency to which the human ear is very sensitive
B. The vibration of a glass due to the Brownian motion of its component atoms
C. An amplification due to the superposition of a travelling wave with its reflection
D. A group of frequencies which are pleasing to the ear when played together

2 marks

During a performance, Emilia plays a note of wavelength 0.45m, emitting sound equally in all directions.
At a point 5m from Emilia, the sound intensity level is L dB.

Question 5

What would the sound intensity level be at a point 10m from Emilia?

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

2 marks

Area 3.3 - continued

The sound intensity level is measured to be 64dB at one position in the orchestra pit.

Question 6

What is the sound intensity at this position?

A. 6.4×10^{-6} Wm^{-2}
B. 2.5×10^{-6} Wm^{-2}
C. 3.2×10^{-6} Wm^{-2}
D. 1.28×10^{-5} Wm^{-2}

2 marks

Question 7

Which of the following best describes the motion of a dust particle floating in the air directly in front of Emilia's french horn?

A It remains at rest
B It vibrates vertically up and down at the frequency of the sound wave
C It travels horizontally away from the horn, in the direction of the sound wave
D It vibrates horizontally back and forth at the frequency of the sound wave

2 marks

Question 8

What is the frequency of the note played by Emilia?

A. 640Hz
B. 723Hz
C. 733Hz
D. 490Hz

2 marks

An audience member arrived late to the concert and is waiting outside the door to the auditorium, as shown in Figure 2 below.

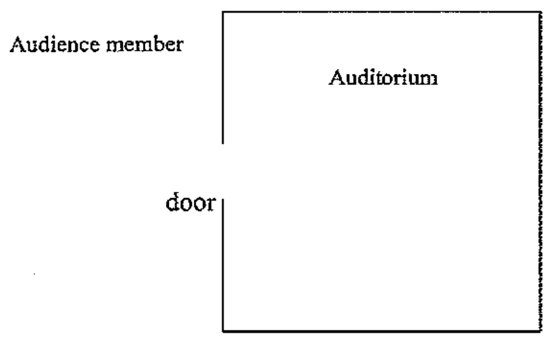


Figure 2

Area 3.3 - continued

Question 9

Which of the following best describes the sound reaching the audience member around the corner?

A. The sound waves have been refracted around the door, with the lower frequencies being refracted more strongly and thus being more audible to the listener
B. The sound waves have been diffracted around the door, with the higher frequencies being diffracted more strongly and thus being more audible to the listener
C. The sound waves have been refracted around the door, with the higher frequencies being refracted more strongly and thus being more audible to the listener
D. The sound waves have been diffracted around the door, with the lower frequencies being diffracted more strongly and thus being more audible to the listener

2 marks

Question 10

The best explanation for how a loudspeaker generates sound waves from electrical signals is:

A. Electrical energy produces movement of the coil
B. Movement of the coil is produced through a series of mechanical levers
C. Interaction between a current and magnetic field produces movement of the coil
D. Movement of the coil is induced via magnetic resonance

2 marks

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PHYSICS Unit 4

MULTIPLE CHOICE ANSWER SHEET

Colour the box after the letter corresponding to your answer.

3.1 Synchrotron & its Applications

1. A☐ B☐ C☐ D☐
2. A☐ B☐ C☐ D☐
3. A☐ B☐ C☐ D☐
4. A☐ B☐ C☐ D☐
5. A☐ B☐ C☐ D☐
6. A☐ B☐ C☐ D☐
7. A☐ B☐ C☐ D☐
8. A☐ B☐ C☐ D☐
9. A☐ B☐ C☐ D☐
10. A☐ B☐ C☐ D☐

3.2 Photonics

1. A☐ B☐ C☐ D☐
2. A☐ B☐ C☐ D☐
3. A☐ B☐ C☐ D☐
4. A☐ B☐ C☐ D☐
5. A☐ B☐ C☐ D☐
6. A☐ B☐ C☐ D☐
7. A☐ B☐ C☐ D☐
8. A☐ B☐ C☐ D☐
9. A☐ B☐ C☐ D☐
10. A☐ B☐ C☐ D☐

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PHYSICS Unit 4

MULTIPLE CHOICE ANSWER SHEET

Colour the box after the letter corresponding to your answer.

3.3 Sound

1. A☐ B☐ C☐ D☐

2. A☐ B☐ C☐ D☐

3. A☐ B☐ C☐ D☐

4. A☐ B☐ C☐ D☐

5. A☐ B☐ C☐ D☐

6. A☐ B☐ C☐ D☐

7. A☐ B☐ C☐ D☐

8. A☐ B☐ C☐ D☐

9. A☐ B☐ C☐ D☐

10. A☐ B☐ C☐ D☐

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SUGGESTED SOLUTIONS TO 2008 PHYSICS UNIT 4 TRIAL EXAM

AREA OF STUDY 1 - Electric Power

Question 1

Definition of Volt = Joule/Coulomb.
Thus, a 12V car battery will supply 12J to every Coulomb of charge. **12J** ANS

Question 2

Energy drawn = work done by battery, and P = W/t
Thus , W = change in E = Pt = area under the Power vs time graph.
Between 5 and 10 seconds, area under graph = 1.4 x 5 = **7 J** ANS

Question 3

P = VI
From graph, P supplied at 7 secs is 1.4W
Thus, 1.4 = 12I ⇒ I = **0.12A** ANS

Question 4

Q = It and between 5 and 10 seconds, the current drawn is 0.12A
⇒ Q = 0.12 x 5 = **0.6C** ANS

Question 5

For a transformer: N1/N2 = V1/V2
⇒ 2000/N2 = 9 x 10^3/ 240
⇒ N2 = **53 turns** ANS

Question 6

P = VI
⇒ 350 x 10^3 = 9 x 10^3 x I rms
⇒ I rms = **39A** ANS

Question 7

Ploss $= I^2R = (39)^2 \times 50$ = **76 kW ANS**

Question 8

Since P loss in wires is given by P loss = I^2R, the lower I can be made, the smaller the power loss (R is fixed once the lines are up). A low I corresponds to a high V (by P = VI), and thus transmission occurs at a relatively high V and low I in order to reduce power loss in the transmission wires.

Question 9

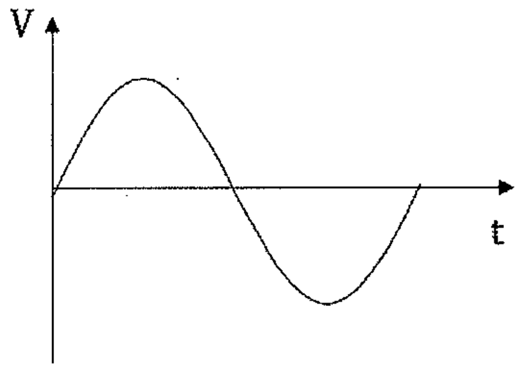
Flux ϕ = BA
= $0.5 \times (0.12 \times 0.09)$
= **5.4×10^{-3} Wb ANS**

Question 10

$\varepsilon = n\Delta\phi/\Delta t$
After ¼ rotation, the area of the loop of foil perpendicular to the field = 0. Thus ϕ at that point = 0
$\Rightarrow \quad \Delta\phi = 5.4 \times 10^{-3}$
f = 12Hz
Thus, period, T = 1/12 for one rotation, so time for a quarter turn is 1/12 x 1/4 = 1/48 = 0.02 secs
Magnitude of $\varepsilon = n\Delta\phi/\Delta t$
$= 1 \times 5.4 \times 10^{-3} / 0.02 =$ **0.26 V ANS**

Question 11

The emf will alternate between maximum (coil perpendicular to the field) and minimum values (coil parallel to the field) in a sinusoidal fashion.



Question 12

Change in flux as before (from completely in field to out of field where flux=0)

$\Rightarrow \Delta\phi = 5.4\text{x}10^{-3}$

$\varepsilon = n\Delta\phi/\Delta t$

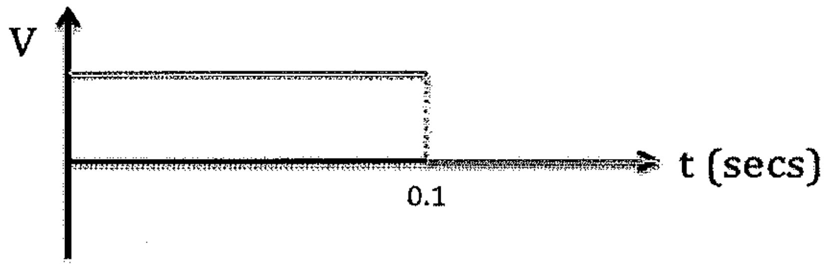
Speed is 1.2m/s, thus time taken to move 12cm out of field is $12\text{x}10^{-2}/1.2 = 0.1$secs (from v=d/t)
Magnitude of $\varepsilon = n\Delta\phi/\Delta t$

$= 1 \text{ x } 5.4 \text{ x } 10^{-3}/ 0.1 =$ **0.054 V ANS**

Question 13

Using the right hand slap rule, current flows **clockwise around the coil ANS**
Question 14

Flux is changing at a constant rate (constant speed of coil), so emf generated will be constant until the coil leaves the field, when it drops to 0.



Question 15

F = BIl

Thus, $0.03 = B(1.2)(30 \text{ x}10^{-3})$
So, B = **0.83T ANS**

Question 16

Using the right hand rule, the force is **down ANS**

Question 17

With an ac power supply, the direction of the current, and thus the resulting force, will alternate (every 1/50th of a second in this case, since T=1/100) . This will cause the wire to **vibrate.** The average size of the force will be similar to that for the DC supply.
This could be very interesting for Caz's art exhibition, as the light reflecting from the vibrating wire may create a spectacular effect.

Question 18

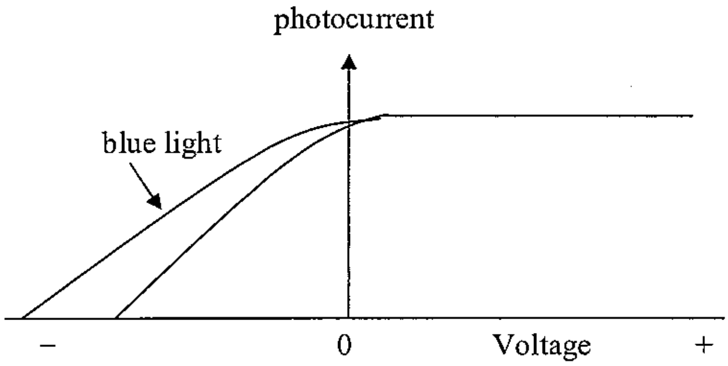
In a **generator**, the **coil rotates within a magnetic field.**
In an **altenator**, the **magnet rotates with a stationary coil.**

AREA OF STUDY 2 – Interactions of Light and matter.

Question 1

Energy per second = E/t = number of photons per sec x hf (energy per photon)
Thus, E/t = 3.2 x 10^{14} x (6.63 x 10^{-34}) (1 x 10^{15}) = 2 x 10^{-4} J/sec ANS

Question 2



With blue light, the intercept with the x-axis will change (larger retarding voltage needed to stop the more energetic electrons ejected by the higher energy blue light), but the maximum photocurrent, as stated, remains the same.

Question 3

The shape of the graph will not change, and neither will the gradient (= Planck's **constant**). The intercept on the x – axis represents the **threshold frequency** – the minimum incident frequency at which electrons will be ejected. This will be different for different metals, as will the intercept on the y-axis, which represents the **work function** of the metal – the minimum energy required to remove an electron from the surface of the metal.
Thus, the significant changes will be in **A and B ANS**

Question 4

Increasing the intensity of light has no effect on the KE of the electrons. This is because the energy given to each electron depends on the energy, and hence the frequency, of the incident light.
Thus, there will be no significant change in the graph. **D ANS**

Question 5

* Incorrect prediction of the change of the speed of light during refraction through different media (predicts incorrectly that light speeds up when passing from a less dense to more dense medium).
* Unable to satisfactorily explain partial reflection and refraction.
* Inability to explain diffraction and interference (Young's 2-slit experiment).

Question 6

The energy given to each electron depends on the energy, and hence the frequency, of the incident light. If a frequency above the threshold (minimum frequency needed to release a surface electron) is used then electrons will be ejected from the metal.
In the photoelectric effect, a photon of light gives up all of its energy to an electron in the metal. Any excess energy above that required for the electron to break free appears as kinetic energy of the electron.
If the frequency of the incident light is equal to the threshold frequency, the light will provide the surface electrons with enough energy to just leave the metal. At this point, ejected electrons will be detected but will have a kinetic energy of zero, since all the energy from the photon of light has been used for the electron to break free of the metal and none remains to be converted to kinetic energy of the electron. As the frequency is increased, the electrons are given more and more energy by the photon of light, and since the energy required to break free of the metal surface remains constant, the higher the frequency the greater the resultant KE of the ejected electron.

Question 7

$E = Vq, = 10 \times 10^3 \times 1.6 \times 10^{-19}$,
$\Rightarrow$ $= \mathbf{1.6 \times 10^{-15}\ J}$ **ANS**

Question 8

$p = h/\lambda$.
Thus, $\lambda = h/p$, and $p = \sqrt{(2Em)}$ (since $p=mv$ and $E= KE = \frac{1}{2} mv^2$)
$\lambda = (6.63 \times 10^{-34}) / \sqrt{(2 \times 1.6 \times 10^{-15} \times 9.1 \times 10^{-31})}$
$= \mathbf{1.2 \times 10^{-11}\ m}$ **ANS**

Question 9

The photons of light used in the optical microscope have a longer wavelength (around 500nm) than the electrons used in the electron microscope (see λ above). Thus, the photons diffract more, leading to greater degradation of the image quality in an optical microscope image as compared with an electron microscope.

Question 10

They would observe two bright regions of light, corresponding to the two slits they have cut in the cardboard. How disappointing!

Question 11

In order to observe diffraction effects, the slits in the cardboard must be comparable in size to the wavelength of light used in the experiment.

From $v = f\lambda$

$\Rightarrow$ $3 \times 10^8 = 5.2 \times 10^{14} \times \lambda$

$\Rightarrow$ $\lambda = 5.8 \times 10^{-7}$ m

Thus, the slits are WAY too wide and their width needs to be reduced until it is comparable to the wavelength calculated above.

Question 12

Young's experiment supports the wave model of light. The interference pattern produced on the screen is evidence of constructive and destructive interference, which is the result of the superposition of waves as they meet in phase or out of phase.

A dark region is created by a region of destructive interference (nodes), where the superposition of light waves causes cancelling (waves out of phase). The bright regions are regions of constructive interference where an antinode is formed when the waves meet in phase and reinforce.

AREA OF STUDY 3.1 – Synchrotron and its applications

Question 1

Using Bragg's equation, $2d\sin\theta = n\lambda$

Thus, $d = n\lambda/2\sin\theta$

For n=1, $d = 1(0.12 \times 10^{-9})/2\sin(15) = 2.3 \times 10^{-10}$ m = 2.3Å

The atomic plane spacing in the material is **2.3Å** Thus, **C ANS**

Question 2

For the next angle of reflection, n=2.

Thus, $2(0.12 \times 10^{-9})/2(2.3 \times 10^{-10}) = \sin\theta$

Thus, $\theta = \mathbf{32^0}$ Thus, **A ANS**

Question 3

Elastic scattering of this type is known as **Thomson scattering.** We can use these scattered X-rays to gain information about the structure of matter. Thus, **C ANS**

Question 4

This inelastic scattering is referred to as **Compton scattering**. X-ray photons interact with electrons and transfer some of their energy to the electron, resulting in the X-ray photon emerging with a longer wavelength (less energy) and the ejection of an electron. This scattering gives further evidence to the fact that photons possess momentum and can behave in a particle-like manner, and is useful for providing information about momentum density distribution of electrons in materials. Thus, **B ANS**

Question 5

This result would most likely be caused by **diffuse scattering**, which occurs when X-rays are directed at a sample with a disordered, random orientation of molecules in its array. This diffuse scattering produces a pattern of circular rings on the detector and features of the sample are difficult to discover, unlike those of regular, well-ordered crystalline samples. X-ray diffuse scattering techniques may be used to discover fluctuations in the lattice structure of crystalline solids. Thus, **A ANS**

Question 6

Total energy lost by the incident X-ray is 3.2 + 76 = **79.2eV** Thus, **B ANS**

Question 7

Energy of incident photon, $E = hf = hc/\lambda$
Thus, $E = (6.63 \times 10^{-34})(3 \times 10^{8}) / (1.4 \times 10^{-10}) = 1.4 \times 10^{-15}J = 8880eV$
Energy of scattered photon = $8880 - 79.2 = 8800.8eV = 1.4 \times 10^{-15}J$
$1.4 \times 10^{-15} = hc/\lambda = (6.63 \times 10^{-34})(3 \times 10^{8}) / \lambda$
So, $\lambda = 1.4 \times 10^{-10}m = 14nm$ Thus, **D ANS**

Question 8

The experiment supports the **particle model** of light. A single photon reacts with a single electron, with conservation of energy between the two. The wave model would not explain these discrete interactions. **B ANS**

Question 9

Electrons are produced in an **electron gun.** **A ANS**

Question 10

Electrons are accelerated to speeds close to the speed of light by the linear accelerator **(linac)**.
C ANS

AREA OF STUDY 3.2 – Photonics

Question 1

$E = hf = hc/\lambda$
$= (6.63 \times 10^{-34})(3 \times 10^{8}) / (640 \times 10^{-9})$
$= 3.1 \times 10^{-19}$J   Thus,   **B ANS**

Question 2

A smaller band gap means less energy and thus longer wavelength, so the **red LED will have a smaller band gap energy than the blue. B ANS**

Question 3

Light emitting diodes are far **more efficient** than incandescent bulbs at converting electricity into visible light, they are rugged and compact, and can often last around 100 times longer than incandescent bulbs. LEDs are fundamentally **monochromatic** emitters, and are thus ideal for applications requiring high-brightness, single-color lamps (eg: automotive tail-lights, turn signals, traffic signals, runway lights at airports, warning lights).
While there is a higher initial cost for LEDs, this can often be recovered quickly due to their higher efficiency in producing light, which is accomplished without the need for filtering.
Thus, **A and D ANS**

Question 4

n_2=1.44, n_1=1.47
$\sin \theta_c = n_2 / n_1$
Thus, $\sin \theta_c = 1.44/1.47$ So, $\boldsymbol{\theta_c = 78.4^0}$ **D ANS**

Question 5

$n_{ext} \sin \theta_1 = \sqrt{(n^2_{core} - n^2_{cladding})}$ where θ_1 = angle of acceptance
Thus, $1.33 \sin \theta_1 = \sqrt{(1.47^2 - 1.44^2)}$
So $\boldsymbol{\theta_1 = 12.8^0}$ **ANS**   **C ANS**

Question 6

Single-mode fibre is superior to multimode in both bandwidth capabilities and pulse dispersion properties, but is more expensive in terms of installation and network connection than multimode fibre. Since pulse spreading is minimal over a short distance, multimode fibre is satisfactory and more cost-effective for short-distance applications. Thus, **B and C ANS**

Question 7

Modal dispersion occurs when various rays spread out and travel different distances down the fibre and arrive out of phase with each other. If the diameter of the fibre can be reduced, the difference between the central ray and those taking the longer path will be reduced.
Thus, **C ANS**

Question 8

Single-mode fibre would minimise modal dispersion; monochromatic, intense laser light minimises material dispersion. Thus, **B ANS**

Question 9

A laser (Light Amplification by Stimulated Emission of Radiation) produces light by the stimulated emission of radiation.
The best definition is **B ANS**

Question 10

A laser light is superior to an LED in being more coherent, more monochromatic, more intense and less divergent.
Thus, **B and C ANS**

AREA OF STUDY 3.3 – Sound

Question 1

Taking the lowest and highest audible frequencies for that sound intensity – reading from the graph:
Lowest = 40Hz
Highest = 20kHz B ANS

Question 2

From the graph, the ratio = $10^{-6} / 10^{-10} = 10^4$
Converting to dB:
The ratio = $10\log_{10}(10^4) =$ **40 A ANS**

Question 3

Emilia's ear is most sensitive at the lowest point on the graph. This is the frequency at which the lowest intensity of sound is required to just hear it.
Thus, **5000Hz = 5kHz D ANS**

Question 4

Resonance occurs when the frequency imposed corresponds to the natural frequency of vibration. For example, in a resonant tube, this would depend on column length. When resonance occurs, a standing wave is set up in the tube, consisting of the superposition of the travelling sound wave with its reflection, and an amplification of sound occurs. Thus, **C ANS**

Question 5

If distance is doubled, intensity is reduced by a factor of 4.
Thus, change in L = $10\log(I_1/I_2)$ where $I_1/I_2 = 1/4$
So, change in L = -6 **C ANS**

Question 6

Sound level = $10\log(I / I_O)$, where $I_O = 1.0 \times 10^{-12}$ Wm^{-2}

$\Rightarrow 64 = 10\log(I / 1.0 \times 10^{-12})$

So, I = **2.5×10^{-6} Wm^{-2}** **B ANS**

Question 7

Sound is a **longitudinal** wave, and travels as a series of alternating compressions and rarefactions. The air particles do **not** travel from the source to the listener, but only vibrate about their mean positions, and in doing so cause neighbouring air particles to undergo a similar vibration.
Thus, **D ANS**

Question 8

λ=0.45m
Speed of sound = 330m/s
$v = f\lambda$
$\Rightarrow$ $330 = f \times 0.45$
$\Rightarrow$ **f = 733 Hz** Thus, **C ANS**

Question 9

The door is acting as a single slit, through which sound is **diffracted.** Diffraction is the **bending** of waves as they pass around the edges of an obstacle or through an aperture. The amount of diffraction depends on the slit width, w, and wavelength, λ, of the sound wave, and is proportional to λ/w. Lower frequency waves have a longer wavelength than higher frequency waves, and will therefore diffract more and be heard more clearly by the audience member around the door. Thus, **D ANS**

Question 10

The amplifier's signal is sent to a speaker coil which then contains a varying electric current. Since the coil is within a magnetic field, the interaction between the current and the magnetic field produces movement of the coil. Since the moving coil is attached to the speaker cone, this also moves, vibrating and pushing the air with a series of compressions and rarefactions which we may interpret as sound. Thus, **C ANS**