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PHYSICS

2015

Trial Examination

(2 hours 30 minutes)

Motion in one and two dimensions
Electronics and photonics
Electric power
Interactions of light and matter
Sound

(Note: Use the formula/data sheets supplied by VCAA)

SECTION A – Core studies (128 marks)

Instructions for Section A
Answer all questions in this section.
You should take the value of g to be 10 N kg^{-1}.
Appropriate working should be shown in questions worth more than 1 mark.
Diagrams are not drawn to scale unless stated otherwise.

Area of study – Motion in one and two dimensions

Question 1
The Melbourne Star is a giant Ferris wheel in the Waterfront City precinct in the Docklands area of Melbourne. It has 21 completely enclosed air-conditioned cabins. Each cabin weighs 1.3×10^4 kg, and can accommodate up to 20 passengers. The whole structure (including the cabins) consists of 1.9×10^6 kg of solid steel. The wheel has a radius of 60 metres and rotates at a constant speed. It takes 30 minutes to complete one revolution.

a. Determine the weight of the whole structure. 2 marks

N

b. Determine the speed of each cabin. 2 marks

m s^{-1}

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c. Determine the net force on a 65 kg passenger inside a cabin while the wheel is in motion. 2 marks

N

d. Determine the magnitude and direction of the reaction force of the wheel on an empty cabin when the cabin reaches the highest point of its rotation.

3 marks

N, direction:

e. Determine the magnitude and direction of the reaction force of the wheel on an empty cabin when the cabin reaches the lowest point of its rotation.

1 mark

N, direction:

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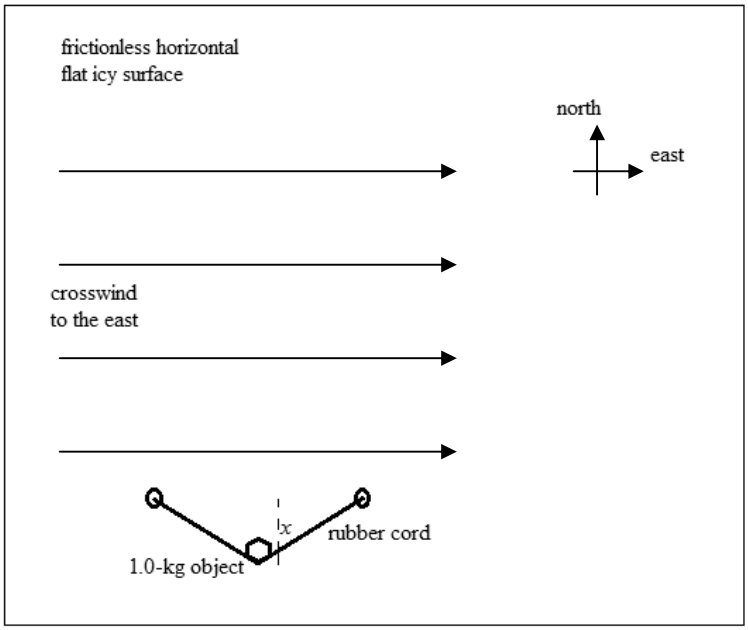
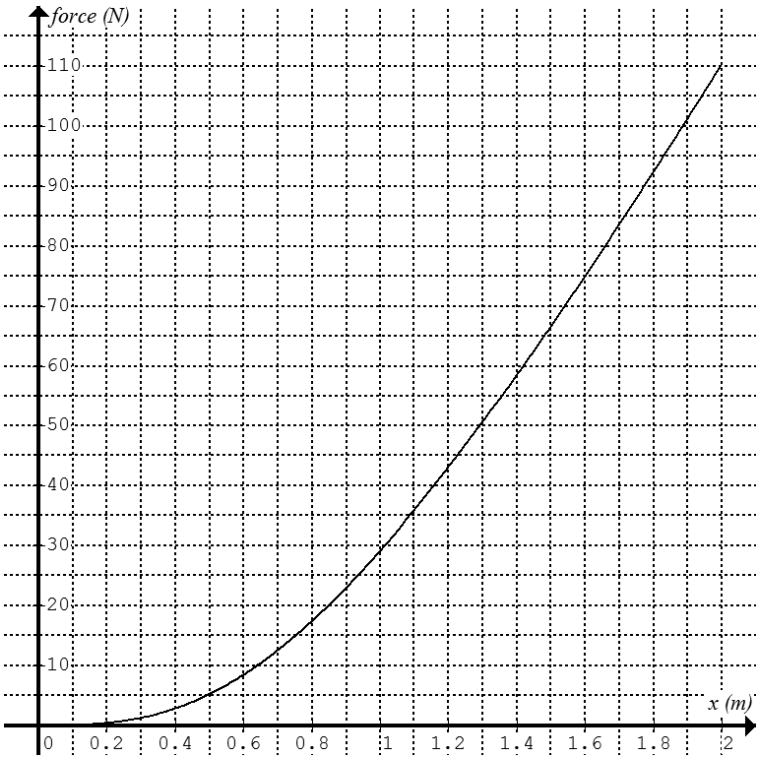
Question 2

A 1.0-kg object is projected to the north on a frictionless flat icy surface by a rubber cord as shown below.



The force exerted by the rubber cord on the 1.0-kg object when it is pulled back by x m is shown in the following graph.



a. Determine the force exerted by the rubber cord on the 1.0-kg object when it is pulled back by 1.5 m. 1 mark

N

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b. Estimate the potential energy stored in the rubber cord when it is pulled back by 1.5 m. 2 marks

J

c. Calculate the speed of the 1.0-kg object sliding on the icy surface after leaving the rubber cord. Assume that the mass of the rubber cord and the effect of the crosswind are negligible.

2 marks

m s^{-1}

Assume that the 1.0-kg object slides to the north at 8.0 m s^{-1} initially. The crosswind to the east exerts a 5.0-N force on the sliding object and it affects the motion of the object.

d. Determine the magnitude of the acceleration of the object in the crosswind. 1 mark

m s^{-2}

e. Determine the direction of motion of the 1.0-kg object after 5.0 seconds in the crosswind. 2 marks

f. Determine the change in kinetic energy of the 1.0-kg object after 5.0 seconds in the crosswind. 2 marks

J

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Question 3

The following picture shows 2 choo choo trains in Noumea.
Each train has a front engine towing 3 passenger carriages.

flickr

Assume that:
i the choo choo train travels in a horizontal straight road
ii the resistive force to the motion of the train is negligible
iii the front engine and the carriages (with passengers) have the same mass of 3000 kg each

The train speeds up uniformly to 2.5 m s^{-1} from rest after a displacement of 5.0 m, and then it maintains the speed of 2.5 m s^{-1}.

a. Calculate the acceleration of the choo choo train. 2 marks

m s^{-2}

b. Calculate the driving force of the engine. 1 mark

N

c. Determine the total force of friction between the road and the tyres of the front engine. 1 mark

N

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d. Calculate the tension in the tow bar towing the last carriage. 2 marks

N

e. Calculate the reaction force on a 75-kg passenger sitting in the last carriage while the train is accelerating. 2 marks

N

f. The train comes to a stop in 8.0 s. Determine the average power of the brakes in stopping the train. 2 marks

kW

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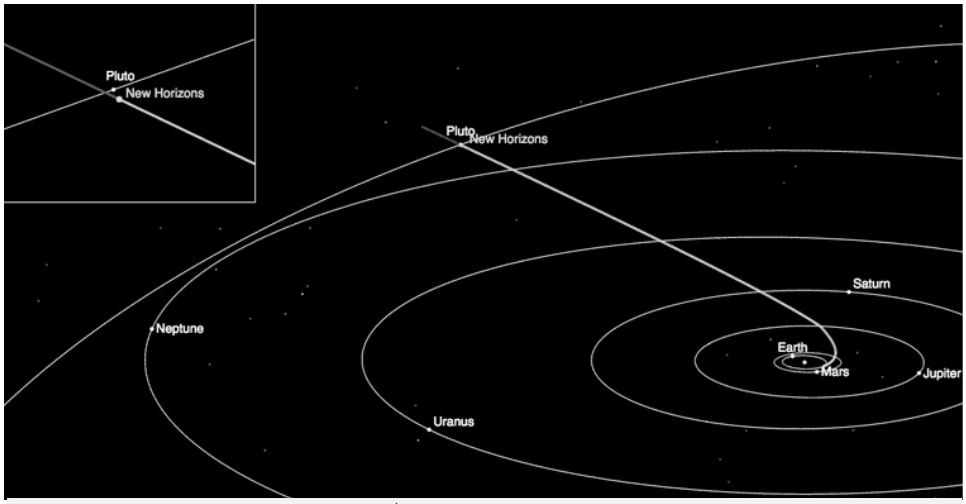
Question 4

The New Horizons probe was the first spacecraft to visit Pluto on 14 July 2015.



New Horizons' trajectory through the solar system. (**JHU/APL**) Vox Science and Health

The orbital period of Pluto around Sun is 248 years. The orbital radius of Earth around Sun is 1.5×10^{8} km.

The mass of Pluto is $\frac{1}{455}$ that of Earth. The radius of Pluto is $\frac{2}{11}$ that of Earth.

Assume circular orbits around Sun in this question.

a. Find the value of the ratio $\frac{\text{orbital radius of Pluto around Sun}}{\text{orbital radius of Earth around Sun}}$. 2 marks

b. Find the orbital radius of Pluto around Sun. 1 mark

m

c. Find the value of the ratio $\frac{\text{the weight of a person on Earth}}{\text{the weight of the person on Pluto}}$. 2 marks

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Question 5

A 75-kg skydiver takes off from a light plane. With arms and legs outstretched the terminal speed reached is $50\ \text{m s}^{-1}$ after falling for 25 seconds.

a. Calculate the change in momentum of the skydiver in the first 25 seconds. 1 mark

kg m s^{-1}

b. What is the apparent weight of the skydiver while falling at the terminal speed? 1 mark

N

c. Calculate the average drag force on the skydiver during the fall. 2 marks

N

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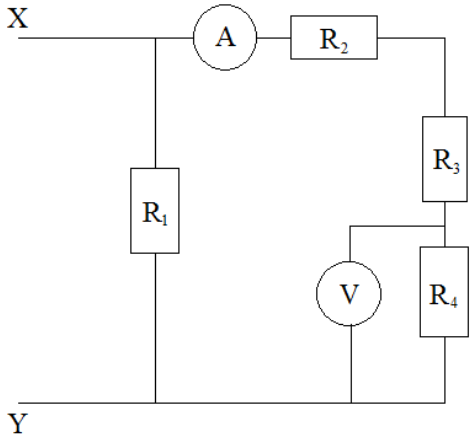
Area of study – Electronics and photonics

Question 6

The following diagram shows a part of a circuit with ammeter A and voltmeter V connected as shown.
R_1, R_2, R_3 and R_4 are ohmic resistors of the same resistance.
The readings on the ammeter and voltmeter are 22.5 mA and 3.0 V respectively.



a. Determine the current in R_1. 2 marks

mA

b. The electric potential at point Y is higher than that at point X. The electric potential at point X is 2.0 V.
Determine the electric potential at point Y. 2 marks

V

c. Find the resistance of a single ohmic resistor that can replace the four resistors R_1, R_2, R_3 and R_4. 2 marks

Ω

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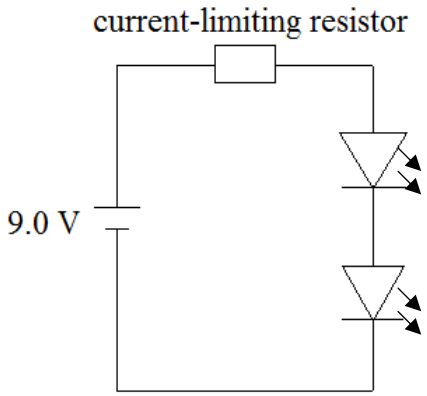
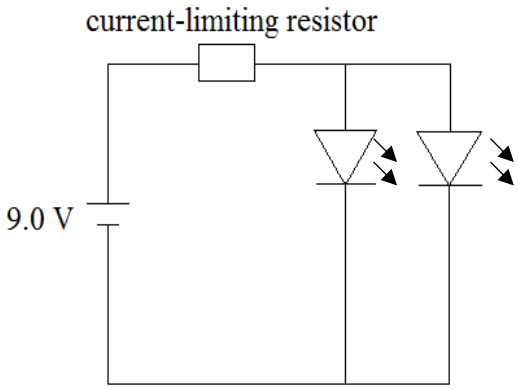
Question 7

A student attempts to make a simple torch light. She has 2 identical white LEDs (switch-on voltage 3.2 V each) and a 9.0 V battery. There are two possible circuits, Circuit **A** and Circuit **B**, she can make. She needs a current-limit resistor to complete the circuit. The current in each LED is 20 mA to get the required brightness.

Circuit **A**



Circuit **B**



a. Determine the resistance of the current-limiting resistor in each circuit. 3 marks

A: Ω	**B**: Ω

b. Explain (include calculations) which circuit is more efficient in producing light. 2 marks

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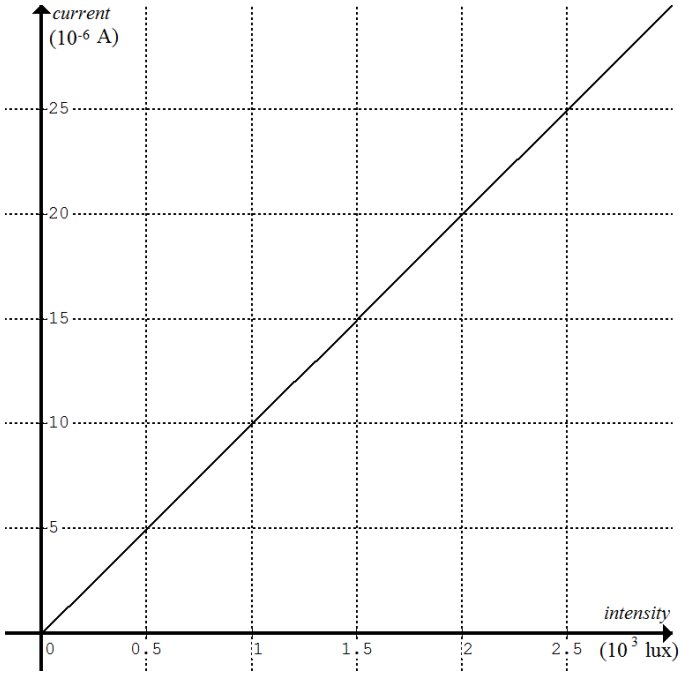
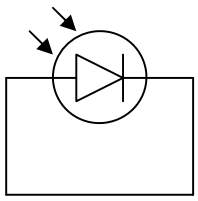
Question 8

The following graph shows the current -light intensity relationship of a photodiode.

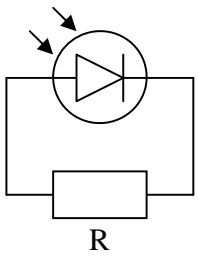


A student makes two circuits with the photodiode and an ohmic resistor R, $R = 5\,\text{k}\Omega$.
The student directs a 1000 lux light beam at the photodiode in each circuit.

Circuit **A**



Circuit **B**



a. Write down the voltage across the photodiode in Circuit A. 1 mark

V

b. Determine the voltage across the photodiode in Circuit B. 2 marks

V

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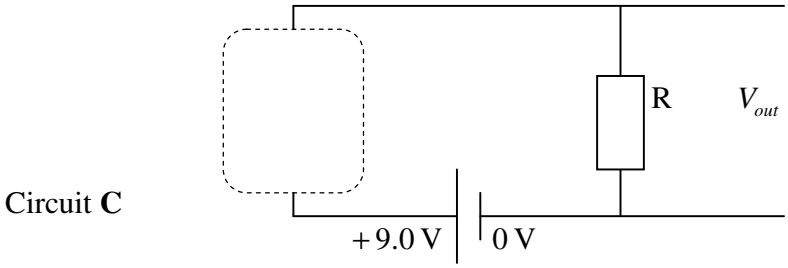
The student makes a third circuit, Circuit **C**, using a 9.0 V battery and the same photodiode and resistor.
Circuit **C** is a voltage divider and it is used to activate a switch to turn on/off outdoor lights.
The photodiode is placed outdoor. $V_{out} < 10\,\text{mV}$ will activate switch on. $V_{out} > 10\,\text{mV}$ will activate switch off.
The circuit diagram is shown below with the photodiode missing.

c. Insert the photodiode inside the dotted box to show the correct connection. 2 marks



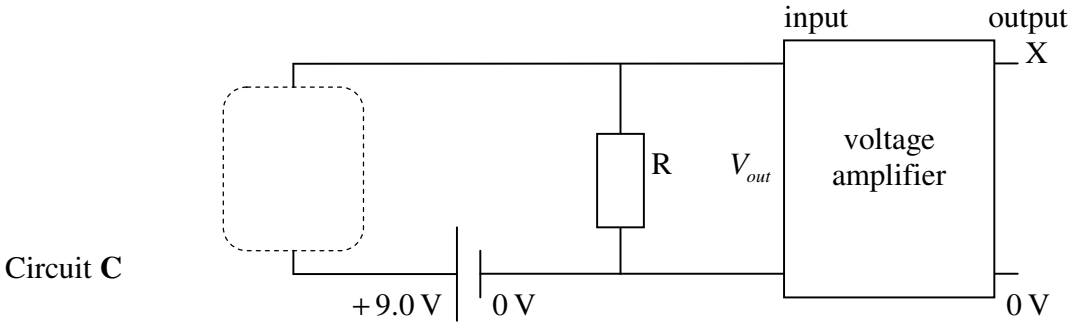
d. Calculate the voltage across the photodiode when the light intensity is 1000 lux. 2 marks

V

e. Determine the outdoor light intensity that will turn on the outdoor lights. 2 marks

lux

The student sometimes uses Circuit **C** to receive laser light signals from her friend at night when all outdoor lights are off. The student chooses to connect a voltage amplifier to Circuit **C** to amplify the electrical signals at V_{out}.



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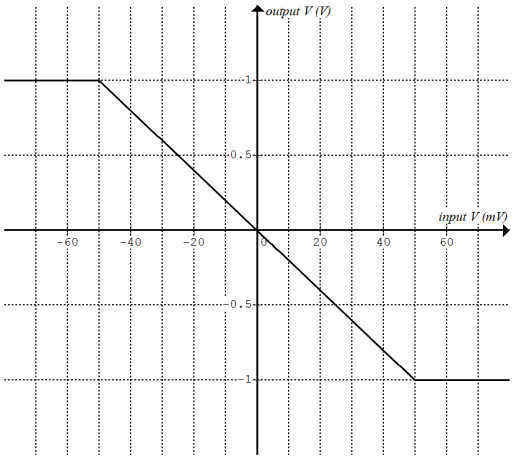
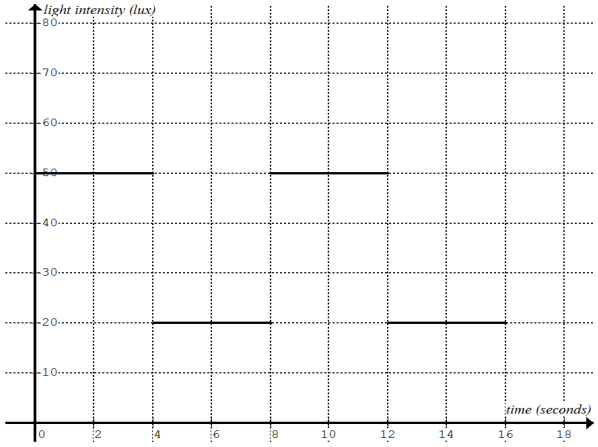
The voltage transfer graph of the voltage amplifier is shown below.

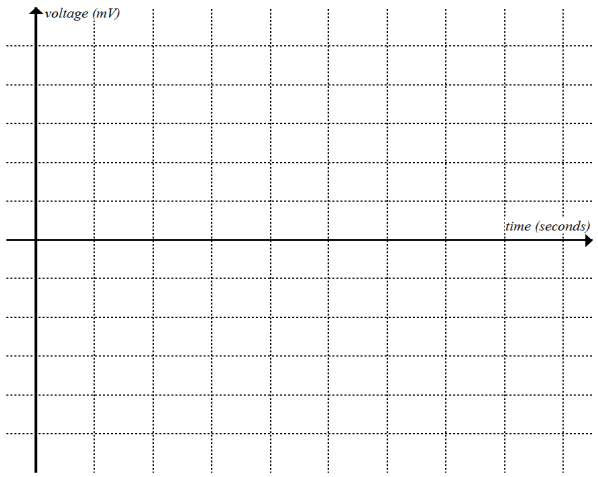


f. Calculate the magnitude of the voltage gain of the voltage amplifier. 2 marks

The following graph shows the variation of the laser beam intensity at the photodiode.



g. Sketch a graph showing the voltage variation at point X at the output of the voltage amplifier. 3 marks



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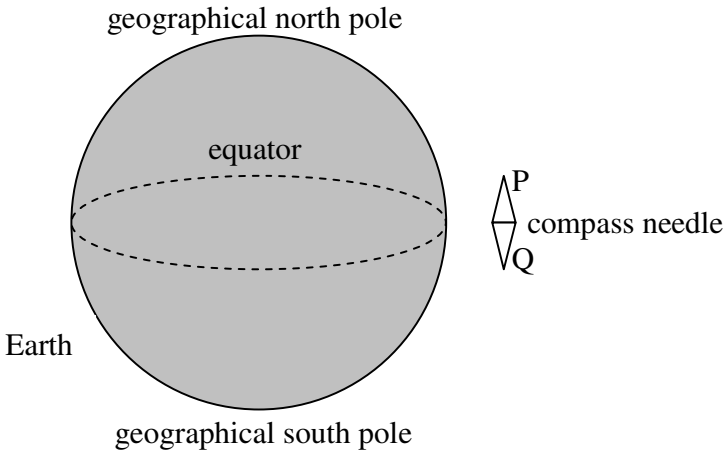
Area of study – Electric power

Question 9

Magnetic field of Earth is 4.0×10^{-5} tesla and it is horizontal at the equator.
A 12-metre cable is located at the equator and carries a current of 200 A from east to west.
The cable makes a $30°$ angle with the horizontal.
PQ is a compass needle.



a. Specify point Q of the compass needle as magnetic north pole or magnetic south pole. 1 mark

b. Calculate the magnetic force on the 12-metre cable due to the magnetic field of Earth. 2 marks

N

c. The direction of the magnetic force on the cable is (circle one of the following choices) 1 mark

A to the east

B to the north

C downwards to the ground

D none of the above

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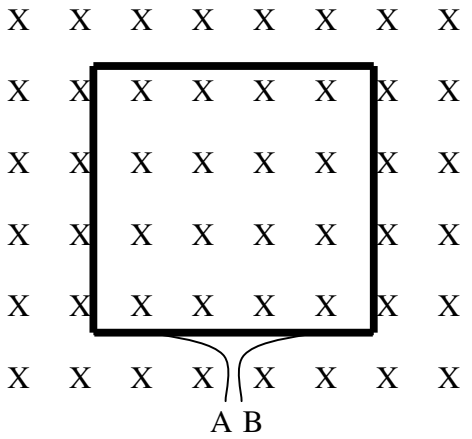
Question 10

A rigid square coil consists of 20 turns of an insulated conducting wire. The total resistance of the wire is $1.2\,\Omega$.
The side length of the square coil is 15 cm.
The coil is placed in a uniform magnetic field which decreases uniformly from 1.50 T at $t = 0$ to zero at $t = 1.5\,\text{s}$.
The magnetic field is perpendicular to the plane of the coil (into the page) as shown below.



'X' represents magnetic field into the page

a. Calculate the potential difference between the two ends, A and B, of the insulated wire at $t = 0.5\,\text{s}$. 2 marks

V

b. What is the potential difference between the two ends at $t = 1.0\,\text{s}$? 1 mark

V

c. Use Lenz's law to determine the polarity $(+ \text{ or } -)$ of points A and B while the magnetic field is decreasing. Explain.

3 marks

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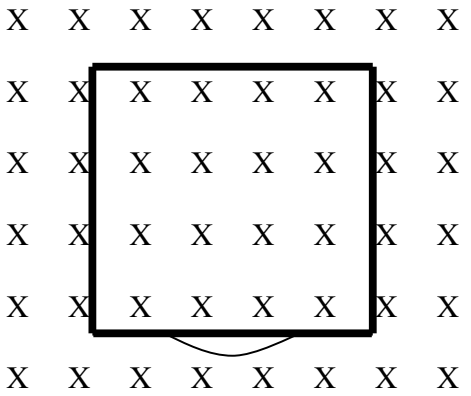
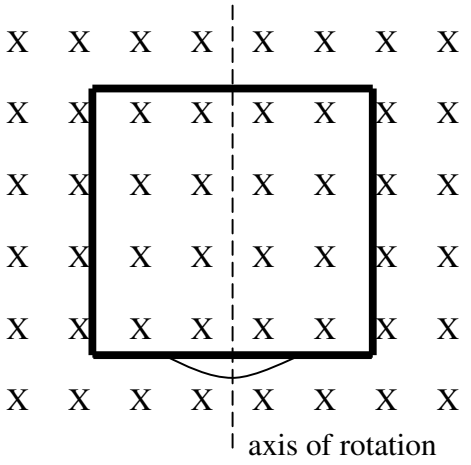
d. Now the two ends (A and B) are joined.
Calculate the electric power of the coil while the magnetic field is decreasing. 2 marks



W

e. Now the magnetic field is kept constant at 1.50 T, and the two ends (A and B) are joined.
The coil is forced to rotate about the axis of rotation.
Describe and explain the direction of any induced current in the coil. 2 marks



f. The magnetic field is kept constant at 1.50 T, and the two ends (A and B) are connected to a 9.0-V battery.
Describe and explain any rotational motion of the coil in terms of magnetic force and torque.

2 marks

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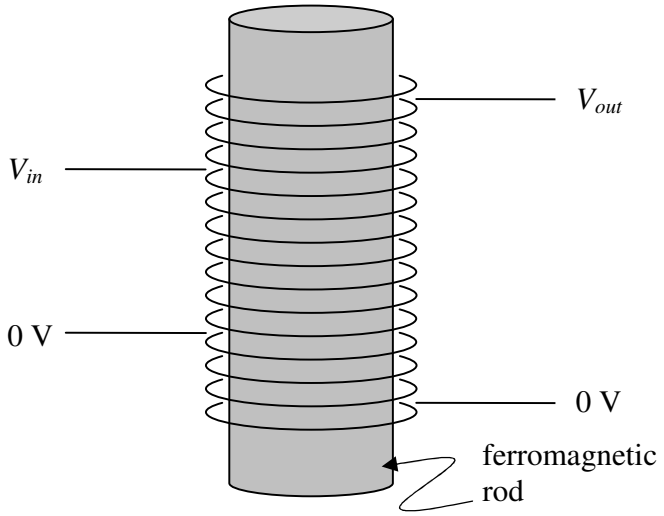
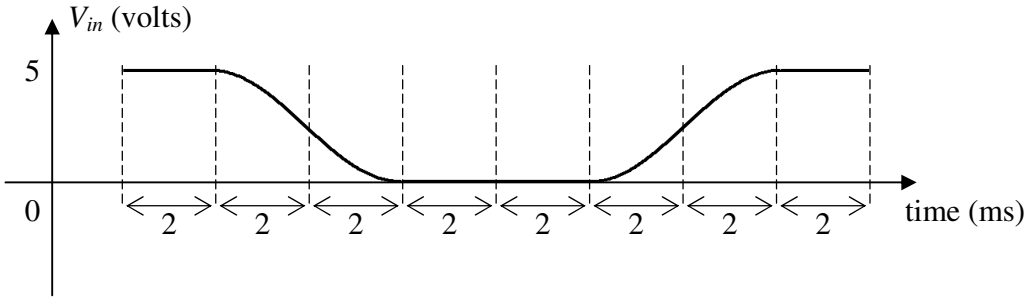
Question 11

The following figure shows a simple step-up transformer. The value of the ratio $N_s : N_p$ is 10, where N_p is the number of turns in the primary coil and N_s in the secondary coil.



A cycle of V_{in} is shown in the following graph.



a. Sketch the graph of a cycle of V_{out} corresponding to V_{in} shown above. Specify the maximum and minimum values of V_{out} .

4 marks

b. Explain the working of the simple step-up transformer in relation to Faraday's law. 2 marks

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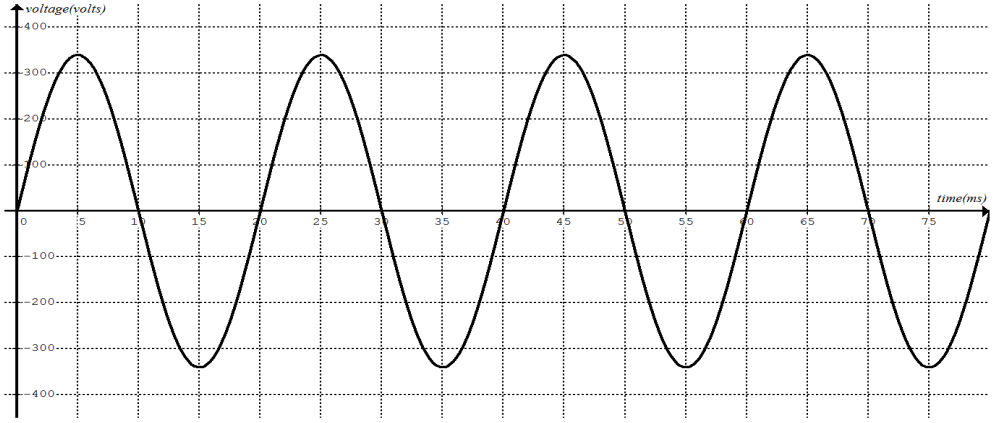
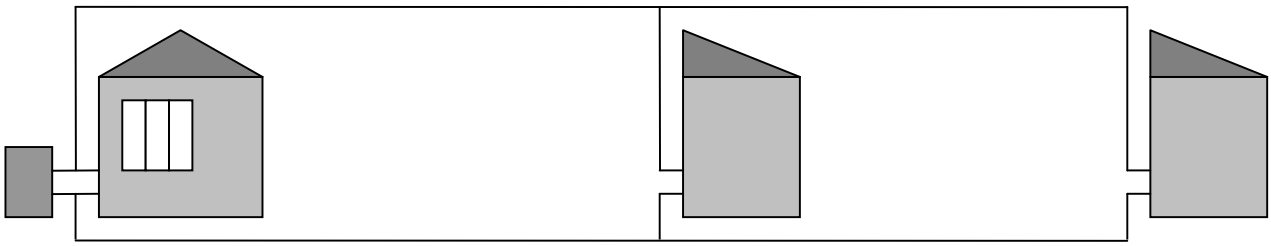
Question 12

A farm house has its standby generator in case of mains power outage. The generator provides a sinusoidal voltage as shown in the following graph to the farm house.



The generator also supplies power to two farm sheds.
The total resistance of the cables from the generator to the farm house is negligible.
The total resistance of the cables from the generator to Shed 1 is $1.0\,\Omega$, and from Shed 1 to Shed 2 is $0.6\,\Omega$.
All electrical devices in Shed 1 and Shed 2 are turned off.



a. Determine the rms voltages at the house and at Shed 2. 2 marks

House: V	Shed 2: V

Now the electrical devices in Shed 1 and Shed 2 are turned on.
The total current through the devices in Shed 1 is $5.0\,A$, and through the devices in Shed 2 is also $5.0\,A$.

b. Determine the rms voltages at the house and at Shed 2. 4 marks

House: V	Shed 2: V

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c. Calculate the total power loss in the cables. 2 marks

W

d. Calculate the total power of the electrical devices in Shed 1. 2 marks

W

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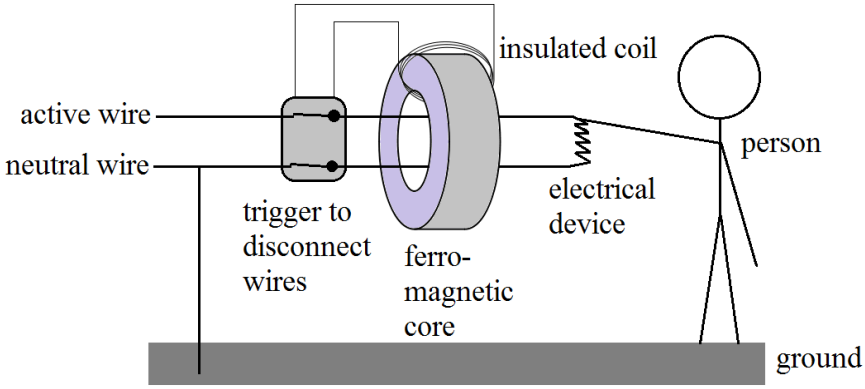
Question 13

A **residual-current device** (**RCD**) is an electrical wiring device that disconnects a circuit whenever it detects that the electric current is not balanced between the active wire and the neutral wire. In normal circumstances, these two wires are expected to carry matching currents, and any difference usually indicates a short circuit or other electrical anomaly is present. RCDs are designed to disconnect the active and neutral wires quickly enough to prevent serious injury to a person from such shocks.

In the following diagram (not drawn to scale), the RCD consists of the ferromagnetic core, the insulated coil and the trigger.



a. Compare the currents in the active wire and the neutral wire (i) before and (ii) while the person comes in contact with the active wire as shown in the diagram.

2 marks

b. In terms of electromagnetism explain the working of the RCD when the person comes in contact with the active wire as shown in the diagram.

2 marks

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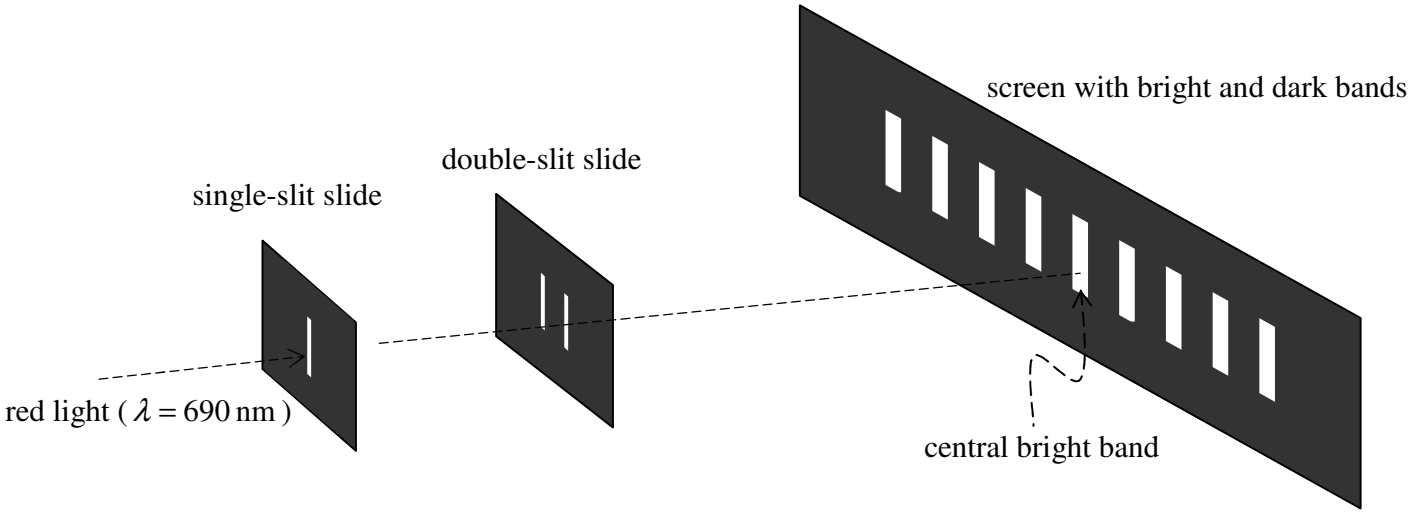
Area of study – Interactions of light and matter

Question 14

The following diagram illustrates the setup of Young's double slit experiment.
Initially red light ($\lambda = 690\,\text{nm}$) is used in the experiment.



a. Calculate the difference between the distances from the two slits on the double-slit slide to the **second** dark band (counting from the central bright band).

2 marks

m

b. Describe and explain the effects on the pattern on the screen when blue light is used instead of red light.

2 marks

c. Describe and explain the effects on the pattern on the screen when the single-slit slide is removed.

2 marks

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Question 15

A metal surface is illuminated by ultraviolet light (250 nm).

a. Describe two possible interactions of the ultraviolet light with the electrons in the metal. Give the names of the two possible interactions.

3 marks

The maximum kinetic energy of the emitted electrons is 2.7 eV.

b. Calculate the work function of the metal. 2 marks

eV

c. Calculate the minimum frequency of light required for the emission of electrons from the metal. 2 marks

Hz

d. Explain why the emitted electrons have a range of kinetic energy. 2 marks

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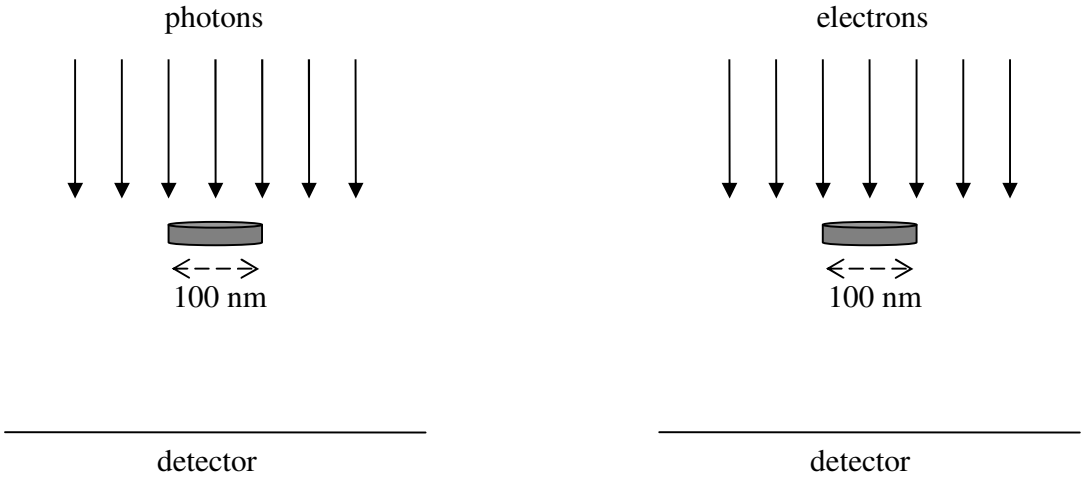
Question 16

Consider the following thought experiment.
A beam of photons (photon momentum $= 9.0 \times 10^{-27}$ kg m s^{-1}) is directed at a 100 nm wide particle and a beam of electrons (electron energy $= 1.6 \times 10^{-17}$ J) is directed at an identical particle.



a. Calculate the wavelength of the beam of photons. 1 mark

nm

b. Calculate the wavelength of the beam of electrons. 2 marks

nm

c. Discuss/explain which one will produce a sharper (better defined) image of the particle at the detector in terms of wave natures. 3 marks

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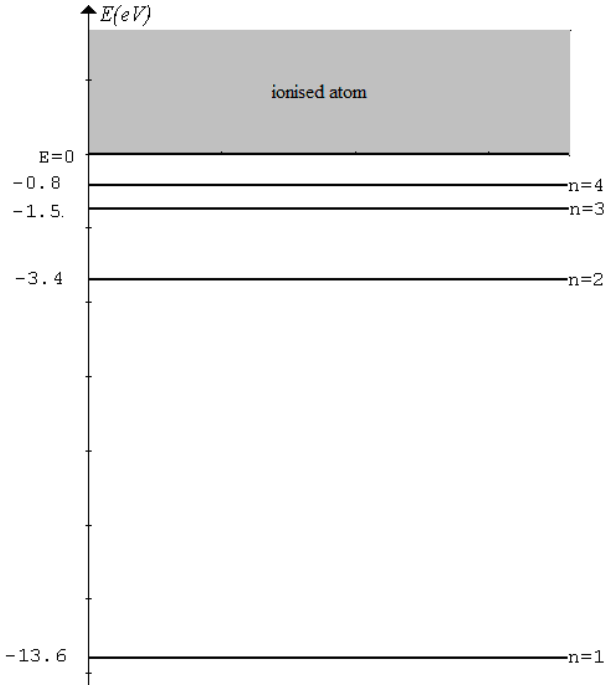
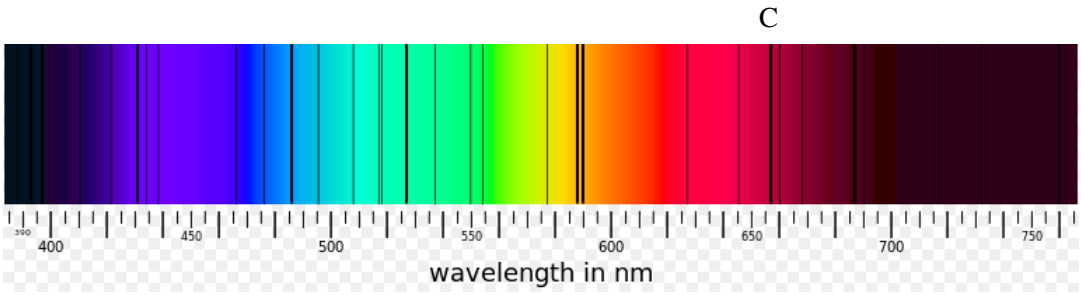
Question 17

An energy-level diagram ($n = 1$ to 4) for the hydrogen atom and the visible spectrum of sunlight are shown below.





a. Light from the Sun has to pass through the photosphere surrounding it. Atoms are present in the photosphere of the Sun. Explain the appearance of dark lines in the visible spectrum of sunlight. 2 marks

b. The dark line labeled as C in the red region has a wavelength of 656.28 nm. Show a calculation and use the energy-level diagram of hydrogen atom to explain the appearance of dark line C in the spectrum. 3 marks

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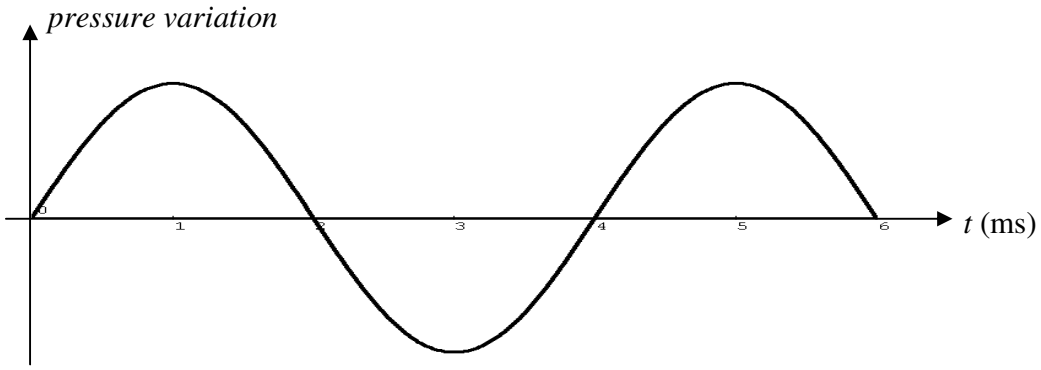
SECTION B

Answer **all** questions in this section.
Choose the response that is **correct** for the question.
A correct answer scores 2, an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.

Detailed study 6 – Sound **Circle the best choice in each question**

Use the following information to answer Questions 1, 2, 3 and 4

The following graph shows the pressure variation at a **particular point** in space where a sound wave exists. The speed of sound is 340 m s^{-1}.



Question 1

The frequency (Hz) of the sound wave is closest to

A. 150

B. 160

C. 250

D. 260

Question 2

The wavelength (m) of the sound wave is closest to

A. 1.3

B. 1.4

C. 2.1

D. 2.3

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Question 3

The speed of sound can be increased by

A. increasing the amplitude

B. increasing the frequency

C. increasing the wavelength

D. increasing the air temperature

Question 4

At the **particular point**

A. there is a compression

B. there is a rarefaction

C. there is a pressure anti-node

D. there is a pressure node

Use the following information to answer Questions 5 and 6

Anita, Betty and Cathy are in three different hot air balloons at some distance from each other above the ground. Anita makes a loud sound. The difference in sound intensity levels measured by Betty and Cathy is 5.8 dB. Assume that the only sound source is from Anita.

Question 5

The ratio of the sound intensities measured by Betty and Cathy is closest to

A. 5.2

B. 2.8

C. 0.85

D. 0.25

Question 6

Anita increases the output of the sound source by doubling it whilst maintaining her distances from Betty and Cathy. The difference in sound intensity levels (dB) measured by Betty and Cathy is closest to

A. 6

B. 12

C. 24

D. 48

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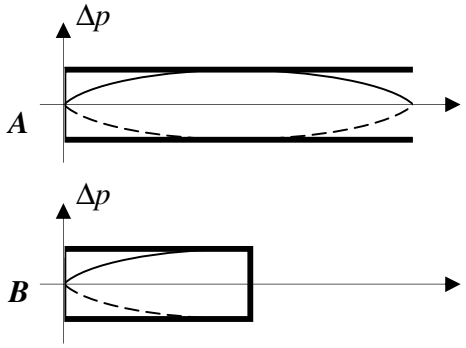
Use the following information to answer Questions 7 and 8

Open pipe ***A*** is 2 times the length of closed pipe ***B***. The length of closed pipe **B** is 0.50 m.
The pressure variation patterns of the air inside the pipes are shown below.
The speed of sound in air is 340 m s^{-1}.



Question 7

Which of the following statements is correct?

A. The sound from ***A*** has a higher frequency than the sound from ***B***.

B. The sound from ***A*** has a lower frequency than the sound from ***B***.

C. The sound from ***A*** has the same frequency as the sound from ***B***.

D. The sound from ***A*** is louder than the sound from ***B***.

Question 8

Which of the following statements is correct?

A. The first overtone of the sound from ***A*** has a higher frequency than the first overtone of the sound from ***B***.

B. The first overtone of the sound from ***A*** has a lower frequency than the first overtone of the sound from ***B***.

C. The first overtone of the sound from ***A*** has the same frequency as the first overtone of the sound from ***B***.

D. The first overtone of the sound from ***A*** is louder than the first overtone of the sound from ***B***.

Question 9

Loudspeakers are used to set up the pressure variations as shown in the diagrams above.
Loudspeaker A is placed near an open end of pipe ***A***, and loudspeaker B is placed near the open end of pipe ***B***.
Which of the following statements is ***not*** correct?

A. The frequency of loudspeaker A is 170 Hz.

B. The frequency of loudspeaker B is 170 Hz.

C. The frequency of loudspeaker B is two times that of loudspeaker A.

D. The frequency of loudspeaker B is the same as that of loudspeaker A.

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Use the following information to answer Questions 10 and 11

A loudspeaker is placed in the open and three signals of low, mid-range and high frequencies are sent to it one by one.

A person, standing 5 metres directly in front of the loudspeaker in the open, measures the sound intensity levels of the three signals to be the same, i.e. $L_{low} = L_{mid} = L_{high}$.

The loudspeaker is then placed at the corner of a hall and the same signals of low, mid-range and high frequencies are sent to it. The person stands at 5 metres directly in front of the loudspeaker and measures the sound intensity levels of the signals again.

Question 10

Which of the following statements is correct?

A. $L_{low} = L_{mid} = L_{high}$

B. $L_{low} > L_{high}$

C. $L_{low} < L_{high}$

D. $L_{mid} > L_{low}$ and $L_{mid} > L_{high}$

Question 11

The behaviours of sound which help to explain your choice for **Question 10** are

A. refraction and diffraction

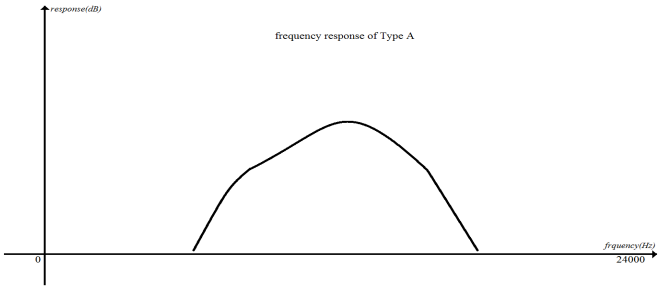
B. diffraction and reflection

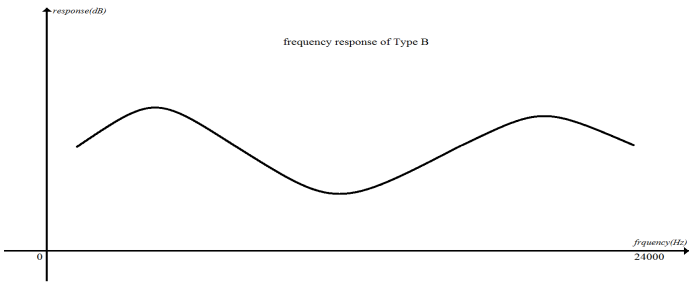
C. interference and reflection

D. refraction and interference

Question 12

Two types of microphones are purpose-made by a manufacturer. The frequency response graphs of the two types of microphones are shown below. Which type(s) is/are suitable for musical concerts?





A. Type A only

B. Type B only

C. Both Type A and Type B

D. Neither Type A nor Type B

End of examination

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