Question 12 (5 marks)

Students are testing two identical radio transmitters, R1 and R2, on a football field. The transmitters are positioned 24 m apart, as shown in Figure 15. The transmitters are in phase, both emitting crests simultaneously, and emit waves of wavelength 18 m in all directions. The students are standing at point X, which is located 72 m away from the nearest transmitter, R1.

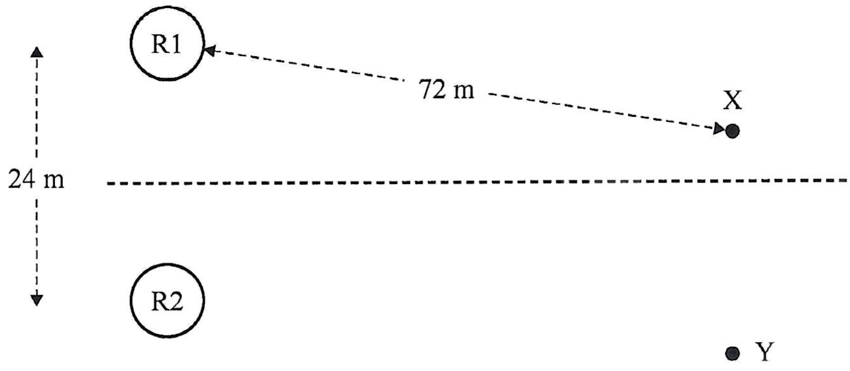

Figure 15

a. During testing, the radio signal received at point X is detected to be a minimum.

Calculate the shortest distance that point X could be from R2. Show your working. 2 marks

$R_2X - R_1X = \frac{\lambda}{2} = 9\,m$

$R_2X - 72 = 9$

81 m

b. At another location on the football field, point Y, the students detect a maximum.

Explain why the two observations at points X and Y would support the wave model of light. 3 marks

These observations are due to the interference
Destructive interference at X and constructive
at Y. Interference is a wave phenomenon

Question 13 (4 marks)

The boundary between two transparent materials, Medium 1 and Medium 2, each having different refractive indices, is shown in Figure 16. An incident ray at an angle θ_i is also shown.

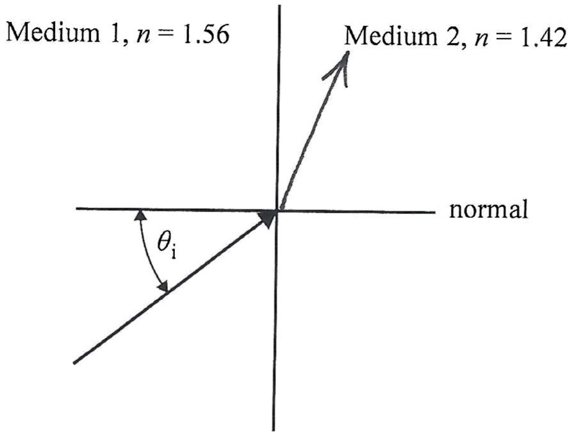

Figure 16

a. The refracted ray appears in Medium 2.

Sketch the approximate direction of the refracted ray in Medium 2 on Figure 16. 1 mark

b. What range of incident angles, θ_i, would result in a light ray emerging in Medium 2? Show your working. 3 marks

$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1.42}{1.56}\right) = 65.5^{\circ}$

65.5°

Question 14 (2 marks)

To explain different aspects of mechanical waves, a Physics teacher sets up a demonstration in a Physics laboratory using a 0.80 m wide loudspeaker and a microphone. The microphone measures the sound intensity at different positions on a circle around the speaker from position A to position B, as shown in Figure 17.

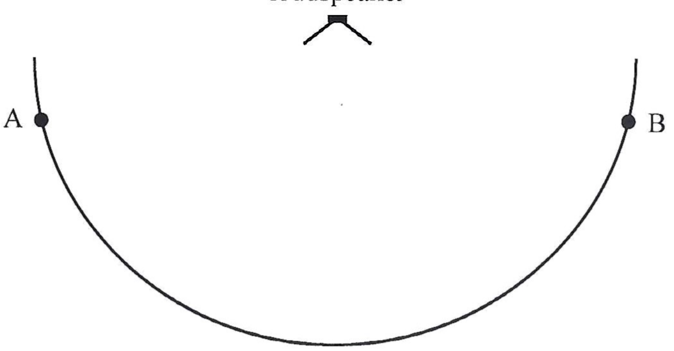

Figure 17

The speed of sound in the Physics laboratory is 334 m s^{-1}. Measurements are made at frequencies of 100 Hz and 10 000 Hz. The loudspeaker emits the 100 Hz and 10 000 Hz frequencies with equal intensity. Figure 18 shows the intensity, *I*, measured for each frequency at positions on the semicircular line shown in Figure 17 between positions A and B.

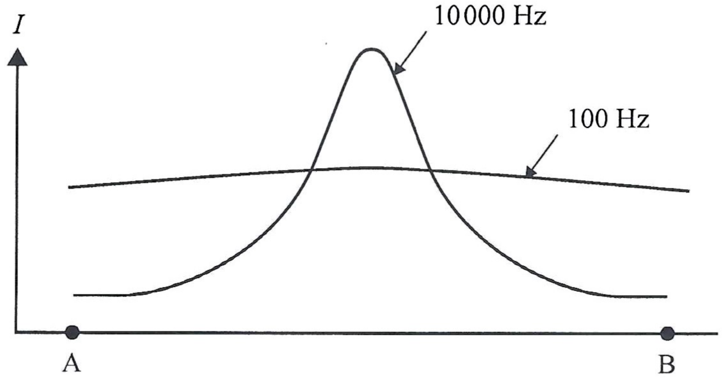

Figure 18

Explain why the response at 10 000 Hz has a greater intensity directly in front of the loudspeaker, while the response at 100 Hz is nearly the same at all positions.

At 10000 Hz $\lambda = \frac{334}{10000} = 0.0334$ m $\frac{\lambda}{w} = \frac{0.0334}{0.8} = 0.0375 << 1$ – very little diffraction. At 100 Hz $\lambda = \frac{334}{100} = 3.34$ $\frac{\lambda}{w} = \frac{3.34}{0.8} = 4.18 > 1$ – significant diffraction

Question 15 (7 marks)

The apparatus shown in Figure 19 is used to investigate the photoelectric effect. Light of various wavelengths is shone onto a silver plate (cathode). The work function of silver is 4.9 eV.

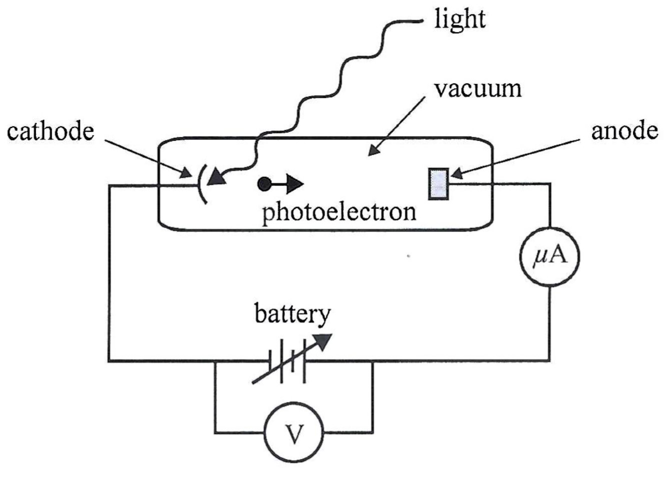

Figure 19

a. Explain what happens when light of wavelength 400 nm hits the silver plate. Use calculations to support your answer. 2 marks

$E = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3\times10^{8}}{400\times10^{-9}} = 3.1\,eV$

$3.1 < 4.9$

No electrons emitted

b. Explain what happens when light with a photon energy of 5.4 eV hits the silver plate. 2 marks

$E_K = hf - W = 5.4 - 4.9 = 0.5\,eV$

Photoelectron with energy 0.5 eV will be emitted.

c. Which model of light does this photoelectric investigation support? Give two reasons to justify your answer. 3 marks

Model of light particle

1. Threshold frequency. No electrons emitted if energy of photons < 4.9 eV

2. Energy of photon depends on frequency, higher frequency light results in electron emission

Question 16 (6 marks)

X-rays of wavelength 2.0 nm are emitted from an X-ray source.

a. Calculate the energy of **one** photon of these X-rays. Show your working. 3 marks

$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{2 \times 10^{-9}}$

621 eV

b. The 2.0 nm X-rays are incident on a single narrow slit of width 5×10^{-8} m.

Would a diffraction pattern be observed? Justify your answer. 3 marks

$\frac{\lambda}{w} = \frac{2 \times 10^{-9}}{5 \times 10^{-8}} = 0.04 << 1$ No diffraction will be observed

Question 17 (5 marks)

Light from a mercury vapour lamp shows a line spectrum related to discrete energy levels. Some of the energy levels for the mercury atom are shown in Figure 20.

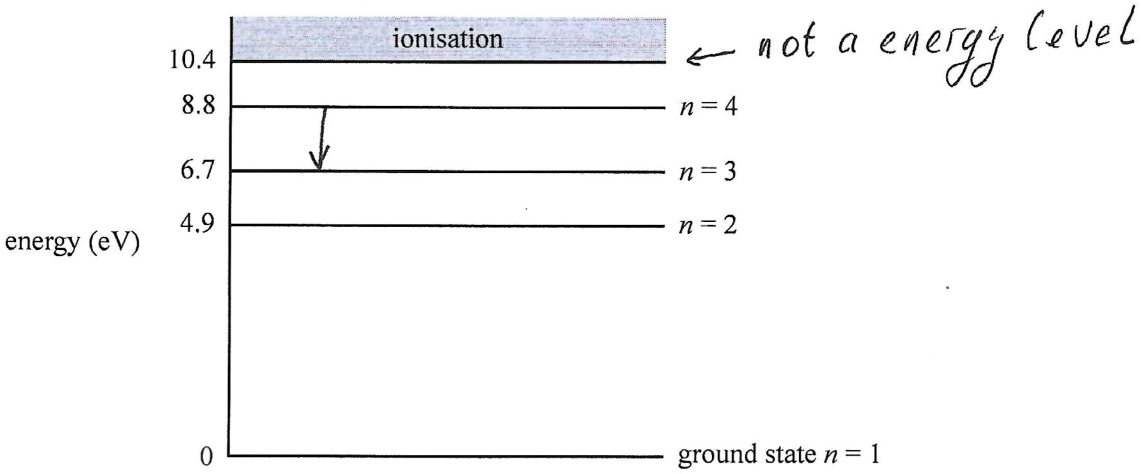

Figure 20

a. Draw an arrow on Figure 20 to indicate the transition between the listed energy states that would produce the lowest frequency of an emitted photon. 1 mark

b. Calculate the energy of the light emitted when the mercury atom makes a transition from the third energy level ($n = 3$) to its ground state ($n = 1$). Show your working. 2 marks

$E = 6.7\ eV = 6.7 \times 1.6 \times 10^{-19}$

1.07×10^{-18} J

c. Explain what happens to a mercury atom in its ground state if a photon of energy 2.1 eV is incident on it. 2 marks

Nothing, not enough energy for transition to higher level.