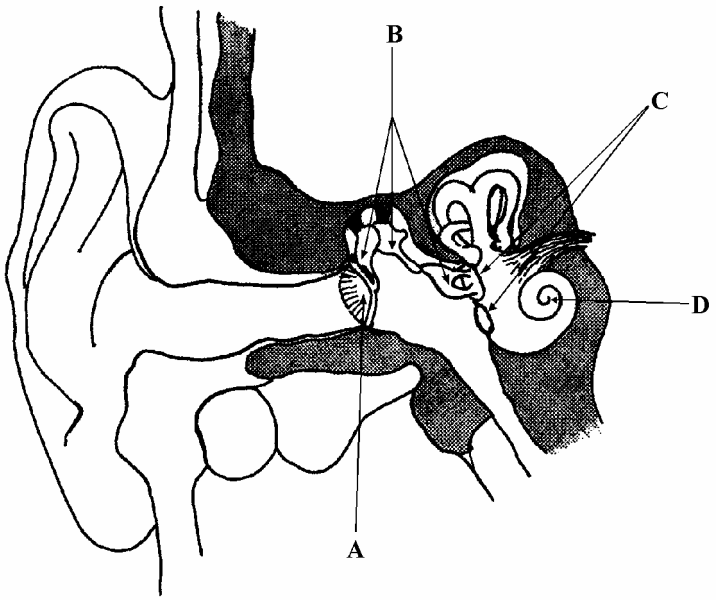
1. The diagram shows a vertical section through the human ear. Solid bone is shaded grey.



Name and state the function of the parts labelled A, B, C and D.

A name .....

function .....

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B name .....

function .....

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C name .....

function .....

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D name .....

function .....

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(Total 8 marks)

2. (a) The *threshold of hearing* is quoted as 1.0×10^{-12}W m^{-2}. Explain what is meant by the *threshold of hearing* and state the frequency at which the threshold has this value.

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(2)

(b) Sound intensity levels are usually measured in decibels. Give **two** reasons why this *logarithmic* scale is used.

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(2)

(c) Why was it necessary to introduce an adapted scale referred to as the dBA scale, which is used on some sound level matters?

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(1)

(d) Modern hi-fi equipment and televisions often have volume controls which allow the sound volume to be increased in steps. If each of these steps produces an increase in the sound intensity level of 2.0 dB, calculate

(i) the ratio by which the sound intensity is increased for each step up in volume,

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(ii) the ratio by which the sound intensity is increased for a total of 10 identical steps up in the volume.

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(4)

(Total 9 marks)

3. (a) State what is meant by the *threshold of hearing* and state the frequency at which the reference threshold is quoted.

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(b) Sketch a curve on the axes to show how the threshold of hearing varies with frequency across the full range audible to a normal human ear. Add a suitable frequency scale to the frequency axis.

(5)

(c) (i) Calculate the intensity of a sound which is found to have an intensity level of 60 Db above the threshold of hearing. The intensity of the threshold of hearing is $1.0 \times 10^{-12} \text{Wm}^{-2.}$

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(ii) The smallest increase in sound intensity which the human ear can detect is about 12%. Express this change in decibels.

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(4)
(Total 11 marks)

4. (a) State **two** reasons why the *logarithmic* dB scale is used to compare sounds of different intensities.

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(2)

(b) Another scale used to compare sounds of different intensities is the dBA scale. What are the main differences between the dBA and the dB scales?

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(3)

(c) A reading of 94 dB is obtained on a sound meter placed near a drill. Calculate the intensity of the sound incident on the meter.

reference threshold intensity $I_0 = 1.0 \times 10^{-12}$ W m^{-2}

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(3)

(d) An identical drill is now placed next to the first drill and both are switched on. Calculate the new reading on the sound meter.

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(2)
(Total 10 marks)

5. (a) The acoustic impedance, Z, of a medium is equal to the product of the medium's density and the speed of sound in that medium. When sound is incident on the boundary between two media of acoustic impedances Z_1, and Z_2 respectively, some sound is reflected and some transmitted. The ratio of the reflected intensity, I_r, to the incident intensity, I_i, is given by the equation

$$\frac{I_r}{I_i} = \left[\frac{(Z_2 - Z_1)}{(Z_2 + Z_1)}\right]^2$$

speed of sound in air = 330 m s^{-1}
speed of sound in tissue = 1540 m s^{-1}
density of air = 1.3 kg m^{-3}
density of tissue = 1100 kg m^{-3}

(i) Calculate, giving the appropriate unit, the acoustic impedance of air.

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(ii) Calculate the acoustic impedance of tissue.

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(iii) Show that the ratio $\frac{I_r}{I_i}$ at an air/tissue boundary is approximately 1.

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(3)

(b) Use your answer to part (a)(iii) to explain why a coupling gel is needed between an ultrasound probe and a patient's skin. State and explain what the ideal value of the acoustic impedance would be for such a gel.

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(3)

(c) An A-scan is used to find information about the depth and size of organs within a patient's body. Explain

(i) the basic physical principles behind the A-scan,

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(ii) how the results are used to find the size of an organ.

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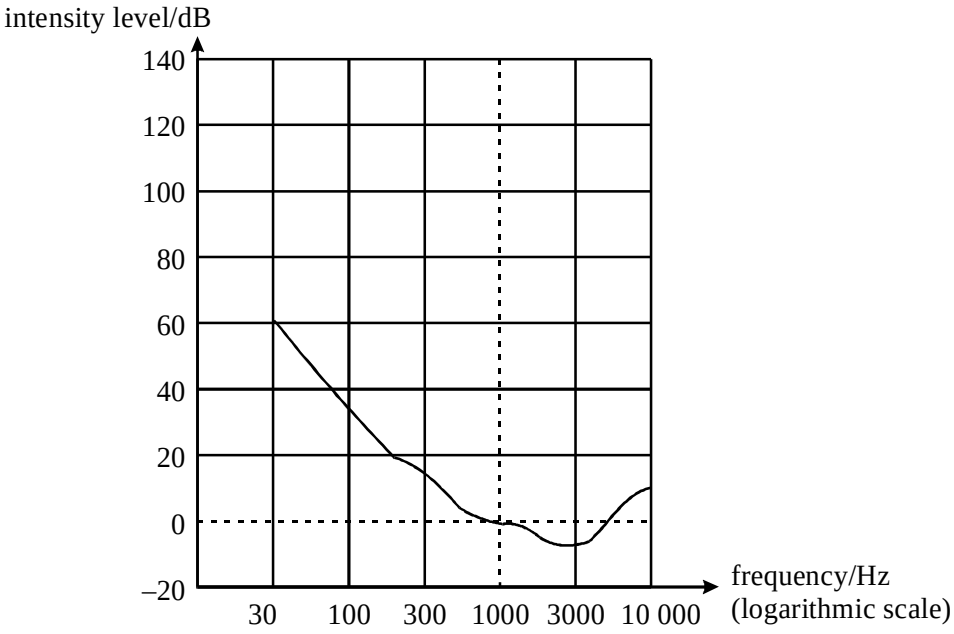
(4)
(Total 10 marks)

6. (a) The graph shows the equal loudness curve for the threshold of hearing.



(i) On the diagram sketch the equal loudness curve which has an intensity level of 120 dB at a frequency of 1000 Hz. (120 phon)

(ii) What is the main similarity between the two curves?

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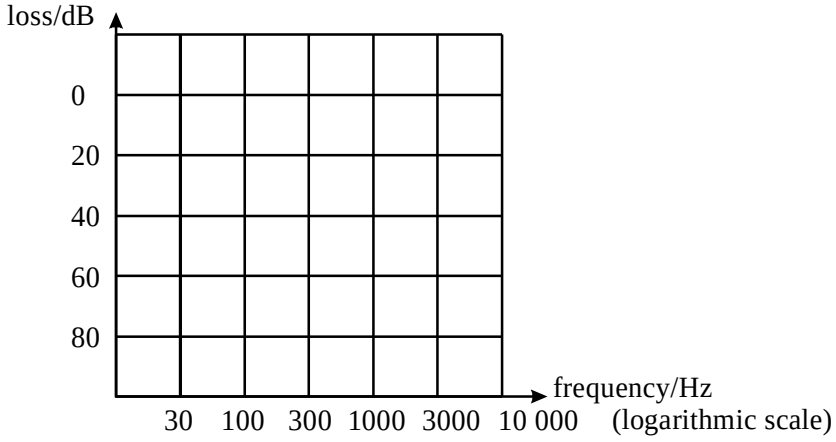
(2)

(b) On the axes below draw the curves for:

(i) age-related hearing loss and label it A,

(ii) noise-induced hearing loss and label it B.



(iii) What is the main difference between the two types of hearing loss?

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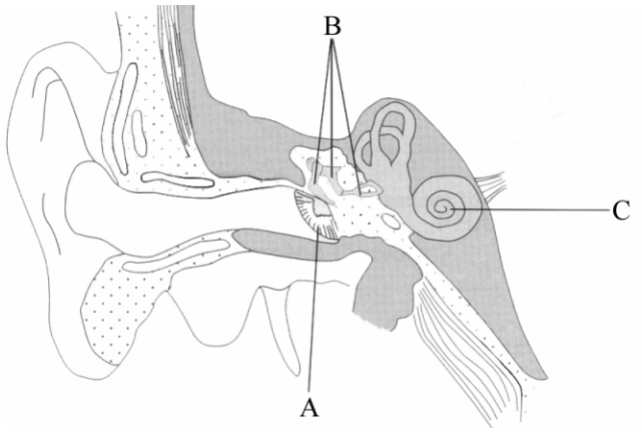
(4)
(Total 6 marks)

7. The diagram shows a vertical section through a human ear.



(a) Name and state the functions of the parts labelled A, B and C in the diagram.

A name .....

function .....

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B name .....

function .....

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C name .....

function .....

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(6)

(b) An ear has a threshold of hearing at a particular frequency at an intensity level of 42 dB. Calculate the intensity of sound incident on the ear.

$I_0 = 1.0 \times 10^{-12}$ W m^{-2}

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(2)
(Total 8 marks)

8. A ship sounds its foghorn. A person on a cliff hears the sound which has an *intensity* of 0.13 mW m^{-2}.
The sound suffered *attenuation* in travelling between the ship and the person.

(a) (i) Define intensity.

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(ii) State what is meant by attenuation and what causes it.

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(3)

(b) Calculate the intensity level of the sound heard by the person described above.

threshold of hearing $I_0 = 1.0 \times 10^{-12}$ W m^{-2}

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(2)
(Total 5 marks)

9. (a) (i) State the main difference between the dB scale and the adapted dBA scale used to measure sound intensity levels.

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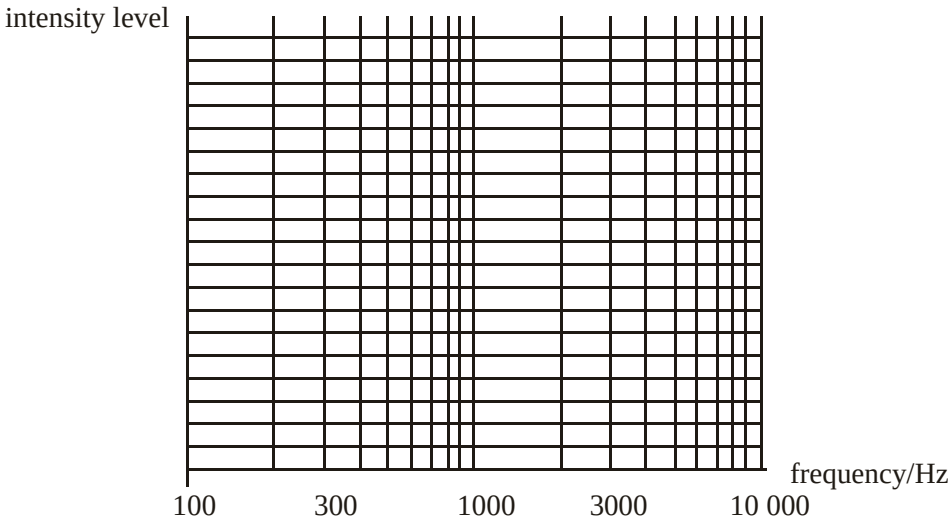
(ii) A variable frequency sound source produces sound of equal intensity at all frequencies. Two sound meters are placed equidistant from the source. One meter is switched to the dB scale. The other meter is switched to the dBA scale.

On the axes below sketch the response of the two sound meters as the frequency varies from 100 Hz to 10 000 Hz. Label each curve dB or dBA.



(5)

(b) A sound of intensity level 85 dB is incident on a human ear. The cross-sectional area of the ear canal is 65×10^{-6} m^2. Calculate the power incident on the ear-drum.

threshold intensity level, $I_0 = 1.0 \times 10^{-12}$ W m^{-2}

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(3)
(Total 8 marks)

10. A patient has a hearing test to obtain an equal loudness curve at a level above the threshold of hearing. The curve obtained is shown in **Figure 1**.

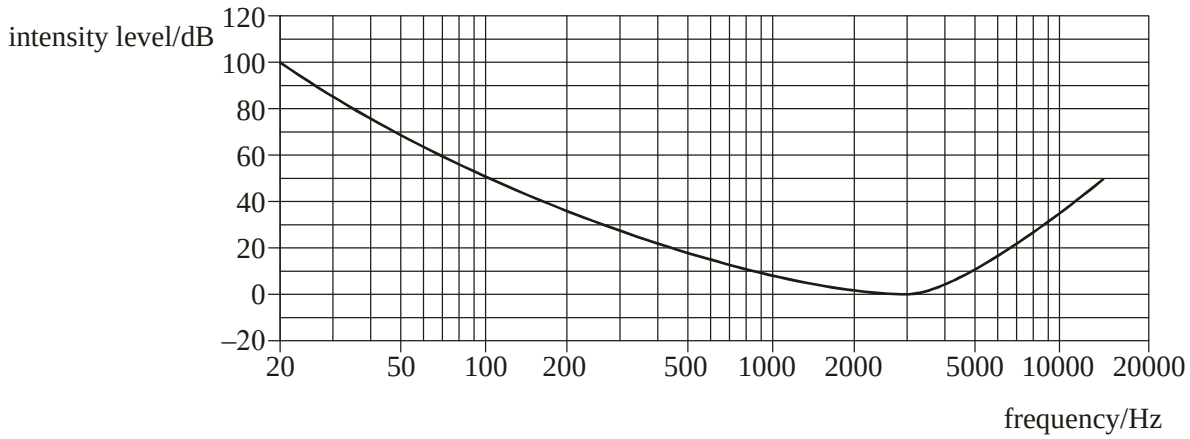

Figure 1

(a) (i) Describe how such a curve is obtained.

You may be awarded marks for the quality of written communication in your answer.

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(ii) On **Figure 1** draw an equal loudness curve which passes through 100 dB at a frequency of 1 kHz.

(5)

(b) (i) Define the threshold of hearing, I_0.

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(ii) A drill is heard by a passer-by. The intensity of the sound reaching the passer-by is 1.3×10^{-3} W m^{-2}. Calculate the intensity level of the sound heard.

$I_0 = 1.0 \times 10^{-12}$ W m^{-2}

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(4)
(Total 9 marks)

11. (i) Explain what is meant by the *half-value thickness* of lead for X-rays.

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(ii) Calculate the linear attenuation coefficient of lead for 90 keV X-ray photons.

half value thickness of lead for 90 keV X-ray photons = 12mm.

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(iii) Calculate the thickness of lead needed to reduce the intensity of a beam of 90 keV X-ray photons to 5.0 % of the intensity incident on the lead.

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(Total 6 marks)

12. (a) State the frequency of sound at which the normal ear is most sensitive.

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(1)

(b) State the main features of hearing loss in terms of frequency response for

(i) age-related hearing loss,

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(ii) noise-related hearing loss.

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(2)

(c) At the site of a machine in a factory, a sound meter was used to measure the sound level. The relative intensity level with the machine operating was 86 dB. The sound intensity reaching the meter when the machine was not operating was 7.0×10^{-5} Wm^{-2}.

(i) Show that with the machine operating, the sound intensity reaching the meter was about 4×10^{-4} Wm^{-2}.

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(ii) Calculate the relative intensity level due to the machine alone.

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(4)
(Total 7 marks)

13. (i) State the **two** physical properties of a material which determine its acoustic impedance.

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(ii) Under what condition is ultrasound strongly reflected at a boundary between two types of material?

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(iii) State where a coupling medium or gel is used in an ultrasound scan and explain why it is necessary.

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(Total 6 marks)