A-Level Physics

Physics of the Ear

Mark Scheme

Time available: 70 minutes
Marks available: 37 marks

Mark schemes

1.

(a) Calculation of area

A (= $4\pi r^2$) = $4\pi 12^2$(= 1810) ✓$_1$ (m^2)

Calculation of intensity

$I = \frac{P}{A} = \frac{17}{1810}$ (= 9.49×10^{-3}) ✓$_2$ (W m^{-2})

ecf for ✓$_2$ if area calculation attempted

Calculation of intensity level

I = 10 log $\frac{9.49\times10^{-3}}{10^{-12}}$ = 100 ✓$_3$

ecf for ✓$_3$ even if no area calculation attempted

3

(b) The sound would be quieter ✓

ear is most sensitive at 3 kHz ✓

2

[5]

2.

(a) $I \propto \frac{1}{A} = \frac{1}{r^2}$ or

$P = IA$ = $3.4 \times 10^{-8} \times 4\pi 11^2$ ✓ (=5.17×10^{-5} W)

Either ($I = \frac{3.4\times 10^{-8}\times 11^2}{7^2}$ or $I = \frac{P}{A} = \frac{5.17\times 10^{-5}}{4\pi 7^2}$)

= 8.4×10^{-8} W m^{-2} ✓

M1 Working mark

Evidence of either a proportion calculation or calculation of power from intensity

Use of $I \propto \frac{1}{r^2}$ with the wrong factor for r still scores M1 (but not M2)

M1 cannot be awarded if πr^2 is used for the area but M2 can still be awarded.

1

1

(b) One from

$I_1 = I_0 10^{\frac{IL}{10}} = 10^{-12} \times 10^{4.2} = 1.58 \times 10^{-8}$ W m^{-2} or

$I_2 = I_0 10^{\frac{IL}{10}} = 10^{-12} \times 10^{6.5} = 3.16 \times 10^{-6}$ W m^{-2} or

$\frac{I_2}{I_1} = 10^{6.5-4.2}$ or $\frac{I_2}{I_1} = \frac{10^{6.5}}{10^{4.2}}$ ✓

$\frac{I_2}{I_1}\left(= \frac{3.16 \times 10^{-6}}{1.58 \times 10^{-8}} \text{ or } 10^{6.5-4.2}\right) = 200$ ✓

Correct values for I_1 or I_2 or a correct rearranged substitution can gain M1

Ignore any units given

Accept anything from a correct calculation that rounds to 200 to 2SF

1
1

(c) Intensity level must be stated

uses a **logarithmic** scale ✓

which matches the response of the human ear ✓

*Do not allow matches the **frequency** response of the human ear for the second mark.*

Mark 2 is dependent on mark 1

1
1

(d) **P and Q** would hear (all frequencies) at lower volume/quieter than **R**. ✓

P would experience most hearing loss at high frequencies (compared to **R**) ✓

Q would experience most hearing loss at/around 4 kHz (compared to **R**) ✓

If no other marks are given allow 1 mark for

P hears at a lower volume/quieter than R and Q's hearing loss is frequency dependent✓

1
1
1

[9]

3. (a) Frequency does not change ✓

1

Amplitude is reduced ✓

1

(b) Ossicles lever system produces increase in force ✓

1

Area of oval window much less than area of ear drum ✓

1

Pressure = F / A so large increase in pressure ✓

1

(c) I = 1.0 x 10^{-12} W m^{-2} ✓ x $10^{8.2}$ ✓

1

I = 1.6 x 10^{-4} W m^{-2} ✓

1

(d) P = 1.6 x 10^{-4} x 4 x π x 2.02 ✓

1

P = 8.0 x 10^{-3} W ✓

1

[10]

4. (a) Minimum intensity heard by normal / average ear ✓
At frequency of 1kHz ✓

2

(b) Response of ear is logarithmic ✓
Allows very large range of intensities to be on sensible scale ✓

2

(c) (i) Ageing; loss increases as f increases ✓
Allow higher frequencies are lost

1

(ii) Noise; loss increases up to 4 kHz ✓
then decreases after this frequency ✓
Allow loss increases and then decreases for 1 mark
Allow greatest loss at 4kHz for 2 marks

2

[7]

5. (a) (i) Reading would be 60 dBA as 1 kHz is the reference frequency
(at the threshold of hearing).

1

(ii) dB reading would be 60 dB as power is the same/not frequency dependent.

dBA reading would be less than 60 as 500 Hz has a higher threshold intensity / ear is less sensitive.

2

(b) Intensity at meter = $2/(4 \times \pi \times 5 \times 5)$ $(= 6.37 \times 10^{-3})$

Intensity reading = $10 \log((2/(4 \times \pi \times 5 \times 5))/1.0 \times 10^{-12})$

Intensity reading = 98 dB

Allow ecf here from intensity calc. to get a 'correct' answer:

Use of 2 as intensity gains 0 for 123 dB

Use of 2/5 as intensity gains 1 for 116 dB or any use of 2 and a power of 5 **multiplied** also for 1 mark.

Use of $2/5^2$ as intensity gains 2 for 109 dB or use of $2/\pi 5^2$ gains 2 marks

3

[6]