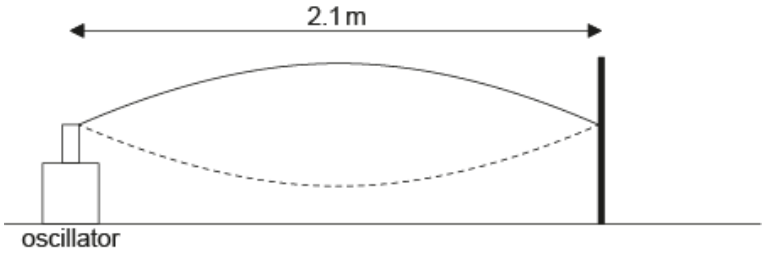
| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 3. | a | i | $v = \text{«}\frac{0.05}{0.20\times10^{-3}} = \text{»}\ 250\ \text{«m s}^{-1}\text{»}$ ✓ | | 1 |
| 3. | a | ii | $\lambda = 0.30\ \text{«m»}$ ✓<br>$f = \text{«}\frac{250}{0.30} = \text{»}\ 830\ \text{«Hz»}$ ✓ | *Allow ECF from (a)(i)*<br>*Allow ECF from wrong wavelength for MP2* | 2 |
| 3. | b | | Q ✓<br>acceleration is proportional to displacement «and Q has larger displacement» ✓ | | 2 |
| 3. | c | i | 3 «points» ✓ | | 1 |
| 3. | c | ii | first harmonic mode drawn ✓<br>  | *Allow if only one curve drawn, either solid or dashed.* | 1 |

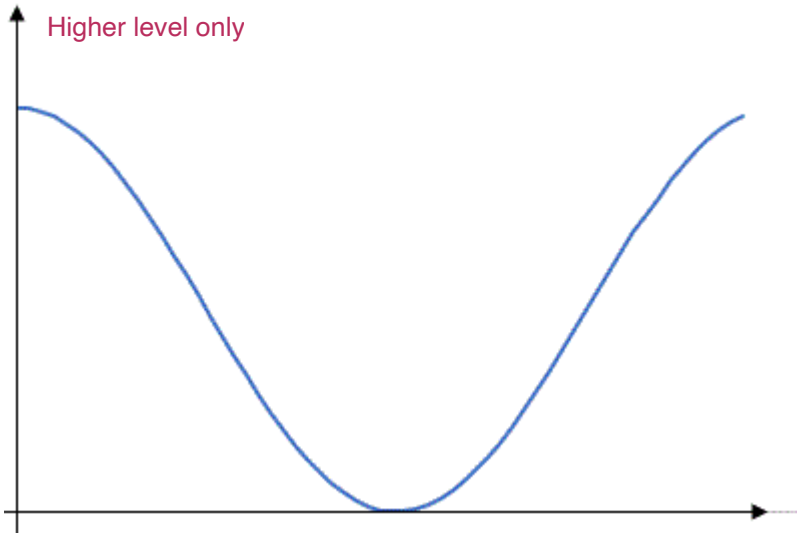
*(Question 2 continued)*

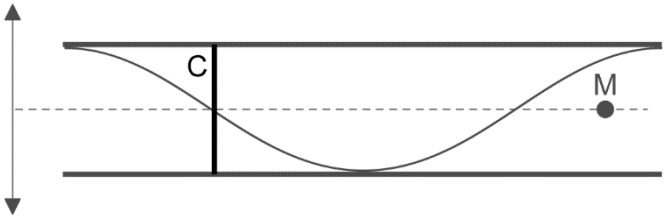
| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| **2.** | **c** | | models need testing/new information may change models/new technology may bring new information/Models can be revised/***OWTTE*** ✓ | | **1** |

| | | | | | |
|---|---|---|---|---|---|
| **3.** | **a** | | two waves superpose/mention of superposition/mention of **«**constructive**»** interference ✓<br>they arrive in phase/there is a path length difference of an integer number of wavelengths ✓ | | **2** |
| **3.** | **b** | | path difference = 0.062 **«**m**»**✓<br>so wavelength = 0.031 **«**m**»**✓<br>frequency = $9.7 \times 10^9$ **«**Hz**»**✓ | *Award **[2 max]** for $4.8 \times 10^9$ Hz.* | **3** |
| **3.** | **c** | | intensity is modulated by a single slit diffraction envelope ***OR*** intensity varies with distance ***OR*** points are different distances from the slits ✓ | | **1** |

*(continued…)*

*(Question 3 continued)*

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| **3.** | **d** | | Higher level only<br>  <br>$\cos^2$ variation shown ✓<br>with zero at 90° (by eye) ✓ | *Award **[1 max]** for an inverted curve with maximum at 90°.* | **2** |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| 3. | a | | Expression or statement showing acceleration is proportional to displacement ✓<br>so «$7.9 \times \frac{2.3}{3.2}$» $= 5.7$ «$\text{m s}^{-2}$» ✓ | | 2 |
| 3. | b | | $\sin\theta = \frac{340}{6010} \times \sin 54^0$ ✓<br>$\theta = 2.6^0$ ✓ | | 2 |
| 3. | c | | $\lambda =$ «$\frac{340}{250}$ =» $1.36 \approx 1.4$ «m» ✓ | | 1 |
| 3. | d | i | horizontal arrow «at M» pointing left ✓ | | 1 |
| 3. | d | ii | any point labelled C on the vertical line shown below ✓<br>*eg:*<br>displacement to the right<br>  <br><br>displacement to the left | | 1 |

*(continued…)*

*(Question 3 continued)*

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| **3.** | **e** | **i** | $f' = 2500 \times \frac{340}{340 + 280}$ ✓<br>$f' = 1371 \approx 1400$ **«Hz»** ✓ | | **2** |
| **3.** | **e** | **ii** | $\lambda' = \frac{340}{1371} \approx 0.24 / 0.25$ **«m»** ✓ | | **1** |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| **4.** | **a** | | «air molecule» moves to the right and then back to the left ✓<br>returns to X/original position ✓ | | **2** |
| **4.** | **b** | | wavelength $= 2 \times 1.4$ « $= 2.8$ m» ✓<br>$c =$ « $f\lambda =$» $120 \times 2.8$ « $= 340\ \text{m s}^{-1}$» ✓<br>$K =$ « $\rho c^2 = 1.3 \times 340^2 =$» $1.5 \times 10^5$ ✓ | | **3** |
| **4.** | **c** | **i** | construction showing formation of image ✓ | *Another straight line/ray from image through the wall with line/ray from intersection at wall back to transmitter. Reflected ray must intersect boat.* | **1** |
| **4.** | **c** | **ii** | interference pattern is observed<br>***OR***<br>interference/superposition mentioned ✓<br>maximum when two waves occur in phase/path difference is nλ<br>***OR***<br>minimum when two waves occur $180^\circ$ out of phase/path difference is (n + ½) λ ✓ | | **2** |

| | | | | | |
|---|---|---|---|---|---|
| **3.** | **a** | **i** | superposition of light from each slit / interference of light from both slits ✓<br>with path/phase difference of any half-odd multiple of wavelength/any odd multiple of $\pi$ (in words or symbols) ✓<br>producing destructive interference ✓ | *Ignore any reference to crests and troughs.* | **3** |
| **3.** | **a** | **ii** | light waves (from slits) must have constant phase difference / no phase difference / be in phase ✓ | *OWTTE* | **1** |
| **3.** | **a** | **iii** | evidence of solving for $D$ **«**$D = \frac{sd}{\lambda}$**»** ✓<br>**«**$\frac{4.50 \times 10^{-3} \times 0.300 \times 10^{-3}}{633.0 \times 10^{-9}} \times 2$**»** $= 4.27$**«**m**»** ✓ | *Award **[1]** max for 2.13 m.* | **2** |

*(continued…)*

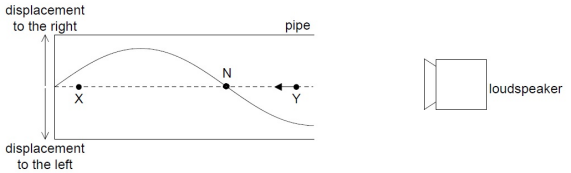
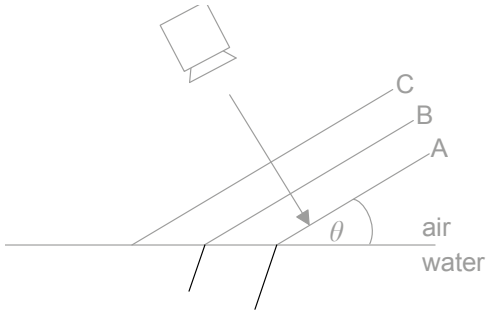
*(Question 3 continued)*

| | | | | | |
|---|---|---|---|---|---|
| **3.** | **b** | **i** | $\sin\theta = \frac{4 \times 633.0 \times 10^{-9}}{0.300 \times 10^{-3}}$ ✓<br>$\theta = 0.0084401\ldots$ ✓<br>final answer to three sig figs (*eg* 0.00844 or 8.44 x $10^{-3}$) ✓ | *Allow ECF from (a)(iii).*<br>*Award **[1]** for 0.121 rad (can award MP3 in addition for proper sig fig)*<br>*Accept calculation in degrees leading to 0.481 degrees.*<br>*Award MP3 for <u>any</u> answer expressed to 3sf.* | **3** |
| **3.** | **b** | **ii** | use of diffraction formula **«**$b = \frac{\lambda}{\theta}$**»**<br>***OR***<br>$\frac{633.0 \times 10^{-9}}{0.00844}$ ✓<br>**«**=**»** 7.5**«**00**»** $\times 10^{-2}$ **«**mm**»** ✓ | *Allow ECF from (b)(i).* | **2** |

*(continued…)*

*(Question 3 continued)*

| | | | | | |
|---|---|---|---|---|---|
| **3.** | **c** | | wavelength increases (so frequency decreases) / light is redshifted ✓<br>galaxy is moving away from Earth ✓ | *Allow ECF for MP2 (ie wavelength decreases so moving towards).* | **2** |
| **3.** | **d** | **i** | $\frac{633.0}{1.33} = 476$ **«**nm**»** ✓ | | **1** |
| **3.** | **d** | **ii** | distance between peaks decreases ✓<br>intensity decreases ✓ | | **2** |

| | | | | | |
|---|---|---|---|---|---|
| **3.** | **a** | **i** | the incident wave **«**from the speaker**»** and the reflected wave **«**from the closed end**»** superpose/combine/interfere ✓ | *Allow superimpose/add up*<br>*Do not allow meet/interact* | **1** |
| **3.** | **a** | **ii** | Horizontal arrow from X to the right ✓ | *MP2 is dependent on MP1*<br>*Ignore length of arrow* | **1** |
| **3.** | **a** | **iii** | P at a node ✓ |  | **1** |
| **3.** | **a** | **iv** | wavelength is $\lambda = «\frac{4 \times 0.30}{3} =» 0.40 «\text{m}»$ ✓<br>$f = «\frac{340}{0.40} =» 850 «\text{Hz}»$ ✓ | *Award **[2]** for a bald correct answer*<br>*Allow ECF from MP1* | **2** |
| **3.** | **b** | **i** | $\frac{\sin\theta_C}{340} = \frac{1}{1500}$ ✓<br>$\theta_C = 13 «^\circ»$ ✓ | *Award **[2]** for a bald correct answer*<br>*Award **[2]** for a bald answer of 13.1*<br>*Answer must be to 2/3 significant figures to award MP2*<br>*Allow 0.23 radians* | **2** |
| **3.** | **b** | **ii** | correct orientation ✓<br>greater separation ✓ | *Do not penalize the lengths of A and B in the water*<br>*Do not penalize a wavefront for C if it is consistent with A and B*<br>*MP1 must be awarded for MP2 to be awarded*<br>*eg*:<br>  | **2** |

| Question | | | Answers | Notes | Total |
|---|---|---|---|---|---|
| **4.** | **a** | **i** | «$v = c\frac{\sin i}{\sin r} =$» $\frac{3\times10^8\times\sin(33)}{\sin(46)}$ ✓<br><br>$2.3\times10^8$ «$\text{m s}^{-1}$» ✓ | | **2** |
| **4.** | **a** | **ii** | light strikes AB at an angle of $57^\circ$ ✓<br><br>critical angle is «$\sin^{-1}\left(\frac{2.3}{3}\right) =$» $50.1^\circ$ ✓<br><br>angle of incidence is greater than critical angle so total internal reflection<br>***OR***<br>light strikes AB at an angle of $57^\circ$ ✓<br><br>calculation showing sin of "refracted angle" $= 1.1$ ✓<br><br>statement that since $1.1 > 1$ the angle does not exist and the light does not emerge ✓ | *$49.2^\circ$ from unrounded value* | **3 max** |
| **4.** | **a** | **iii** | total internal reflection shown ✓<br><br>ray emerges at opposite face to incidence ✓ | *Judge angle of incidence = angle of reflection by eye or accept correctly labelled angles*<br><br>*With sensible refraction in correct direction* | **2** |

*(continued…)*