<table>
<tr><th>Question</th><th>Evidence</th><th>1-4 marks</th><th>5-6 marks</th><th>7-8 marks</th></tr>
<tr><td>1 (a)</td><td>$v^2 = \text{m}^2\,\text{s}^{-2}$

$g\,\lambda = \text{m s}^{-2}\,\text{m} = \text{m}^2\,\text{s}^{-2}$ (and 2π is dimensionless)

$2\,\pi\,\gamma = \text{kg m s}^{-2}\,\text{m}^{-1} = \text{kg s}^{-2}$
$\lambda\,\rho = \text{m kg m}^{-3} = \text{kg m}^{-2}$

$\dfrac{2\pi\gamma}{\lambda\rho} = \dfrac{\text{kg s}^{-2}}{\text{kg m}^{-2}} = \text{m}^2\,\text{s}^{-2}$
All terms have the same dimensions.</td><td rowspan="5">Thorough understanding of these applications of physics.

OR

Partially correct mathematical solution to the given problems.

AND / OR

Partial understanding of these applications of physics.</td><td rowspan="5">(Partially) correct mathematical solution to the given problems.

AND / OR

Reasonably thorough understanding of these applications of physics.</td><td rowspan="5">Correct mathematical solution to the given problems.

AND

Thorough understanding of these applications of physics.</td></tr>
<tr><td>(b)</td><td>$v^2 = \dfrac{9.8 \times 10}{2\pi} + \dfrac{2\pi \times 7.2 \times 10^{-2}}{10 \times 10^3}$
$v^2 = 15.597 + 4.5 \times 10^{-5} = 15.597045$
$v = 3.95\ \text{m s}^{-1}$</td></tr>
<tr><td>(c)</td><td>$f = \dfrac{v}{\lambda} = \dfrac{3.95}{10} = 0.395\ \text{Hz}$
$v_{\text{max}} = 2\pi f \times A = 2\pi \times 0.395 \times 0.2 = 0.496\ \text{m s}^{-1}$</td></tr>
<tr><td>(d)</td><td>$f = \dfrac{C}{\lambda} = \dfrac{15.3 - 8}{150} = 0.049\ \text{Hz}$</td></tr>
<tr><td>(e)</td><td>The ship does not want its natural pitch frequency to be the same as the frequency with which the waves are moving the ship. Such a resonance will produce increasing amplitudes in the ship's rise and fall and will strain the structure of the vessel and become more uncomfortable for the passengers.
The ship has to avoid frequency 0.125 Hz (1/8 Hz).
Speed to avoid is given by:
$0.125 = \dfrac{V_{\text{ship}} \pm C_{\text{water}}}{75}$
$V_{\text{ship}} = 9.375 \pm 10.8 = -1.425\ \text{m s}^{-1}$ or $20.2\ \text{m s}^{-1}$</td></tr>
</table>

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
2 (a)	The travelling wave generated by the vibrator meets the wave reflected from the pulley. If the wave speed and frequency are such that the two waves interfere constructively and destructively at fixed positions then a standing wave is formed.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)(i)	$v^2 = \frac{T}{\mu}$ $v^2 = f^2\lambda^2$ $T = \mu f^2\lambda^2$			
(ii)	$T = ma =$ kg m s^{-2} $\mu f^2\lambda^2 =$ kg m^{-1} s^{-2} m^2 = kg m s^{-2}			
(c)	$\lambda_2 = 1.5\,\lambda_3$ $T_3 = mg = \mu f^2\lambda_3^2$ $T_{\text{new}} = \mu f^2\lambda_2^2 = \mu f^2(1.5\lambda_3)^2 = 2.25$ mg			
(d)	Diffraction illustrates the wave aspect of light. Diffraction is the spreading out of a wavefront when passing through a gap or obstacle. The wavefront acts as a series of secondary sources. A stream of particles passing through a gap would not spread out in this manner. Light striking a metal surface can lead to emission of an electron. That electron’s maximum energy is directly related to the frequency of the incident light and not the intensity.			

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<tr><td>3 (a)</td><td>$f = \mathrm{s}^{-1} \quad r = \mathrm{m} \quad v_\mathrm{w} = \mathrm{m\ s}^{-1}$
$\mathrm{St} = \frac{fr}{v_\mathrm{w}} = \frac{\mathrm{s}^{-1}\ \mathrm{m}}{\mathrm{m\ s}^{-1}} = 1$ (dimensionless)</td><td rowspan="6">Thorough understanding of these applications of physics.
OR
Partially correct mathematical solution to the given problems.
AND / OR
Partial understanding of these applications of physics.</td><td rowspan="6">(Partially) correct mathematical solution to the given problems.
AND / OR
Reasonably thorough understanding of these applications of physics.</td><td rowspan="6">Correct mathematical solution to the given problems.
AND
Thorough understanding of these applications of physics</td></tr>
<tr><td>(b)</td><td>If the tension increases, then effectively a mass element in the wire will experience a greater acceleration leading to a greater velocity. If the mass / length is lower, then the acceleration experienced will also be greater leading to a greater velocity. Overall the velocity will be proportional to the tension and inversely proportional to the mass / length.</td></tr>
<tr><td>(c)</td><td>$T = \frac{175 \times 9.81}{2} = 858\ \mathrm{N}$
$\mathrm{St} = \frac{fr}{v_\mathrm{w}} \Rightarrow r = 10^{-2}\ \mathrm{m}$
$\mu = \pi \times (10^{-2})^2 \times 1 \times 8 \times 10^3 = 2.51\ \mathrm{kg\ m}^{-1}$
$v = \sqrt{\frac{858}{2.51}} = 18.48 = 18\ \mathrm{m\ s}^{-1}$</td></tr>
<tr><td>(d)(i)</td><td>$T_1 + T_2 = 175 \times g = 1716.75\ \mathrm{N}$
$4\ T_1 = 2 \times 100 \times g + 3 \times 75 \times g$
$T_1 = \frac{4169.25}{4} = 1042\ \mathrm{N}$
$T_2 = 674.4375\ \mathrm{N}$
$v_1 = \sqrt{\frac{T_1}{\mu}} = 20.365\ \mathrm{m\ s}^{-1}$
$v_2 = \sqrt{\frac{T_2}{\mu}} = 16.381\ \mathrm{m\ s}^{-1}$
Wavelength $1 = \frac{v_1}{200} = 10.18\ \mathrm{cm}$
Wavelength $2 = \frac{v_2}{200} = 8.19\ \mathrm{cm}$</td></tr>
<tr><td>(d)(ii)</td><td>Beats require slightly different frequencies. If the wind is to produce the frequency, then the wires have the same radius then this will not result. So one possibility is to slightly alter the radius of one of the wires.</td></tr>
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<tr><td>4 (a)</td><td>Velocity unit is m s^{-1} Tension is N = kg m s^{-2} μ is kg m^{-1} Dividing T by μ we get m^2 s^{-2}.Then taking square root we get the desired result.</td><td rowspan="3">Thorough understanding of these applications of physics.

OR

Partially correct mathematical solution to the given problems.

AND / OR

Partial understanding of these applications of physics.</td><td rowspan="3">(Partially) correct mathematical solution to the given problems.

AND / OR

Reasonably thorough understanding of these applications of physics.</td><td rowspan="3">Correct mathematical solution to the given problems.

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Thorough understanding of these applications of physics.</td></tr>
<tr><td>(b)</td><td>String 1 : $v_1 = \sqrt{\frac{T_1}{\mu_1}} = \sqrt{\frac{m_1 g}{\mu_1}}$
$\lambda_1 = 2L \quad v_1 = \lambda_1 f_1$
$2Lf_1 = \sqrt{\frac{m_1 g}{\mu_1}}$
String 2 : $\lambda_2 = \frac{2}{3}L$
The linear mass density is four times as much as for the first string (twice the diameter, so 4× as much mass per metre).
$v_2 = \sqrt{\frac{T_2}{\mu_2}} = \sqrt{\frac{m_2 g}{4\mu_1}} = \sqrt{\frac{m_1 g}{4\mu_1}} = \frac{1}{2}v_1$
$\frac{1}{2}\sqrt{\frac{m_1 g}{\mu_1}} = \frac{2}{3}Lf_2$
Combining expressions:
$\frac{2}{3}Lf_2 = \frac{1}{2}2Lf_1$
$\Rightarrow f_2 = \frac{3}{2}\frac{1}{2}2f_1 = \frac{3}{2}\times 200$ Hz
$f_2 = 300$ Hz</td></tr>
<tr><td>(c)</td><td>The tension is the same as for having one end of the string stuck to a wall. Frequency of the nth harmonic
$= n \times$ frequency of first harmonic
Fifth harmonic = $5 \times 200 = 1000$ Hz</td></tr>
<tr><td>(d)</td><td>The modulation is due to beats, so $f_1 - f_2 = 4.5$ Hz
(or $f_2 - f_1 = 4.5$ Hz)
The wavelength of the waves forming the standing wave pattern on string 1 obeys $\frac{(n_1 - 1)\lambda_1}{2} = L_1$
The wave velocity is given by
$v_1 = \lambda_1 f_1 = \frac{2L_1}{n_1 - 1}\times f_1$
Similarly, for the second string we have
$\lambda_2 = \frac{2L_2}{n_2 - 1} = \frac{2L_2}{n_1}$ (the question says $n_2 = n_1 + 1$)
$v_2 = \lambda_2 f_2 = \frac{2L_2}{n_1}\times f_2$
We also know that $v_1 = v_2$ (equivalent medium, same tension)
Thus $\frac{2L_1}{n_1 - 1}\times f_1 = \frac{2L_2}{n_1}\times f_2$ Insert $L_1 = 1.00$ m, and $L_2 = 1.18$ m. Plugging these in along with $f_1 = 400$ Hz and $f_2 = 395.5$ Hz, we find that $n_1 = 7$, i.e., 7 nodes.</td><td></td><td></td><td></td></tr>
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<tr><td>5(a)</td><td>$C = 2.8 \times 3.0 \times 10^{-6} = 8.4\ \mu\text{F}$
Assumption:
The wax completely fills the distance between the plates.</td><td rowspan="5">Thorough understanding of these applications of physics.

OR

Partially correct mathematical solution to the given problems.

AND / OR

Partial understanding of these applications of physics.</td><td rowspan="5">(Partially) correct mathematical solution to the given problems.

AND / OR

Reasonably thorough understanding of these applications of physics.</td><td rowspan="5">Correct mathematical solution to the given problems.

AND

Thorough understanding of these applications of physics.</td></tr>
<tr><td>(b)</td><td>The dielectric material is polarised by the electric field between the plates. There is now an electric field inside the dielectric, which opposes (weakens) the field between the plates. Reduced field strength, with the same amount of charge stored, means reduced voltage (assuming not connected to battery) and therefore the capacitance has increased. ($C = Q / V$) If capacitor is connected to the battery the voltage is fixed but the capacitance still increases as more charge is able to ‘fit in’.</td></tr>
<tr><td>(c)</td><td>At distance d_1 the energy stored in the capacitor is
$E = \frac{1}{2}CV^2 = \frac{1}{2}\frac{\varepsilon_0 A V^2}{d_1}$ as the capacitance is $C = \frac{\varepsilon_0 A}{d_1}$.
As the distance between plates increases from d_1 to d_2, the capacitance changes to $C = \frac{\varepsilon_0 A}{d_2}$ and the energy stored is now $\frac{1}{2}\frac{\varepsilon_0 A V^2}{d_2}$. $\Delta E = \frac{V^2 \varepsilon_0 A}{2}\left(\frac{1}{d_1} - \frac{1}{d_2}\right) = \frac{V^2 \varepsilon_0 A}{2}\left(\frac{d_2 - d_1}{d_1 d_2}\right)$</td></tr>
<tr><td>(d)</td><td>As the capacitor is still connected to the battery, the voltage across the capacitor must remain constant at V. As the capacitance decreases as the distance between the two plates increases $C \propto \frac{1}{d}$, the energy stored in the capacitor must decrease (as $E = \frac{1}{2}CV^2$).The amount of charge on the plates must also decrease by ΔQ (as $Q = VC$). The “lost” charge is driven back through the battery to the opposite capacitor plate by the work done to separate the plates and the potential energy removed from the capacitor. This missing energy is converted into heat of the connecting wires and into potential energy stored in the battery.</td></tr>
<tr><td>(e)</td><td>The plates, being oppositely charged, attract each other. In separating them, they have to be dragged apart. Work must be done and this energy is stored as electric potential energy in the field between the plates. We express this by talking of an increase in the voltage between the plates.
$C = \frac{\varepsilon A}{d}$ so as d increases, C reduces.Energy $= \frac{Q^2}{C_2} - \frac{1}{2}\frac{Q^2}{C_1}$.
Q is constant so as C decreases, the energy must increase – work is being done to drag the plates apart.

Work done $= \frac{1}{2}\frac{Q^2}{C_2} - \frac{1}{2}\frac{Q^2}{C_1}$
$\frac{1}{2}Q^2\left(\frac{1}{C_2} - \frac{1}{C_1}\right) = \frac{Q^2\left(d_2 - d_1\right)}{2\varepsilon A}$</td></tr>
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<tr><td>6(a)</td><td>A displacement node.
The centre of the star will not move. As a place of zero displacement, it must be a node.
Alternative:
If there is an antinode at the surface, there must be a node at the centre.</td><td rowspan="4">Shows some understanding of the underlying physics of he proposed model

AND/OR

(partially) correct mathematical solution to given problem.</td><td rowspan="4">Correct discussion of the underlying physics of the proposed model

OR

A reasonable understanding of the underlying physics of the proposed model

AND

(partially) correct mathematical solution to given problem.</td><td rowspan="4">Correct discussion of the underlying physics of the proposed model

AND

Correct mathematical solution to the given problem.</td></tr>
<tr><td>(b)</td><td>A standing wave is formed by two travelling waves with the same frequency, amplitude, wavelength and speed, travelling in opposite directions. This is created in this situation by a reflection from the surface (open end of the tube).

At the resonant frequency, the reflected wave will meet the incoming wave in such a way that the two wave displacements will constructively sum (form an antinode) at the open end of the tube.

The mechanism for the reflection can be explained by considering, a) the particle collisions (some must reflect) or equally validly via a mechanism where the external pressure (atmospheric pressure) is higher than the pressure node that exists at the boundary – this effectively creates a mechanism for particles to be “pulled” down the tube.</td></tr>
<tr><td>(c)</td><td>At the fundamental mode $\lambda = 4R$
$v_{\text{av}} = f\lambda$
$v_{\text{av}} = f4R$
$f = \dfrac{1}{T} \Rightarrow v_{\text{av}} = \dfrac{4R}{T}$
$T = \dfrac{4R}{v_{\text{av}}}$</td></tr>
<tr><td>(d)</td><td>$T = \dfrac{4R}{v_{\text{av}}}$
$T = \dfrac{4R\sqrt{\rho}}{\sqrt{\beta}}$
$T = \dfrac{4 \times 9 \times 10^{-3} \times 6.96 \times 10^{8} \times \sqrt{1 \times 10^{10}}}{\sqrt{1.33 \times 10^{22}}}$
$T = 20\ \text{s}$</td></tr>
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