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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Level 3 Physics, 2014

91523 Demonstrate understanding of wave systems

2.00 pm Tuesday 25 November 2014
Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of wave systems.	Demonstrate in-depth understanding of wave systems.	Demonstrate comprehensive understanding of wave systems.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

Make sure that you have Resource Booklet L3–PHYSR.

In your answers use clear numerical working, words and/or diagrams as required.

Numerical answers should be given with an SI unit, to an appropriate number of significant figures.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–8 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 22

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QUESTION ONE: THE SEA ORGAN

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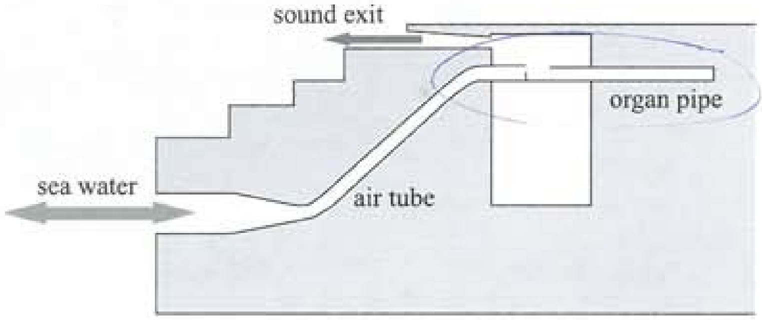
The Sea Organ in Zadar, Croatia, is a musical instrument that creates its musical notes through the action of sea waves on a set of pipes that are located underneath the steps shown in the picture. The sound from the pipes comes out through the regular slits in the vertical part of the top step.

For copyright reasons, this image cannot be reproduced here.

http://travelforsomeday.wordpress.com/2012/03/06/the-sea-organ-morske-orgule-zadar-croatia/

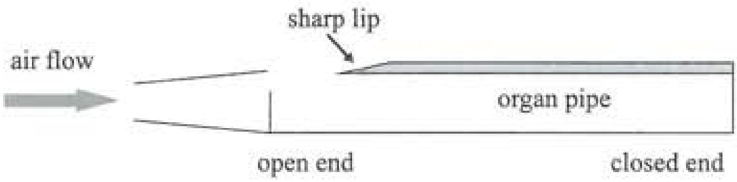
To produce a sound, the organ pipes must have air blown into them, so each organ pipe is connected to the top end of a tube, as shown in the diagram on the right.

The action of the waves pushes water in and out of a tube, creating a flow of air at the upper end of the tube.



The diagram on the right shows the inside of an organ pipe.

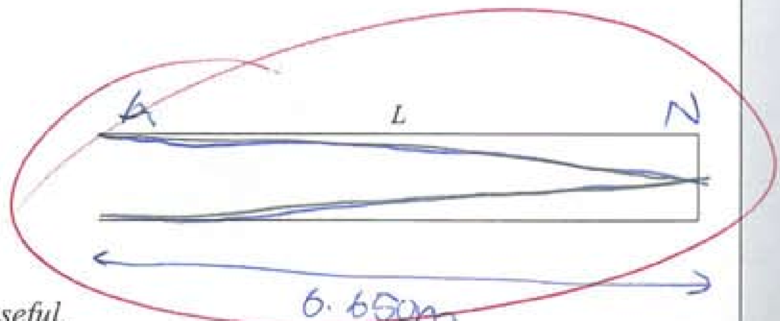
These organ pipes have one closed end.



$\frac{\lambda}{4} = L$

(a) Calculate the length, L, of an organ pipe, with one closed end, that produces a fundamental standing wave of wavelength 2.60 m.

You may find the diagram on the right useful.



$\frac{\lambda}{4} = L$

$L = \frac{2.60}{4} = 0.650\text{m}$ (3sf)

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(b) Air is driven against a sharp lip, producing oscillations in the air, with a range of frequencies.

Explain why not all frequencies produce standing waves in the pipe.

have frequencies that match natural oscillation of pipes

Only frequencies that produce standing waves in the open pipe will cause the pipe to resonate and cause frequencies to be heard. In 0.650 m pipe, there must be a Node at closed end and an antinode at the open end. Only "f" that have a corresponding λ $(f=\frac{v}{\lambda})$ that produce antinode and node at correct positions will "fit" in the pipe and cause a standing wave to form and f will be heard. (Open pipes do not resonate in even harmonics.)

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(c) The Sea Organ contains organ pipes of several different lengths.

$v=f\lambda$

Explain why the differences in length of the organ pipes affect the sounds that are heard.

Different lengths of pipe organs will have different fundamental wavelengths of $\frac{\lambda}{4}=L$, note heard is that of fundamental λ, and so longer wavelengths of standing waves can be produced in the longer lengthed pipes. As $\lambda \propto \frac{1}{f}$ $(v=\lambda f)$ as different fundamental λ are produced in each pipe, different frequencies (pitches/notes) are played. It is always the note of fundamental frequency that is heard/played. Hence different lengths of pipe produce different notes.

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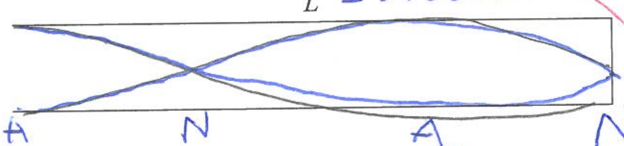
(d) The speed of sound in cold air is slower than it is in warm air.

V↓ faster V↑

Calculate the difference between the 3rd harmonic frequency (1st overtone) heard in summer (35°C), and the 3rd harmonic frequency heard in winter (–2°C).

Speed of sound in air at 35°C = 353 m s^{-1}
Speed of sound in air at –2°C = 330 m s^{-1}

You may find the diagram on the right useful.



$f=\frac{v}{\lambda}$

$\frac{3\lambda}{4}=L$

$\lambda=\frac{4}{3}\times 0.650$

$\lambda = 0.867$ m (3sf)

λ remains same,

In winter a lower frequency is heard (lower pitch) 380 Hz in summer a higher frequency is heard (higher pitch) = 407 Hz

$f_{summer\ 35°C}=\frac{353}{0.867}=407$ Hz (3sf)

$f_{winter\ (-2°C)}=\frac{330}{0.867}=380.769$

$=381$ Hz (3sf)

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QUESTION TWO: INTERFERENCE

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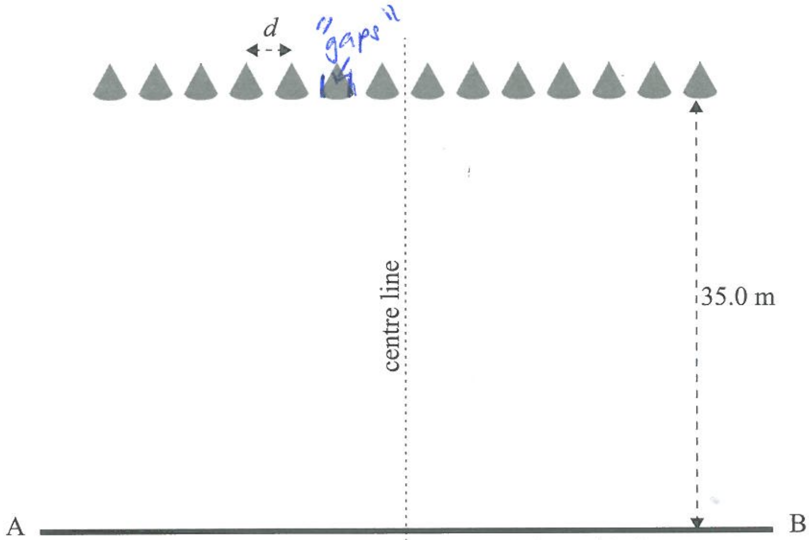
The diagram shows a series of speakers connected together, and to a frequency generator producing a single frequency. The speakers act like a diffraction grating.



interference pattern to be observed along this line

(a) The sound wave source is producing a note of wavelength 0.600 m.
The distance between the speakers and the line AB is 35.0 m.
When a person walks along the line AB, the distance between two loud positions is 7.40 m.

$\lambda = 0.600$ m
$L = 35.0$ m
antinodes $x = 7.40$ m

Calculate the separation of the speakers, *d*.

$d\frac{x}{L} = n\lambda$

$d = \frac{L}{x}\lambda = \frac{35.0}{7.40} \times 0.600 = 2.837$

$= 2.84$ m (3sf)

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(b) Explain how the path difference of the waves causes positions of constructive and destructive interference along the line AB.

pd

If path difference is whole numbers of λ ($pd = n\lambda$) then constructive interference is occuring as crest meet crest and trough meet trough, waves are in phase, and displacement add to give (this is a antinodal line) (loud sounds) double the amplitude. Hence constructive interference. If path difference is half numbers of λ ($pd = n - \frac{1}{2}\lambda$) then destructive interference is occuring where trough meets crest and are waves are 180° out of phase, so displacements add to give zero/minimum amplitude. – this is (nodal line) · quiet sounds

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$d\frac{x}{L} = n\lambda \quad d \propto \frac{1}{x}$

(c) Explain the effect on the interference pattern of reducing the distance between the speakers.

If the distance between the speakers are reduced the spacing of interference pattern is increased as $d \propto \frac{1}{x}$, so fringes are more spaced out on either side of the central bright fringe $n=0$. Interference pattern is more spread out.

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(d) The frequency generator is now set so that several different frequencies are emitted by each speaker. $x \propto \lambda$ $f = \frac{v}{\lambda}$

Explain how the sound heard by someone walking along AB would differ from that described in part (b) of this question.

As $x \propto \lambda$, the frequencies with the longest wave lengths will be diffracted further (frequency with low frequencies) and the frequencies with shortest wavelengths will diffract the least so will be closer to central ~~point~~ antinode $n=0$ (frequencies that are high)

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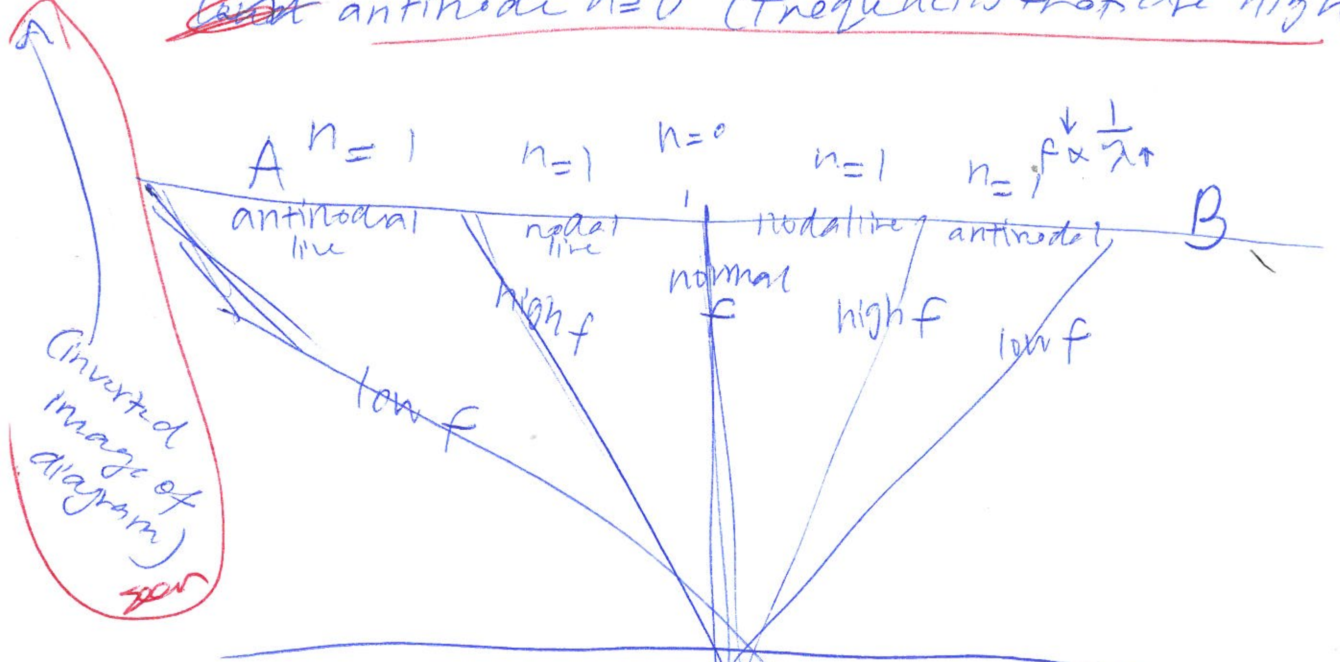

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So person walking from one side B to A, will hear low frequencies (notes) that gradually increases to high frequencies [this occurs at every antinodal line] then nothing (nodal line) then at central frequency $n=0$, frequency will be normal pitch / f note played by speakers. Then person as he/she walks from $n=0$ outwards (towards A), will hear high f to lowest frequency when walking past antinodal lines and nothing when walking past nodal lines.

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QUESTION THREE: THE DOPPLER EFFECT

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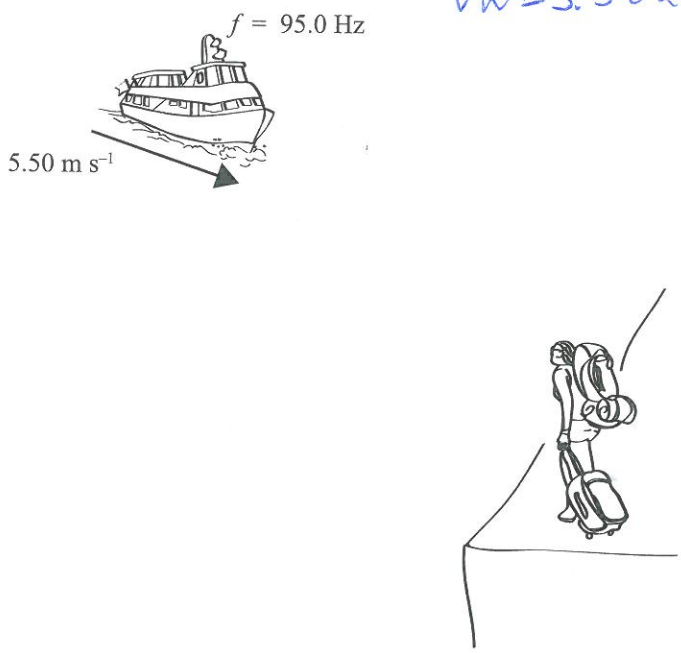
$V_s = 5.50\,ms^{-1}$

A tourist is watching a ferry boat coming towards her. The speed of the ferry is 5.50 m s^{-1}. The ferry sounds its horn, producing a note of frequency 95.0 Hz. $f = 95.0\,Hz$

The speed of sound in the air over the water is 3.50 × 10^2 m s^{-1}.
$V_w = 3.50 \times 10^2\,ms^{-1}$



(a) Calculate the frequency of the note that the tourist hears.

$f' = f \frac{V_w}{V_w - V_s}$

$f' = 95.0 \times \frac{3.50\times10^2}{3.50\times10^2 - 5.50} = 96.5\ Hz$ (3sf) 4

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(b) Explain why the sound of the horn heard by the tourist does not have the same pitch as the sound emitted by the horn.

In the time ~~As~~ the horn / boat produces a wavefront towards tourist the boat and the next wavefront has moved closer towards the tourist, effectively reducing the (λ) wavelength. As $\lambda\downarrow = \frac{V}{f\uparrow}$ the apparent frequency tourist hears is higher ~~[illegible]~~ $f' = 96.5\ Hz$ than the frequency (pitch) of ~~boa~~ horn $f = 95.0\,Hz$ so tourist hears different pitch (f) to ~~that~~ pitch ~~not~~ (f) played by horn due to the doppler effect. 4

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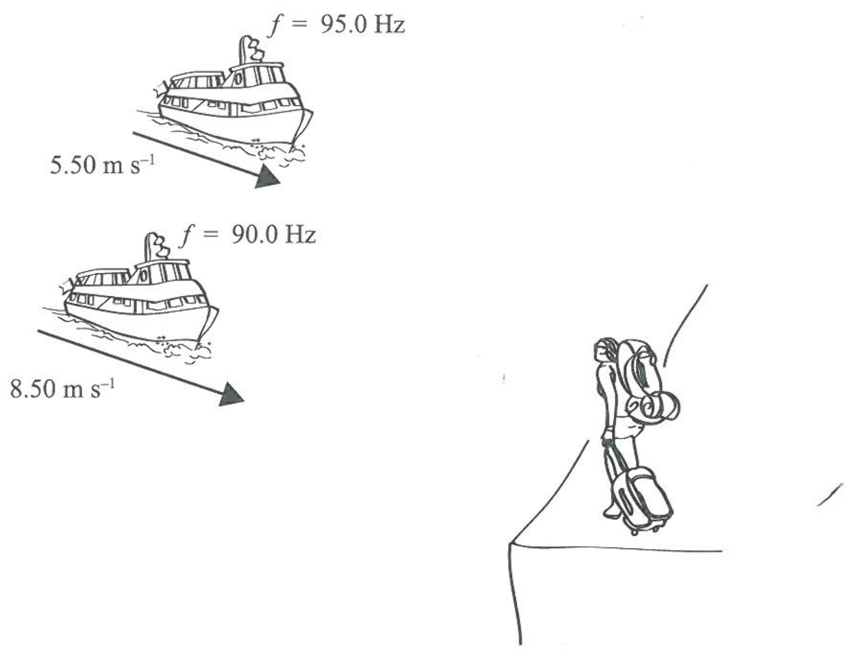

(c) A second ferry, which is overtaking the first, also sounds its horn, producing a note of frequency 90.0 Hz. For a few moments, both ferries are the same distance from the tourist, quite close together, and both are sounding their horns. The tourist hears beats.

(i) Calculate the frequency of the beats that are heard by the tourist.

$f_b = |95.0 - 90.0| = 5.00$ Hz (3sf)

tourist hears a beating of 5.00 Hz (3sf)

(ii) Describe what beats are, and explain how they are created.

Beating is the regular pulsating of loudness (amplitude) that is hear as two sources play sounds of slightly different frequencies. It is equivalent to the difference between two frequencies $f_b = |f_1 - f_2|$. At times of loud sounds, waves are in phase and constructive interference is occurring, where waves displacement add to give double maximum amplitude and hence loudness. → back

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E8

Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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3)c)ii) At times of quiet sound, waves are 180° out of phase and are destructively interfering to give a displacement of zero / minimum amplitude (loudness) hence quiet sounds are heard.

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Excellence exemplar for 91523 2014		Total score	22
Q	**Grade score**	**Annotation**	
1	M6	Part (b) does not state what types of interference must occur at each end of the pipe or explain the importance of these in producing a standing wave that will be sustained and heard outside the pipe. The answer to part (c) shows understanding that the pipe length is proportional to wavelength and that the frequency will decrease as the wavelength increases. In part (d) the candidate has found the first overtone frequencies as required. They have not calculated the difference between them, which would have gained them Excellence.	
2	E8	The description given of the sound heard in part (d) is detailed and correct with a useful diagram. A reference to x being proportional to λ is made. A reference to low frequency increasing to high occurring “at every antinodal line” is made. The positions of the different sounds heard are initially attributed to varying amounts of diffraction, which is not occurring. There is sufficient evidence to conclude that the candidate understands that the pattern is due to interference to award excellence.	
3	E8	The explanation for the Doppler effect correctly describes a decreased wavelength, attributing the changed wavelength to the movement of the boat and wavefront before the production of the next wavefront. The beat frequency found would be correct if the ferries were not moving. Beats are recognised as being due to two waves with different frequencies interfering as they move in and out of phase. The effect of this changing phase is used to accurately describe the resulting change in wave amplitude at a fixed point and what this will sound like to an observer.	