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91523

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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.

Merit

TOTAL 18

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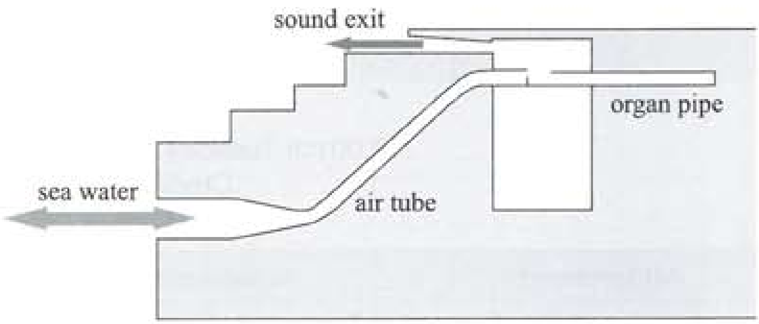
QUESTION ONE: THE SEA ORGAN

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.

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

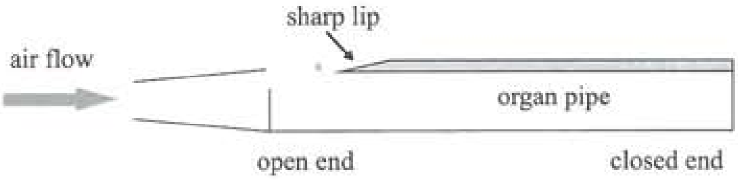
To produce a sound, the organ pipes must have air blown into them, so each organ pipe is connected to the top end of a tube, as shown in the diagram on the right.

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.

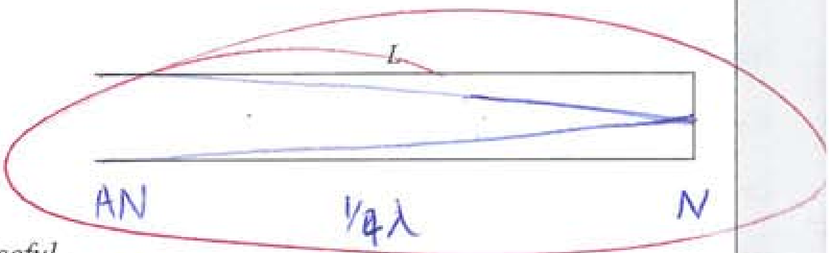


The diagram on the right shows the inside of an organ pipe.

These organ pipes have one closed end.



(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.

fundamental wave = $\frac{1}{4}\lambda$

$\therefore$ $L = \frac{1}{4}\lambda = \frac{2.6}{4} = 0.65\text{ m}$

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

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

Only f that fits within the pipe exactly will produce standing waves ie. $\frac{1}{4}\lambda$, $\frac{3}{4}\lambda$, $1\frac{1}{4}\lambda$ ...

the wave must travel to form a node at the closed end, and reflect to form a standing wave with the on-coming waves. As the wave reflects, it becomes out of phase.

The wave must also feature an antinode at the open end.

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

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

The length of the pipe determines the λ for waves at fundamental frequency, and therefore the f of the waves. Shorter pipes will have shorter λ, and $\therefore$ higher f (as $f \propto \frac{1}{\lambda} \rightarrow v = f\lambda$) which will produce a higher pitched sound. Longer pipes will produce a lower f

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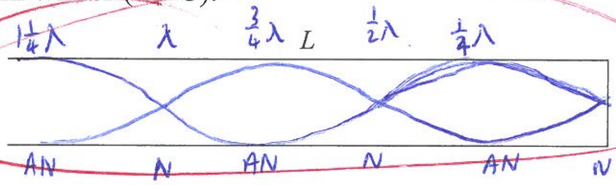
(d) The speed of sound in cold air is slower than it is in warm air.

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.



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

~~since λ ...~~

~~assuming λ = 2.60m.~~

assuming 0.65m pipe is used,

$1\frac{1}{4}\lambda = 0.65$

$\lambda = 0.52$

summer:

$f = \frac{353}{0.52} = 678.846$

winter:

$f = \frac{330}{0.52} = 634.61538$

diff. in $f = f_{sum} - f_{win}$

$= 44.23076918$

$= 44.2$ Hz (3sf)

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QUESTION TWO: INTERFERENCE

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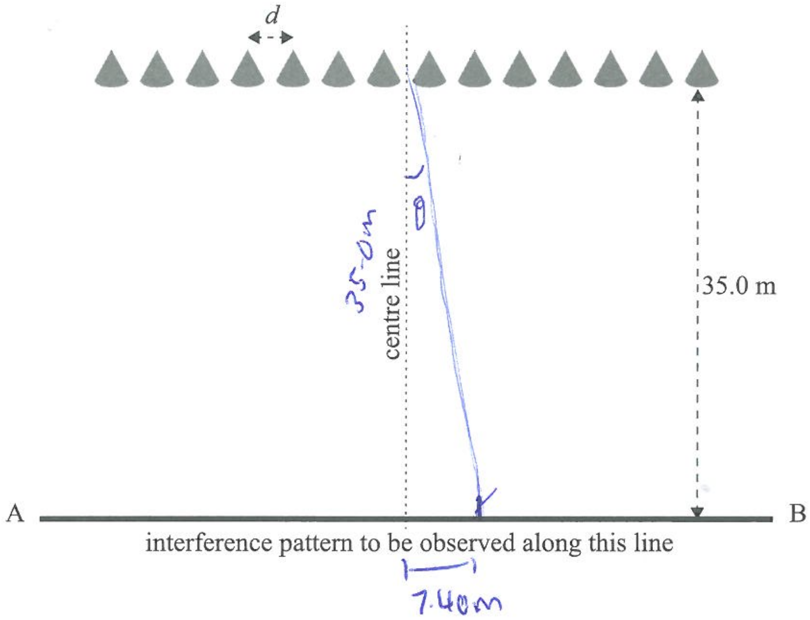
The diagram shows a series of speakers connected together, and to a frequency generator producing a single frequency. The speakers act like a diffraction grating.



(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.

~~d=22.98057.~~

Calculate the separation of the speakers, *d*.

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

$\theta = \tan^{-1}\left(\frac{7.4}{35}\right) = 11.938°$

$d = \frac{n\lambda}{\sin\theta}$

$d = \frac{0.600}{\sin(11.938)} = 2.90057 = 2.90m$ (3sf).

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

When path difference $= n\lambda$ where $n = 1, 2, 3 \ldots$ the interfering waves are ~~out~~ in phase, and so constructive interference occurs. ~~2 waves~~ Peaks (or troughs) from both waves interfere to produce a wave with larger amplitude, heard by a loud spot.

When p.d $= \frac{1}{2}n\lambda$, waves destructively interfere to produce 0 amplitude with a quiet spot as peak of one wave combines with trough of another.

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

reducing d would increase spacing between loud positions (as $d \propto \frac{1}{x}$ → $n\lambda = \frac{dx}{L}$). Loud positions would also be louder. ~~more defined as there would be~~

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(d) The frequency generator is now set so that several different frequencies are emitted by each speaker.

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

Different frequencies would make interference patterns less clear and defined. as constructive interference is occuring less often., and less fully

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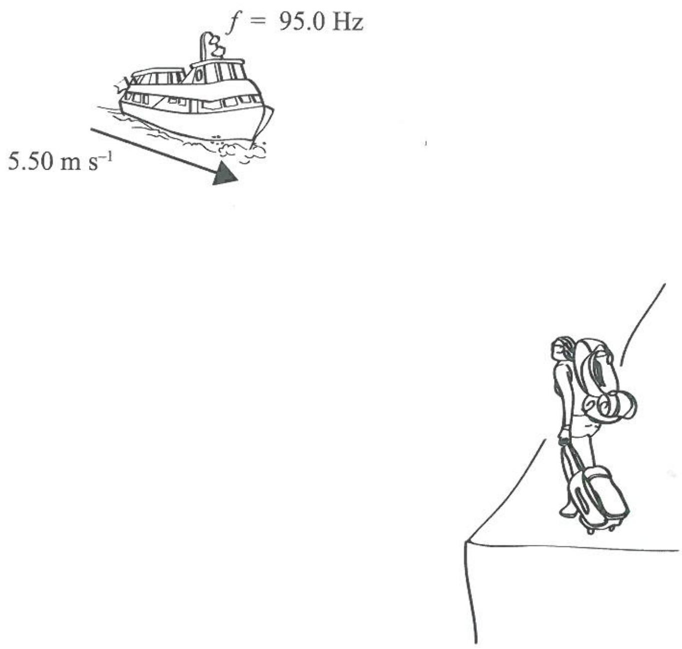
QUESTION THREE: THE DOPPLER EFFECT

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

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



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

$f' = f \frac{v_w}{v_w - v_s}$

$f' = 95\left(\frac{350}{350 - 5.5}\right)$

$= 96.51669 \quad = 96.5\ \text{Hz (3sf)}$

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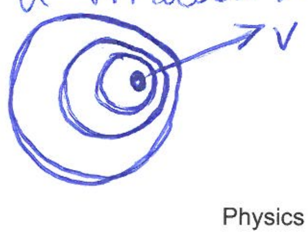
(b) Explain why the sound of the horn heard by the tourist does not have the same pitch as the sound emitted by the horn.

The perceived λ of the sound heard by the tourist is smaller than the actual λ. ~~This is because the relative speed of the boat causes the~~ The motion of the boat causes the sound waves emitted ~~by the boat~~ to be created closer to the last wave, than if the boat were stationary, creating a smaller λ, and $\therefore$ larger f.



The apparent larger f causes a higher pitch to be heard by the tourist.

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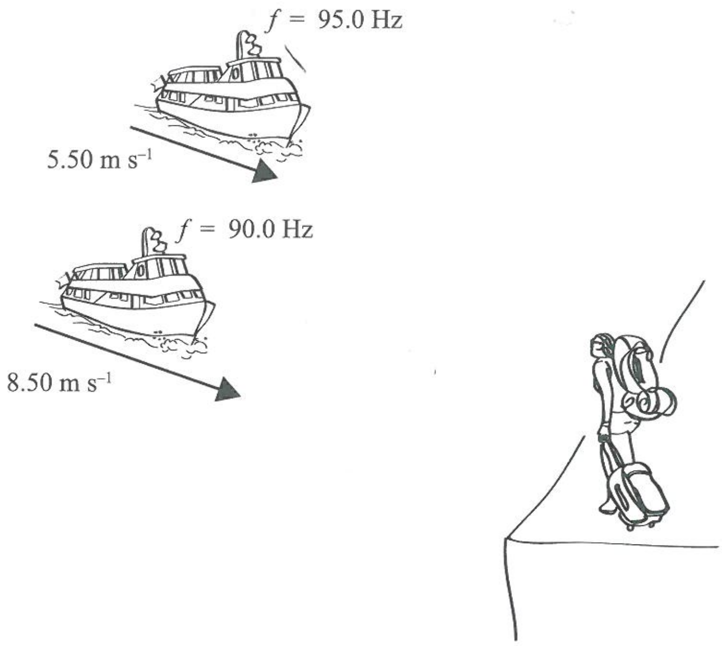

(c) A second ferry, which is overtaking the first, also sounds its horn, producing a note of frequency 90.0 Hz. For a few moments, both ferries are the same distance from the tourist, quite close together, and both are sounding their horns. The tourist hears beats.

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

$f_2' = f \frac{v_w}{v_w - v_s}$

$= 90 \frac{350}{350-8.5}$

$= 92.24011$

$= 92.2\text{ Hz (3sf)}$

$f_B' = f' - f_2'$

$= 96.516 - 92.240$

$= 4.27657$

beat f heard $=$ 4.28 Hz

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

Beats are created when waves interfere that only have a slight difference in f. These are heard as periods of loudness (due to the constructive interference of the waves) or periods of quiet (due to destructive interference). The tourist will hear the beats produced by the two boat horns as 4 'pulses' every second, of loudness.

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

QUESTION NUMBER

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Merit exemplar for 91523 2014		**Total score**	**18**
Q	**Grade score**	**Annotation**	
1	M6	In part (b), the requirement for a node at the closed end and an antinode at the open end is not linked to the relationship between wavelength and pipe length, or the type of interference that must occur at the ends. In part (d) the candidate has found the second overtone rather than the first overtone frequencies as required.	
2	M6	A minor error has been made in part (b) – "½n" instead of (n-½) – however, there is adequate evidence to show in-depth understanding of the situation. In part (c) the relationship between speaker separation and the spacing of loud positions is described in words and explained mathematically.	
3	M6	A comparison is made between the production of waves when sources are stationary and moving, to explain the decreased wavelength and increased frequency in front of the boat. The beats answer would be Excellence if it explained that differing frequencies of waves do not stay in phase over time, but alternate between being in phase and being out of phase, and that this causes an alternation between constructive and destructive interference.	