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90520

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Level 3 Physics, 2004

90520 Demonstrate understanding of wave systems

Credits: Four
9.30 am Thursday 18 November 2004

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 answer ALL the questions in this booklet.

For all 'describe' or 'explain' questions, the answers should be written or drawn clearly with all logic fully explained.

For all numerical answers, full working must be shown and the answer must be rounded to the correct number of significant figures and given with an SI unit.

Formulae you may find useful are given on page 2.

If you need more space for any answer, use the page provided at the back of this booklet and clearly number the question.

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.

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Achievement Criteria		
Achievement	**Achievement with Merit**	**Achievement with Excellence**
Identify or describe aspects of phenomena, concepts or principles.	Give descriptions or explanations in terms of phenomena, concepts, principles and/or relationships.	Give concise explanations that show clear understanding in terms of phenomena, concepts, principles and/or relationships.
Solve straightforward problems.	Solve problems.	Solve complex problems.
Overall Level of Performance (all criteria within a column are met)		

You are advised to spend 40 minutes answering the questions in this booklet.

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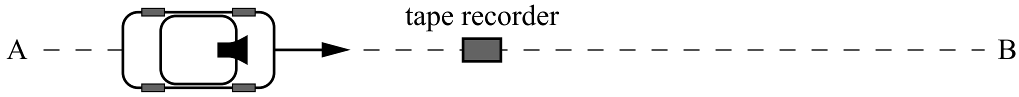
You may find the following formulae useful.

$$d\sin\theta = n\lambda \qquad n\lambda = \frac{dx}{L} \qquad f' = f\frac{v_W}{v_W \pm v_S} \qquad v = f\lambda \qquad f = \frac{1}{T}$$

INVESTIGATING THE SPEED OF SOUND

Some students were given the task of designing an experiment to measure the speed of sound. To do this they were given an air horn that sounded a single note of frequency 426 Hz.

The experiment they designed involved driving a car from A to B at a constant speed over a tape recorder, with the horn sounding.



The students carried out several trials. For each trial, they made a recording of the sound of the horn as the car moved from A to B and noted the speed of the car.

Back at school, the students determined the frequency of the notes they had recorded.

QUESTION ONE: AN EXPERIMENTAL VALUE FOR THE SPEED OF SOUND

The students observed that the recorded pitch of the sound from the horn as it moved toward the tape recorder was different from the pitch as the horn moved away from the recorder.

(a) What is this phenomenon called?

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For one of the trials, the speed of the car was noted as 31 km h^{-1} (8.6 m s^{-1}). Two notes from the horn were recorded. The higher-pitched note had a frequency of 437 Hz.

(b) By rearranging the appropriate formula, show that this data gives a speed of sound of 340 m s^{-1}.

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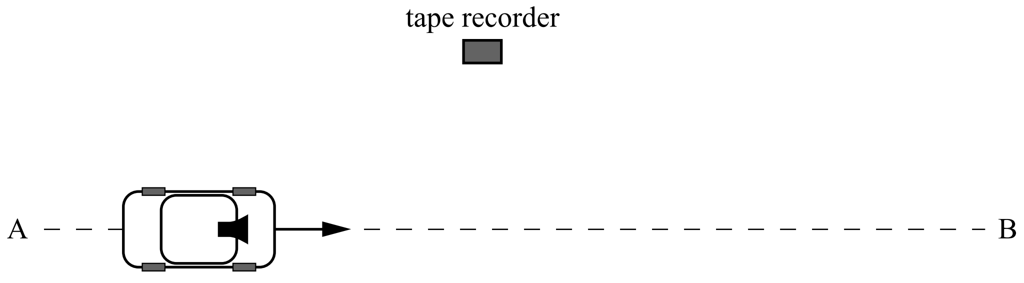
(c) Explain why there is a difference in the frequency of the two notes recorded.

(d) Calculate the frequency of the lower-pitched note of the two that were recorded.

frequency =

(e) On one occasion, the path AB of the car was some distance from the recorder, as shown in the diagram below. In the recording for this run, the students noticed the change in pitch was gradual rather than sudden. Explain why this is so.



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To find the frequency of the notes they had recorded, the students compared the recordings to the sound produced by a speaker connected to a variable frequency (signal) generator.

The students noticed that sometimes, when they were listening to both sounds at the same time, there was a regular variation in the loudness of the sound. This phenomenon is known as 'beats'.

(f) Explain, using physical principles, how beats are produced.

(g) For one of the trials, when the recorded note was sounded at the same time as the signal generator note, a beat frequency of 5.0 Hz was heard. The signal generator note had a frequency of 425 Hz.

(i) What does this indicate about the frequency of the recorded note?

(ii) When the signal generator frequency was **increased** the beat frequency **decreased**.

Explain how this information enables the frequency of the sound on the recording to be found.

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QUESTION TWO: QUALITY OF THE SOUND

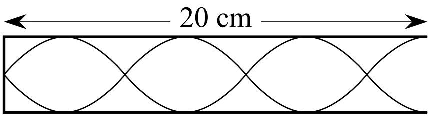
Use $v = 3.40 \times 10^2$ m s^{-1} for the speed of sound.

An air horn is a type of wind instrument and so can be modelled by a pipe. The length of the horn the students used was 20 (2 sf) cm and the sound it produced had a frequency of 426 Hz.

(a) Show by calculation that this data indicates that a **closed** pipe, not an open pipe, models an air horn. (Note: a closed pipe is closed at one end; an open pipe is open at both ends.)

When the students were matching the sound from the recording with the sound from the speaker, they noticed that although the frequencies were the same, the quality (timbre) of the notes was different. They knew that this is because the horn produces many higher harmonics (overtones), as well as the 1st harmonic (fundamental), all of which add together.

The diagram below shows the shape of a higher harmonic.



(b) Show that the wavelength of the harmonic is 0.11 m.

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(c) Calculate the frequency of the harmonic. Give your answer to the correct number of significant figures.

frequency = ______________

Harmonics are numbered in such a way that the frequency of the nth harmonic has $n \times$ the frequency of the 1st harmonic (eg the 3rd harmonic has $3 \times$ the frequency of the 1st harmonic).

(d) Which harmonic is illustrated on the previous page?

harmonic is ______________

As well as pitch, the loudness (or intensity) of sound is an important property. Intensity, I, is **directly** proportional to the **power**, P, (rate at which energy is) transmitted by the wave, and **inversely** proportional to the **area**, A, over which the energy is spread. The constant of proportionality is dimensionless.

(e) Use this information to **derive** a **unit** for intensity of sound.

unit for intensity of sound is ______________

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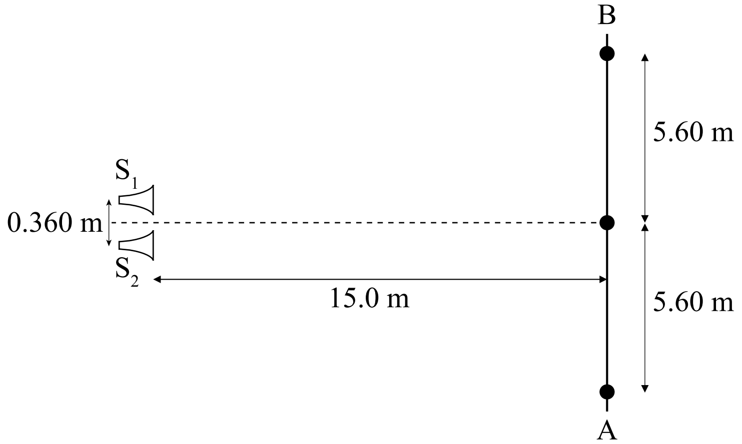
QUESTION THREE: ANOTHER EXPERIMENTAL VALUE

The students were then asked to design an interference experiment to measure the speed of sound. One of the windows of the laboratory faced out over the playing fields. The students set the signal generator to a frequency of 2680 Hz, connected two speakers S_1 and S_2, and aimed the sound from them out of this window.

Each student walked along the line AB and marked the positions at which the sounds were loudest. From these marks, they estimated that the distance between adjacent positions of loud sound was 5.60 m.

The diagram (not to scale) shows the distances they used.



(a) Explain why the sound the students heard varied in loudness.

(b) Using information from the diagram, show that the students calculated the wavelength of sound to be 0.126 m.

(c) From this wavelength, calculate the speed of sound.

speed of sound = ____________

Extra paper for continuation of answers if required.
Clearly number the question.

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Question number