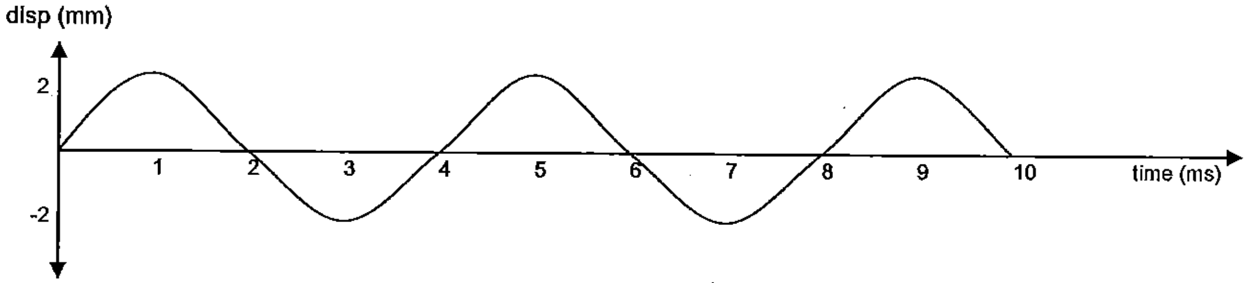
SCOTCH
COLLEGE

60 mins | Sound and Waves Test 2013 | [60] marks

Name: ______________________________

Question 1 **[10 marks]**

The graph shown below represents a sound wave moving in air at 25°C.



(a) Determine each of the following quantities for this sound wave. [4 marks]

Amplitude A = 2mm

Period T = 4ms = 0·004 s

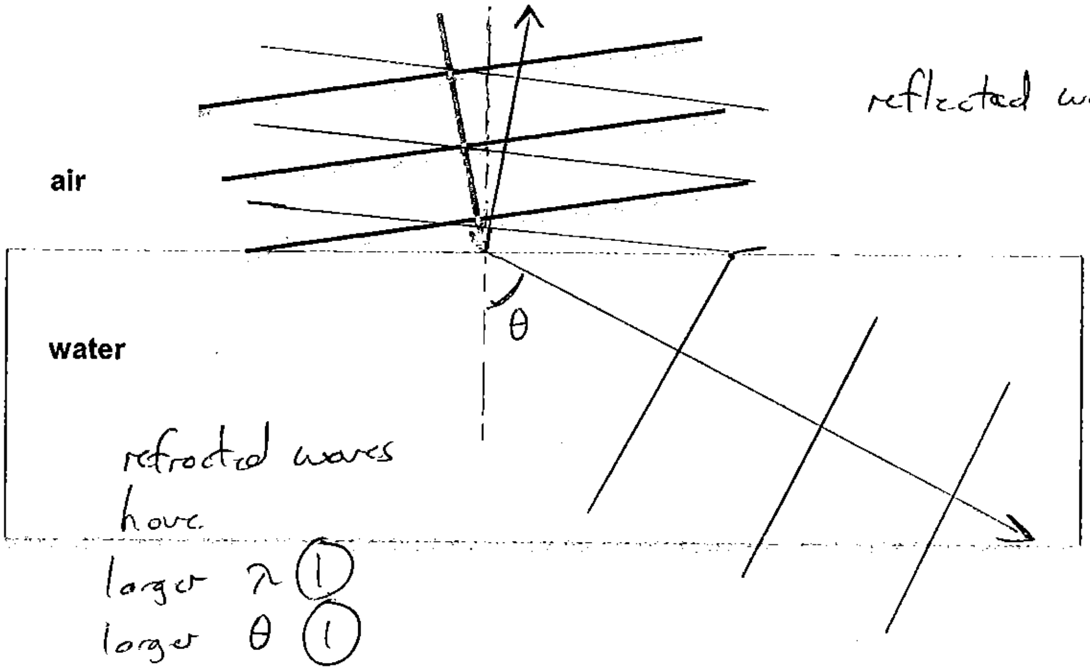
Frequency f = 250 Hz

Wavelength λ = 1·38 m

(b) Which of the quantities amplitude, frequency and/or wavelength would remain constant if the sound wave crossed from air into water? Explain your answer. [3 marks]

Frequency remains constant 1, as the number of waves per second leaving the air must equal the number of waves per second entering the water 1 at the interface between air and water. Both amplitude and wavelength will change as the sound wave enters a new medium 1

(c) Complete the sketch below by showing how the sound wave behaves as it meets the boundary between the air and water at a slight angle to the normal. [3 marks]

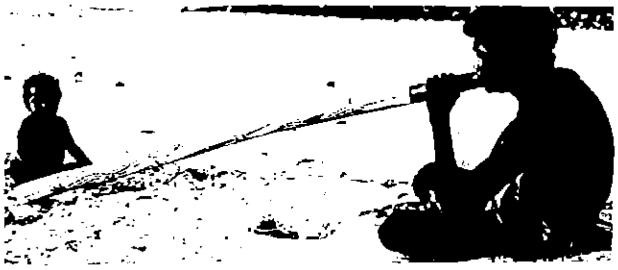


reflected waves 1

refracted waves have
larger λ 1
larger θ 1

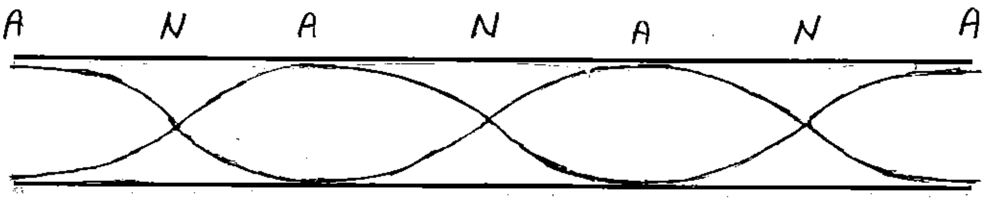
Question 2 **[9 marks]**

The didgeridoo is a traditional Aboriginal wind instrument. It is a hollow pipe, open at both ends, and usually about 1.5 m long. The didgeridoo has no holes, keys or valves like orchestral wind instruments have, but overtones or harmonics may be sounded by overblowing (blowing more strongly).



3rd harmonic

(a) Draw the standing wave (displacement-distance envelope) produced when the instrument is blown so that the second overtone is heard. Label each node and antinode. [2 marks]



1

1

(b) Given that the speed of sound in cool desert air is 336 m/s, calculate the frequency of the second overtone produced from a 1.50 m long didgeridoo. [2 marks]

For 2nd overtone (3rd harmonic) $\frac{3}{2}\lambda_3 = L = 1.5\,m$

$\therefore \lambda_3 = \frac{2}{3}(1.5\,m) = 1.0\,m$ 1 $\rightarrow f_3 = \frac{V}{\lambda_3} = \frac{336\,m/s}{1.0\,m} = \underline{336\,Hz}$ 1

(c) Determine the frequency of the fundamental note from this didgeridoo. [1 mark]

$f_1 = \frac{1}{3} \times 336\,Hz = \underline{112\,Hz}$ 1

(d) A second didgeridoo sounds its fundamental note of frequency 107 Hz. Which of the two instruments is longer? Explain. [2 marks]

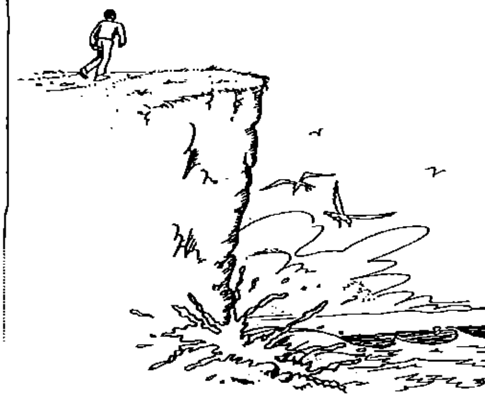
Since fundamental frequency $f_1 = \frac{V}{2L}$ 1, the longer a pipe is, the lower the frequency. Hence the <u>second didgeridoo</u> is longer 1

(e) If the original instrument and the second instrument are both sounded together at the same loudness, describe the sound that would be heard. Include a simple numerical calculation in your answer. [2 marks]

The combined sound would be a pulsating sound 1 of alternating loudness and softness, with a beat frequency of 2 $112 - 107 = \underline{5\,Hz}$ 1

Question 3 **[4 marks]**

You are walking along a path on a cliff above a beach. The path is not quite on the cliff edge, so you cannot actually see the surf, nor can you see the seagulls that are flying below the cliff. Explain why you **can** hear the pounding of the surf, but you **cannot** hear the cries of the seagulls.



The pounding of the surf is a low-pitched rumbling noise, so its sound waves have large wavelengths (1) and hence diffract significantly around the cliff edge so you can hear them. (1) The cries of the seagulls are high-pitched and hence of small wavelength (1) so they don't diffract very much around the edge of the cliff (1)

Question 4 **[7 marks]**

Two loudspeakers are 8.00 m apart and emitting a frequency of 230 Hz in air where the speed of sound is 345 m/s. The speakers are in phase with each other and face towards each other. A person hears a series of quiet and loud spots as they walk from one speaker towards the other.

(a) What does "in phase with each other" mean? [2 marks]

In phase with each other means that as a certain part of the wave cycle is leaving one speaker, exactly the same part of the wave cycle is leaving the other speaker

(b) What is the distance between a quiet and loud spot? [2 marks]

$$\lambda = \frac{v}{f} = \frac{345\,m/s}{230\,Hz} = 1.50\,m \quad (1)$$

$$\text{distance (node–antinode)} = \frac{1}{4}\lambda = \underline{0.375\,m} \quad (1)$$

(c) What will be heard by someone who is between the two speakers and 3.25 m from one of the speakers? [3 marks]

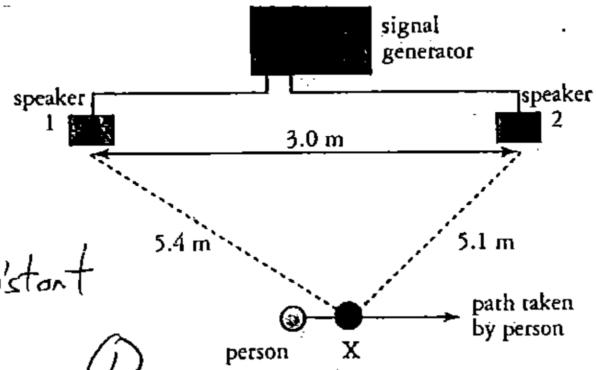
3.25 m from one speaker $\Rightarrow$ 8.00 − 3.25 = 4.75 m from other speaker (1)

$\therefore$ path diff = 4.75 m − 3.25 m = 1.50 m = 1λ (1)

Hence they are at an antinode, and the sound is loud (1)

Question 5 **[7 marks]**

A signal generator is connected in phase to two loudspeakers that are 3.0 m apart in a room. A person stands in front of the midpoint between the speakers as shown at right.



(a) Why does the person hear a loud sound at the midpoint between the speakers? [2marks]

At the midpoint they are equidistant from the speakers, so the path 1 difference for the sound waves is zero and the waves arrive in phase and interfere constructively 1

The person then moves slowly to the right. At point X along this path, the sound reaches a minimum. Beyond point X the sound increases in strength again, then decreases, and continues to alternate in strength as they move steadily to the right.

(b) Explain why the person hears the sound level alternate as he moves to the right. [2marks]

As he moves to the right the path difference for the sound waves from the two speakers changes continually 1, and so he moves through spots of constructive then destructive interference 1

(c) Calculate the frequency of the sound coming from the sound generator. [3 marks]

Point X is the first minimum, so the path diff $= \frac{1}{2}\lambda$ 1

$\therefore 5.4\,m - 5.1\,m = \frac{1}{2}\lambda \rightarrow \lambda = 0.6\,m$ 1

$\therefore f = \frac{v}{\lambda} = \frac{346\,m/s}{0.6\,m} = 577\,Hz$ 1

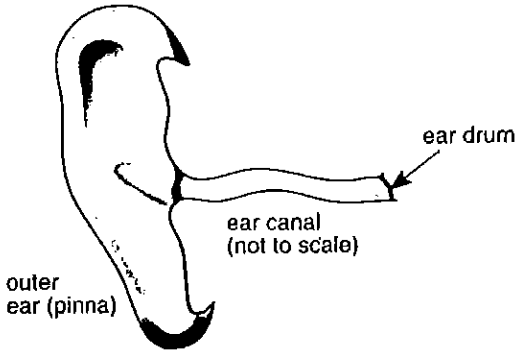
Question 6 **[4 marks]**

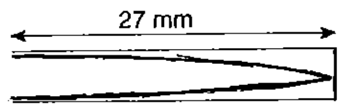
An opera singer sings a pure note next to a piano and notices that when he stops some strings on the piano have begun to vibrate. Explain why the strings begin vibrating.

The frequency of the pure note must match a natural frequency of those strings 1. Hence the sung note acts as a driving force 1 at the natural frequency of the strings and causes them to resonate 1, building up large amplitude vibrations that persist when he 1 stops singing the pure note.

Question 7 **[8 marks]**

The outer human ear can be modelled as a pipe 27 mm long and closed at one end. Sound entering the ear travels along the tube and is reflected back causing a standing wave in the tube.





1

1

(a) Use the diagram above right to draw the wave pattern for the first mode of vibration. Label each node and antinode. [2 marks]

(b) Is this standing wave produced transverse or longitudinal? Explain. [2 marks]

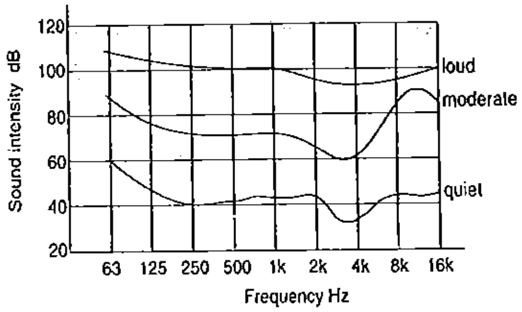
The standing wave is longitudinal 1, as it is generated by interference between sound waves in the ear canal 1

(c) Calculate the wavelength of this standing wave, and its frequency in air at 25°C. [2 marks]

$$\lambda = 4L = 4 \times 27\,mm = 108\,mm = 0.108\,m \quad 1$$

$$\therefore f = \frac{v}{\lambda} = \frac{346\,m/s}{0.108\,m} = \underline{3200\,Hz} \quad 1$$

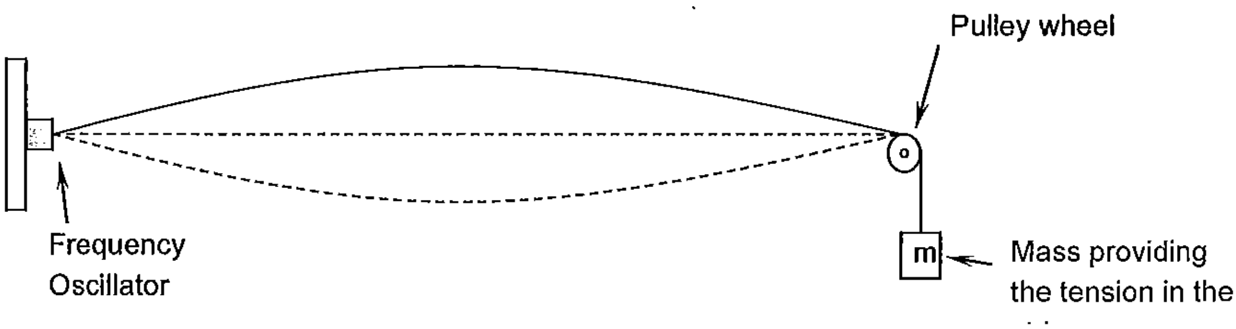
(d) The graph at right shows how the perceived loudness (sound intensity) of a sound depends on its pitch (frequency). Explain whether the graph supports the calculation in part (c) above. [2 marks]



The graph supports the calculation above as sounds with frequencies around 3-4 kHz are perceived to be as loud 1 as other sounds when their intensity is less → these frequencies are amplified by the standing wave in the 1 ear canal causing resonance to occur

Question 8 **[11 marks]**

An experiment to investigate the relationship between the tension in a guitar string and the frequency of transverse waves in the string is set up using apparatus like that shown below. The frequency oscillator is used to vary the rate at which the **1.20 m long** string is forced to vibrate.



Using this apparatus the mass providing the tension in the string was altered over several trials; each trial the frequency was varied until resonance occurred and produced the fundamental standing wave pictured above. The results are shown in the table below.

mass m (g)	100	200	300	400	500	600
frequency f (Hz)	175	250	305	350	395	430
f^2 (Hz^2)	30625	62500	93025	122500	156025	184900

For a stretched string of given mass per unit length μ and under tension F, the velocity v of a wave in the string is given by the equation: $v = \sqrt{\frac{F}{\mu}}$

(a) Using this equation, the equation for the fundamental frequency of waves on a string and the equation for the weight of a mass, <u>derive</u> the following relationship between frequency f and mass m (note L is the string length and g is the acceleration due to gravity) [3 marks]

$$f^2 = (g/4\mu L^2)\, m$$

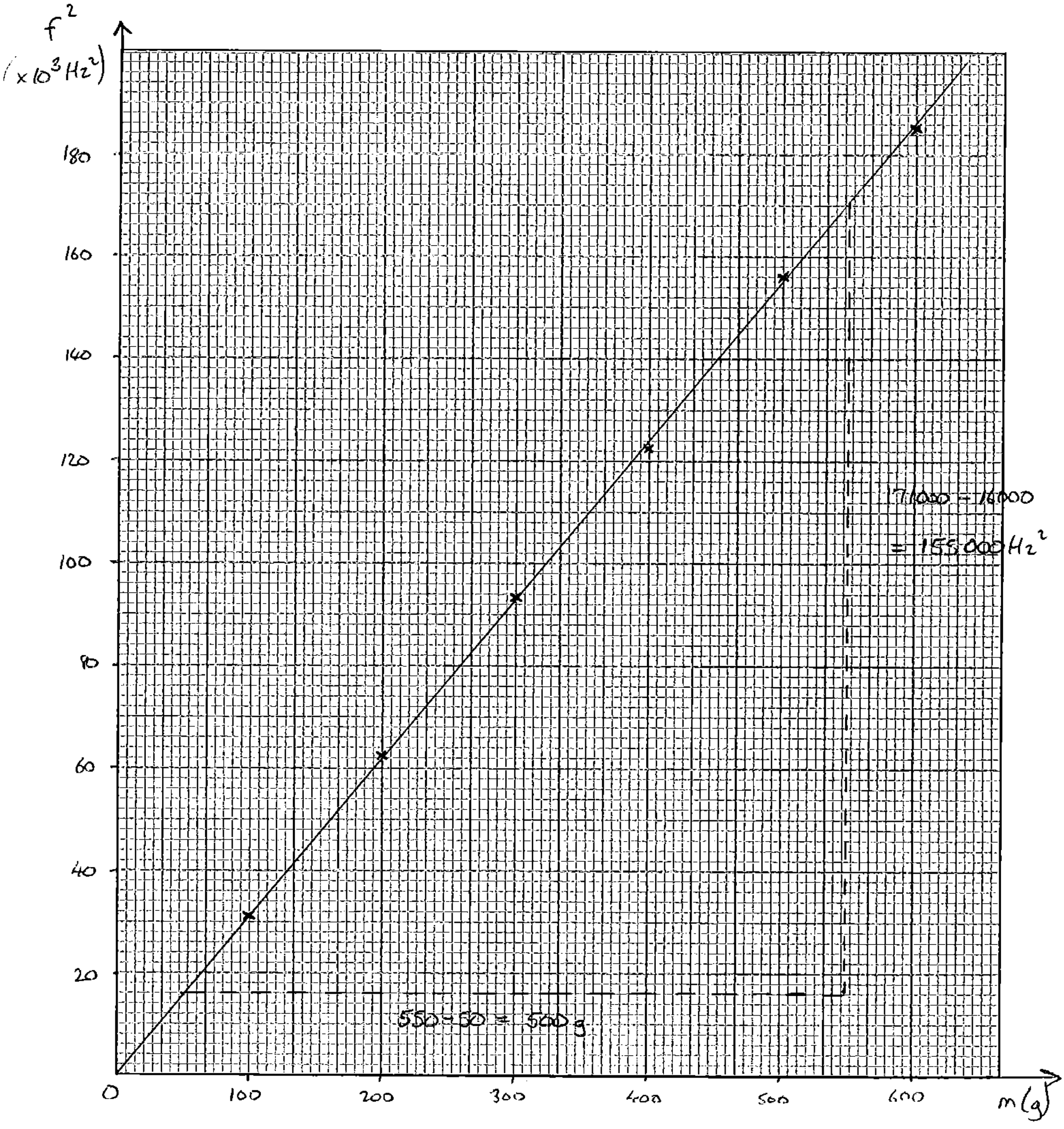
$v = \sqrt{\frac{F}{\mu}}$ (1) fundamental frequency $f = \frac{v}{2L}$ (2) weight $F = mg$ (3)

Rearrange (2) $\rightarrow$ $v = 2Lf$ (4)

Substitute (3) and (4) into (1) $\rightarrow$ $2Lf = \sqrt{\frac{mg}{\mu}}$

$\therefore 4L^2f^2 = \frac{mg}{\mu}$ $\rightarrow$ $f^2 = \left(\frac{g}{4\mu L^2}\right) m$

(b) Modify the data in the table above so that you can plot a straight-line graph to show this relationship between frequency and mass. Plot the graph below [4 marks]



(c) From your graph, determine the mass per unit length (μ) of the guitar string. [4 marks]

$$\text{gradient} = \frac{\text{rise}}{\text{run}} = \frac{155000\ \text{Hz}^2}{500\ \text{g}} = 310\ \text{Hz}^2\,\text{g}^{-1}$$ 1 1

$$\therefore \frac{g}{4\mu L^2} = 310\ \text{Hz}^2\,\text{g}^{-1}$$ 1

$$\therefore \mu = \frac{g}{4L^2(310\ \text{Hz}^2\,\text{g}^{-1})}$$

$$= \frac{9.8\ \text{m}\cancel{\text{s}^{-2}}}{4(1.2\text{m})^2(310\ \cancel{\text{s}^{-2}}\ \text{g}^{-1})}$$

$$= 5.5 \times 10^{-3}\ \text{g/m}$$ 1

$$(= 5.5 \times 10^{-6}\ \text{kg/m})$$

END OF TEST