SCOTCH
COLLEGE

Stage 3 Physics: Sound and Waves Test 2014

Time: 60 minutes Total Marks = 60

Name: ____________________

Question 1 **(4 marks)**

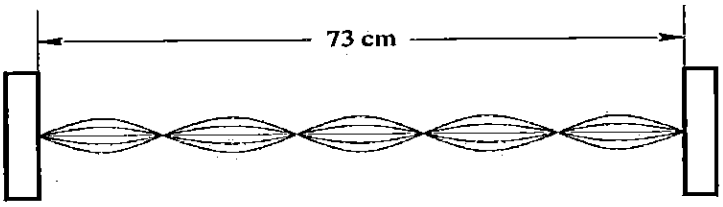
Explain the difference between a transverse and a longitudinal wave. Give an example of each in your explanation.

In a transverse wave the oscillations of the wave are perpendicular to the direction of propagation of the wave (1) e.g. electromagnetic waves, water waves, waves on a string (1)

In a longitudinal wave the oscillations are parallel to the direction of propagation of the wave (1) e.g. sound waves, cars in traffic jam, compressions in slinky (1)

Question 2 **(6 marks)**

A standing wave is set up on a stretched string of length 73 cm, as shown at right. The string vibrates at a frequency of 750 Hz when oscillating in the mode shown in the diagram. The amplitude of the antinodes is 10 mm.



(a) Which harmonic is shown in the diagram? (1 mark)

5th

(b) What is the wavelength of the standing wave shown above? (1 mark)

$\lambda = 2L/5 = 2(73\text{cm})/5 = 29.2\text{ cm}$

(c) What is the speed of the waves in the string? (2 marks)

$v = \lambda f = (0.292\text{m})(750\text{ Hz}) = 219\text{ m/s}$ (1) (1)

(d) What is the maximum displacement of the string from its rest position? (1 mark)

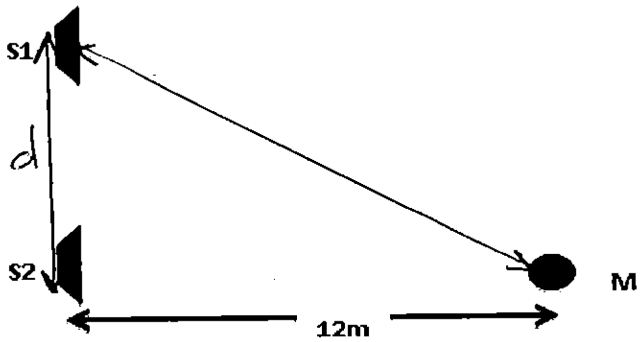
10 mm (amplitude ≡ max disp from rest)

(e) How many times per second is the string completely straight? (1 mark)

1500 times/sec (twice per oscillation)

Question 3 **(6 marks)**

Two loudspeakers (S1 and S2) are connected in phase to a frequency generator. A microphone M is placed 12 m directly in front of speaker S2. The frequency of the sound generated is varied so that the microphone detects a series of maximum and minimum intensity sounds. The lowest frequency at which a **minimum** intensity sound is detected at microphone M is 173 Hz.



(a) Explain how this minimum intensity sound is produced. (2 marks)

This minimum intensity sound is produced when sound waves from each speaker arrive out of phase (1), and so interfere destructively to cause a soft sound (1)

(b) Calculate the distance between the two speakers. $\lambda = \frac{v}{f} = \frac{346}{173} = 2m$ (1) (4 marks)

node at M $\Rightarrow$ path diff $= \frac{1}{2}\lambda = 1m$ (1)

$\therefore$ distance S1-M = S2-M + 1m = 13 m (1)

$\therefore 13^2 = 12^2 + d^2 \rightarrow d = 5m$ (1)

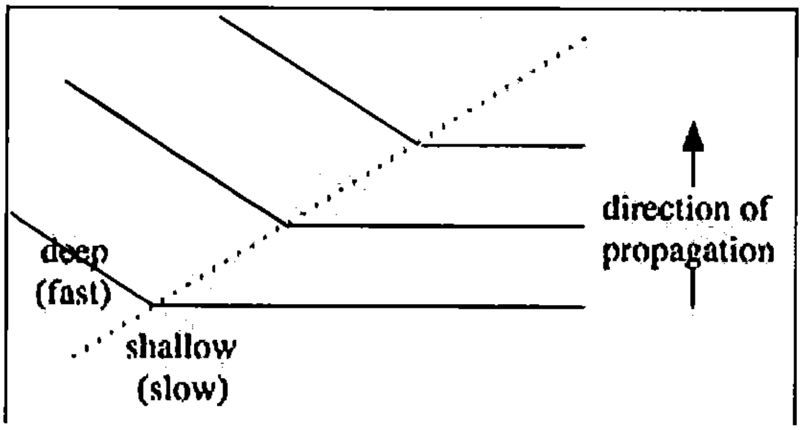
Question 4 **(4 marks)**

When an infantry brigade is crossing a bridge, the soldiers are instructed to break stride and to stop marching in order to prevent the possibility of the bridge collapsing. Explain how soldiers marching in time with one another could pose a danger to the structural integrity of the bridge. Use appropriate Physics terms in your explanation.

Soldiers marching across the bridge could provide a periodic driving force (1) that matches a natural frequency (1) of oscillation of the bridge. If this happened then resonance would occur (1), where the amplitude of the oscillations would build up (1) and possibly damage / destroy the bridge

Question 5 **(5 marks)**

The diagram at right shows water waves in a ripple tank moving towards a boundary between regions of shallow water and of deep water.



(a) State whether each of the following quantities increases, decreases or stays the same as the waves cross the boundary between the two regions. (3 marks)

Wave speed increases

Frequency stays same

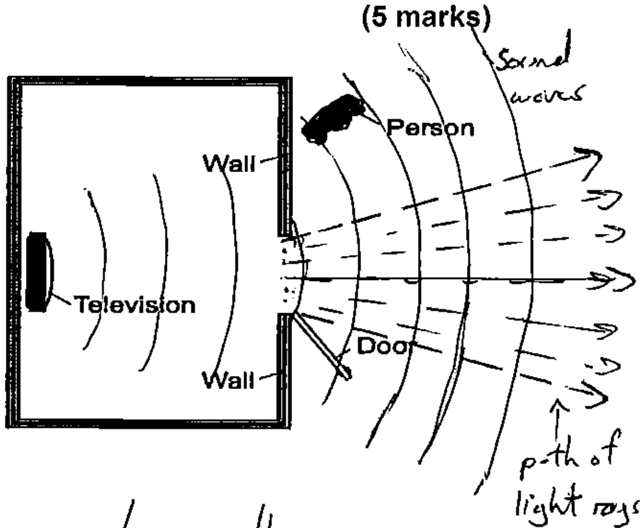
Wavelength increases

(b) Complete the diagram to show the behaviour of the waves as they cross the boundary between the two regions. (2 marks)

wavefronts still parallel (1)
larger λ, bent away from normal (1)

Question 6 **(5 marks)**

A television is switched on in a room. A person outside the room can hear the sound when the door is open, but cannot see the television from where he is standing.



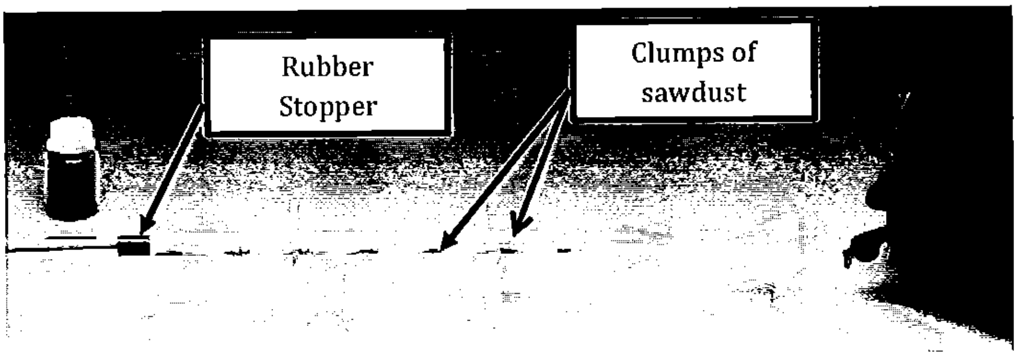
(a) On the diagram at right, sketch the path of the light waves passing through the doorway, and also show the behaviour of the sound waves as they pass through the doorway. Clearly label each type of wave. (2 marks)

(b) Explain why each type of wave behaves as it does. (3 marks)

The wavelength of the light is much smaller than the width of the doorway (1), so it experiences very little diffraction and passes through the doorway as a directional beam. (1) The wavelength of the sound is similar to the width of the doorway, so it experiences significant diffraction. (1)

Question 7 **(9 marks)**

A glass tube can have its effective length varied by moving a rubber stopper at the end of a metal rod as shown below. Initially, there is sawdust spread evenly inside the tube along its length. Jill blows a whistle at a constant frequency, while Jack steadily moves the rubber stopper until the sound suddenly gets very loud and the observation below is achieved.



Jack measures the distance between the clumps of sawdust and finds this to be 7.5 cm.

(a) Explain why the sawdust forms *clumps* as shown in the photograph. (2 marks)

When the sound gets very loud resonance is occurring and a standing wave is set up in the pipe. (1) The clumps are where nodes occur and the air is not moving (1)

(b) State why the sawdust clumps at the left end, next to the rubber stopper. (1 mark)

There is a node at the closed end of the tube

(c) The observations depicted in the photograph show that a standing wave is present in the glass tube. Explain how this standing wave has formed. Be sure to use appropriate Physics terms in your explanation. (3 marks)

Sound waves from the whistle travel up the pipe and reflect from the rubber stopper. (1) As the original waves and reflected waves pass through each other (1) they interfere constructively at certain (1) points (antinodes) and destructively at other points (nodes) creating the standing wave (Note: sound waves also partially reflect back from the open end of the pipe)

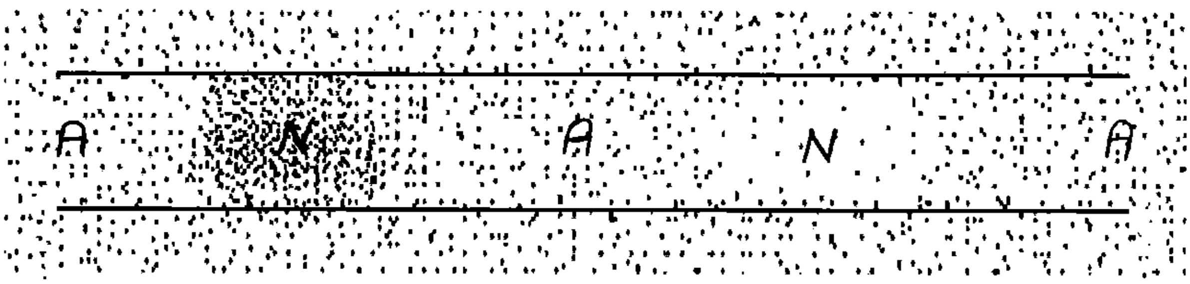
(d) What is the frequency of the wave produced by Jill's whistle? (3 marks)

internodal distance = 7.5 cm → λ = 15 cm (1)

$v = \lambda f \rightarrow f = \frac{v}{\lambda} = \frac{346 \text{ m/s}}{0.15 \text{ m}} = 2310 \text{ Hz}$ (1) (1)

Question 8 **(12 marks)**

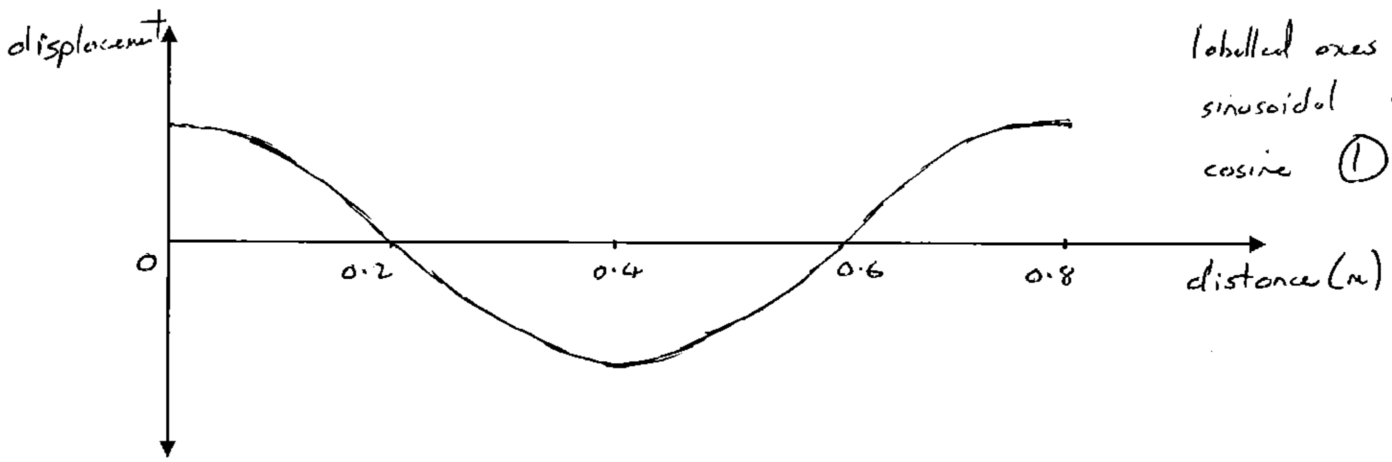
The figure below shows the distribution of air particles in a pipe open at both ends that has a standing wave in it. At the instant shown in the figure, the particles are at their maximum displacement from their 'rest' positions. The pipe has a length of 0.80 m.



(a) Mark the position of any displacement nodes (N) and antinodes (A) in the pipe. (3 marks)

alternating (1) 3A + 2N (1)

(b) Sketch a graph showing the displacement of the air particles as a function of distance along the pipe. You should assume that displacement to the "right" is positive. (3 marks)



labelled axes (1)
sinusoidal (1)
cosine (1)

(c) Which *harmonic* is present in the pipe? Explain. (2 marks)

2nd harmonic (1) – there are 2 displacement nodes (1) inside the pipe (the nth harmonic has n nodes)

(d) What are the frequency and the period of this standing wave? (3 marks)

For 2nd harmonic, $\lambda = L = 0.8$ m (1)

$\therefore f = v/\lambda = 346 \text{ m/s} / 0.8 \text{ m} = 432$ Hz (1)

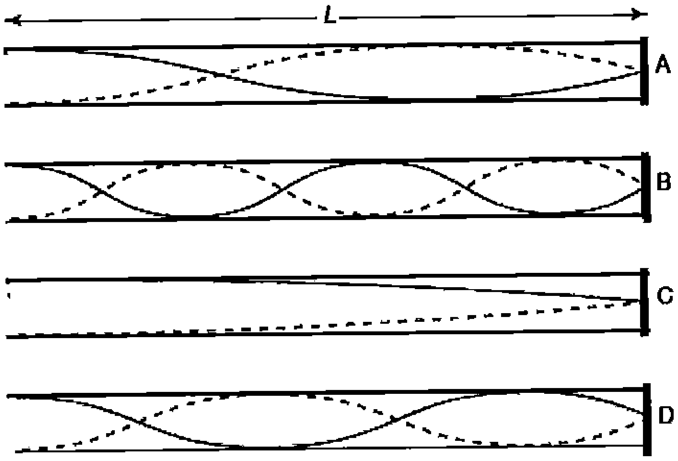
$\therefore T = 1/f = 2.31 \times 10^{-3}$ s (1)

(e) What is the fundamental frequency of this pipe? (1 mark)

$f_1 = \frac{1}{2}(432) = 216$ Hz (1)

Question 9 **(4 marks)**

The figure below represents four standing wave in a pipe of length L. The pipe is closed at one end. Use this figure to complete the table.



PIPE	NODES	ANTINODES	λ	HARMONIC
D	3	3	$\frac{4L}{5}$	Fifth
C	1	1	4L	First
A	2	2	4L/3	Third
B	4	4	4L/7	Seventh

① for each correct row

Question 10 **(5 marks)**

Dolphins and bats both use ultrasound waves with frequencies of up to 120 000 Hz as a form of sonar, emitting the waves and then listening for reflections, in order to navigate through their respective environments. Which animal would be better at distinguishing small objects and why?

The wavelengths of their respective max frequency ultrasound signals would be ①

bat : $\lambda = v/f = 346/120000\,Hz = 2.9 \times 10^{-3} = 2.9\,mm$ ①

dolphin: $\lambda = v/f = 1500/120000\,Hz = 1.25 \times 10^{-2} = 1.25\,cm$

Objects only cause significant reflection and thus can be detected by waves whose wavelengths are smaller than the size of the object. Hence bats can detect smaller objects ① down to a few mm, compared to dolphins, above one cm (larger v → longer λ → less resolution) ②