PERTH MODERN SCHOOL
Exceptional schooling. Exceptional students.

Final score: /50

Year 11 Physics

Waves Test

Time allowed: 50 minutes

Name: Teacher:

Answer all questions in the spaces provided.

Show all working.

Scientific calculators only.

Give calculated answers to three (3) significant figures and estimates to two (2) significant figures unless otherwise stated.

There are three sections:

1. Short response	22 marks
2. Problem solving	20 marks
3. Comprehension	8 marks
Total:	50 marks

Section One: Short Response (22 marks)

Question 1: (4 marks)

While waiting at Victoria Quay in Fremantle for the ferry to Rottnest, a physics student hears the cry of a seagull and sees the water waves formed as a tugboat is heading out to sea. In terms of how waves are defined in physics – what is **one key similarity** between these waves, and what is **one key difference** between them? Briefly **explain** your answers.

Both waves are mechanical waves (1 mark) i.e. they require a medium in order to propagate (1 mark)

Sound waves are longitudinal waves and (surface) water waves are transverse waves (1 mark)

The direction of displacement of particles in the medium is parallel to the direction of propagation for longitudinal waves, and perpendicular to the direction of propagation for transverse waves (1 mark)

Question 2: (4 marks)

When the ferry is about to leave, the skipper sounds the horn. A startled tourist bumps against their travelling companion, who has been taking a picture of an interesting piece of seaweed in the water with their mobile phone. The mobile is flung out into the water. A series of circular ripples spread out from the point at which the mobile disappears. After 6 seconds, there are 17 ripples and the diameter of the outermost ripple is 11.0 metres.

What was the frequency of the ripples?

$s = 11.0/2 = 5.50$ m **(1 mark)**

$v = s/t$
$= 5.50/6$
$= 0.9167$ m s^{-1} **(1 mark)**
$\lambda = 5.50$ m/17 ripples
$= 0.3235$ m **(1 mark)**
$f = v/\lambda$
$= 0.9167/0.3235$
$= 2.83$ Hz **(1 mark)**

OR

$T = 6.00$ s/17 ripples
$= 0.3259$ s $ripple^{-1}$
$f = 1/T$
$= 1/0.3259$
$= 2.83$ Hz

Question 3: **(3 marks)**

As the ferry approaches the jetty at Rottnest, the student notices that the waves are approaching the shore at an angle. Complete the diagram below to show how the waves change in terms of their direction and the distance between crests as they enter the shallower water, which is the slower medium.

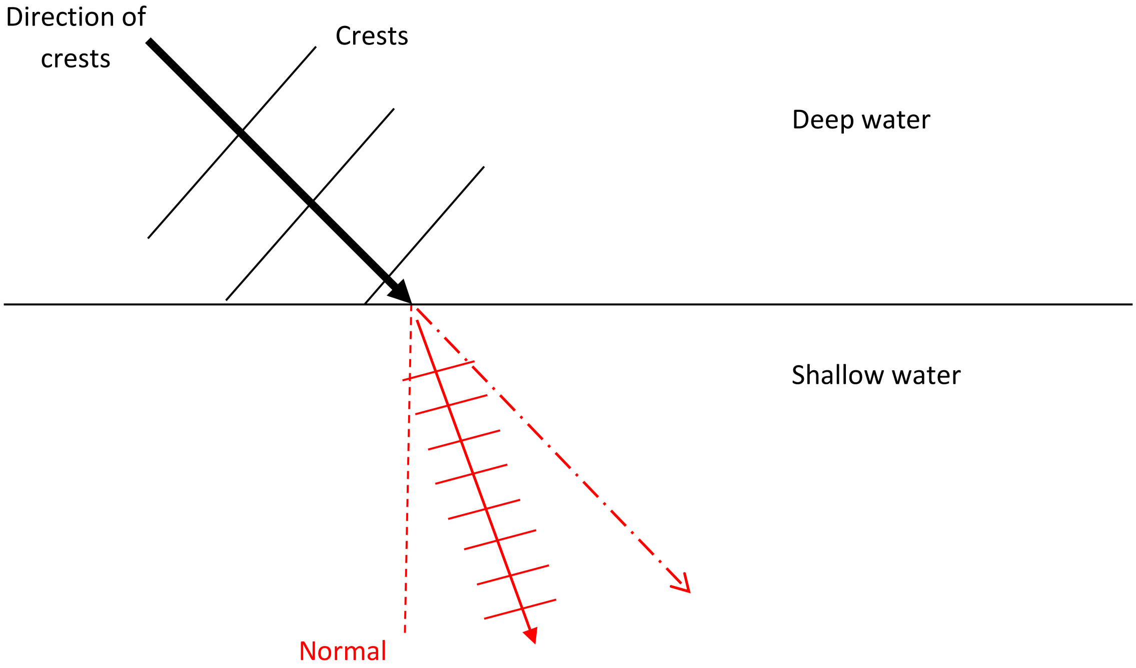


Diagram shows labelled normal as a dotted line **(1 mark)**

Direction of crests bends towards the normal **(1 mark)**

Crests are closer together **(1 mark)**

NB: there is no particular angle or number of crests required – but it should be **obvious** from the diagram that they are bent towards the normal and crests are closer together. A line showing the continuation of the original direction of the crests is not necessary (but it helps). If lines are not drawn with a ruler – feel free to deduct a mark.

Question 4: **(3 marks)**

The skipper gives another blast on the horn as the ferry is tied up. The student hears the sound echoing from the limestone wall facing the harbour 1.80 s later. How far away is the wall? State any assumptions made.

Assumption: air temperature is 25.0°C, so speed of sound is 346 m s^{-1} (from Data Sheet). Any other <u>reasonable</u> assumption concerning speed of sound may be given. **(1 mark)**

s = vt = 346 m s^{-1} x 1.80 s = 622.8 m **(1 mark)**

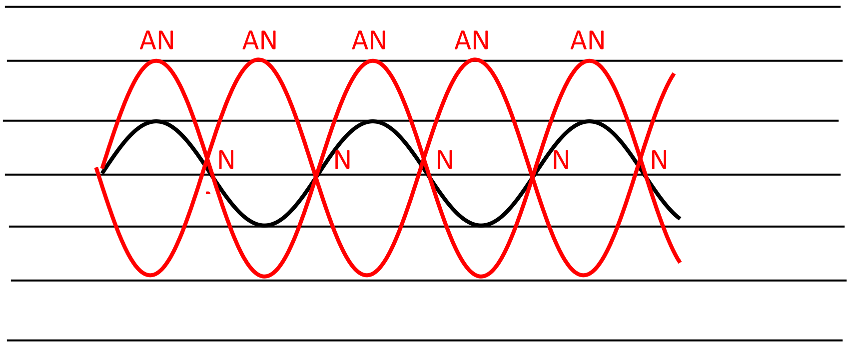
Distance to wall is 622.6/2 = 311 m **(1 mark)**

Question 5: **(3 marks)**

After cycling up to Bathurst Lighthouse, the student sees some water waves in the bay (represented in the diagram below) that are about to reach a cliff. The waves are reflected off the cliff, and the reflected waves interfere with oncoming waves to form a standing wave.

(a) Draw curves to show the envelope of the standing wave that is produced.

(b) Label the nodes (N) and antinodes (AN)



Standing wave envelope shown (1 mark)

Amplitude doubled (1 mark)

Nodes & antinodes labelled (1 mark)

Question 6: **(3 marks)**

While having dinner at the Lodge, the student notices another diner wetting their finger and running it around the rim of a wine glass, producing a clear note which increases in volume. State the term used to describe this physics phenomenon and explain how the sound is produced and why its volume increases.

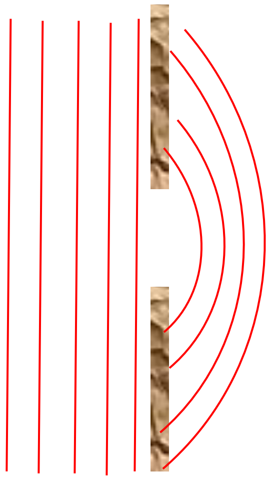
This is an example of resonance **(1 mark)**
Running a finger around the rim of the glass produces vibrations which result in sound of various frequencies including the natural resonant frequency of the glass **(1 mark)**
The continual production of sound waves of the natural resonant frequency of the glass results in superposition of these waves and an increased amplitude of the sound of that particular frequency – resulting in an increase in the volume **(1 mark)**
Other relevant points such as forcing frequency etc. are also valid for marks

Question 7: **(2 marks)**

On the way to West End, the student stops off at Cathedral Rocks to see the sea lion colony. As the waves pass through two large rocky outcrops, the student observes them behaving in a way which indicates that the wavelength of the waves is much greater than the distance of the gap between the two rocks. State the name of the wave behaviour that this illustrates, and sketch some waves as they approach and pass through the gap shown below.

Diffraction **(1 mark)**

Wave diffraction shown in diagram below **(1 mark)**



Section Two: Problem-solving **(20 marks)**

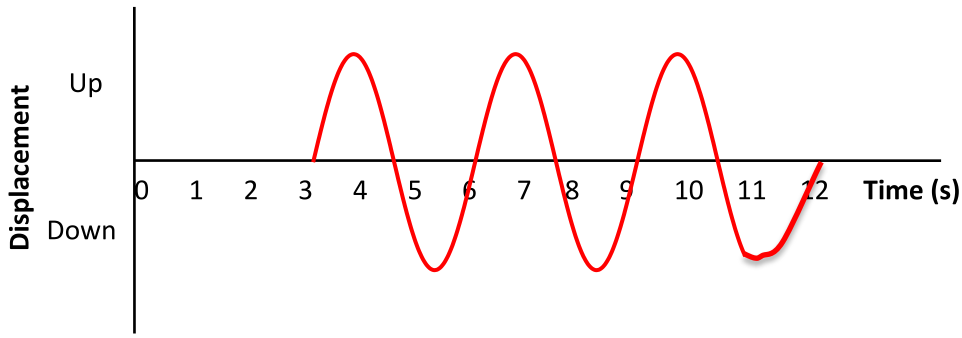
Question 8: **(7 marks)**

A tourist throws a large rock into one of the salt lakes on Rottnest. Waves spread out at 6.00 m s^{-1} and soon reach a stationary floating water bottle which is 18.0 m away from where the rock lands in the water. The bottle now oscillates, bobbing up and down every 3.00 seconds. Take time zero to be the moment the rock lands in the water. Assume that a crest reaches the bottle first.

(a) Draw a displacement-time graph that shows the motion of the bottle during the 12.0 seconds following the splash. No scale is required for the y-axis. Show your working for any calculations.

(4 marks)

- Time taken for waves to reach the bottle = 18.0 m/6.00 m s^2 = 3.00 s **(1 mark)**
- Graph should show bottle moving up first crest **(1 mark)**
- Bottle should commence movement at 3.00 s **(1 mark)**
- Graph should show 3 peaks and 3 troughs **(1 mark)**
- NB: waves should lose energy over time – it is not necessary to illustrate this.



(b) How many times is the bottle in a trough during the 12.0 seconds? (1 mark)

Three times **(1 mark)**

NB: If the answer to (b) is incorrect, but agrees with an incorrect graph in (a) the mark may be given

(c) How does the amplitude of the waves behave as they spread out from the source of the splash? Explain your answer briefly. (2 marks)

Amplitude decreases with distance from source. **(1 mark)**
This is due to the inverse square law whereby intensity decreases with the inverse square of the radius of the distance from the source as per $I \propto 1/r^2$. **(1 mark)**

Question 9: **(6 marks)**

After a snack at the bakery, the student blows across the top of an empty 1.25 L water bottle and produces a note. The bottle measures 284 mm from the top to the bottom.

(a) What would the fundamental frequency (first harmonic) of the note produced by the empty bottle be? (Ignore end effect) (3 marks)

The bottle is acting as a closed pipe so:

$\lambda_n = 4L/n$ where n = 1 **(1 mark)**

$= 4 \times 0.284$ m

$= 1.136$ m **(1 mark)**

$f = v/\lambda$

$= 346/1.136$

$= 305$ Hz **(1 mark)**

(b) What depth of water would need to be added to the bottle in order to change the fundamental frequency of the note produced by blowing across the top to 440 Hz? (3 marks)

$\lambda = v/f$

$= 346/440$

$= 0.784$ m **(1 mark)**

$L = \lambda/4$

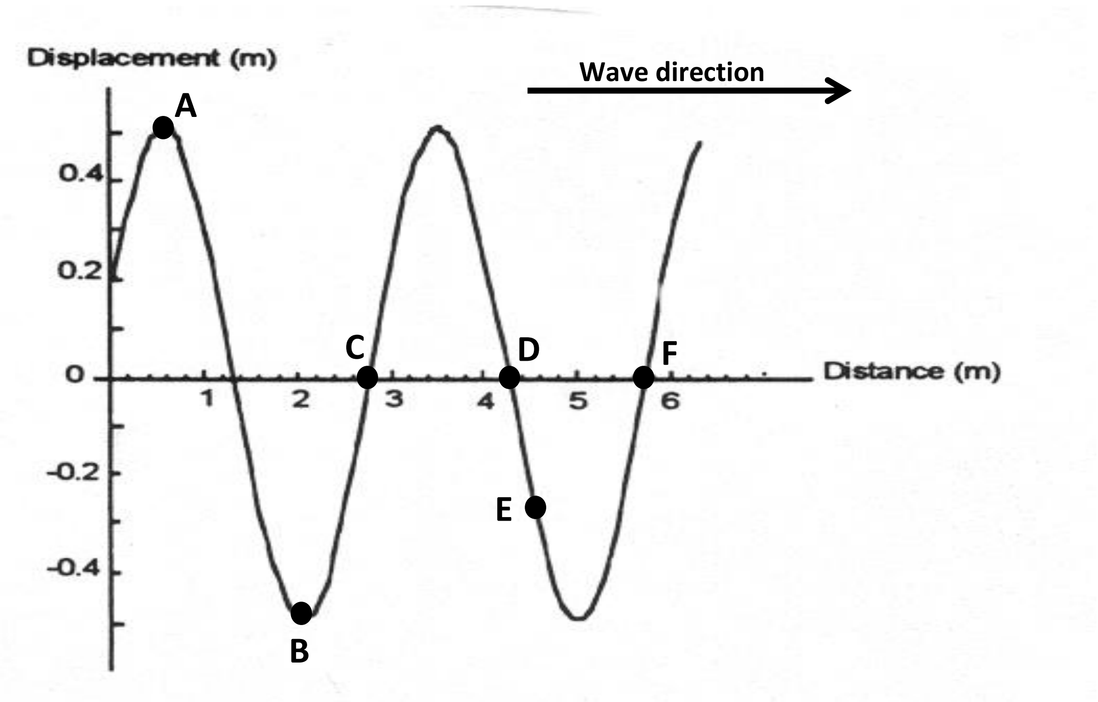
$= 0.1966$ m **(1 mark)**

Since the bottle is 284 mm long, the amount of water to be added to change the depth to 196.6 mm is 284 – 1966 = 87.4 mm **(1 mark)**

NB: Not particularly worried if they don't use SI units here since it would be practical/sensible to use mm if indeed one had a ruler. If students have been careless with their significant figures then I would be inclined to dock them a mark in this question. If they have been good – then let them off with a warning.

Question 10: **(7 marks)**

Two children in Geordie Bay have found some washed up craypot rope. They each hold an end and one of them moves their end up and down to send a transverse wave towards the other end as shown in the following displacement-distance graph:



(a) What is the amplitude of the wave? ____________0.5 m (1 mark)

(b) What is the wavelength of the wave? ____________3.0 m (1 mark)

(c) If the frequency of the wave is 8.8 Hz. What is its speed? (Show your working). (1 mark)

$v = \lambda f = 3.0 \times 8.8 = 26.4 \text{ m s}^{-1}$

(d) Choose one letter on the graph that represents a point on the wave that is:

moving upwards _______ D or E

momentarily at rest _______ A, B (2 marks)

(e) Choose two letters that represent two points that are in phase.____________ C, F (1 mark)

(f) What distance does point E move in one period?_________ 2.0 m (1 mark)

Section Three: Comprehension **(8 marks)**

Sound chamber makes echoes to order

By Barry Fox, from the *New Scientist* (Issue 1965)

(Paragraph 1)

Sound engineers have built the first test chamber capable of offering an almost infinitely variable range of acoustics. Bell Laboratories, the research wing of the American communications giant AT&T, calls its room a “varechoic chamber”. Its acoustics vary from an anechoic state, in which there are no echoes and sounds die almost immediately, to an echo chamber in which the walls reflect sound so strongly that it stays alive for well over a second.

(Paragraph 2)

The chamber is clad with hundreds of specially made panels, each of which can be switched between a “dead” state in which it absorbs sound, and a “live” state in which sound is reflected. This is a simple idea, but it is hard to put into practice and no one has managed it before.

(Paragraph 3)

Bell built the chamber to help it design microphone and loudspeaker equipment for teleconferencing, where two or more groups of people in different places hold a meeting over the phone lines, using microphones and loudspeakers rather than telephone handsets. The microphones must pick up sound from only one person at a time, and ignore the loudspeaker and any noise from someone else in the room.

(Paragraph 4)

A system designed in a dead room will not work well in a real room, where sound may reflect from the walls into the wrong microphone. And all real rooms reflect sound differently. Gary Elko of Bell’s acoustics department worked with mechanical engineer William Ward to design a solution. The varechoic chamber took a year to build and cost $500 000.

(Paragraph 5)

The room is about the size of a large living room or office. Its walls, ceiling and floor are clad with 368 mechanically operated panels, behind which lies a thick layer of sound-absorbing fibreglass. Each panel is made of a pair of stainless steel sheets punctured with a pattern of small holes.

(Paragraph 6)

The sheets are held tightly together to make them airtight but can slide past each other. When the holes align, sound waves pass through and are lost in the fibreglass. When the panels are out of alignment, the holes are blocked off and sound bounces off the steel sheets.

(Paragraph 7)

The outer sheet of each panel is magnetic, and large magnets fitted at the back pull it tightly against its partner to give a good seal. The panels are made completely airtight by a layer of thick oil between the steel sheets.

(Paragraph 8)

Each panel is equipped with a solenoid switch that controls a high pressure pneumatic air line to manoeuvre it between the open and closed positions. The switch is controlled by a personal computer linked to a hand-held remote control. A light detector in each panel senses whether it is open or closed, and feeds this information back to the control system.

(Paragraph 9)

At one extreme, when all the panels are open and the room is fully damped, sound reverberates for only 0.1 seconds, making speech sound very dead. At the other extreme, when all the panels are closed, the reverberation time is 1.6 seconds and the room sounds like a cathedral. Closing the panels in a pair of facing walls creates a fluttering echo effect.

(Paragraph 10)

Bell has not patented its design and has published the basic details in a technical paper. So anyone with the necessary engineering expertise and $500 000 can build one of their own.

Question 11: **(8 marks)**

(a) **Estimate** what time would elapse for a sound to travel from one side of the chamber to the other. List the assumptions you make in your calculation. (3 marks)

- Assume the distance between the sides of the chamber to be 2.5 m
- Assume a temperature of 25.0°C (i.e. the speed of sound will be 346 m s^{-1})
- Estimated time of travel: t = s/v = 2.50 m/346 m s^{-1} = 7.2 x 10^{-3} s **(2 sig figs for estimate)**

NB: answer will vary depending on assumed distance. It is fine to give an alternative estimate for the speed of sound as long as it is reasonable

(b) In Paragraph 1 the term "varechoic chamber" is used. What is the meaning of this term as it is used in the article? (1 mark)

The acoustic properties of the walls of the chamber are able to be varied in terms of the amount of reflection of sound which occurs from the surfaces of the room

Question 11 (cont.)

(c) Why are the panels made of stainless steel sheets rather than fibreglass, and why do the panels have a pattern of small holes? (2 marks)

- The panels are made of stainless steel sheets because this is a hard surface which maximises reflection
- The panels have a pattern of small holes so that when the holes in the sheets are aligned, the sound waves can pass through and be absorbed by the fibreglass surface, thus allowing the reflective properties of the walls to be varied

(d) What is the meaning of "reverberation time" as referred to in the article? (2 marks)

- This is the amount of time that it takes for a sound to die away completely after it has been produced
- A very absorbent surface such as fibreglass will have a very short reverberation time, while a very reflective surface such as stainless steel will have a relatively long reverberation time.
- Where the sound is produced in a room with very highly reflective surfaces, the sound energy will largely rely on being converted into kinetic energy of the air particles

NB: there must be two good points made to attract both marks

END OF TEST