11 PHYSICS ATAR
ASSIGNMENT 6: WAVE MOTION

NAME: SOLUTIONS **DUE DATE:** ______________ **TOTAL:** $\frac{\quad}{43}$

1. Some examples of waves are sound, radio, microwaves, water waves and X-rays. Classify each of these waves under the correct heading.

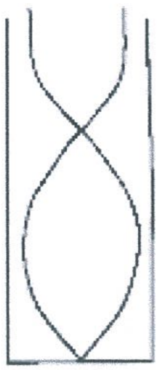
Mechanical Waves	Electromagnetic Waves
sound water waves	radio microwaves X-rays

[½ mark off each mistake]

(2)

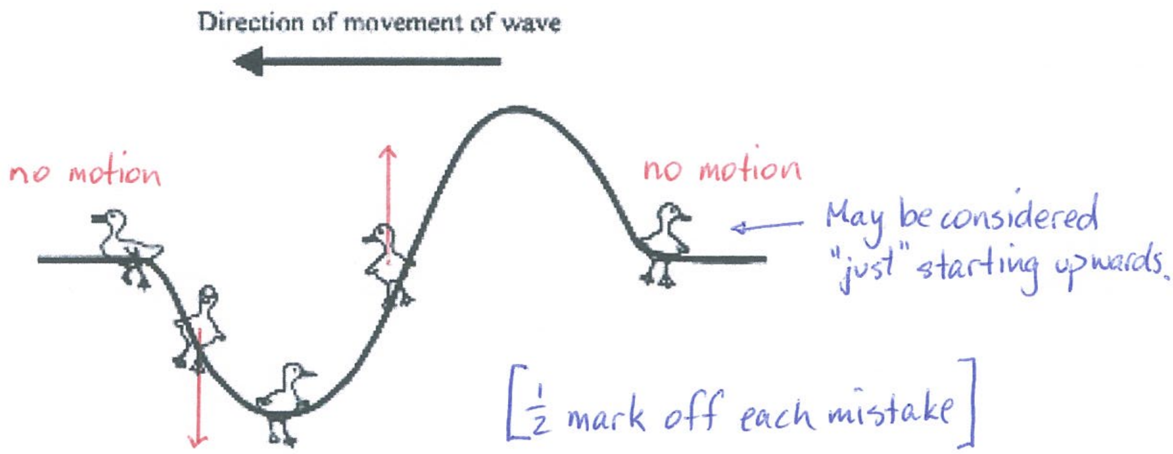
2. Bridgette has seen a diagram of standing waves in a tube, and asks you what the curved lines mean. Explain clearly what these lines represent.

- Represents a standing wave.
- Shows the displacement of the particles.
- Represents the third harmonic.



(3)

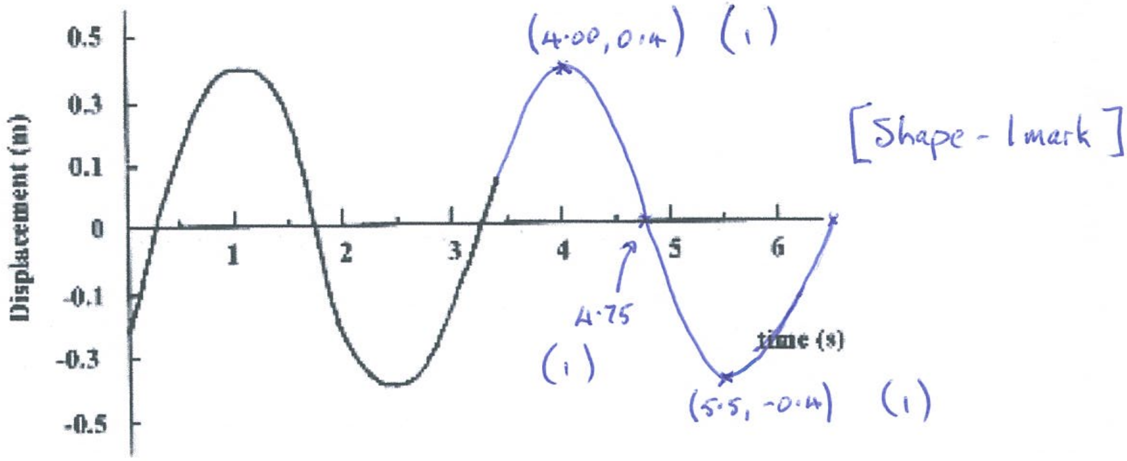
3. Brigette is watching some ducklings, which are paddling on a pond, when a wave approaches them. Use arrows to show the direction of movement of each duckling at the instant shown on the diagram. If there is no movement, label "no motion".



[½ mark off each mistake]

(2)

4. Draw the continuation of the periodic waveform shown up to 6 s.



(4)

5. Twin-engined aircraft, such as those used by the Royal Flying Doctor Service, often produce a sound that rises and falls in loudness.

(a) What is the name given to this effect?

Beats. (1)

(1)

(b) What are the conditions necessary for this effect to occur?

- Two waves of slightly different frequencies. (1)
- Difference must be less than 10 Hz for the ear to detect it. (1)

(2)

6. Two identical tuning forks vibrate at a frequency of 256 Hz. One of them has a drop of wax placed on it. This lowers its frequency. When the two tuning forks are sounded, 6.0 beats per second are heard. What is the frequency of the tuning fork with the wax on it? Show your working.

Assume $f_2 = 256$ Hz

$\Rightarrow f_1 =$ lower.

$f_{beat} = |f_2 - f_1|$ (1)

$\Rightarrow 6{\cdot}0 = 256 - f_1$ (1)

$\Rightarrow f_1 = 250$ Hz. (1)

(3)

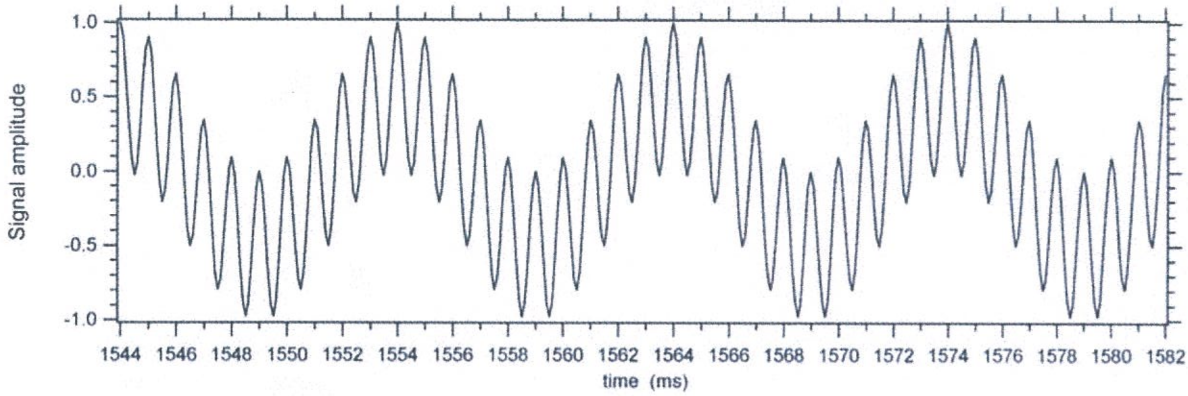
7. For the three properties of a sound wave (frequency, wavelength and speed), complete the table below, stating whether the property is changed or unchanged when undergoing reflection, refraction and diffraction. One property for diffraction has been completed for you.

Property	Reflection	Refraction	Diffraction
frequency	unchanged	unchanged	unchanged
wavelength	unchanged	changed	unchanged
speed	unchanged	changed	unchanged.

[$\frac{1}{2}$ mark each]

(4)

8. The following oscilloscope trace shows the superposition of two waves. The horizontal axis is in milliseconds.



Calculate the frequency of each wave.

Wave with large time period gives the "general shape"

$T = 1559 - 1549$

$= 10 \text{ ms}$ (1)

$f = \frac{1}{T}$

$= \frac{1}{10 \times 10^{-3}}$

$= \underline{1.00 \times 10^{2} \text{ Hz}}$ (1)

Wave with smaller time period has 10 oscillations in 10 ms

$\therefore T = 1.0 \text{ ms}$ (1)

$f = \frac{1}{T}$

$= \frac{1}{1.0 \times 10^{-3}}$

$= \underline{1.00 \times 10^{3} \text{ Hz}}$ (1)

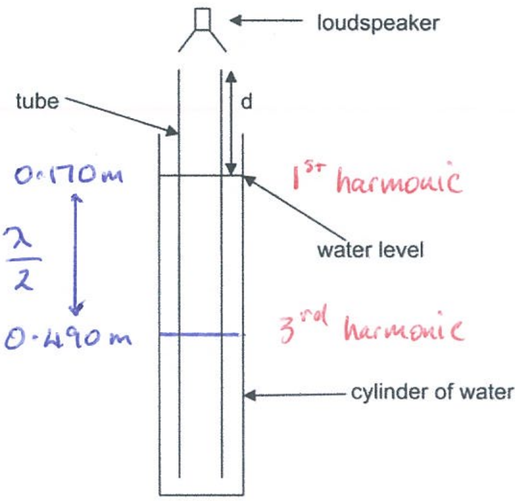
(4)

9. (a) Apart from the phenomenon of vibrating air columns, provide one example in which resonance may be observed. Explain how resonance occurs in the example that you have chosen.

- Suitable example. (1)
  e.g. Ringing wine glass, Tacoma Bridge, rattle in a car, etc.
- Explanation should mention:
  - natural frequency. (1)
  - driving frequency equals the natural frequency. (1)

(3)

A loudspeaker emitting a single frequency is held over a tube that has one end placed in a cylinder of water at 25.0 °C. As the length of tube in the water is changed, the sound heard also changes. The equipment is illustrated in the diagram below.



The first resonance is heard when the length of the air column above the water (labelled **d** in the diagram) is 17.0 cm and a second is heard when the length of the air column is 49.0 cm.

(b) Calculate the wavelength of sound in the cylinder.

Distance between harmonics $= \frac{\lambda}{2}$

$\therefore \frac{\lambda}{2} = 0.490 - 0.170$ (1)

$\Rightarrow \lambda = 0.640\text{ m}$ (1)

(2)

(c) Calculate the frequency being emitted by the loudspeaker.

$v = f\lambda$

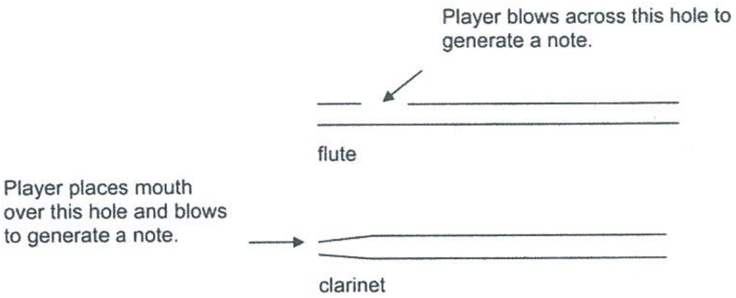
$\Rightarrow f = \frac{v}{\lambda}$

$= \frac{346}{0{\cdot}640}$ (1)

$= \underline{5{\cdot}41 \times 10^{2}\ Hz}$ (1)

(2)

(d) The diagrams below show very simple versions of a flute and a clarinet.



(i) The ratio of the first three frequencies heard in the flute $f_1:f_2:f_3$ is 1:2:3. Determine the ratio of the first three frequencies heard in the clarinet.

Clarinet behaves as a closed pipe.

$\therefore f_1 : f_3 : f_5 = \underline{1 : 3 : 5}$ (1)

(1)

(ii) Using your knowledge of vibrations in air columns, explain the differences between the frequencies heard in the flute and those in the clarinet.

- Flute is an open pipe. (1)
- Clarinet is a closed pipe. (1)
- Closed pipes only have odd harmonics. (1)

(3)

(d) Many instruments, such as the violin, work by setting up a standing wave in a string.

(i) How would you be able to tell there is a standing wave produced?

- "loops" appear in the vibrating string with nodes that don't appear to move. (1)

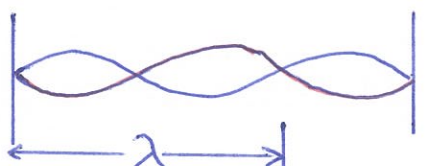
(1)

(ii) Explain how the standing wave is caused, describing the conditions necessary to cause a standing wave.

- Need 2 waves of:
  - equal amplitude $(\frac{1}{2})$, wavelength $(\frac{1}{2})$, speed $(\frac{1}{2})$
  - travelling in opposite directions $(\frac{1}{2})$ in the same medium.

(2)

(iii) With the aid of a diagram, explain a method you could use to measure the wavelength of the standing wave.



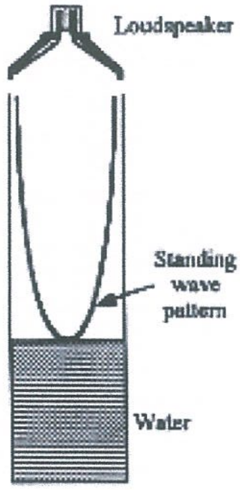
(1)

- Set the string vibrating.
- Measure:
  - distance between 3 nodes
  - double the distance between successive nodes.

Either is OK. (1)

(2)

10. Longitudinal sound waves propagated down a tube are reflected at the closed end and a standing wave is produced by the interference of the incident and reflected waves.



The air is at rest at the closed end, which is therefore a node. The antinode is actually a short distance e beyond the end of the tube, thus $\mathbf{l + e = l/4}$, where l is the length of the air column.

The speed of sound in the laboratory is given by $\mathbf{v = f l}$.

Hence

$$l = \frac{v}{4}\frac{1}{f} - e$$

In an experiment to determine the speed of sound, a student uses a tube in which the length of the air column can be adjusted by varying the height of water in the tube.

A small loudspeaker is set up just above the tube. The length of the tube is set at a number of different values, and the sound frequency adjusted for resonance at each length.

The results obtained are given on the next page.

You are required to determine the speed of sound **v** in the laboratory and the distance **e** by drawing a straight-line graph.

(a) Explain how you will process the data to obtain a straight-line graph.

- $l \propto \frac{1}{f}$ (1)
- Plot l against $\frac{1}{f}$. (1)

(2)

(b) Plot the straight-line graph for the following results.

l	140	190	250	300	350	400	450	(mm)
f	513	408	307	263	235	200	187	(Hz)
$\frac{1}{f}$	1·95	2·45	3·26	3·80	4·26	5·00	5·35	$(\times 10^{-3}\ s)$ (1)

Sig fig ~ 1 mark

(5)

(c) From the straight-line graph determine:

(i) the speed of sound in the laboratory, **v**.

$$\text{gradient} = \frac{\frac{1}{f}}{l}$$

$$= \frac{(5{\cdot}40 - 0{\cdot}45) \times 10^{-3}}{(0{\cdot}450 - 0{\cdot}00)} \quad (1)$$

$$= 1{\cdot}10 \times 10^{-2}\ sm^{-1} \quad (1)$$

Units - 1 mark

$$\text{gradient} = \frac{4}{V}$$

$$\Rightarrow V = \frac{4}{\text{gradient}}$$

$$= \frac{4}{1{\cdot}10 \times 10^{-2}} = \underline{3{\cdot}64 \times 10^{2}\ ms^{-1}} \quad (1)$$

(4)

(ii) the distance **e**.

From the graph, when $l = 0$, $\frac{1}{f} = 0{\cdot}400 \times 10^{-3}\ s$. (1)

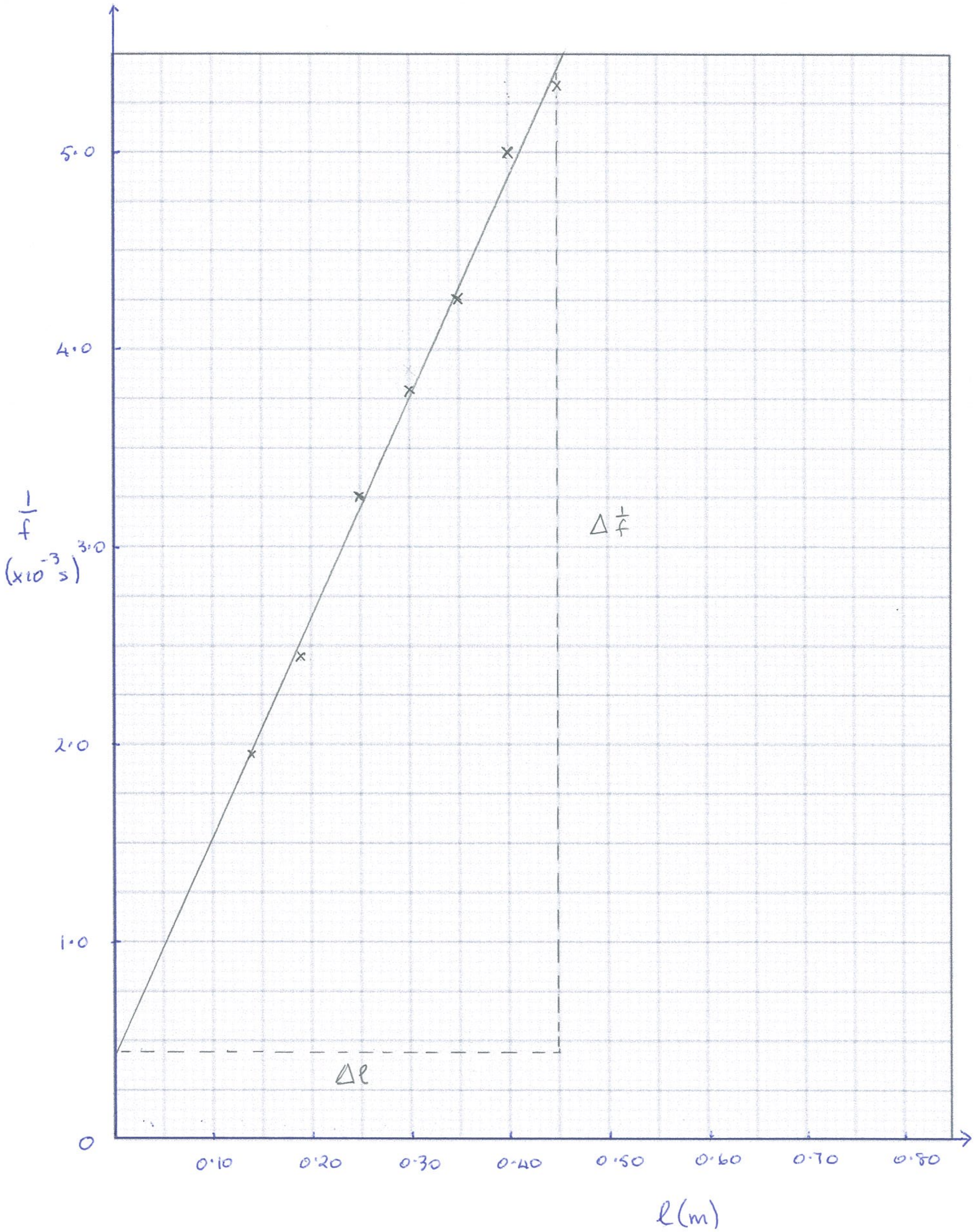
$$l = \frac{v}{4} \cdot \frac{1}{f} - e$$

(3)

If $l = 0 \Rightarrow e = \frac{v}{4} \cdot \frac{1}{f}$ (1)

$$= \frac{3{\cdot}64 \times 10^{2}}{4} \cdot 0{\cdot}400 \times 10^{-3}$$

$$= \underline{3{\cdot}64 \times 10^{-2}\ m} \quad (1)$$



Labels + units – 1 mark

Plotting – 1 mark

Line of best fit – 1 mark