Physics ATAR - Year 11

Waves
Unit Test
2017

Name: SOLUTIONS

Mark: / 60

= %

Time Allowed: 50 minutes

Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(7 marks)**

A student observes waves moving towards him alongside a jetty. The two posts of the jetty are 5.00 m apart and he observes that there are always 8 crests between the two posts at all times. The student observes one wave and measures that it takes 6.50 seconds to travel from the far post to the near post.

(a) Calculate the frequency of one wave.

(3 marks)

$8\lambda = 5.00\text{m}$

$\lambda = 0.625\text{m}$ (½)

$v = \frac{s}{t}$ (½)

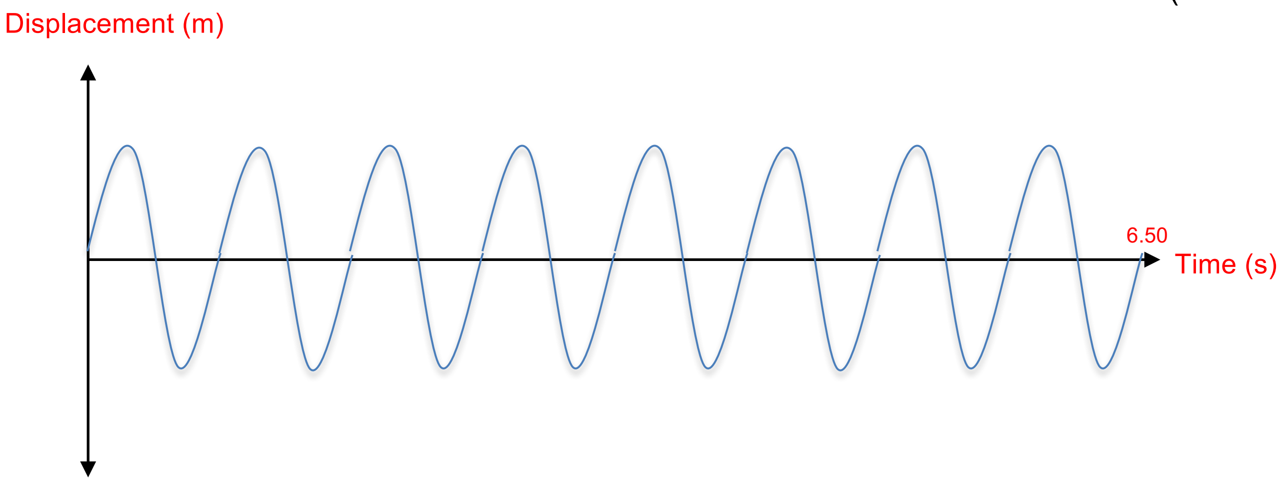
$= \frac{5}{6.5} = 0.769\ \text{ms}^{-1}$ (½)

$v = f\lambda$ (½)

$f = \frac{0.769}{0.625} = 1.23\ \text{Hz}$ (1)

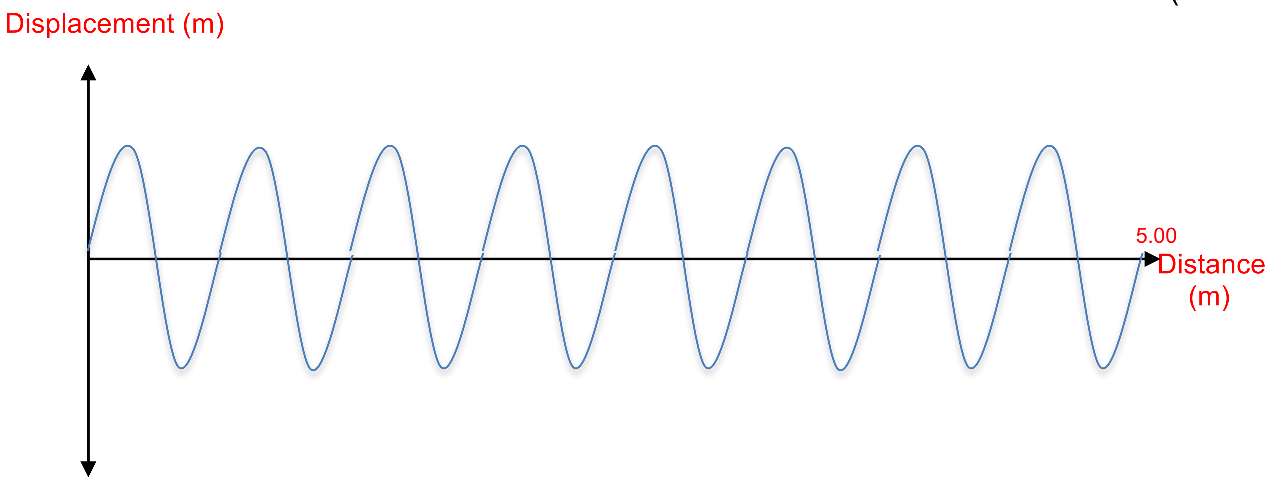
(b) One the graph below, plot a labelled Displacement-Time graph for the entire journey of one wave from post to post.

(2 marks)



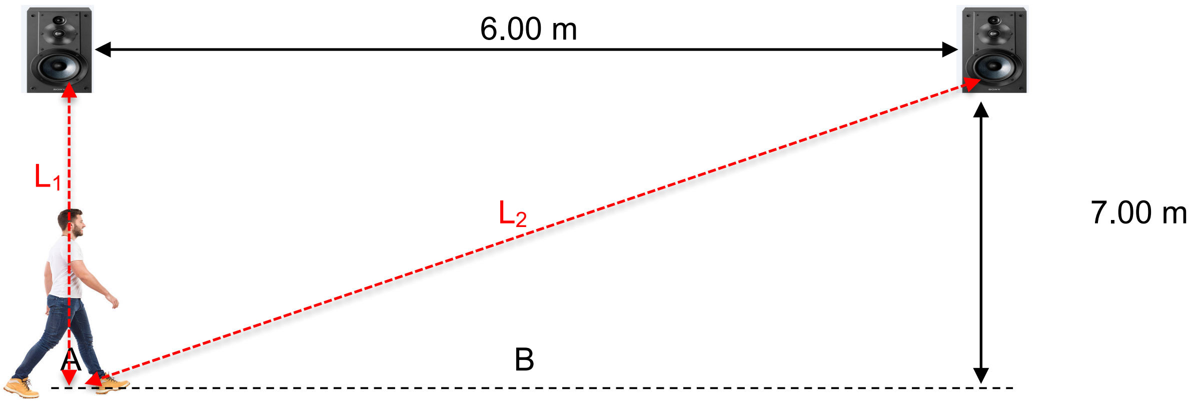
(c) One the graph below, plot a labelled Displacement-Distance graph from post to post.

(2 marks)



Question 2 **(10 marks)**

Two speakers 6.00 m apart are connected to a signal generator producing a frequency of 5.39 x10^2 Hz. A person 7.00 m away walks along a line parallel to the speakers as shown in the diagram below. The speed of sound in air is 342 ms^{-1}.



(a) State what the person will hear as he walks along the dashed line indicated and explain why.

(3 marks)

- They will hear consecutive loud and soft spots
- As the waves from both speakers are in phase, they will interfere with each other
- When waves are - in phase, constructive interference occurs = Loud
  - out of phase, destructive interference occurs = quiet

(b) Loud regions are heard when the path difference is a whole integer "n" and $n = \left|\frac{l_1 - l_2}{\lambda}\right|$. Determine if the person will hear a loud or soft sound in the location in the diagram.

(5 marks)

L_1 = 7.00m

$L_2 = \sqrt{7^2 + 6^2}$
= 9.22 m (1)

$\lambda = \frac{v}{f} = \frac{342}{539}$ (½)
= 0.635m (½)

$n = \left|\frac{l_1 - l_2}{\lambda}\right|$ (½)
$= \left|\frac{7 - 9.22}{0.635}\right|$ (½)
= 3.50 (1)

since n is not a whole integer = quiet region (1)

(c) The person walks from Point A to point B, which is midway between the speakers. State how many loud regions he will hear as he walks and explain why.

(2 marks)

- At A, the path difference is 3.5 λ, at B, the path difference is 0 λ
- As each whole integer is a loud region 3, 2, 1, 0 = 4 loud regions.

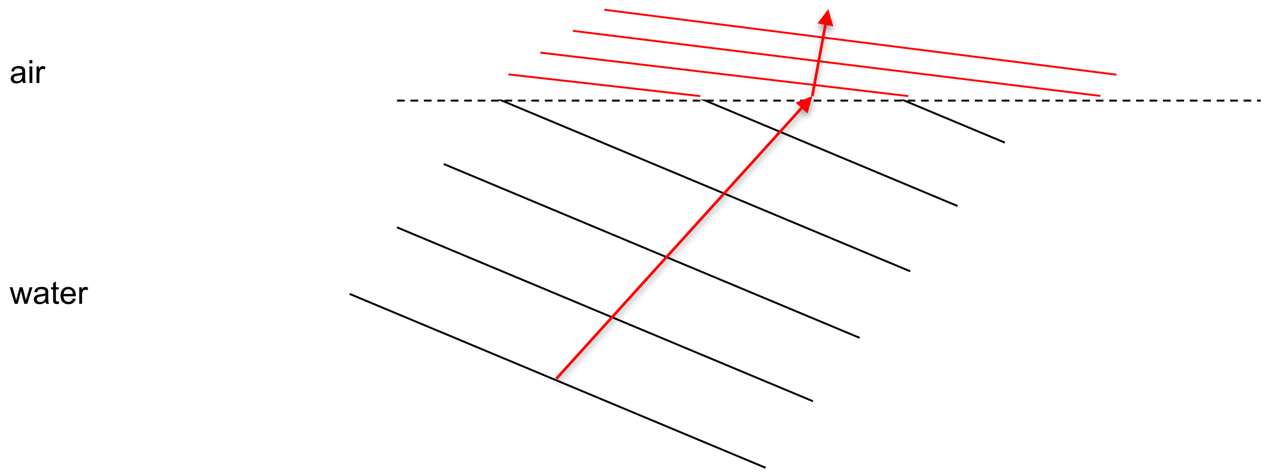
Question 3 **(6 marks)**

The diagram below shows 6 wave fronts approaching a boundary from water to air. The speed of sound in water is 4.30 times greater than the speed of sound in air.

(a) Complete the wave-front diagram below to show how the path of a sound wave changes as it moves from water to air.

(3 marks)

1 mark bends towards normal
1 mark parallel lines
1 mark for even spaced, reduced wavelength
(ray not required)



The equation that relates the properties of the wave as it passes through a boundary of different wave speeds is known as Snell's Law:

$$\frac{sin\theta_i}{sin\theta_r} = \frac{v1}{v2} = \frac{\lambda 1}{\lambda 2}$$

(b) If the wavelength in air is measured to be 0.170 m, calculate the wavelength of the sound wave when it was moving through the water.

(3 marks)

$\frac{v1}{v2} = \frac{\lambda 1}{\lambda 2}$ (½)

$\frac{4.3}{1} = \frac{\lambda 1}{0.170}$ (1)

$\lambda 1 = \frac{0.17 \times 4.3}{1}$ = 0.731m

(½) (1)

Question 4 **(16 marks)**

When an acoustic guitar string is plucked, the fundamental frequency is produced. The guitar player can then vary the frequency by pressing at varying lengths of the fret board, to vary the length of the standing wave. The equation for the frequency of a standing wave in a string is:

$$f_n = \frac{n}{2l} \cdot \sqrt{\frac{T}{\mu}}$$

where:
n = harmonic number
l = length of string (m)
T = Tension (kgms^{-2}) or (N)
μ = linear density (kgm^{-1})

(a) Show that the section of the equation $\sqrt{\frac{T}{\mu}}$ has the units ms^{-1} (2 marks)

$\sqrt{\frac{T}{\mu}} = \left[\frac{kgms^{2}}{kgm^{-1}}\right]^{1/2}$ ½

$= [m^2 s^{-2}]^{1/2}$ ½

$= [ms^{-1}]$ 1

The student plucks the 1.25 m long 'E string' which has a linear density of 0.00320 kgm^{-1} and a tension of 429 N.

(b) Determine the frequency of the sound that the guitar string produces. (3 marks)

n = 1 ½

$f_n = \frac{n}{2l} \cdot \sqrt{\frac{T}{\mu}}$ ½

$= \frac{1}{2(1.25)} \cdot \sqrt{\frac{429}{0.0032}}$ 1

= 146 Hz 1

(c) The student requires that frequency of the E string produce a higher frequency to be in tune. State what the student must do to the tension and include a theoretical explanation (without reference to the above equation.)

(4 marks)

- Student must increase the tension
- When the string is plucked/displaced, the restoring force will be greater
- Causing the particles to accelerate to their equilibrium point at a greater rate
- This increases the wave speed and hence, the frequency of the harmonic.

(d) If the required frequency of the E string is 1.50 x10^2 Hz, calculate the required tension in the string.

(4 marks)

$$f_n = \frac{n}{2l} \cdot \sqrt{\frac{T}{\mu}}$$ (1)

$$f^2 = \frac{1}{4l^2} \cdot \frac{T}{\mu}$$ (1)

T = $f^2 4l^2 \mu$ = 150^2(4)(1.25^2)(0.0032) (1)

= 450 N

= 4.50 x10^2 N (3 sig.fig) (1)

(e) Explain how the acoustic guitar is able to amplify the sound of the string so it can be easily heard by the student.

(3 marks)

- String causes a forced vibration in the guitar body
- Causing a greater surface area to vibrate
- Increasing the amplitude of the sound heard

Question 5 **(6 marks)**

A student is investigating the intensity of sound at various distances from a speaker. At 2.40m from the source, the intensity registers as 122 mW/m^2.

(a) Calculate the distance from the source the student is to measure the intensity to be 30.5 mW/m^2

(3 marks)

$I \propto \frac{1}{r^2}$ ½

$I_1 r_1^2 = I_2 r_2^2$ ½

$r_2 = \sqrt{\frac{I_1 r_1^2}{I_2}} = \sqrt{\frac{122 \times 2.40^2}{30.5}}$ 1

$= 4.80$ m 1

(b) Calculate the intensity when the student is 0.500 m from the source.

(3 marks)

$I \propto \frac{1}{r^2}$ ½

$I_1 r_1^2 = I_2 r_2^2$ ½

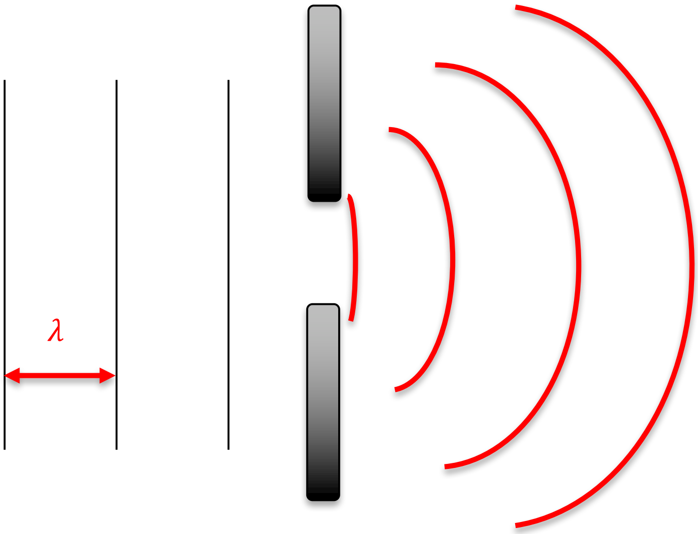
$I_2 = \frac{I_1 r_1^2}{r_2^2} = \frac{122 \times 2.40^2}{0.5^2}$ 1

$= 2810$ mW/m^2 1

Question 6 **(7 marks)**

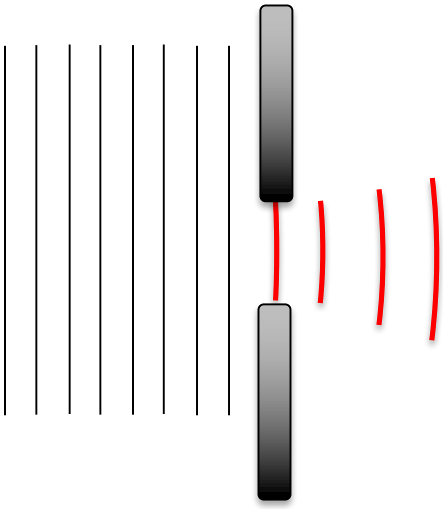
A student is playing with a ripple tank that produces uniform linear wave fronts. Barriers can be placed in the path of the wave fronts in order to observe wave phenomena. Complete the two diagrams (drawn to scale) by drawing 4 complete wave fronts as they pass through the barriers.

a) (2 marks)



1 mark large diffraction
1 mark constant spacing

b) (2 marks)



1 mark smaller diffraction
1 mark constant spacing

c) If the frequency of the source in a) is set to 5.60 Hz, use the diagram to estimate the speed of the wave fronts. (3 marks)

from diagram, $\lambda = 15\ mm$
$= 15 \times 10^{-3}$ m (½)

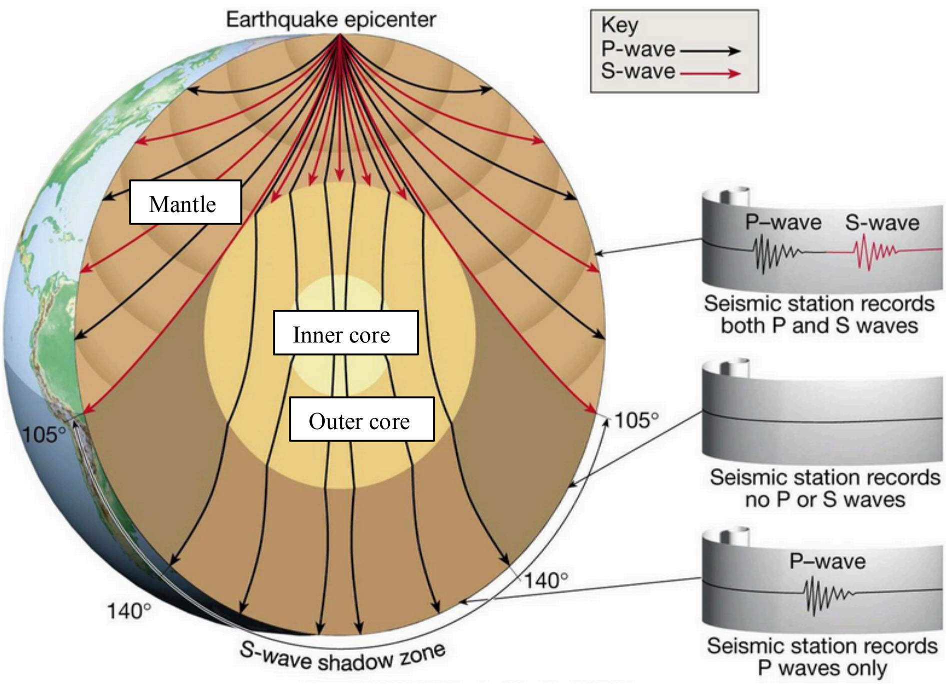
$v = f\lambda$ (½)

$= 5.60 \times 15 \times 10^{-3}$ (1)

$= 0.084\ ms^{-1}$ (2 sig fig) (1)

Question 7 **(8 marks)**

When earthquakes occur, seismic waves travel through the ground in S-waves (transverse motion) and P-waves (longitudinal motion). As the density of the rock they are travelling through increases, the waves refract and are detected at various locations from the epicentre.



By measuring the location and amplitude of the P and S waves, seismologists are able to infer the internal structure of the Earth's interior, such as density, elasticity, state and size. Seismologists have been able to infer that the outer core is liquid while the inner core, due to the immense pressure, remains solid.

(a) Explain, making reference to the properties of P and S waves, why it is thought that the outer core is liquid. (4 marks)

- S-waves are transverse which cannot pass from solid to liquid (due to the lack of elasticity/restoring force in liquids)
- Whereas P-waves do as pressure waves can pass through all substances.
- The S-wave shadow zone on the other side of the Earth,
- Suggests that the outer core is made of a liquid substance.
-

(b) State whether the speed of the seismic wave increases or decreases as they travel to greater depths below the surface. (1 mark)

increase (as the waves refract away from the normal)

(c) P-Waves refract at the boundary between the mantle and the outer core. State and explain**, making reference** to the diagram, in which region the seismic wave travels fastest. (3 mark)

- Fastest in the mantle
- As the wave refracts towards the normal when it passes into the outer core
- Which occurs when the wave slows down.

End of Test