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Level 3 Physics, 2015

91523 Demonstrate understanding of wave systems

9.30 a.m. Friday 20 November 2015
Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of wave systems.	Demonstrate in-depth understanding of wave systems.	Demonstrate comprehensive understanding of wave systems.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

Make sure that you have Resource Booklet L3–PHYSR.

In your answers use clear numerical working, words and / or diagrams as required.

Numerical answers should be given with an SI unit, to an appropriate number of significant figures.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–8 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Merit

TOTAL 17

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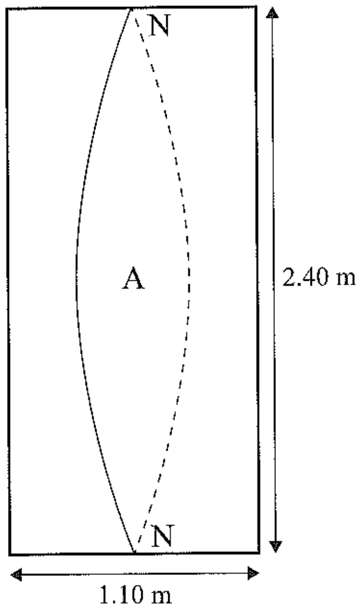
QUESTION ONE: STANDING WAVES AND PLUMBING

Speed of sound in air = 3.43×10^2 m s^{-1}
Speed of sound in water = 1.49×10^3 m s^{-1}

A shower acts like a closed pipe with a node at both ends. Matthew's shower has a height of 2.40 m, with a square base of width 1.10 m. The diagram shows a side view of the shower with one of the standing sound waves that can be set up in the shower. The displacement antinode (A) and nodes (N) are shown on the diagram.



(a) Show that the frequency of the vertical standing sound wave drawn is 71.5 Hz.

$\frac{\lambda}{2} = L \quad \lambda = 4.8$

$\frac{348}{4.8} = 71.5 \text{ Hz}$

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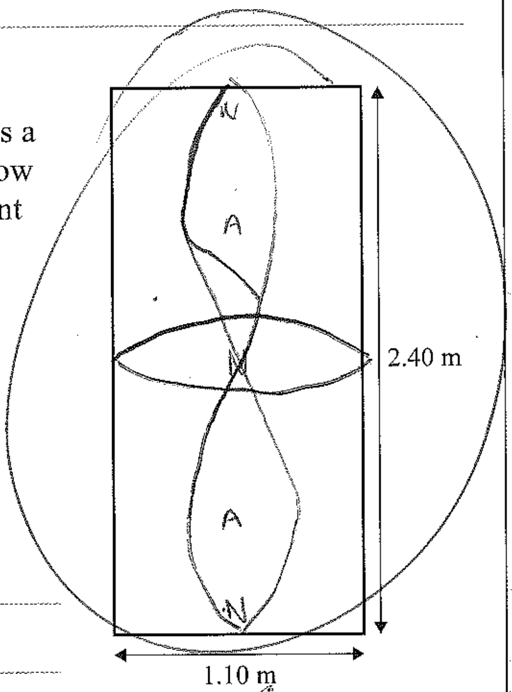
(b) Matthew loves singing in the shower. Although Matthew is a talented singer he cannot sing a note to resonate at this low a frequency. However, Matthew can produce two resonant frequencies:

- a vertical standing wave at 143 Hz
- a horizontal standing wave at 156 Hz.

Draw these two standing waves in the box on the right.

Show the calculations you used, in order to draw the two waves.



$\lambda = L = 2.40$ m

$\lambda = \frac{v}{f} = \frac{343}{143} = 2.40$ m   2nd harmonic

$\frac{\lambda}{2} = L = 1.10$ m   1st harmonic

$\lambda = \frac{v}{f} = \frac{343}{156} = 2.20$ m

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(c) One day, Matthew finds his shower is filling with water because the shower waste pipe is blocked. Matthew drains water from the waste pipe, and attempts to locate the position of the blockage.

With a loudspeaker, Matthew detects the fundamental frequency, and then detects the next two adjacent resonant frequencies at 1.80×10^2 and 3.00×10^2 Hz. Matthew uses these resonant frequencies to estimate that the pipe is blocked 1.43 m from the open end.

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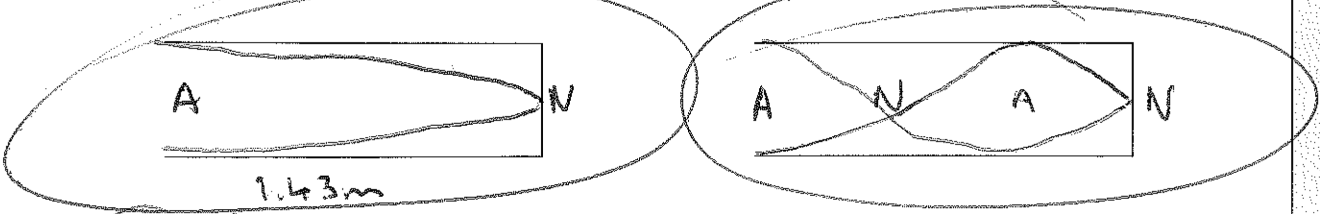
Show how Matthew calculated that the pipe is blocked 1.43 m from the open end.

You may want to draw waveforms in the diagrams below to help you.



~~2nd~~ 2nd harmonic $L = \frac{3\lambda}{4}$ $\lambda = \frac{v}{f} = \frac{343}{180} = 1.90$m

$L = \frac{5.72}{4} = 1.43$m

u1

(d) With the loudspeaker still set at 3.00×10^2 Hz, Matthew fills the waste pipe with water. He uses his loudspeaker to make sound waves in the water, and puts his ear in the water and listens, but the sound no longer resonates.

Calculate one of the frequencies that Matthew should set the loudspeaker to in order to get resonance again.

In your answer you should:

- describe how the water affects the speed of the sound wave
- explain why the sound in the waste pipe no longer resonates at 3.00×10^2 Hz
- calculate one of the resonant frequencies.

The speed of sound in air is 343 m/s, while the speed of sound in water is 1440 m/s. $\lambda = \frac{v}{f}$ So having something the same frequency in different speed means λ will be different in this case it is 4.97m. To get a resonant frequency, $\frac{\lambda}{4} = L$. Because the wavelength has changed, 300Hz no longer produces a resonant frequency.

$\lambda = 4L = 5.72$m

$f = \frac{v}{\lambda} = \frac{1440}{5.72} = 260.5$Hz

260.5Hz produces a resonant frequency in the water filled pipe

M6

QUESTION TWO: INTERFERENCE

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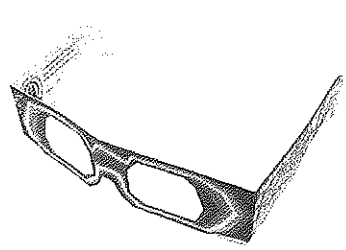
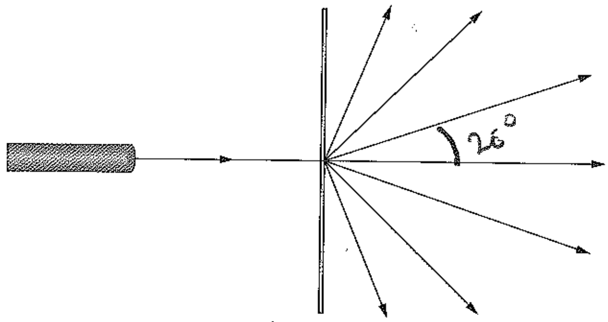


Rianne uses a pair of novelty glasses to produce a laser show.

When she shines a laser through the centre of one of the eyepieces, the laser light splits up into a number of beams.

She suspects that the novelty glasses contain a diffraction grating.

Rianne measures the angle between the bright central beam of light and the 1st order maximum in the horizontal direction to be 26.0°. The laser light has a wavelength of 532×10^{-9} m.



(a) Calculate the slit spacing of the novelty glasses.

$d\sin\theta = n\lambda$

~~$d = 6.48\times10^{-7}$ m~~

~~$d = 2.33$~~

$d = 1.21\times10^{-6}$ m

u

(b) Rianne experiments by shining her laser light through different parts of the glasses. There are more lines per metre in the middle of each eyepiece (smaller slit spacing) than there are at the edges.

Describe the differences in the patterns Rianne would see when she shines the laser light through the two different sections of the glasses.

$n\lambda = \frac{dx}{L}$ assuming L is the same, smaller slit spacing (smaller d) would mean that the distance between the bands of light would be larger (x). If d were larger, the distance between the bands of light would be smaller.

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$1.667e^{-6}$ m

$\lambda = 532 \times 10^{-9}$

(c) Rianne visits a physics laboratory where she replaces the novelty glasses with a 600 000 lines per metre diffraction grating.

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Calculate the spacing in degrees between the central maximum and the 2nd order maximum for her laser light when it passes through the diffraction grating.

$d = 1.667 \times 10^{-6}$ m

$d \sin\theta = n\lambda$

$\sin\theta = 0.638$

$\theta = 39.6°$

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(d) Rianne wonders whether it would be possible to use the diffraction grating to create a laser light show, where a blue laser light with a wavelength of 460×10^{-9} m creates a pattern that overlaps with a pattern created by a red laser light with a wavelength of 690×10^{-9} m.

Explain what the complete pattern would look like.

In your answer you should:

- calculate the number of maxima for blue laser light
- calculate the number of maxima for red laser light
- explain why there will be a limit to the number of maxima for each laser light
- show that one of the red maxima is at the same angle as one of the blue maxima.

$d \sin\theta = n\lambda$

$d \sin 90 = n\lambda$

blue $n = 3.62 = 3$ red $n = 2.41 = 2$

There will be a limit to the number of maxima as θ cannot exceed 90°. The maxima must also have one full wavelengths path difference.

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The third blue maxima and second red maxima will have the same angle

red 2 = 55.89° blue 3 = 55.89°

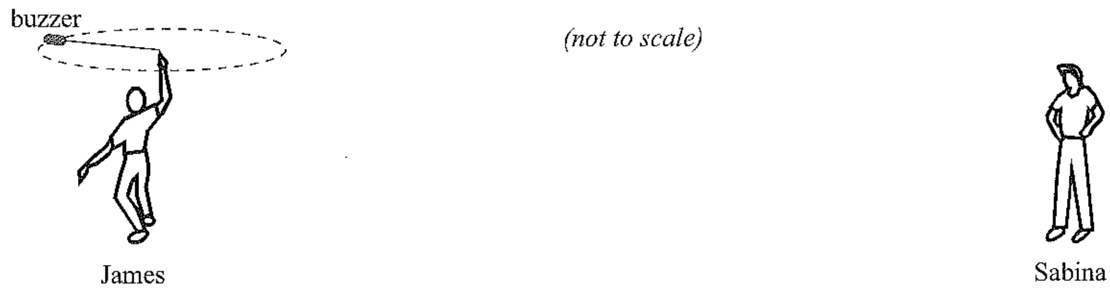
red 1 = 24.45°

M6

QUESTION THREE: THE WHIRLING BUZZER

Speed of sound in air = 3.43×10^2 m s^{-1}

James attaches a buzzer to the end of a piece of string. James whirls the buzzer above his head in a horizontal circle of radius 1.02 m at a constant speed of 16.0 m s^{-1}.



Sabina stands a long distance away and listens.

(a) Describe the motion of the buzzer when Sabina receives sound waves with the shortest wavelength.

The buzzer will be moving towards Sabina when it has the shortest wavelength.

(b) If the frequency emitted by the buzzer is 512 Hz, show that the lowest frequency heard by Sabina is 489 Hz.

$f' = f \frac{v_w}{v_w + v_s}$

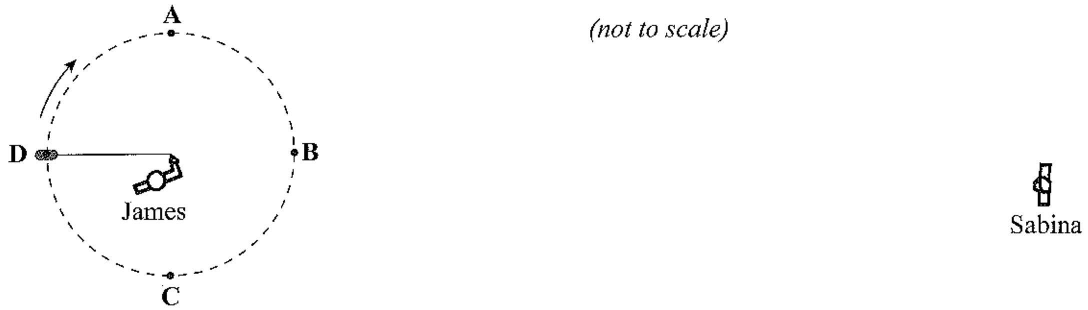
$f' = 512 \frac{343}{359}$

$f' = 489 \text{ Hz}$

(c) Sabina stands a very long way away from James and listens to the buzzer. The sound appears to be increasing in frequency as the buzzer travels from point C to point A.

Explain why Sabina hears an increasing frequency between point C and point A.

You may want to use calculations to assist your answer.



Because Sabrina is standing a long distance away, she is hearing the buzzer out of sync with what she is seeing with her eyes. The sound she is hearing is from D to B but she is hearing it a few moments later, giving the impression of rising freq. from C-A.

(d) James wants Sabina to hear beats. He puts a second buzzer, which is also emitting a sound of frequency 512 Hz, on the ground. James again whirls the original buzzer above his head, but at a different speed. When the buzzer is at point A, James lets go of it, so the buzzer flies towards Sabina.

Sabina hears a 10 Hz beat as James releases the string.

Calculate the velocity of the buzzer at the point of release.

$f' = f_1 - f_2$

$512 + 10 = \underline{522\text{ Hz}}$

$f' = f \dfrac{V_w}{V_w \pm V_s}$

$522 = 512 \dfrac{343}{343 - V_s}$

$V_s = 6.57\text{ m/s}$

Merit exemplar for 91523, 2015		Total score	17
Q	**Grade score**	**Annotation**	
1	M6	1c has shown that the wavelength of the 3rd harmonic is 1.90m and that the length of the pipe corresponds to ¾ of this. The candidate has called this the “2nd” harmonic however this error is considered trivial. 1d The candidate has correctly identified the new resonant frequency, but their explanation does not describe an **increase** in wavelength of waves at the same frequency due to the **increase** in wave speed.	
2	M6	2d correct values are calculated that can be used to determine the number of blue and red maxima, but these are not used to find the totals. Credit is given for stating that θ cannot exceed 90º, and merit for stating that the third blue maxima will be at the same angle as the second red one and calculating the angle.	
3	M5	3b for this “show” question full working is required. This means showing how any number used was obtained. 3c The candidate is claiming that the frequency increases between points D and B. This is incorrect although the frequency of the waves travelling towards Sabrina are higher than 512 Hz during most of this time. E7/8 was only given to candidates who produced correct evidence for at least three of the four question parts.	