3

SUPERVISOR'S USE ONLY

91523

915230

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

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.

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Low Achievement

TOTAL 7

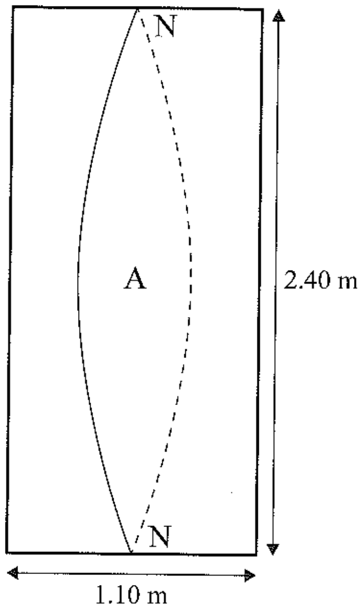
ASSESSOR'S USE ONLY

QUESTION ONE: STANDING WAVES AND PLUMBING

ASSESSOR'S USE ONLY

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.

$v = 3.43 \times 10^2$ m, $\lambda = 2.4 \times 2 = 4.8$ m

$v = f\lambda$

$f = v/\lambda = 3.43 \times 10^2 / 4.8$

$= 71.458$

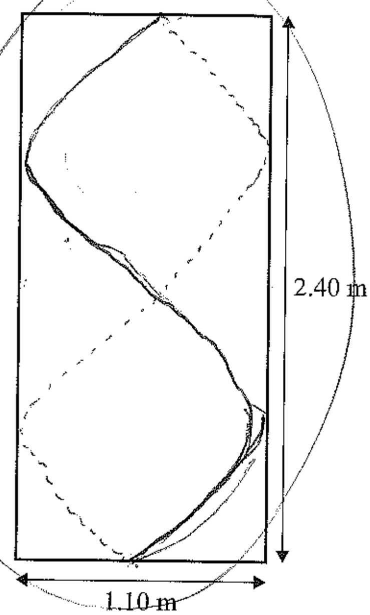
$= 71.5$ Hz

(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.



Vertical: $\lambda = v/f = \frac{3.43 \times 10^2}{143} = 2.398$
$v = 3.43 \times 10^2$ m s^{-1}, $f = 143$ Hz
$= 2.40$ m

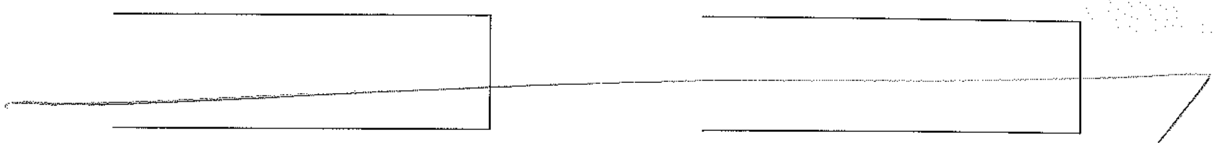
Horizontal: $\lambda = v/f = \frac{3.43 \times 10^2}{156} = 2.1987$
$v = 3.43 \times 10^2$, $f = 156$
$= 2.20$ m

(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.

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.



(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.

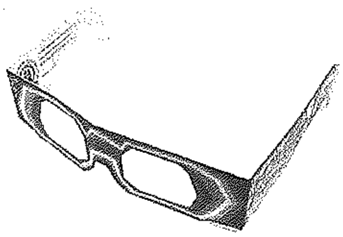
ASSESSOR'S USE ONLY

A3

ASSESSOR'S USE ONLY

QUESTION TWO: INTERFERENCE

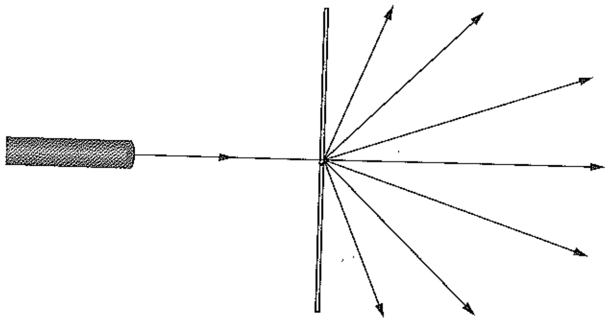
Rianne uses a pair of novelty glasses to produce a laser show.



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.

$\lambda = 532 \times 10^{-9}$ m
$\theta = 26.0°$

$d \sin\theta = n\lambda$

$d = \frac{n\lambda}{\sin\theta} = \frac{1 \times (532 \times 10^{-9})}{\sin 26} = 4.88356007 \times 10^{-6}$

$= 4.88 \times 10^{-6}$ m

(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.

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

ASSESSOR'S USE ONLY

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.

$d \sin \theta = n\lambda$

$d = 1 : 600\,000$

$= 1.67 \times 10^{-6}$ m

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

$n = 2$

$\theta = \sin^{-1}\left(\frac{n\lambda}{d}\right)$

$= \sin^{-1}\left(\frac{532 \times 10^{-9} \times 2}{1.67 \times 10^{-6}}\right)$

$= 0.6907633774$

$= 0.690°$

4

(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.

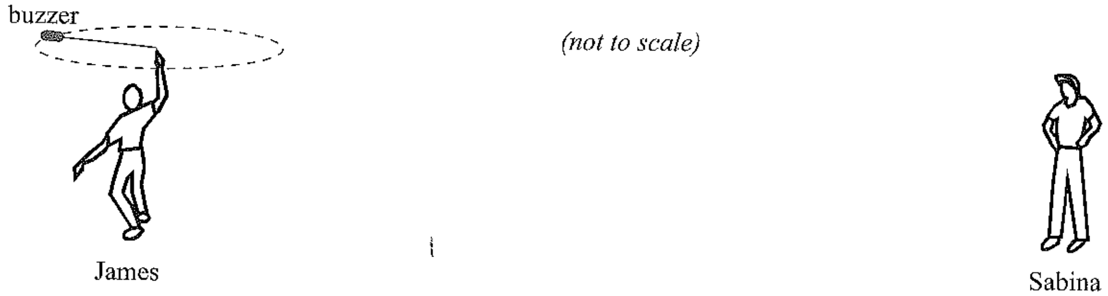
N1

QUESTION THREE: THE WHIRLING BUZZER

ASSESSOR'S USE ONLY

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.

Sabina will recieve the shortest soundwaves when the buzzer is coming towards her in the circle. This is because as the object approaches it is going at a speed where the soundwaves bunch up.

4

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

$f' = f \frac{V_w}{V_w + V_s}$

$= 512 \times \frac{3.43 \times 10^2}{3.43 \times 10^2 + 16}$

$= 489.18$

$= 489$ Hz

$f = 512$

$V_w = 3.43 \times 10^2$ ms^{-1}

$V_s = 16$ ms^{-1}

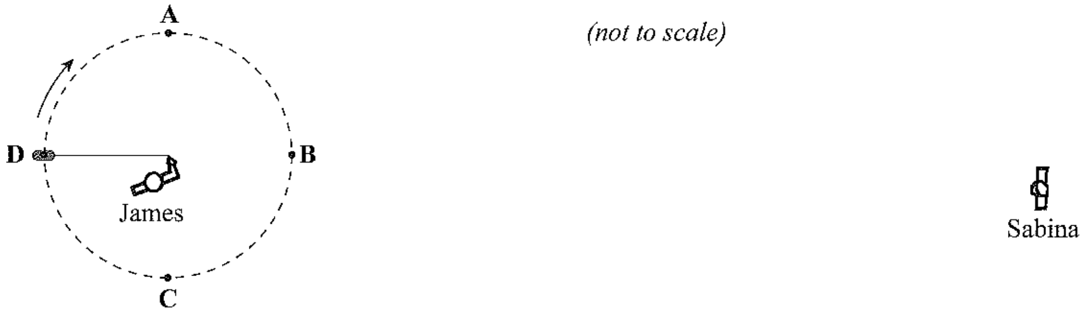
f' = frequency heard.

4

(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.



As the buzzer moves from point C to point D Sabina hears the longest wavelengths and from point D to A the wavelengths shorten. If the velocity stays constant, according to the formula $v = f\lambda$ if the wavelength lengthens the frequency must decrease meaning if the wavelength shortens the frequency increases. Since the wavelength shortens from C to A the frequency must increase.

U

(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.

ASSESSOR'S USE ONLY

A3

3

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High Achievement

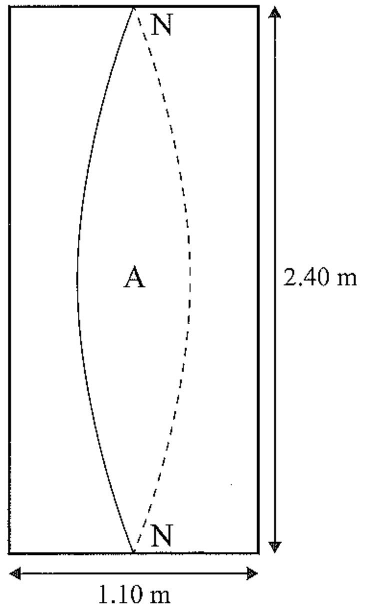
TOTAL 11

ASSESSOR'S USE ONLY

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.

$f = \frac{V}{\lambda}$

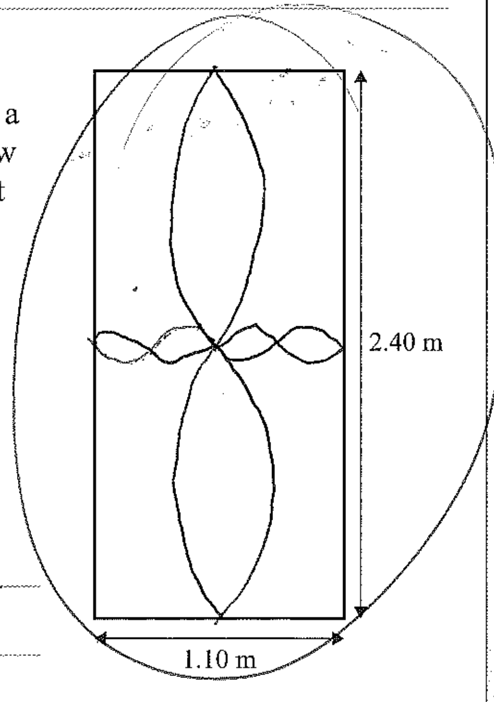
$71.5 = \frac{3.43 \times 10^2}{1.2}$

(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.



Vertical $143 = \frac{3.43 \times 10^2}{2.4}$

horizontal $156 = \frac{3.43 \times 10^2}{2.2}$

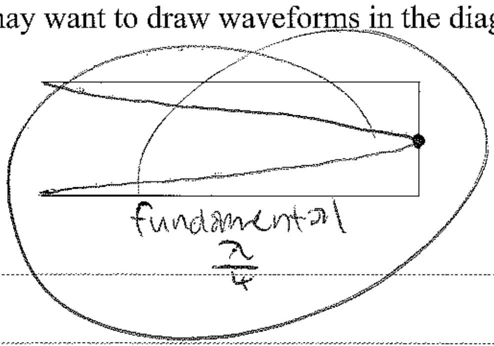
(c) One day, Matthew finds his shower is filling with water because the shower waste pipe is blocked. Matthew drains water from the waste pipe, and attempts to locate the position of the blockage.

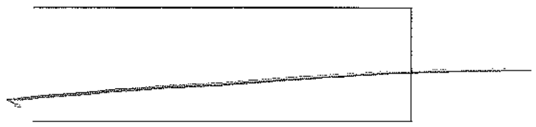
With a loudspeaker, Matthew detects the fundamental frequency, and then detects the next two adjacent resonant frequencies at 1.80×10^2 and 3.00×10^2 Hz. Matthew uses these resonant frequencies to estimate that the pipe is blocked 1.43 m from the open end.

ASSESSOR'S USE ONLY

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.





u

(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.

Because sound travels much faster in water this will change the frequencies the sound will resonate at.

$f = \frac{1.49 \times 10^3}{5.72}$ ← (velocity component is changed resulting in different frequency)

new resonant frequency $= 260.5$ Hz

u

i

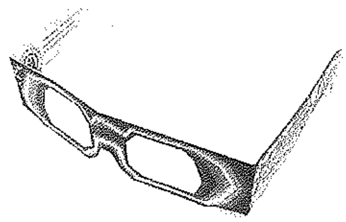
A4

QUESTION TWO: INTERFERENCE

ASSESSOR'S USE ONLY

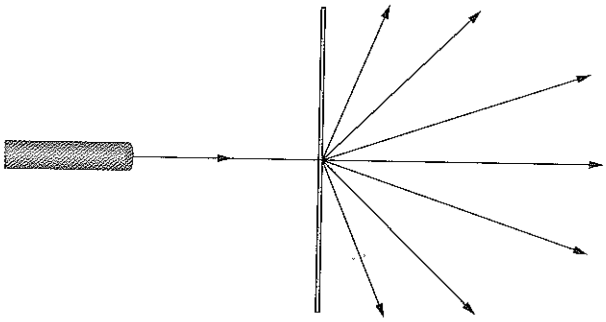
Rianne uses a pair of novelty glasses to produce a laser show.

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.

$d \sin\theta = n\lambda$

$d = \frac{n\lambda}{\sin\theta}$

$= 1.214 \times 10^{-6}$ 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.

~~ ~~ when d increases θ decreases meaning the lines ~~ ~~ of light will be closer when they are displayed on a wall.

u

ASSESSOR'S USE ONLY

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

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.

$\frac{1}{600000} \sin \theta = 532 \times 10^{-9}$

$\theta = 0.325$ radians

$= 18.6°$

u

(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.

blue ~~sin θ 600000~~ $\frac{\sin \theta}{600000} = 460 \times 10^{-9}$

$\theta = 16°$

number of maxima = 5

red $\theta = 24°$ n° maxima = 3

there is a limit to the number of maxima because the light can't defract past 180° (past the grating itself)

16 24
32 48
48 72
64
80

u

The pattern will show blue then red the blue ~~then~~ on the 1st and and 4th line of light the lines will overlap.

A4

QUESTION THREE: THE WHIRLING BUZZER

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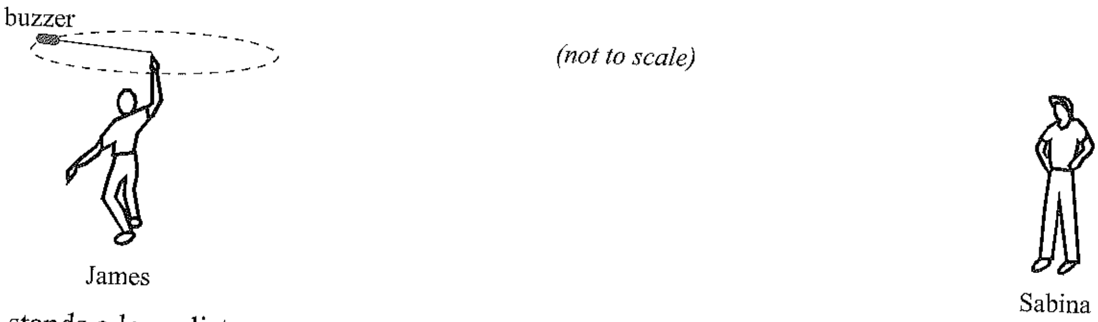
Speed of sound in air = 3.43×10^2 m s^{-1}

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 going towards sabina.

u

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

$$f' = f \frac{V_w}{V_w + V_s}$$

$$489 = 512 \times \frac{3.43 \times 10^2}{16 + 3.43 \times 10^2}$$

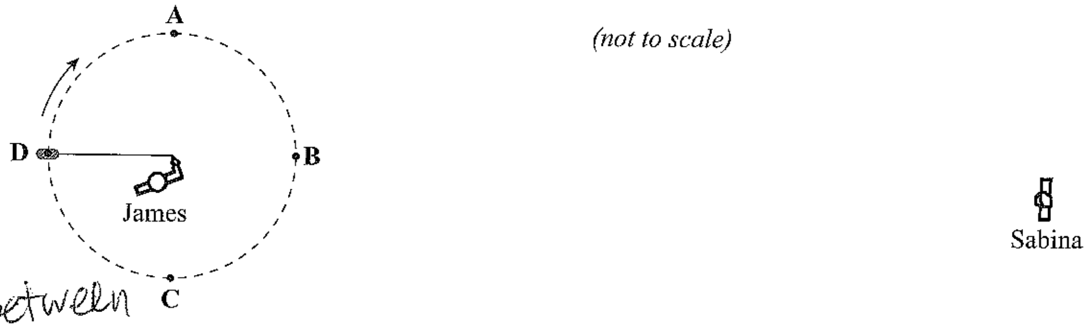
u

(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.

ASSESSOR'S USE ONLY

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

You may want to use calculations to assist your answer.



between points C to D the buzzer has a lower frequency but from D to A the source of the sound is moving closer to sabina so the distance between the wave and the source is shortened so the frequency increases

U

(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.

A3

Annotated Exemplar 91523 2015

Low Achieved exemplar for 91523, 2015			Total score	07
Q	**Grade score**	**Annotation**		
1	A3	1a correct working (1 simple calculation) that “show”s that the frequency will be 71.5 Hz. 1b a correct diagram for the vertical standing wave, but nothing drawn for the horizontal standing wave. Credit is also given for correct use of a calculation to find the wavelength of either the vertical or horizontal standing waves.		
2	N1	2a is incorrect due to the candidate using n=7 instead of n=1 2c uses the correct value of n and d but has given the answer in radians, where the question asked for the answer to be given in degrees.		
3	A3	3a and 3b are correct 3c describes the frequency being lower between C and D, then higher between D and A, but implies that the frequency will remain the same between C and D, and between D and A, instead of explaining the gradual change that is taking place.		

High Achieved exemplar for 91523, 2015			Total score	11
Q	**Grade score**	**Annotation**		
1	A4	1b Calculations are fine but one of the standing waves drawn is incorrect. Whilst there is some evidence at the merit level on this page, there is insufficient to award M5		
2	A4	2b a correct relationship is described between the slit spacing (d) and the angle (θ) although this is poorly described. 2c the correct slit spacing is used but the question asks for the 2nd order maximum and n=2 has not been used. 2d has the correct number of maxima but without calculations. The final statement could be correct but is ambiguous and has no calculations supporting it.		
3	A3	3c identifies that the frequency will become higher as the buzzer passes point D. It does not explain the continuously changing frequency heard by Sabina.		