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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Physics 2023

91523 Demonstrate understanding of wave systems

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 appropriate SI unit.

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.

Do not write in any cross-hatched area. This area will be cut off when the booklet is marked.

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

Achievement 10

$L = 0.331$ $v = 342$

QUESTION ONE: SAM'S VIOLIN

Assume that the speed of sound in air is 342 m s^{-1}.

A violin is a stringed instrument onto which the strings are fixed at both ends. The fixed points are 0.331 m apart. Sam plays the violin, making the strings vibrate by pulling and pushing a bow across the strings.

https://stock.adobe.com/nz/search?k=lady+playing+violin

One string (called the "G") is arranged to play a fundamental frequency of 196 Hz. $0.1655\underline{\underline{m}}$ $\lambda = \frac{1}{2}L$ i.e.

(a) Calculate the speed of the wave that travels along the string.

$32.438 ms^{-1}$ because

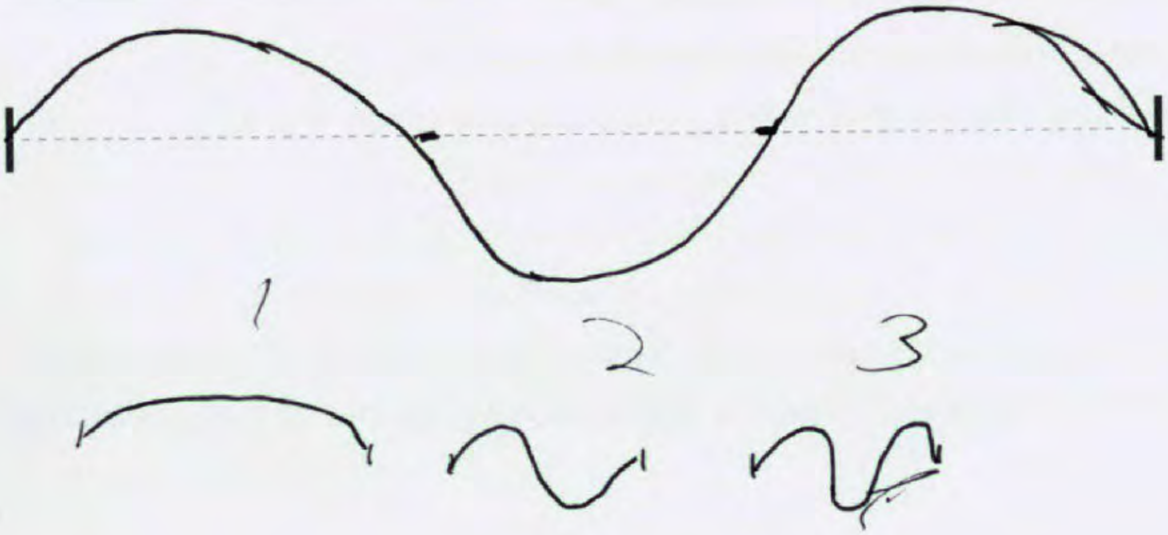
$\lambda = \frac{L}{2} = 0.1655m$ & $v = f\lambda$

(b) Analysis of the sound produced by the vibrating string shows that it also vibrates at 392 Hz and 588 Hz.

State the harmonic that causes the vibration at 588 Hz.

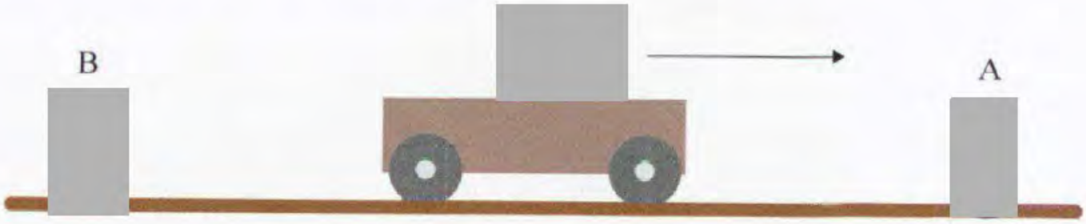
Your answer should include a sketch that shows the location of the nodes and antinodes.

The 3rd harmonic of G is 588Hz



5.3 ms^{-1}

(c) Sam plays her violin (with a fundamental frequency of 196 Hz) as she sits on a moving trailer. The trailer is moving at 5.30 m s^{-1} directly towards microphone A.



Sources: https://www.freepik.com/premium-vector/young-woman-playing-violin-cartoon-character-violinist-playing-classical-music-vector-illustration-isolated-white-background_21596785.htm
www.freepik.com/free-photos-vectors/microphone-clip-art

Calculate the frequency recorded by microphone A.

$$\left(\frac{342}{342-5.3}\right) \times 196\,Hz = 199.1\,Hz$$

(d) Microphone B is directly behind the moving trailer, whereas microphone A is directly in front of the moving trailer.

Explain how the motion of the trailer with Sam sitting on it playing the violin affects:

- the frequency of the string
- the speed of the sound in the air
- the wavelength of the sound in the air in front of and behind the violin
- the frequencies detected by microphones A and B.

The motion of the vehicle has no affect on the frequency of the string itself or the speed of sound in the air. Because the speed of the soundwave doesn't change, ~~the distance from front of the sound~~, as the wave progresses from a crest to a trough, the source of the sound moves, relative to the wave - differently to the speed of sound.

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

QUESTION TWO: VIOLIN TUNING

On a hot day, the violin easily goes out of tune – Sam has to adjust the tension in the string to keep the "G" string so that it still vibrates at 196 Hz.

(a) Describe what happens to the fundamental frequency of the string when the string gets longer (and nothing else changes).

because v remains the same, fundamental frequency must decrease. because λ increases

(b) Sam uses a tuning fork that will always vibrate at 196 Hz. She plays the string while sounding the tuning fork and hears a beat.

- Describe what is meant by a beat.
- Explain why beats are heard.

A beat is a periodic interference of amplitude between waves of different frequency. This means that, on a regular basis, the volume of tones heard will increase & decrease. Here, even though the waves should have the same frequency, due to the doppler effect, the perceived frequency may differ. ~~because the~~ Furthermore, as explained earlier, the strings may also simply need retuning to create the correct frequency.

1✗ & thereby you wouldn't expect a beat under this definition.

1✓

(c) Sam hears a beat of 2.1 Hz.

(i) Determine the possible frequencies at which the string is vibrating.

$f_b = 2.1$ ∴

$f_s = 196 \pm 2.1$ ∴

$f_s = 193.9$ Hz or 198.1 Hz

$f\uparrow \therefore f_s\uparrow\ f_b\uparrow$ Hence

She increases the speed of the wave along the string by ~~increasing~~ results in the tension in the string and the beat frequency increases. $f_s > f_t$

(ii) Use this information to determine the frequency at which the string was vibrating before adjustment.

$f_s = 198.1\text{Hz}$, because $f_s > f_t$ & that frequency fits every criteria

(iii) Explain what Sam must do to get the string to vibrate at 196 Hz.

decrease the tension along the string in order to lower f_s to f_t so that $f_s = f_t$ again.

(iv) State how she will know when the string is vibrating at 196 Hz.

When the beat frequency is 0Hz i.e. has stopped because, then, $f_s - f_t = 0$ & $\therefore$ is $f_s = f_t$

(d) When Sam plays a frequency of 564 Hz near a wine glass, the wine glass rattles on the shelf.

Give an in-depth explanation of this phenomenon by:

(i) describing the phenomenon

(ii) explaining how she might stop the wine glass from vibrating when she plays the violin.

~~other~~ ~~other~~

When the sound waves travel through objects, it will also exert the sound wave onto objects touching that surface.

This means that, when passing through a lighter or less secure medium, ~~it may exert so on~~ the force exerted on it by the sound wave may be enough to considerably move it.

$\lambda = 6.43 \times 10^{-7}$ m

$L = 1.43$

$x = 0.875$ m

QUESTION THREE: DIFFRACTION GLASSES

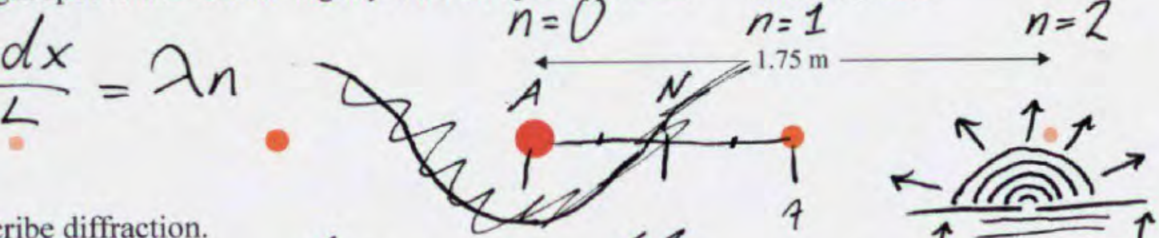
At a fair, children are buying "Rainbow Glasses" made of diffraction gratings in a cardboard frame.

Steve shines a laser pointer through one of the diffraction gratings onto a wall. The laser pointer produces light with a wavelength of 643 nm (6.43×10^{-7} m). The light makes a pattern on the wall, with a bright red spot at the centre, and with slightly dimmer red spots either side.

Source: https://mindsetsonline.co.uk/shop/diffraction-glasses/

The wall is 1.43 m from the grating. The distance from the central bright spot to the second slightly dimmer spot is 1.75 m.

$\frac{dx}{L} = \lambda n$



(a) Describe diffraction.

Diffraction is the process of bending waves around a small slit. This causes the slit to function somewhat like a source, dispersing the sound outwards.

(b) Give an in-depth explanation why this pattern is observed by:

- explaining how diffraction and interference cause bright spots
- explaining why there are large sections where there is no light between the bright spots.

Because the diffraction causes the slit to act like a source, 2-source wave interference occurs, & this interference results in nodes & antinodes, creating areas of varying amplitude.
We observe large areas of darkness between bright spots because of this destructive interference where the amplitude of the wave & thereby the brightness cancels out.

(c) Calculate the slit separation in the grating.

$\frac{\lambda L}{x} = d \therefore d = 1.05 \times 10^{-6}$ m

~~$A_d = \frac{A_w}{1+n}$~~ $A_d = A_w \times 2^{-n}$

(d) When the children look at a spot of white light through the glasses, they see the white spot with spectra on either side (which they describe as "rainbows").

Give an in-depth explanation of this phenomenon by:

- describing where the spectra will occur
- explaining the position of the colours in the spectra
- explaining why they are in these locations.

Include a labelled sketch to show the positions of different coloured light in the space below.

Space for labelled sketch:

R = Red
O = orange
Y = yellow
G = green
B = blue
V = violet

W = white

The spectra will be on either side of the white light.

This is because the diffracted light of the white takes on slightly different wavelengths as the spectrum moves away from the white light.
Initially, they will see red spectra, but, as the light moves away from the white point, its wavelength increases, becoming more green & then more blue, wrapping around to violet, before the wavelength is so high its no longer visible & we can't see it.

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER

1 D) Because of this, the distance from a peak to a corresponding peak will actually be different than what would be expected.

This means that, a source moving towards you has a higher observed frequency due to the decreased wavelength et vice versa.

Hence, in front of the violin, the wavelength will be smaller & behind it will be longer than ~~if the~~ what is expected.

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2D) In order to stop this, Sam could place damping underneath the glass. This would result in the energy ~~force~~ from the sound wave to be properly & more ~~[illegible]~~ thoroughly dispersed ~~many~~ meaning less force is put on the glass & it stops rattling

QUESTION NUMBER

3:d) This all occurs because, as x increases but n, L, & d remain the same in the equation

$n\lambda = \frac{dx}{L}$, λ must increase to account ~~be~~ for differences. This means that, the furtherm from the white spot, the more distorted the wavelength will be, resulting in the rainbows forming.

Standard	91523			Total score	10
Q	**Grade score**	**Marker commentary**			
1	A4	Wavelength in 1a was incorrect. 3rd harmonic was correctly identified in 1b but nodes and antinodes were not shown on the diagram. Formula is not shown but apparent frequency is calculated correctly. Doppler effect is not described, but no effect on the strings frequency of the speed of sound in air is correctly identified.			
2	A3	Describes beats, but does not explain how the change in volume is produced. Correctly identifies the answer for each part of 2c but is unable to justify why. Does not recognise that resonance is the key concept of 2d.			
3	A3	The explanation in 3b shows no link in describing why the interference is constructive. The approximation of $n\lambda = \frac{dx}{L}$ is used, rather than recognising that as the angle to the maxima is large, the approximation of $\sin\theta = \tan\theta$, is not valid. Gives the incorrect order of spectra seen through a diffraction grating.			