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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 (DO NOT WRITE IN THIS 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.

Merit 15

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QUESTION ONE: SAM'S VIOLIN

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

One string (called the "G") is arranged to play a fundamental frequency of 196 Hz.

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

$v = f\lambda$ at fundamental ~~$\lambda = L$~~ $L = \frac{1}{2}\lambda$ so $\lambda = 2L$

$v = f2L$ $L = 0.331$m $f = 196$ Hz $v = 196 \times 2 \times 0.331$

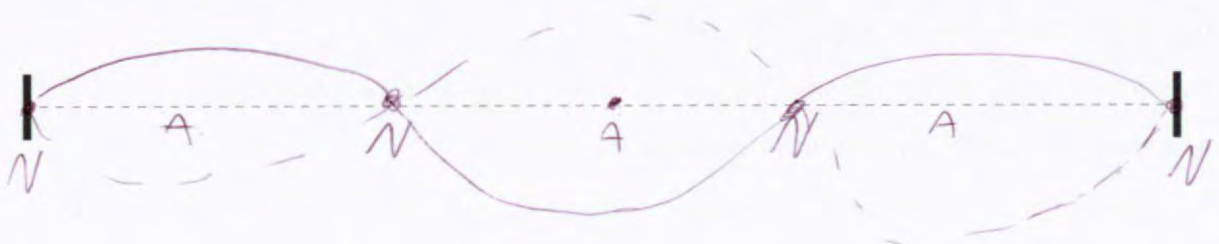
$V =$ ~~130 Hz~~ 130 ms^{-1} (129.7Hz)

(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.

~~588÷16~~ 588 ÷ 196 = 3 so 3rd harmonic
(3 times the fundamental frequency)



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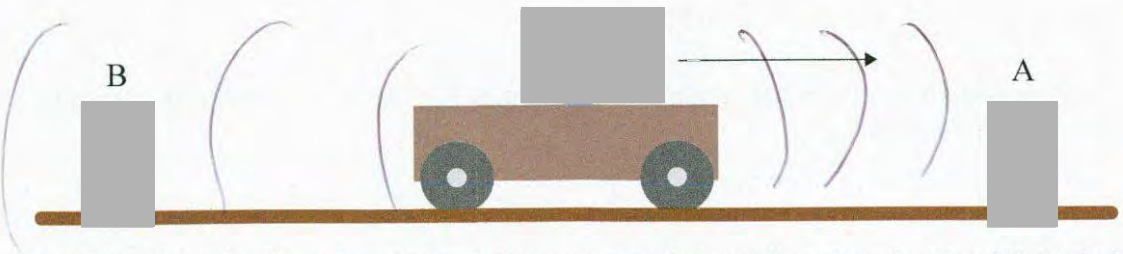
(c) Sam plays her violin (with a fundamental frequency of 196 Hz) as she sits on a moving trailer. The trailer is moving at 5.30 m s^{-1} directly towards microphone A.



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.

$f' = f\frac{V_w}{V_w \mp V_s}$ moving towards A so $f' = f\frac{V_w}{V_w - V_s}$

$V_w = 342\ ms^{-1}$ $V_s = 5.3\ ms^{-1}$ $f = 196\ Hz$ $f' = 196 \times \frac{342}{342-5.30}$

$f' = \cancel{199\ Hz}$ 199 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 same
- the speed of the sound in the air → same
- the wavelength of the sound in the air in front of and behind the violin in front ↓ behind ↓
- the frequencies detected by microphones A and B. → A↑ B↓

The frequency ~~&~~ of the string changes because of the ~~moti~~ motion of the trailer, which causes the ~~dop~~ Doppler effect to apply. As the ~~a~~ trailer moves, the wavefronts in front of Sam compress, causing a shorter wavelength in front of the ~~violin~~ violin, so ~~A~~ microphone A detects a higher frequency ~~to the~~ of the string. Behind the trailer, the ~~wo~~ distance between wavefronts increases, so the wavelength increases, and microphone ~~B~~ B detects a lower frequency.

~~I~~ Unless temperature or tightness of the string change, the speed of sound in air remains unchanged.

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.

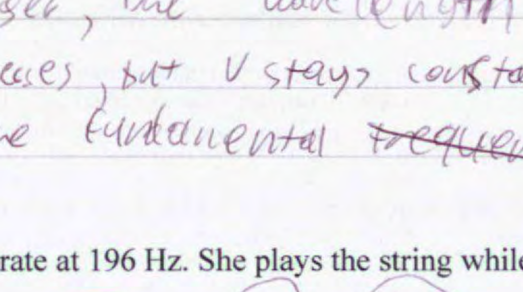
$\lambda = 2L$

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

As the string gets longer, the wavelength increases. Since $v = f\lambda$, if λ increases, but v stays constant, then f will decrease, so the fundamental ~~frequency~~ frequency will decrease.

(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 ~~the~~ the oscillation in loudness of waves at a similar frequency, but with the same amplitude.
Beats are heard as the waves are only slightly out of phase. This ~~can~~ causes periodic change in constructive and destructive interference. As the waves interfere constructively, the ~~amp~~ wave superposition and the amplitude increases, so does the loudness. When waves interfere destructively, the superposition decreases amplitude and the loudness decreases.

(c) Sam hears a beat of 2.1 Hz.

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

196 − 2.1 = ~~193.~~ ≈ 194 Hz (193.9 Hz)
196 + 2.1 = 198 Hz (198.1 Hz)

She increases the speed of the wave along the string by increasing the tension in the string and the beat frequency increases.

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

$V\uparrow = f\lambda$ ~~If beats increases~~ If $v = f\lambda$ λ is the same and V increases, then frequency must ~~decrease~~ increase, so she ~~is~~ was playing 198 Hz, as the beats increased.

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

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

Since the beats ~~force~~ frequency increases as she tightens the string, Sam should loosen the string as it would slow down the vibration and decrease frequency.

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

She will know when the sting vibrates at 196 Hz when she does not hear beats as the ~~violin~~ sting and fork will vibrate at the same frequency.

(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.

This phenomenon is called Resonance. It occurs when two objects vibrate at the same frequency, which is a natural frequency, or when the wavelength fits the shape of an ~~object~~ object.

To stop the glass from vibrations, Sam could change the frequency of the ~~sound~~ sound the violin creates by loosening the ~~string~~ string (~~increasing~~ decreases frequency) or tightening the string (increasing frequency) as the frequency played would no longer fit the glass, causing it to vibrate.

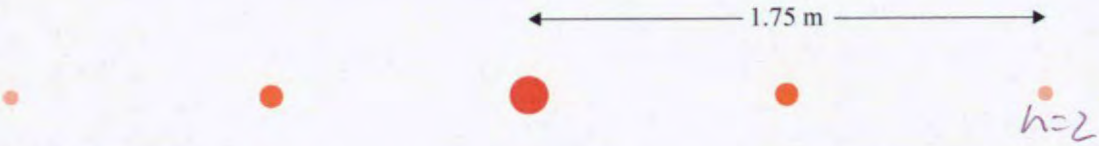
QUESTION THREE: DIFFRACTION GLASSES

Source: https://mindsetsonline.co.uk/shop/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.

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.



(a) Describe diffraction.

~~Diffraction~~ Diffraction occurs when wavefronts bend due to a barrier, causing the wavefronts to curve.

(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.

As the wavefronts bend, ~~they interfere with~~ due to the lines of the diffraction grating, they will interfere with each other. In some places, the waves interfere constructively and will form antinodal lines, ~~so~~ where brightness is the highest, which will result in bright spots on either side of the central maxima. The large sections where there is no light are a result of nodal lines, where the destructive ~~interference~~ interference will cause ~~light to~~ the waves to cancel out, so no light will be observed.

(c) Calculate the slit separation in the grating.

$n\lambda = \frac{dx}{L}$ $\quad n\lambda L = dx$ $\quad \frac{n\lambda L}{x} = d$ $\quad n = 2 \quad \lambda = 6.43 \times 10^{-7}$ m

$L = 1.43$ m $\quad x = 1.75$ m $\quad d = \frac{2 \times 6.43 \times 10^{-7} \times 1.43}{1.75} = 1.05 \times 10^{-6}$ m

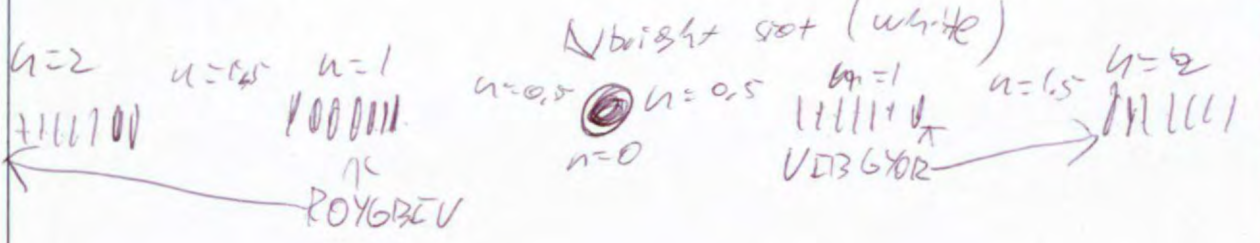
(d) When the children look at a spot of white light through the glasses, they see the white spot with spectra on either side (which they describe as "rainbows").

Give an in-depth explanation of this phenomenon by:

- describing where the spectra will occur → ~~two~~ bright spot
- explaining the position of the colours in the spectra – Red orange yellow, green, blue, indigo, violet,
- explaining why they are in these locations. – Path difference → Red has longest λ, so it will experience greatest θ so it is outermost

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

Space for labelled sketch:



~~A~~ The spectra will occur at ~~no~~ antinodal lines, where n is a whole number. This is caused by a greater path difference in light. Since $d\sin\theta = n\lambda$, if λ increases, so will θ. A greater θ will cause ~~light~~ the ~~spe~~ different wave lengths of light to have greater path difference. Since red light has the ~~lowest~~ highest wave length, it will experience the ~~highest~~ most diffraction and its path difference ~~on~~. This means that red light will always be on the outermost fringe of the spectra. Violet light has the lowest wave length so a lesser path difference and it will appear on the innermost fringe. The other wavelengths will appear in the ROYGBIV sequence.

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

QUESTION NUMBER

91523

Standard	91523			Total score	15
Q	**Grade score**	**Marker commentary**			
1	M5	3rd harmonic correctly identified and drawn. Frequency toward microphone A correctly calculated. Candidate does not show a causation between the wavelength decreasing and the frequency increasing (while the speed of sound in air is constant) or vice versa. This is most easily done by linking to $v = f\lambda$.			
2	M5	Beats are correctly described, but there is no mention of why the interference is constructive or linking this to the volume. It is incorrectly stated that as the waves are slightly out of phase that there is both constructive and destructive interference. The explanation for 2cii is restating the information given in the question without providing a logical causation. 2d Identifies Resonance correctly, but is unclear to the link to the natural frequency of the wine glass. The building of energy and hence a maximum amplitude is not mentioned.			
3	M5	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.			