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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.**

Excellence 23

## 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.

$\lambda = 2L = 0.662 m$

$v = f\lambda$

$v = 196 \times 0.662 = 129.75 ms^{-1}$

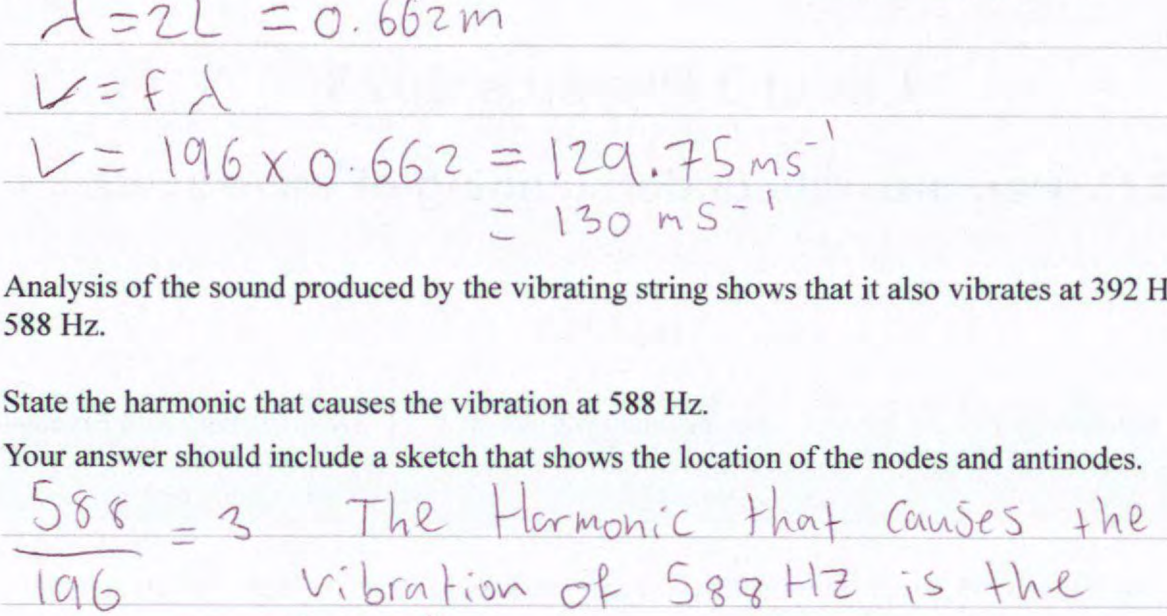
$= 130 ms^{-1}$

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

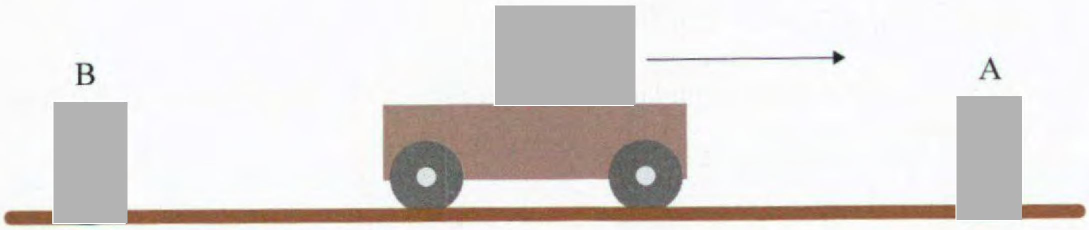
State the harmonic that causes the vibration at 588 Hz.

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

$\frac{588}{196} = 3$ The Harmonic that causes the vibration of 588 HZ is the third harmonic



(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.

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

$f' = 196 \frac{342}{342 - 5.3}$

$f' = 199$ 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 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 velocity of the trailer causes each succesive wavefront to be created closer to the last as Sam moves towards microphone A relative to microphone A. This causes for more waves to be observed in the same distance causing a bunching effect relative to the microphone A. As V is constant an observed decrease in $\lambda$ will cause mic A to hear a higher frequency of the string as $v = f\lambda$.
Sam is moving away from mic B which causes each succesive wavefront to be produced further away than the last relative to mic B. An observed

extra space answer continued

## 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).

node + node means that fundamental $\lambda = 2L$
AS $\lambda = 2L$ if $L$ increases the fundamental $\lambda$ will increase. As $V = f\lambda$ an increased fundamental $\lambda$ will cause a decrease in the fundamental frequency

(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 formed when two sources produce sound waves at different frequencys. This causes the two waves to be in and out of phase at varying/incostient intervals. When they are in phase they will constructively intefer to form a loud sound and when they are out of phase they will destructively intefer to form a quiet sound. Each beat - A sound with varying/incostent loud and quiet sounds heard - will be caused by one difference in frequency (Hz). Sams is playing a different frequency (Hot day) than the tuning fork so she is hearing beats.

(c) Sam hears a beat of 2.1 Hz.

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

$f_b = f_1 - f_2$ $\quad 196 - 2.1 = 193.9\text{ Hz} = 194\text{ Hz}$
~~She~~ $\quad$ or $\quad 196 + 2.1 = 198.1\text{ Hz} = 198\text{ Hz}$
Beats can occour in any direction in the difference ~~change~~ of frequency as they are caused by a ~~than~~ difference in frequencys.

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.

theBeat frequencies increasing means that the difference in frequencies is getting larger. Thelefore the initial frequency must of been larger than 196 there fore the frequency of the string must of been 198 Hz.

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

$v \propto \sqrt{T}$ so Sam must increase the tension of the string to increase the v. An increase in v and a constant λ will cause

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

The two Sources will be in phase So no beats will be heard.

(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.

Resonance is when the driving frequency applied to an object matches the natural frequency. This Causes energy to be added to the amplitude until it reaches its max amplitude as all other energy is lost to heat. Sam is playing the violin at a the frequency that causes resonance of the wine glass (increased amplitude causes it to vibrate) So by playing a lower different frequency She could not apply a driving force at the natural frequency of the wine glass which would stop resonance which would cause for the amplitude of the wine glass to decrease and stop vibrating

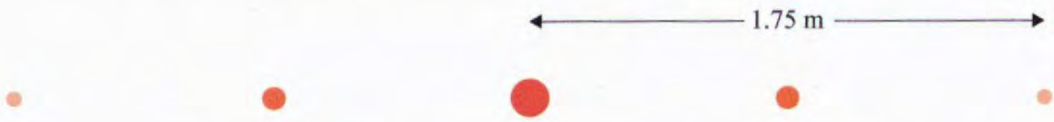
## QUESTION THREE: DIFFRACTION GLASSES

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 ($6.43 \times 10^{-7}$ 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.

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




(a) Describe diffraction.

When waves ~~are shone through slits~~ to pass through a "Slit" and bend.

(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.

Diffraction causes the waves to travel towards the wall having of spread out from travelling through slits. Because there are mutiple waves ~~Sources~~ the waves can have a path difference/phase difference ~~and intefer~~ or be in phase. When $n=1$ the waves ~~Sources~~ are in phase so will constructively intefer to form bright spots. There are alot of waves produced with diffraction grating so when $n \neq 1$ there will be a dark region. This is because ~~A~~ when $n \neq 1$ there is a path difference. A small path difference can

(c) Calculate the slit separation in the grating.

~~dx sin~~ $n\lambda = \frac{dx}{L}$ , $\frac{(6.43 \times 10^{-7})(1.43)}{\frac{1.75}{2}} = d$

$d = 1.05 \times 10^{-6}$ m

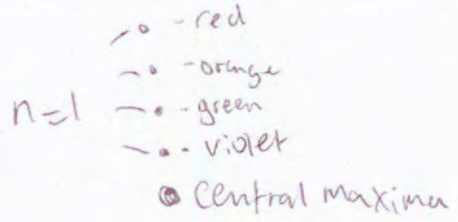
(d) When the children look at a spot of white light through the glasses, they see the white spot with spectra on either side (which they describe as "rainbows").

Give an in-depth explanation of this phenomenon by:

- describing where the spectra will occur
- 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:




There is no path difference at the first maxima. This causes all the Spectra of light to Constructively intefer to form a recombinant white light. For the first n each Color of light will form its own bright Spot. This is because ~~the~~ each colour of light has a different $\lambda$ so a different path difference. light with the Smallest $\lambda$ has the path difference will be in phase to constructively intefer at the smallest angle so form a bright Spot ~~fro~~ from the Central maxima first. As the $\lambda$ of light increases and the path difference, the light will be in phase at an increasing angle from the central maxima where it will constructively intefer to form a bright spot. This will Cause for each n a complete Spectra of bright spots beginning from the Smallest $\lambda$ Color of light upto the largest. This is due to the angle they reach being in phase for each color increases with $\lambda$ of colour because of the path difference This pattern will repeat itself for each n.

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

QUESTION NUMBER

decrease in the number of waves in the same distant causes there to be an increased $\lambda$ relative to mic B as v is constant. $v=f\lambda$, So an increase in $\lambda$ will cause for mic B to observe a lower frequency of the string than what Sam is playing. Sam experiences no relative velocity so will hear the actual frequency.

Q2 c iii) $v \propto \sqrt{T}$ So Sam must decrease the tension in order to decrease the velocity. The decrease in velocity ~~will cause~~ and a constant $\lambda$ will cause a decrease in the f as $v=f\lambda$. The frequency Sam is playing is higher so as decreasing the tension will decrease the f, the frequency can be decreased from 198Hz to 196Hz

Q3B Cause de~~cons~~structive inteferance as it is the result of all waves intefering. Destructive inteferance causes dark ~~regio~~ spots. The region of dark spots is large ~~small~~ as destructive inteferance can occur with a small path difference ($n \neq 1$) as it is the result of all waves intefering and there are many waves produced in difraction grating. This is because each slit, causes diffraction which produces many waves. lots of slits

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| Standard | 91523 | | | Total score | 23 |
|---|---|---|---|---|---|
| **Q** | **Grade score** | **Marker commentary** | | | |
| 1 | E8 | The motion of the trailer producing wavefronts further from each previous wavefront is supported by the decrease in the number of waves in the same distance. This could have been improved upon by stating that as the wave and the vehicle are moving in opposite directions the distance between the wavefront and the vehicle when the next wavefront is emitted, is greater than it otherwise would have been had the vehicle been stationary. | | | |
| 2 | E8 | The explanation clearly describes that as the beat frequency increases the difference between the two frequencies increases. As the frequency is increasing as the tension is increasing this can only occur if the string frequency is 198.1 Hz.<br><br>Clear explanation of Resonance caused by the driving frequency matching the natural frequency and causing energy and hence amplitude to increase. | | | |
| 3 | E7 | In addition to identifying that waves that have a path difference of exactly and whole number of wavelengths will result in waves being exactly in phase. The candidate has described that with many sources, a small path difference ($n \neq integer\ values$) will result in destructive interference from the many waves.<br><br>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. | | | |