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NZQA

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Physics 2025

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 2–15 in the correct order and that none of these pages is blank.

Do not write in the margins (░░). 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 TOTAL **15**

QUESTION ONE: THE DOPPLER EFFECT

Martin and Kerryn are riding their jet skis on a lake. Martyn's jet ski is fitted with an air horn that emits a frequency of 1043 Hz. At one point, Kerryn stops and Martyn travels directly towards her at a speed of 27.3 m s⁻¹. The speed of sound in air is 343 m s⁻¹.
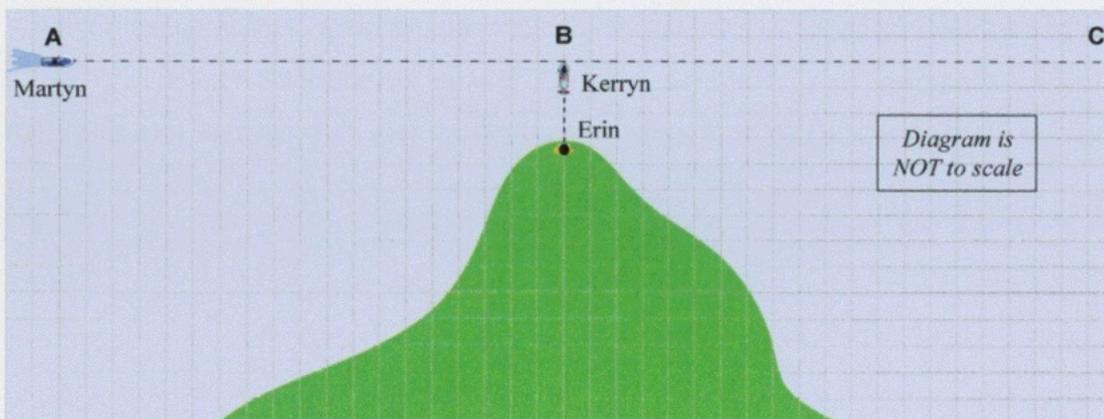
(a)   Calculate the frequency of the sound that Kerryn hears.

$$1043 \times \frac{343}{343 - 27.3} = 1133 \text{ Hz}$$

(b)   Explain why Kerryn hears a different frequency than that emitted by the jet ski's air horn.

As Martyn is travels toward her, the wavefronts emitted by the air horn decreases, and the velocity is constant, so the frequency will increase when Kerryn hearing.

(c)   Kerryn is floating very close to the path of Martyn's jet ski, while her friend Erin is watching from a bank on the edge of the lake.

A   Martyn

B   Kerryn
     Erin

C

Diagram is NOT to scale

The graph shows the frequency of the sound heard by Kerryn and Erin as the jet ski travels from A to C.
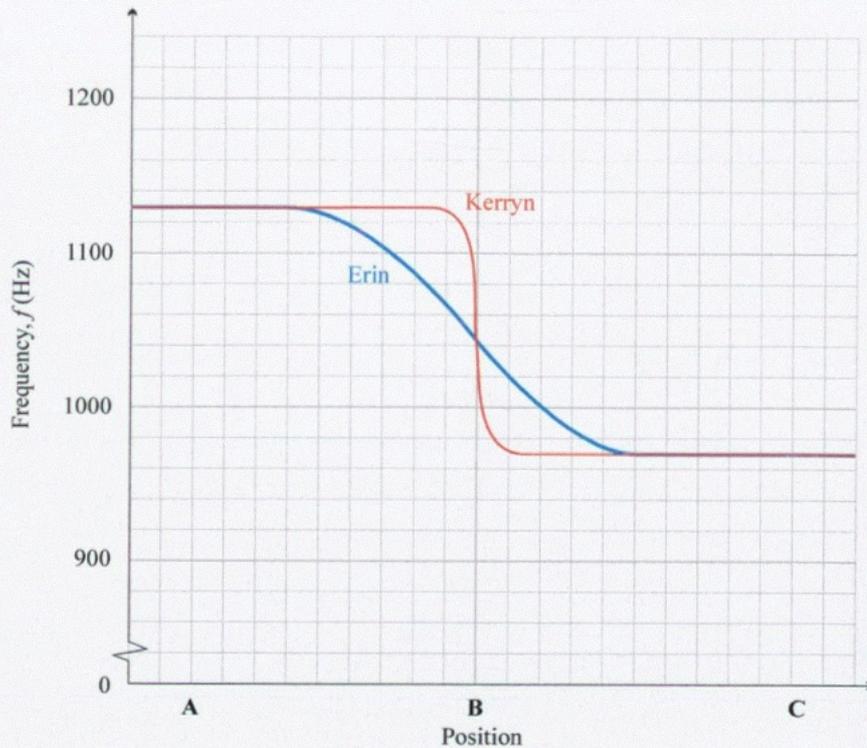
Explain why the frequency that Kerryn hears is the same or different to that which Erin hears.

Kerryn is closer to Martyn than Erin, where Martyn is coming to the position B, Kerryn can hear higher frequency than Erin, due to the wavelength emitted by the air horn is decreasing to the front. At position B Kerryn still can hear higher frequency than Erin. At position C and A, both of them are hearing the same frequency, because the wavelength emits to them is the same.

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(d) An underwater microphone has been submerged in the lake to monitor noise pollution from jet ski engines. Martyn's jet ski engine makes a sound at 574.0 Hz. As the jet ski travels away from the underwater microphone at 27.3 m s⁻¹, the microphone measures a frequency of 563.6 Hz coming from the jet ski engine.

Calculate the velocity of sound in water.

$$563.6 = 574 \frac{V_w}{V_w + 27.3}$$

$$0.9818 = \frac{V_w}{V_w + 27.3}$$

$$0.9818 V_w + 26.81 = V_w$$

$$26.81 = 0.0181 V_w$$

$$V_w = 1480 \text{ ms}^{-1}$$

QUESTION TWO: STANDING WAVES

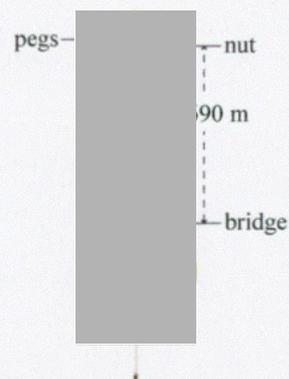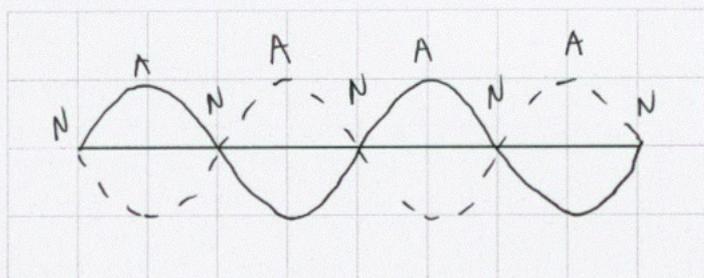The cello is a stringed instrument belonging to the violin family.

The strings are supported at each end by a piece of wood called the bridge and the nut respectively.

The length of the strings between the supported ends is 0.690 m.

When the cello is played, the strings can vibrate in different harmonics.

pegs— —nut

90 m

—bridge

Source: https://en.wikipedia.org/wiki/
Cello#/media/File:Cello_front_side.png

(a) Draw a diagram of the 4th harmonic.

Label the nodes and antinodes.

If you need to redraw your response, use the diagram on page 11.

(b) Sometimes if the cello has been in storage, the tension in the strings will decrease, and the instrument will be out of tune. The strings will therefore play a frequency that is other than the desired frequency.

Use the equation below to explain how this could have caused the frequency to be higher or lower than the desired frequency.

$$v_{\text{wave on string}} = \sqrt{\frac{\text{tension}}{\text{mass per unit length}}}$$

No calculations are required.

$$\text{Tension} = \frac{v_{\text{wave on string}}^2}{\text{mass per unit length}}$$

$$\text{Tension} = v_{\text{wave on string}}^2 \times \text{mass per unit length}$$

Since the mass per unit length is constant, decrease in tension will per proportional decrease $v_{\text{wave on string}}$, as the wavelength is unchanged, the frequency also decreases. $v = f\lambda$, so the frequency will be lower than desired frequency. If tension increased, the frequcy also increases.

(c) When a 0.690 m string is played, the first harmonic has a frequency of 147 Hz. A finger is then pressed onto the string, changing the length of the string to play a first harmonic with a frequency of 207 Hz.

Calculate the new length of the string when the second note of 207 Hz is played.

Assume that the tension in the string remains constant.

$\lambda = 2L$ $\lambda = 2 \times 0.69 = 1.38$ m $1.38 \times 147 = 203$ ms^{-1}

$\lambda = 203 \div 207 = 0.981$ m $L = \frac{0.981}{2} = 0.490$ m

(d) Two strings that are next to each other can be played at the same time. When string 2 is played (without a finger being pressed on it), it produces a note with a frequency of 98.0 Hz. Strings 1 and 2 are played at the same time that a finger is pressed onto string 1, and the length of string 1 is gradually reduced until a beat is heard.

(i) Explain why beats form.

The beats is formed by the difference between two frequencies.

Strings 1 2 3 4

(ii) Explain what will be heard as the <u>length of the string</u> continues to be <u>gradually reduced.</u>

Reducing the length of the string will increase the frequency, if two strings have different frequency, then the beat will be heard. The difference between two frequencies increases, the frequency of beat also increases.

QUESTION THREE: INTERFERENCE PATTERNS

A laser shines green light onto a double slit, which has a slit separation of 1.25×10^{-4} m. Each slit then acts as a light source that is in phase, producing an interference pattern on a screen with fringes that are close together.

Diagram is NOT to scale

Source: https://courses.lumenlearning.com/suny-physics/chapter/27-3-youngs-double-slit-experiment/

When the screen is 3.40 m from the slits, the distance from the central maxima to the 3rd order maxima is 4.20×10^{-2} m.

(a) Show that the laser has a wavelength of 515 nm.

$$L = 3.4 \quad x = 4.20 \times 10^{-2} \quad d = 1.25 \times 10^{-4} \quad n = 3$$

$$\lambda = \frac{1.25 \times 10^{-4} \times 4.2 \times 10^{-2}}{3 \times 3.9}$$

$$= 5.15 \times 10^{-7} \text{ m}$$

$$= 515 \text{ nm}$$

(b) Explain why the intensity of the light on the screen varies, as shown.

2 slits

The bright place is where the constructive interference of the light waves, and the dark place in between the bright is where the destructive interference of the light waves.
This the diffraction gratiun, which is many waves through a gap.

(c) The double slit is replaced with a diffraction grating which has more closely-spaced slits.

Describe and explain the changes to the interference pattern observed on the screen.

More closely-spaced slits means more sources are interfering, causing destructive interferences.

λ

(d) In another experiment, a green laser, of wavelength 515 nm, is shone through a different diffraction grating and 7 maxima are seen on the screen. The screen is 0.900 m wide and is 1.20 m from the diffraction grating.

d
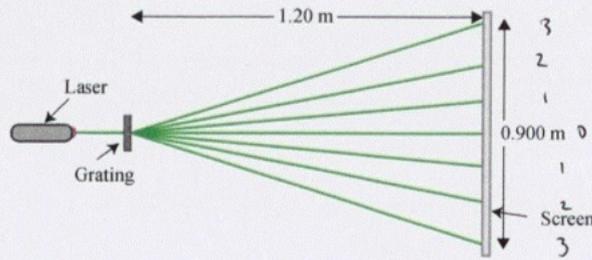
Calculate the possible range of values for the slit separation of the diffraction grating.

$L = 1.2$ $x = 0.45$ $n = 3$ $\lambda = 5.15 \times 10^{-7}$

$$3 \times 5.15 \times 10^{-7} = \frac{0.45 d}{1.2}$$

$$d = 4.12 \times 10^{-6} \, m$$

Merit

Subject: L3 Physics

Standard: 91523

Total score: 15

Q	Grade score	Marker commentary
One	6	(1c) requires candidates to explain how the motion *towards* the observer of the jet ski affects the frequency observed, restating the information provided is insufficient.
Two	6	The candidate has provided correct answers for (a), (b), and (c). (d)(i) requires the candidate to explain how similar frequencies will alternate being in phase, and so constructively interfere to produce a loud sound and out of phase and so destructively interfere to produce a quiet sound. In (d)(ii), the candidate correctly identifies that decreasing the wavelength increasing the frequency, however, as the question states that the frequency of string 1 is less than that of string 2, the frequency of string one is approaching string two, so the beat frequency is decreasing as the string becomes more similar. The candidate does not mention that the beat frequency will disappear when the two frequencies are the same.
Three	3	In (a), the candidate has provided the correct answer. In (b), the candidate identifies that constructive interference causes a bright region, but does not specify that this occurs when the waves are in phase, due to a path difference of a whole number of wavelengths (and likewise for destructive interference being due to the waves being out of phase when the path difference is odd multiples of half wavelengths). In (c), the candidate does not identify or explain the changes that are observed. In (d), candidate identifies that the 3rd order fringe is observed on the screen but uses the small angle approximation formula for a large angle. The candidate does not identify that the edge of the screen is between the 3rd and 4th fringe.