EXPERIMENTS

EXPERIMENT 01 - STANDING WAVE IN A ROPE

OBJECTIVES: Analyzing experimentally the properties of a standing wave in a rope and to obtain the relation between the tractive force applied to the rope and:
- **the wavelength.**
- **the wave frequency.**
- **the linear density of the rope.**

Part I - Relation between the tractive force and the wavelength in a standing wave.

>>> ***Material Used*** >>

Code	*Quant.*	*Unit*	*Description*
63002049	*01*	*UN.*	*STATIONARY WAVE GENERATOR BASE WITH ROTATIONAL SYSTEM, ELECTRONIC CONTROL AND FREQUENCY METER*
63005071	*01*	*UN.*	*EXPANDABLE ROD FOR DYNAMOMETER*
63005200	*01*	*UN.*	*EXPANDABLE ROD WITH PULLEY*
62001247	*01*	*UN.*	*DYNAMOMETER 1N*
38039005	*01*	*UN.*	*POWER SUPPLY DC 12V/2A*
48005004	*01*	*UN.*	*BUTTERFLY NUT ¼"*
53004003	*01*	*UN.*	*THUMB SCREW*
50002003	*01*	*UN.*	*WASHER ¼"*
63005192	*01*	*UN.*	*ROPE DENSITY 3*

>>> ***Experimental Procedures*** >>>

Device used in the experiments with standing wave in the rope

1. Assemble the equipment according to the figure. The device used to generate standing wave on the rope performs the programmed experiments always varying the tractive force, by moving the dynamometer up or down. During the experiment adjust the frequency so it remains constant.

2. Fix the three-thread rope at the appropriate location and measure the rope length.

3. Apply to the dynamometer a tractive force approximately equal to 0,10N.

4. Turn on the equipment and adjust the oscillator to a frequency close to 30 Hz. Move the rod that fixes the dynamometer to obtain the first vibration mode (1st harmonic).

Note:
If the frequency or rating is too high, the security system of the device will be triggered and the message

5. Once the first harmonic is obtained, adjust the frequency to 30 Hz. Wait a few seconds for the frequency to be practically stable and note the power value indicated by the dynamometer, the number of nodes, the number of wombs and the wavelength.

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6. Move the dynamometer up or down while simultaneously adjusting the frequency to 30 Hz to obtain the highest amplitude standing wave.

Setting the standing wave in the fundamental mode.

7. Repeat the procedures to collect the values of the tractive force (F) and the wavelength (λ) for the 2nd, 3rd and 4th modes of vibration, always maintaining the frequency at 30 Hz.

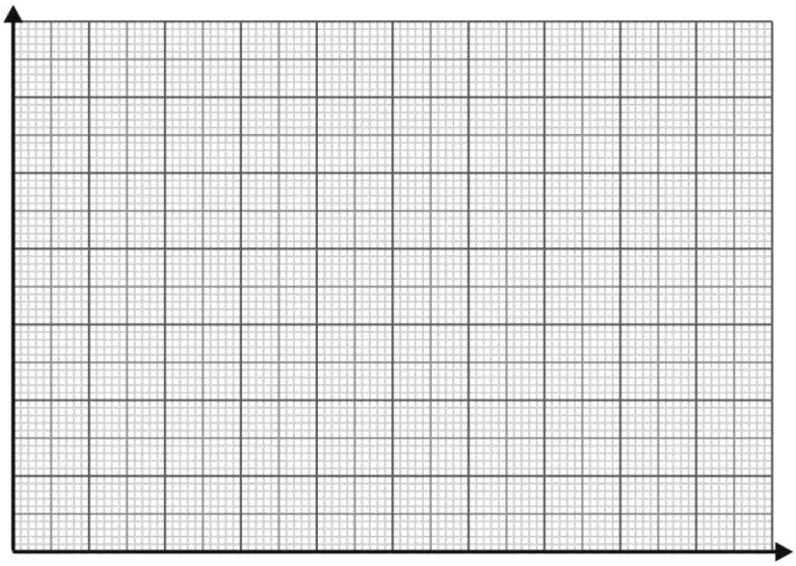
8. To find the second harmonic we must decrease the tractive force value by moving the dynamometer down. When finding the second harmonic, adjust the frequency (30 Hz) and the tractive force. (The procedures are the same for the other suggested harmonics)

Table 1

Vibration Mode	number of nodes	number of wombs	F(N)	λ(m)	$\lambda^2(m^2)$
1st					
2nd					
3rd					
4th					

>>> ***Analysis of Results and Conclusions*** >>

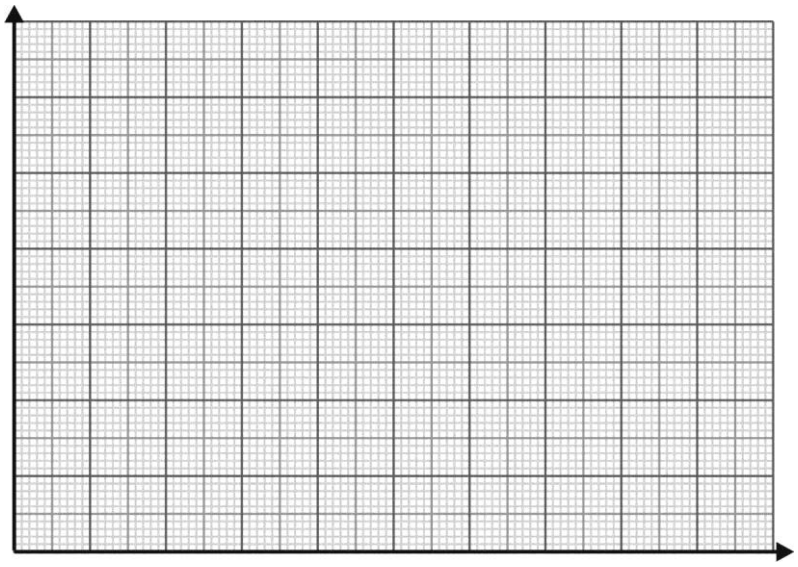
9. Draw the graph F=f(λ) (tractive force according to wavelength).



10. What does the curve look like?

11. What is the likely relationship between F and λ?

12. Use the appropriate variable change to linearize the graph.



13. Obtain with the aid of Excel the equation that relates the strength and the wavelength, F=f(λ) and the relation of proportionality between the two quantities.

Part II - Relation between Tractive Force and wave frequency

>>> ***Material Used*** >>>

Code	*Quant.*	*Unit*	*Description*
63002049	*01*	*UN.*	*STATIONARY WAVE GENERATOR BASE WITH ROTATIONAL SYSTEM, ELECTRONIC CONTROL AND FREQUENCY METER*
63005071	*01*	*UN.*	*EXPANDABLE ROD FOR DYNAMOMETER*
63005200	*01*	*UN.*	*EXPANDABLE ROD WITH PULLEY*
62001247	*01*	*UN.*	*DYNAMOMETER 1N*
38039005	*01*	*UN.*	*POWER SUPPLY DC 12V/2A*
48005004	*01*	*UN.*	*BUTTERFLY NUT ¼"*
53004003	*01*	*UN.*	*THUMB SCREW*
50002003	*01*	*UN.*	*WASHER ¼"*
63005192	*01*	*UN.*	*ROPE DENSITY 3*

>> ***Experimental Procedures*** >>

1. Use the same assembly as in the first part.

2. Fix the three-thread rope at the appropriate location and measure the rope length.

3. Apply to the dynamometer a tractive force approximately equal to 0,10N.

4. Turn on the equipment and adjust the oscillator to a frequency close to 10 Hz. Move the stem that fix the dynamometer to obtain the first vibration mode (1st harmonic), with the greatest possible amplitude of the standing wave.

5. Wait a few seconds for the frequency to be practically stable and note in the table the force value indicated by the dynamometer and the frequency of the wave.

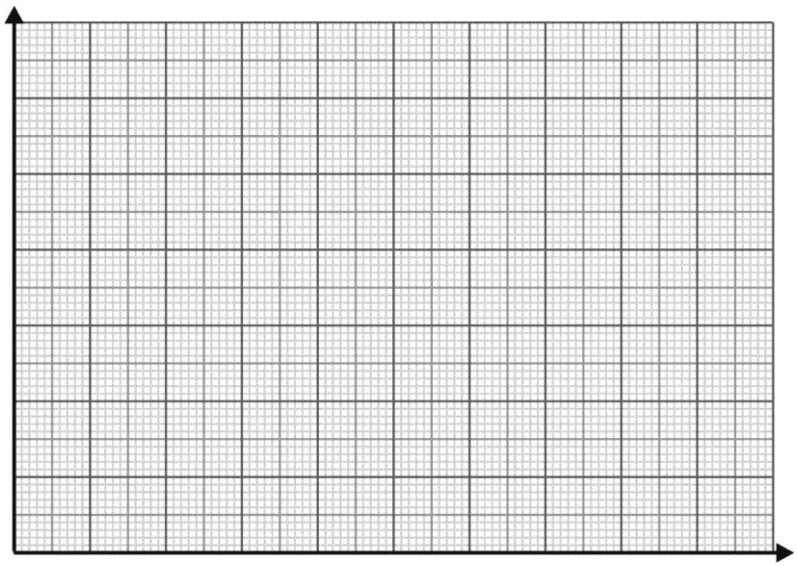
6. Increase the frequency by approximately 3 to 4 Hz. Move the dynamometer in order to obtain the maximum amplitude of the standing wave corresponding to 1st harmonic and note the strength and frequency values.

7. Repeat the previous procedure for new frequency values always using the first harmonic (up to a maximum value of approximately 30 Hz).

Frequency f (Hz)	Strength F (N)

>>> ***Analysis of Results and Conclusions*** >>

8. Draw the graph F=f(λ) (tractive force according to wavelength).

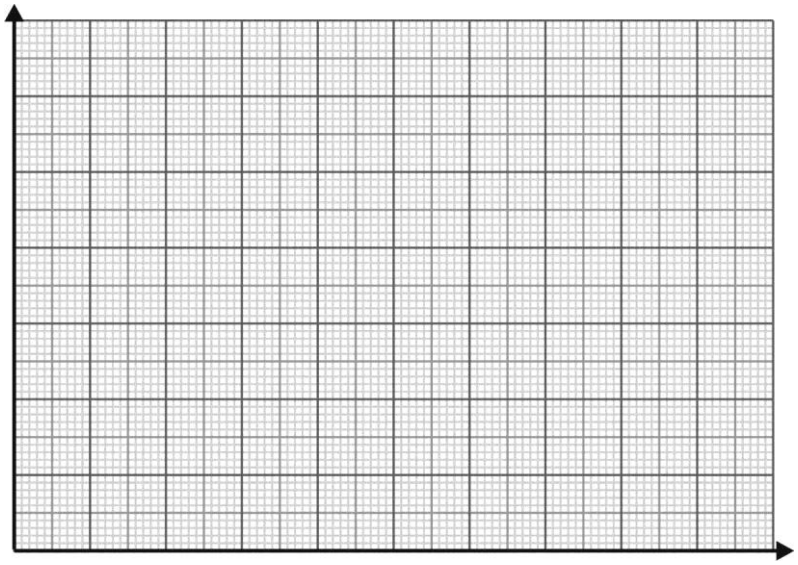


9. What does the curve look like?

10. What is the likely relationship between F and f?

11. Use the appropriate variable change to linearize the graph.

Frequency f (Hz)	Strength F (N)	$f^2(Hz)^2$



12. Obtain with the aid of Excel the equation that relates the strength and the wavelength, F=f(λ) and the relation of proportionality between the two quantities.

Part III – Relation between Tractive Force and Linear Density

>>> ***Material Used*** >>>

Code	*Quant.*	*Unit*	*Description*
63002049	*01*	*UN.*	*STATIONARY WAVE GENERATOR BASE WITH ROTATIONAL SYSTEM, ELECTRONIC CONTROL AND FREQUENCY METER*
63005071	*01*	*UN.*	*EXPANDABLE ROD FOR DYNAMOMETER*
63005200	*01*	*UN.*	*EXPANDABLE ROD WITH PULLEY*
62001247	*01*	*UN.*	*DYNAMOMETER 1N*
38039005	*01*	*UN.*	*POWER SUPPLY DC 12V/2A*
56001001	*10*	*UN.*	*HOOK TYPE “S”*
48005004	*01*	*UN.*	*BUTTERFLY NUT ¼”*
53004003	*01*	*UN.*	*THUMB SCREW*
50002003	*01*	*UN.*	*WASHER ¼”*
63005193	*01*	*UN.*	*ROPE DENSITY 4*
63005192	*01*	*UN.*	*ROPE DENSITY 3*
63005191	*01*	*UN.*	*ROPE DENSITY 2*
63005190	*01*	*UN.*	*ROPE DENSITY 1*

>>> ***Experimental Procedures*** >>

Device used in standing wave experiments

1. Assemble the equipment as shown in the figure.

2. Attach the rope to the equipment with a thread.

3. Turn the equipment on by letting it vibrate at 25 Hz.

4. Adjust the dynamometer by moving it up or down until you find the first vibration mode..

5. Keep the frequency (25 Hz) and the wavelength constant. Note in the table below the tractive

force intensity and the wavelength.

6. In the experiment consider the following convention:

- Rope with one thread will be considered with a linear density equal to $\boldsymbol{\rho_o}$.
- Rope with two threads will be considered with a linear density equal to $\boldsymbol{2\rho_o}$.
- Rope with three threads will be considered with a linear density equal to $\boldsymbol{3\rho_o}$.
- Rope with four threads will be considered with a linear density equal to $\boldsymbol{4\rho_o}$.

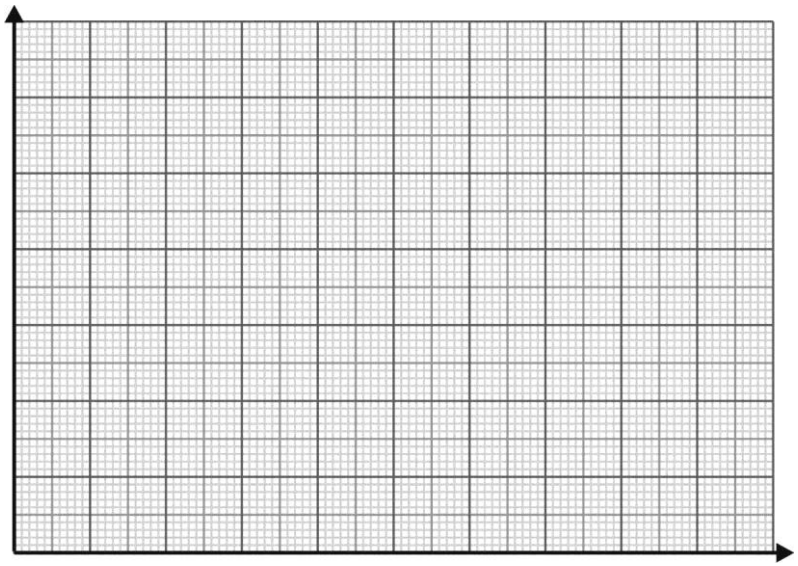
$\rho(\rho_0)$	f (Hz)	λ(m)	F(N)
1	25		
2			
3			
4			

7. Turn off the equipment and replace the one-thread rope with the two-thread rope.

8. Repeat the previous experimental procedures for the ropes with densities 2, 3 and 4, keeping the frequency fixed at approximately 25 Hz.

>>> ***Analysis of Results and Conclusions*** >>

9. Draw the graph F=f(ρ) (tractive force according to linear density measured by the number of threads).



10. What is the aspect of the curve obtained in the graph F versus ρ ?

11. What is the relation of proportionality between the tractive force in the rope and the linear density?

Part IV – Relation between frequency and wavelength

>>> ***Material Used*** >>>

Code	*Quant.*	*Unit*	*Description*
63002049	*01*	*UN.*	*STATIONARY WAVE GENERATOR BASE WITH ROTATIONAL SYSTEM, ELECTRONIC CONTROL AND FREQUENCY METER*
63005074	*01*	*UN.*	*EXPANDABLE ROD FOR DYNAMOMETER*
	01	*UN.*	*ROPES*
56001001	*10*	*UN.*	*HOOK TYPE "S"*
62001247	*01*	*UN.*	*DYNAMOMETER 1N*
38039005	*01*	*UN.*	*POWER SUPPLY DC 12V/2A*

>>> ***Experimental Procedures*** >>

1. Assemble the equipment as shown in the figure, with the four-thread rope.

2. Hang on the thread end 4 HOOK TYPE S masses.

3. Adjust the oscillator to minimum frequency.

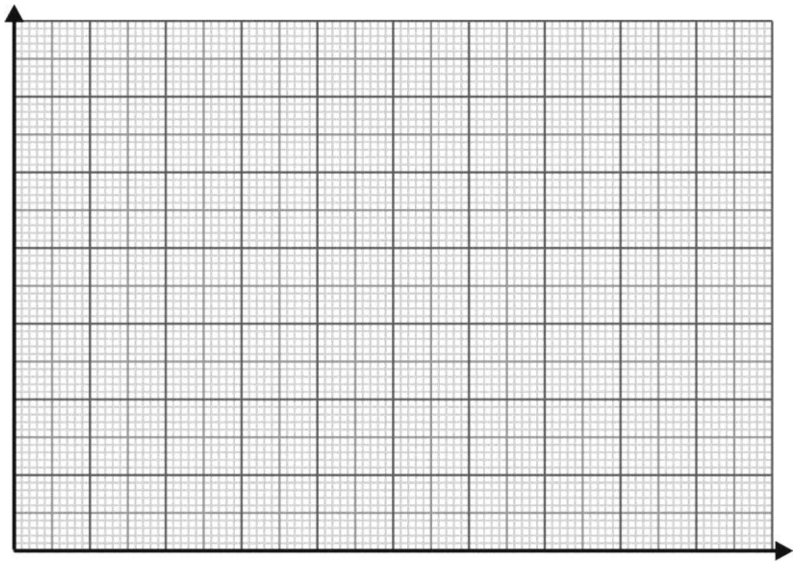
4. Turn on the oscillator and slowly increase the frequency until it reaches the first mode of vibration. Note the frequency and wavelength values in the table.

5. Slowly increase the vibration frequency to get the second and third modes of vibration and complete the table.

Mode	λ	f	1/λ
1	0,980		
2	0,490		
3	0,327		

>>> ***Analysis of data and conclusions*** >>

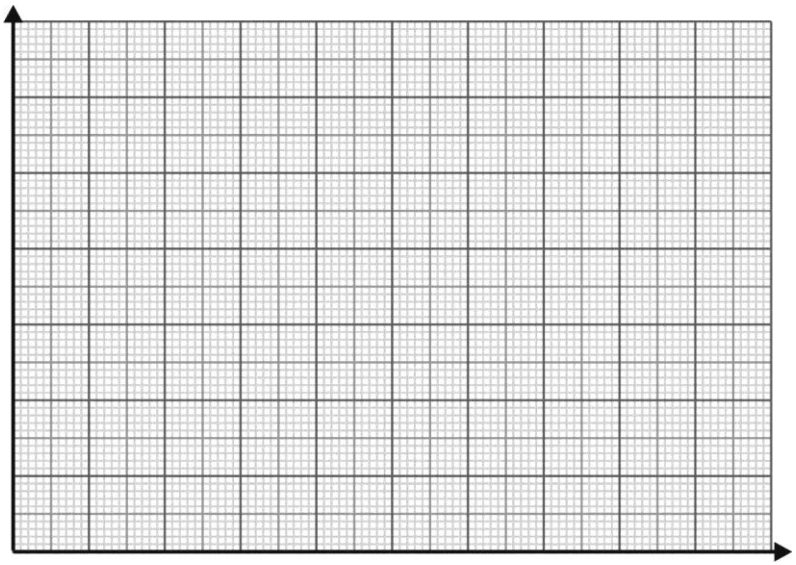
6. Draw the graph of the frequency according to wavelength.



7. What is the aspect of the curve in the graph f versus λ?

8. What should be the likely relationship between frequency and wavelength?

9. Use the required variable change and linearize the graph.



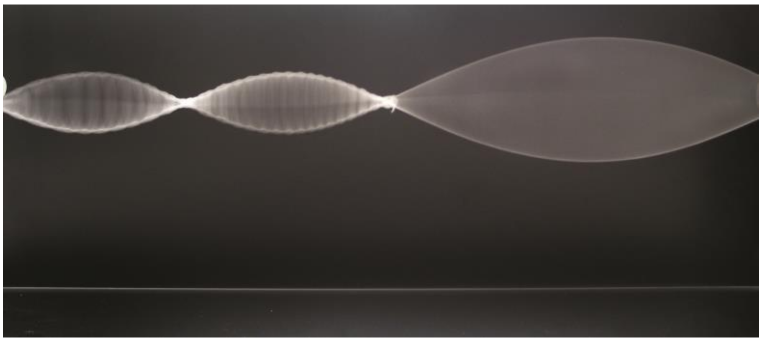
10. According to the linearized graph, what should be the relation between the frequency and wavelength of the standing wave in a rope subjected to a constant tractive force?

11. What is the physical meaning of the angular coefficient of the linearized graph?

Part V – Refraction of wave on a rope

>>> ***Material Used*** >>

Code	*Quant.*	*Unit*	*Description*
63002049	*01*	*UN.*	*STATIONARY WAVE GENERATOR BASE WITH ROTATIONAL SYSTEM, ELECTRONIC CONTROL AND FREQUENCY METER*
63005071	*01*	*UN.*	*EXPANDABLE ROD FOR DYNAMOMETER*
63005200	*01*	*UN.*	*EXPANDABLE ROD WITH PULLEY*
62001247	*01*	*UN.*	*DYNAMOMETER 1N*
38039005	*01*	*UN.*	*POWER SUPPLY DC 12V/2A*
48005004	*01*	*UN.*	*BUTTERFLY NUT ¼"*
53004003	*01*	*UN.*	*THUMB SCREW*
50002003	*01*	*UN.*	*WASHER ¼"*
63005194	*01*	*UN.*	*COMBINED ROPE*



>>> ***Experimental Procedures*** >>>

1. Use the same assembly as in the third part.

2. Attach to the equipment the rope consisted of two parts with different densities.

3. Turn on the oscillator and adjust the frequency to approximately 25 Hz.

4. Adjust the dynamometer by moving it up or down until you find the first vibration mode, in the thinnest part of the rope.

5. Note the wave frequency value presented by the oscillator.

>>> ***Analysis of Results and Conclusions*** >>

6. Consider the thinnest part of the rope with wavelength λ_1 and the thickest part with wavelength λ_2.

7. Obtain the wavelengths of each wave propagating in the two means.

8. The wave propagates in the rope from the mean 1 (less dense) to mean 2 (denser).

9. When changing mean, did the wave frequency change? Justify.

10. What should be the relationship between the wave velocities in the two means?