Standing waves on a string with tension

Criteria: CE, MS

Aim
To determine the wave velocity of standing waves on a string with tension in two different ways.

Apparatus
String, tools for attachment, weights, oscillator, marker-pen, ruler.

Idea of experiment
The string is fixed in both ends.
How can we assume this knowing that the oscillator is actually moving up and down in one end of the string?

The wave velocity can be determined in two different ways.
How can we talk about wave velocity for a standing wave?

1. The wave velocity, v (m/s) can be expressed by the tension of the string, T (N), and the mass per unit length, μ (kg/m): $v = \sqrt{\frac{T}{\mu}}$.
   The tension is given by the weight with mass m_w (kg) on the string, and the acceleration of gravity, $g = 9.8\ m/s^2$. $T = m_w\, g$.

   The mass per unit length, μ, can be determined this way:
   For a piece of un-tensioned string measure the total mass m_{string} and the full length of the string.
   Then: $\mu_{relax} = m_{string}/L_{string}$

   With a pen make two marks on the part of the string you are going to use. Length between marks when string is un-tensioned: L_{relax}. With a certain load this length is changed by tension to: L_{tens}. Then the mass of the tensioned string per unit length becomes: $\mu_{tens} = \mu_{relax}\, L_{relax}/L_{tens}$.
   If the string can be assumed reasonable inelastic you can skip this part, and in the following just assume that $\mu_{tens} = \mu_{relax}$.
2. The wave velocity can be expressed by the wavelength, λ (m), and the frequency, f (Hz) of the harmonics of standing waves on the string, $v = \lambda f$.
   The wavelength can be expressed using our knowledge of combinations of nodes - antinodes of the harmonics of standing waves on the string. It is expressed by the length of the string between the two fixed points, L_f (m), and the number of the mode of harmonics of the standing wave, n: $\lambda = \frac{2L_f}{n}$, with n = 1,2,3, ...
   The frequency can be read on the oscillator-display.

Conclusion and Evaluation
Discuss your results considering random and systematic errors. Consider carefully how random errors can influence your results.
Discuss possible systematic errors and consider carefully which consequences these can have on your measurements and results. Suggest improvements.

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Measurements

m_{string}, L_{string}, μ_{relax}, L_{relax}, L_f and g are measured/calculated/given to be used for all later measurements.

The measurements of the oscillating string are done for different weigths, m_w.

For each weight you must do measurements of at least three harmonic modes (first, second and third harmonics) by adjusting the frequency of the oscillator.

Put up the following tables:

General values of the experimental setup:

Name	**Unit**	**Formula**	**Value**	**Explanation**
m_{string}	kg			mass of string
L_{string}	m			length of string
μ_{relax}	kg/m	m_{string}/L_{string}		mass per unit length when string relaxed
L_{relax}	m			distance between markings when string relaxed
L_f	m			distance between basic nodes
g	m/s^2			acceleration of gravity

Measurements and calculations:

mass of load	tension of string	distance between markings when string tense (*)	mass per unit length when string tense (*)	speed of wave from tension formula	harmonic mode	frequency	bølgelængde	speed of wave from harmonic formula
m_w	T	L_{tens}	μ_{tens}	v_1	n	f	λ	v_2
kg	N	m	kg/m	m/s		Hz	m	m/s
	$m_w\, g$		μ_{relax} * L_{relax}/L_{tens}	$v = \sqrt{\frac{T}{\mu}}$			$\lambda = \frac{2L_f}{n}$	$\lambda\, f$
					1			
					2			
					3			
					....			
					1			
					2			
					3			
					....			

(*) If the string can be assumed reasonable inelastic you can skip measuring L_{tens}, and in the following just assume that $\mu_{tens} = \mu_{relax}$.