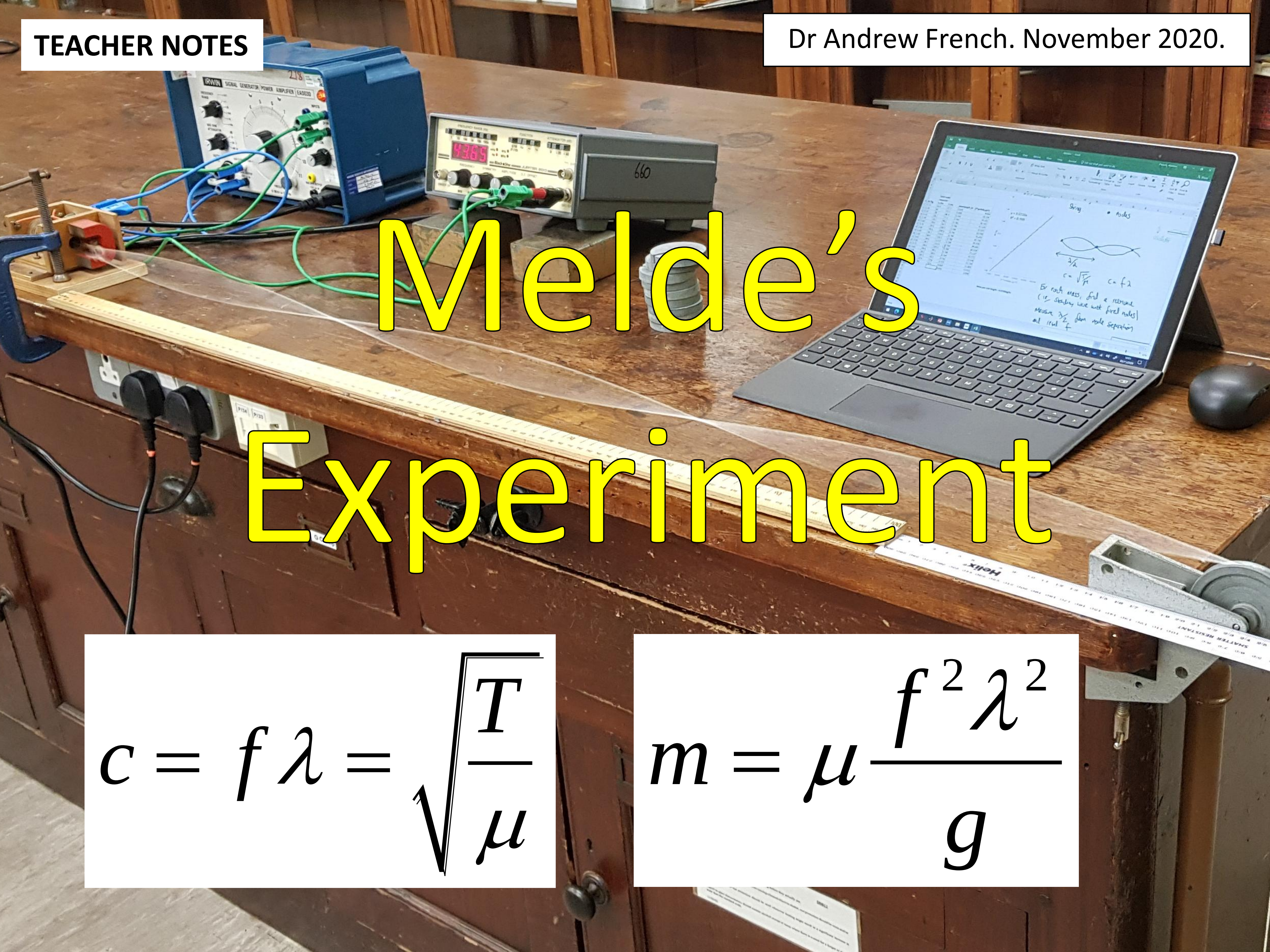
TEACHER NOTES

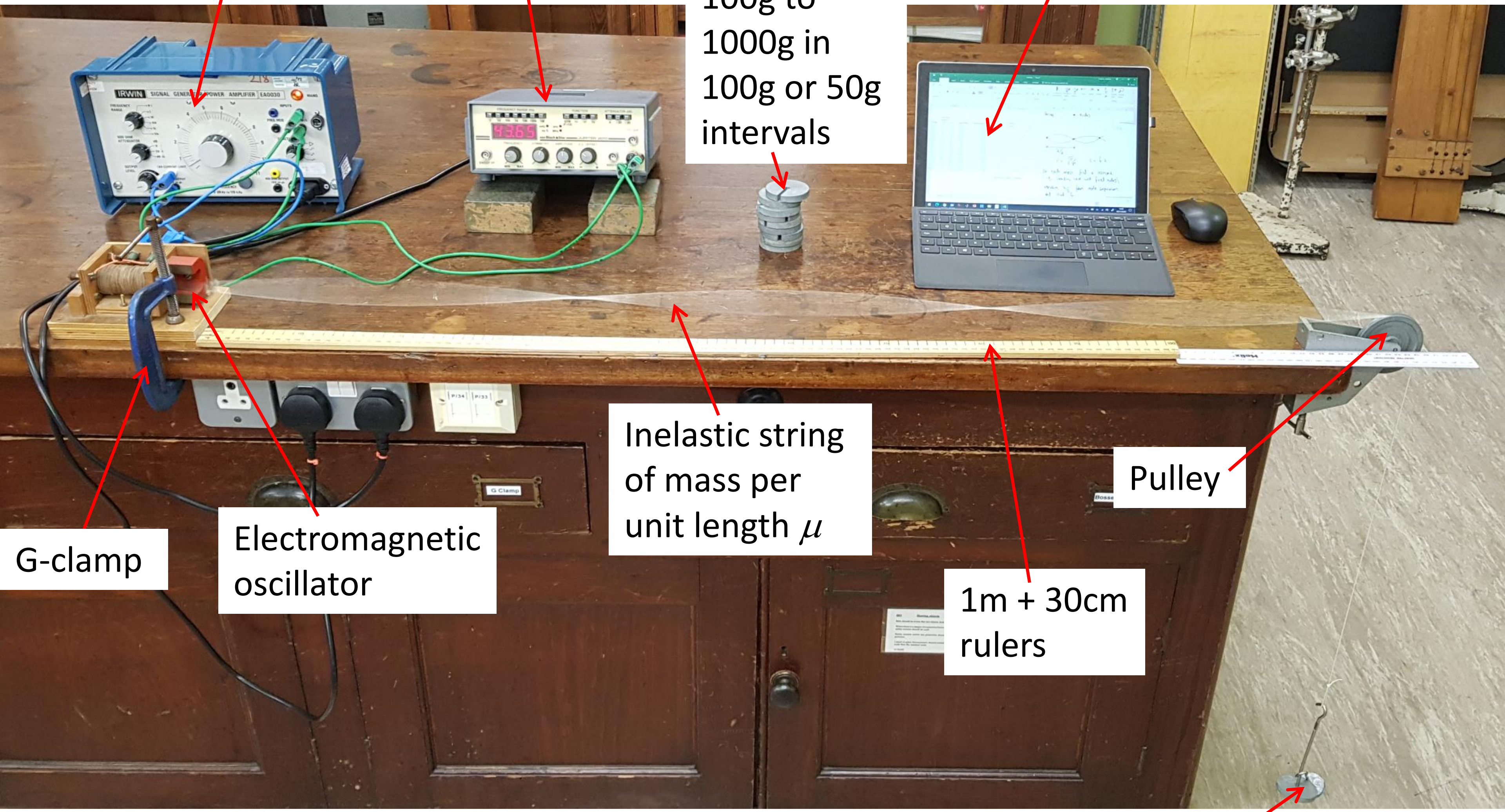
Dr Andrew French. November 2020.



Melde’s Experiment

$$c = f\lambda = \sqrt{\frac{T}{\mu}}$$

$$m = \mu \frac{f^2 \lambda^2}{g}$$


Signal generator used as a power amplifier
Signal generator
100g to 1000g in 100g or 50g intervals
Laptop + spreadsheet for recording data
G-clamp
Electromagnetic oscillator
Inelastic string of mass per unit length μ
1m + 30cm rulers
Pulley
10 x 0.1kg masses including hook

Equipment

Select triangle (power amplifier) mode.
i.e. don't use this as a signal generator,
just a power amplifier.

Input from signal generator

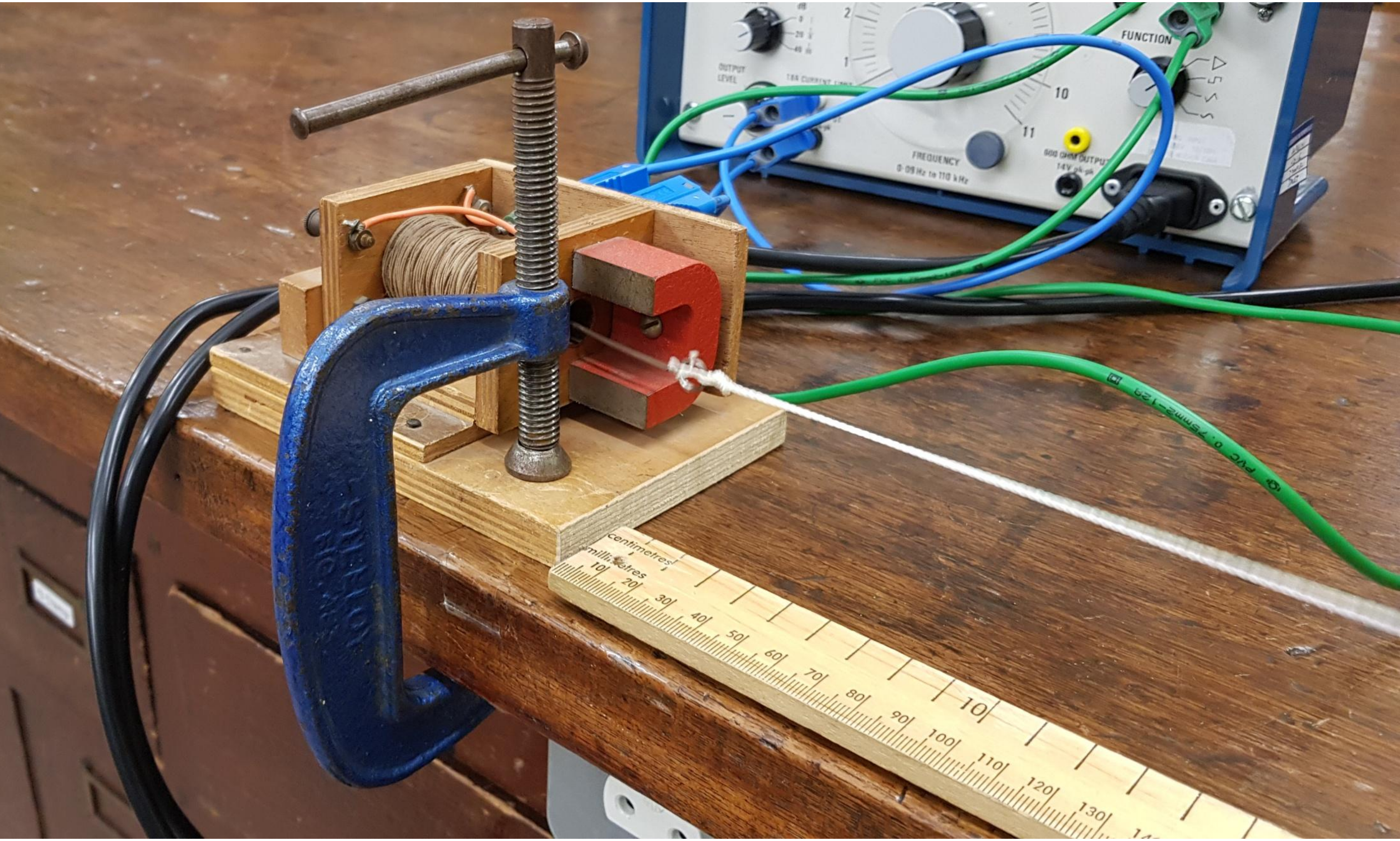
Output to electromagnetic oscillator

Start with *low power,* and increase slowly only if amplitude at resonance is too small to be obvious.

Select sine wave output

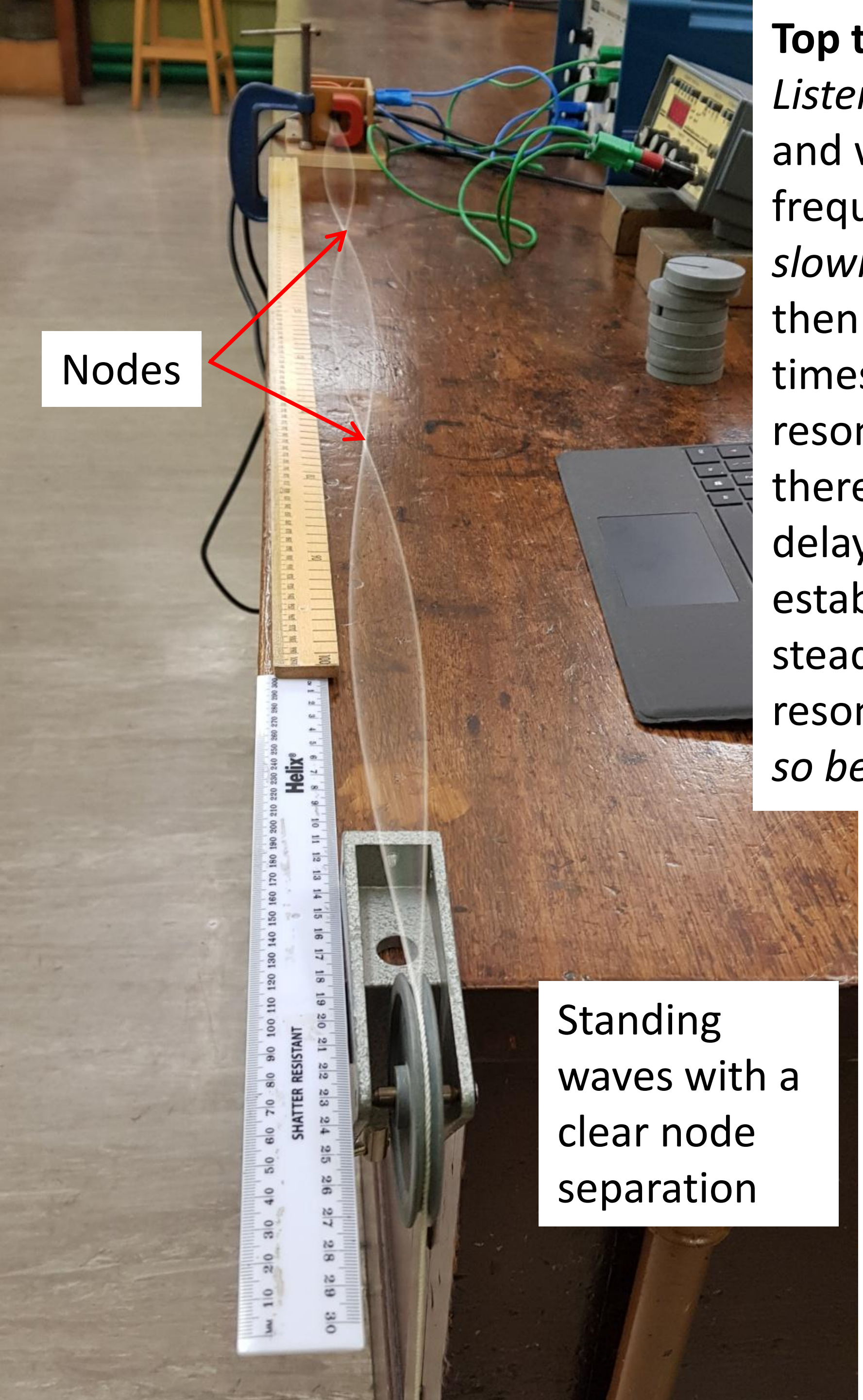
Turn off attenuation

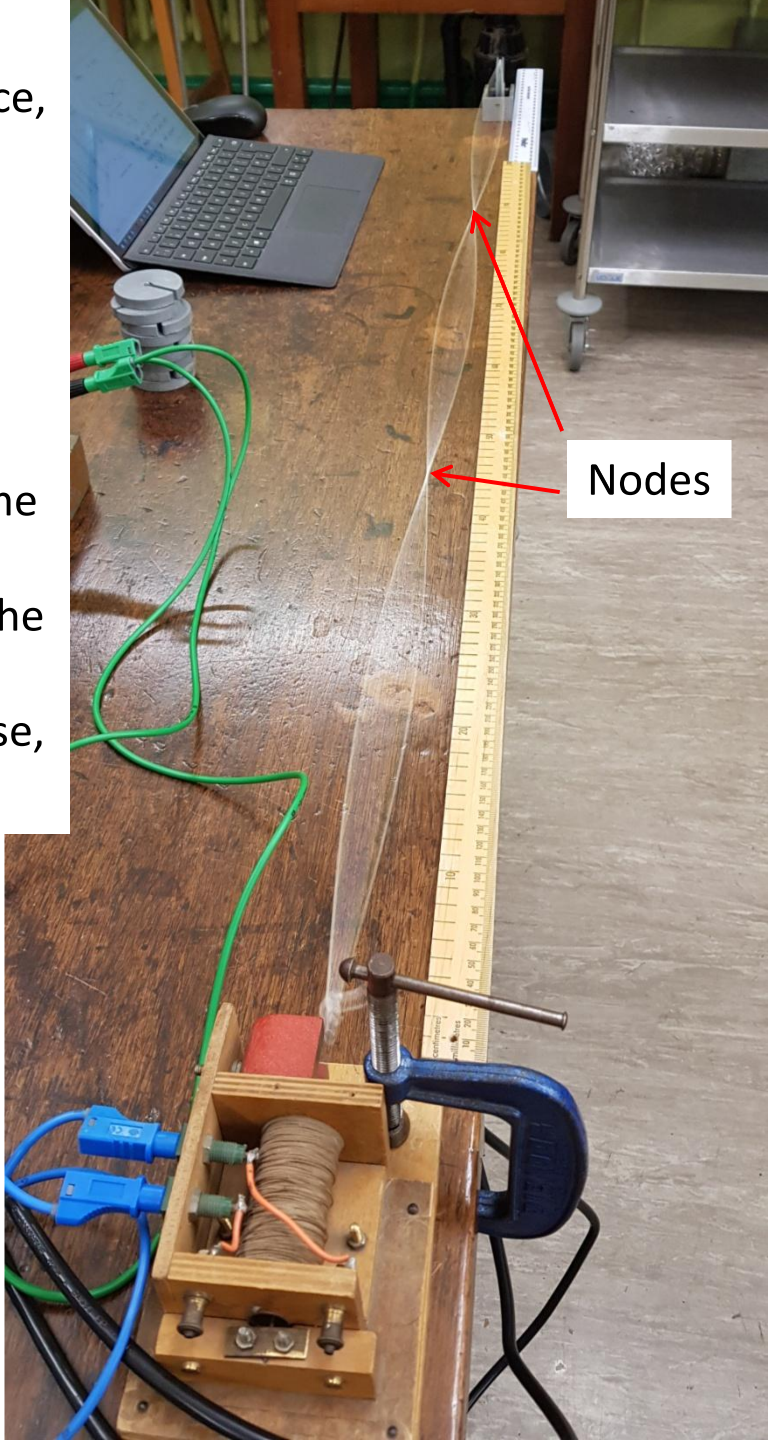
Using masses in the range 0.1 to 1.0 kg, expect strong resonances (i.e. standing waves with clear nodes and maximum amplitude antinodes) in the frequency range 35 to 120Hz.



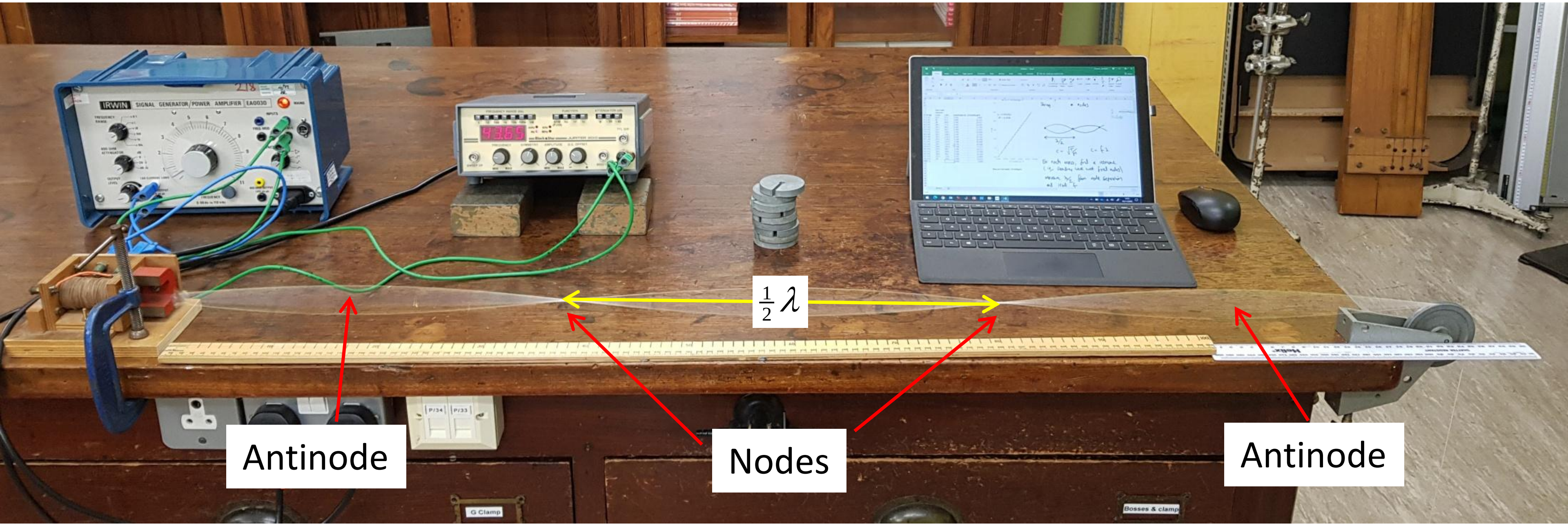
Electromagnetic oscillator. Make sure you G-clamp this to the bench, and don't provide excessive tension. 1kg of mass on the string should be the maximum.

Top tip:
Listen for resonance, and wiggle the frequency knob *slowly* (above and then below a few times) to achieve resonance. Note there is a slight time delay for the establishment of the steady-state resonance response, *so be patient.*





Progressive waves on the tensioned string propagate from the oscillator, reflect (and invert) from the pulley end, and **superpose** with the incoming waves. At certain frequencies, resonant standing waves will form, i.e. where the **nodes** (points of zero movement) are fixed and the **antinodes** have maximum amplitude.



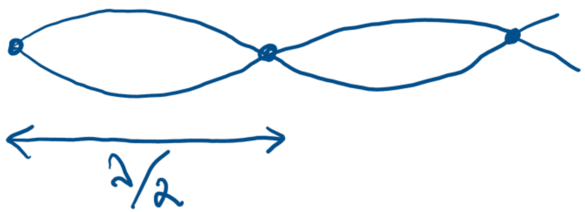
Separation between nodes of standing waves at resonance is **half a wavelength**.

Rather than opt for the *fundamental* frequency, i.e. the lowest standing wave frequency, a higher *harmonic* will **often yield more clearly defined nodes.**

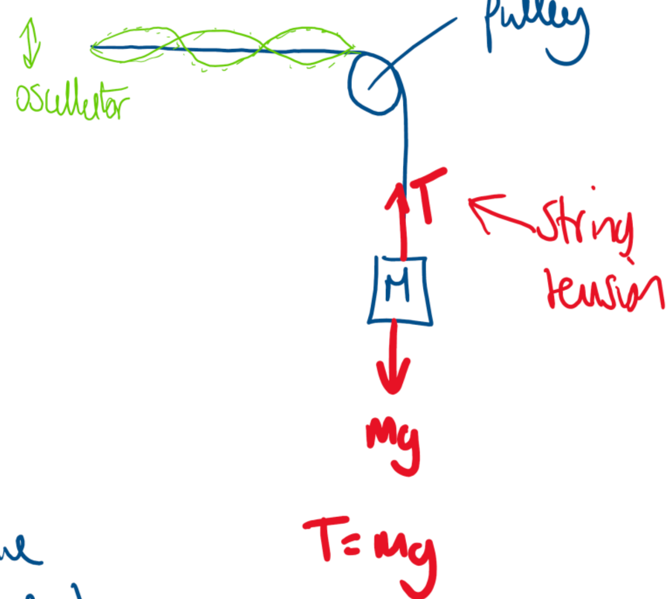
For maximum precision, record the ruler position of **two adjacent nodes**, for each mass on the string, and take the *difference* of these node position measurements to be half a wavelength.

Standing waves on a string.

• nodes



$c = \sqrt{T/\mu}$ $\quad c = f\lambda$



Waves on a tensioned string propagate at speed:

$$c = f\lambda = \sqrt{\frac{T}{\mu}}$$

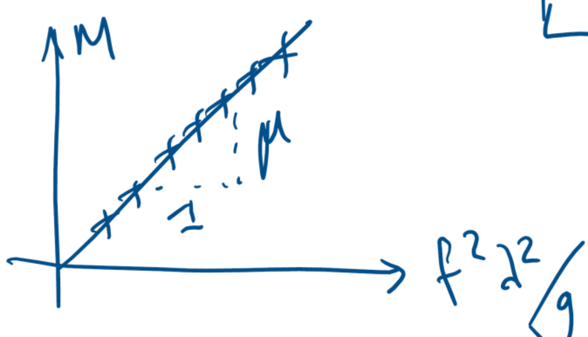
T tension /N

μ mass per unit length (kg/m)

For each mass, find a resonance (ie standing wave with fixed nodes)

Measure $\lambda/2$ from node separation and read f

$f^2\lambda^2 = mg/\mu \quad \therefore \quad M = \mu \dfrac{f^2\lambda^2}{g}$



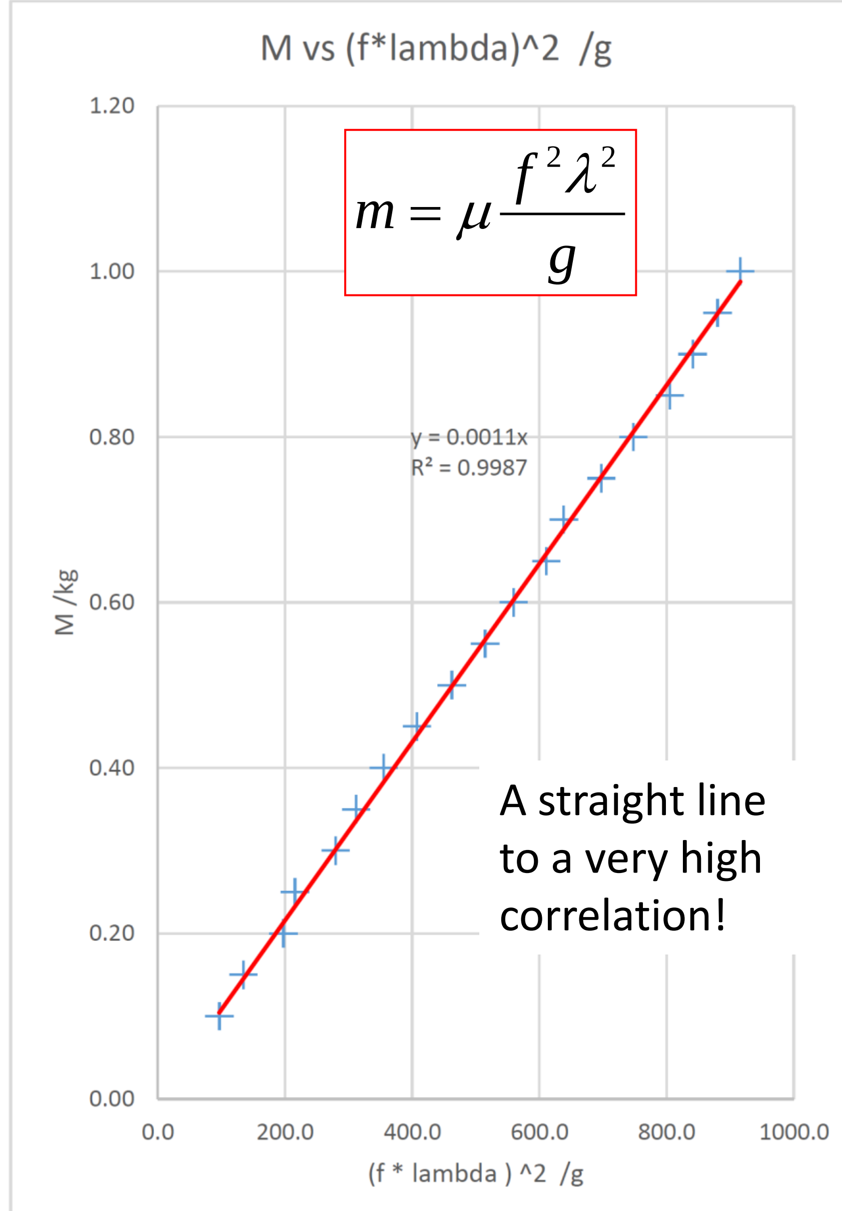
i.e. we anticipate a graph of the mass m hanging off the string plotted against the *square* of (frequency x wavelength / strength of gravity) to be a **straight line**, with **gradient** being the mass per unit length μ of the string.

MELDE'S EXPERIMENT (STANDING WAVE RESONANCE IN A VIBRATING STRING)

Andrew French. Winchester College P5. 3/11/2020.

g /Nkg^-1 | 9.81

M /kg	Inter node separation /cm	f /Hz	wavelength /m	(f*lambda)^2 /g
0.10	41.4	37.2	0.828	96.8
0.20	43	51.2	0.860	197.7
0.30	38	68.9	0.760	279.6
0.40	38.2	77.3	0.764	355.1
0.50	39.1	86.1	0.782	462.4
0.60	39.2	94.5	0.784	559.4
0.70	39.3	100.7	0.786	638.6
0.80	39.5	108.4	0.790	747.6
0.90	39.7	114.4	0.794	841.1
1.00	39.4	120.3	0.788	916.0
0.95	39.4	117.9	0.788	879.9
0.85	39.7	111.9	0.794	804.7
0.75	39.4	105.0	0.788	697.8
0.65	39.3	98.5	0.786	610.9
0.55	39.2	90.6	0.784	514.4
0.45	38.3	82.5	0.766	407.4
0.35	37.6	73.6	0.752	312.0
0.25	43	53.5	0.860	216.0
0.15	41.6	43.7	0.832	134.4



$$m = \mu \frac{f^2 \lambda^2}{g}$$

A straight line to a very high correlation!

Mass per unit length = 0.0011kg/m

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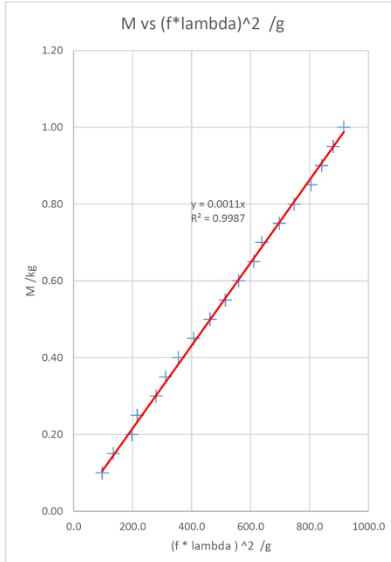
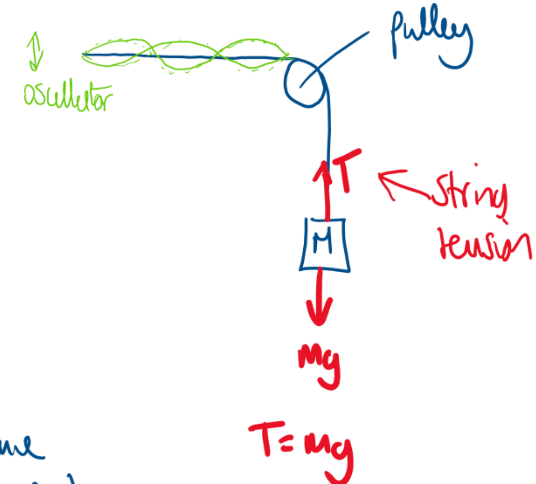
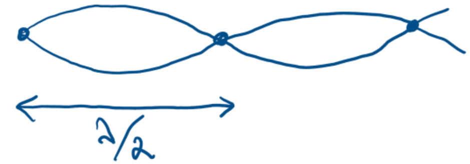


Mass per unit length = 0.0011kg/m

Standing waves on a string. • nodes





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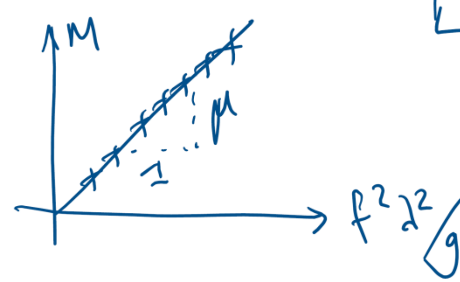

Exemplar Excel sheet for Melde's Experiment.

Top tip: *set up the spreadsheet first*, such that the 'graph plots itself' as measurements are made.