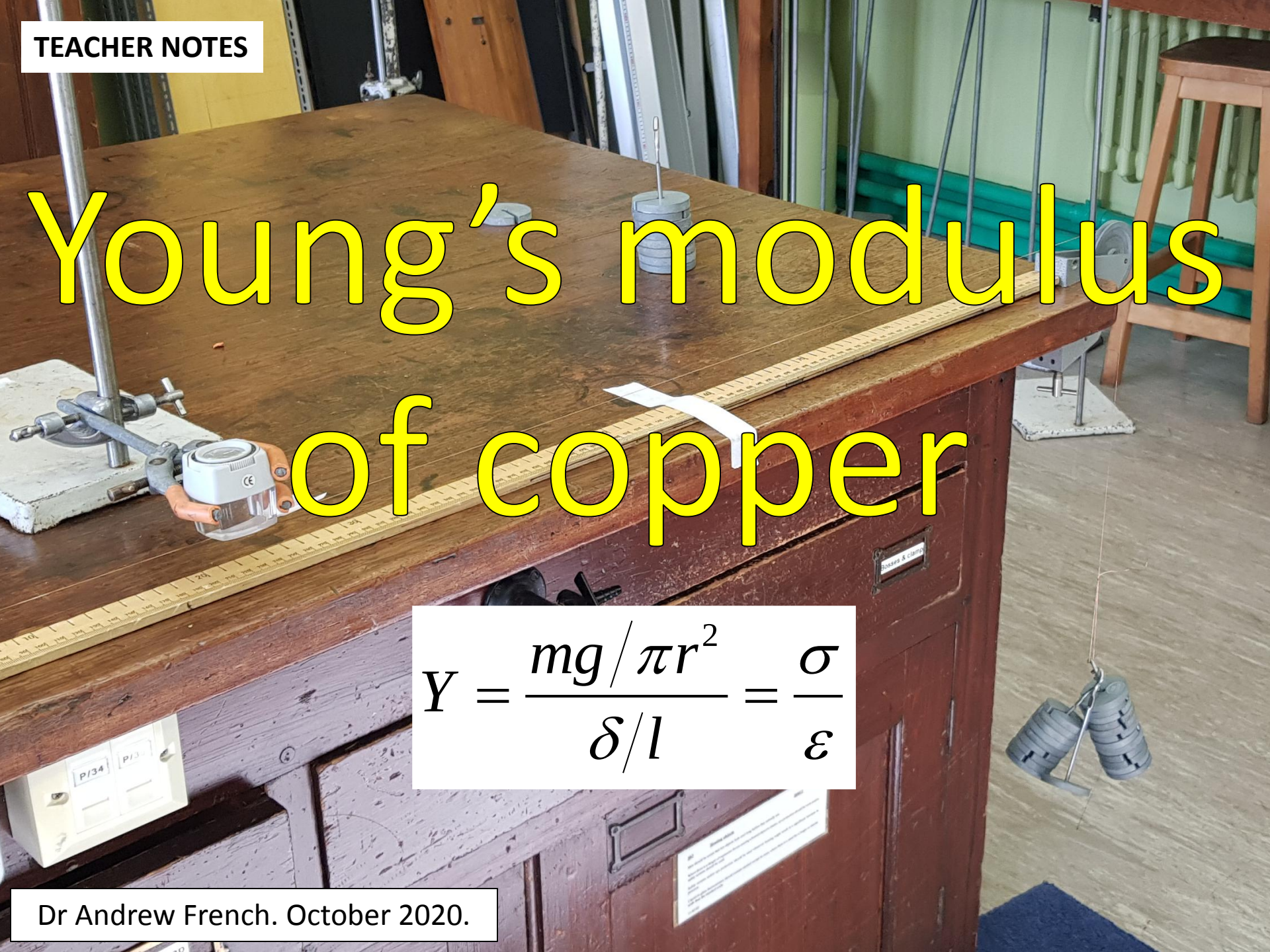
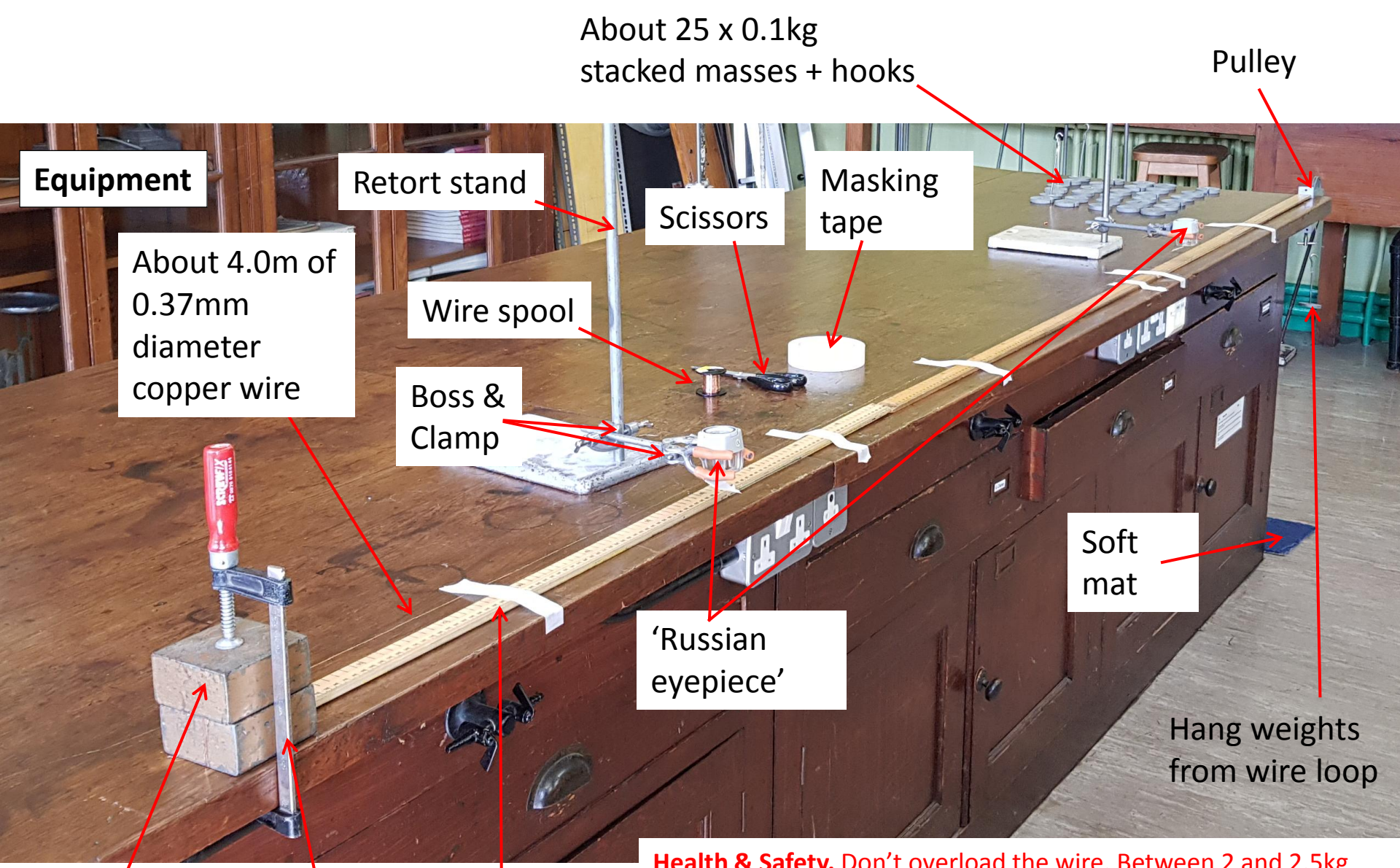
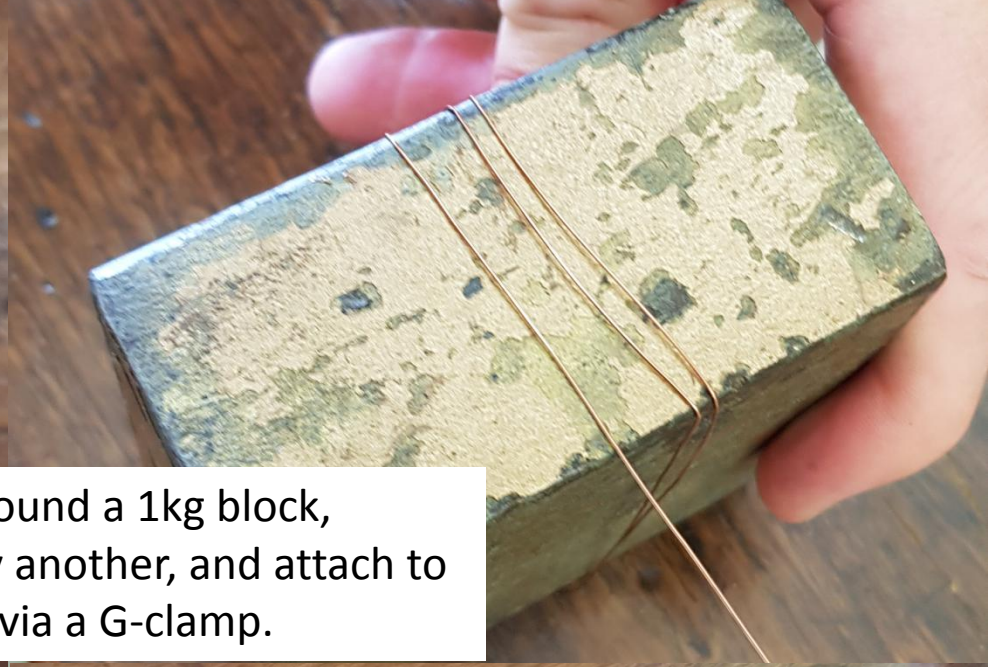
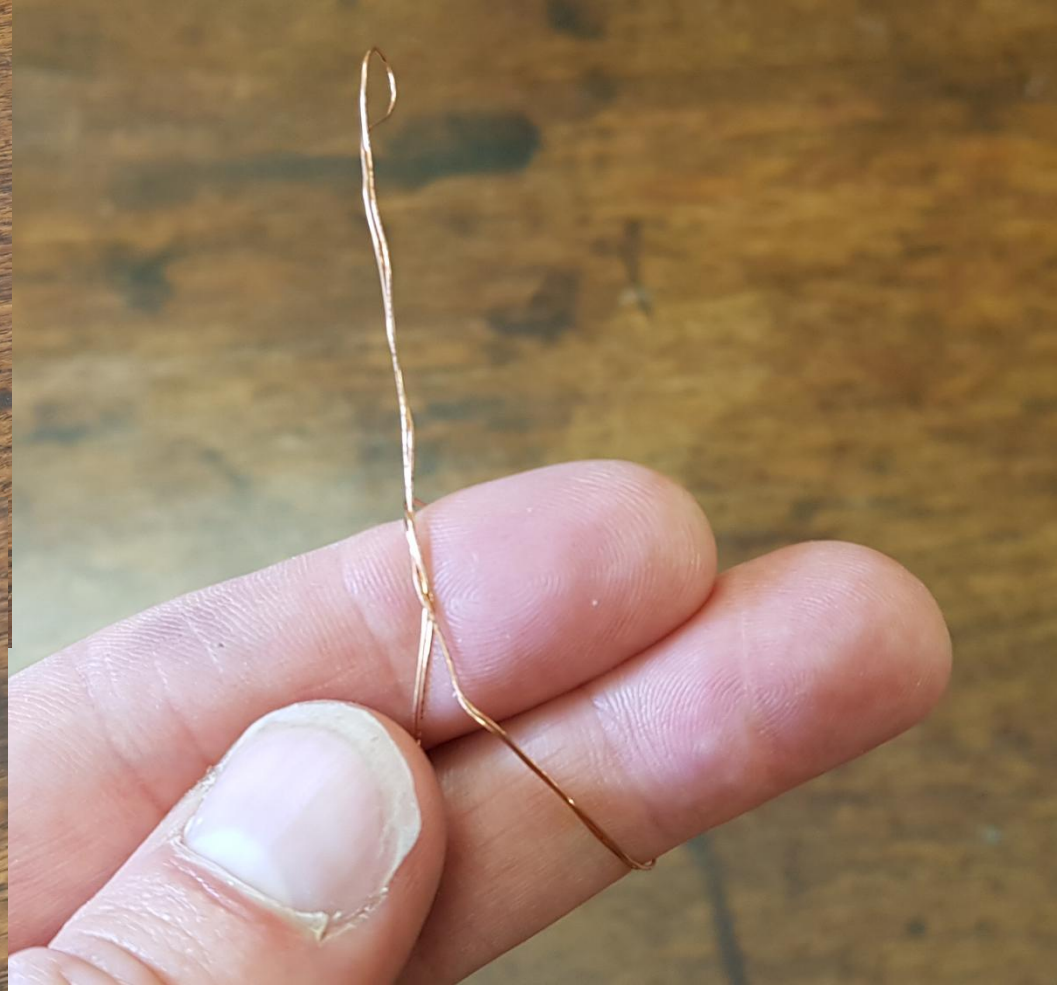

TEACHER NOTES
Young's modulus of copper
$$Y = \frac{mg/\pi r^2}{\delta/l} = \frac{\sigma}{\varepsilon}$$
Dr Andrew French. October 2020.



Health & Safety. Don't overload the wire. Between 2 and 2.5kg should be an absolute maximum. To measure the Young's Modulus you only need the linear region, which should be for masses up to about 1.5kg. Eye protection is recommended just in case the wire snaps. Do use a soft mat to protect the floor (and feet) in case masses are dropped.

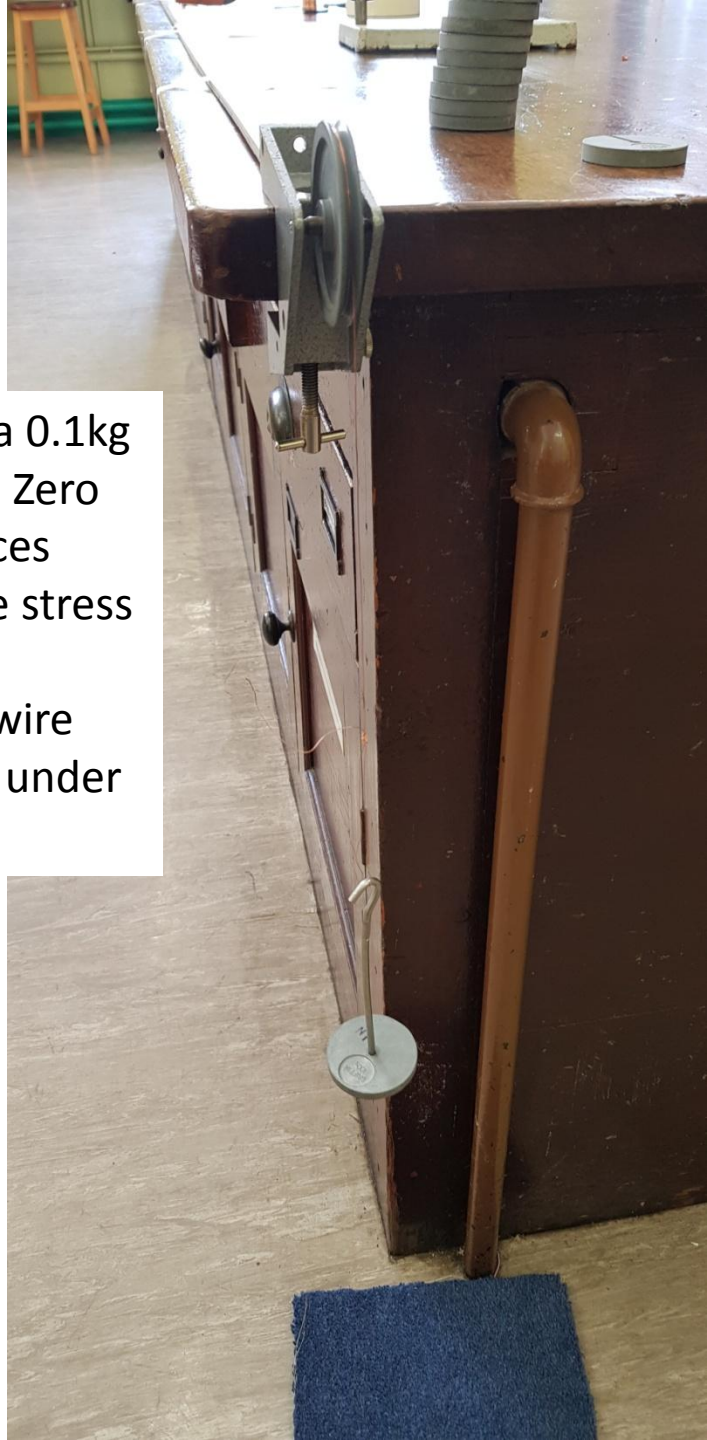


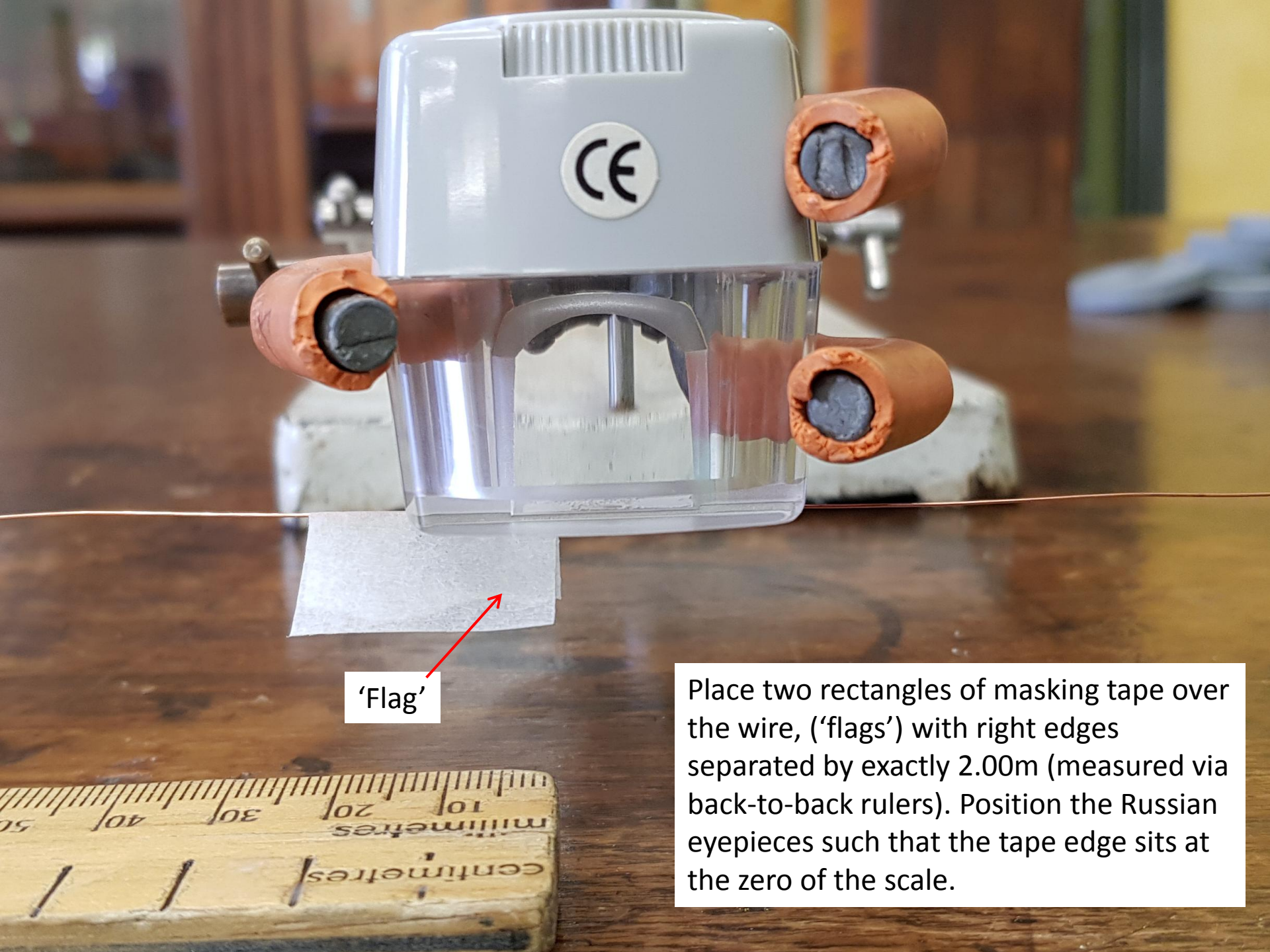
Wind wire round a 1kg block, sandwich by another, and attach to a lab bench via a G-clamp.

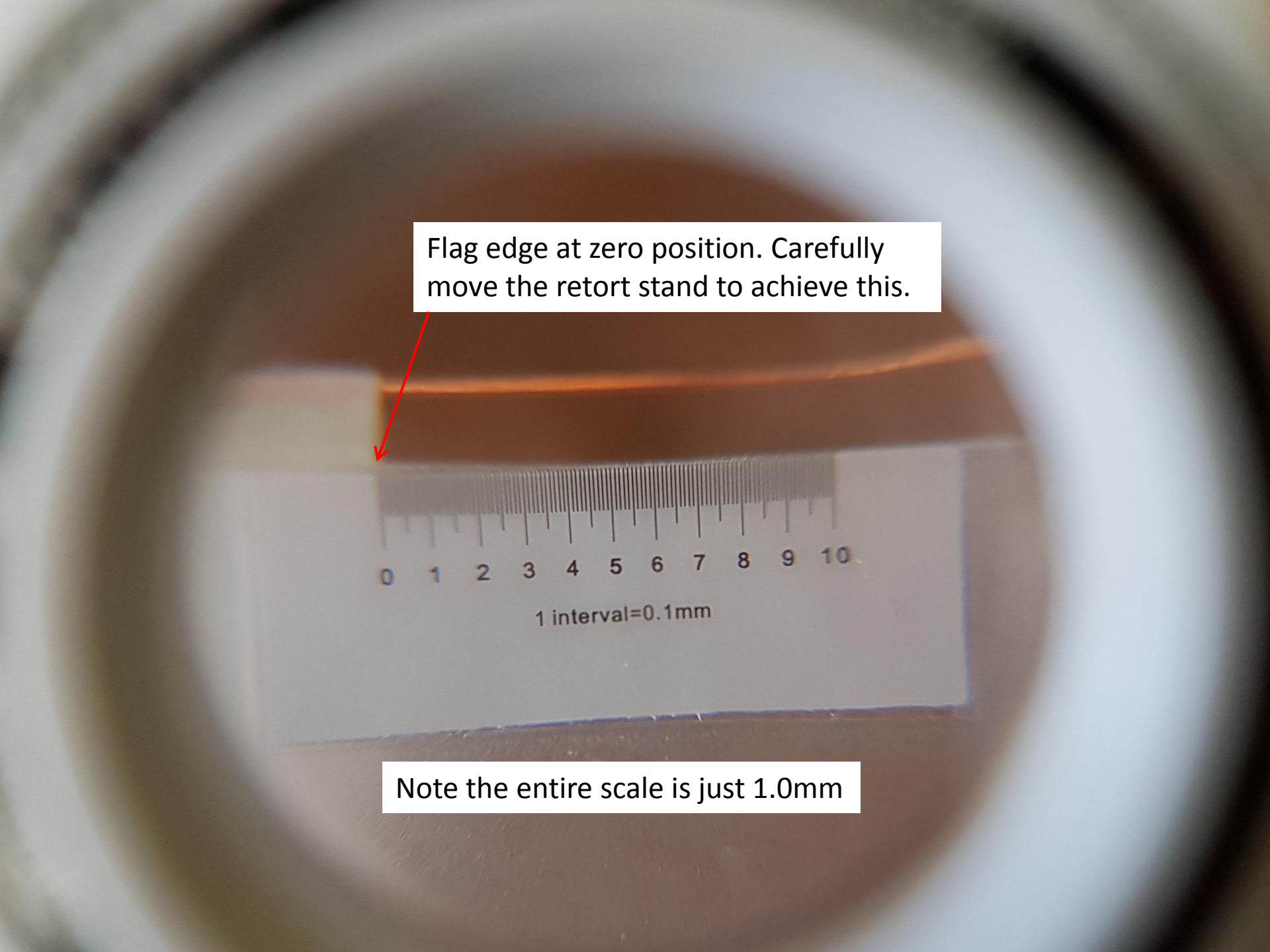


To make a wire loop, double the end (i.e. ‘take a bight of wire’), loop this around two fingers and tie into a small lasso-like loop.

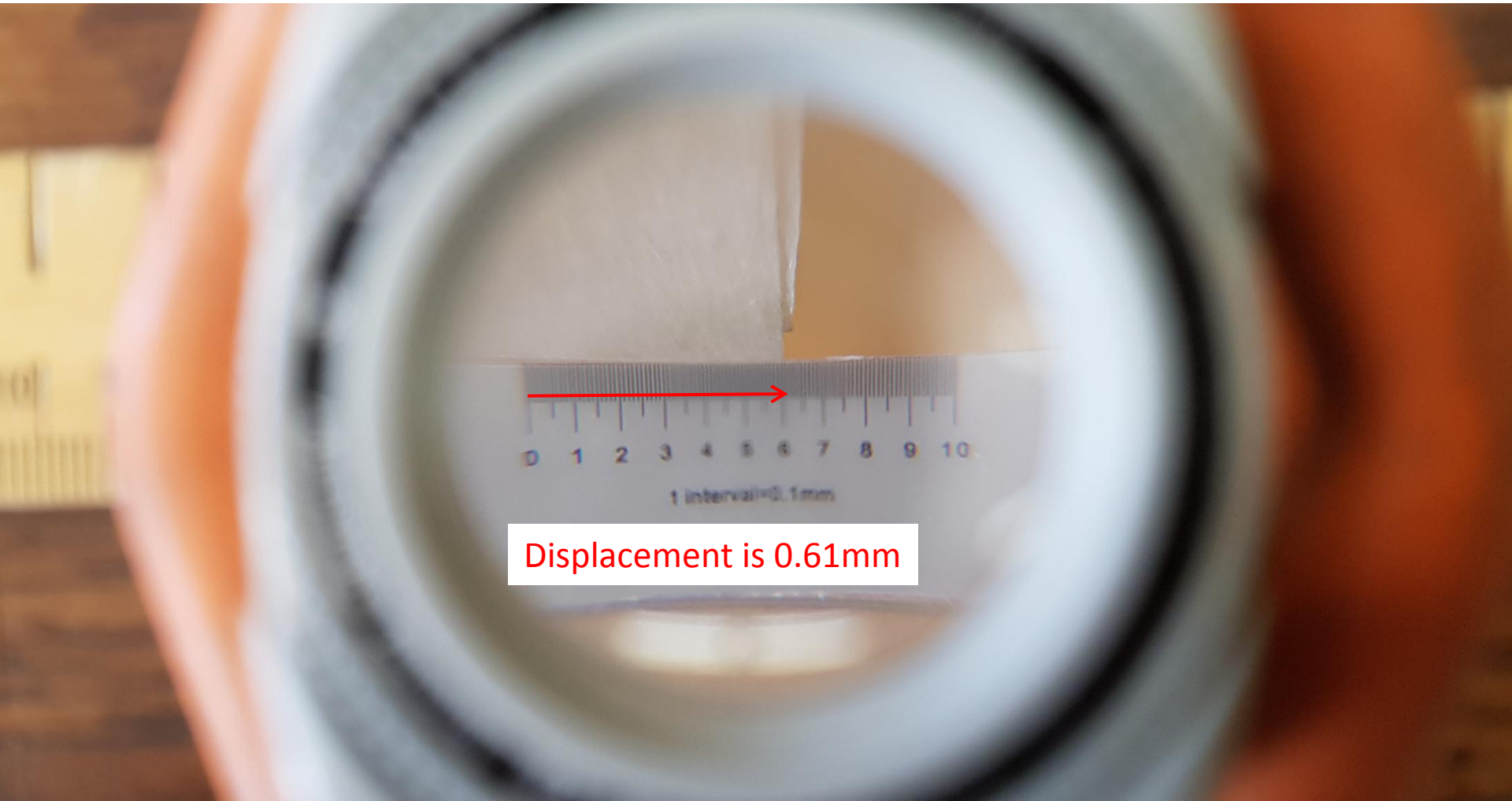
Start with hanging a 0.1kg mass off the pulley. Zero the Russian eyepieces from here. The wire stress and strain will be negligible, but the wire will be straight and under tension.




‘Flag’
Place two rectangles of masking tape over the wire, (‘flags’) with right edges separated by exactly 2.00m (measured via back-to-back rulers). Position the Russian eyepieces such that the tape edge sits at the zero of the scale.


Flag edge at zero position. Carefully move the retort stand to achieve this.
0 1 2 3 4 5 6 7 8 9 10
1 interval=0.1mm
Note the entire scale is just 1.0mm

Now add masses, 0.1 kg at a time, and record the displacements of **both** the flags. The difference in their displacements is the extension δ of the 2.00m wire section. Just before the flag reaches the end of the scale, **zero and add the previous displacement in the table of displacements**. You might need to do this two or three times before significant yield means more than 1mm of extension for an additional 0.1kg added. At this point, the eyepieces cease to be a useful measuring instrument, and measuring directly off a ruler is more appropriate.



To maintain tension, swap the second set of masses with a *third*, that is always 0.1kg more massive than the one hanging. This is preferable to removing a large amount of mass, placing the wire under less tension, and then re-loading with a greater mass.

YOUNG'S MODULUS OF COPPER WIRE

Dr A. French. Winchester College P5. 22/10/2020.

Average radius of wire /m: 1.85E-04

Strength of gravity /Nkg^-1: 9.81

Flag 1 position /mm (minimal load 0.1 kg just to keep witre straight): 0

Flag 2 position /mm: 2000

Inter flag distance (effectively unloaded) /m: 2.000

Masking tape flag displacements viewed using Russian eyepieces

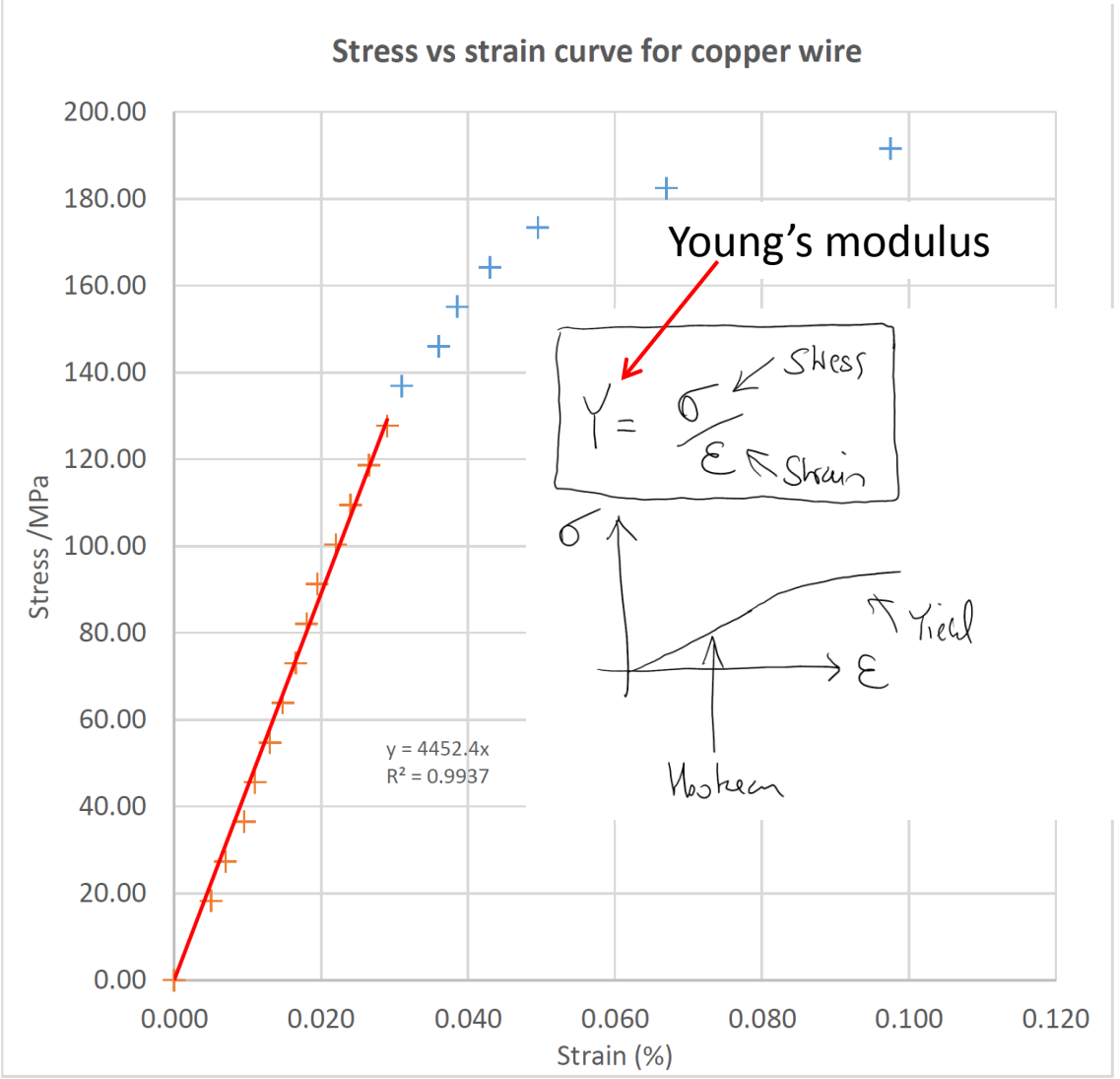
Flag 1 displacement /mm	Flag2 displacement /mm	Load /kg	Extension /mm (delta)	Stress /MPa	Strain %
0.00	0.00	0	0.00	0.00	0.000
0.05	0.15	0.2	0.10	18.25	0.005
0.12	0.26	0.3	0.14	27.37	0.007
0.15	0.34	0.4	0.19	36.50	0.010
0.18	0.40	0.5	0.22	45.62	0.011
0.20	0.46	0.6	0.26	54.74	0.013
0.22	0.52	0.7	0.30	63.87	0.015
0.25	0.58	0.8	0.33	72.99	0.017
0.28	0.64	0.9	0.36	82.11	0.018
0.29	0.68	1	0.39	91.24	0.020
0.32	0.76	1.1	0.44	100.36	0.022
0.33	0.81	1.2	0.48		4
0.36	0.89	1.3	0.53		7
0.38	0.96	1.4	0.58		9
0.41	1.03	1.5	0.62		1
0.44	1.16	1.6	0.72		6
0.47	1.24	1.7	0.77		9
0.52	1.38	1.8	0.86		3
0.56	1.55	1.9	0.99		0
0.67	2.01	2	1.34		7
0.77	2.72	2.1	1.95	191.60	0.098

$$Y = \frac{\sigma}{\varepsilon}$$

$$\sigma = mg/\pi r^2$$

$$\varepsilon = \delta/l$$

The wire should extend in a fairly linear ('Hookean') fashion until after about 1.5kg is added. After this it starts to *yield*. Note the extension after 2.0kg of mass added may take up to a minute to fully complete. If you watch carefully you will see the extension manifest before your eyes!



Using a line of best fit for the Hookean region

$\frac{\sigma/MPa}{\varepsilon \times 100} = 4452$

$\therefore \frac{\sigma}{\varepsilon}/GPa = 100 \times \frac{4452}{1000}$

$= 445$

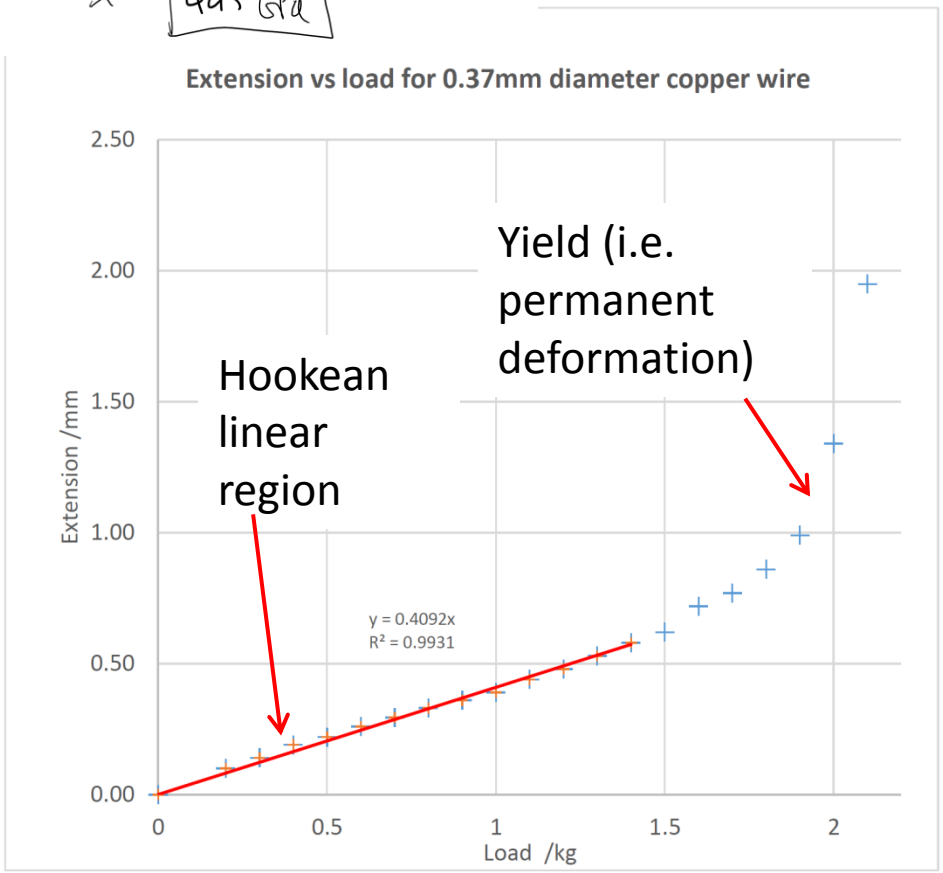
∴ Young's Modulus of Copper is ≈ 445 GPa

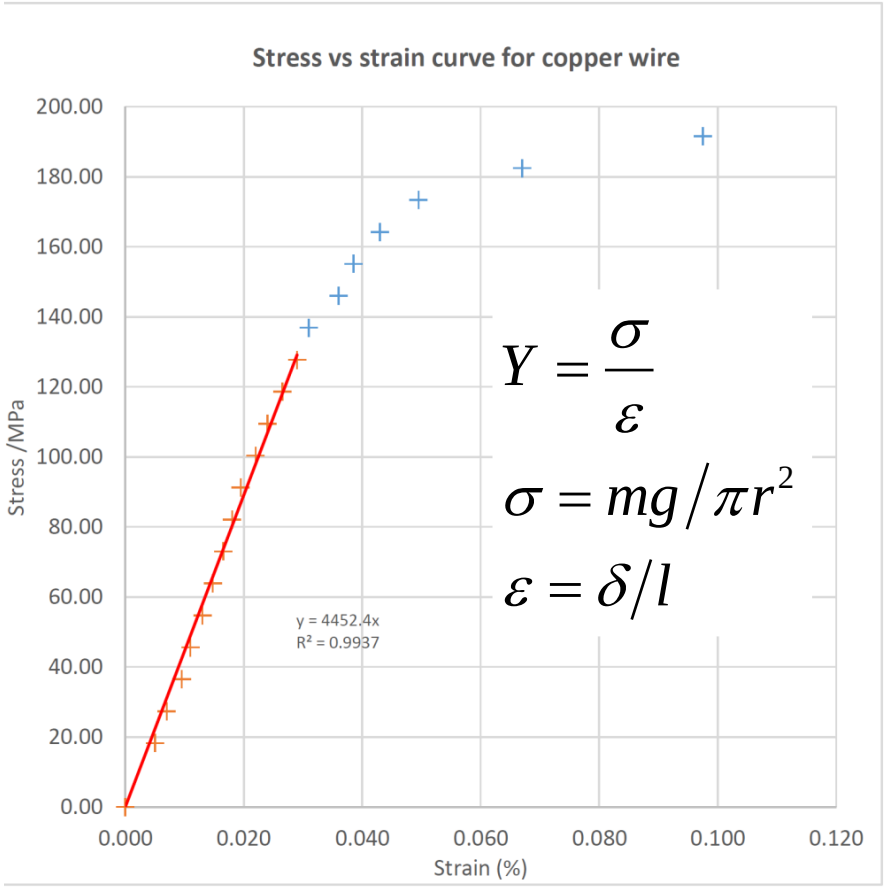
Textbook values:

http://www.mit.edu/~6.777/matprops/copper.htm **130 GPa**

https://www.engineeringtoolbox.com/young-modulus-d_417.html **117 GPa**

Strangely for this experiment (which was repeated to check consistency) the Young's Modulus of the copper wire was calculated to be about 445GPa. This is about 3.4 times the 'official' value. Perhaps the wire is not pure copper?





YOUNG'S MODULUS OF COPPER WIRE

Dr A. French. Winchester College P5. 22/10/2020.

FLAGS MOVED SO BOTH CHANGE SIGNIFICANTLY. FIX INITIAL FLAG SEPARATION AT 2.000m

Average radius of wire /m: 1.85E-04

Strength of gravity /Nkg^-1: 9.81

Flag 1 position /mm (minimal load 0.1 kg just to keep witre straight): 0

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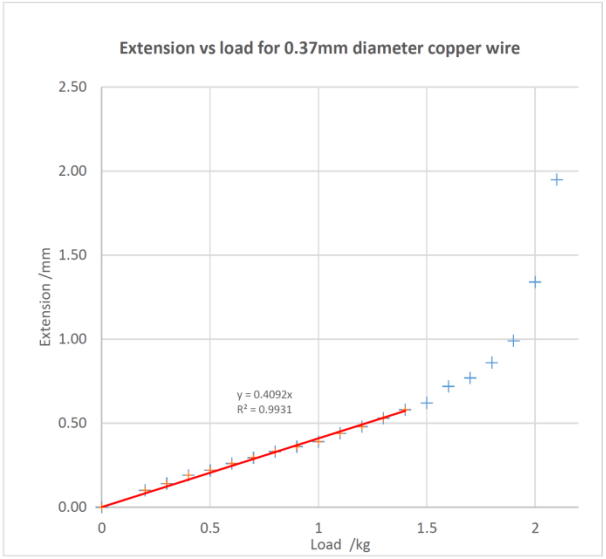
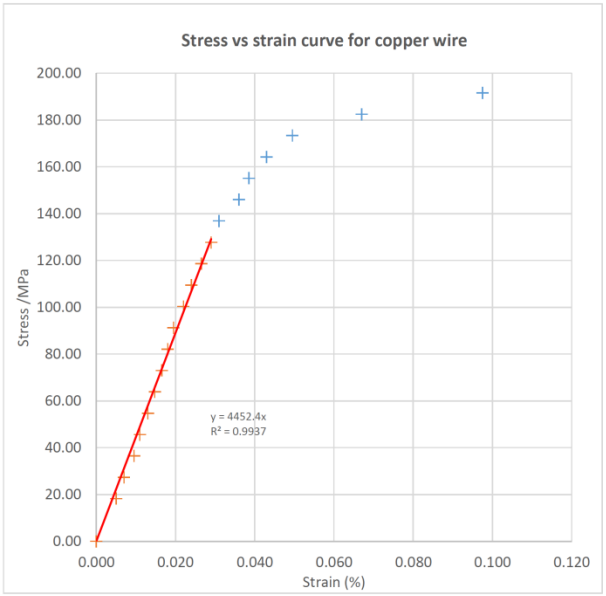
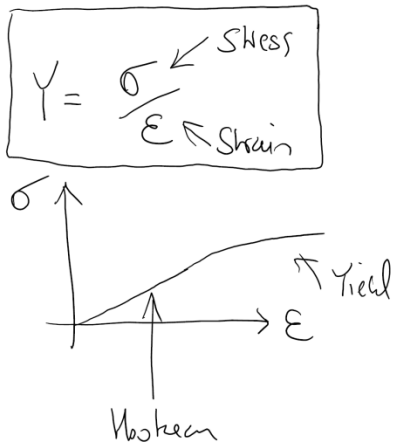
0.29	0.68	1	0.39	91.24	0.020
0.32	0.76	1.1	0.44	100.36	0.022
0.33	0.81	1.2	0.48	109.49	0.024
0.36	0.89	1.3	0.53	118.61	0.027
0.38	0.96	1.4	0.58	127.73	0.029
0.41	1.03	1.5	0.62	136.86	0.031
0.44	1.16	1.6	0.72	145.98	0.036
0.47	1.24	1.7	0.77	155.10	0.039
0.52	1.38	1.8	0.86	164.23	0.043
0.56	1.55	1.9	0.99	173.35	0.050
0.67	2.01	2	1.34	182.48	0.067
0.77	2.72	2.1	1.95	191.60	0.098







Copy of the Excel sheet for the experiment.

Note it was set up in advance to plot the graphs as data was collected.

Using a line of best fit for the Hookean region

$$\frac{\sigma/\text{MPa}}{\varepsilon \times 100} = 4452$$

$$\therefore \frac{\sigma}{\varepsilon}\Big/\text{GPa} = 100 \times \frac{4452}{1000}$$

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