4. Hook's Law

4.1 Objective

- To investigate Hooke's law (the relation between force stretch for a spring) and determine the spring constants of elastic spring.

- To determine the effective mass (m) of the spring.

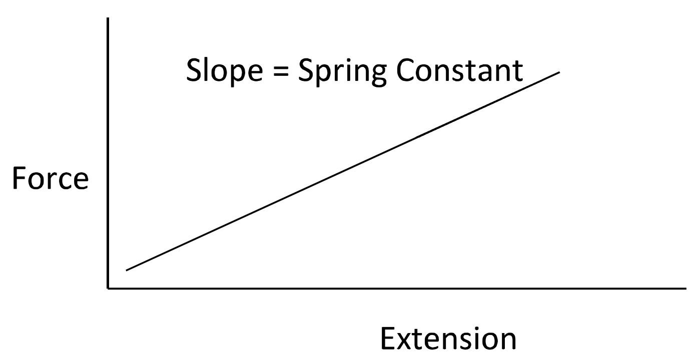
4.2 Theoretical Background

Hooke's Law is stating that "the restoring force acting on an object is proportional to the negative of the displacement (deformation) of the object",

mg

$$F = -k \, \Delta x$$

Here, F is the restoring force provided by whatever is being stretched (or compression), x is the displacement of the thing being stretched (or compression). and k is the spring constant. The negative sign (-) is meaning to the restoring force is in opposite direction to the displacement. The following simple graph of force and extension (or compression) yields a linear slope defined as the spring constant:



A spiral spring is subjected to extension or compression by an applied load conforms to Hook's law, which states that the stress is proportional to the strain, i.e. the load is proportional to the extension it produces. If a graph is drawn, after the initial loading, where some force is required to separate the turns of the spring which are pressed against each other, a straight line is obtained of extension against load. From this portion, the extension (n) in cm per gram of load can be obtained from the gradient: k = g/slope, where the slope=BC / AC (Fig. 2).

If, now, a mass M is attached to the spring, and the spring be extended a further distance x, a restoring force of F is called into play. The spring on being released executes vertical oscillations, the motion is thus simple harmonic and the periodic time T is

$$T = 2\pi \sqrt{\frac{\overset{150}{\cancel{M}} + m}{k}}$$

$$T^2 = 4\pi^2 \frac{M + m}{k}$$

The load must be increased by an amount m equal to the effective mass of the spring.

If a graph of T^2 against M is drawn, a straight line is obtained from which k and *m* can be found.

$$\text{The slope of the line} = \frac{4\pi^2}{k}$$

The intercept OD on the axis of M gives the effective mass (m) of the spring.

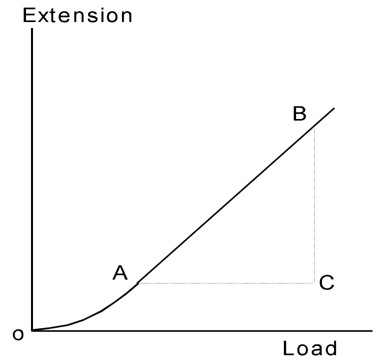


Fig. 2

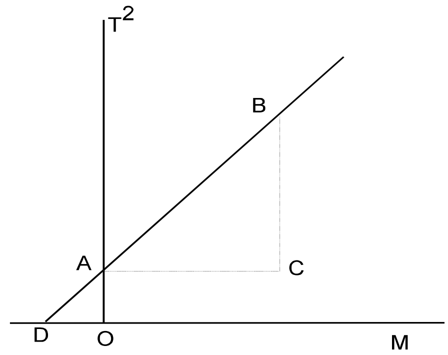
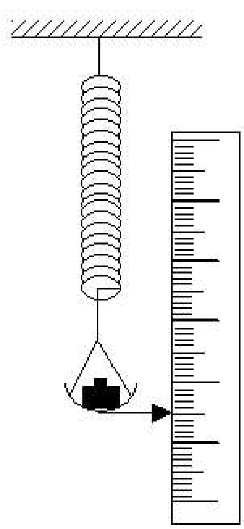


Fig. 3

4.3 Equipment

Spiral spring with attached by plasticine at its end, rigid stand, clamp, meter ruler, scale-pan, weights, and stop-watch.



4.5 Method

(A) To verify Hook's law and to find k.

1- The spring, with scale-pan attached, is firmly clamped and meter scale placed vertically so that the pointer moves lightly over it.

2- The scale readings are also taken when unloading the spring and the means extension thus obtained.

3- Weight is added to the scale-pan and the corresponding extensions of the spring are recorded. This is repeated with different Weights.

4- A graph of extension against load is plotted from which the extension (n) per unit load is calculated.

(B) To determine k and the effective mass (m) of the spring.

1- A Weight is added to the pan which is set in vertical vibration by giving it a small additional displacement.

2- The periodic time (T) is obtained by timing 10 vibrations. This is repeated with different Weights.

3- A graph of T^2 against Weights is plotted, from which k and m are found.

4.6 Results

(A)

Load M (g)	Extensions		Mean extension
	Load increasing cm	Load decreasing	
100	9.8		
200	19.6		
300	29.4		
400	39.3		
500	49		

$mgf = -kax$

600	58.7		
700	68.7		
800	78.5		

From Fig.2 with extension expressed in meters and load in Kg for SI units

k = N M^{-1}

(B)

M g	Time for 20 s Vibrations	T s	T^2 s^2
100	19.6	0.98	0.96
200	23.15	1.16	1.34
300	26.3	1.32	1.73
400	29	1.45	2.1
500	31.5	1.58	2.5
600	34	1.7	2.89
700	36	1.8	3.24
800	38.14	1.91	3.34

From fig. 3

k = N M^{-1}

m = Kg

Errors Analysis:

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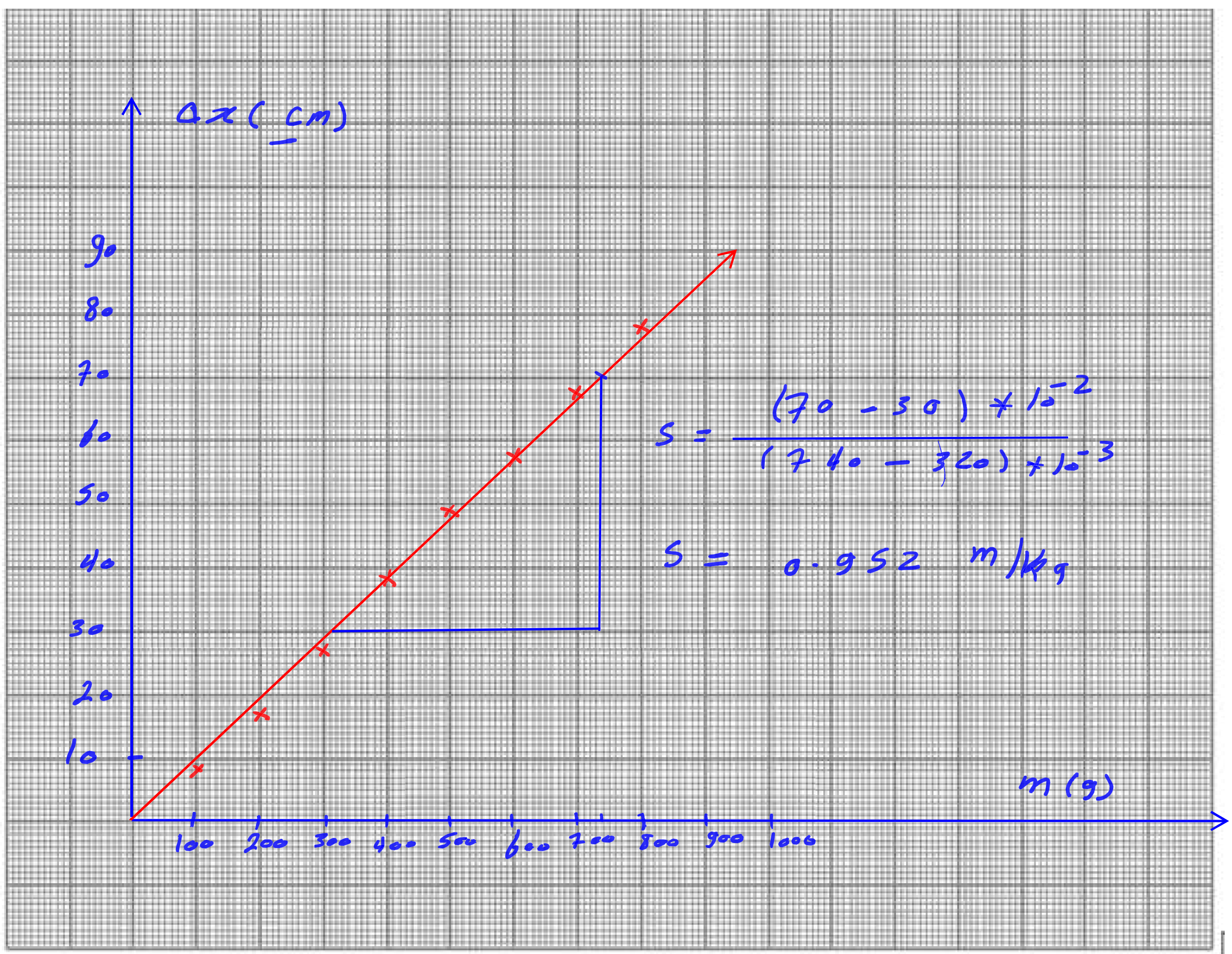
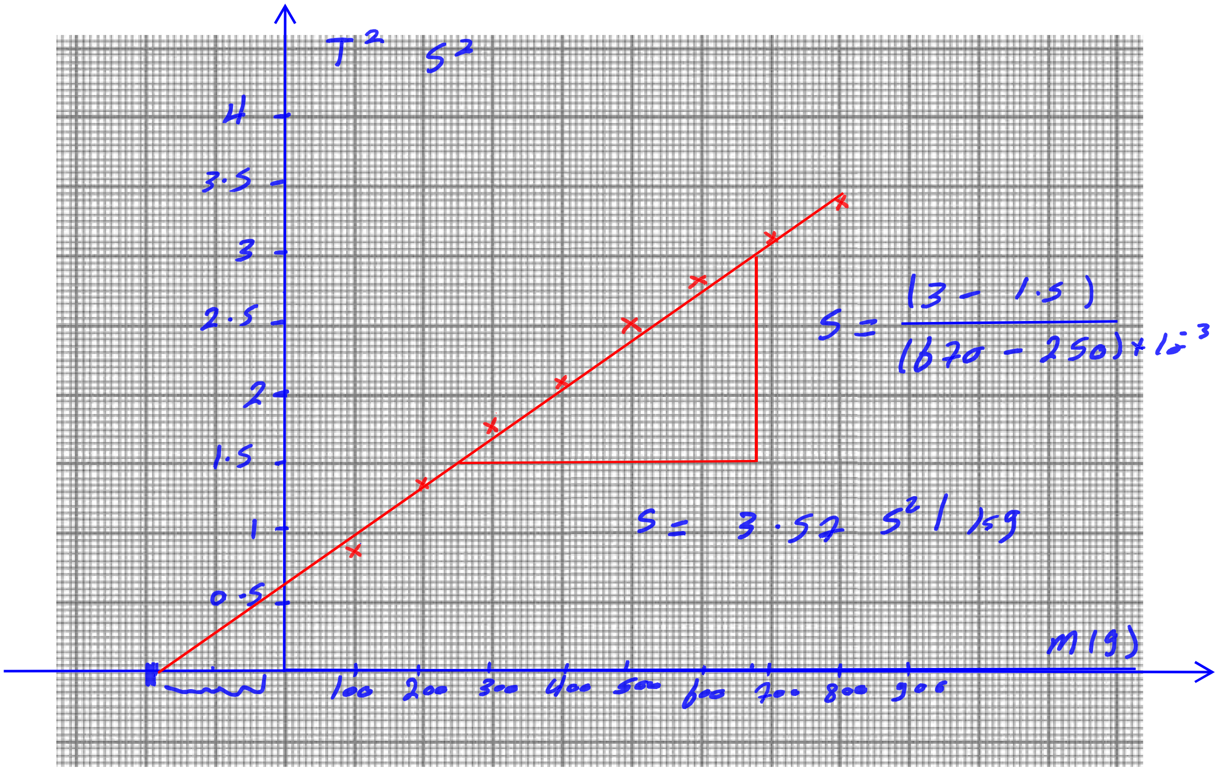


$$f = \frac{\cancel{m}g}{\cancel{m}} = -k\frac{\Delta x}{m} \Rightarrow g = -k\,s$$

$$k = \frac{g}{s} = \frac{9.81}{0.952} = 10.3 \text{ N/m}$$



$$T = 2\pi \quad \frac{m+M}{k} \Rightarrow T^2 = 4\pi^2 \frac{M_1}{k}$$

$$S = \frac{T^2}{m} = \frac{4\pi^2}{k} \Rightarrow k = \frac{4\pi^2}{3.57} = 11 \ N/m$$

$$M = +180\ g = 0.18\ kg$$