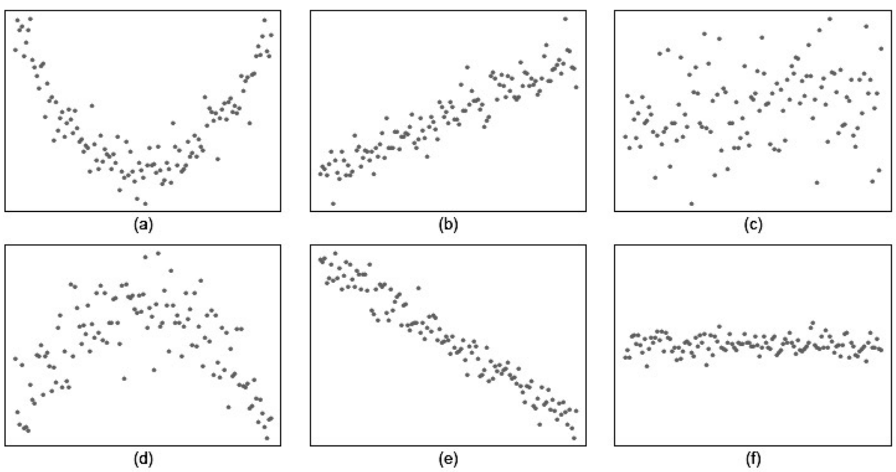
Laboratory 1 Pre-Lab (value: *2 marks*)

Submit to your lab instructor ***by 4pm the day BEFORE*** your lab period.

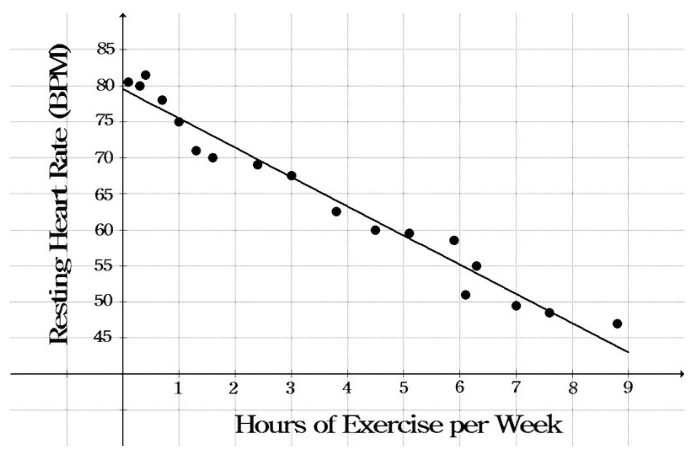
1. How much force is required to stretch a spring 9.0 cm if it requires 22 N to stretch it 3.0 cm?

2. Write the equation for the ***slope-intercept form*** *of a straight line* & identify/label each part.

3. Circle all *linear* graphs from those shown below and mark them with a '+' , '-' or 'zero' slope.



4. Calculate the slope of the (linear) data shown below. Show *all* work, points chosen, units, etc.



Laboratory 1: Force Constant of a Spring

Experiments are to be completed on the provided laboratory sheets below; any supporting material (eg. graphs) should be attached. Make sure your name and your partners name(s) are clearly indicated on the front page of your lab. **Neatness and clarity count!** Explain your answers clearly and concisely. If an equation is to be used in a calculation, *write the equation down* and then insert numbers and solve. Report your final answer to the appropriate significant figures.

The lab write-up is due by the end of the lab. Late labs will not be accepted.

APPARATUS

Bench stand and support rod, spring, pointer, mass hanger, slotted masses, stop watch, stand with metre-stick clamp, metre stick.

OBJECTIVE

1. To determine the force constant of a spring directly using Hookes law and indirectly from its period of oscillation.

THEORY

Part A. Hooke's Law applied to a vertical spring

When an ideal spring is stretched by an applied force, the elongation of the spring is proportional to the applied force. This is Hooke's Law for a spring, which may be written as

$$F = kx \tag{1}$$

where k is the force constant of the spring and x measures the amount the spring is stretched. Consider a spring that hangs vertically with a hanger and pointer attached, as shown in Figure 1a.

Applying Hooke's Law, it follows that

$$M_o g = k(y_o - y_u)$$

and

$$(M + M_o)g = k(y - y_u)$$

where M_o is the mass of the hanger & pointer (as well as an extra factor due to the mass of the spring itself) and M is the additional mass added. Rearranging these equations results in

$$y = \frac{g}{k}M + y_o$$

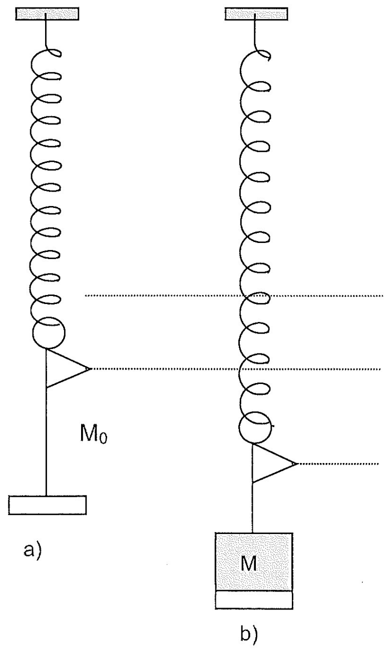


Figure 1: The extension of a vertical spring by the addition of mass.

Comparing this equation with the *slope-intercept form for a straight line*, $y = mx + b$, a graph of y (pointer position) versus M (additional mass added) is equivalent to a straight line with a slope m equal to

$$m = \frac{g}{k} \quad (2)$$

Part B. Oscillation of a vertical spring

If the mass $M + M_o$ is pulled down below the equilibrium position shown in Figure 1b and then released, the system will oscillate in simple harmonic motion with a period, T, given by

$$T = 2\pi\sqrt{\frac{M + M_o}{k}}$$

This can be rewritten as

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

Comparing this equation with the *slope-intercept form for a straight line*, a graph of T^2 (period squared) versus M (additional mass added) is equivalent to a straight line with a slope m equal to

$$m = \frac{4\pi^2}{k} \quad (3)$$

NAME:
DATE: PARTNER:

Laboratory 1:
Force Constant of a Spring

DATA COLLECTION

1. Clamp the stand to the bench and suspend the spring from the short horizontal rod. Attach the pointer and the mass hanger to the lower end of the spring ∼40 cm above it. Mount the metre stick in the clamp **with the zero end 'up' and the cm scale facing out**.

2. [***4 marks***] Place a 100 g mass (the initial *total added mass*, M) onto the mass hanger and record the *position* y of the pointer, at rest, in the table. Raise the mass hanger slightly (∼ 2 cm with the tip of a pencil) and release it. Make certain the mass is oscillating *vertically* and NOT bouncing side-to-side. **Measure the time** T_{10} for 10 *FULL oscillations* of the system. **Do this a couple of times to make CERTAIN you are getting consistent times AND counting 10 FULL oscillations**. *Hint: Start counting/timing with 0 ('zero') rather than 1 as you only COMPLETE the first oscillation ('one') a full cycle AFTER you begin.* Record a (consistent) 'typical' value for T_{10} in Table 1. Increase M by 50 g and repeat, up to a total added mass of $M = 300$ g. ** NOTE: M is the total ADDED mass & EXCLUDES the mass of the hanger; it is good to ±1g. **

M (kg)	y (cm)	y (m)	T_{10} (s)	T_{avg} (s)	T^2_{avg} (s^2)
0.100					
0.150					
0.200					
0.250					
0.300					

Table 1: vertical spring observational and calculated data.

3. [***2 marks***] **Calculate the average time** for ONE oscillation, T_{avg}, and its square, T^2_{avg}. **Show a FULL set of sample calculations** for the *ENTIRE first row of the table* (i.e. $M = 0.100$ kg).

Part A:

1. [*4 marks*] **Plot a graph of pointer position y (m) vs. total mass added M (kg)**. Fill the graph paper as much as possible and label your graph *FULLY*, i.e. title, axes, units, data points, etc.

2. [*3 marks*] **Draw the *line of best fit* for your graph**. Pick and clearly mark two (widely separated) and easy-to-read points **ON this line** (they do NOT have to be data points!). *Using these points*, determine the rise (Δy) and run (Δx), using appropriate significant figures and units:

rise (Δy) = ____________________ = _______ *run* (Δx) = ____________________ = _______

Calculate the slope ($\Delta y/\Delta x$) of your line. Show ALL work, including sig fits, units, etc.

3. [*3 marks*] **Calculate the force constant k of the spring** (in units of N/m) using Equation 2 and your calculated slope (above). Assume $g = 9.81$ m/s^2. Show ALL work/steps, etc.

Part B:

1. [***4 marks***] **Plot a graph of the square of the average period T_{avg}^2 (s^2) vs. total mass added M (kg)**. Fill the graph paper as much as possible and label your graph *FULLY*.

2. [***3 marks***] **Draw the *line of best fit* for your graph**. Pick and clearly mark two (widely separated) and easy-to-read points **ON this line** (they do NOT have to be data points!). *Using these points*, determine the rise (Δy) and run (Δx), using appropriate significant figures and units:

rise (Δy) = ____________________ = _______ *run* (Δx) = ____________________ = _______

Calculate the slope ($\Delta y/\Delta x$) of your line. Show ALL work, including sig fits, units, etc.

3. [***3 marks***] **Calculate the force constant k of the spring (in units of N/m)** using Equation 3 and your calculated slope (above). Show ALL work/steps, etc.

4. [***2 marks***] **Compare** your values of k (using *percent difference*) & **comment** on their agreement.

5. If your graphs are linear AND your k values are consistent then dismantle and tidy the apparatus.