Lab 8: Simple Harmonic Motion

- Part I: Mass on spring

(a) Preliminaries:

- Theory: a spring pulls with a force of magnitude $k\Delta x$ towards its equilibrium (note omission of negative). $k$ accounts for the stiffness of the spring.

- Experiment: measure $k$, by taking 4-5 masses (roughly equally spaced up to 750 g) and hanging them. $F_{spring}$ is equal to $mg$ if mass is at rest, so then $F_{sp}$ vs. $\Delta x$ can be plotted; slope should be $k$. *linest* function will give $k \pm \Delta k$. Now that we know about $k$, we have that piece of preliminary info for the next part.

- N.B. $\Delta x = \text{(stretched length)} - \text{(original equilibrium length)}$ where ‘equilibrium length’ is when there are no masses (not even the hanger) on the spring.

- To be safe, work in SI units throughout. You can almost always tell if you’ve used the wrong units by looking at the value you get for the predicted period.

- To get predicted period, use a mass of your choice (the lab manual suggests 100g), but stick to it when you do the period measurement.

- To get error in predicted period, use tactic you used in the projectile experiment:

\[
\Delta T = T_{max} - T_{nominal} \tag{1}
\]
where

\[ T_{\text{nominal}} = 2\pi \sqrt{\frac{m}{k}} \]

\[ T_{\text{max}} = 2\pi \sqrt{\frac{m}{k - \Delta k}} \]

- Since \( F = -kx \), units of \( k \) = \( \frac{\text{units of } F}{\text{units of } x} \)

(b) Main Spring part:

- \textit{Theory}: says that \( T = 2\pi \sqrt{\frac{m}{k}} \). Also, explicitly note that \( T \) does NOT depend on \( A \) (amplitude of motion); this is what makes harmonic motion “simple”... no amplitude dependence. \( T \) here is the period of oscillation i.e. time taken for mass to get back to where is started the second time round with the SAME VELOCITY (i.e. moving in the same direction too).

- A theoretical \( T_{\text{min}} \), \( T_{\text{mean}} \), and \( T_{\text{max}} \) can be obtained by plugging \( k_{\text{min}} \), \( k_{\text{mean}} \), \( k_{\text{max}} \) from preliminary part into \( T \) formula.

- \textit{Experiment}: Get time it takes to do 10 oscillations, divide by 10 to get \( T \). (this minimizes reaction time error). Each group member should do this independently, repeat a few times, so 4-5 different experimental \( T \) values are obtained.

- \( T \pm \sigma_{\text{mean}} = T_{\text{experiment}} \pm \text{error} \).

- \textbf{PLEASE NOTE: PLEASE IGNORE +1/3 MASS PART. IF YOU USE A MASS LARGER THAN RECOMMENDED IN THE LAB MANUAL (they recommend 100g; I would say try 200 g), THEN THE RESULTS SHOULD COME OUT VERY WELL, SINCE THE SPRING MASS IS A MORE NEGLIGIBLE AMOUNT OF THE TOTAL SYSTEM MASS.}
Ideally, ranges of $T_{\text{experimental}}$ and $T_{\text{theory}}$ (note both have ranges) will overlap.

- Part II: Pendulum
  
  (a) Skip Parts B(1) and B(4)
  
  (b) Theory: $T = 2\pi \sqrt{\frac{L}{g}}$. Also, explicitly note that $T$ does NOT depend on mass, or starting angle IF SMALL.
  
  (c) Mass and starting angle (IF SMALL) doesn’t matter. You can roughly test the mass dependence (result sheet Part B1) but, by definition, YOU WILL NEED TO KNOW THAT THE STARTING ANGLE NEEDS TO BE SMALL, AND THEREFORE NEED TO KEEP IT SMALL DURING ALL DATA TAKING. Therefore, result sheet part B4 can be neglected.
  
  (d) Experiment: Pick 4-5 different lengths, and plot $T^2$ vs. $L$ (Can you see why, from the theoretical formula above, plotting this should yield a straight line with slope $\frac{4\pi^2}{g}$?). Linest function can be applied to get slope $\pm$ error. This can be inverted to find $g_{\text{experimental}} \pm$ error, which can be compared against $g_{\text{theory}} = 9.8 m s^{-2}$. How does your experimental value of $g$ compare with the expected value? (Manual doesn’t ask you for this, but it’ll be a good exercise to see if it works out)