

Quiz 5

Simple harmonic motion is how we observe an object that oscillates back and forth on a spring or pendulum about an equilibrium point. My real-life example is my water bottle swinging in my hand as I walk. To represent this, I used a 500ml bottled water to make a pendulum, measured in time required to complete five cycles. I tied it to a cable using tape as markers to ensure a consistent length as I released the system from rest. I kept the bottle full so my mass would be consistent.

System:



Calculations:

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Length measured
period for each trial

$L = 20 \text{ in}$
 $1 \text{ in} = 0.0254 \text{ m}$
 $\downarrow$
 $L = 0.508 \text{ m}$

$T = \frac{t}{5}$, where t is the time for 5 cycles
 $f = \frac{1}{T}$, $\omega = 2\pi f$

Avg. t (s)	T (s)	f_n (Hz)	ω_n (rad/s)
7.27	1.454	0.688	4.32

Calculated

$\omega_n = \sqrt{\frac{g}{L}} = \sqrt{\frac{9.81 \text{ m/s}^2}{0.508 \text{ m}}} = 4.39 \text{ rad/s}$
 $f_n = \frac{1}{2\pi} \omega_n = \frac{1}{2\pi} 4.39 \text{ rad/s} = 0.699 \text{ Hz}$

$T = \frac{1}{f}$
 $T = 1.430 \text{ s}$

Equation of motion

$\ddot{\theta} + \frac{g}{L} \sin \theta = 0$
 $\sin \theta \approx \theta$
 $\ddot{\theta} + \frac{g}{L} \theta = 0$

	measured	calculated
f_n	0.699	0.688
ω_n	4.32	4.39
T	1.454	1.430

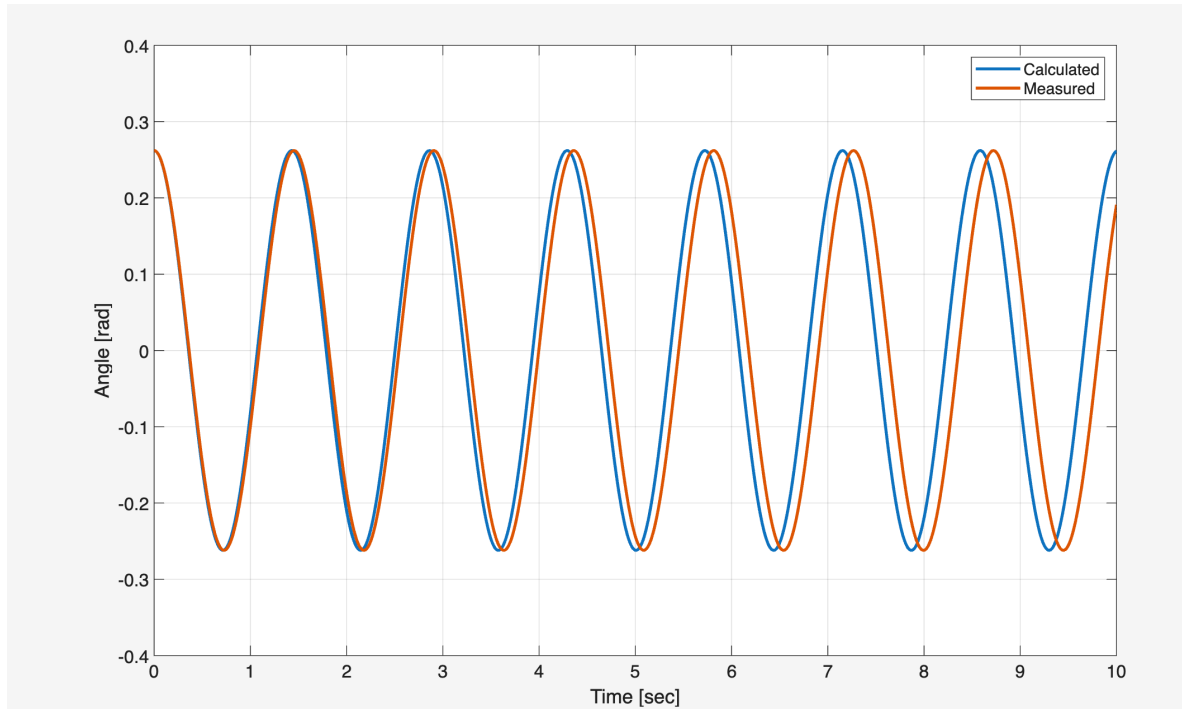
Where the variables are:

- L = pendulum length (0.508 m)
- g = acceleration due to gravity (9.81 m/s²)
- T = period of oscillation (seconds)
- f_n = natural frequency (Hz)
- ω_n = angular natural frequency (rad/s)
- θ = angular displacement (radians)

Excel Tables:

Run #	Total time (s)	Period T (s)	Frquency (Hz)
1	7.09	1.418	0.705
2	7.26	1.452	0.689
3	7.34	1.468	0.681
4	7.25	1.45	0.69
5	7.36	1.472	0.679
6	7.25	1.45	0.69
7	7.43	1.486	0.673
8	7.39	1.478	0.677
9	7.35	1.47	0.68
10	7.22	1.444	0.693
11	7.09	1.418	0.705
12	7.13	1.426	0.701
13	7.27	1.454	0.688
14	7.4	1.48	0.676
15	7.23	1.446	0.692
Average	7.27	1.454	0.688

MATLAB Plot:



The difference in the measurements to the calculations makes sense. My measured frequency was 0.688 Hz while my calculated was 0.699 Hz. While both numbers are similar, there are many reasons why the measured frequency is lower. The biggest error being human error. It is impossible to perfectly start the stopwatch every trial or start the pendulum at the exact angle. Everything was approximate. There could also be small inaccuracies in measuring pendulum length as a tape measure can only be but so accurate. Air resistance is another factor that the equations do not account for. Finally, the theoretical equation assumes small angles while I released my pendulum between 15 and 20 degrees. Regardless of these differences, the plot shows that the calculations and measurements agree over a 10 second interval. The percent difference between the two frequencies is 1.57% (where $\%error = \frac{0.699 - 0.688}{0.699} \times 100 = 1.573676681$), proving that the errors do not invalidate the experiment. To conclude, the measured data matches what is expected from the calculations, showing that the system exercises simple harmonic motion.

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Average	7.27	1.454	0.688

```

clc;
clear;
close all;

% Parameters
A = 0.262;    % I dropped my pendulum from about 20 degrees
              % so here is the conversion to radians

f_measured = 0.688;
f_calculated = 0.699;

% Time vector, this gives me my data points and adds detail to the plot
t = linspace(0,10,2000);

% Simple Harmonic Motion equations
theta_measured = A*cos(2*pi*f_measured*t);
theta_calculated = A*cos(2*pi*f_calculated*t);

% this is the part that actually plots my data and compares it to my
% calculations
figure

plot(t,theta_calculated,'LineWidth',2)
hold on

plot(t,theta_measured,'LineWidth',2)

grid on
xlabel('Time [sec]')
ylabel('Angle [rad]')

legend('Calculated','Measured','Location','northeast')

xlim([0 10])
ylim([-0.4 0.4])

set(gca,'FontSize',12)

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