PHYS 5120: homework1

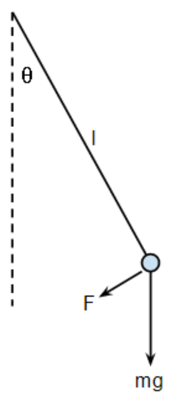
NOTE for all submissions: Submit your report in the PDF format along with computer codes (.py) to the Canvas website. Pack and compress all the submitted files in the ZIP format. TA will run your codes, so write step-by-step how to do and what your compiler version is. The programming language must be Python3. Please avoid noncommon libraries, modules or packages. For your reference, our programming environment is Ubuntu.

The report doesn't have to be very long, but you must include some concise discussions. Figures must contain axis labels, units, legends, and captions (see figures in published papers).

You are expected to work independently. Directly copying output from any AI tools, e.g. ChatGPT, is considered as plagiarism. Cheating or plagiarism in any form is extremely prohibited and may result in disciplinary action. See: `http://acadreg.ust.hk/generalreg.html`

1. The linear and nonlinear pendulums

Consider a pendulum with a arm of length $l = 2.5$ m holding a bob of mass m. The arm is a massless and rigid rod. The gravitational acceleration $g = 9.81$ m/s^2. Ignore any friction.



1. A simple pendulum is linear, i.e., $sin\theta \approx \theta$. Write an equation of motion for the pendulum using Newton's second law. Derive the analytic solution. How long is the swing period?

2. The pendulum is released from a *standstill* at θ=2.5° . Write a program to solve the *linear* pendulum using the *velocity Verlet* method and a proper time step. Is the numerical solution consistent with the analytical one? How would you explain the difference between numerical and analytical results?

3. Let's consider a nonlinear pendulum, i.e., $sin\theta \neq \theta$, which is released from a *standstill* at θ=125°. What is the total energy if you solve the motion equation exactly without any numerical errors?

   Use the *velocity Verlet* method to solve this nonlinear pendulum numerically. Plot the energy as a function of time and show at least 15 swing periods. Compare the exact and numerical energies. Generally increase your time step (e.g., multiply your initial time step by 2, 4, 8, 16...) until you find an obvious energy drift; that is, the total energy increases or decreases over a long time (not short time fluctuations). See, e.g., `https://en.wikipedia.org/wiki/Energy_drift`. Discuss your findings.

01:27 Saturday 6$^{\text{th}}$ September, 2025