PS 12A Names:

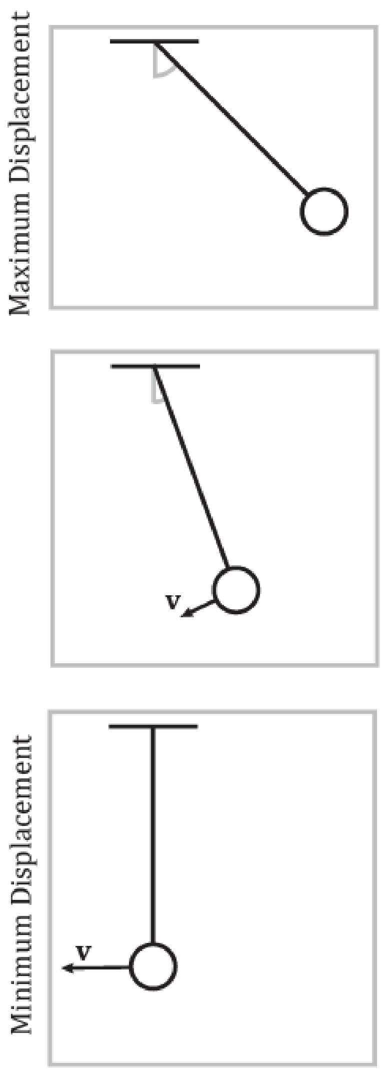
Lab 10: Phase Space and the Pendulum

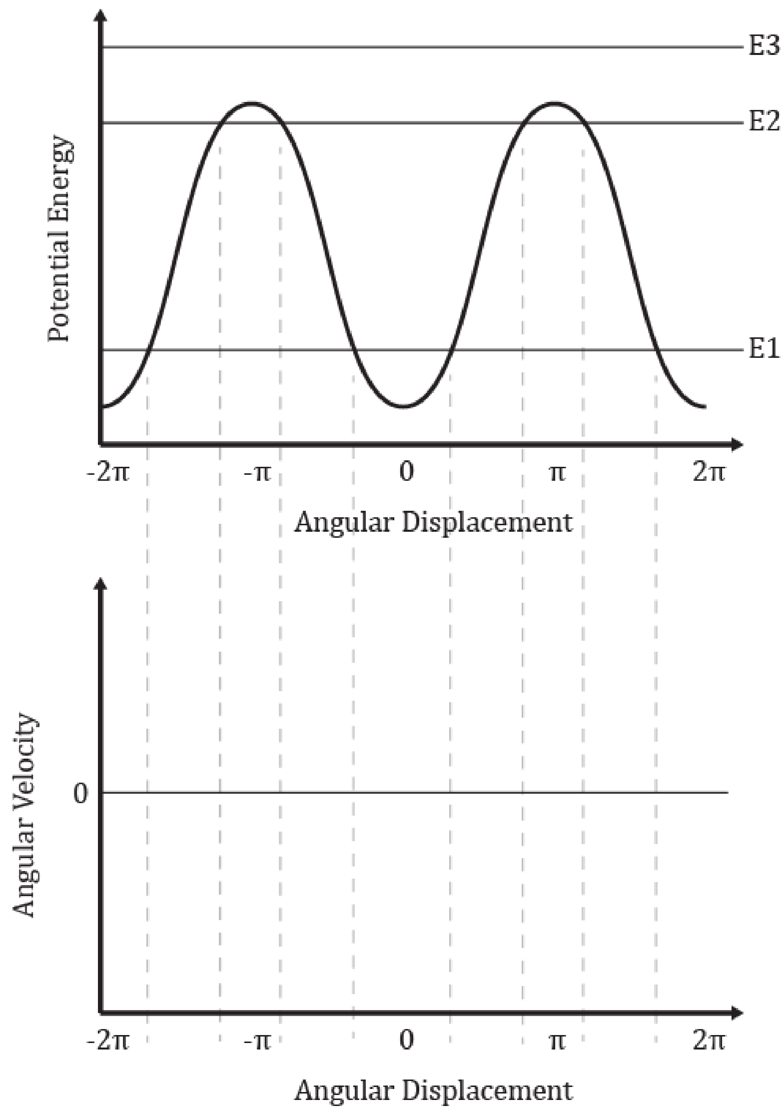
In this lab we will be investigating the phase space and nonlinear behavior of the pendulum system.

Part 1: Concept Review

Q1: Draw the total acceleration vector on the pendulum mass for each snapshot in time

Q2: Draw contours of the pendulum phase space diagram for energies E1, E2, and E3 labeled on the potential energy graph.





Part 2: MATLAB Phase Space Plotter

Download `phase_space_plotter.m` from the lab materials page on the course site. Look over the script and then try to run it. Click around on the plot and see what happens!

Q3: The position coordinate `x` is measuring an angular displacement, so it should be periodic in 2π. Change the range of the x-axis so that it runs from – π to π, and add code after line 27 to force `x` to be periodic in 2π. Hint: you might find the `mod` function useful. Write down your added code below:

Q4: Look at the phase space curves generated by the following four points. Describe what you would see the pendulum doing:

(x=0, v = 4)

(x=0, v = -4)

(x=0, v = 8)

(x=0, v = -8)

Part 3: Dimensional Analysis

Dimensional analysis is an extremely useful tool in physics. You can use dimensional analysis to intelligently guess the answer to a problem, and it will almost always be correct (up to some dimensionless coefficient). For example, a spring system has parameters k and m which have units:

[k] = M/T^2 [m] = M

If we wanted to find the angular frequency of the system (which has units [ω] = 1/T) without solving any pesky equations we can just look at k and m and try to combine them in a way that gives us the units of ω. So:

[k]/[m] = (M/T^2)/(M) = 1/T^2 = [ω]^2

And thus ω = √(k/m)

Q5: The pendulum system has the parameters:

$[g] = L/T^2$ $[m] = M$ $[L] = L$

Unlike the spring system, the displacement for a pendulum is measured in radians and thus is essentially dimensionless. You will need to tack on a dimensionless parameter f(θ) to the answer that you get through dimensional analysis. Write ω in terms of g, m, L, and f(θ) (show your work!):

ω = ________________________________

Part 4: Nonlinear Behavior

With the pendulum setup and Logger Pro you can measure angular amplitude and frequency of the pendulum.

Q6: How will you determine f(θ)?

Q7: Make a plot of f(θ) vs θ. Print and attach or upload to the course dropbox.

Q8: What is f(θ) for small values of θ?