Butikov **HW Set #1 Exercises 1.5 - 1.7 from Chapter 1**

(Still) Case 1: UNDAMPED Free Oscillations:

Remember, Butikov calls this is a "virtual lab." That's why all of your Butikov homework has been going into your lab notebook! — Here, you need to use all of the normal habits expected or a lab notebook including, of course, whatever you observe in an experimental test, write it down, and think about it! My OneNote follows every lab with an explicitly separate page of discussion, to make sure I always consider the "big picture!"

1.5 – The Phase Diagram and Energy Transformations:
Hint: note that this question (along with all the rest in this homework set) considers the special (idealized) case of NO FRICTION.
Compare the phase trajectory with the plot shown above it in Butikov's simulations, which is of potential energy versus the angle of deflection. You might miss it if you don't look carefully, but the energy is traced out as a blue curve (which may be at the very top of the plot). The positioning of plots on the display screen (if you open the window "Phase diagram") is intended for comparison between this plot at the top and the phase trajectory below.

a) Make sure there is ***no*** viscous friction turned on. Reset, then when you START the simulation, pay special attention to the positions of the extreme points on the phase trajectory and in the parabolic potential well. **Write down** what you've observed, explicitly connecting the position of the representative point in the phase trajectory with the components of energy within the *potential well*.

b) **Write down** the potential energy and the kinetic energy, both at the extreme points *of the phase trajectory* and at the equilibrium position, in terms of the *general* initial conditions $\phi_0 \equiv \varphi(0)$ and $\Omega \equiv \dot{\varphi}(0)$.

c) **Write down** the extreme deflection $\varphi_{\max}$ and the maximal angular velocity $\omega_{\max}$ of the flywheel, for the *general* initial conditions $\varphi_0 \equiv \varphi(0)$ and $\Omega \equiv \dot{\varphi}(0)$. That is, determine how the maxima attained depend (algorithmically) upon the initial conditions (*i.e.*, find a *formula* for each, in terms of the initial conditions).

When you perform these computer experiment tests, you need to make sure to "un-check" the tick box for "Viscous friction" in the upper right portion of the main simulation panel.

1.6 – The Shape and the Frequency of Energy Oscillations.

Along the left side of the main simulation panel, use a *checkmark* to indicate that you wish to display "Energy Graphs." This will open another window containing plots of the time dependence of kinetic energy (in red) and potential energy (in **black**), while the total energy is also shown as a trace along the top (in blue).

(a) i) What can you say about the *maximal* and *average* values of the kinetic and potential energies?

ii) Compare these plots with the plots of the angular displacement and the angular velocity, and write down your observations about the *maximal* and *average* values of *those* quantities.

(b) i) At what frequency do the oscillations of each kind of energy occur?

ii) Again, what are the limits (the extreme values) of each kind of energy in these oscillations?

iii) Again, what are the mean values (averaged over a period) of each kind of energy in these oscillations? [Hint: *somehow*, a lot of students write down an incorrect answer the first time we ask the question, but when we ask them to "look again" they often catch their mistake.]

1.7 – The Phase Trajectories with the Same Energy.

Consider the oscillations of a **conservative** oscillator at different initial conditions but with the ***same*** total energy. What differences do you observe in the plots and the phase trajectories in these cases?