Prof. Daniel J. Bodony
AE199IAC, Fall 2013

HW #1

Due in one week to DJB

(Released 2–6 September, 2013)

Videos required for this assignment: 1–6

Create an `m`-file named ⟨ FirstName_LastName_1.m ⟩ for this homework and e-mail it and the image files to the TA with the subject "AE199IAC: HW1: FirstName LastName".

Problem 1 An object with an initial temperature of T_0 that is placed at time $t = 0$ inside a chamber that has a constant temperature T_s will experience a temperature change according to the equation

$$T = T_s + (T_0 - T_s)e^{-kt} \tag{1}$$

where T is the temperature at time t (in hours), and k is a constant. A soda can at temperature 120 °F is placed inside a refrigerator where the temperature is 38 °F.

(a) Determine, to the nearest degree, the temperature of the can after three hours of being inside the fridge assuming $k = 0.45$ hrs^{-1}. Use the Matlab command `round`.

(b) Plot the temperature versus time from time 0 to time 3 hrs. Label your x and y-axes. Save your plot as a Portable Network Graphics (png) file named ⟨ FirstName_LastName_HW_1_Problem_1.png ⟩. Type `help print` to learn how to save a plot to a file.

Problem 2 A charged particle of mass m and charge q moving with a component of its velocity perpendicular to a uniform magnetic field will follow a helical trajectory around the magnetic field lines. If the magnetic field is aligned in the z-direction with strength B_0 and the particle's initial velocity is $\boldsymbol{v} = v_\perp \hat{e}_x + v_\parallel \hat{e}_z$, then the final trajectory will be

$$x = \rho \cos \omega t \tag{2}$$

$$y = \rho \sin \omega t \tag{3}$$

$$z = v_\parallel t, \tag{4}$$

where

$$\rho = \frac{m v_\perp}{q B_0} \tag{5}$$

is the radius and

$$\omega = \frac{q B_0}{m} \tag{6}$$

is the cyclotron frequency.

(a) Using Matlab's `plot3` command, plot the path of a proton of mass $m = 1.67 \times 10^{-27}$ kg, charge $q = 1.60 \times 10^{-19}$ C, moving through a uniform magnetic field of magnitude 0.35 T. Assume that $v_\perp = 4.69 \times 10^6$ m/s and $v_\parallel = 1$ m/s. What is the radius ρ and the cyclotron frequency ω? Save your plot as a Portable Network Graphics (png) file named ⟨ FirstName_LastName_HW_1_Problem_2a.png ⟩.

(b) If an electron moves perpendicular to the same magnetic field with the same speed, what is its orbit radius ρ and frequency ω?

Problem 3 Pick a suitable spacing for vectors `t` and `v` and use the `subplot` command to plot the function $z = e^{-t/2}\cos(20t - 6)$ for $0 \le t \le 8$ to the left of a plot of the function $u = 6\log_{10}(v^2 + 20)$ for $-8 \le v \le 8$. Label each axis and use the `text` command to include the equation in the corresponding subfigure. Save your plot as a Portable Network Graphics (png) file named ⟨ FirstName_LastName_HW_1_Problem_3.png ⟩

Problem 4 The geometry for the 4-digit NACA series of airfoils are given in *Theory of Wing Sections* by Abbott and von Doenhoff (Dover, 1959). The airfoil geometry is described in terms of its thickness $y_{\text{thick}}(x)$ and camber $y_{\text{camb}}(x)$. The upper and lower surfaces are given by

$$y_u(x)/c = y_{\text{camb}}(x)/c + y_{\text{thick}}(x)/c \tag{7}$$

$$y_d(x)/c = y_{\text{camb}}(x)/c - y_{\text{thick}}(x)/c, \tag{8}$$

with the thickness distribution

$$\frac{y_{\text{thick}}(x/c)}{c} = \frac{(t/c)}{0.2}\left(0.29690\sqrt{x/c} - 0.12600(x/c) - 0.35160(x/c)^2 + 0.28430(x/c)^3 - 0.10150(x/c)^4\right) \tag{9}$$

where t/c is the percentage thickness. (Note that the thickness is not zero at the trailing edge, so the trailing edge is open.) The camber distribution is given by

$$\frac{y_{\text{camb}}(x/c)}{c} = \begin{cases} \dfrac{m}{p^2}(2p(x/c) - (x/c)^2) & \text{for } x/c \le p \\ \dfrac{m}{(1-p)^2}[(1-2p) + 2p(x/c) - (x/c)^2] & \text{for } x/c > p \end{cases} \tag{10}$$

The NACA 4-digit airfoils use the following nomenclature: a NACA *mptt* airfoil has a maximum camber of $m/100$ located at position $p/10$ and thickness $tt/100$, all as percentages of the chord. For example, a NACA 1408 has a maximum camber of $m = 0.01$ located at position $p = 0.4$ and thickness of $t/c = 0.08$.

Create a Matlab script that prompts the user for the 4-digit number as a string and then *parses* the string to extract the values of m, p, and tt. Plot the airfoil geometry with x/c on the x-axis and y/c on the y-axis. Be sure to use the command `axis equal` to get the proper scaling, and label your axes and title accordingly. Use the `get` and `set` commands to make the line width for the upper and lower surfaces equal to 2. Create at least one airfoil that is not a NACA 1408 and save your plot as a Portable Network Graphics (png) file named ⟨ FirstName_LastName_HW_1_Problem_4.png ⟩.