

Complete the following problems and upload your solutions to the D2L dropbox by 9:00 PM on Friday, 10 February 2017.

1. (8 points) The density of water in the range $5 \leq T \leq 40^\circ\text{C}$ can be approximated by

$$\rho = 999.85308 + 6.32693 \times 10^{-2}T - 8.523829 \times 10^{-3}T^2 + 6.943248 \times 10^{-5}T^3 - 3.821216 \times 10^{-7}T^4 \quad (1)$$

where T is in $^\circ\text{C}$, and ρ is in kg/m^3 .

- Write an m-file function called `densityH20` that computes $\rho(T)$ from Equation (1). Your function should have one input, T , and one output `rho`.
- The kinematic viscosity of a fluid is $\nu = \mu/\rho$. In homework assignment 2, you wrote a function to compute $\mu(T)$ for water. Write an m-file function called `propertyTable` that uses your `densityH20` function from part (a) and your `viscosityH20` function from homework assignment 2 to print a three-column table of water density and kinematic viscosity as a function of temperature in 5°C increments between 5°C and 40°C . Put a simple header on the table. The final result should look something like this:

T(C)	rho(kg/m ³)	nu(m ² /s)
5	1000.0	1.537e-06
10	999.7	1.330e-06
15	999.1	1.163e-06
20	998.2	1.025e-06
25	997.0	9.102e-07
30	995.6	8.144e-07
35	994.0	7.337e-07
40	992.2	6.652e-07

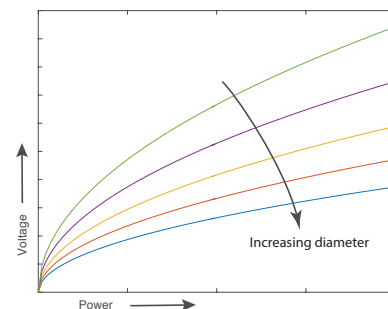
Hints

- You will need to use the `fprintf` command to format the output.
 - Use colon notation like this, `T = 5:5:40`, to create a vector of temperatures.
2. (12 points) Suppose you want to create a simple foam cutter like the ones shown on these web sites

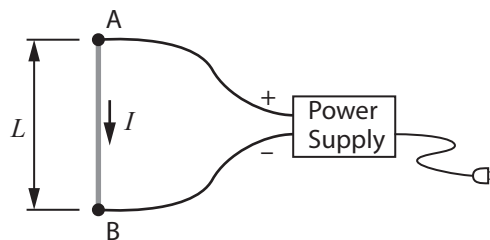
<http://inventorartist.com/diy-hot-wire-foam-cutter/>

<http://www.instructables.com/id/Simple-Styrofoam-Hot-Wire-Cutter/>

The purpose of this exercise is to evaluate formulas for the electrical power consumption of the heater wire in the foam cutter to help choose an appropriate power supply. We start by writing down the formulas that relate the heater power to the applied voltage, the wire diameter and resistivity of the wire. We then use those equations to make plots that help us make engineering design decisions. The plot to the right is a qualitative version of one of the two plots you will create in your solution to this exercise.



The sketch at the right depicts a heater wire of length L connected to a power supply. A real foam cutter will need additional components, but the schematic shows the essential features necessary for the analysis in this assignment. Assume that the wire is made of nichrome, and is one of the standard wire diameters in the set $d = 28, 30, 32, 34,$ and 36 AWG units. You will need to look up the equivalent diameters in meters.



The electrical resistance of the heater wire is

$$R = \frac{\rho L}{A} \quad (2)$$

where ρ is the resistivity of the wire material, L is the length of the wire and $A = \pi d^2/4$ is the cross-sectional area of the wire of diameter d . The electrical power consumed by the wire is

$$P = \frac{V^2}{R} \quad (3)$$

where P is the power in watts, and V is the voltage applied across the wire in volts, i.e., V_{AB} in the schematic. The current flowing through the wire can be computed with Ohm's law, $V = IR$.

Assignment

- a. Combine Equations (2), (3) and Ohm's law to create formulas for computing, R , V and I given the other parameters of the problem. The order of the calculations is

$$R = f(\rho, L, d)$$

$$V = f(P, R)$$

$$I = f(V, R)$$

In each of the preceding expressions, f is a different algebraic function. Also note that the order of the computation matters: you need to compute R before you can compute V or I . Assume that ρ , L , d and P are known. In particular, $L = 15$ cm and ρ are fixed, and we will vary d and P .

- b. Write a MATLAB function that plots $V = f(P, R)$ for wire diameters of 28, 30, 32, 34 and 36 AWG units. Let \mathbf{P} be a vector in the range $0 \leq P \leq 20$ W, i.e., $\mathbf{P} = \text{linspace}(0, 20)$.
- c. Either extend the m-file from part (b), or write another m-file to create a plot of $I = f(V, R)$ for the same set of wire diameters.
- d. Now that you have the plots created in part (b) and part (c), you can answer some design questions. The answers to these questions can be obtained by looking at the plots.
- Suppose you have the choice of either a 6V and a 12V DC power supply. What is the smallest diameter wire (in AWG units) that will work with a 6V power supply if the target heater power is 10W?
 - What is the smallest diameter wire that will work with a 12V power supply if the target heater power is 20W?
 - What is the largest diameter wire that will work with a 6V power supply if that power supply can only supply 1A of current?

- iv. What is the largest diameter wire that will work with a 12V power supply if that power supply can only supply 1.5A of current?

With the answers to these questions, you could begin a more detailed design of the foam cutter, and you could order wire to be used as the heating element and cutter.

For both plots in part (b) and (c), make sure you label the axes and use a legend to identify the curves for the different wire diameters.

What to Turn In

In the word-processing document you submit for your solution, include the source code of your m-file(s), the two plots and the answers to the questions (i) through (iv). Write your answers in complete sentences. Upload your m-file(s) in addition to the word-processing document.

Hints:

- You need to check the units of all quantities.
- Even though L and ρ are fixed, it is good practice to use MATLAB variables, as opposed to fixed numerical values, in all equations that use these quantities.
- The following code structure should work

```
rho = ...           % Resistivity of nichrome, Ohm*m
L = 15.0e-2;        % Length of heater wire, m
dawg = [28 30 32 34 36]; % Wire diameter in AWG units (handy for labels)
d = ...            % Wire diameter in meters
P = linspace(0,20); % Range of power to analyze, W

for i = 1:length(dawg)

    % ... add lines here to perform engineering calculations
    %     ending with V = f(P,R)
    %
    plot(P,V);      % Let MATLAB choose the symbol type

end
xlabel(...)
ylabel(...)
legend(...)
```