Name:

**Instructions:**

1. Put your name on every sheet of paper you hand in for grading, including these sheets. You are required to hand in these exam papers along with your solution.
2. Read each question carefully and make sure you provide all the requested information.
3. Please provide clear, well-presented solutions if partial credit is desired. If I cannot understand your solution, no partial credit will be given.
4. While this is an open book/notes exam, you are not allowed to use any communications, electronic or otherwise during the exam. This includes accessing the Internet, using cell phones, wireless PDAs, or any other form of information/communications.
5. You may use computers and calculators for computations, as needed. If plots/graphs are provided, please make sure these are appropriate (smooth curves, data points shown, etc.). Please supply any relevant programs/spreadsheets, etc. as appropriate to your solution, if partial credit is desired. You may email these to Dr. Tao, provided you have included your name on each page of the file so your work can be clearly identified.

**Problem 1 (60 points)**

TAOCO has invented a new zero calorie candy is made by heating a complex mixture of proprietary ingredients to a fluid state at 250 oF, so that it can be formed into a spherical shape (radius = 2 cm). Since the candy is somewhat fluid after molding, it is important to cool the candy to at least 71 oF before further processing/packaging. This is done by blowing ambient air on the candy.

Unfortunately, data on the physical and thermal properties of this candy are not available, so temperature measurements have taken to determine the cooling rate (see below).





1. **(30 points) Create a numerical model** for the temperature of the candy (oF) vs. time (min). **Clearly explain/justify your choice** of numerical model and **provide an appropriate plot of your model**, including the data points for comparison. **Calculate the time** needed to cool the candy to 71 oF.
2. **(30 points)** The marketing folks want to different sizes of the candy. For example, they want to make a larger version of this candy, with a radius of 4 cm. Using your model (part a) and the following assumptions, **determine the time needed to cool this larger candy to 71o F**. The candy physical properties are unchanged, on the size is increased.

Assumptions:

The heat conduction inside the candy is much faster than the rate of heat transfer to the outside air (i.e. the candy temperature is uniform), so the temperature of the candy can be modeled using an energy balance as:

Cp\* V\* dT/dt = -h\*A\*(T – Tair)

Where :

Cp = candy heat capacity

 = candy density

V – candy volume

A – candy area

h = convective heat transfer coefficient in air

Tair = ambient air temperature = 70 oF (assumed constant)

To = initial candy temperature = 250 oF

T = candy temperature

t = time

Problem 2 **(40 points)**

The set of data below are measurements of vapor-liquid equilibrium values for binary mixtures of water and acetic acid. P is the vapor pressure (mm Hg), L is the liquid water mole fraction equilibrium composition data, and V is the vapor water mole fraction equilibrium composition data.







acetic acid-water binary mixture

1. **(20 points)** Create cubic spline numerical models for the vapor-liquid equilibrium curves for this binary system and **provide an appropriate plot of P vs. composition.**
2. **(10 points)** Using your model**, calculate the composition of the azeotrope** that exists for this binary system.
3. **(10 points)** Using your models, **calculate the amounts (moles) and compositions (mole fraction)** of the equilibrium liquid and vapor phases at a pressure of 180 mm Hg resulting from separating 20 moles of an initial mixture composed of 30 mol% water.