CEIC6706 - 2015
COMSOL ASSIGNMENT

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A glass is filled to the brim with fresh apple juice initially at a uniform temperature of 25°C, then put in a refrigerator where temperature is maintained at 5°C. Newton's cooling law may be assumed over all surfaces, with a heat transfer coefficient of 11.5 $W.m^{-2}K^{-1}$ at the free liquid surface and 7.5 $W.m^{-2}K^{-1}$ on all other surfaces Convection in the liquid may be ignored. You may assume a uniform wall thickness of 3 mm, except for the stem and base of the glass. The geometry of the glass is determined by your student ID:

- The shape of the glass is determined by the last (rightmost) digit of your student ID, as shown in the figure below.
- The height of the glass in mm is given by 120 + 4b, where b is the next-to-last digit of your student ID.

For example, if your student ID is 3023468 you will model glass no. 8 with a height of 144 mm.

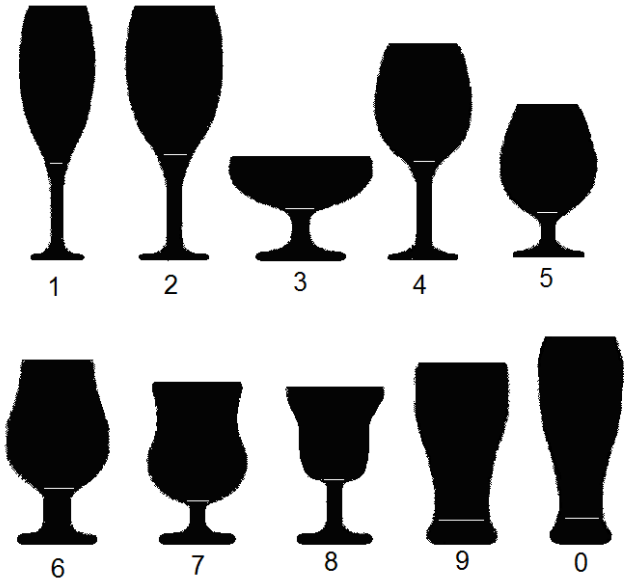

Figure 1. Glass geometry. White lines indicate bottom level of liquid.

Task 1: using Comsol, calculate and plot the temperature history at four points: a point in the liquid next to the glass wall at mid-level, the centre of the liquid free (top) surface, the centre of the liquid bottom surface, and the thermal centre of the liquid (see figure below). Plot also the average temperature. Stop the plot when the thermal centre's fractional temperature change reaches 0.9. Using a log-linear plot, determine the parameters a and τ for the exponential decay period of the average and thermal centre temperatures ($\ln\frac{T-T_a}{T_i-T_a}=ae^{-t/\tau}$).

Figure 2. Locations of temperature probes. The red circles indicate the locations where the temperature must be monitored for plotting, however the thermal centre position is only approximate.

Task 2: The glasses (still at the same initial temperature, 25°C) are now put in a freezer at -15°C. Plot temperature histories at the same location, stopping when the thermal centre reaches -10°C. One way to model the latent heat of freezing is to have a 1 K wide triangular pulse around the freezing point in the specific heat curve, such that the area under the pulse, $\int_{T_1}^{T_2} c_p dT$, equals the latent heat of freezing (in J/kg). An improved cruve will earn better marks. (To build a piecewise linear function, right click Global Definitions/ Function/ Interpolation).

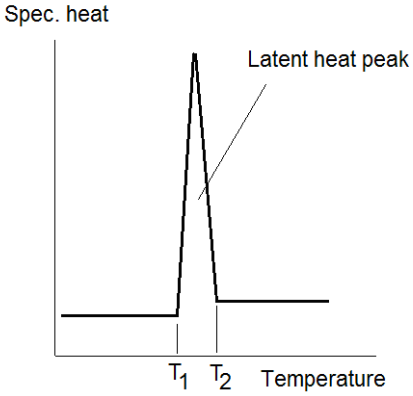

Figure 3. Apparent specific heat curve for a freezing material.

Hints:

- The wall of the glass may be modelled as a separate domain, or as an extra heat transfer resistance which is added to the heat transfer coefficient (you can try doing it both ways and compare resutls). Thicker parts (i.e. the bottom) must be modelled as a separate domain (draw as a separate domain then create a new "Heat transfer in solid" region and add the domain to it).
- Thermal properties of water and foods may be estimated from methods cited in, say, Gulati T., Datta A.K. (2013) J. Food Eng. 116: 483–504. Fruit juice may be considered as a mixture of water and sugars (carbohydrates).
- Comsol can import Autocad Interchange (.dxf) geometry files drawn in CAD software (including Visio).

REPORT LAYOUT & MARKING SCHEME

The main report should be in MS Word or PDF and include:

1. THEORY (10% of total mark)

- State assumptions made in developing the models.
- Lists all equations used (transport equations, boundary and initial conditions).
- List all material properties values, and give the source of the data including all equations used to calculate properties.

2. GEOMETRY (10%)

Show picture of product (from Figure 1) and meshed finite element model, including the scale.

3. THERMAL MODEL RESULTS (40%)

For each task, show the required time-temperature plots and a colour coded plot of the final temperature profile. You may include other results that you find interesting or relevant.

5. DISCUSSION (20%)

(Maximum one page)

- Discuss validity of your methods, equations and assumptions and possible sources of errors.
- Obeservations on the exponential decay correlations
- Compare results from the two cases (cooling and freezing). Explain or discuss any significant observation.

MARK FOR REPORT STYLE & PRESENTATION: 20%

Factors that may affect the style & presentation mark include

- general layout
- grammar and syntax
- formatting of tables and graphs, of numbers (decimal digits)
- style. Be clear and concise. Include all necessary/relevant information but avoid padding/waffling, which will be penalised with negative marks.

APPENDICES

In addition to the main report as outlined above, you **must** submit online the following supporting materials:

- a Comsol-generated "intermediate" report, in Word or HTML format.
- all Comsol files used.

A zero mark will be given for the assignment if any of the above is not submitted by due date.