An iPhone / iPad Energy App for Heat Transfer

CACHE Energy Task Force
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For the past several years, a CACHE task force has been developing modules to introduce concepts of hydrogen and hydrogen fuel cells into the chemical engineering undergraduate curriculum. To date, about two dozen modules have been developed for the following ChE courses:

- Material and Energy Balances
- Thermodynamics
- Fluid Mechanics
- Heat and Mass Transport
- Kinetics and Reaction Engineering
- Separations
- Process Safety and Process Design
- Materials Science and Engineering

Under the leadership of the energy task force chair, Jason Keith of Mississippi State University, worked with undergraduate students to develop a iPhone / iPad app called "Heat Transfer for Students." This app is available for free on the iTunes store.

This app solves the traditional unsteady-state heat transfer equation given by:

$$\rho C_p \frac{\partial T}{\partial t} = k \frac{\partial^2 T}{\partial x^2} \tag{1}$$

over a range from $x = -L$ to $x = L$. There is no flux at $x = 0$, such that $\partial T / \partial x = 0$. The boundary condition at $x = L$ is $-k\partial T / \partial x = h(T - T_f)$. Finally, the initial temperature at time t = 0 is a constant, with $T = T_0$.

Invoking the standard separation-of-variables technique gives:

$$T = T_f + (T_0 - T_f)\sum_{n=1}^{\infty} A_n \cos\left(\frac{\lambda_n x}{L}\right)\exp\left(-\frac{\lambda_n^2 kt}{\rho C_p L^2}\right) \tag{2}$$

The coefficient λ_n is described by the transcendental relationship:

$$\lambda_n \tan \lambda_n = Bi \tag{3}$$

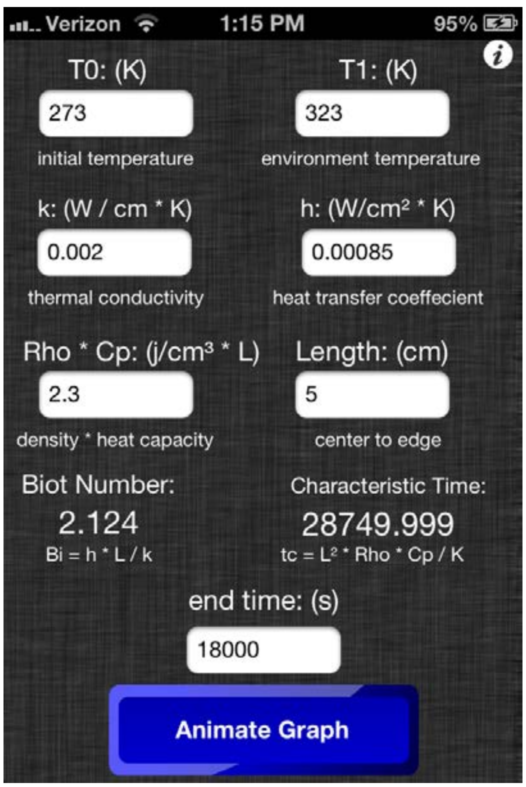
where Bi is the Biot number, given by $Bi = hL/k$.

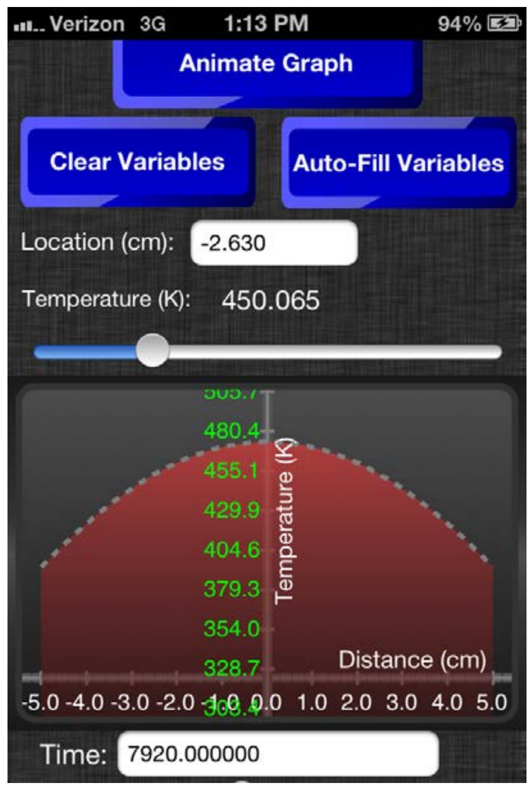
The parameter A_n is obtained from the initial condition. For a constant initial condition of T_0, the result is:

$$A_n = \frac{\dfrac{\sin \lambda_n}{\lambda_n}}{\dfrac{1}{2} + \dfrac{\sin 2\lambda_n}{4\lambda_n}}$$

Today's undergraduate student has difficulty connecting the mathematics with the physics of this problem. The purpose of the app is to allow students to visualize the heat conduction process, and how it changes for different values of dimensionless time $kt/(\rho C_p L^2)$ and the dimensionless heat transfer coefficient, the Biot Number.

Screenshots of the parameter input area and the temperature profile of a cooling simulation are shown in the figures below.





More information on this work will be presented at the 2013 ASEE annual meeting.

Download the iPhone / iPad app "Heat Transfer for Students" for free from the iTunes store.

For any questions, comments, or ideas for new modules, please contact energy modules task force chair Jason Keith at keith@che.msstate.edu.