AC 2009-815: USE OF THE KNOWLEDGE AND SKILL BUILDER (KSB) FORMAT IN A SENIOR MECHANICAL ENGINEERING LABORATORY

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Use of the Knowledge and Skill Builder (KSB) Format in a Senior Mechanical Engineering Laboratory

Overview

This paper discusses the use of the Knowledge and Skill Builder (KSB) format in Hofstra University's ENGG 170 laboratory course during the Spring 2008 semester.

The current investigation is a fifth-year research project of the NSF-funded MSTP Project, "Mathematics Across the Middle School MST Curriculum" [1, 2]. KSBs were previously used by the author in a sophomore level Measurements and Instrumentation Laboratory course (ENGG 160A) [3]. The success of the KSBs in that course led to the extension of KSB usage to the ENGG 170 laboratory course.

The ENGG 170 laboratory course is taken by mechanical engineering seniors. There were twelve (12) students in the Spring 2008 offering of the course. This paper describes the course and the use of KSBs in detail. It includes one of the KSB documents developed for the course. It also discusses the students' responses to the use of KSBs and outlines planned future work.

Background

Knowledge and Skill Builders (KSBs) were originally developed for middle school students. They are a progression of short, focused activities by which students increase their knowledge and skill base before addressing a specific design problem. The KSBs are an integral part of the "informed" design process developed and validated through the NSF-funded NYSCATE (New York State Curriculum for Advanced Technological Education) Project [4].

As an example of KSBs: One popular design activity for middle school students involves the students designing their bedroom in a house they are moving to[5]. The problem definition includes several constraints: minimum room size, minimum ceiling height, minimum window area, specified construction cost per square foot of floor area. The student must design the bedroom, including furnishings, and keep within a specified budget. The student must consider alternative designs, and must construct a scale model of the successful, chosen design. Before starting on the bedroom design, the students engage in KSB activities to enhance their knowledge and skills in areas pertinent to the design project. There are KSBs on geometric shapes, ratios and proportions, scaling of drawings, aesthetics, and cost calculations. The KSBs prepare the students for the actual design activity.

From 2003 to 2008, the author was a participant in the above-mentioned MSTP Project. In this project, he worked with middle school technology teachers on Long Island, New York on several design activities based on the informed design/KSB approach. The success of this approach with middle school (and also high school) students caused the author to believe that the KSB format might be successfully applied to college-level courses. In Fall 2006, the KSB format was used by the author in a design activity associated with a sophomore level Measurements and Instrumentation Lab course [6]. The KSB format was well-received by the students and judged a success. As a result, the author decided to use this approach in a senior level mechanical engineering laboratory course (ENGG 170). This was first done in the Spring 2008 semester.

Rationale for the Use of KSBs in ENGG 170

ENGG 170, "Mechanical Engineering Laboratory II", is a required course for senior mechanical engineering students. It is currently given in spring semesters. The course consists primarily of experiments in the heat transfer area of mechanical engineering. However, there are also experiments in fluid mechanics and HVAC areas.

A major difficulty experienced by students in the ENGG 170 laboratory course is due to the scheduling of the course. The lab course is taken a semester subsequent to the heat transfer lecture course. It is also taken two or more semesters after the fluid mechanics and thermodynamics courses. During the time between the lecture courses and the lab, students lose momentum and forget a lot of material. When lab experiments are performed in ENGG 170, the students have problems recalling the relevant theory. The laboratory course also includes experiments in areas (e. g., HVAC, pumps, fans) that are only briefly covered in previous lecture courses. Use of the KSB format in the ENGG 170 laboratory course reacquaints the students with the lecture material and provides them with theoretical background for the experiments.

Use of KSBs in the Course

Prior to the Spring 2008 semester, a typical ENGG 170 lab session consisted of a lecture by the instructor followed by student performance of the lab experiment. The lecture portion was a very passive activity for the students. In Spring 2008, the lectures were, for the majority of the experiments, replaced or augmented by the use of KSBs.

The students worked in groups of three or four persons to complete the KSBs prior to performance of the experiments. There was a lot of group activity and group discussion rather than passive listening to a lecture by the instructor. The students welcomed this interactive learning experience. They enjoyed the group-activity aspects, and believed that the KSBs gave excellent (and needed) preparation for performance of the experiments. The instructor agrees with this viewpoint, and believes that use of the KSBs in the laboratory setting is superior to the previous "chalk-and-talk" lectures.

KSB documents for ENGG 170 have thus-far been developed for five of the laboratory experiments, specifically the experiments on: cooling of a metal plate by natural convection and radiation; pressure drops in piping and pump selection; linear heat conduction; convection from geometric objects; and fan performance and fan laws. One KSB document, "Experiment No. 3 – Transient Heat Transfer with Convection and

Radiation Boundary Conditions" is included as Appendix A to this paper. The experiment deals with the cooling of a plate by natural convection and thermal radiation. The document contains KSBs for: determination of convective coefficients using empirical relations; the criteria for use of the lumped approach of analysis; transient response if only convection is considered; and transient response (including computer solution) if both convection and radiation are included.

To illustrate the parts of a typical KSB, the first KSB for this experiment follows:

KSB No. 1 Determination of the Convective Coefficient Using Empirical Relation

An empirical relation often used for natural convection from a vertical plate to surrounding fluid is:

$$Nu = \frac{hL}{k} = C \left(GrPr\right)^n \qquad (1)$$

where: Nu is the Nusselt Number (dimensionless)

Pr is the Prandtl Number (dimensionless)

Gr is the Grashof Number (dimensionless)

L is the height of the plate (m, ft)

h is the convective coefficient (w / m^2 C, BTU / h ft^2 F)

k is the thermal conductivity of the fluid (w / m C, BTU / h ft F)

C and n are empirical constants

The Grashof Number, Gr, is

$$Gr = \frac{g\beta L^3 \left(T_s - T_\infty\right)}{\upsilon^2} \qquad (2)$$

where: g = acceleration of gravity

υ = kinematic viscosity of the fluid

T_s = surface temperature of the plate

T_∞ = temperature of the fluid

β = coefficient of expansion of the fluid

$= \frac{1}{T}$ (for ideal gases, where T is absolute temperature)

= tabulated for liquids

Fluid properties in equations (1) and (2) are to be evaluated at the film temperature, T_f

$$T_f = \frac{T_s + T_\infty}{2}$$

Example No. 1

A copper plate (alloy 110) is square (4 inches by 4 inches) and 1/8 inch thick. The plate is heated to 100 C and then cools in the 20 C room air until it reaches 40 C. Estimate the convective coefficient *h* for the process. (Note: 1 m = 39.37 inch)

Solution

The average temperature of the plate as it cools is

T_s = average temperature of the plate surface during the cooling

$$= \frac{100 + 40}{2} = 70\,\mathrm{C}$$

The film temperature at which fluid properties are to be evaluated is:

$$T_f = \frac{T_s + T_\infty}{2} = \frac{70 + 20}{2} = 45\,\mathrm{C} = (45 + 273.15)\,\mathrm{K} = 318.15\,\mathrm{K}$$

At this temperature, the properties of air are (from heat transfer book)

Air
k = 0.0274 w / m C
υ = 1.80 x 10^{-5} m^2 / s
Pr = 0.723

$$Gr = \frac{g\beta L^3 (T_s - T_\infty)}{\upsilon^2} = \underline{\hspace{4cm}}$$

(Remember, for gases, $\beta = 1 / T_f$ where the temperature is <u>absolute</u> temperature. Also, use $g = 9.807 \ \mathrm{m/s^2}$.)

$Gr\,Pr$ = ____________________

From equation (1),

$$Nu = \frac{hL}{k} = C \left(GrPr\right)^n$$

From heat transfer texts: For $Gr\,Pr = 10^4 - 10^9$, C = 0.59 and n = 1/4

For $Gr\,Pr = 10^{10} - 10^{13}$, C = 0.1 and n = 1/3

Nu = _____________________

Determine the convective coefficient h

$h = \frac{k}{L}\left(Nu\right) =$ _____________ $\mathrm{w/m^2\ C}$

As noted above, the entire KSB document for this experiment is in Appendix A.

To summarize, a KSB document contains a discussion of the pertinent theory. It also contains exercises (i. e., calculations and worksheets) for the students to complete prior to performance of the experiment. Finally, the KSB document includes a design problem which can be assigned as a homework assignment. The KSB document reacquaints the students with theory presented in earlier lecture courses. It also gives the students knowledge of material needed for the experiment but not covered in previous courses. After reading the KSB document and performing the exercises, the students should be well-prepared to perform the experiment and analyze/discuss the experimental results.

In developing a KSB, one must decide which material should be included and also the extent to which the material should be included. For example, one KSB in the Experiment No. 3 document deals with numerical solution of the differential equation for cooling of the plate by combined convection and radiation. A decision had to be made as to whether or not include the details of a Matlab program which could be used for solution of the differential equation. It was decided to include the program in the KSB document for the following two reasons: First, the computer programming course is taken by freshmen and the lab course by seniors. From discussions with students, it became clear that many students needed to be reacquainted with the details of Matlab programming. In addition, although the details of the Matlab program are given in the KSB document, the students still have to modify the program significantly to apply it to the particular plates being used in the experiment and to fulfill the analysis and reporting requirements for the experiment. The students could not use the given program without modification.

Planned Future Activities

The KSB approach will be used in future offerings of ENGG 170, and KSB documents will be prepared for additional laboratory experiments. (Such documents are already in various stages of completion for the other lab experiments.)

Work is planned to increase the design content of the course. During the Spring 2008 offering of the course, there was difficulty including design activities to the desired extent. Each KSB document contains a comprehensive design problem. However, additional work is needed to integrate the design activity with the other parts of the course. It is indeed difficult to properly address all desired aspects of the course (i. e., KSB lectures and exercises, performance of the lab experiment, student design experience) in a one-credit, 2-1/2 hours per week course. Attention will be given to achieving such results in the future.

Students' Comments on the Use of KSBs

A student survey regarding the KSB approach was completed by the students on the last day of class (May 7, 2008). The details of the survey results are given in Appendix B to this paper.

The overwhelming majority of the 12 students in the class were very favorable to the use of KSBs. They enjoyed the KSB approach and thought it was very helpful towards the performance of the experiments. They thought it was beneficial to work in a group on the KSBs and worksheets. The KSB approach helped them to learn the concepts and to better apply what they had learned in previous lecture courses.

The overall rating of the 12 students regarding the use of the KSB format in the course was: Excellent (7), Good (4), Fair (1).

Conclusion

The ENGG 170 laboratory course has been modified to incorporate the Knowledge and Skill Builders (KSB) format. The modified course was first offered in Spring 2008 and it proved to be a success from both the students' and instructor's viewpoints. So far, KSB documents have been developed for five of the lab experiments in the course. In light of the very positive results, it is planned to extend the KSB approach to the other experiments in the course and ultimately to other courses (e. g., capstone design courses).

Bibliography

1. MSTP Project: Mathematics Across the Middle School MST Curriculum. Retrieved from www.hofstra.edu/mstp on March 5, 2009.

2. Hunter, Margaret A. and Forsberg, Charles H.; *Experiences of Engineering University Faculty in a Middle School Math, Science and Technology Partnership (MSTP),* Proceedings of the ASEE Mid-Atlantic Spring 2005 Conference; April 15 & 16, 2005; Fairleigh Dickinson University; Teaneck, NJ.

3. Forsberg, Charles H.; *Use of Knowledge and Skill Builders (KSBs) in a Measurements Laboratory Course,* Proceedings of the ASEE Mid-Atlantic Spring 2007 Conference; April 13 & 14, 2007; New Jersey Institute of Technology; Newark, NJ.

4. New York State Curriculum for Advanced Technological Education. Retrieved from www.hofstra.edu/nyscate on March 5, 2009.

5. Hacker, Michael, and Burghardt, David, *Technology Education: Learning by Design.* Prentice-Hall, 2004, Upper Saddle River, NJ.

6. The design activity consisted of student groups designing a weighing scale using a strain gage as the sensor. It is described in the paper of item 3 above.

APPENDIX A - KSB Document for Experiment No. 3

Hofstra University
ENGG 170 **Experiment No. 3**

Transient Heat Transfer with Convection and Radiation Boundary Conditions

(NOTE: The heat transfer equations in this document are found in essentially all undergraduate heat transfer texts.)

Object

To investigate the cooling, by convection and thermal radiation, of a heated metal plate. The plate's characteristics are such that the "lumped" analysis technique is appropriate.

Apparatus

Two plates, identical in size. One plate is polished, the other is spray painted with flat black paint. A thermocouple is attached to the center of each plate to measure the plate's temperature as it cools.

Experimental Procedure

The plates are heated in turn to about 125 C on an electric hot plate. They are then hung vertically on a stand in the room air. Temperature-time data is collected as the plates cool from 100 C to 40 C.

KSB No. 1 Determination of the Convective Coefficient Using Empirical Relation

An empirical relation often used for natural convection from a vertical plate to surrounding fluid is:

$$Nu = \frac{hL}{k} = C \left(GrPr\right)^n \qquad (1)$$

where: Nu is the Nusselt Number (dimensionless)

Pr is the Prandtl Number (dimensionless)

Gr is the Grashof Number (dimensionless)

L is the height of the plate (m, ft)

h is the convective coefficient (w / m^2 C, BTU / h ft^2 F)

k is the thermal conductivity of the fluid (w / m C, BTU / h ft F)

C and n are empirical constants

The Grashof Number, *Gr,* is

$$Gr = \frac{g\beta L^3\left(T_s - T_\infty\right)}{\upsilon^2} \qquad (2)$$

where: g = acceleration of gravity

υ = kinematic viscosity of the fluid

T_s = surface temperature of the plate

T_∞ = temperature of the fluid

β = coefficient of expansion of the fluid

$= \frac{1}{T}$ (for ideal gases, where T is absolute temperature)

= tabulated for liquids

Fluid properties in equations (1) and (2) are to be evaluated at the film temperature, T_f

$$T_f = \frac{T_s + T_\infty}{2}$$

Example No. 1

A copper plate (alloy 110) is square (4 inches by 4 inches) and 1/8 inch thick. The plate is heated to 100 C and then cools in the 20 C room air until it reaches 40 C. Estimate the convective coefficient h for the process. (Note: 1 m = 39.37 inch)

Solution

The average temperature of the plate as it cools is

T_s = average temperature of the plate surface during the cooling

$$= \frac{100 + 40}{2} = 70\,\mathrm{C}$$

The film temperature at which fluid properties are to be evaluated is:

$$T_f = \frac{T_s + T_\infty}{2} = \frac{70 + 20}{2} = 45\,\mathrm{C} = (45 + 273.15)\,\mathrm{K} = 318.15\,\mathrm{K}$$

At this temperature, the properties of air are (from heat transfer book)

Air k = 0.0274 w / m C
υ = 1.80 x 10^{-5} m^2 / s
Pr = 0.723

$$Gr = \frac{g\beta L^3 (T_s - T_\infty)}{\upsilon^2} = \underline{\qquad\qquad\qquad}$$

(Remember, for gases, $\beta = 1 / T_f$ where the temperature is <u>absolute</u> temperature. Also, use g = 9.807 m / s^2 .)

$$Gr\,Pr = \underline{\qquad\qquad\qquad\qquad}$$

From equation (1),

$$Nu = \frac{hL}{k} = C\ (GrPr)^n$$

From heat transfer texts: For $Gr\,Pr = 10^4 - 10^9$, C = 0.59 and n = 1/4

For $Gr\,Pr = 10^{10} - 10^{13}$, C = 0.1 and n = 1/3

$$Nu = \underline{\qquad\qquad\qquad\qquad}$$

Determine the convective coefficient h

$$h = \frac{k}{L}(Nu) = \underline{\qquad\qquad\qquad}\ \mathrm{w / m^2\ C}$$

KSB No. 2 The Lumped Analysis Approach

A major assumption of this experiment is that there is no spatial variation of temperature within the plates at a given instant of time. That is, all points in the plate have essentially the same temperature at a given instant. So, $T(x, y, z, t)$ simplifies to $T(t)$. This is called the "lumped" approach.

The Biot Number (Bi) is calculated to determine whether or not the lumped approach is valid. If the Biot Number is less than 0.1 , then the lumped approach gives good results.

$$\text{Biot No.} = \frac{h\left(\dfrac{V}{A}\right)}{k_s}$$

where: h is the convective coefficient

V is the volume of the plate

A is the total surface area of the plate (both sides, plus edge if significant)

k_s is the thermal conductivity of the plate material

(Note: From heat transfer text, the h value for natural convection in gases typically ranges from 2 to 20 $w / m^2 C$.)

Material Properties

Brass	Stainless Steel	Alloy 110 Copper
$\rho = 7930 \text{ kg/m}^3$	$\rho = 8500 \text{ kg/m}^3$	$\rho = 8940$ kg/m3
$c = 385$ J/kg C	$c = 460$ J/kg C	$c = 385$ J/kg C
$k_s = 121$ w/m C	$k_s = 16.3$ w/m C	$k_s = 390$ w/m C

Example No. 2

Calculate the Biot No. for the plate of Example No. 1 above. In the calculation, use the h value you got in Example No. 1.

Bi = ________________

As noted above, if $Bi < 0.1$, the lumped technique is appropriate.

Can we use the lumped technique in our experiment ? (Yes / No)

KSB No. 3 Transient Response with Lumped Technique

For the lumped technique, the transient response of the plate is given by

$$T(t) = T_\infty + (T_i - T_\infty)\, e^{\frac{-hA}{\rho c V} t} \qquad (3)$$

where: $T(t)$ = temperature of the plate at time t

T_∞ = constant temperature of the room air

T_i = initial uniform temperature of the plate

ρ = density of the plate

c = specific heat of the plate

A = total surface area of the plate, including both sides and edge, if significant.

h = convective heat transfer coefficient

t = time

Note: Thermal conductivity k_s does not appear in equation (3) since the equation is for the "lumped analysis" where the temperature is uniform throughout the body at a given instant of time. Conduction through the body is not relevant. However, the thermal conductivity of the solid was used in KSB No. 2 to determine if use of the lumped analysis is appropriate.

Example No. 3

A copper plate (alloy 110) is square (4 inches by 4 inches) and 1/8 inch thick. The plate is heated to 100 C and is hung vertically on a stand. It cools in the 20 C room air.

(a) How long will it take for the plate to cool from 100 C to 80 C?

(b) How long will it take for the plate to cool from 100 C to 40 C?

(Note: 1 m = 39.37 inch.)

(a) Calculate the time for the plate to cool from 100 C to 80 C

(b) Calculate the time for the plate to cool from 100 C to 40 C

KSB No. 4 Transient Heat Transfer with Both Convection and Radiation

Since we are defining *h* as being the convective coefficient and not a combined convective and radiative coefficient, the first three KSBs included only convection. In this KSB, radiation as well as convection will be included.

Consider a heated plate of total surface area *A*, volume *V*, and having the properties density ρ, specific heat *c*. At time zero, the plate has a uniform temperature of T_i. It then convects to a surrounding fluid which is at T_∞ and radiates to the surrounding surfaces which are at T_{surr}. The convective coefficient is h and the emissivity of the plate is ε .

From an energy balance viewpoint, the rate of decrease in internal energy of the plate is equal to the rate of heat transfer by convection to the surrounding fluid plus the rate of heat transfer by radiation to the surroundings. The differential equation is:

$$-\rho c V \frac{dT}{dt} = hA\left(T - T_\infty\right) + \varepsilon A \sigma \left(T^4 - T_{surr}^4\right) \qquad (4)$$

where: T is the temperature of the plate at time t

σ is the Stefan-Boltzmann constant = 5.67×10^{-8} w / m^2 K^4

One way to solve equation (4) is by numerical integration, working forward in time from time = 0.

Let's rearrange equation (4) by dividing both sides by -ρcV. We get

$$\frac{dT}{dt} = -\frac{hA\left(T - T_{\infty}\right)}{\rho cV} - \frac{\varepsilon\sigma A\left(T^4 - T_{surr}^4\right)}{\rho cV} \qquad (5)$$

Let's further change this equation to finite-difference form:

$$\Delta T = \ - \left(\frac{hA\left(T - T_{\infty}\right)}{\rho cV} + \frac{\varepsilon\sigma A\left(T^4 - T_{surr}^4\right)}{\rho cV}\right) \ \Delta \mathrm{t} \qquad (6)$$

In this equation, Δt is the arbitrarily-chosen time step, and ΔT is the temperature change for the particular time step; that is, the temperature change from the beginning of the time step to the end of the time step.

That is, $\Delta T = T_{new} - T_{old}$, where T_{new} is the temperature at the end of the particular time step and T_{old} is the temperature at the beginning of the time step. Equation (6) can therefore be written as:

$$T_{new} = \ \mathrm{T}_{\mathrm{old}} \ - \left(\frac{hA\left(T_{old} - T_{\infty}\right)}{\rho cV} + \frac{\varepsilon\sigma A\left(T_{old}^4 - T_{surr}^4\right)}{\rho cV}\right) \ \Delta \mathrm{t} \qquad (7)$$

Equation (7) is applied over-and-over again, working forward in time. Each application of equation (7) increases the time value by an amount Δt.

Example No. 4

A copper plate (alloy 110) is square (4 inches by 4 inches) and 1/8 inch thick. The plate is initially at 100 C. It cools by convection to the 20 C room air and radiates to the surroundings, which are also at 20 C. The convective coefficient is 4 w / m^2 C and the emissivity of the plate surfaces is 0.7. Determine the temperature of the plate for the first minute of cooling.

Solution

For the plate, we have,

$A = (4)(4)(2\text{sides})/39.37^2 = 0.02065\ \text{m}^2$ (Edge area deemed negligible so omitted.)

$V = (4)(4)(1/8)/39.37^3 = 3.277 \times 10^{-5}\ \text{m}^3$

$\rho = 8940\ \text{kg/m}^3$

$c = 385$ J/kg C

$T_i = 100\ \text{C} = 373.15\ \text{K}$ (Must work in "Kelvin" since radiation is involved)

$T_\infty = T_{surr} = 20\ \text{C} = 293.15\ \text{K}$

$\sigma = 5.67 \times 10^{-8}\ \text{w/ m}^2\ \text{K}^4$

$\varepsilon = 0.7$ and $h = 4\ \text{w / m}^2\ \text{C}$

We now have to select a time step Δt . Since we want the temperature for one minute, let's select the time step as one second. Therefore we have to repeat equation (7) sixty (60) times to cover the one-minute period. Each time we repeat equation (7), the temperature valued is updated for one-second later.

With the values of this example problem, equation (7) becomes:

$$T_{new} = \mathrm{T}_{\mathrm{old}} - \left(7.323 \text{ x } 10^{-4}\left(T_{old} - 293.15\right) + 7.267 \text{ x } 10^{-12}\left(T_{old}^4 - 293.15^4\right)\right)\ (1) \qquad (8)$$

For the first time step (from t = 0 to t = 1 s), we have, from equation (8)

$T_{old} = T_i = 373.15$

$$T_{new} = 373.15 - \left(7.323 \text{ x } 10^{-4}\left(373.15 - 293.15\right) + 7.267 \text{ x } 10^{-12}\left(373.15^4 - 293.15^4\right)\right)\ (1)$$

$T_{new} = 373.15 - 0.146 = 373.004$ K

This is the temperature after one second. To get the temperature after two seconds, we apply equation (8) again, with $T_{old} = 373.004$ K. This gets us Tnew = 372.859 K, which is the temperature after two seconds.

We continue to apply equation (8) over-and-over for the full one-minute time period.

These calculations may be done using a variety of software packages, such as Excel and Matlab. A Matlab program and its results are as follows:

Matlab Program

```
% Cooling of Vertical Plate
clc, clear
tk(1)=373.15;
tc(1)=100;
t(1)=0;
for i=2:61
        tk(i)=tk(i-1)-(7.323e-4*(tk(i-1)-293.15)+7.267e-12*(tk(i-1)^4-293.15^4))*(1);
        tc(i)=tk(i)-273.15;
        t(i)=t(i-1)+1;
end
disp('t (s)         T  (K)              T  (C)')
Table(:,1)=t;
Table(:,2)=tk;
Table(:,3)=tc;
fprintf('%.0f%12.3f%12.3f\n',Table')
plot(t,tc),xlabel('t  (s)'),ylabel('T  (C)'),title('Cooling of Plate','fontsize',16)
```

Results

```
t (s)          T  (K)          T  (C)
0             373.150        100.000
1             373.004         99.854
2             372.859         99.709
3             372.714         99.564
4             372.569         99.419
5             372.425         99.275
6             372.280         99.130
7             372.137         98.987
8             371.993         98.843
9             371.850         98.700
10            371.707         98.557
11            371.565         98.415
12            371.422         98.272
13            371.280         98.130
14            371.139         97.989
15            370.998         97.848
16            370.857         97.707
17            370.716         97.566
```

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18          370.576     97.426
19          370.436     97.286
20          370.296     97.146
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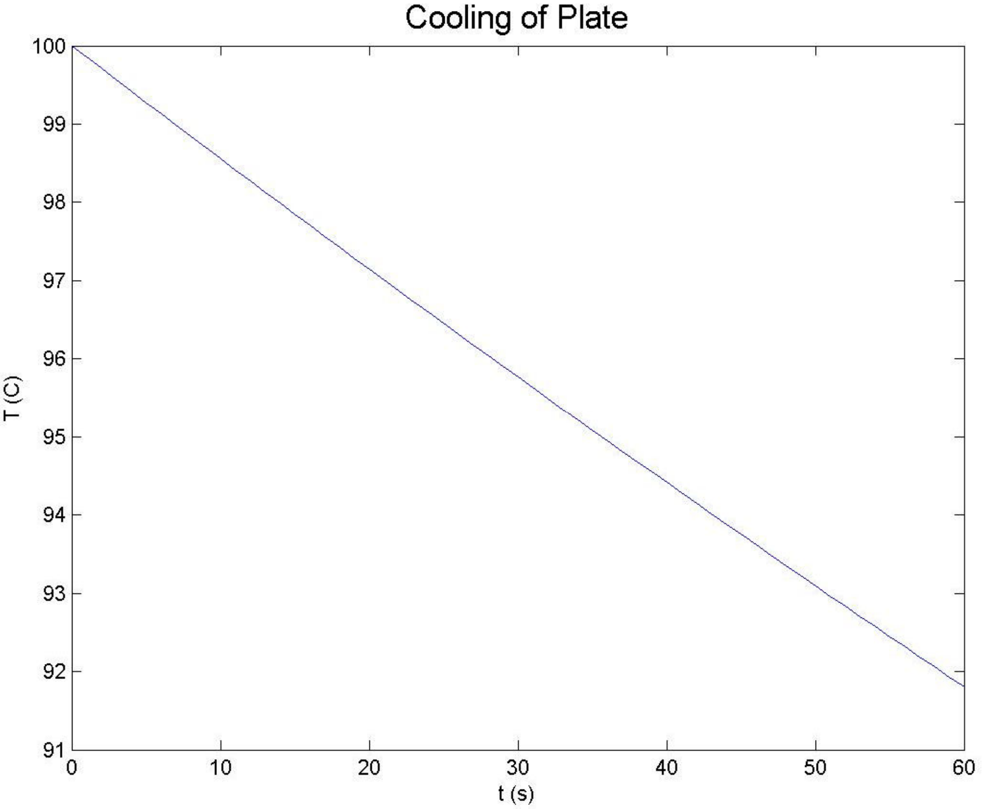
51          366.114     92.964
52          365.983     92.833
53          365.853     92.703
54          365.724     92.574
55          365.594     92.444
56          365.464     92.315
57          365.336     92.186
58          365.208     92.058
59          365.079     91.929
60          364.951     91.801
```



It is seen that the temperature of the plate decreases from 100 C to 91.8 C in the first minute of cooling. From the graph, it appears that the temperature-time curve is linear. This is really not the case. It only appears linear because we are looking at a very small time interval. If we ran the program for 10 minutes (600 time steps) rather than one minute, the exponential form of the solution would be very obvious.

Design Problem

Carbon steel plates are taken out of an oven and slowly moved to another location in the shop. The plates are 2 ft. by 2 ft. by 1/2 inch thick and are hung vertically as they are moved. The plates are at a temperature of 500 C when they leave the oven, and it takes the plates 5 minutes to move from the oven to the new location. How hot are the plates when they reach the new location? (Make appropriate assumptions and list them in your solution.)

APPENDIX B - THE STUDENT SURVEY

Student Survey on the Use of KSBs in ENGG 170
Spring 2008 Semester

On the last day of class (May 7, 2008), students were asked to complete a survey regarding the use of KSBs in the course. This survey was developed by the staff of the Center for Advanced Study in Education of the CUNY Graduate Center. Many thanks to Dr. Deborah Hecht, Maria Russo, and other staff members.

All twelve students in the class participated in the survey, and the results are given below.

All students were seniors in mechanical engineering. There were 11 male students and one female student. Ten students had taken the heat transfer lecture course in the previous semester. One student had taken heat transfer several years previously. One student had not yet taken the heat transfer lecture course.

The numbers below the categories indicate the number of students responding in the various categories.

WHAT YOU THINK ABOUT WHAT YOU LEARNED

How easy or hard was it to learn from the KSBs?

Very easy	Somewhat easy	Neither easy or hard	Somewhat hard	Very hard
7	5	0	0	0

What was the hardest thing about the way this class was taught?

"Having to relate back to heat transfer course."

"Trying to remember all the thermo book work of past."

"I found some calculations difficult for the lab reports because I had not taken heat transfer."

"Labs very long / monotonous."

"Nothing, enjoyed it actually."

"Not always having chart information available."

"Some concepts were vague since some concepts haven't been taught to me in a long time."

"Experiments took a long time to complete and were tough to stay focused. KSBs helped think about the lab while it was running."

"Write-ups."

"The lab write-ups. Little vague on requirements."

PLEASE TELL ME HOW YOU FEEL

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
The KSBs helped me better apply what I had learned in previous courses.	SD 1	D	N	A 5	SA 6
I learned NEW engineering and design concepts through use of KSBs.	SD 1	D 1	N 5	A 2	SA 3
The engineering concepts I learned were important.	SD 1	D	N 1	A 2	SA 8
I would recommend this approach be used by other instructors.	SD 1	D	N	A 3	SA 8
The performance of the experiments took less time to complete because of the KSBs.	SD 1	D 1	N 2	A 6	SA 2
I enjoyed the KSB approach.	SD 1	D	N	A 3	SA 8
The activities were presented in an order that makes sense.	SD 1	D	N 2	A 2	SA 7
The KSBs were difficult to understand.	SD 6	D 6	N	A	SA

	SD	D	N	A	SA
There was adequate time in a lab period to complete all activities.	1	1	2	5	3
The KSBs are important.	1		1	7	3
The KSBs helped me learn the concepts.	1		2	3	6
The KSBs would be useful in facilitating the design of a system, process, or equipment item.	1		2	6	3
It helped me to do the KSBs before performing the lab experiments.	1			7	4
I benefited from working in a group on the KSBs and worksheets.	1			4	7
Too much time was spent on the KSBs.	2	7	3		
As a result of the working on the KSBs, I think my lab submittals were of better quality.	1		3	4	4
Working on the KSBs helped me do better in this class than I would have without the KSBs.	1		2	4	5

(Instructor Comment: In looking at the various items, it is seen that several items have one entry of "SD" while the other responses are weighted towards the "A" or "SA" end. The "SD" responses were from the same student, who appeared to be negative on the use of KSBs, but curiously rated the use of KSBs (next question) as "excellent". Perhaps the student had an overall "attitude" problem about the lab!)

OVERALL REACTIONS

How would you rate the use of KSBs?

Poor	Fair	Good	Excellent
0	1	4	7

How would you change or improve the use of KSBs?

Six of the 12 students provided comments, as follows:

"Maybe have them done in a smaller group, not entire class."
(Instructor comment: Although everyone in the class did the KSBs at the same time, students worked at different tables in groups of four.)

"Provide more resources when asking for information that needs it; i. e., charts needed to solve a question."

"Make sure the length of the KSB allowed for ample time to complete lab."

"It's good the way it is."

"Use them more often in labs. They refresh the theory that lies behind the practical lab work for students."

"I think the KSBs were very useful especially for me because I didn't take heat transfer (before the lab class). The KSBs provided a good background which aided in my understanding of the lab."