

**Math 2250**  
**MAPLE TUTORIAL and PROJECT I HINTS**  
Fall 2002

**This document is a tutorial for Math 2250 students who may not have done previous work with MAPLE or in the Math lab, or who may just want to brush up on their skills. At the end of the tutorial there is an introduction to the first project. Links to the precise template for your project answers and to an on-line version of this tutorial can be found at the home page for 2250 maple projects, <http://www.math.utah.edu/~korevaar/2250fall02>**

The Math 2250 projects can be done in versions five and above of Maple, with minor changes. The Math Lab, EMCB, and Marriott Library all have version 7 of Maple. A student version for home computers is available from the bookstore for approximately \$100.

**1) Using the Math Computer Lab:**

The Math Department has a walk-in computer lab in the Math Student Center, located underneath the plaza connecting JWB to LCB. There is also a computer classroom in LCB 115, where introductory tutorials will be held. Useful information about most aspects of the lab can be found by following links from the Math Department web pages, e.g. starting at <http://www.math.utah.edu/ugrad/lab>. You can find out about lab hours, X-windows, Maple, Unix commands, Netscape, file editing, mail, etc.

**1a) Logging on:**

Almost all students who are registered in Math 2250, or in any other math class, will already have accounts set up in our lab. Since these accounts are created from University class lists, late-registering students may not be accounted for. If you fit in this case the lab assistant can help you apply for an account - provided you have brought your student I.D. to show that you are a University student.

The lab machines are left on - move the mouse or hit a key to wake yours up. The Math system is UNIX based. If your machine is on the login screen you may click on **options**, then **session**, and then choose between the **CDE** (Common desktop environment) or the **openwindows** environments. If you're used to MS windows or MACs you probably prefer **CDE**, which is more graphically designed. If you like command based systems choose **openwindows**.

Now it is time to log on: Your **login name** is made out of your initials. If your name is **Karl Fred Gauss**, then your login name is c-gskf, following the recipe: c-(first letter of last name)(last letter of last name)(first letter of first name)(middle initial). If there are multiple people registered this term with the same initials, then rather than c-gskf, they are assigned login names with a numerical suffix, c-gskf1, c-gskf2, c-gskf3, etc. Mr. Gauss would not know beforehand which case he fell into, so would probably try c-gskf first, followed by his password (see below). In case of failure he would then try c-gskf1, then c-gskf2, etc, through c-gskf4. Then he would find a lab assistant. After entering your try at a login name, type the "return" key and the cursor should be in the password box.

Your **initial password** is just the gskf part of your login name (NOT the numerical suffix), followed by the last four digits of your student I.D. number. If Mr. Gauss has ID number 000735421 then his initial password is gskf5421, regardless whether his login name was c-gskf or c-gskf3. If the login fails try

again and then try the different login names suggested above. One possibility is that your account was created using your social security number (which used to be used for student ID number). If failure continues find a lab assistant and he/she will help you.

If you chose the **CDE** environment a desktop will appear after your successful login, with various icons. At the bottom of the screen you will see a Maple leaf-like object which is the icon for MAPLE. Also note a netscape icon for the internet.

If you chose the openwindows environment a “local” window should appear. Notice that it has various parts: borders on the top (title bar), borders on the side (scroll bar), etc. If you move your mouse on its pad your pointer (called cursor) moves around the screen. If you want to work in a window, the cursor should be in it. You can make multiple local windows by pressing the right mouse button and highlighting "local". In this environment you can find X MAPLE V7 on your middle mouse button. Netscape lives under WWW Browsers, also on the middle mouse button.

**1b) Changing password:** Some time within the first several weeks of classes you must change your default password into a personal one. You do this as follows: In CDE create a terminal window using the icon at the bottom of your desktop, and move your cursor to it. In openwindows get your cursor into a local window. Type the unix command *passwd*, followed by return, and follow the directions. Your new password should be exactly 8 characters long. Don't choose a word in the dictionary or a proper name. Composites of dictionary words, like strawdog, are good. Even better is to use one or two upper case letters, e.g. strAwdog. For still more security, use some digits, e.g. strAw4o9. It takes about 15 minutes for a new password to take effect. If a password is not changed within the first several weeks of class, then your computer account will be disabled for security reasons. Make sure to write down your password in a secure place, in case your memory is not perfect.

**1c) Logging out:** In CDE there is a logout icon at the bottom of your desktop. In openwindows move the cursor out of all windows (into the background), press the left mouse button and choose the last menu item: Exit X-Windows. (You probably don't want to do this now, but at least locate the menu item for later.)

## **2) Opening netscape, maple, mail, more:**

For your Math 2250 purposes you need to be able to open Netscape (to download files) and Maple (to work on them). Open Netscape and Maple now: in CDE use the icons at the bottom of the desktop. In openwindows use the middle mouse button, or alternately move your cursor into a local window and then type **netscape &**, followed by <ENTER>. The **&** tells X-windows to create a separate process for netscape, keeping your local window free for more UNIX commands. You start Maple the same way, by typing **xmaple &**, followed by <ENTER>.

You can find out more information about the student services in the Math Department by going to the URL <http://www.math.utah.edu/ugrad>. If you choose the Undergraduate Computer Lab link, or go directly to <http://www.math.utah.edu/ugrad/lab> you can find out about lab hours, software, etc.

## **3) Maple:**

If you are starting the tutorial at this point (because you're doing it on your own at another location or already knew the Math Lab system), you should have opened a mapleV7 ( V5 and V6 should also work) window as well as a web browser.

Maple is partly just a very fancy calculator; it can do practically any undergraduate mathematics computation or symbolic manipulation. You can write programs in Maple and draw pictures as well. If you are doing a homework assignment you can intersperse text with computations using the toolbar: to get a computation prompt click on the “[>]” box near the top. To insert text click on the “T” box. Or you can change command fields (starting with “[>]”) into text fields by putting the cursor into them and then choosing “T”. You can use the mouse to cut, paste, and edit a document. You can change fonts, formats, and use other standard text editing tools by choosing appropriate menu items. This document you are reading is a Maple document even though it is largely text. You will learn by doing - and by asking your neighbor or the lab assistant.

### **New User’s Tour and more:**

Under the Help button at the top right of your Maple window you will find the choice “New User’s Tour”. This is a good way to learn generally about what Maple can do. After making this menu choice Maple may hide the beginning of the tour behind other active windows; use the “Window” menu item to bring the tour window to the front. If you wish you can explore now, or you can continue with the Math 2250 notes below and come back to the tour later. To close the new tour (or any other top window), use the “close” option inside the “file” menu item. To keep the tour open but bring another window to the front, use “window” menu item.

Another good introduction to Maple is located at <http://www.math.utah.edu/~gardiner/Intro.mws>. If you have a browser open you can open Maple files directly off the internet by using clicking successively on **File -> Open URL**, in the Maple menu items at the top of the Maple window. Alternately you can save .mws files from your browser and then open them from Maple.

### **Entering Maple commands:**

To give you a brief taste of what Maple can do, we will try a few commands. Move your cursor into the “Untitled” (new) Maple window which you created in step (2). Commands begin on lines having a command prompt “>”, and should be ended with either a semicolon ; or a colon : If you end with a semicolon you will see visible output, if you end with a colon the output will be suppressed even though the command is executed. Maple will not execute a command until you type the “return” or “enter” key. **If you have a multiline command use “shift-return” to change lines without executing.**

If you incorrectly align parentheses or brackets, or do something else which makes your command unexecutable you will get a “syntax error” message and Maple will try to point out your mistake with the cursor and cryptic diagnostic phrases. After a while you will become good at fixing these mistakes but they can be annoying at first. Spaces are ignored in Maple, so you may use them to make input easier to read. You can enter explanatory comments in a command line by inserting a “#” to the left of the comments; Maple ignores any text after the #. Sometimes this is more informative than entering nearby explanatory text, especially if you are explaining various steps in a subroutine.

Now, let’s try some commands. (You try just the math commands, the editorial comments were only added to explain what the particular commands are illustrating !) Check that you understand what each command is doing.

```
> 3+4; 4+5: 6 * 7;      #one of these computations will not be shown
                          #even though all three will be done, illustrating the
                          #difference between a semicolon and a colon
```

```

[ > (3+4)7;          #if you want to multiply you must use *, so after
                        #trying the command as given, insert a * to fix the
                        #resulting syntax error. You can execute a line or
                        #execution group (bracketed on the left) if
                        #your cursor is anywhere in it. You can move the
                        #cursor with the mouse or the arrow keys. Maple will
                        #try to put it in a good place if it detects an error.
Error, unexpected number
[ > (3+4)^2/7; 3+4^2/7; evalf(3+4^2/7); #the evalf command gives a
                        #decimal approximation instead of an algebraic
                        #expression. Notice that if given a choice, Maple
                        #computes powers first, then multiplies and divides,
                        #and finally adds or subtracts.
[ > diff(x^2,x); #''differentiate x^2 with respect to x''
[ > diff(exp(sin(x))*x^3,x); #a harder differentiation problem
                        #you should get output:
                                cos(x)esin(x)x3+3esin(x)x2
[ > f:= x-> exp(sin(x))*x^3; #this is the syntax for defining a
                        #function, in this case the function we just
                        #differentiated
[ > diff(f(x),x);          #should get the same answer as before.
[ > int(t^2*exp(t),t);    #''integrate (t^2)*exp(t) with respect
                        #to t'' (Maple doesn't put in the integration constant.)
[ > int(t^3*exp(sin(t)),t); #this shows that Maple is not God, you
                        #will get
                                
$$\int t^3 e^{\sin(t)} dt$$

[ >          # since if Maple can't find an elementary function
                        #antiderivative it just echos what you put in.
[ > evalf(int(t^3*exp(sin(t)),t=0..1)); #But you could do
                        #a definite integral (numerically) even if Maple
                        #can't compute an elementary antiderivative
[ > Pi;exp(1);evalf(Pi);evalf(exp(1));infinity;
                        #some important numbers

```

### Entering Text:

Scroll to somewhere in your worksheet and add some text with the “T” menu item. (If you move your cursor to a command field and then press the [>] button with your mouse, Maple makes a new command field directly below it. If you move to the new command field and press the T button you will have a text field into which you may write, using the rudimentary word processing tools on the Maple menu bar.

Now scroll to the top of your file and insert the title “My first Maple worksheet” (center it with the menu option on the right side of the toolbar), as well as your name and today’s date. When you are doing

your Maple projects you will be expected to hand in more than a page of computations: You will be expected to add text explanations of what you've been doing.

### **Saving Files:**

It is always a good idea to save your maple file periodically. Do this now using the tool bar, using the "save" option under the "File" menu item. The first time you save a new file, and any time you use the "save as" option, you will be asked to name your file and say where you want to keep it. You name it in the left part of the box, being careful to keep the suffix ".mws" so that Maple knows this file is a **Maple Work Sheet**. If your directory is new you probably haven't made any subdirectories yet (unix command `mkdir`, in a local window), but as you create more files you may wish to organize where you save them using the tree structure of Unix directories, which you can follow in the right side of your saving box. You use various UNIX commands in your local or terminal window to organize your directories. For more information about this, go to <http://www.math.utah.edu/ugrad/unix/unix-commands.html>

It will probably happen some time that you will crash Maple long after your last save. This will not make you feel happy but will teach you an important lesson.

### **Printing:**

In the menu bar click successively on **file->print->print command**. Then in the print command box choose the name of the printer you want to use. In UNIX you also need the prefix `lpr -P` (spaces important), which stands for line printer - P. For example, the printer in the math center room 115 is called `mc155c`, so you want to enter **`lpr -Pmc155`** into the print command box, and then click on the **print** box at the bottom of the window and your file should print. The print command in the room LCB 115 would be **`lpr -P lcb115`**. **If you have trouble printing ask a lab assistant for help. One glitch which seems to occur is that figures don't print correctly.** If this happens try modifying the print command to `lpr -l-Pmc155` or `lpr -oraw-Pmc155`. You can also print postscript files to your math directory by using the "output to file" choice in the printing dialog box.

### **Downloading Maple documents:**

This xeroxed tutorial is available online in several formats, if you follow the links from the 2250 Maple homepage at <http://www.math.utah.edu/~korevaar/2250fall02>. Files with suffix ".mws" or ".txt" can be downloaded from your browser and then opened from Maple.

Go to the course homepage address using your browser, and find and save the **2250falltut.mws** file to your home directory.

Now return to your Maple window and use the "file" menu item to open **2250falltut.mws**. It should appear in the central box after you choose "open". Click on it with the mouse to highlight it and then click "OK" or type "return". A copy of this tutorial should then appear in your Maple window, as a Maple document that you can work in. Notice you can use the "Window" menu item at the top of your Maple window to change between various open files. (Sometimes when you open a new file it goes to the back of your pile. Then use the Window option to bring it back to the front.)

If you know the exact URL of a Maple file and have a browser open you can use **File->Open URL** to have Maple do the downloading and opening for you. For example, the URL of this tutorial is <http://www.math.utah.edu/~korevaar/2250fall02/2250falltut.mws>.

### **Execution Groups:**

You can modify the text and input using the toolbar and menu options. You will notice many brackets on the left of the document. These are execution groups. Maple will execute everything in one execution group at once, and then move the cursor to the next execution group. You can create large execution groups by highlighting sections of a document, using **Edit->Split or Join->Join Execution Groups**. You can remove brackets by highlighting them with the mouse and deleting them with the delete key or the menu option. And you already learned how to insert new prompts or new text wherever your cursor is, by using the [ $\>$ ] and T buttons on your toolbar.

4)

## INTRODUCTION TO PROJECT I

### A preliminary paragraph of advice:

Students often approach the task of reading mathematical material as if they were reading a novel; they sort of skim along quickly. That approach is O.K. to get an overview, but in order to have a chance at real understanding you must be prepared to proceed much more slowly, sentence by sentence and thought by thought. Otherwise you will almost certainly find yourself partly lost after several paragraphs and completely lost after several more. (This might happen anyway.) If you are working properly it can easily take half an hour to read through one page of mathematical text. This takes a certain amount of discipline, patience, and practice. With the Math 2250 computer projects there is the added temptation of having Maple execute commands in successive command sections by repeatedly hitting the enter (return) key, without pausing to digest the interlaced text or the meaning of the commands. There is a seductive appeal in having this capability. Resist it.

Open your text book to page 55, and follow along. We will go through the Maple commands and text corresponding to the section 1.5 Computing Project of Edwards-Penney. If you go through this section carefully now, then your life should be relatively easy when you download the solution template from the course home page. Make sure you understand what each command is doing, and what each equation is saying, in the work below.

For further information about syntax and options related to commands below, use the help menu button at the upper right corner of your Maple window.

```
[ > restart: #When you start new work it is often a good idea
      #to clear all old definitions etc. restart does this.
      #Of course, then you must then reload any packages you need
      #and redefine anything you need as well.
[ > with(DEtools): #load diffeq tools, for later. If you want
      #to see the list of commands in the DEtools
      # package, end your command with ";" rather than ":"
```

At the start of the the project, on page 55, we see how to automate the method of solving a general first order DE initial value problem, see equation (11) on page 48. So  $P(x)$  and  $Q(x)$  will be as shown there, except we will use lower case  $p$  and  $q$  like on page 55. On page 55 we are considering the particular first order linear differential equation

```
[ > deqtn:=diff(y(t),t) + y(t) = t;
      #notice how we write the derivative of y
      #with respect to t
```

$$\text{deqtn} := \left( \frac{\partial}{\partial t} y(t) \right) + y(t) = t$$

Following the algorithm on page 48 (with the roles of  $x$  and  $t$  reversed as on page 55!) the text tells us to set

```
> p:=t->1;
    #this is how to define functions in Maple;
    #the command is saying p(t)=1. The := should
    #be read as "is defined to be." The arrow
    #can be thought of as saying "goes to"
q:=t->t;
    #this command is saying q(t)=t
r:=t->exp(int(p(x),x=t0..t));
    #the integrating factor r(t)
y:=t->(1/r(t))*(y0+int(r(x)*q(x),x=t0..t));
    #the solution y(t) to the IVP with y(t0)=y0.
```

For example, if we wanted to solve the differential equation on page 55, with  $y(0)=2$ , we would set

```
> t0:=0;
    y0:=2;
```

and evaluate

```
> y(t);
```

$$\frac{3 + e^t t - e^t}{e^t}$$

You might want to verify this answer to the initial value problem by hand. Of course Maple can solve DE's symbolically too, with the single command "dsolve." If you want to read about the syntax required for this command, you should use the Help menu item at the upper right corner of your Maple window, and search the topic "dsolve". Once you have a rough idea about a command it is often helpful to scan down to the bottom of the help file to see worked out examples. If you do this you will eventually decide to try something like

```
> dsolve({deqtn, y(0)=2}, y(t));
Error, (in pdsolve/sys/info) required an indication of the dependent variables in the given system
```

This command didn't work. It would've worked, except that you have defined  $y(t)$  just above here, so when Maple evaluates the differential equation "deqtn" which you defined earlier, it plugs in the  $y(t)$  you defined subsequently, so that the deqtn evaluates to  $t=t$ , yielding the error message. ???!!!! You can fix problem by never using the same symbols twice, or more practically, by restarting, to clear out conflicting definitions:

```
> restart: #clears all definitions and memory
with(DEtools):
```

**Restarting and Reopening:** Every time you reopen a Maple file you will need to re-enter commands and definitions. Similarly, if you restart but want some old definitions to hold, move your cursor to the appropriate command fields and reenter them using the <enter> key..

```
> deqtn:=diff(y(t),t) + y(t) = t;
```

```

#I moused in same deqtn from above
dsolve({deqtn,y(0)=2},y(t));
#and same dsolve command above. Now
#it should work, and even give an answer
#which agrees with your ealier one

```

$$deqtn := \left( \frac{\partial}{\partial t} y(t) \right) + y(t) = t$$

$$y(t) = t - 1 + 3 e^{(-t)}$$

We now continue with the book's discussion at the top of page 56.

```

> A:=t->a0 + a1*cos(omega*t) + b1*sin(omega*t);
#formula for ambient temperature, with free
#parameters a0, a1, b1, omega. This is equation
#(1) on the top of page 56. When you enter multi-line
#commands hold down the shift key while you hit
#"enter" or "return", to prevent premature execution

```

$$A := t \rightarrow a0 + a1 \cos(\omega t) + b1 \sin(\omega t)$$

```

> deqtn3:=diff(u(t),t)=-k*(u(t)-A(t));
#we name our DE "deqtn3" since it's equation (3)
#on page 56.

```

$$deqtn3 := \frac{\partial}{\partial t} u(t) = -k(u(t) - a0 - a1 \cos(\omega t) - b1 \sin(\omega t))$$

We will find the general solution to deqtn3 first, with all the free parameters, and then fix the parameters for a July day in Athens Georgia second. You should be able to use the integral table entries 49,50, or alternately have the computer follow the recipe method we just outlined to find the general solution. However, it is easier to just use dsolve. You should verify that the solution you get below agrees with equation (4) on page 56.

```

> eqtn4:=dsolve({deqtn3,u(0)=u0},u(t));

```

$$eqtn4 := u(t) = - \frac{e^{(-kt)} (k^2 a1 - k b1 \omega + a0 k^2 + a0 \omega^2 - u0 k^2 - u0 \omega^2)}{k^2 + \omega^2}$$

$$+ \frac{a0 k^2 + a0 \omega^2 + k^2 a1 \cos(\omega t) + k a1 \omega \sin(\omega t) - k b1 \omega \cos(\omega t) + k^2 b1 \sin(\omega t)}{k^2 + \omega^2}$$

Now we set the parameters equal to the values at the bottom of page 56, so that we are studying something like summer days in Athens Georgia:

```

> a0:=80;
#average ambient temp in Georgia in July
a1:=-5;
b1:=-5*sqrt(3.0);
#the a1 and b1 values were worked out by hand,
#using the cosine addition
#angle formula, assuming 4 a.m. temp min and 4 p.m max,
#and range from 70 to 90 degrees,
#for trigonometric temp oscillation.

```

```

omega:=Pi/12;
  #this makes the period equal to 24 (hours)
k:=0.2;
  #constant for a well-insulated building

```

With these parameter values, we get equation (5) on the bottom of page 56:

```

> eqtn5:=simplify(eqtn4);
  #It automatically plugged in the parameter
  #values I defined above. I asked for "simplify"
  #because otherwise the expression looked too messy.

```

$$\begin{aligned}
 eqtn5 := u(t) = & -82.33510564 e^{(-.2000000000 t)} + 80. + e^{(-.2000000000 t)} u_0 \\
 & + 2.335105624 \cos(.2617993878 t) - 5.603607924 \sin(.2617993878 t)
 \end{aligned}$$

Read along with the text on page 57. Notice that no matter what the initial house temperature was, the negative exponential terms die out rapidly and one is left with the steady periodic solution given by equation (6) in the text. We can extract it from our eqtn5 above, by using the mouse to cut and paste:

```

> usp:=t-> 80 +
  2.335105624*cos(.2617993878*t)-5.603607924*sin(.2617993878*t);
  usp := t -> 80 + 2.335105624 cos(.2617993878 t) - 5.603607924 sin(.2617993878 t)

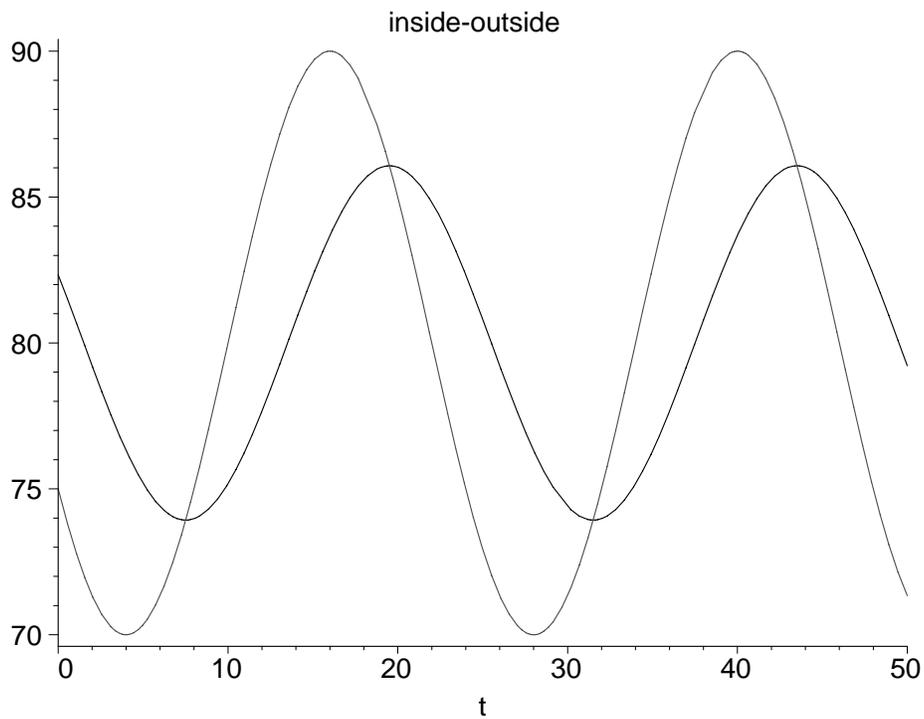
```

We can reproduce figure 1.5.10 (it would take more work to get all the labels in) as follows

```

> with(plots):
  #this is the plotting package. End with ;
  #to see command list
Warning, the name changecoords has been redefined
> ambient:=plot(A(t),t=0..50, color=red):
  #this is a plot of ambient temp defined
  #above, with Athens parameters. Make sure
  #to end this command with colon, not semicolon,
  #or you will get a very long list of points.
inside:=plot(usp(t),t=0..50, color=black):
  #the steady periodic inside temperature
display({ambient,inside}, title="inside-outside");
  #display both plots together

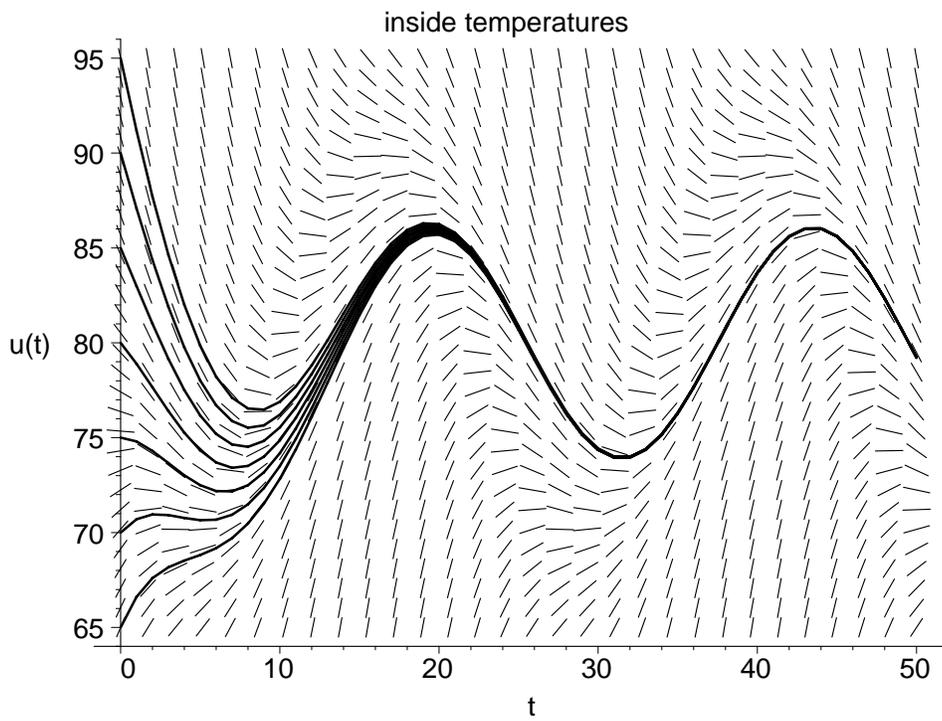
```



As the text remarks, you see that the inside temperature oscillates trigonometrically with a smaller amplitude and with a time delay, relative to the outside temperature. (The annual seasonal temperature variations on earth lag behind the solstice-equinox dates, for a similar reason.)

We can recover figure 1.5.9, together with the slope field, with a DEplot command. This picture illustrates geometrically the fact that all solutions converge to the steady periodic one:

```
> DEplot(deqtn3, u(t), t=0..50, {[u(0)=65], [u(0)=70],
  [u(0)=75], [u(0)=80], [u(0)=85], [u(0)=90], [u(0)=95]},
  arrows=line, color=black, linecolor=black,
  dirgrid=[30,30], stepsize=1,
  title="inside temperatures");
```



This is the end of the tutorial. To download your instructions and template for project 1, follow the links from <http://www.math.utah.edu/~korevaar/2250fall02>, as they become available.