

**Math 2250**  
**MAPLE TUTORIAL and PROJECT I HINTS**  
Spring 2001

**This document is a tutorial for Math 2250 students who may not have done previous work with MAPLE or in our lab, or who may just want to brush up on their skills. At the end there is an introduction to the first project. You should download the precise template for your project answers from the course home page <http://www.math.utah.edu/~korevaar/2250spring01.html>, where this tutorial is also available.**

**0) A preliminary word 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.

**We will assume you are working in the Math Department computer lab. If you are in another lab (e.g. Engineering lab in EMCB or Library lab in Marriot) or on your own computer, you will get started differently.**

**1a) Logging in to a Math Lab machine:** The Math Department Computer Lab is located in the South Physics 205, i.e. inside the 2-story brick building just north of the Math building JWB, and south-east of the physics classrooms in the circular part of JFB. Room 205 is in the back (East) of the building, on the second floor (from the west), which equals the level of the ground on the uphill, east entrance.

The following information about logging in and your initial password is summarized from the handout *Introduction to the Undergraduate Computer Lab Department of Mathematics, University of Utah, SLC, Utah 84112*. This and other useful handouts are available on a table in the front of the lab.

Everyone who is registered in Math 2250 should automatically have an account set up in our lab. These accounts are created from University class lists so it sometimes happens that late-registering people don't have accounts yet. If you turn out to be one of these people you will need to consult the lab assistant about getting an account. Make sure to bring your student I.D. because the first thing the assistant must do is verify that you are a University student.

If your machine looks asleep jiggle the mouse or hit any key to wake it back up. A window should appear which asks you to select a server. Since the Math Department is sharing this lab with Physics, there are physics and math server computers. You want to select one from the list of choices which has ".math" in its name. If a ".physics" computer is highlighted, use your cursor to choose one of the ".math" computers, and then O.K. your choice by clicking in the "accept" box. In a few seconds a login window should appear, asking for your login name and password, and have "Mathematics" written in red on the top. (If the login window says "Physics" you have accidentally chosen a physics server, and you should type "control C" to go back to the previous step.)

Your default login name is made out of your student I.D. number and your actual name, as follows.

All names from classes begin with ‘c-’. 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 who would have the same login name, say c-gskf, then they are instead assigned login names as 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. 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 c-gskf part of your login name 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. Another 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.

Once you are logged in successfully 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.

**1b) Changing password:** Sometime within the first several weeks of classes you must change your default password into a personal one. You do this as follows: 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. Note that it takes about 30 minutes for a new password to take effect. Also, you should be aware that if a password is not changed within the first two weeks of class, then your computer account will be disabled for security reasons.

**1c) Logging out:** 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.)

At this point you are ready to get used to the X-windows:

**2) X-windows, opening netscape, maple, mail, more:** Go through the document *Introduction to Xwindows in the Lab*, which you should have a copy of. There should also be copies of this document in the front of the room. Xwindows are like most windows in most ways; your aim here is to experiment to see how to open and close windows, resize them, move them about, and find them if they happen to get hidden. When you get to the end of the document you should also have opened a NETSCAPE window and a MAPLE window. Note: The command for the current (default) version of Maple is *xmaple &*, which you can type into a local window, followed by <enter>. This is version 6, and you can also find it as an option on one of your mouse buttons, it’s your choice. If you are using an earlier version of Maple (V5 or V4, for example), there are slight differences in commands and syntax, and they may confuse you once or twice.

**Further information:** If you want more in-depth information about the computing facilities in this lab, you might pick up a copy of the handout *A Crash Course on CSC Facilities*, from the front table.

If you are starting the tutorial at this point (because you're doing it on your own at another location), you should have opened a mapleV6 window and a web browser window.

**3a) Math Department resources:** There is introductory material about Maple on our web pages. If you wish to see what's available use the browser window you made in step (2) above, and go to the Math Department home page <http://www.math.utah.edu/>. By following links from here you can find current and future course offerings, faculty information, and much more. Since you are students, interested in Maple information, click on "students" (at the upper left of the page), and you are directed to <http://www.math.utah.edu/ugrad/>, the undergraduate home page. If you choose "Undergraduate Computer Lab", followed by "Selected software and tools", you will find some links to Maple information.

**3b) More Information.** Maple has its own introduction, as well as a new user's tour, see item 5 below.

**4) Maple:** Move your cursor into the "Untitled" (new) Maple window which you created in step (2). 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.

To give you a flavor of what Maple can do, we will try a few commands. They should begin on a line 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 mess up your 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. 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

```

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. If you need more help saving your file see the instructions in the *Introduction to Maple V.4 in the Undergraduate Computer Lab* handout at the front of the lab, or ask an assistant. It will probably happen some time that you will crash Maple long after your last save. This will not make you feel happy.

Now we will see how to print a hard copy of our file. First, scroll to somewhere in your worksheet and add some text with the "T" menu item. Maybe scroll to the top and put 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.

Now, go to the **file** menu option and choose the **print** option. You get a little printer setup box. If you then click on the **print command** diamond, followed by "enter" or by a click on the **print** box at the bottom of the window, a paper copy will come out of one of the printers at the side of the lab. Do this now. Alternately, if you want to use a different printer, you can use the **output to file** diamond to create a postscript file which you can then print anywhere, using the appropriate unix commands. For example, to print a postscript file to the lab printers from a local window, the command would be "lpr -P b129lab1", or "lpr -P b129lab2", followed by the return key. You do not put in the quote marks, but you are careful to leave spaces exactly as indicated. The lpr stands for line printer, the -P stands for print, and the b129lab1 or b129lab2 are the names of the two printers. If you have trouble printing ask a lab assistant for help.

**5) Differential Equations, and using Maple's help windows:** So, it looks like Maple might be interesting to use in Calculus, but how do we find out what it can do for us in that subject, or in another subject, say differential equations? An answer for DE's can be obtained by perusing your Computing Projects textbook (which you can pick up for free at the main Math office JWB 233), but it is also instructive to use the **Help** directory located at the upper right-hand corner of the maple window. That's what you're going to do now.

**5a) In mapleV6 (and V5) there's an online tutorial:** Click on the "Help" box, and then on the choice "New User's Tour". Probably this tour will superimpose onto your current Maple session. Or maybe you can't see the new tour because its hidden behind your current window. In the latter case use the "window" menu option to change windows. The tutorial gives examples from many areas of mathematics, including differential equations, which you can peruse at your leisure. In this tour you will be able to put your cursor onto any command line, type return, and see what the command does. 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.

**5b) Getting an on-line copy of this Math 2250 tutorial:** (This is also the process you will go through to get your project solution templates.) This xeroxed tutorial is available online in several formats, if you first go to our course homepage at <http://www.math.utah.edu/~korevaar/2250spring01.html>. Files with suffix ".mws" or ".txt" can be downloaded from your browser and then opened from Maple. The ".mws" suffix means the file is a Maple Worksheet, and should open from Maple to look just like this file. The ".txt" suffix is Maple text, and you should only try it if the ".mws" file doesn't open. It's a cruder form of this file, but potentially more universal. The ".pdf" or ".html" are versions of the file which you can read from your browser (or with Acrobat reader), but you can't execute these from Maple.

Go to the course homepage address in your browser, and save the **2250springtut.mws** file to your home directory.

Now return to your Maple window and use the "file" menu item to open **2250springtut.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 couldn't open the Maple worksheet file, go back to your browser and save the ".txt" version of

the tutorial. Then go back to Maple, and follow these directions: In order to open a ‘‘Maple text’’ document, which this is, you must chose **open** from the **file** menu option. In the resulting **open file** dialog box go to the **filetype** box at the bottom, click on the triangle to see the list of choices, and use your mouse to choose ‘‘Maple text.’’ At this point ‘‘2250tutorial.txt should appear as a choice in the central box. 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. The copy is not as pretty as your xerox (the execution groups are all single lines, and the text formatting is not as neat, and some output may be lost), but it is O.K. It has text and it has Maple input.

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, going to the **Edit** option and picking **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 can insert new prompts or new text wherever your cursor is, by using the > or T buttons on your toolbar.

6)

## INTRODUCTION TO PROJECT I

You should open your 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

```

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

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 sdsolve/info) required an indication of the dependent variables in the given system

This command 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 this by restarting to clear out conflicting definitions:

```

> restart:with(DEtools):

```

```

> 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 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));

```

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

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.
eqtn5 := u(t) = -82.33510564 e(-2000000000 t) + 80. + e(-2000000000 t) u0
+ 2.335105624 cos(.2617993878 t) - 5.603607924 sin(.2617993878 t)

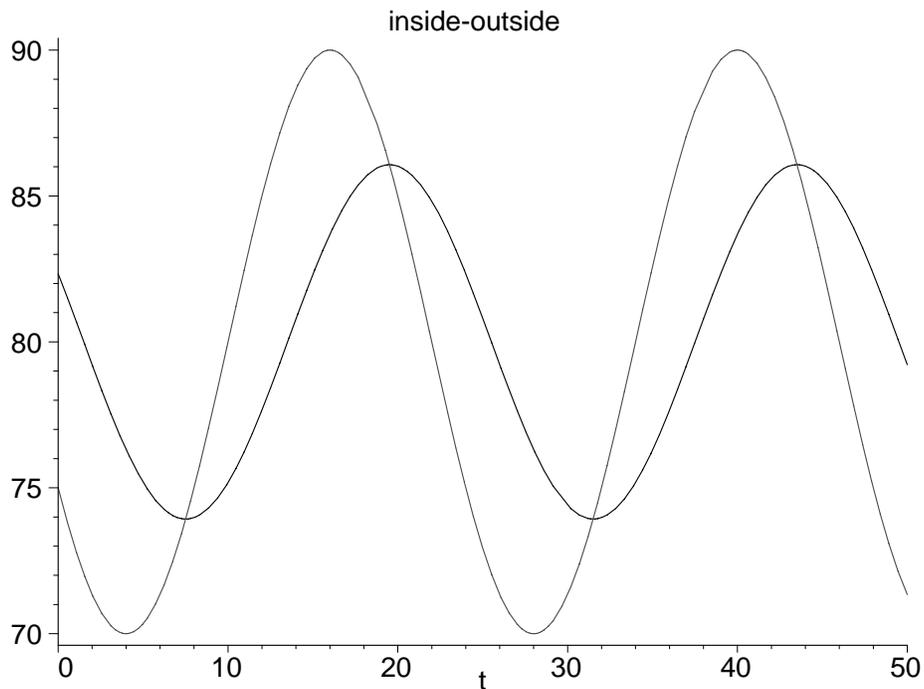
```

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");
```

