- Review sections §12.1-§12.5 in Hughes-Hallett, the course text.
- The odd numbered problems in the Exercise sections (the first chunk of problems) in each section are worthwhile practice for before a problem set. *Answers are in the back for odd numbered problems, and solutions are in the student solutions manual.*
- The problems and strengthen your understanding questions are a source of worthwhile practice questions as preparation for quizzes.

0. In addition to attending office hours, questions about the problem set can be posted to the #questions channel of the course Slack.

   - Submit your problem set work via Gradescope. Include screenshots of your Matlab work where it is part of the answer to the question. Work submitted on Gradescope is what will be graded.
   - When prompted by Gradescope, tag problem parts within your Gradescope submission.
   - For completeness / academic integrity purposes, submit your matlab source code via Canvas.

1. Complete the problems assigned via WeBWorK. `https://courses1.webwork.maa.org/webwork2/harvard-apmth-22b/`

   Your username is the text before the @ in your @college.harvard.edu email address. Your initial password is your HUID.

2. (Three plot commands) Matlab: I am assuming that you have Matlab installed on your machine, or that you have set up Matlab in the cloud (Harvard has a subscription: `https://matlab.mathworks.com`). If the command `syms x` does not work, add the symbolic math toolbox to your installation, or switch to `https://matlab.mathworks.com`.

   Some symbolic toolbox plotting commands
   `fplot`: plot the graph of a function of one variable, $f(x)$.
   `fplot3`: plot a curve in three-space, $(f(t), g(t), h(t))$.
   `fsurf`: plot a surface in three-space, $(f(s,t), g(s,t), h(s,t))$.
   `fimplicit`: plot the graph of solutions to an equation $f(x,y) = 0$ (a plot in 2-space).
   `fimplicit3`: plot the graph of solutions to an equation $f(x,y,z) = 0$ (a plot in 3-space).

   You'll use three different plotting methods to make the same plot: `fsurf`, `fimplicit3`, and `surf` (non-symbolic).

   (a) Modify the matlab file, following the instructions below.

      1. Open the matlab file associated with this problem set in the matlab editor (or in an editor of your choosing, but remember to turn on syntax highlighting).
      2. Find the `Section` associated with `PSet 01, Q01` and run the section.
      3. At the command line, use `doc meshgrid` to look up the meshgrid command. In line 12, add a comment describing the contents of `x1` and `y1`.
      4. Right now the plots are in a $n \times 1$ grid. Edit the code so that they are in a $1 \times n$ grid.

5. In the command for the third plot, try `'='` instead of `'=='`. What does `matlab` tell you about the difference between `'='` and `'=='`? Add a comment about this in line 27, in your own words.
6. Lines 32-42 are formatting the plots. Comment out the `axis` command. Do all of the commands use the same default axes ranges? Edit the comment in line 35 with your answer.
7. Adjust the axes so that they are tighter on the surface.
8. At the command line, use `doc caxis`. What is this command doing? Edit the comment in line 40 with your answer.
9. Choose a new color range that is too small (so some z-values are outside of the range on each side).
10. The `EdgeColor` of the plots is currently set to green. Change it to `'none'`.
11. At the command line, if you type `plotlist(1).plot.` and then press tab, you'll see a list of plot properties that you can edit *(Note the . after the word plot....* Choose `'FaceAlpha'`, which sets the transparency of the surface. Make the surface at least 50% transparent (choose a number below 0.5.

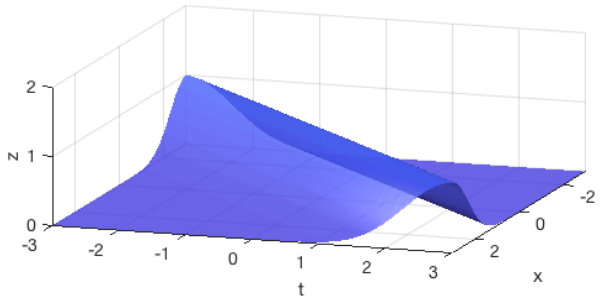
(b) Print the figure to a file.

On line 44 there is a print command that has been commented out. Replace my initials with yours, and copy the command part of the line to the command line to export your figure to an eps-file. *If you are using a Mac the path should work as written. If you are using a PC, edit the directory listings to match PC syntax.*

(c) Print a new figure to a second file.

Change the function from x^2+y^2 to a different quadratic function (of your choice). Run the section (after your edits above) with the new function, and print your new figure (substitute `p2` for `p1` in the file name).

3. (wave travel) A wave travels in an irrigation channel, with x its distance along the channel and t the time. Let z be the height of the water above a baseline level. The graph of z as a function of x and t is given below.



(a) Is the plot given in txz-space or in xtz-space? *You may want to redraw the positive parts of the axes for yourself. Then think about the axes labels in analogy to xyz-space. Is txz a right-handed coordinate system or is xtz?.*

(b) Consider the following four functions: $f(x,t) = -(x+t)^2 + 2$, $f(x,t) = -(x-t)^2 + 2$, $f(x,t) = e^{-(x-t)^2}$,$f(x,t) = e^{-(x+t)^2}$.

- Find the `Section` associated with `PSet 01, Q02b`. In that section, create code to use `plot` or `fplot` to plot two cross-sections for each function, one at $t = 0$ and one at $t = 1$. Make these plots in xz-space.
  The command `hold on` will allow you to add a second plot to the same axes.
- Export your set of plots to `PSet01Q02p1-yourinitials.eps`.

(c) Which of these cross-sections best match the wave above? Identify the details that you used to make the match.

(d) Is the wave traveling in the direction of increasing x or decreasing x? Explain how you decided.

(e) Based on the function options I provided, the surface is either a parabolic cylinder or a Gaussian cylinder. Which is it?

(f) Use Matlab to make a plot where the wave is moving in the opposite direction as time increases.

4. (windmill power)

   The power, P (units of $\mathsf{ML}^2\mathsf{T}^{-3}$), produced by a windmill is proportional to the density of the air pushing the blades, d (units ML^{-3}) to the square of the diameter of the windmill, r (units L), and to the cube of the wind speed, v (units LT^{-1}). (M = mass, L = length, T = time). See `https://canvas.harvard.edu/files/11684882/` for more information.

   Following the instructions in the WeBWorK problem, sketch a contour diagram for P.

   It is fine to make the diagram in Matlab - I don't know how to do the contour labeling via Matlab at the moment, so if you figure it out please let us know via Slack. Or you can use Matlab to help you figure out the contours that you sketch and label by hand. Note: stay in a physically plausible range for the values of the variables.

5. (coastal Massachusetts contour plot) You'll try different smoothings to make a contour plot of coastal Massachusetts. Run lines 57 to 105. Those will produce an initial contour plot.

   `ALOSMA.tif` holds elevation data (in meters). Assume that each pixel in the original file represents a region that is 30m by 30m.

   (a) If `wiener2.m` doesn't run you'll need to install the `image processing` toolbox. To do that, head to your Mathworks account, open your individual license file, download the installer, run the installer, and keep proceeding until the installer offers a variety of options. At that point, choose the image processing toolbox as the one that you'll install.

   (b) Look up any commands you don't already know using `doc command-name`. Make a list of those commands here.

   (c) Describe, in your own words, what is happening in lines 57 to 105.

   (d) From line 107 onwards, provide your own code, making your own choices about

   - downsampling `imageuse`
   - smoothing `smoothimage`
   - the contour interval / contour curves to be included in the plot.

6. (land lost to sea level change) Assuming that sea levels rose by 15 cm over the 20th century (`https://www.pnas.org/content/early/2017/05/16/1616007114/tab-figures-data`), approximate how much coastal land in the `ALOSMA.tif` image was lost to sea level rise during the 20th century.

   You might assume that the slope of the land near the coast is similar on land and under water.

   Describe your assumptions, your approximation method, and your conclusion. Any associated matlab code should be in the matlab file.

Late work policy: Because of the unusual circumstances of our semester, all students have access to deadline flexibility when needed. You may assume that extensions of up to two days will be approved without issue. Request those via direct message on Slack. When you request an extension, specify your preferred new deadline for the assignment.

Late WeBWorK is difficult to arrange (it requires a manual override of the course settings), so I suggest planning ahead to complete it on time.