<div style="border:1px solid black; text-align:center;">Homework #4, ENGN 100-300, F15. Due **Thu. Nov. 6, in class**</div>

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- This is an individual assignment, not a group project. Refer to the course syllabus for the collaboration policies.
- For unstapled solutions, only the first page will be graded.
- The purpose of this assignment is to help you better understand the `Matlab` commands that are particularly useful for music signal processing. In ENGN 101 you will learn more of the "general purpose" `Matlab` commands like `switch` and `elseif` but here we focus on the commands used in our labs and projects.
- Some of these problems you can solve just by typing the commands into `Matlab`. For example, if you are asked what the output of the command `sum(sum(ones(6,5)))` is, you can type that in and find that the answer is `30`. But you need to understand what is happening well enough that in the future you could answer such questions without using `Matlab` itself.
- To help you develop this skill, some questions will be expressed in terms of *variables*, rather than specific numerical values, and you must express your answer in terms of those variables. For example, if you were asked what the output of the command `sum(sum(ones(m,n)))` is, you assume that `m` and `n` are scalar variables that were previously defined, and the correct answer is "mn," *i.e.*, the product of the values of those two variables. For such problems if you do not know the answer right away, you can experiment with specific values of `m` and `n` to see what is happening, *e.g.*, by typing something like: `m=4; n=5; sum(sum(ones(m,n)))`. But after you understand it you must report your final answer in terms of the variables such as `m` and `n`.

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1. [0]   What is the size (# of rows and columns) of the array `y` produced by the following `Matlab` commands?
`x = 1:10; y = reshape(x, 5, 2);`

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2. [5]   What are all of the pairs of values of `m` and `n` for which the following `Matlab` commands will execute without errors? `x = 1:12; y = reshape(x, m, n);`

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3. [0]
   (a) [0] What is the size of the array `p` produced by the following commands?
   `a = 10:5:50; b = 4:-1:1; p = a' * b`
   Hint: you can use the `size` command to find a variable's size.
   (By the way, the mathematical term for a column vector times a row vector is a *outer product*.)
   (b) [0] What does `p(2,:)` return?

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4. [10]
   (a) [5] What is the size of the array `c` produced by the following commands, assuming that `n` and `m` are even?
   `a = 0:2:n; b = 1:2:m; c = a' * b`
   (b) [5] What is the size of `c(:,3)`, assuming that `m ≥ 5`.

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5. [0]   What is the size and value of the variable `d` produced by the following commands?
`a = ones(1,9); b = 1:9; d = a * b'`
(By the way, the mathematical term for a row vector times a column vector is an *inner product*.)

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6. [10]   What is the size and value of the variable `f` produced by the following commands?
`a = ones(1,m); b = 3*a; f = a * b'`

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7. [10]   The following `Matlab` commands make a sinusoidal signal array and then reshapes it into one long signal—a song.
`x = 0.9 * cos(2*pi*[150:50:350]'*[1:2000]/8192);`
`y = reshape(x', 1, numel(x)); sound(y)`
(a) [5] How many notes are in this song and what are the frequencies of each note?
(b) [5] What is the duration of this (short) song?

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8. [10]   Drawing inspiration from the previous problem, write down a sequence of at most 4 `Matlab` commands that synthesizes the first 8 notes of the chorus of the Pink Floyd song "Another Brick in the Wall," *i.e.*, the part with lyrics "we don't need no eduction." Hint. This part of the song is in the key of D minor and the notes are D E F E D E F E. Each note in your song should be 0.25 seconds long. (So the rhythm will not quite match the original.) The last of your commands will be `sound(y)`. Try your commands in `Matlab` to be sure they are correct.

9. [5]   The following two `Matlab` commands generate samples of a sawtooth wave signal and plays it:
`x = 0.1 * (mod(0:3999,20)-10); sound(x, 8192)`
Assuming that the sampling rate is $S = 8192$ Hz, determine the fundamental frequency of this signal.
Hint. Try `plot(x(1:90), '.-')`

10. [5]   Assuming that the sampling rate is $S = 8192$ Hz, and assuming that `n` $\gg$ `m`, determine the fundamental frequency of the sampled signal generated by the following `Matlab` command:
`x = (mod(1:n,m) - m/2);`

11. [10]   Consider the following `Matlab` commands.
`x = 0.9 * cos(2*pi*151*[0:1999]/8192);`
`y = cos(2*pi*[100:50:350]'*[0:1999]/8192);`
`corr = x * y';`
`[biggest index] = max(corr);`
(a) [5] What is the size of the (correlation) array `corr`?

(b) [0] What is the value of the variable `index`?

(c) [5] From a signal processing perspective, why is the 2nd element of `corr` the largest?