Signals Systems and Transforms
EEET-332
Lab 9

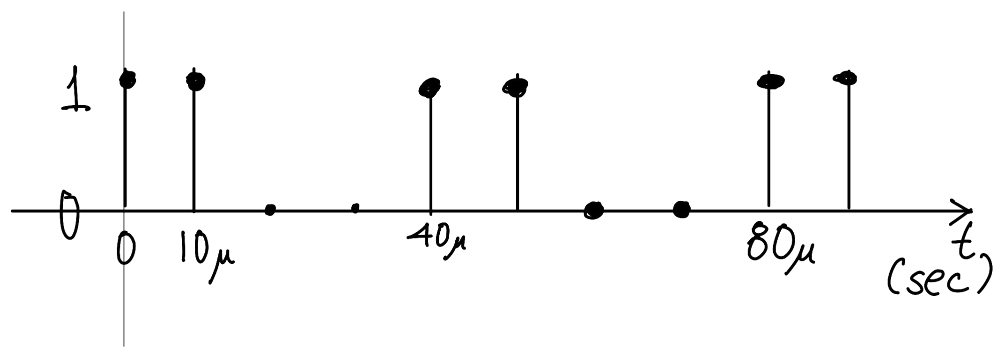
For each section using MATLAB:

1) Create a new *.m (or *.mlx) file and call init() in the first line. Save it. Remember, no spaces in the file name!
2) Copy last lab's init.m, make_plot.m and make_stem.m (or *.mlx) functions to the same directory. Use the files defined fig_num as a global so that both make_plot and make_stem can use it.

A quiz will be given at the beginning (1st 10 minutes) of the lab covering the content of the prelab. One quiz will be dropped. NO make-up quizzes will be given.

Prelab:

1) Find the DFT (Discrete Fourier transform) for the waveform below. Note that Ts = 10us.



$$c_m = \frac{1}{N}\sum_{n=0}^{N-1} f(nTs)\, e^{-jm2\pi n/N}$$

Note: The book uses the spectral density function F(m) rather than the Euler phasor c_m.

NOTE: The Matlab fft() returns the spectral density function F(m) just like the book. Dividing each term by N changes F(m) to the Euler phasors cm. The equation above is for cm. Although cm is more common, F(m) saves time by not dividing by N.

Signals Systems and Transforms
EEET-332
Lab 9

Refer to Lab 8, section 1, for help with the next question.

2) Write the MATLAB command that creates the vector, t, below.

t =

0   0.1000   0.2000   0.3000   0.4000   0.5000

3) Complete the find command to return the indexes of t with values: 0.3, 0.4, and 0.5.

find(t______________________)

ans =

4   5   6

4) Complete the find command to return the indexes of t with a value of: 0.2.

find(t______________________)

ans =

3

5) Complete the find command to return the indexes of t with a value of: 0. Note, that the first index in any MATLAB array is 1.

find(t______________________)

ans =

1

Signals Systems and Transforms
EEET-332
Lab 9

Section 1: Arrays – the essence of MATLAB

1) Run each command in the "command window" of MATLAB and fill in the empty cells.
T = 4;
t = 0:T/5:T

0		1.6	2.4		

y = zeros(size(t))

0		0	0		

Next, find the indexes where t is greater than 2. Enter the command below.

ind1=find(t>2)

4		6

t(ind1)

2.4		4

We can find the location where t == 1.6s.

ind2=find(t==1.6)

And then actually select this value of t.

t(ind2)

t(ind1) is a subset of array t. t(ind2) contains the elements of t where "t" is greater than 2. This allows us to work with small portions of an array which is useful in building non-continuous functions like square waves, rectified sine waves and many others. The example below sets only the values of array y where t is greater than 2 and less than 3.5.

Signals Systems and Transforms
EEET-332
Lab 9

Use the command below to fill the values of y where t is greater than 2 but less than 3.5 with 2*t. y and t are the same size so they both can use ind1. Note: the 2 heavily outlined cells are overwritten (all elements in y were zero).

ind1=find(t>2 & t<3.5);

y(ind1) = 2*t(ind1)

0		0	4.8000		0.0000

2) Complete the command below such that y = t^2 when t is less than 2. Remember to use a dot in front of ^ when squaring elements in an array. The three left cells (with heavy outline) are overwritten.

ind2=find(_______________________)

y(ind2) = t(________________)________________

Answer

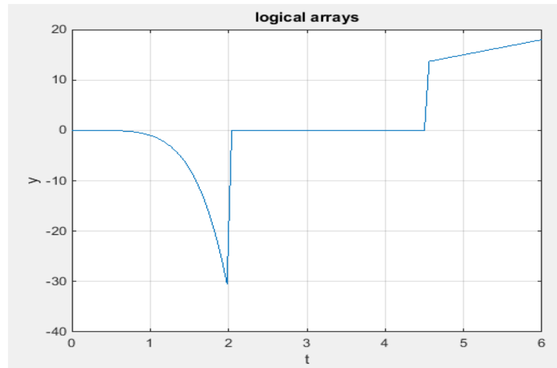
0	0.6400	2.5600	4.8000	6.4000	0.0000

3) Complete the script to create y below to make the plot shown below.

```
init();
T = 6;
%create t, so it starts a 0, ends at T, and has 101 points
t = ______________________________
if ( length(t) == 101)
    disp('length of t is correct!')
else
    disp('length of t is incorrect:')
    disp(length(t))
end

y = zeros(size(t));
%for values of t from 0 to 2, y = -t^5
ind1 = find(___________________);
y(ind1)=-t(ind1).^5;

%for values of t from 4.5 to 6, y = 3t
ind2 = find(___________________);
y(ind2)=_____________________________________
make_plot(t,y,'piece-wise function','t','y');
```

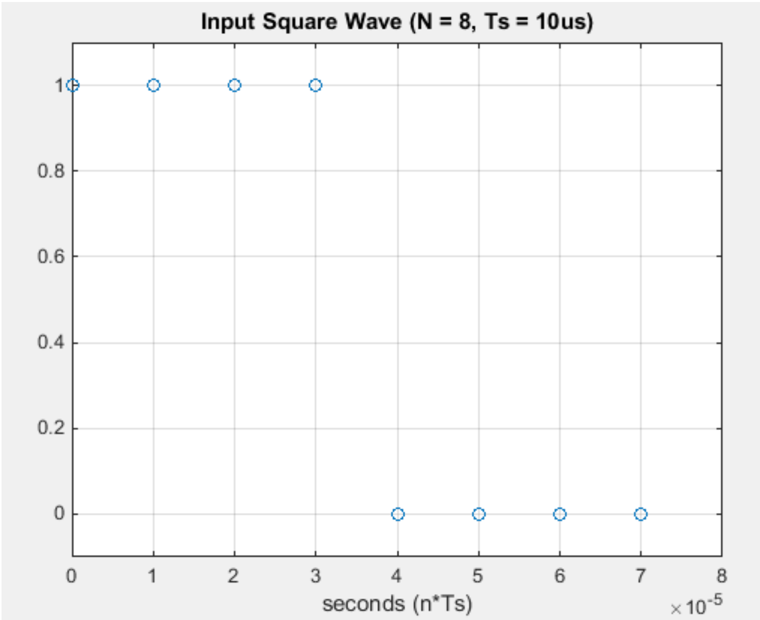
Signals Systems and Transforms
EEET-332
Lab 9

Prepare this plot for sign-off.



Signals Systems and Transforms
EEET-332
Lab 9

Section 2: Discrete Fourier Coefficients



Taking the DFT of a square wave.

6) The square wave shown above is f(nTs) that will be transformed. Use the formula for the discrete Fourier transform (DFT) below to complete the cm and frequency columns of table 1. <u>There is a sample calculation of c_1 on the next page</u>. Note: the 8 (N=8) samples are Ts (10us in this case) apart.

$$c_m = \frac{1}{N}\sum_{n=0}^{N-1} f(nTs)\, e^{-jm2\pi n/N}$$

m	c_m by hand	frequency	c_m *
0	0.5	DC	0.5
1	0.125 - 0.3018j	fo (fundamental) = 1/(N*Ts) = 12.5KHz	0.125 - 0.3018j
2			
3			
4		4th harmonic = 4/(N*Ts) = 50KHz	
5	0.125 + 0.05178j	-3rd harmonic = -3/(N*Ts) = -37.5KHz	
6	0	-2nd harmonic = -2/(N*Ts) = -25KHz	
7	0.125 + 0.3018j	-fo (fundamental) = -1/(N*Ts) = -12.5KHz	

Table 1

Signals Systems and Transforms
EEET-332
Lab 9

* c_m column filled in later using MATLAB (not by hand). Columns 1 and 3 will be the same.

Sample calculation for c_1

$$c_1 = \frac{1}{8}\sum_{n=0}^{7} f(nTs)\, e^{-j(1)2\pi n/8}$$

Since the function has four values that are one and the others are zero, there will only be four terms.

$$c_1 = \frac{1}{8}\left(1e^{-j(1)2\pi(0)/8} + 1e^{-j(1)2\pi(1)/8} + 1e^{-j(1)2\pi(2)/8} + 1e^{-j(1)2\pi(3)/8}\right)$$

The exponential form (radians) is converted to the polar (degrees) form.

$$c_1 = \frac{1}{8}(1\angle 0 + 1\angle -45 + 1\angle -90 + 1\angle -135) = 0.125 - 0.302j$$

Note: the book uses the spectral density function F(m) rather than the Euler phasors, c_m.

$$c_m = \frac{F(m)}{N}$$

7) Now use MATLAB to calculate the c_m values for the rectangular waveform.

```
init();
N = 8;      % DFT, data point count (make EVEN, best power of 2)
n = 0:N-1;  % index
Ts = 10E-6; % sampling period, sample freq = 1/Ts
t = n*Ts;   % time of each sample
T = N*Ts;   % period of waveform

% Rectangular pulse
y = zeros(size(t));
ind1 = find(t<T/2);
y(ind1) = 1 %create square wave
% Plot the square wave
make_plot(t,y,'Input Square Wave (N = 8, Ts = 10us)','seconds (n*Ts)','y');
ylim([-0.1,1.1]); % stretch y axis so data points can be seen

%later in lab, fft_ifft function call goes here
ylim([-0.1,1.1]); % stretch y axis so data points can be seen
```

Signals Systems and Transforms
EEET-332
Lab 9

9) Now let MATLAB calculate the discrete Fourier transform (DFT) using the FFT (fast Fourier transform). Create a function fft_ifft.m (*.mlx) using the code below. Add a function call to the original script and confirm the cm values entered in Table 1. The values of cm can be read from the “command window” if the semicolon is removed from the line defining cm or from the “workspace” window by double-clicking on cm.

The function also takes the IFFT used later.

```
function [cm,yy] = fft_ifft(t,n,y,N)
  % NOTE: Matlab fft() returns the spectral density function F(m)
  %         Dividing by N, F(m) changes to the Euler phasors cm.
  %         Although cm is more common, F(m) saves time by not dividing by N.
  %       Matlab ifft() multiply by N before using IFFT.

  cm = fft(y,N)/N;
  make_stem(n,abs(cm),'spectrum amplitude','n','abs(cm)');

  % Reconstruct y (called yy) using inverse FFT (IFFT).
  yy = real(ifft(N*cm)); % real function scrubs imaginary vestiges
  make_plot(t,yy,'Regenerated Waveform','seconds','reconstructed y');
end
```

Submit the following in your report:

a) **Hand calculations of c_2 = cm(m==2), c_3 = cm(m==3) and c_4 = cm(m==4).**

b) **Table 1 (handwritten values are acceptable).**

Signals Systems and Transforms
EEET-332
Lab 9

Section 3: Regeneration of f(nTs)

1) Use the inverse discrete Fourier transform (IFFT) and the cm values to recreate the function, now called yy, by filling in the blanks. yy = y because the FFT transforms the waveform and the IFFT recreates it.

$$yy = \sum_{m=0}^{N-1} cm(m) * e^{j2\pi mn/N} = 0.5 + (0.125 - 0.3018j)e^{j2\pi n/8} + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + (0.125 + 0.05178j)e^{j10\pi n/8} + 0 + (0.125 + 0.3018j)e^{j14\pi n/8}$$

2) The function you created in the last step already found the inverse FFT (IFFT). yy is the original square wave.

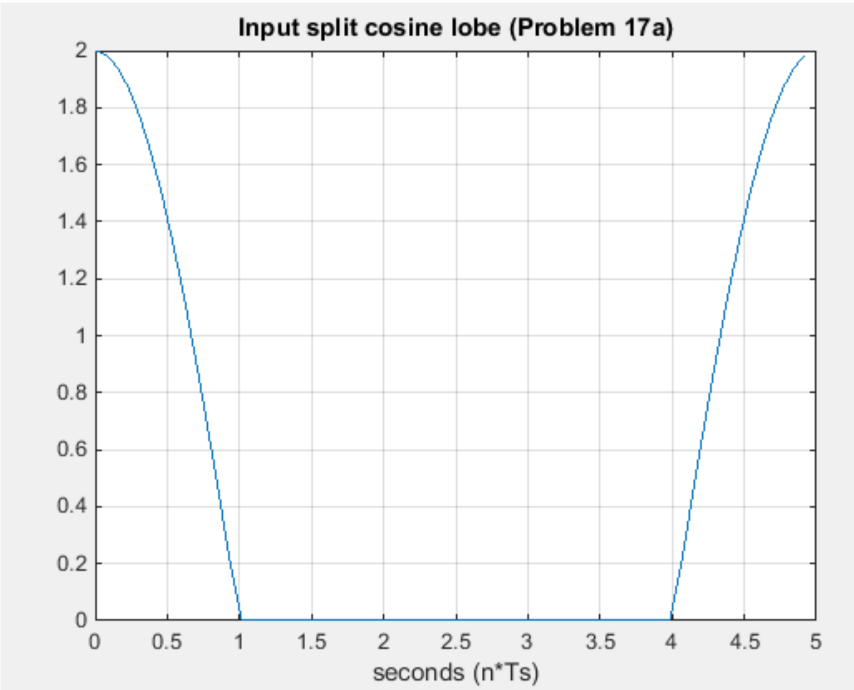
Submit the following in your report

a) Completed equation (handwritten is acceptable).
b) Printout of the regenerated waveform.

Signals Systems and Transforms
EEET-332
Lab 9

Section 4: Other waveforms

1) Create a new script and use the code below to create the split cosine in problem 17a of the text. The code below is similar to the code used in section 3 with the following exceptions:
    a. The rectangular wave is replaced with the partial cosine wave shown in problem 17a of the text.
    b. The number of points increased to 64 (N=64).
    c. The period changed to 5 sec, and Ts were calculated using T and N.



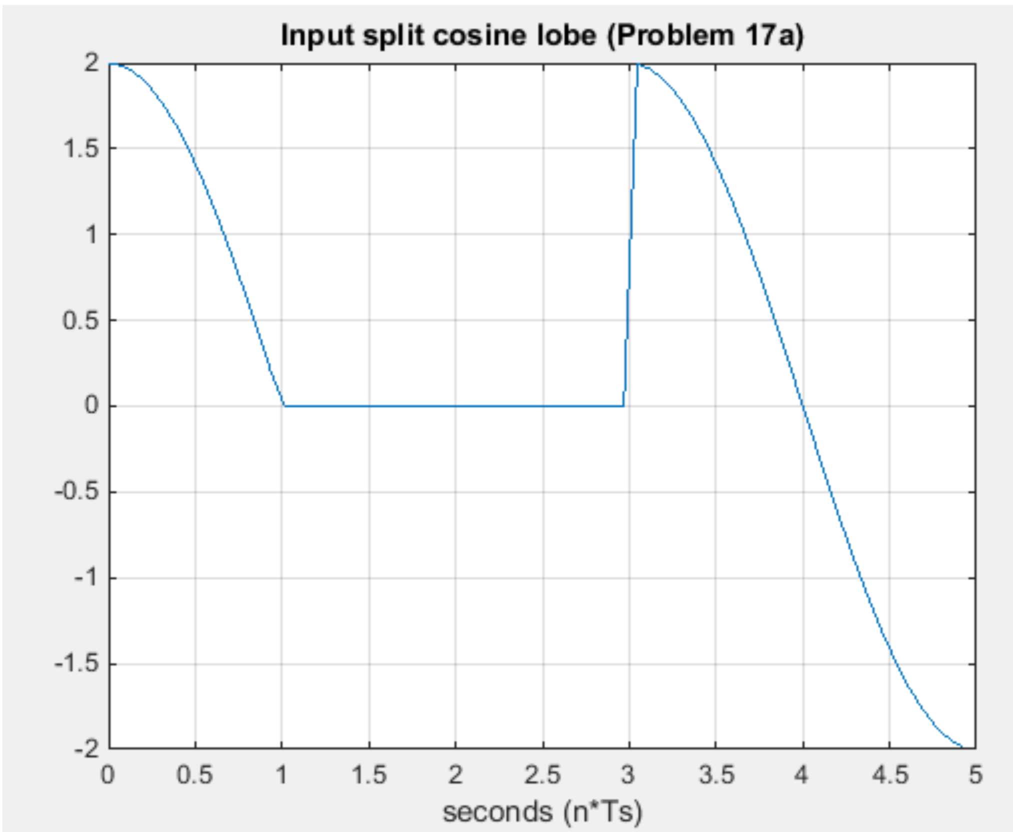

```
init();
N = 64;           % DFT, data point count (make EVEN, best power of 2)
n = 0:N-1;        % index
nc = -N/2:N/2-1;  % centered index
T = 5;            % waveform period
Ts = T/N;         % sampling period, sample freq = 1/Ts
t = n*Ts;         % time of each sample

% Problem 17a: split cosine lobe
y = zeros(size(t));
wsig = 2*pi/4; %w of signal = 2pi/Tsig
ind1=find(t<1);
ind2=find(t>4);
y(ind1) = 2*cos(wsig*t(ind1)); %notice the use of logical arrays
y(ind2) = 2*sin(wsig*t(ind2));
make_plot(t,y,'Split sine wave (N = 64)','seconds (n*Ts)','y');
m=n;
[cm,yy] = fft_ifft(t,n,y,N);
```

Signals Systems and Transforms
EEET-332
Lab 9

2) Change the equation for y in the script as follows:

```
y(ind2) = - 2*sin(wsig*t(ind2));
```

Modify ind2 to display the waveform below.



Signals Systems and Transforms
EEET-332
Lab 9

3) Complete Table 2 for the new waveform. Run the find function in the command window to get the indexes for cm and the values of cm (FFT column).

m	Matlab Array Index for cm	frequency	FFT
0	1	DC	0.2828
1	2		
2			
5		5^{th} harmonic = 5/(N*Ts) = 1Hz	0.0111 - 0.2017i
45			
50		-14^{th} harmonic = (50-N)/(N*Ts) = -2.8Hz	0.0188 + 0.0185i
63	64		

Table 2

Prepare the completed Table 2 (handwritten is acceptable) for sign-off.

Signals Systems and Transforms
EEET-332
Lab 9

Report:

Create your own cover page.

Submit your cover page, the requested prints (sections 2 and 3 only), and this sign-off sheet on the second page.

Sign-offs

Name ______________________

Section 1: Plot

	/ /
Signature	Date

Section 4: Table 2

	/ /
Signature	Date