SOLUTIONS

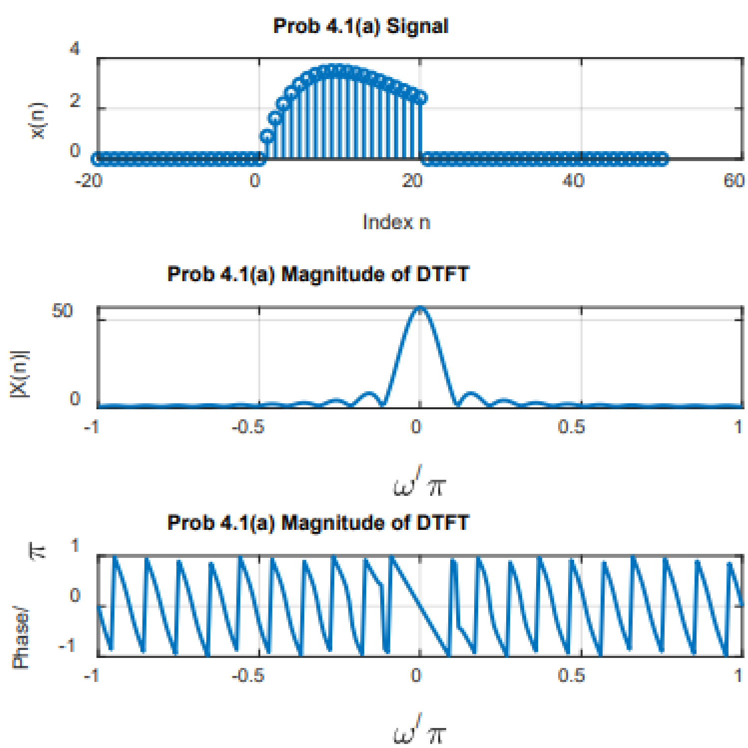
Assignment 4: Frequency Analysis of LTI Systems

Digital Signal Processing (EN.525.627.8X)

1. A)

```
n=[-20:50];  %Index n exceeds interval where signal is non-zero
n1=n(1); n2=n(end);  %Limits for index n
x=n.*(0.9).^n.*[stepseq(0,n1,n2)-stepseq(21,n1,n2)];
```

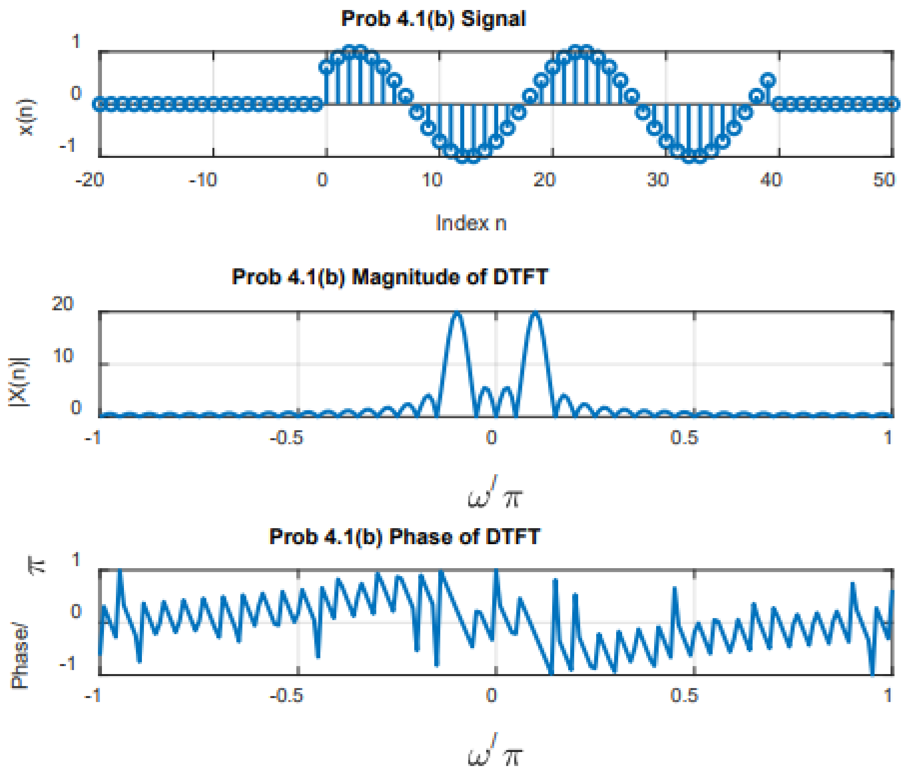
```
%Calculate and Display DTFT
w=[-100:100]*pi/100;
X=dtft(x,n,w);
MagX=abs(X);
PhaseX=angle(X)/pi;
subplot(3,1,2), plot(w/pi,MagX,'LineWidth',2);grid on;
   set(gca,'FontSize',16);
   ylabel('|X(n)|'); xlabel('\omega/\pi');
```



1B)

```
%Create and Display DT Signal x(n)
n=[-20:50];  %Index n exceeds interval where signal is non-zer
n1=n(1); n2=n(end);  %Limits for index n
x=cos(pi*n/10-pi/4).*[stepseq(0,n1,n2)-stepseq(40,n1,n2)];
```

```
PhaseX=angle(X)/pi;
subplot(3,1,2), plot(w/pi,MagX,'LineWidth',2);grid on;
   set(gca,'FontSize',16)
   ylabel('|X(n)|'); xlabel('\omega/\pi');
```



2.

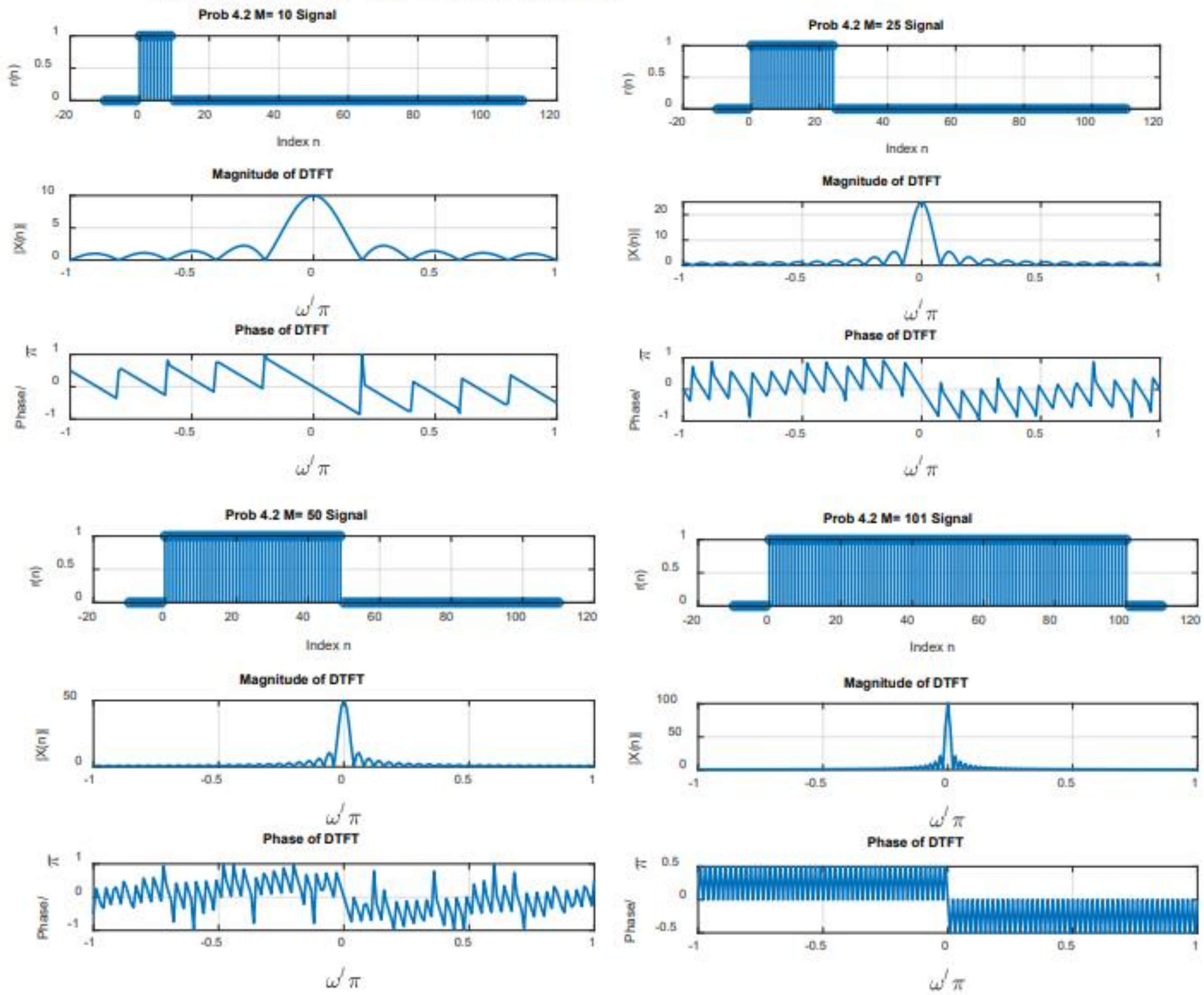
a. & b.) Key lines of MATLAB code

```
n=[-10:110];  %Index n exceeds interval where signal is non-zero
n1=n(1); n2=n(end);  %Limits for index n
    MM=[10 25 50 101];
for m=[1:4]

    M=MM(m);
    r=[stepseq(0,n1,n2)-stepseq(M,n1,n2)];
```

```
%Calculate and Display DTFT
    w=[-100:100]*pi/100;
    R=dtft(r,n,w);
    MagR=abs(R);
    PhaseR=angle(R)/pi;
    subplot(3,1,2), plot(w/pi,MagR,'LineWidth',2);grid on;
    set(gca,'FontSize',16)
    ylabel('|X(n)|'); xlabel('\omega/\pi');
```

For part b divide by max(abs(R)) to normalize peak to 1



c.) Width of DTFT peak appraoches zero a M increases, signal approaching DC which has zero frequency

3A:

Definition of DTFT:

$$X(\omega)=\sum_{n=-\infty}^{\infty} x(n)e^{-j\omega n}$$

$$Euler's Indenity:\ \cos\omega=\frac{1}{2}\left(e^{j\omega}+e^{-j\omega}\right)$$

$$X(\omega)=3+e^{j\omega}+e^{-j\omega}+2e^{j2\omega}+2e^{-j2\omega}$$

From definition above:

$$x(n)=2\delta(n+2)+\delta(n+1)+3\delta(n)+\delta(n-1)+2\delta(n-2)$$

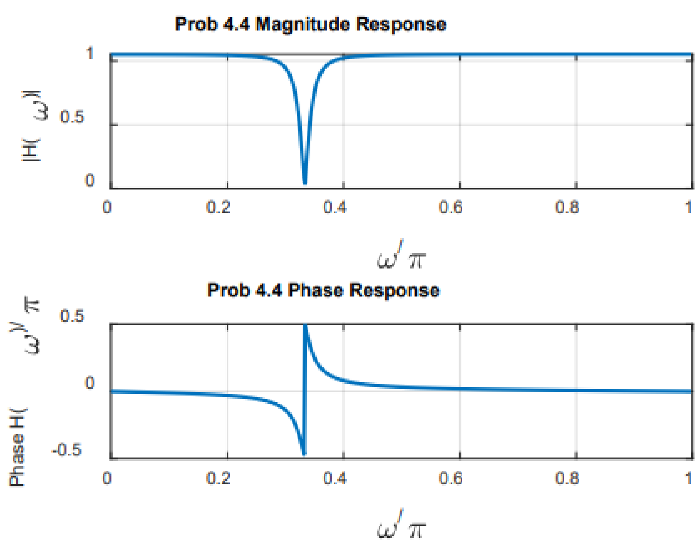
3B:

b.) Follow same appraoch using Euler's Identity to convert sinusoidal signals into exponential signals. Then multiply by the exponential which will change exponents and finally determine x(n) from definition

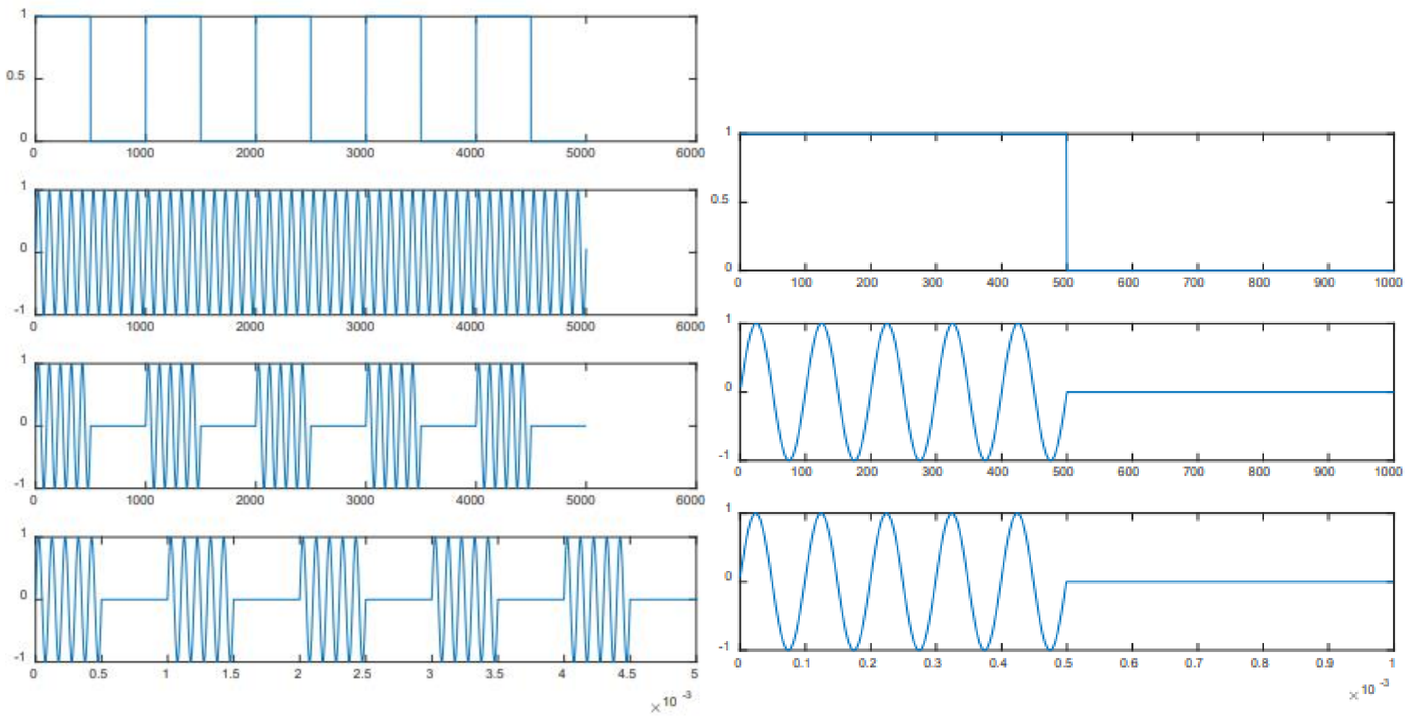
4:

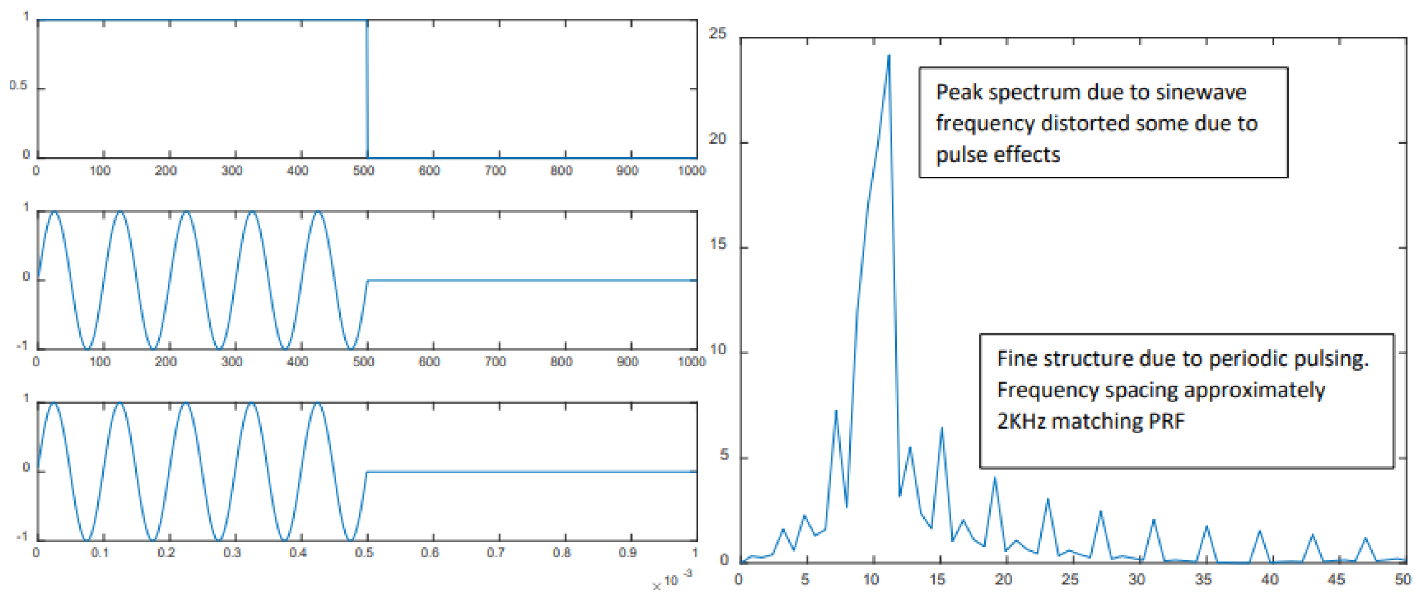
```
%Determine Frequency response magntidue and phase
%y(n)=x(n)-x(n-1)+x(n-2)+0.95y(n-1)-0.9025y(n-2)
%Group y terms on left and x terms on right
%y(n)-0.95y(n-1)+0.9025y(n-2)=x(n)-x(n-1)+x(n-2)
%A and B Coefficients
A=[1 -0.95 0.9025]; B=[1 -1 1];
[H,w]=freqz(B,A);
subplot(2,1,1)
   plot(w/pi,abs(H),'Linewidth',2),grid on
   set(gca,'FontSize',16)
   xlabel('\omega/\pi'), ylabel('|H(\omega)|')
   title('Prob 4.4 Magnitude Response')

subplot(2,1,2)
   plot(w/pi,angle(H)/pi,'Linewidth',2),grid on
   set(gca,'FontSize',16)
   xlabel('\omega/\pi'), ylabel('Phase H(\omega)/\pi')
   title('Prob 4.4 Phase Response')
```



5: Expected plots





5: Example Code

```
% HW4_5_627_SU2020_Script.m
close all
clear
clc

ms=1e-3;
KHz=1e3;
PRT=1*ms;
PRF=1*KHz;
F=10*KHz;
Ta=.001*ms;  % Time increment for representing analog signals
Ts=.01*ms;   % A2D samplng period

% Set up Index(n) and time(t)
%----------------------------
% Index(n)           Time(ms)
%   1                  0
%   500                500*Ta
%   501                501*Ta
%   1000              1000*Ta
%   1001
%   1500
%   1501
%   2000
%   2001
%
%
%   4001
%   4500               4500*Ta
%   5001               5001*Ta
%-----------------------------
n=[1:5001];
t=(n-1)*Ta;

figure(1)  % 5 replica periodic pulsed sinewave
set(gcf,'Position',[280 358 560 520])
subplot(4,1,1)
p1=stepseq(1,1,5001)-stepseq(500,1,5001);
p2=stepseq(1001,1,5001)-stepseq(1500,1,5001);
p3=stepseq(2001,1,5001)-stepseq(2500,1,5001);
p4=stepseq(3001,1,5001)-stepseq(3500,1,5001);
p5=stepseq(4001,1,5001)-stepseq(4500,1,5001);
p=p1+p2+p3+p4+p5;
plot(n,p)

subplot(4,1,2)
s=sin(2*pi*F*Ta*n);
plot(n,s)

subplot(4,1,3)
out=p.*s;
plot(n,out)
```

```
subplot(4,1,4)  %Pulsed sinewave as a function of time
plot(t,out)


figure(2)  % One pulse repetition period sinewave
set(gcf,'position',[700 310  560  420])
n1=1:1000;
subplot(3,1,1)
   p_onecycle=p(n1);
   plot(n1,p_onecycle)

subplot(3,1,2)
   out_onecycle=out(n1);
   plot(n1,out_onecycle)

subplot(3,1,3)
   t1=(n1-1)*Ta;
   plot(t1,out_onecycle)

figure(3)  % sampled pulsed sinewave signal

ns=[1:10:5001];
ts=(ns-1)*Ts;

out_sampled=p(ns).*s(ns);
subplot(2,1,1)
plot(n,out); hold on
plot(ns,out_sampled,'ro','markersize',2')
grid on
set(gca,'Ylim',1.5*[-1 1])

subplot(2,1,2)
n1s=1:10:1000;
t1s=(n1s-1)*Ts;
plot(n1,out(n1)); hold on
plot(n1s,out(n1s),'ro','markersize',2')
grid on
set(gca,'Ylim',1.5*[-1 1])

figure(4)  % Determine DTFT
w=[0:200*pi]/200;
X=dtft(out_sampled,ns,w);
magX=abs(X);
plot(1e3*w/(2*pi),magX)
set(gca,'Xlim',[0 50])
```