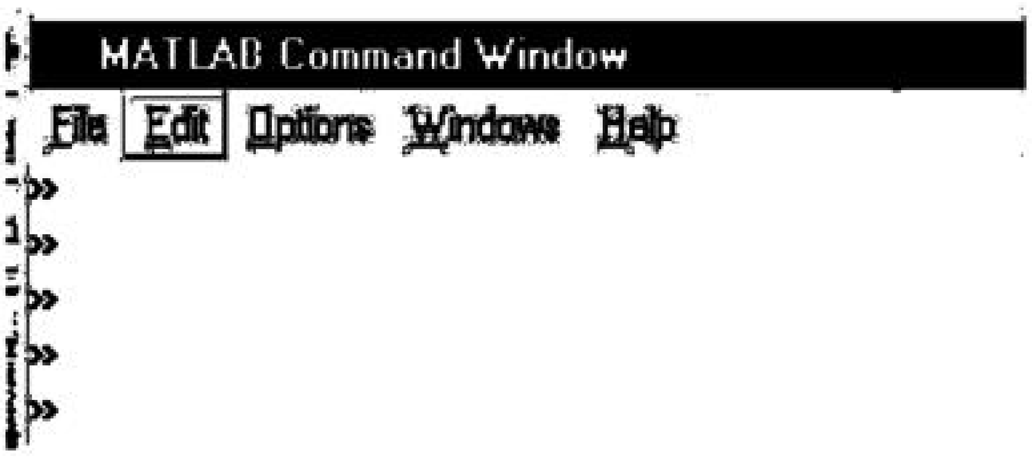
MATLAB USER GUIDE

1- Start the MATLAB program.
You will get a window like



\>>

2- You can make simple calculations as follows

```
>>a=5; b=6; c=a*b; d=a/b; e=sin(a);

>>a=5, b=6, c=a*b,
```

3- Complicated calculations

```
>> a=5;  b=6;  c=7;
>> y=2*a+3*b+log(c)
```

$y=2a+3b+\ln(c)$

```
>>z=a^2+b^3+exp(c)
```

$z=a^2+b^3+e^c$

COMPLEX NUMBERS

```
 Complex numbers are treated similar to
real numbers.
>>a=1+2j,
>>e=abs(a), d=angle(a), f=phase(a)
    e=2.236067,    d=1.107,    f=1.107
abs :  magnitude
angle: angle
phase: angle (pahse and angle are same)

In the above example
>>a=1+2j,    d=abs(a)
```

$$\sqrt{1^2+2^2}=\sqrt{5}= 2.236067$$

```
>>e=angle(a)
```

$$\text{angle}(a)=\tan^{-1}(2/1)=1.107$$

```
Of course
d*cos(e)=2.236067*cos(1.10714)=1
and
d*sin(e)=2.236067*sin(1.10714)=2
```

Matlab uses **radian** in angle calculations.
If you want to convert to **degree**

\>>g=e*180/π = 1.107 *180 /3.14 = 63.5
$g=63.5^0$

Complex Number Addition Sustraction , Multiplication, Division

```
>> a=1+3*j,   b=3+4*j,

>> c= a+b,
        4+7j

>> d = a*b,
        -9+13j,

>> e=a/b
        0.6+0.2j
```

Real and Imaginary parts

```
>> g= -12 + 15j
>>real(g)
      -12
  imag(g)
      15
```

Example Problem: Calculate the magnitude and phase of the following numbers.
a)3+4j, b)-3+4j, c)3-4j d)-3-4j

Answer :

```
>>abs(3+4j), angle(3+4j)*180/pi

>>abs(-3+4j), angle(-3+4j)*180/pi

>>abs(3-4j), angle(3-4j)*180/pi

>>abs(3-4j), angle(3-4j)*180/pi
```

VECTORS

```
>> a = [ 7 2  5 ],    b = [ 9  0 3 ]
>>c=1:5
  c= 1 2 3 4 5

>>d=5:8
   d= 5  6  7  8

>>e=0:2:10
   0 2 4  6 8  10

>>f=0:0.1:0.6
  0  0.1  0.2   0.3  0.4 0.5  0.6

>>g=zeros(1,6)
 0  0  0  0  0  0

>>h=zeros(1,4)
    0  0  0  0

>>k=ones(1,7)
    1  1  1  1  1 1  1

>>m=ones(1,3)
    1  1  1
```

ADDITION AND SUBTRACTION

```
>>a=[ 2  8  10],   b=[ 1  4  3]

>> c= a + b
     2   8   10
+    1   4    3
--------------------
      3   12   13

c=[ 3   12    13]


>>d=10*a
  d=[ 20  80  100]

>>e=5*b
     5  20  15

>>f=10*a + 5*b
     25  100  115

>>g= a-b
   2   4   7
```

NESTED VECTORS

```
>>h = [ 1:5 ]
  1 2  3 4 5

>>k = [ 1:5    1:3 ]
  1  2 3 4  5   1  2 3

>>m = [ 0:2:10   10:3:22 ]
0 2 4  6 8   10  13  16  19   22

>> a = [ 8 10 3 ],  b= [4  7  8]
>> c= [ a  b ]
  8 10 3  4 7 8

>> d = [ a a  a ]
  8 10 3     8 10 3     8 10 3
```

complex vectors

```
>> a = [ 3+4*j   -6 +9j       2+5j      -7j    30]

>> w = abs(a)
          5    10.81      5.38    7    30
```

$\sqrt{3^2+4^2}$ =5, $\sqrt{6^2+9^2}$ =10.81 ...

```
>> p=angle(a)
              0.92   2.15    1.19   -1.57     0

>> s=angle(a)*180/pi
       53.13     123.69    68.19     -90      0
```

$$\tan^{-1}(\frac{4}{3})=0.92^{radian} = 53.13^0$$

$$\tan^{-1}(\frac{9}{-6})=2.15^{radian} = 123.69^0$$

MATRIX DEFINITION:
You can define matrices in MATLAB different ways.

If you write
>> a=[10 20 30; 40 50 60; 100 80 90];b=[1 2 3; 4 5 6; -2 8 9];   c=[15 25 35];
d=[1 2 5]';
then, the following matrices are defined:

$$a=\begin{bmatrix}10 & 20 & 30\\ 40 & 50 & 60\\ 100 & 80 & 90\end{bmatrix}, b=\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\\ -2 & 8 & 9\end{bmatrix},$$

$$c=[15 \quad 25 \quad 35],\ d=\begin{bmatrix}1\\ 2\\ 5\end{bmatrix}$$

The apostrophe sign ' is used to get the transpose of a matrix.

Multiplication, summution, substraction are similar to scalars.

>>qq=a+b, ww=a-b; ee=a*d; ff=a+j*b

$$qq=\begin{bmatrix}11 & 22 & 33\\ 44 & 55 & 66\\ -98 & 88 & 99\end{bmatrix}, \qquad ww=\begin{bmatrix}9 & 18 & 27\\ 36 & 45 & 54\\ 102 & 72 & 81\end{bmatrix},$$

$$ee=\begin{bmatrix}200\\ 440\\ 710\end{bmatrix}$$

$$ff=\begin{bmatrix}10+j & 20+2j & 30+3j\\ 40+4j & 50+5j & 60+6j\\ 100-2j & 80+8j & 90+9j\end{bmatrix},$$

gg=[1+j 2+3j 4+5j; 8+8j 10 11]

$$gg=\begin{bmatrix}1+j & 2+3j & 4+5j\\ 8+8j & 10 & 11\end{bmatrix}$$

Rows and columns of a matrix

Rows and columns of a matrix are prosessed as in the following example.

Write a matrix as:

>> G=[10 20 30 40; 210 220 230; 310 320 330 340; 410 420; 430; 440];

$$G=\begin{bmatrix}10 & 20 & 30 & 40\\ 210 & 220 & 230 & 240\\ 310 & 320 & 330 & 340\\ 410 & 420 & 430 & 440\end{bmatrix}$$

and write the following commands

>>h=G(:,1), k= G(:,2), m= G(:,4), n=G(1,:), p=G(2,:),

You will get the following submatrices.

$$h=\begin{bmatrix}10\\ 210\\ 310\\ 410\end{bmatrix}, k=\begin{bmatrix}20\\ 220\\ 320\\ 420\end{bmatrix}, m=\begin{bmatrix}40\\ 240\\ 340\\ 440\end{bmatrix},$$

$$n=[10 \quad 20 \quad 30 \quad 40]$$

$$p=[410 \quad 420 \quad 430 \quad 440]$$

Futhermore, r=G(1:2,:), t=G(:,1:2), s=G(1:2,1:2) produce

$$r=\begin{bmatrix}10 & 20 & 30 & 40\\ 210 & 220 & 230 & 240\end{bmatrix}, t=\begin{bmatrix}10 & 20\\ 210 & 220\\ 310 & 320\\ 410 & 420\end{bmatrix},$$

$$s=\begin{bmatrix}10 & 20\\ 210 & 220\end{bmatrix},$$

>> aa=1:10 →

$aa=[1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6 \quad 7 \quad 8 \quad 9 \quad 10]$

>> aa=1:7, bb=sin(aa), → bb=[sin(1) sin(2) sin(3) sin(4) sin(5) sin(6) sin(7)];

Matrices can be nested into each other. Examine the following examples.

>>a=[1 2 3]; b=[10 100 200]; c=[11 22 33]; d=[a; b; c]; e=[a b c];

$$d=\begin{bmatrix}1 & 2 & 3\\ 10 & 100 & 200\\ 11 & 22 & 33\end{bmatrix},$$

$$e=[1 \quad 2 \quad 3 \quad 10 \quad 100 \quad 200 \quad 11 \quad 22 \quad 33]$$

>>a=[1 2; 3 4]; b=[a [10 20]'; 7 8 9]

$$a=\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}, \quad b=\begin{bmatrix}1 & 2 & 10\\ 3 & 4 & 20\\ 7 & 8 & 9\end{bmatrix}$$

Built-in defined matrices

zeros(n,m) an n x m matrix that, all elements are zero.
ones(n,m) an n x m matrix that, all elements are 1.
eye(n) an n x n unit matrix (diagonal elements are 1, all other elements are zero)
size(qq) size of the matrix qq(number of rows and number of columns)
qq' Transpose of the matrix qq
inv(qq) inverse of the matrix qq
diag(qq) diagonal of the matrix qq
sum(qq) sum of the elements of columns of matrix qq
all(qq), any(qq) To test whether any elements of the matrix qq is zero.
det(qq) determinant of the matrix qq.

Example 1)

>>ww=ones(2,3), ff=zeros(3,4), gg=eye(3),

$$ww = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}, \quad ff = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix},$$

$$gg = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Example 2)

>>[wrow wcolumn]=size(ww),
wrow=2 wcolumn=3

>>[frow fcolumn]=size(ff),
frow=3 frow=4

Example 3)

>>q=[1 2; 3 4], p=[10 20; 30 40];

r=[[q zeros(2,2)] [ones(2,2) p]]

$$q = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}, \quad q = \begin{bmatrix} 10 & 20 \\ 30 & 40 \end{bmatrix},$$

$$r = \begin{bmatrix} 1 & 2 & 0 & 0 & 1 & 1 & 10 & 20 \\ 3 & 4 & 0 & 0 & 1 & 1 & 30 & 40 \end{bmatrix}$$

Example 4)

>> e = [zeros(1,4) ones(1,3)]
0 0 0 0 1 1 1

>> e = [zeros(1,4) ones(1,3)]
0 0 0 0 1 1 1

>> f = [ones(1,3) 10*ones(1,4)]
1 1 1 10 10 10 10

>> g = 10*[1:3]
10 20 30

>> h = [ones(1,3) 10:2:20]
1 1 1 10 12 14 16 18 29

>> k =[10*ones(1,3) 17 10:3:19]
10 20 30 17 10 13 16 19

>> f = [ones(1,3) 10*ones(1,4)]
1 1 1 10 10 10 10

>> g = 10*[1:3]
10 20 30

>> h = [ones(1,3) 10:2:20]
1 1 1 10 12 14 16 18 29

>> k =[10*ones(1,3) 17 10:3:19]
10 20 30 17 10 13 16 19

Example 5)

>>aa=sum(r)
aa=[4 6 0 0 2 2 40 60]
Elements in each column are added.
>>bb=sum(aa)
bb=114
All the elements of vector is added.

Example 6)

Most built-in functions (sin,cos,tan, exp..) also works for matrices.
>>a=[1 2; 3 4];

>> b=sin(a);

$$b=\begin{bmatrix}\sin(1) & \sin(2)\\ \sin(3) & \sin(4)\end{bmatrix}=\begin{bmatrix}0.841 & 0.909\\ 0.141 & -0.756\end{bmatrix},$$

>> c=exp(a);

$$c=\begin{bmatrix}e^1 & e^2\\ e^3 & e^4\end{bmatrix}=\begin{bmatrix}2.718 & 7.389\\ 20.08 & 54.59\end{bmatrix}$$

>>d=a•^2;

$$d=\begin{bmatrix}1^2 & 2^2\\ 3^2 & 4^2\end{bmatrix}=\begin{bmatrix}1 & 4\\ 9 & 16\end{bmatrix},$$

>> g=a^2

$$g=\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}=\begin{bmatrix}7 & 10\\ 15 & 22\end{bmatrix}$$

Notice the **difference between a•^2 and a^2**

VECTOR MULTIPLICATION AND DIVISION

>> a = [15 16 12 20], b = [10 4 6 5]
>> x=a*b
??? Error using ==> mtimes
Inner matrix dimensions must agree.
Correct form is below
>> a = [15 16 12 20], b = [10 4 6 5]
>> x=a.*b
150 64 72 100

15 * 10 = 150
16 * 4 = 64
12 * 6 = 72
20 * 5 =100

>> a = [15 16 12 20], b = [10 4 6 5]
>>y=a/b
2.18
(This is not you wanted !!!!!)

Correct form is below
>> a = [15 16 12 20], b = [10 4 6 5]

>>y=a./b
1.5 4 2 4

15 / 10 = 1.5
16 / 4 = 4
12 / 6 = 2
20 / 5 = 4

DIMENSION ERROR

>> a = [2 5 4], b = [8 3 12 5]
>>x = a + b

?? Error using ==> plus
Matrix dimensions must agree.

a and b must be same size. Here a has 3 elements b has 4 elements. **We cannot add a and b**
x = a*b, y = a.*b, z = a/b w=a./b
all of them have dimension error

VECTOR SQUARE and POWER
>> a=[2 5 7 -8], b=a^2
??? Error using ==> mpower
Matrix must be square.

Correct form is below
>> a=[2 5 7 -8], b=a.^2
4 25 49 64

$2^2 = 4$ $5^2 = 25$ $7^2 = 49$ $(-)8^2 = 64$

>> a=[2 5 7 -8], b=a.^3
8 125 343 -512

Problem: $y = 3x^2 + e^{0.1x} - 20\sin(x)$
Calculate y for x=0, x=0.5 , x=1, and x=2

Long method:
>> x=0, y = 3*x^2 + exp(0.1*x) -20*sin(x)
1
>> x=0.5, y = 3*x^2 + exp(0.1*x) -20*sin(x)
-7.78

>> x=1, y = 3*x^2 + exp(0.1*x) -20*sin(x)
-12.72

Short method

```
>> x=[0  0.5  1   2],
>> y = 3* x.^2 + exp(0.1*x) - 20*sin(x)
      1    -7.78    -12.72    -4.96
```

Notice **the dot .** in x.^2

for

```
 >> for kk=1:4,  aa(kk)=kk^3; end;

aa=[1^3   2^3   3^3  4^3 ]

aa=[  1   8  27  64]
```

Example 431 : Calculate $y=3x^2+5x+7$ for x=[0 1 8 5], Show in a table.

Method 1.

```
    a1=0;  b1=3*a1^2 + 5*a1 +7

    a2=1;  b2=3*a2^2 + 5*a2 +7

    a3=8;  b3=3*a3^2 + 5*a3 +7

    a4=5;  b4=3*a4^2 + 5*a4 +7

tt=[a1 b1;  a2 b2;  a3 b3; a4 b4]
    tt=
     0      7
     1     15
     8    239
     5    107
```

Method 2.

```
    aa=[0 1 8  5]
    aa_Length=length(aa);
 for kk=1:aa_Length,
bb(kk)= 3* aa(kk) ^2 + 5*aa(kk) +7
 end;
bb=[7    15   239   107]

tt=[aa' bb']

 tt=
     0      7
     1     15
     8    239
     5    107
```

Method 3.

```
    aa=[0 1 8  5]
    bb=3*aa.^2 + 5*aa +7
```

Method 4.

```
    aa=[0 1 8  5]
    pol_coef =[3 5 7]

  b1=polyval(pol_coef,0)

  b2=polyval(pol_coef,0)

  b3=polyval(pol_coef,0)

  b4=polyval(pol_coef,0)
bb=[ b1 b2 b3 b4]
```

Method 5.

```
  aa=[0 1 8  5]
  pol_coef =[3 5 7]
  bb=polyval(pol_coef,aa)
```

Exercise: 11)

A=[1 2 3; 4 5 6; 7 8 8]; b=[10 20 30]';

a)find $x = A^{-1}b$

b)Calculate Ax. Is Ax=b ?

b)write C=A^2 and D=A.^2

why C and D are different.

c)Find Ab

d) Calculate determinat of A

Exercise 12)

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$$

Calculate determinat and inverse of A.

Exercise 3)

\>>A=[1 2 3; 10 20 30; 40 50 60],

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 10 & 20 & 30 \\ 40 & 50 & 60 \end{bmatrix}$$

Obtain matrix B from A by exchanging the rows of A.

Obtain matrix C from A by exchanging the columns of A.

$$B=\begin{bmatrix}1 & 2 & 3\\ 40 & 50 & 60\\ 10 & 20 & 30\end{bmatrix},\quad C=\begin{bmatrix}1 & 3 & 20\\ 40 & 60 & 50\\ 10 & 30 & 20\end{bmatrix}$$

Exercise 4)Obtain the following matrices by MATLAB commands

$$A=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix},$$

$$B=\begin{bmatrix}0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0\end{bmatrix},\ C=\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix},\quad D=\begin{bmatrix}100 & 100\\ 100 & 100\end{bmatrix},$$

Exercise 5) Obtain the following matrices

$$q\left\{\begin{bmatrix} \overbrace{1\ \ 1\ \ ..\ \ 1\ \ 1}^{n} & \overbrace{0\ \ 0\ ..\ 0}^{m}\\ 1\ \ 1\ \ ..\ \ 1\ \ 1 & 0\ \ 0\ ..\ \ 0\\ ..\ \ ..\ \ ..\ \ ..\ \ .. & ..\\ 1\ \ 1\ \ ..\ \ 1\ \ 1 & 0\ \ 0\ ..\ \ 0\end{bmatrix}\right.$$

a)

$$q\left\{\begin{bmatrix} \overbrace{1\ \ 1\ \ ..\ \ 1\ \ 1}^{n} & \overbrace{0\ \ 0\ ..0}^{m} & \overbrace{2\ \ 2\ \ ...\ 2}^{k}\\ 1\ \ 1\ \ ..\ \ 1\ \ 1 & 0\ \ 0\ ..\ 0 & 2\ \ 2\ \ ...2\\ ..\ \ ..\ \ ..\ \ ..\ \ .. & .. & \\ 1\ \ 1\ \ ..\ \ 1\ \ 1 & 0\ \ 0\ ..\ 0 & 2\ \ 2\ \ ...2\end{bmatrix}\right.$$

b)

$$\begin{bmatrix} q\left\{\begin{matrix} \overbrace{1\ \ 1\ \ ..\ \ 1\ \ 1}^{n}\\ 1\ \ 1\ \ ..\ \ 1\ \ 1\\ ..\ \ ..\ \ ..\ \ ..\ \ ..\\ 1\ \ 1\ \ ..\ \ 1\ \ 1\end{matrix}\right.\\ m\left\{\begin{matrix} 0\ \ 0\ ..\ \ 0\ \ 0\\ 0\ \ 0\ ..\ \ 0\ \ 0\\ ..\ \ ..\ \ ..\ \ ..\ \ ..\\ 0\ \ 0\ ..\ \ 0\ ..\ \ 0\end{matrix}\right.\\ k\left\{\begin{matrix} 1\ \ 0\ ..\ \ 0\ \ ..\ 0\\ 0\ \ 1\ ..\ \ 0\ ..\ \ 0\\ ..\ \ ..\ \ ..\ \ 0\ ..\ \ 0\\ 0\ \ \ 0\ \ ..0\ \ 1\ ..\ \ 0\end{matrix}\right.\\ p\ \{0\ \ \ 0\ \ ..\ 0\ \ 0\ ..\ 0\end{bmatrix}$$

C)

$$\begin{bmatrix} \overbrace{1\ \ 1\ \ ..\ \ 1\ \ 1}^{n} & \overbrace{0\ \ 0\ ..\ 0}^{m} & \overbrace{0\ ..\ 0}^{k}\\ p\left\{\begin{matrix}1\ \ 1\ \ ..\ \ 1\ \ 1\\ ..\ \ ..\ \ ..\ \ ..\ \ ..\\ 1\ \ 1\ \ ..\ \ 1\ \ 1\end{matrix}\right. & \begin{matrix}0\ \ 0\ ..\ 0\\ ..\ \ ..\ \ ..\\ 0\ \ 0\ ..0\end{matrix} & \begin{matrix}0\ ..\ 0\\ .\\ 0\ ..0\end{matrix}\\ q\left\{\begin{matrix}4\ \ 4\ \ ..\ \ 4\ \ 4\\ 4\ \ 4\ \ ..\ \ 4\ \ 4\\ ..\ \ ..\ \ ..\ \ ..\ \ ..\\ 4\ \ 4\ \ ..\ \ 4\ \ 4\end{matrix}\right. & \begin{matrix}1\ \ 0\ \ ..\ 0\\ 0\ \ 1\ \ ..0\\ ..\ \ ..\ \ ..\\ 0\ \ 0\ \ ..1\end{matrix} & \begin{matrix}0\ ..\ 0\\ 0\ ..\ 0\\ .\\ 0\ ..\ 0\end{matrix}\\ r\left\{\begin{matrix}0\ \ 0\ \ ..\ \ 0\ \ 0\\ ..\ \ ..\ \ ..\ \ ..\ \ ..\\ 0\ \ 0\ ..\ \ 0\ \ 0\end{matrix}\right. & \begin{matrix}0\ \ 0..\ \ 0\\ ..\ \ ..\ \ ...\\ ..\ \ 0\ \ \ 0\end{matrix} & \begin{matrix}0\ ..\ 0\\ \\ 0\ ..\ 0\end{matrix}\end{bmatrix}$$

d)

$$A=\begin{bmatrix}15 & 2 & 3 & 4 & 5 & 6\\ 30 & 3 & 2 & 0 & 0 & 3\\ 11 & 0 & 0 & 3 & 8 & 6\\ 7 & 1 & 3 & 0 & 3 & 12\\ 7.5 & 0 & 3 & 4 & 0 & 6\end{bmatrix}$$

A(2,:)= A(2,:) – A(1,:)*A(2,1)/A(1,1)

A(3,:)= A(3,:) – A(1,:)*A(3,1)/A(1,1)
A(4,:)= A(4,:) – A(1,:)*A(4,1)/A(1,1)
A(5,:)= A(5,:) – A(1,:)*A(5,1)/A(1,1)

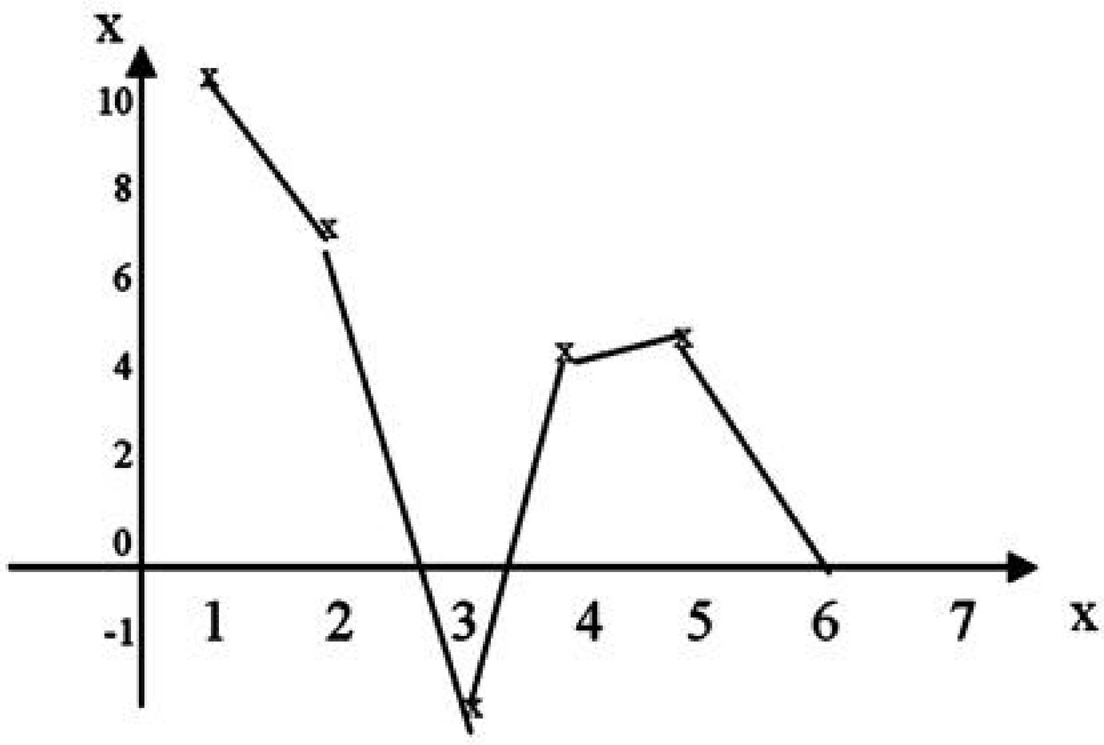
A(3,:)= A(3,:) – A(2,:)*A(3,2)/A(2,2)
A(4,:)= A(4,:) – A(2,:)*A(4,2)/A(2,2)
A(5,:)= A(5,:) – A(2,:)*A(5,2)/A(2,2)

A(4,:)= A(4,:) – A(3,:)*A(4,3)/A(3,3)
A(5,:)= A(5,:) – A(3,:)*A(5,3)/A(3,3)

A(5,:)= A(5,:) – A(4,:)*A(5,4)/A(4,4)

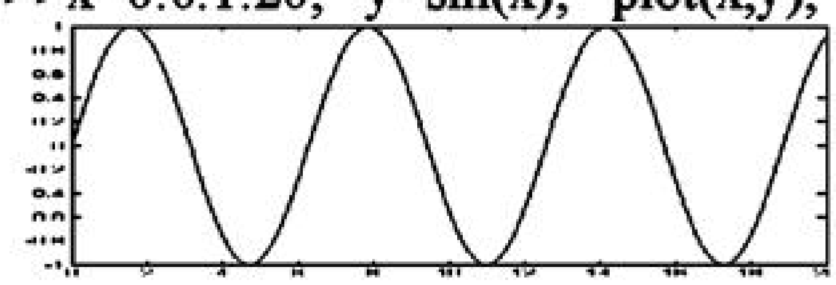
MATLAB GRAPHICS

x=[1 2 3 4 5 6]; y=[10 7 -1 5 6 0];
If we plot y versus x we get the following



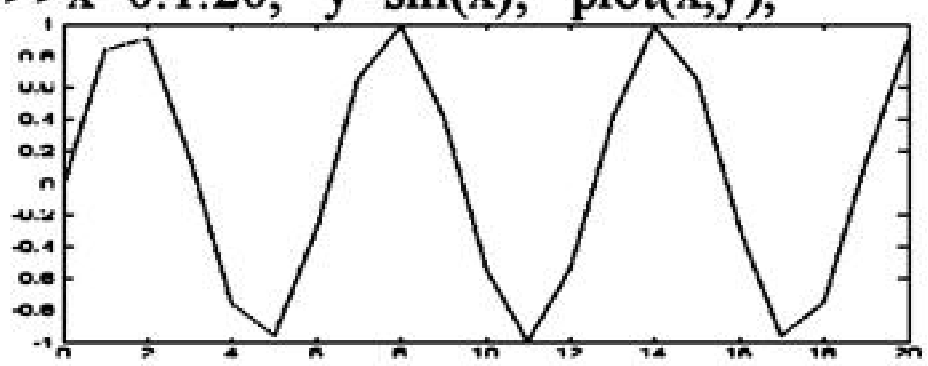
Matlab command to plot y versus x is
plot(x,y)

```
>>x=0:0.1:20;   y=sin(x);   plot(x,y),
```

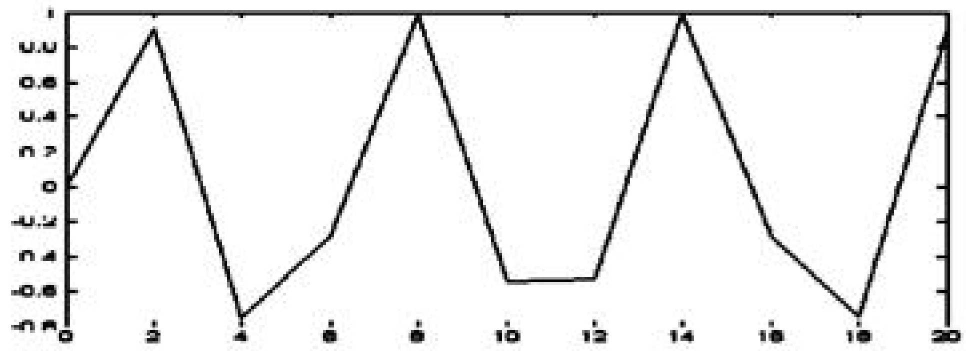


Graphic Resolution

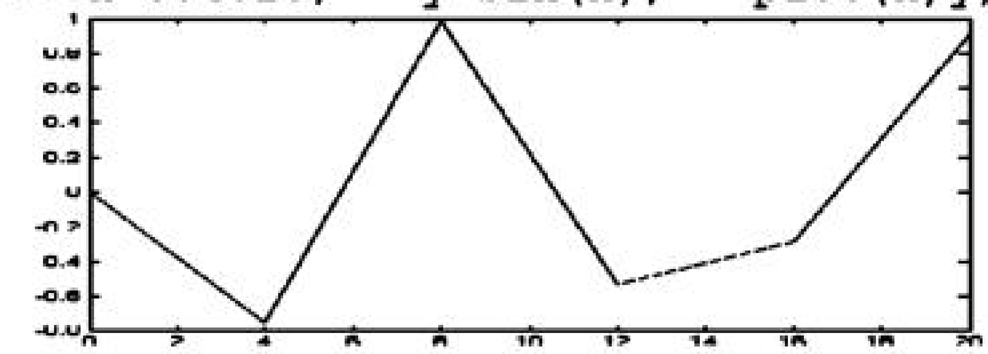
```
>>x=0:1:20;   y=sin(x);   plot(x,y),
```



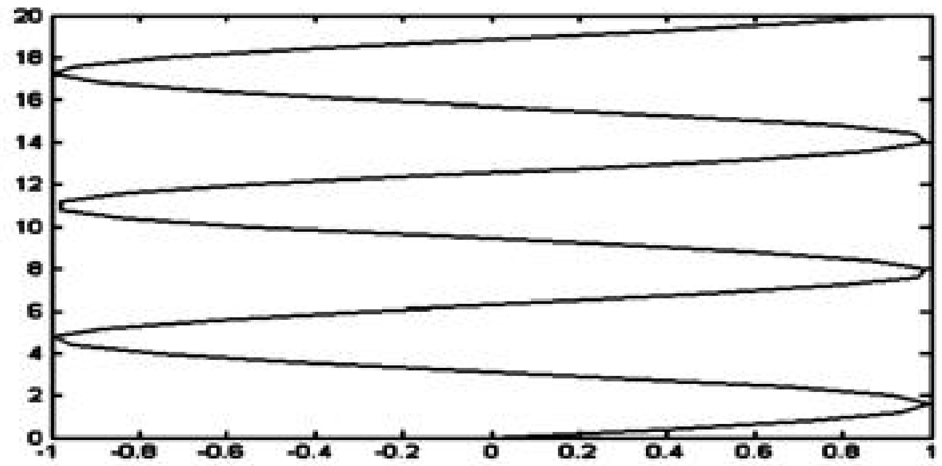
```
>>x=0:2:20;    y=sin(x);    plot(x,y),
```



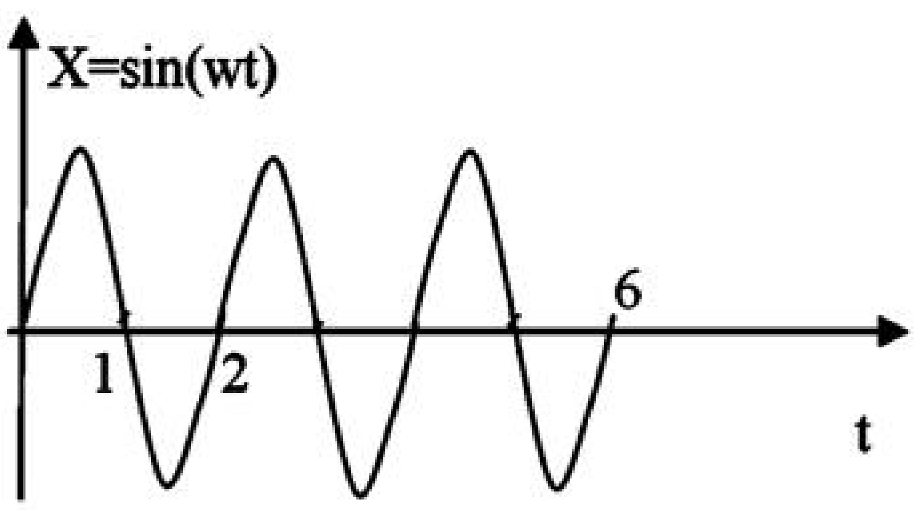
```
>> x=0:4:20;    y=sin(x);    plot(x,y),
```



```
>> x=0:0.1:20;    y=sin(x);    plot(y,x),
```



Problem 32: Draw the following graph

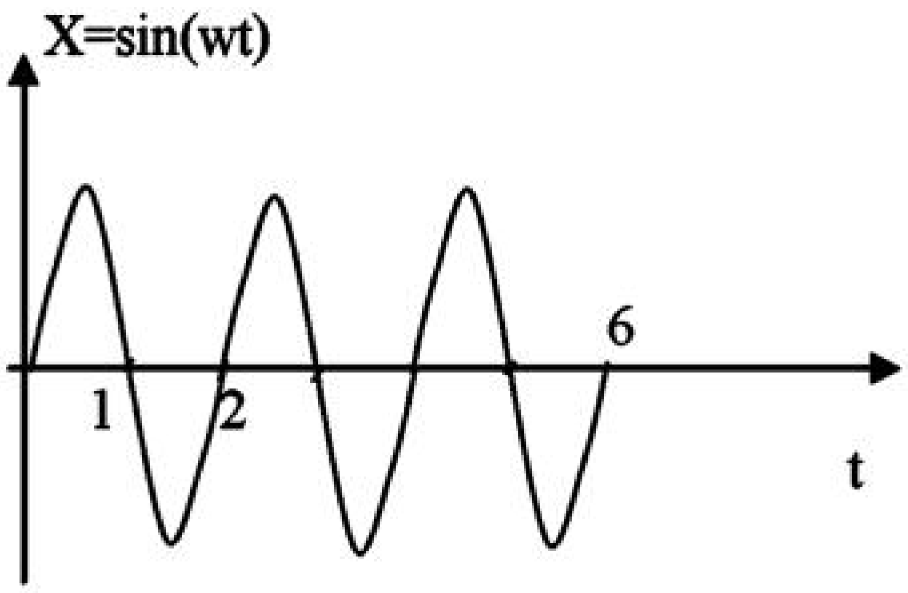


Solution

```
t=0:0.1:6;
TT=2;
w=2*pi/TT;
x=sin(w*t);
plot(t,x);

t=0:0.1:6; TT=2; w=2*pi/TT; x=sin(w*t);plot(t,x);
```

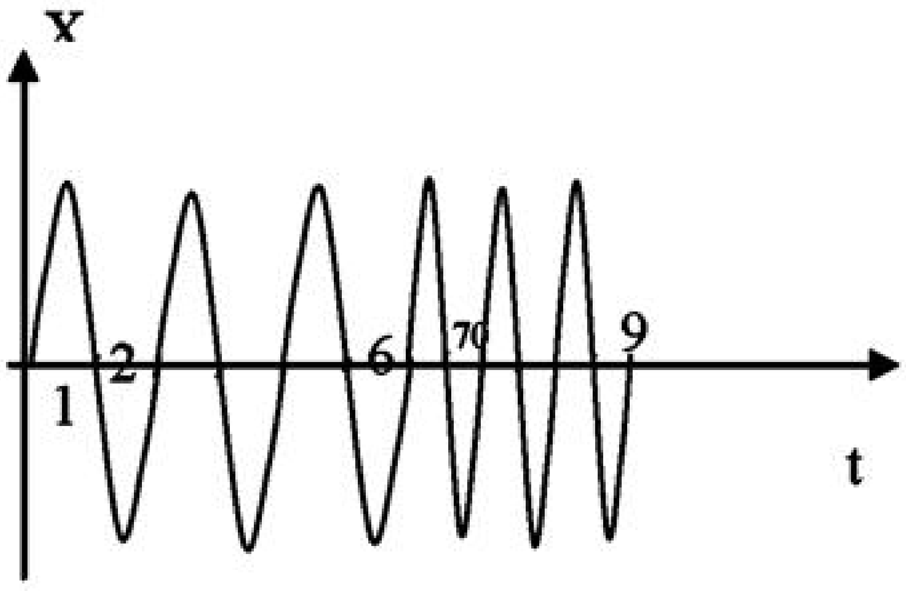
Problem 33: Draw the following graph



Solution

```
t=0:0.1:60; TT=20; w=2*pi/TT; x=sin(w*t); plot(t,x);
```

Problem 34: Draw the following graph.
Note: frequency is doubled from t=60 to t=90



Solution

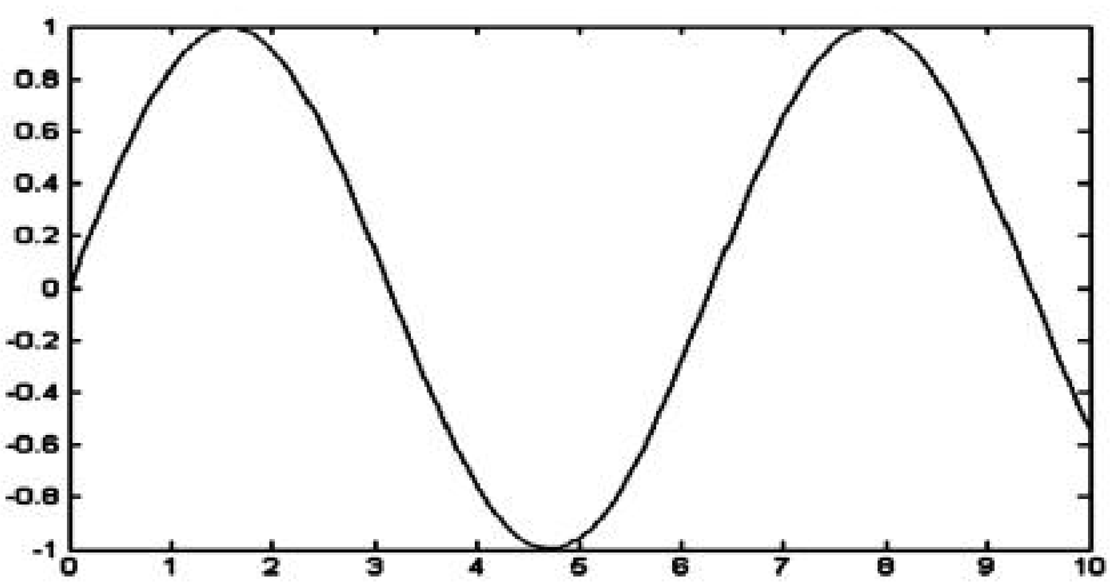
```
t1=0:0.1:60; TT1=20; w1=2*pi/TT1; x1=sin(w1*t1);

t2=60:0.1:90; TT2=10; w2=2*pi/TT2; x2=sin(w2*t2);

tTotal=[t1 t2];  xTotal=[x1 x2]; plot(tTotal,xTotal);
```

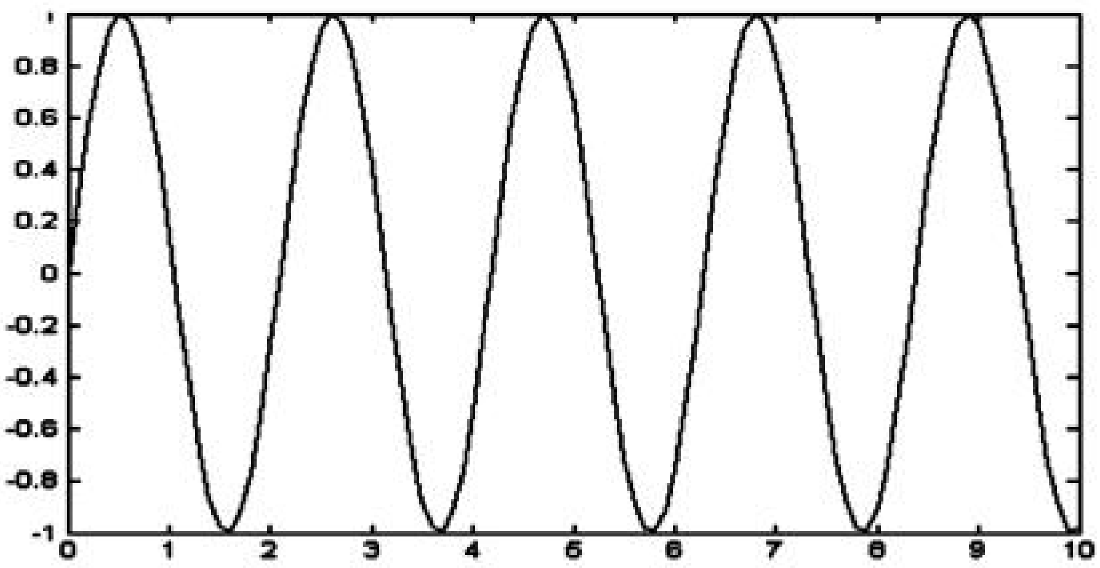
Problem 35: Draw x=sin(t)   t=0 to 10
Solution:

```
t=0:0.1:10;  w1=1; x1=sin(w1*t); plot(t,x1);
```



Problem 36: Draw x=sin(3t)   t=0 to 10
Solution:

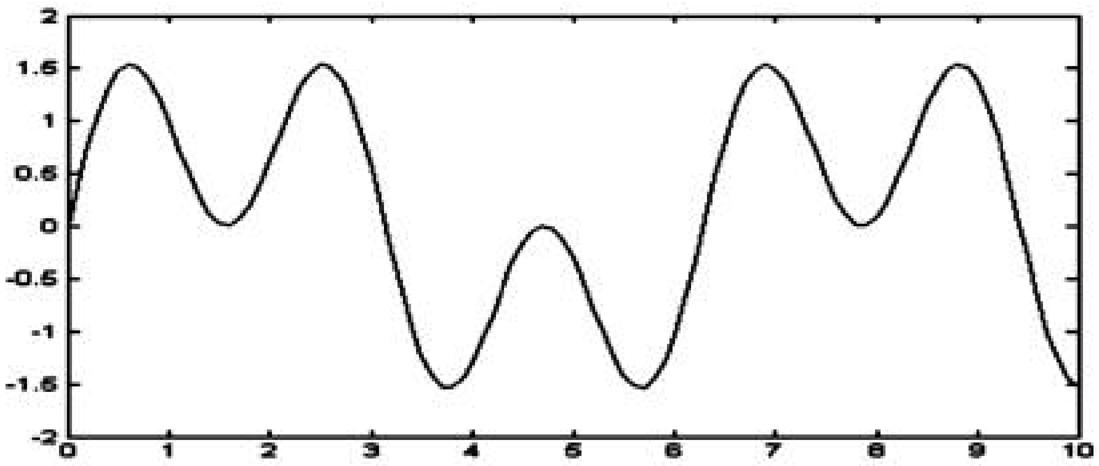
```
t=0:0.1:10;  w1=3; x1=sin(w1*t); plot(t,x1);
```



Problem 37: Draw x= sin(t) + sin(3t)   t=0 to 10
Solution:

```
t=0:0.1:10;  w1=1; w2=3;

x1=[sin(w1*t)+sin(w2*t)];   plot(t,x);
```

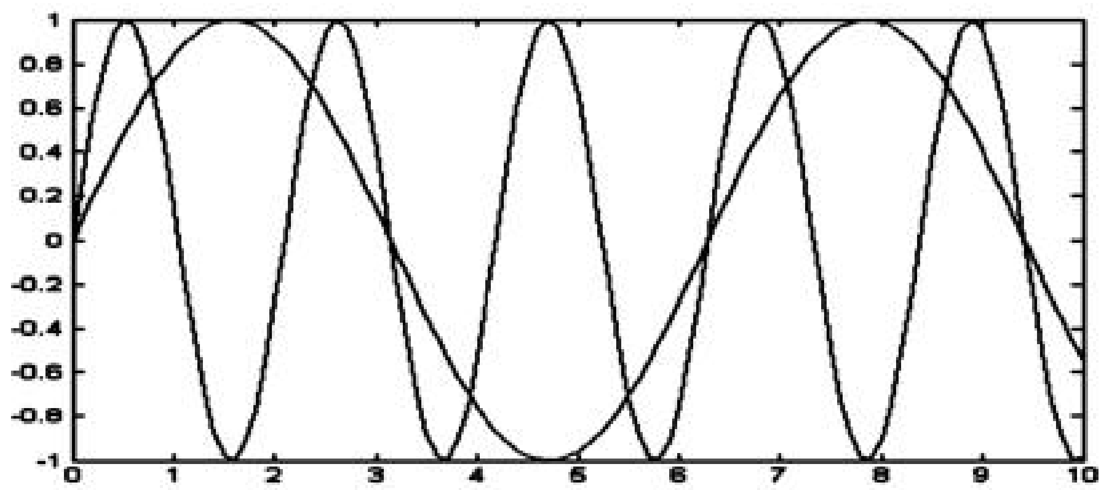


Problem 38: Draw x1= sin(t) and x2= sin(3t)   t=0 to 10
Solution

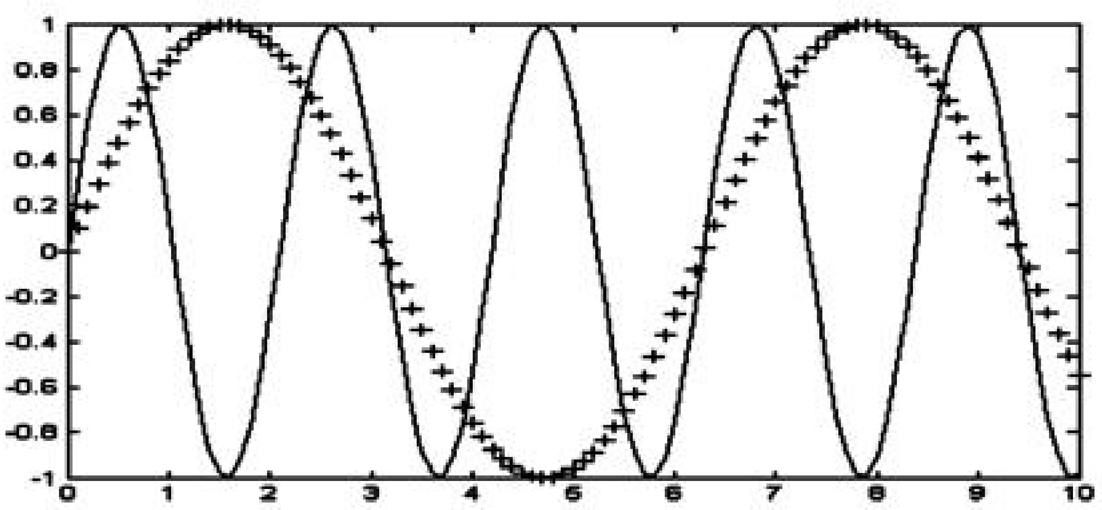
```
t=0:0.1:10;  w1=1; w2=3;

x1=[sin(w1*t)]; x2=[sin(w2*t)];
```

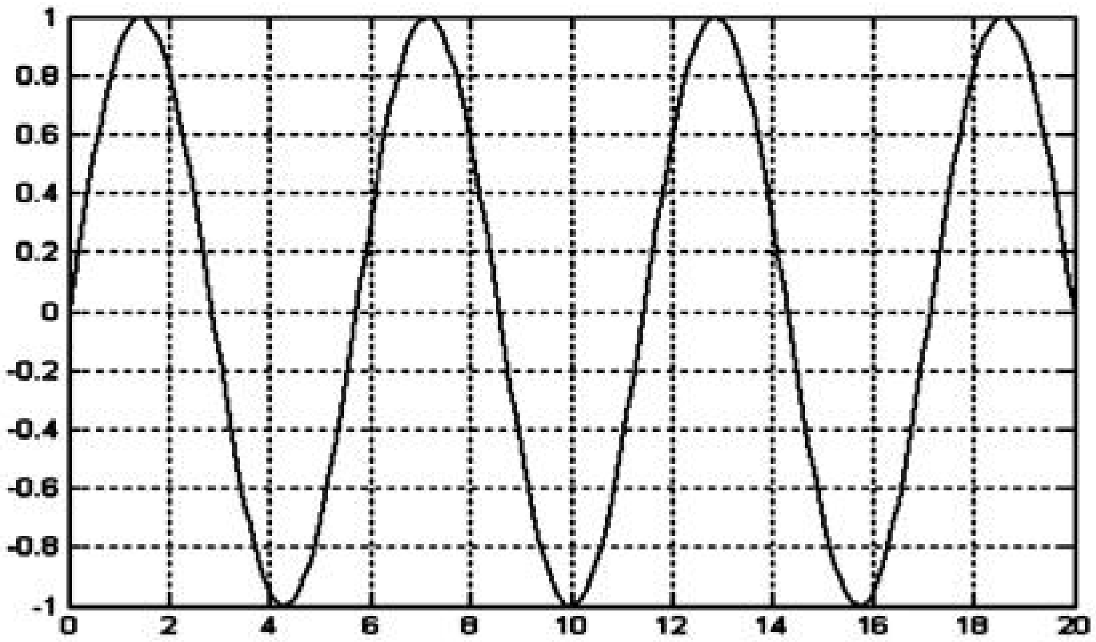
```
plot( t, x1 , t , x2 );
```



```
plot( t, x1 ,'+',  t , x2 );
```



Exercise 57. Find the period and frequency of the following sinewave



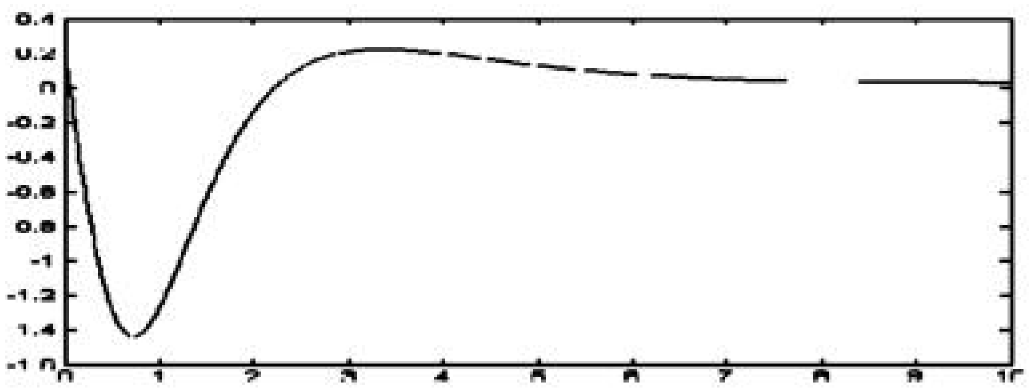
T= f= w=

T=17/3=5.666 ???

Problem 41: $y=\dfrac{3x^2+e^{0.1x}-20\sin(x)}{x^4+4x^2+5}$

plot x,y graph for x=0 to x=10

```
x=0:0.1:10;    aa=3* x.^2+ exp(0.1*x) - 20*sin(x);
bb= x.^4 +  4*x.^2  +5;     yy=aa./bb;  plot(x,yy)
```



Problem 413:

$F(z)=\dfrac{s+1}{s^2+2s+2}$ fonksiyonunda s=jw koyup genlik ve faz spektrumunu cizin. Genligin maximum oldugu frekansi bulun.

a) s yerine $s=iw$ koyun.
b) $F(w)$, $|F(w)|$, ve $<F(w)$ yi asagidaki w degerlei icin hesaplayin. w=[0 0.5 1 1.1 1.2 2 5 10]

c)x ekseni w y ekseni $|F(w)|$ olacak sekilde $|F(w)|$ *ve* $< F(w)$ *yi cizin.*
d) $|F(w)|$ nin maximum degerini grafikten bulun.

Cozum

$$F(iw)=\frac{iw+1}{(iw)^2+2iw+2}=\frac{1+i\,w}{(2-w^2)+i\,2w}=\frac{N(w)}{D(w)}$$

for w=0. N(0)= 1+ i 0=1 D(0)=(2-0^2)+ i 2x0 = 2

$$F(0)=\frac{N(0)}{D(0)}=\frac{1}{2}=0$$

for w=0.5 N(0.5)= 1+ i 0.5
D(0.5)= (2-0.5^2)+ i 2x0.5 =1.75+i

$$F(i0.5)=\frac{N(0.5)}{D(0.5)}=\frac{1+0.5i}{1.75+i}=0.553-0.03i$$

$$|F(i0.5)|=\sqrt{0.553^2+0.03^2}=0.554$$

$$<F(i0.5)=\tan^{-1}\left(\frac{-0.03}{0.553}\right)=-0.055^{\text{radian}}=-3.18^0$$

Benzer sekilde

$F(i)= 0.6-0.2i$ $|F(1)|=0.6325$, $<F(1)=-18.4^0$

$F(1.1i)=0.587-0.24i$ $|F(1.1)|=0.633$, $<F(1.1)=-22^0$

$F(1.2i)=0.56-0.28i$ $|F(1.2)|=0.634$, $<F(1.2)=-26.6^0$

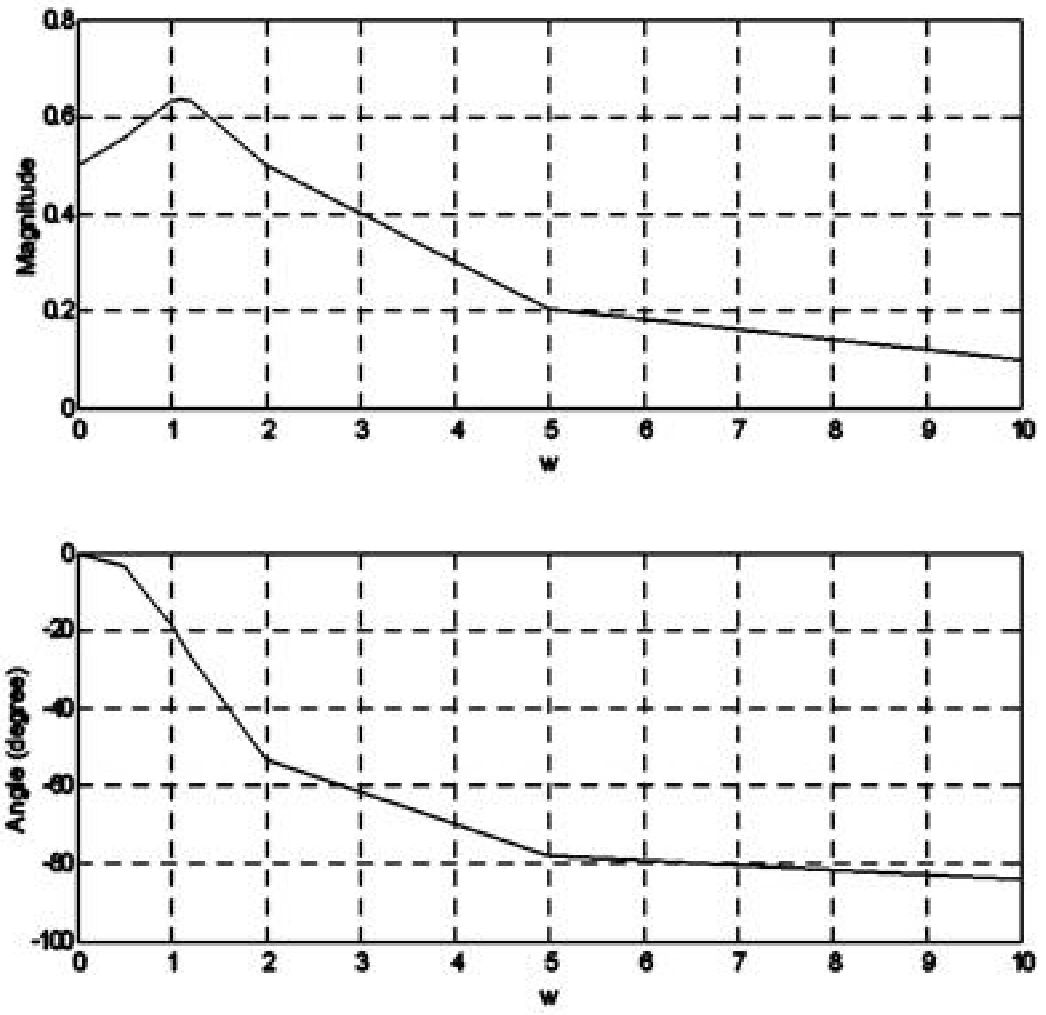
$F(2i)= 0.3-0.4i$ $|F(2)|=0.5$, $<F(1)=-53.1^0$

$F(5i)= 0.042-0.198i$ $|F(2)|=0.203$, $<F(5)=-77.8^0$

$F(10i)=0.01--0.1i$ $|F(10)|=0.1005$, $<F(5)=-84.1^0$

$F(\infty)=0-0\,i$ $|F(\infty)|=0$, $<F(\infty)=-90^0$

w	F_R	F_{IM}	|F(iw)|	< F(iw) degree
0	0.5	0	0.5	0
0.5	0.553	-0.03	0.554	-3.17
1	0.6	-0.2	0.632	-18.43
1.1	0.587	-0.243	0.63	-22.52
1.2	0.566	-0.284	0.633	-26.67
2	0.3	-0.4	0.5	-53.13
5	0.042	-0.198	0.203	-77.81
10	0.010	-0.1	0.1005	-84.17
∞	0	0	0	-90



Grafikten gorulecegi gibi naximum deger $|F(iw)| = 0.636$. This maximum deger w=1.1 de meydana gelmektedir.

Example 424:

Draw amplitude and phase spectrum of the transfer function

$$H(s)=\frac{10(s+1)}{s^2+4s+13}$$

```
>> w=0; s=j*w; hh=10* (s+1)/(s^2+4*s+13);
amp=abs(hh), pp=phase(hh)

 amp =  0.769
  pp =  0

>> w=0.1;  s=j*w; hh=10* (s+1)/(s^2+4*s+13);
amp=abs(hh), pp=phase(hh)
  amp =  0.773
  pp =  0.689

>> w=0.2; s=j*w; hh=10* (s+1)/(s^2+4*s+13);
amp=abs(hh), pp=phase(hh)
    amp =  0.785
    pp =  0.1357

>> w=0.3; s=j*w; hh=10* (s+1)/(s^2+4*s+13);
amp=abs(hh), pp=phase(hh)
    amp =  0.805
    pp =  0.1988

……………………………
>> w=1; s=j*w; hh=10* (s+1)/(s^2+4*s+13);
amp=abs(hh), pp=phase(hh)
    amp =  1.118
    pp =  0.4636
```

Make an array

```
 >> ww = [     0        0.1        0.2        0.3       1
]
>>total_amp=[0.769    0.773    0.785    0.805
1.118  ]
>>total_ph=[  0        0.689    0.1357    0.198
0.463  ]

>>plot(ww,total_amp),   figure,  plot(ww,total_ph)
```

KISA YOL

```
>>ww=0:0.1:1; s=j*w;   num=(s+1), den=s.^2 +.4 .* s +13,   hh=num./den, amp=abs(hh), >> ph=phase(hh)
>>plot(ww,amp),   figure,  plot(ww,ph)
```

Note: x=[3+4j   2+5j   5+3j -8j   -7]
y=abs(x)
y=[5   5.38   5.831   8.   7.]

COK KISA YOL

```
pay=10*[1 1];
payda=[1 4 13];
ww=0:0.01:30;
hh= freqs(pay,payda,ww);
plot(ww,abs(hh));
plot(ww,180*angle(hh)/pi);
```

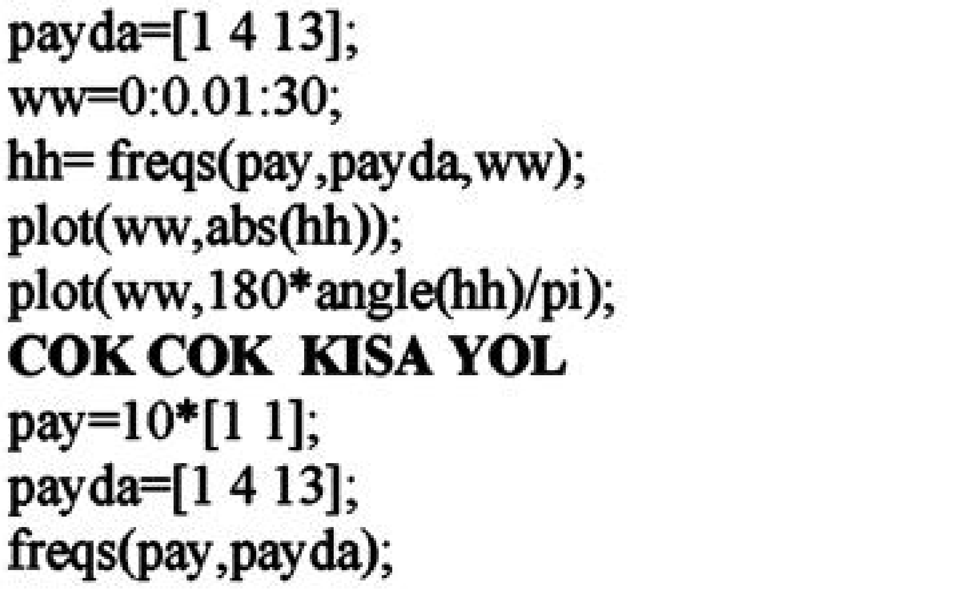
COK COK KISA YOL

```
pay=10*[1 1];
payda=[1 4 13];
freqs(pay,payda);
```

Problem. $H(jw)= (jw)^3 + 5\,(jw)^2 + 10\,(jw) + 8$
Draw amplitude and phase spectrum for w=0 to w=5

Solution:

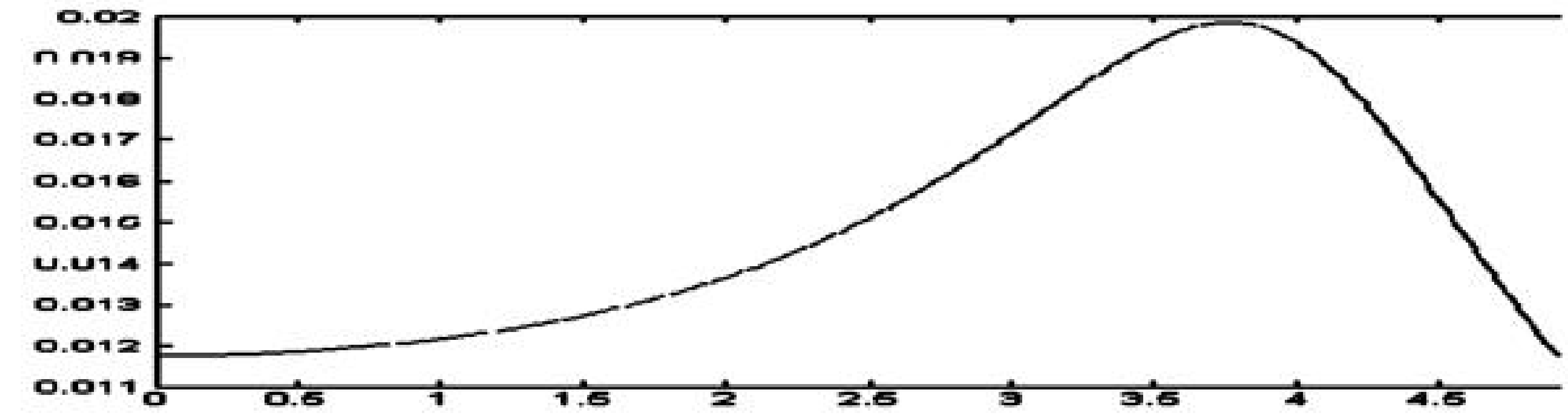
```
w=0:0.01:5;   s=j*w;
 hh =1*s.^3+7*s.^2+27*s+85;
plot(w, abs(hh) )
```



Problem 42: $H(jw)=\dfrac{1}{(jw)3\ + 5\,(jw) + 10\,(jw)\ + 8}$

Draw amplitude and phase spectrum for w=0 to w=5
Solution:

```
w=0:0.01:5;   s=j*w;
 hh =1*s.^3+7*s.^2+27*s+85;
 hh=1 ./ hh;    plot(w, abs(hh) )
```



Exercise 54

Draw amplitude and phase spectrum of

a). $H(s)=\dfrac{s^2+3s+4}{s^3+5s^2+10s+8}$

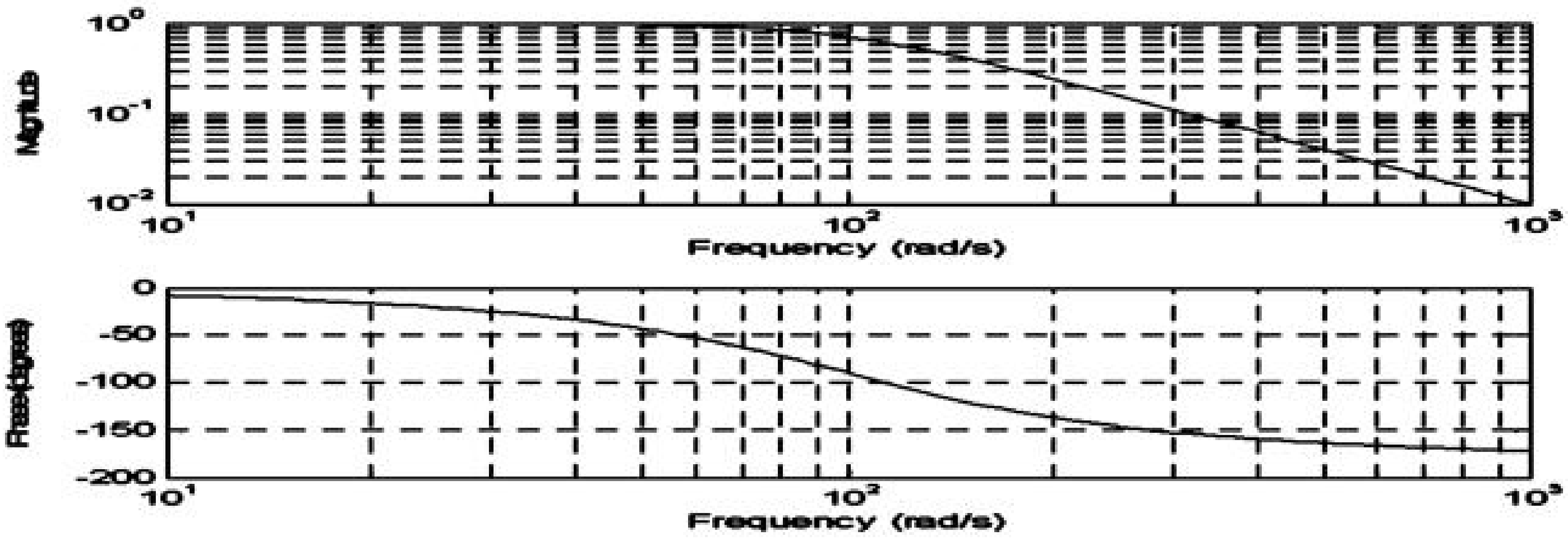
b)

$H(s)=\dfrac{10000}{s^2+141+10000}$

Example 411

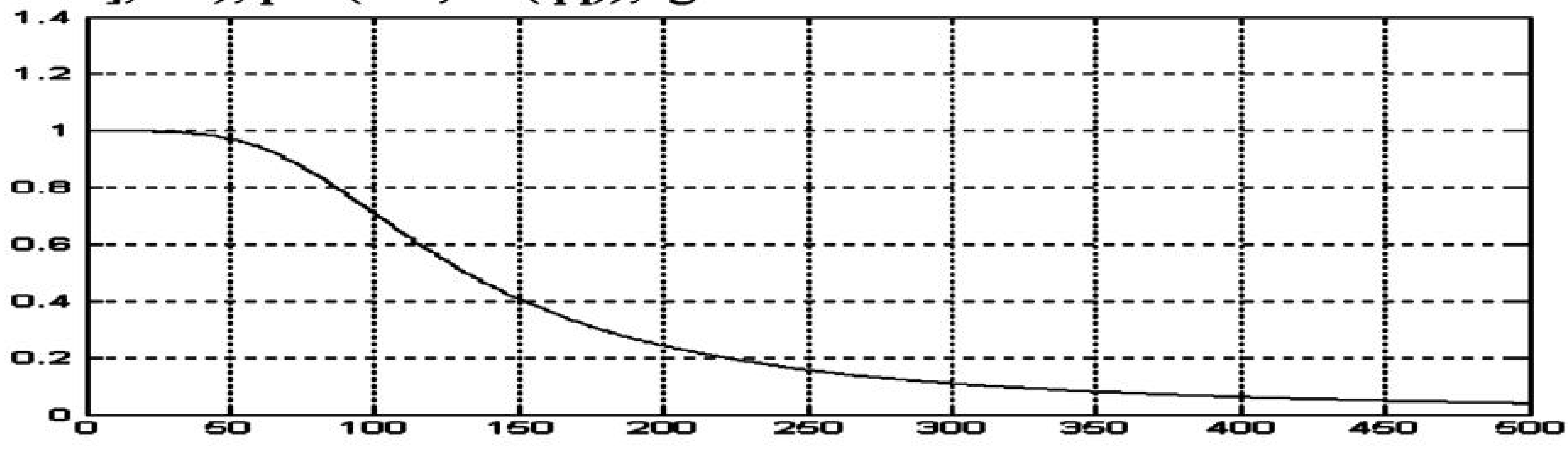
plot the frequency response

```
freqs( [10000],  [1  141   10000])
```



Example 76)

```
ww=0:1:500; qq=freqs( [10000],  [1  141
10000],ww); plot(ww,abs(qq));  grid
```



FAST FOURIER TRANSFORM

Fast Fourier Transform (FFT) is discrete Fourier Transform. It is a **fast algorithm** to calculate discrete Fourier Transform (DFT)

MATLAB command fft calculates FFT.

Example. x(t)=sin(t); This is an analog (continuous) signal. We want to see the amplitude and phase spectrum of this signal.

Sampling:

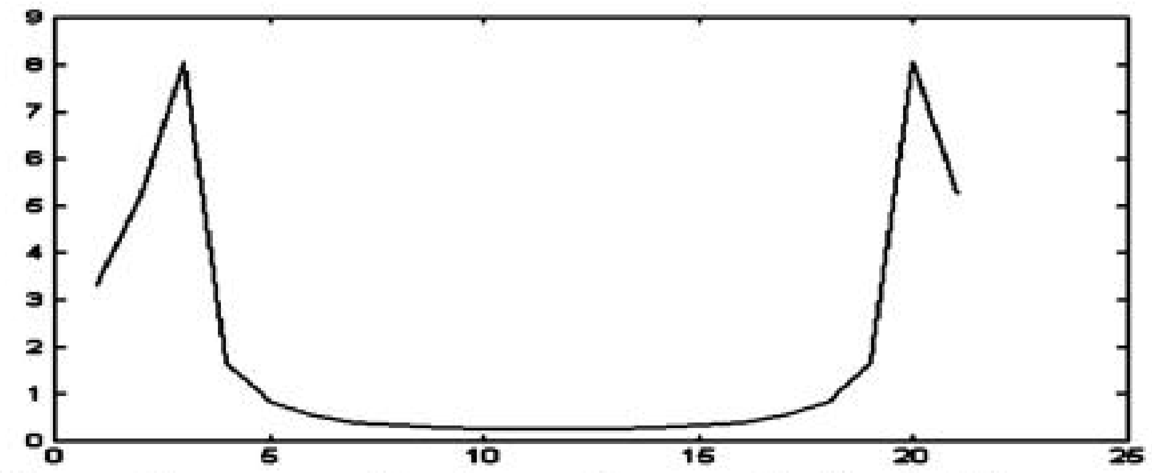
t = [0 0.5 1 1.5 2 ……. 9.5 10]

x(n) = [sin(0) sin(0.5) sin(1) ……. sin(9.5) sin(10)]

x(n)=[0 0.48 0.84 ……. -0.075 -0.54];

MATLAB format is

```
t=0:0.5:10;    x=sin(t);
frx = fft(x);    framp=abs(frx);   plot(framp);
```

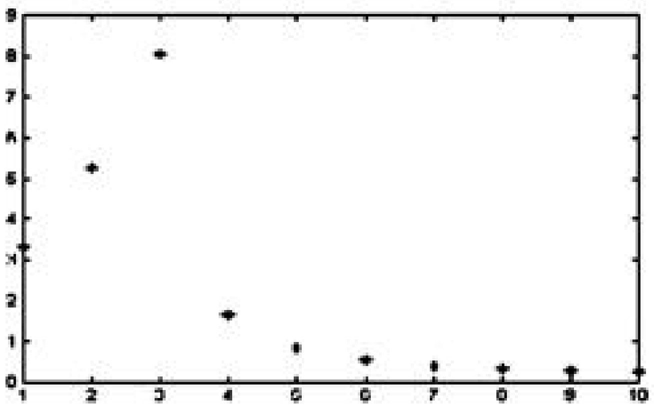


Since its symmetrical we draw only the half.

```
>>plot(framp(1:end/2));
```

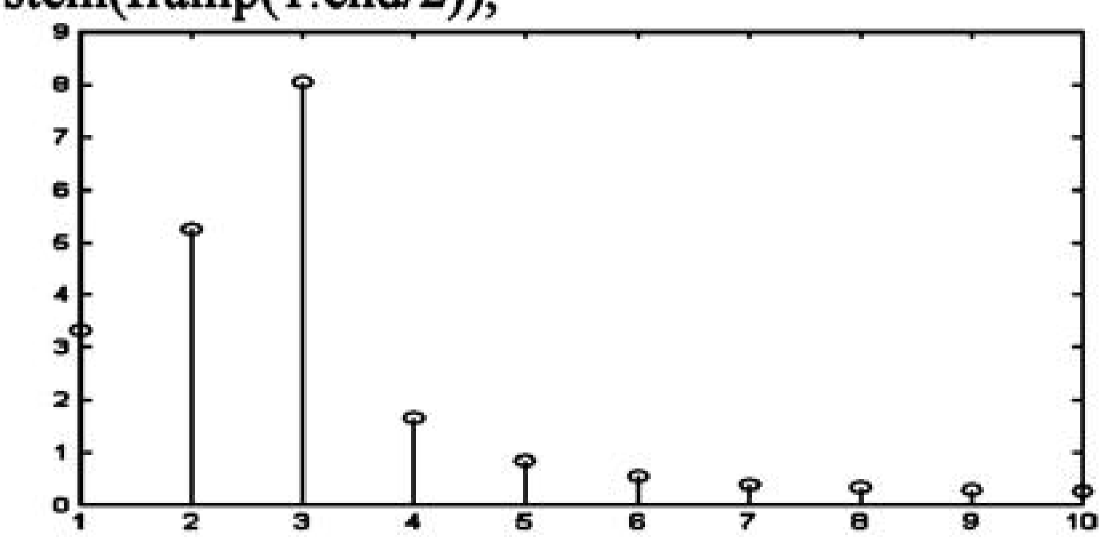
It may be a good idea to see only the values.

```
plot(framp(1:end/2));
```



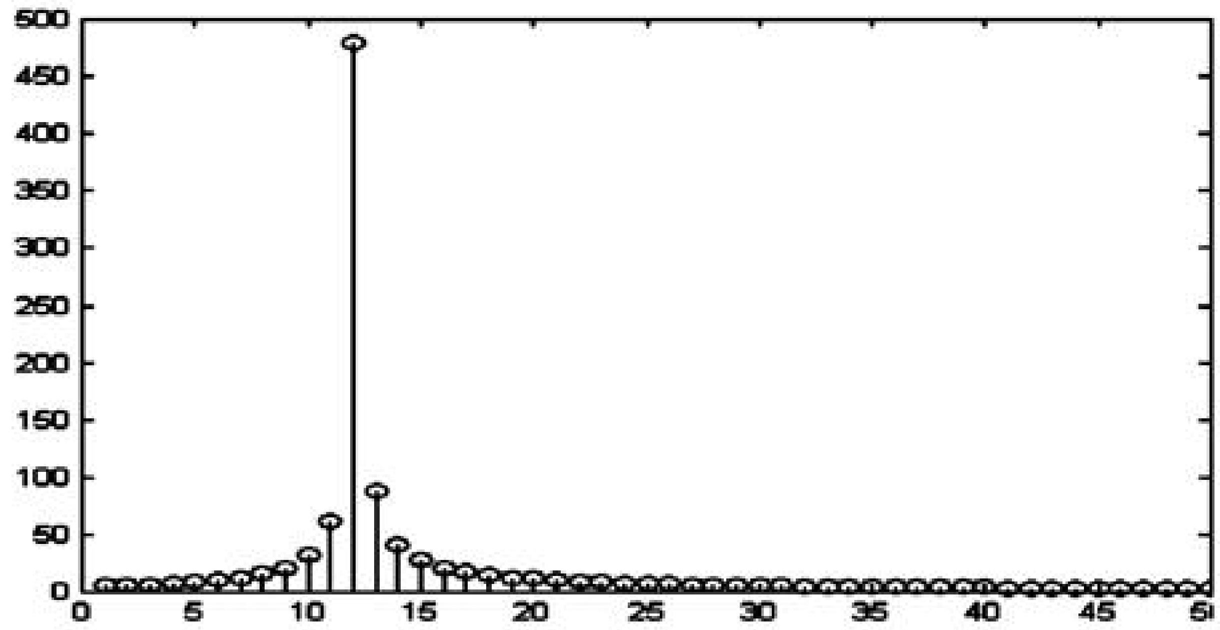
Or more clearly

```
stem(framp(1:end/2));
```



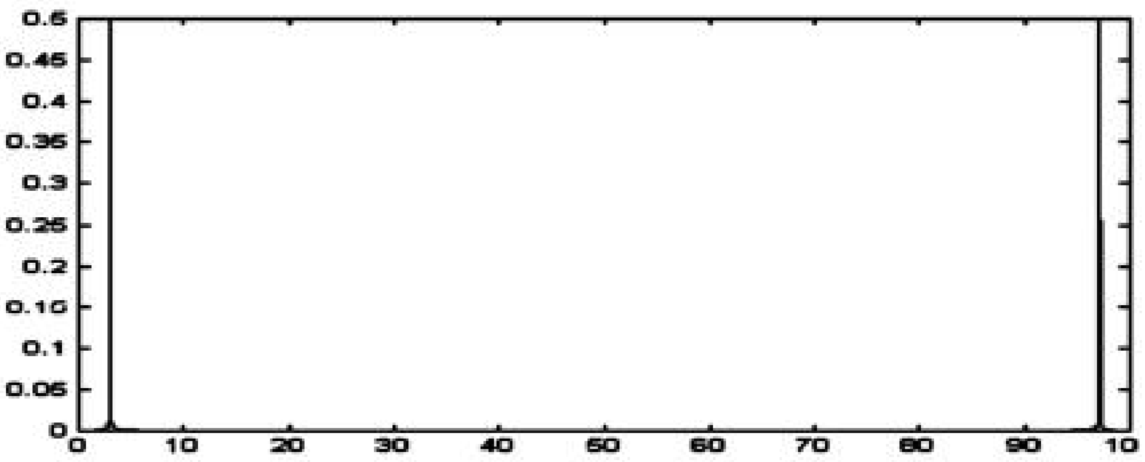
Try the followings

```
t=0:0.01:10;    x=sin(7*t);
frx = fft(x);    framp=abs(frx);   stem(framp);
```



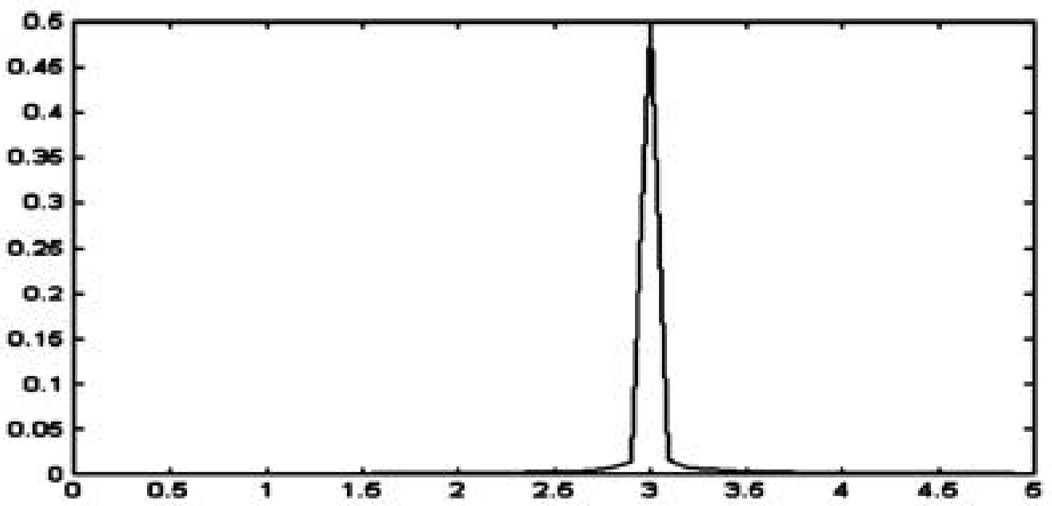
SCALING THE FREQUENCY AXIS

```
t=0:0.01:10;    x=sin(2*pi*3*t);
total_time=10;
 NN=length(t);
 frr=fft(x);     framp=abs(frr)/NN;
 Ts=total_time/NN;      fs=1/Ts;
 freq_axes=fs*[0:NN-1]/NN;
 plot(freq_axes,framp);
```

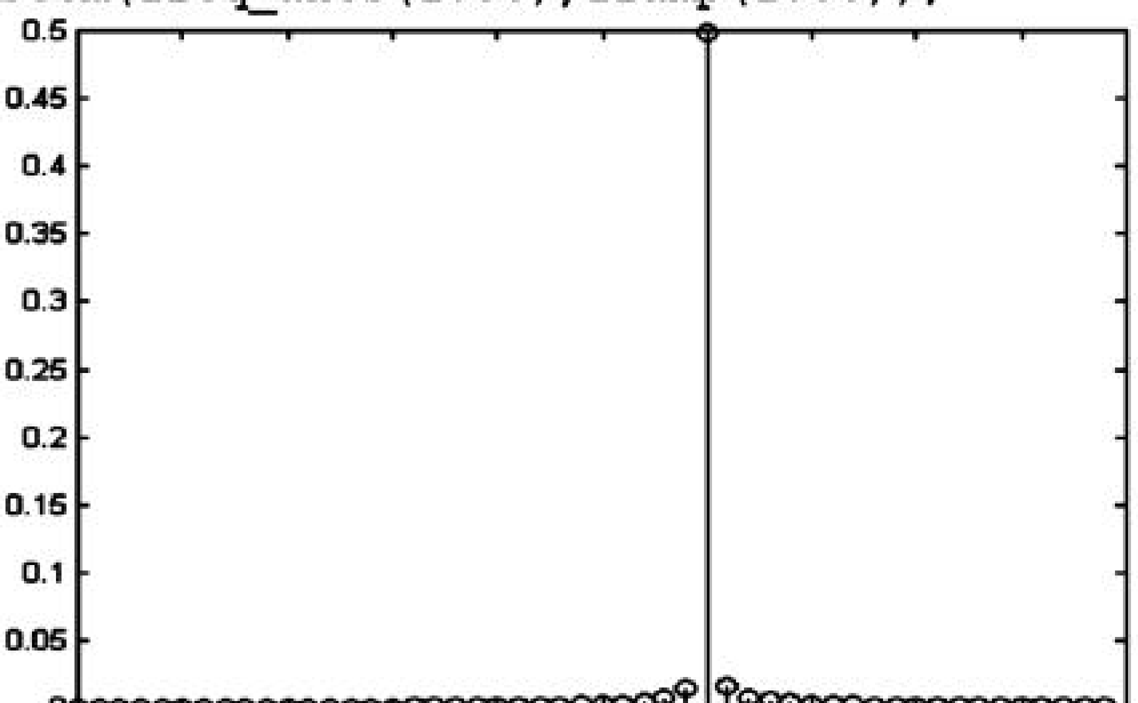


To see clearly

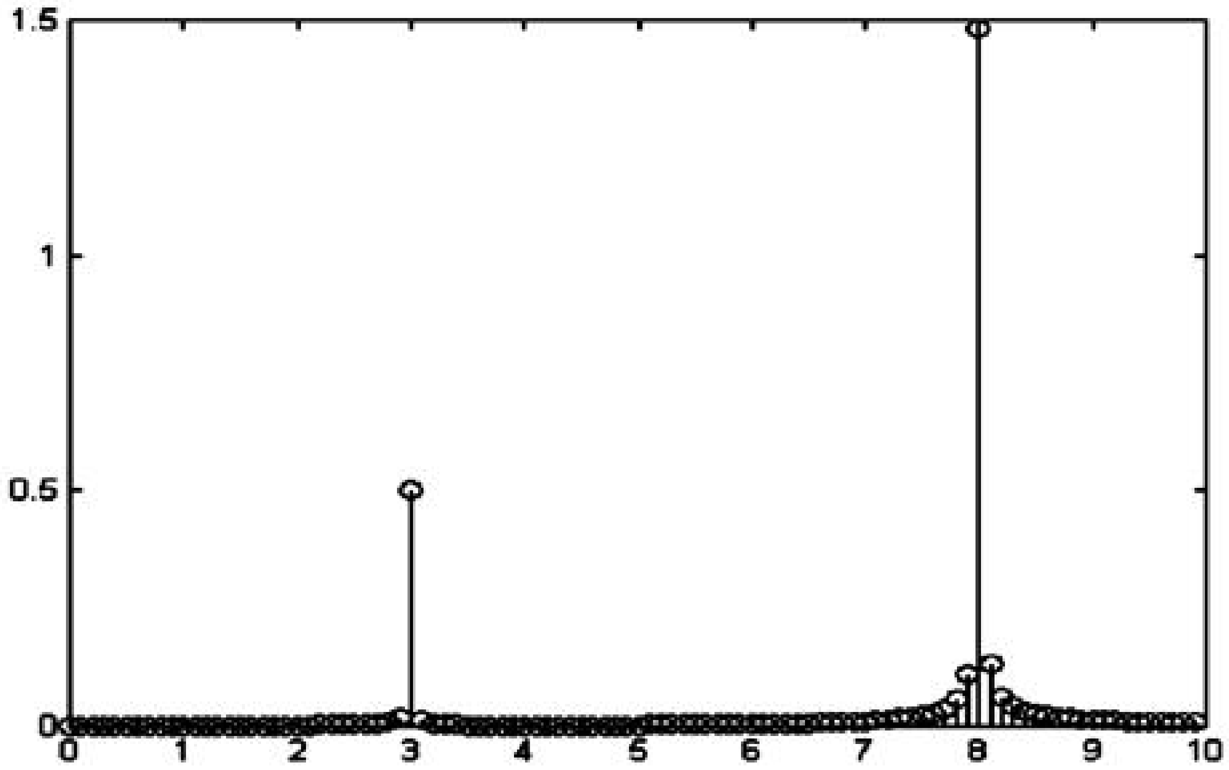
```
plot(freq_axes(1:50),framp(1:50));
```



```
stem(freq_axes(1:50),framp(1:50));
```

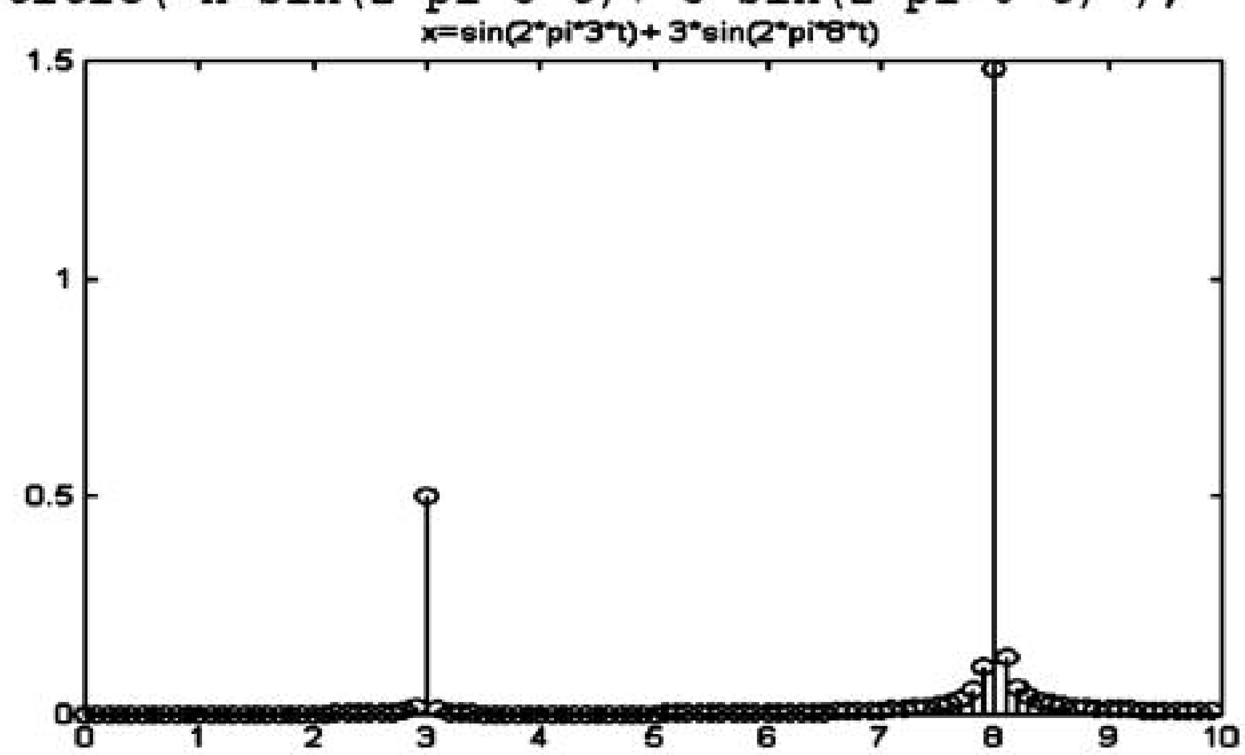


```
x=sin(2*pi*3*t);
   -----------------------------------------
t:0.01:10;
x=sin(2*pi*3*t)+ 3*sin(2*pi*8*t);
  total_time=10;
  NN=length(t);
  frr=fft(x);    framp=abs(frr)/NN;
  Ts=total_time/NN;
  fs=1/Ts;
  freq_axes=fs*[0:NN-1]/NN;
  stem(freq_axes(1:100),framp(1:100),'k');
```



Put a title on the figure

```
title('x=sin(2*pi*3*t)+ 3*sin(2*pi*8*t)');
```



CASE STUDIES

Example 1.

Run the file. See the figure. Listen to the voice.

```
  total_T=1;
  NN=16000;
   t_axis=([0:NN-1]/NN)*total_T;
   xx= sin(2*pi*1000*t_axis);
   Ts=total_T/NN;   fs=1/Ts;
   f_axis=([0:NN-1]/NN)*fs;
   yy=abs(fft(xx));
   subplot(211);   plot(t_axis,xx); grid;
    title('Time response ');
    subplot(212);   plot(f_axis,yy); grid;
    title('Amplitude spectrum ');
  wavplay(xx,16000)
```

```
Note: [0:5]   ==>    0 1 2 3 4 5
      [0:5]/5   ===>   0 0.2 0.4 0.6 0.8 1
     30*[0:5]/5   ==>   0 6   12   18   24 30
      [0:NN-1]/NN)* total_T  from zero to
total time.  step size is total_T/NN .
```

Example 2. Change frequency 400,300,200 and listen to the voice

```
 sin(2*pi*400*t_axis);
```

Example 3. Change frequency 4000,5000,7000 and listen to the voice

```
sin(2*pi*7000*t_axis);
```

Example 4. Add two frequency listen to the voice see the spectrum

```
 xx= sin(2*pi*500*t_axis)+
      sin(2*pi*7000*t_axis);
```

Example 5. Add three or more frequency listen to the voice see the spectrum

```
xx= sin(2*pi*500*t_axis)+
     sin(2*pi*2000*t_axis)+
     sin(2*pi*3000*t_axis) +
     sin(2*pi*7000*t_axis);
```

Example 3

```
x= sin(2*pi*10*t)+ sin(2*pi*20*t);
x= 0.3*sin(2*pi*10*t)+ sin(2*pi*20*t);
x= sin(2*pi*10*t)+ 0.3*sin(2*pi*20*t);

x= sin(2*pi*10*t) + sin(2*pi*20*t)+
    sin(2*pi*30*t) + sin(2*pi*40*t);
```

sampling_period = total_time/Number_of_sampling;
sampling_frequency = 1/sampling_period;
freq_axes=sampling_frequency*[1:NN]/NN;

\>> plot(freq_axes,framp); grid;

\>> plot(freq_axes(1:15),framp(1:15)); grid;
\>> stem(freq_axes(1:15),framp(1:15)); grid;
t=0:0.5:10; x=sin(t); Ts=1; fs=1/0.5=2
time axes has 20 elements. Frequency axes has 20 elements.
t varies from zero to 10. (step size 0.5)

f varies from zero to 2. (step size is 0.1)
freq_axes=[0 0.1 0.2 0.3 0.4 ... 1.9 2]

-- ----

Odev:
qq=[.......] seklinde bir dizi verilsin.
Iki data arasindaki zaman 0.2milisaniye olarak veriliyor.
a)Isaretin frekans spektrumunu cizin.
b)Isaretin icindeki genligi en buyuk olan frekans bilesenini bulun.
Program baslangicinda qq=[1 2 3 4 5 6 7] varsayarak programi yazin.

-- ----

------------------------------ ----

```
total_T=1;
  NN=16000;
   t_axis=([0:NN-1]/NN)*total_T;
   xx= sin(2*pi*1000*t_axis);
   Ts=total_T/NN;   fs=1/Ts;
   f_axis=([0:NN-1]/NN)*fs;
   yy=abs(fft(xx));
   subplot(211);
plot(t_axis(1:end/50),xx(1:end/50)); grid;
    title('Time response ');
    subplot(212);   plot(f_axis,yy); grid;
    title('Amplitude spectrum ');
  wavplay(xx,16000)
```

----------------------- ----------

```
clear all
total_T=0.5;
NN=16000;
tt=([0:NN-1]/NN)*total_T;
w1=300; w2=w1*2; w3=w1*3;  w4=w1*4;
w5=w1*5;
xa= [ sin(2*pi*w1*tt) sin(2*pi*1000*tt)
sin(2*pi*w2*tt) sin(2*pi*w3*tt)
sin(2*pi*w4*tt) sin(2*pi*w5*tt) ] ;

w1=800; w2=w1*2; w3=w1*3;  w4=w1*4;
w5=w1*5;
xb= [ sin(2*pi*w1*tt) sin(2*pi*1000*tt)
sin(2*pi*w2*tt) sin(2*pi*w3*tt)
sin(2*pi*w4*tt) sin(2*pi*w5*tt) ] ;
xc=[xa xb];
wavplay(xc,16000)
```

-------------------------- -----

ANALOG FILTER DESIGN

```
[b,a] = butter(2,100,'s');
```

2^{nd} order Lowpass Butterworth filter cutoff frequency 100 rad/sec=100*2*π=314Hz

b =

10000

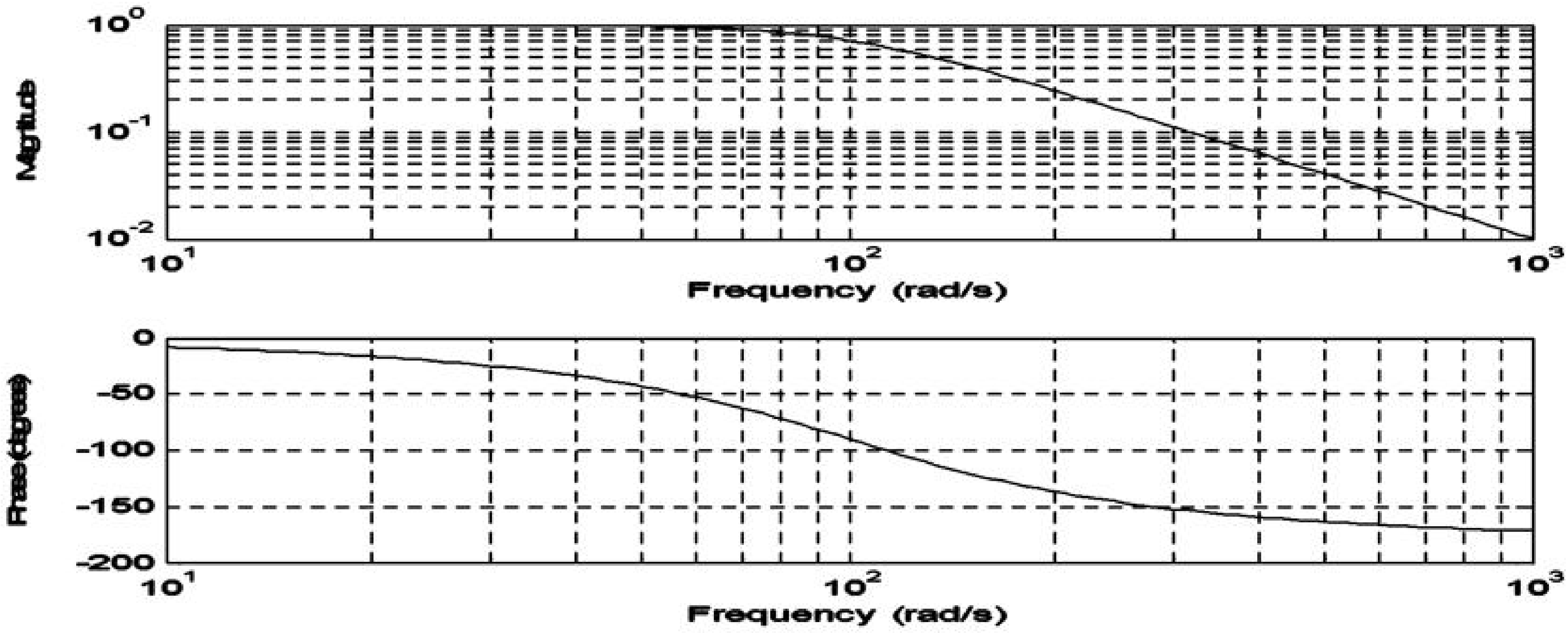
a =

1 141 10000

$$H(s)=\frac{10000}{s^2+141+10000}$$

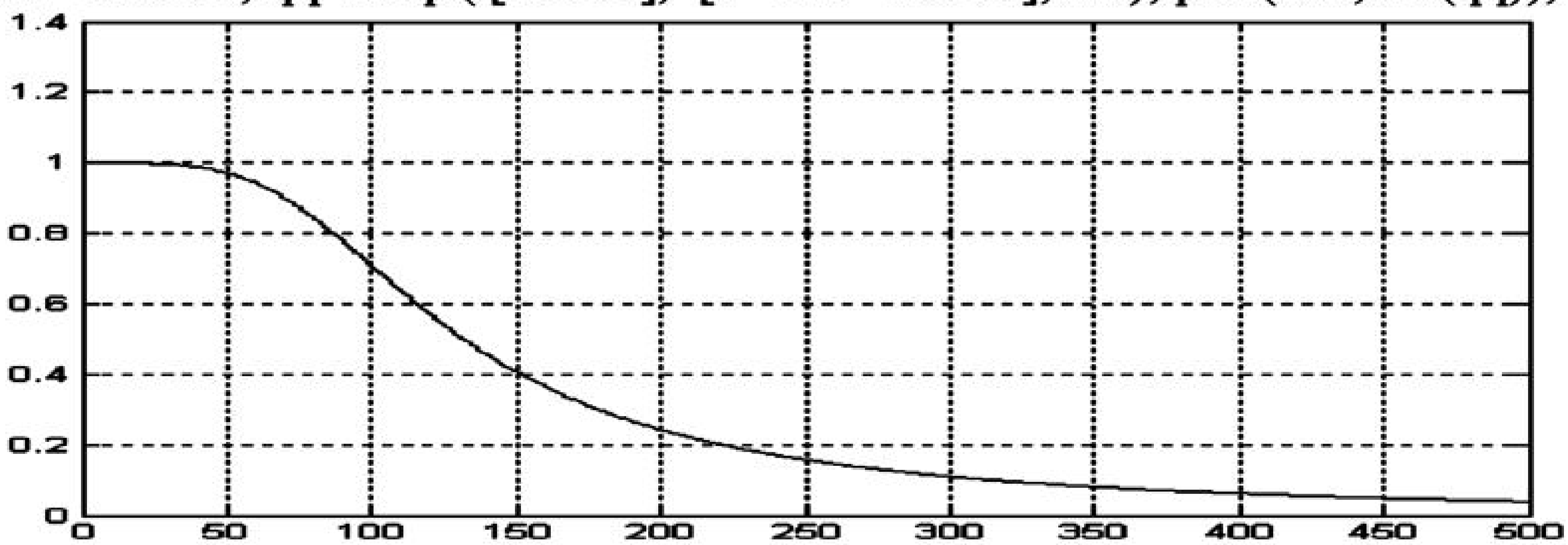
plot the frequency response

```
freqs( [10000], [1 141 10000])
```



Example 76)

```
ww=0:1:500; qq=freqs( [10000], [1 141 10000],ww); plot(ww,abs(qq)); grid
```



At w=100 |H(jw)|=0.707

Example 77)

```
[b,a] = butter(2,100,'high','s')
```

b=

1 0 0

a=

1 141 10000

$$H(s)=\frac{s^2}{s^2+141+10000}$$

```
ww=0:1:500; qq=freqs( [1 0   0 ],  [1  141   10000],ww); plot(ww,abs(qq));  grid
```


```
[b,a] = cheby1(4,1,[100 200],'s'); % Bandpass Chebyshev Type I
[b,a] = cheby2(6,60,[100],'high','s'); % Highpass Chebyshev Type II
[b,a] = ellip(3,1,60,[100 150],'stop','s'); % Bandstop elliptic
```

Butterworth [n,Wn] = buttord(Wp,Ws,Rp,Rs)

Chebyshev Type I [n,Wn] = cheb1ord(Wp, Ws, Rp, Rs)

Chebyshev Type II [n,Wn] = cheb2ord(Wp, Ws, Rp, Rs)

Elliptic [n,Wn] = ellipord(Wp, Ws, Rp, Rs)

The relationship between LAPLACE, Z FOURIER, DISCRETE FOURIER TRANSFORM

$\mathcal{L}\{g(t)\}=G(s)$ $\mathcal{L}\{f(nT)\}=F(z)$ or $\mathcal{Z}\{f(nT)\}=F(z)$
g(t) → continuous (analog signal)
f(nT) → discrete (digital) signal.

$\mathcal{F}\{g(t)\}=G(jw)$ $\mathcal{F}\{f(nT)\}=F(e^{jwT})$

If all poles of G(s) are on the left plane then $G(jw)=G(s)|_{s=jw}$

If all poles of F(z) are inside unit circle then $F(e^{jw})=F(z)|_{z=e^{jw}}$

Examples

$H(s)=\frac{10(s+2)}{(s+7)}$ → $H(jw)=\frac{10(jw+2)}{(jw+7)}$

$H(s)=\frac{10(s+2)}{(s-7)}$ → H(jw) does not exists

$H(s)=\frac{10(s+2)}{(s-7)(s+3)}$ → H(jw) does not exists

$h(t)=u(t)$ → $H(s)=\frac{1}{s}$ H(jw) exists but $H(jw) \neq G(s)|_{s=jw}$ $H(jw)=\frac{1}{jw}+\delta(jw)$

$H(s)=\frac{10(s+2)}{(s^2+4)}$ → H(jw) exists but $H(jw) \neq G(s)|_{s=jw}$

POLES and ZEROS of transfer functions

$H(s)=\frac{10(s+2)}{(s+7)}$ This function has a zero at s=-2 and has a pole at s=-7,
If s=-2 then H(s)=0 (zero at s=-2)
if s=-7 $H(s)=\infty$ (pole at s=-7)

$H(s)=\frac{(s+1)(s-2)(s+3)}{(s+4)(s-5)(s-6)(s+7)}$ This function has three zeros at s=-1, s=+2, s=-3,
and has four poles at s=-4, s=+5, s=+6, s=-7

$H(s)=\frac{(s+5+9j)(s-8-15j)}{(s+2-j3)(s+6-11j)}$ This function has two zeros at s=-5-9j, s=+8+15j,
and has two poles at s=-2+3j, s=-6+11j

$H(s)=\dfrac{(s+5+9j)(s+5-9j)}{(s-2+j3)(s-2-3j)}$ This function has two zeros at s=-5-9j, s=-5+9j,
and has two poles at s=2-3j, s=2+3j

$H(s)=\dfrac{s^2+4s+13}{s^2+5s+6}$, This function has two zeros at s=-2+3j, s=-2-3j,
and has two poles at s=-2, s=-3

$H(s)=\dfrac{s^4+6s^3+23s^2+34s+26}{s^5+10s^4+51s^3+156s^2+302s+260}$, This function has four zeros at -1+j -1-j -2+3j -2-3j

and has five poles at -1+3j, -1-3j, -3+2j, -3-2j, -2

MATLAB commands

```
>>roots([1 4 13])
```

will find the roots of $s^2+4s+13$, s=-2+3j, s=-2-3j,

```
>>roots([1 10 51 156 302 260])
```

will find the roots of $s^5+10s^4+51s^3+156s^2+302s+260$
-1+3j, -1-3j, -3+2j, -3-2j, -2

```
>>poly([ -2 -3 ])
```

Will produce the polynomial,
1 5 6 ➔ s^2+5s+6

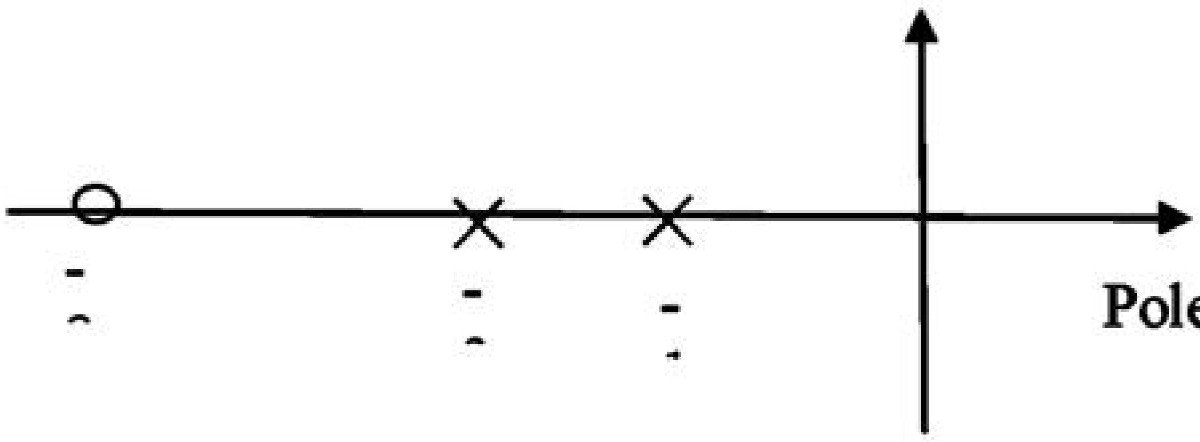
```
>>poly([ -2+3j -2-3j ])
```

Will produce the polynomial,
1 4 13 ➔ $s^2+4s+13$

```
>>poly([ -1+3j -1-3j -3+2j -3-2j -2])
```

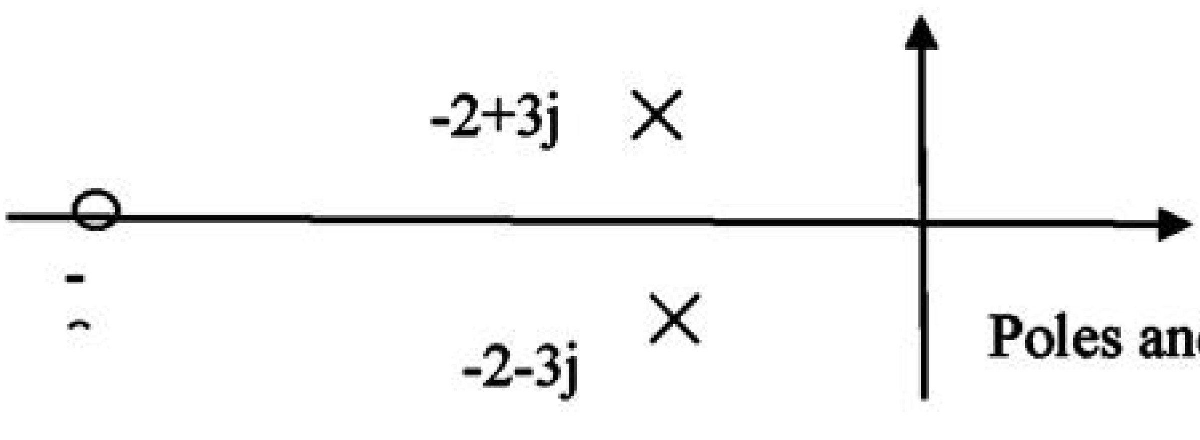
Will produce the polynomial,
1 10 51 156 302 260 ➔ $s^5+10s^4+51s^3+156s^2+302s+260$

Pole zero graphics



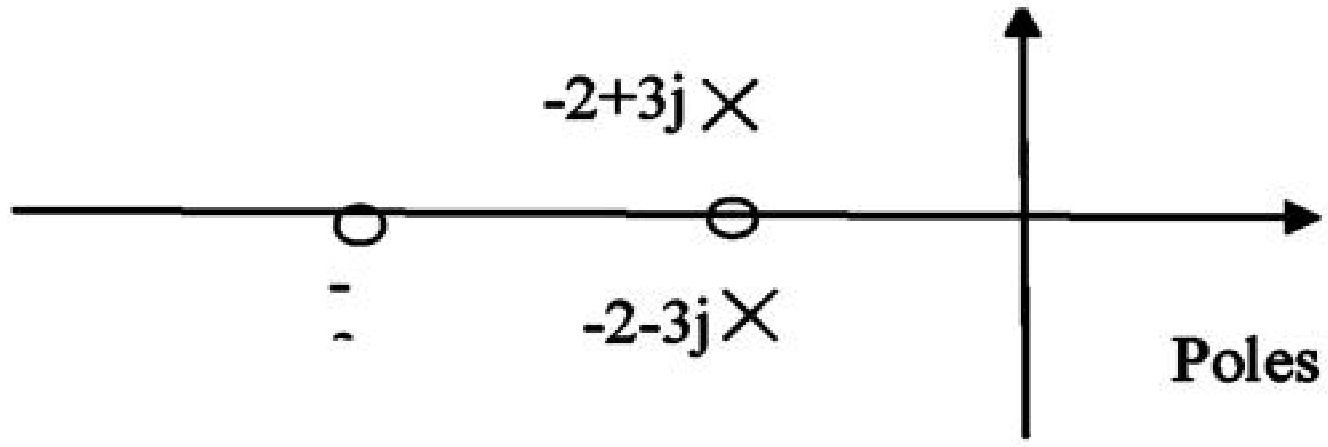
$H(s)=\dfrac{s+8}{s^2+5s+6}$

Poles and zeros are on the left plane



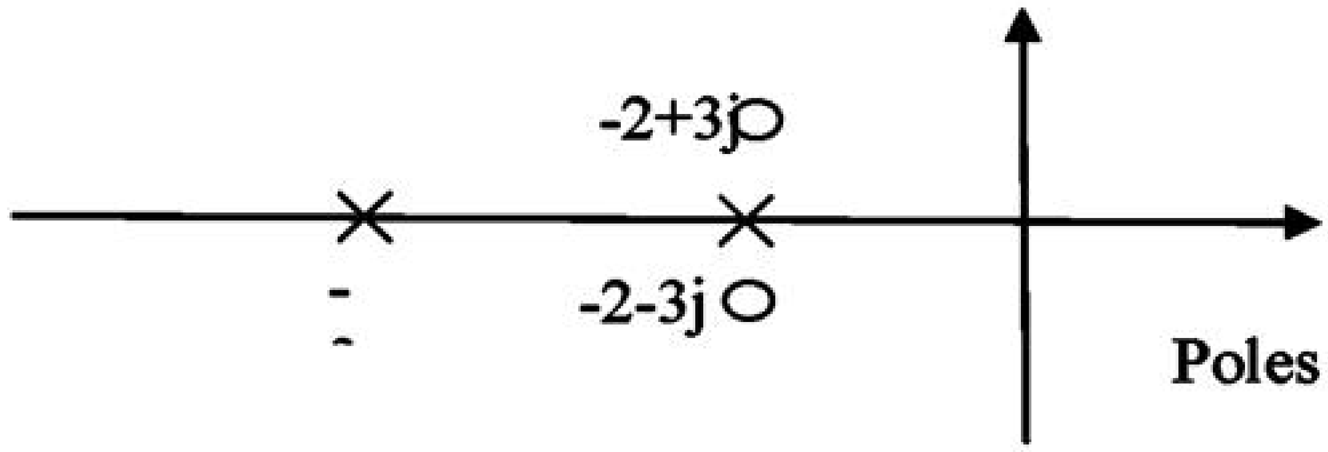
$H(s)=\dfrac{s+8}{s^2+4s+13}$

Poles and zeros are on the left plane



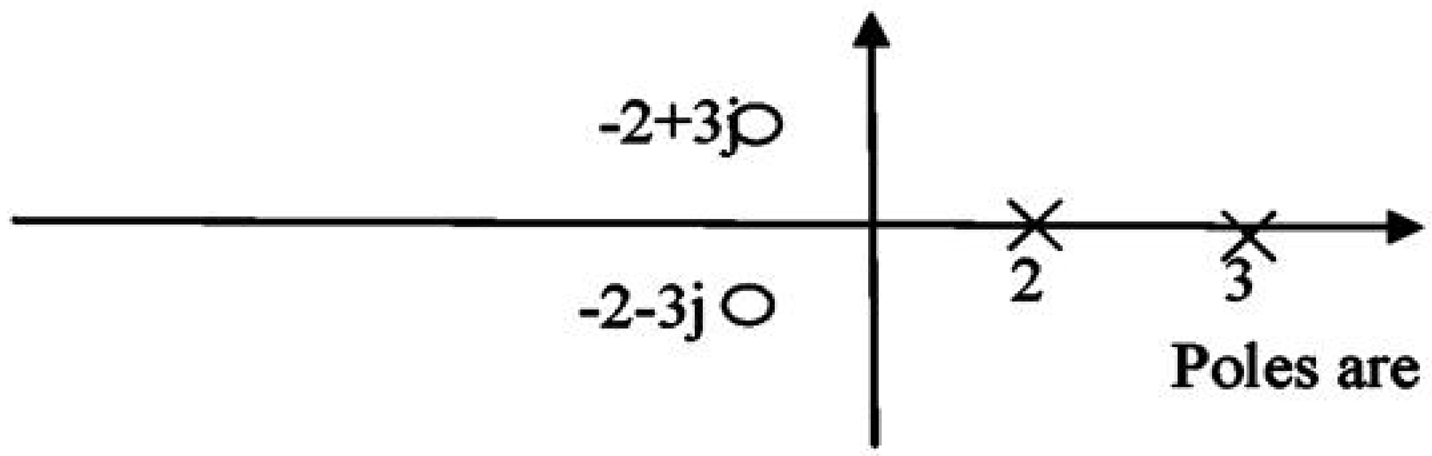
$$H(s)=\frac{s^2+5s+6}{s^2+4s+13}$$

Poles and zeros are on the left plane



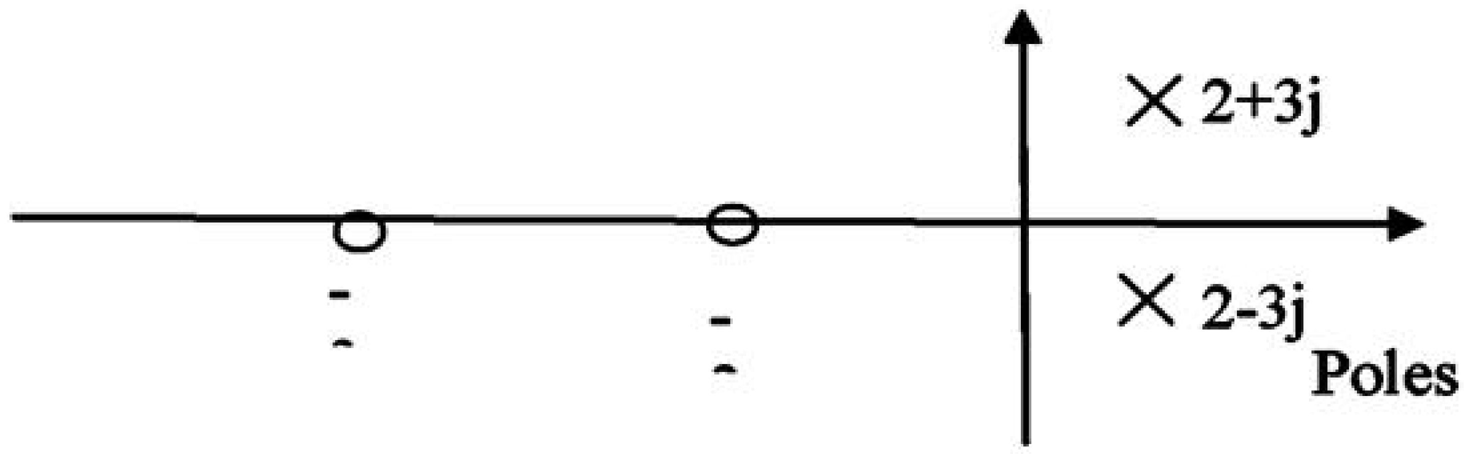
$$H(s)=\frac{s^2+4s+13}{s^2-5s+6}$$

Poles and zeros are on the left plane



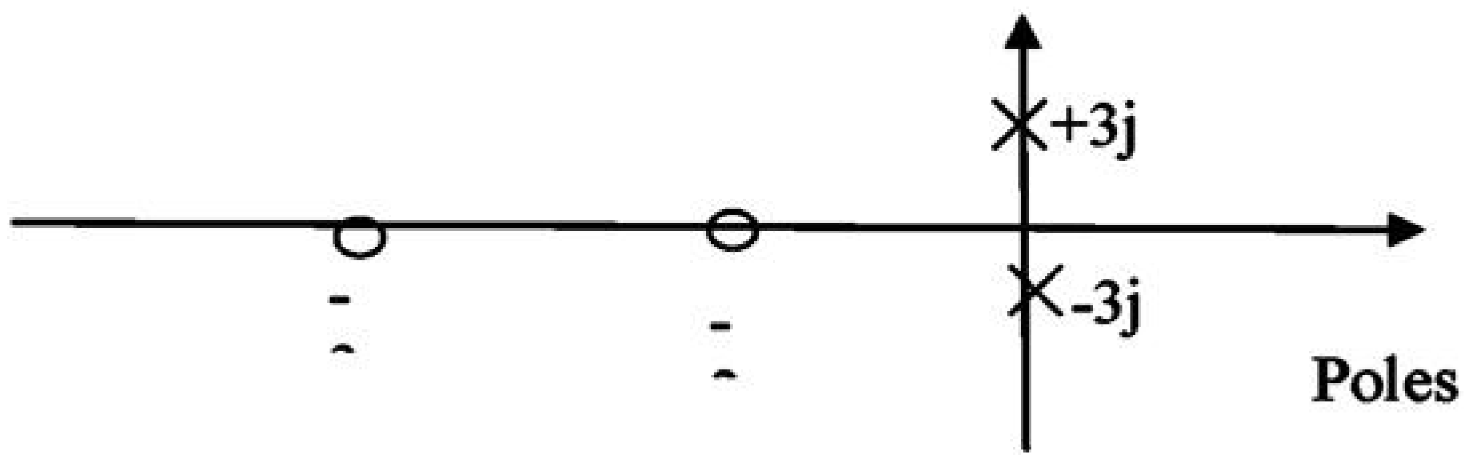
$$H(s)=\frac{s^2+4s+13}{s^2-5s+6}$$

Poles are on the right plane



$$H(s)=\frac{s^2+5s+6}{s^2-4s+13}$$

Poles are on the right plane



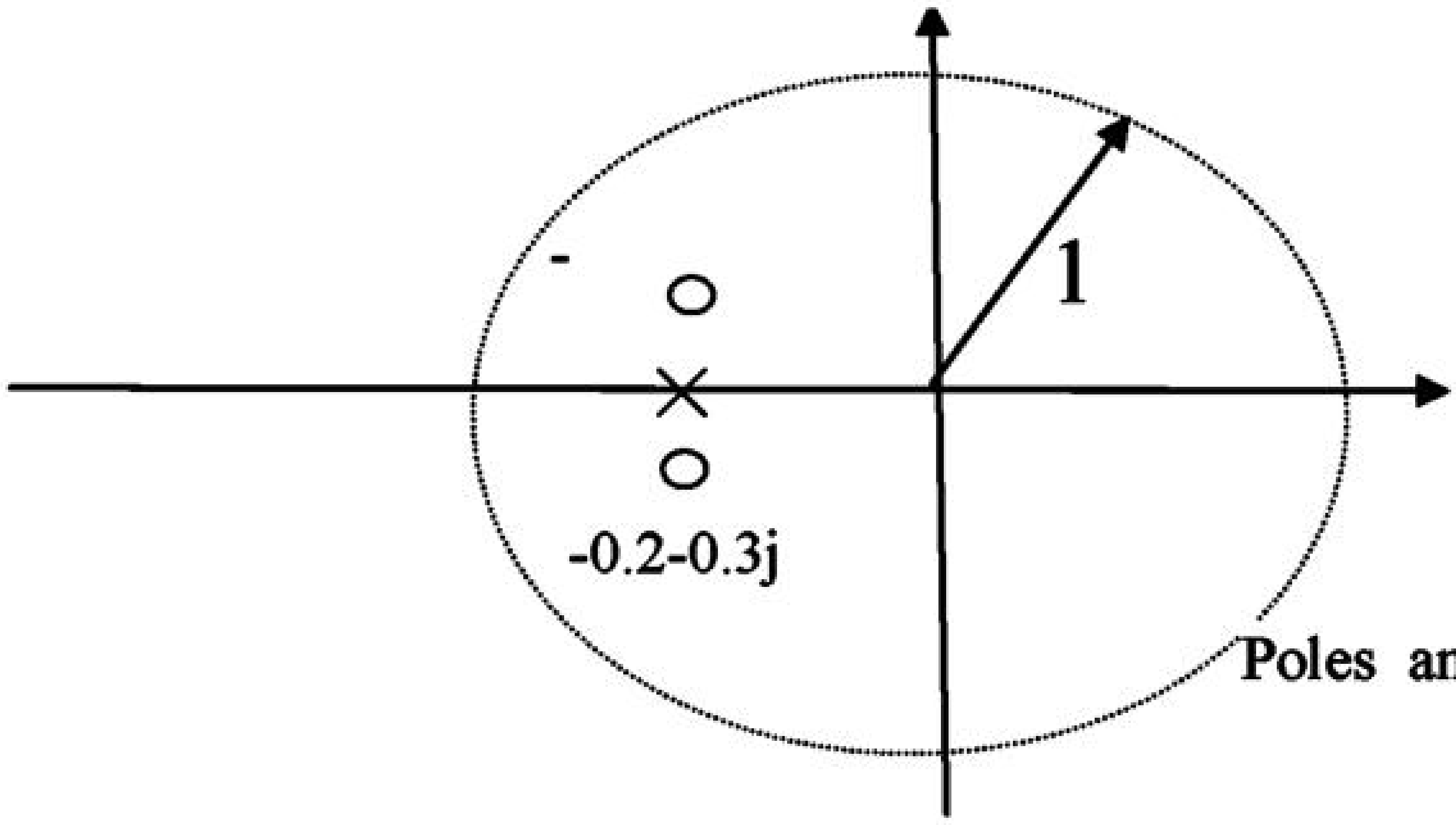
$$H(s)=\frac{s^2+5s+6}{s^2+9}$$

Poles are on the imaginary axis

$H(s)=\dfrac{(s+1)(s-2)(s+3)}{(s+4)(s-5)(s+6)(s+7)}$ This function has one pole on the right half plane (s=5).

$H(s)=\dfrac{s^4+6s^3+23s^2+34s+26}{s^5+10s^4+51s^3+156s^2+302s+260}$, This function has all poles are on the left plane

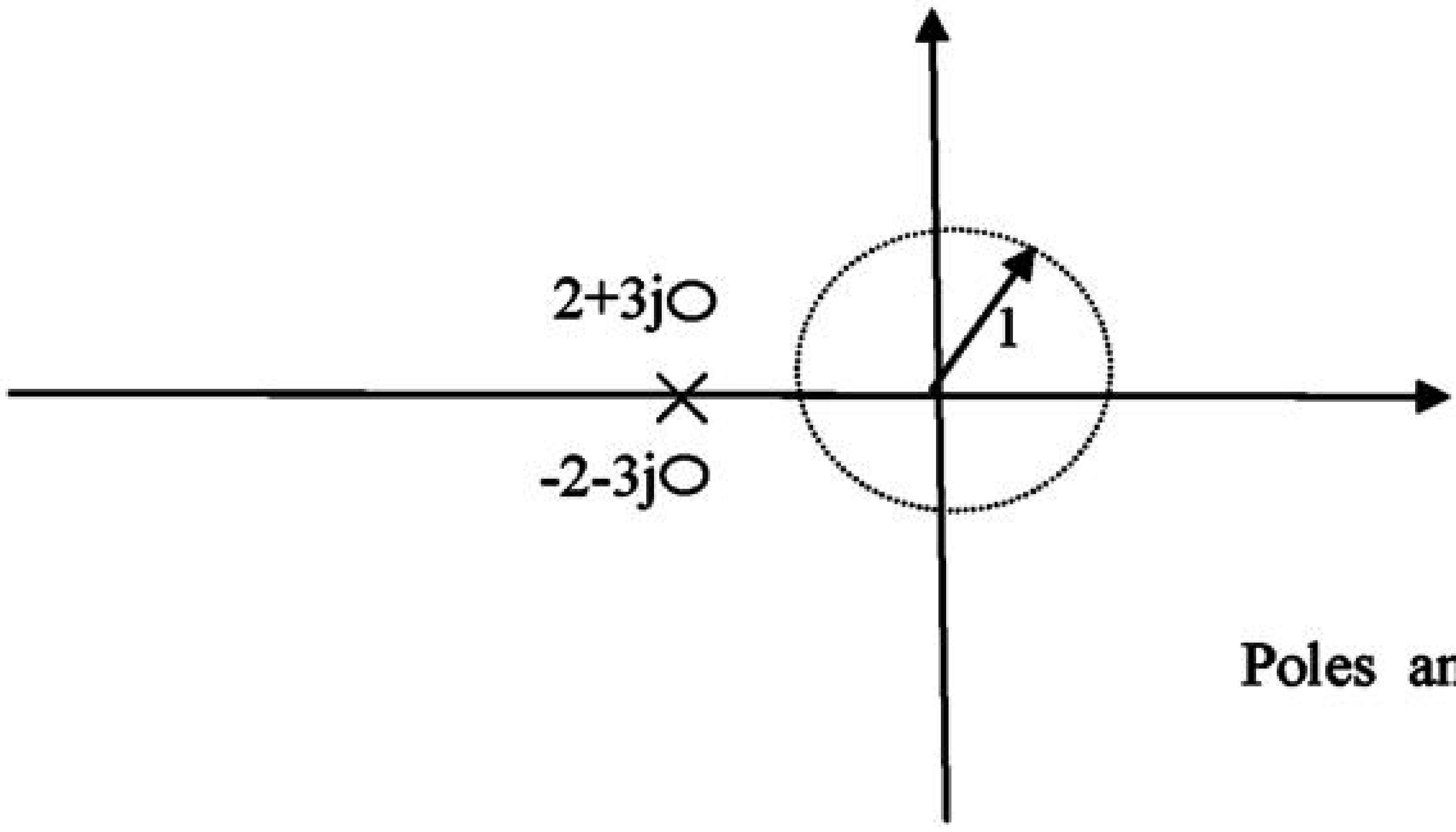
(poles -1+3j, -1-3j, -3+2j, -3-2j, -2)



$$H(s)=\frac{s^2+0.4s+0.13}{s+0.2}$$

Poles and zeros are inside unit circle

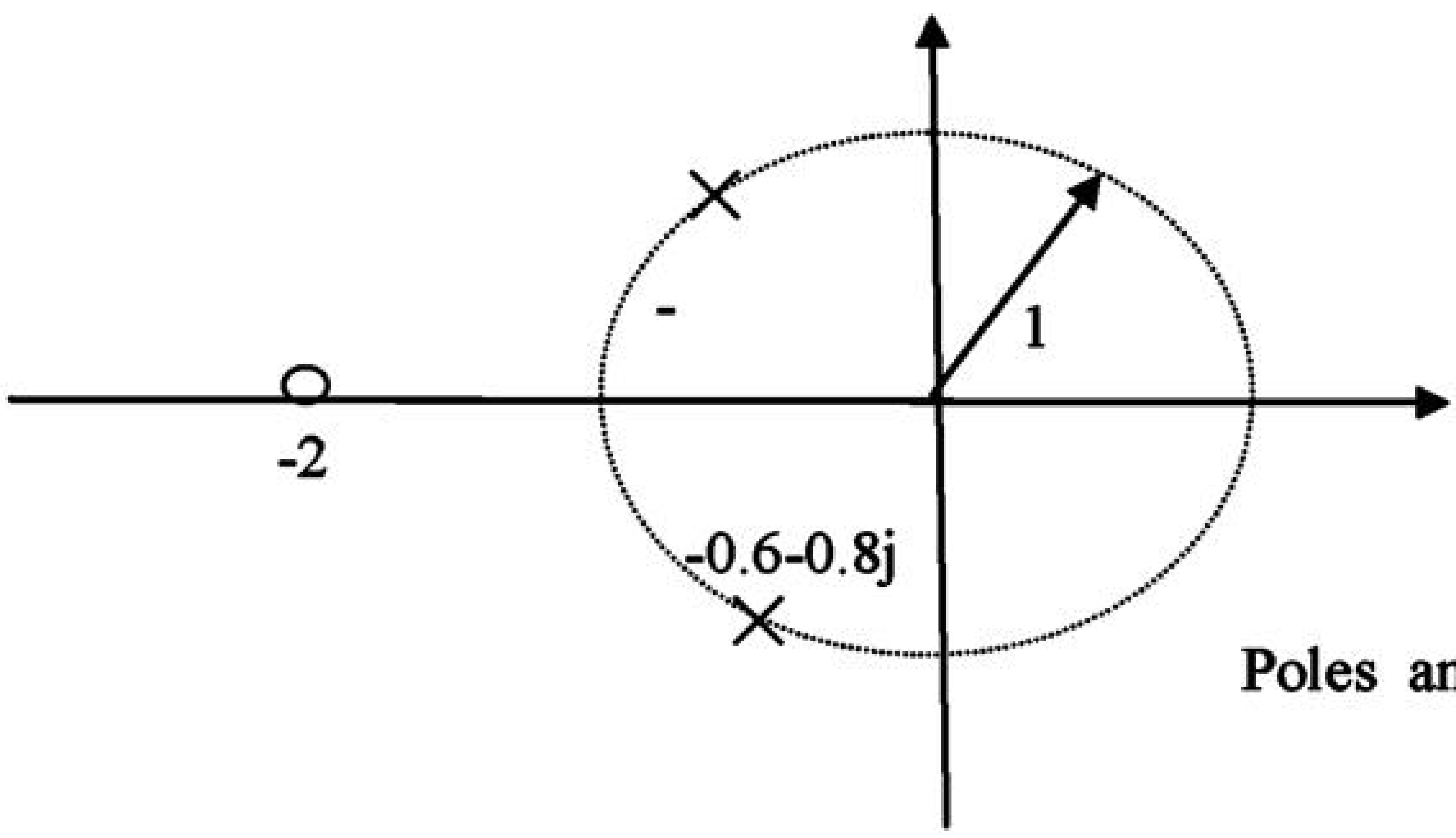
$\sqrt{0.2^2+0.3^2}=0.36<1$ inside unit circle



$$H(s)=\frac{s+3}{s^2+4s+13}$$

Poles and zeros are outside of the unit circle

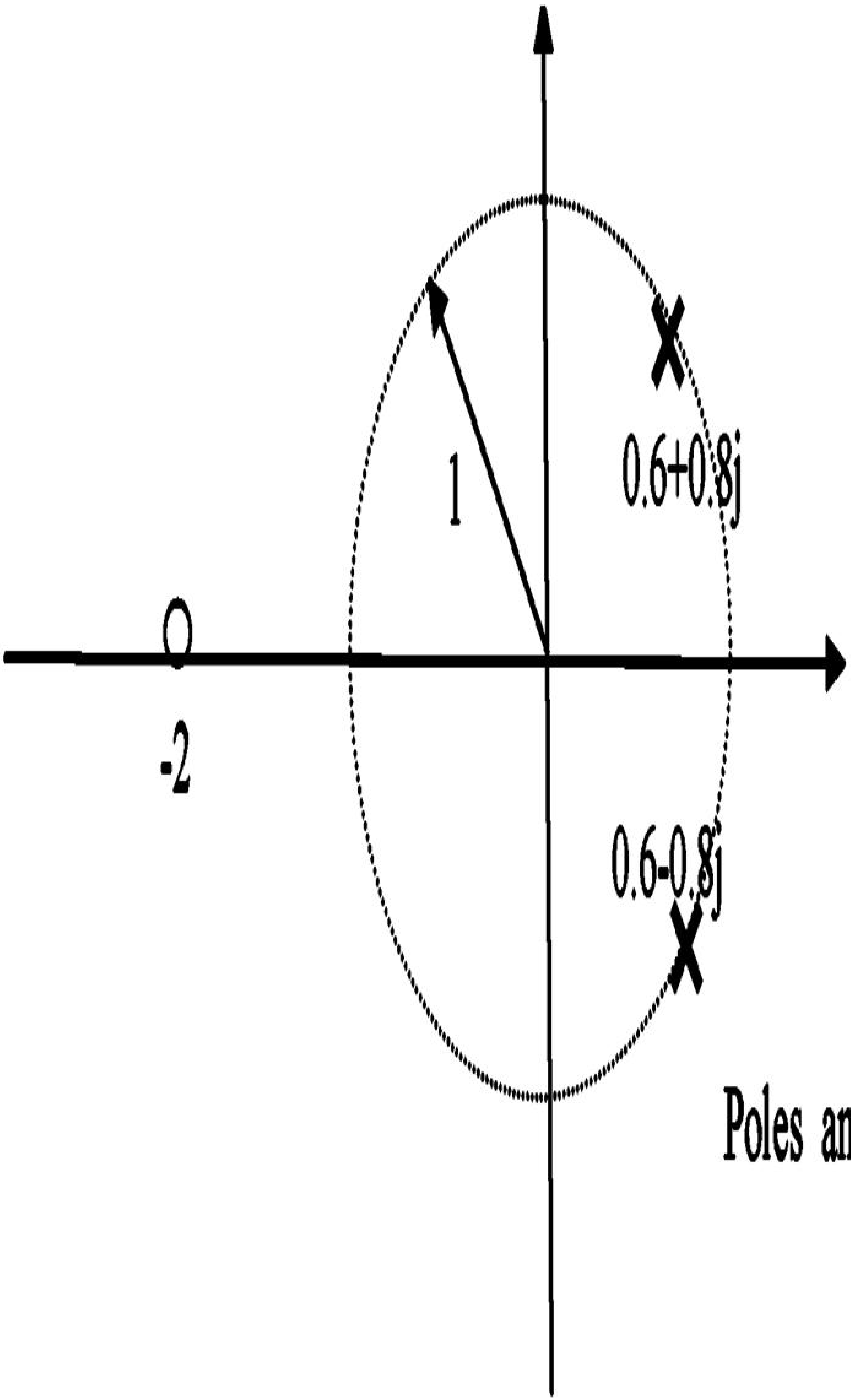
$\sqrt{2^2+3^2}=3.6>1$ outside unit circle



$$H(s)=\frac{s+2}{s^2+1.2s+1}$$

Poles and on the unit circle

$\sqrt{0.6^2+0.8^2}=1$ on the unit circle



$$H(s)=\frac{s+2}{s^2+1.2s+1}$$

Poles and on the unit circle

$\sqrt{0.6^2+0.8^2}=1$ on the unit circle