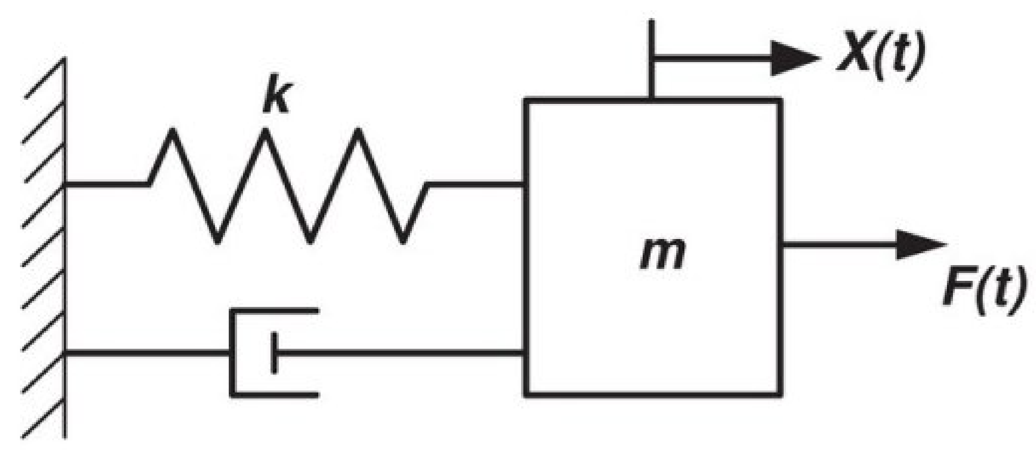
NED University of Engineering & Tech. Electrical Engineering Department

Spring Semester 2020 TE-ME / TE-EE / TE-EL

Lab Session 07

Exercise:

Question 1:
Write Transfer function $X(s)/F(s)$ for the system shown below. Find Rise time, Peak time, Overshoot, and Settling time for the transfer function using formulae derived in Chapter 4. Verify your results using a MATLAB script present at the end of Lab 7 in the manual. Change the time vector to *[0:0.001:300]* in the script.



System Parameters:
M = 705
B = 30
K = 15

Nothing to write below this line. Use blank A4 sheets to solve the given problem and attach them with this document.

Solution

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At equilibrium,

$$F(t) = f_k(t) + f_B(t) + f_M(t)$$

$$= Kx(t) + B\frac{d}{dt}x(t) + M\frac{d^2x(t)}{dt^2}$$

Taking laplace transform

=>

$$F(S) = Kx(S) + BSx(S) + MS^2x(S)$$

$$\frac{F(S)}{x(S)} = K + BS + MS^2$$

and

$$\frac{x(S)}{F(S)} = \frac{1}{MS^2+BS+K} \quad \text{——} (1)$$

We know that general equation

$$G(S) = \frac{\omega_n^2}{S^2+2\zeta\omega_n+\omega_n^2} \quad \text{——} (A)$$

Compare both equ and rewrite eq(1) in form of general equ

$$G(S) = \frac{x(S)}{F(S)} = \frac{1/M}{S^2+\frac{B}{M}S+\frac{K}{M}} \quad \text{——} (2)$$

Now by comparision of eq (A) and (2) we get

$$\omega_n^2 = \frac{K}{M} \quad \text{and} \quad 2\zeta\omega_n = \frac{B}{M}$$

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NATURAL FREQUENCY:-

$$\omega_n^2 = \frac{K}{M} \Rightarrow \omega_n = \sqrt{\frac{K}{M}} = \sqrt{\frac{15}{705}}$$

$$\boxed{\omega_n = 0.14586\ 1/s}$$

DAMPING RATIO:-

$$2\zeta\omega_n = \frac{B}{M} \Rightarrow \zeta = \frac{B}{2\omega_n M} = \frac{B}{2\sqrt{MK}} = \frac{30}{2\sqrt{705(15)}}$$

$$\boxed{\zeta = 0.14586}$$

RISE TIME:-

$$\omega_n T_r = 1.76\zeta^3 - 0.417\zeta^2 + 1.039\zeta + 1$$

$$= 1.76(0.14586)^3 - 0.417(0.14586)^2 + 1.039(0.14586) + 1$$

$$T_r = \frac{1.1481}{\omega_n} = \frac{1.1481}{0.14586}$$

$$\boxed{T_r = 7.87\ sec}$$

PEAK TIME:-

$$T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$$

$$= \frac{\pi}{0.14586\sqrt{1-(0.14586)^2}}$$

$$\boxed{T_p = 21.77\ sec}$$

% OVERSHOOT:-

$$\%OS = e^{\left(-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}\right)}$$

$$\%OS = e^{\left(\frac{-0.14586(\pi)}{\sqrt{1-(0.14586)^2}}\right)}$$

$$\boxed{\%OS = 0.629}$$

OR $\boxed{\%OS = 62.9\%}$

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PLOT SCRIPT:

```
clc, clear;
zeta = input ('Enter the value of damping ratio ');
wn = input ('Enter the value of Natural frequency ');
n = wn*wn;
d = [1 2*zeta*wn wn*wn];
disp (' The transfer function is: ')
printsys (n,d);
t = 0:0.01: 300;
[y,x,t] = step (n,d,t) ;
plot (t,y); grid on; title ('step response');
k = 1;  % rise time
while y(k) <=0.1;
    k = k+1;
end ; tenpercent = t(k);
while y(k) <=0.9;
    k = k+1;
end
nintypercent = t(k);
rtime = nintypercent - tenpercent
fprintf ('The rise time is: %f sec \n', rtime);
for k = 1:length(t)-1;          % maximum overshoot
    if y(k+1) <= y(k);
    break;
    end;
end;
Oshoot = y(k)-y(length(t)-1);
fprintf ('The overshoot is: %f sec \n', Oshoot)
```

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```
tp = t(k);
fprintf('the peak time is :%f sec\n', tp);
% settling time
tot = 0.02;
for k = length(t)-1 : -1 : 2;
    if (abs(y(k) - y(length(t) - 1)) > tot)
    break;
    end;
end;
stime = t(k);
fprintf('the settling time is :%f sec\n', stime);
```

RESULT :-

The rise time is : 7.86800 sec
The overshoot is : 0.630416 sec
the peak time is: 21.770000 sec
the settling time is : 177.940000 sec

CONCLUSION :-

Values of rise time, peak time, % overshoot are same in both theoritical and MATLAB calculations and plot also verifies all values.

Transfer Function from MATLAB we get :

The transfer function is:

```
      0.021275
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s^2 + 0.04255 s + 0.021275
```

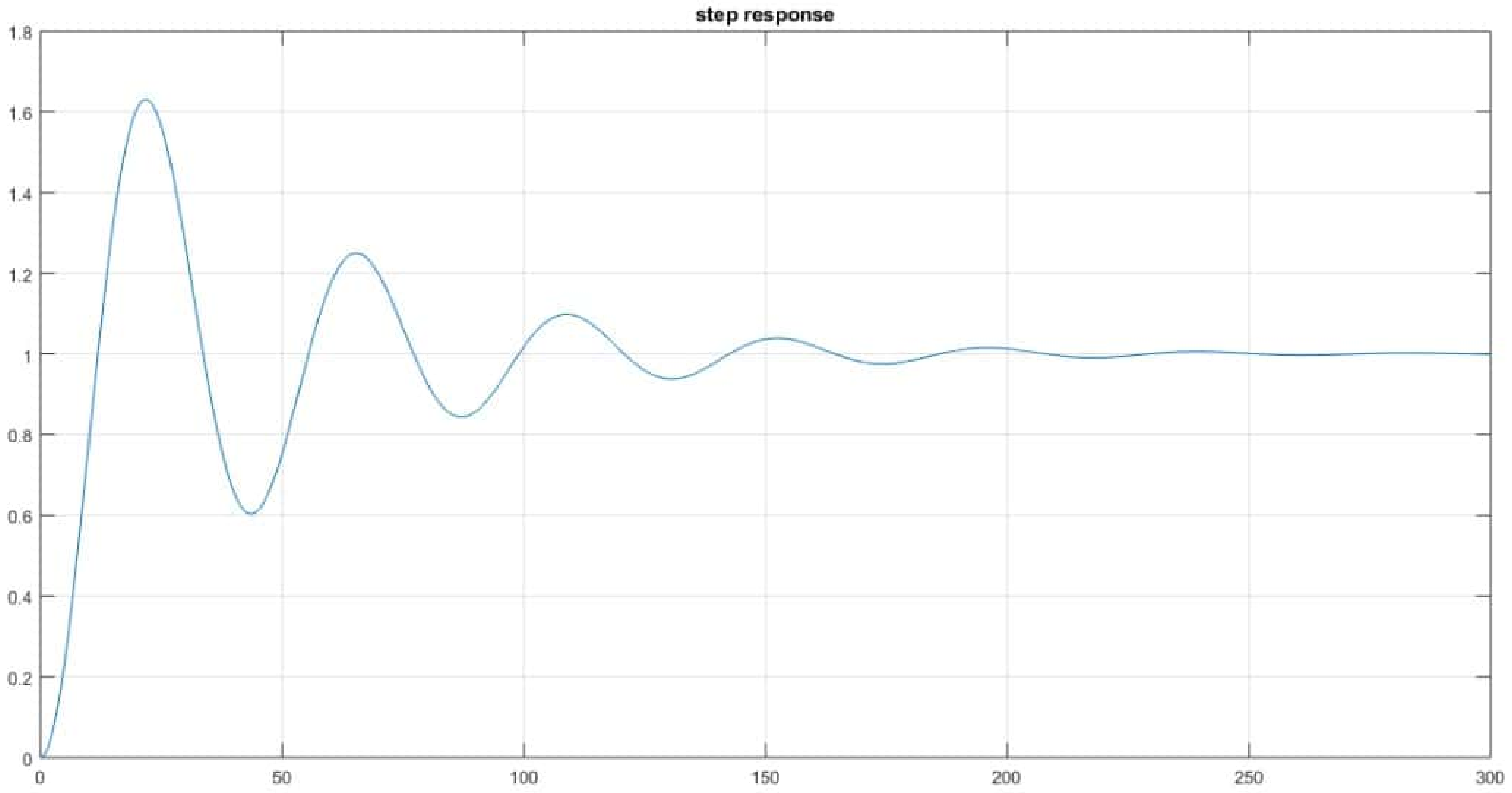
step response
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300