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ME 432-002
Project

P1

Design P, PI, PD, PID type controllers for 60° phase margin. Calculate the quality parameters (fill the table given below). Display the unit step response and the control signal.

The plant is given by the following transfer function: -

$$P(s) = \frac{1}{(1+10s)(1+s)(1+0.2s)}$$

Let the controllers are given as under:

P: k_c

PI: $k_c\ (1+10s)/s$

PD: kc (1+s)/(1+0.1s)

PID: kc [(1+10s)(1+s)]/[s(1+0.1s)]

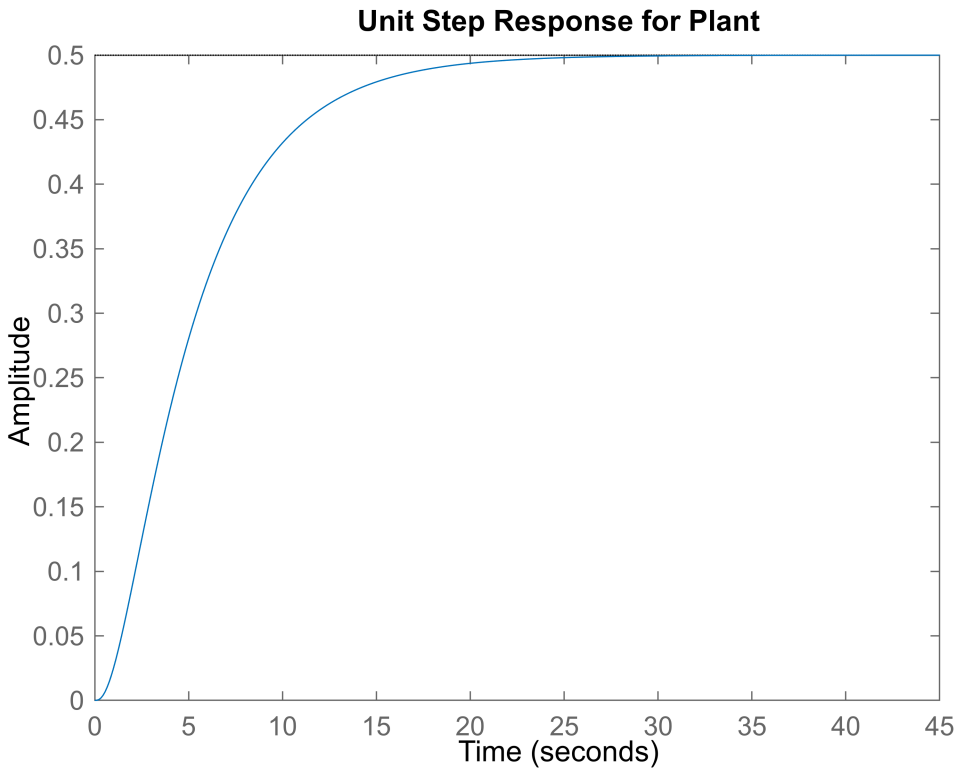
	$G_c(s)$	$G(s)=Gc(s)\ P(s)$	k_c	MOS	e_{ss}	u_{max}	t_s
Plant		$\frac{1}{2s^3+12.2s^2+11.2s+1}$	1	0	0.5006	1	18.06
P	K_c	$\frac{7.5156}{2s^3+12.2s^2+11.2s+1}$	7.5158	15.34	0.1174	7.5158	8.97
PI	$\frac{k_c(1+10s)}{s}$	$\frac{5.088s+0.5088}{2s^4+12.2s^3+11.2s^2+s}$	0.5088	8.0570	7×10^{-4}	5.2102	8.68
PD	$\frac{k_c(1+s)}{1+0.1s}$	$\frac{21.78s+21.78}{0.2s^4+3.22s^3+13.32s^2+11.3s+1}$	21.77	10.5005	0.0439	217.76	1.96
PID	$\frac{k_c[(1+10s)(1+s)]}{s(1+0.1s)}$	$\frac{19.41s^2+21.35s+1.941}{0.2s^5+3.22s^4+13.32s^3+11.3s^2+s}$	1.94	7.7822	-1.7×10^{-8}	194.0774	2.13

ME 432 - Project Part 1 - Team 3

```
close all;
clc;

s=tf('s');
Plant=1/((1+10*s)*(1+s)*(1+0.2*s));

%PLANT

t=0:0.01:30;
figure (1)
Gplant=Plant                          %Open Loop Transfer Function for Plant
```

```
Gplant =

                1
  ----------------------------
  2 s^3 + 12.2 s^2 + 11.2 s + 1

Continuous-time transfer function.
Model Properties
```

```
Hplant=feedback(Gplant,1);          %Closed Loop Transfer Function for Plant
step(Hplant)
title('Unit Step Response for Plant')
```




```
stepinfo(Hplant)
```

```
ans = struct with fields:
         RiseTime: 9.8655
    TransientTime: 18.0646
     SettlingTime: 18.0646
      SettlingMin: 0.4505
      SettlingMax: 0.5000
        Overshoot: 0
       Undershoot: 0
             Peak: 0.5000
         PeakTime: 47.2048
```

```
uPlant=ones(1,length(t));
[y,t]=lsim(Hplant, uPlant,t);
essPlant=uPlant(end)-y(end)                    %Steady State Error for Plant
```

```
essPlant = 0.5006
```

```
uPlantmax=1/(1+Gplant);
umax = stepinfo(uPlantmax);                          %Max Control Signal Output for
Plant
umax.Peak
```

```
ans = 1
```

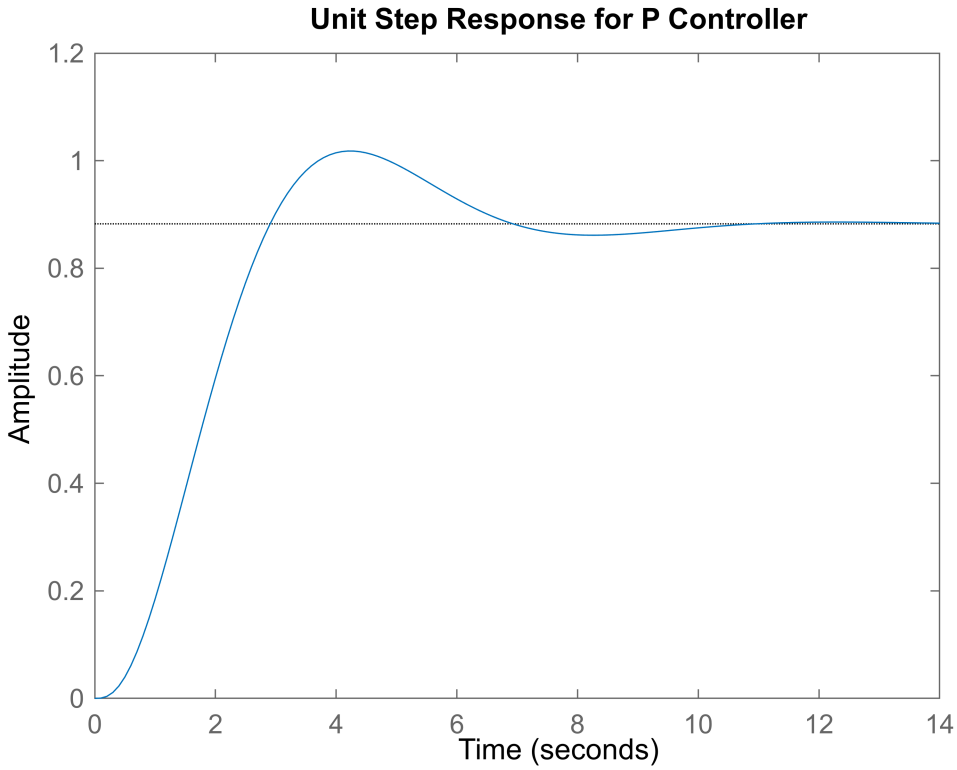
```
%P CONTROLLER

t=0:0.01:20;
figure(2)
GPinitial=Plant;

[mag, phase, w]=bode(GPinitial);
gain_margin_P=margin(mag, phase-60, w);
kcp=gain_margin_P
```

```
kcp = 7.5158
```

```
GCP=kcp;                                                %Controller for P
GP=kcp*GPinitial                          %Open Loop Transfer Function for P
```

```
GP =

             7.516
  ----------------------------
  2 s^3 + 12.2 s^2 + 11.2 s + 1

Continuous-time transfer function.
Model Properties
```

```
HP=feedback(GP,1);                       %Closed Loop Transfer Function for P
step(HP)
    title('Unit Step Response for P Controller')
```




```
    stepinfo(HP)
```

```
ans = struct with fields:
         RiseTime: 1.8654
    TransientTime: 8.9751
     SettlingTime: 8.9751
      SettlingMin: 0.8020
      SettlingMax: 1.0180
        Overshoot: 15.3425
       Undershoot: 0
             Peak: 1.0180
         PeakTime: 4.1919
```

```
uP=ones(1,length(t));
[y,t]=lsim(HP, uP,t);
essP=uP(end)-y(end)                                  %Steady State Error for P
```

```
essP = 0.1174
```

```
uPmax=GCP/(1+GP);
umax = stepinfo(uPmax);                          %Max Control Signal Output for P
umax.Peak
```

```
ans = 7.5158
```

```
%PI CONTROLLER
```

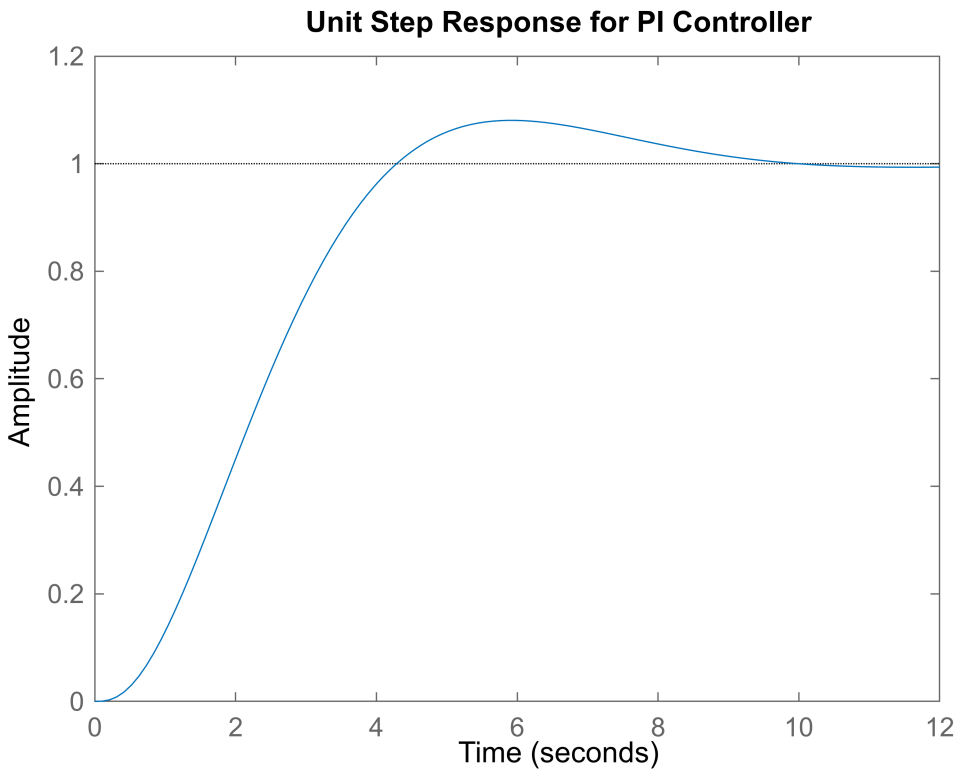
```
t=0:0.01:15;
figure(3)
GPIinitial=Plant*(1+10*s)/s;

[mag, phase, w]=bode(GPIinitial);
gain_margin_PI=margin(mag, phase-60, w);
kcpi=gain_margin_PI
```

```
kcpi = 0.5088
```

```
GCPI=kcpi*(1+10*s)/s;                                    %Controller for PI
GPI=kcpi*GPIinitial                          %Open Loop Transfer Function for PI
```

```
GPI =

         5.088 s + 0.5088
  -------------------------------
  2 s^4 + 12.2 s^3 + 11.2 s^2 + s

Continuous-time transfer function.
Model Properties
```

```
HPI=feedback(GPI,1);                    %Closed Loop Transfer Function for PI
step(HPI)
    title('Unit Step Response for PI Controller')
```




```
    stepinfo(HPI)
```

```
ans = struct with fields:
         RiseTime: 2.7486
    TransientTime: 8.6890
     SettlingTime: 8.6890
      SettlingMin: 0.9070
      SettlingMax: 1.0806
        Overshoot: 8.0570
       Undershoot: 0
             Peak: 1.0806
         PeakTime: 5.8650
```

```
uPI=ones(1,length(t));
[y,t]=lsim(HPI, uPI,t);
essPI=uPI(end)-y(end)                                %Steady State Error for PI
```

```
essPI = 7.0596e-04
```

```
uPImax=GCPI/(1+GPI);
umax = stepinfo(uPImax);                            %Max Control Signal Output for PI
umax.Peak
```

```
ans = 5.2102
```

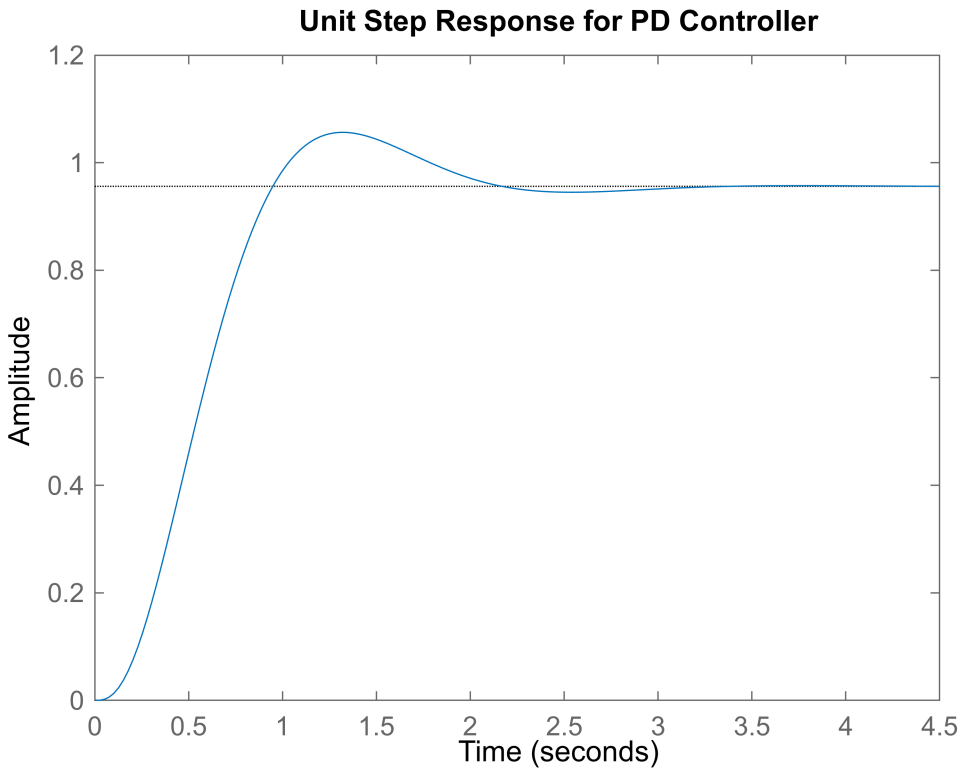
```
%PD CONTROLLER

t=0:0.01:10;
figure(4)
GPDinitial=Plant*(1+s)/(1+0.1*s);

[mag, phase, w]=bode(GPDinitial);
gain_margin_PD=margin(mag, phase-60, w);
kcpd=gain_margin_PD
```

```
kcpd = 21.7764
```

```
GCPD=kcpd*(1+s)/(1+0.1*s);                                  %Controller for PD
GPD=kcpd*GPDinitial                          %Open Loop Transfer Function for PD
```

```
GPD =

               21.78 s + 21.78
  ------------------------------------------
  0.2 s^4 + 3.22 s^3 + 13.32 s^2 + 11.3 s + 1

Continuous-time transfer function.
Model Properties
```

```
HPD=feedback(GPD,1);                       %Closed Loop Transfer Function for PD
step(HPD)
    title('Unit Step Response for PD Controller')
```




```
    stepinfo(HPD)
```

```
ans = struct with fields:
         RiseTime: 0.5981
    TransientTime: 1.9642
     SettlingTime: 1.9642
      SettlingMin: 0.8745
      SettlingMax: 1.0565
        Overshoot: 10.5005
       Undershoot: 0
             Peak: 1.0565
         PeakTime: 1.3221
```

```
uPD=ones(1,length(t));
[y,t]=lsim(HPD, uPD,t);
essPD=uPD(end)-y(end)                              %Steady State Error for PD
```

```
essPD = 0.0439
```

```
uPDmax=GCPD/(1+GPD);
umax = stepinfo(uPDmax)                           %Max Control Signal Output for PD
```

```
umax = struct with fields:
         RiseTime: 0
    TransientTime: 1.3393
     SettlingTime: NaN
      SettlingMin: -19.7572
      SettlingMax: 217.7635
        Overshoot: 2.2676e+04
       Undershoot: 2.0665e+03
```

```
            Peak: 217.7635
        PeakTime: 0
```

```
umax.Peak
```

```
ans = 217.7635
```

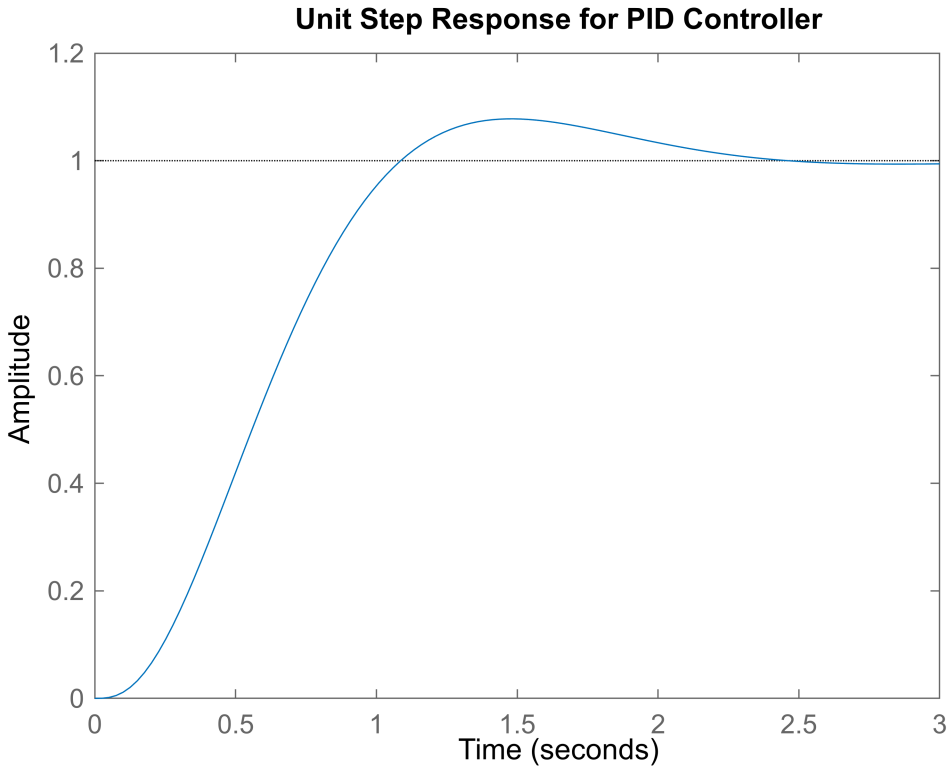
```
%PID CONTROLLER

t=0:0.01:10;
figure(5)
GPIDinitial=Plant*((1+10*s)*(1+s))/(s*(1+0.1*s));

[mag, phase, w]=bode(GPIDinitial);
gain_margin_PID=margin(mag, phase-60, w);
kcpid=gain_margin_PID
```

```
kcpid = 1.9408
```

```
GCPID=kcpid*((1+10*s)*(1+s))/(s*(1+0.1*s));              %Controller for PID
GPID=kcpid*GPIDinitial                  %Open Loop Transfer Function for PID
```

```
GPID =

          19.41 s^2 + 21.35 s + 1.941
  ---------------------------------------------
  0.2 s^5 + 3.22 s^4 + 13.32 s^3 + 11.3 s^2 + s

Continuous-time transfer function.
Model Properties
```

```
HPID=feedback(GPID,1);               %Closed Loop Transfer Function for PID
step(HPID)
    title('Unit Step Response for PID Controller')
```




```
    stepinfo(HPID)
```

```
ans = struct with fields:
         RiseTime: 0.6824
    TransientTime: 2.1397
     SettlingTime: 2.1397
      SettlingMin: 0.9074
      SettlingMax: 1.0778
        Overshoot: 7.7822
       Undershoot: 0
             Peak: 1.0778
         PeakTime: 1.4877
```

```
uPID=ones(1,length(t));
[y,t]=lsim(HPID, uPID,t);
essPID=uPID(end)-y(end)                          %Steady State Error for PID
```

```
essPID = -1.7331e-08
```

```
uPIDmax=GCPID/(1+GPID);
umax = stepinfo(uPIDmax);                         %Max Control Signal Output for PID
umax.Peak
```

```
ans = 194.0774
```