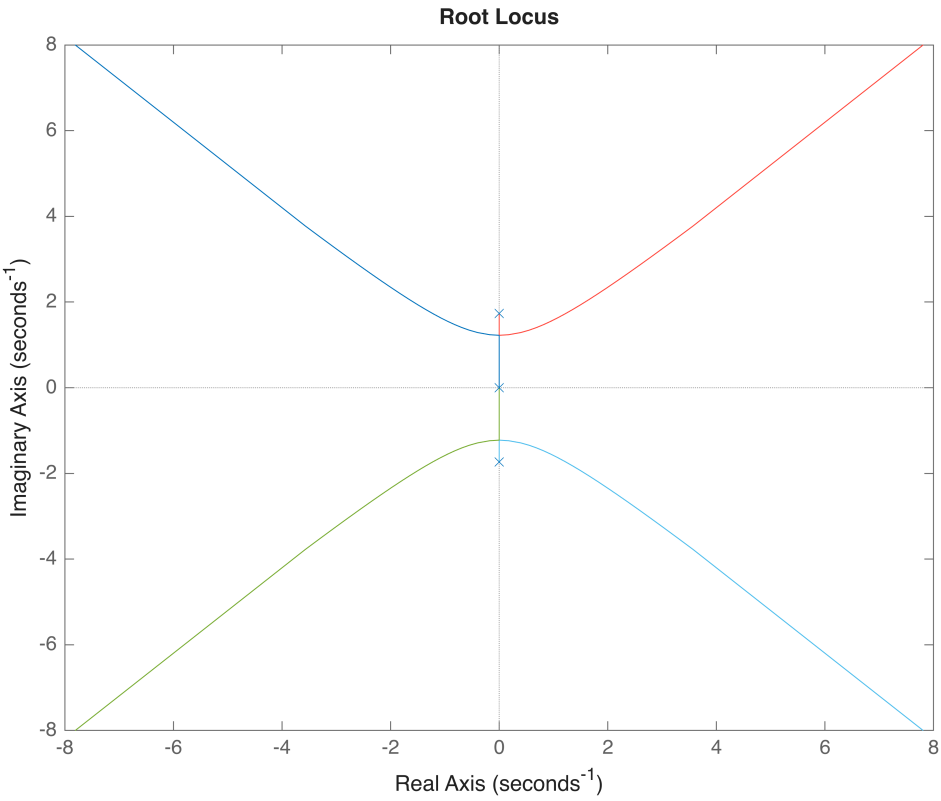
problem 4

```
% givens
s = zpk('s');
G = 2/(s^2*(s^2+3));

% display
G
```

```
G =

       2
  -------------
  s^2 (s^2 + 3)

Continuous-time zero/pole/gain model.
Model Properties
```

part a

```
fig = figure;
rlocusplot(G);
saveas(fig, './images/s04a.png');
```



part b

```
% givens
syms a2 a1 a0 b3 b2 b1 b0 s_sym
```

```
HD = s_sym^3+a2*s_sym^2+a1*s_sym+a0;
HN = b3*s_sym^3+b2*s_sym^2+b1*s_sym+b0;
desired = (s_sym-(-1+1j))*(s_sym-(-1-1j))*(s_sym+4)^5;

% solution
[G_num, G_den] = tfdata(G);
GN = poly2sym(G_num, s_sym);
GD = poly2sym(G_den, s_sym);

CL_den = expand(GD*HD+GN*HN);
coeffCL = coeffs(CL_den, s_sym, 'All');
coeffT  = coeffs(desired, s_sym, 'All');

eqs = coeffCL(2:end) == coeffT(2:end);
sol_sym = solve(eqs, [a2 a1 a0 b3 b2 b1 b0]);
sol = structfun(@double, sol_sym);

H_num = transpose(sol(4:7));
H_den = [1, transpose(sol(1:3))];

Hb = zpk(tf(H_num, H_den));
Lb = G*Hb;
Tb = feedback(Lb, 1);
poles_Tb = pole(Tb);
zeros_Tb = zero(Tb);

% display
Hb, Tb, poles_Tb, zeros_Tb
```

```
Hb =

  1141.5 (s+0.4939) (s^2 + 0.4093s + 1.816)
  -----------------------------------------
      (s+11.86) (s^2 + 10.14s + 78.74)

Continuous-time zero/pole/gain model.
Model Properties

Tb =

  2283 (s+0.4939) (s^2 + 0.4093s + 1.816)
  ---------------------------------------
          (s+4)^5 (s^2 + 2s + 2)

Continuous-time zero/pole/gain model.
Model Properties
poles_Tb = 7×1 complex
  -4.0075 + 0.0000i
  -4.0023 + 0.0071i
  -4.0023 - 0.0071i
  -3.9939 + 0.0044i
  -3.9939 - 0.0044i
  -1.0000 + 1.0000i
  -1.0000 - 1.0000i
zeros_Tb = 3×1 complex
  -0.2046 + 1.3321i
```

```
  -0.2046 - 1.3321i
  -0.4939 + 0.0000i
```

part c

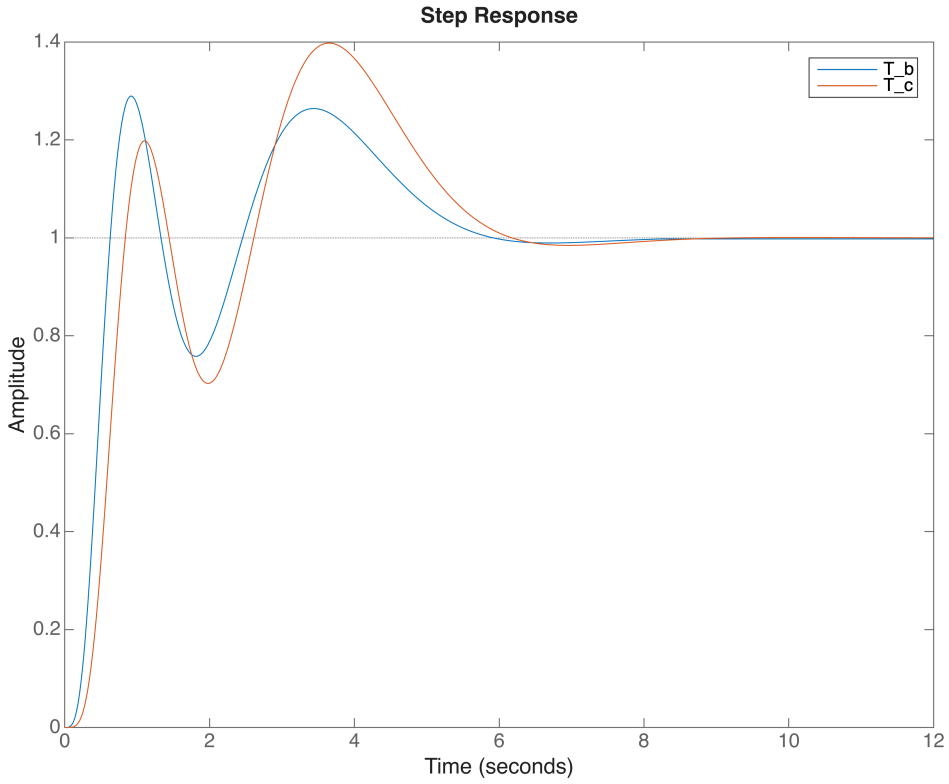
```
% givens
syms a3 a2 a1 a0 b3 b2 b1 b0 s_sym
HD = s_sym^4+a3*s_sym^3+a2*s_sym^2+a1*s_sym+a0;
HN = b3*s_sym^3+b2*s_sym^2+b1*s_sym+b0;
desired = (s_sym-(-1+1j))*(s_sym-(-1-1j))*(s_sym+4)^6;

% solution
[G_num, G_den] = tfdata(G);
GN = poly2sym(G_num, s_sym);
GD = poly2sym(G_den, s_sym);

CL_den = expand(GD*HD+GN*HN);
coeffCL = coeffs(CL_den, s_sym, 'All');
coeffT  = coeffs(desired, s_sym, 'All');

eqs = coeffCL(2:end) == coeffT(2:end);
sol_sym = solve(eqs, [a3 a2 a1 a0 b3 b2 b1 b0]);
sol = structfun(@double, sol_sym);

H_num = transpose(sol(5:8));
H_den = [1, transpose(sol(1:4))];

Hc = zpk(tf(H_num, H_den));
Lc = G*Hc;
Tc = feedback(Lc, 1);
poles_Tc = pole(Tc);
zeros_Tc = zero(Tc);

% display
Hc, Tc, poles_Tc, zeros_Tc
```

```
Hc =

     5597 (s+0.4116) (s^2 + 0.125s + 1.778)
  ------------------------------------------
  (s^2 + 20.06s + 115.9) (s^2 + 5.939s + 51.91)

Continuous-time zero/pole/gain model.
Model Properties

Tc =

  11194 (s+0.4116) (s^2 + 0.125s + 1.778)
  ---------------------------------------
          (s+4)^6 (s^2 + 2s + 2)

Continuous-time zero/pole/gain model.
Model Properties
poles_Tc = 8×1 complex
```

```
  -4.0247 + 0.0000i
  -4.0123 + 0.0214i
  -4.0123 - 0.0214i
  -3.9877 + 0.0213i
  -3.9877 - 0.0213i
  -3.9753 + 0.0000i
  -1.0000 + 1.0000i
  -1.0000 - 1.0000i
zeros_Tc = 3×1 complex
  -0.0625 + 1.3320i
  -0.0625 - 1.3320i
  -0.4116 + 0.0000i
```

part d

```
% solution
fig = figure;
hold on;
stepplot(Tb);
stepplot(Tc);
legend(["T_b" "T_c"]);
hold off;
saveas(fig, './images/s04d.png');
```




```
Tb_info = stepinfo(Tb);
Tc_info = stepinfo(Tc);

% display
```

```
Tb_info, Tc_info
```

```
Tb_info = struct with fields:
         RiseTime: 0.3510
    TransientTime: 5.5002
     SettlingTime: 5.5002
      SettlingMin: 0.7579
      SettlingMax: 1.2897
        Overshoot: 28.9658
       Undershoot: 0
             Peak: 1.2897
         PeakTime: 0.9193
Tc_info = struct with fields:
         RiseTime: 0.4342
    TransientTime: 5.8635
     SettlingTime: 5.8635
      SettlingMin: 0.7028
      SettlingMax: 1.3977
        Overshoot: 39.7657
       Undershoot: 0
             Peak: 1.3977
         PeakTime: 3.6616
```