8.

a. Pole: -2; $c(t) = A + Be^{-2t}$; first-order response.

b. Poles: -3, -6; $c(t) = A + Be^{-3t} + Ce^{-6t}$; overdamped response.

c. Poles: -10, -20; Zero: -7; $c(t) = A + Be^{-10t} + Ce^{-20t}$; overdamped response.

d. Poles: $(-3+j3\sqrt{15})$, $(-3-j3\sqrt{15})$; $c(t) = A + Be^{-3t}\cos(3\sqrt{15}\,t + \phi)$; underdamped.

e. Poles: j3, -j3; Zero: -2; $c(t) = A + B\cos(3t + \phi)$; undamped.

f. Poles: -10, -10; Zero: -5; $c(t) = A + Be^{-10t} + Cte^{-10t}$; critically damped.

9.

Program:

```
p=roots([1 6 4 7 2])
```

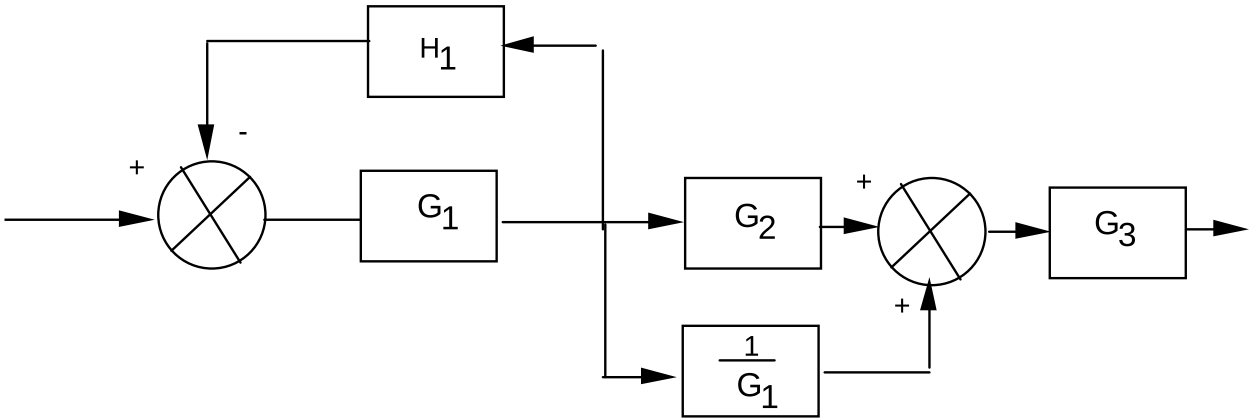
Computer response:

```
p =

  -5.4917
  -0.0955 + 1.0671i
  -0.0955 - 1.0671i
  -0.3173
```

2.

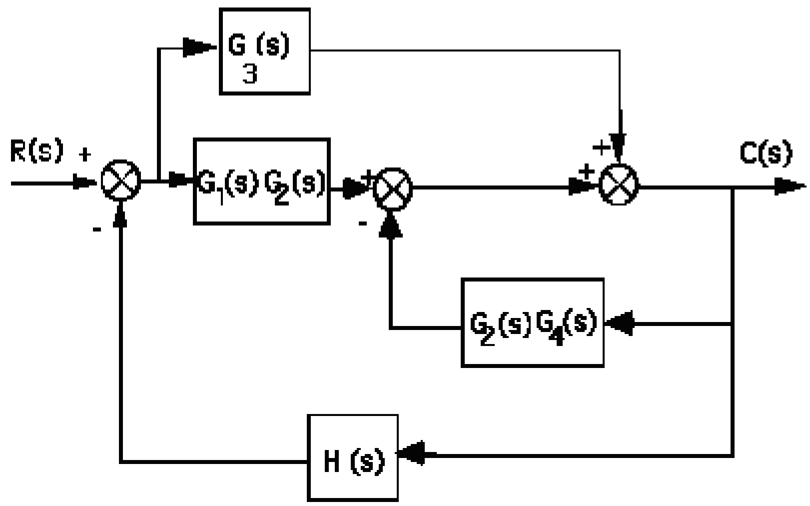
Push $G_1(s)$ to the left past the pickoff point.



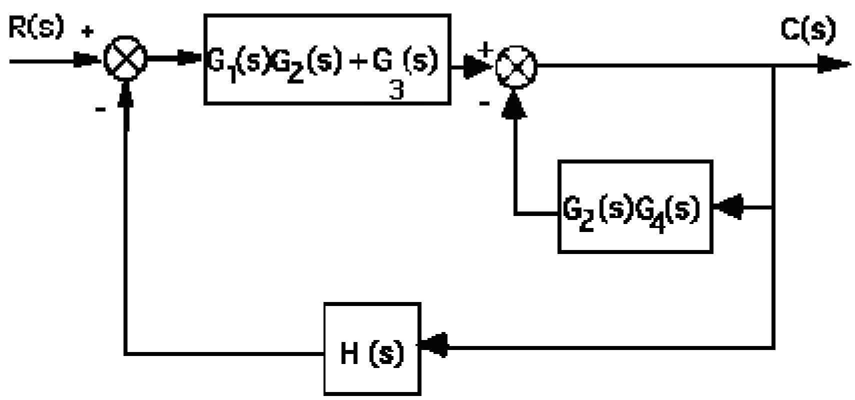
Thus, $T(s) = \left(\frac{G_1}{1+G_1H_1}\right)\left(G_2 + \frac{1}{G_1}\right)G_3 = \frac{(G_1G_2+1)G_3}{(1+G_1H_1)}$

4.

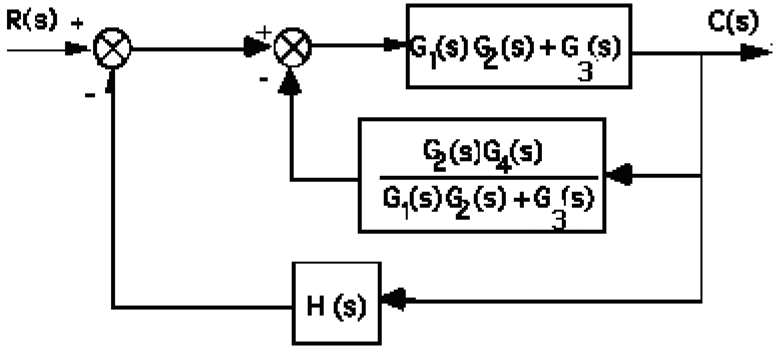
Push $G_2(s)$ to the left past the summing junction.



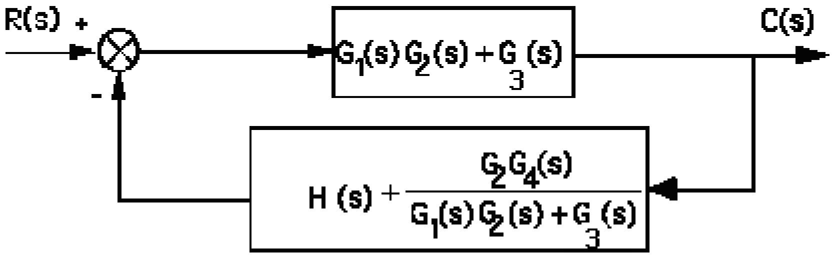
Collapse the summing junctions and add the parallel transfer functions.



Push $G_1(s)G_2(s) + G_5(s)$ to the right past the summing junction.



Collapse summing junctions and add feedback paths.



Applying the feedback formula,

$$T(s) = \frac{G_3(s) + G_1(s)G_2(s)}{1 + [G_3(s) + G_1(s)G_2(s)]\left[H + \dfrac{G_2(s)G_4(s)}{G_3(s) + G_1(s)G_2(s)}\right]}$$

$$= \frac{G_3(s) + G_1(s)G_2(s)}{1 + H[G_3(s) + G_1(s)G_2(s)] + G_2(s)G_4(s)}$$

26.

$\Delta = 1 + [G_2G_3G_4 + G_3G_4 + G_4 + 1] + [G_3G_4 + G_4]$; $T_1 = G_1G_2G_3G_4$; $\Delta_1 = 1$. Therefore,

$$T(s) = \frac{T_1\Delta_1}{\Delta} = \frac{G_1G_2G_3G_4}{2 + G_2G_3G_4 + 2G_3G_4 + 2G_4}$$

27.

Closed-loop gains: $G_2G_4G_6G_7H_3$; $G_2G_5G_6G_7H_3$; $G_3G_4G_6G_7H_3$; $G_3G_5G_6G_7H_3$; G_6H_1; G_7H_2

Forward-path gains: $T_1 = G_1G_2G_4G_6G_7$; $T_2 = G_1G_2G_5G_6G_7$; $T_3 = G_1G_3G_4G_6G_7$; $T_4 =$

$G_1G_3G_5G_6G_7$

Nontouching loops 2 at a time: $G_6H_1G_7H_2$

$\Delta = 1 - [H_3G_6G_7(G_2G_4 + G_2G_5 + G_3G_4 + G_3G_5) + G_6H_1 + G_7H_2] + [G_6H_1G_7H_2]$

$\Delta_1 = \Delta_2 = \Delta_3 = \Delta_4 = 1$

$$T(s) = \frac{T_1\Delta_1 + T_2\Delta_2 + T_3\Delta_3 + T_4\Delta_4}{\Delta}$$

$$= \frac{G_1G_2G_4G_6G_7 + G_1G_2G_5G_6G_7 + G_1G_3G_4G_6G_7 + G_1G_3G_5G_6G_7}{1 - H_3G_6G_7(G_2G_4 + G_2G_5 + G_3G_4 + G_3G_5) - G_6H_1 - G_7H_2 + G_6H_1G_7H_2}$$

28.

Closed-loop gains: $-s^2; -\frac{1}{s}; -\frac{1}{s}; -s^2$

Forward-path gains: $T_1 = s; T_2 = \frac{1}{s^2}$

Nontouching loops: None

$$\Delta = 1 - (-s^2 - \frac{1}{s} - \frac{1}{s} - s^2)$$

$$\Delta_1 = \Delta_2 = 1$$

$$G(s) = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta} = \frac{s + \frac{1}{s^2}}{1 + (s^2 + \frac{1}{s} + \frac{1}{s} + s^2)} = \frac{s^3+1}{2s^4+s^2+2s}$$