(1) $G(s) = \dfrac{6(s+5)}{s(s+1)(s+3)(s+10)}$

This is a type 1 System.

Therefore, steady state error is $\underline{\text{zero}}$ for the step input

Now for ramp input,

$$e_{ss} = \frac{A}{K_v}$$

$$K_v = \lim_{s \to 0} s \cdot G(s)$$

$$= \lim_{s \to 0} s \times \frac{6(s+5)}{s(s+1)(s+3)(s+10)}$$

$$= \frac{5 \times 6}{1 \times 3 \times 10}$$

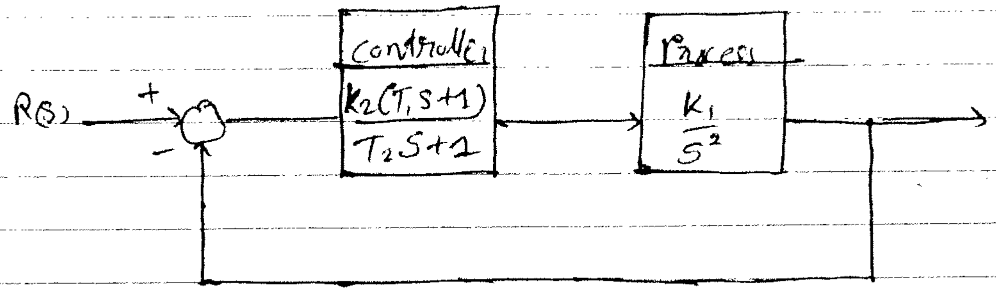
$$K_v = 1$$

$\therefore$ steady state error $e_{ss} = \dfrac{A}{K_v}$

$$= \frac{A_0}{1}$$

$$\boxed{e_{ss} = A_0}$$

(2)



$T_1 = 1$

$T_2 = 0$

$$\therefore K(s)G(s) = \frac{K_1K_2(s+1)}{S^2}$$

$$\therefore \text{Transfer function} = \frac{K_1K_2(s+1)/S^2}{1 + K_1K_2(s+1)/S^2}$$

$$= \frac{K_1K_2(s+1)}{S^2 + K_1K_2 s + K_1K_2}$$

assume $\xi = 0.70$

$\omega_n = \sqrt{K_1K_2}$

$$\therefore 2\xi\omega_n = K_1K_2$$

$$2\xi\sqrt{K_1K_2} = K_1K_2$$

$$\therefore 4\xi^2 = K_1K_2$$

$$K_1K_2 = 1.96$$

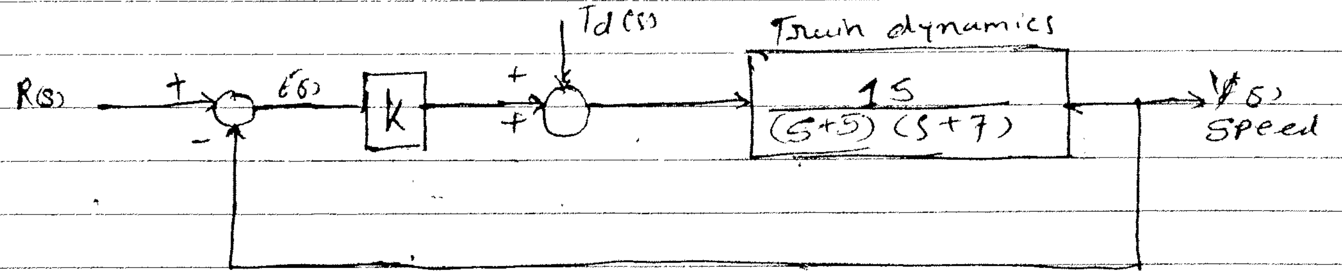
now, checking the value for K_1 & K_2

$T_s = \frac{4}{\xi\omega_n} = \frac{4}{0.98} \approx 4\,sec$ this is very slow respon

now at $\xi = 1 \Rightarrow T_s = 4/\xi\omega_n = 4/2 = 2\,sec$.

Therefore, value for the K_1K_2 should be greate than 1.96

(3)



(a) $e_{ss} = \dfrac{1}{1+K_p}$ & $Y(s) = \dfrac{15K}{(s+7)(s+5)+15K} R(s) + \dfrac{15}{(s+7)(s+5)+15K} Td(s)$

$K_p = \lim_{s \to 0} \dfrac{15k}{(s+5)(s+7)}$

$= \dfrac{15K}{35}$

Now,

$K_1 = 1$, $K_p = 0.3$, $e_{ss} = 0.76$

$K = 10$, $K_p = 4.28$, $E_{ss} = 0.186$

$K = 100$, $K_p = 42.85$, $e_{ss} = 0.0228$

(c) $\dfrac{Y(s)}{Td(s)} = \dfrac{15}{(s+7)(s+5)+15K}$

$= \dfrac{15}{s^2+12s+35+15K}$

$\left[\dfrac{Y(s)}{Td(s)}\right]_{max} = \dfrac{15}{35+15K}$

Now

$K = 1 \Rightarrow (Y/Td)_{max} = 0.3$

$K = 10 \Rightarrow (Y/Td)_{max} = 0.081$

$K = 100 \Rightarrow (Y/Td)_{max} = 0.0097$

K	e_{ss}	$(Y/Td)_{max}$	T_s (matlab)	P.O. (matlab)
1	0.76	0.3	0.591	0
$\boxed{10}$	0.186	0.081	0.615	21.3
100	0.0228	0.0097	0.652	61.4

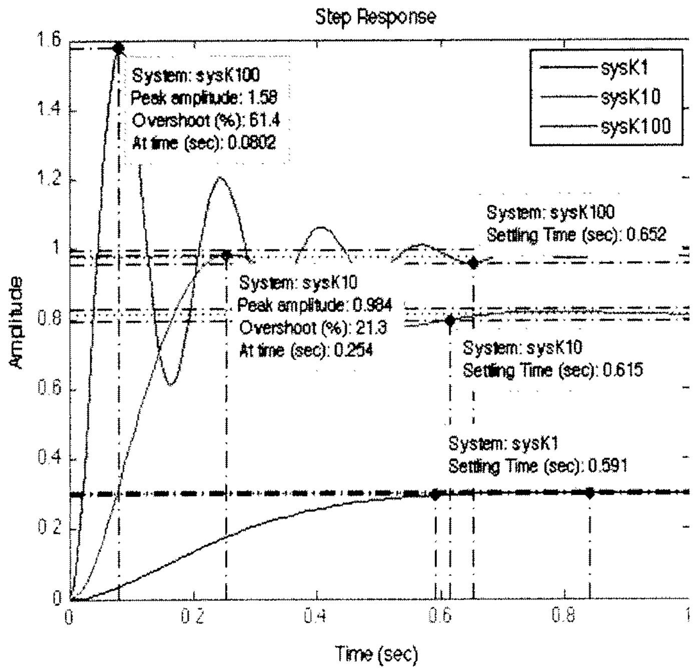
⇒ best compromise value for

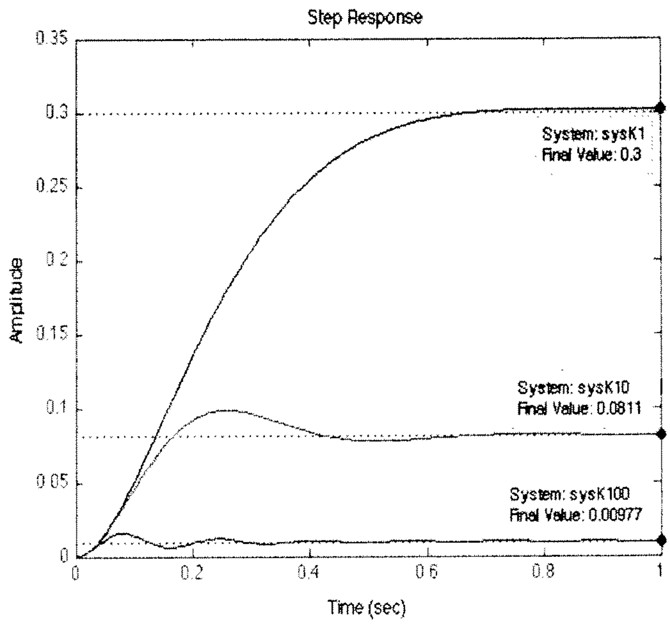
Step response for Y(s), R(s)

```
>> num=15;
>> den=[1 12 50];
>> sysK1=tf(num,den)
 Transfer function:
     15
---------------
s^2 + 12 s + 50
 >> step(sysK1)
>> hold on
>> num=150;
>> den=[1 12 185];
>> sysK10=tf(num,den)
 Transfer function:
     150
----------------
s^2 + 12 s + 185
 >> step(sysK10)
>> hold on
>> num=1500;
>> den=[1 12 1535];
>> sysK100=tf(num,den)
 Transfer function:
     1500
-----------------
s^2 + 12 s + 1535
 >> step(sysK100)
```

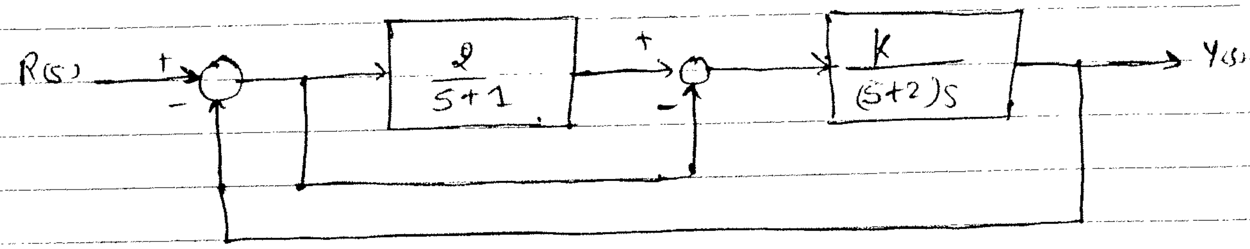
Step response for Td(s), Y(s)

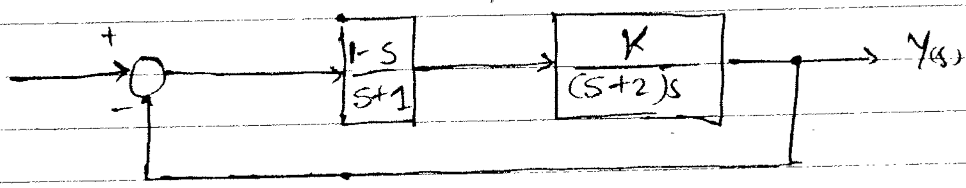
```
>> num=15;
>> den=[1 12 50];
>> sysK1=tf(num,den)
 Transfer function:
     15
---------------
s^2 + 12 s + 50
 >> step(sysK1)
>> hold on
>> den=[1 12 185];
>> sysK10=tf(num,den)
 Transfer function:
     15
----------------
s^2 + 12 s + 185

>> step(sysK10)
>> hold on
>> den=[1 12 1535];
>> sysK100=tf(num,den)
 Transfer function:
     15
-----------------
s^2 + 12 s + 1535
 >> step(sysK100)
```





(4)





$\therefore$ characteristic eqn $= 1 + G(s)\,K(s) = 0$

$$\therefore 1 + \frac{K}{(s+2)s} \times \frac{(1-s)}{(s+1)} = 0$$

$$\therefore s(s+2)(s+1) + K - Ks = 0$$

$$\therefore s^2 + 3s^2 + 2s - Ks + K = 0$$

$$s^2 + 3s^2 + (2-K)s + K = 0$$

s^3	1	$(2-K)$
s^2	3	K
s^1	$\frac{3(2-K)-K}{3}$	0
s^0	K	

$K = 0$ & $\therefore \frac{3(2-K)-K}{3} = 0$

$$\therefore 6 - 4K = 0$$

$$K = \frac{6}{4}$$

$$K = 1.5$$

therefore range of K is $0 < K < 1.5$ for stable system otherwise ~~system~~ any value of K system goes unstable

(5) $L(s) = \frac{K(s+2)}{s(s-1)}$

$\therefore$ Characteristic eqn $= 1 + \frac{K(s+2)}{s(s-1)} = 0$

$\therefore s(s-1) + K(s+2) = 0$

$\therefore s^2 - s + Ks + 2K = 0$

$s^2 + (K-1)s + 2K = 0$

$\omega_n = \sqrt{2K}$

$2\xi\omega_n = K-1$

Now $\xi = 0.707$

$2(0.707)\sqrt{2K} = K-1$

$\therefore 4(0.499)2K = K^2 - 2K + 1$

$\therefore 4K = K^2 - 2K + 1$

$K^2 - 6K + 1 = 0$

$\therefore \frac{+6 \pm \sqrt{36-4}}{2}$

$= \frac{+6 \pm \sqrt{32}}{2}$

$\therefore K = 5.825$ & $K = 0.175$

for stability K must be greater than 1.

$\boxed{\therefore K = 5.825}$