$* J\ddot{\theta} + B\dot{\theta} = T_c \quad , \therefore T_c = K(\theta_r - \theta)$

$\therefore J\ddot{\theta} + B\dot{\theta} = K(\theta_r - \theta)$

$\therefore J\theta(s)s^2 + B\theta(s)s = K\theta_r - K\theta(s)$

$\therefore \underset{\uparrow o/p}{\theta(s)}[Js^2 + Bs + K] = K\underset{\uparrow i/p}{\theta_r}$, we need θ to track θ_r

$\therefore$ **$T.F = \frac{\theta(s)}{\theta_r} = \frac{K}{Js^2 + Bs + K}$ #** Second order system.

C)

$J = 600*10^3 \quad , B = 20*10^3$

$\therefore 600*10^3 s^2 + 20*10^3 s + K = 0$

s^2	$600*10^3$	K
s^1	$20*10^3$	0
s^0	K	

$\therefore$ System is stable for all values of $K > 0$

since there's no upper limit, $\therefore K_{max} = +\infty$

D)

K_{max} For $M_p < 0.1$

$* \therefore Js^2 + Bs + K = 0$

$\therefore s^2 + \frac{B}{J}s + \frac{K}{J} = 0$

$\therefore 2\zeta\omega_n = \frac{B}{J} \quad , \therefore \omega_n = \sqrt{\frac{K}{J}}$

$\therefore \frac{B}{2J\zeta} = \sqrt{\frac{K}{J}}$

$\therefore K = J\left(\frac{B}{2J\zeta}\right)^2$

$\because M_p = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} = 0.1$

$\therefore \zeta = 0.59$

$\therefore K = 600*10^3\left(\frac{20}{2*600*0.59}\right)^2$

$\therefore$ **$K_{max} = 479$**

E)

Values of K to provide rise time < 80 sec

$\because t_r = \frac{\pi - \cos^{-1}(\zeta)}{\omega_n\sqrt{1-\zeta^2}} < 80$

$\therefore \frac{\pi - \cos^{-1}(\zeta)}{\frac{B}{2J\zeta}\sqrt{1-\zeta^2}} < 80$

$\therefore \zeta = 0.53$

$\therefore$ **$K > 592$**

h)

Find steady state error for each K

- Step input

$\rightarrow \theta(s) = T.F \cdot \frac{1}{s}$

$\therefore \theta(s) = \frac{K}{s(Js^2 + Bs + K)}$

$\begin{cases} error = \theta(\infty) - 1 \\ \theta(\infty) = \lim_{s \to 0} s\theta(s) \end{cases}$ (t)

$\begin{cases} \therefore \theta(\infty) = \lim_{s \to 0} \frac{K}{Js^2 + Bs + K} = \frac{K}{K} = 1 \\ \therefore error = 1 - 1 = 0 \end{cases}$