2 (a) $G(s) = \frac{K}{s^2(s+4)(s+12)}$

$$\frac{Y(s)}{R(s)} = \frac{G(s)}{1+G(s)}$$

$$1 + \frac{K}{s^2(s+4)(s+12)} = 0$$

$$s^4 + 16s^3 + 48s^2 + K = 0$$

Routh array :

s^4	1	48	K
s^3	16	0	
s^2	48	K	
s^1	$-\frac{1}{3}K$		
s^0	$\frac{1}{K}$		

range of K cannot be found since K cannot be greater than 0 and less than $-\frac{1}{3}$ at the same time

∴ The system cannot be stabilized by pure gain adjustment.

(b) damping ratio $= \zeta = \frac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}} = 0.4504$

The real part of dominant poles $\sigma_d = \frac{4}{3}$

$\Rightarrow \omega_n = \frac{\sigma_d}{\zeta} = \frac{\frac{4}{3}}{0.4504} = 2.9603$

∴ dominant poles at $-(0.4504)(2.9603) \pm j(2.9603)\sqrt{1-(0.4504)^2}$

$= -1.333 \pm j2.643$

The angle contributed by the added compensator =

$$-\theta - \left[180° - \tan^{-1}\left(\frac{2.643}{-1.333}\right)\right] - \tan^{-1}\left(\frac{2.643}{-4+1.333}\right) - \tan^{-1}\left(\frac{2.643}{-12+1.333}\right) + \left[180° - \tan^{-1}\left(\frac{2.643}{-1.333+0.02}\right)\right] = -180°$$

$$\theta = 120.996°$$

$$\frac{1.333}{-2.643 - \sigma_d} = \tan(120.996°)$$

$$\sigma_d = -1.842$$