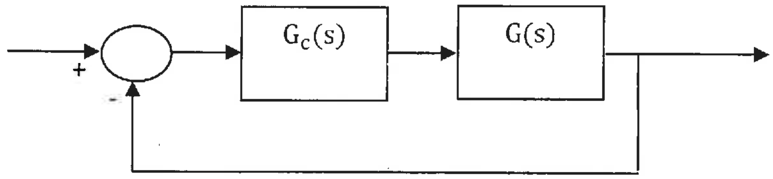
SOLUTION

Consider the following system for questions (8-17)



where,

$$G(s) = \frac{A(1-\frac{s}{\omega_1})}{1+\frac{s}{Q\omega_2}+\left(\frac{s}{\omega_2}\right)^2}$$

$A = 12{,}000$

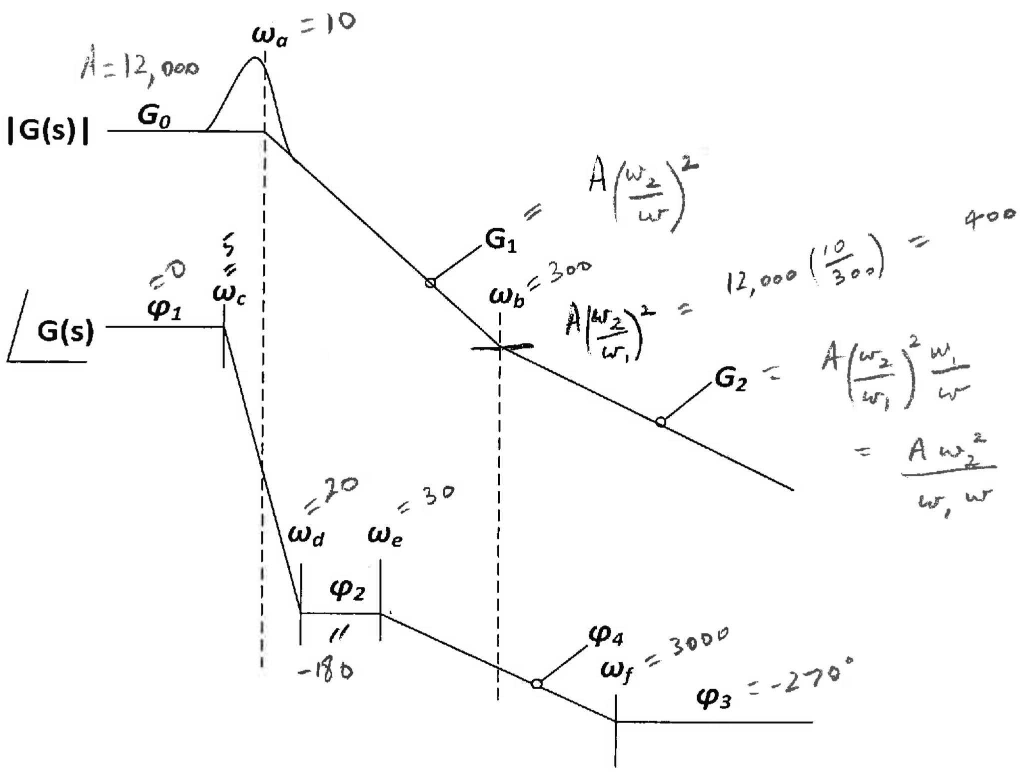
$\omega_1 = 300 rds/s$

$\omega_2 = 10 rds/s$

$Q = 1.6$

[Hint: $10^{1/2Q} \approx 2$]

Except where noted, we will assume $G_c(s) = 1$. The asymptotic Bode plot of G(s) is shown below.



8. The expression for the gain G_1 along the sloping line segment is

a. $\frac{A\omega_2}{\omega}$

b. $A\left(\frac{\omega}{\omega_2}\right)^2$

c. $A\left(\frac{\omega_2}{\omega}\right)^2$

d. $A\omega$

e. $\left(A\frac{\omega}{\omega_2}\right)^2$

9. The expression for the gain G_2 along the sloping line segment is

a. $\frac{A{\omega_2}^2}{\omega_1\omega}$

b. $A\left(\frac{\omega_2}{\omega\omega_1}\right)^2$

c. $\frac{A\omega_1{\omega_2}^2}{\omega}$

d. $A\omega$

e. $\left(A\frac{\omega\omega_1}{\omega_2}\right)^2$

10. The frequency ω_c shown in the above plot has an approximate value of

a. 5 rds/s

b. 20 rds/s

c. 1 rds/s

d. 30 rds/s

e. None of the above

11. The expression for the phase ϕ_4 along the sloping line segment is

a. $-180 - 45\log_{10}(\frac{10\omega}{\omega_1})$

b. $-270 + 45\log_{10}(\frac{10\omega_1}{\omega})$

c. $-180 - \arctan(\frac{\omega}{\omega_1})$

d. Both (a) and (c)

e. (a), (b) and (c)

12. Unity gain crossover frequency is

a. 2000rds/s

b. 3500rds/s

c. 4000rds/s

d. 5000rds/s

e. None of the above

$$\frac{A\omega^2}{\omega_1\omega_c} = \frac{12{,}000 \times (10)^2}{300 \times \omega_c} = 1$$

$$= \omega_c = \frac{12{,}000 \times 1\cancel{00}}{3\cancel{00}} = 4{,}000$$

13. The phase margin is

a. 90

b. 0

c. -180

d. -90

e. -270

Phase @ ω_c = -270

$\Rightarrow$ $pm = 180 - 270 = -90^o$

→ NOTE SYSTEM IS UNSTABLE ⇒ $e_{ss} = \infty$

14. The steady state error of the closed loop system for a unit step (assuming $G_c(s) = 1$) is

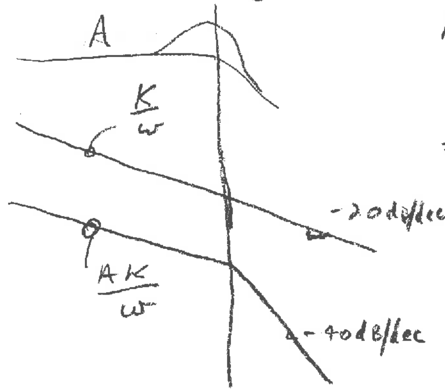
   a. 0
   b. 1
   c. 0.5
   d. ∞
   e. 2

DON'T USE (TYPE 0 SYSTEM ⇒ $e_{ss} = \frac{1}{1+K_p}$ $K_p = \lim_{s \to 0} G(s)$)

15. We now use a compensator such that $G_c(s) = \frac{K}{s}$ where K is a constant. The value of K required so that the loop gain has a unity gain crossover frequency of 2 rds/s is

   a. 10×10^{-3}
   b. 2×10^{-3}
   c. 10
   d. $\frac{1}{12} \times 10^{-3}$
   e. $\frac{1}{6} \times 10^{-3}$

$\omega_2 = 10$



$\frac{AK}{\omega_c} = 1$

$\Rightarrow K = \frac{\omega_c}{A} = \frac{2}{12{,}000} = \frac{1}{6{,}000} = \frac{1}{6} \times 10^{-3}$

16. For your design of question (15), the phase margin is

   a. 90
   b. 0
   c. -180
   d. -90
   e. -270

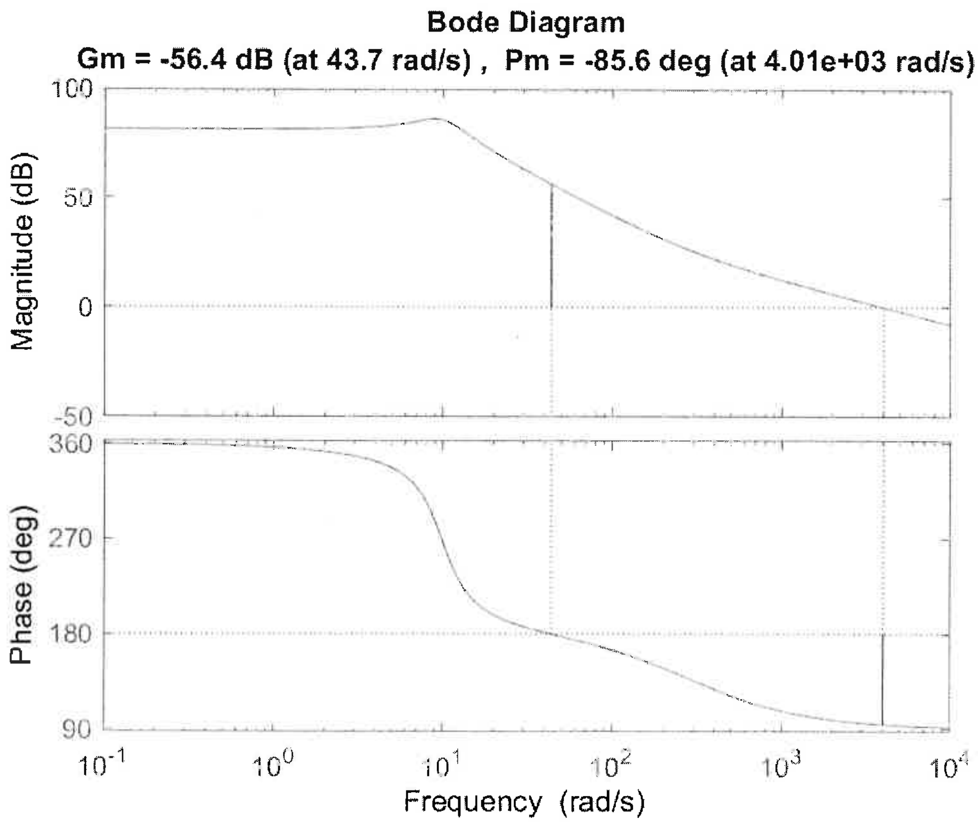
PHASE @ $\omega_c = 2$ $= -90$ ⇒ PM $= 180° - 90° = 90°$

17. For your design of question (15), the steady state error of the closed loop system to a unit step is

   a. 1
   b. 0.5
   c. ∞
   d. 2
   e. 0

Now TYPE 1 SYSTEM ⇒ $e_{ss} = 0$

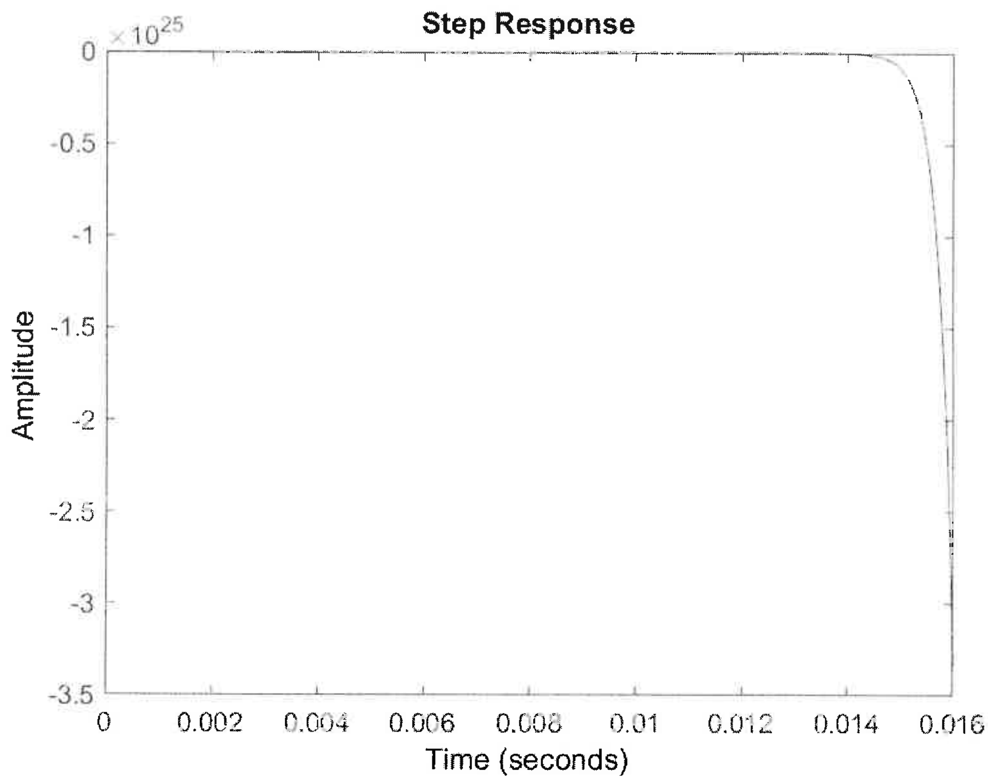
OPEN-LOOP UNCOMPENSATED



STEP RESPONSE

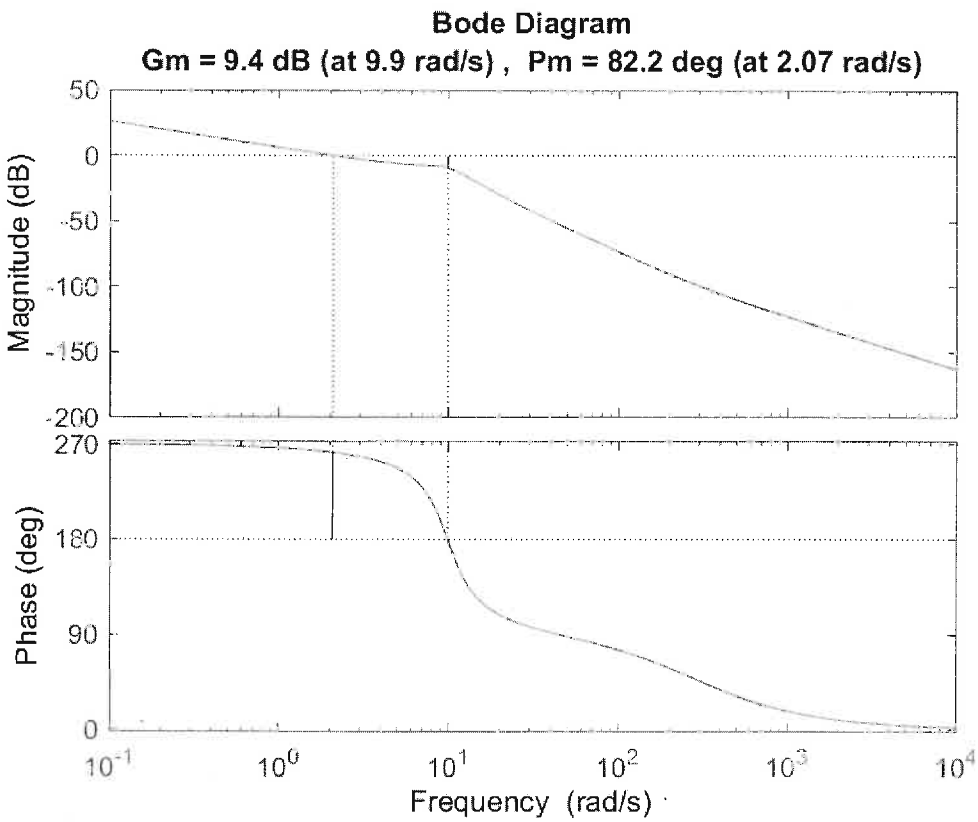
— UNCOMP. CLOSED LOOP SYSTEM

→ UNSTABLE



COMPENSATED LOOP GAIN

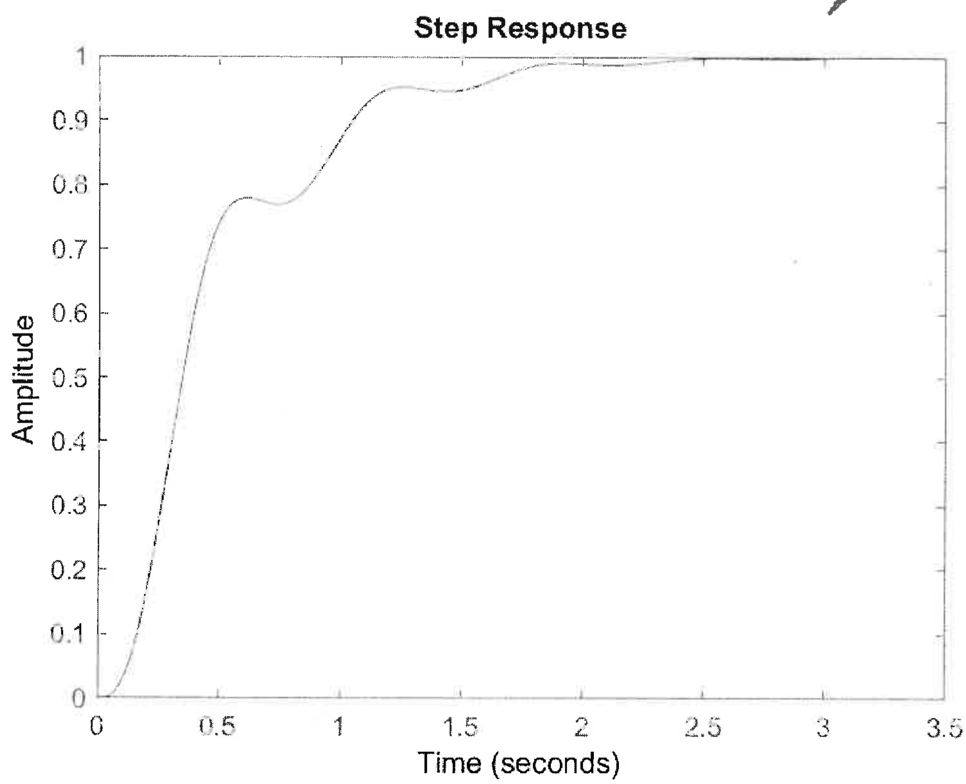
$$G_c(s) = \frac{K}{s}, \quad K = \frac{1}{6} \times 10^{-3}$$



STEP RESPONSE
– COMPENSATED

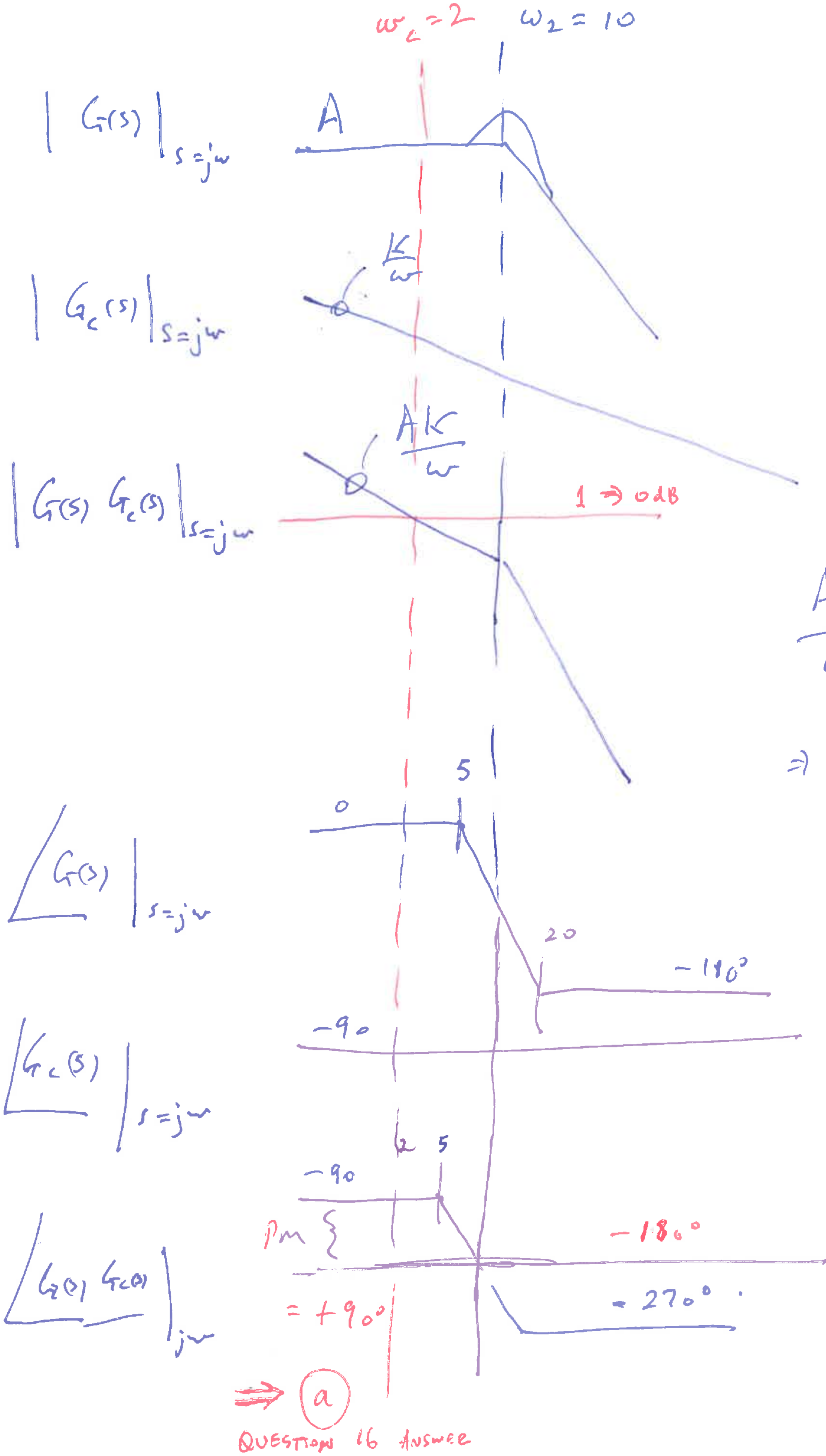
FINAL OUTPUT VALUE = 1 $\Rightarrow$

$e_{ss} = 0$



```
clear
close all
format compact

% Questions 8-17 on ECE317 Final


w1 = 300
wo = 10
H = 1
Go = 12000
Q = 1.66

T0 = Go*H

s = tf('s')

T = T0 * (1- s/w1)/(1+s/(Q*wo)+(s/wo)^2)
figure(1)
margin(T)

Tcl = T/(1+T)
figure(2)
step(Tcl)


K = 1/6 * 10^(-3)
Tcomp = K/s * T0 * (1-s/w1)/(1+s/(Q*wo)+(s/wo)^2)


Tcl_comp = Tcomp/(1+Tcomp)

figure(3)
step(Tcl_comp)

figure(4)
margin(Tcomp)
```

4



$$\frac{AK}{\omega_c} = 1$$

$$\Rightarrow K = \frac{\omega_c}{A} = \frac{2}{12{,}000} = \frac{1}{6} \times 10^{-3}$$

$\Rightarrow$ e

QUESTION 15 ANSWER