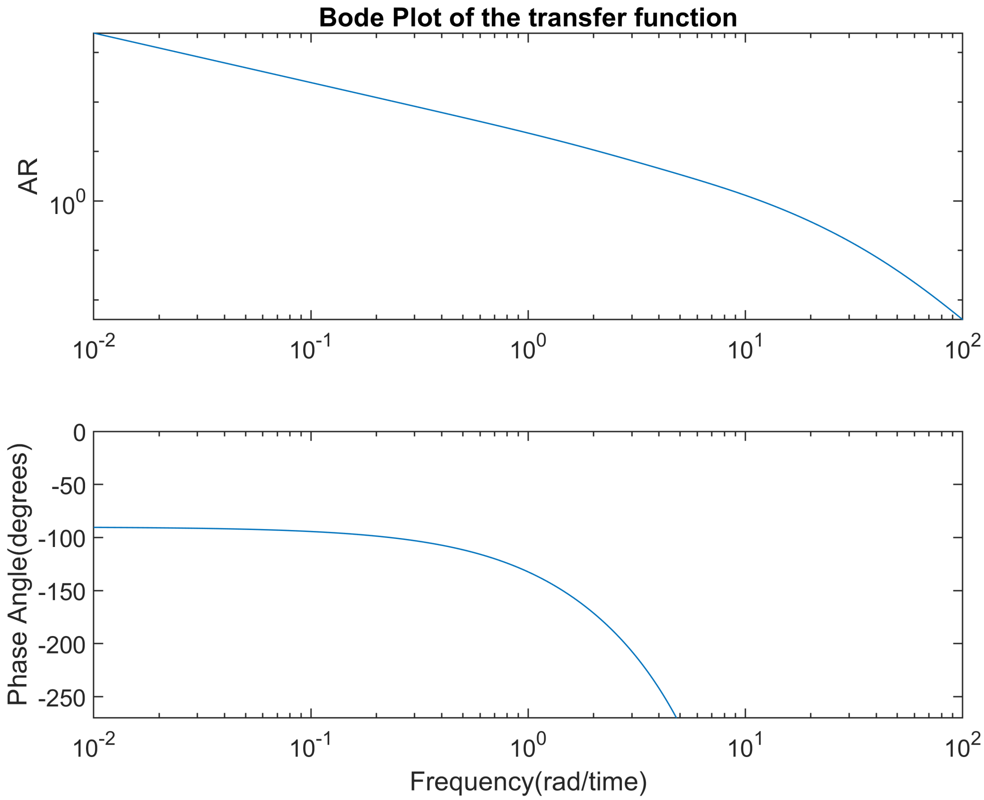
```
num=[7.4 24.64];
tdead=0.5;
den=[1.46e-5 0.00168 0.05738 0.556 1 0];
G=tf(num,den)
```

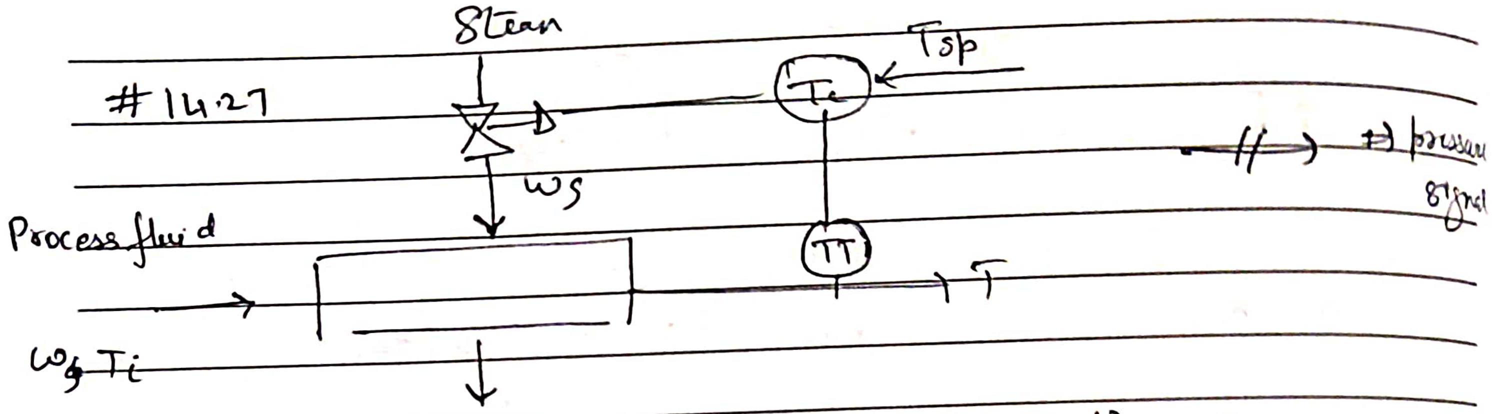
```
G =

                     7.4 s + 24.64
  --------------------------------------------------------
  1.46e-05 s^5 + 0.00168 s^4 + 0.05738 s^3 + 0.556 s^2 + s

Continuous-time transfer function.
```

```
points =500;
ww=logspace(-2,2,points);
[mag,phase,ww]=bode(G,ww);

AR=zeros(points,1);
PA=zeros(points,1);

for i=1:points
    AR(i)=mag(1,1,i);
    PA(i)=phase(1,1,i)-((180/pi)*tdead*ww(i));
end
figure
subplot(2,1,1)
loglog(ww,AR)
title('Bode Plot of the transfer function')

%axis([0.01 100 .001 25])
ylabel('AR')
subplot(2,1,2)
semilogx(ww,PA)
axis([0.01 100 -270 0])
ylabel('Phase Angle(degrees)')
xlabel('Frequency(rad/time)')
```


Bode Plot of the transfer function
AR
10^0
10^-2
10^-1
10^0
10^1
10^2
Phase Angle(degrees)
0
-50
-100
-150
-200
-250
10^-2
10^-1
10^0
10^1
10^2
Frequency(rad/time)

Manan Mohnot
190110043

#1427



$$G_m = \frac{0.12}{0.024 s + 1}$$

$$G_v = \frac{w_s'}{p'} = \frac{112 \times 0.047}{0.083 s + 1} \quad \frac{lb/min}{psi}$$

$$G_p = \frac{2}{(0.432 s + 1)(0.017 s + 1)} \quad \frac{°F}{lb/min}$$

$G_c = 2$

dominant time constant $= 0.432$

$1 + G_{OL} = 0$

$1 + G_c G_p G_v G_m = 0$ Characteristic Eqn

	K_c	τ_I
PI	$0.45 K_{cu}$	$P_u / 1.2$

$G_c = K_c$ $\therefore G_{OL} = K_c \, G_{P} \, G_V \, G_m$

$1 + G_{OL} = 0$

$\downarrow s = j\omega$

$(Eq\ 1) + j(Eq\ 2) = 0$

Eq 1 & Eq 2 $\Rightarrow \omega$ & K_{cu}

$\omega = 2\pi f = \frac{2\pi}{P}$

Method 2

$|G_{OL}| = 1$

$\angle G_{OL} = -180^\circ$

$$GM = \frac{1}{AR_c} \quad \& \quad PM = 180 + \phi_c$$

$$AR_c = |G_c(j\omega)| = K_c\sqrt{1 + \frac{1}{(\omega \tau_I)^2}} \Rightarrow K_c \frac{\sqrt{(\omega \tau_I)^2 + 1}}{\omega \tau_I}$$

$$\Rightarrow 5.85 \frac{\sqrt{(\omega \times 0.28)^2 + 1}}{\omega \times 0.28}$$

$$\phi_c = \angle G_c(j\omega) = \tan^{-1}(-1/\omega\tau_I)$$

$$= \tan^{-1}(\omega \tau_I) - 90^\circ$$

~~$AR_{OL} = 1 = \sqrt{}$~~

for ~~$\phi = -180^\circ$~~, ~~$-180 = \tan^{-1}(\omega \times 0.28) - 90$~~

~~-90~~

$$\overset{\pi}{-180} = \overset{\pi/2}{-90} + \tan^{-1}(0.28\omega_c) - \tan^{-1}(0.083\,\omega_c) - \tan^{-1}(0.432\,\omega_c) - \tan^{-1}(0.017\,\omega_c) - \tan^{-1}(0.024\,\omega_c)$$

$$\omega_c = 15.11 \text{ rad/min}$$

$$A_c = AR_{OL}\Big|_{\omega=\omega_c} = \left(\frac{5.85\sqrt{(\omega \times 0.28)^2+1}}{\omega \times 0.28}\right)\left(\frac{5.264}{\sqrt{(0.083\omega_c)^2+1}}\right)\frac{2}{\sqrt{\left[(0.432\,\omega_c)^2+1\right]\left[(0.017\omega_c)^2+1\right]}} \cdot \frac{0.12}{\sqrt{(0.024\,\omega_c)^2+1}}$$

$$A_c \quad \boxed{\cancel{\omega_c} = 0.649} \quad \text{for } \omega_c = 15.11$$

$$GM = 1/A_c \Rightarrow 1.54$$

& when $AR_{OL}\big|_{\omega=\omega_g} = 1$ $\quad \omega_g = 11.78$ rad/min

$$\phi_g = (-90) + \tan^{-1}(0.28 \times \omega_g) - \tan^{-1}(0.083\,\omega_g) - \tan^{-1}(0.432\,\omega_g) - \tan^{-1}(0.017\,\omega_g) - \tan^{-1}(0.024\,\omega_g) = -166.8^\circ$$

$$PM = 180^\circ + \phi_g = 13.2^\circ$$

December 22

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Not a well tuned controller.

$$G_c = 5.85\left[r + \frac{1}{0.28\,s} \right]$$

$$G_{OL} = G_c G_v G_p G_m$$

$$5.85\left[1 + \frac{1}{0.28s}\right]\left[\frac{5.264}{0.083s+1}\right]\left[\frac{2}{(0.432s+1)(0.017s+1)}\right]\left[\frac{0.12}{0.024s+1}\right]$$

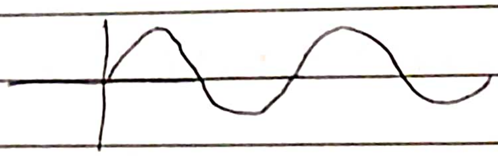
$$\approx \frac{7.4s + 24.64}{1.46\times10^{-5}s^5 + 0.00168s^4 + 0.05738s^3 + 0.556s^2 + s}$$

plot at end

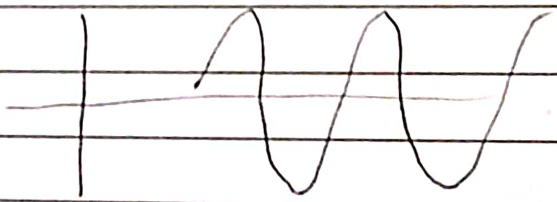
System is stable

Tutorial 11

$\boxed{1404}$

$p' =$  $0.5 \sin(0.2t)$

$\omega = 0.2$

$T_m' -$  $3.\cancel{64}464 \sin(0.2t + \phi)$

$p' \to \boxed{} \xrightarrow{s'} \boxed{} \xrightarrow{T} \boxed{} \to T_m'$

$\frac{T_m'}{T'} = \frac{1}{0.2s+1} \Rightarrow T' = T_m'(0.2s+1)$

$\Rightarrow |T'| = |T_m'|\,|0.2j\omega+1| \Rightarrow 3.464\sqrt{(0.2\times0.2)^2+1}$

$\Rightarrow 3.467$

for T_m' & T $\angle\phi_D = \angle\phi_{T'} - \angle\phi_{T_m'}$

$\angle\phi_{T_m'} = \phi$

$\angle\phi_D = -\tan^{-1}(0.2\times0.2)$

$\angle\phi_{T'} = \phi - \tan^{-1}[0.04]$

$\simeq \phi - 0.0\cancel{8}4$

if $T' = 3.467 \sin(\omega t)$

then $T_m' = 3.464 \sin(\omega t - 0.04)$

December 22

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

$T' - T_m' = 3.464 \sin(\omega t) - 3.464 \sin(\omega t - 0.04)$

$3.467 \sin(0.2t) - 3.464 (\sin(0.2t) \cos 0.04 + \cos(0.2t) \sin 0.04)$

$\approx 1.3686 \cos(0.2t)$

which at max is $\boxed{0.1386}$ when $\cos(0.2t) = 1$

Max error = 0.1386

December 22

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

14.5

a) $G_c G_v G_p G_m = \frac{2K_c}{S+1}$

$G_{OL} = \frac{2K_c}{S+1}$

$1 + G_{OL} = 0$

$1 + \frac{2K_c}{S+1} = 0$

$S+1 + 2K_c = 0$

$S = -(1+2K_c)$

$1+2K_c = 0$

$K_c = -1/2$

No, can't be made unstable.

14.6

Engineer A seems correct.

1st order + time delay can be unstable.

December 22

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31