Modified

CBCS SCHEME

USN | | | | | | | | | | |

18ME71

Seventh Semester B.E. Degree Examination, Feb./Mar. 2022
Control Engineering

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Explain closed loop system with an example. **(06 Marks)**

b. What are the ideal requirements of a control system? Explain them briefly. **(06 Marks)**

c. Explain proportional plus integral plus derivative control action with the characteristics. **(08 Marks)**

OR

2 a. Draw the equivalent mechanical system of the given system shown in Fig.Q2(a). Hence the set of equilibrium equations for it and obtain electrical analogous circuits using (i) F-V analogy (ii) F-I analogy.

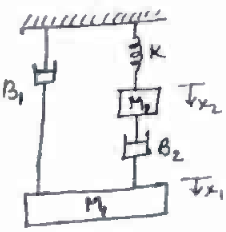

Fig.Q2(a) **(12 Marks)**

b. A thermometer is dipped in a vessel containing liquid at a constant temperature of $\theta_i(t)$. The thermometer has a thermal capacitance for storing heat as 'C' and thermal resistance to limit heat flow as R. If the temperature indicated by the thermometer is $\theta_0(t)$. Obtain the transfer function of the system. **(08 Marks)**

Module-2

3 a. Obtain an expression for response of first order system for unit step input. **(06 Marks)**

b. Explain different types of input signals. **(06 Marks)**

c. Obtain an expression for response of first order system for parabolic input. **(08 Marks)**

OR

4 a. Derive the expression of steady state error for a simple closed loop system and state the factors on which it depends. **(10 Marks)**

b. A second order system has natural frequency $\omega_n = 5$ rad/sec and damping ratio is 0.6. Calculate (i) Delay time (ii) Rise time (iii) Peak time (iv) Maximum overshoot. **(10 Marks)**

Module-3

5 a. Reduce the given block diagram shown in Fig.Q5(a) and obtain the transfer function C(s)/R(s).

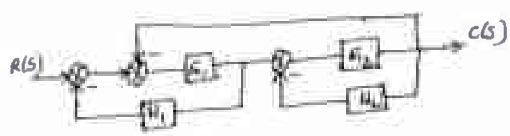

Fig.Q5(a) **(10 Marks)**

b. Find the overall transfer function by using Mason's gain formula for the signal flow graph shown in the Fig.Q5(b).

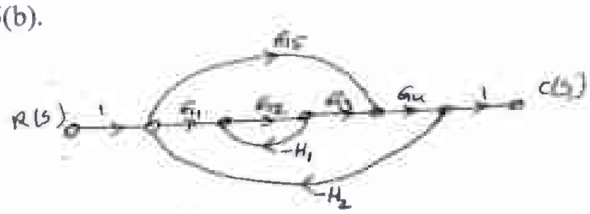

Fig.Q5(b) **(10 Marks)**

OR

6 a. Draw the corresponding signal flow graph of a given block diagram in Fig.Q6(a) and obtain transfer function by using Mason's gain formula.

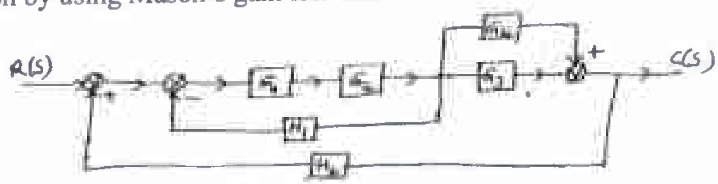

Fig.Q6(a) **(10 Marks)**

b. A system is governed by the differential equation $\frac{d^3y}{dt^3}+6\frac{d^2y}{dt^2}+11\frac{dy}{dt}+10y=8u(t)$ where y is the output and u is the input of the system. Obtain a state space representation of the system. **(10 Marks)**

Module-4

7 a. The characteristic equation of a system is given by

$$s^6+3s^5+4s^4+6s^3+5s^2+3s+2=0$$

Determine the stability using RH criteria. **(08 Marks)**

b. By applying Routh criterion, discuss the stability of the closed loop system as a function of K for the following open loop transfer function $G(s)H(s)=\frac{K(s+1)}{s(s-1)(s^2+4s+16)}$ **(12 Marks)**

OR

8 Sketch the rough nature of root locus of a given transfer function

$$G(s)H(s)=\frac{K(s+1)}{s(s+2)(s^2+2s+5)}$$ **(20 Marks)**

Module-5

9 a. Sketch the polar plot of given transfer function

$$G(s)H(s)=\frac{1}{s(1+5s)(1+10s)}$$ **(06 Marks)**

b. The transfer function $G(s)H(s)=\frac{10}{s(s+1)(s+2)}$

Sketch the rough nature of Nyquist plot and comment on stability. **(14 Marks)**

OR

10 Draw the Bode plot for the transfer function

$$G(s)=\frac{36(1+0.2s)}{s^2(1+0.05s)(1+0.01s)}$$

From Bode plot determine :

(i) Phase crossover frequency (ii) Gain crossover frequency

(iii) Gain margin (iv) Phase margin **(20 Marks)**

Re: Sir, regarding Modification of Scheme and solution

"Dr M S Govinde Gowda" <msggowda1964@gmail.com> February 21, 2022 11:34 AM

To: boe@vtu.ac.in

Dear Sir,
PFA for the corrected solution and scheme of 18ME71-Control Engg for your final approval.
Further to mention on the scheme and solution given by the paper setter, later on it is corrected fully:
1. For some questions, the scheme was not appropriate and hence the scheme is revised for detailed split-up as shown in the soft copy.
2. Solution given for Q..6(c) was not convincing and hence the detailed solution is given the convenience of evaluators
3. Solution given for Q.10 (which carries 20 marks) on the Bode plot was wrong and, hence the correct and detailed solution is given on the graph. The corrected solution is also verified by using MATLab and other simulation software as shown in the attachment.

With regards

Dr M.S.Govinde Gowda
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and
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On Wed, Feb 16, 2022 at 1:27 PM <boe@vtu.ac.in> wrote:

Approved

Registrar (Evaluation)
Visveswaraiah Technological University
Belgaum 590 014

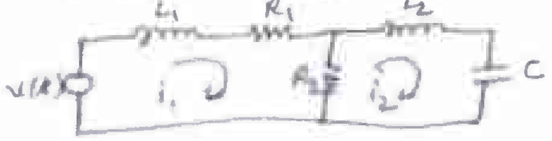
Visvesvaraya Technological University

Belagavi, Karnataka - 590 018

Signature of Scrutinizer

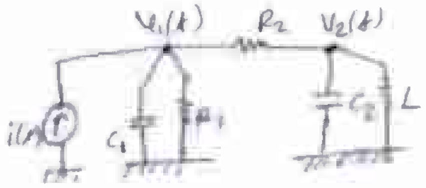
Scheme & Solutions

Subject Title : Control Engineering **Subject Code :** 18ME71

Question Number	Solution	Marks Allocated
Ans. (1) (a)	Explaination Example	3 3
1. (b)	Accuracy, Sensitivity, Stability, Bandwidth, Speed, oscillations } Explaination	6
1. (c)	$\frac{C(S)}{R(S)} = K_p + \frac{K_p}{T_i S} + K_p T_i S$ characteristics	6 2
Ans. (2) (a)	Equilibrium eqn $f(t) = M_1 \frac{d^2 x_1}{dt^2} + B_1 \frac{dx_1}{dt} + B_2 \frac{d(x_1 - x_2)}{dt}$ $0 = B_2 \frac{d(x_2 - x_1)}{dt} + M_2 \frac{d^2 x_2}{dt^2} + K x_2$	4
	i) F-V analogy $V(t) = L_1 \frac{di_1}{dt} + R_1 i_1 + R_2 (i_1 - i_2)$ $0 = R_2 (i_2 - i_1) + L_2 \frac{di_2}{dt} + \frac{1}{C} \int i_2 dt$ 	4

Subject Title : CE

Subject Code : 18ME71

Question Number	Solution	Marks Allocated
	ii) F-I analogy. $i(t) = C_1 \frac{dV_1}{dt} + \frac{1}{R_1}V_1 + \frac{1}{R_2}(V_1 - V_2)$ $0 = \frac{1}{R_2}(V_2 - V_1) + C_2\frac{dV_2}{dt} + \frac{1}{L}\int V_2 dt$ 	4
2. (b)	$TF = \frac{\theta_o(s)}{\theta_i(s)} = \frac{1}{1+sRC}$	8
Ans 3 (a)	**R(s)=1/s ---1M** $C(s) = KR\left[1 - e^{-t/T}\right]$ **---1M** **Derivation= 4M**	6
3. (b)	Step input, Ramp input, parabolic input & sinusoidal input with explanation	6
3. (c)	**R(s)=a/s² ---2M** Derivation= 4M $C(s) = KR\left[T^2 - Tt + \frac{1}{2}t^2 - T^2 e^{-t/T}\right]$ **---2M**	8
Ans 4 (a)	$E(s) = \frac{R(s)}{1+G(s)H(s)}$ Factors	08 02
4. (b)	i) $t_d = 0.284$ sec **---3M** $t_r = 0.5535$ sec **---2M** $t_p = 0.7853$ sec **---2M** $M_p = 0.09478$ **---3M**	10
Ans 5 (a)	$TF = \frac{C(s)}{R(s)} = \frac{G_1G_2}{1+G_2H_2+G_1G_2+G_1H_1(1+G_2H_2)}$ — 04M Step by Steps reduction — 06M	6+4= 10

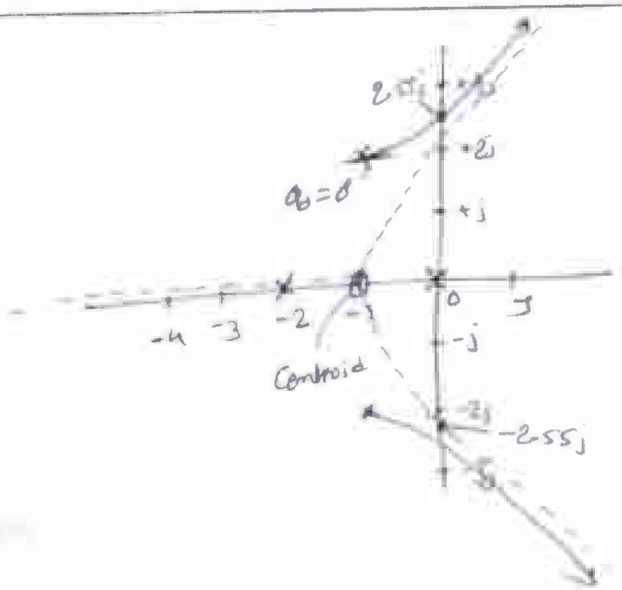
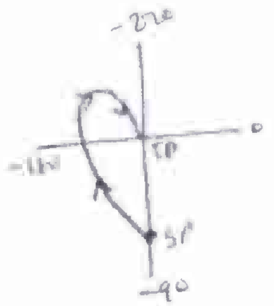
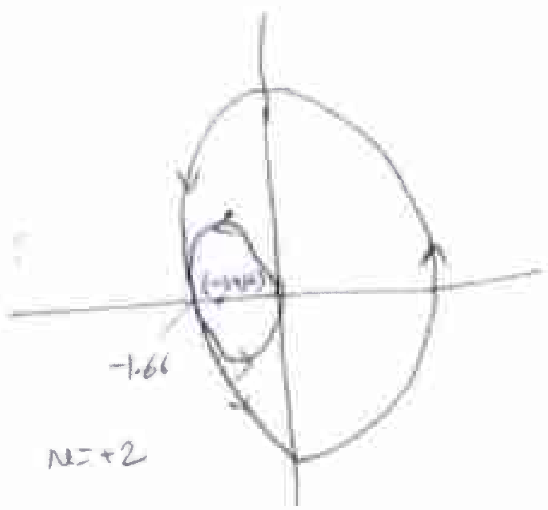
Subject Title : CE

Subject Code : 18ME71

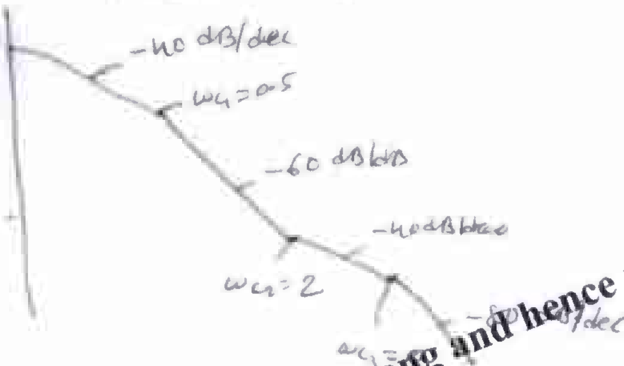
Question Number	Solution	Marks Allocated
5. (b)	SFG - (1M) $TF = \dfrac{G_1G_2G_3G_4 + G_5G_4(1+G_2H_1)}{1+G_2H_1 + G_1G_2G_3G_4H_2 + G_5G_4H_2 + G_2H_1G_5G_4H_2}$ — (05M) MGF - (03M) value of $\Delta, \Delta_1 \cdots$ - (02M)	5+3+2 = (10)
Ans 6 (a)	$TF = \dfrac{G_1G_2G_3 + G_1G_2G_4}{1 + G_1G_2H_1 - G_1G_2G_3H_2 - G_1G_2G_4H_2}$ SFG - (3M) MGF - (1M) Δ, Δ_1 - (02M) TF - (4M) **Refer Page no.p-6 for detailed derivation and scheme**	3+1+2+4 = (10)
6. (b)	$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -10 & -11 & -6 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 8 \end{bmatrix} u(t)$ $y = [1 \ 0 \ 0] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$	08 02
Ans 7 (a)	s^6 | 1 4 5 2 s^5 | 3 6 3 0 s^4 | 2 4 2 s^3 | 4 4 0 s^2 | 2 2 0 s^1 | 4 0 0 s^0 | 2 $A(s) = s^4 + 2s^2 + 1 = 0$ $s = \pm j$ The system is unstable	8
7. (b)	$1 + G(s)H(s) = 0$ $\therefore s^4 + 3s^3 + 12s^2 + s(K-16) + K = 0$ for $0 < K < 23.31$ — System is unstable for $23.31 < K < 35.68$ — System is Stable for $K > 35.68$ — System is unstable	2 10

Subject Title : CE

Subject Code : 18ME71

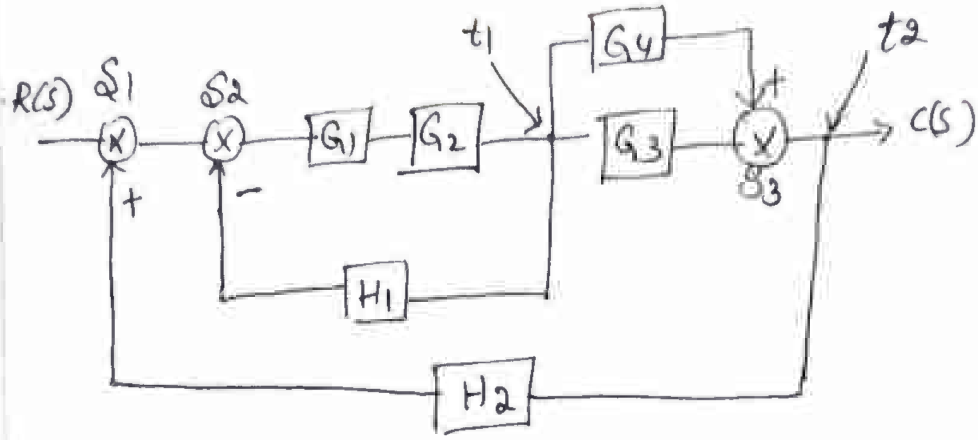
Question Number	Solution	Marks Allocated
Ans (8)	 P = Z = No of loci - No of Asym - σa = } (06) θk = B.P. & Angle of depart (03) Intersection with IA - (03) Fig - (08)	20 6+3+3 +8 = (20)
Ans (9) (a)		(06)
(b)	 $\omega_{pc} = 1.414$ Intersection point = -1.667	(14)

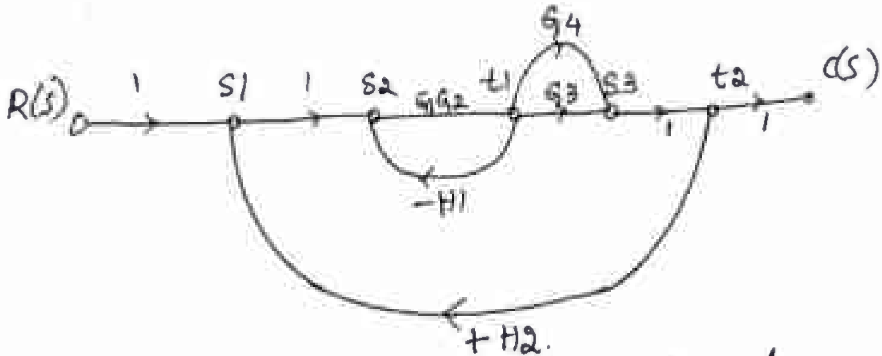
Subject Title : CE Subject Code : 18ME71

Question Number	Solution	Marks Allocated
Ans (10)	Magnitude plot  K = 4 (12 dB)	8
	Phase plot  ω_{gc} = 1.2 rad/sec ω_{pc} = 0 rad/sec PM = −45° GM = −20 dB Absolutely unstable	12 (20)

The given solution is wrong and hence refer Page no.p-7 for solution and scheme

Q.6





→ 2M

To find $\frac{C(S)}{R(S)}$, use Mason's gain formula.

No. of forward path = k = 2.

$T_1 = G_1G_2G_3$ & $T_2 = G_1G_2G_4$. → 2M

$$\frac{C(S)}{R(S)} = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta}.$$ → 1M

Individual feedback loops are:

$L_1 = -G_1G_2H_1$, $L_2 = +G_1G_2G_3H_2$, $L_3 = +G_1G_2G_4H_2$. → 3M

Consider, T_1, All loops are touching, $\therefore \Delta_1 = 1$

T_2, All loops are touching $\therefore \Delta_2 = 1$

$$\Delta = 1 - [L_1 + L_2 + L_3]$$

$$TF = \frac{C(S)}{R(S)} = \frac{G_1G_2G_3 + G_1G_2G_4}{1 - G_1G_2G_3H_2 - G_1G_2G_4H_2 + G_1G_2H_1}.$$ → 2M

10M

$$T.F = \frac{G_1G_2(G_3+G_4)}{1 + G_1G_2H_1 - G_1G_2(G_3+G_4)H_2}.$$

Sub: Control Engg.   Subcode: 18ME71.

Q.10. Draw the Bode Plot for the transfer function

$$G(s) = \frac{36(1+0.2s)}{s^2(1+0.05s)(1+0.01s)}$$

From Bode plot determine:

(i) Phase crossover frequency (ii) Gain cross over frequency

(iii) Gain Margin (iv) Phase Margin

Soln:

$$G(s) = \frac{36(1+0.2s)}{s^2(1+0.05s)(1+0.01s)}$$

Step 1: The equivalent sinusoidal transfer function is obtained by replacing s by jw

$$G(jw) = \frac{36(1+j0.2w)}{(jw)^2(1+j0.05w)(1+j0.01w)}$$

Step 2: Magnitude plot: Identify factors & find corner frequencies for all basic factors of given G(jw). Initial slope of magnitude plot is −40 dB/decade & intersects 0dB axis @ $w = \sqrt{K} = \sqrt{36} = 6$ rad/s

Factors	Corner frequency rad/s	Asymptotic log-magnitude characteristic
$\frac{36}{(jw)^2}$	None	A straight line of slope −40 dB/decade. It intersects the 0 dB axis at $w = \sqrt{36} = 6$ rad/s.
$1+j0.2w$	5	A straight line of slope +20dB/decade & originating from $w_{c_1} = 5$.
$\frac{1}{1+j0.05w}$	20	A straight line of slope −20dB/decade & originating from $w_{c_2} = 20$.
$\frac{1}{1+j0.01w}$	100	A straight line of slope −20dB/decade and originating from $w_{c_3} = 100$.

-- 4 Marks

Step 8: Phase Angle plot: The resultant Phase angle is given by ..

$$\phi = \angle G(j\omega)$$

$$= \angle 0^\circ + \angle 1 + j0.2\omega + \angle\left(\frac{1}{j\omega}\right)^2 + \angle\frac{1}{(1+j0.05\omega)} + \angle\frac{1}{(1+j0.001\omega)}$$

$$= 0^\circ - \tan^{-1} 0.02\omega - 180^\circ - \tan^{-1} 0.05\omega - \tan^{-1} 0.001\omega$$

The Phase angles for different Values of frequency are given in table

ω	$\angle\frac{1}{(j\omega)^2}$	$+\tan^{-1} 0.2\omega$	$-\tan^{-1} 0.05\omega$	$-\tan^{-1} 0.01\omega$	ϕ
1	-180°	11.3°	-2.86°	-0.57°	-172.1°
5	-180°	45	-14.03°	-2.86	-151.9°
10	-180°	63.4°	-26.56°	-5.7°	-148.8°
30	-180°	80.5°	-56.3°	-16.7°	-172.5°
50	-180°	84.3°	-68.2°	-26.56°	-190.4°
100	-180°	87.13°	-78.7°	-45°	-216.6°

— 6 Marks

Mark the above points on the Semilog sheet and get the Phase angle plot.

From the Magnitude & Phase angle Bode Plot, it is found that

Gain crossover frequency - ω_{gc} = 7.9 rad/sec.

The phase Margin - PM = + 31.59°.

Phase crossover frequency - ω_{pc} = 37.41 rad/sec.

Gain Margin - GM = + 21.33 dB.

0½ Marks each ⇒ (02) M.

Magnitude plot ⇒ (04) M, Phase Angle plot ⇒ (04) M.

Total = (20) Marks

Approved by

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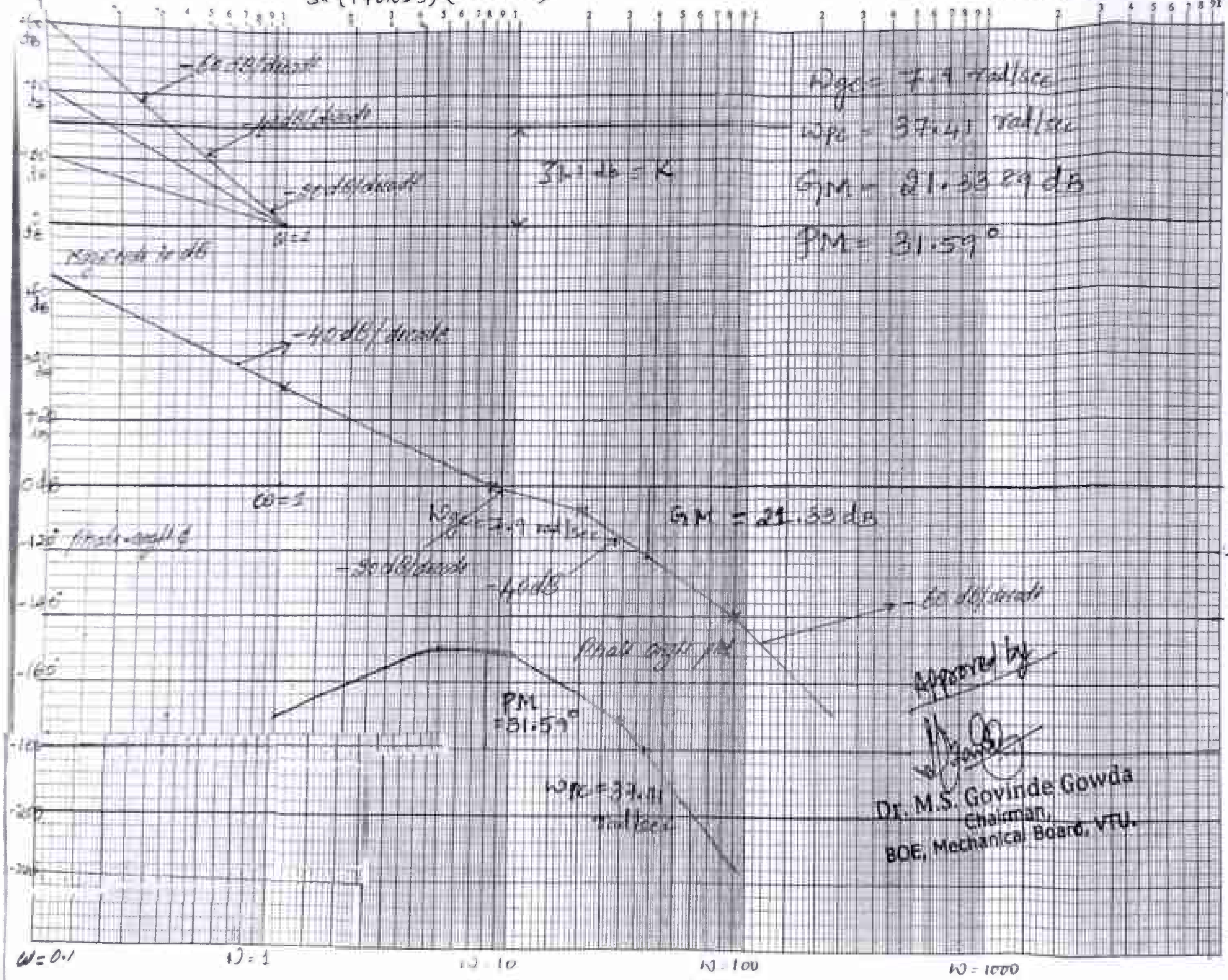
BOE, Mechanical Board, VTU.

Approved

Registrar (Evaluation)
Visveswaraiah Technological University
Belgaum 590 014

$$G(s) = \frac{36(1+0.2s)}{s^2(1+0.05s)(1+0.01s)}$$

SEMI - LOG PAPER (5 Cycles x 1/10)



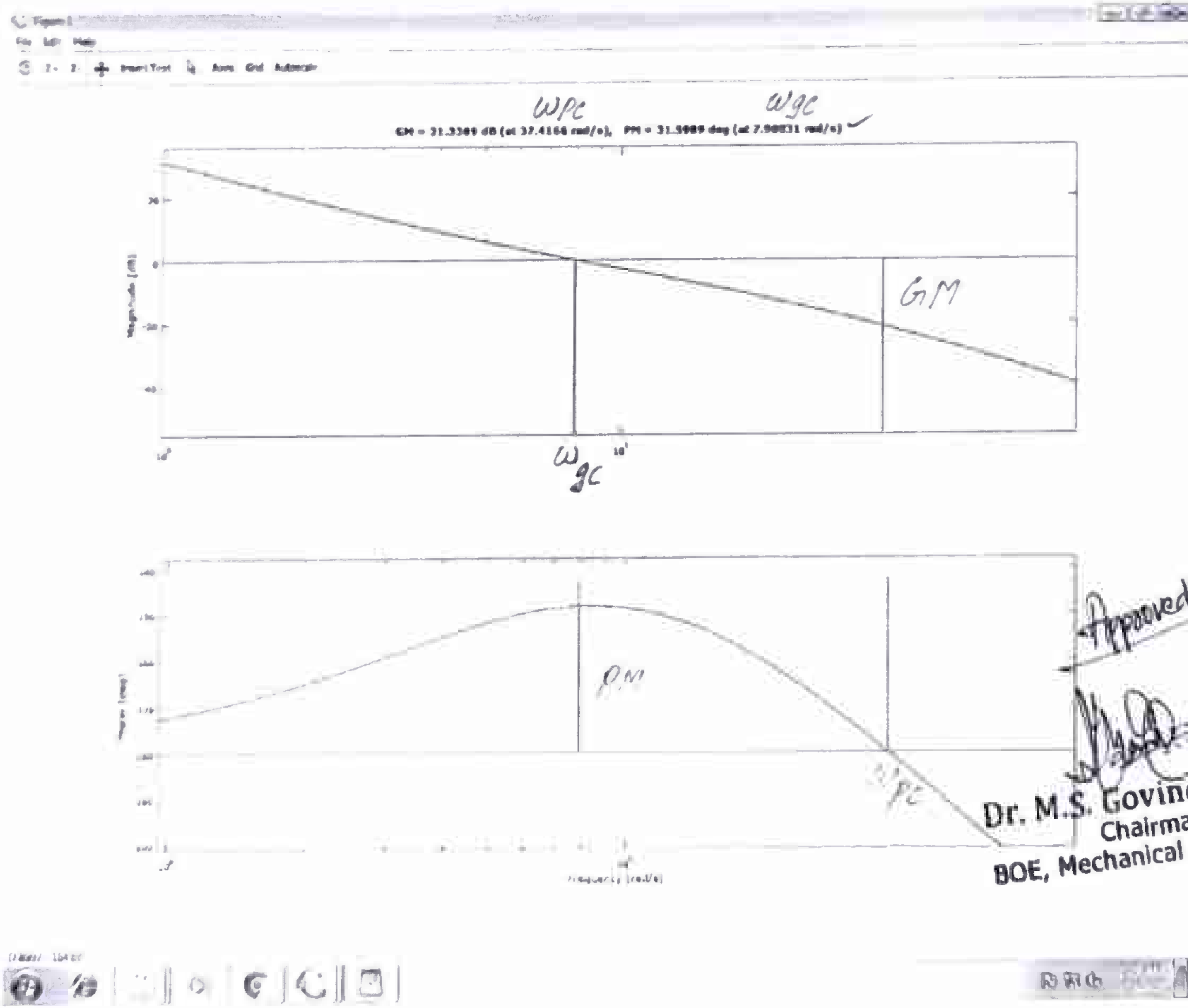
VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

SEMI LOG SHEET

GNU Octave Code

$$G(s) = \frac{36\,(1+0.2s)}{s^2(1+0.05s)(1+0.01s)}$$

```
num = [7.2 36]; %NUMERATOR
den = [0.0005 0.06 1 0 0]; %DENOMINATOR
sys = tf(num, den); %Transfer Function
bode(sys) %Frequency response
margin(sys)
```



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BOE, Mechanical Board, VTU.

Matlab Code and Output

```
clc
clear all;
close all;
num=[7.2 36]
den=[0.0005 0.06 1 0 0]
G=tf(num,den);
[gm,pm wep weg]=margin(G)
bode(G),grid
```

num = 7.2000 36.0000

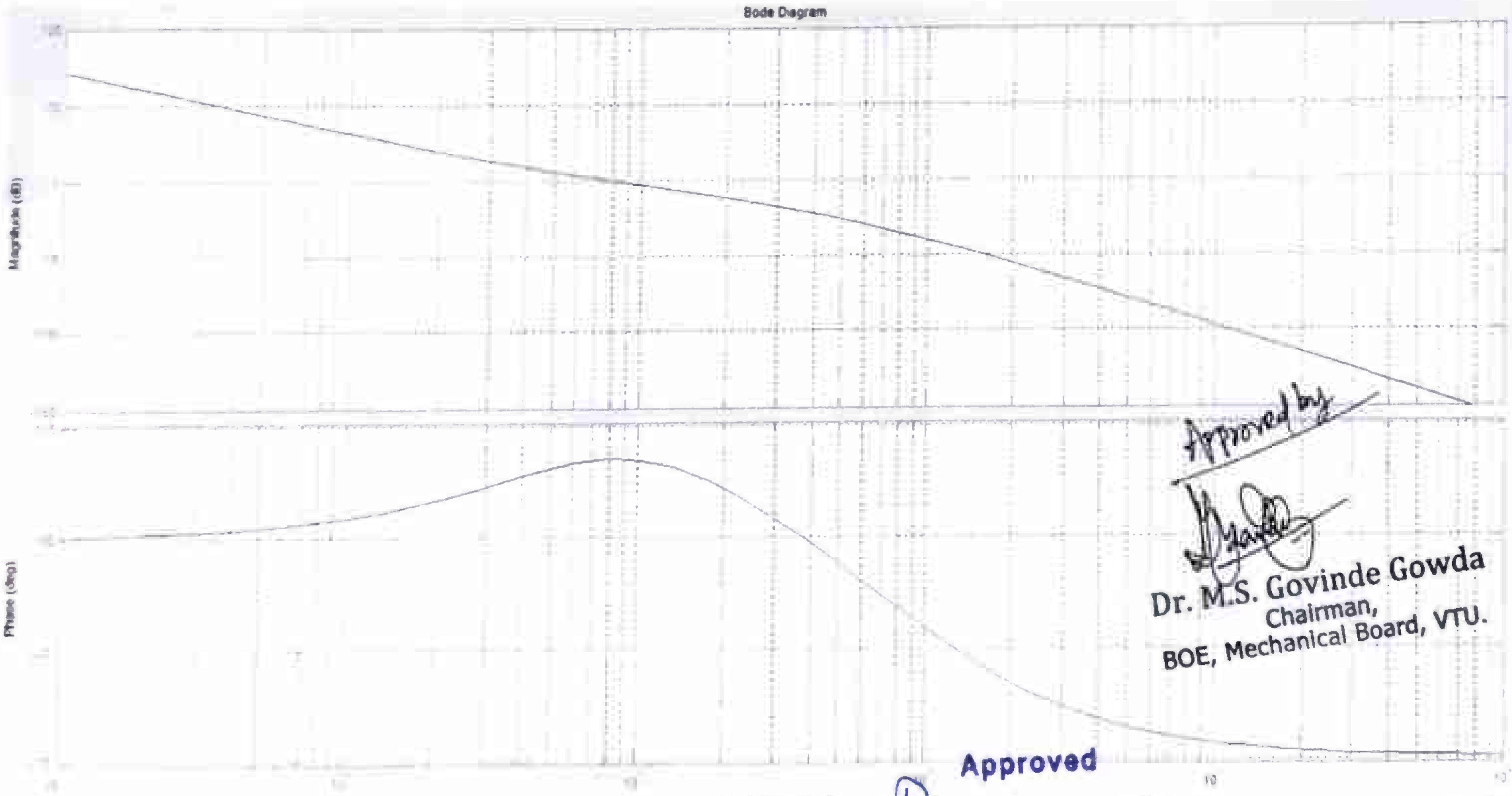
den = 0.0005 0.0600 1.0000 0 0

gm = 21.3376 dB = GM

pm = 31.5989° = PM

wep = 37.4091 rad/s = ω_{pc}

weg = 7.9003 rad/s = ω_{gc}.



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