Bode and Log Magnitude Plots

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Problem 5.1 Bode Magnitude and Phase Plots

Given the transfer function

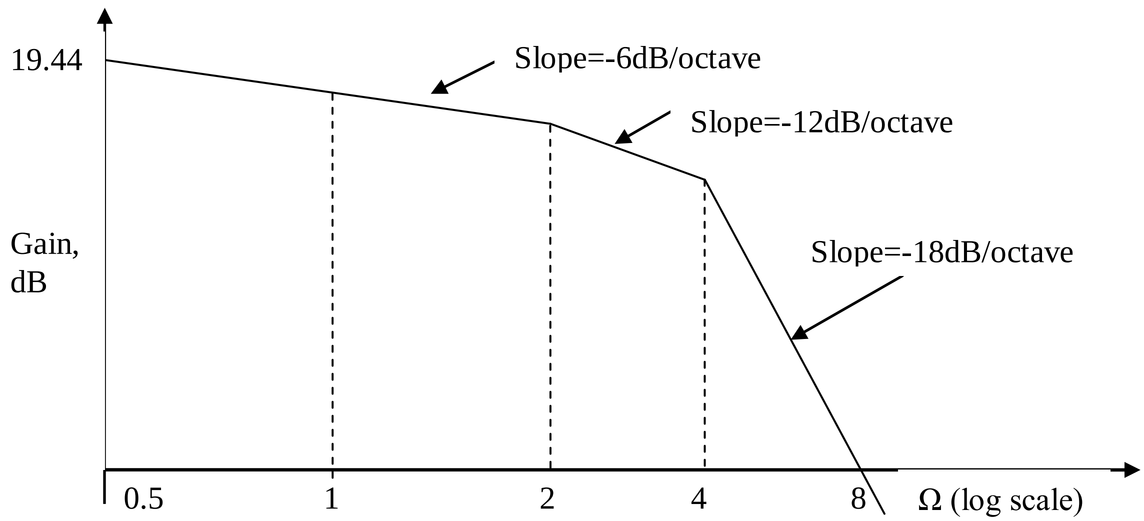
G(s) = 300/[s(s+4)(s+8)]

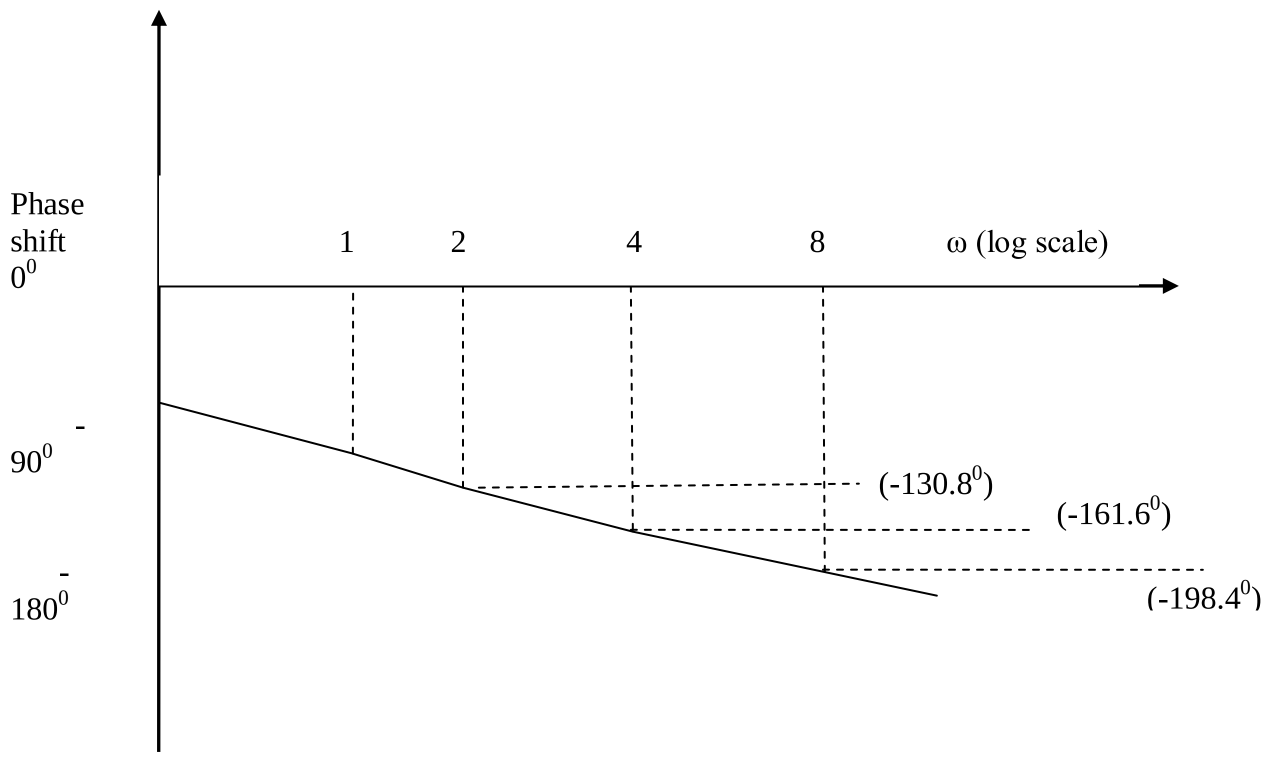
(a) sketch the Bode magnitude and phase plots
(b) sketch the polar plot
(c) sketch the log-magnitude/phase diagram.
(d) Why does using logarithmic co-ordinates reduce the drudgery in plotting the Bode plots considerably?
(e) How are the gain and phase margins determined by using the Bode plots?

Solution:

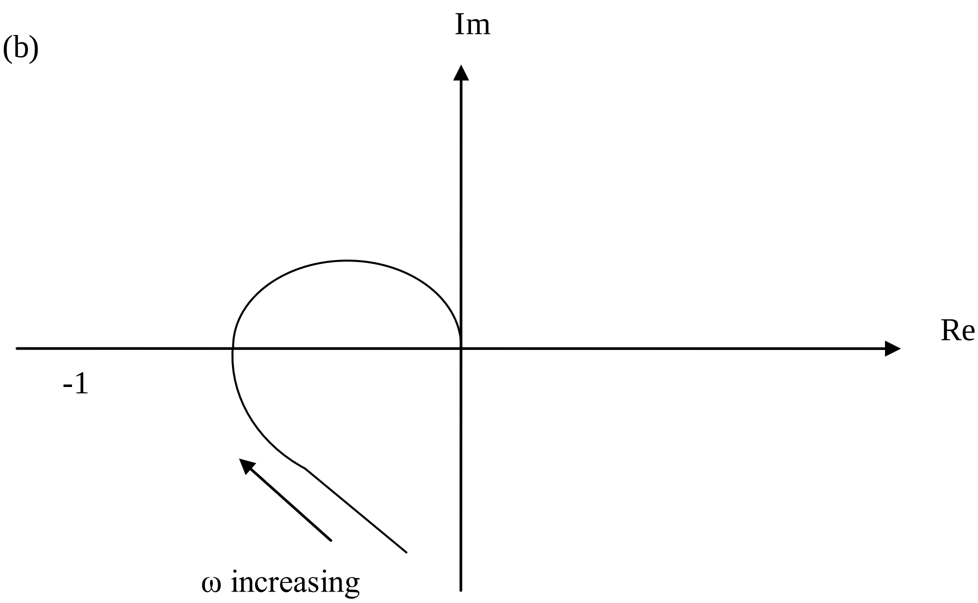
G(s) = 300/[s(s+4) (s+8)] = (75/8)/[s (1+ s/4) (1+s/8)

(a)

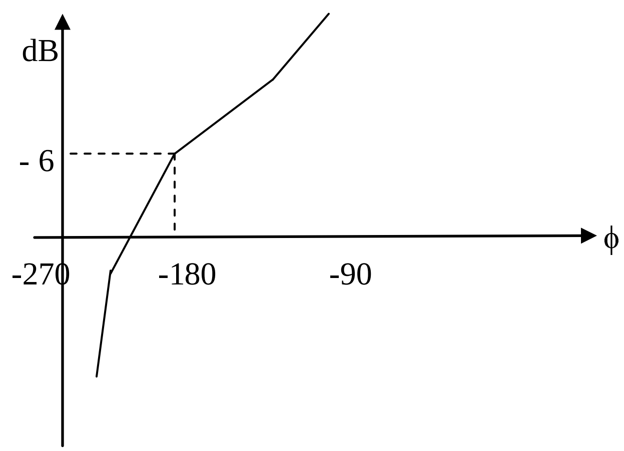

19.44
Slope=-6dB/octave
Slope=-12dB/octave
Slope=-18dB/octave
Gain,
dB
0.5
1
2
4
8
Ω (log scale)


Phase
shift
0⁰
1
2
4
8
ω (log scale)
-
90⁰
(-130.8⁰)
(-161.6⁰)
-
180⁰
(-198.4⁰)

(b)



(c)



(d) Log scale is used for the w axis. The simplification in the Bode plot results due to the basic advantage of logarithmic representation that multiplication and division are replaced by addition and subtraction respectively. There are several other advantages of Bode plots.

(e) Theoretical.

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Problem 5.2 System Gain and Phase Margins & Bandwidths

(a) Obtain the phase and gain margins of a unity feedback system whose open loop transfer function is

G(s) = K/[s(s+1)(s+5)]

for the two cases where K=10 and K =100 respectively.

(b) For the following two systems:

System I:

C(s)/R(s)= 1/(s+1)

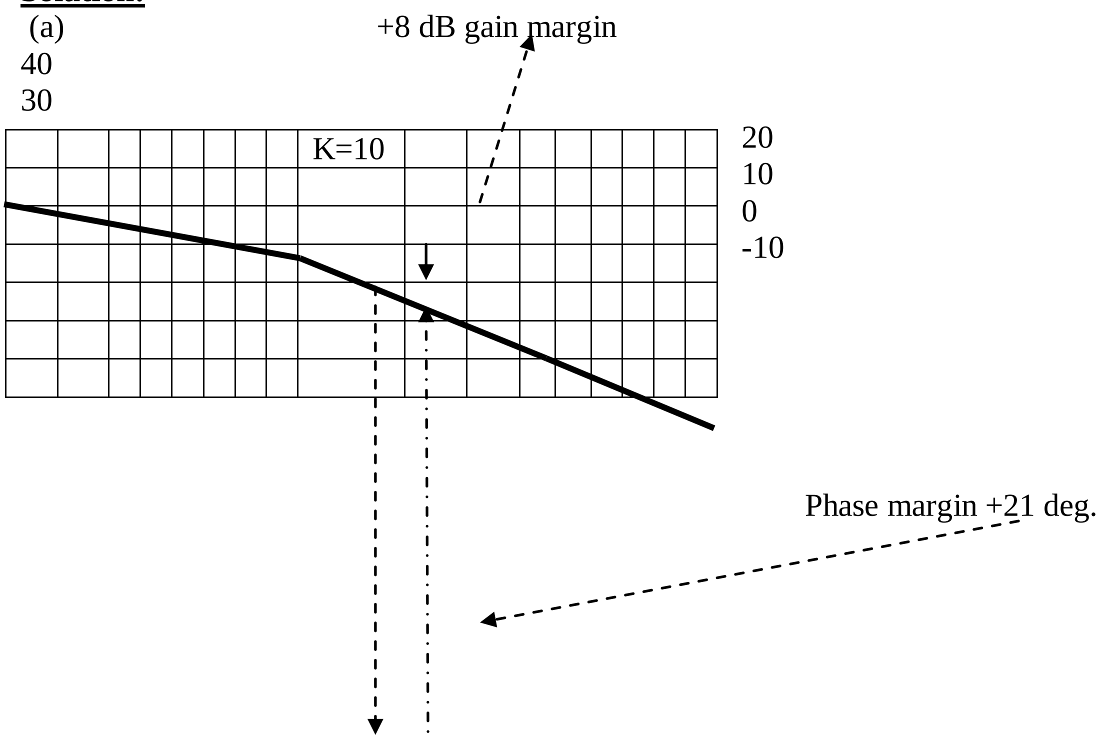
System II:

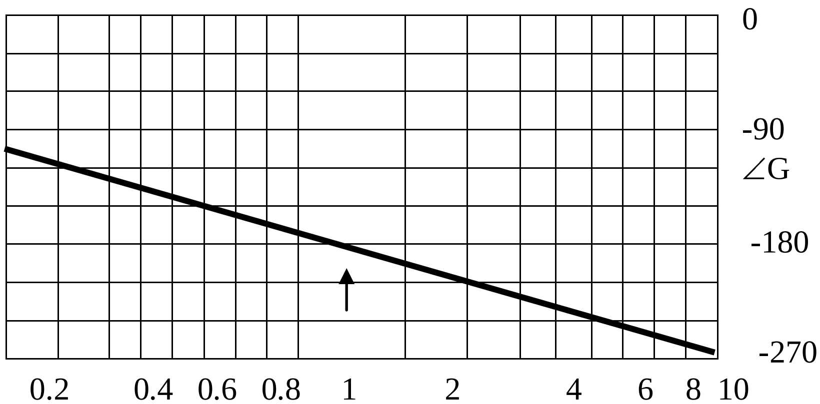
C(s)/R(s) = 1/(3s+1)

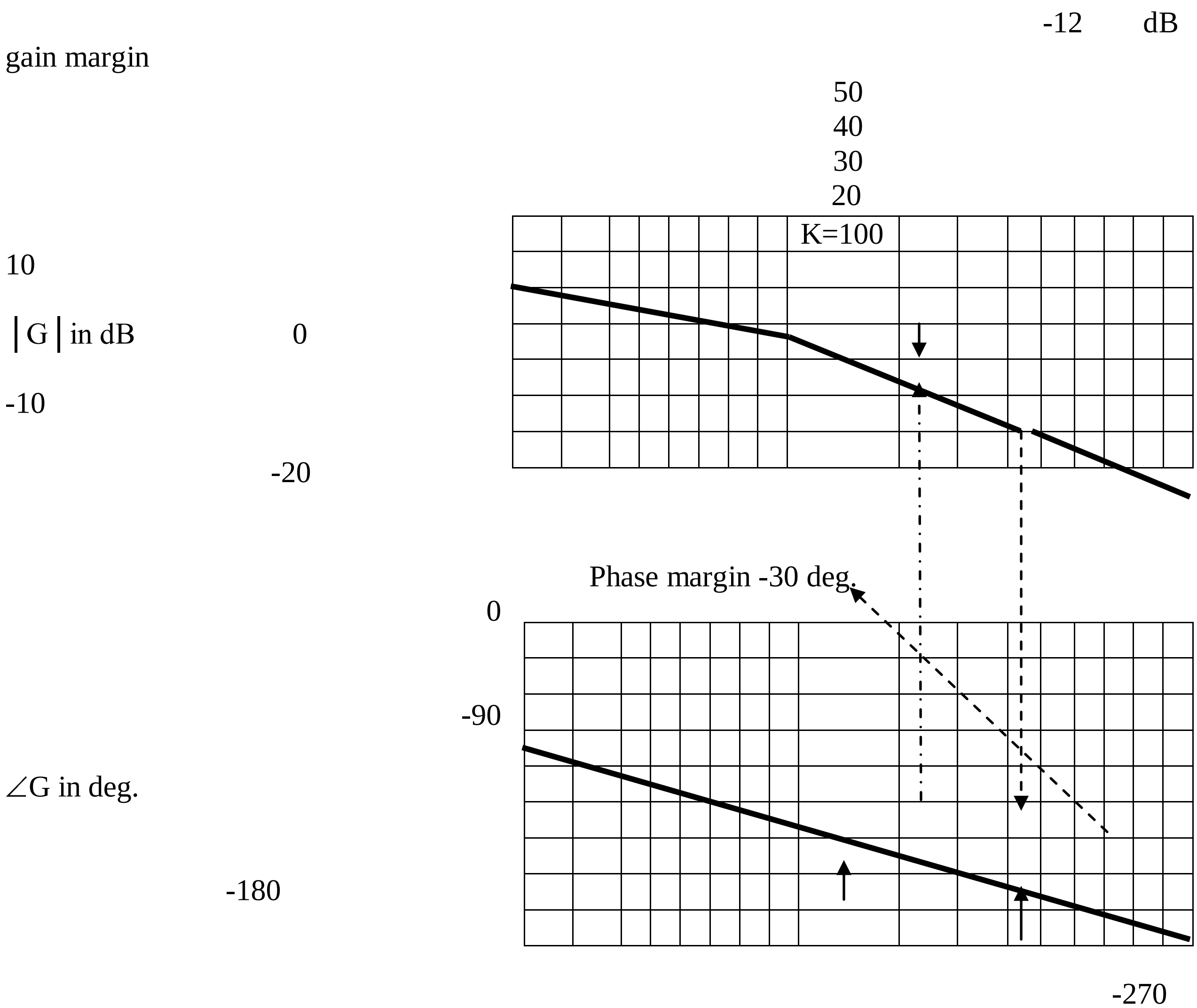
i. Draw the Bode magnitude graphs
ii. Compare the bandwidths of the two systems
iii. Show the step-response and ramp-response curves for the two systems.
iv. Which one of the two systems has a faster speed of response and therefore can follow the input much better?

Solution:

(a)

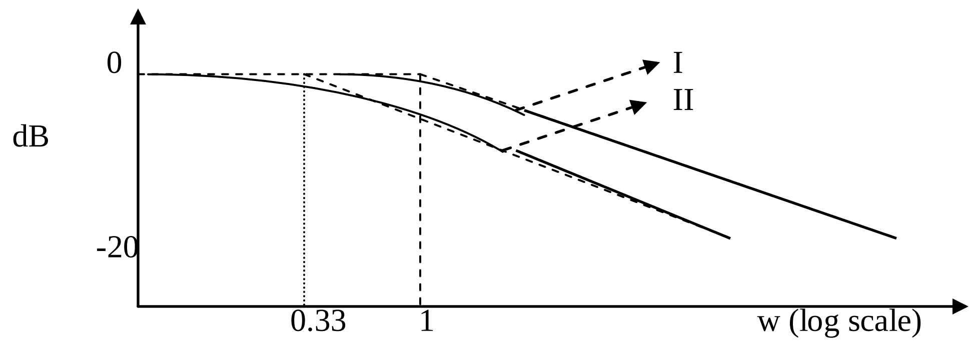



0
-90
∠G
-180
-270
0.2
0.4
0.6
0.8
1
2
4
6
8
10


-12 dB
gain margin
50
40
30
20
K=100
10
|G| in dB
0
-10
-20
Phase margin -30 deg.
0
-90
∠G in deg.
-180
-270

0.2 0.4 0.6 0.8 1 2 4 6 8 10

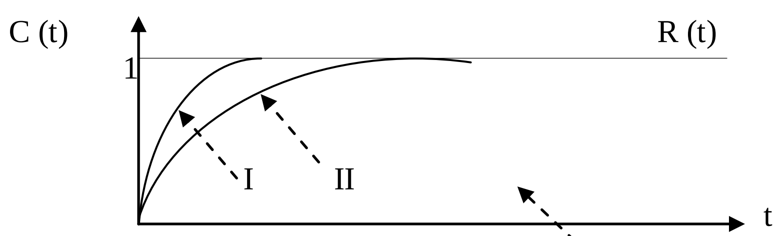
(b) (i)



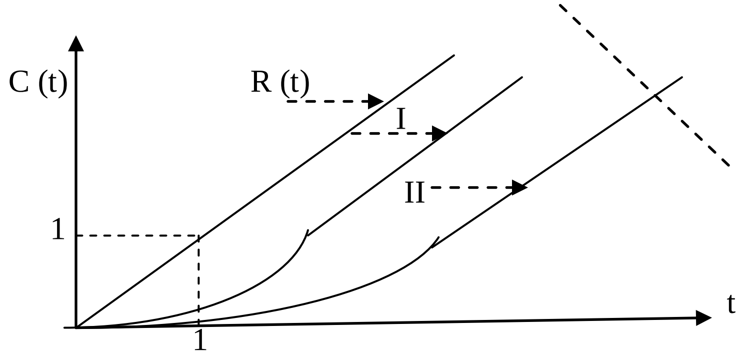
The above figure shows the closed loop response curves for the two systems (Asymptotes are shown by dotted lines)

(ii) System I: Bandwidth is $0 \leq w \leq 1$ rad/s
System II: Bandwidth is $0 \leq w \leq 0.33$ rad/s

(iii)



The above Figure shows the step response curves of the two systems



The above Figure shows the ramp response curves of the two systems.

(iv) System I whose bandwidth is three times wider than that of system II has a faster speed of response and can follow the input much better.

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Problem 5.3 Polar Plot and Bode Diagrams

(a) Sketch the polar plot of the frequency response for the following transfer function at ω = 0, 1, 5…infinity:

$$GH(s) = \frac{1}{(1+0.5\,s)\,(1+2s)}$$

(b) Draw the Bode diagram representation of the frequency response for the transfer function given in Part (a). Show the points on the diagram at ω =0.5, 1, 2, 8, and so on.

Solution:

(a)

ω	0	1	5	∞
|GH|	1	0.4	0.037	0
ϕ	0^0	-90^0	-153^0	-180^0

(b)

ω	0.5	1	2	8
dB	-3.27	-8	-15.3	-36.4
ϕ	-59^0	-90^0	-121^0	-162^0

The polar plot and Bode diagrams can be plotted from the above calculations.

Problem 5.4 Transfer Function from Bode Plots

The frequency response of a control system is given in Table 1. Sketch the Bode plots and hence estimate the transfer function.

Table 1

ω	M (dB)	ϕ	ω	M (dB)	ϕ
0.1	20.0	-90.3^0	10	-14	-180^0
0.2	14.0	-90.3^0	15	-26.8	-239^0
0.4	8.0	-90.3^0	20	-36	-252^0
0.6	4.46	-90.3^0	30	-47.8	-259^0
1	0.08	-90.3^0	40	-55.6	-262^0
2	-5.71	-90.3^0	50	-61.6	-264^0
4	-10.77	-90.3^0	60	-66.5	-265^0
6	-12.55	-90.3^0	80	-74.1	-266^0
8	-12.7	-90.3^0	100	-79.9	-267^0

Solution:

Draw the magnitude and phase plots.

As ω tends to zero, ϕ tends to infinity. Hence, we have one pole at the origin. For large ω, ϕ tends to –270 deg. Hence the excess of poles over zeroes is three.
A rapid change in ϕ near ω = 10 indicates a pair of complex conjugate poles with ω_n= 10. Since ϕ = -180deg. For ω= 10, we have ω_n= 10. Thus
$G(s)= K/[s\ (s^2+2\xi\omega_{n+}\omega_n^{2)}]$
As the gain approaches 0 dB foe small values of ω, we have $K=\omega_n^2= 100$.
For ω= 10, s=j10, hence
G (j10) = 0.1/2$\xi\angle$180deg. The gain for ω= 10 is –14 db or $10^{-14/20}$=0.2
Or, ξ= 0.25
Hence G(s)= 100/[(s $(s^2+5s+100)$)]

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Problem 5.5 Bode Plots of Open Loop and Closed Loop Systems

(a) The block diagram of a speed-control system is shown in Fig.1.

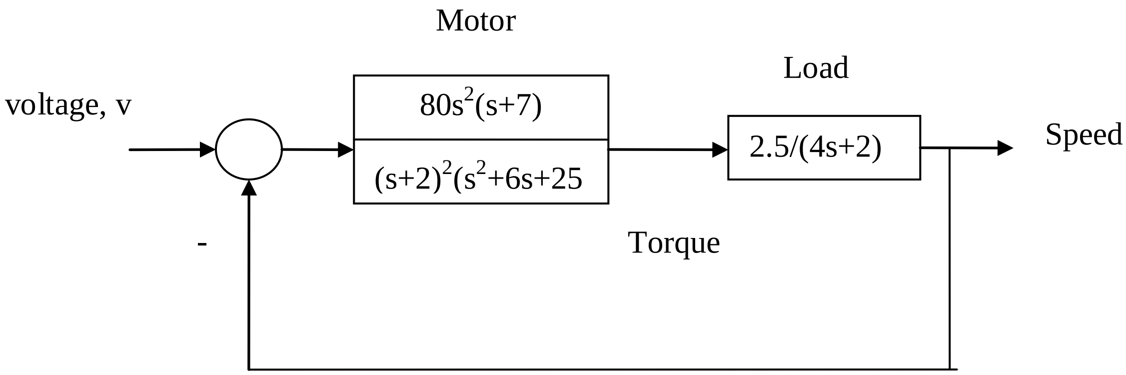
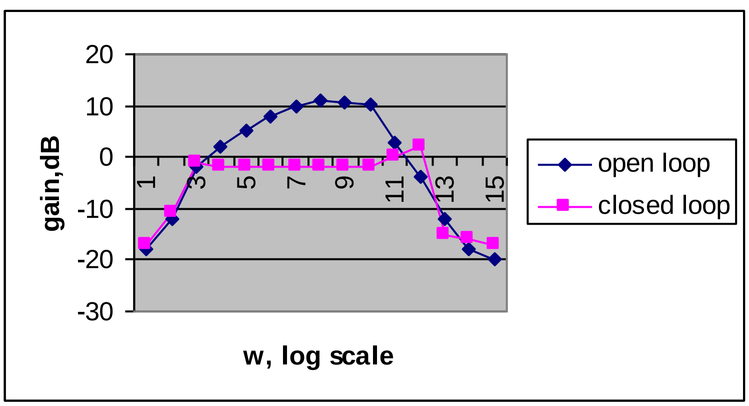
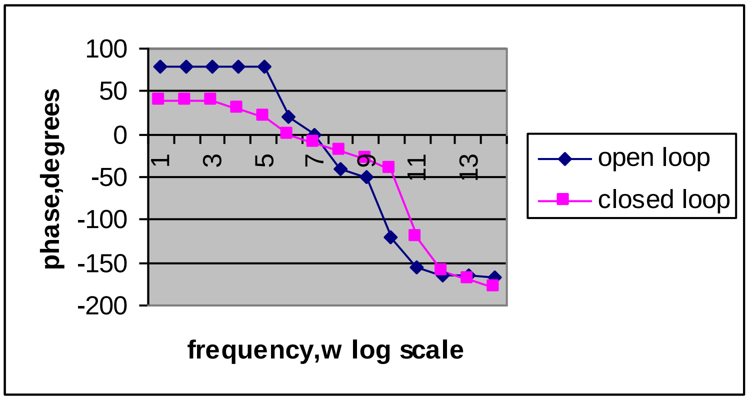


Fig.1

Draw and label the Bode magnitude and phase plots of the open-loop and the closed- loop systems.

(b) State the practical use of the Bode plots.





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Objective type questions:

(i) The desirable frequency- domain specifications for a control system are:

(a) relatively large resonant magnitude, M_{pw}
(b) relatively large bandwidths so that the system time constant, $\tau = 1/\xi\omega_n$, is sufficiently small
(c) relatively small resonant magnitude, M_{pw}
(d) relatively large bandwidths so that the system time constant, $\tau = 1/\xi\omega_n$, is sufficiently large

Ans:(b)

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