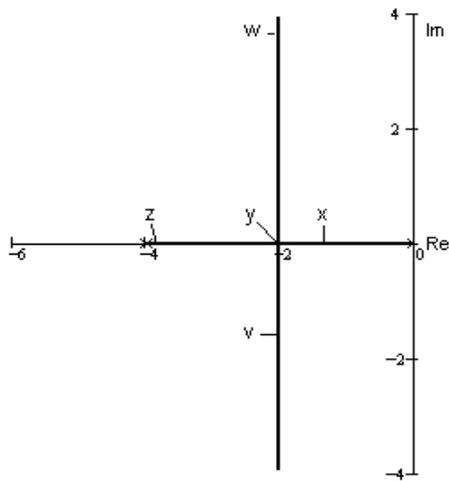


# ECE 3510 Exam 3 given: Spring 07

1. (17 pts) Each root-locus plot below shows a number of closed-loop pole locations labeled "a", "b", "c", etc.. Each plot has at least two poles. In answering the questions below consider all the closed-loop poles, not just the pole at the labeled location. That is, consider where the other pole(s) are when the gain places the labeled pole at the labeled location.

- List the closed-loop pole locations (labeled "a", "b", "c", etc.) in order of speed of step response, **regardless of overshoot**. List them slowest to fastest.
- List the pole locations which would result in a step response with absolutely no overshoot.
- List the closed-loop pole locations (not listed in part b) in order of % overshoot. List them least to most.

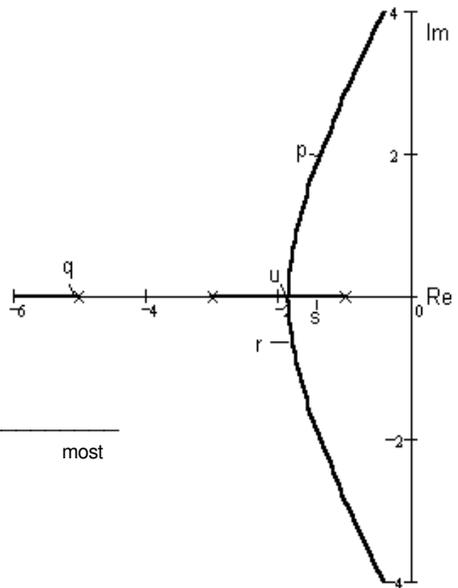


For the root locus at left:

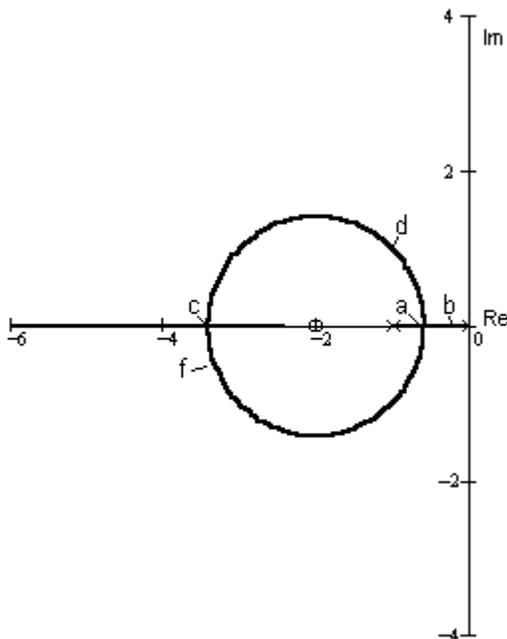
- \_\_\_\_\_ slowest \_\_\_\_\_ fastest
- \_\_\_\_\_ absolutely no overshoot \_\_\_\_\_ least overshoot \_\_\_\_\_ most

For the root locus at right:

- \_\_\_\_\_ slowest \_\_\_\_\_ fastest
- \_\_\_\_\_ absolutely no overshoot



- \_\_\_\_\_ least overshoot \_\_\_\_\_ most



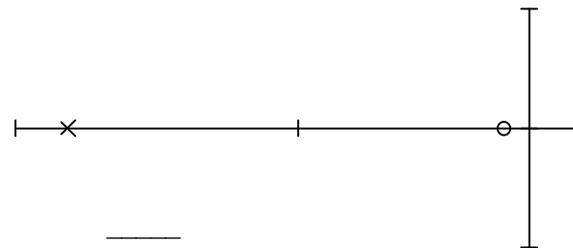
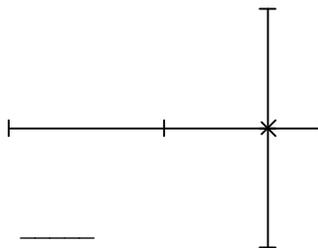
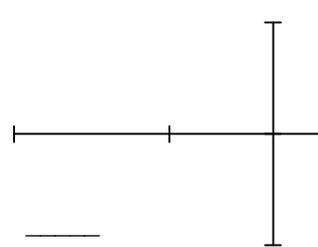
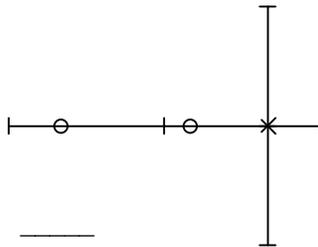
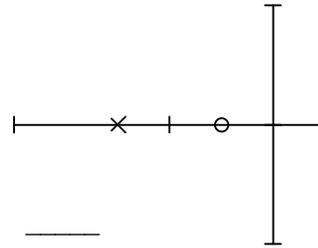
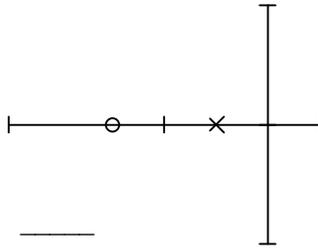
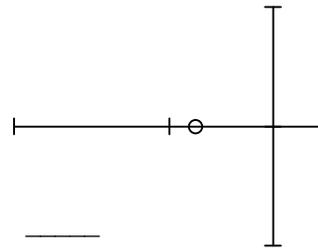
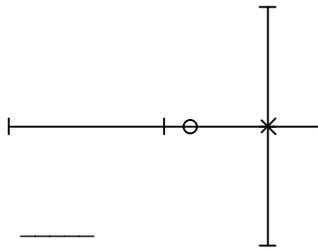
For the root locus at left:

- \_\_\_\_\_ slowest \_\_\_\_\_ fastest
- \_\_\_\_\_ absolutely no overshoot \_\_\_\_\_ least overshoot \_\_\_\_\_ most

2. (14 pts) Each of the pole-zero diagrams below represent a controller or compensator. Identify each of them with the possible answers listed.

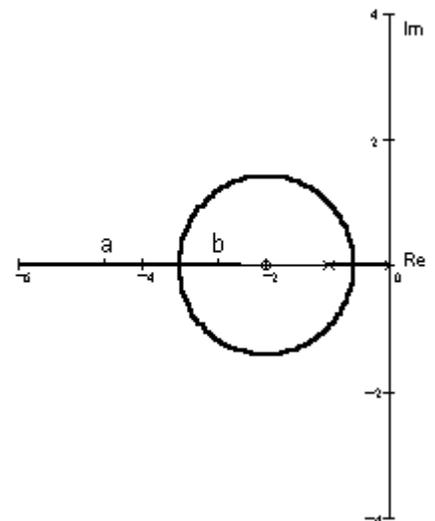
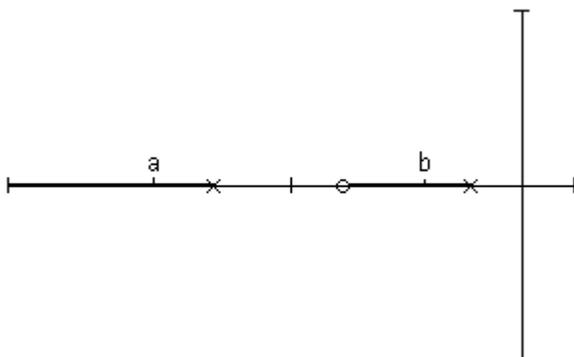
**ECE 3510 Exam 3 Spring 07 p2**

Listed below are the possible answers. You may use some answers more than once. Some answers may not be used at all.

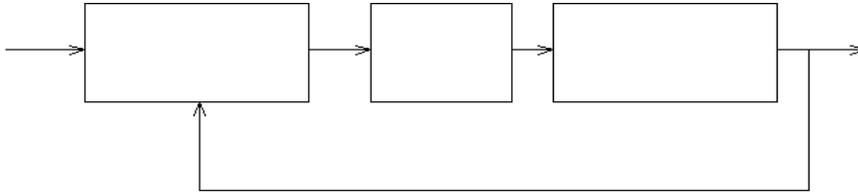


- P
- PD
- PI
- I
- PID
- Lag
- Lead
- Zig
- Zag
- Over
- Under
- Mickey
- Mouse

3. (4 pts) In the root locus plots shown below, the gain has been adjusted so the the closed-loop poles are at the positions marked "a" and "b". Circle the dominant pole in each case.

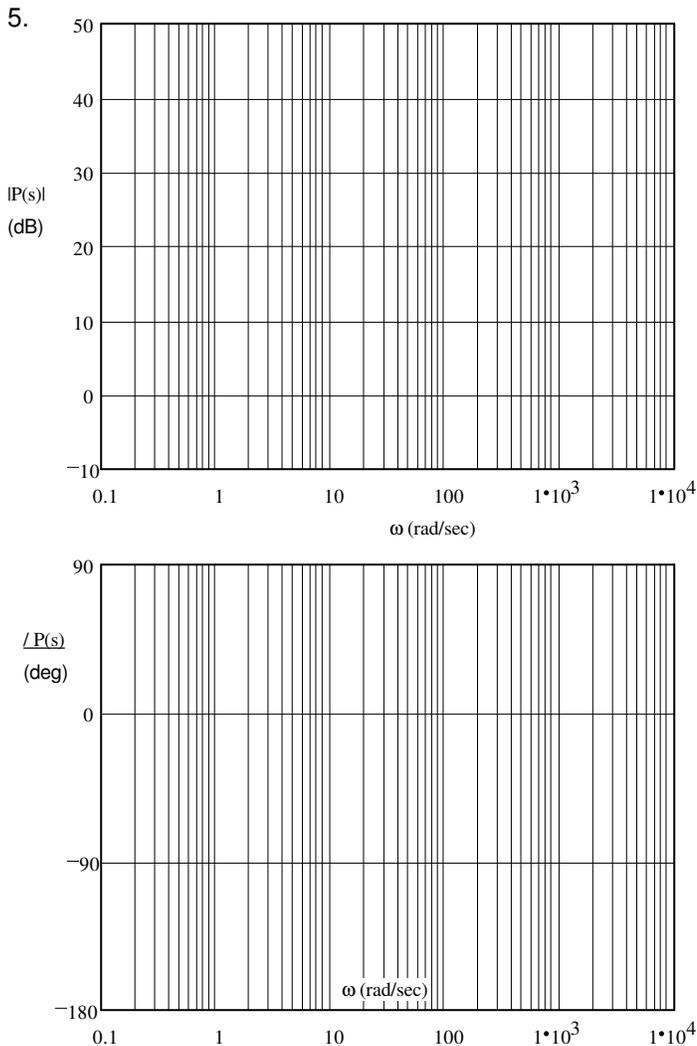


4. (5 pts) Identify the blocks (in words) in the phase-locked-loop shown below. **ECE 3510 Exam 3 Spring 07 p3**

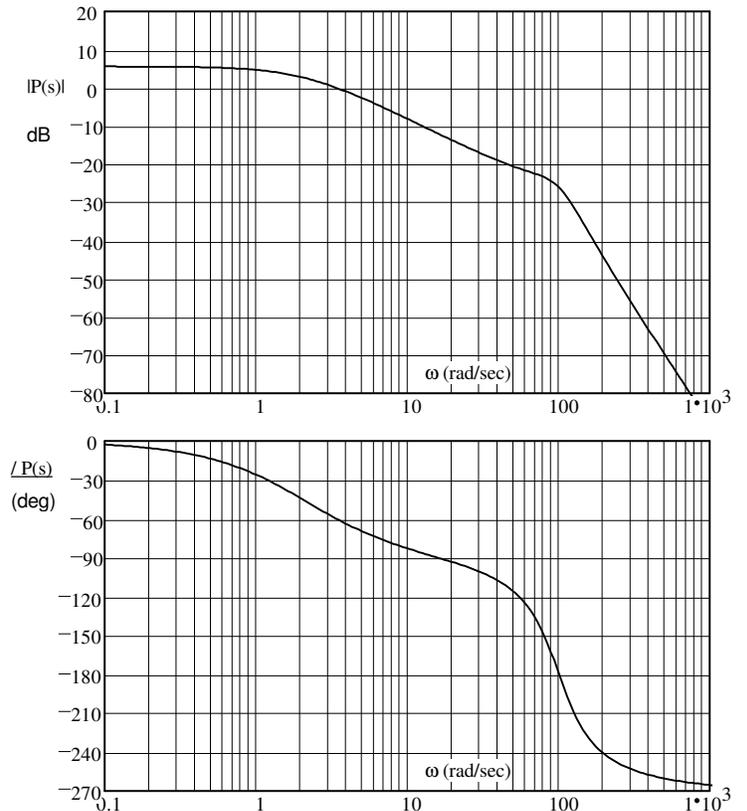


5. (20 pts) Sketch the Bode plots for the following transfer function. Make sure to label the graphs, and to give the slopes of the lines in the magnitude plot. Also draw the "smooth" lines.

$$P_a(s) = \frac{s \cdot (s + 2000)}{(s + 4) \cdot (s + 100)}$$

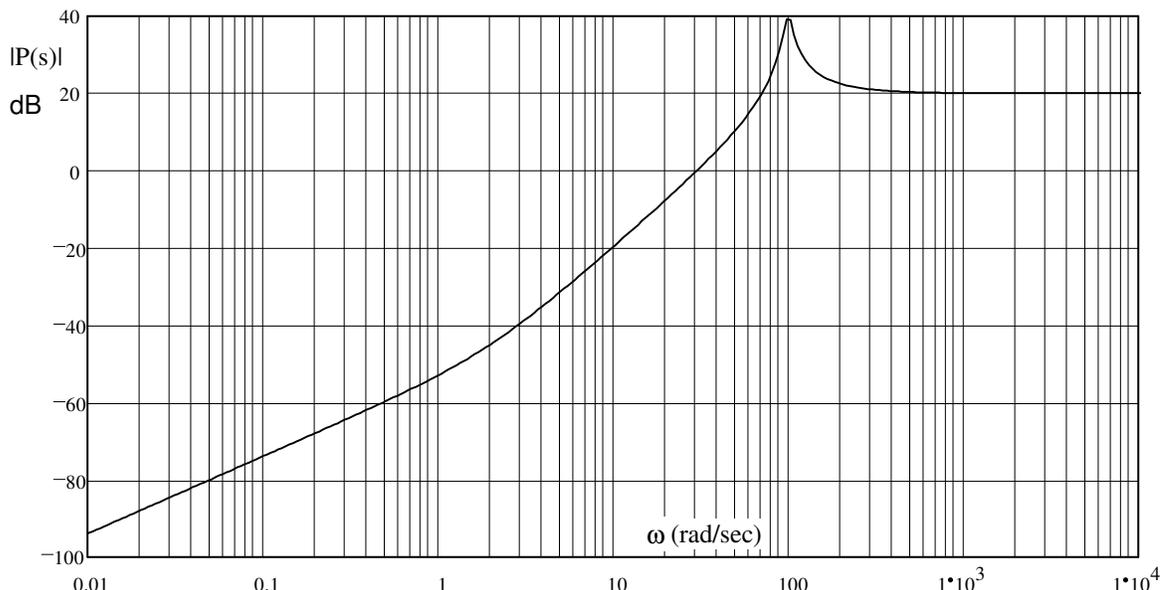


6. (7 pts) The system whose Bode plots are given at right is stable in closed-loop. Find its gain margin and phase margin. Show your work on the drawings.



Some Bode plot information is shown on the last page of the exam

7. (14 pts) Given the magnitude Bode plot of a system, estimate of the transfer function of the system. Assume there are no negative signs in the transfer function (all poles and zeros are in the left-half plane). Show your work (how you made your estimate).

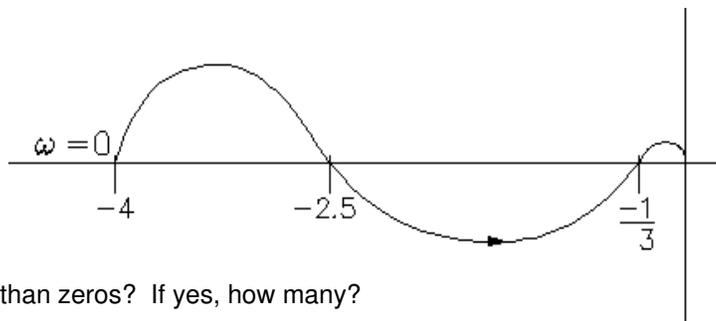


8. (9 pts) A Nyquist curve is shown at right (only the portion for  $\omega > 0$  is plotted).

a) Knowing that the closed-loop system is stable, how many unstable poles could the open-loop system have?

b) What is (are) the gain margin(s)?

c) Does the open-loop system have more poles than zeros? If yes, how many?



9. (17 pts) All parts of this problem refer to the system whose Nyquist curve is shown at right (only the portion for  $\omega > 0$  is plotted). Recall that the Nyquist curve represents the frequency response of the open-loop system, or  $G(j\omega)$ . If  $G(s)$  is the open-loop transfer function. The closed-loop transfer function is  $G(s)/(1 + G(s))$ .

The open-loop system is stable.

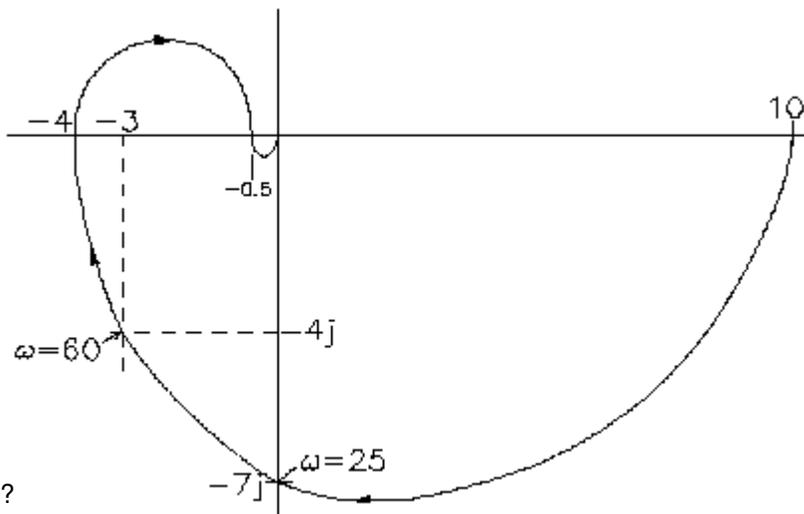
a) Can the closed-loop system be stable?

Show why or why not.

b) Could the closed-loop system be stable if the gain were increased by a factor of 4?

Show why or why not.

c) Give the steady-state response  $y_{ss}(t)$  of the open-loop system to an input  $x(t)=3\cos(25t)$ .



9, continued. The gain is reduced by a factor of 5 (multiplied by 0.2) for the remainder of this problem.

d) Is the closed-loop system stable now?

Show why or why not.

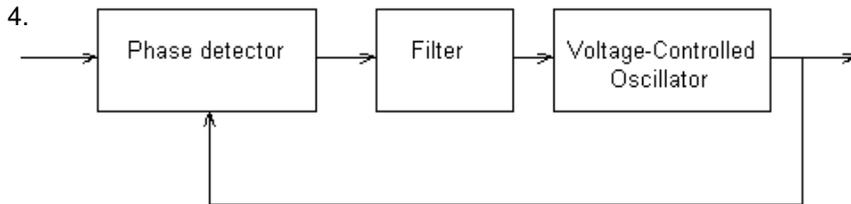
e) Estimate the phase margin of the closed-loop system.

f) Give the steady-state response  $y_{ss}(t)$  of the closed-loop system to an input  $x(t) = 9$

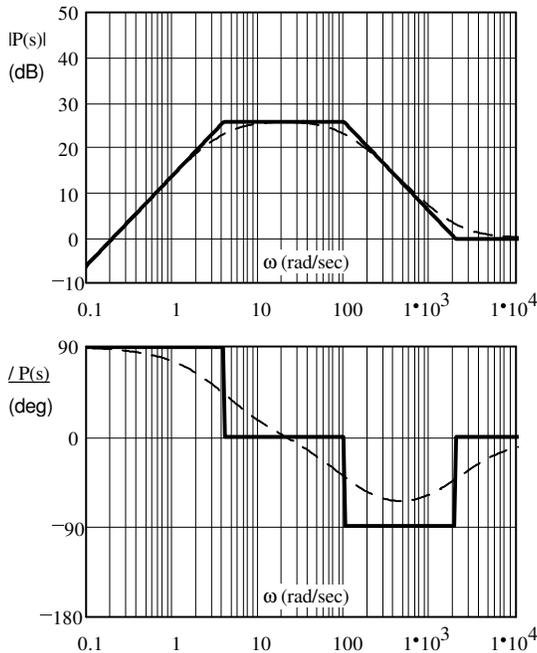
**Answers**

- 1.1 a) z x y v w    b) z y x    c) v w  
 1.2 a) q s u r p    b) q u s    c) r p  
 1.3 a) b a d c f    b) c a b    c) f d

2. PI    PD    3. a a  
 Lag    Lead  
 PID    P  
 I    Lead



5.



6. GM := 25·dB    PM := 120·deg

7. 
$$P(s) = \frac{10 \cdot s \cdot (s + 2)}{(s^2 + 10 \cdot s + 10000)}$$

8. a)  $P_{max} := 1$

b)  $\frac{1}{2.5} = 0.4 < \text{gain} < \frac{1}{\left(\frac{1}{3}\right)} = 3$

c) yes, approach angle is  $-270^\circ$     so:  $n - m = 3$

9. a)  $N := 2$      $P$  cannot be negative    No  
 b)  $N := 0$     Yes, it would be stable since     $P := 0$   
 c)  $21 \cdot \sin(25 \cdot t)$   
 d) Yes     $N := 0$      $Z := N + P$      $Z = 0$   
 e)  $90 \cdot \text{deg} - \text{atan}\left(\frac{3}{4}\right) = 53.13 \cdot \text{deg}$   
 f)  $\frac{2}{1+2} \cdot 9 = 6$

ECE 3510 Exam 3 Arn Stolp

Name \_\_\_\_\_

Scores:

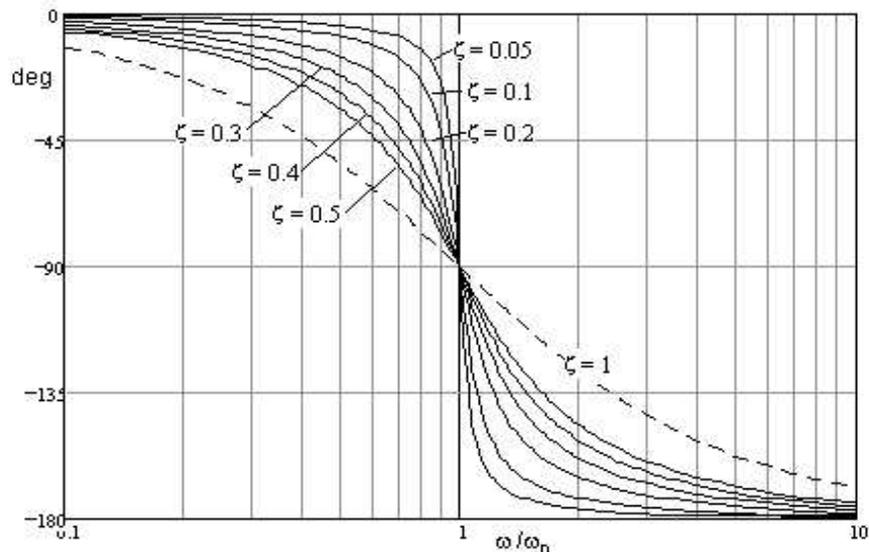
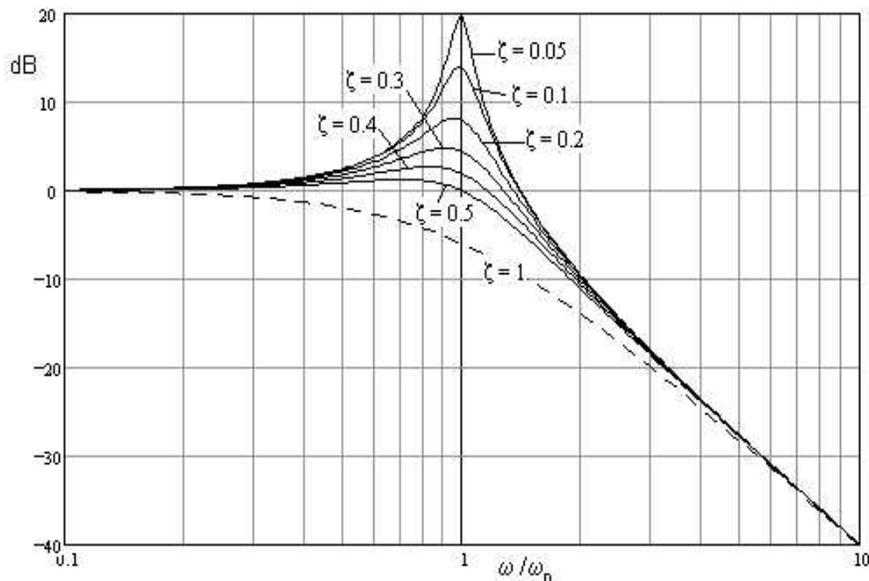
Pages 1&2 \_\_\_\_\_ of a possible 38 pts

Pages 3&4 \_\_\_\_\_ of a possible 36 pts

Page 5&6 \_\_\_\_\_ of a possible 26 pts

Total \_\_\_\_\_ of a possible 100 pts

# Information



$$2 = 6 \cdot \text{dB}$$

$$\frac{1}{2} = -6 \cdot \text{dB}$$

$$5 = 14 \cdot \text{dB}$$

$$4 = 12 \cdot \text{dB}$$

$$10 = 20 \cdot \text{dB}$$

Add dB to multiply numbers

inverse tangents

$$\text{atan}\left(\frac{1}{4}\right) = 14 \cdot \text{deg}$$

$$\text{atan}\left(\frac{1}{3}\right) = 18.4 \cdot \text{deg}$$

$$\text{atan}\left(\frac{1}{2}\right) = 26.6 \cdot \text{deg}$$

$$\text{atan}\left(\frac{1}{1}\right) = 45 \cdot \text{deg}$$

$$\text{atan}\left(\frac{2}{1}\right) = 63.4 \cdot \text{deg}$$

$$\text{atan}\left(\frac{3}{4}\right) = 36.9 \cdot \text{deg}$$

$$\text{atan}\left(\frac{4}{3}\right) = 53.1 \cdot \text{deg}$$

$$(s^2 + 2 \cdot \zeta \cdot \omega_n \cdot s + \omega_n^2)$$

natural frequency  $\omega_n = \sqrt{\omega_n^2}$

damping factor:  $\zeta = \frac{2 \cdot \zeta \cdot \omega_n}{2 \cdot \omega_n}$

if complex pole is expressed:

$$[(s+a)^2 + b^2]$$

natural frequency  $\omega_n = \sqrt{a^2 + b^2}$

damping factor  $\zeta = \frac{a}{\omega_n}$

At  $\omega_n$  the actual magnitude is:

$$\frac{1}{2 \cdot \zeta} \quad \text{in dB: } 20 \cdot \log\left(\frac{1}{2 \cdot \zeta}\right)$$