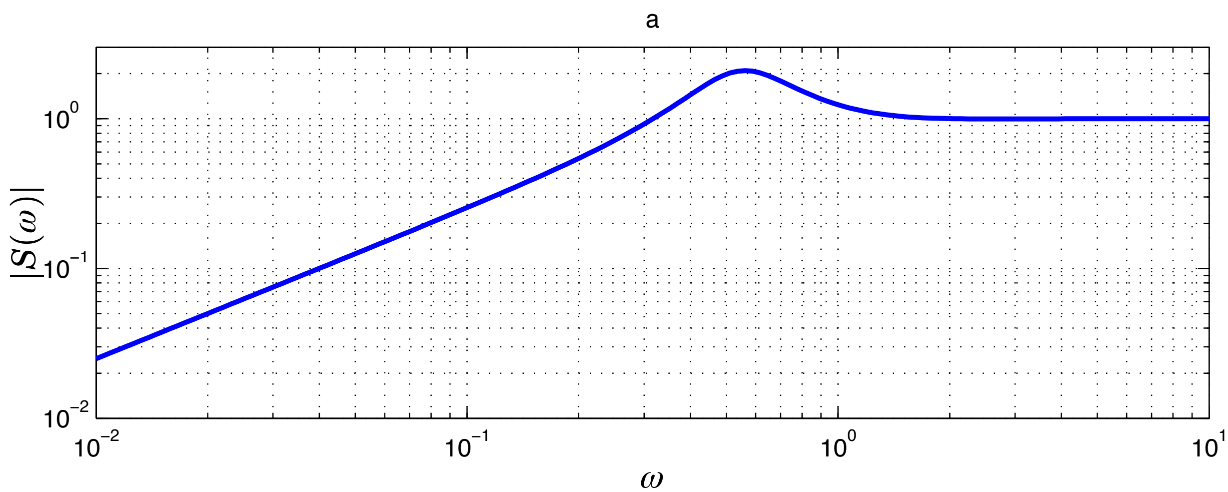
Due Friday 5/25 by 5 pm in the ME 155A drop box at the north east corner of ENG II, 2nd floor

1. The figure below shows the gain curves for the sensitivity function $S := \frac{1}{1+PC}$ for a unity feedback control system used for precision machining. The requirements are that the steady state response between reference and output should have a precision better than 1%. Give a the frequency range where this can be guaranteed.

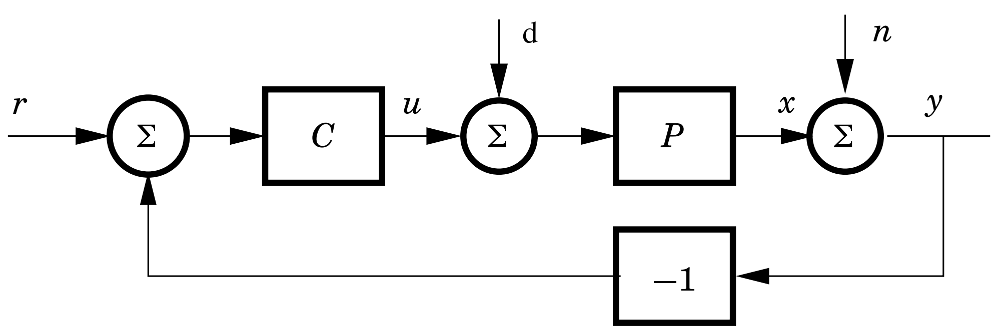
   Recall that in a unity feedback configuration, $1/(1+PC)$ is the transfer function from reference signal to the tracking error signal.



   You may have to extend the frequency response shown above in the low frequency range. Not that in that range, the plot is essentially a straight line, thus easy to extend.

2. *For this problem, it will help to review the additional material in HW 4 Solutions, Problem 1.*

   The figure below shows feedback control system with reference signal r, disturbance signal d and measurement noise n.



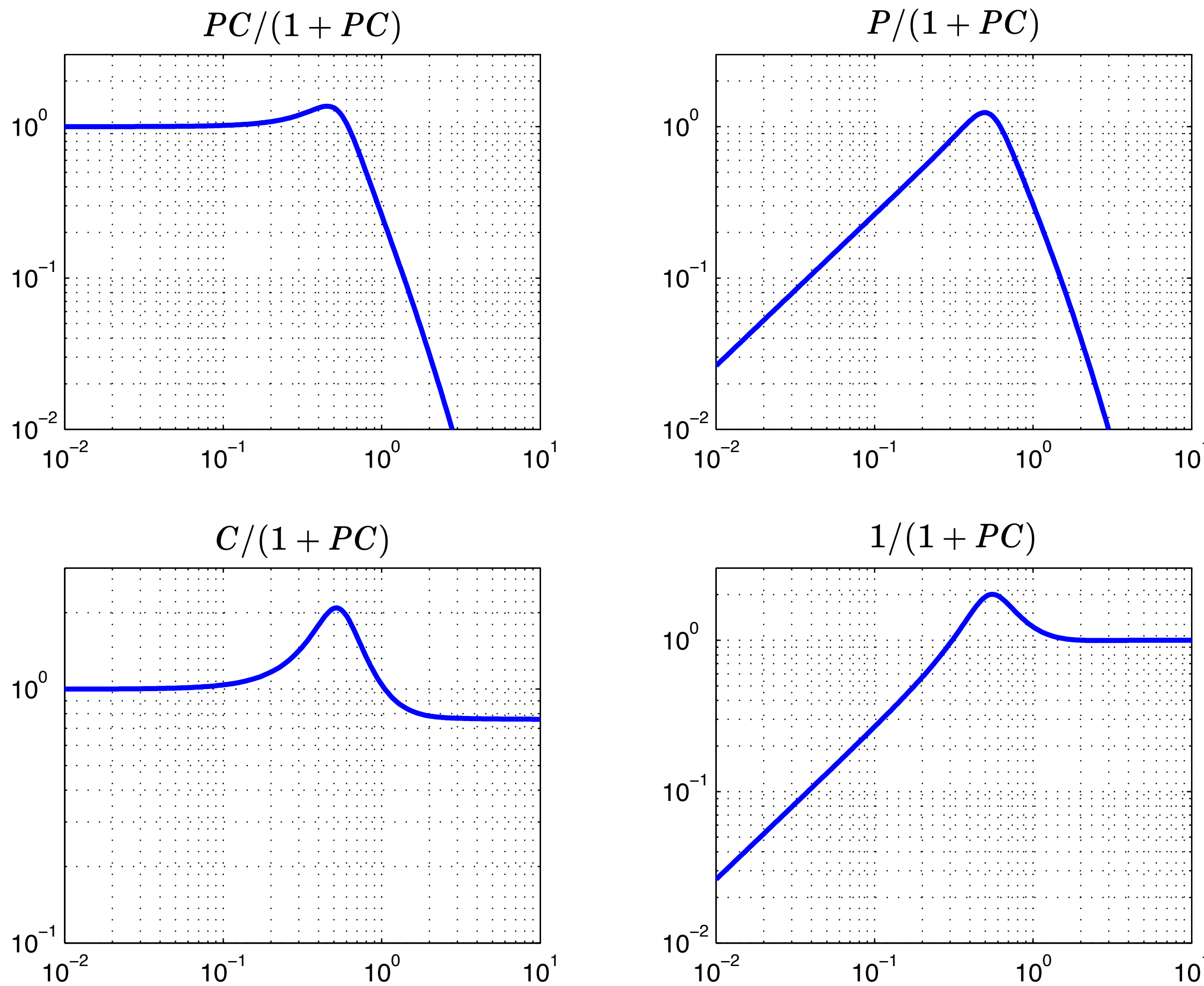
   The process has the transfer function

$$P(s) = \frac{1}{(s+1)^4}.$$

   and the controller is a PI controller with error feedback,i.e.

$$C(s) = k + \frac{k_i}{s}.$$

   The controller parameters are $k = 0.76$ and $k_i = 0.38$. The magnitude Bode plots of the four relevant transfer functions are shown below.



Many properties of the closed loop system such as effects of disturbances, measurement noise and process variations, can be determined from these curves. Answer the following questions.

a. Give the frequency ranges where the closed loop system reduces the effect of disturbances on the output by more that 50% compared to the open loop system.
The disturbance response of the open loop system assumes that the disturbance d enter the process P and we measure their effect on the output y with no controller in feedback, i.e. $C = 0$. So this is simply the frequency response of P. This assumes that the desired reference value for y is 0. It will be helpful to draw the bode plots of P and the relevant closed loop transfer function on the same plot and compare the two.

b. What is the largest amplification of disturbances to output (over all frequencies) of the feedback system?

c. Give the frequency range where the system follows reference signals well. (with e.g. at most 10% error)

d. Assume that there is high frequency measurement noise with frequencies above 2 rad/s with an amplitude of 0.1. How large are the variations in in the control signal caused by the noise?

3. Problem B-7-3 from Ogata. Plot both Bode plots side-by-side (i.e. 2 subplots) to more easily compare them. Explain the similarities and the differences. Keep in mind that a phase of 360° equals a phase of 0°. Matlab will sometimes start the phase plot at multiplies of 360° rather than 0°.