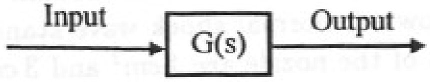
1. An open loop system of the general form shown below is subjected to a step input of magnitude 2.5. The output response is shown in the figure below.



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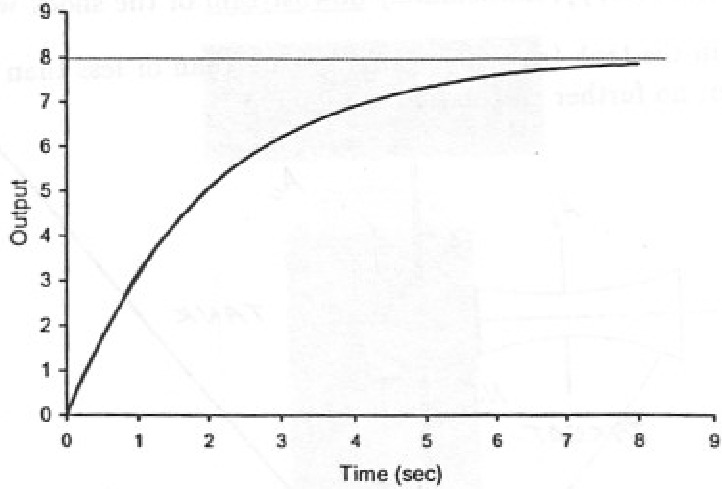


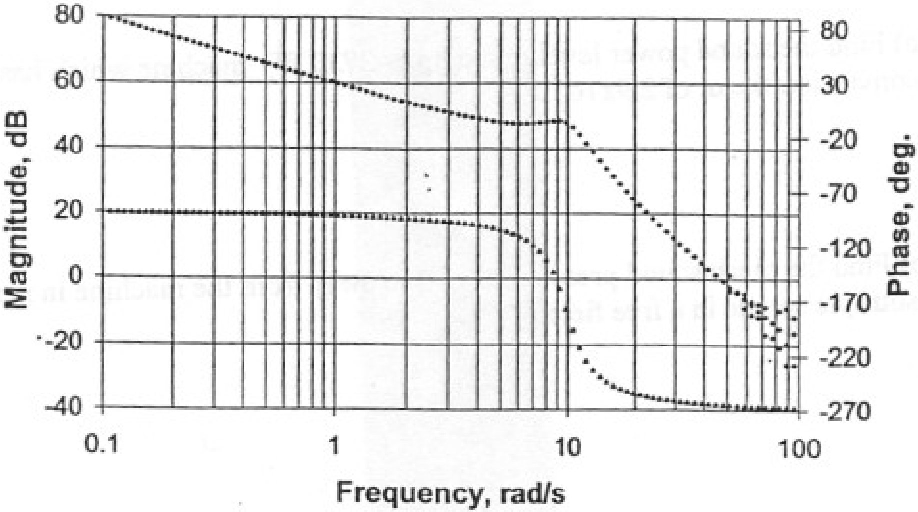
(5) a) Estimate the system transfer function G(s).

(3) b) What experimental test would you use to determine whether the system was truly first order or actually of a higher order?

(4) 2. Given a complex industrial system, it is desired to design a PID type feedback controller. Explain briefly how the terms P (proportional), I (integral), and D (derivative) in the feedback controller play important roles towards the contribution of *present, past* and *future components* of information on the error signal for improving the transients and steady-state performance of the system.

(9) 3. The following Bode gain and phase diagram were generated from the sinusoidal frequency response of an open loop system obtained by a spectrum analyzer.

a) Draw the corresponding asymptotes on the diagram.
b) Determine the open loop transfer function for the system.
c) Explain the difference between the experimental data and the asymptotes, especially at the break frequencies and at the high frequency range.



(4) 4. Sound power and sound pressure calculations are often carried out assuming a free field environment. Using the equations in your lab manual to support your argument, show why there is a 6 dB drop in sound pressure level for a doubling of the measuring distance in a free field.

(8) 5. a) Find the sound power level of a 5 hp (~ 3730 W) machine which has a sound power conversion factor of 2.9×10^{-5}.

b) Find the mean sound pressure level 2 m away from the machine in part a). Assume an isotropic source in a free field.

c) Given the directivity indices listed in the table below, determine the true sound pressure level 2 m away from the source in each of the five directions. Please write answers in the spaces provided in the table. (Directions are similar to those in Lab V1.)

Directivity Indices

Direction	DI	L_p
1	1.75	
2	0.65	
3	-0.65	
4	-2.05	
5	-0.66	

d) Find the mean sound pressure level using the values from part c). Show your work.

(8) 6. To cancel the vibration in a mechanical system being operated at its natural frequency, an absorber can be added. This situation is shown schematically in Figure V3. An ideal absorber would have the same natural frequency as the main system. If the main mass is 11 kg and the main spring has a stiffness of 23 000 N/m:

a) Calculate the mass of an ideal absorber with an absorber spring stiffness of 6300 N/m.
b) What is the amplitude of vibration if the system is operated at a frequency 20 rad/s less than its natural frequency with a sinusoidal force of amplitude F_0=115 N?

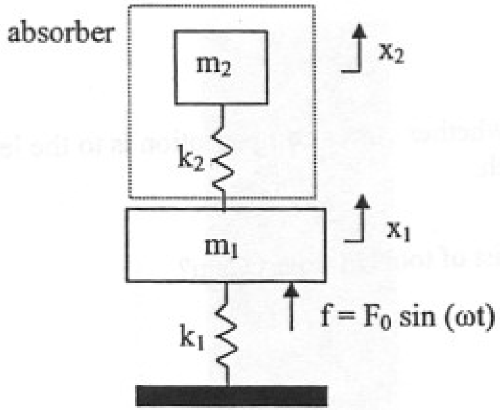


Figure V3 Mechanical system with an absorber.

(20) 7. a) Why are the Servo motors on our CNC lathe in the laboratory different from each other?

b) Which parts on our CNC lathe in the laboratory are pneumatically operated?

c) How do you determine whether cutter compensation is to the left or right of a shape to be machined? Make a sketch.

d) Which file contains the list of tools in Smart Cam?

e) Why is the spindle on a CNC machine belt driven and not gear driven?

f) The creation of an accurate CNC program requires a number of steps and revisions. One of the revisions that may be necessary after a first run is to evaluate and calculate new offset values.
How do you find these offset values?

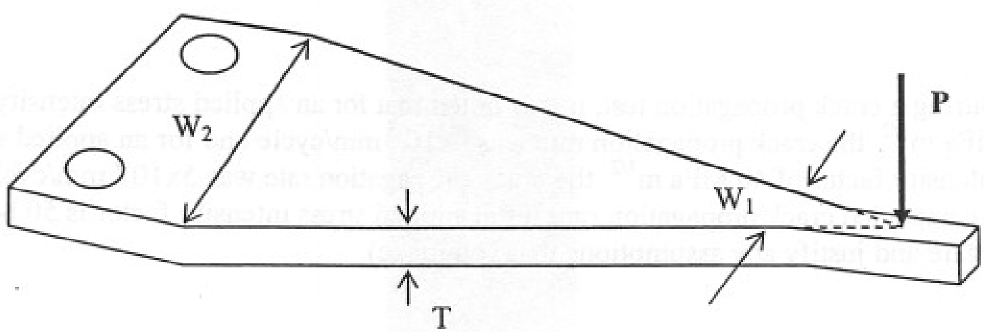
g) How do we determine a direction of rotation on tool machines?

h) During machining of the internal diameter of a work piece, chattering (vibration) of the boring bar occurs. What measures can be taken to solve this problem?

(7) 8. The cantilevered flat plate fatigue specimen shown, of uniform thickness T, has its sides tapered to form a triangle with its apex passing through the point of application of vertical load P.

(a) Show that the top plate surface experiences a uniform bending stress between widths W_1 and W_2 if stress concentrations are neglected.

(b) Which fatigue testing machines employ this type of specimens?



(6) 9. A hydraulic oil sample is tested in the Cannon-Fenske viscometer using capillary tube #1509 with a constant C of 0.02506. It takes 20 minutes for the oil to flow between the two scribed lines at a temperature of 40°C. The specific gravity of the oil is 0.861.

(a) Find the kinematic viscosity of the oil in centiStokes (cSt) at 40°C.

(b) What ISO viscosity grade would apply to this hydraulic oil sample?

(13) 10. Using the geometry of the converging-diverging nozzle for compressible air flow in laboratory T2, assume the diverging section is removed (ie. only the converging section exits). Air is supplied by the large storage tank connected to the nozzle at a plenum pressure of 1000 ± 50 kPa gauge and a temperature of 41 ± 2°C, where the uncertainty is given for each. For a barometric pressure of 100 ±1 kPa and dry air in the tank with a gas constant of $R=287\ J\ kg^{-1}K^{-1}$, calculate the mass flow rate of air through this nozzle and its uncertainty if the back pressure (after the converging section) is atmospheric.

(13) 11. During a crack propagation test, it was noted that for an applied stress intensity factor of 20 MPa $m^{1/2}$ the crack propagation rate was $9x10^{-5}$ mm/cycle and for an applied stress intensity factor of 40 MPa $m^{1/2}$ the crack propagation rate was $5x10^{-4}$ mm/cycle. Calculate the expected crack propagation rate if the applied stress intensity factor is 50 MPa $m^{1/2}$ (State and justify any assumptions that you make)