1. Most ship stabilization systems use fins or hydrofoils Projecting into the water in order to generate a stabilization torque on the ship. A simple diagram of a ship stabilization system is shown in the Fig.1. The rolling motion of a ship can be regarded as an oscillating pendulum with a deviation from the vertyical of θ degrees and a typical period of 3 sec. The transfer function of a typical ship is $G(s) = \dfrac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$

where $\omega_n = 2\pi/T$. T=3.14 sec and ζ=0.10. With low damping factor ζ, the oscillations continue for several cycles and the rolling amplitude can reach 18° for the expected amplitude of waves in normal sea.

Determine and compare the open-loop and closed -loop system for

(a) senstivity to changes in the actuator constant K_a and Ki. (10%)

(b) the ability to reduce the effects of the disturbance of the waves. (10%)

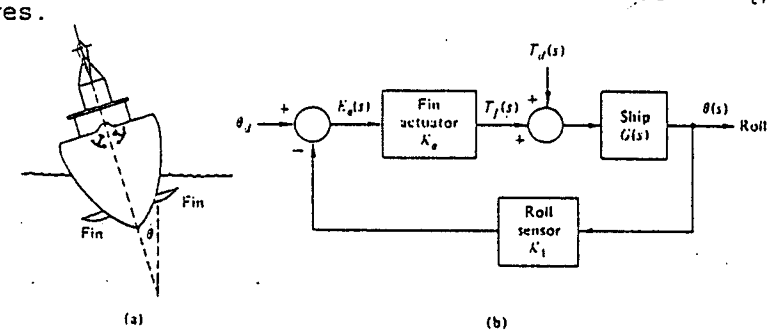


Fig. 1.

2. The block diagram of a dc-servomotor driven control system is shown in the Fig.2.

(a) Determine the limiting gain for a stable system. (5%)

(b) Determine a suitable gain so that the overshoot to a step command is approximately 5 %. (5%)

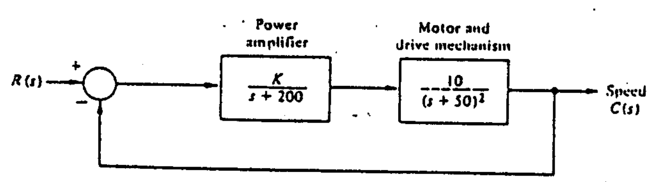


Fig. 2.

3. If the open loop transfer function of a unity feedback control system is

$$G(s) = \frac{K(s+z_1)(s+z_2)\cdots\cdots(s+z_M)}{(s+p_1)(s+p_2)\cdots\cdots(s+p_N)}, \quad N > M$$

where $p_{1\cdots N}$ are the poles and $z_{1\cdots M}$ are the zeros on the real axis

(a) Try to answer and explain the locations of the root locus if $K \to \infty$ (4%)

(b) Try to answer the intersection point of the asymptotes and the angles of the asymptotes, if they exist. And, try to prove the above results those you have answered. (10%)

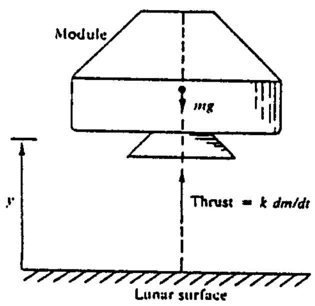
(c) Try to explain that how to judge the stability and to design a closed-loop control system by using root locus technology. (6%)

4. (20%) In the following figure we show the landing of a lunar spacecraft descending on the moon.

(a) Derive the equations of motion for this system. In the model, m is the total mass of the spacecraft including the liquid fuel in the rocket, y is the altitude of the spacecraft, f = k dm/dt is the thrust force, and g is the gravity acceleration on the moon surface.

(b) Define the state variables as $x_1 = y$, $x_2 = dy/dt$, $x_3 = m$ and control $u = dm/dt$. Derive the state-space equation. Is this a linear system ?

(c) What are the design specifications for the task of landing softly on the moon surface ?



Lunar module landing control.

5. (10%) (a) A first order system has two parameters, i.e., d.c. gain & time constant. How to use frequency response method to find these two parameters ?

(b) Take an example and design an experiment. List your experiment setup and procedures.

6. (20%) (a) Explain why and how for a unit feedback system we can use the open-loop frequency response function to determine the stability of the closed-loop system ?

(b) Plot the Nyquist plot of a general third-order system which has three real poles and no finite zero and discuss on the stability of the closed-loop system if a unit feedback is employed for the third-order system.