1. Figure 1 shows a non-ideal operational amplifier with negative feedback. Show the configuration of this circuit connection is unstable. (10%)

2. The following question is for modifying stability criterion for robotics:
(a) Routh-Hurwitz Criterion for Autonomous Robots: Modify the Routh-Hurwitz criterion to ensure that all system poles are to the left of σ>0.5 in the complex plane for an autonomous robot's navigation system. Apply the modified criterion to the polynomial $s^3 + 4s^2 + 5s + K = 0$, and determine the range of K that guarantees stability. (10%)
(b) Impact of Stability on Trajectory Control: Discuss how this stability analysis directly impacts the robot's ability to maintain a precise trajectory in a cluttered environment. Include practical scenarios such as obstacle avoidance and abrupt direction changes. (10%)

3. Consider the state equation: $\dot{x} = \begin{bmatrix} 0 & 1 \\ 7 & -4 \end{bmatrix} x + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u, \quad y = [1 \quad 3]x$
(a) Draw the block diagram for the plant with the condition that one integrator for each state variable. (5%)
(b) Find the transfer function. (5%)
(c) Find the closed-loop characteristic equation if the "state feedback" is $u = -[K_1 \quad K_2]x$; (5%)
(d) Find the closed-loop characteristic equation if the "output feedback" is $u = -K \cdot y$. (5%)

4. Consider the electrical circuit shown in Fig. 2.
(a) Write the state equation for the circuit. The input $u(t)$ is a current, and the output y is a voltage. Let $x_1 = i_L$ and $x_2 = v_C$ (5%)
(b) Write conditions on $R, L,$ and C will guarantee that the system is controllable. (5%)
(c) Write conditions on $R, L,$ and C will guarantee that the system is observable. (5%)

5. For the closed loop system shown in Fig. 3.
(a) Using Routh's stability criterion, determine all values of K for which the system is stable. (5%)
(b) Sketch the root locus versus K. Try to estimate the values for K just about the cross the imaginary-axis crossings. (10%)

6. The following question is for operational amplifier design for some real-world applications:
(a) Design a PI controller using an operational amplifier for a temperature control system in a chemical reactor. The system must maintain the temperature within ±2°C of the setpoint despite external disturbances. Draw the circuits, and explain how the proportional and integral terms impact the performance, and include a practical method for tuning these parameters. (10%)
(b) Design a band-pass filter using an operational amplifier to filter out high-frequency noise (above 1 kHz) in an electrocardiogram (ECG) signal. Connect this filter to the PI controller designed in part (a) and explain how the integration improves the overall system performance. Draw the circuit diagrams, and justify your choices. (10%)

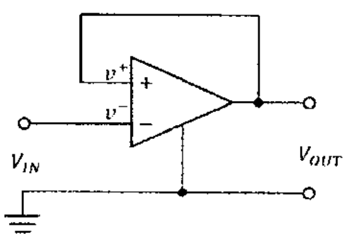

Fig. 1.

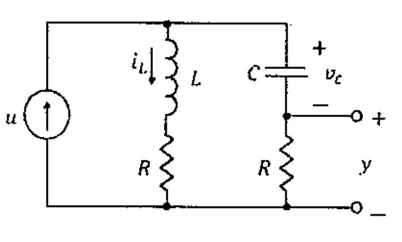

Fig. 2.

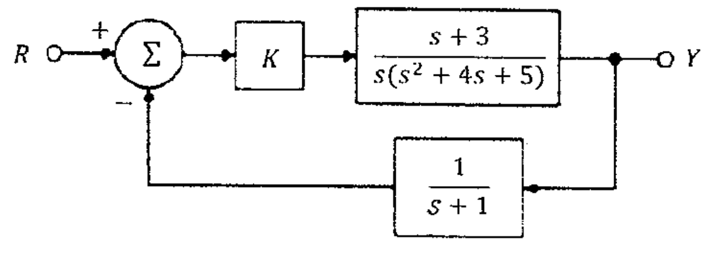

Fig. 3

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