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B.E. DEGREE EXAMINATIONS: APRIL / MAY 2023

(Regulation 2018)

Fourth Semester

AERONAUTICAL ENGINEERING

U18AEI4202**:** Automatic Control Systems

COURSE OUTCOMES

CO1: Determine the transfer function of mechanical and electrical systems.
CO2: Analyze the time response of LTI systems.
CO3: Design compensators / controllers for control systems.
CO4: Explain the behavior of aircraft autopilot systems.

Time: Three Hours   **Maximum Marks: 100**

Answer all the Questions:-
PART A (10 x 2 = 20 Marks)
(Answer not more than 40 words)

1. Draw the block diagram of a position (angular) control servomechanism and name the blocks.   CO1   [K₂]

2. The transfer function of an LTI system is given by, $\dfrac{C(s)}{R(s)} = \dfrac{s+3}{s^3 + 11s^2 + 12s + 18}$, where $R(s)$ is

   the system's input and $C(s)$ is the system's output. Find the differential equation of the system.   CO1   [K₃]

3. A ship has a mass m and a resistance C times the forward velocity $u(t)$. The thrust from the

   propeller is K times its angular velocity $\omega(t)$. The parameters of the vessel are: m =

   $20800{\times}10^3$ kg, C = 160000 Ns/m, and K = 96000 Ns/rad. Determine the first-order differential

   equation and hence the transfer function relating $U(s)$ and $\omega(s)$. Also, find the time constant.   CO1   [K₃]

4. For the system shown below, find the rise time and the settling time.   CO2   [K₃]
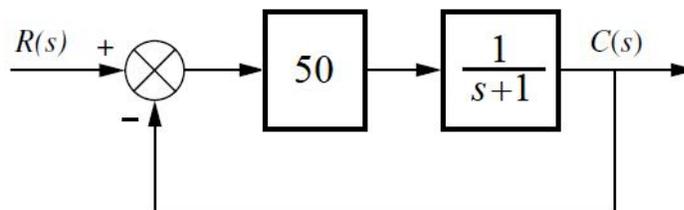

5. What is the **dominant pole** for LTI systems?   CO2   [K₂]

6. What is meant by compensation in control systems design?   CO3   [K₂]

7. A unity negative feedback control system has an open-loop transfer function, $G(s) = \dfrac{K}{s(s^2 + 7s + 12)}$. Find the value of gain K for which $s = -1 + 1j$ will lie on the root locus of this system.   CO3   [K₃]

CO3 [K3]

8. What is the functional similarity and difference between PI controller and lag compensator?   CO3 [K2]

9. What is the main function of automatic flight control systems in aircraft?   CO4 [K2]

10. What is the purpose of adding a rate feedback as an inner loop in pitch autopilot system?   CO4 [K2]

Answer any FIVE Questions:-
PART B (5 x 16 = 80 Marks)
(Answer not more than 400 words)

11.   A sketch of the basic components of a dc motor is given in Figure.   (16)   CO1   [K3]
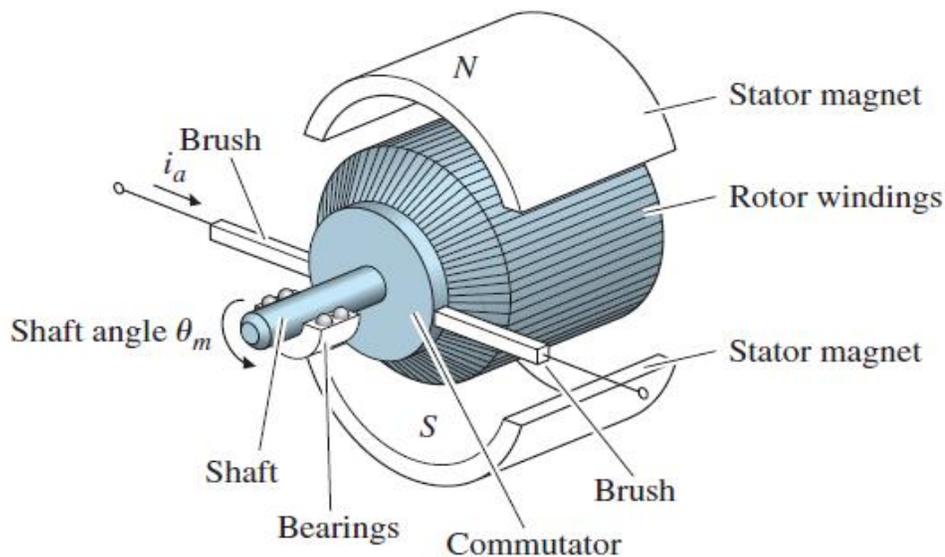
Figure. Sketch of an armature-controlled dc motor.

In addition to housing and bearings, the non-turning part (stator) has magnets, which establish a field across the rotor. The magnets may be electromagnets or, for small motors, permanent magnets. The brushes contact the rotating commutator, which causes the current always to be in the proper conductor windings so as to produce maximum torque. If the direction of the current is reversed, the direction of the torque is reversed. Assume that the rotor has inertia J_m and there is no friction in the motor. Obtain the differential equations for the behavior of the motor. Also, for the below given specifications, derive a transfer function for the motor relating the output shaft angle, θ_m to the input armature voltage, v_a.

Specification	Value	Unit
Motor torque constant	0.72	Nm/A
Armature resistance	5.5	Ohm
Armature inductance	10	mH
Back emf constant	0.65	volts/(rad/s)
Rotor inertia	0.01	kg.m^2

12. Consider a second-order negative unity feedback system with $\xi = 0.6$, $\omega_n = 5$ rad/sec. Calculate the rise time, peak time, maximum overshoot, and settling time when a unit-step input is applied to the system. Assume the steady-state gain constant as 1. Also, find the steady-state error for a unit ramp input. (16) CO2 [K3]

13. The block diagram of a radar antenna position control system is shown in Figure. (16) CO3 [K3]
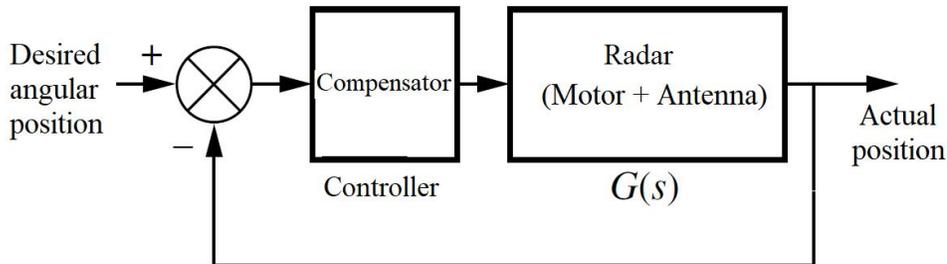

Figure. Block diagram of position control of a radar antenna

It is desired to control the position of the radar whose open-loop transfer function is

$$G(s) = \frac{K}{s(s+7)(s+100)}, \quad K > 0$$

For that, design a lag compensator as shown in Figure by placing the compensator pole at –0.01 so that the system is operating at 5% overshoot (damping ratio = 0.69, dominant poles are –3.37±3.54j) with 20 times improvement in the steady-state error over the uncompensated system. Also, find the loop gain K of the compensated system.

14. Consider a unity negative feedback system with $G(s) = \frac{K}{(s+4)^3}$. Find the location of the dominant poles to yield a 1.6 second settling time and an overshoot of 25%. If a compensator with a zero at '–5' is used to achieve the requirement, what must the angular contribution of the compensator pole be? (16) CO3 [K3]

Find the location of the compensator pole and the gain required to meet the design requirements.

15. A unity negative feedback system with $G(s) = \dfrac{K(s+6)}{(s+2)(s+3)(s+5)}$ is operating (16) CO3 [K₃]

with a damping ratio of 0.707 (dominant poles are $-2.32 \pm 2.32j$). Design a PD controller so that the settling time is reduced by a factor of 2.

16. a) With a neat block diagram explain the working of a longitudinal displacement (8) CO4 [K₂] autopilot for a jet transport aircraft.

b) With a block diagram explain the airspeed control system for aircraft. (8) CO4 [K₂]

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