

Core Concepts Practice

MAE 4182 - Electromechanical Control System Design

Foundations | Laplace | Local linearization | Block diagrams

40 questions | 24 multiple choice + 16 fill in the blank

Name: _____ Date: _____

Closed book; no personal notes. Formulas for the short calculations are printed with the questions. No calculator is needed.

Choose one answer for each multiple-choice item. Complete both blanks in each fill-in item. No derivations or written explanations are required.

Notation: $u_s(t)$ is the unit step. Transform-table signals are causal. Angles are in radians. Equivalent answers are accepted.

Part A - Multiple Choice

1. A motor receives a voltage command and a sensor measures its shaft angle. Which quantity is the applied input?

- A. The measured shaft angle.
- B. The voltage command.
- C. The sampling interval.
- D. The desired final angle.

2. To predict future motion using a given dynamic model, which information is generally needed?

- A. Only the current input.
- B. Only the desired output.
- C. The present state and future inputs.
- D. Only the number of sensors.

3. Which input-output relation satisfies superposition?

- A. $y = -3u$
- B. $y = u^2$
- C. $y = u + 4$
- D. $y = \sin u$

4. Why is $y = 3u + 1$ not a linear input-output map?

- A. Its graph is not a straight line.
- B. It contains a constant multiplier.
- C. It has one input.
- D. Zero input produces a nonzero output.

5. A model has fixed parameters and no explicit absolute-time dependence. Its state is moving. Which statement is correct?

- A. Motion necessarily makes the model time-varying.
- B. The model can still be time-invariant.
- C. The input and state must be identical.
- D. The model cannot be nonlinear.

Part A - Multiple Choice (continued)

6. One aircraft has four independently commanded motors and several measured attitude outputs. The chosen model is:
- A. MIMO.
 - B. SISO because there is one aircraft.
 - C. Neither, because aircraft move.
 - D. Necessarily linear.
7. A pendulum is recorded by a digital logger. Which statement is correct?
- A. The physical pendulum moves only at the sample instants.
 - B. The logger makes the physical motion discrete-time.
 - C. The stored record must be continuous-time.
 - D. The physical motion is continuous-time; the stored samples are discrete-time.
8. In feedback control, what is the reference?
- A. The measured output in every situation.
 - B. The error signal.
 - C. The desired value or behavior.
 - D. The internal state in every situation.
9. Using a Laplace transform can help us:
- A. Rewrite a linear differential equation as algebra while keeping initial-condition terms.
 - B. Make all nonlinear models exactly linear.
 - C. Erase the physical state.
 - D. Replace every time variable with a frequency value without integration.
10. What does an inverse Laplace transform recover from $F(s)$?
- A. A new equilibrium input.
 - B. The time-domain signal.
 - C. A sensor location.
 - D. A different physical plant.
11. Which description matches a unit step signal?
- A. It exists only at one instant with unit area.
 - B. It rises linearly forever.
 - C. It switches on to 1 and stays there.
 - D. It must be sinusoidal.
12. When a rectangular pulse becomes very narrow to model a unit impulse, what must be preserved?
- A. A height of 1.
 - B. A width of 1.
 - C. A fixed time delay.
 - D. An area of 1.

Part A - Multiple Choice (continued)

13. For an ordinary signal, why should the term $f(0^+)$ not automatically be removed from $sF(s) - f(0^+)$?

- A. It always equals the final value.
- B. It records the actual initial condition.
- C. It makes the model nonlinear.
- D. It represents a time delay.

14. Sine and cosine transforms can have the same denominator. What still needs to be checked when using a transform table?

- A. The numerator and any scale factor.
- B. Only whether the denominator is quadratic.
- C. Only the name of the input.
- D. Nothing; the two transforms are identical.

15. Which transform-domain expression represents delaying a causal signal by 2 seconds?

- A. $F(s+2)$
- B. $2F(s)$
- C. $F(s)/2$
- D. $e^{-2s}F(s)$

16. Two pendulums have the same angle but different angular velocities. Under the same future torque, their future motion:

- A. Must be identical.
- B. Cannot be predicted by any model.
- C. Can differ because their states differ.
- D. Must have zero acceleration at all times.

17. Which condition defines an equilibrium under a constant input?

- A. All state rates are zero.
- B. All state values are zero.
- C. The input must be zero.
- D. Only the acceleration is zero.

18. Can a constant nonzero torque hold a pendulum at a nonzero equilibrium angle?

- A. No, equilibrium always requires zero torque.
- B. Yes, when the torque balances gravity and angular velocity is zero.
- C. Yes, at every angle regardless of the torque.
- D. No, equilibrium always requires zero angle.

19. A pendulum passes through the bottom with nonzero angular velocity. Its acceleration is zero at that instant. It is:

- A. At equilibrium because its acceleration is zero.
- B. At equilibrium because its angle is zero.
- C. No longer a dynamic system.
- D. Not at equilibrium because its angle is still changing.

Part A - Multiple Choice (continued)

20. A local linear approximation is most appropriate for:

- A. Every possible movement of a nonlinear system.
- B. Only a zero absolute state.
- C. Sufficiently small changes near the selected operating point.
- D. Replacing the actual physical system with a new one.

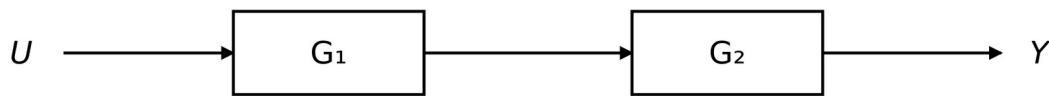
21. For $\theta = \pi + \delta\theta$, what does $\delta\theta = 0$ mean?

- A. $\theta = \pi$.
- B. $\theta = 0$.
- C. The input must stay zero for all time.
- D. The model is exact for large motion.

22. If $D=0$ in an angle-output model, which statement is correct?

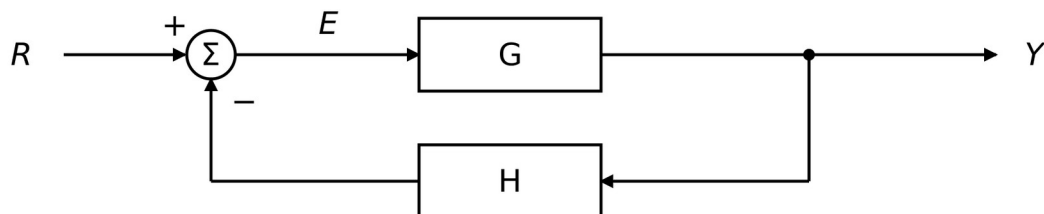
- A. The input can never influence the output.
- B. The input may affect the output through the state dynamics.
- C. B must be zero.
- D. The state has no role in the output.

23. What connection is shown below?



- A. Additive parallel.
- B. Negative feedback.
- C. Positive feedback.
- D. Series.

24. In the diagram below, what signal comes back through the feedback path to the summing point?



- A. Y/H
- B. GR
- C. HY
- D. R

Part B - Fill in the Blank

25. Enter SISO or MIMO for each chosen model.

(a) One voltage input and one measured angle output _____

(b) Four independent motor inputs and several attitude outputs _____

26. Use the supplied transform pairs.

$$u_s(t) \leftrightarrow 1/s, e^{-at} \leftrightarrow 1/(s+a)$$

(a) $L\{2u_s(t)\} =$ _____

(b) $L\{e^{-5t}\} =$ _____

27. For $t \geq 0$, use the supplied pairs in reverse.

$$u_s(t) \leftrightarrow 1/s, e^{-at} \leftrightarrow 1/(s+a)$$

(a) $L^{-1}\{1/s\} =$ _____

(b) $L^{-1}\{1/(s+2)\} =$ _____

28. There is no impulse at the starting time. Apply the supplied derivative rule.

$$L\{\dot{f}\} = sF(s) - f(0^+)$$

(a) If $f(0^+) = 0$, then $L\{\dot{f}\} =$ _____

(b) If $f(0^+) = 3$, then $L\{\dot{f}\} =$ _____

29. Write $L\{\sin(2t)\} = a/(s^2+b)$. Use the sine pair below.

$$L\{\sin(\omega t)\} = \omega/(s^2+\omega^2)$$

(a) $a =$ _____

(b) $b =$ _____

Part B - Fill in the Blank (continued)

30. At an operating point, a spring force is 10 N and its local stiffness is 2 N/cm. Use the additional compression of 0.1 cm.

$$\Delta F \approx k_{local} \Delta x, F \approx F(x^*) + \Delta F$$

(a) Predicted additional force _____

(b) Predicted total force _____

31. The operating position is $x^* = 5$ m. Use $\delta x = x - x^*$.

(a) If $x = 5.2$ m, then $\delta x =$ _____

(b) If $\delta x = -0.1$ m, then $x =$ _____

32. Treat these as two separate signal operations.

(a) A signal of value 4 splits into two branches. EACH outgoing signal has value _____

(b) A summing point receives +9 and -2. Its output is _____

33. Two scalar gains are $G_1 = 3$ and $G_2 = 4$. Use the supplied rules.

$$G_{series} = G_2 G_1, G_{parallel} = G_1 + G_2$$

(a) Equivalent series gain _____

(b) Equivalent parallel gain when both outputs are added _____

34. The pendulum states are $x_1 = \theta$ and $x_2 = \dot{\theta}$. Use the word bank: angular velocity | angular acceleration.

(a) The rate $\dot{x}_1$ represents _____

(b) The rate $\dot{x}_2$ represents _____

35. Complete the equilibrium statements.

(a) At an equilibrium, $f(x^*, u^*) =$ _____

(b) With the input held at its equilibrium value, the exact equilibrium state stays (constant or changing)

Part B - Fill in the Blank (continued)

36. In $\delta \dot{x} = A \delta x + B \delta u$, use the word bank: state | input | output.

- (a) A describes the effect of the current _____
(b) B describes the effect of the _____

37. Let δx_1 be angle deviation and δx_2 be angular-velocity deviation. With $D=0$, $\delta y = C \delta x$.

- (a) $C = \begin{bmatrix} 1 & 0 \end{bmatrix}$ selects _____
(b) $C = \begin{bmatrix} 0 & 1 \end{bmatrix}$ selects _____

38. Complete the first-order linearization statements.

- (a) Retain $2 \delta x$ or $(\delta x)^2$? Retained term: _____
(b) This approximation is intended for (small or arbitrarily large) deviations _____

39. Let R be the reference and B the returned measurement signal. Here B is a signal, not a matrix. Enter + or -.

- (a) Negative feedback: the sign joining R and B in E is _____
(b) Positive feedback: the sign joining R and B in E is _____

40. Choose an operation from: multiply | add | divide.

- (a) Operation for combining scalar gains in series _____
(b) Operation for combining parallel gains when both outputs are added _____