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Director's Message

B. Singh (Ex. IES)

Engineering is one of the most chosen graduating field. Taking engineering is usually a matter of interest but this eventually develops into "purpose of being an engineer" when you choose engineering services as a career option.

Train goes in tunnel we don't panic but sit still and trust the engineer, even we don't doubt on signalling system, we don't think twice crossing over a bridge reducing our travel time; every engineer has a purpose in his department which when coupled with his unique talent provides service to mankind.

I believe *"the educator must realize in the potential power of his pupil and he must employ all his art, in seeking to bring his pupil to experience this power".* To support dreams of every engineer and to make efficient use of capabilities of aspirant, MADE EASY team has put sincere efforts in compiling all the previous years' ESE-Pre questions with accurate and detailed explanation. The objective of this book is to facilitate every aspirant in ESE preparation and so, questions are segregated chapterwise and topicwise to enable the student to do topicwise preparation and strengthen the concept as and when they are read.

I would like to acknowledge efforts of entire MADE EASY team who worked hard to solve previous years' papers with accuracy and I hope this book will stand up to the expectations of aspirants and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

B. Singh (Ex. IES)
CMD, MADE EASY Group

Volume-II

ELECTRONICS & TELECOM. ENGG.

Objective Solved Questions

of UPSC Engineering Services Examination

Contents

UNIT

I

Control Systems

Syllabus

Signal flow graphs, Routh-Hurwitz criteria, root loci, Nyquist/Bode plots; Feedback systems-open &close loop types, stability analysis, steady state, transient and frequency response analysis; Design of control systems, compensators, elements of lead/lag compensation, PID and industrial controllers.

Contents

❍❍❍❍

1 Basics, Block Diagrams and Signal Flow Graphs

1.1 **Assertion (A):** Feedback control systems offer more accurate control over open-loop systems.

Reason (R): The feedback path establishes a link for input and output comparison and subsequent error correction.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE-2000]**

1.2 Consider the following statements:

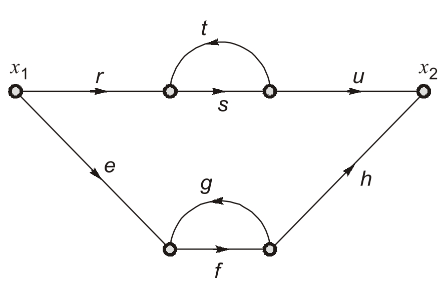
1. The effect of feedback is to reduce the system error
2. Feedback increases the gain of the system in one frequency range but decreases in another.
3. Feedback can cause a system that is originally stable to become unstable

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE-2000]

1.3 For the signal flow diagram shown in the given figure, the transmittance between x_2 and x_1 is



(a) $\dfrac{rsu}{1-st}+\dfrac{efh}{1-fg}$ (b) $\dfrac{rsu}{1-fg}+\dfrac{efh}{1-st}$

(c) $\dfrac{efh}{1-ru}+\dfrac{rsu}{1-eh}$ (d) $\dfrac{rst}{1-eh}+\dfrac{rsu}{1-st}$

[ESE-2001]

1.4 Consider the following statements with respect to feedback control systems:

1. Accuracy cannot be obtained by adjusting loop gain.
2. Feedback decreases overall gain.
3. Introduction of noise due to sensor reduces overall accuracy.
4. Introduction of feedback may lead to the possibility of instability of closed loop system.

Which of the statements given above are correct?

(a) 1, 2, 3 and 4 (b) Only 1, 2 and 4
(c) Only 1 and 3 (d) Only 2, 3 and 4

[ESE-2006]

1.5 A control system whose step response is $-0.5\,(1 + e^{-2t})$ is cascaded to another control block whose impulse response is e^{-t}. What is the transfer function of the cascaded combination?

(a) $\dfrac{1}{(s+1)(s+2)}$ (b) $\dfrac{1}{s(s+1)}$

(c) $\dfrac{-1}{s(s+2)}$ (d) $\dfrac{0.5}{(s+1)(s+2)}$

[ESE-2007]

1.6 If the initial conditions for a system are inherently zero, what does it physically mean?

(a) The system is at rest but stores energy
(b) The system is working but does not store energy
(c) The system is at rest or no energy is stored in any of its parts
(d) The system is working with zero reference input

[ESE-2007]

1.7 The impulse response of a linear time invariant system is given as

$$g(t) = e^{-t},\ t > 0.$$

The transfer function of the system is equal to

(a) $1/s$ (b) $1/[s(s + 1)]$
(c) $1/(s + 1)$ (d) $s/(s + 1)$

[ESE-2008]

1.8 In case of DC servo-motor the back-emf is equivalent to an "electric friction" which tends to
(a) improve stability of the motor
(b) slowly decrease stability of the motor
(c) very rapidly decrease stability of the motor
(d) have no effect on stability [ESE-2008]

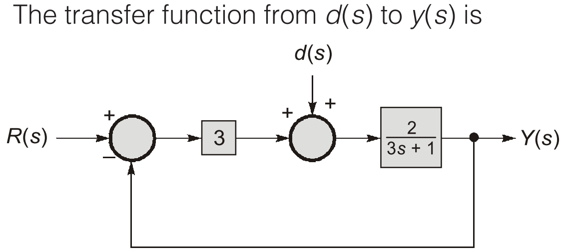
1.9 The transfer function of a linear-time-invariant system is given as $\frac{1}{(s+1)}$. What is the steady-state value of the unit-impulse response?
(a) Zero (b) One
(c) Two (d) Infinite [ESE-2009]

1.10 In closed loop control system, what is the sensitivity of the gain of the overall system, M to the variation in G?
(a) $\frac{1}{1+G(s)H(s)}$ (b) $\frac{1}{1+G(s)}$
(c) $\frac{G(s)}{1+G(s)H(s)}$ (d) $\frac{G(s)}{1+G(s)}$
[ESE-2009]

1.11 A linear time-invariant system initially at rest, when subjected to a unit-step input, gives a response $y(t) = te^{-t}$, $t > 0$. The transfer function of the system is:
(a) $\frac{1}{(s+1)^2}$ (b) $\frac{1}{s(s+1)^2}$
(c) $\frac{s}{(s+1)^2}$ (d) $\frac{1}{s+1}$ [ESE-2010]

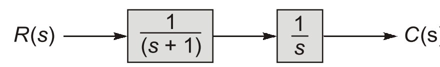
1.12 Consider the function $F(s) = \frac{5}{s(s^2+3s+2)}$, where $F(s)$ is Laplace transform of function $f(t)$. The initial value of $f(t)$ is:
(a) 5 (b) 5/2
(c) 5/3 (d) 0
[ESE-2010]

1.13 The transfer function from $d(s)$ to $y(s)$ is



(a) $\frac{2}{3s+7}$ (b) $\frac{2}{3s+1}$
(c) $\frac{6}{3s+7}$ (d) $\frac{2}{3s+6}$ [ESE-2010]

1.14 What is the unit impulse response of the system shown in figure for $t \geq 0$?



(a) $1 + e^{-t}$ (b) $1 - e^{-t}$
(c) e^{-t} (d) $-e^{-t}$ [ESE-2011]

1.15 An electric motor is developing 10 kW at a speed of 900 rpm. The torque available at the shaft is
(a) 106 N-m (b) 66 N-m
(c) 1600 N-m (d) 90 N-m
[ESE-2013]

1.16 **Statement (I):** Many of the linear control system transfer functions do not have poles or zeros in the right half of s-plane.
Statement (II): These are called minimum-phase transfer functions.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.
[ESE-2013]

1.17 A tachometer has a sensitivity of 5 V/1000 rpm. The gain constant of the tachometer is
(a) 0.48 V/rad/sec (b) 0.048 V/rad/sec
(c) 4.8 V/rad/sec (d) 48 V/rad/sec
[ESE-2014]

1.18 The closed loop transfer function of a unity negative feedback system is $\frac{100}{s^2+8s+100}$. Its open loop transfer function is
(a) $\frac{100}{s+8}$ (b) $\frac{1}{s^2+8s}$
(c) $\frac{100}{s^2-8s}$ (d) $\frac{100}{s^2+8s}$
[ESE-2015]

1.19 The Laplace transform of $e^{-2t}\sin(2\omega t)$ is

(a) $\dfrac{2s}{(s+2)^2+2\omega^2}$ (b) $\dfrac{2\omega}{(s-2)^2+4\omega^2}$

(c) $\dfrac{2\omega}{(s+2)^2+4\omega^2}$ (d) $\dfrac{2s}{(s-2)^2+2\omega^2}$

[ESE-2015]

1.20 In a closed loop system for which the output is the speed of a motor, the output rate control can be used to

(a) Limit the speed of the motor
(b) Limit the torque output of the motor
(c) Reduce the damping of the system
(d) Limit the acceleration of the motor

[ESE-2015]

1.21 In a servo-system, the device used for providing derivative feedback is known as

(a) Synchro (b) Servomotor
(c) Potentiometer (d) Techogenerator

[ESE-2015]

1.22 The transfer function of any stable system which has no zeros or poles in the right half of the s-plane is said to be

(a) Minimum phase transfer function
(b) Non-minimum phase transfer function
(c) Minimum frequency response function
(d) Minimum gain transfer function

[ESE-2015]

1.23 A dominant pole is determined as

(a) the highest frequency pole among all poles.
(b) the lowest frequency pole at least two octaves lower than other poles.
(c) the lowest frequency pole among all poles.
(d) the highest frequency pole at least two octaves higher than other poles.

[ESE-2017]

1.24 Consider the following statements for signal flow graph:

1. It represents linear as well as non-linear systems.
2. It is not unique for a given system.

Which of the above statements is /are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE-2018]

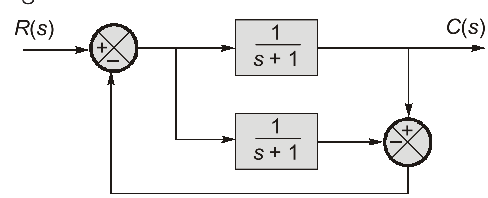
1.25 The open-loop transfer function of a system is

$$\frac{10K}{1+10s}$$

When the system is converted into a closed-loop with unity feedback, the time constant of the system is reduced by a factor of 20. The value of K is

(a) 1.9 (b) 1.6
(c) 1.3 (d) 1.0 [ESE-2018]

1.26 The closed-loop transfer function $\dfrac{C(s)}{R(s)}$ of the system represented by the block diagram in the figure is



(a) $\dfrac{1}{(s+1)^2}$ (b) $\dfrac{1}{s+1}$

(c) $s + 1$ (d) 1 [ESE-2018]

1.27 The price for improvement in sensitivity by the use of feedback is paid in terms of

(a) loss of system gain
(b) rise of system gain
(c) improvement in transient response, delayed response
(d) poor transient response [ESE-2019]

1.28 Consider the following open-loop transfer function:

$$G=\frac{K(s+2)}{(s+1)(s+4)}$$

The characteristic equation of the unity negative feedback will be

(a) $(s + 1)(s + 4) + K(s + 2) = 0$
(b) $(s + 2)(s + 1) + K(s + 4) = 0$
(c) $(s + 1)(s - 2) + K(s + 4) = 0$
(d) $(s + 2)(s + 4) + K(s + 1) = 0$ [ESE-2019]

1.29 The signal flow graph of a system is constructed from its

(a) Differential equations
(b) Algebraic equations
(c) Algebraic equations through the cause-and-effect relations
(d) Differential equations through the cause-and-effect relations [ESE-2020]

1.30 The important aspects in the study of feedback systems are to control

1. Sensitivity
2. Effect of an internal disturbance
3. Distortion in a nonlinear system

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE-2020]

1.31 The subsystem that generates the input to the plant or process is known as

(a) controller (b) controlled variable
(c) controllability (d) compensator

[ESE-2022]

1.32 The open-loop DC gain of a unity negative feedback system with closed-loop transfer function $\dfrac{s+4}{s^2+7s+13}$ is

(a) $\dfrac{4}{13}$ (b) $\dfrac{2}{3}$
(c) $\dfrac{1}{3}$ (d) $\dfrac{4}{9}$

[ESE-2023]

■■■

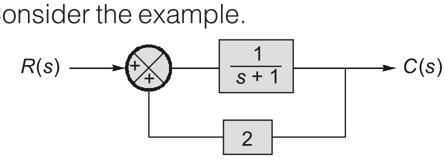
Answers Basics, Block Diagrams and Signal Flow Graphs

1.1 (a)	1.2 (a)	1.3 (a)	1.4 (d)	1.5 (*)	1.6 (c)	1.7 (c)	1.8 (a)	1.9 (a)
1.10 (a)	1.11 (c)	1.12 (d)	1.13 (a)	1.14 (b)	1.15 (a)	1.16 (a)	1.17 (b)	1.18 (d)
1.19 (c)	1.20 (a)	1.21 (d)	1.22 (a)	1.23 (c)	1.24 (b)	1.25 (a)	1.26 (b)	1.27 (a)
1.28 (a)	1.29 (c)	1.30 (d)	1.31 (a)	1.32 (d)				

Explanations Basics, Block Diagrams and Signal Flow Graphs

1.2 (a)

Feedback is applied to reduce the system error. Consider the example.



$$\frac{C(s)}{R(s)} = \frac{G(s)}{1-G(s)H(s)} = \frac{\dfrac{1}{s+1}}{1-\dfrac{2}{s+1}} = \frac{1}{s-1}$$

Thus, we see that the closed loop system is unstable while the open loop system is stable.

1.3 (a)

$$\frac{X_2}{X_1} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

$P_1 = rsu$, $\Delta_1 = 1 - fg$

$P_2 = efh$, $\Delta_2 = 1 - st$, $\Delta = 1 - fg - st + fgst$

$$\frac{X_2}{X_1} = \frac{rsu(1-fg)+efh(1-st)}{1-fg-st+fgst}$$

$$= \frac{rsu(1-fg)+efh(1-st)}{(1-fg)(1-st)}$$

$$\frac{X_2}{X_1} = \frac{rsu}{1-st}+\frac{efh}{1-fg}$$

1.5 (*)

$$\text{TF}_1 = sL[sR]$$

$$= s\left[\frac{-0.5}{5}-\frac{0.5}{s+2}\right] = \frac{-(s+1)}{s+2}$$

$$\text{TF}_2 = L[IR] = \frac{1}{s+1}$$

$$\therefore \quad \text{TF} = TF_1 \times TF_2 = \frac{-1}{s+2}$$

1.6 (c)

A system with zero initial conditions is said to be at rest since there is no stored energy.

1.7 (c)

Impulse response, $g(t) = e^{-t}$, $t > 0$

Transfer function, $G(s) = L\{g(t)\} = \dfrac{1}{s+1}$

1.9 (a)

Steady state value $= \lim\limits_{s\to 0} s\dfrac{1}{(s+1)} = 0$

1.10 (a)

$$M(s) = \frac{G(s)}{1+G(s)H(s)}$$

Sensitivity of M to the variation in G is

$$\frac{dM}{dG} \times \frac{G}{M}$$

$$\frac{dM}{dG} = \frac{1+G(s)H(s)-G(s)H(s)}{\{1+G(s)H(s)\}^2}$$

$$\frac{dM}{dG} \times \frac{G}{M} = \frac{1}{\{1+G(s)H(s)\}^2} \times \frac{G(s)}{\frac{G(s)}{1+G(s)}}$$

$$= \frac{1}{1+G(s)H(s)}$$

1.11 (c)

Given, Input $x(t) = u(t)$

and output $y(t) = t \cdot e^{-t}$, $t > 0$

Taking Laplace transform

$$X(s) = \frac{1}{s} \quad ; \quad Y(s) = \frac{1}{(s+1)^2}$$

Therefore transfer function

$$H(s) = \frac{Y(s)}{X(s)} = \frac{\frac{1}{(s+1)^2}}{1/s} = \frac{s}{(s+1)^2}$$

1.12 (d)

$$F(s) = \frac{5}{s(s^2+3s+2)}$$

The initial value of $f(t)$ is

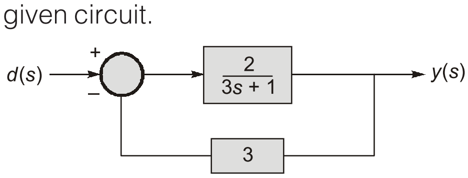
$$\underset{t\to 0}{f(t)} = \underset{s\to\infty}{sF(s)}$$

$$= \underset{s\to\infty}{s} \cdot \frac{5}{s(s^2+3s+2)} = \frac{5/s^2}{s\to\infty\left(1+\frac{3}{s}+\frac{2}{s^2}\right)}$$

$$\underset{t\to 0}{f(t)} = 0$$

1.13 (a)

To calculate $\frac{y(s)}{d(s)}$, set $R(s) = 0$ and now redraw the given circuit.



$$\therefore \quad \frac{y(s)}{d(s)} = \frac{\frac{2}{3s+1}}{1+3\times\frac{2}{3s+1}} = \frac{2}{3s+7}$$

1.14 (b)

$$\frac{C(s)}{R(s)} = H(s) = \frac{1}{s(s+1)}$$

$$\Rightarrow \quad H(s) = \frac{1}{s} - \frac{1}{s+1}$$

Taking inverse Laplace transform;

$$h(t) = (1 - e^{-t})\, u(t)$$

1.15 (a)

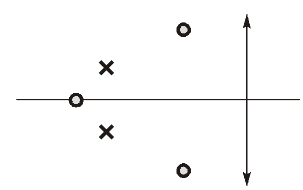
$$\text{Torque} = \frac{9.544\times\text{Power}}{\text{Speed in rpm}} = \frac{9.544\times 10\times 10^3}{900}$$

$$= 106.04 \text{ N-m}$$

1.16 (a)

The transfer function which does not have any pole or zero in the right half of the s-plane is called minimum-phase transfer function.

If all poles lie in L.H.S. of s-plane then the system is linear and always stable.



Minimum phase transfer function

1.17 (b)

$$\text{Tachometer sensitivity} = \frac{5}{1000}\left(\frac{V}{\text{rpm}}\right)$$

$$\omega = \frac{2\pi\times N}{60}$$

For $N = 1000$, $\omega = \frac{2\pi\times 1000}{60}$

$$\therefore \quad \text{Gain constant} = \frac{5\times 60}{2\pi\times 1000}\left(\frac{V}{\text{rad/ sec}}\right)$$

$$= 0.048 \text{ V/rad/sec}$$

1.18 (d)

$$G(s)H(s) = \frac{100}{s^2+8s+100} = \frac{\frac{100}{s^2+8s}}{1+\frac{100}{s^2+8s}}$$

These for a unity feedback system with negative feedback

$$G(s) = \frac{100}{s^2+8s} = \frac{100}{s(s+8)}$$

1.19 (c)

$$L\{\sin(at)\} \leftrightarrow \frac{a}{s^2+a^2}$$

$$L\{e^{-bt}\sin(at)\} \leftrightarrow \frac{a}{(s+b)^2+a^2}$$

in the giving question $a = 2\omega$
$b = 2$

$$\therefore L\{e^{-2t}\sin(2\omega t)\} \leftrightarrow \frac{2\omega}{(s+2)^2+4\omega^2}$$

1.21 (d)

Tachogenerator provides a derivative feedback when used in a servo system.

1.22 (a)

For a minimum phase system all the poles and zeroes of a transfer function must lie on the left side of the $(j\omega)$ axis.

1.23 (c)

Dominant pole is the one which has large time constant i.e. small frequency.

1.25 (a)

$$\text{OLTF} = \frac{10K}{1+10s}$$

Open time constant = 10

$$\text{CLTF} = \frac{10K/1+10K}{1+\frac{10}{1+10K}s}$$

$$\text{Closed loop time constant} = \frac{10}{1+10K}$$

Given, $\frac{10}{1+10K} = \frac{10}{20}$

$\therefore$ $K = 1.9$

1.26 (b)

Using Mason gain formula

$$\frac{C}{R} = \frac{\frac{1}{s+1}(1-0)}{1-\left[\frac{-1}{s+1}+\frac{1}{s+1}\right]+0} = \frac{1}{s+1}$$

1.27 (a)

Feedback (negative) decreases both gain and sensitivity.

1.28 (a)

$$q(s) = 1 + G(s)H(s) = 0$$

$$q(s) = 1+\frac{K(s+2)}{(s+1)(s+4)} = 0$$

$$q(s) = (s+1)(s+4) + K(s+2) = 0$$

1.29 (c)

SFG is graphical representation and mathematical relation between variables of a system in the form of set of linear algebraic equation in cause-effect form.

1.30 (d)

Feedback in control system is used to control sensitivity, effect of disturbance and non linearities.

1.31 (a)

The subsystem that generates the input to the plant or process is known as controller.

1.32 (d)

The open loop transfer function is given by,

$$\text{OLTF} = \frac{s+4}{s^2+7s+13-s-4}$$

$$\text{OLTF} = \frac{s+4}{s^2+6s+9} \quad \text{...(1)}$$

* For open-loop DC gain of a unity negative feedback can be found by making s = 0 in equation (1).

$\therefore$ Open loop DC gain $= \frac{4}{9}$

■■■

2 Time Domain Analysis

2.1 **Assertion (A):** The largest undershoot corresponding to a unit step input to an underdamped second order system with damping ratio ξ and undamped natural frequency of oscillation ω_n is $e^{-2\xi\pi/\sqrt{1-\xi^2}}$.

Reason (R): The overshoots and undershoots of a second order underdamped system is

$$e^{-\xi n\pi/\sqrt{1-\xi^2}}, n = 1, 2, ...$$

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE-2000]

2.2 Which one of the following transfer functions represents the critically damped system?

(a) $H_1(s) = \dfrac{1}{s^2 + 4s + 4}$

(b) $H_2(s) = \dfrac{1}{s^2 + 3s + 4}$

(c) $H_3(s) = \dfrac{1}{s^2 + 2s + 4}$

(d) $H_4(s) = \dfrac{1}{s^2 + s + 4}$ **[ESE-2000]**

2.3 A second order system has the damping ratio ξ and undamped natural frequency of oscillation ω_n. The settling time at 2% tolerance band of the system is

(a) $2/\xi\omega_n$ (b) $3/\xi\omega_n$
(c) $4/\xi\omega_n$ (d) $\xi\omega_n$

[ESE-2000]

2.4 Two identical first-order systems have been cascaded non-interactively. The unit step response of the systems will be

(a) overdamped (b) underdamped
(c) undamped (d) critically damped

[ESE-2001]

2.5 Which one of the following is the response $y(t)$ of a causal LTI system described by

$$H(s) = \frac{(s+1)}{s^2 + 2s + 2}$$

for a given input $x(t) = e^{-t} u(t)$?

(a) $y(t) = e^{-t} \sin t\, u(t)$
(b) $y(t) = e^{-(t-1)} \sin(t-1)\, u(t-1)$
(c) $y(t) = \sin(t-1)\, u(t-1)$
(d) $y(t) = e^{-t} \cos t\, u(t)$

[ESE-2001]

2.6 Which one of the following is the steady-state error for a step input applied to a unity feedback system with the open loop transfer function

$$G(s) = \frac{10}{s^2 + 14s + 50}?$$

(a) $e_{ss} = 0$ (b) $e_{ss} = 0.83$
(c) $e_{ss} = 1$ (d) $e_{ss} = \infty$

[ESE-2001]

2.7 The unit step response of a particular control system is given by $c(t) = 1 - 10e^{-t}$. Then its transfer function is

(a) $\dfrac{10}{s+1}$ (b) $\dfrac{s-9}{s+1}$

(c) $\dfrac{1-9s}{s+1}$ (d) $\dfrac{1-9s}{s(s+1)}$

[ESE-2001]

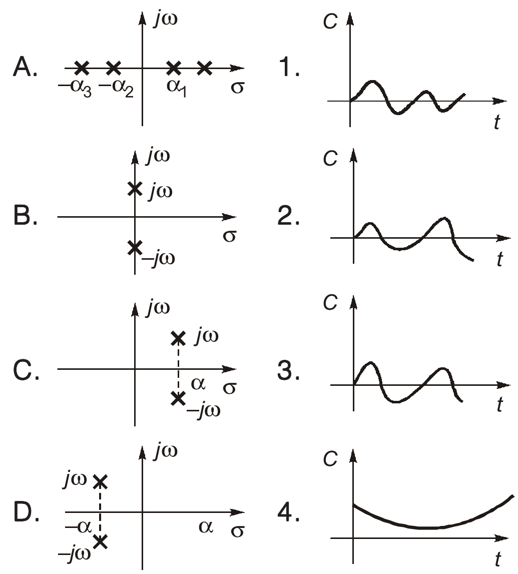
2.8 A third-order system is approximated to an equivalent second order system. The rise time of this approximated lower order system will be

(a) same as original system for any input
(b) smaller than the original system for any input
(c) larger than the original system for any input
(d) larger or smaller depending on the input

[ESE-2001]

2.9 Match **List-I** (Pole-zero plot of linear control system) with **List-II** (Responses of the system) and select the correct answer:

List-I List-II



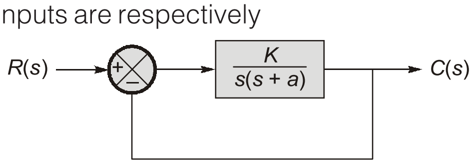
Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	4	3	2	1
(c)	3	4	2	1
(d)	3	4	1	2

[ESE-2002]

2.10 A system has a single pole at origin. Its impulse response will be
(a) constant
(b) ramp
(c) decaying exponential
(d) oscillatory [ESE-2002]

2.11 Consider the unity feedback system as shown below. The sensitivity of the steady state error to change in parameter K and parameter a with ramp inputs are respectively



(a) 1, –1 (b) –1, 1
(c) 1, 0 (d) 0, 1 [ESE-2003]

2.12 Which one of the following is the transfer function of a linear system whose output is t^2e^{-t} for a unit step input?

(a) $\dfrac{s}{(s+1)^3}$ (b) $\dfrac{2s}{(s+1)^3}$

(c) $\dfrac{1}{s^2(s+1)}$ (d) $\dfrac{2}{s(s+1)^2}$

[ESE-2003]

2.13 Assuming unit ramp input, match **List-I** (System Type) with **List-II** (Steady State Error) and select the correct answer using the codes given below the lists:

List-I	List-II
A. 0	1. K
B. 1	2. ∞
C. 2	3. 0
D. 3	4. $1/K$

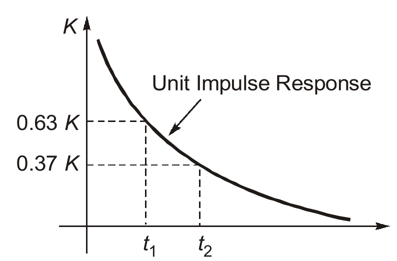
Codes:

	A	B	C	D
(a)	2	4	3	3
(b)	1	2	2	4
(c)	2	1	4	3
(d)	1	2	4	3

[ESE-2003]

2.14 When the time period of observation is large, the type of the error is
(a) Transient error
(b) Steady state error
(c) Half-power error
(d) Position error constant [ESE-2003]

2.15 The unit impulse response of a system having transfer function $K/(s + \alpha)$ is shown below. The value of α is



(a) t_1 (b) $1/t_1$
(c) t_2 (d) $1/t_2$

[ESE-2003]

2.16 What is the unit step response of a unity feedback control system having forward path transfer function $G(s) = \dfrac{80}{s(s+18)}$?

(a) Overdamped
(b) Critically damped
(c) Underdamped
(d) Undamped oscillatory

[ESE-2004]

2.17 Consider the following statements:
Feedback in control system can be used
1. to reduce the sensitivity of the system to parameter variations and disturbances
2. to change time constant of the system
3. to increase loop gain of the system

Which of the statements given above are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3
[ESE-2004]

2.18 Which one of the following statements is correct?
A second-order system is critically damped when the roots of its characteristic equation are
(a) negative, real and unequal
(b) complex conjugates
(c) negative, real and equal
(d) positive, real and equal
[ESE-2004]

2.19 A linear network has the system function

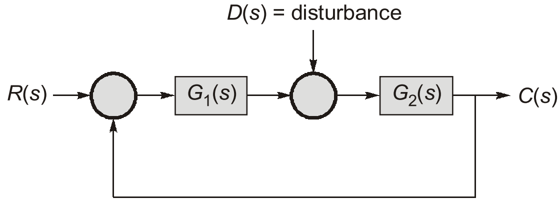
$$H\frac{(s+c)}{(s+a)(s+b)}$$

The outputs of the network with zero initial conditions for two different inputs are tabled as

Input $x(t)$	Output $y(t)$
$u(t)$	$2+De^{-t}+Ee^{-3t}$
$e^{-2t}u(t)$	$Fe^{-t}+Ge^{-3t}$

Then the values of c and H are, respectively
(a) 2 and 3 (b) 3 and 2
(c) 2 and 2 (d) 1 and 3 **[ESE-2005]**

2.20 For the given system, how can be steady state error produced by step disturbance be reduced?



(a) By increasing dc gain of $G_1(s)G_2(s)$
(b) By increasing dc gain of $G_2(s)$
(c) By increasing dc gain of $G_1(s)$
(d) By removing the feedback **[ESE-2005]**

2.21 Which one of the following expresses the time at which second peak in step response occurs for a second order system?

(a) $\frac{\pi}{\omega_n\sqrt{1-\xi^2}}$ (b) $\frac{2\pi}{\omega_n\sqrt{1-\xi^2}}$
(c) $\frac{3\pi}{\omega_n\sqrt{1-\xi^2}}$ (d) $\frac{\pi}{\sqrt{1-\xi^2}}$
[ESE-2005]

2.22 With negative feedback in a closed loop control system, the system sensitivity to parameter variations:
(a) Increases (b) Decreases
(c) Becomes zero (d) Becomes infinite
[ESE-2005]

2.23 An underdamped second order system with negative damping will have the two roots:
(a) On the negative real axis as real roots
(b) On the left hand side of complex plane as complex roots
(c) On the right hand side of complex plane as complex conjugates
(d) On the positive real axis as real roots
[ESE-2005]

2.24 Match **List-I** (System $G(s)$) with **List-II** (Nature of Response) and select the correct answer using the code given below the Lists:

List-I	List-II
A. $\frac{400}{s^2+12s+400}$	1. Undamped
B. $\frac{900}{s^2+90s+900}$	2. Critically damped
C. $\frac{225}{s^2+30s+225}$	3. Underdamped
D. $\frac{625}{s^2+625}$	4. Overdamped

Codes:

	A	B	C	D
(a)	3	1	2	4
(b)	2	4	3	1
(c)	3	4	2	1
(d)	2	1	3	4

[ESE-2005]

2.25 Given a unity feedback system with $G(s)=\frac{K}{s(s+4)}$, what is the value of K for a damping ratio of 0.5?
(a) 1 (b) 16
(c) 4 (d) 2
[ESE-2005]

2.26 What is the steady state error for a unity feedback control system having $G(s) = \frac{1}{s(s+1)}$, due to unit ramp input?

(a) 1 (b) 0.5
(c) 0.25 (d) $\sqrt{0.5}$ **[ESE-2005]**

2.27 What is the value of K for a unity feedback system with $G(s) = \frac{K}{s(1+s)}$ to have a peak overshoot of 50%?

(a) 0.53 (b) 5.3
(c) 0.6 (d) 0.047 **[ESE-2006]**

2.28 Consider the following statements:
For the first order transient systems, the time constant is
1. a specification of transient response
2. reciprocal of real-axis pole location
3. an indication of accuracy of response
4. an indication of speed of the response

Which of the statements given above are correct?
(a) Only 1 and 2 (b) Only 1, 2 and 4
(c) Only 3 and 4 (d) 1, 2, 3 and 4
[ESE-2006]

2.29 The unit step response of a second order system is $= 1 - e^{-5t} - 5t\,e^{-5t}$
Consider the following statements:
1. The undamped natural frequency is 5 rad/s.
2. The damping ratio is 1.
3. The impulse response is $25t\,e^{-5t}$.

Which of the statements given above are correct?
(a) Only 1 and 2 (b) Only 2 and 3
(c) Only 1 and 3 (d) 1, 2 and 3
[ESE-2006]

2.30 The unit step response of a system is $1 - e^{-t}(1 + t)$. Which is this system?
(a) Unstable (b) Stable
(c) Critically stable (d) Oscillatory
[ESE-2006]

2.31 **Assertion (A):** The impulse response is only a function of the terms in natural response.
Reason (R): The differentiation and differencing operations eliminate the constant terms associated with the particular solution in the step response and change only the constants associated with exponential terms in the natural response.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true **[ESE-2006]**

2.32 The relation between input $x(t)$ and output $y(t)$ of a continuous-time system is given by

$$\frac{dy(t)}{dt} + 3y(t) = x(t)$$

What is the forced response of the system when $x(t) = k$ (a constant)?
(a) k (b) $k/3$
(c) $3k$ (d) 0 **[ESE-2007]**

2.33 How can the steady-state error in a system be reduced?
(a) By decreasing the type of system
(b) By increasing system gain
(c) By decreasing the static error constant
(d) By increasing the input **[ESE-2007]**

2.34 For second-order system

$$2\frac{d^2y}{dt^2} + 4\frac{dy}{dt} + 8y = 8x$$

what is the damping ratio?
(a) 1 (b) 0.25
(c) 0.333 (d) 0.5 **[ESE-2007]**

2.35 For a second-order system, ξ is equal to zero in the transfer function given by

$$\frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

Which one of the following is correct?
(a) Closed-loop poles are complex conjugate with negative real part
(b) Closed-loop poles are purely imaginary
(c) Closed-loop poles are real, equal and negative
(d) Closed-loop poles are real, unequal and negative
[ESE-2007]

2.36 For the unity feedback system with $G(s) = \frac{10}{s^2(s+4)}$, what is the steady state error resulting from an input $10t$?
(a) 10 (b) 4
(c) Zero (d) 1 **[ESE-2007]**

2.115 Consider the following statements:

1. Rise time for the underdamped system is the time required for the response to rise from 5% to 95% of its final value.
2. The amount of maximum overshoot directly indicates the relative stability of the system.
3. Settling time is the time required for the response to reach and maintain within a specified tolerance band, i.e. either 3% or 6% of the final value.

Which of the above statements are not correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE-2024]

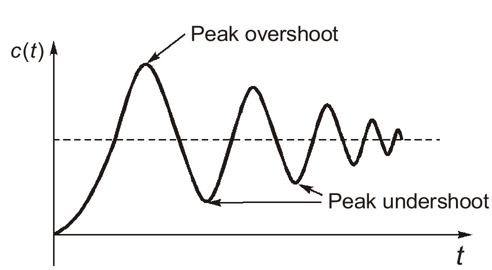
■■■

Answers Time Domain Analysis

2.1	(a)	2.2	(a)	2.3	(c)	2.4	(d)	2.5	(a)	2.6	(b)	2.7	(c)	2.8	(a)	2.9	(b)
2.10	(a)	2.11	(b)	2.12	(b)	2.13	(a)	2.14	(b)	2.15	(d)	2.16	(a)	2.17	(b)	2.18	(c)
2.19	(a)	2.20	(c)	2.21	(c)	2.22	(b)	2.23	(c)	2.24	(c)	2.25	(b)	2.26	(a)	2.27	(b)
2.28	(b)	2.29	(d)	2.30	(b)	2.31	(a)	2.32	(b)	2.33	(b)	2.34	(d)	2.35	(b)	2.36	(c)
2.37	(d)	2.38	(d)	2.39	(c)	2.40	(a)	2.41	(d)	2.42	(d)	2.43	(d)	2.44	(b)	2.45	(b)
2.46	(d)	2.47	(b)	2.48	(b)	2.49	(b)	2.50	(b)	2.51	(c)	2.52	(d)	2.53	(a)	2.54	(b)
2.55	(b)	2.56	(d)	2.57	(b)	2.58	(c)	2.59	(a)	2.60	(a)	2.61	(c)	2.62	(c)	2.63	(d)
2.64	(d)	2.65	(c)	2.66	(c)	2.67	(d)	2.68	(d)	2.69	(a)	2.70	(b)	2.71	(b)	2.72	(a)
2.73	(c)	2.74	(d)	2.75	(b)	2.76	(c)	2.77	(a)	2.78	(c)	2.79	(c)	2.80	(a)	2.81	(c)
2.82	(c)	2.83	(*)	2.84	(d)	2.85	(*)	2.86	(c)	2.87	(a)	2.88	(b)	2.89	(d)	2.90	(b)
2.91	(*)	2.92	(a)	2.93	(c)	2.94	(a)	2.95	(c)	2.96	(d)	2.97	(a)	2.98	(d)	2.99	(b)
2.100	(b)	2.101	(d)	2.102	(a)	2.103	(d)	2.104	(d)	2.105	(a)	2.106	(a)	2.107	(d)	2.108	(b)
2.109	(b)	2.110	(d)	2.111	(c)	2.112	(d)	2.113	(c)	2.114	(d)	2.115	(b)				

Explanations Time Domain Analysis

2.1 (a)



$$M_P = e^{-\xi n\pi/\sqrt{1-\xi^2}} \quad \text{for } n = 1, 2, 3, \ldots$$

2.2 (a)

$$H_1(s) = \frac{1}{s^2 + 4s + 4} = \frac{1}{(s+2)^2}$$

since both roots are negative real and equal, it is a critically damped system.

2.3 (c)

Settling time at 2% of tolerance band of the system,

$$t_s = \frac{4}{\xi\omega_n}$$

Settling time at 5% of tolerance band of the system,

$$t_s = \frac{3}{\xi\omega_n}$$

2.4 (d)

$$\left(\frac{1}{s+\tau}\right)\cdot\left(\frac{1}{s+\tau}\right) = \frac{1}{(s+\tau)^2}$$

Since both are cascaded non-interactively, the overall unit step response will be as shown above. It is clear that the above response is critically damped.

Alternate Solution:

Transfer function of first order system is $\frac{1}{1+sT}$

when two such are cascaded overall transfer function is (TF_1)

$$TF_1 = \frac{1}{1+sT}\cdot\frac{1}{1+sT}$$

$$= \frac{1}{s^2T^2+2sT+1} = \frac{1/T^2}{s^2+\frac{2s}{T}+\frac{1}{T^2}}$$

Comparing with standard second order transfer function, we get

$$\omega_n = \frac{1}{T}$$

and $2\xi\omega_n = \frac{2}{T}$

$$\xi = 1$$

∴ Critically underdamped.

2.5 (a)

$$X(s) = \frac{1}{s+1}$$

$$Y(s) = X(s)H(s)$$

$$= \frac{1}{(s+1)}\cdot\frac{(s+1)}{\{(s+1)^2+1\}} = \frac{1}{(s+1)^2+1}$$

$$\Rightarrow y(t) = e^{-t}\sin t\, u(t)$$

2.6 (b)

$$G(s) = \frac{10}{s^2+14s+50}$$

It is type 0 system. Input is step input.

$$e_{ss} = \frac{1}{1+K_p}$$

where $K_p = \lim_{s\to 0} G(s)H(s)$

$$K_p = \lim_{s\to 0}\frac{10}{s^2+14s+50}$$

$$= \frac{10}{50} = 0.2$$

$$e_{ss} = \frac{1}{1+0.2} = \frac{1}{1.3} = 0.83$$

2.7 (c)

$$\text{TF} = s\,L[\text{Step response}] = \frac{1-9s}{s+1}$$

2.10 (a)

$$G(s) = \frac{1}{s} \Rightarrow g(t) = 1$$

The impulse response of the system is constant.

2.11 (b)

$$R(s) = \frac{1}{s^2}$$

Steady state error

$$e_{ss} = \lim_{s\to 0}\frac{sR(s)}{1+G(s)H(s)}$$

$$\Rightarrow \quad e_{ss} = \lim_{s\to 0}\frac{s.1/s^2}{1+\frac{K}{s(s+a)}.1}$$

$$\Rightarrow \quad e_{ss} = \lim_{s\to 0}\frac{s+a}{s(s+a)+K}$$

$$\Rightarrow \quad e_{ss} = \frac{a}{K}$$

Sensitivity of e_{ss} to change in K is

$$S_K^{e_{ss}} = \frac{de_{ss}}{dK}\times\frac{K}{e_{ss}} = \frac{-a}{K^2}\times\frac{K}{a/K}$$

$$\Rightarrow \quad S_K^{e_{ss}} = -1$$

Now, $S_a^{e_{ss}} = \frac{de_{ss}}{da}\times\frac{a}{e_{ss}} = \frac{1}{K}\times\frac{a}{a/K}$

$$\Rightarrow \quad S_a^{e_{ss}} = 1$$

2.12 (b)

$$c(t) = t^2 e^{-t}$$

$$C(s) = \frac{2}{(s+1)^3}$$

$$R(s) = \frac{1}{s}$$

Transfer function

$$G(s) = \frac{C(s)}{R(s)} = \frac{2/(s+1)^3}{1/s}$$

$$\Rightarrow \quad G(s) = \frac{2s}{(s+1)^3}$$

2.13 (a)

Table for steady state error

Type \ Input	Unit step	Unit Ramp	Unit Parabola
Type 0	$\frac{1}{1+K_p}$	∞	∞
Type 1	0	$\frac{1}{K_v}$	∞
Type 2	0	0	$\frac{1}{K_a}$

Where $K_p = \lim_{s\to 0} G(s)H(s)$

$K_v = \lim_{s\to 0} sG(s)H(s)$

$K_a = \lim_{s\to 0} s^2G(s)H(s)$

2.14 (b)

Steady state error is the error at $t \to \infty$.

2.15 (d)

$$G(s) = \frac{C(s)}{R(s)} = \frac{K}{s+\alpha}$$

$$\Rightarrow \quad C(s) = \frac{K}{s+\alpha} \text{ since } R(s) = 1$$

$$\Rightarrow \quad c(t) = Ke^{-\alpha t}$$

Time constant $\tau = 1/\alpha$

Time constant is the time at which

$$c(t) = Ke^{-1} = 0.37\text{ K}$$

So, $\tau = t_2 = \frac{1}{\alpha} \Rightarrow \alpha = \frac{1}{t_2}$

2.16 (a)

$$\frac{G(s)}{1+G(s)} = \frac{80}{s^2+18s+80} \qquad \omega_n = \sqrt{80}$$

$$\xi = \frac{18}{2\sqrt{80}} = 1.00623$$

So, the system is overdamped.

2.17 (b)

(i) In open-loop system, transfer function $T = G$

Sensitivity of open-loop system is

$$S_G^T = \frac{\partial T}{\partial G}\times\frac{G}{T} = 1 \qquad [\because T = G]$$

In closed-loop system, transfer function

$$T = \frac{G}{1+GH}$$

$$S_G^T = \frac{\partial T}{\partial G}\times\frac{G}{T}$$

$$= \frac{1+GH-GH}{(1+GH)^2}\times\frac{G}{G/(1+GH)}$$

$$S_G^T = \frac{1}{1+GH}$$

Thus feedback is used to reduce the sensitivity of the system.

(ii) Feedback is the fraction of output. It reduces the loop gain.

2.18 (c)

(i) Roots of 2nd order underdamped system are complex conjugates.

(ii) Roots of 2nd order critically damped system are negative, real and equal.

(iii) Roots of 2nd order overdamped system are negative, real and unequal.

2.19 (a)

$$T(s) = H\frac{(s+c)}{(s+a)(s+b)} \qquad \text{...(i)}$$

When input is $u(t)$ output is

$$= 2 + De^{-t} + Ee^{-3t}$$

When input is $e^{-2t}u(t)$ output is

$$= Fe^{-t} + Ge^{-3t}$$

Using equation (i) when input is $u(t)$ output is

$$\frac{H(s+c)}{s(s+a)(s+b)} = \frac{K_1}{s}+\frac{D}{s+a}+\frac{E}{s+b}$$

Taking inverse Laplace transform

$$= 2 + De^{-t} + Ee^{-3t}$$

So, $a = 1$ and $b = 3$

Using final value theorem

$$\lim_{s\to 0}\frac{s\cdot H(s+c)}{s(s+a)(s+b)} = \lim_{t\to\infty} 2+De^{-t}+Ee^{-3t}$$

$$\frac{Hc}{ab} = 2 \text{ and } Hc = 6$$

Using equation (i) when input is $e^{-2t}u(t)$ output is

$$\frac{H(s+c)}{(s+2)(s+a)(s+b)}$$

Only two terms are present in the response.

Hence $s + c = s + 2$

$\Rightarrow \quad c = 2$

$H = 3 \qquad (\because HC = 6)$

2.20 (c)

Output due to disturbance $D(s)$ is

$$C_D(s) = \frac{G_2}{1+G_1G_2}\cdot D(s)$$

$$C_D(s) \equiv \frac{G_2}{G_1G_2}\cdot D(s) \qquad [\because\ G_1G_2 >> 1]$$

$$C_D(s) \approx \frac{1}{G_1(s)}\cdot D(s)$$

Thus effect of disturbance can be reduced by increasing $G_1(s)$.

2.21 (c)

Time for peak overshoots are

$$t_p = \frac{n\pi}{\omega_n\sqrt{1-\xi^2}} \qquad n = 1, 3, 5, \ldots$$

For first peak overshoot, $n = 1$

$$t_{p1} = \frac{n\pi}{\omega_n\sqrt{1-\xi^2}}$$

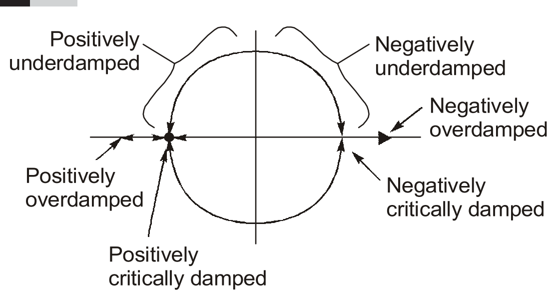
For second peak overshoot, $n = 3$

$$t_{p2} = \frac{3\pi}{\omega_n\sqrt{1-\xi^2}}$$

2.22 (b)

With negative feedback, stability of the system increases and as stability is inversely proportional to sensitivity, therefore sensitivity decreases.

2.23 (c)



2.24 (c)

$s^2 + 12s + 400 = 0$

$$\Rightarrow \xi = \frac{12}{2\sqrt{400}} = \frac{12}{40} < 1$$

$\Rightarrow$ underdamped $s^2 + 90s + 900 = 0$

$$\Rightarrow \xi = \frac{90}{2\sqrt{900}} = \frac{90}{2\times 30} > 1$$

$\Rightarrow$ overdamped $s^2 + 30s + 225 = 0$

$$\Rightarrow \xi = \frac{30}{2\sqrt{225}} = \frac{30}{2\times 15} = 1$$

$\Rightarrow$ critically damped

$s^2 + 625 = 0$

$\Rightarrow \xi = 0 \Rightarrow$ undamped.

2.25 (b)

$$\frac{G(s)}{1+G(s)} = \frac{K}{s^2+4s+K}$$

$$\xi = \frac{4}{2\sqrt{K}} = 0.5$$

$$\Rightarrow \quad \sqrt{K} = \frac{4}{2\times 0.5} = 4$$

$$\Rightarrow \quad K = 16$$

2.26 (a)

For type 1, ramp input

$$e_{ss} = \frac{1}{K_v}$$

where $$K_v = \lim_{s\to 0} sG(s)$$

$$= \lim_{s\to 0} s\cdot\frac{1}{s(s+1)} = 1$$

So, $$e_{ss} = \frac{1}{K_v} = 1$$

2.27 (b)

$$\frac{G(s)}{1+G(s)} = \frac{K}{s^2+s+K}$$

$$\xi = \frac{1}{2\sqrt{K}}$$

$$\frac{-\frac{1}{2\sqrt{K}}.\pi}{\sqrt{1-\frac{1}{4K}}} = ln(0.5) = -0.693$$

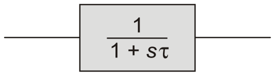
$$\Rightarrow \quad \frac{\pi^2}{4K} = 0.48\left(1-\frac{1}{4K}\right)$$

$$\Rightarrow \quad 4K - 1 = \frac{\pi^2}{0.48}$$

$$\Rightarrow \quad 4K = 21.56$$

$$\Rightarrow \quad K = 5.39$$

2.28 (b)



(i) Time constant is a specification of transient response.
(ii) $s = -1/\tau$
(iii) The time constant τ also affect the steady state value of the system. Hence the accuracy is also governed by it.
(iv) Time constant is an indication of speed of the response.

2.29 (d)

$$C(s) = \frac{1}{s} - \frac{1}{s+5} - \frac{5}{(s+5)^2}$$

$$= \frac{(s+5)^2 - (s+5)s - 5s}{s(s+5)^2}$$

$$= \frac{25}{s(s+5)^2}$$

$$C(s) = \frac{25}{s(s^2+10s+25)}$$

$$R(s) = \frac{1}{s}$$

$$G(s) = \frac{C(s)}{R(s)} = \frac{25}{s^2+10s+25}$$

$$\omega_n = \sqrt{25}$$

$$\Rightarrow \quad \omega_n = 5 \text{ rad/s}$$

$$\xi = \frac{10}{2 \times 5} = 1$$

$$\text{Impulse response} = \frac{d}{dt}(1 - e^{-5t} - 5te^{-5t})$$

$$= 5e^{-5t} - 5e^{-5t} + 25te^{-5t} = 25te^{-5t}$$

2.30 (b)

$$C(s) = \frac{1}{s} - \frac{1}{s+1} - \frac{5}{(s+1)^2}$$

$$= \frac{(s+1)^2 - s(s+1) - s}{s(s+1)^2} = \frac{1}{s(s+1)^2}$$

$$R(s) = \frac{1}{s}$$

$$G(s) = \frac{C(s)}{R(s)} = \frac{1}{(s+1)^2} = \frac{1}{s^2+2s+1}$$

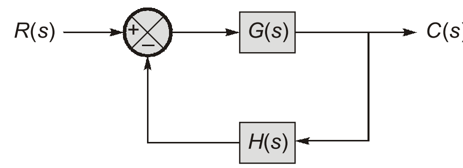
$$\therefore \quad \xi = 1$$

So given system is critically stable.

2.33 (b)

Steady state error,

$$e_{ss} = \lim_{s \to 0} \frac{sR(s)}{1 + G(s)H(s)}$$



(i) By increasing the input $R(s)$, e_{ss} increases.
(ii) By decreasing the type of system, e_{ss} increases.

(iii) $e_{ss} \propto \dfrac{1}{\text{Static error constant}}$

Therefore, by decreasing the static error constant (K_p, K_v or K_a), e_{ss} increases.

2.34 (d)

$$2\frac{d^2y}{dt^2} + 4\frac{dy}{dt} + 8y = 8x$$

$$\text{or} \quad \frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 4y = 4x$$

Taking Laplace transform,

$(s^2 + 2s + 4)\, y(s) = 4X(s)$

$$\text{or} \quad \frac{Y(s)}{X(s)} = \frac{4}{s^2+2s+4}$$

Comparing the transfer function with

$$\frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

$$\omega_n^2 = 4$$

$$\Rightarrow \quad \omega_n = 2$$

$$2\xi\omega_n = 2$$

$$\Rightarrow \quad \xi = \frac{2}{2\omega_n} = \frac{2}{2 \times 2} = 0.5$$

Therefore, the damping ratio, $\xi = 0.5$.

2.35 (b)

Characteristic equation

$s^2 + 2\xi\,\omega_n s + \omega_n^2 = 0$

If $\xi = 0$, then $s_2 + \omega_n^2 = 0$

$\Rightarrow \quad s = \pm j\omega_n$

It is clear that the closed-loop poles are purely imaginary.

2.36 (c)

$$e_{ss} = \lim_{s\to 0}\frac{sR(s)}{1+G(s)H(s)}$$

Given that,

$$\text{input } r(t) = 10t$$

$$\Rightarrow \quad R(s) = 10/s^2$$

$$G(s) = \frac{10}{s^2(s+4)},\quad H(s) = 1$$

$$\because \quad e_{ss} = \lim_{s\to 0}\frac{s\cdot 10/s^2}{1+\dfrac{10}{s^2(s+4)}}$$

$$= \lim_{s\to 0}\frac{10s(s+4)}{s^2(s+4)+10} = 0$$

2.37 (d)

Characteristic equation = $4s^2 + 6s + 1 = 0$

$$s^2+\frac{6}{4}s+\frac{1}{4} = 0$$

Comparing with standard characteristic equation

$$s^2+2\xi\omega_n s+\omega_n^2 = 0$$

$$\omega_n = \frac{1}{2} = 0.5 \text{ rad/sec}$$

$$2\xi\omega_n = \frac{3}{2}$$

$$\xi = \frac{3}{4}\times 2 = 1.5$$

$\therefore$ System is overdamped.

2.38 (d)

$$C(\infty) = \lim_{s\to 0} s\times\frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}\times\frac{1}{s} = 1$$

2.39 (c)

Comparing the transfer function

$$\frac{16}{s^2+4s+16} \text{ with } \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}$$

$$\omega_n^2 = 16 \quad \Rightarrow \omega_n = 4 \text{ rad/s}$$

$$2\xi\omega_n = 4 \quad \Rightarrow = \frac{4}{2\omega_n}$$

$$\Rightarrow \quad \xi = \frac{4}{2\times 4}$$

Time for first overshoot

$$t_p = \frac{\pi}{\omega_n\sqrt{1-\xi^2}} = \frac{\pi}{4\sqrt{1-\dfrac{1}{4}}} = \frac{\pi}{2\sqrt{3}}s$$

2.40 (a)

The response of an amplifier with three (or more) poles is determined approximately by the two lowest poles, p_1 and p_2, provided that $|p_3/p_2| \geq 4$.

2.41 (d)

This is the Laplace transform of sin t.

So, $f(t)$ = sin t

Steady-state value of $f(t)$ is undetermined because poles of $F(s)$ are not in LHS of s-plane. Therefore, steady-state value will vary between – 1 and +1.

2.42 (d)

$$G(s) = \frac{4}{s^2+0.4s}\ ;\ H(s) = 1$$

Characteristic equation

$$1 + G(s)\,H(s) = 0$$

$$\Rightarrow \quad 1+\frac{4}{s^2+0.4s}\cdot 1 = 0$$

$$\Rightarrow \quad s^2 + 0.4s + 4 = 0 \qquad ...(1)$$

Comparing equation (1) with standard equation of second order system i.e.

$$s^2+2\xi\omega_n s+\omega_n^2 = 0$$

we have

$$2\xi\omega_n = 0.4 \Rightarrow \boxed{\xi\omega_n = 0.2}$$

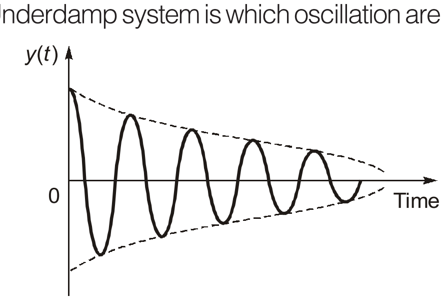
settling time within 2% tolerance band

$$t_s = \frac{4}{\xi\omega_n} = \frac{4}{0.2}$$

$$\Rightarrow \quad t_s = 20 \text{ sec}$$

2.43 (d)

Underdamp system is which oscillation are damped.



2.45 (b)

Integral controller improves steady state performance while derivative controller improves transient state response.