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ESE-2018 : Preliminary Examination

Electronics and Telecommunication Engineering : Volume-II

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Director's Message

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 carrier option.

B. Singh (Ex. IES)

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

Contents

E&T Engineering Volume-II

Objective Solved Questions

of UPSC Engineering Services Examination

■■■■

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 When a human being tries to approach an object, his brain acts as
(a) an error measuring device
(b) a controller
(c) an actuator
(d) an amplifier

[ESE-1999]

1.2 For two-phase *AC* servomotor, if the rotor's resistance and reactance are respectively *R* and *X*, its length and diameter are respectively *L* and *D*, then
(a) X/R and L/D are both small
(b) X/R is large but L/D is small
(c) X/R is small but L/D is large
(d) X/R and L/D are both large

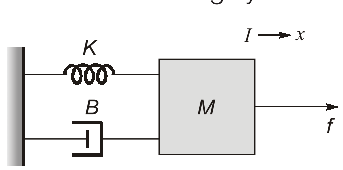
[ESE-1999]

1.3 Consider the following statements relating to synchros:
1. The rotor of the control transformer is either disc shaped
2. The rotor of the transmitter is so constructed as to have a low magnetic reluctance.
3. Transmitter and control transformer pair is used as an error detector

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE-1999]

1.4 Consider the following systems:

1.


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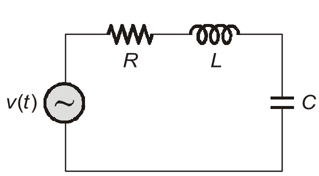

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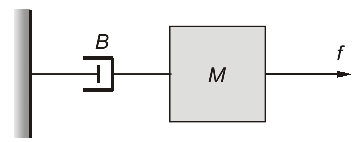

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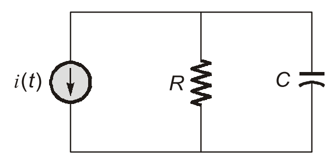


Which of these systems can be modelled by the differential equation,

$$a_2\frac{d^2y(t)}{dt^2}+a_1\frac{dy(t)}{dt}+a_0y(t)=x(t)?$$

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

[ESE-1999]

1.5 Match **List-I** (Functional components) with **List-II** (Devices) and select the correct answer:

List-I
A. Error detector
B. Servometer
C. Amplifier
D. Feedback

List-II
1. Three-phase FHP induction motor
2. A pair of synchronous transmitter and control transformer
3. Tachogenerator
4. Armature controlled FHP DC motor
5. Amplidyne

Codes:

	A	B	C	D
(a)	2	4	1	5
(b)	4	2	5	3
(c)	2	4	5	3
(d)	1	2	3	5

[ESE-2000]

1.6 **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]

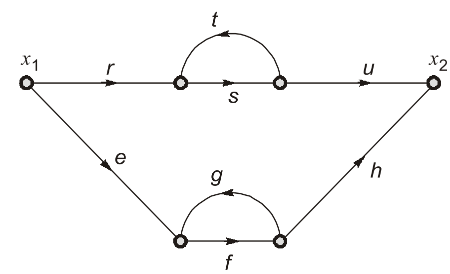
1.7 Consider the following statements:
1. The effect of feedback is to reduce the system error
2. Feedback increases the gain of the system in one frequency range but decreases in another.
3. Feedback can cause a system that is originally stable to become unstable
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3
[ESE-2000]

1.8 Consider the following servomotors:
1. AC two-phase servomotor
2. DC servomotor
3. Hydraulic servomotor
4. Pneumatic servomotor
The correct sequence of these servomotors in increasing order of power handling capacity is
(a) 2, 4, 3, 1 (b) 4, 2, 3, 1
(c) 2, 4, 1, 3 (d) 4, 2, 1, 3
[ESE-2000]

1.9 Open loop transfer function of a system having one zero with a positive real value is called
(a) zero phase function
(b) negative phase function
(c) positive phase function
(d) non-minimum phase function
[ESE-2001]

1.10 **Assertion (A):** The stator winding of a control transformer has higher impedance per phase.
Reason (R): The rotor of control transformer is cylindrical in shape.
(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-2001]

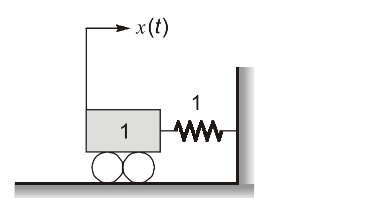
1.11 For the signal flow diagram shown in the given figure, the transmittance between x_2 and x_1 is



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

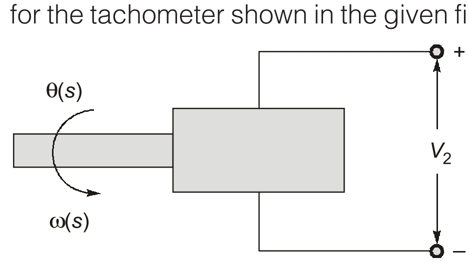
(c) $\frac{efh}{1-ru}+\frac{rsu}{1-eh}$ (d) $\frac{rst}{1-eh}+\frac{rsu}{1-st}$
[ESE-2001]

1.12 Consider the mechanical system shown in the given figure. If the system is set into motion by unit impulse force, the equation of the resulting oscillation will be



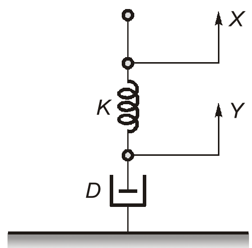
(a) $x(t) = \sin t$ (b) $x(t) = \sqrt{2}\sin t$
(c) $x(t) = 1/2 \sin 2t$ (d) $x(t) = \sin\sqrt{2}t$
[ESE-2001]

1.13 Which one of the following relations holds good for the tachometer shown in the given figure?



(a) $V_2(s) = sk_t\omega(s)$ (b) $V_2(s) = k_t s^2\theta(s)$
(c) $V_2(s) = k_t s^2\omega(s)$ (d) $V_2(s) = k_t s\,\theta(s)$
[ESE-2001]

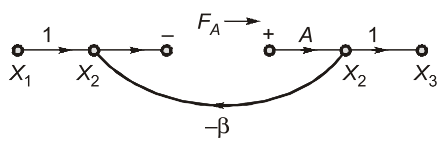
1.14 The mechanical system shown below has its pole(s) at



(a) $-K/D$ (b) $-D/K$
(c) $-DK$ (d) O, $-K/D$

[ESE-2002]

1.15 Consider the following signal-loop feedback structure illustrating the return difference:



The return difference for A is
(a) $A\beta$ (b) $1 + A\beta$
(c) $\frac{A\beta}{1+A\beta}$ (d) $\frac{A\beta}{1-A\beta}$

[ESE-2002]

1.16 **Assertion (A):** In a shunt regulator, the control element is connected in shunt with the load to achieve constant output voltage.
Reason (R): The impedance of the control element varies to keep the total current flowing through the load and the control element constant.
(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-2003]

1.17 **Assertion (A):** In the error detector configuration using a synchro transmitter and synchro control transformer, the latter is connected to the error amplifier.
Reason (R): Synchro control transformer has almost a uniform reluctance path between the rotor and the stator.
(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-2004]

1.18 **Assertion (A):** The error detector in a position control system using synchro pairs employs synchro transmitter for reference signal and synchro control transformer for the feedback signal.
Reason (R): Synchro control transformer rotor has a uniform magnetic reluctance.
(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-2004]

1.19 Consider the following statements for a.c. series motors:
1. The rotor is designed so that its R/X ratio is small.
2. $dT/d\omega < 0$ where T and ω are torque and speed respectively.
3. The reference and control voltages should be in phase quadrature, but their magnitudes need not be equal.

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]

1.20 A tachometer feedback is used as an inner loop in a position control servo-system. What is the effect of feedback on the gain of the sub-loop incorporating tachometer and on the effective time constant of the system?
(a) Both are reduced
(b) Gain is reduced but the time constant is increased
(c) Gain is increased but the time constant is reduced
(d) Both are increased

[ESE-2004]

1.21 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]

1.22 **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]

1.23 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]

1.24 Match **List-I** (Components) with **List-II** (Functions) and select the correct answer using the code given below the lists:

List-I		**List-II**
A. Servomotor		**1.** Error detector
B. Amplidyne		**2.** Transducer
C. Potentiometer		**3.** Actuator
D. Flapper valve		**4.** Power amplifier

Codes:

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

[ESE-2007]

1.25 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) $\frac{1}{(s+1)(s+2)}$ (b) $\frac{1}{s(s+1)}$
(c) $\frac{1}{s(s+2)}$ (d) $\frac{0.5}{(s+1)(s+2)}$

[ESE-2007]

1.26 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]

1.27 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]

1.28 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 stabililty of the motor
(d) have no effect on stability

[ESE-2008]

1.29 Consider the following statements for pneumatic and hydraulic control systems:

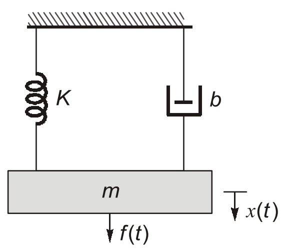
1. The normal operating pressure of pneumatic control is very much higher than that of hydraulic control.
2. In pneumatic control, external leakage is permissible to a certain extent, but there should be no leakage in a hydraulic control.

Which of the statements given above is/are correct?

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

[ESE-2008]

1.30 Which one of the following represents the linear mathematical model of the physical system shown in the below figure?



(a) $m\dfrac{d^2x(t)}{dt^2} + b\dfrac{dx(t)}{dt} + kx(t) = f(t)$

(b) $m\dfrac{d^2x(t)}{dt^2} + b\dfrac{dx(t)}{dt} + kx(t) = 0$

(c) $m\dfrac{d^2x(t)}{dt^2} + b\dfrac{dx(t)}{dt} + kx(t) + f(t) = 0$

(d) $m\dfrac{d^2x(t)}{dt^2} + b\dfrac{dx(t)}{dt} - kx(t) - f(t) = 0$

[ESE-2008]

1.31 The transfer function of a linear-time-invariant system is given as $\dfrac{1}{(s+1)}$. What is the steady-state value of the unit-impulse response ?

(a) Zero (b) One
(c) Two (d) Infinite [ESE-2009]

1.32 Which of the following can be used as a tachogenerator in control system?

(a) Microsyn (b) DC servomotor
(c) AC servomotor (d) Magnetic amplifier

[ESE-2009]

1.33 In closed loop control system, what is the sensitivity of the gain of the overall system, M to the variation in G?

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

(c) $\dfrac{G(s)}{1+G(s)H(s)}$ (d) $\dfrac{G(s)}{1+G(s)}$

[ESE-2009]

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

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

[ESE-2010]

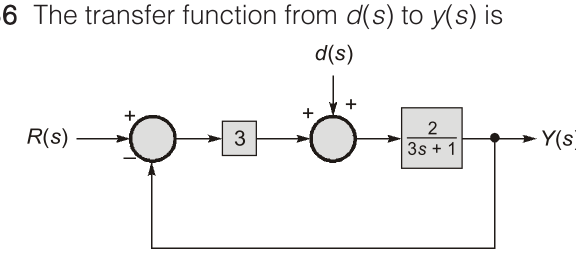
1.35 Consider the function $F(s) = \dfrac{5}{s(s^2+3s+2)}$,

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]

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

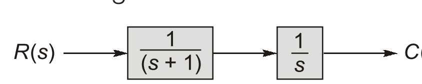


(a) $\dfrac{2}{3s+7}$ (b) $\dfrac{2}{3s+1}$

(c) $\dfrac{6}{3s+7}$ (d) $\dfrac{2}{3s+6}$

[ESE-2010]

1.37 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]

1.38 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]

1.39 **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]

1.40 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]

1.41 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]

1.42 The Laplace transform of $e^{-2t}\sin(2\omega t)$ is
(a) $\frac{2s}{(s+2)^2+2\omega^2}$ (b) $\frac{2\omega}{(s-2)^2+4\omega^2}$
(c) $\frac{2\omega}{(s+2)^2+4\omega^2}$ (d) $\frac{2s}{(s-2)^2+2\omega^2}$
[ESE-2015]

1.43 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]

1.44 In a servo-system, the device used for providing derivative feedback is known as
(a) Synchro (b) Servomotor
(c) Potentiometer (d) Techogenerator
[ESE-2015]

1.45 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]

1.46 In Force-Voltage Analogy
(a) Force is analogous to current
(b) Mass is analogous to capacitance
(c) Velocity is analogous to current
(d) Displacement is analogous to magnetic flux linkage
[ESE-2016]

1.47 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]

1.48 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]

1.49 The open-loop transfer function of a system is

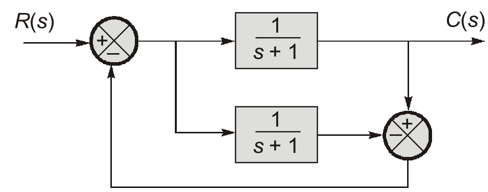
$$\frac{10K}{1+10s}$$

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]

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



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

(c) $s + 1$ (d) 1

[ESE-2018]

■■■

Answers Basics, Block Diagrams and Signal Flow Graphs

1.1 (b)	1.2 (c)	1.3 (c)	1.4 (a)	1.5 (c)	1.6 (a)	1.7 (a)	1.8 (c)	1.9 (d)
1.10 (b)	1.11 (a)	1.12 (a)	1.13 (d)	1.14 (a)	1.15 (b)	1.16 (c)	1.17 (c)	1.18 (d)
1.19 (c)	1.20 (a)	1.21 (a)	1.22 (a)	1.23 (a)	1.24 (d)	1.25 (a)	1.26 (c)	1.27 (c)
1.28 (a)	1.29 (c)	1.30 (a)	1.31 (a)	1.32 (c)	1.33 (a)	1.34 (c)	1.35 (d)	1.36 (a)
1.37 (b)	1.38 (a)	1.39 (a)	1.40 (b)	1.41 (d)	1.42 (c)	1.43 (a)	1.44 (d)	1.45 (a)
1.46 (c)	1.47 (c)	1.48 (b)	1.49 (a)	1.50 (b)				

Explanations Basics, Block Diagrams and Signal Flow Graphs

1.2 (c)

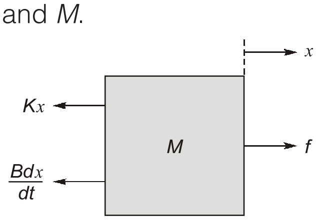
Small X/R gives linear speed torque characteristic. Large L/D gives less inertia and good acceleration characteristic.

1.3 (c)

Rotor of control transformer is made cylindrical in shape so that air gap is practically uniform.

1.4 (a)

This is a second order differential equation which means that there must be present all the three components in the system, i.e. either R, L and C or K, B and M.



Free body diagram of M in Fig. 1

In figure 1,

$$f - Kx - B\frac{dx}{dt} = M\frac{d^2x}{dt^2}$$

Or $$M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Kx = f \quad \text{... (i)}$$

In figure 2,

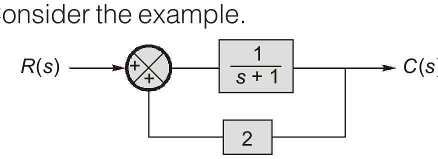
$$v(t) = Ri + \frac{Ldi}{dt} + \frac{q}{c}$$

Or $$v(t) = \frac{Ld^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{c} \quad \text{... (ii)}$$

Both the equations are symmetric to the given equation.

1.7 (a)

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



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

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

1.9 (d)

(i) When transfer function has at least one pole or zero in the RHS of s-plane, it is called **non-minimum phase transfer function.**

(ii) When transfer function has no pole or zero in the RHS of s-plane. It is called **minimum phase transfer function.**

1.11 (a)

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

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

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

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

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

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

1.12 (a)

Force equation is

$$\frac{Md^2x}{dt^2} + f\frac{dx}{dt} + Kx = F$$

Taking Laplace transform –

$(Ms^2 + fs + k)\ X(s) = F(s)$

Given:

$M = 1,\ k = 1,\ F(s) = 1$

Let $f = 0$ (Assume)

$\Rightarrow (s^2 + 1)\ X(s) = 1$

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

$$\Rightarrow \quad x(t) = \sin t$$

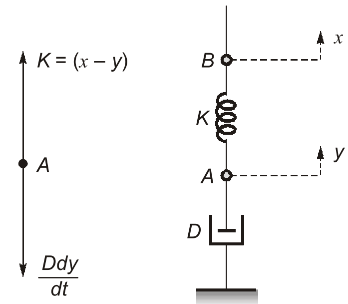
1.13 (d)

$$v_2(t) = K_t\frac{d\theta}{dt}$$

$$\Rightarrow \quad V_2(s) = K_t s\theta(s)$$

1.14 (a)

F.B.D. of point A:



so, $K(x-y) = \dfrac{Ddy}{dt}$

Taking Laplace transform –

$K\{X(s) - Y(s)\} = DsY(s)$

$\Rightarrow (Ds + K)\ Y(s) = KX(s)$

$$\Rightarrow \frac{Y(s)}{X(s)} = \frac{K}{D\left(s+\frac{K}{D}\right)}$$

Thus the pole of the system is at $s = -\dfrac{K}{D}$.

1.20 (a)

Techometer feedback reduces both gain and effective time constant.

1.21 (a)

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

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

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

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

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 $s + c = s + 2$

$\Rightarrow c = 2$

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

1.25 (a)

The step response of the first system

$= -0.5\,(1 + e^{-2t})$

$\therefore$ Impulse response of the first system

$$= \frac{d}{dt}\left[-0.5(1+e^{-2t})\right] = e^{-2t} \quad \text{...(i)}$$

The impulse response of the second system

$$= e^{-t} \quad \text{...(ii)}$$

$\therefore$ The overall response of the cascaded system

$$= \mathcal{L}\left[(e^{-2t})\times(e^{-t})\right] = \frac{1}{(s+2)(s+1)}$$

1.26 (c)

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

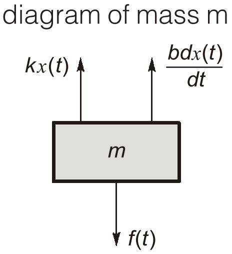
1.27 (c)

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

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

1.30 (a)

Free body diagram of mass m is shown below:



At balance,

$$f(t) - \frac{b\,dx(t)}{dt} - kx(t) = \frac{md^2\,x(t)}{dt^2}$$

or

$$\frac{m\,d^2x(t)}{dt^2} + \frac{bdx(t)}{dt} + kx(t) = f(t)$$

1.31 (a)

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

1.33 (a)

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

Sensitivity of M to the variation in G is

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

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

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

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

1.34 (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

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

1.35 (d)

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

The initial value of $f(t)$ is

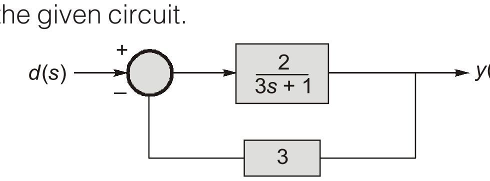
$$\underset{t\to 0}{f(t)} = \underset{s\to\infty}{sF(s)}$$

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

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

1.36 (a)

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



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

1.37 (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;

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

1.38 (a)

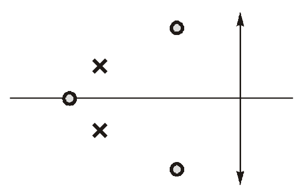
$$\text{Torque} = \frac{9.544 \times \text{Power}}{\text{Speed in rpm}} = \frac{9.544 \times 10 \times 10^3}{900}$$

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

1.39 (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

1.40 (b)

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

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

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

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

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

1.41 (d)

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

These for a unity feedback system with negative feedback

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

1.42 (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 $a = 2\omega$

$b = 2$

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

1.44 (d)

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

1.45 (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.

1.46 (c)

As per theory of analogy,

$$\begin{array}{ccccccc} F & \to & T & \to & V & \to & I \\ M & \to & J & \to & L & \to & C \\ B & \to & K & \to & R & \to & 1/R \\ k & \to & k & \to & 1/C & \to & 1/L \\ \nu & \to & \omega & \to & i & \to & v \\ x & \to & \theta & \to & q & \to & \phi \end{array}$$

1.47 (c)

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

1.49 (a)

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

Open time constant = 10

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

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

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

$$\therefore \quad K = 1.9$$

1.50 (b)

Using Mason gain formula

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

■■■