BITS, PILANI – DUBAI, INTERNATIONAL ACADEMIC CITY, DUBAI
FIRST SEMESTER 2009 – 2010
AAOC C321 CONTROL SYSTEMS
COMPREHENSIVE EXAMINATION

MAXIMUM MARKS: 60 WEIGHTAGE: 20%
DATE: 23-12-2009 DURATION: 3 hours

Note:
1. Answer each part (Part A, B & C) in separate answer script.
2. Write the ID no on the graph sheet

PART A

1. The open loop transfer function of a unity feedback system is given by G(s) = $\frac{0.382K}{s(0.1s+1)(1+0.06s)}$. Determine the limiting values of "K" for the system to be stable. Use routh stability criterion [8M]

2. Derive the output response of a typical second order system for an under damped case when being subjected to a unit step input. [7M]

PART –B

3. The open loop transfer function for the unity feedback system is $G(s)=\frac{K}{s(s+3)(s^2+2s+2)}$

. Plot the root locus in the graph sheet. [9 M]

4. A unity feedback control system has an open loop transfer function G(s)=

$\frac{10}{s(s+2)}$ **.Find the rise time, percentage overshoot, peak over shoot, peak time and settling time for 2% & 5% for a step input of 12 units.** [6 M]

PART -C

5. Obtain the overall transfer function C/R from the signal flow graph (Figure 1)using Masons gain formula [7M]

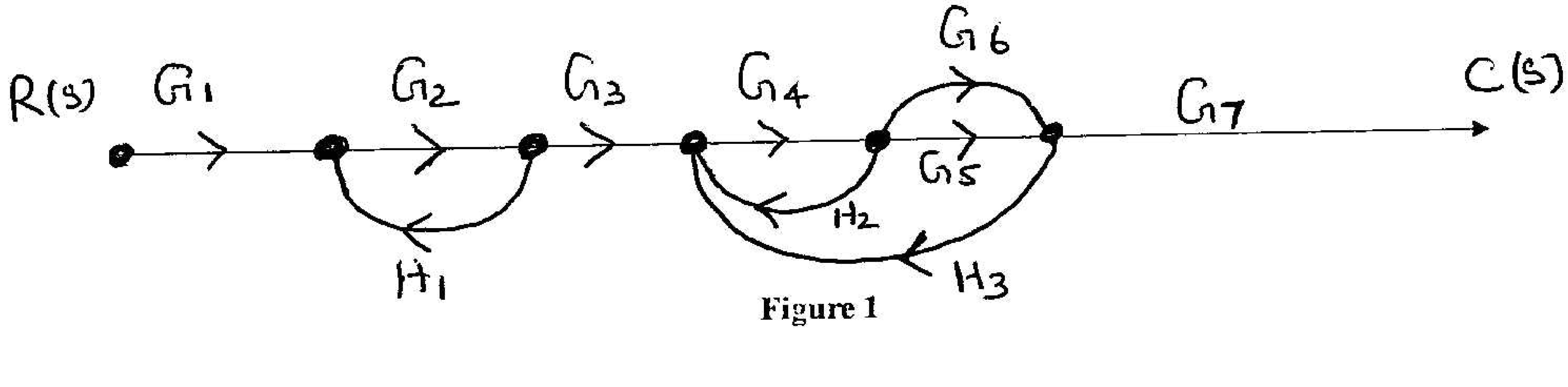

Figure 1

6. Convert the block diagram to signal flow graph (Figure 2) [2 M]

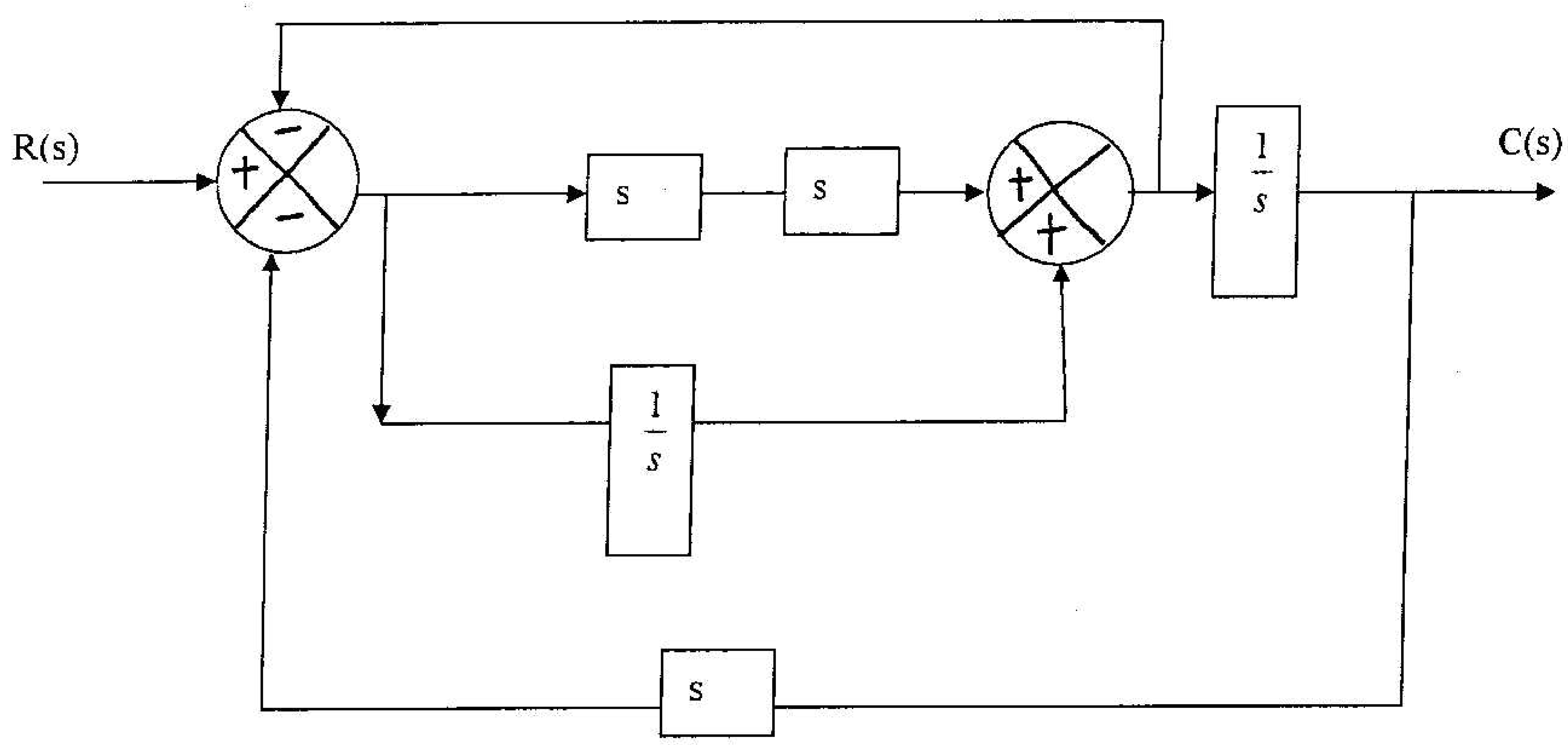

Figure 2

7. The open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{(1+0.2s)(1+0.025s)}{(1+0.001s)(0.005s+1)s^3}$$

. **Sketch a polar plot** (without graph sheet). [6 M]

8. With reference to the following figure (figure 3) of the speed control system of a DC motor, the generator field winding time constant is negligible. The generator is driven at a constant speed giving a generated voltage of "Kg" volt/field-amp. The DC motor is separately excited and it maintains a back emf of "Kb" volts per radian /sec. It produces a torque of "K_T" Newton –meter /amp. The combined inertia of motor a nd load is "J" Kg-m^2.The friction is negligible. The tachometer has a gain of "K_t" volts per radian /sec and the amplifier gain "K_A" amperes / volt. Find out the transfer function Ω(s) / Ei(s) where Ω(s) is the Laplace transform of speed ω(t) and Ei(s) is the laplace transform of e_i (t). Assume negligible load torque (T_L=0). With the system originally at rest, a control voltage, e_i = 100 V is suddenly applied. Determine the steady state speed (in radians per sec).

<u>Given data</u>

J= 6 Kg-m^2, K_A = 3 amperes / volt, K_T = 1.5 Newton –meter /amp, Kg= 50 volt/field-amp, K_t= 0.2 Newton –meter /amp, Ra=1 ohm K_b =K_T in M.K.S units. [12M]

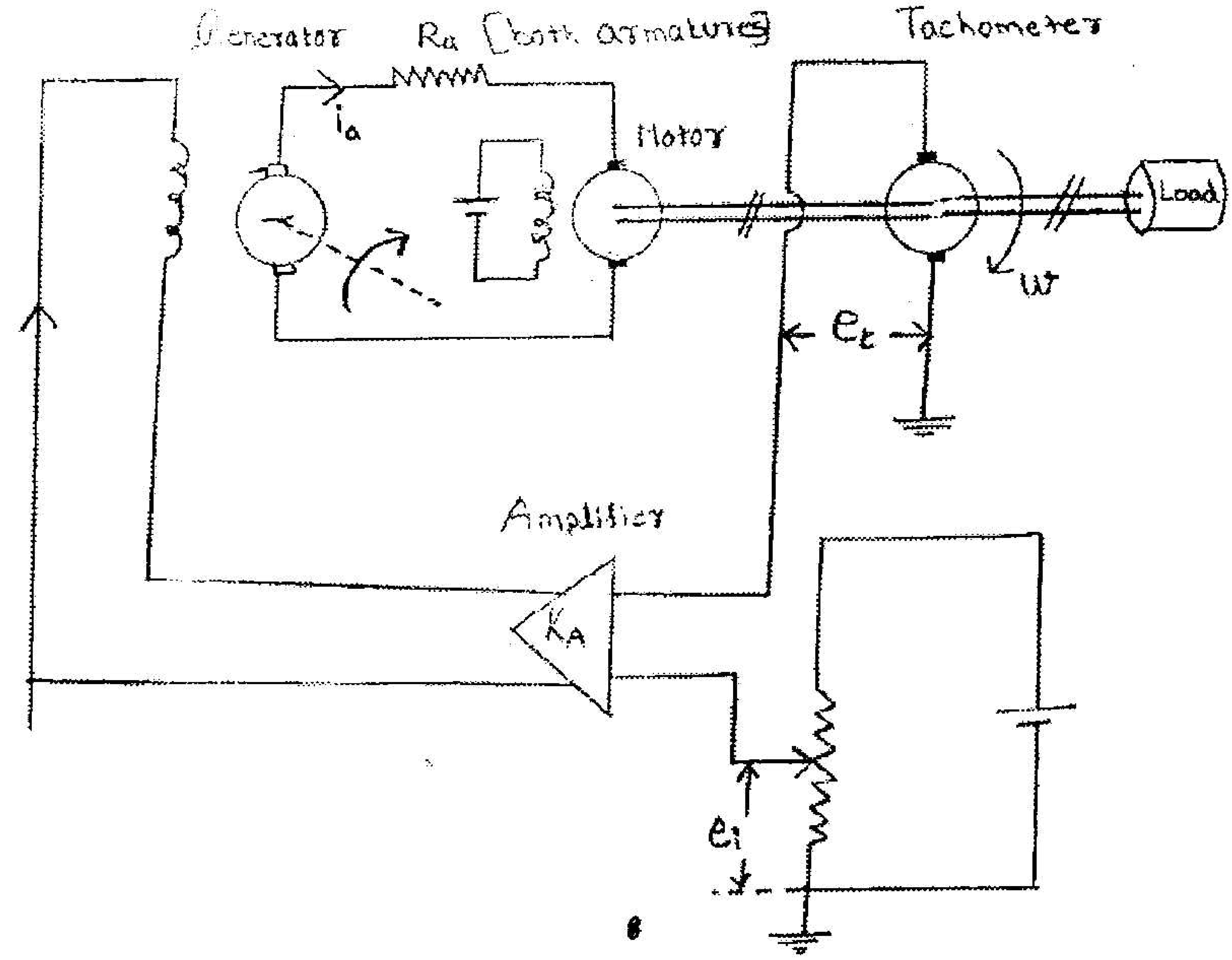

Figure 3

9. With reference to the following figure (Figure 4), find S_K^T. [3M]

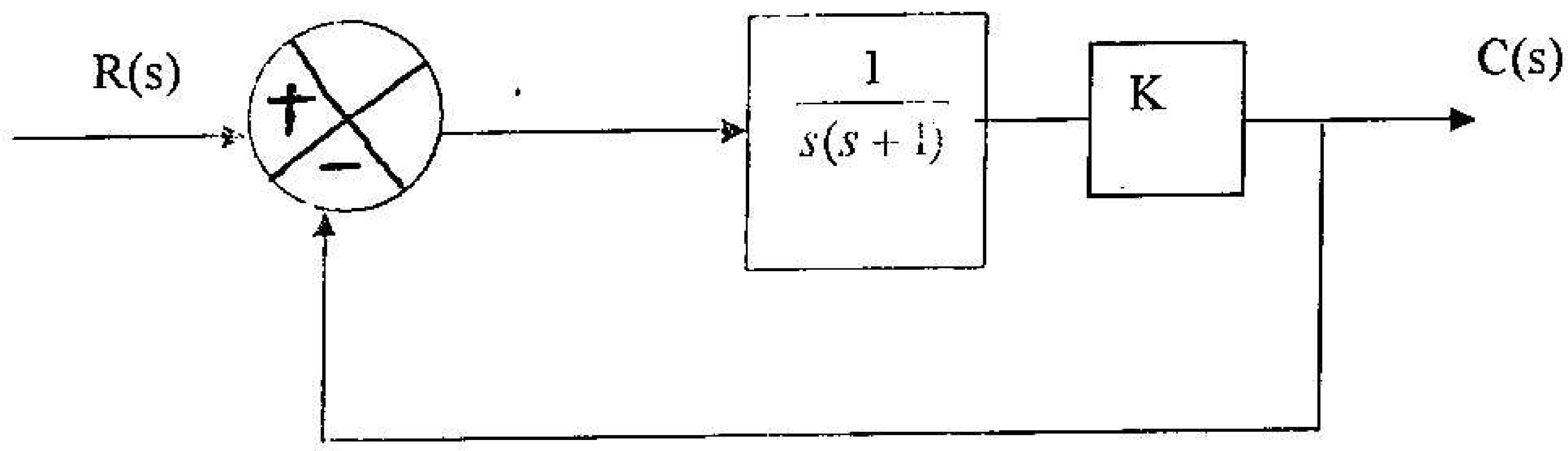

Figure 4

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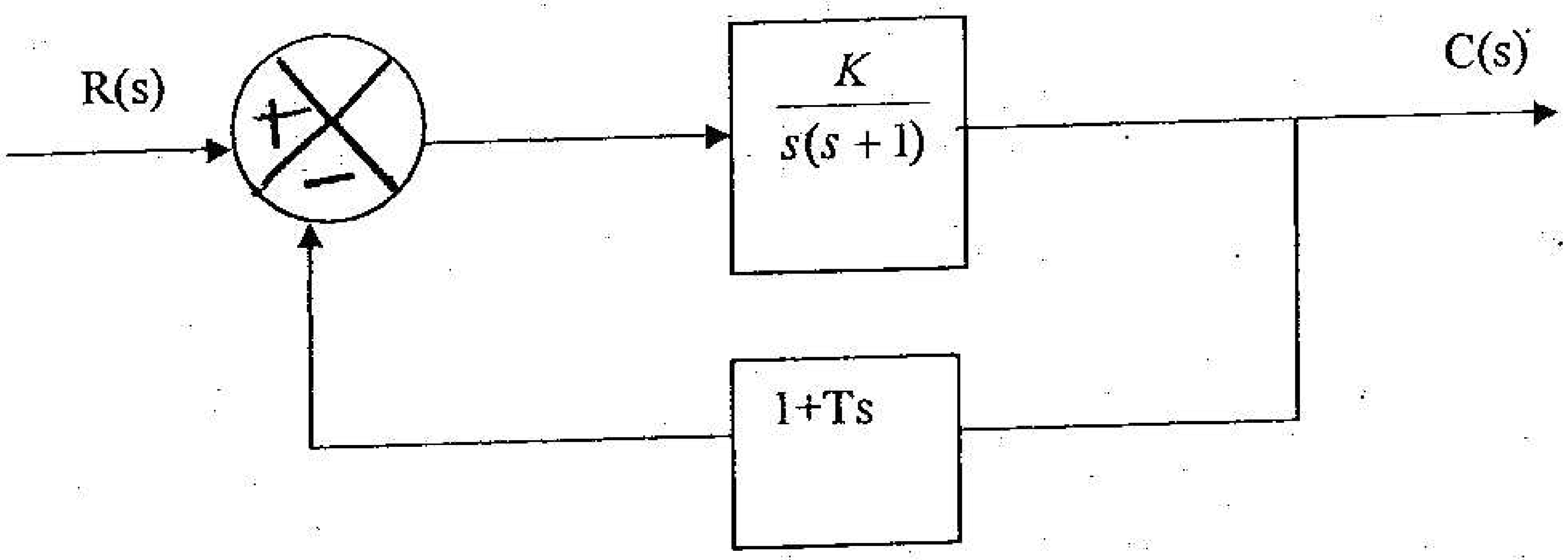
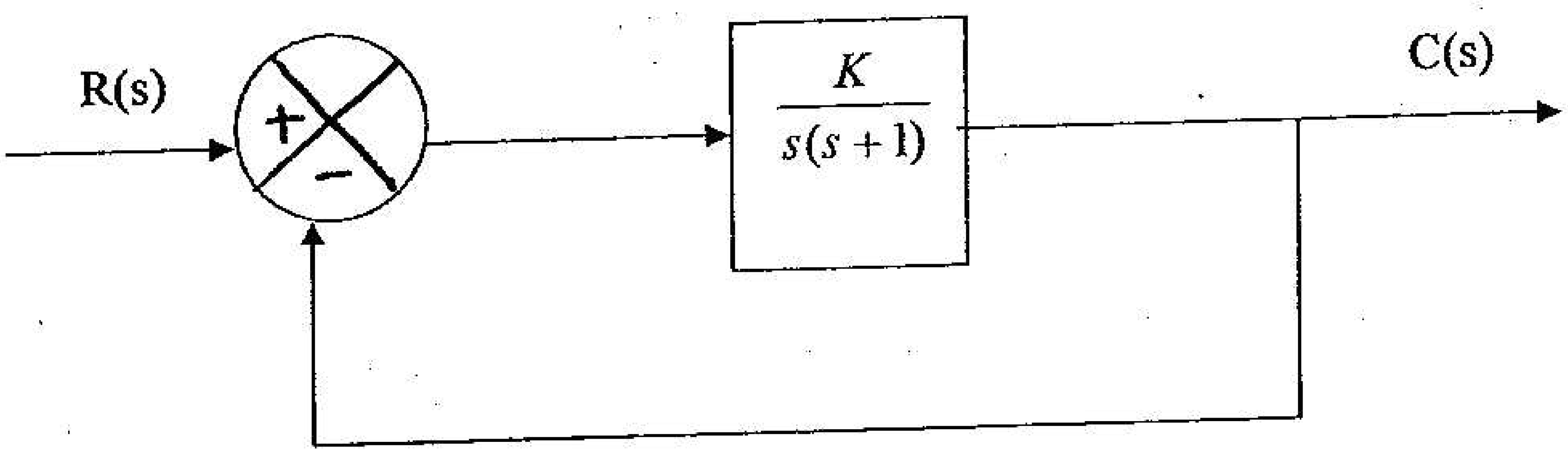
FIRST SEMESTER 2009 – 2010
AAOC C321 CONTROL SYSTEM
Test 2 (OPEN BOOK)

MAXIMUM MARKS: 20 **WEIGHTAGE: 20%**
DATE: 22-11-2009 **DURATION: 50 minutes**

1. For the system shown in figure, it is designed to determine the values of "K" and the velocity feedback constant "T" so that the maximum overshoot is 0.2 and peak time is 1 second. With these values of "K" and "T" determine the ξ and ω_n. [5M]

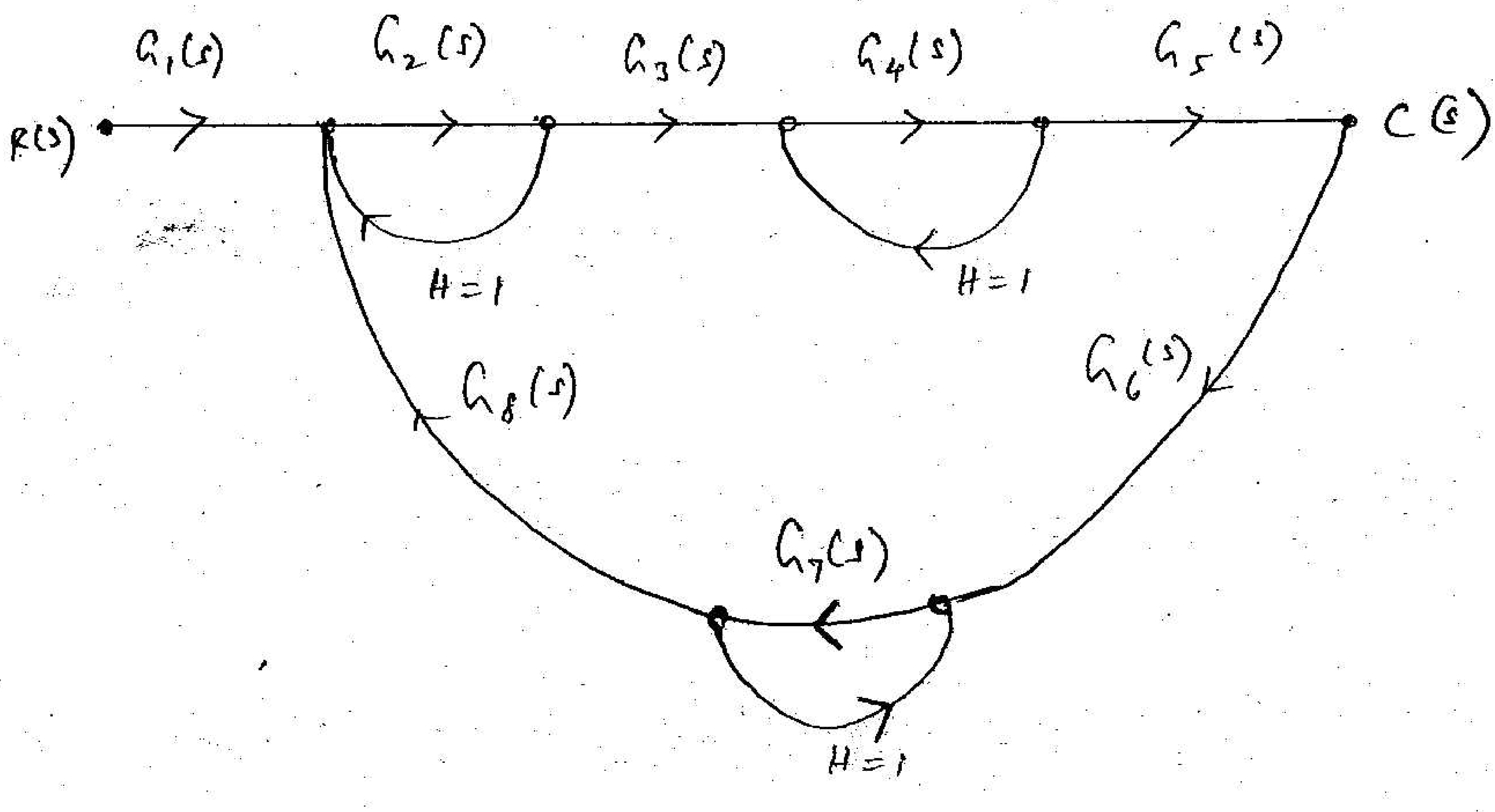


2. For the system shown below, the value of ω = 1 rad/sec and $\left|S_K^T\right|$=1. What are the possible values of "K". Which value of K can be accepted? [5M]



3. For a unity feedback system ,find the steady state error constants and steady state error whose open loop transfer function is given by $G(s) = \frac{1}{s(0.2s+1)(0.5s+1)}$ for a unit ramp input. [5M]
The feedback is negative.

4. Find the Transfer function C(s)/R(s) for the signal flow graph shown in figure. [5M]



Solution :

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

$$H(s) = 1 + Ts$$

$$M_p = 0.2 = 20\%$$

$$t_p = 1 \text{ sec}$$

Required : K, T and hence t_r and t_s

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

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

$$= \frac{K}{s(s+1) + K + Ts} \qquad \ldots(a)$$

The standard form is

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \qquad \ldots(b)$$

$K = \omega_n^2$ and

$$1 + T = 2\zeta\omega_n$$

$$\therefore T = 2\zeta\omega_n - 1$$

$$M_p = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}$$

$$0.2 = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}$$

Taking natural logarithms on bothsides, we get

$$l_n\, 0.2 = l_n\, e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}$$

$$-1.61 = -\frac{\pi\zeta}{\sqrt{1-\zeta^2}}$$

$$\therefore \frac{\zeta}{\sqrt{1-\zeta^2}} = \frac{1.61}{\pi} = 0.512$$

$$\text{Or } \zeta^2 = 0.262\,(1 - \zeta^2)$$

$$\text{or } 1.262\,\zeta^2 = 0.262$$

$$\Rightarrow \zeta = 0.46$$

Also

$$t_p = \frac{\pi}{\omega_d} = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$$

$$\omega_n = \frac{\pi}{t_p\sqrt{1-\zeta^2}} = \frac{\pi}{1\sqrt{1 - 0.46^2}} = 3.54 \text{ rad / sec}$$

$$K = \omega_n^2 = (3.54)^2 = 12.53$$

$$T = 2\zeta\omega_n - 1 = 2(0.46)(3.54) - 1 = 2.26$$

Answers

$K = 12.53$ [1.25 M]

$T = 2.26$ [1.25 M]

$\zeta = 0.46$ [1.25 M]

$\omega_n = 3.54$ rad/sec [1.25 M]

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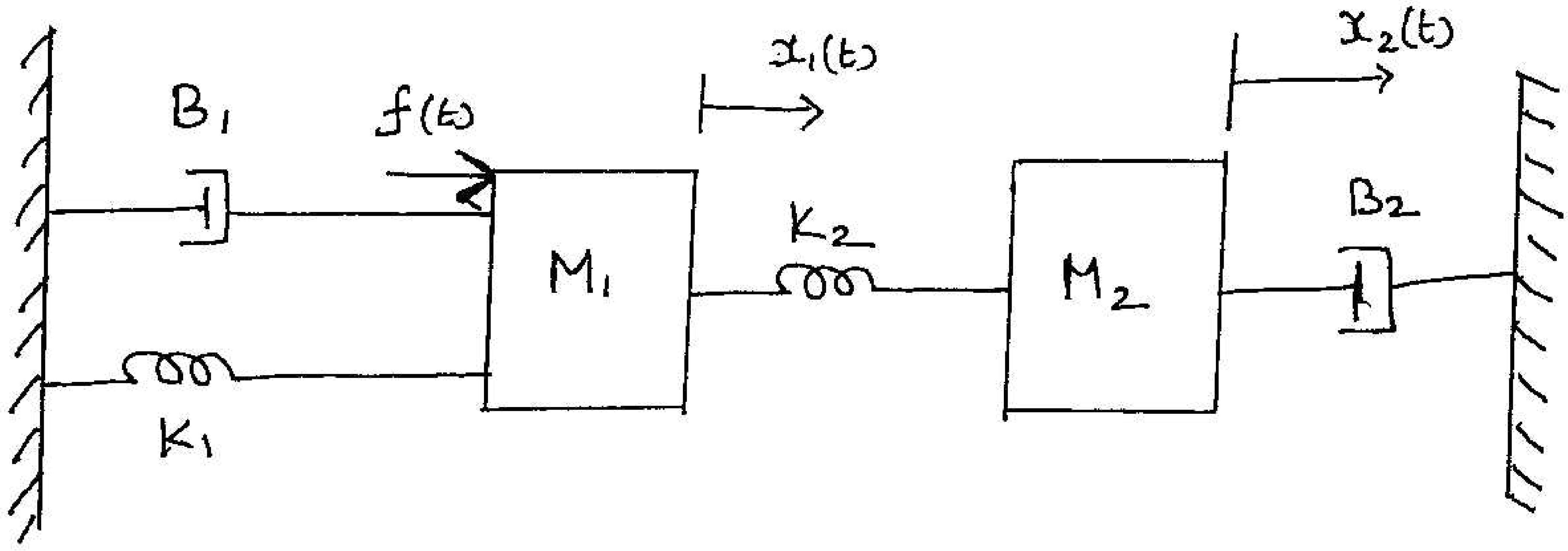
FIRST SEMESTER 2009 – 2010
AAOC C321 CONTROL SYSTEM
Test 1 (CLOSED BOOK)

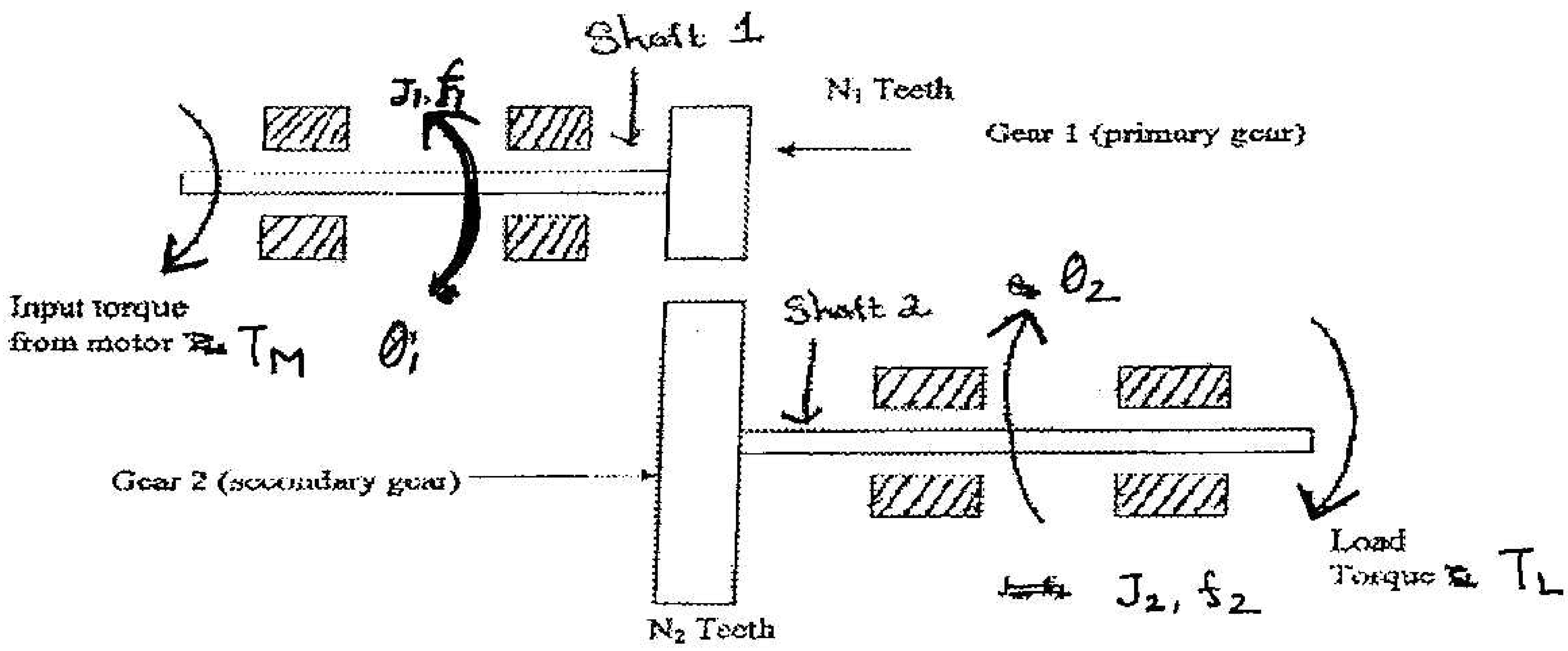
MAXIMUM MARKS: 25 WEIGHTAGE: 25%
DATE: 4-10-2009 DURATION: 50 minutes

1. For the mechanical system shown below , write down the differential equations of motion and hence determine the transfer functions $X_1(s)$ / $F(s)$ & $X_2(s)/F(s)$ [7M]



2. Derive the transfer function of an armature controlled DC motor with respect to motor gain and time constants. [6M]

3. Derive the torque equation of the system shown, referred to motor shaft 1 [8M]



4. The following data refers to field controlled DC motor [4M]

Torque constant of the motor	$= 3.5 \times 10^{-3}$ Nm / mA
Moment of inertia	= 0.4 kgm^2
Viscous friction coefficient	= 3.5 Nm / (rad /sec)
Resistance of the field winding	=100 ohms
Inductance of the field winding	= 0.1 H

Determine the transfer function relating the output shaft position to the input voltage of the field.

q. P

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AAOC C321 CONTROL SYSTEM
Quiz -II (CLOSED BOOK)

MAXIMUM MARKS: 21 **WEIGHTAGE: 7%**
DATE: 16-11-2009 **DURATION: 25 minutes**

Attention: Transfer the best answers to the table below.
Overwritten answers will not be evaluated

1. A	2. b	3. A	4. b	5. A
6. b	7. A	8 d	9 a	10 b

1. For a standard second order system with ω_n = 1 rad /sec, $\xi = 1$ and r (t)=δ(t), C(t) will be…
   a) $t\,e^{-t}$ b) $t^3 e^{-t}$ c) t sin(t) d) $t\,e^{-2t}$

2. If h(t) is the unit impulse response of a system, then for any input r(t), the response C(t) can be expressed as , (where τ is a dummy variable)

   a) $C(t)=\int_0^t \{h(t)\}^2 r(t)\, d\tau$ b) $C(t)=\int_0^t \{h(t-\tau\}\ r(\tau)\, d\tau$

   c) $C(t)=\int_0^t \{h(t)\}^2 r(t-\tau)\, d\tau$ d) $C(t)=\int_0^t \{2h(t)\} r(t-\tau)\, d\tau$

3. $S_G^T + S_H^T$ for a closed loop system will be

   a) $(1-(GH)^2) / (1 + GH)^2$ b) 2/(1+GH) C) $1/(1+GH)^2$ d) H/(1+GH)

4. The static error constant and steady state error of type 1 system subjected to Unit ramp input is
   a) $1/K_v$ and K_v b) K_v and $1/K_v$ c) 0 & infinity d) None of the above

5. A unity feedback system has an open loop transfer function of

   G(s) = 10/(s (s+1) (s+2)). The steady state error for unit ramp input is,

   a) 0.2 b) 0.5 c) 0 d) 1

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6. The expression for the first undershoot is

a) $\Pi / (\omega_n \sqrt{(1-\xi^2)}$ b) $2\Pi / (\omega_n \sqrt{(1-\xi^2)}$

c) $3\Pi / (\omega_n \sqrt{(1-\xi^2)}$ d) $4\Pi / (\omega_n \sqrt{(1-\xi^2)}$

7. The sensitivity of the open loop system is

b) One b) Zero c) Infinite d) $\pi/2$

8. If the roots are real , negative and unequal for a second order system (unit step input) then it is a

a) Over damped system b) Undamped system c) Critically damped system
d) Under damped system

9. For the following transfer function determine type and order of the system

$$G(s)\,H(s)= K/\ s^3\,(\,s^2+2s+1)$$

a) Type 3 order 5
b) Type 4 order 2
c) Type 6 order 5
d) Type 5 order 6

10. What will be the steady state error for a type 4 system , when the input signal is unit step

a) Constant b) Zero c) Infinite d) Undefined

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FIRST SEMESTER 2009 – 2010
AAOC C321 CONTROL SYSTEM
Quiz 1 (CLOSED BOOK)

MAXIMUM MARKS: 12 WEIGHTAGE: 8%
DATE: 26-10-2009 DURATION: 20 minutes

1. In the following pickup the linear systems [2.5M]

A) $d^2y(t)/dt^2 + a_1dy(t)/dt + a_2y(t) = 0$
B) $y\,dy(t)/dt + a_1y(t) = a_2\,u(t)$
c) $2\,d^2y(t)/dt^2 + t\,dy(t)/dt + t^2y(t) = 5$

(i) (A) & (B) (ii) (A) only
(iii) (A) & (C) (iv) None of the above

2. The number of individual feedback loop in figure 1 is ________ [2M]

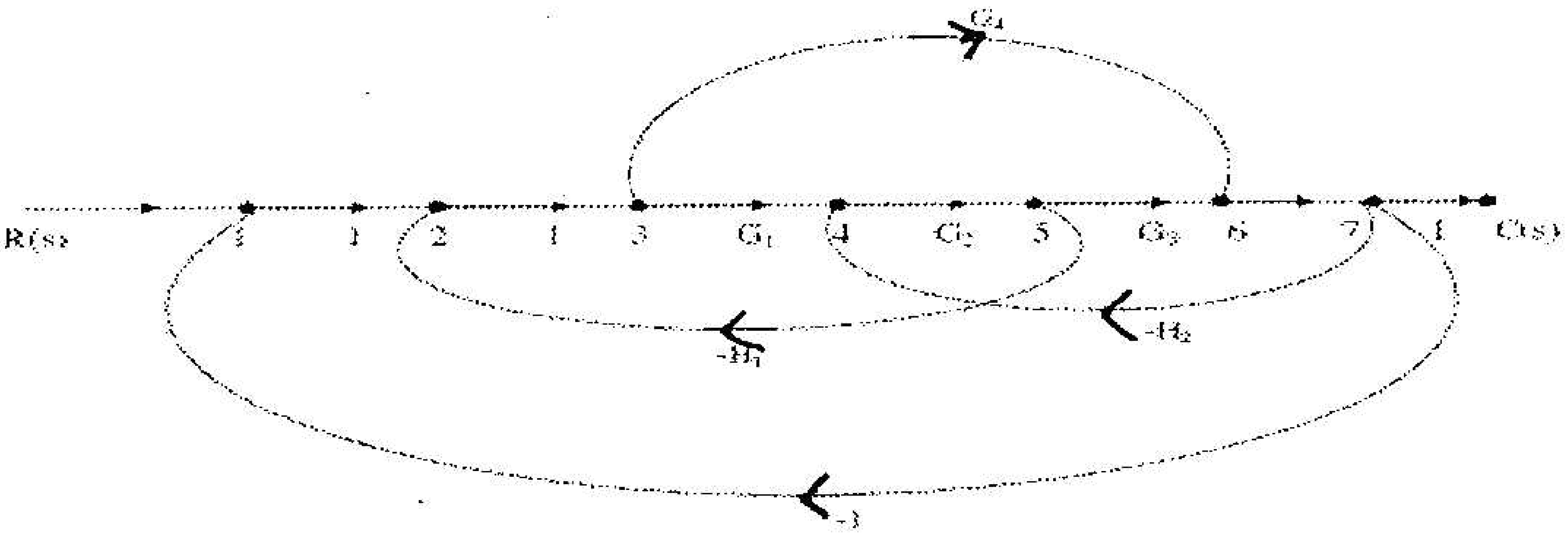

Figure 1

3. Effect of backemf in armature controlled DC motor is to________ [2M]
A) increase motor friction , thereby reducing motor time constant
B) increase motor friction , thereby increasing motor time constant
C) increase motor inertia, thereby reducing motor time constant
D) increase motor inertia, thereby increasing motor time constant

4. The overall TF of the physical system consisting more than one element can be obtained by multiplying the individual elements TF provided ______________

-- ------ [2 M]

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5. What is the basis for framing the rules of block diagram reduction technique? [2M]

____

____

6. Draw the rule for moving the summing point before the block. [1.5M]

7. Draw the rule for eliminating the negative feedback loop. [1M]

8. The term " Servomechanism" usually refers to __________________

____ [2M]

9. The output of a tachometer is 0V for 0 rpm, and 5V for 1000rpm. The Transfer Function for the tachometer is [2M]

Name: ID:

10. Given $\frac{y(s))}{x(s)} = \frac{s^2}{s^2 + \frac{K}{M} + \frac{f}{M}s}$. Under what condition $\frac{y(jw)}{x(jw)} = \frac{-w^2}{K/M}$? [3M]

11. Every Geometric linearity does not correspond to system linearity. Justify Mathematically. [4M]