SriVidya College of Engineering and Technology
Virudhunagar

EC6405-CONTROL SYSTEM ENGINEERNG
Unit I PART A

1. What is control system?

A system consists of a number of components connected together to perform a specific function. In a system when the output quantity is controlled by varying the input quantity then the system is called control system.

2. What are the two major types of control system?

The two major types of control system are open loop and closed loop

3. Define open loop control system.

The control system in which the output quantity has no effect upon the input quantity is called open loop control system. This means that the output is not feedback to the input for correction.

4. Define closed loop control system.

The control system in which the output has an effect upon the input quantity so as to maintain the desired output value is called closed loop control system.

5. What are the components of feedback control system?

The components of feedback control system are plant, feedback path elements, error detector and controller.

6. Distinguish between open loop and closed loop system

Open loop system	Closed loop system
1. Inaccurate	Accurate
2. Simple and economical	Complex and costlier
3. The changes in output due to external disturbance are not corrected	The changes in output due to external disturbances are corrected automatically
4. They are generally stable	Great efforts are needed to design a stable system

7. Why negative feedback is invariably preferred in closed loop system?

The negative feedback results in better stability in steady state and rejects any disturbance signals.

8. Define transfer function.

The transfer function of a system is defined as the ratio of the Laplace transform of output to Laplace transform of input with zero initial conditions.

9. What are the basic elements used for modeling mechanical translational system.

Mass, spring and dashpot.

10. What are the basic elements used for modeling mechanical rotational system?

Moment of inertia J, dashpot with rotational frictional coefficient B and torsional spring with stiffness K.

11. Write the force balance equation of an ideal mass element.

$F = M\, d^2x/dt^2$

12. Write the force balance equation of ideal dashpot element.

$F = B\, dx/dt$

13. Write the force balance equation of ideal spring element.

$F = kx$

14. Name two types of electrical analogous for mechanical system.

The two types of analogies for the mechanical system are Force voltage and force current analogy.

15. Write the analogous electrical elements in force voltage analogy for the elements of mechanical translational system.

a. Force-voltage e
b. Velocity v-current i
c. Displacement x-charge q
d. Frictional coefficient B-Resistance R
e. Mass M- Inductance L
f. Stiffness K-Inverse of capacitance 1/C

16. Write the analogous electrical elements in force current analogy for the elements of mechanical translational system.

a. Force-current i
b. Velocity v-voltage v
c. Displacement x-flux φ
d. Frictional coefficient B-conductance 1/R
e. Mass M- capacitance C
f. Stiffness K-Inverse of inductance 1/L

17. What is block diagram?

A block diagram of a system is a pictorial representation of the functions performed by each component of the system and shows the flow of signals. The basic elements of block diagram are block, branch point and summing point.

18. What is the basis for framing the rules of block diagram reduction technique?

The rules for block diagram reduction technique are framed such that any modification made on the diagram does not alter the input output relation.

19. What is a signal flow graph?

A signal flow graph is a diagram that represents a set of simultaneous algebraic equations. By taking L. T the time domain differential equations governing a control system can be transferred to a set of algebraic equations in s-domain.

20. What is transmittance?

The transmittance is the gain acquired by the signal when it travels from one node to another node in signal flow graph.

21. What is sink and source?

Source is the input node in the signal flow graph and it has only outgoing branches.
Sink is an output node in the signal flow graph and it has only incoming branches.

22. Define non touching loop

The loops are said to be no touching if they do not have common nodes.

23. Write Masons Gain formula.

Masons Gain formula states that the overall gain of the system is

$$T = \frac{1}{\Delta} \sum_k P_k \Delta_k$$

k- Forward path in the signal flow graph

P_k- Forward path gain of k^{th} forward path

Δ = 1-[sum of individual loop gains] +[sum of gain products of all possible combinations of two non touching loops]-[sum of gain products of all possible combinations of three non touching loops]+…

Δ_k = Δ for that part of the graph which is not touching k^{th} forward path.

24. What is servomechanism?

The servomechanism is a feedback control system, in which the output is mechanical position (or time derivatives of position velocity and acceleration).

25. What is servomotor?

The motors used in automatic control systems or in servomechanism are called servomotors. They are used to convert electrical signal into angular motion.

26. What is synchro?

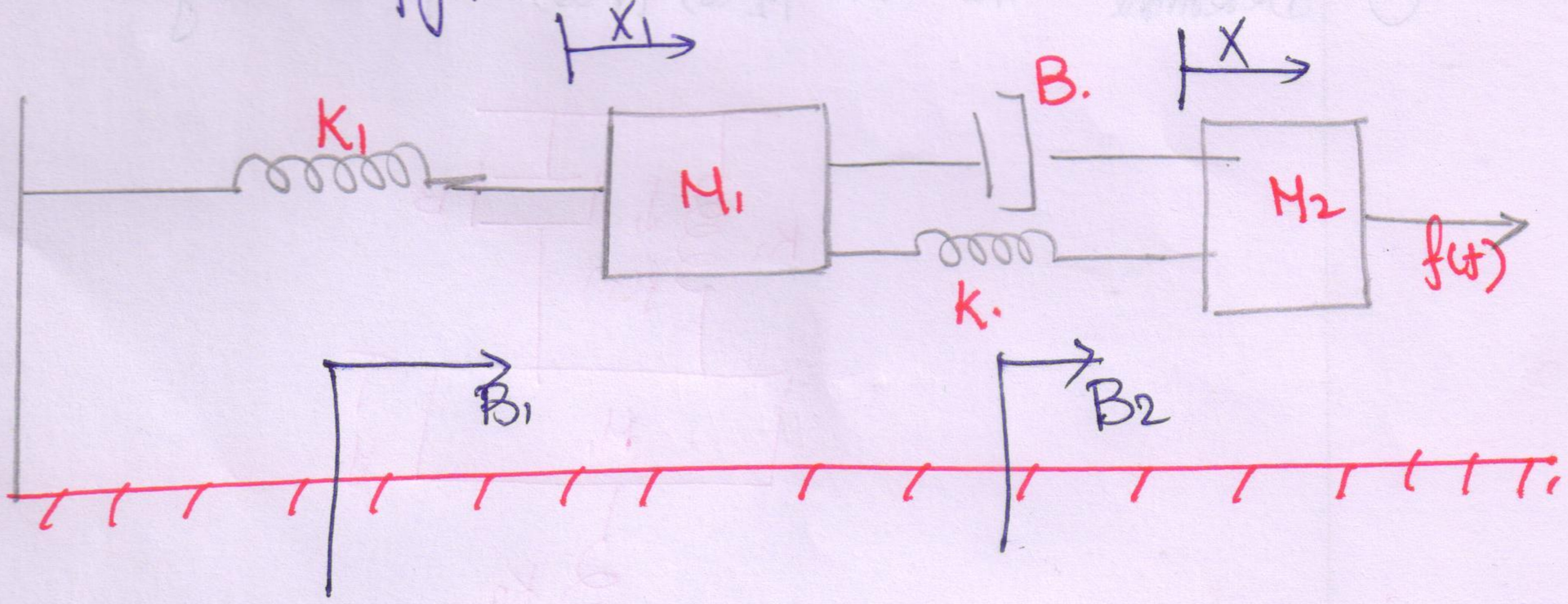
A synchro is a device used to convert an angular motion to an electrical signal or vice versa.

PART-B: Unit-I.

EC6405 - Control System Engineering.

ANSWER KEY:

(1) Write the differential equations Governing the Mechanical system shown in fig.



Solution:

Transfer function is $\frac{X(s)}{F(s)}$.

(i) Free body diagram: M_1

(ii) Take differential equation.

(iii) Find $X_1(s) = X(s) \frac{(Bs+K)}{M_1s^2+(B_1+B)s+(K_1+K)}$.

→ 8 Marks.

Formula:

Mechanical Translational system.

Mass → $M \cdot \frac{d^2x}{dt^2}$.

Spring → Kx

dashpot → $B \cdot \frac{dx}{dt}$.

(i) Free body diagram: M_2:

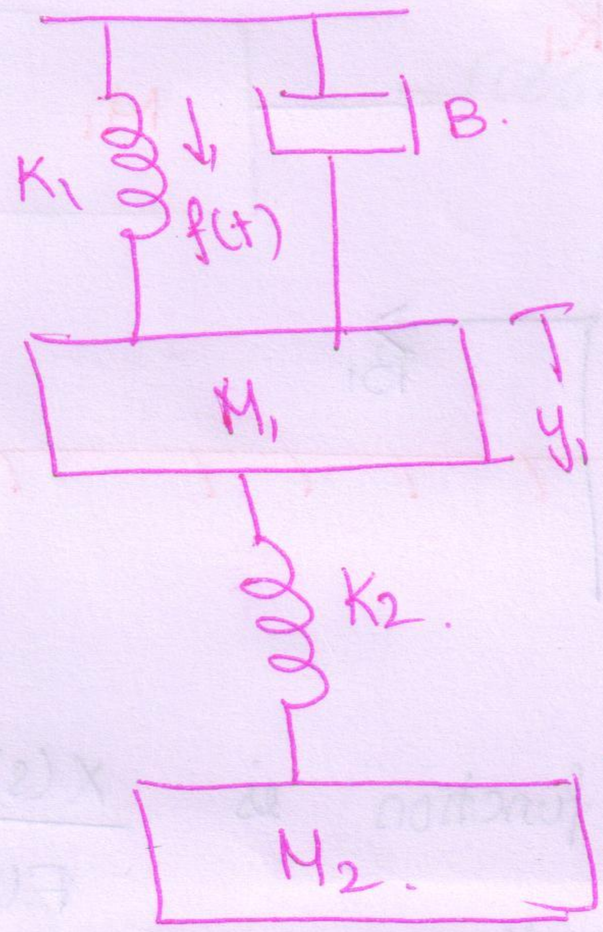
Take differential equation.

Find: $\frac{X(s)}{F(s)} = ?$.

$$\frac{X(s)}{F(s)} = \frac{M_1 s^2 + (B_1+B)s + (K_1+K)}{M_1 s^2 + (B_1+B)\left[M_2 s^2 + (B_2+B)s + K\right] - (Bs+K)^2}$$

→ 8 Marks.

(2) Determine the TF $Y_2(s)/F(s)$ of the system shown in fig.



Transfer function.

Free body diagram Mi:

Take the differential equation. → 8 Marks.

To find Transfer function.

Free body diagram M_2

Take the differential eqn → 7 Marks.

To find Transfer fn.

Result:

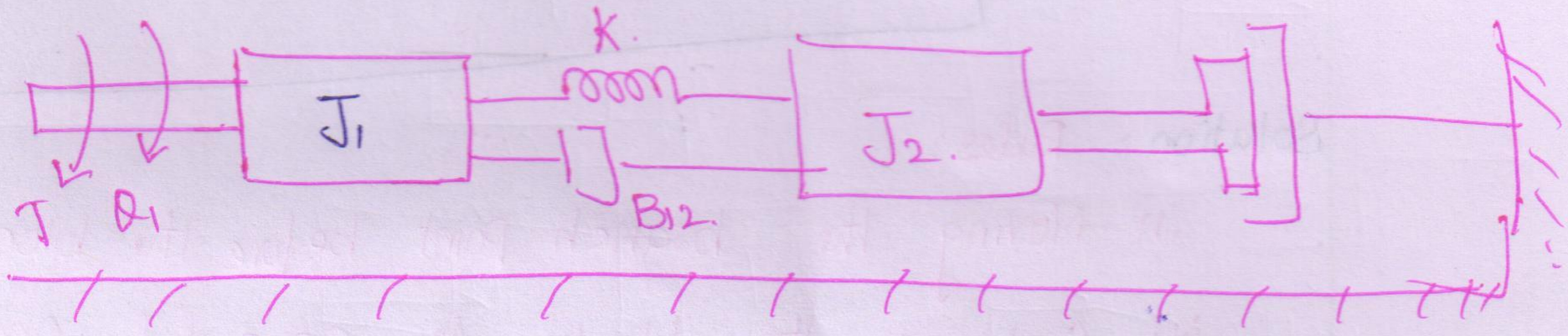
The differential equation governing the system are

(1) $M_1 \frac{d^2y_1}{dt^2} + B\frac{dy_1}{dt} + K_1 y_1 + K_2(y_1 - y_2) = f(t)$.

(2). $M_2 \frac{d^2y_2}{dt^2} + K_2(y_2 - y_1) = 0$.

$$\frac{Y_2(s)}{F(s)} = \frac{K_2}{\left[M_1 S^2 + BS + (K_1 + K_2)\right]\left[M_2 S^2 + K_2\right] - K_2^2}$$

③. Write the differential equations governing the Mechanical system



Solution:

i) Transfer function: $\frac{\theta(s)}{T(s)}$.

ii) Newton's second Law: $T_{J_1} + T_{B12} + T_K = T$

iii) Free body diagram: J_1

iv) Find: $\theta_1(s) = \left[\frac{s^2 J_2 + S(B_{12} + B) + K}{(S B_{12} + K)}\right] \theta(s)$

Free body diagram J_2.

To find $\frac{\theta(s)}{T(s)} = \frac{(S B_{12} + K)}{(J_1 S^2 + S B_{12} + K)\left(S(B_{12} + B) + K\right] - (S B_{12} + K)^2}$.

Result:

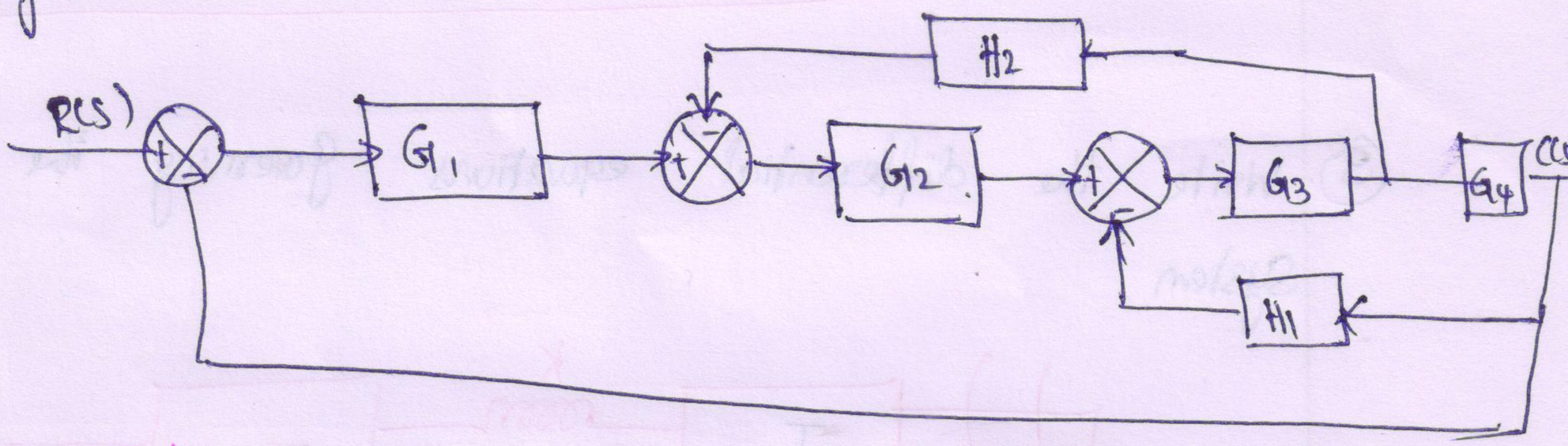
① $J_1 \frac{d^2\theta_1}{dt^2} + B_{12} \frac{d}{dt}(\theta_1 - \theta) + K(\theta_1 - \theta) = T$

② $J_2 \frac{d^2\theta}{dt^2} - B_{12} \frac{d\theta_1}{dt} + \frac{d\theta}{dt}(B_{12} + B) + K(\theta - \theta_1) = 0$.

③. Transfer function:

$$\frac{\theta(s)}{T(s)} = \frac{(SB_{12} + K)}{(J_1 S^2 + SB_{12} + K)\left(J_2 S^2 + S(B_{12} + B) + K\right] - (SB_{12} + K)^2}$$

(4) Determine the over all T/F C(S)/R(S) for the system shown in fig.



Solution: Rules:

(i) Moving the branch point before the block.

(ii) Combining the blocks in cascaded and rearranging the branch points.

(iii) Eliminating the feed back path

(iv) Combining the blocks in cascaded and eliminating feed back path.

(v) Combining the blocks in cascade.

(vi) Eliminating the feedback path.

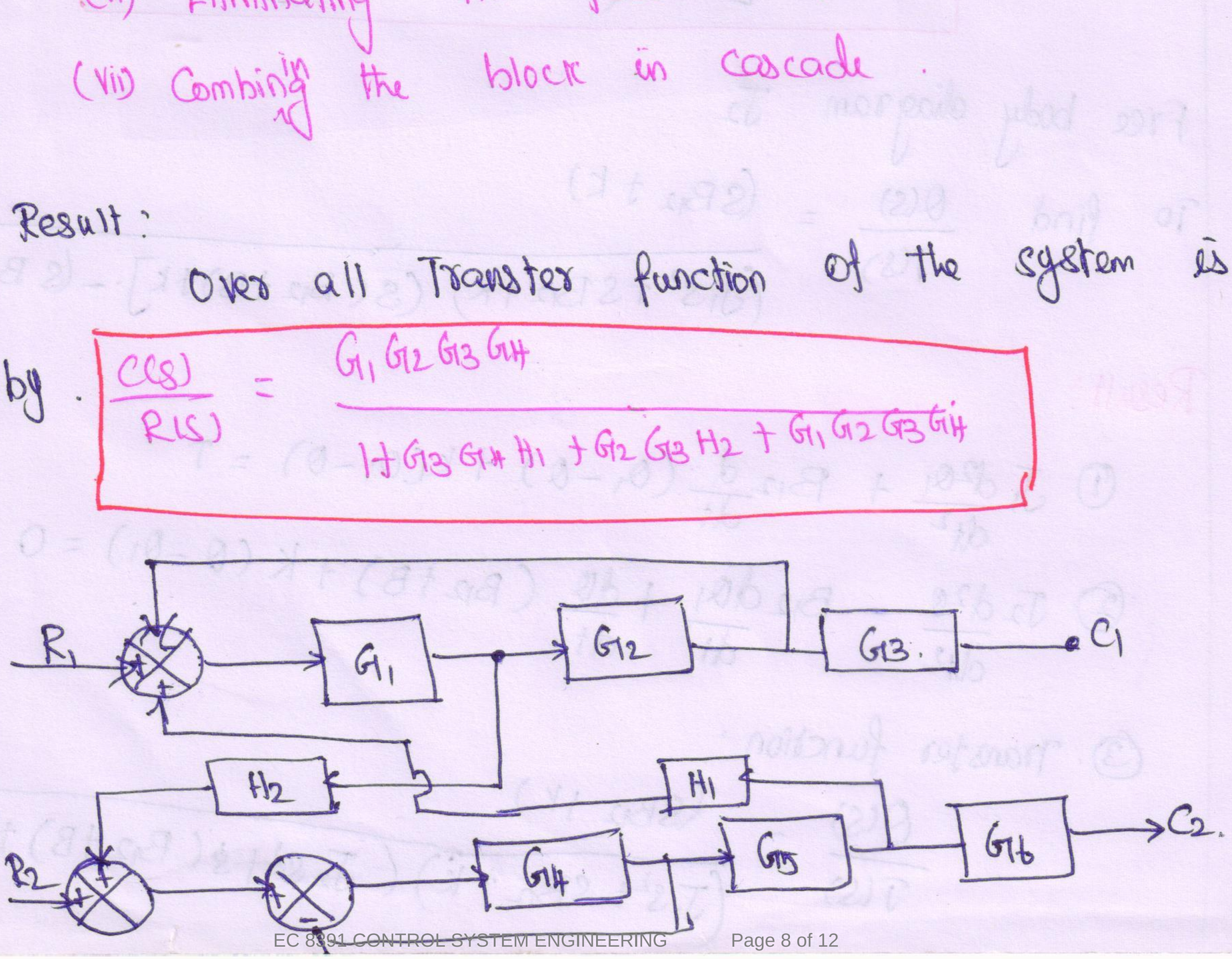
(vii) Combining the block in cascade.

Result:

Over all Transfer function of the system is given by.

$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3 G_4}{1 + G_3 G_4 H_1 + G_2 G_3 H_2 + G_1 G_2 G_3 G_4}$$

(5).



Solution:

To find $\frac{C_1}{R_1}$

(i) Eliminating the f/b path

(ii) Combining the blocks.

(iii) Eliminating the f/b path

(iv) Combining the blocks in cascade.

(v) Eliminating the f/b path.

(vi) Combining the blocks in cascade.

To find $\frac{C_2}{R_2}$

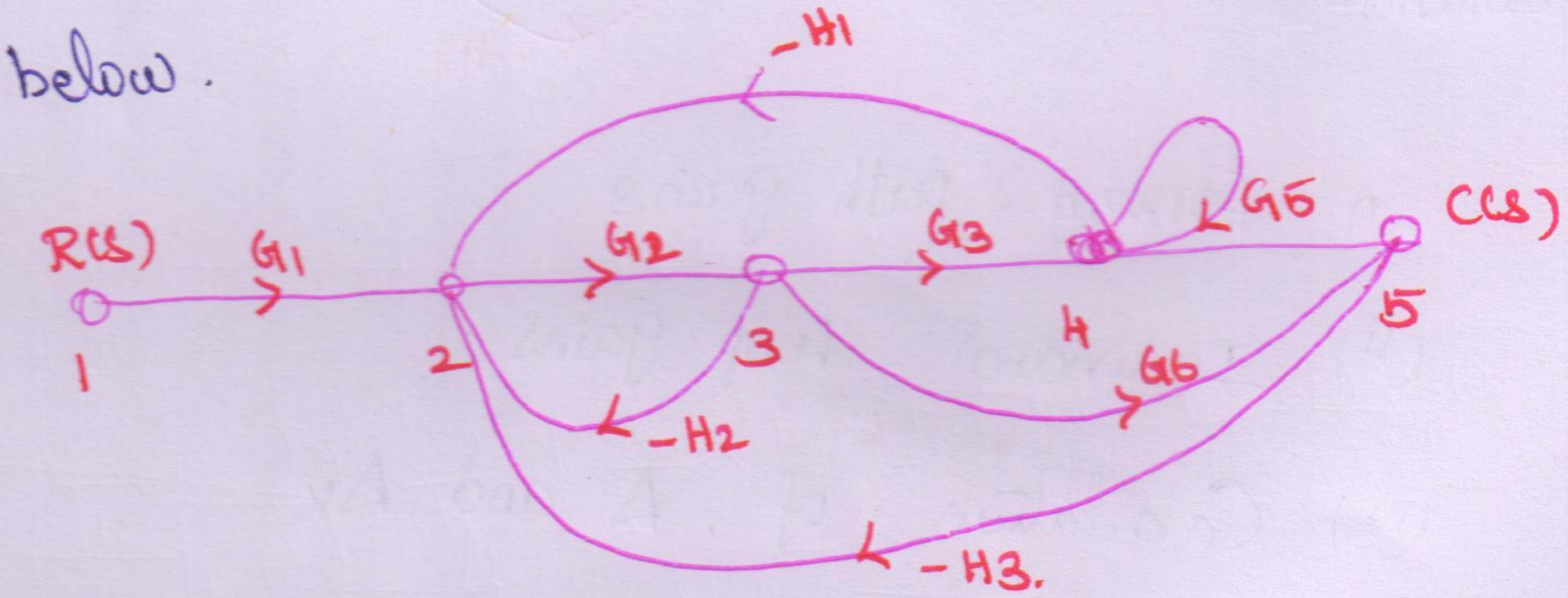
Same procedure to find $\frac{C_2}{R_2}$.

Result:

$$\frac{C_1}{R_1} = \frac{G_1G_2G_3(1+G_4)}{(1+G_1G_2)(1+G_4) - G_1G_4G_5H_1H_2}.$$

$$\frac{C_2}{R_1} = \frac{G_1G_4G_5G_6H_2}{(1+G_4)(1+G_1G_2) - G_1G_4G_5H_1H_2}.$$

⑥. Find the over all gain C(s)/R(s) for the signal flow graph shown below.



Solution:

(i) forward path gains.

(ii) Individual loop gain

(iii) Gain products of Two non touching loops.

(iv) Calculation of Δ and Δ_K.

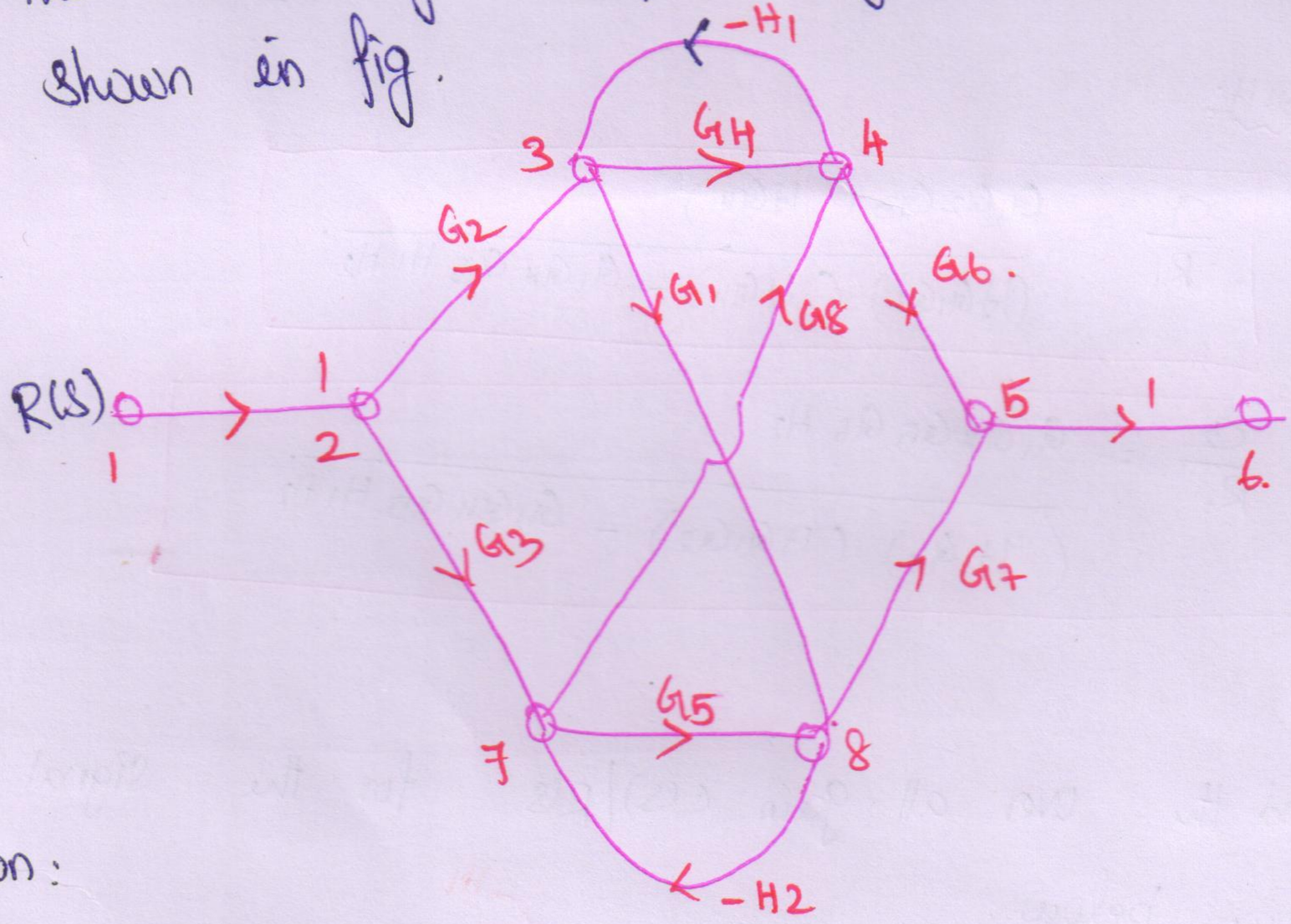
(v) Transfer function:

Mason's gain formula.

$$T = \frac{1}{\Delta} \sum P_K \Delta_K$$

$$T = \frac{G_1G_2G_3G_4 + G_1G_2G_6 - G_1G_2G_5G_6}{1 + G_2G_3H_1 + H_2G_2 + G_2G_3G_4H_3 - G_5 + G_2G_6H_3 - G_2H_2G_5 - G_2G_5G_6G_7}$$

(8) Find the over all gain of the system whose signal flow graph shown in fig.



Solution:

(i) forward path gains

(ii) Individual loop gains.

(iii) Calculation of Δ and Δ_K

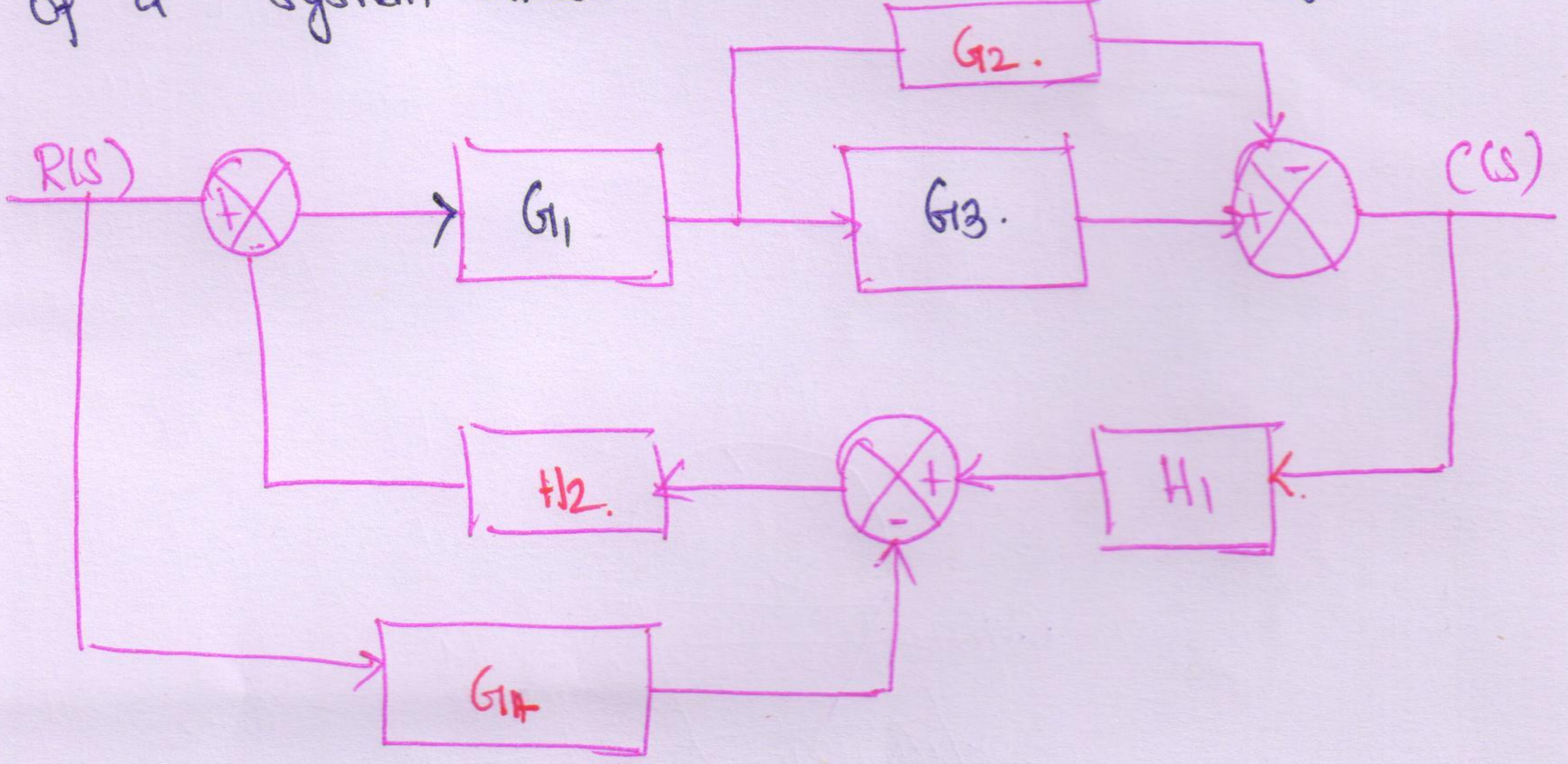
(iv) Transfer function.

$$T = \frac{1}{\Delta} \sum P_K \Delta_K$$

$$T = \frac{1}{\Delta}\left(P_1\Delta_1 + P_2\Delta_2 + P_3\Delta_3 + P_4\Delta_4 + P_5\Delta_5 + P_6\Delta_6\right)$$

$$T = \frac{-G_1G_3G_7G_8H_1 - G_1G_2G_6G_8H_2}{1 + G_4H_1 + G_5H_2 - G_1G_8H_1H_2 + G_4G_5H_1H_2}$$

(9) Draw the signal flow graph and evalute the closed loop TF of a system whose block is shown in fig.



Solution:

* Forward path gains.
* Individual loop gains
* Gain products of Two non-touching loops.
* Calculation of Δ and Δk.

* Transfer function T.

$$T = \frac{1}{\Delta}\sum_k P_k\Delta_k = \frac{P_1 + P_2 + P_3 + P_4}{\Delta}$$

$$= \frac{G_1G_3 - G_1G_2 + G_1G_3G_4H_2 - G_1G_2G_4H_2}{1 + G_1G_3H_1H_2 - G_1G_2H_1H_2}$$

$$= \frac{G_1 (G_3 - G_2) + G_1 G_4 H_2 (G_3 - G_2)}{1 + G_1 H_1 H_2 (G_3 - G_2)}$$

$$T = \frac{G_1 (G_3 - G_2)(1 + G_4 H_2)}{1 + G_1 H_1 H_2 (G_3 - G_2)}$$