

**BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI  
(END SEMESTER EXAMINATION)**

**CLASS: B. TECH.  
BRANCH: CHEMICAL ENGINEERING**

**SEMESTER: VI  
SESSION: SP/2025**

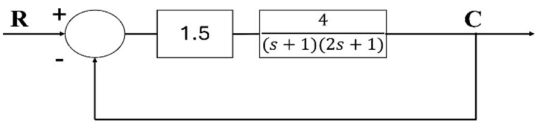
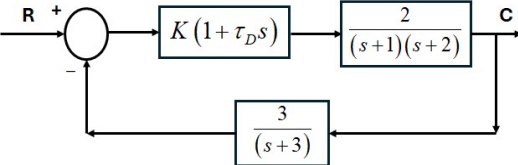
**SUBJECT: CL333 PROCESS CONTROL & INSTRUMENTATION**

**TIME: 3 Hours**

**FULL MARKS: 50**

**INSTRUCTIONS:**

1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
4. Tables/Data handbook/Graph paper etc., if applicable, will be supplied to the candidates:

- |   | [2.5<br>+2.5] | CO<br>CO1 | BL<br>4 |
|---|---------------|-----------|---------|
| <p>Q.1(a) A process consists of two non-interacting tanks in series, each having a cross-sectional area of 2 m<sup>2</sup>. A constant inflow rate of 4 m<sup>3</sup>/h enters the first tank, and the liquid exits the second tank at the same rate. Each tank is perfectly mixed and initially empty.</p> <p>i) Derive the transfer function of the system (output height of the second tank with respect to the inlet flow rate).</p> <p>ii) If a step change of 4 m<sup>3</sup>/h is applied at the input, calculate the liquid level in the second tank after 30 minutes, assuming the outflow is proportional to the liquid height with a time constant of 15 minutes per tank.</p> |               |           |         |
| <p>Q.1(b) A process has a transfer function <math>G(s) = \frac{Y(s)}{X(s)} = \frac{20}{90000s^2 + 240s + 1}</math>;</p> <p>Initially the process is at steady state with <math>x(t=0) = 0.4</math> and <math>y(t=0) = 100</math>. If a step change in <math>x</math> is given from 0.4 to 0.5, Find the maximum value of <math>y</math> that will be observed before it reaches the new steady state.</p>   | [3]           | CO2       | 4       |
| <p>Q.1(c) A process control loop has <math>G_c</math> as PI controller. Process is an integrating element with a process gain of <math>K</math>. Control valve and measuring element have unity transfer function. Find the relationship among <math>K</math>, <math>K_p</math> and <math>K_i</math> for a damping factor of 0.5.</p>   | [2]           | CO3       | 3       |
| <p>Q.2(a) The set point in the loop is shown in the figure below and is given a step change of magnitude 5 units. Determine the maximum value of <math>C</math> and the time at which it occurs, the offset and the period of oscillation.</p> <div style="text-align: center;">  </div>   | [5]           | CO3       | 4       |
| <p>Q.2(b) Determine the stability of the loop shown in figure for <math>\tau_D = 0.1</math>.</p> <div style="text-align: center;">  </div> <p style="text-align: right;">(using Routh test)</p>  | [5]           | CO3       | 4       |
| <p>Q.3.(a) A unity feedback control system has an open loop T.F.</p> $G(s) = \frac{k(s + 4/3)}{s^2(s + 12)}$ <p>Draw the root locus of the given system.</p>  | [4]           | CO3       | 3       |
| <p>Q.3.(b) For loop system whose transfer function is given by,</p> $G(s)H(s) = \frac{K(s+1)}{s(s-1)(s^2 + 4s + 16)}$ <p>Determine the values of angle of asymptotes, break away point and intersection to imaginary axis.</p>  | [6]           | CO3       | 4       |

Q.4(a) Find the gain margin and phase margin of a feedback system with [3.5] CO3 5

$$G(s)H(s) = \frac{s}{(s+100)^3}, \text{ without making Bode plot.}$$

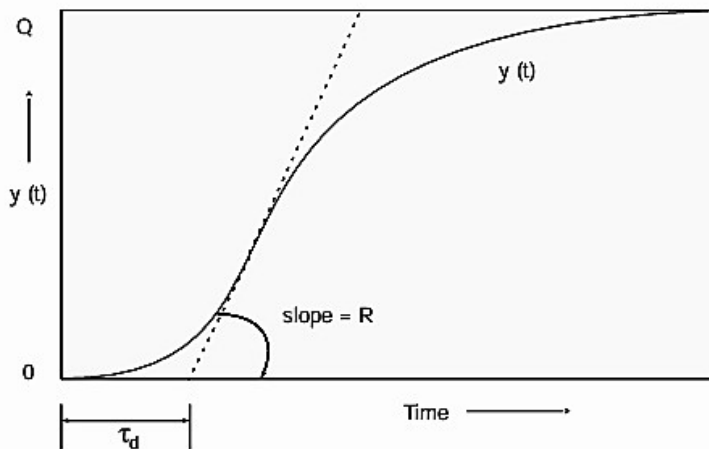
Q.4(b) Find the gain margin and phase cross over frequency from the T.F., [3.5] CO3 5

$$G(s)H(s) = \frac{1}{s(1+2s)(1+s)} \text{ without making Bode plot.}$$

Q.4(c) The transfer functions are given below, [3] CO4 5

$$G_v = \frac{5}{2s+1}; G_m = \frac{0.4}{5s+1}; G_p = \frac{2}{s+1} \text{ with a P-controller. Find the tuning parameters for PID controller using Z-N method.}$$

Q.5(a) The experimental response of the controlled variable  $y(t)$  for a step change of magnitude  $P$  in the manipulated variable  $x(t)$  is shown below, [3] CO4 4



Find the appropriate transfer function of the process (using Cohen-coon method).

Q.5(b) Draw a hierarchical DCS structure and explain function of each level. Explain the [2.5] CO5 2

three main components of the SCADA +2.5]

Q.5(c) Briefly discuss about the ratio control using one example. [2] CO5 2