

*Teaching Computational Skills and Problem-Solving
with MATLAB and Simulink Workshop
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UTILIZING MATLAB TO ENHANCE LEARNING & PROBLEM-SOLVING



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Khairiyah Mohd-Yusof is the President for the Society of Engineering Education Malaysia, Deputy Secretary General of the Academy of Professors Malaysia, and the founding Director of Universiti Teknologi Malaysia Centre for Engineering Education. She first used MATLAB as a graduate student in the US in 1990 in the Advanced Process Control course. She feels fortunate that she has been assigned to teach Process Control since her early days in UTM because most Chemical Engineering instructors do not like the subject, allowing her to improve and innovate the course to help students to learn better.

She is a practitioner and researcher of student-centered approaches in engineering education and is currently on the Editorial and Advisory Boards of several journals, such as the ASEAN Journal of Engineering Education, Journal of Engineering Education, Journal of Education for Chemical Engineers and European Journal of Engineering Education. For her work, she had received several awards including the 2018 IFEEES Duncan Fraser Global Award for Excellence in Engineering Education, 2017 Student Platform on Engineering Education Mentoring Award and 2015 Frank Morton IChemE Global Award for Chemical Engineering Education Excellence.





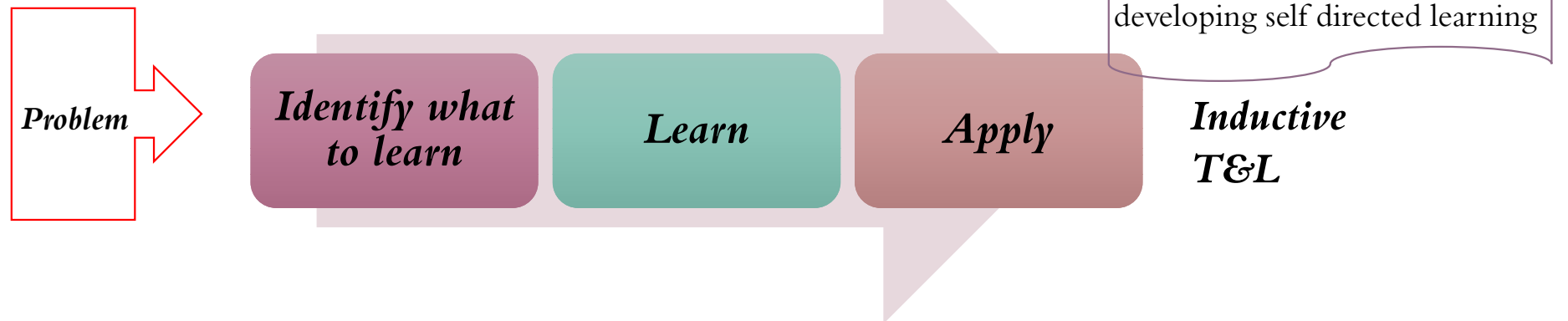
Issues in Teaching Chemical Engineering Undergraduates Process Control & Dynamics

- ❖ Highly mathematical content → lost in mathematics, not able to relate physically what is happening
- ❖ Complex problem-solving became one of the required attributes of engineering graduates under the Washington Accord
- ❖ Students not motivated to learn and understand a deep level to be able to solve complex problems
- ❖ How to develop complex problem-solving skills?
- ❖ Fast-changing world and virtual resources → need to develop self-directed learning

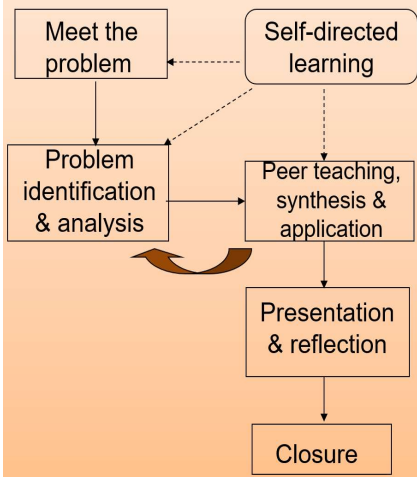
Commonly used Teaching and Learning (T&L) Models



Problem-Based Learning Model

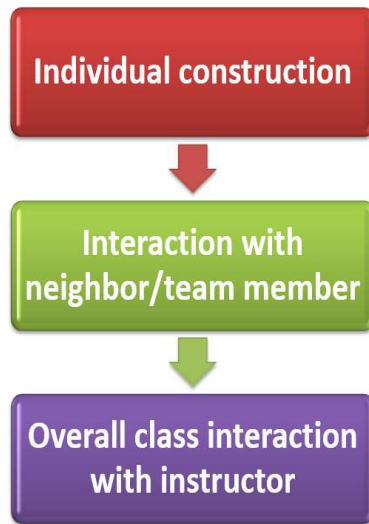


The PBL Process

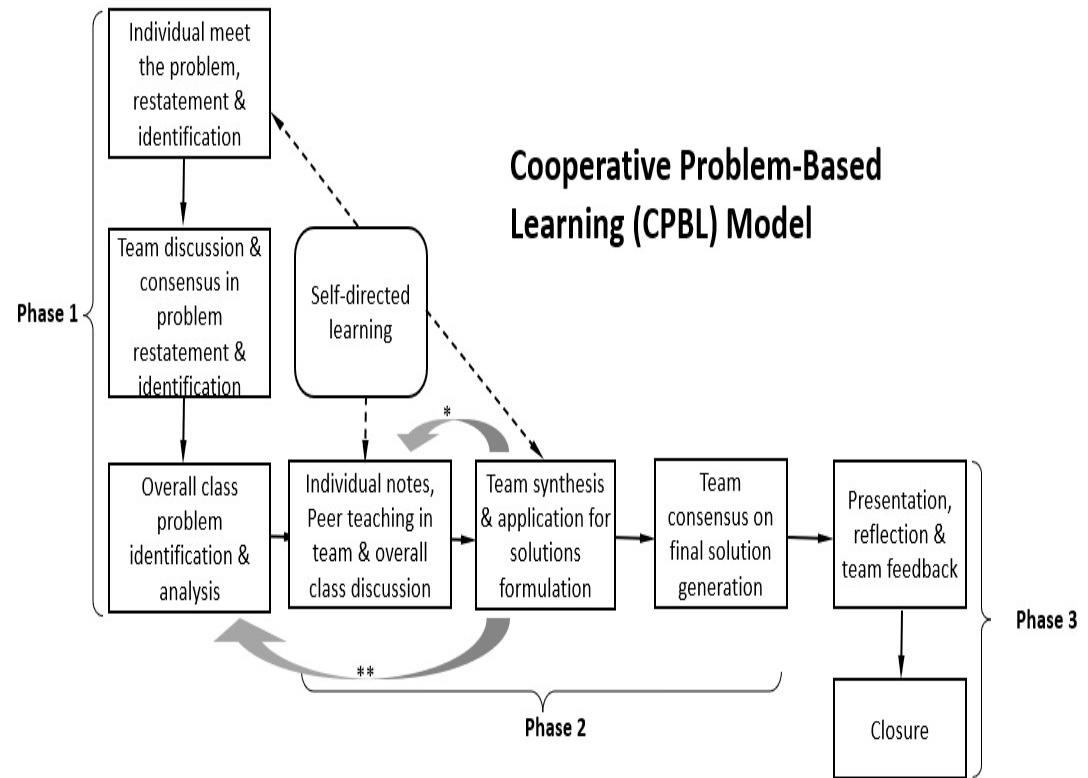


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Pattern in CL

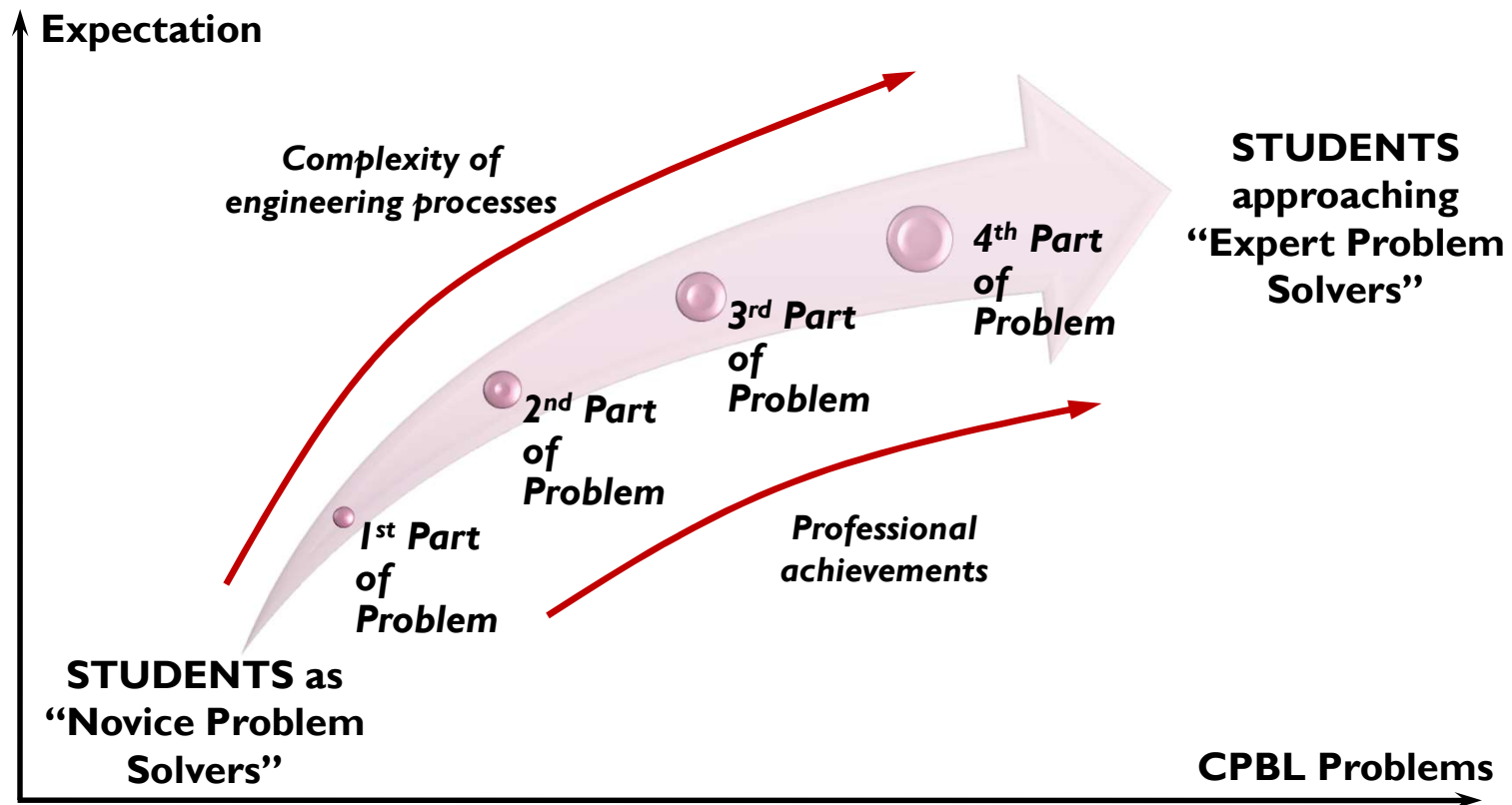


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Series of Problems

Scaffolding in organization of problems for a whole semester in a course



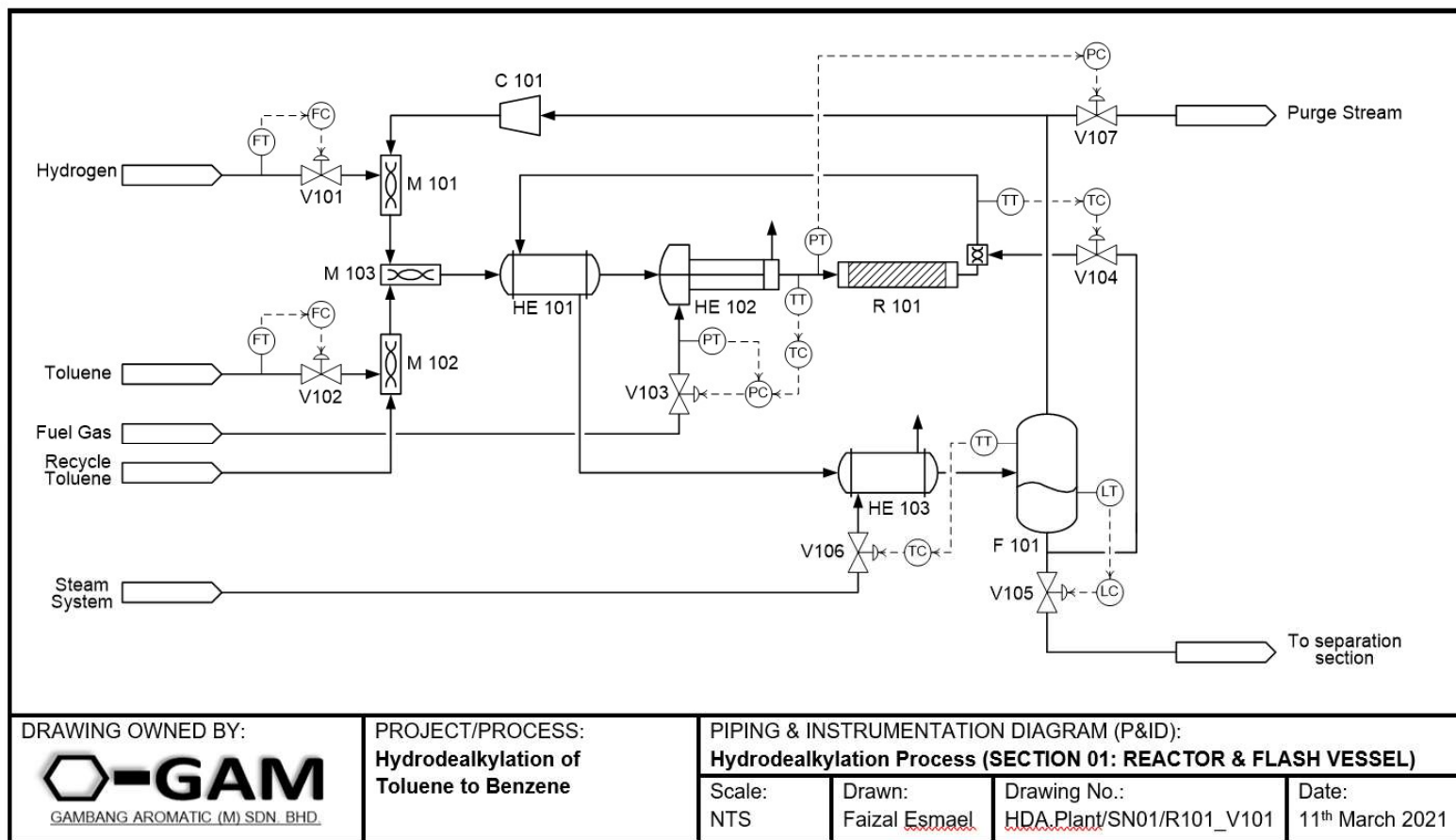
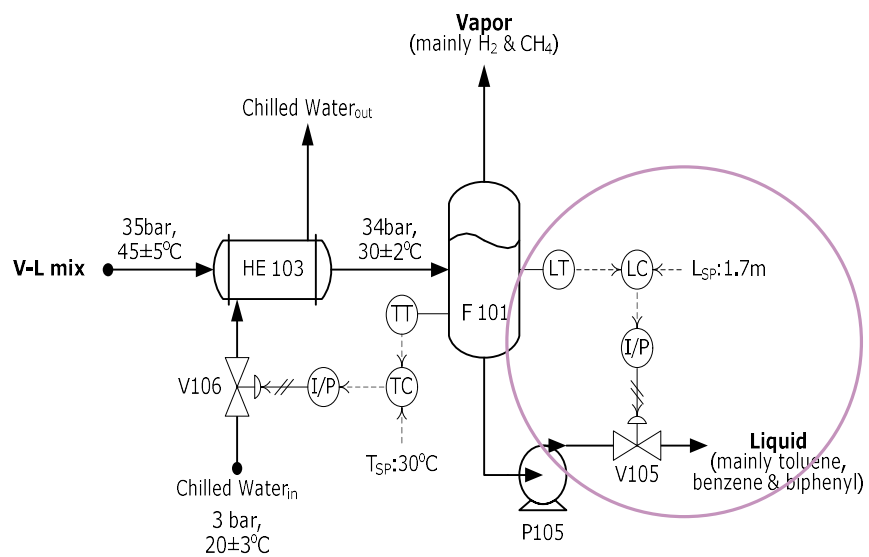
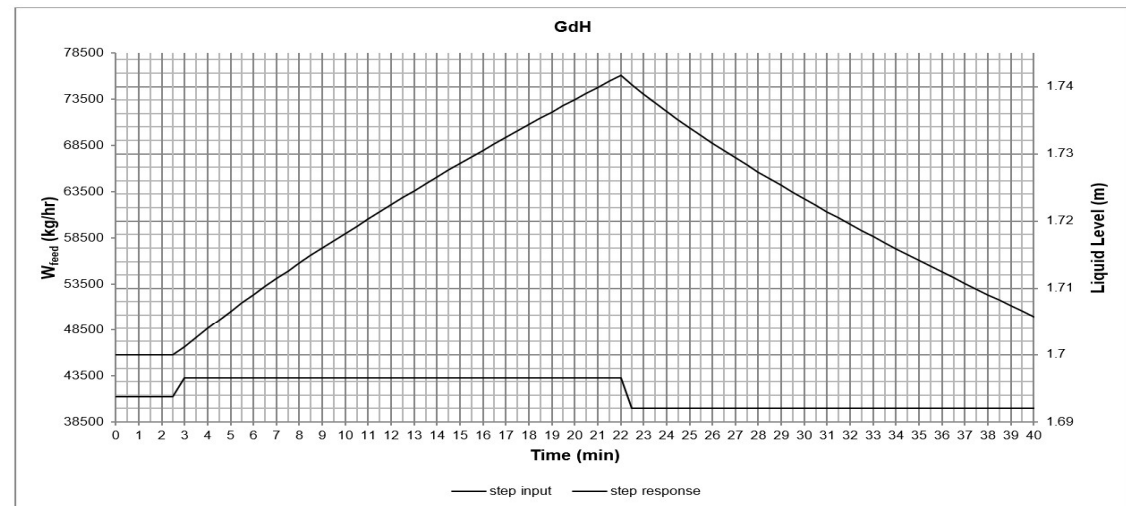


Figure 1: Hydrodealkylation Process



Step Test: Level Controller (GdH)



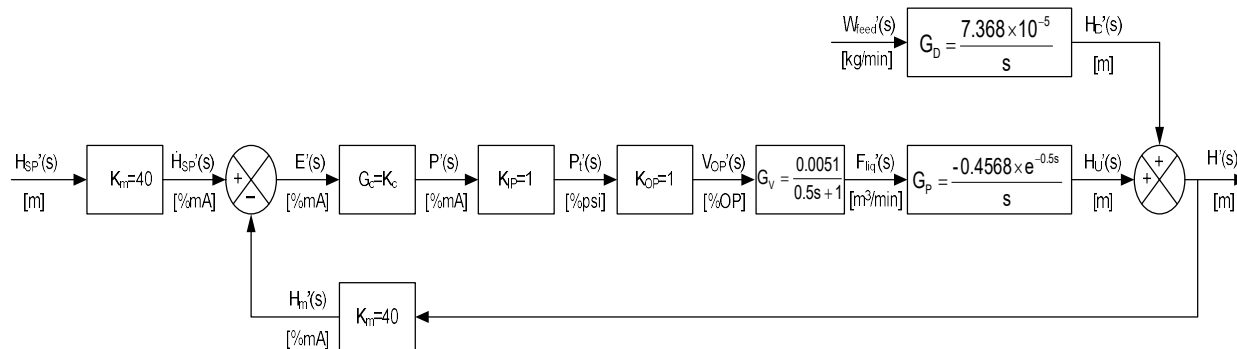
$$+ \text{ve slope} = \frac{(1.73051 - 1.71025) \text{ m}}{(16.0 - 6.5) \text{ min}} = 2.133 \times 10^{-3} \frac{\text{m}}{\text{min}}$$

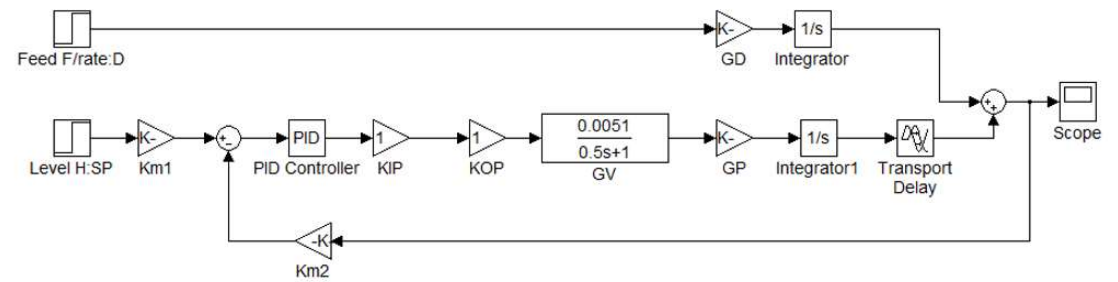
$$- \text{ve slope} = \frac{(1.71072 - 1.73047) \text{ m}}{(37.0 - 26.5) \text{ min}} = -1.881 \times 10^{-3} \frac{\text{m}}{\text{min}}$$

$$G_D(H) = \frac{H}{W_{\text{feed}}} = \frac{7.368 \times 10^{-5} \text{ m/min}}{\text{s}} \frac{\text{kg/min}}{\text{kg/min}}$$

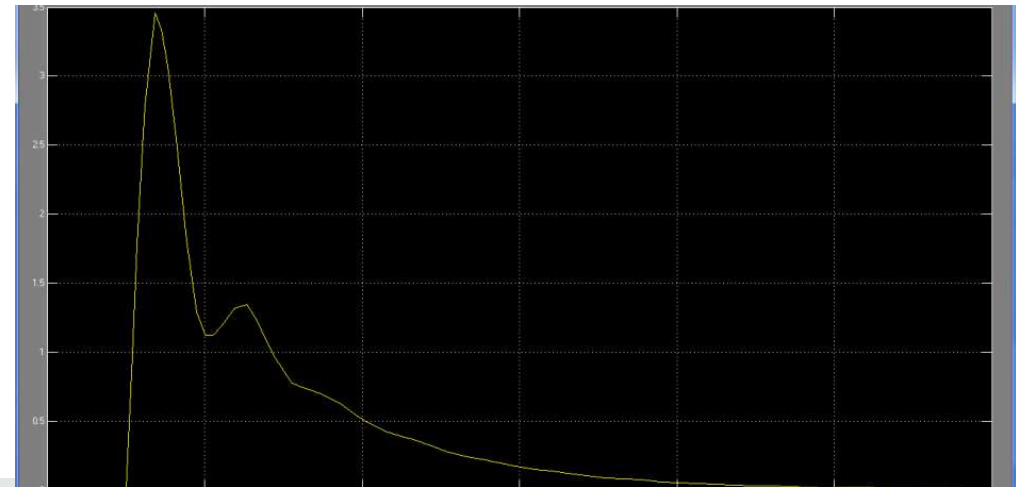
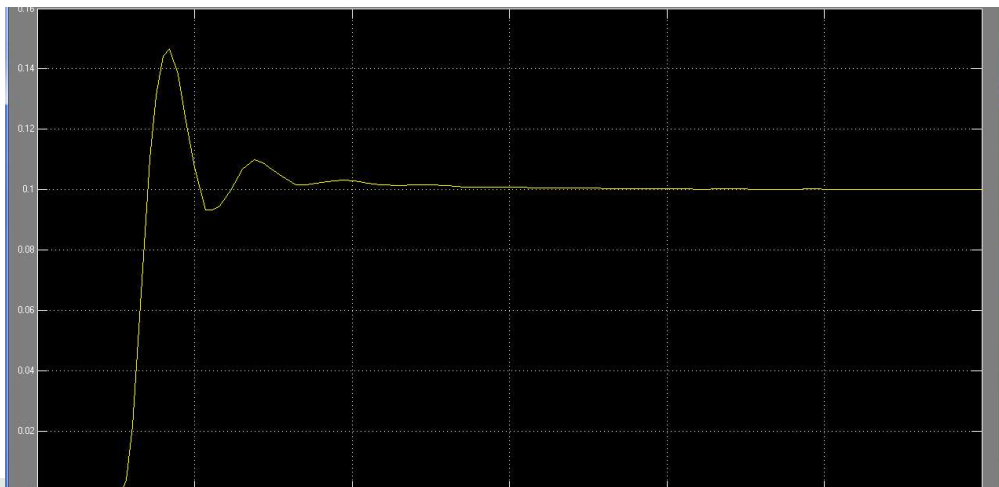
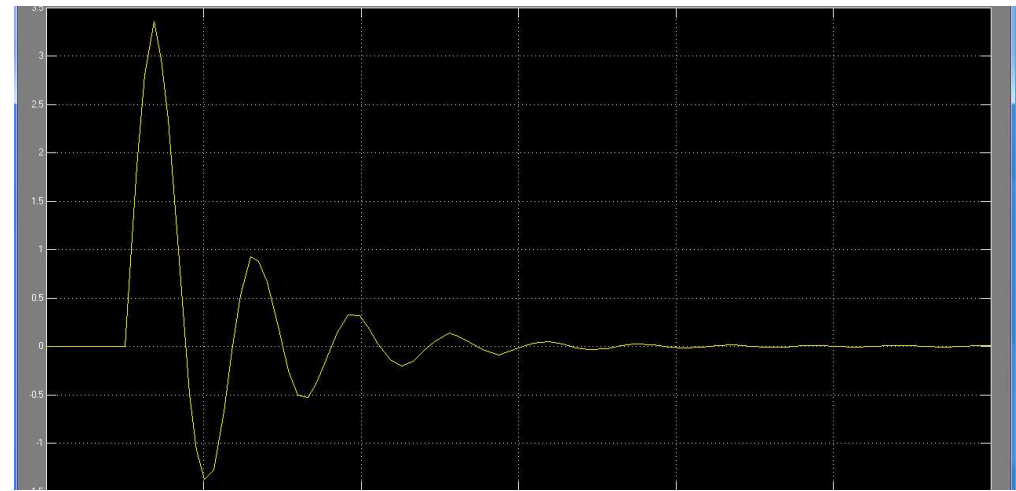
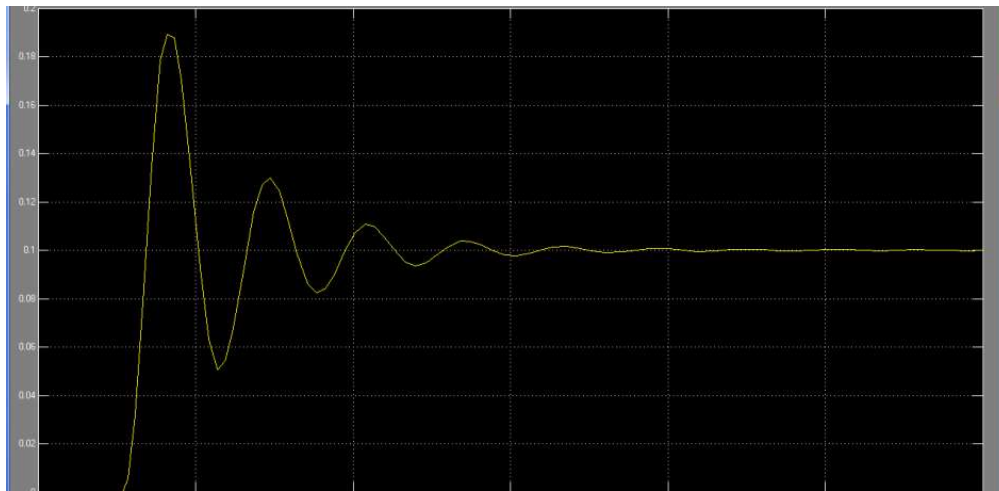
$$K_D = \frac{(-1.881 \times 10^{-3}) - (2.133 \times 10^{-3}) \text{ m/min}}{(40000 - 43270) \text{ kg/hr}} = 1.228 \times 10^{-6} \frac{\text{m/min}}{\text{kg/hr}} \quad \theta_D = 0 \text{ min}$$

$$K_D = 7.368 \times 10^{-5} \frac{\text{m/min}}{\text{kg/min}}$$





Level Control with fine tuning: Which is servo? Which is regulator?



The graph displays the step response of the GpT system. The x-axis represents Time in minutes, ranging from 0 to 20. The left y-axis represents F_{cw} in m^3/hr , ranging from 40 to 80. The right y-axis represents T_{flum} in $^{\circ}C$, ranging from 29.9 to 30.3. A step change in F_{cw} is indicated by a vertical dashed line at $t_{0\%}$ (approx. 2.5 min). The step response of F_{cw} (solid line with circles) rises from 50 to 80 m^3/hr . The step response of T_{flum} (dashed line with circles) falls from 30.0 to 29.95 $^{\circ}C$. Key time points are marked: $t_{0\%}$, $t_{28\%}$, and $t_{63\%}$.

$$\theta = 1.3 \text{ min}$$
$$\tau = 2.7 \text{ min}$$

The graph displays the step response of the temperature of the cooling water (T_{cw}) and the temperature of the fluid (T_{fum}) over time. The x-axis represents Time (min) from 0 to 25. The left y-axis represents T_{cw} (°C) from 19 to 49. The right y-axis represents T_{fum} (°C) from 29.9 to 30.7. A step change in T_{cw} occurs at $t=0$, from 23.5°C to 24.5°C. The T_{fum} response is shown as a curve starting at 29.9°C and rising to 30.6°C. Key time points are marked: $t_{0\%}$ at 2.5 min, $t_{28\%}$ at 4.5 min, and $t_{63\%}$ at 6.5 min.

$$\begin{aligned}\theta_{D1} &= 1.1 \text{ min} \\ \tau_{D1} &= 2.7 \text{ min}\end{aligned}$$

The figure consists of two parts: a process flow diagram (top) and a control scheme (bottom).

Process Flow Diagram:

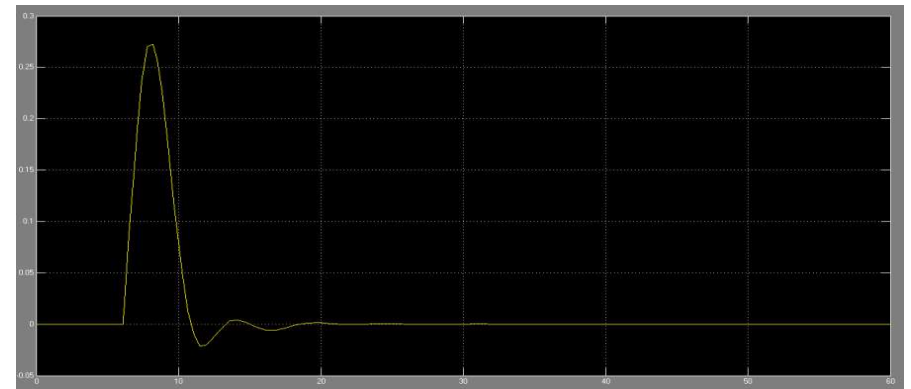
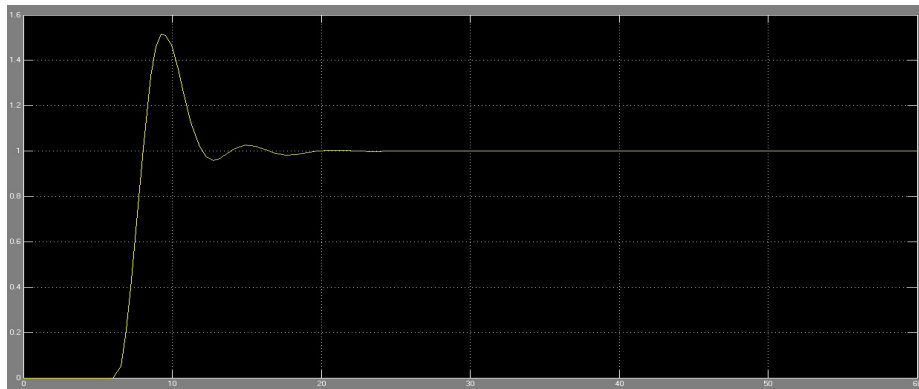
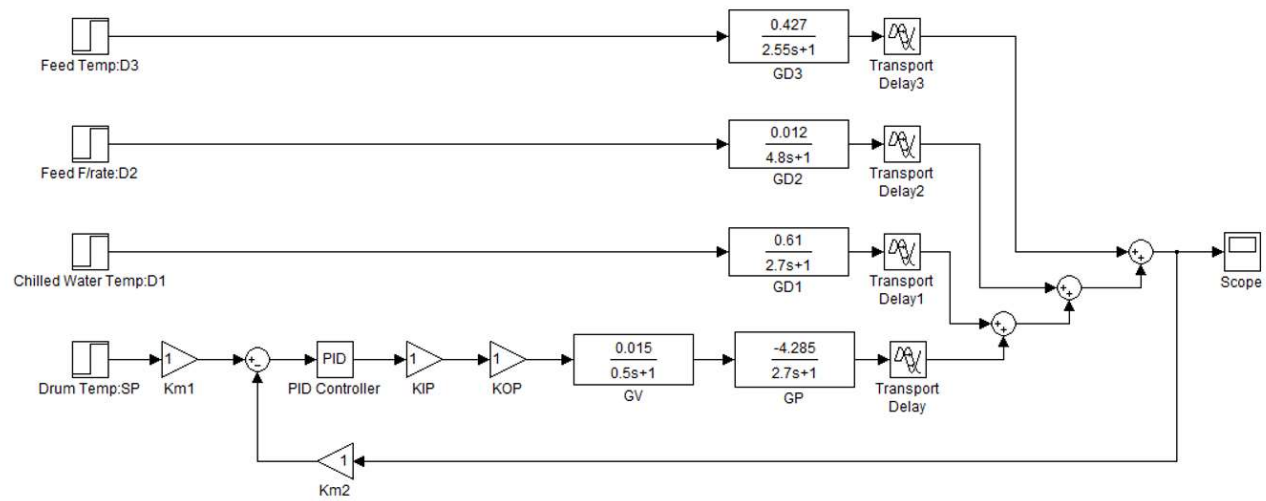
- V-L mix** (35 bar, $45 \pm 5^\circ\text{C}$) enters **HE 103** (Heat Exchanger).
- Chilled Water_{in}** (3 bar, $20 \pm 3^\circ\text{C}$) enters **HE 103** through valve **V106**.
- Chilled Water_{out}** exits **HE 103**.
- The output of **HE 103** enters **F 101** (Distillation Column) at 34 bar, $30 \pm 2^\circ\text{C}$.
- Vapor** (mainly H_2 & CH_4) exits the top of **F 101**.
- Liquid** (mainly toluene, benzene & biphenyl) exits the bottom of **F 101** through pump **P105** and valve **V105**.
- Control Loop:** A temperature sensor **TT** measures the temperature at the column bottom. The signal is compared with a setpoint $T_{SP} = 30^\circ\text{C}$ at a summing junction. The error signal is processed by a controller **I/P** (Integral/Proportional) and sent to valve **V106** to adjust the chilled water flow.
- Level Control:** A level sensor **LT** measures the liquid level in the column. The signal is compared with a setpoint $L_{SP} = 1.7\text{m}$ at a summing junction. The error signal is processed by a controller **I/P** and sent to valve **V105** to adjust the liquid outflow.

Control Scheme:

The control scheme shows the transfer functions for the process and the feedback loops:

- Temperature Control Loop:**
 - Disturbance: $T_{feed}'(s)$ [°C] → $G_{D3} = \frac{0.427e^{-0.65s}}{2.55s+1}$ → $T_{D3}'(s)$ [°C]
 - Disturbance: $W_{feed}'(s)$ [kg/min] → $G_{D2} = \frac{0.012e^{-1.2s}}{4.8s+1}$ → $T_{D2}'(s)$ [°C]
 - Disturbance: $T_{CW}'(s)$ [°C] → $G_{D1} = \frac{0.61e^{-1.1s}}{2.7s+1}$ → $T_{D1}'(s)$ [°C]
 - Process: $T_{in}(s)$ [°C] → $K_{T1}=1$ → $\dot{T}_{SP}'(s)$ [%mA] → $E(s)$ [%mA] → $G_C=K_C$ → $P'(s)$ [%mA] → $K_{V1}=1$ → $P_1'(s)$ [%psia] → $K_{V2}=1$ → $V_{OP}'(s)$ [%OP] → $G_V = \frac{0.015}{0.5s+1}$ → $F_{CW}'(s)$ [m³/min] → $G_P = \frac{-4.285e^{-1.3s}}{2.7s+1}$ → $T_{II}'(s)$ [°C]
 - Feedback: $T_{II}(s)$ [°C] → $K_{T2}=1$ → $T_{II}'(s)$ [%mA] → Summing Junction 1.
- Level Control Loop:**
 - Disturbance: $T_{D3}'(s)$ [°C] → Summing Junction 2
 - Disturbance: $T_{D2}'(s)$ [°C] → Summing Junction 2
 - Disturbance: $T_{D1}'(s)$ [°C] → Summing Junction 2
 - Process: $T_{II}'(s)$ [°C] → Summing Junction 2 → $T'(s)$ [°C] → Summing Junction 3
 - Feedback: $T'(s)$ [°C] → Summing Junction 3 → $T_{II}'(s)$ [%mA] → Summing Junction 1.

Feedback Block Diagram in SIMULINK: Temperature



Integration of problem/project for 3 first year courses:
Latest effort to increase engagement and support in learning

