Name.. Student-ID..............................

King Mongkut's University of Technology Thonburi

Final Examination for the 1st semester, Academic Year 2015

CHE 461 Process Dynamics and Control — Chem. Eng. Student, 4th year

27th November 2015 — Time: 13:00-16:00

Instructions

1. This exam contains 8 pages including the cover page, 6 questions, and 100 points total.
2. Only the following book is allowed during the examination

   Coughanowr, D. R., and LeBlance, S. E., xxxx. ***Process Systems Analysis and Control***, McGraw-Hill.

   - It can be any edition. If the copy of this book is used, it must be bound together.
   - Any other document or paper except this book is not allowed.
   - Any handwriting notes on any page of the book are allowed.
3. The calculator according to the university's regulation is allowed.
4. The exam will not be changed, if you have any quetions or doubts, please write a note.
5. The answer should be written on the provided space or the back of each page.
6. Write your name clearly in the space above each page.

Special Instruction

Students are reminded that any dishonest behaviors may result in their dismissal from the examination and may follow disciplinary action.

Examiner only

No.	Score
1	
2	
3	
4	
5	
6	
Total	

Asst. Prof. Dr. Veera Loha

Asst. Prof. Dr. Wimolsiri Pridasawas

Examiner

Tell. 9222

This exam has been prooved by the ChE Examination Committee.

(Assoc. Prof. Dr. Piyabutr Wanichpongpan)

Head of the Chemical Engineering Department

ชื่อ-สกุล.. รหัสนักศึกษา...............................

1. A control valve is installed for regulating flow rate of liquid. The pressure drop over piping system is proportional to the square of the flow rate. The upstream pressure is 40 psi. The pressure drop across the control valve is 20 psi at flow rate of 120 gal/min.

a) Design the rated C_v of linear valve that is half open at the flow rate of 120 gal/min. (7 points)

b) Design the equal percentage valve (α=50) for the maximum flow rate of 160 gal/min. Find the valve stem position at flow rate of 120 gal/min. (8 points)

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2. The level of liquid in the condensate vessel is controlled by adjusting an outlet flowrate through a control valve. The cross sectional area of the vessel is 3 m^2. The controlled level is 1 to 5 meters and the steady state (set point) is operated at level of 4 meters. The liquid level signal (4 to 20 mA) is transmitted to compare the value with set point. The controller mode is a proportional controller. The controlling signal from the controller (4 to 20 mA) is transmitted to a transducer (3 to 15 psi) to lift the control valve stem. The liquid flow rates range from 0 to 4 m^3/s. The rated Cv is 4.

2.1 Draw the control loop diagram (5 points)

2.2 Determine the transfer function of the control variable for a set point change. (10 points)

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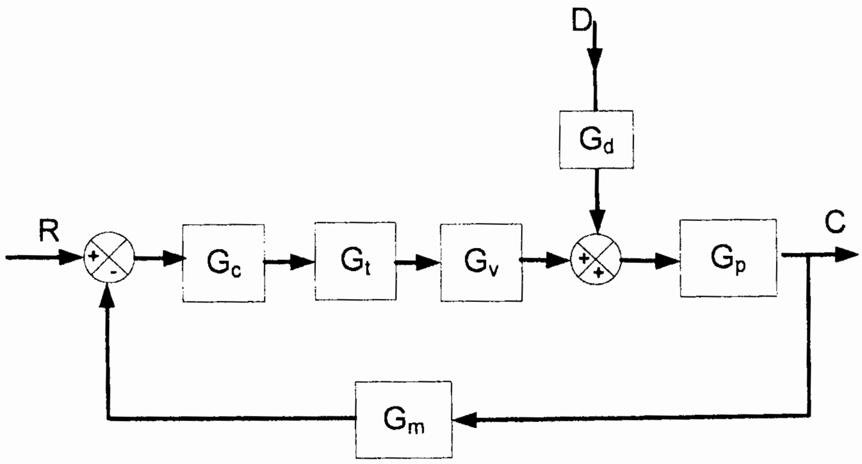
3. Determine the value of K_c for the given control loop by Routh Stability Criteria. (15 points)



Where

$$G_c = K_c\left(1+\frac{1}{3s}\right); \quad G_T = \frac{3}{4}; \quad G_v = \frac{3}{2s+1}; \quad G_p = \frac{4(s+1)}{(3s+1)(4s+1)}$$

$$G_d = \frac{3}{5s+1}; \quad G_m = \frac{1}{2s+1}$$

ชื่อ-สกุล.. รหัสนักศึกษา...............................

4. The dynamic behavior of the heat exchanger shown in the following figure can be described by the following transfer functions. The valve lift, x, is measured in centimeters.

Process:

$$\frac{T'}{W_s'} = \frac{(4°C/kg\,\text{min})e^{-0.32s}}{(0.8s+1)}$$

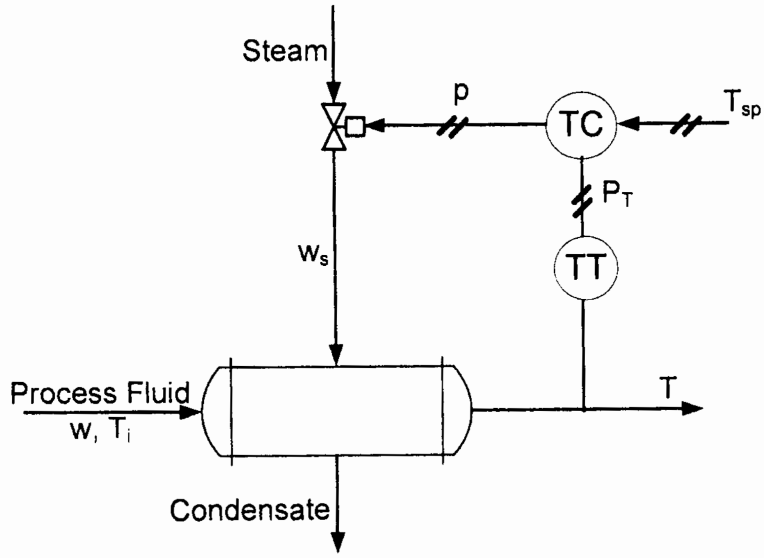
Control Valve:

$$\frac{X'}{P'} = \frac{0.2cm/kPa}{0.4s+1}$$

$$\frac{W_s'}{X'} = 100\frac{kg}{\text{min}\cdot\text{cm}}$$

Temperature Sensor-Transmitter

$$\frac{P_T'}{T'} = 1kPa/°C$$



4.1 Determine the PI-controller setting parameters by Ziegler-Nichols. (10 points)

4.2 Estimate the corresponding phase gain and phase margins. (15 points)

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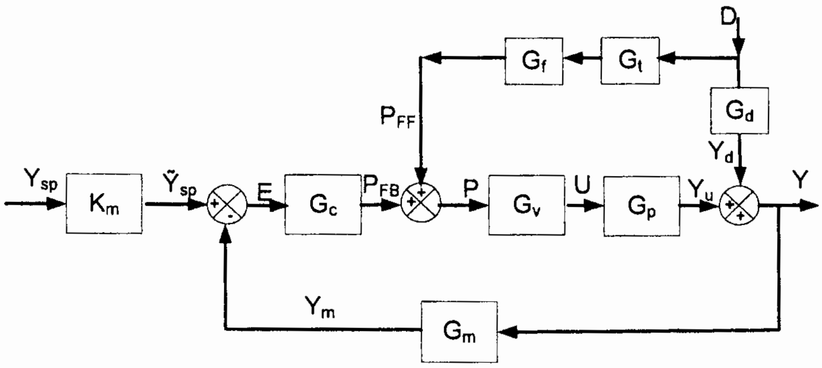
5. The closed-loop system has the following transfer functions:

$$G_p = \frac{1}{s+1}; \quad G_d = \frac{2}{(s+1)(5s+1)}; \quad G_v = G_m = G_t = 1$$



5.1 Design a feedforward controller (G_f) based on a steady-state analysis. (5 points)

5.2 Design a feedforward controller (G_f) based on a dynamic analysis. (5 points)

5.3 Design a feedback PI-controller based on the IMC approach, setting the filter parameter λ =2, and n=1. Also indicate the transfer function of the all-pass filter (G_{ma}), the transfer function that has minimum phase characteristics (G_{mm}), and the transfer function of the internal model controller. (10 points)

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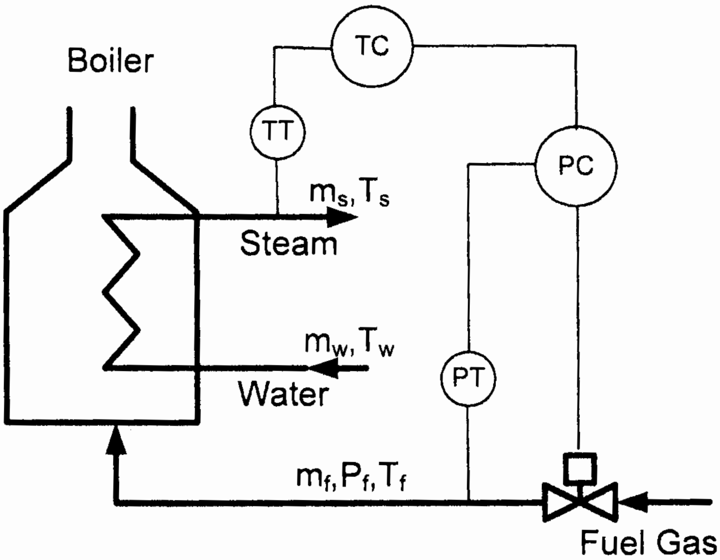
6. Draw a control block diagram of the following system and indicate the master and slave controllers. (10 points)



1. $\delta(t)$ (Unit Impulse)	1
2. $S(t)$ (Unit Step)	$\frac{1}{s}$
3. t (Ramp)	$\frac{1}{s^2}$
4. t^{n-1}	$\frac{(n-1)!}{s^n}$
5. e^{-bt}	$\frac{1}{s+b}$
6. $\frac{1}{\tau} e^{-t/\tau}$	$\frac{1}{\tau s+1}$
7. $\frac{t^{n-1} e^{-bt}}{(n-1)!}$ (n>0)	$\frac{1}{(s+b)^n}$
8. $\frac{1}{\tau^n (n-1)!} t^{n-1} e^{-t/\tau}$	$\frac{1}{(\tau s+1)^n}$
9. $\frac{1}{b_1 - b_2}\left(e^{-b_2 t} - e^{-b_1 t}\right)$	$\frac{1}{(s+b_1)(s+b_2)}$
10. $\frac{1}{\tau_1 - \tau_2}(e^{-t/\tau_1} - e^{-t/\tau_2})$	$\frac{1}{(\tau_1 s+1)(\tau_2 s+1)}$
11. $\frac{b_3 - b_1}{b_2 - b_1} e^{-b_1 t} + \frac{b_3 - b_2}{b_1 - b_2} e^{-b_2 t}$	$\frac{s+b_3}{(s+b_1)(s+b_2)}$
12. $\frac{1}{\tau_1} \frac{\tau_1 - \tau_3}{\tau_1 - \tau_2} e^{-t/\tau_1} + \frac{1}{\tau_2} \frac{\tau_2 - \tau_3}{\tau_2 - \tau_1} e^{-t/\tau_2}$	$\frac{\tau_3 s+1}{(\tau_1 s+1)(\tau_2 s+1)}$
13. $1 - e^{-t/\tau}$	$\frac{1}{s(\tau s+1)}$
14. $\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
15. $\cos \omega t$	$\frac{s}{s^2+\omega^2}$
16. $\sin(\omega t + \phi)$	$\frac{\omega \cos\phi + s \sin\phi}{s^2+\omega^2}$
17. $e^{-bt} \sin \omega t$ $\langle s, \omega \text{ real}) \rangle$	$\frac{\omega}{(s+b)^2+\omega^2}$
18. $e^{-bt} \cos \omega t$ $\langle s, \omega \text{ real}) \rangle$	$\frac{s+b}{(s+b)^2+\omega^2}$
19. $\frac{1}{\tau\sqrt{1-\zeta^2}} e^{-\zeta t/\tau} \sin\left(\sqrt{1-\zeta^2}\,\frac{t}{\tau}\right)$; $(0 \le \lvert\zeta\rvert < 1)$	$\frac{1}{\tau^2 s^2 + 2\zeta\tau s + 1}$
20. $1 + \frac{1}{\tau_2 - \tau_1}(\tau_1 e^{-t/\tau_1} - \tau_2 e^{-t/\tau_2})$;$(\tau_1 \ne \tau_2)$	$\frac{1}{s(\tau_1 s+1)(\tau_2 s+1)}$
21. $1 - \frac{1}{\sqrt{1-\zeta^2}} e^{-\zeta t/\tau} \sin\left(\sqrt{1-\zeta^2}\,\frac{t}{\tau} + \psi\right)$ $\psi = \tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$; $(0 \le \lvert\zeta\rvert < 1)$	$\frac{1}{s(\tau^2 s^2 + 2\zeta\tau s + 1)}$
22. $1 - e^{-\zeta t/\tau}\left[\cos\left(\sqrt{1-\zeta^2}\,\frac{t}{\tau}\right) + \frac{\zeta}{\sqrt{1-\zeta^2}} \sin\left(\sqrt{1-\zeta^2}\,\frac{t}{\tau}\right)\right]$ $(0 \le \lvert\zeta\rvert < 1)$	$\frac{1}{s(\tau^2 s^2 + 2\zeta\tau s + 1)}$
23. $1 + \frac{\tau_3 - \tau_1}{\tau_1 - \tau_2} e^{-t/\tau_1} + \frac{\tau_3 - \tau_2}{\tau_2 - \tau_1} e^{-t/\tau_2}$ $,\tau_1 \ne \tau_2$	$\frac{\tau_3 s+1}{s(\tau_1 s+1)(\tau_2 s+1)}$
24. $\frac{df}{dt}$	$sF(s) - f(0)$
25. $\frac{d^n f}{dt^n}$	$s^n F(s) - s^{n-1} f(0) - s^{n-2} f^{(1)}(0) - \ldots - sf^{(n-2)}(0) - f^{(n-1)}(0)$
26. $f(t-t_0)S(t-t_0)$	$e^{-t_0 s} F(s)$