UNIVERSITY OF MINES AND TECHNOLOGY, TARKWA

FIRST SEMESTER EXAMINATIONS, NOV. / DEC. 2018

COURSE NO: ES 467
COURSE NAME: INSTRUMENTATION & CONTROL
CLASS: ES IV **TIME:** 3 HOURS

Name**:** ____ Index Number: _______________

ANSWER ALL QUESTIONS (60MARKS)

QUESTION ONE (20 MARKS)

(a) A process liquid level needs to be held within 5 ft of 150 ft in a large tank. A pressure transmitter monitors the liquid's level using a pressure reading and sends the result to a controller. The controller compares the level reading to the set point and opens or closes an inflow or outflow pipe depending on the liquid level. Keeping in mind the given scenario, match the terms in Column A with their values in Column B. **(4 marks)**

	Column A	**Column B**
1.	Inferred process variable	(A) 150 ft
2.	Manipulated variable	(B) Pressure
3.	Measured variable	(C) Flow of liquid to the tank
4.	Set point	(D) Level

(b) The process and instrumentation diagram (P & ID, Fig.1) with split-*ranged control valves* show a practical example of split-ranging with reagent feed for pH neutralisation process, where the pH value of process liquid is brought closer to neutral by the addition of either acid or caustic reagent liquids. The split-ranged control valves call for a form of valve sequencing where either the acid valve or caustic valve is fully closed or opened at a certain percentage of the controller output (direct action) signal.

(i) Using this P & ID (Fig.1) and the given principle of the split-ranged control valves, explain clearly how such a control system would work to neutralised the process liquid's pH. **(8 marks)**

(ii) State the pneumatic signal output range by the I/P transducer (AY) at which both reagent control valves operate. **(1 mark)**

(iii) Since the controller's action on the split-ranged control valves is direct, what do you think would be the calibrated operating range of pneumatic signal on the Air-To-Open (ATO) acid valve and that of the Air-To-Close (ATC) caustic valve? **(2 marks)**

(iv) The table below shows the relationship between valve stem position for each control valve and the controller's output. Indicates the position of each control valve as "*fully shut*", "*fully open*" and "*half-open*" at each controller output % and signal.

(5 marks)

Controller Output (%)	**I/P Output** (PSI)	**Acid Valve** (stem position)	**Caustic Valve** (stem position)
0	3		
25	6		
50	9		
75	12		
100	15		

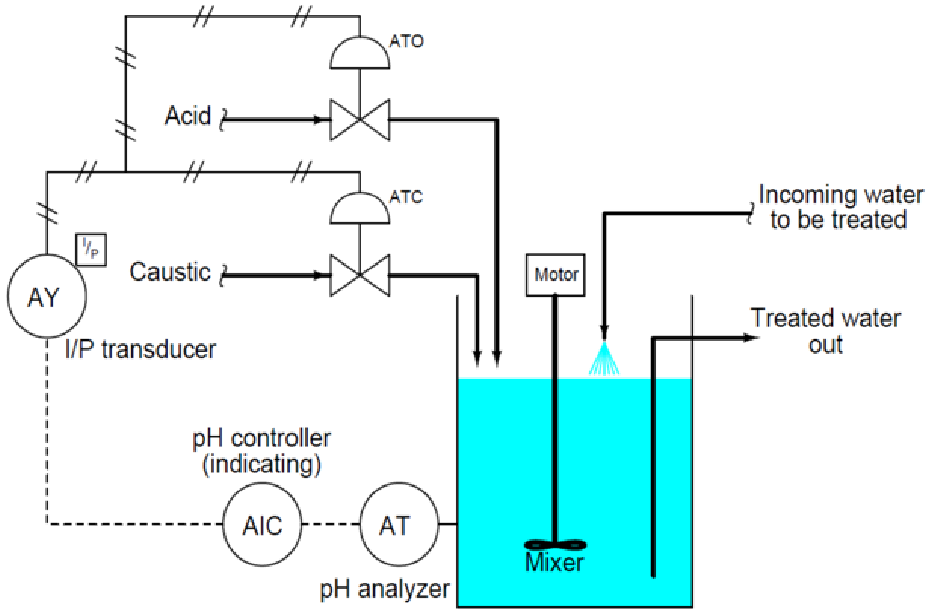


Fig.1 P & ID of a pH neutralisation control system with split-ranged control valve.

QUESTION TWO (20 MARKS)

(a) For the conversion of an organic substance into carbon in a pyrolysis reactor, a type J thermocouple is used as the temperature sensing instrument to determine the carbonisation temperature. A voltage of 19.50 mV is measured across a type J thermocouple at 5°C reference. Find the temperature at the measurement junction using Table B -1. **(3 marks)**

(b) Explain briefly how the *displacer level instrument* works during the detection of liquid level in process vessel or tank. **(2 marks)**

(c) Determine a basic 5-point (0%, 25%, 50%, 75% and 100%) calibration table for the displacer level transmitter shown in Fig. 2. The cylindrical displacer weighs 8 pounds (dry) and has a diameter of 2.5 inches. The process liquid is at a temperature of 52 °F and has a density of 60 lb/ft³. The 0% process liquid level (LRV) is even with the bottom of the displacer. Assume an electronic transmitter mechanism with an output range of 4 to 20 mA, and a calibration tolerance of ± 0.2% (of span). **(15 marks)**

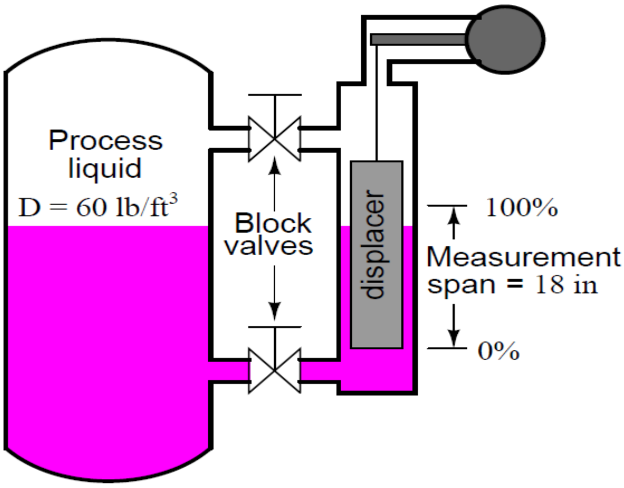


Fig. 2 A displacer level instrument used to measure the level of process liquid in a process vessel.

Process level (inch)	Percent of span (%)	Buoyant force (lb)	Output Signal Ideal (mA)	Output Signal Min. (mA)	Output Signal Max. (mA)
	0				
	25				
	50				
	75				
	100				

NB: Please take 1ft to be equivalent to 12 inches. Be sure to show all your mathematical work so that the examiner will be able to check the conceptual validity of your technique(s).

QUESTION THREE (20 MARKS)

(a) Determine the following terms as they apply to the level controller shown in this P & ID (LIC 135) Fig. 3, controlling the level of liquid in the horizontal receiver vessel:

(i) Process Variable (PV) and Setpoint (SP)

(ii) Manipulated Variable (MV)

(iii) Process alarm

(3 marks)

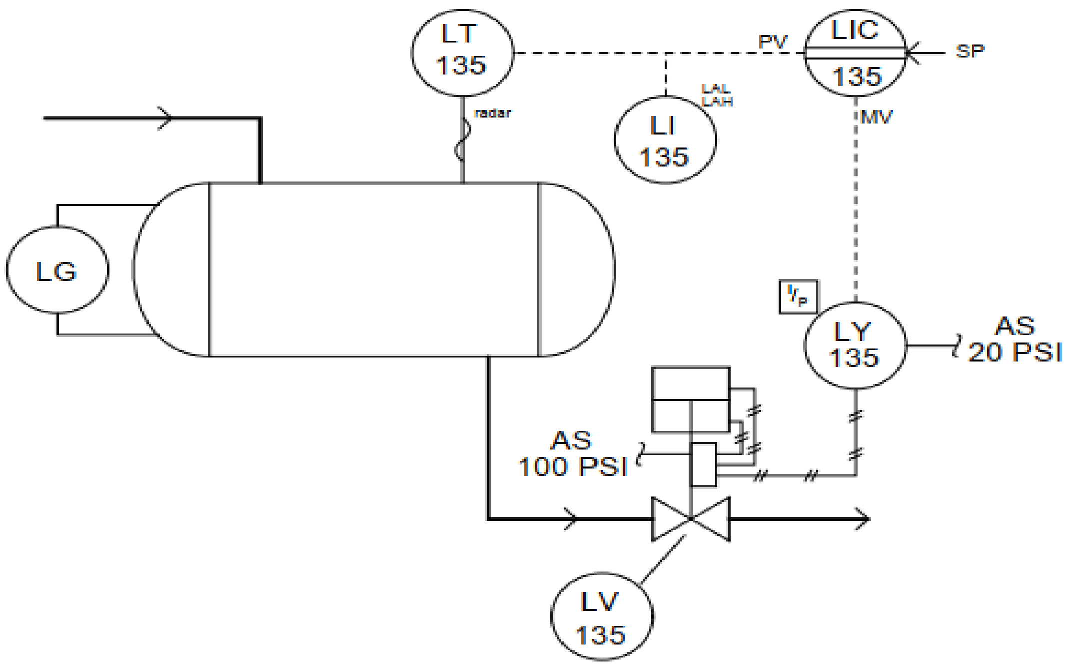
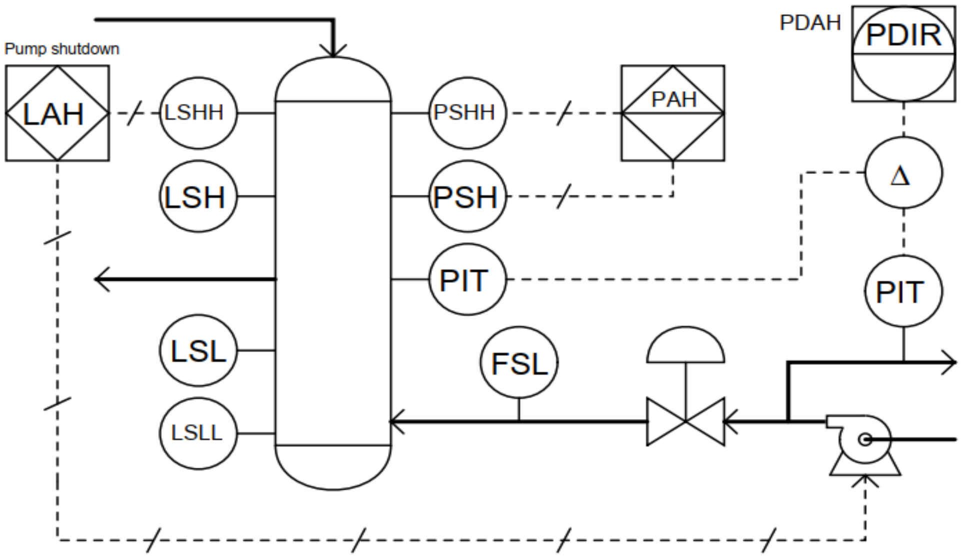


Fig. 3 P & ID (LIC 135) showing the control of liquid level in the horizontal receiver vessel.

(b) Identify the meaning of the following instruments in this P & ID in Fig. 4:

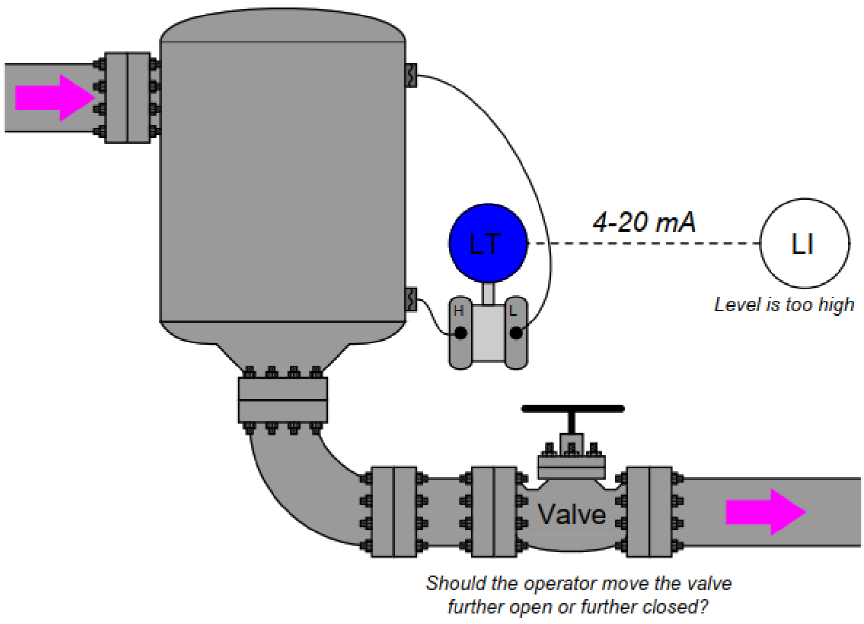


(6 marks)

Fig. 4 P & ID with various transmitters and control devices

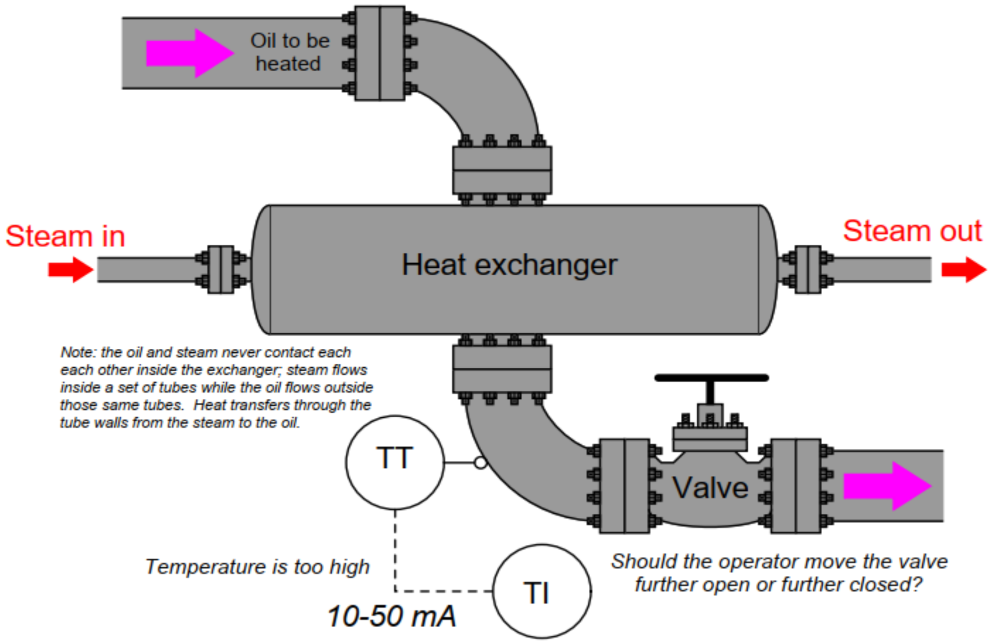
(c) Suppose you were giving instructions as a human operator regarding which way to move a hand operated control valve to maintain a process variable at setpoint. In each of these examples, determine and explain which way should you move the valve to counteract an increase in the process variable resulting from independent change in the process:

Example 1: Level control application (***level is too high***)



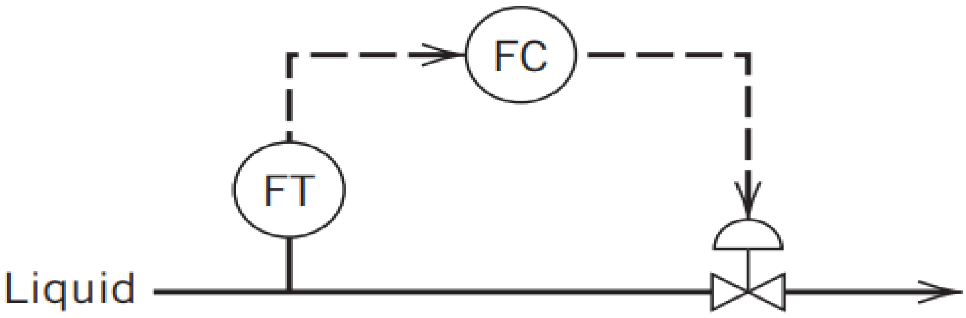
(1 mark)

Example 2: Temperature control application ***(temperature is too high)***

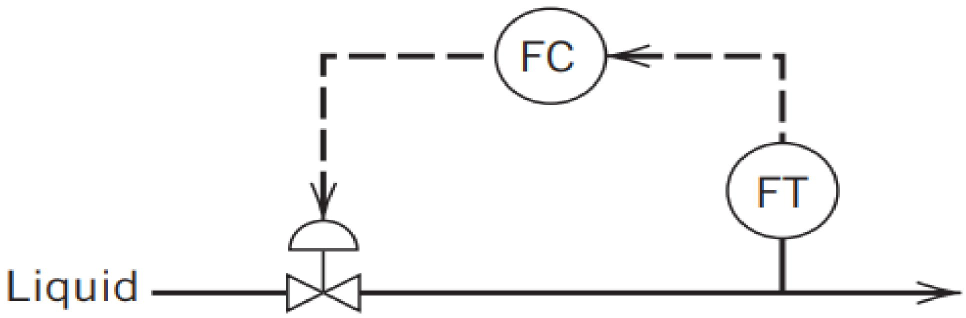


Explain the rationale behind your direction of valve motion in this example. **(2 marks)**

(d) Two flow control loops are shown in Fig. 5. Indicate whether each system is either a feedback or a feedforward control system. Justify your answer. It can be assumed that the distance between the flow transmitter (FT) and the control valve is quite small in each system.



System A



System B

(2 marks)

(e) Calculate the pH of the following aqueous solutions and the voltage (ideally) generated by a pH electrode pair, given the hydrogen ion molarity of each solution. Assume a solution temperature of 25°C:

$[H^+]$	pH	V_{probe} (mV)
$0.001995\ M$		
$6.309 \times 10^{-7} M$		
$7.943 \times 10^{-13} M$		
$3.881 \times 10^{-5} M$		
$1.452 \times 10^{-11} M$		

(6 marks)

Take Universal Gas Constant (R) = 8.315 $JK^{-1}mol^{-1}$ and Faraday's constant (F) = 96485 $Cmol^{-1}$

Table B-1. Type J: Iron-Constantan

°C	0	5	10	15	20	25	30	35	40	45
–150	–6.50	–6.66	–6.82	–6.97	–7.12	–7.27	–7.40	–7.54	–7.66	–7.78
–100	–4.63	–4.83	–5.03	–5.23	–5.42	–5.61	–5.80	–5.98	–6.16	–6.33
–50	–2.43	–2.66	–2.89	–3.12	–3.34	–3.56	–3.78	–4.00	–4.21	–4.42
–0	0.00	–0.25	–0.50	–0.75	–1.00	–1.24	–1.48	–1.72	–1.96	–2.20
+0	0.00	0.25	0.50	0.76	1.02	1.28	1.54	1.80	2.06	2.32
50	2.58	2.85	3.11	3.38	3.65	3.92	4.19	4.46	4.73	5.00
100	5.27	5.54	5.81	6.08	6.36	6.63	6.90	7.18	7.45	7.73
150	8.00	8.28	8.56	8.84	9.11	9.39	9.67	9.95	10.22	10.50
200	10.78	11.06	11.34	11.62	11.89	12.17	12.45	12.73	13.01	13.28
250	13.56	13.84	14.12	14.39	14.67	14.94	15.22	15.50	15.77	16.05
300	16.33	16.60	16.88	17.15	17.43	17.71	17.98	18.26	18.54	18.81
350	19.09	19.37	19.64	19.92	20.20	20.47	20.75	21.02	21.30	21.57
400	21.85	22.13	22.40	22.68	22.95	23.23	23.50	23.78	24.06	24.33
450	24.61	24.88	25.16	25.44	25.72	25.99	26.27	26.55	26.83	27.11
500	27.39	27.67	27.95	28.23	28.52	28.80	29.08	29.37	29.65	29.94
550	30.22	30.51	30.80	31.08	31.37	31.66	31.95	32.24	32.53	32.82
600	33.11	33.41	33.70	33.99	34.29	34.58	34.88	35.18	35.48	35.78
650	36.08	36.38	36.69	36.99	37.30	37.60	37.91	38.22	38.53	38.84
700	39.15	39.47	39.78	40.10	40.41	40.73	41.05	41.36	41.68	42.00

Examiners: Dr S. Fosu*/Dr I. Quaicoe*