The University of British Columbia
Department of Mining Engineering
MINE 432: Industrial Automation and Robotics

Time Limit: 24 hours FINAL EXAM Date: December 13, 2008

1. a. Why is the relationship in the diagram below concave upward. What is the shape of the plant-operating curve?

   b. If we know that the expected plant results show variations in concentrate grade and recovery of 3-6 %Cu and 80-85 % respectively, would you recommend approval of the plan to include beneficiation ahead of leaching? Why or why not? Regardless of your answer, what additional factors would you want to study?

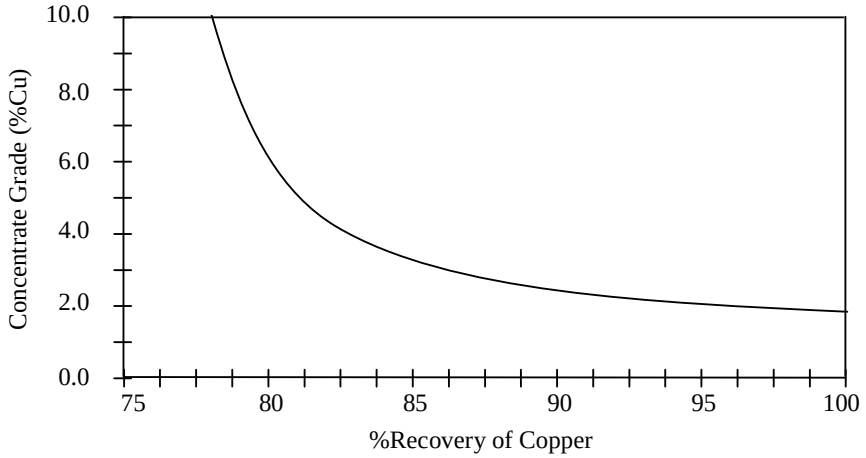
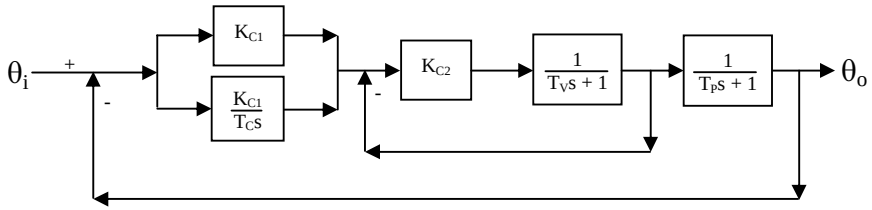


Diagram 1: Concentrate Grade and Recovery for the addition of a beneficiation plant to the processing of an oxide copper ore by mining, crushing, and leaching for a new development. The above diagram is for the following conditions:

Head Grade = 1.0 %Cu	Total capital cost (base case) = $135 million
Leach Plant Recovery = 85 %	Leaching & SX/EW capital cost = $100 million
Acid consumption (A) = 200 kg/t	Beneficiation capital cost = $60 million
Copper Production = 150 tpd	Total operating cost (base case) = $13.00/t
Operating days per year = 355 days	Leaching & SX/EX operating cost = $(1.25 + 0.05*A) /t
Project life (base case) = 20 years	Beneficiation operating cost (base case) = $2.50/t
Copper price = 99 ¢/lb.	NPV @ 15% = 15.8 million
	Leverage = 75%

Value = 15 marks

2. a. For the following control system, determine the control ratio as a function of the individual transfer functions. Invert this ratio back into the dynamic response equation for the system responding to a step change, i.e., θ_i = A/s. List all assumptions.

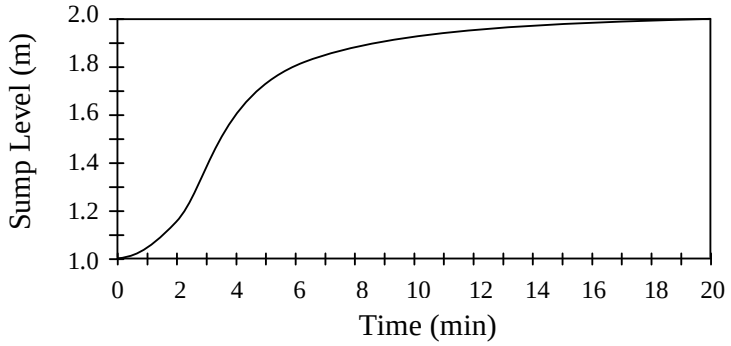


b. Identify the type of control system and the type of controller(s) in use.

c. What is the purpose of the inner feedback loop?

Value = 15 marks

3. Pulp is flowing into a sump under steady state conditions at 600gpm and is being pumped out to a cyclone at the same rate to maintain a set sump level. To compensate for changes in pulp flowrate, water is being added to the sump to maintain a constant level in response to a float valve. The reaction curve below was obtained for the open loop sump-level control system when the water flowrate was stepped up by 100 gpm.



a. Draw the control diagram for this system showing all components of the system for PID control.

b. What are the parametric values for T_d, T_P and K_P for this sump assuming it can be modelled by a pure time lag and a first order process? Use fractional changes in flowrate and sump level to perform this calculation.

$T_d =$
$T_P =$
$K_P =$

c. For a PID controller to adjust the valve that controls water flowrate, what K_C, T_I and T_D parameter values are required to achieve a response that exhibits quarter-decay ratios? Use Zeigler-Nichols Rules for PID Control

$K_C = 1.2\ R / K_P$ where $R = T_d / T_P$
$T_I = 2.0\ T_d / K_C$
$T_D = 0.5 T_d K_C$

d. For the digital equation of the form:

$$P(t+1) = P(t) + K_1 * \varepsilon(t) + K_2 * \varepsilon(t-1) + K_3 * \varepsilon(t-2)$$

what values for K_1, K_2 and K_3 should be used? (If you are unable to obtain a numerical answer, you may leave your answer as an expression of K_1, K_2 and K_3 as functions of T_d, T_p and K_p.) – Assume $\Delta t = 0.1$ minutes.

$K_1 =$
$K_2 =$
$K_3 =$

Value = 15 marks

4. a. A model of a column flotation cell has been developed as a first order plus time delay transfer function with K_p = 10, T_p = 20 minutes, and T_d = 5 minutes. A control system is in use to manipulate the addition rate of a collector reagent in response to copper content measurements of the tailing stream from an XRF analyzer. The analyzer reports a new reading every 7 minutes. The tailings stream sample line to the analyzer is 5cm in diameter and 18m in length. A flow rate of 22 L/minute is delivered continuously to the analyzer. If the reagent addition undergoes a step change, how long will it take before the measured concentration of copper reaches 63% of its final steady state value in an open-loop test?

   b. A process has been tested using step changes of the manipulated variable of different magnitudes M_i, yielding steady-state changes in the output variable Δy_i as follows:

(a)	$M_1 = 2.0$	$\Delta y_1 = 4.0$
(b)	$M_2 = 4.0$	$\Delta y_2 = 6.0$

   Is this process linear or nonlinear? Explain why.

Value = 15 marks

5. Indicate which of the following statements are true and which are false:

a. Expert Systems and Artificial Neural Networks both process knowledge as symbols. F

b. Artificial Neural Networks model data by developing their parameters using a learning procedure. F

c. Fuzzy Logic got its name because the mainstream scientific community believed the method was folk-art. F

d. Artificial Neural Networks became an accepted method after a way to model non-separable problems was discovered. T

e. Fuzzy Logic describes a system in which the boundaries between adjacent concepts are not crisp. T

f. The use of a bias node in Artificial Neural Networks is similar to using a Confidence Level in Expert Systems. T

g. An Expert System can explain its knowledge and this is one of its major attributes. T

h. The weights of the connections between nodes in an Artificial Neural Network must be scaled between $-\infty$ and $+\infty$. F

i. An Expert System cannot find a reasonable solution unless all the input information is available. F

j. The future of Artificial Intelligence will see the merging of the three technologies of Fuzzy Expert Systems, Artificial Neural Networks, and Genetic Algorithms into hybrid systems that exploit the major benefits of each. T

k. Artificial Neural Networks require all input and output signals to be scaled between 0 and 1. F

l. The most widely used learning algorithm in the field of Artificial Neural Networks is called Back-Propagation. T

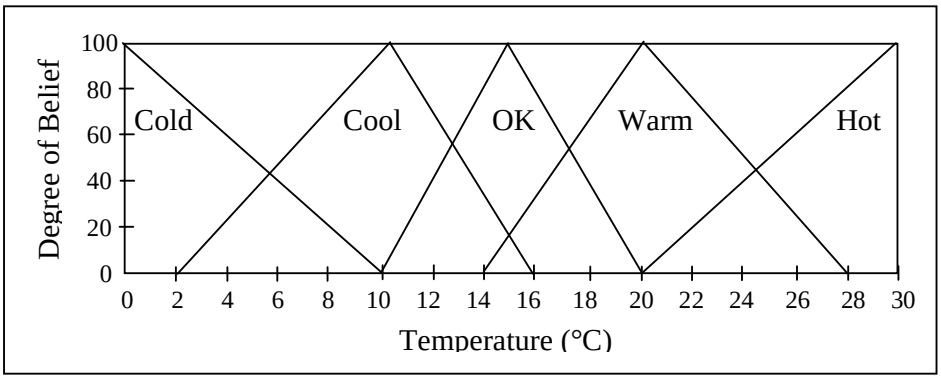
m. Instantiation refers to a process by which facts are combined to calculate the Net Degree of Truth of a rule. T

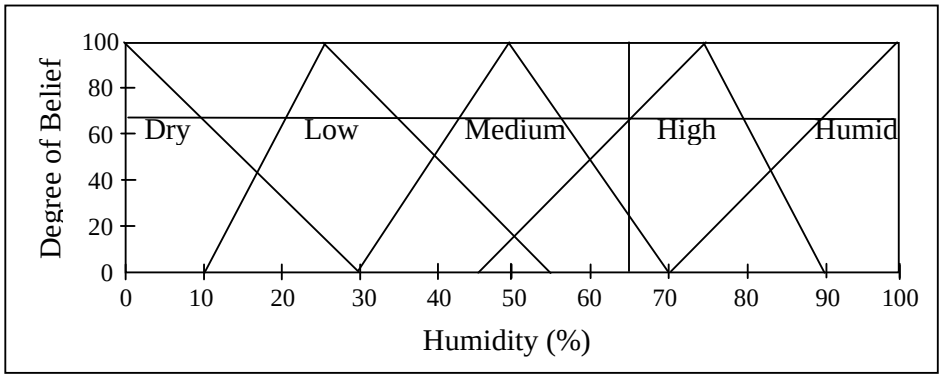
n. The use of a hidden layer in an Artificial Neural Network allows the method to deal with non-separable problems. T

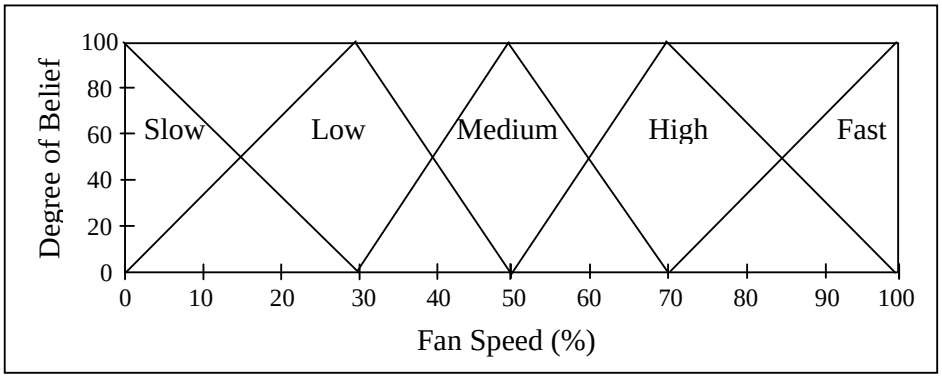
o. To calculate the Net Degree of Truth in an Expert System rule premise, the system selects the maximum value of the degrees of belief in two statements that are connected by an OR operand. T

Value = 15 marks

6. In the Fuzzy System below, calculate the output value for inputs of 24 °C and 65% humidity using the weighted average defuzzification method that takes the maximum DoB of each output fuzzy set. Show your work.







Fuzzy Associative Map relating Fan Speed to Temperature and Humidity

Humidity (%)	Temperature (°C)				
	Cold	Cool	OK	Warm	Hot
Dry	Slow	Slow	Low	Low	Medium
Low	Slow	Slow	Low	Medium	Medium
Medium	Slow	Low	Medium	Medium	High
High	Low	Low	Medium	High	Fast
Humid	Low	Medium	High	Fast	Fast

Value = 15 marks

7. You have been hired for a summer job by a mine to work on a neural network that attempts to correlate several output variables from a mill to certain input variables. In examining an existing artificial neural network that was developed the previous summer by a Queen's University engineer, you observe that a single network was used to output discrete numerical values for 4 different variables. The network consists of 10 inputs, 20 hidden nodes in a single layer, and 4 output nodes. No bias node has been used. A total of 10,000 input/output data sets are available to train this network, but the format of the data has not been normalized. All of this data was used to train the network. The network training error was reported as 10% by the Queen's engineer - which was interpreted as unreliable.

   List the steps you would implement to improve the utility of this network?

   Explain why you believe each change will reduce the network error.

   Value = 15 marks