

**National Exams December 2017**  
**16–Chem–B5**  
**Pulp and Paper Technology**

**3 hour duration**

**Notes:**

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. Candidates may use one of two calculators, the Casio or Sharp Approved models. This is an OPEN BOOK exam.
3. Any 3 questions constitute a complete paper. Only the first three questions as they appear in your answer book will be marked.
4. All questions are of equal value. Marks for question parts are indicated under each question.
5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

**Question 1**

**Parts (a) – (e) are worth 10 marks each. Part (f) is worth 20 marks.**

- (a) Sketch and describe the multiple effect evaporation system used in the recovery of kraft mill black liquor. Define steam economy, and give a typical value that might be expected for a 6-stage evaporator section.
- (b) Describe the steam generation technology of a kraft recovery boiler. Also describe how the recovery boiler serves in the recovery of pulping chemicals, explaining any chemical reactions that occur.
- (c) What is Tall Oil? What material is recovered in a kraft mill to produce Tall Oil? How it is produced? Which wood species would you expect to achieve higher yields of Tall Oil and why?
- (d) Two processes are available to you to cook wood chips using the Kraft process – batch digesters and conventional Kamyr digester. Each process has its advantages and disadvantages over the other process. Describe these differences and how one process would be more advantageous than the other.
- (e) The Kappa number of the pulp leaving a continuous digester is low. What operating variables can the operator of the digester house use to increase the Kappa Number to the desired target range? Sketch a continuous digester and indicate how and where changes to these variables are made.

**Part (f) is worth 20 marks.**

- (f) A pulp mill uses 6 batch digesters to cook wood chips. Each of the 6 digesters has a volume of 175 cubic meters. During a cook, the digester is filled to 80% of its rated volume with hardwood chips at a bulk density of 285 kg/m<sup>3</sup>. The wood moisture is 45% on total wood mass. The pulp yield on oven dry (O.D.) wood is 54%.
  - 1) Calculate the required application of white liquor on wood in L/batch for an application rate of 15.0 % E.A. (effective alkali) on O.D. Wood. The white liquor has an effective alkali concentration of 93 g/L and its density is 1.09 g/mL.
  - 2) Calculate the volume of black liquor in L/batch, required to maintain an L/W (Liquor / Wood) ratio of 4.1:1. What is the purpose of the addition of this black liquor?
  - 3) Calculate the production rate of brown stock that will be produced from this digester house.
  - 4) The white liquor from the recausticizing plant at this mill has an effective alkali concentration of 93 g/L, a sulphidity of 28%, a causticizing efficiency of 82%, and a reduction of 92%. Calculate the flow of white liquor in L/min that the recausticizing plant must make to supply the digester house above. Also calculate the stoichiometric amount of lime to be applied in the slaker and the amount of lime mud produced. (Ca = 40.1, Na = 23.0; S = 32.0; O = 16.0; H = 1.01)

**Question 2**

**Parts (a) – (c) are worth 10 marks each. All 3 parts are to be answered.**

- (a) A Conventional Bleach Plant uses the sequence DEopDEpD for kraft pulp bleaching. What does each of the letters refer to, in this sequence? What are the typical conditions of the first ( $D_0$ ), fourth ( $D_1$ ) and last stage ( $D_2$ ) of this sequence, including temperature, consistency, pH, chemical dose, Kappa Factor and residence time? Assume that the Bleach Plant is being fed with 25 Kappa Number pulp.
- (b) How are BOD, AOX, Toxicity and TSS measured? How are these parameters affected by a kraft mill bleach plant? How is bleach plant effluent treated before it is discharged to the environment?
- (c) Describe the two technologies for oxygen delignification in use today, giving typical delignification conditions. How does each of these technologies promote the mixing and diffusion of oxygen into the pulp? How much delignification can be reasonably accomplished by each oxygen delignification process and what limits the delignification?

**Parts (d) – (f) are worth 20 marks each. Only 2 parts of the 3 are required to complete Question 2. Only the first two parts as they appear in your answer book will be marked.**

- (d) Chlorine dioxide can be made by the following net reaction:



- 1) What is the reducing agent used in the above  $\text{ClO}_2$  production process?
- 2) What are the typical concentrations of the sodium chlorate, sulphuric acid and sodium sulphate in the generator under normal operating conditions?
- 3) What are the typical feed strengths for the raw materials required for this generator?
- 4) How is the by-product sodium sulphate separated from the generator liquor?
- 5) What are the typical uses for the by-product sodium sulphate in a bleached kraft pulp mill?
- 6) Using the reaction above, if a 42 metric ton per day  $\text{ClO}_2$  Plant (92.5% efficient) produces 2000 L/min of  $\text{ClO}_2$  solution by absorbing  $\text{ClO}_2$  in 6°C water, what is the concentration of  $\text{ClO}_2$  produced? What flowrate (kg/min) of 50% hydrogen peroxide solution is required? What flowrate of 6.2M sodium chlorate solution is required? (Cl – 35.45; O – 16.0; H – 1.008; Na – 23.0)

- (e) A pulp mill produces 1500 metric tons per day of softwood bleached kraft pulp. In this mill, oxygen delignification is used prior to the bleach plant. Assuming a 45% yield from the digester producing pulp at 27.5 Kappa Number and a 42% delignification in the oxygen delignification stage:
- 1) Calculate the flow of chlorine dioxide solution in L/min required in the delignification  $D_0$  Stage, given a chlorine dioxide solution of 10.5 g/L, incoming Kappa Number of 27.5 prior to oxygen delignification and a  $D_0$  Kappa Factor of 0.195. (Cl – 35.45; O – 16.0; H – 1.008)
  - 2) Using the information above, calculate the wood supply required assuming a chip moisture of 44%, a reject rate of 3.25 ADMT/day and a yield loss from the bleaching process of 5%.
  - 3) Describe the purpose of washing of the pulp prior to and after oxygen delignification. What equipment can be used for washing? What component is removed from the pulp during this washing stage? How is it used in a pulp mill?
- (f) In an energy reduction project, a pulp mill is considering an installation of a chlorine dioxide heat exchanger to heat chlorine dioxide solution prior to mixing with the pulp in the  $D_1$  and  $D_2$  bleaching stages:
- 1) What sources of filtrate or water could a pulp mill use to heat the chlorine dioxide solution?
  - 2) What design criteria, should the engineering department of the pulp mill use to design the heat exchanger?
  - 3) What safety parameters should they be aware of in this design?
  - 4) Will metallurgy be important? Why?
  - 5) If the temperature of the stock from the preceding extraction stage is 60°C and the target operating temperature of the  $D_1$  steam mixer is 75°C, what savings in steam consumption in the  $D_1$  Stage can be achieved, by heating the incoming chlorine dioxide solution from 4°C to 43°C in an heat exchanger that uses  $E_1$  stage filtrate at 76°C? What will be the resulting  $E_1$  filtrate temperature? Use the following assumptions for the calculation:
    - i) Incoming  $E_1$  Kappa Number = 6.0
    - ii)  $D_1$  Stage Kappa Factor = 0.76
    - iii) Bleach Plant production rate = 800 ADMT/d
    - iv)  $D_1$  Stage operating consistency = 11% AD
    - v)  $ClO_2$  Solution Strength = 10.5 g/L

Please calculate for the following:

    - vi) Chlorine dioxide solution flowrate to  $D_1$  Stage
    - vii)  $E_1$  Filtrate flowrate required
    - viii)  $E_1$  Filtrate Temperature out of heat exchanger
    - ix) Steam savings achieved by using the  $ClO_2$  Heat Exchanger

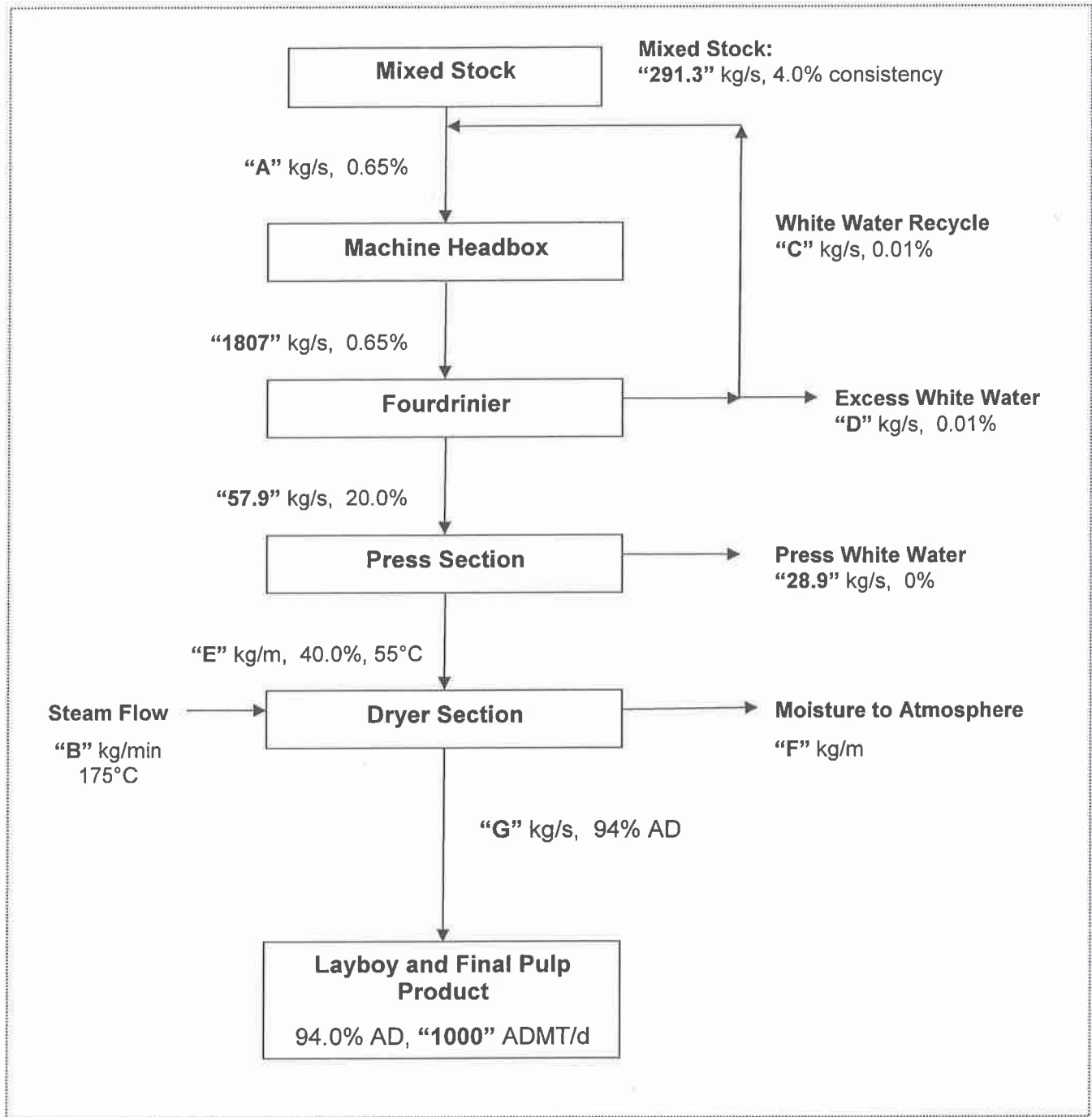
**Question 3**

**Parts (a) – (e) are worth 10 marks each. Part (f) is worth 20 marks.**

- (a) Describe the test for Canadian Standard Freeness (CSF). What does it measure? As pulp is refined in preparation for papermaking, what happens to the Canadian Standard Freeness?
- (b) Describe the paper strength tests and give typical values with units for tensile index, tear index and burst index for a kraft pulp. How do these properties vary as the pulp is refined in preparation for papermaking? What is the purpose of a PFI Mill for the purpose of determining pulp strength?
- (c) Pulp cleaning systems – What is the purpose of pulp cleaning systems prior to the pulp or paper machines and what is the principle of operation? Describe a typical cleaning system. Sketch a system and label the components.
- (d) Describe how paper is dried in the dryer section of a paper machine. Describe how condensate is removed from dryer cans and why this is important.
- (e) Sketch a diagram of a fourdrinier wet end, showing and clearly labelling the drainage elements.

**Part (f) is worth 20 marks.**

- (f) Complete the water and fibre balance in the following block diagram of a pulp machine, by determining the values for A, B, C, D, E, F and G. The stock flows in kg/s are total flows, including water and the stock consistencies are in mass percent. See the block diagram on the next page:



**Question 4**

**Parts (a) – (e) are worth 10 marks each. Part (f) is worth 20 marks.**

- (a) Why is jackpine not a suitable species for making mechanical pulp for newsprint? Why is aspen not a suitable species for newsprint? Name a boreal forest species which is suited for newsprint and why it is suitable.
- (b) Two methods can be used to produce mechanical pulp for newsprint. What are they? Why is one process more favourable than the other? What are the disadvantages of one process over the other? What equipment is used for each process?
- (c) What are two methods for bleaching groundwood pulp? What are the typical conditions and type of equipment needed for each method of bleaching? What brightness improvement gains may be expected? Which is the most common method and why?
- (d) Differentiate between the groundwood, TMP, CTMP and Kraft pulping processes. What are the typical advantages and disadvantages of each process? Which processes are not typically used for high quality, high brightness, high strength papers and why? Where do groundwood, TMP and CTMP pulps have an advantage over kraft pulps?
- (e) With the aid of a sketch show a typical configuration of primary and secondary screening in a TMP mill. Also sketch a diagram depicting a typical pressure screen.

**Part (f) is worth 20 marks.**

- (f) A 40 ADMT/day grinder consumes 1500/ kWh/ADMT. The wood enters the grinder at 25°C and 42% moisture (total mass basis). For simplicity you may assume that both wood and water have the same heat capacity of 4.18 kJ/kg°C. Also assume 99% yield.

- 1) How much shower water (kg/s) supplied at 40°C, is required to keep the vat temperature at 70°C?

