

Name: _____ Student ID _____

**Prince of Songkla University
Faculty of Engineering**

**Exam: Final Exam, Semester II
Date: February 18, 2009
Subject: 230-560 Food Unit Operations**

**Academic Year: 2008 – 2009
Time: 1:30 – 4:30 PM
Room: R200**

ทฤษฎีในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทฤษฎี และพักการเรียน 1 ภาคการศึกษา

Instructions: This exam is a Closed Book Exam. The points for each problem are not distributed evenly. Place your name and the student ID number on every page. Students are allowed to use only a pen or pencil and a calculator. Write your English Nickname and your Team Name above.

Points Distribution (For Grader Only)		
Part	Points Value	Score
I	45	
II	30	
III	30	
IV	45	
V	30	
Total	180	

**Exam prepared by
Ram Yamsaengsung
February 14, 2009**

**PLEASE CHECK TO MAKE SURE THAT
YOU HAVE ALL 12 PAGES OF THE EXAM BEFORE BEGINNING
(not including the cover sheet).
GOOD LUCK!**

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CLOSED BOOK EXAM (180 points)

Part I. Fill in the blanks (45 points)

1. There are two major types of heat exchangers. The _____ type includes the steam infusion and surface injection, while the _____ type includes the plate, tubular, shell-in-tube, and scraped surface.
2. _____ is the process of using heat from the processed product to raise the temperature of the incoming “raw” product.
3. The two types of flow direction that can occur in a double-pipe tubular heat exchanger are _____ and _____.
4. The _____ heat exchanger is useful in removing fouling from the tube wall.
5. The thermal process that produces products that does not require refrigeration is called _____.
6. It is easier for material with _____ (high/low) yield stress to achieve turbulence.
7. For turbulent flow to occur in Power-Law and Bingham Plastic fluids, the Reynolds ($N_{Re,PL}$ or $N_{Re,B}$) number must be more than the _____.
8. Under _____ conditions, some Newtonian fluid can become turbulent at Reynolds number of 1,350.
9. The _____ (negative/positive) sign in the heat conduction equation indicates that heat flows from high temperature region to low temperature region.
10. Conduction heat flux is proportional to the _____ of the material and inversely proportional to the _____ of the material.
11. _____ convection is due to the density difference caused by temperature gradients or turbulent flow, while _____ convection involves the use of some mechanical means, such as pumps or fans, to induce the movement of the fluid.
12. For _____ (laminar/turbulent) flow of _____ (Newtonian/Power-Law/Herschel Bulkley/Bingham Plastic), the kinetic energy correction factor (α) is always 1.
13. The friction loss coefficients (k_f) values _____ (increase/decrease) with _____ (increasing/decreasing) pipe diameter.

14. The two major types of friction losses that occur in the flow of fluid through a pipe are _____ and _____.
15. The Biot number is a ratio of the _____ and the _____.
16. For a Biot number less than 0.1, the _____ can be neglected (ignored).
17. _____ products do not require refrigeration.
18. Sterilization takes place at about _____ degree Celsius.
19. Rapid freezing _____ (increases/decreases) the number of nuclei formed.
20. During thermal processing, the population of the microorganisms is reduced in a _____ (linear/logarithmic) manner.
21. Most microorganisms can grow best at _____ (low/intermediate) pH and _____ (high/low) a_w .
22. The metabolic activity of microorganisms can _____ (increase/decrease) the pH of foods.
23. The _____ is the time required to cause a 10% reduction in the decimal reduction time.
24. The decimal reduction time _____ (increases/decreases) with increasing process temperature.
25. _____ is the process of using heat from the processed product to raise the temperature of the incoming "raw" product.
26. Chemical preservatives, such as _____ and _____, can be added to foods to help prevent microbial growths.
27. Products in glass containers require _____ (quick/slow) heating and cooling for an effective thermal treatment.
28. The _____ is generally 12 times that of the decimal reduction time.
29. The thermal process that produces products that require refrigeration is called _____.
30. The _____ can be obtained by plotting a semi-log plot between the decimal reduction time and temperature.
31. _____ is generally used to heat mushrooms in canned containers.
32. Superior quality products require _____ (high/low) temperature and _____ (long/short) time for thermal treatment.
33. The _____ is a plot between the change in microbial population versus thermal treatment time.
34. _____ can be used to fry high sugar products such as ripened bananas and durian chips.



Part II. Flow Through Pipe (30 points)

1. Beginning with the relationship between shear stress and shear rate, derive the velocity profile for a Power Law fluid flowing through a tube viscometer. Please, show all your work. (10 points)

$$u(r) = \left[\frac{\Delta P}{2LK} \right]^{1/n} \left[\frac{n}{n+1} \right] \left[R^{\frac{(n+1)}{n}} - r^{\frac{(n+1)}{n}} \right] \quad (1)$$

2. From (1), show that the volumetric flow rate (Q) is given by the following equation. (10 points)

$$Q = \pi \left[\frac{\Delta P}{2KL} \right]^{1/n} \left[\frac{n}{3n+1} \right] R^{(3n+1)/n} \quad (2)$$

3. For flow of a Power-Law fluid with a $K = 5.2 \text{ Pa s}^n$ and $n = 0.60$, is the flow laminar or turbulent if the diameter of the pipe is 4.2 cm and the average velocity of 2.5 m/s. The density of the fluid is constant ($\rho = 1250 \text{ kg/m}^3$). **(10 points)**

Part III. Shorts Answers (30 points)

1. Name 2 examples of direct contact freezing systems. What type of freezing system is used for hardening (making) ice cream? Name 2 types of refrigerants that are commonly used in freezing systems. **(6 points)**
2. Name 6 different units or ways that can be used to cook chicken. **(6 points)**
3. What is the difference between PSL and HQL? **(4 points)**
4. Name 4 advantages of vacuum frying? **(4 points)**
5. Discuss the heat and mass transfer processes that take place during the frying of French fries. Draw a diagram and use arrows to show direction of heat and mass transfer. What are some major differences between French fries and potato chips? Which contains more oil? **(10 points)**

Part IV. Short Calculations (45 points)

1. Experimental results with a concentric cylinder viscometer used for banana puree at 340 K were as followed:

Shear Rate [10^{-3} x 1/s]	Shear Stress [10^{-4} x Pa]
1.0	2.40
1.5	3.20
2.0	3.50
3.0	4.50
4.0	4.60
5.0	4.90
6.0	5.20
7.0	5.30

Assuming Power-Law behavior, determine the rheological parameters required to describe the product. **(8 points)**

2. If the maximum velocity of a power law fluid flowing through a pipeline system is 2.0 times that of the average velocity, what is the flow behavior index of the material? **(2 points)**

3. For the pasteurization of guava juice, a regenerative heating/cooling section is used. After the “starter” raw juice has been heated to 82°C, it is passed through a holding loop and into a regeneration section. The juice then heats up the incoming raw juice from 30°C to 60°C. While the “starter” juice temperature decreases to 39°C. Compute the % regeneration of the system. **(5 points)**
4. For Problem 3, what is the flow rate of the chilled water required to reduce the temperature of pasteurized juice from 39°C to 5°C? The specific heat of guava juice is 3.76 kJ/kg°C and the specific heat of the chilled water is 4.18 kJ/kg°C, and the mass flow rate of the guava juice is 500 kg/hr. Chilled water enters the heat exchanger counter-currently at 2°C and leaves at 8°C. **(5 points)**
5. What does LMTD stand for (abbreviation for)? For a countercurrent flow regime in Problem 4, if a double pipe heat exchanger is used, what is the LMTD of the system? What is the length of the pipe if the internal diameter of the pipe is 10 cm and the overall heat transfer coefficient is 2,000 W/m² K? **(10 points)**

6. The results of a thermal resistance experiment gave a D value of 8.5 minutes at 105°C. If there were 9.5×10^9 survivors after 17 minutes of processing, determine the microbial population, N, at 10, 20, and 30 minutes. **(5 points)**
7. If the decimal reduction time at 105°C, D_{105} , is 4.5 minutes, how long does it take to reduce the number of microorganisms from 505,000,000,000 to 1 at 121°C if the thermal resistance constant equals 8°C? **(5 points)**
8. If the thermal death time is $F_{115}^{6.5}$, what is the spoilage probability of a 300-seconds process at 128°C, when $D_{115} = 20$ minutes and the initial population is 10^7 per container. **(5 points)**

Part V: Food Processes (35 points)

1. Name the following product based on the information given. You must be EXACT to obtain full credit. **(10 points)**

- 1.1 Sugar, condensed milk, egg, mustard, vinegar, cooking oil: _____.
- 1.2. Gelatin, sugar, water, grated orange rind, juice: _____.
- 1.3. Salad dressing, pear, guava, apples, onions, tuna: _____.
- 1.4. Watermelon, corn syrup, flavoring agents: _____.
- 1.5. Water chestnut, apples, syrup, coconut milk: _____.
- 1.6. Fruit, filter press, pasteurized, sold in bottles: _____.
- 1.7. Filling machine, dicing machine, tapioca, hot water: _____.
- 1.8. Sold in packages of 2 pieces for 20 baht: _____.
- 1.9. Good looking people get 10% discount: _____.
- 1.10 Free one if you find "Free" under package: _____.

2. You just won the Thailand lottery worth 10,000,000 baht and have inside news that countries in the Middle East, Europe, and China are very interested in Thai desserts and snacks. Using YOUR TEAM'S PRODUCT, discuss your new dessert or snack products that you plan to export to Europe, China or the Middle East. List the **major ingredients, how to make it, what processes and equipment** will you need, how to **package it, the price per unit, the units per package**, etc. Finally, discuss additional **marketing strategies** that could be used to increase profit. Don't forget to **name your product** and give a **slogan**. **(20 points)**

BONUS QUESTION: (5 Points)

1. What is the name of the city and country where the pictures of me and my kids were taken?
2. Match the following Ajarns with the university where they got their PhD.

A. Ram	(a) Johns Hopkins University
A. Pakamas	(b) Texas A&M University
A. Pimphan	(c) Lehigh University
A. Chayanoot	(d) Colorado School of Mines
A. Kulchanat	(e) Cranfield University (UK)
A. Sukitira	(f) University of Missouri

Useful Equations:

$$\sigma = \frac{\Delta Pr}{2L}$$

$$Q = \int_0^R u(r) 2\pi r dr = \bar{u}A$$

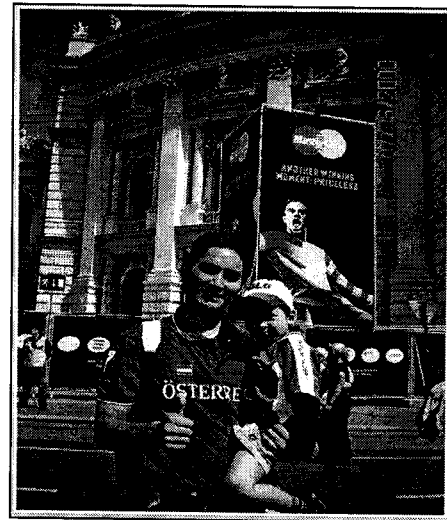
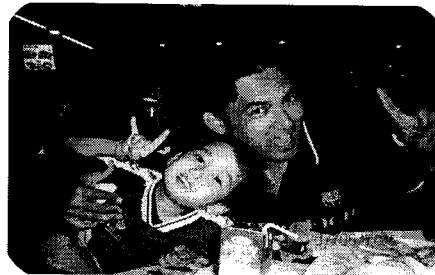
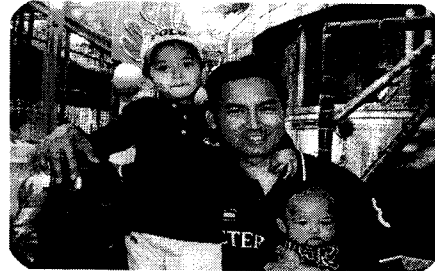
$$\frac{u_{\max}}{\bar{u}} = \frac{1+3n}{1+n}$$

$$N_{\text{Re,PL}} = \left(\frac{D^n (\bar{u})^{2-n} \rho}{8^{n-1} K} \right) \left(\frac{4n}{3n+1} \right)^n$$

$$(N_{\text{Re,PL}})_{\text{critical}} = \frac{6464n}{(1+3n)^2 \left(\frac{1}{2+n} \right)^{(2+n)/(1+n)}}$$

$$\frac{N}{N_0} = \left(10^{-\frac{l}{D}} \right) \quad \frac{1}{r} = (N_0) \left(10^{-\frac{l}{D}} \right)$$

$$z = \frac{T_2 - T_1}{\log D_{T_1} - \log D_{T_2}}$$



**END OF EXAM!
CONGRATULATIONS!
GOOD LUCK ON YOUR JOB SEARCH
AND
HAVE A GOOD VACATION!**