Name: _____ Student ID _____

Prince of Songkla University
Faculty of Engineering

Exam: Final Exam, Semester II
Date: February 22, 2012
Subject: 230-560 Food Unit Operations

Academic Year: 2011 – 2012
Time: 1:30 – 4:30 PM
Room: S201

ทุจริตในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต 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	35	
II	20	
III	40	
IV	40	
V	30	
VI	45	
Total	210	

Exam prepared by
Ram Yamsaengsung
February 15, 2012

PLEASE CHECK TO MAKE SURE THAT
YOU HAVE ALL 16 PAGES OF THE EXAM BEFORE BEGINNING
(not including the cover sheet).
GOOD LUCK!

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CLOSED BOOK EXAM (220 points)

Part I. Fill in the blanks (35 points)

1. The _____ (negative/positive) sign in the heat conduction equation indicates that heat flows from high temperature region to low temperature region.
2. The two types of flow direction that can occur in a double-pipe tubular heat exchanger are _____ and _____.
3. The _____ heat exchanger is useful in removing fouling from the tube wall.
4. 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.
5. _____ can be used to fry high sugar products such as ripened bananas and durian chips.
6. 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 _____.
7. Superior quality products require _____ (high/low) temperature and _____ (long/short) time for thermal treatment.
8. _____ is the process of using heat from the processed product to raise the temperature of the incoming "raw" product.
9. It is easier for material with _____(high/low) yield stress to achieve turbulence.
10. For _____ (laminar/turbulent) flow of _____ (Newtonian/Power-Law/Herschel Bulkley/Bingham Plastic), the kinetic energy correction factor (α) is always 1.
11. Conduction heat flux is proportional to the _____of the material and inversely proportional to the _____ of the material.
12. The _____ is the amount of temperature increase required to cause a 90% reduction in the decimal reduction time.
13. _____ 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.
14. Sterilization takes place at about _____ degree Celsius.

15. The two major types of friction losses that occur in the flow of fluid through a pipe are _____ and _____.
16. The thermal process that produces products that require refrigeration is called _____.
17. Products in glass containers require _____ (quick/slow) heating and cooling for an effective thermal treatment.
18. Chemical preservatives, such as _____ and _____, can be added to foods to help prevent microbial growths.
19. During thermal processing, the population of the microorganisms is reduced in a _____ (linear/logarithmic) manner.
20. The decimal reduction time _____ (increases/decreases) with increasing process temperature.
21. Rapid freezing _____ (increases/decreases) the number of nuclei formed.
22. Most microorganisms can grow best at _____ (low/intermediate) pH and _____ (high/low) a_w.
23. The metabolic activity of microorganisms can _____ (increase/decrease) the pH of foods.
24. The _____ is generally 12 times that of the decimal reduction time.
25. The _____ can be obtained by plotting a semi-log plot between the decimal reduction time and temperature.
26. The _____ is a plot between the change in microbial population versus thermal treatment time.

Part II. Rheology Calculations (20 points)

1. Experimental results with a concentric cylinder viscometer used for banana puree at 310 K were as followed:

Shear Rate [10^{-3} x 1/s]	Shear Stress [10^{-4} x Pa]
1.0	2.30
1.5	2.85
2.0	3.40
3.0	4.30
4.0	5.30
5.0	6.40
6.0	7.60
7.0	8.50

Assuming Power-Law behavior, determine the rheological parameters required to describe the product. Is the product shear-thinning or shear-thickening? **(15 points)**

Part III. Flow Through Pipe (40 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. Show all your work. **(10 points)**

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

2. Consider a typical flow illustrated in Figure 1 below. The system has a 4.0 cm diameter pipe with a volumetric flow rate of 1.65×10^{-3} m^3/s. The density of the fluid is constant ($\rho = 1{,}400$ kg/m^3) and the pressure drop across the strainer is 200 kPa. Additional friction losses occur in the entrance, the plug valve and in the three long radius elbows. **(30 points)**

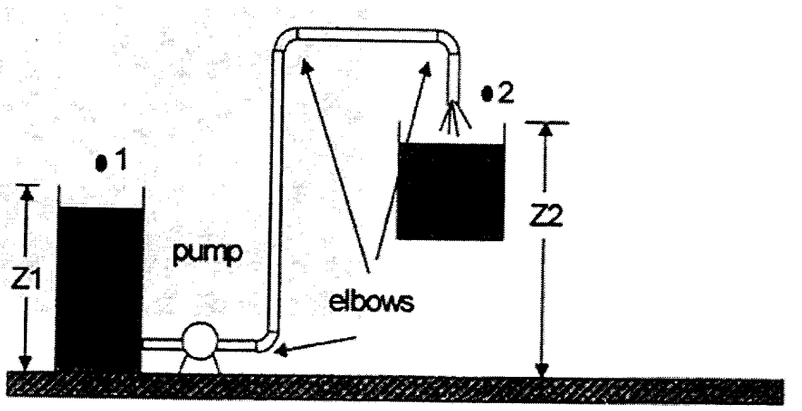


Figure 1: Pipeline system for above.

(a) What is the mass flow rate (kg/s) and the average velocity (m/s) of the product? **(5 points)**

(b) For flow of a Power-Law fluid with a $K = 4.5$ Pa s^n and $n = 0.50$, is the flow laminar or turbulent. **(10 points)**

(c) If the total length of the pipe is 12.5 m and the distance from the pump to the pipe discharge is 3 m, determine the work input and the pressure drop. Use the following information to help you with the calculations. **(15 points)**

- **k_f, long radius elbow = 0.45**
- **k_f, plug valve (disc) = 9.0**

Part IV. Shorts Answers (40 points)

1. Name 3 examples of direct contact freezing systems. Name 2 types of refrigerants that are commonly used in freezing systems. **(5 points)**

2. Discuss the differences between steaming, grilling, and microwave cooking. What is the heat and mass transfer mechanism of each? **(6 points)**

3. Name 6 different units or ways that can be used to cook chicken. **(3 points)**

4. What is the difference between PSL and HQL? Give two examples of products that need to have HQL. **(4 points)**

5. Draw a typical drying curve (plot between the moisture content and the drying time) for dried bananas. Name 3 major drying parameters that affect the rate of drying of food products? What is the general final moisture content for dried or fried snack food? **(6 points)**

6. What is the difference between the crust region and the crumb region of a product? Draw a picture showing these regions and give 3 examples of foods that have both regions. **(6 points)**

7. 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 V. Short Calculations (30 points)

1. For the pasteurization of guava juice, a regenerative heating/cooling section is used. After the "starter" raw juice has been heated to 80°C, it is passed through a holding loop and into a regeneration section. The juice then heats up the incoming raw juice from 25°C to 63°C. While the "starter" juice temperature decreases to 30°C. Compute the % regeneration of the system. **(5 points)**

2. For Problem 2, what is the flow rate of the chilled water required to reduce the temperature of pasteurized juice from 30°C to 5°C? The specific heat of guava juice is 3.25 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 350 kg/hr. Chilled water enters the heat exchanger counter-currently at 2°C and leaves at 10°C. **(5 points)**

3. What does LMTD stand for (abbreviation for)? For a countercurrent flow regime in Problem 2, 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 5 cm and the overall heat transfer coefficient is 1,300 W/m^2 K? **(10 points)**

4. The results of a thermal resistance experiment gave a D value of 6.5 minutes at 103°C. If there were 8.5×10^9 survivors after 15 minutes of processing, determine the microbial population, N, at 10, 20, and 30 minutes. **(5 points)**

5. If the decimal reduction time at 105°C, D_{105}, is 8.5 minutes, how long does it take to reduce the number of microorganisms from 50,000,000,000 to 1 at 121.5°C if the thermal resistance constant equals 5.5°C? **(5 points)**

6. If the thermal death time is F^7_{105}, what is the spoilage probability of a 15-seconds process at 126°C, when $D_{105} = 12$ minutes and the initial population is 10^{13} microbes per container. **(5 points)**

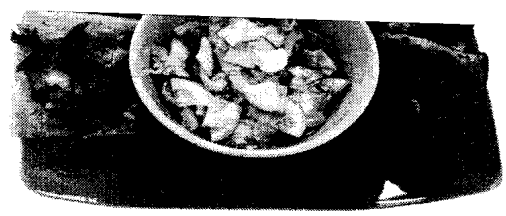
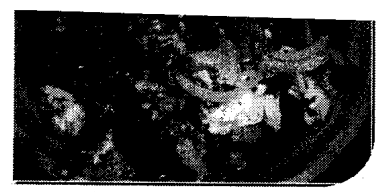
Part VI: Food Processes (45 points)

1. From the industrial processes that you and your friends presented, write down the product(s) uses each the following processes. **(10 points)**

   A = French Fries, B = Mama Instant Noodle, C = Ice Cream, D = Sugar, E = Beer

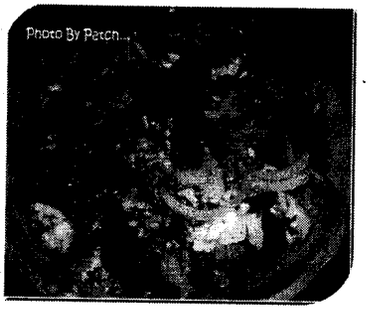
   1.1 Purification:
   1.2 Blanching:
   1.3 Cooling:
   1.4 Evaporation:
   1.5 Forming:
   1.6 Fermentation:
   1.7 Peeling:
   1.8 Air Incorporation:
   1.9 Aging:
   1.10 Mashing:
   1.11 Slicing:
   1.12 Frying:
   1.13 Pasteurization:
   1.14 Homogenization:
   1.15 Crystallization:
   1.16 Seasoning:
   1.17 Boiling:
   1.18 Blending:
   1.19 Freezing:
   1.20 Diffusion:

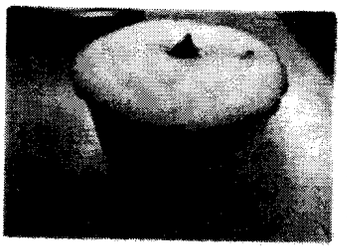
2. For the industrial process that you and your teammates presented, write a flow diagram of the production process from raw materials through packaging and transportation. **(5 points)**

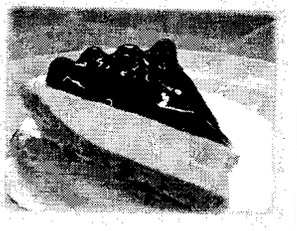




3. Name the following product and commercial processes that your friends presented based on the information given. You must be EXACT to obtain full credit. **(15 points)**

3.1 Iceberg Lettuce, Pea Sprouts, Egg: _____.
3.2 Lemon, Butter, Sweetened Condense Milk, Gelatin: _____.
3.3 Breading, Eggs, Salt, Wheat Flour: _____.
3.4 Butter, Salt, Sugar, Eggs, Flour, Milk: _____.
3.5 Mushroom, Sugar, Fish Sauce, Eggs, Cilantro, Oil: _____.
3.6 Mixer, Refrigerator, Microwave, Crusher: _____.
3.7 Mixer, Mold, Oven: _____.
3.8 Mixer, Cutter, Batter, Frying, Refrigerator: _____.
3.9 Cutter, Mixer, Meat Grinder, Fryer: _____.
3.10 Fryer, Cutter, Refrigerator, Washer, Lime Squeezer: _____.
3.11 "You can eat anywhere, anytime": _____.
3.12 "Sweet Meal, Sweet Life": _____.
3.13 "Delicious, (Single) one piece is never enough": _____.
3.14 "Good Health, Good Life": _____.
3.15 "Good Food, Good Break": _____.







4. 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**. **(15 points)**

Useful Equations:

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

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

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

$$\alpha = \frac{2(2n+1)(5n+3)}{3(3n+1)^2}$$

$$\left(\frac{(\bar{u}_2)^2 - (\bar{u}_1)^2}{\alpha}\right) + g(z_2 - z_1) + \frac{P_2 - P_1}{\rho} + \Sigma F + W = 0$$

$$\Sigma F = \frac{2f(\bar{u})^2 L}{D} + \frac{\sum k_f (\bar{u})^2}{2}$$

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

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

$$\frac{N}{N_0} = \left(10^{-\frac{t}{D}}\right)$$

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

$$f = \frac{16}{N_{\mathrm{Re},pl}}$$

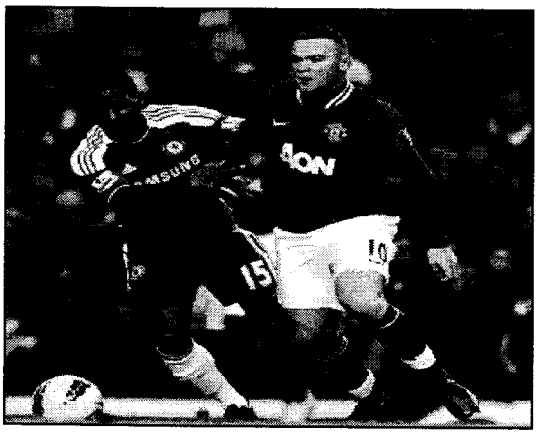
$$k_f = A/N$$

$$A = (k_f)_{turbulent}(500)$$

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

Bonus:

What song did N'Bright dance to at his Saengthong New Year's Party?
(a) Looks Like Love or (b) Loving You So Much



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