Lab 5: Molten chocolate cake & ice cream

Lab sections on Tuesday Oct 9 – Friday Oct 12

In this lab you will utilize heating and cooling to make a delicious desert – molten chocolate cake with liquid nitrogen ice cream. For the molten chocolate cake, you will study how heat transfers into cake batter as the cake cooks, resulting in a "crust front" that moves toward the center of the cake as the batter gradually reaches the temperature at which it solidifies. By taking measurements along the way, you will be able to calculate the heat diffusion constant of cake batter. Ice cream made with liquid nitrogen is made by the opposite process. The ice cream ingredients are almost instantly cooled down when brought in contact with the liquid nitrogen at -196˚C. Since larger ice crystals do not have time to form, the result is an ice cream that is very smooth in texture.

Equations of the week:

$$T(t) = (T_{initial} - T_{external})e^{(-t/\tau)} + T_{external}$$

$$where \quad \tau = \frac{R^2}{4D}$$

$$L = \sqrt{4Dt}$$

	Description	Units
T(t)	Temperature at cooking time t	˚C
$T_{initial}$	Initial temperature of food	˚C
$T_{external}$	Temperature of surroundings	˚C
t	Cooking time	sec
τ	Time constant	sec
R	Shortest distance to center	m
D	Diffusion constant of heat	m^2/sec

	Description	Units
L	Distance of diffusion	m
D	Diffusion coefficient	m^2/sec
t	Time to diffuse	sec

Part I: Molten chocolate cake

Materials:

- 1 pot
- 1 induction burner
- 8 ramekins
- 1 medium bowl (wet ingredients)
- 1 small bowl (dry ingredients)
- 1 scale
- 2 cutting boards
- 1 ruler
- 1 spoon
- 1 knife
- 1 whisk
- 1 spatula
- 1 oven mitt
- 1 convection oven/table

Ingredients:

For 8 ramekins

- 120 g dark chocolate chips
- 113 g butter (1 stick)
- 120 g sugar
- 5 eggs
- 60 g flour
- 0.5 g (pinch) salt
- Non-stick baking spray

Procedure:

1. Preheat the oven to 350°F (=177 °C) with the middle dial turned to "convection".
2. Melt chocolate and butter on low heat while stirring.
3. Combine eggs and sugar in a medium sized bowl and beat until well mixed.
4. Combine flour and salt in another bowl and mix.
5. With one person whisking and another person pouring, slowly add the chocolate mixture to the egg mixture.
6. Little by little, add the flour and salt to the wet ingredients and whisk well. Make sure all of the flour is completely mixed with the batter.
7. One of the groups at your table will continue to the next step, the other group will gather for a demo of liquid nitrogen ice cream, and then come back to the next step when the oven is free.
8. Spray 8 ramekins with non-stick baking spray and place them on a cutting board.
9. Fill the ramekins with cake batter so that they are a little more than half full (~1.5-2 cm from the top edge).
10. Place the ramekins in the oven (middle rack).
11. Take out 1 cake after 10 minutes, 2 after 12 minutes, 2 after 13 minutes, 2 after 14 minutes, and 1 after 15 minutes and place them on a white tray.
12. Remove the cakes from the ramekins right after you take them out of the oven.
13. Slice the cakes in half and measure the distance of diffusion, i.e. the radius of

the cake minus the radius of "uncooked" cake. Record your measurements on the worksheet.

One of the student teams (with help from your TF) will prepare one ramekin with a heat probe sensor. The heat probe has four thermometers, each arranged to measure temperatures ~1cm apart in the cake. To set this up, follow these steps:

1. Attach the heat probe to one of the ramekins. Place the sensors in a line from the center of the cake to the edge of the cake (i.e. along the radius).
2. Place this ramekin in the oven (middle rack).
3. While baking, record the four temperatures as well as the oven temperature on the white board.

Part II: Liquid nitrogen ice cream – demonstration by TF

Materials:

- 1 kitchen aid
- 1 ladle

Ingredients:

- 460 ml heavy cream
- 600 ml milk
- 250 g sugar
- 0.5 g (pinch) salt
- syrup or flavor of your choice
- Liquid nitrogen

Procedure:

1. Premix all ice cream ingredients.
2. Pour the ice cream mix into a kitchen aid and start on the lowest speed.
3. Carefully and slowly pour in the liquid nitrogen. Occasionally scrape down the sides.
4. Enjoy with your molten chocolate cake!

Lab 5: Worksheet

Name: _________________ TF:__________________

Part I: Molten chocolate cake

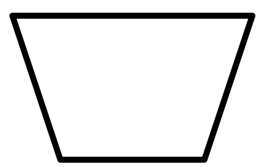
1. Enter the temperature measurements from the white board here:

Time (min)	oven temperature (˚C)	$cake_{edge}$ temperature (˚C)	$cake_{edge-1}$ temperature (˚C)	$cake_{center+1}$ temperature (˚C)	$cake_{center}$ temperature (˚C)
0					
2					
4					
5					
6					
7					
8					
10					
12					

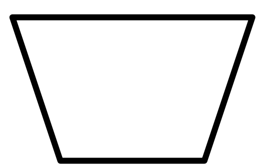
2. Enter your measurements for crust thickness here, and calculate L and L^2. You will need your measurements for the problem set so make sure to save your data.

Time (min)	Time (sec)	Radius of the cake (cm)	Radius of "uncooked" cake (cm)	L Distance of diffusion (cm)	L^2 (Distance of diffusion)^2 (cm^2)
10					
12					
12					
13					
13					
14					
14					
15					

3. Draw a sketch of a **cross-section** of the temperature distribution inside the chocolate cake before you started baking it.



4. Draw a sketch of the temperature distribution inside the chocolate cake right as you take it out of the oven after 12 min.



5. Looking at the data for L and temperature above, try to estimate what the transition temperature of cake batter is. Hint: read a value for L from the table in question 2, note the time, and estimate what the temperature at that distance from the edge is by looking at the temperature measurements on the table in question 1. By looking at several values and taking an average you will get a good estimate.

6. Pick one of your crust thicknesses above and use the equation of the week to calculate the heat diffusion constant of cake batter.

7. Given that cake batter is mostly water, one would expect it to have a heat diffusion constant similar to water, i.e. $1.4 \cdot 10^{-3}$ cm^2/sec. How do your calculations compare to this number? What experimental factors may have contributed to your heat diffusion constant being different?