



## Grill Master

### Activity 7

#### NCTM Standards

- ♦ Communication Standard – Organize and consolidate their mathematical thinking through communication.
- ♦ Connections Standard - Recognize and apply mathematics in contexts outside of mathematics.

#### Materials

- ♦ TI-89

#### Topics in Calculus:

Differential Equations, Newton's Law of Cooling (Reversed)

#### Overview:

This enrichment activity is perfect for an end of the year activity in an honors Calculus course. The activity uses differential equations to predict the cooking times of various meats. Only a minimal understanding of differential equations needs to be understood to complete the activity. The TI-89 will assist the students with the differential equations.

#### Teacher Directions:

#### OPTIONAL STRATEGIES

- Plan an end of the year picnic for your students. Use the activity as a precursor to the picnic. Bring a grill and cook several of the items on the worksheet. Use a CBL2 to measure the grill's temperature and the temperature of the food as it is cooked.
- Purchase Troli® Mini Gummi Burgers for everyone in the class. They can be found at almost any candy distributor or candy store. Each piece costs about \$.10, however they can be in bulk. This fun candy will help theme the activity to grilling.

This activity will be very challenging for the students and should be used toward the end of the course as an enrichment activity. The TI-89 will do all of the difficult calculations, however a general understanding of differential equations will greatly benefit the students.

The example on the worksheet can be used as an introduction.



## Answer Key

1.

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$\blacksquare \text{ deSolve}(y' = k \cdot (y - 250)) \text{ ar} \blacktriangleright$ $y = 250 - 200 \cdot e^{k \cdot t}$ $\blacksquare \text{ solve}(y = 250 - 200 \cdot e^{k \cdot t}, k)$ $k = \frac{\ln(5/8)}{15}$					
MAIN RAD AUTO FUNC 2/30					

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$k = \frac{\ln(5/8)}{15}$ $\blacksquare \frac{\ln(5/8)}{15} \rightarrow k$ $\blacksquare \text{ solve}(160 = 250 - 200 \cdot e^{k \cdot t})$ $t = 25.4841$					
MAIN RAD AUTO FUNC 4/30					

The hot dogs will be done in 25 minutes, at 5:25 P.M.

2.

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$\blacksquare \text{ deSolve}(y' = k \cdot (y - 300)) \text{ ar} \blacktriangleright$ $y = 300 - 250 \cdot e^{k \cdot t}$ $\blacksquare \text{ solve}(y = 300 - 250 \cdot e^{k \cdot t}, k)$ $k = \frac{\ln(7/10)}{25}$					
MAIN RAD AUTO FUNC 2/30					

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$k = \frac{\ln(7/10)}{25}$ $\blacksquare \frac{\ln(7/10)}{25} \rightarrow k$ $\blacksquare \text{ solve}(160 = 300 - 250 \cdot e^{k \cdot t})$ $t = 40.6405$					
MAIN RAD AUTO FUNC 4/30					

The hamburgers will be done in 49 minutes, at 5:49 P.M.

3.

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$\blacksquare \text{ deSolve}(y' = k \cdot (y - 325)) \text{ ar} \blacktriangleright$ $y = 325 - 275 \cdot e^{k \cdot t}$ $\blacksquare \text{ solve}(y = 325 - 275 \cdot e^{k \cdot t}, k)$ $k = \frac{-\ln(11/8)}{30}$					
MAIN RAD AUTO FUNC 2/30					

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$k = \frac{-\ln(11/8)}{30}$ $\blacksquare \frac{-\ln(11/8)}{30} \rightarrow k$ $\blacksquare \text{ solve}(160 = 325 - 275 \cdot e^{k \cdot t})$ $t = 48.1224$					
MAIN RAD AUTO FUNC 4/30					

The shish kabob will be done in 48 minutes, at 5:48 P.M.

4.

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$\blacksquare \text{ deSolve}(y' = k \cdot (y - 350)) \text{ ar} \blacktriangleright$ $y = 350 - 300 \cdot e^{k \cdot t}$ $\blacksquare \text{ solve}(y = 350 - 300 \cdot e^{k \cdot t}, k)$ $k = \frac{\ln(3/4)}{45}$					
MAIN RAD AUTO FUNC 2/30					

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$k = \frac{\ln(3/4)}{45}$ $\blacksquare \frac{\ln(3/4)}{45} \rightarrow k$ $\blacksquare \text{ solve}(160 = 350 - 300 \cdot e^{k \cdot t})$ $t = 71.4474$					
MAIN RAD AUTO FUNC 4/30					

The barbeque ribs will be done in 71 minutes, at 6:11 P.M.

5.

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$\blacksquare \text{ deSolve}(y' = k \cdot (y - 450)) \text{ ar} \blacktriangleright$ $y = 450 - 400 \cdot e^{k \cdot t}$ $\blacksquare \text{ solve}(y = 450 - 400 \cdot e^{k \cdot t}, k)$ $k = \frac{\ln(13/16)}{30}$					
MAIN RAD AUTO FUNC 2/30					

F1	F2	F3	F4	F5	F6
Tools	Algebra	Calc	Other	Pr3mID	Clean Up
$k = \frac{\ln(13/16)}{30}$ $\blacksquare \frac{\ln(13/16)}{30} \rightarrow k$ $\blacksquare \text{ solve}(160 = 450 - 400 \cdot e^{k \cdot t})$ $t = 46.4628$					
MAIN RAD AUTO FUNC 4/30					

The T-bone steak will be done in 46 minutes, at 5:46 P.M.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

# GRILL MASTER

Five various meats, each initially at 50° F, is put on one of five grills set at the temperature listed, at 5:00 P.M. After the amount of time listed it is found that the temperature  $T(t)$  of the roast is 125° F. The differential equation,  $y' = k(y - t_s)$ , represents the situation, where  $k$  is the constant,  $t$  is time and  $y$  is the unknown function. Using the TI-89 calculator, analytically find when the meat will be 160° F (minimum required temperature). Copy the equations from the calculator and write your answer in the space below. Can you find all the times and become a Grill Master?

**Example:** A five-pound steak, initially at 50° F, is put on a grill set at a temperature at 375° F, at 5:00 P.M. After 75 minutes it is found that the temperature  $T(t)$  of the roast is 125° F. When will the steak be 150° F (medium rare)?

**STEP ONE:** Press **[F3]**, then **⊖** to select **deSolve(**, then press **[ENTER]**.

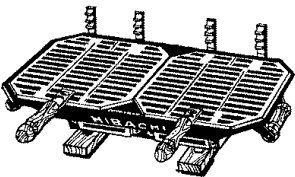
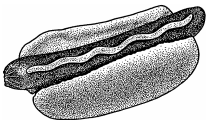
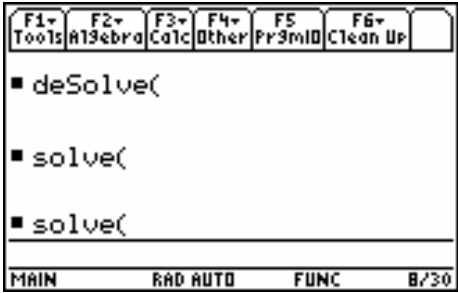
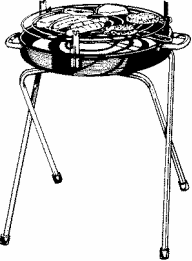

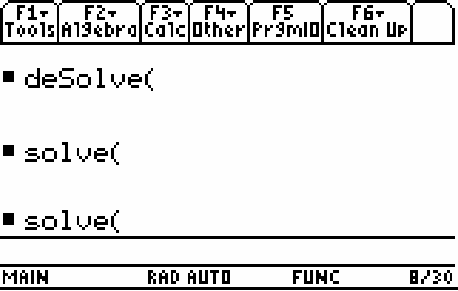
**STEP TWO:** Enter the equation and initial condition and press **[ENTER]**. **deSolve(y' = k · (y-375) and y(0) = 50, t, y)**



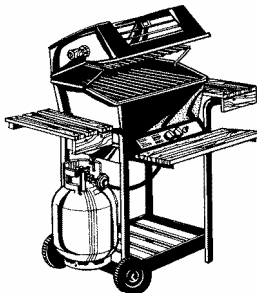
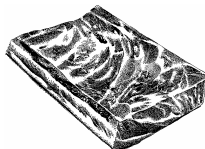
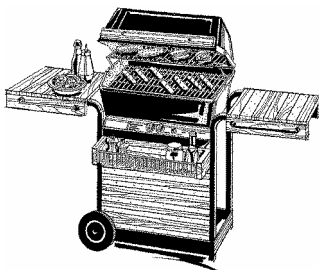

**STEP THREE:** Press **[F2]**, then **[ENTER]** to select **solve(**.

**STEP FOUR:** Press **⊖** (to select the previous answer) and press **[ENTER]**. Then press **[,]** **[alpha]** **[EE]** **[1]** to finish the command. Then, press **[1]** and enter the initial conditions. Press **[ENTER]** to find  $k$ . **Solve(y = 375 - 325 · e<sup>k·t</sup>, k) | t = 75 and y = 125**

**STEP FIVE:** Press **[F2]**, then **[ENTER]** to select **solve(**.

**STEP SIX:** Enter the equation with all of the variables you solved for and press **[ENTER]**. **150 = 375 - 325 e<sup>(k·t)</sup>, t)**

<p>1</p> 	 <p><b>Hibachi Grill</b> Temperature: 250°</p> <p>Meat Reached 125° in 15 minutes</p>	 <p>Time <b>hot dog</b> is done: _____</p>
<p>2</p> 	 <p><b>Round Grill</b> Temperature: 300°</p> <p>Meat Reached 125° in 25 minutes</p>	 <p>Time <b>hamburger</b> is done: _____</p>

3		 <div>Charcoal Grill Temperature: 325°</div> Meat Reached 125° in 30 minutes	<table><tr><td>F1+ Tools</td><td>F2+ Algebra</td><td>F3+ Calc</td><td>F4+ Other</td><td>F5 Pr3miD</td><td>F6+ Clean Up</td><td></td></tr></table> <div>■ deSolve(  ■ solve(  ■ solve(  <table><tr><td>MAIN</td><td>RAD AUTO</td><td>FUNC</td><td>B/30</td></tr></table></div> <div>Time <b>shish kabob</b> is done: _____</div>	F1+ Tools	F2+ Algebra	F3+ Calc	F4+ Other	F5 Pr3miD	F6+ Clean Up		MAIN	RAD AUTO	FUNC	B/30
F1+ Tools	F2+ Algebra	F3+ Calc	F4+ Other	F5 Pr3miD	F6+ Clean Up									
MAIN	RAD AUTO	FUNC	B/30											
4		 <div>Propane Grill Temperature: 350°</div> Meat Reached 125° in 45 minutes	<table><tr><td>F1+ Tools</td><td>F2+ Algebra</td><td>F3+ Calc</td><td>F4+ Other</td><td>F5 Pr3miD</td><td>F6+ Clean Up</td><td></td></tr></table> <div>■ deSolve(  ■ solve(  ■ solve(  <table><tr><td>MAIN</td><td>RAD AUTO</td><td>FUNC</td><td>B/30</td></tr></table></div> <div>Time <b>bbq ribs</b> are done: _____</div>	F1+ Tools	F2+ Algebra	F3+ Calc	F4+ Other	F5 Pr3miD	F6+ Clean Up		MAIN	RAD AUTO	FUNC	B/30
F1+ Tools	F2+ Algebra	F3+ Calc	F4+ Other	F5 Pr3miD	F6+ Clean Up									
MAIN	RAD AUTO	FUNC	B/30											
5		 <div>Deluxe Grill Temperature: 450°</div> Meat Reached 125° in 30 minutes	<table><tr><td>F1+ Tools</td><td>F2+ Algebra</td><td>F3+ Calc</td><td>F4+ Other</td><td>F5 Pr3miD</td><td>F6+ Clean Up</td><td></td></tr></table> <div>■ deSolve(  ■ solve(  ■ solve(  <table><tr><td>MAIN</td><td>RAD AUTO</td><td>FUNC</td><td>B/30</td></tr></table></div> <div>Time <b>T-bone steak</b> is done: _____</div>	F1+ Tools	F2+ Algebra	F3+ Calc	F4+ Other	F5 Pr3miD	F6+ Clean Up		MAIN	RAD AUTO	FUNC	B/30
F1+ Tools	F2+ Algebra	F3+ Calc	F4+ Other	F5 Pr3miD	F6+ Clean Up									
MAIN	RAD AUTO	FUNC	B/30											