



# Fuel Strategy (Exponential Decay)

STEM Lesson for TI-Nspire™ Technology

**Objective:** Collect data and analyze the data using graphs and regressions to understand conservation of energy and exponential decay. Then use the analysis to decide fuel strategies.

**About the Lesson:** NASCAR cars run on gas and a team's fuel strategy on race day can be a huge factor on winning versus losing. Some teams literally coast across the finish line on fumes while others do not get their calculations quite right and end up running out on the last lap (to their defense, there are a lot of variables to consider). With gasoline powered cars, they run if there is gas in the tank and do not run if there is no gas in the tank. Performance is not hurt because the fuel is running low. In fact, it can be helped because the car is lighter. The T80SRC car, on the other hand, is an electric car; so as the fuel drains, its performance worsens. T80SRC teams also have to devise a fuel strategy. For example, when should you do a pit stop to replace the battery or should you simply add two batteries to the car? This lesson will explore the drain on the battery of a car through various means.

**Materials:** RC car (optional – sample data provided)  
A 50- to 75-ft long drag strip  
2 or 3 fully charged batteries  
*Fuel\_Strategy.tns* TI-Nspire file  
Student worksheets

**Prerequisite skills:** Students should have a basic understanding of graphing and regressions. Students should also be familiar with forces and energy for this lesson. Finally, students should be proficient at taking a percentage.

## Procedure:

1. Divide the class into groups of 3-5 students.
2. Set up a drag strip that is 50 to 75 feet long for each group.
3. Have each group select a driver, timers, and a recorder.
4. With a fully charged battery. Set the car at the start line and decide what the "GO" signal will be.
5. Make sure all time keepers are ready and have another student give the "GO" signal. Make sure all time keepers can see the start and finish line clearly.
6. Drive from the start line to the finish line. Once you cross the finish line, let go of the throttle so the car slows without wasting energy. Pick the car up and bring back to the start line. Time keepers measure the time it takes to drive the drag strip while the driver drives.

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7. Record the trial number and measured drive times.
8. Repeat steps 6 and 7 until the battery is dead.
9. Average the drive times for each lap and record.
10. Repeat the test using new batteries once or twice.

**Teacher Tip & Sample Data:** *Make sure each person in the group has a job. One student can do both a stopwatch and record times for small classes. If you don't have the time or resources to collect the data, use the table below. Also students can take turns driving during one fuel run if you choose, but the data may be skewed at the driver change points.*

Lap (75 feet)	Lap time, t sec	Avg. Lap Speed ft / sec
1	2.96	25.34
2	2.92	25.51
3	3.01	25.31
4	2.93	25.38
5	2.92	25.44
6	2.97	25.41
7	2.99	25.36
8	2.94	25.38
9	2.98	25.36
10	3.01	25.31
11	3.06	25.24
12	3	25.22
13	3.15	25.10
14	3.09	25.04
15	3.18	24.94
16	3.25	24.81
17	3.19	24.73
18	3.29	24.62
19	3.46	24.44
20	3.83	24.14
21	3.76	23.90
22	3.62	23.74
23	3.82	23.52
24	3.91	23.30
25	4.06	23.06
26	4.25	22.79
27	4.36	22.52
28	4.69	22.20
29	4.78	21.89
30	4.96	21.56

**Analysis:**

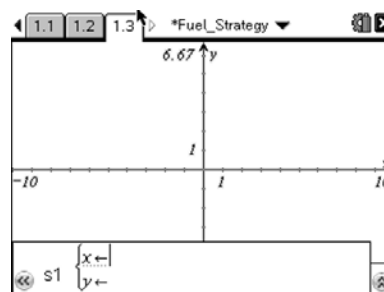
1. On your handheld, go to My Documents and open the file named *Fuel\_Strategy.tns*.
2. Use **ctrl** to move to page **1.2**.

We will first analyze data of what happens to lap time as you accelerate continuously. This means that you are accelerating throughout most of the lap. The faster you accelerate (change your gear ratio), the slower your top speed.

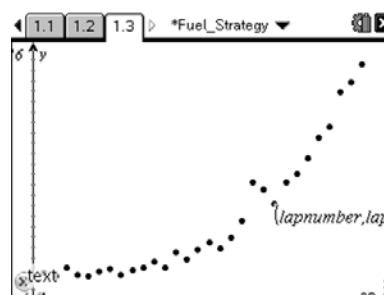
3. At the top of each column, type the titles, **lapnumber**, **laptime**, and **lapspeed**. Enter your data into the spreadsheet under the appropriate columns. Make sure to start in row 1 and not the diamond row.

	lapnu...	laptime	lapspeed
1	1	2.96	25.34
2	2	2.92	25.51
3	3	3.01	25.31
4	4	2.93	25.38
5	5	2.92	25.44

4. Move to page **1.3**. Press **menu** then choose **Graph Type > Scatter Plot**. Notice the function bar at the bottom of the screen changes from f1 to s1.



5. Press **var** and choose *lapnumber*. Press **▼** then **var** and choose *laptime*. Press **enter**. Now adjust your window to view the data by pressing **menu** then choosing **Window/Zoom > Zoom – Data**.



6. This graph shows how time changes as the lap changes. As the laps increase, what happens to the time for each lap?

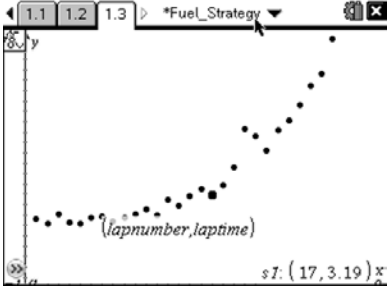
**Answer: It stays the same at first then it slowly increases.**

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7. Why do you think this is happening?

**Answer: Answers will vary.**

8. Estimate the lap number where the time begins to make an impact by tracing the graph. Press **(menu) > Trace > Graph Trace**. Press **▶** and **◀** to move along the graph.



9. Where does the time seem to start increasing rapidly?

**Answer: Lap 19 or 20**

10. Move back to page **1.2**. We need to find the average lap speed per lap. Title column D **averagespeed**. Move down to the cell in row 1 of column D. Cells are named with the column letter and the row number in that order. This cell is called **D1**.

11. We can type a formula to have the calculator average the data for us. For 30 laps, in cell **D1** type **=sum(c1:c30)/30**. Change the 30 for your number of laps. Press **(enter)**.

lapnu...	laptime	lapspeed	averag...
1	2.96	25.34	24.352
2	2.92	25.51	
3	3.01	25.31	
4	2.93	25.38	
D1 = sum(c1:c30)/30			

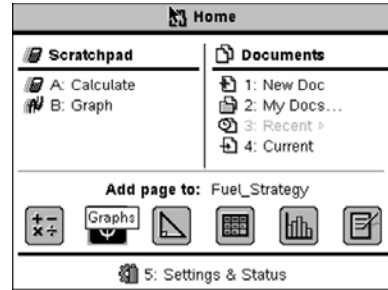
**Teacher Tip:** Make sure the students understand the formula and enters it correctly.

**Navigator Tip:** You can make one of the students the presenter have them model how to enter the formula while you explain the process.

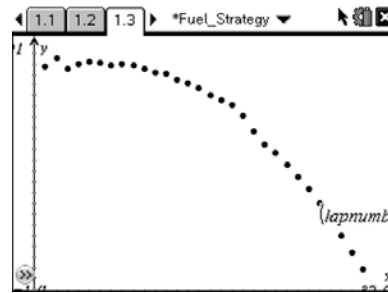
12. Now type the average into the rest of the rows. You can also type it into **D2** and copy and paste it down. Make sure to fill the same number of rows as laps.

laptime	lapspeed	averag...
28	4.69	22.2
29	4.78	21.89
30	4.96	21.56
D1 = sum(c1:c30)/30		

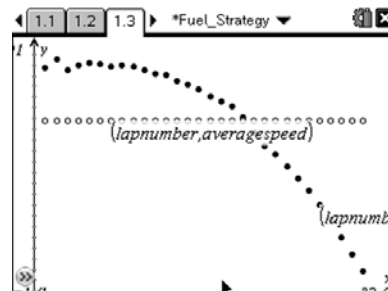
13. Now we need to create a new graph page to graph *lapspeed* vs. *lapnumber* and *averagespeed* vs. *lapnumber*. Press **(on)** and click on the **Graphs** icon.



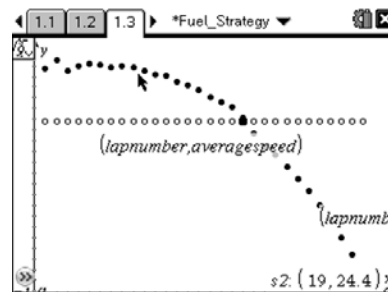
14. Change the graph type to scatter plot again and Press **(var)** and choose *lapnumber*. Press **▼** then **(var)** and choose *lapspeed*. Press **(enter)**. Now adjust your window to view the data by pressing **(menu)** then choosing **Window/Zoom > Zoom – Data**.



15. Press **(tab)** to bring the function bar back and graph *averagespeed* vs. *lapnumber*.



16. Press **(menu) > Trace > Graph Trace**. Press **▶** and **◀** to move along the graph. Press **▲** and **▼** to switch graphs.



17. At what lap number do the two intersect?

**Answer: 19**

18. Is this approximately the same lap number you suggested when you were looking only at time?

**Answer: Yes**

19. Look at the average lap speed and the point where the speed starts to drop off. Make a suggestion during what lap you would change a battery to get your peak performance.

**Answer: around lap 19 or 20**

20. If you were only looking at the engine and lap time, do you think a gas powered vehicle would provide the same data? Why or why not?

**Answer: No. Gas power doesn't fall off slowly. The car stops when it is out of gas and not before.**

21. As the battery uses its energy, what type of decay does it seem to follow?

**Answer: Exponential**

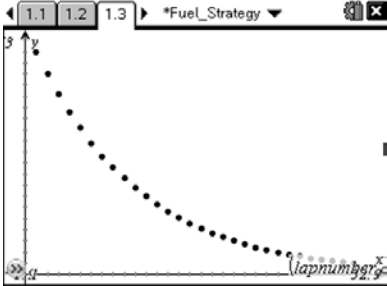
If we assume a battery loses 10% of its overall energy as it makes a lap, we can get an idea of what happens with the battery's life from a graph.

22. Move back to page 1.2. Move to column E and title it **charge**. Type 100 in cell E1 for 100% charge, and move down to E2. Type **=e1-(0.10\*e1)** to calculate a 10% decrease of the previous charge. Press (enter).

23. Now we need to copy this formula down the whole column. Press (ctrl) (enter) > **Fill Down**. Press (v) until the dashed rectangle surrounds all of the empty cells then press (enter).

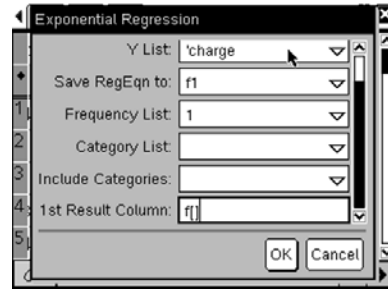
	lapspeed	averag...	charge
1.	25.34	24.352	100
2.	25.51	24.352	90.
3.	25.31	24.352	81.
4.	25.38	24.352	72.9
5.	25.44	24.352	65.61

24. Insert another **Graphs** page and graph a scatter plot of *charge* vs. *lapnumber*. Use the same procedure as in step 15 above.

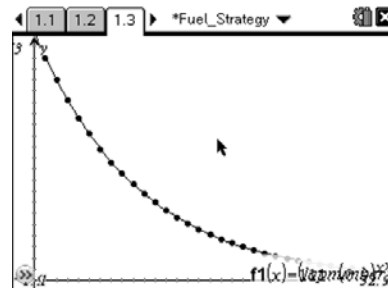


25. Now we need a regression line to make predictions. Move back to page 1.2 and cell F1.

26. Press (menu) then choose **Statistics > Stat Calculations > Exponential Regression**. The regression template will pop up. Click the arrow at the right of each box to access the drop down menus. Choose *lapnumber* for the X List and *charge* for the Y list. Tab through the other options until you get to 1<sup>st</sup> Result Column. Click beside the letter and change it to 'f' if it isn't already. Click OK.



27. Move to page 1.3. Press (menu) > **Graph Type > Function**. Press ▲ to f1 and press (enter). This graph will allow you to predict the percent of charge left in the battery after any number of laps.



28. If you had a gas car and you were driving at a constant speed vs. accelerating for an extended period of time, which would use more gas?

**Answer: Accelerating**

29. What does this answer imply about the accelerating vs. driving at a constant speed with a battery?

**Answer: When you accelerate, you use up the energy of the battery more than when you move at a constant throttle.**

To accelerate a 4 lbs RC car to 35 ft/sec (top speed) in approximately 50 ft (~ 0.6 g acceleration) consumes as much energy as driving the car for 200 ft at a constant speed of 35 ft/sec. Similar ratios are also true for full size cars--accelerating quickly away from a traffic light consumes far more gasoline than driving smoothly at highway speeds.

The data shown in this lab shows an example of conservation of energy. The electrical energy of the battery is turned into kinetic energy for the car. However, the kinetic energy of the car will not equal the total energy lost in the battery.

30. If total energy is always conserved, where do you think the rest of the energy goes?

**Answer: Electrical resistance in the wires, friction from various things like tires, gears, and belts, air resistance**