Tire Pressure

STEM Lesson for TI-Nspire™ Technology

Objective: Use Boyle's law and graphs to analyze data and use the results to determine the best tire pressure to use in a NASCAR race.

About the Lesson: This lesson will focus on understanding the pressure in tires. Tire pressure is one of the major decision points for teams because the wearing down of tires has a huge impact on a car's handling and speed. The pressure in tires will vary as you drive in a race because the temperature of the tire will change. Since temperature is so varied, race cars will fill their tires with nitrogen. Nitrogen is the most abundant gas in air but does not expand as much as air, so teams can control tire pressure better this way. Nitrogen acts almost like an ideal gas. An ideal gas follows the ideal gas law, $PV = kT$, where P is pressure, V is volume, k - Stephan Boltzman's constant and T is temperature. The relationship that P/T = constant is called Gay-Lussac's Law. As tires round corners in races they will begin to wear down. This will have an impact on everything about how the car runs - handling, speed, etc. The question that needs to be asked at the beginning of a race is what pressure should the tires be initially inflated to give the best performance throughout the race. This will depend on several things including the maximum speed the car will need to reach, if there are many turns or not, what type of surface and tires are being used, among many others.

Materials: *Tire_Pressure.tns*
             Student Worksheets

Analysis:

1. On your handheld, go to My Documents and open the file named *Tire_Pressure.tns.*

Tire pressure data is collected by placing a car on a surface and filling the tires with a certain amount of pressure. The car is then pulled to the side until it begins to slide then the force is measured. This force is called the lateral load. The pressure is then increased in the tire and the process repeated. The data measured is provided below.

| Tire Press	
gauge, psi	Lat Load, lbsf
14	204
18	166.6667
22	140
26	116.6667
30	103.3333
34	96.66667

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2. Use / ¢ to move to page 1.2. Use the touchpad to move around the screen. Move to the top of column A and type **gauge**. Move to column B and type **Latload**. You cannot put spaces or numbers in the titles, so be sure to type only letters or an underscore. Enter the data into the appropriate columns you titled.

gauge	latload
14	204
18	166.667
22	140
26	116.667
30	103.333

3. Based on the ideal gas law, what do you think will happen to the pressure if the temperature increases?

4. What type of relationship exists between pressure and temperature direct or indirect?

5. For this data, what is the independent variable?

6. What is the dependent variable?

7. 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.

s1 x←gauge
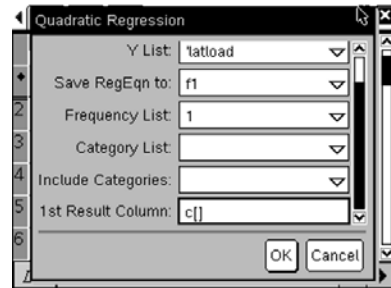   y←latload

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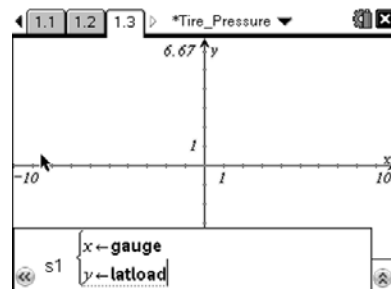
8. Press (var) and choose the *x* variable. Press ▼ then (var) and choose *y* variable. Press (enter). Now adjust your window to view the data by pressing (menu) then choosing **Window/Zoom > Zoom – Data**.
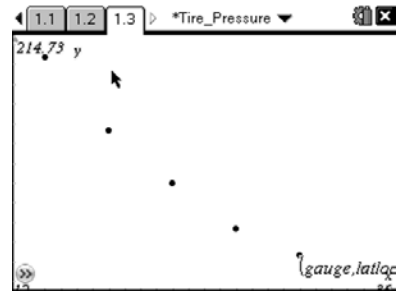
9. What type of relationship do you think the data shows: exponential, power, logarithmic, or quadratic?

10. Let's compare regressions to decide which relationship is the best fit. First, do a quadratic regression analysis on your data. Go back to page **1.2**. Press (menu) then choose **Statistics > Stat Calculations > Quadratic Regression**. The regression template will pop up. Remember to press (tab) to switch boxes. Click the arrow at the right of each box to access the drop down menus. Choose *gauge* for the X List and *latload* for the Y list. Tab through the other options until you get to 1st Result Column. Click beside the letter and change it to 'c' if it isn't already. Click OK.

    Notice one of the rows has an r^2 value. This value ranges from 0 to 1 and tells you how accurately your regression line matches the data with 1 being the best match possible.

11. What is your r^2 value?

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12. Now go back to (menu) **> Statistics > Stat Calculations** to do a logarithmic regression. F2 will be the equation and the result column should be f[]. Always use an empty column for the result column.

13. What is your *r*² value?

14. Repeat the process for an exponential regression and a power regression. It will automatically save to the next f(x) and empty column available. It will prompt you if you accidentally try to save over full columns or functions.

15. What is your *r*² value for each regression?

16. Which regression has an *r*² value closest to 1?

17. Now graph the regressions. Go to page **1.3**. Now graph the regression line. Press (menu) then choose **Graph Type > Function**. Press ▲ until you see f1 then press (enter). You should see your quadratic function on top of your data points.
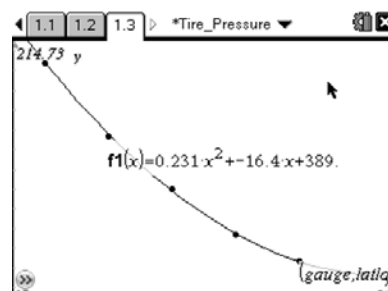
18. Press (tab) to see the function bar again and graph each regression using the same process. Each curve will be labeled with the equation. You can move the equation labels by hovering over the text and pressing (ctrl)(✦) and dragging it. If you lose track of which curve is which, hover over the line and the function number will pop up.
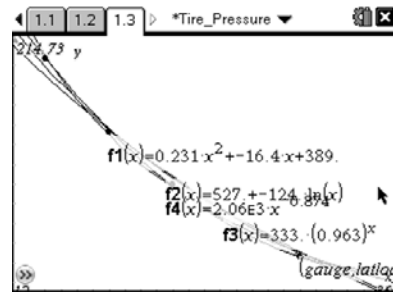
19. Based on the r^2 values and the graphs, what type of relationship exists between the tire pressure and the lateral load: exponential, power, logarithmic, or quadratic?

20. What happens to the Lateral Force that the tire can provide to turn the car on the desired curved path as the tire pressure increases?

21. Make a conjecture about the tire pressure on your own car or parent's car and the amount of gas it uses?

While low tire pressures allow for greater lateral loads in cornering, lower tire pressures also result in MORE rolling drag. The increased rolling drag of low pressure tires is due to the flexing of the tire in the region where the tire is in contact with the ground. Michelin in particular has done extensive develop work to produce a low rolling drag tire for ordinary street vehicles, but keeping them properly inflated is critical to reducing fuel consumption.

Racing tires have much stronger sidewall construction than tires for street vehicles, so very low pressures in conventional tires actually decreases steering control.