Pictometry in the Physics Classroom: A Lesson in Centripetal Force

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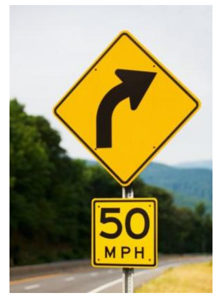
Objective: The student will be able to:

1. Derive an expression for the maximum possible speed to safely negotiate a circular turn by applying Newton's Second Law
2. Calculate the maximum safe speed for a particular roadway in the neighborhood (chosen by student or instructor beforehand)

Pre-lab Discussion Points:



1. "Have you ever noticed those yellow road signs indicating that the roadway ahead turns? Have you also noticed the smaller sign indicating a speed? What do you think that number indicates? Do you know how that number was chosen?
2. "What are the factors that influence how fast your car can safely drive around a curve?"

Method:

1. Review concept of inertia and centripetal force at is pertains to a car rounding a turn
2. Reinforce the idea that some (net) force must be acting radially inward for objects moving in circular motion
3. Present the following problem: A car of mass m traveling at speed v wishes to safely round a circular turn of radius r. Assume the coefficient of static friction between tires and road is μ_s. What is the maximum allowed speed of the car so it has no tendency to slide out of the turn?
4. Students will solve the problem using a free body diagram showing all forces acting on the car and applying Newton's Second Law of Motion for the vertical and radial directions.
5. Students should solve their system of equations simultaneously to derive an expression for v, the maximum safe speed of the car. Note: $v = \sqrt{r\mu_s g}$
6. Discuss the functional dependence of the maximum safe speed: v depends upon (the square root) of g, the acceleration due to gravity; μ_s, the coefficient of friction between tires and road; and most importantly for this lesson, r, the radius of the turn.
7. Students will apply what they have derived to a real-world situation: students will go online to the pictometry web site, explore local roadways and select a circular turn for investigation. See the picture at right for a sample of some candidate curved roadways

8. Since measuring the radius of a turn is often impractical to do in person (e.g. danger from traffic, leaving school grounds, etc.), pictometry is well suited for the task. Using the appropriate tool (circle tool), students will draw several circles whose circumferences best coincide with the turn. Students then must select the circle that best coincides with the roadway. Note: Using the Orthogonal map view works best.
9. Once the best circle is chosen, its radius will be calculated and displayed (at the bottom of the window.)
10. Students will use this measured radius, along with their derived expression to calculate the maximum safe speed for this turn.
11. If a turn is selected beforehand in which the speed is posted, students may now compare their calculated value to the one posted and discuss any discrepancies. Students will report their results to student and instructor and turn in all work.

Post-lab Discussion point:

1. If students assume a typical coefficient of static friction for rubber and concrete of about 0.8 under dry conditions, the calculated value may be much higher than the posted value. Why? Perhaps the posted maximum safe speed is based on non-ideal conditions and wet pavement? Repeat the calculation using a typical value for rubber and concrete under wet conditions such as 0.3 or some other reasonable value.

Assessment:

1. Monitor student progress and assist as needed. Check that students have a correct free body diagram and derivation of the velocity as a function of radius and known constants before moving on to the pictometry part of the assignment.
2. Verify that students have chosen a reasonably circular turn for investigation and that students are using the appropriate tools and units when determining the radius of their turn. Insure that students have chosen the circle that best approximates the turn and have measured the radius correctly.
3. Check all student work and calculations for correctness – discuss any discrepancies.

Materials:

1. Calculator
2. Computer with Internet access for pictometry, printer (optional)

State Standards Addressed:

4.4.11.E - Demonstrate mathematical solutions to problems (e.g., in the physical sciences).

2.6.11.B - Use appropriate technology to organize and analyze data taken from the local community

3.4.12.C.5 - Interpret a model that illustrates circular motion and acceleration.

3.7.12.A - Apply advanced tools, materials and techniques to answer complex questions.

7.1.12.A - Analyze data and issues from a spatial perspective using the appropriate geographic tools.