CE 3500: Homework 4
Due Wednesday, April 6

Problem 1. A vertical curve needs to be designed on a freeway, connecting a 4% downgrade to a 2% upgrade. The design speed is 65 mi/hr, reaction time is 2.5 seconds, and the coefficient of braking friction is 0.348. Design the curve, with the point of vertical curvature PVC occuring at station 137+03 and elevation 7330 feet (that is, at PVC, at each whole station, and at the point of vertical tangency, provide the curve elevation).

Problem 2. A horizontal curve has a radius of 1000 feet, and an intersection angle of 40 degrees. The point of curvature PC is at station 205+15. The curve is level, and there will be no superelevation.

1. For the point of tangency PT, and each whole station between PC and PT, provide the deflection angle and chord lengths.
2. If the coefficient of side friction is 0.16, is the radius large enough for vehicles to safely navigate the turn at the design speed?
3. At the apex of the curve, there is a large rock located 10 feet from the innermost travel lane. If reaction time is 2.5 seconds, and the coefficient of braking friction when braking is 0.348, does this rock present a safety hazard that needs to be removed?

Problem 3. Derive the braking-distance formula

$$D_b = \frac{u_0^2}{2g(f+G)}$$

using a free-body diagram, where u_0 is the initial velocity, g is acceleration due to gravity, f is the coefficient of braking friction, and G is the percent grade (uphill is positive). Assume that the vehicle's brakes are powerful enough that the limiting factor is friction between the tires and road. Remember that D_b is measured *horizontally*, not along the angle of the roadway (that is, D_b is the distance between the initial and stopping points as measured from an aerial photo), and that the grade $G = \tan\theta$, where θ is the angle between the horizontal and the roadway surface in the direction of travel.

Bonus Question. For the design of crest curves, we had the two formulas $L_{min} = \frac{|A|(SSD)^2}{2158}$ if $SSD \leq L_{min}$ and $L_{min} = 2SSD - \frac{2158}{|A|}$ if $SSD \geq L_{min}$ for minimum curve length. For the design of sag curves, we have $L_{min} = \frac{A(SSD)^2}{400+3.5SSD}$ if $SSD \leq L_{min}$ and $L_{min} = 2SSD - \frac{400+3.5SSD}{A}$ if $SSD \geq L_{min}$. We proposed a trial-and-error approach: pick an equation, see if the condition is satisfied, and if not try the other. Prove that (i) this recipe is consistent and always works (i.e., no matter what SSD is, there is one and only one minimum curve length L_{min} corresponding to those equations, so we can write $L_{min} = f(SSD)$ for some function f); (ii), furthermore, that this relationship f is continuous; and (iii), that f is differentiable for $SSD > 0$.