True or False (questions worth 2 points each)

1. Driveline slippage generally ranges from 2% to 5%. **T**

2. For practical stopping distance, a deceleration rate of 11.2ft/s² is used as recommended by AASHTO. **T**

3. The mass factor used to determine acceleration, $\gamma_m$, is assumed to be 1.04. **F**

4. For design $K$ values, the length of the vertical curve is always assumed to be greater than the stopping distance. **T**

5. If the normal component of centripetal force were taken into account in highway design, curve radii would always be shorter than current design practices which ignore this component of centripetal force. **T**

6. On a 2-lane undivided highway with 12-ft lanes $R$ will be 6 ft longer than $R_v$. **T**

7. For passing sight distance, the assumed height of the oncoming vehicle is 3.5 ft. **T**

8. For determining overpass clearance, the height of a vehicle's tail light is a critical element and it is assumed to be 2 ft. **T**

9. The recommended minimum clearance height for an overpass is 16.5 ft. **F**

10. A curve with $G_1 = -3.7\%$ and $G_2 = +3.7\%$ will have its high point at exactly $L/2$ from the curve's PVC. **F**
25 points
1. A car is traveling up a 3% grade on a road that has good, wet pavement. The engine is running at 2500 revolutions per minute. The radius of the wheels is 15 inches, the driveline slippage is 3%, and the overall gear reduction ratio is 2.5 to 1. A deer jumps out onto the road and the driver applies the brakes 291 feet from a deer. The car's antilock braking system fails, the brakes immediately lock and the driver hits the deer at a speed of 20 mi/h. If aerodynamic resistance is ignored, what was the vehicle's braking efficiency?

30 points
2. A sag equal tangent vertical curve is designed for 45 mi/h. The low point is 237 ft from the PVC at station 112+37 and the final offset at the PVT is 19.355 ft. If the PVC is at station 110+00, what is the elevation difference between the PVT and a point on the curve at station 111+00?

25 points
3. A crest curve has been designed for 70 mi/hr to connect a 2% initial grade and a -1% final grade for a new vehicle that has 3 ft drivers eye height and the curve was designed to avoid an object that is 1 ft high. Standard practical stopping distance design was used but unlike current design standards, the vehicle was assumed to make a 0.5 g stop, although driver reactions are assumed to be the same as current highway design standards. If the PVC of the curve is at 848 ft and station at 43+48, what is the station and elevation of the highest point of the curve?
SOLUTIONS

\[ V_1 = \frac{2\pi \eta B (1-\eta)}{E_0} = \frac{2(3.14)\frac{15}{12} \left(\frac{2500}{60}\right)(0.97)}{2.5} = 126.92 \, \text{ft/s} \]

Eq. 2.5

\[ f_{r2} = 0.01 \left[ 1 + \frac{126.92 + (20)(1.97)}{147} \right] = 0.01532 \]

USE Eq. 2.43

\[ s = \frac{\frac{V_0}{2g} (V_1^2 - V_2^2)}{2g(\eta B + f_{r2} \pm \sin \theta_3)} \]

\[ \mu = 0.6 \quad \text{(TABLE 2.4: 0.6108)} \quad \text{so} \]

\[ 291 = \frac{1.04 \left(126.92^2 - 29.4^2\right)}{64.4(\eta_B(0.6) + 0.01532 + 0.03} \]

\[ \eta_B = 1.33 \quad \text{which is not possible} \]

But \( \eta_B \mu = 1.33(0.6) = 0.80 \)

\[ \mu = 0.9 \quad \text{if ABS 0.10 not fail} \]

\[ \eta_B(0.9) = 0.8 \quad \text{gives} \quad \eta_B = 0.89 \]

\[ \text{so distance is possible} \quad \text{if ABS did not fail} \]
2

\[ k = 79 \text{ ft} @ 45^\circ \text{/hr} \quad \text{table 3.3} \]

\[ Y_f = \frac{AL}{200} \quad \Rightarrow \quad 19.355 = \frac{AL}{200} \quad \text{with} \quad L = KA, \]

\[ \frac{A^2 K}{200} = 19.355 = \frac{A^2 (79)}{200} \quad \Rightarrow \quad A = 7 \]

\[ L = KA = 79 (7) = 553. \]

At low PT \( x_{h8} = KG_1 \Rightarrow 237 = 79 G_1 \Rightarrow G_1 = 3 \]

Given \(-3 \text{ since sag}\)

so \( G_2 = 4 \)

\[ y = ax^2 + bx + c, \text{ set } c = 0 \quad (\text{since interested in differences}) \]

\[ a = \frac{4 - (-3)}{2(5.53)} = 0.633 \quad \text{eq 3.6} \]

\[ b = -3 \quad (\text{sag curve}) \]

\[ y_{100} = 0.633 \cdot 1^2 - 3 \cdot 1 = -2.367' \]

\[ y_{553} = 0.633 (5.53)^2 - 3 (5.53) = 2.768 \]

so elevation diff. = 2.768 - (-2.367) = 5.135 ft
3. (EQ 2.47)

\[ d = \frac{V_i}{g} \left( \frac{a}{g} \pm C \right) = \frac{(70 \times 1.47)^2}{64.4 \times (0.5)} = 328.83 \]

\[ d_n = 2.5 \times (70 \times 1.47) = 257.25 \]

\[ s = 328.83 + 257.25 = 586.08 \text{ ft} \]

\[ L > S \quad \text{(ALWAYS)} \quad \text{EQ 3.13} \]

\[ L = \frac{AS^2}{200(VH_1 + VH_2)^2} = \frac{3(586.08)^2}{200(2.8 + 1.1)^2} = 690.29' \]

\[ y = ax^2 + bx + c \]

\[ a = \frac{G_2 - G_1}{2L} = \frac{-1 - 2}{2 \times (6.9)} = -0.2174 \]

\[ b = 2; \quad c = 848 \]

HIGH PT: \quad 2ax + b = 0

\[ 2(-0.2174)x + 2 = 0 \quad x = 4.60 \text{ STA} \]

STA H.P. = 43 + 48 + 4 + 60 = 48 + 08

ELEV H.P.

\[ y = ax^2 + bx + c \]

\[ = -0.2174(4.6)^2 + 2(4.6) + 848 \]

\[ = -4.6 + 9.2 + 848 \]

\[ = 852.6 \text{ ft} \]