CEE 320 Midterm Examination (50 minutes)

- Please write your name on this cover.
- Please write you last name on all other exam pages
- This examination is open-book, open-note.
- There are 5 questions worth a total of 100 points.
- Each question lists the point value for that question.
- Please work quietly and respect other people's space.
- Carefully read each question and ensure that you answer what is asked.
- If you need additional workspace, use the back of the page or the blank page included at the end of the examination.
- If you need to unstaple pages, I have a stapler to restaple them at the end of the examination.

SOLUTION

Name (first, last): ______________________________

Question 1: Short Answers (2 points each for a total of 10 points)

a) Is the following statement true or false?
Vehicle miles traveled in the US have increased at a faster rate than miles of roadway over the last 50 years.

TRUE

b) Is the following statement true or false?
Sag vertical curve design differs from crest vertical curve design in the sense that sight distance on a sag vertical curve is governed by nighttime conditions.

TRUE

c) Is the following statement true or false?
The highpoint of a vertical curve always occurs at L/2.

FALSE

d) Is the following statement true or false?
Passenger vehicles are often ignored in pavement design.

TRUE

e) Is the following statement true or false?
The primary source of rolling resistance for a typical vehicle driving on paved roadway is the deformation of the tire as it passes over the roadway surface.

TRUE

Question 2: Short Answers (5 points each for a total of 15 points)

A vehicle is able to achieve a maximum deceleration of 0.15 g's (1 "g" is the force of gravity at sea level). If the vehicle is traveling packed snow, what is the vehicle's braking efficiency? Show your calculations.

From table 2.4, µ = 0.25

$$\eta_b = \frac{g_{max}}{\mu} = \frac{0.15}{0.25} = 0.6$$

A two-lane road (12 ft wide lanes) has a 575 ft long horizontal curve with a central angle of 30° and a 10% superelevation. What is the curve's design speed to the nearest 5 mph?

$$L = \frac{\pi}{180} * R * \boldsymbol{\Delta}$$

$$R = \frac{180 * 575}{\pi * 30} = 1098.17\ ft$$

$$R_v = R - 6 = 1092.17\ ft$$

From table 3.5, $R_v(55) = 880\ ft, R_v(60) = 1905, \therefore\ choose\ design\ speed = 55\ mph$

A vehicle slows from 80 mph down to 20 mph on a flat grade. Using the standard AASHTO recommended deceleration rate, what is the braking distance over which this occurs?

$$d = \frac{V_1^2 - V_2^2}{2g * \left[\frac{a}{g} \pm G\right]} = \frac{V_1^2 - V_2^2}{2a} = \frac{(80 * 1.47)^2 - (20 * 1.47)^2}{2 * 11.2}$$

$$d = 578.81\ ft$$

Problem 3 (20 points)

A new pavement must be built for the I-5 off-ramp to the Metro bus facility just south of N 175 St. in Shoreline. Assume all buses at the facility are 60 ft Flyer hybrid diesel-electric buses. They are always empty (one driver only) when they drive across the off-ramp and enter the facility. Metro logs show an average of 400 buses per day use the off-ramp with no expected growth rate. The off-ramp pavement is to be doweled rigid (portland cement concrete – PCC) pavement using a hot mix asphalt (HMA) base and 85% reliability.

Report the following:

- The number of ESALs for a single bus
- Total number of ESALs over 50 years
- The design PCC slab thickness for a 50-year pavement life using the WSDOT table provided at the end of this exam.

Condition	Weight when bus is empty
Front axle	13,300 lb
Middle axle	18,200 lb
Rear axle	12,200 lb

$$\textbf{ESALS/bus} = \left[\frac{13300+150}{18000}\right]^4 + \left[\frac{18200}{18000}\right]^4 + \left[\frac{12200}{18000}\right]^4 = 1.57$$

$$\textit{Total ESALS} = 1.57 * 400 * 365 * 50 = 11,446,166$$

From WSDOT table (back of exam) slab thickness = 0.79 ft

Problem 4 (20 points)

A 2-lane (10 ft wide lanes) combined horizontal and crest vertical curve is currently posted for a 35 mph speed limit and reportedly designed for 40 mph. Both curves begin at point A and end at point B.

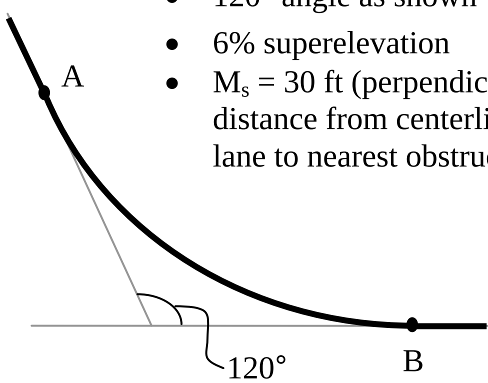
Given the data below, is this section of roadway adequately designed for 40 mph? Show appropriate calculations to support your conclusion.

Horizontal Curve Data

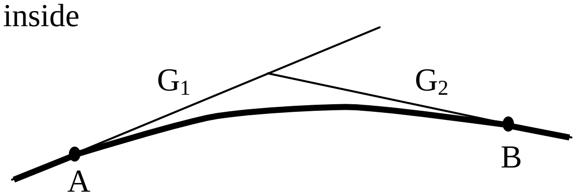
- Curve length = 580 ft
- 120° angle as shown
- 6% superelevation
- M_s = 30 ft (perpendicular distance from centerline of inside lane to nearest obstruction)

Vertical Curve Data

- Curve length = 580 ft
- G_1 = 3%
- G_2 = -2.5%



Plan View



Profile View

Horizontal:

$$R = \frac{180 * L}{\pi * \Delta} = \frac{180 * 580}{\pi * 60} = 553.88\ ft$$

$$R_v = 553.88 - 5 = 548.88\ ft$$

In table 3.5, e = 6%, @ 40mph, $R_v = 510\ ft; 548.88\ ft > 510\ ft\ \therefore OK$

$$SSD = \frac{\pi * R_v}{90} * \left[\cos^{-1}\left(\frac{R_v - M_S}{R_v}\right)\right]$$

$$SSD = \frac{\pi * 549}{90} * \left[\cos^{-1}\left(\frac{549 - 30}{549}\right)\right] = 364.15\ ft$$

From table 3.1, SSD required =305 ∴ OK

Vertical:

$$K = \frac{L}{A} = \frac{580}{3 + 2.5} = 105.45$$

From table 3.2, K = 44 ∴ OK

Question 5 (20 points)

A truck is climbing up a 5% grade towards Manastash Summit on Interstate 82 just outside of Ellensburg. It is just able to maintain a constant speed of 45 mph as it ascends the grade. What is the engine generated tractive effort given the following?

- Truck weight = 105,500 lbs
- Coefficient of drag = 1.00
- Frontal area = 80 ft^2
- Air density = 0.0020 $slugs/ft^3$
- Interstate 82 grade = 6%

$$R_a = \frac{\rho}{2} * C_D * A_f * V^2$$

$$R_a = \frac{0.002}{2} * 1.0 * 80 * (45 * 1.47)^2$$

$$R_a = 350.07$$

$$R_{rl} = f_{rl} * W$$

$$R_{rl} = 0.01 * \left(1 + \frac{45 * 1.47}{147}\right) * 105{,}500 = 1529.8$$

$$R_g = W * G = 105{,}500 * 0.05 = 5275$$

$$F = \sum R = 350.07 + 1529.8 + 5275 = 7154.9\ lb$$

WSDOT Rigid Pavement Slab Thicknesses Design Table for New or Reconstructed Pavements

(English Version)

Design Period ESALs	Slab Thickness[1] (feet)		
	Reliability = 75%	Reliability = 85%	Reliability = 95%
Undoweled Joints, Crushed Stone Base Material			
< 5 million	0.74	0.79	0.85
5 - 10 million	0.82	0.87	0.95
10 - 15 million	0.89	0.94	1.02
Undoweled Joints, HMA Base Material			
< 5 million	0.71	0.75	0.84
5 - 10 million	0.80	0.85	0.94
10 - 25 million	0.94	0.98	1.08
Doweled Joints, Crushed Stone Base Material			
< 25 million	0.85	0.90	0.98
25 - 50 million	0.95	1.00	1.02
> 50 million	1.02	1.07	1.16
Doweled Joints, HMA Base Material			
< 25 million	0.75	0.79	0.87
25 - 50 million	0.84	0.90	0.97
> 50 million	0.90	0.95	1.03

1. Based on the 1993 AASHTO *Guide for Design of Pavement Structures* for rigid pavements with the following inputs:

$\Delta PSI = 1.5$ $E_c = 26{,}700$ MPa (4,000,000 psi) Modulus of subgrade reaction (k):

$S_0 = 0.40$ $S'_c = 4{,}480$ kPa (650 psi) k = 54 MPa/m (200 pci) for stone base

$C_d = 1.0$ J = 3.4 for undoweled pavement k = 108 MPa/m (400 pci) for HMA base

J = 2.7 for doweled pavement assumes unyielding subgrade conditions