CEE 320 Midterm Examination (50 minutes)

- Please write your name on this cover.
- Please write your 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 re-staple them at the end of the examination.

Name (first, last): ___________________________________________
Question 1: Short Answers (5 points each for a total of 15 points)

Based on the short reading, *Environmental Justice & Transportation: A Citizen’s Handbook*, to what does the term “environmental justice” refer?

Why is automobile traffic typically ignored when calculating pavement structural design?

A vehicle slows from 60 mph down to 30 mph on a flat grade. Using the standard AASHTO recommended deceleration rate, what is the braking distance over which this occurs?
Problem 2 (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.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Weight when bus is empty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front axle</td>
<td>13,300 lb</td>
</tr>
<tr>
<td>Middle axle</td>
<td>18,200 lb</td>
</tr>
<tr>
<td>Rear axle</td>
<td>12,200 lb</td>
</tr>
</tbody>
</table>

photo by Ned Ahrens (from Metro website)
Problem 3 (20 points)

Shirley Muldowney, a five-time world champion top fuel dragster, set a personal best speed of 327.66 mph in 2003 in Chicago. Information about this run:

- Dragster weight = 2150 lbs (with driver)
- Coefficient of drag = 0.12
- Frontal area = 12 ft^2
- Air density = 0.0020 slugs/ft^3
- Grade = 0% (flat)

At the very end of this quarter-mile run, assume Shirley is at top speed (327.66 mph) in her dragster and at constant velocity (no acceleration). What engine generated tractive effort is required to maintain this top speed?

Bonus:
The NHRA is drag racing’s governing body in the U.S. What does NHRA stand for?
Problem 4 (20 points)
The road up Mt. Baker is being redesigned to accommodate a 35 mph design speed. Part of this road has an existing curve with a 280 ft radius and zero superelevation. Answer the following 2 questions about the redesign of this curve:

1. If the existing curve radius is kept unchanged, what superelevation is required for the curve to accommodate a 35 mph design speed (use $f_s = 0.23$).
2. How far back from the edge of the road must the rock outcropping be to allow adequate sight distance for a 35 mph design speed?

Plan View of Road

Curve radius (R) = 280 ft
Two 12 ft. wide lanes
Find this distance for part 2
Rock Outcropping
Problem 5 (25 points)

You are designing the vertical alignment of an east-west portion of SR 528 through Marysville. An equal tangent crest vertical curve must go over an existing north-south Olympic oil pipeline. According to safety regulations, the top of the pipeline must be at least 6 ft below the centerline roadway surface. Known grades, stationing and elevations are given in the drawing below. Design the curve for the highest possible design speed without violating the pipeline’s 6 ft cover requirement.

Report the curve length, and the associated design speed rounded down to the nearest 5 mph (be careful with units in your calculations!).

Profile View

G₁ = 2.5%
G₂ = -4.5%

Oil Pipeline
Diameter = 1 ft
Station = 19+00
Elevation of center = 324 ft

PVI
Station = 20+00
Elevation = 335 ft

PVC

6 ft minimum

Y = ?

PVT
Blank Page for Additional Work Space
# WSDOT Rigid Pavement Slab Thicknesses Design Table for New or Reconstructed Pavements

(English Version)

<table>
<thead>
<tr>
<th>Design Period ESALs</th>
<th>Slab Thickness (1) (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reliability = 75%</td>
</tr>
<tr>
<td>Undoweled Joints, Crushed Stone Base Material</td>
<td></td>
</tr>
<tr>
<td>&lt; 5 million</td>
<td>0.74</td>
</tr>
<tr>
<td>5 - 10 million</td>
<td>0.82</td>
</tr>
<tr>
<td>10 - 15 million</td>
<td>0.89</td>
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<tr>
<td>Undoweled Joints, HMA Base Material</td>
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</tr>
<tr>
<td>&lt; 5 million</td>
<td>0.71</td>
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<tr>
<td>5 - 10 million</td>
<td>0.80</td>
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<tr>
<td>10 - 25 million</td>
<td>0.94</td>
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<tr>
<td>&lt; 25 million</td>
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</tr>
<tr>
<td>25 - 50 million</td>
<td>0.95</td>
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<tr>
<td>&gt; 50 million</td>
<td>1.02</td>
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<tr>
<td>Doweled Joints, HMA Base Material</td>
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<td>25 - 50 million</td>
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<tr>
<td>&gt; 50 million</td>
<td>0.90</td>
</tr>
</tbody>
</table>

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

To solve a quadratic equation (in case you forgot)

Where: \(ax^2 + bx + c = 0\)  The solution is:  \(x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\)