Carleton University, Department of Civil & Environmental Engineering
CIVE 3304A/GEOG4304A: Transportation Engineering and Planning,
Instructor: K. Ismail, October 2011

Midterm Examination (1 hour)

Last Name	[redacted]
Student Number	[redacted]
Model	A

Attempt all questions

The exam is composed of two parts.

Part I (70 Marks) is a set of problems. Make arrangement to answer the questions within the specified space. Some pages are left blank to be used as a space for writing answers. These spaces are indicated as "Answer".

Part II (30 Marks) is a set of Multiple Choice Questions. Select the BEST answer and mark it in the answer sheet on page 5.

If not indicated in the question, you can use the following:

If not indicated in the question, you can use the following design parameters:
1. Perception and brake reaction time = 2.5 seconds
2. Longitudinal coefficient of friction = 0.33
3. Maximum lateral friction = 0.14
4. Lane width = 3.6 metres
5. Cross-slope of a crown section is ±2%
6. On horizontal curves, longitudinal grades are given in the direction of the inside lane.

Part I

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Problem 1 (35 Marks)

A 900m horizontal curve is being designed on a highway with a design speed of 90 km/h. The horizontal curve lies on a -3% downgrade.

Following is a summary of relevant design and road parameters:

1. The road is composed of two lanes, each lane serves one direction.
2. There is no median, just a pavement marking separating the two sides.
3. Lane width is 3.6m.
4. The cross-section is fully-superelevated at 3%. = e
5. Maximum longitudinal friction can be taken as 0.33.
6. Longitudinal friction is influenced by lateral friction.
7. Perception and brake reaction time (PRT) is 2.5 seconds.

What is the closest visually obstructing roadside object be placed to the centreline of the inside lane of the roadway while maintaining adequate stopping sight distance?

Answer

(Hint: You may structure you solution as follows: [i] reduced longitudinal friction, [ii] stopping sight distance, [iii] radius at lane centreline, and [iv] minimum lateral clearance (noted as m))

$L = 900m$
$V = 90 km/h$
$g = -0.03$

i) $f_1 = 0.33$
$f_2 = 0.14$ (assume)

reduced longitudinal friction = $f = \sqrt{f_1^2 - f_2^2}$ 5

$0.03 + f_2 = \frac{90^2}{127 \times 900}$

$= \sqrt{(0.33)^2 - (0.14)^2}$

$f = 0.299$

ii) $SSD = 0.278 \cdot V \cdot PRT + \left(\frac{V^2}{254(f \pm G)}\right)$

$f = \sqrt{0.33^2 - f_2^2}$

$= 0.278(90)(2.5) + \left[\frac{(90)^2}{254(0.299 - 0.03)}\right]$ 15

$SSD = 181.1 m$

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iii) R @ ℄

$R = \frac{V^2}{g(e+f)}$

$= \frac{\left(90\frac{km}{h} \cdot \frac{1000m}{km} \cdot \frac{h}{3600s}\right)^2}{(9.81 \frac{m}{s^2})(0.03 + 0.299)}$

$R = 193.6 m$ (= radius to ℄ of inside lane)

$R = 900 - \frac{w}{2}$

iv) $m = R\left[1 - \cos\left(\frac{28.65 S}{R}\right)\right]$

$m = (193.6)\left[1 - \cos\left(\frac{28.65(181.1)}{193.6}\right)\right]$

$m = 20.8 m$

∴ the closest visually obstructing object can be 20.8 m from the centre line of the inside lane of the road to maintain adequate SSD.

Problem 2 (35 Marks)

[a] Determine the minimum length of a vertical curve between +1.5% grade and a -2.0% grade for a road with a 90 km/h design speed. The vertical curve must provide 170 m stopping sight distance.

Assume the following:
1. Driver eye height is 1.07m
2. Object height is 0.15m

[b] Comment on how the curve length in part [a] would change if you are designing the same vertical curve under risk of washout, not risk of colliding with an object on the road. No calculations are required.

Answer

$g_1 = +1.5\%$
$g_2 = -2.0\%$ } crest curve
$V = 90$ km/h
$SSD = 170$ m
$h_1 = 1.07$ m
$h_2 = 0.15$ m

a) assume $L > S$

$$L = \frac{|A| S^2}{200(\sqrt{h_1} + \sqrt{h_2})^2}$$

$$L = \frac{|(-2-1.5)|(170)^2}{200(\sqrt{1.07} + \sqrt{0.15})^2}$$

$$L = \frac{(3.5)(170)^2}{200(\sqrt{1.07} + \sqrt{0.15})^2}$$

$L = 355.7$ m, > 170 m, ∴ assumption was correct.

∴ Minimum curve length is 355.7m.

b) The curve length would become larger if you were designing for washout, because $h_2 \approx 0$, and L_{min} is inversely related to object height.

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Q1	Which of the following modes of travel generates the best Economy of Scale?
A	Railways
B	For-hire publicly-accessible privately-owned passenger cars (a fancy way to say *Taxis*)
C	Planes
D	Commercial long-distance buses

Q2	Which of the following is a typical example of "traffic flow control systems"?
A	Vehicles
B	Drivers
C	Traffic signs
D	At-grade intersections

Q3	Vehicle size may influence the design of which of the following elements?
A	Clearance beneath overpasses
B	Pavement width on horizontal curves
C	Lane width
D	All of the above

Q4	Human factors are important in road design. Several driver characteristics are variable in nature. The principle behind selecting a representative value for a distribution of driver behaviour characteristics is to ensure the safety of a reasonable percentage of the population. For pedestrian walking speed, following is the most suitable percentile value in order to design the length signal time allocated for pedestrian crossing (flashing upright hand):
A	99th (the value 99% of the population walk slower than)
B	85th (the value 85% of the population walk slower than)
C	50th (the median value)
D	15th (the value 15% of the population walk slower than)

Q5	The so-called "design vehicle" is an important design parameter. The dimensions, weight, and power of the design vehicle are used for road geometric design. The attributes of the design vehicle are selected in most design guides as follows:
A	Most critical attributes, *e.g.* heaviest vehicle with lowest power/weight ratio.
B	The most common vehicle brand expected to be on the road.
C	The vehicle brand which will yield the most favourable design conditions.
(D)	No specific vehicle brand is used. Rather, a collection of attributes defined based on statistical basis, *e.g.,* to cover a certain percentage of all vehicles expected to use the road.

Q6	Roads can be classified based on their functional attributes. Which of the following statements best reflects the rating of roads based on their *mobility* and *access* functions?
A	A collector provides higher mobility than an arterial road
B	A collector road offers the best mobility among all road classes
C	A freeway offers better access than a collector road
(D)	Roads which offer the highest mobility may provide the poorest access

Q7	The available longitudinal friction between the tires of a the design passenger car navigating a horizontal curve and the road surface is likely to *decrease* under which of the following conditions?
(A)	Horizontal curve radius is *decreased*
B	Pavement conditions changed from *wet* to *dry*
C	Design speed is *decreased*
D	The vehicle is driving along a *signalized* intersection instead of *un-signalized* intersection

Q8	Passing sight distance depends on which of the following factors:
A	Perception and reaction time
B	Speed of opposing vehicle (opposite direction to the passing vehicle)
C	Speed of the passed (impeding) vehicle
(D)	All of the above factors

Remember: select the best answer

Q9	A horizontal curve is to be designed as part of a new highway. Design speed was selected to be 100km/h. Maximum lateral friction is provided as 0.14. The horizontal curve radius at the inner lane centreline is 300m. What would be your recommendation to ensure lateral stability of vehicles navigating this horizontal curve
A	Use a superelevation less than 10%.
B	Use a superelevation of approximately 12%.
C	Increase lateral friction in order to use less superelevation.
D	Reduce design speed so that superelevation is not excessive.

V = 100
f = 0.14
R = 300
$e = \frac{V^2}{gR} - f$
$= \frac{(...)^2}{9.81(300)} - ...$
e = 12.7%

Q10	Which road class would have the lowest maximum superelevation?
A	Low-speed urban roads
B	Low-speed rural roads
C	High-speed urban roads
D	High-speed rural roads

Q11	As a designer, you may have control over the force used to counteract the centrifugal force on horizontal curves, *i.e.*, lateral friction or superelevation. Which of the following may reflect a sound design strategy?
A	Lateral *friction* should be the first option against centrifugal force on *low-speed urban* roads
B	Lateral *friction* should be the first option against centrifugal force on *high-speed rural* roads
C	*Superelevation* should be used primarily to counteract centrifugal force on all *urban* roads.
D	Maximum superelevation should always be used first on all classes.

Q12	In cases when the right-of-way (area allocated for road construction including all cross-section elements) is restricted, the unnecessary use of transition curves may result in which of the following effects?
A	Use-up more roadside space
B	Driver confusion
C	Excessive lateral acceleration
D	Increased risk of vehicles falling/skidding inside the curve

Q13	When developing superelevation prior to a horizontal curve, by rotating the cross-section around the centreline, which of the following is the cross-section point that starts the *earliest* to change elevation?
A	Outer edge
B	Centreline
C	Inner edge
D	Possibly all of the above

Q14	What is the most likely design requirement for well-illuminated sag vertical curves that will determine the minimum vertical curve length?
A	Provision of stopping sight distance
B	Provision of passing sight distance
C	Limiting the vertical acceleration to which the driver is subjected, *i.e.*, provide improved comfort.
D	Superelevation rate if the vertical curve is superimposed on a horizontal curve

Q15	Where does empirical evidence point as to the relationship between [i] the difference in operating speed (85th percentile speed) on two successive road elements and [ii] collision frequency?
A	Empirical evidence suggests that higher operating speed variability leads to higher collision frequency.
B	Empirical evidence suggests that higher operating speed variability leads to lower collision frequency.
C	Empirical evidence suggests that higher operating speed variability leads to improved road consistency.
D	It is generally a *recommended* design practice to surprise the driver by creating roads which dictate abrupt change in driving speed.

==End of Exam==