**National Examinations –May 2016**

**98-Civ-B10 Traffic Engineering**

**3 Hour Duration**

NOTES

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer book a clear statement of any assumptions made.

2. Any data required, but not given, can be assumed.

3. This is an **"OPEN BOOK"** examination. Any non-communicating calculator is permitted.

4. A total of **five** solutions is required. Only the first five as they appear in your answer book will be marked.

5. All questions are of equal value.

**Grading Scheme:**

Question 1 (a) to (e) – 4 marks each

Question 2 (a) to (e) – 4 marks each

Question 3 (a) to (e) – 4 marks each

Question 4 (a) – 4 marks, (b) and (c) – 8 marks each

Question 5 (a) and (c) – 2 marks each, (b) and (d) – 8 marks each

Question 6 (a) and (d) – 3 marks each, (b) 12 marks, (c) 2 marks

Question 7 (a) and (c) – 4 marks each, (b) and (d) – 2 marks each, (e) – 8 marks

1. Define and discuss each of the following:

   (a) Circular vs. Spiral curves

   (b) Peak hour factor

   (c) Pedestrian clearance time

   (d) Gap acceptance behaviour

   (e) Effective green vs. displayed green

2. The Ambassador Bridge has only one customs officer booth open where cars arrive at a rate of 25 per hour to enter into Canada. The customs officer processes these cars at a mean service rate of 28 cars per hour.

   (a) What is the probability that the customs office is free from processing a car?

   (b) How many cars on average are waiting to be processed?

   (c) Calculate the average number of cars in line.

   (d) Calculate the average wait time for a car and the average time a car spends being processed by the customs officer.

   (e) If the line of cars is longer than five vehicles, a second customs officer booth is opened, what is the probability of a second booth being opened?

3. Highway 400 typically has two lanes open in each direction, but a construction project will require two lanes closed in the NB direction. Therefore, the SB lanes will be used for two way traffic with one lane of traffic in each direction. On this stretch of highway one lane will provide enough capacity for typical traffic except for Friday nights from 4PM to 6PM. During this two hour time window, the NB traffic flow is 2800 vph and the lane only has a capacity of 2580 vph. After 6PM the traffic flow drops to 1350 vph.

   (a) What is the maximum length of the queue?

   (b) What is the longest expected time any vehicle will spend in the queue?

   (c) At what time will the queue dissipate?

   (d) What is the total delay from 4PM until the queue is cleared?

   (e) What is the average time a vehicle spends in the queue?

4. Curves

| Metric | | | | | US Customary | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Stopping sight distance | | | | | Stopping sight distance | |
| Design speed (km/h) | Brake reaction distance (m) | Braking distance on level (m) | Calculated (m) | Design (m) | Design speed (mph) | Brake reaction distance (ft) | Braking distance on level (ft) | Calculated (ft) | Design (ft) |
| 20 | 13.9 | 4.6 | 18.5 | 20 | 15 | 55.1 | 21.6 | 76.7 | 80 |
| 30 | 20.9 | 10.3 | 31.2 | 35 | 20 | 73.5 | 38.4 | 111.9 | 115 |
| 40 | 27.8 | 18.4 | 46.2 | 50 | 25 | 91.9 | 60.0 | 151.9 | 155 |
| 50 | 34.8 | 28.7 | 63.5 | 65 | 30 | 110.3 | 86.4 | 196.7 | 200 |
| 60 | 41.7 | 41.3 | 83.0 | 85 | 35 | 128.6 | 117.6 | 246.2 | 250 |
| 70 | 48.7 | 56.2 | 104.9 | 105 | 40 | 147.0 | 153.6 | 300.6 | 305 |
| 80 | 55.6 | 73.4 | 129.0 | 130 | 45 | 165.4 | 194.4 | 359.8 | 360 |
| 90 | 62.6 | 92.9 | 155.5 | 160 | 50 | 183.8 | 240.0 | 423.8 | 425 |
| 100 | 69.5 | 114.7 | 184.2 | 185 | 55 | 202.1 | 290.3 | 492.4 | 495 |
| 110 | 76.5 | 138.8 | 215.3 | 220 | 60 | 220.5 | 345.5 | 566.0 | 570 |
| 120 | 83.4 | 165.2 | 248.6 | 250 | 65 | 238.9 | 405.5 | 644.4 | 645 |
| 130 | 90.4 | 193.8 | 284.2 | 285 | 70 | 257.3 | 470.3 | 727.6 | 730 |
| | | | | | 75 | 275.6 | 539.9 | 815.5 | 820 |
| | | | | | 80 | 294.0 | 614.3 | 908.3 | 910 |

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 $m/s^2$ [11.2 $ft/s^2$] used to determine calculated sight distance.

Source: AASHTO, 2001

   (a) Define Perception-Reaction Time and Braking Distance

   (b) Determine the minimum length of a crest vertical curve that has a design speed of 100 km/h, an entering grade of 2.5 percent and a departing grade of 3.5 percent to provide adequate stopping sight distance. Assume that the driver's height is 1070 mm and the stopping sight distance is to be designed for large wildlife entering the roadway with a design height of 1295 mm.

   (c) A 150 m vertical crest curve is designed to connect a +4% tangent with a -2% tangent. What should the design speed be to provide ample stopping sight distance? Use standard heights for the driver and object of 1080 mm and 600 mm, respectively.

5. A car is travelling along a highway up a 4.5% grade at a speed of 110 km/h. If the perception and reaction time is 2.5 seconds and the coefficient of friction is 0.25 answer the following questions.

   (a) The distance travelled during the perception-reaction time

   (b) The braking distance and total stopping sight distance

   (c) Will the coefficient of friction increase or decrease in icy road conditions?

   (d) Calculate the stopping sight distance if the coefficient of friction is changed to 0.1 and the car is travelling down a grade of 3%.

6. A traffic planner is determining the traffic systems needed for the downtown core. The roads run in the north-south direction with block lengths of 150 m and the east-west streets have block lengths of 270 m. The City requires that the speeds of progression are 45 km/h in the north-south direction and 40 km/h in the east-west direction in the downtown area.

   (a) Describe single-alternate, double-alternate, and triple-alternate systems

   (b) Determine the appropriate alternate system

   (c) Calculate the cycle length

   (d) Calculate the actual speeds of progression for two-way progression in both directions of the grid. Do these values meet the speed progression requirements set out by the City?

7. Intersections

(a) A four-legged intersection has two lanes in each direction and a two-phase cycle. One phase of the intersection has two lanes, one for left-turns and straight-through traffic and the other lane for right-turns and straight-through traffic. The design flow rates and saturation flow rates are found below. Calculate the critical flow ratio for this phase and determine which lane is the critical lane.

| Lane Description | Design Flow Rate (pcu/hr) | Saturation Flow Rate (pcu/hr) |
|---|---|---|
| NB – L, S | 600 | 1200 |
| NB – R, S | 500 | 1700 |
| SB – L, S | 450 | 1330 |
| SB – R, S | 720 | 1600 |

(b) An intersection approach has 3 lanes, permitted left turns, 12% left turns with a through vehicle equivalent of 5.25, and a saturation flow rate of 1830 vehicle per hour of green per lane for through vehicles under prevailing conditions. What is the left turn adjustment factor for this intersection?

(c) For the intersection in part (b), determine the saturation flow rate and saturation headway for the approach, including impact of left-turning vehicles.

(d) For the intersection in part (b), if the effective green time is 50 seconds in a cycle with a length of 80 seconds, what is the capacity of the approach in vehicles per hour?

(e) A two-phase cycle has the same saturation flow rate for each phase and a total available green time of 75 seconds. Calculate the available green time for each of the two phases using the data in the following table.

| Intersection Number | Phase 1 Flow Rate (pcu/hr) | Phase 2 Flow Rate (pcu/hr) |
|---|---|---|
| 1 | 400 | 200 |
| 2 | 300 | 100 |
| 3 | 160 | 40 |
| 4 | 80 | 70 |