UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	ADVANCED TRAFFIC ENGINEERING
COURSE CODE	:	BFT 40503
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

Q1 (a) Explain how a shockwave in traffic is formed.

(4 marks)

(b) By considering two very different flow conditions q_1 and q_2 on a highway segment with corresponding densities k_1 and k_2, show that the resulting shockwave speed, v_w can be determined using the following equation.

$$v_w = \frac{q_2 - q_1}{k_2 - k_1}$$

(7 marks)

(c) **Figure Q1.1** shows speed and flow for upstream and downstream traffic on an expressway that merges with an on-ramp. Perform a shockwave assessment for the upstream traffic within 1.5 km of the merging area.

(14 marks)

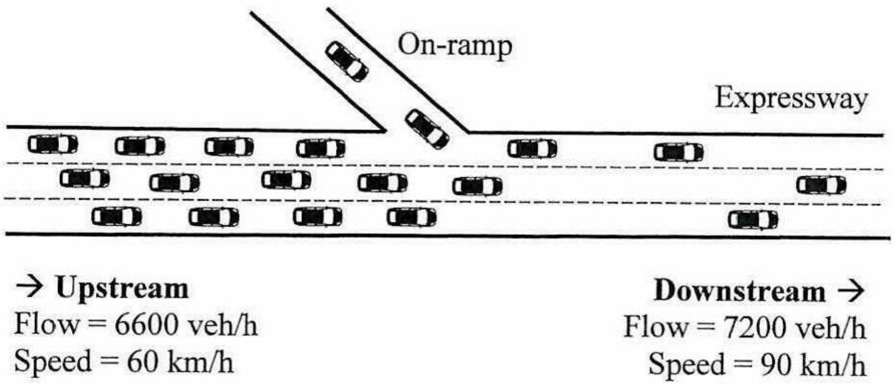


Figure Q1.1: Speed and flow for upstream and downstream traffic

Q2 A Class II two-lane arterial section passes two pre-timed signalised intersections at spacings of 400 m and 600 m. The green times are 27 sec and 36 sec respectively. The following information is given:

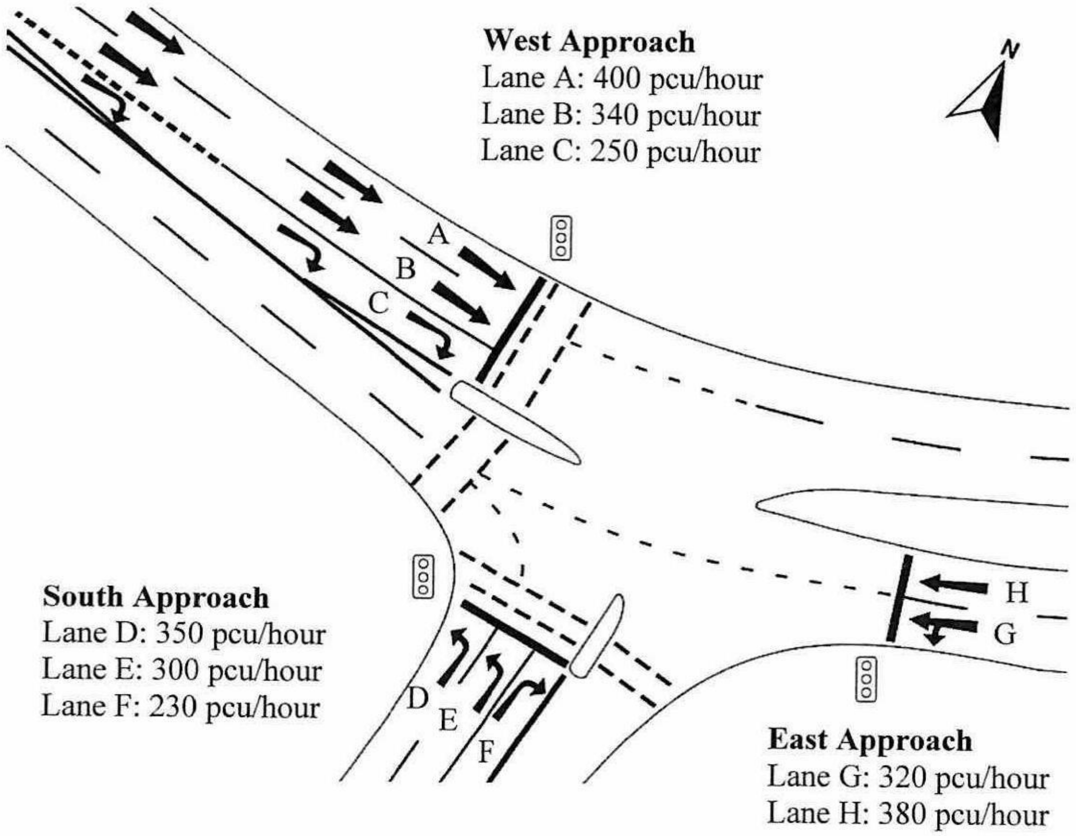
Field measured free flow speed (*FFS*)	= 65 km/h
Cycle length (*C*)	= 90 sec
Lane group capacity (*c*)	= 1,800 veh/h
Arrival type	= 2
Analysis period (*T*)	= 0.25 hours
Initial queue (Q_b)	= None
Volume-to-capacity ratio (*X*)	= 0.85
Upstream filtering/metering adjustment factor (*I*)	= 0.40

Based on the information provided above, evaluate the level of service for each segment. Use the worksheet provided in **Table Appendix A.1** and attach it in your answer script.

(25 marks)

Q3 The layout and design flows (v) of a proposed 3-phase signalised intersection are shown in **Figure Q3.1**. The saturation flows (s) and pedestrian volumes (N_{ped}) are given in **Table Q3.1**. The following information is also provided:

All red interval (R)	= 2 sec
Yellow interval per phase (τ)	= 3 sec
Lost time per phase (l)	= 4 sec
Effective pedestrian crosswalk width (W_E)	= 2.5 m
Pedestrian crosswalk length (L)	= 12 m
Average pedestrian speed (S_P)	= 1.3 m/s
Desired critical volume-capacity ratio (X_c)	= 0.85



Note: pcu is passenger car unit

Figure Q3.1: Layout and design flows of the proposed intersection

Table Q3.1: Saturation flows and pedestrian volumes at the proposed intersection

Phase	1			2			3	
Approach	West			South			East	
Movement	Through		Right	Left		Right	Through + Left	Through
Lane	A	B	C	D	E	F	G	H
Saturation flow [a]	1700		1600	1500		1500	1700	1700
Number of pedestrians crossing [b]	30			20			Not Applicable	

Note: a The unit for saturation flow is passenger car unit/hour.
B The unit for number of pedestrians crossing is pedestrians/interval/direction.

(a) A cycle time (C) of 80 seconds will be used for the signal design. Show that this value is acceptable.

(13 marks)

(b) Calculate the actual green times (G_a) for all three phases.

(6 marks)

(c) Check whether the minimum green time required for pedestrian crossing (G_p) is adequate or not.

(6 marks)

Q4 (a) Walkable communities are defined as communities that consider persons, not their automobiles, at the center of the design scale. Briefly discuss **FIVE (5)** criteria that can make a community such as a residential area or a university campus "walkable".

(10 marks)

(b) **Figure Q4.1** shows a sketch of an existing urban street that is being considered to be re-designed into a pedestrian and cyclist friendly street. As a traffic engineer, you have been assigned to re-design the street. Produce a proposal that introduces **FIVE (5)** new design features. Include a sketch showing all five features. For each feature, mention its advantage.

(15 marks)

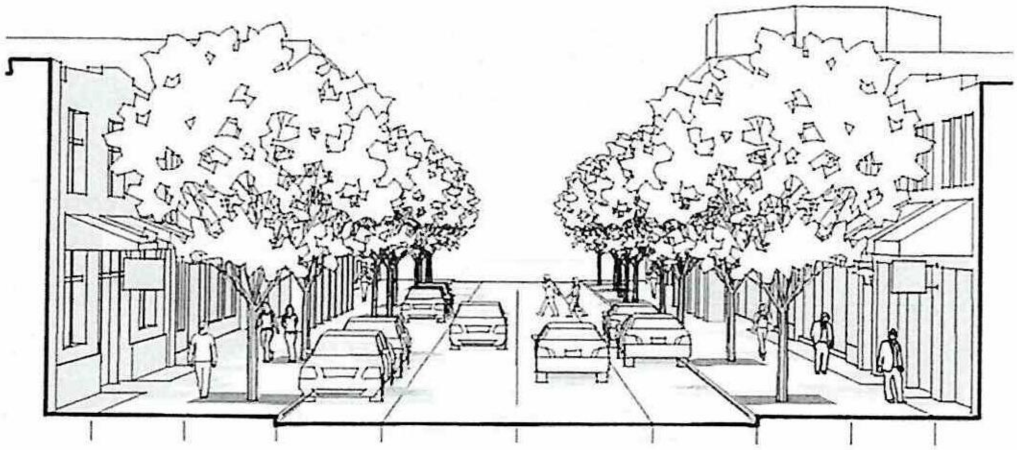


Figure Q4.1: Sketch of existing urban street

- END OF QUESTIONS -

APPENDIX A: Design Charts And Tables

Name: .... Matric Card No.: ....

Note: Use this worksheet to answer Q2 and attach it in your answer script

Table APPENDIX A.1 Arterial Level of Service Worksheet

Input Parameters		
Descriptor	**Segments**	
	1	**2**
Cycle length, C (s)	90	90
Green time, g (s)	27	36
Green-to-cycle length ratio, g/C		
Volume-to-capacity ratio for lane group, X	0.85	0.85
Capacity of lane group, c (veh/h)	1,800	1,800
Arrival type, AT	2	2
Length of segment, L (km)	0.4	0.6
Initial queue, Q_b (veh)	0	0
Arterial class	II	II
Free flow speed, FFS (km/h)	65	65
Running time, T_R (s)		
Delay Computation		
Uniform delay, d_1 (s)		
Signal control adjustment factor, k		
Upstream filtering / metering adjustment factor, I	0.40	0.40
Incremental delay, d_2 (s)		
Initial queue delay, d_3 (s)	0	0
Progression adjustment factor, PF		
Control delay, $d = d_1 * PF + d_2 + d_3$		
Segment LOS Determination		
Segment travel time, ST (s) $ST = T_R + d$		
Segment travel speed, S_A (km/h)		
Segment LOS		

Table Appendix A.2: Urban street LOS by class

Urban Street Class	I	II	III	IV
Range of free-flow speeds (FFS)	90 to 70 km/h	70 to 55 km/h	55 to 50 km/h	55 to 40 km/h
Typical FFS	80 km/h	65 km/h	55 km/h	45 km/h
LOS	Average Travel Speed (km/h)			
A	> 72	> 59	> 50	> 41
B	> 56–72	> 46–59	> 39–50	> 32–41
C	> 40–56	> 33–46	> 28–39	> 23–32
D	> 32–40	> 26–33	> 22–28	> 18–23
E	> 26–32	> 21–26	> 17–22	> 14–18
F	≤ 26	≤ 21	≤ 17	≤ 14

Table Appendix A.3: Relationship between arrival type and platoon ratio

Arrival Type	Range of Platoon Ratio (R_p)	Default Value (R_p)	Progression Quality
1	≤ 0.50	0.333	Very poor
2	> 0.50–0.85	0.667	Unfavorable
3	> 0.85–1.15	1.000	Random arrivals
4	> 1.15–1.50	1.333	Favorable
5	> 1.50–2.00	1.667	Highly favorable
6	> 2.00	2.000	Exceptional

Table Appendix A.4: Progression adjustment factors for uniform delay calculation

Green Ratio (g/C)	Arrival Type (AT)					
	AT 1	AT 2	AT 3	AT 4	AT 5	AT 6
0.20	1.167	1.007	1.000	1.000	0.833	0.750
0.30	1.286	1.063	1.000	0.986	0.714	0.571
0.40	1.445	1.136	1.000	0.895	0.555	0.333
0.50	1.667	1.240	1.000	0.767	0.333	0.000
0.60	2.001	1.395	1.000	0.576	0.000	0.000
0.70	2.556	1.653	1.000	0.256	0.000	0.000
f_{PA}	1.00	0.93	1.00	1.15	1.00	1.00
Default, R_p	0.333	0.667	1.000	1.333	1.667	2.000

Notes:
$PF = (1 - P)f_{PA}/(1 - g/C)$.
Tabulation is based on default values of f_p and R_p.
$P = R_p \cdot g/C$ (may not exceed 1.0).
PF may not exceed 1.0 for AT 3 through AT 6.

Table Appendix A.5: Segment running time per kilometer

Urban Street Class	I			II			III		IV		
FFS (km/h)	90[a]	80[a]	70[a]	70[a]	65[a]	55[a]	55[a]	50[a]	55[a]	50[a]	40[a]
Average Segment Length (m)	Running Time per Kilometer (s/km)										
100	b	b	b	b	b	b	-	-	-	129	159
200	b	b	b	b	b	b	88	91	97	99	125
400	59	63	67	66	68	75	75	78	77	81	96
600	52	55	61	60	61	67	d	d	d	d	d
800	45	49	57	56	58	65	d	d	d	d	d
1000	44	48	56	55	57	65	d	d	d	d	d
1200	43	47	54	54	57	65	d	d	d	d	d
1400	41	46	53	53	56	65	d	d	d	d	d
1600	40[c]	45[c]	51[c]	51[c]	55[c]	65[c]	d	d	d	d	d

Notes:

a. It is best to have an estimate of FFS. If there is none, use the table above, assuming the following default values:

For Class	FFS (km/h)
I	80
II	65
III	55
IV	45

b. If a Class I or II urban street has a segment length less than 400 m, (a) reevaluate the class and (b) if it remains a distinct segment, use the values for 400 m.

c. For long segment lengths on Class I or II urban streets (1600 m or longer), FFS may be used to compute running time per kilometer. These times are shown in the entries for a 1600-m segment.

d. Likewise, Class III or IV urban streets with segment lengths greater than 400 m should first be reevaluated (i.e., the classification should be confirmed). If necessary, the values above 400 m can be extrapolated.

Although this table does not show it, segment running time depends on traffic flow rates; however, the dependence of intersection delay on traffic flow rate is greater and dominates in the computation of travel speed.

Table Appendix A.6: Signal control adjustment factor for controller type

Unit Extension (s)	Degree of Saturation (X)					
	≤ 0.50	0.60	0.70	0.80	0.90	≥ 1.0
≤ 2.0	0.04	0.13	0.22	0.32	0.41	0.50
2.5	0.08	0.16	0.25	0.33	0.42	0.50
3.0	0.11	0.19	0.27	0.34	0.42	0.50
3.5	0.13	0.20	0.28	0.35	0.43	0.50
4.0	0.15	0.22	0.29	0.36	0.43	0.50
4.5	0.19	0.25	0.31	0.38	0.44	0.50
5.0[a]	0.23	0.28	0.34	0.39	0.45	0.50
Pretimed or Nonactuated Movement	0.50	0.50	0.50	0.50	0.50	0.50

Notes:

For a unit extension and its k_{min} value at X = 0.5: $k = (1 - 2k_{min})(X - 0.5) + k_{min}$, where $k \geq k_{min}$, and $k \leq 0.5$.

a. For a unit extension more than > 5.0, extrapolate to find k, keeping $k \leq 0.5$.

APPENDIX B: Formulas

$$v_w = \frac{q_2 - q_1}{k_2 - k_1} \qquad q = vk \qquad N = vkt \qquad X_c = \sum \left(\frac{v}{s}\right)_c * \frac{C}{C - L}$$

$$L = \sum_{i=1}^{\emptyset} l_i + R \qquad G_a = G_e + l - \tau \qquad \tau_{min} = \delta + \frac{W + L}{v_o} + \frac{v_o}{2a}$$

$$G_e = \frac{Y_i}{Y_1 + Y_2 + \cdots + Y_\emptyset} G_{te} = \frac{Y_i}{Y_1 + Y_2 + \cdots + Y_\emptyset}(C - L)$$

$$G_p = 3.2 + \frac{L}{S_P} + \left(2.7\frac{N_{ped}}{W_E}\right) \qquad for\ W_E > 3\ m$$

$$G_p = 3.2 + \frac{L}{S_P} + \left(0.27N_{ped}\right) \qquad for\ W_E \leq 3\ m$$

$$S_A = \frac{3600L}{T_R + d} \qquad d_1 = \frac{0.5C\left(1 - \frac{g}{C}\right)^2}{1 - \left(\frac{g}{C}\right)min(X, 1.0)}$$

$$d_2 = 900T\left[(X - 1) + \sqrt{(X - 1)^2 + \frac{8kIX}{cT}}\right] \qquad d_3 = \frac{1800Q_b(1 + u)t}{cT}$$

$$t = 0\ if\ Q_b = 0, \quad else \quad t = min\left(T, \frac{Q_b}{c[1 - min(1, X)]}\right)$$

$$u = 0\ if\ t < T, \quad else \quad u = 1 - \frac{cT}{Q_b[1 - min(1, X)]}$$