UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2023/2024

COURSE NAME	:	ADVANCED TRAFFIC ENGINEERING
COURSE CODE	:	BFT 40503
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JANUARY/FEBRUARY 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 4. COMPLETE AND ATTACHED **TABLE APPENDIX A.1** IN YOUR ANSWER BOOKLET

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

Q1 Traffic data were collected at 100 m intervals along a 1-km segment of a highway in order to study the relationship between speed and density. The data is shown in **Table Q1.1**.

Table Q1.1 Traffic data collected at a 1-km highway segment.

Speed (km/h)	Density (vehicles/km)
63	11
41	14
52	11
77	9
45	13
39	14
86	9
53	13
56	9
65	10

(a) Develop a linear equation that relates speed and density using regression analysis.

(11 marks)

(b) If 10 vehicles are traveling along that segment, determine the speed of the vehicles.

(2 marks)

(c) Evaluate the strength of correlation between speed and density.

(4 marks)

(d) Estimate the jam density, optimal speed and maximum flow for this segment.

(8 marks)

Q2 In Malaysia, road classifications are grouped according to their functions namely Urban and Rural groups. Arterial road is considered as Urban Road classification group.

(a) Define an 'Arterial Road' in your own words.

(2 marks)

(b) The first step in the analysis of arterial performance is to determine the Arterial class. State **TWO (2)** basis that are used to determine the Arterial class.

(2 marks)

(c) A two-lane urban arterial (Class II) with two intersections has various spacings as shown in **Table APPENDIX A.1** experiences high right-turn volume, served by a permitted phase and an exclusive turn lane. Estimate the level of service by segment and for the entire facility by completing **Table APPENDIX A.1**, given the following:

Field measured FFS = 55 km/h
Cycle length = 80 sec
Lane group capacity = 1,750 veh/hr
Initial queue at Intersection 1 and 2 = 0 vehicles
Arrival Type = 2 (for all segments)
Signal control type = Pretimed signals
Analysis period = 0.25 hours
g/C and v/c ratios = refer to **Table APPENDIX A.1**

(21 marks)

Q3 The layout and actual flows of a T-intersection that is to be upgraded to a signalised intersection are shown in **Figure Q3.1**. The saturation flows and pedestrian volumes are given in **Table Q3.1**. Based on the following information:

All red interval (R) = 2 sec
Yellow interval per phase (τ) = 3 sec
Lost time per phase (l) = 4 sec
Desired critical volume-capacity ratio (Xc) = 0.85
Effective pedestrian crosswalk width (W_E) = 2.25 m
Pedestrian crosswalk length (L) = 12 m
Average pedestrian speed (S_p) = 1.22 m/s

(a) Calculate whether a cycle time (C) of 100 seconds is suitable.

(13 marks)

(b) Determine the actual green time (G_a) for each phase.

(6 marks)

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

(6 marks)

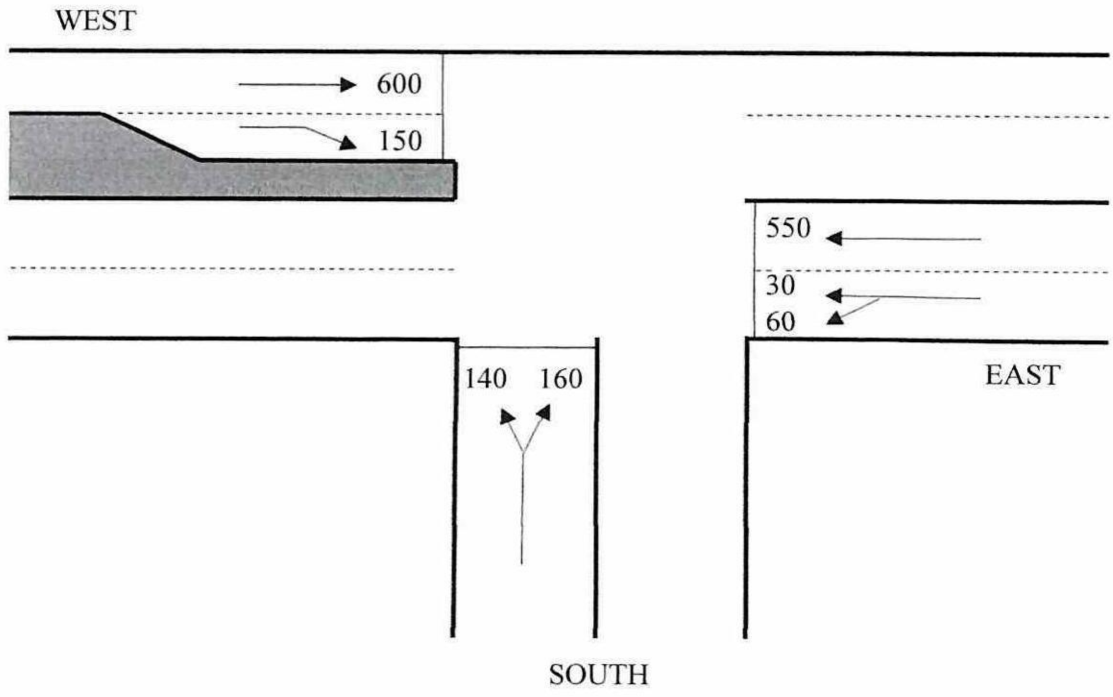

Figure Q3.1 Layout and actual flows (pcu/hour) of the T-intersection.

Table Q3.1 Saturation flows and pedestrian volumes at the T-intersection.

Phase	1		2		3	
Approach	West		East		South	
Movement	Through	Right	Through	Through + Left	Left	Right
Saturation flow [a]	1800	1600	1800	1800	1600	1600
Number of pedestrian crossing [b]	20		10		25	

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

Q4 Approximately, a total number of 5,200 vehicles and 2,700 motorcycles enter the UTHM main campus daily. This is really a concern since the use of private vehicles will affect our environment negatively due to the emissions contributed by the private vehicles. Thus, it is crucial to promote and enhance the use of non-motorised transportation or modes (e.g., walk, cycle, small-wheeled transport and wheelchair travel) in the campus in order to reduce the emissions rate as well as to promote active and healthy lifestyle among students and staff.

(a) In your opinion, why students and staff in UTHM main campus do not prefer to use non-motorised modes on campus? Give **FIVE (5)** reasons.

(10 marks)

(b) Cycling seems to have high potential as one of the main sustainable modes for travel on campus especially among students since it is relatively inexpensive, space-efficient, and accessible. Describe **FIVE (5)** basic design principles if we want to provide good bicycle facilities on campus.

(15 marks)

- END OF QUESTIONS -

APPENDIX A

Name:______________________________________ **Matrix number:** _______________

Note: Kindly fill in your answer in this **Table APPENDIX A.1 and attached this sheet in your answer booklet.*

Table APPENDIX A.1 Data input for arterial segments.

INPUT PARAMETERS		
	Segment	
	1	**2**
Cycle length, C (s)	80	80
Effective green to cycle length ratio, g/c	0.5	0.6
v/c ratio for lane group, X	0.856	1.105
Capacity of lane group, c (veh/hr)	1,750	1,750
Arrival type, AT	2	2
Length of segment, L (km)	0.6	0.4
Initial queue, Q_b (veh)	-	-
Urban street class, SC	II	II
Free flow speed, FFS (km/hr)	55	55
Running time, T_R (s)		
DELAY COMPUTATION		
Uniform delay, d_1 (s)		
Signal control adjustment factor, k		
Upstream filtering/metering adjustment factor, I		
Incremental delay, d_2 (s)		
Initial queue delay, d_3 (s)		
Progression adjustment factor, PF		
Control delay, d (s) $d = d_1 * PF + d_2 + d_3$		
SEGMENT LOS DETERMINATION		
Segment travel time, ST (s) $ST = T_R + d + other\ delay$		
Segment travel speed, S_A (km/hr) $S_A = (3600 * L)/ST$		
Segment LOS		
URBAN STREET LOS DETERMINATION		
Total travel time, ΣST (s)		
Total length, ΣL (km)		
Total travel speed, $S_A = (3600 * \Sigma L)/\Sigma ST$ (km/hr)		
Total urban street LOS		

APPENDIX B

Table APPENDIX B.1 Urban street level of service (LOS) according to street 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 B.2 Segment running time per kilometre.

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 B.3 Progression adjustment factors for uniform delay.

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 B.4 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 ≤ 0.5.*

Table APPENDIX B.5 Recommended upstream filtering or metering adjustment factor for lane group upstream signals.

	Degree of Saturation at Upstream Intersection, X_u						
	0.40	0.50	0.60	0.70	0.80	0.90	≥ 1.0
I	0.922	0.858	0.769	0.650	0.500	0.314	0.090

Note: $I = 1.0 - 0.91\,X_u^{2.68}$ and $X_u \leq 1.0$.

APPENDIX C

These formulas may be useful to you. The symbols have their usual meaning.

$$v = v_f - \frac{v_f}{k_j}k \qquad Y = a - bX \qquad a = \frac{\sum Y}{n} - b\frac{\sum X}{n}$$

$$b = \frac{n(\sum XY) - (\sum X)(\sum Y)}{n(\sum X^2) - (\sum X)^2} \qquad r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{(n(\sum X^2) - (\sum X)^2)(n(\sum Y^2) - (\sum Y)^2)}}$$

$$a = \frac{\sum Y}{n} - b\frac{\sum X}{n} \qquad C_o = \frac{1.5L + 5}{1 - \sum_{i=1}^{\emptyset} Y_i} \qquad L = \sum_{i=1}^{\emptyset} l_i + R$$

$$l = G_a + \tau - G_e \qquad G_a = G_e + l - \tau$$

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

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

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

$$d = d_1 * PF + d_2 + d_3 \qquad d_1 = \frac{0.5C\left(1 - \frac{g}{C}\right)^2}{1 - \left(\frac{g}{C}\right)\min(X, 1.0)} \qquad PF = \frac{(1 - P)f_{PA}}{\left(1 - \frac{g}{C}\right)}$$

$$d_2 = 900T\left[(X - 1) + \sqrt{(X - 1)^2 + \frac{8kIX}{cT}}\right] \qquad I = 1.0 - 0.91X_u^{2.68}$$

$$d_3 = \frac{1800Q_b(1 + u)t}{cT} \qquad t = 0\ if\ Q_b = 0, \quad else\ t = min\left(T, \frac{Q_b}{c[1 - \min(1, X)]}\right)$$

$$u = 0\ if\ t < T, \quad else\ u = 1 - \frac{cT}{Q_b[1 - \min(1, X)]} \qquad S_A = \frac{3600 * L}{T_R + d}$$