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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	ADVANCED TRAFFIC ENGINEERING
COURSE CODE	:	BFT 40503
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER ALL QUESTIONS.
		2. THIS FINAL EXAMINATION IS CONDUCTED VIS **CLOSED BOOK**.
		3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSE BOOK

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

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Q1 The performance of a 1.2 km of divided four-lane principal arterial with two signalised intersections at spacings of 700 m and 500 m is analysed. The green times are 30 sec and 35 sec respectively. The following information is provided:

Speed limit	= 70 km/h
Traffic volume (v)	= 850 veh/h
Saturation flow (s)	= 1,850 pc/h/ln
Signal type	= Pretimed
Arrival type	= Type 3
Initial queue delay (d_3)	= 0 sec
Cycle length (C)	= 120 sec
Analysis period (T)	= 0.25 hours

(a) Determine the class and free flow speed of the arterial.

(4 marks)

(b) Calculate the capacity (c), degree of saturation (X) and running time (T_R) for each segment.

(10 marks)

(c) Evaluate the performance of each segment in terms of control delay (d) and travel speed (S_A).

(11 marks)

Q2 (a) According to the statistics of road accident deaths in Malaysia, pedestrian fatalities ranked third highest after car and motorcycle fatalities for the year 2008 until 2017. On average, 562 pedestrians killed per year on Malaysian roads in which 40% of pedestrian casualties were involving children with the aged between 6 to 10 years old. Therefore, it is important to provide safe facilities for pedestrian especially for young children.

As an engineer, explain in detail the factors that need to be considered in providing safe pedestrian facilities so that the fatalities involving pedestrians can be reduced in future.

(15 marks)

(b) As a myriad of studies have found that child pedestrians are at high risks when they are crossing the roads due to their physical limitations and lower cognitive abilities compared to adults. As a road safety engineer, the decisions on what types of pedestrian crossing applied on various types of road conditions and environments are crucial in ensuring the safety of child pedestrians especially school children.

In your opinion, determine the best type of pedestrian crossing that can be provided near to the school that has the surrounding elements as follows, and justify the reasons to your answer.

Road functional class	:	Primary arterial
Number of lanes per direction	:	2
Lane width	:	3.65 m
Central median	:	1.00 m
Refuge island	:	None
Accident history for the last 3 years	:	5 accidents involving pedestrians
Number of pedestrians	:	180 pedestrians/hour for each of any 8-hour periods
Vehicular traffic flow	:	2,160 vehicles per hour (sum of both directions) for each of any 8-hour periods
Nearest pedestrian crossing distance	:	500 m

(10 marks)

Q3 Data on accepted and rejected gaps of vehicles turning left from the minor road of an unsignalised intersection is shown in **Table Q3**. The peak hour volume is 1,200 veh/hr and the arrival of the major road vehicles is assumed to follow a Poisson distribution.

(a) Estimate the critical gap using Raff's calculation method.

(13 marks)

(b) Verify your answer in **Q3(a)** by using a graphical method.

(7 marks)

(c) Predict the number of acceptable gaps that will be available for minor road vehicles turning left onto the major road during the peak hour.

(5 marks)

Q4 (a) Greenberg assumed a logarithmic relation between speed and density. He proposed the following model:

$$v = C\ln\left(\frac{k_j}{k}\right)$$

where $\boldsymbol{v}$ = speed (km/h), $\boldsymbol{k}$ = density (veh/km), $\boldsymbol{k_j}$ = jam density (veh/km) and $\boldsymbol{C}$ = constant.

Prove that the constant C is actually the value of the optimal speed (v_m).

(7 marks)

(b) **Table Q4** illustrates density and speed data collected from traffic surveillance along an exit ramp of an expressway.

(i) Develop a linear equation to show the relationship between speed and density on this exit ramp using regression analysis.

(12 marks)

(ii) Estimate the maximum flow along the exit ramp based on the equation that you have developed in **Q4(b)(i)**.

(6 marks)

- END OF QUESTIONS -

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Table Q3: Accepted and rejected gaps

Gap, t (sec)	Number of Accepted Gaps < t	Number of Rejected Gaps > t
1	3	108
2	11	85
3	29	54
4	54	32
5	90	10
6	112	2

Table Q4: Speed and density data obtained along the exit ramp of an expressway

Density (veh/km)	Speed (km/h)
80	12
72	22
65	23
66	26
54	31
59	30
47	37
41	42

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APPENDIX A

Table I: Urban street class based on functional and design categories (HCM, 2000)

Design Category	Functional Category	
	Principal Arterial	Minor Arterial
High-Speed	I	N/A
Suburban	II	II
Intermediate	II	III or IV
Urban	III or IV	IV

Table II: Functional and design categories (HCM, 2000)

Criterion	Functional Category	
	Principal Arterial	Minor Arterial
Mobility function	Very important	Important
Access function	Very minor	Substantial
Points connected	Freeways, important activity centers, major traffic generators	Principal arterials
Predominant trips served	Relatively long trips between major points and through-trips entering, leaving, and passing through the city	Trips of moderate length within relatively small geographical areas

Criterion	Design Category			
	High-Speed	Suburban	Intermediate	Urban
Driveway/access density	Very low density	Low density	Moderate density	High density
Arterial type	Multilane divided; undivided or two-lane with shoulders	Multilane divided; undivided or two-lane with shoulders	Multilane divided or undivided; one-way, two-lane	Undivided one-way, two-way, two or more lanes
Parking	No	No	Some	Significant
Separate left-turn lanes	Yes	Yes	Usually	Some
Signals/km	0.3–1.2	0.6–3.0	2–6	4–8
Speed limit	75–90 km/h	65–75 km/h	50–65 km/h	40–55 km/h
Pedestrian activity	Very little	Little	Some	Usually
Roadside development	Low density	Low to medium density	Medium to moderate density	High density

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Table III: Urban street LOS by class (HCM, 2000)

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 IV: Relationship between arrival type and platoon ratio (HCM, 2000)

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

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Table V: Segment running time per kilometer (HCM, 2000)

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 VI: Recommended upstream filtering / metering adjustment factor for lane groups with upstream signals (HCM, 2000)

	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 $X_u \leq 1.0$.

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Table VII: Progression adjustment factors for uniform delay calculation (HCM, 2000)

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 VIII: Signal control adjustment factor for controller type (HCM, 2000)

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 $k \leq 0.5$.

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APPENDIX B

$$v = v_f - \frac{v_f}{k_j}k \qquad v = v_f e^{\left(\frac{-k}{k_j}\right)} \qquad v = C\ln\left(\frac{k_j}{k}\right) \qquad Y = a - bX \qquad a = \frac{\sum Y}{n} - b\frac{\sum X}{n}$$

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

$$S_A = \frac{3600L}{T_R + d} \qquad d = d_1 * PF + d_2 + d_3 \qquad d_1 = \frac{0.5C\left(1 - \frac{g}{C}\right)^2}{1 - \left(\frac{g}{C}\right)min(X, 1.0)}$$

$$d_2 = 900T\left[(X-1) + \sqrt{(X-1)^2 + \frac{8kIX}{cT}}\right] \qquad I = 1.0 - 0.91X_u^{2.68} \qquad d_3 = \frac{1800Q_b(1+u)t}{cT}$$

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

$$u = 0 \; if \; t < T, \quad else \quad u = 1 - \frac{cT}{Q_b[1 - min(1, X)]} \qquad v_w = \frac{q_2 - q_1}{k_2 - k_1} \qquad X = \frac{v}{c}$$

$$c = s \times N \times \left(\frac{g}{C}\right) \qquad \tau_{min} = \delta + \frac{W + L}{v_o} + \frac{v_o}{2a} \qquad C_o = \frac{1.5L + 5}{1 - Y}$$

$$L = \sum l + R \qquad G_e = \frac{y}{Y}(C - L) \qquad G_a = G_e + l - \tau$$

$$If \; W_E > 3, \quad G_p = 3.2 + \frac{L}{S_p} + \left(2.7\frac{N_{ped}}{W_E}\right) \qquad If \; W_E \leq 3, \quad G_p = 3.2 + \frac{L}{S_p} + \left(0.27N_{ped}\right)$$

$$X_c = \sum\left(\frac{v}{s}\right)_c * \frac{C}{C - L} \qquad t_c = t_1 + \frac{(t_2 - t_1)(p - q)}{(r - s) + (p - q)} \qquad \lambda = \frac{V}{T} \qquad \mu = \lambda t$$

$$P(h \geq t) = e^{-\lambda t} \qquad P(h < t) = 1 - e^{-\lambda t}$$

$$Freq.(h \geq t) = (V - 1)e^{-\lambda t} \qquad Freq.(h < t) = (V - 1)(1 - e^{-\lambda t})Z$$