First Semester Examination
2020/2021 Academic Session

February 2021

EAL431 – Highway Design

Duration : 1 hour

Please check that this examination paper consists of **FOUR (4)** pages of printed material before you begin the examination.

Instructions : This paper contains **TWO (2)** questions. Answer **ALL** questions.

All questions **MUST BE** answered on a new page.

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1. (a). Roads are designed to conform to the requirements of the driver, traffic, and vehicle. The vehicle characteristics and dimension play a role in determining the road geometric design.

(i). Specify **THREE (3)** types of design vehicle and its abbreviation in accordance with the AASHTO specification

[5 marks]

(ii). Elaborate the relationships between the design vehicle with the turning radius and the driver eye height

[7 marks]

(b). A crest vertical curve for road hierarchy R4 passing through flat terrain topography is required for a road construction. The curve connects an uphill grade of 4% and downhill grade of 3.5%, respectively. The design speed is 90 km/h

Consider the following assumptions:
Driver's eye height = 0.92 m
Obstruction object height = 0.15 m
Stopping sight distance = 180 m
Acceptable centrifugal force for driver comfort = 0.3 m/s^2
K Value for Crest Vertical Curve (ATJ 8/86) = 59

State other assumptions used, if any.

(i). Calculate the length of the vertical curve based on the following criteria:
- Stopping sight distance
- Comfort

Also, calculate the length based on the given K value.

(ii). Based on these results, what is the minimum length of curve that you will adopt for design purposes? Justify your answer.

[23 marks]

(c). Cycling has emerged as a famous individual and family choice for sport activity. However, current approach of road design does not emphasise enough on the needs of bicycle lane. Based on your understanding;

(i). Provide sketches to include bicycle lane as part of the road cross section details.

(ii). Specify **TWO (2)** reasons why is it important to have specific lane for cyclist.

(iii). Explain **ONE (1)** approach how to protect the cyclist from the moving traffic (show in your sketch).

[15 marks]

2. (a). Horizontal curves provide transitions between two tangent lengths of roadway for the attainment of safe and smooth flowing roads. To attain a smooth transition of a road passing through a reserved forest, a simple circular curve that has a point of intersection at 17+50 m, with the tangent entry S78°W, and the tangent exit S75°E have been considered in the design work. The chord length of the curve is specified at 325 m. Based on the given information; you are required to:

(i). Sketch an appropriate diagram by considering all the information given

[5 marks]

(ii). Determine the tangent length and the radius of curve

[8 marks]

(iii). Calculate the curve length and the degree of curvature

[8 marks]

(b). Engineers had developed a basic set of conflict definitions for intersections, corresponding to the different types of maneuvers and related accident patterns. Explain the following intersection conflicts that are causing unwanted vehicle accidents:

(i). Same Direction Conflict

(ii). Cross Traffic Conflict

(iii). Pedestrian Conflict

[15 marks]

(c). Traffic Management Plans (TMP) is an important aspect that will be assessed during the Road Safety Audit (RSA). The TMP shows the placement and type of traffic control devices to be used in a work zone. It should be prepared and understood by all responsible parties before a construction site is occupied. With the aid of sketches, elaborate the types and arrangements of sign for the advance warning zone and the transition zone.

[14 marks]

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Answer Script

Question 1

[a] Roads are designed to conform to the requirements of the driver, traffic, and vehicle. The vehicle characteristics and dimension play a role in determining the road geometric design.

i. Specify **THREE (3)** types of design vehicle and its abbreviation in accordance with the AASHTO specification (3 Marks / *Markah*)

Answer

1. Passenger Car – P design vehicle
2. Rigid Truck – SU design vehicle
3. Semi-Trailer – WB-15 design vehicle

ii. Elaborate the relationships between the design vehicle with the turning radius and the driver eye height (4 Marks / *Markah*)

Answer

- Larger physical dimensions require larger turning radius. The largest of all the several design vehicles are usually accommodated in the design of freeways.

- Regarding the driver eye height, larger vehicle has higher driver eye height. P is lower compared to SU and WB-15

TABLE 3-1-DIMENSION OF DESIGN VEHICLES

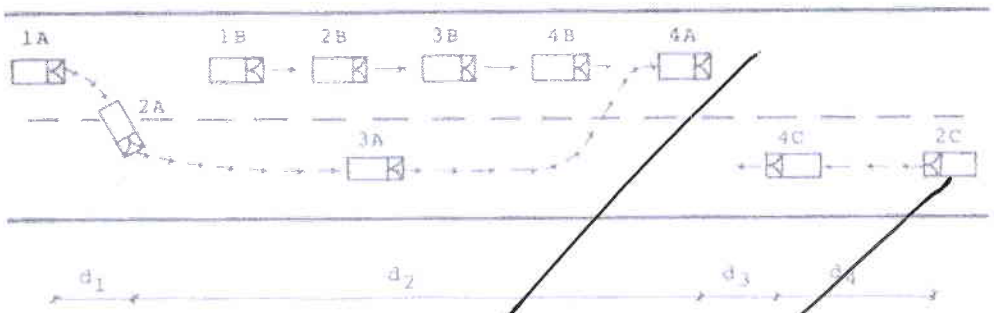
Design Vehicles		Dimension in Metres						Turning Radius (Metres)	
Type	Equivalent Type in AASHTO	Wheel base	Overhang		Overall Length	Overall Width	Height	Inner	Outer
			Front	Rear					
Passenger Car	P	3.4	0.90	1.5	5.8	2.1	1.3	4.2	7.3
Rigid Truck	SU	6.10	1.2	1.8	9.1	2.60	4.10	8.5	12.8
Semi-Trailer	WB-15	9.10	0.9	0.60	16.7	2.60	4.10	5.8	13.7

Note : A. Maximum allowable overall lengths under current Malaysian Legislation are as follows:
(i) Rigid vehicle - 12.2 m (40 ft)
(ii) Articulated vehicle - 16.0 m (52.5 ft)
(iii) Semi-Trailer - 12.5 m (41ft)
(iv) Trailer - 9.0 m (29.5 ft)
(v) Truck Trailer - 18.0 m (59 ft)

B. Maximum allowable overall width under current Malaysian Legislation is 2.5 m.

iii. Based on your understanding, sketch and label **FOUR (4)** distance components that fundamentally consider for the overtaking sight distance (3 Marks / *Markah*)

Answer



Hesitation Distance (d1)
The distance when a driver hesitates if it is safe or not for him to overtake.

Actual Overtaking Distance (d2)
The actual distance when the vehicle performs the overtaking activity and return to its original lane. It is assumed that the overtaking vehicle travels 16 km/h faster than the overtaken vehicle

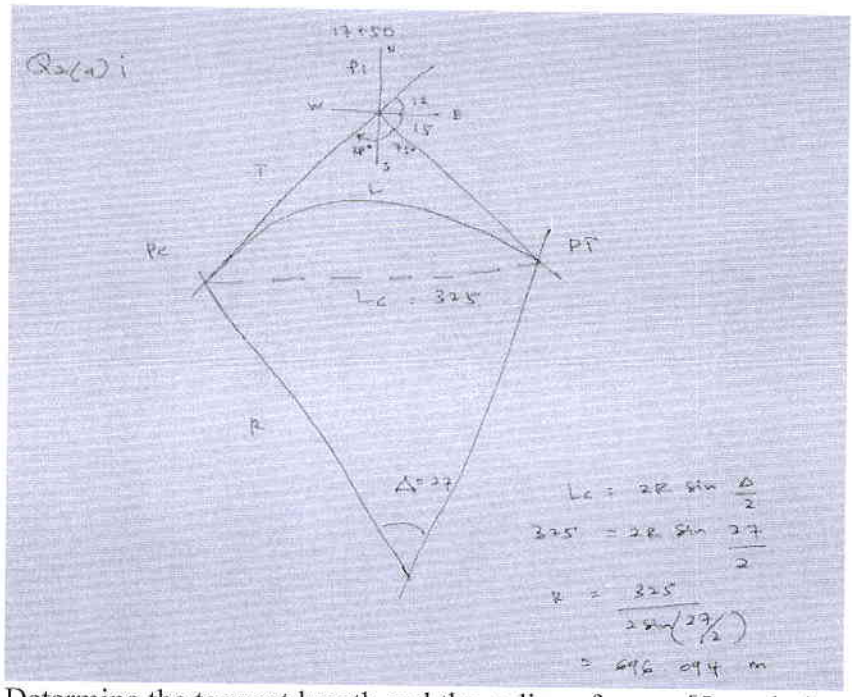
Safety Dimension (d3)
The distance between the overtaking vehicle returns to its original lane after completing overtaking with the opposing vehicle. Ideally, it should be as long as possible but assumed equivalent to distance traversed in 1.5 sec.

Distance Traversed by Vehicle C During Overtaking Operation (d4)
Opposing vehicle C assumed to travel at design speed. d4 is assumed equivalent to two-third the actual overtaking distance

Question 2

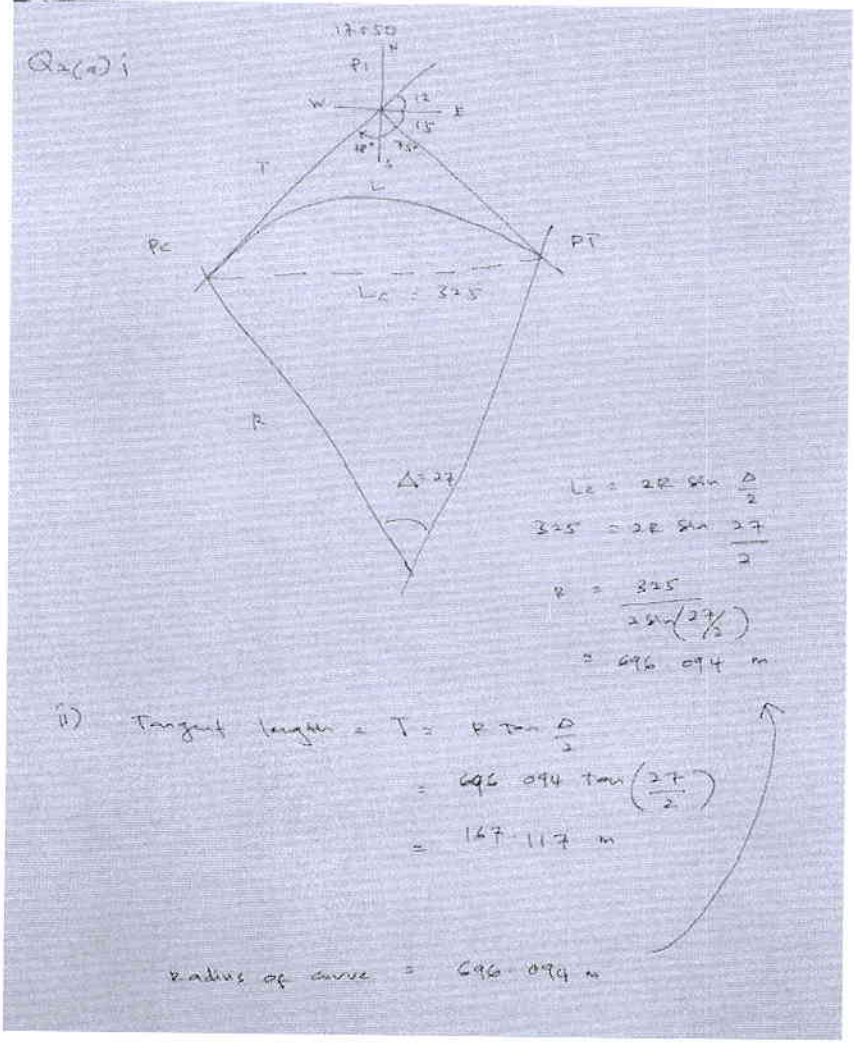
[a] Horizontal curves provide transitions between two tangent lengths of roadway for the attainment of safe and smooth flowing roads. To attain a smooth transition of a road passing through a reserved forest, a simple circular curve that has a point of intersection at 17+50 m, with the tangent entry S78°W, and the tangent exit S75°E have been considered in the design work. The chord length of the curve is specified at 325 m. Based on the given information; you are required to:

i. Sketch an appropriate diagram by considering all the information given [3 marks/*markah*]
Answer



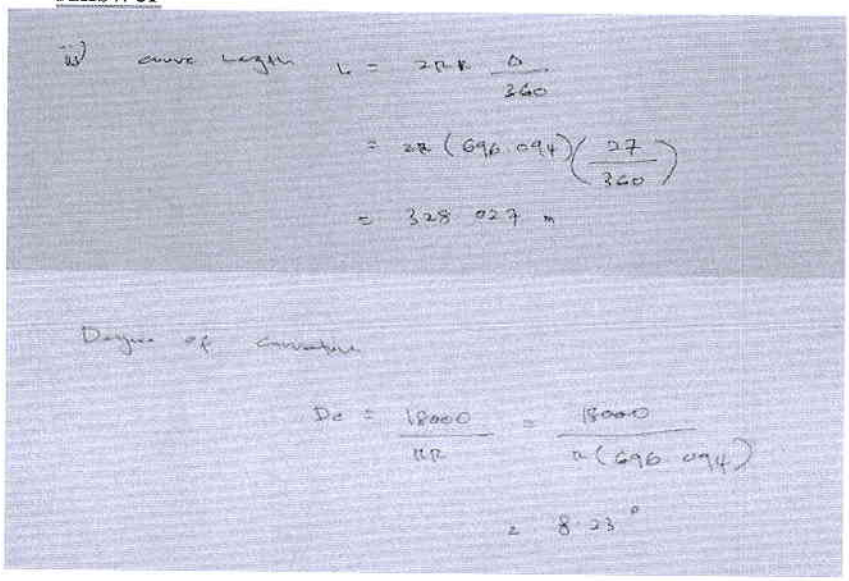
ii. Determine the tangent length and the radius of curve [5 marks/*markah*]

Answer



iii. Compute the curve length and the degree of curvature [5 marks/*markah*]

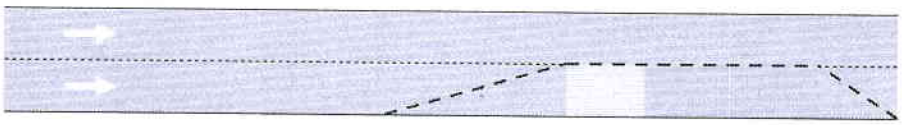
Answer



[c] Traffic Management Plans (TMP) is an important aspect that will be assessed during the Road Safety Audit (RSA) Stage 4. The TMP show the placement and type of traffic control devices to be used in a work zone. It should be prepared and understood by all responsible parties before a construction site is occupied. With the aid of sketches, elaborate the types and arrangements of sign for the advance warning zone and the transition zone. (7 Marks / *Markah*)

Answer

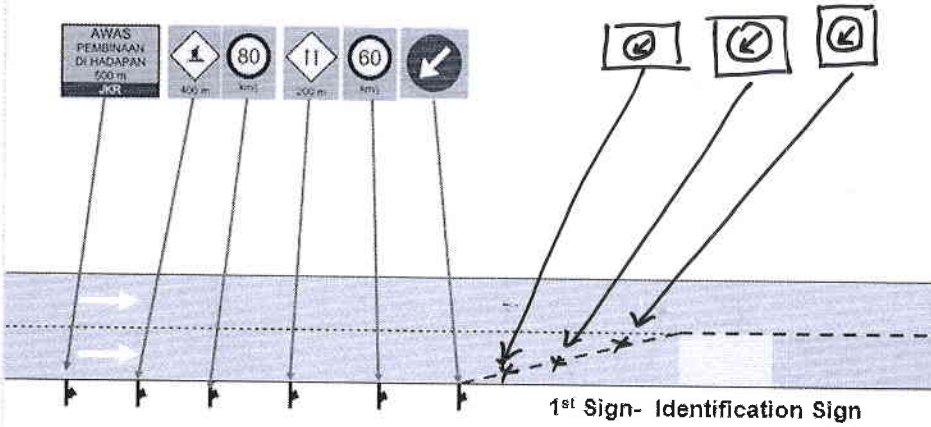
SIGN ARRANGEMENTS



		ZONE A ADVANCE WARNING	ZONE B TRANSITION	ZONE C BUFFER	ZONE D WORK AREA	ZONE E TERMINATE
URBAN						
Low Speed		USE	USE	USE	USE	USE
High Speed						
	1st Sign-	Identification Sign	ARROW SIGNS	ARROW SIGNS	ARROW SIGNS And SPEED LIMIT SIGNS	WARNING SIGN
RURAL	2nd Sign-	Info Sign				
Low Speed	3rd Sign-	Speed Sign				
High Speed	4th Sign-	Info Sign				
	5th Sign-	Speed Sign				
EXPRESSWAYS						
Low Speed						
High Speed						

TRANSITION

ADVANCE WARNING ZONE
- Sign Arrangements –



1st Sign- Identification Sign

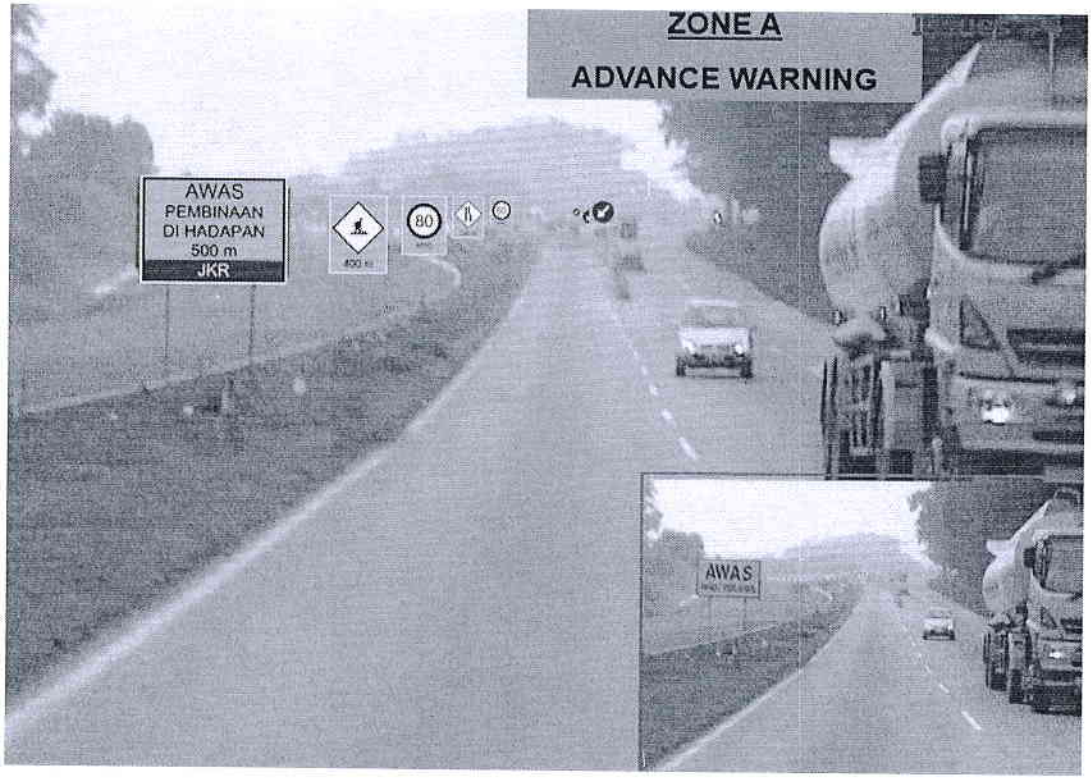
2nd Sign- Info Sign

3rd Sign- Speed Sign

4th Sign- Info Sign

5th Sign- Speed Sign

ARROW SIGN at start of Transition Area- To be placed on high post



Answer:

Stopping Sight Distance

a) Stopping Sight Distance

$S \leq L$

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

$A = |G_2 - G_1| = -3.5\% - 4\% = -7.5\%$

$= |-7.5| = 7.5$

for $S \leq L$

$L = \frac{(7.5)(180)^2}{200(\sqrt{0.92} + \sqrt{0.15})^2}$

$L = \frac{(75)(32400)}{200(0.959 + 0.387)^2}$

$= \frac{243,000}{200(1.8117)}$

$L = \frac{243,000}{362.34}$

$L = 670.6\ m$

$S > L$

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

$L = 2(180) - \frac{362.34}{7.5}$

$= 360 - 48.312$

$= 311.7\ m$

Do not satisfy the condition

Use K value as per ATJ(8/86)

Given $K = 59$

$K = L/A$, $L = KA$

$L = 59 \times 7.5 = 442.5\ m$

Minimum SSD is 160 m.

Comfort

Comfort

$L = \frac{AV^2}{13C} = \frac{(7.5 \times 25\ m/s)(25\ m/s)}{13(0.3\ m/s^2)}$

$= 1,201\ m$ #

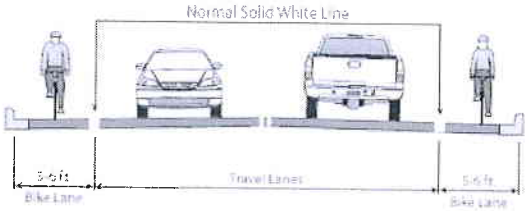
(ii) Based on these results, what is the length of curve that you will adopt for design purposes? Justify your answer.

Based on the calculation;

- the length of the curve equal to 311.7 m does not satisfy the condition for S > L. The length also less than the calculated length based on K value.
- the length of the curve equal to 670.6 meter is acceptable. It satisfies the condition for S < L and the difference from the length calculated based on K value is tolerable.
- Based on the comfort condition, the length of the curve is the longest (1201 m). The length of the curve is too long and uneconomical for construction purposes.
- Therefore, the length of the curve equal to 670.6 meter is acceptable. However, the value must be rounded to an equal number to ease construction purposes.

(b) Cycling has emerged as a famous individual and family choice for sport activity. However, current approach of road design does not emphasise enough on the needs of bicycle lane. Based on your understanding, propose your idea through sketches to include bicycle lane as part of the road cross section details. Give **TWO (2)** reason why is it important to have specific lane for cyclist. Also, suggest **ONE (1)** approach how to protect the cyclist from the moving traffic (show in your sketch).

Sketch:



Why bicycle lane is important?

1. A protected bicycle lane keep cyclist safe and improve safety for vehicles making right turns. Bike lanes add to the turning radius at driveways and intersections, reducing the risk of rear-end crashes. Higher probability that drivers can avoid utility poles and other fixed obstacles due to the greater area cleared of trees and other barriers to visibility. More space to place bus stops, improving safety for bus riders.

2. In urban area, with proper facilities, aprotected bicycle lane will encourage more people to commute using bicycle. Thus, reducing number of engine power vehicles and reducing Green House Gases effects.

How to protect the cyclist?

Build physical barriers that set off bike lanes can include plastic posts, trees and other plants, and even parked cars.

[9 Marks]

(c) Engineers had developed a basic set of conflict definitions for intersections, corresponding to the different types of maneuvers and related accident patterns. Based on your understanding, explain the following intersection conflicts that are causing unwanted vehicle accidents:

- Same Direction Conflict

  - A same-direction conflict occurs when the first vehicle slows and/or changes direction and places the following vehicle in danger of a rear–end collision. The second vehicle brakes or swerves to avoid the accident, then continues to proceed through the intersection area. Four basic types of same-direction conflicts are 1) left turn - same direction conflict, 2) right turn - same direction conflict, 3) slow vehicle - same direction conflict, and 4) lane change conflict.

- Cross Traffic Conflict

  - A cross-traffic conflict occurs when a vehicle (In the cross street turns or crosses into the path of a second vehicle on the main street who has the right-of–way and places the second vehicle in danger of a rear-end, sideswipe, or broadside collision. The second vehicle brakes or swerves to avoid the collision, then proceeds through the intersection area.

- Padestrian Conflict

  Pedestrian conflicts occur when a pedestrian (the road user causing the conflict) crosses in front of a vehicle that has the right–of–way, thus creating a possible collision situation. The

vehicle brakes or swerves, then continues through the intersection area. However, the pedestrian movements on the right and left sides of the intersection are generally not considered to create conflict situations if the movements have the right–of-way, such as during traffic-light WALK phase.

[6 Marks]