Chapter 4

Traffic Engineering

CHAPTER HIGHLIGHTS

- *Introduction*
- *Traffic studies*
- *Traffic speed studies*
- *Speed and delay studies*
- *Origin and destination studies*
- *Accident studies*
- *Traffic flow characteristics*
- *Speed–Flow–Density relations*
- *Derived characteristics*
- *Traffic stream models*
- *Traffic regulation and control*
- *Types of traffic signals*
- *Design of rotary*
- *Road intersections*
- *Interchanges*
- *Parking*
- *Highway lighting*

Introduction

Traffic Engineering is that branch of engineering which deals with the improvement of traffic performance on road network and terminals through systematic traffic studies, scientific analysis and engineering applications. It also includes planning and geometric design on one hand and regulation and control on other.

Traffic Studies

Traffic Volume Study (q)

Traffic volume or flow is expressed as number of vehicles that pass across a given transverse line of the road during unit time. In this study the type and the number of vehicles are counted either manually or by using mechanical or automatic counters.

Method of Volume Count

Manual Count (Best Method) By manual count, it gives data which cannot be collected by mechanical or automatic counts.

1. Classification of different vehicles and their counts at required time.
2. Direction wise and turning movements at intersections.
3. Details of pedestrian volume counts.

Draw back: It is not practicable to carry out manual count of different vehicle classes during 24 hours of a day for 365 days.

Automatic Counters

1. Photo electric cell
2. Electrical method
3. Pneumatic method

- Advantage of it is that it can work throughout the day and night for desired period, recording exact time at which each vehicle crosses. Lane occupancy and speeds of different vehicles can be recorded.
- Drawback is that it cannot classify and record every vehicle type and details of turning movements and also pedestrian flow.
- Suitable for long counts and for permanent installations
- In view of variety of vehicles, based on the vehicle speed, space and characteristics a number is assigned to the vehicle in comparison to car termed as 'Equivalent passenger car unit' (PCU). Using the values in table, the

traffic can be expressed uniformly in terms of passenger car unit (PCU) per hour or per day

Vehicle Type	PCU
Passenger car, Tempo, Jeep, Auto rickshaw, Van, Agricultural tractor	1
Bus, Truck, Agricultural tractor trailer	3
Motor cycle, scooter and cycle	0.5
Cycle rickshaw	1.5
Horse drawn vehicle	4
Bullock cart	8
Small bullock cart	6
Hand cart	6

- As per IRC, traffic counts are taken twice in a year for a village. One during peak season of harvesting and marketing and other during the lean season. It shall be taken for 7 consecutive days and 24 hours each day (24 × 7).

Presentation of Traffic Volume Data

1. **Average annual daily traffic (AADT):** It is the average daily (24 hours) traffic volume recorded for all the 365 days of the year.
2. **Average daily traffic (ADT):** Average daily traffic volume recorded for a period less than a year (6 months, a season, a month, a weak, or 2 days)
3. **Trend charts:** Shows volume trends over period of years. It is used in estimating the rate of growth and for planning future expansion, design and regulation.
4. **Variation charts:** Variation of flow (hourly, daily and seasonally) are prepared. These help in facilitating or regulating traffic at peak traffic periods.
5. **Traffic flow maps:** Traffic flow lines along the routes are drawn. The thickness of the lines represents the traffic volume to any desired scale.
6. Volume flow diagram at intersections to a scale.
7. **30th highest hourly volume:** The hourly volume that will be exceeded only 29 times in a year and all other hourly volumes of the year will be less than this volume.
   - Congestion only during 29 hours in the year.
   - Generally taken as hourly volume for design.
   - Highway facilities are designed for this volume, as it is satisfactory from both facility and economic considerations.
8. **Peak hour factor:** It is in terms of traffic volume during peak hour and it is expressed as percentage of AADT. This peak hour factor is used in the design of transportation facilities of urban transport infrastructure projects.

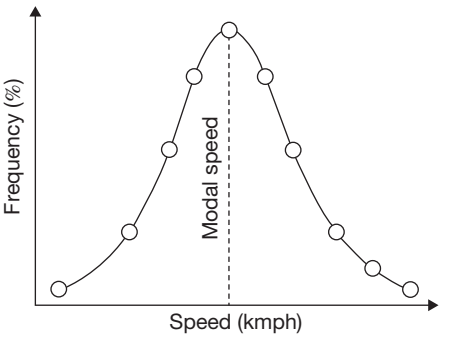
Traffic Speed Studies

1. **Spot speed:** It is the instantaneous speed of a vehicle at specified cross section or location.
2. **Average speed:** It is the average of spot speeds of all the vehicles passing a given point on the highway.
3. **Running speed:** It is the average speed maintained by a vehicle over a particular stretch of road (delays are excluded).
4. **Travel/overall/journey speed:** It is the effective speed of travel all along the route between two terminals (delays are included).

Methods for Spot Speeds

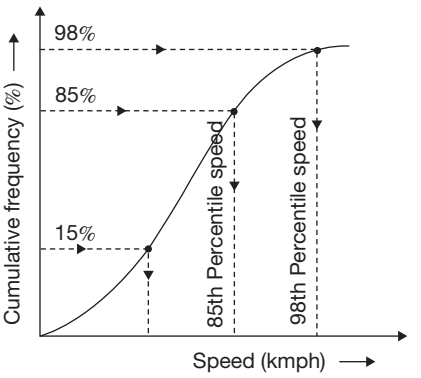
- Radar speed meter method (speed gun and is most efficient and easy to use).
- Electronic meter method.
- Photo-electric meter.
- Enoscope/mirror box method.
  - Mirrors are arranged at 45°.
  - Simple cheap and easy to use.
  - Difficult for heavy multilane traffic and slow method
- Time lapse method
- Pressure contact strip method

Presentation of Spot Speed Data



Frequency distribution diagram

- **Modal speed:** speed at which greatest number of vehicles travel. It is peak of frequency distribution curve.



Cumulative speed distribution diagram

- **98th percentile speed:** For the purpose of highway geometric design (design speed).
- **85th percentile speed:** The speed at or below which 85% of vehicles are passing a point on the highway or only 15% of vehicles exceed the speed at that point (upper speed limit).

  This is adopted for safe seed limit at this zone.
- **15th percentile speed:** The speed value which is used as minimum speed on major highways.
- **50th percentile speed:** The middle or 50th percentile of spot speed is called median/medium speed (median speed).

Types of Spot Speeds

1. **Space mean speed (V_s):** It is the average speed of vehicles in a certain road length at any specified time period. This is the harmonic mean of spot speeds.
2. **Time mean speed (V_t):** It is the average speed of vehicles passing a certain point over some specified time period on a highway.

   It is the **average/mean of spot speeds:**
   - (Average travel time of all vehicles)
     $= \frac{1}{\text{Space mean speed}}$.
   - Space mean speed is slightly lower than time mean speed under typical speed conditions on rural highways

$$V_t = V_s + \frac{\sigma^2}{V_s}$$

   σ^2 = Standard deviation.

   Both space and time mean speeds will be equal only when all vehicles are travelling at the same speed.

Speed and Delay Studies

- Floating car or riding check method
- License plate or vehicle number method
- Interview technique
- Elevated observations
- Photographic technique

Origin and Destination Studies

1. **Methods of conducting *O* and *D* studies:**
   - Road side interview method
   - License plate method
   - Return post card method
   - Tag on car method
   - Home interview method
   - Work place interview method
2. **Applications:**
   - Planning and design of highways (routes and terminals)
   - To improve existing road network.
   - Estimation of future traffic needs.
   - To locate terminal and intermediates stops and plan out facilities for public transport.
   - To locate new bridge if demanded and planning for interchanges.
3. **Presentation of *O–D* data:**
   - '*O*' and '*D*' tables showing number of trips between different zones.
   - Desire lines: (Graphical representation) These are straight line connecting origin with destination in different areas.

     Width of the line represents number of trips.

     Desire line density map enables to decide the interest of road users and helps to find the necessity of new road link, derision, by pass or a new bridge.
   - **Pie charts:** Circles are drawn and diameter is proportional to number of trips.
   - **Contour lines:** Similar to topographic contours shape of contours would indicate general traffic needs of the area.

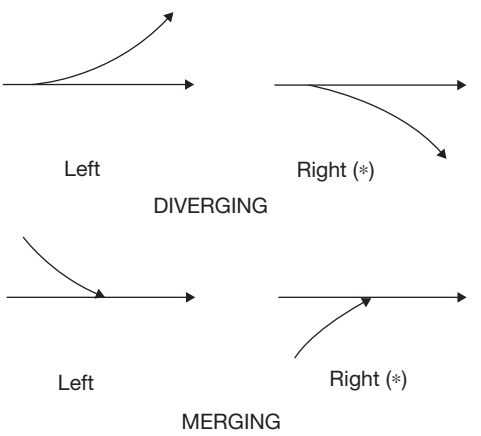
Accident Studies

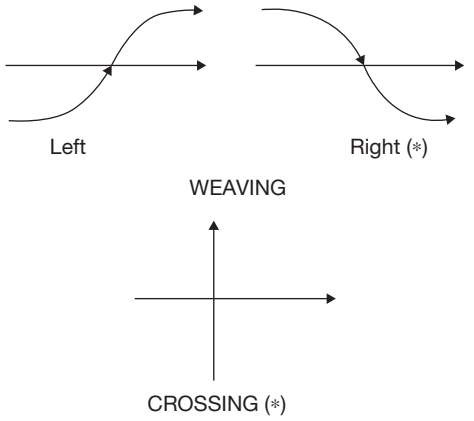
- Accident records are maintained giving all particulars of the accidents, location and other details.
- Collision diagrams are drawn which show the path of vehicle and pedestrians involved in accident. These diagrams are useful to compare the accident pattern before and after the remedial measures are taken.
- Individual and statistical analysis of accidents are done.

Traffic Flow Characteristics

The basic traffic manoeuvres in a traffic stream are

1. Diverging
2. Merging
3. Crossing manoeuvres

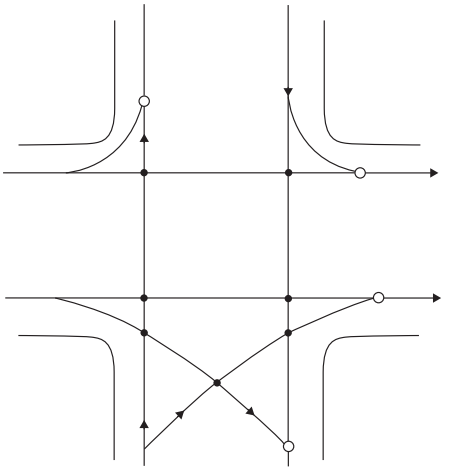




- The manoeuvres with (*) represent conflicting traffic.
- Merging from and diverging to left do not cause much problem.
- Diverging to and merging from right create conflict points.
- Weaving manoeuvre, i.e., merging and diverging in a short stretch always creates a conflict point.
- Crossing also causes a problem where road at a time results in considerable reduction in flow on one capacity of the intersection.

Number of Conflict Points on Cross Roads of Different Number of Lanes

Number of Lanes		Number of Potential Conflicts		
Road A	Road B	Both Roads Two Way	A-One Way B-Two Way	Both Roads One Way
2	2	24	11	6
2	4	32	17	10
4	4	44	25	18



Conflicts on cross roads with one road as one way:

Major conflicts crossing = 7
Minor conflicts = 4
Merging total = 11

Speed–Flow–Density Relations

1. **Traffic density (*K*):** The number of vehicles occupying a unit length (1 km) of a lane of roadway at a given instant

   $S \rightarrow 1$ vehicle

   $(1\text{ km}) = 1000 \rightarrow K = ?$

   $K = \dfrac{1000}{S}$ = Number of vehicle/km [per lane at an instance of time]

   S = Average c/c distance between two successive vehicles.

NOTES

1. Under free flow condition (with design speed) or road empty without traffic condition, density is least.
2. A traffic jam condition before red signal (if all vehicles stopped on road) maximum density will be achieved called 'Jam Density' (K_{max}).

2. Traffic volume $\left(\dfrac{\text{Vehicle}}{\text{hour}}\right) \Rightarrow \boxed{q = V \cdot K}$

   Where

   V = Speed of vehicles (km/hour)

   K = Traffic density (veh/km)

3. **Capacity (C or q_{max}):**

$$C = q_{max} = V\left(\frac{1000}{s}\right)$$

It is the ability of the roadway to allow maximum traffic flow or traffic volume per unit time.

Where

V = Design speed (km/h)

S = c/c spacing of vehicles

(a) Basic/theoretical/ideal capacity: The maximum number of vehicles that pass a given point on a lane or road way during one hour under ideal road way and traffic conditions.

$S = L + 0.7\,V$ in m
S_L = Lag distance = $0.7\,n$
ϑ = Design speed (m/s)
L = Length of rigid wheel base (m) = 6.1 m
t = Reaction time of ideal driver (0.7 second)

- Two roads of same features will be same basic capacities

(b) Practical/design capacity: The maximum number of vehicles that can pass a given point so that they may not cause unreasonable delay, hazards and restrictions to driver's freedom to manoeuvres under the prevailing road

conditions. This is of primary interest to the designers

$S = L + \text{SSD}$

SSD = Stopping sight distance

L = Length of rigid wheel base (6.1 m)

Derived Characteristics

- Derived parameters from speed (V), flow (q), density (k) are:

1. **Time headway (*Ht*):** It is the time gap between two successive vehicles crossing a section of a road,

$$H_t = \frac{1}{q} = \text{h/veh}$$

- Minimum time headway, $H_t = \frac{1}{q_{max}} = \frac{1}{c}$ h/veh
- Maximum theoretical capacity, $q_{max} = C = \frac{3600}{H_t}$

σ…(H_t in seconds)

2. **Space/distance headway (*S*):** It is the average distance between two successive vehicles on the road or it is reciprocal of traffic density,

$$S = \frac{1}{K} \text{ km/veh}$$

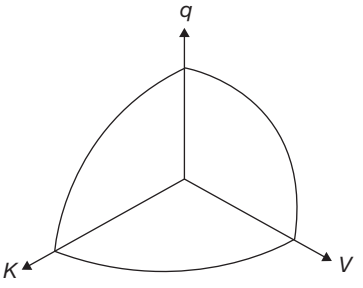
- Maximum space headway = $\frac{1}{K_{max}}$ (At Jam density)

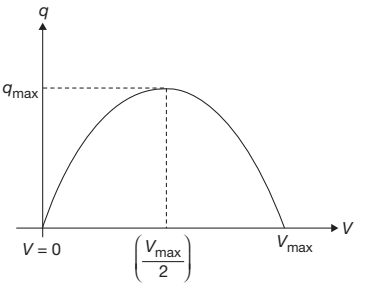
Traffic Stream Models

Green Shield's macroscopic stream model: He assumed a linear speed–density relationship.

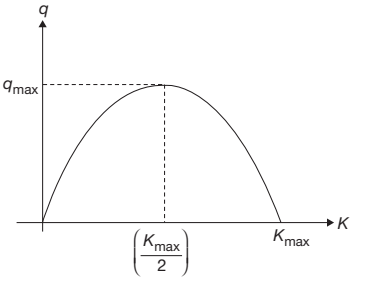
$$V = V_f\left[1 - \frac{K}{K_j}\right]$$

$$Q = VK = V_f\left[1 - \frac{K}{K_j}\right]K$$

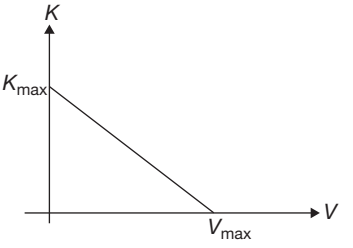




V_{max} = Free flow speed/free mean speed



K_{max} = Maximum Jam density



$$q_{max} = \left(\frac{V_{max}}{2}\right)\left(\frac{K_{max}}{2}\right)$$

SOLVED EXAMPLES

Example 1

The free mean speed on a roadway is found to be 70 km/h. Under stopped condition the average spacing between vehicles is 6.9 m. Determine the capacity of flow (in vehicles/km).

(A) 120 (B) 145
(C) 160 (D) 175

Solution

Spacing between vehicles $S = 6.9$ m

$$\text{Jam density } k_{max} = \frac{1000}{s} = \frac{1000}{6.9}$$

$$k_{max} = 145 \text{ vehicle/km}$$

Hence, the correct answer is option (B).

Example 2

Estimate the theoretical capacity of a traffic lane with one way traffic flow at a stream speed of 50 km/h. If the

average space gap between vehicles to follow the relation $S_g = 0.278Vt$, where V is stream speed (km/h), t is the average reaction time = 0.7 second, assume average length of vehicles = 5 m (capacity in vehicles/hours/lane).

(A) 3260 (B) 3390
(C) 3470 (D) 3580

Solution

$$V = 50 \text{ km/h}$$

c/c spacing of vehicles S

$$= 0.278\ Vt + L$$
$$= 0.278 \times 50 \times 0.7 + 5$$
$$= 14.73 \text{ m.}$$

$$\text{Theoretical capacity, } q = \frac{1000}{S}$$

$$= \frac{1000 \times 50}{14.73}$$

$$= 3394.43 \text{ vehicles/hour/lane}$$

$$q \simeq 3390 \text{ vehicles/hour/lane}$$

Hence, the correct answer is option (B).

Traffic Regulation and Control

To have safe traffic operations on roads, it is desirable to impose adequate traffic regulations and traffic control by providing traffic control devices

Traffic Control devices are:

1. Traffic signs
2. Traffic signals
3. Traffic islands
4. Road markings

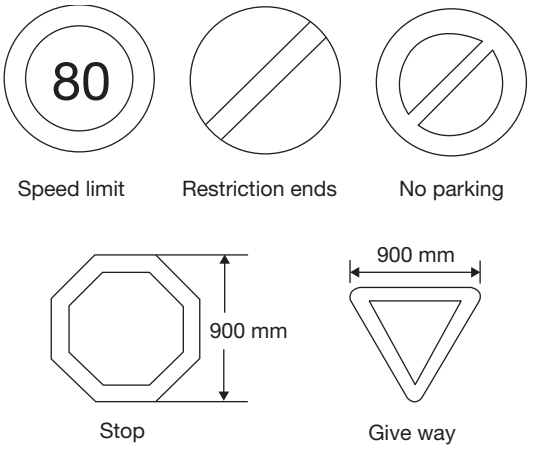
Traffic Signs

There are used with the objective of regulating, warning and guiding the users of motor vehicles

1. **Regulatory/mandatory signs:** These signs are provided to inform the road users certain laws, regulations and prohibitions.

   These are circular in shape, with white colour interior and red border or width 60 mm
   - Stop sign is of octagonal shape and red in colour with a white border of width 30 mm
   - violation of regulatory signs is a legal offence

   Example: No entry, U turn, right turn prohibited, Horn prohibited, speed limit
2. **Warning signs:** These are to warn the road users of certain hazardous conditions that exist on or adjacent to roadway.



These are represented by equilateral triangle with its apex upwards with white background red board and black symbol.

Example: Sharp curve, Narrow bridge, School zone, T-intersection, hill or ghat road.

3. **Informatory or guiding signs:**
   - These are rectangular in shape and used to guide the road users along routes, inform them of destination and the distance, and thus gives information to make travel easier, safe and pleasant.
   - On NH and SH, the informatory signs are of green back ground with borders and words in white colour.

   Example: Destination signs, Direction signs, Route marker signs, Hospital, eating places, etc.
   - (Refer text books for more traffic signs)

Traffic Signals

Provided at intersections where there are a large number of crossing and right turn traffic and there is possibility of several accidents.

- The time elapsed from the beginning of getting red to a particular side to the beginning of next red to the same side is called '**Cycle**'.
- Traffic control signals have three coloured lights

  Red: Vehicles must stop
  Amber: indicates change of signal
  Green: Vehicles can proceed

Types of Traffic Signals

1. **Traffic control signals:**
   (a) Manually operated signals
   (b) Fixed time automatic signals
   (c) Automatic traffic actuated signals
2. **Pedestrian signal:**
   - For pedestrian control
   - It has only Green and Red

3. **Special traffic signal:** 'Flashing beacons' may be installed at certain locations in order to warm the traffic of certain situations.
   - Flashing red signals, are to stop before entering a stop line/cross walk.
   - Flashing yellow signals are cautionary signals to signify that drivers may proceed with caution.

   Signal design methods:
   (a) Trial cycle method
   (b) Approximate method based on pedestrian crossing requirement
   (c) Design based IRC guidelines

4. **Weber's method:**
   - This is an analytical approach of determining the optimum cycle time.
   - 'Optimum signal cycle time' corresponds to least overall delay.
   - Normal flow (q) and saturation flow (S) values per unit time on each road meeting at junction are required for signal design.
   - Optimum cycle time, $C_0 = \dfrac{1.5L+5}{1-Y}$
   - Green time on road 1

   $G_1 = \dfrac{y_1}{Y}(C_0 - L)$
   $Y = y_1 + y_2 + y_3 + \cdots$
   L = Lost time per cycle in seconds = $2n + R$
   N = Number of phases
   R = All red time

   $$Y_1 = \frac{q_1}{S_1} : y_2 = \frac{q_2}{S_2} ; y_3 = \frac{q_3}{S_3}$$

   Effective green time:
   - It is the actual time available for the vehicles to cross the intersection
     (Effective green time = Total Green + Yellow – Lost time)
     (Lane capacity: (q_{max}))

   $$Q_{max} = S_i \frac{g_i}{C_0}$$

   S_i = Saturation flow on ith lane

   $\dfrac{g_i}{C_0}$ = Green ratio

   G_i = Effective green time on ith lane
   C_0 = Cycle time

   Green time for pedestrian crossing:

   $$G_p = t_s + \frac{W}{u_p}$$

   t_s = Start up lost time (As per IRC = 4.7 s)
   W = Width of road
   u_p = Walking speed of pedestrians (15% speed, 1.2 m/s as per IRC)

5. **Traffic islands:** The raised areas constructed within the roadway to establish physical channels through which vehicles can move freely.

   Based on function, traffic islands may be classified as
   (a) Divisional islands: Kerbs which just divide the road into lanes to prevent accidents and head on collisions.
   (b) Channelising islands: To guide the traffic into proper channel through the intersection area at grades especially when the area is large.
   (c) Pedestrian loading/refuge islands: Provided at bus stop after two or three lanes for crossing multilane highways to cross the roads.
   (d) Rotary island: This is larger than channelizing islands and provided at an intersection when number of intersection legs are five or more and all are of equal importance.

Design of Rotary

Design speeds are reduced to 40 km/h for rural highways and 30 km/h for roads in urban areas rotaries can be circular, elliptical, tangential, turbine, etc.
(Turbine is most efficient)

1. **Weaving angle and weaving length:** The angle between the path of a vehicle entering the rotary to that of another vehicle leaving the rotary is called weaving angle.

   It should be small, but ≥ 15°.

   The length of rotary road way between any two adjacent channelising islands is called weaving length.

2. **Radius of rotary:**
   - As per IRC
     Minimum Radius of central island = 1.33 (Radius of entry curve)
   - Radius is calculated keeping super elevation, $e = 0$ and longitudinal coefficient of friction, $f = 0.43$ to 0.47.

3. **Width of carriageway at entry and exit:** Minimum width at entry = 5 m

4. **Width of rotary road way:**

   $$W = \left[\frac{e_1 + e_2}{2}\right] + 3.5$$

   Where
   e_1 = Average width at entry
   e_2 = Average width at non weaving section
   - Practical capacity of rotary road way,

   $$Q_p = \frac{280w\left\{1+\left(\dfrac{e}{w}\right)\right\}\left\{1-\left(\dfrac{p}{3}\right)\right\}}{\left(1+\dfrac{w}{L}\right)}$$

Where

w = Width of weaving section

$e = \frac{e_1 + e_2}{2}$ and $\frac{e}{w} \simeq (0.4 \text{ to } 1.0)$

L = Weaving length

p = Proportion of weaving traffic

$= \frac{b+c}{a+b+c+d}$

b, c are crossing/weaving traffic while entering/leaving rotary.

a, d are non weaving traffic at rotary.

Road Intersections

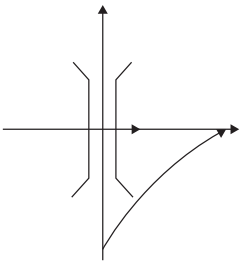
An intersection is where two or more roads join or cross.

1. **Grade intersection:**
   - In this roads cross each other at same level.
   - Relative speed and manoeuvre areas are to be considered in design.
   - During the design, attempts should be made to minimise be the total conflict area, especially major conflict area.
     (a) Un-channelised intersections
     (b) Channelised intersections
     (c) Rotary intersections
     (d) Signalised intersections
2. **Grade separated intersection/interchange ramps (Fly over):**
   - In this roads cross each other at different levels.
   - This causes least delay and hazard to traffic flow and is the highest form of intersection treatment.
   - A bridge is an interchange without ramps.

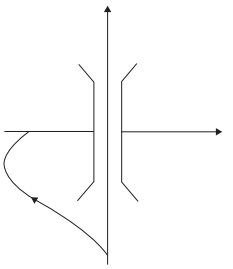
Interchanges

Interchanges are classified as:

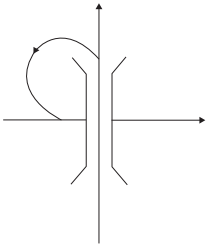
1. Direct
2. Semi-direct
3. Indirect



Direct



Semi-direct



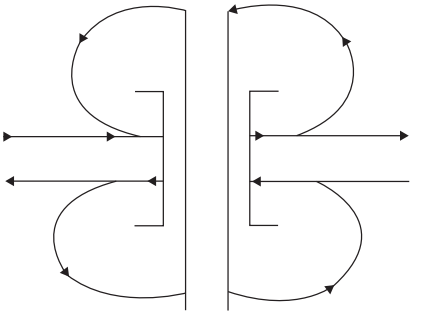
Indirect

Diamond interchange: Provides for transfers of traffic from one road to another crossing, but with reduced speed.

- Used in built-up area

Cloverleaf interchange:

- This is a high speed interchange with least number of conflicts.
- Right turning traffic is completely eliminated.
- Used in open country, when two high speed roads meet at a function.

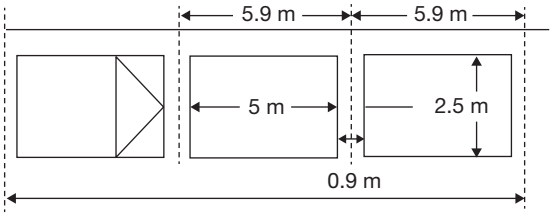


Parking

On Street or Kerb Parking

- Vehicles are parked along the park.
- Width of the kerb required for parking depends on angle of parking.

1. **Parallel parking:**
   - Parallel parking needs less roadway width.
   - This is preferred when the width of kerb parking space and the width of the street are limited.
   - The number of vehicles that can be parked per unit length of road is least.

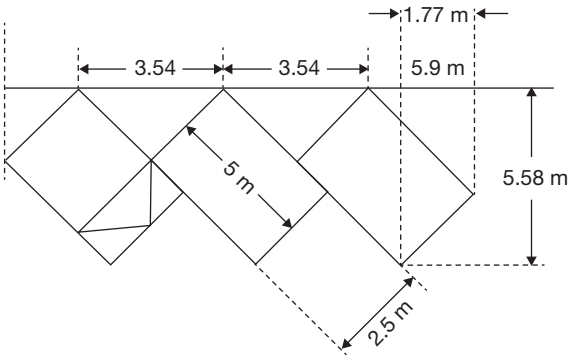


Number of vehicles that can be parked,

$$N = \frac{L}{5.9}$$

2. **Angle parking:**
   - Width of roadway for parking and width required for parking and un-parking operations increase with increase in parking angle up to a maximum at 90° angle.
   - This parking accommodates more vehicles per unit length of kerb.
   - Maximum number of vehicles can be parked at 90°.
   - More convenient for drivers for parking and un-parking operations, but cause more obstruction to the through traffic resulting in accidents.

- **45° Angle parking is considered to be best considering all factors.**



45° Angle parking

- Number of vehicles that can be parked $N = \left(\frac{L - 1.77}{3.54}\right)$ (for 45° parking)

Off Street Parking

- When parking facility is provided at a separate place away from the road side or kerb, it is known as off-street parking.
- There is no due increase in congestion, delay and hindrance to moving traffic as in on street parking.
- Drawback is that it is not possible to provide it at close intervals in business centres of a city and also vehicle users have to walk a greater distance after parking.

Highway Lighting

- As per IRC, the minimum illumination required on important roads is 30 Lux and main roads is 15 Lux

$$\text{Spacing of lamps} = \frac{\text{Lamp lumen} \times \text{Coefficient of utilization} \times \text{Maintenance factor}}{\text{Average lux on road} \times \text{Width of read}}$$

NOTE

Generally maintenance factor is taken as 80%

Exercises

1. The road geometrics in India are designed for the
(A) 98th highest hourly traffic volume.
(B) 85th highest hourly traffic volume.
(C) 50th highest hourly traffic volume.
(D) 30th highest hourly traffic volume.

2. The speed and delay studies on a defined section of high way are conducted by
(A) radar gun.
(B) traffic counters.
(C) moving car method.
(D) enoscope.

3. Name the traffic survey data which is plotted by means of 'desire lines'.
(A) Accident (B) Classified volume
(C) Origin and destination (D) Speed and delay

4. If a two-lane national highway and a two-lane state highway intersect at right angles, the number of potential conflicts points at the intersection, assuming that both the roads are two-way is
(A) 11 (B) 17
(C) 24 (D) 32

5. The average daily traffic on a stretch of road is 300 commercial vehicle per lane per day. Design traffic repetitions for 10 years when vehicle damage factor is 2.5 and traffic growth rate is 7%, is

(A) 3.8 msa (B) 23.5 msa
(C) 45.4 msa (D) 16 msa

6. A traffic stream in a particular direction of a two lane road is moving with a constant speed of 50 km/h, with an average headway of 2.52 seconds. The longitudinal distance between two consecutive vehicles is

(A) 30 m (B) 35 m
(C) 38 m (D) 42 m

7. A traffic company operates a scheduled daily truck service between city *P* and city *Q*. One-way journey time between these two cities is 85 hours. A minimum layover time of 5 hours is to be provided. The number of trucks required to operate daily service from both the cities *P* and *Q*?

(A) 4 (B) 6
(C) 7 (D) 8

8. A single lane unidirectional highway has a design speed of 65 km/h. The perception-brake-reaction time of drivers is 2.5 seconds and the average length of vehicles is 5 m. The coefficient of longitudinal friction of the pavement is 0.4. The capacity of this road in terms of 'vehicles' per hour per lane is

(A) 1440 (B) 750
(C) 710 (D) 680

9. On a urban road, the free mean speed was measured as 70 km/h and the average spacing between the vehicles under jam condition s 7.0 m. The speed-flow-density equation is given by

$$U = U_{sf}\left[1 - \frac{k}{k_j}\right]$$

Where

U = Space-mean speed (km/h);
U_{sf} = Free mean speed (km/h);
k = Density (veh/km);
k_j = Jam density (veh/km);
q = Flow (veh/h).

The maximum flow (veh/h) per lane for this conditions is equal to

(A) 2000 (B) 2500
(C) 3000 (D) None of these

10. On a specific highway, the speed-density relationship follows the Greenberg's model [$V = V_r \log_e(k_j/k)$], where V_r and k_j are the free flow speed and jam density respectively. When the highway is operating at capacity, the density obtained as per this model is

(A) ek_j (B) k_j
(C) $\frac{k_j}{2}$ (D) $\frac{k_j}{e}$

11. For designing 2-phase fixed type signal at an intersection having north-south and east-west road where only straight ahead traffic is time lost per cycle is 12 seconds. The cycle length (seconds) as per Webster's approach is

Parameter	North	South	East	West
Design hour flow (PCU/h)	1000	700	900	550
Saturation flow (PCU/h)	2500	2500	3000	3000

(A) 67 (B) 77
(C) 87 (D) 91

12. On a two-lane two-way highway, a car A was following a truck B and both were traveling at a speed of 40 km/h. While looking for an opportunity to overtake the truck, The driver of the car A saw another car C coming from the opposite direction. At that moment, the distance between A and C was 450 m. After an initial hesitation period of two seconds, the driver of car A started the overtaking operation. The distance between A and B at that instance was 30 m. A over took B by accelerating at an uniform rate of 1.20 m/s^2. When the overtaking operation completes. There was a distance of 25 m between B and A. Determine the distance between the two cars(A and C) at the instance of completion of the overtaking action(in meters). The distance between different vehicles given are as measured from the front bumper of one vehicle to the front bumper of another vehicle. Design speed of the highway is 80 km/h.

13. The vehicle speed affects the design of

(A) sight distance.
(B) super elevation.
(C) length of transition curve.
(D) All of these

14. The speed at which (or) below which 85 per cent of vehicles are passing the point on highway can be assessed is known as

(A) 85th percentile speed.
(B) 20th percentile speed.
(C) 15th percentile speed.
(D) 25th percentile speed.

15. The method of origin and destination studies in which the car is struck with a pre-coded card as it enters the area under study is

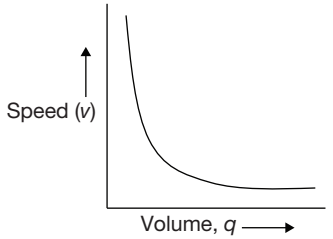
(A) road side interview method.
(B) home interview method.
(C) license plate method.
(D) tag on car method.

16. When a vehicle moves obliquely across the path of another vehicle moving in same direction at small angle of crossing is termed as

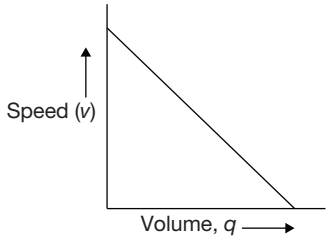
(A) merging. (B) weaving manoeuvre.
(C) crossing manoeuvre. (D) diverging.

17. Which of the following graph represents relation between speed and volume?

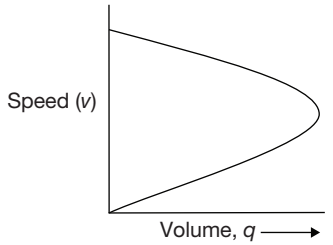
(A)



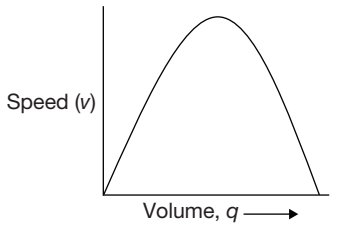
(B)



(C)



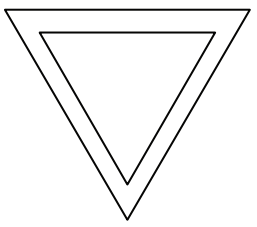
(D)



18. The free mean speed on a roadway is found to be 100 km/h under stopped condition the average spacing between vehicles is 8.9 m. The Jam density of flow is
(A) 113 vehicles/km.
(B) 118 vehicles/km.
(C) 145 vehicles/km.
(D) 148 vehicles/km.

19. The maximum number of vehicles that can pass a given point on a lane or roadway during one hour under prevailing traffic conditions is known as
(A) basic capacity.
(B) practical capacity.
(C) possible capacity.
(D) highway capacity.

20.



The above sign is categorized under
(A) warning signs.
(B) regulatory signs.
(C) informatory signs.
(D) None of these

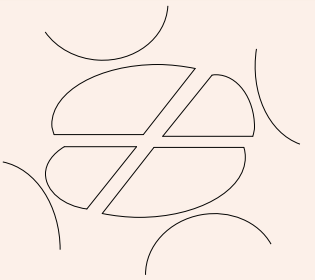
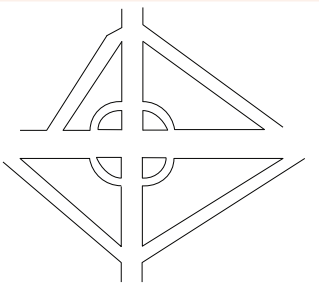
21. The theoretical capacity of traffic lane with one way traffic flow at a stream speed of 80 km/h. The average space gap $S_g = 0.278\ Vt$ and average length of vehicles = 8 m
(A) 3450 veh/h/lane (B) 3395 veh/h/lane
(C) 3530 veh/h/lane (D) 3834 veh/h/lane

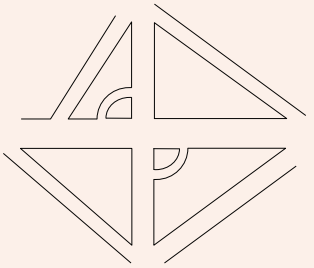
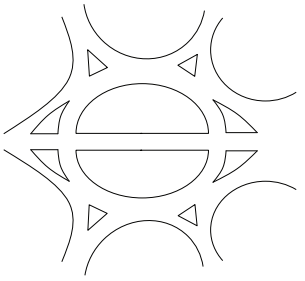
22. The average normal flow of traffic on cross roads A and B during design period are 400 and 250 PCU per hour, the saturation flow values on these roads is estimated to be 1350 and 1200 PCU per hour respectively. The all-red time required for pedestrian crossing is 15 second. The total cycle time using Webster's method is
(A) 62.4 s (B) 63.3 s
(C) 65.53 s (D) 67.5 s

23. I. At intersection the area of conflict should be as small as possible.
II. Sudden change of path should be avoided.
(A) I and II are true.
(B) II and III are false.
(C) I is true II is false.
(D) I is false II is true.

24. In a street light system
Street width = 20 m
Mounting height = 10 m
Lamp size = 5000 lumen
Luminaire type II
Coefficient of utilization = 0.36
Spacing between lighting units if average lighting intensity is 6 Lux
(assume maintenance factor = 0.8)
(A) 16 m (B) 18 m
(C) 15 m (D) 12 m

25. Match the following:

	List I		List II
1.	Diamond	a.	
2.	Rotary	b.	

	List I		List II
3.	Partial clover leaf	c.	
4.	Full clover leaf	d.	

Codes:

	1	2	3	4		1	2	3	4
(A)	a	b	c	d	(B)	a	d	c	b
(C)	d	c	b	a	(D)	c	b	d	a

26. The no parking symbol is represented by
(A) triangle (B) circle
(C) octagonal (D) hexagonal

27. The practical capacity of a rotary is given by the formula

(A) $Q_P = \dfrac{280w(1+w)\left(1-\dfrac{p}{3}\right)}{\left(1+\dfrac{w}{L}\right)}$

(B) $Q_P = \dfrac{280w\left(1+\dfrac{w}{L}\right)\left(1-\dfrac{p}{3}\right)}{\left(1+\dfrac{e}{w}\right)}$

(C) $Q_P = \dfrac{280w\left(1+\dfrac{e}{w}\right)\left(1+\dfrac{w}{L}\right)}{\left(1-\dfrac{p}{3}\right)}$

(D) None of these

28. The average width of entry e_1 is 150 m and average width of exit is 200 m. The width of the rotary roadway is
(A) 182 m (B) 178 m
(C) 176 m (D) 179 m

29. Match the following

	List I (Type of Marking)		List II (Areas)
1.	Markings at intersections	a.	Slow and stop
2.	Carriage way marking	b.	Speed change lanes and stop lines
3.	Object markings	c.	No parking zones and traffic lanes
4.	Word messages	d.	Kerb markings and objects within the carriage way

Codes:

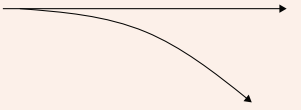
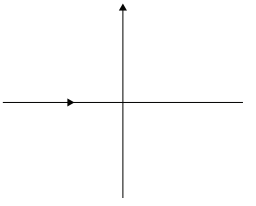
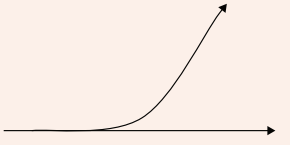
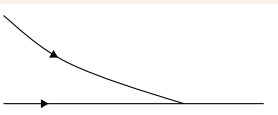
	1	2	3	4		1	2	3	4
(A)	c	a	b	d	(B)	d	c	b	a
(C)	b	c	d	a	(D)	a	d	c	b

30. Desired lines are used in
(A) speed and delay studies.
(B) origin and destination study.
(C) spot speed study.
(D) None of these

31. The spacing between the vehicles allowed by the driver of the following vehicle does not depends on
(A) speed of leading vehicle.
(B) average length and width of vehicle class.
(C) tyre and characteristics of two vehicles.
(D) driver characteristics of following vehicle.

32. The speed of road is 100 km/h and average centre to centre spacing of vehicles (or) space headway is 10 m. The capacity of single lane is
(A) 10^3 veh/h/lane (B) 10^5 veh/h/lane
(C) 10^4 veh/h/lane (D) 10^2 veh/h/lane

33. Match the following

	List I (Traffic Man Oeuvres)		List II (Figures)
1.	Diverging left	a.	
2.	Diverging right	b.	
3.	Crossing right	c.	
4.	Merging left	d.	

Codes:

	1	2	3	4		1	2	3	4
(A)	b	a	c	d	(B)	c	a	b	d
(C)	d	c	a	b	(D)	c	d	b	a

34. The charts showing the volume variations over a period of years are known as
(A) trend charts. (B) variation charts.
(C) traffic flow maps. (D) volume flow diagram.

35. The speed at which greatest number of vehicles travel is called
(A) medium speed.
(B) model speed.
(C) 15th percentile speed.
(D) 98th percentile speed.

36. Match List I (Traffic survey) with List II and select the correct answer using the codes given:

	List I		List II
a.	Spot speed	**1.**	By video tape
b.	Traffic volume	**2.**	By road side interview
c.	*O-D* survey	**3.**	By doppler radar
d.	Parking survey	**4.**	By pneumatic tube

Codes:

	a	b	c	d
(A)	3	1	2	4
(C)	3	4	2	1

	a	b	c	d
(B)	2	4	3	1
(D)	4	2	1	3

37. The design speed of a traffic lane is 70 km/h. What is the theoretical capacity per hour taking the total reaction time to be 2 seconds and average length of vehicles as 8 m?
(A) 828 veh/m/day (B) 735 veh/m/day
(C) 628 veh/m/day (D) 428 veh/m/day

38. On a road the free speed was 65 km/h and the space headway at jam density was 6.25 m. What is the maximum flow which could be expected on this road?
(A) 2600 veh/h (B) 1625 veh/h
(C) 1300 veh/h (D) 406 veh/h

39. The last time due to starting delay on a traffic signal approach is noted to be 3 seconds, the actual green time is 20 seconds and amber time is 3 seconds. How much is the effective green time?
(A) 19 seconds (B) 22 seconds
(C) 27 seconds (D) 31 seconds

40. The free mean speed on a road wing is found to be 60 km/h under stopped condition the average spacing between vehicle is 6 m. The capacity of flow, assuming linear speed density relation is
(A) 2333 veh/h (B) 3333 veh/h
(C) 2870 veh/h (D) 3838 veh/h

41. If the lamp lumen is 30 lux coefficient of utilization is 0.3, maintenance factor is 0.25, average lux on road is 15 and width of road is 7.5, then spacing between the street light is
(A) 2 m (B) 3 m
(C) 2.5 m (D) 3.5 m

42. The capacity of vehicles on a single lane pavement with a design speed of 50 km/h and spacing between vehicles of 59.5 m is
(A) 840.3 (B) 842.8
(C) 848.3 (D) 846.2

43. Two major roads with two lanes each are crossing in an urban area to form an uncontrolled intersection, the number of conflict points when both roads are two way is X and when both roads are one way is Y. the ratio of X and Y is
(A) 0.25 (B) 4
(C) 40 (D) 96

44. If the standard deviation of the spot speed of vehicles in the high way is 9.2 km/h and the mean speed of vehicles is 43 km/h. The coefficient of variation of speed is
(A) 0.213 (B) 0.321
(C) 0.323 (D) 0.314

45. A two lane urban road with one-way traffic has a maximum capacity of 2800 veh/h. Under jam condition, the average length occupied by vehicles is 10 m. The speed versus density relationship is linear, for a traffic volume of 1500 veh/h, the density (in veh/km) is
(A) 43.29
(B) 43.12
(C) 42.19
(D) 42.69

46. A transport company operates a scheduled daily truck service between city P and city Q. Two way journey time between these two cities is 80 hours. A minimum lay over time of 2 hours is to be provided, then the number of trucks required to provide this service is
(A) 4 (B) 2
(C) 6 (D) 8

47. The PCU (Passenger Car Unit) value for cycle on an urban road is
(A) 0.5 (B) 1.0
(C) 3.0 (D) 4.0

48. The average spacing between vehicles in a traffic stream is 100 m, then the density (in veh/km) of the stream is _____.

49. The speed density (U–K) relationship on a single lane road with unidirectional flow is $U = 65–0.65\,k$, where U is in km/h and k is in veh/km. The capacity of the road (in veh/h) is _____.

Previous Years' Questions

1. In signal design as per Indian Roads Congress specifications, if the sum of the ratios of normal flows to saturation flow of two directional traffic flow is 0.50 and the total lost time per cycle is 10 seconds, the optimum cycle length in seconds is **[GATE, 2007]**

(A) 100 (B) 80
(C) 60 (D) 40

2. If the standard deviation of the spot speed of vehicles in a highway is 8.8 km/h and the mean speed of the vehicles is 33 km/h, the coefficient of variation in speed is **[GATE, 2007]**

(A) 0.1517 (B) 0.1867
(C) 0.2666 (D) 0.3646

3. The shape of the STOP sign according to IRC: 67–2001 is **[GATE, 2008]**

(A) circular (B) triangular
(C) octagonal (D) rectangular

4. The capacities of 'one-way 1.5 m wide sidewalk (persons per hour)' and 'one-way 2- lane urban road (PCU per hour, with no frontage access, no standing vehicles and very little cross traffic)' are respectively **[GATE, 2008]**

(A) 1200 and 2400 (B) 1800 and 2000
(C) 1200 and 1500 (D) 2000 and 1200

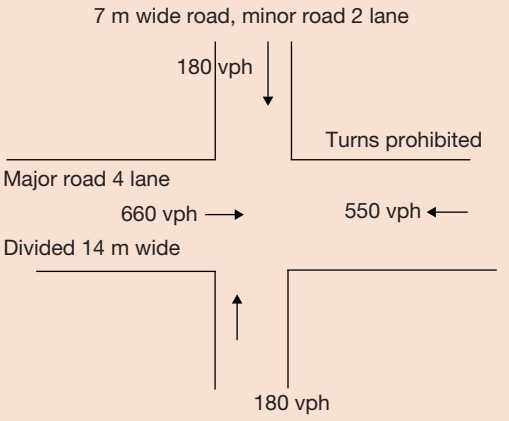
5. A linear relationship is observed between speed and density on a certain section of a highway. The free flow speed is observed to be 80 km/h and the jam density is estimated as 100 vehicles per km length. Based on the above relationship, the maximum flow expected on this section and the speed at the maximum flow will respectively be **[GATE, 2008]**

(A) 8000 vehicles/h and 80 km/h
(B) 8000 vehicles/h and 25 km/h
(C) 2000 vehicles/h and 80 km/h
(D) 2000 vehicles/h and 40 km/h

6. A roundabout is provided with an average entry width of 8.4 m, width of weaving section as 14 m, and length of the weaving section between channelizing islands as 35 m. The crossing traffic and total traffic on the weaving section are 1000 and 2000 PCU per hour respectively. The nearest rounded capacity of the roundabout (in PCU per hour) is **[GATE, 2008]**

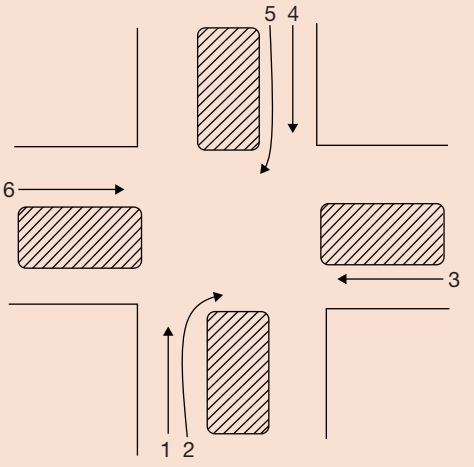
(A) 3300 (B) 3700
(C) 4500 (D) 5200

7. Design parameters for a signalized intersection are shown in the figure below. The green time calculated for major and minor roads are 34 and 18 seconds, respectively. The critical lane volume on the major road changes to 440 vehicles per hour per lane and the critical lane volume on the minor road remains unchanged. The green time will **[GATE, 2008]**



(A) increase for the major road and remain same for the minor road.
(B) increase for the major road and decrease for the minor road.
(C) decrease for both the roads.
(D) remain unchanged for both the roads.

8. A three-phase traffic signal at an intersection is designed for flows shown in the figure below. There are six groups of flows identified by the numbers 1 through 6. Among these 1, 3, 4 and 6 are through flows and 2 and 5 are right turning. Which phasing scheme is **not feasible?** **[GATE, 2009]**



Combination Choice	Phase I	Phase II	Phase III
P	1, 4	2, 5	3, 6
Q	1, 2	4, 5	3, 6
R	2, 5	1, 3	4, 6
S	1, 4	2, 6	3, 5

(A) P (B) Q
(C) R (D) S

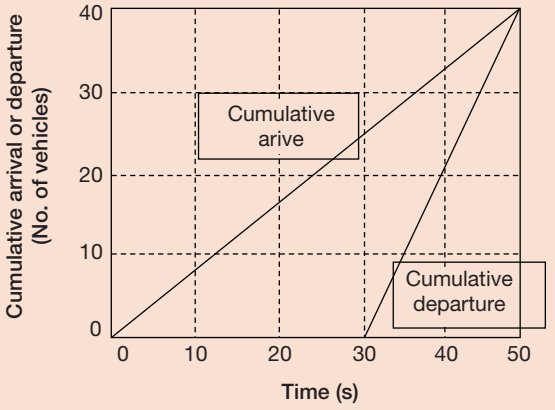
9. As per IRC:67–2001; traffic sign indicating the speed limit on a road should be of **[GATE, 2010]**

(A) circular shape with white background and redborder.
(B) triangular shape with white background and red border.
(C) triangular shape with red background and white border.
(D) circular shape with red background and white border.

10. The jam density is given as k and the free flow speed is given as u, the maximum flow for a linear traffic speed-density model flow for a which of the following options? **[GATE, 2011]**

(A) 1/4 ku (B) 1/3 ku
(C) 3/5 ku (D) 2/3 ku

11. The cumulative arrival and departure curve of one cycle of an approach lane of a signalized intersection is shown in the adjoining figure. The cycle time is 50 seconds and the effective red time is 30 seconds and the effective green time is 20 seconds. What is the average delay? **[GATE, 2011]**



(A) 15 seconds (B) 25 seconds
(C) 35 seconds (D) 45 seconds

12. Two major roads with two lanes each are crossing in an urban area to from an un-controlled intersection. The number of conflict points when both roads are one-way is 'X' and when both roads are two-way is 'Y'. The ratio of X to Y is **[GATE, 2012]**

(A) 0.25 (B) 0.33
(C) 0.50 (D) 0.75

13. A two–lane urban road with one-way traffic has a maximum capacity of 1800 vehicle/h. Under the jam condition, the average length occupied by the vehicles is average length occupied by the vehicles is 5.0 m. The speed versus density relationship is linear. For a traffic volume of 1000 vehicle/h, the density (in vehicles/km) is **[GATE, 2012]**

(A) 52 (B) 58
(C) 67 (D) 33

14. It was observed that 150 vehicles crossed a particular location of a highway in a duration of 30 minutes. Assuming that vehicle arrival follows a negative exponential distribution, find out the number of time head ways grater than 5 seconds in the above observation is _____. **[GATE, 2013]**

15. For two major roads with divided carriageway crossing at right angle, a full clover leaf interchange with four indirect ramps is provided. Following statements are made on turning movements of vehicles to all directions from both roads. Identify the correct statement: **[GATE, 2013]**

(A) Merging from left is possible, but diverging to left is not possible.
(B) Both merging from left and diverging to left are possible.
(C) Merging from left is not possible, but diverging to left is possible.
(D) Neither merging from left nor diverging to left is possible.

16. The minimum value of 15 minutes peak hour factor on a section of a road is **[GATE, 2014]**

(A) 0.10 (B) 0.20
(C) 0.25 (D) 0.33

17. The average spacing between vehicles in a traffic stream is 50 m, then the density (in veh/km) of the stream is _____. **[GATE, 2014]**

18. The speed-density (u-k) relationship on a single lane road with unidirectional flow is $u = 70 - 0.7\,k$, where u is in km/h and k is in veh/km. The capacity of the road (in veh/h) is _____. **(GATE 2014)**

19. An isolated three-phase traffic signal is designed by Weber's method. The critical flow ratios for three phases are 0.20, 0.30 and 0.25 respectively, and lost time per phase is 4 seconds. The optimum cycle length (in seconds) is _____. **[GATE, 2014]**

20. A student riding a bicycle on a 5 km one-way street takes 40 minutes to reach home. The student stopped for 15 minutes during this ride. 60 vehicles overtook the student (assume the number of vehicles overtaken by the student is zero) during the ride and 45 vehicles while the student stopped. The speed of vehicle stream on that road (in km/h) is **[GATE, 2014]**

(A) 7.5 (B) 12
(C) 40 (D) 60

21. On a section of a highway the speed-density relationship is linear and is given by $v = \left[80 - \frac{2}{3}k\right]$; where v is in km/h and k is in veh/km. The capacity (in veh/h) of this section of the highway would be **[GATE, 2014]**

(A) 1200 (B) 2400
(C) 4800 (D) 9600

22. A pre-timed four phase signal has critical lane flow rate for the first three phases as 200, 187 and 210 veh/h with saturation flow rate of 1800 veh/h/lane for all phases. The lost time is given as 4 seconds for each phase. If the cycle length is 60 seconds, the effective green time (in seconds) of the fourth phase is _____. **[GATE, 2014]**

23. The following statements are made related to the lengths of turning lanes at signalized intersections: **[GATE, 2015]**

I. 1.5 times the average number of vehicles (by vehicle type) that would store in turning lane per cycle during the peak hour.

II. 2 times the average number of vehicles (by vehicle type) that would store in turning lane per cycle during the peak hour.

III. Average number of vehicles (by vehicle type) that would store in the adjacent through lane per cycle during the peak hour.

IV. Average number of vehicles (by vehicle type) that would store in all lanes per cycle during the peak hour. As per the IRC recommendations, the correct choice for design length of storage lanes is

(A) Maximum of II and III
(B) Maximum of I and III
(C) Average of I and III
(D) Only IV

24. The relation between speed u (in km/h) and density k (number of vehicles/km) for a traffic stream on a road is, $u = 70 - 0.7k$. The capacity on this road is _____ vph (vehicles/hour). **[GATE, 2015]**

25. In a one-lane one-way homogeneous traffic stream, the observed average headway is 3.0 seconds. The flow (expressed in vehicles/hour) in this traffic stream is_____. **[GATE, 2016]**

26. While traveling along and against the traffic stream, a moving observer measured the relative flows as 50 vehicles/hour and 200 vehicles/hour, respectively. The average speeds of the moving observer while traveling along and against the stream are 20 km/hour and 30 km/hour, respectively. The density of the traffic stream (expressed in vehicles/km) is _____. **[GATE, 2016]**

27. If the total number of commercial vehicles per day ranges from 3000 to 6000, the minimum percentage of commercial traffic to be surveyed for axle load is **[GATE, 2016]**

(A) 15
(B) 20
(C) 25
(D) 30

28. The critical flow ratios for a three-phase signal are found to be 0.30, 0.25, and 0.25. The total time lost in the cycle is 10 seconds. Pedestrian crossings at this junction are not significant. The respective Green times (expressed in seconds and rounded off to the nearest integer) for the three phases are **[GATE, 2016]**

(A) 34, 28, and 28
(B) 40, 25, and 25
(C) 40, 30, and 30
(D) 50, 25, and 25

29. A motorist traveling at 100 km/h on a highway needs to take the next exit, which has a speed limit of 50 km/h. The section of the roadway before the ramp entry has a downgrade of 3% and coefficient of friction (f) is 0.35. In order to enter the ramp at the maximum allowable speed limit, the braking distance (expressed in m) from the exist ramp is_____. **[GATE, 2016]**

Answer Keys

Exercises

1. D	**2.** C	**3.** C	**4.** C	**5.** A	**6.** B	**7.** D	**8.** C	**9.** B	**10.** D
11. B	**12.** 8.4 m	**13.** D	**14.** A	**15.** D	**16.** B	**17.** C	**18.** A	**19.** C	**20.** B
21. B	**22.** D	**23.** A	**24.** D	**25.** B	**26.** B	**27.** A	**28.** D	**29.** C	**30.** B
31. B	**32.** C	**33.** B	**34.** A	**35.** B	**36.** B	**37.** B	**38.** A	**39.** B	**40.** B
41. A	**42.** A	**43.** B	**44.** A	**45.** C	**46.** B	**47.** A	**48.** 10	**49.** 1625	

Previous Years' Questions

1. D	**2.** C	**3.** C	**4.** A	**5.** D	**6.** B	**7.** A	**8.** C	**9.** A	**10.** A
11. A	**12.** A	**13.** C	**14.** 11.86	**15.** B	**16.** C	**17.** 20	**18.** 1750	**19.** 92	**20.** D
21. B	**22.** 15.745		**23.** B	**24.** 1750	**25.** 1200	**26.** 3	**27.** A		
28. A	**29.** 92.32								