# GATE – CIVIL ENGINEERING

## TRANSPORTATION ENGINEERING

## Online Lecture: 6 (16.06.2020)

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# TRANSPORTATION ENGINEERING

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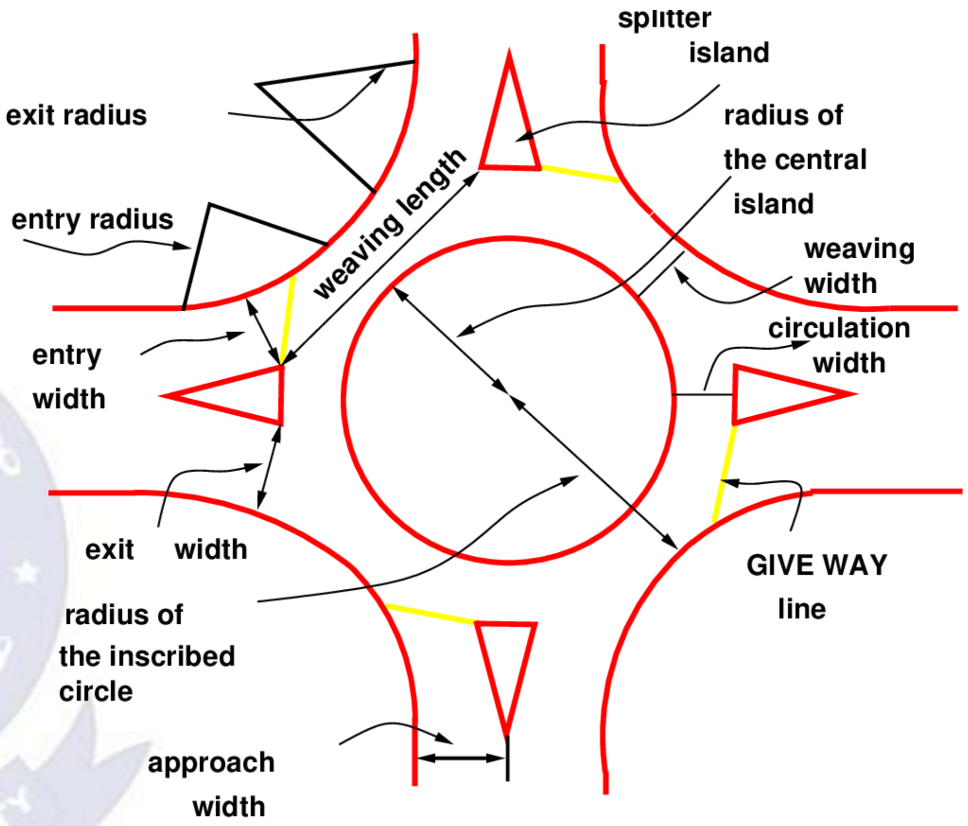
## Rotary intersection:

Radius of rotary roadway, $R = \dfrac{V^2}{127 f}$

$f$ : Coefficient of friction (0.43 to 0.47)

$V$ : Design speed of the vehicle




Capacity of the rotary, $Q_P = \dfrac{280W\left(1+\dfrac{e}{W}\right)\left(1-\dfrac{p}{3}\right)}{\left(1+\dfrac{W}{L}\right)}$

$Q_P$ : Practical capacity of the weaving section of a rotary in PCU per hour.

$W$ : Width of weaving section (6 to 18 m)

$e$ : Average width of entry $e_1$ and width of non-weaving section $e_2$ for the range $e/W$ = 0.4 to 1.0.

$L$ : length of weaving section between the ends of channelizing islands in m for the range of $W/L$ = 0.12 to 0.4.

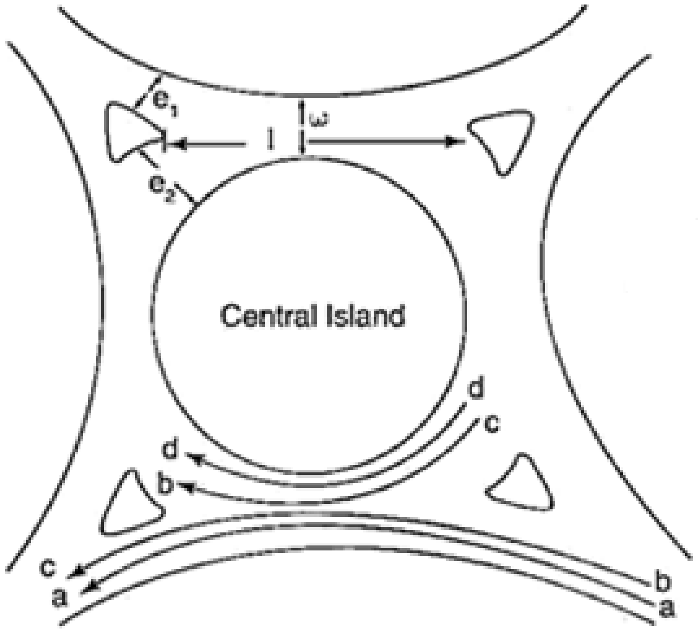
$p$ : Proportion of weaving traffic $= \dfrac{b+c}{a+b+c+d}$ , (Range of $p$ : 0.4 to 1.0)

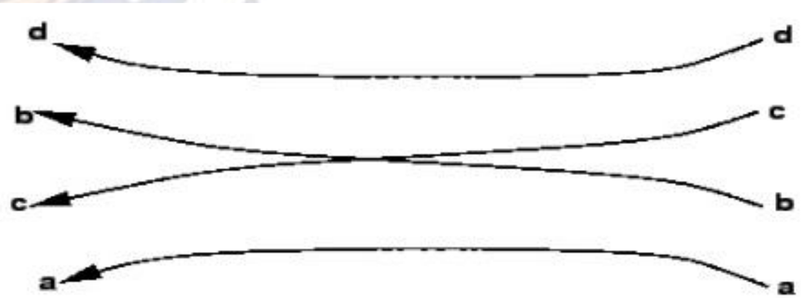
$a$ : Left turning traffic moving along left extreme lane

$d$ : Right turning traffic moving along right extreme lane

$b$ : Crossing/weaving traffic turning towards right while entering the rotary.

$c$ : Crossing/weaving traffic turning towards left while leaving the rotary.

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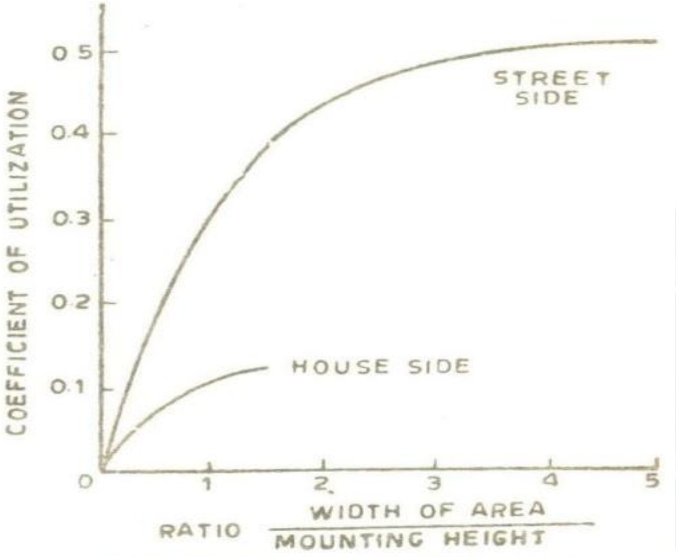
## Design of highway lighting system:




Coefficient of Utilization

$$\text{Spacing of lights} = \frac{\text{Lamp lumen} \times \text{coefficient of utilization} \times \text{Maintenance factor}}{\text{Average lux} \times \text{width of road}}$$

Maintenance factor = 0.8

# TRAFFIC ENGINEERING

## Previous GATE Questions

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1. Traffic volume count has been collected on a 2-lane road section which needs upgradation due to severe traffic flow condition. Maximum service flow rate per lane is observed as 1280 veh/h at level of service ‘C’. The Peak Hour Factor is reported as 0.78125. Historical traffic volume count provides Annual Average Daily Traffic as 12270 veh/day. Directional split of the traffic flow is observed to be 60:40. Assuming that traffic stream consists of ‘All Cars’ and all drivers are ‘Regular Commuters’, the number of extra lane(s) (round off to the next higher integer) to be provided, is…..

GATE CE 2020

01. 6

Number of lanes required, $N = \dfrac{DDHV}{PHF \times MSF \times F_{HV} . f_p}$

DDHV : Directional Design Hourly volume

PHF : Peak Hour Factor =0.78125

MSF : Maximum Service Flow rate =1280 veh/H

$F_{HV}$ : Heavy vehicle familiarity adjustment factor = 1 for car

$f_p$ : Road user familiarity adjustment factor for regular commuters = 1

DDHV = AADT ×K×D

AADT : Annual Average Daily Traffic = 12270 Veh/day

K : Proportion of AADT occurring in peak hour =1 (Assumed)

D : Volume Proportion in major direction = 0.6

DDHV = 12270 ×0.6×1=7362

$$N = \frac{7362}{0.78125 \times 1280 \times 1 \times 1} = 7.362 = 8 \text{ lanes}$$

Number of extra lanes = 8-2 = 6.

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2. The traffic starts discharging from an approach at an interesection with the signal turning green. The constant headway considered from the fourth or fifth headway position is referred to as GATE CE 2020

a. discharge headway

b. effective headway

c. intersection headway

**d.** saturation headway

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3. 24-h traffic count at a road section was observed to be 1000 vehicles on a Tuesday in the month of July. If daily adjustment factor for Tuesday is 1.121 and monthly adjustment factor for July is 0.913, the Annual Average Daily Traffic (in veh/day, round off to the nearest integer) is……. GATE CE 2020

3.1023

24-h traffic count at a road section , T = 1000 vehicles

Daily adjustment factor DAF, = 1.121

Monthly adjustment factor, MAF = 0.913

Annual average daily traffic, AADT = ?

$$AADT = T_{weak}.MAF$$
$$= T_A.DAF \times MAF$$
$$= 1000 \times 1.121 \times 0.913 = 1023.5 \approx 1023 veh/day$$

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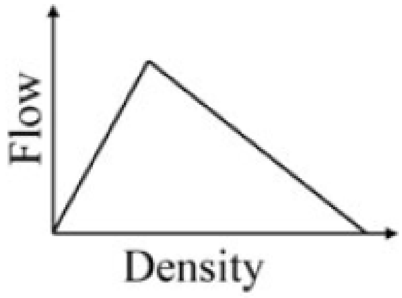
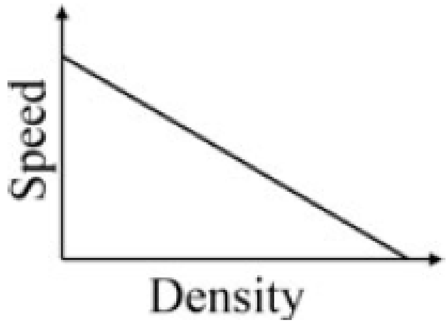
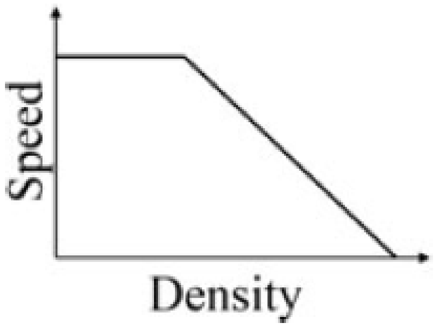
4.The flow-density relationship of traffic on a highway is shown in the figure

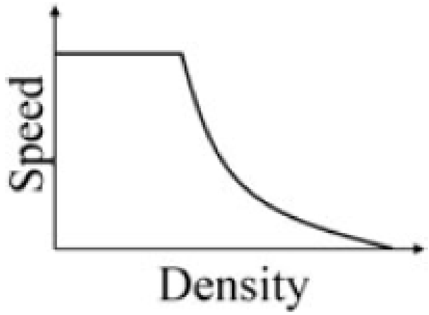


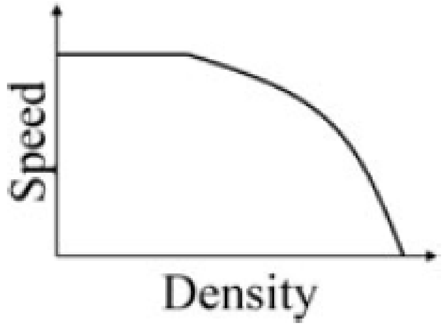

The correct representation of speed-density relationship of the traffic on this highway is

GATE CE 2020



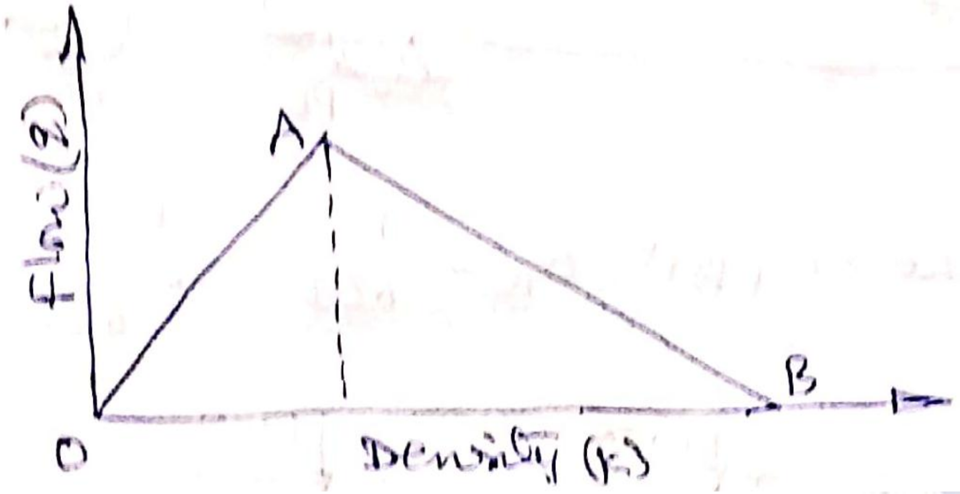



4.c

The flow density relationship of a traffic on highway is given by

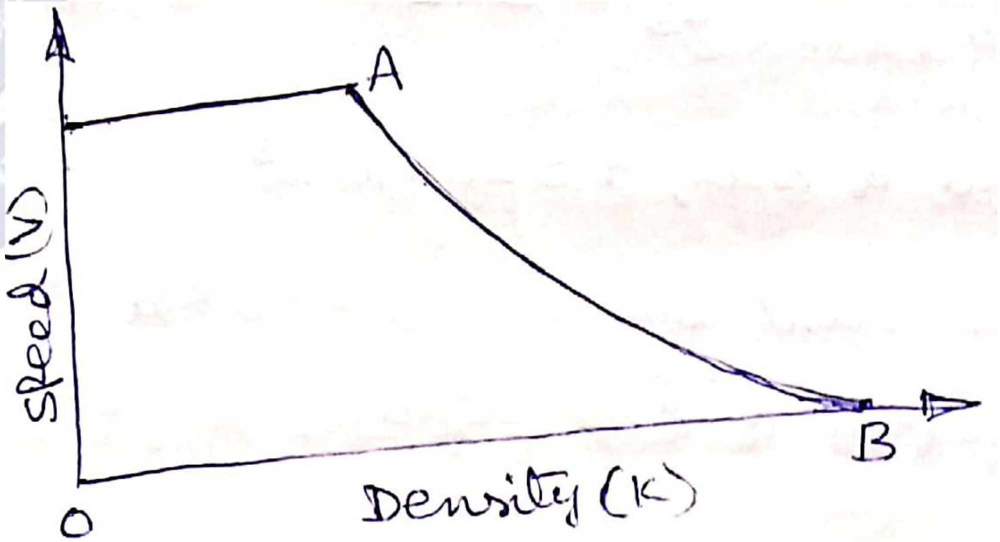



In portion OA, $q \propto K \Rightarrow q = KV \Rightarrow$ V : constant

In position AB, $q = -mk+c$ and $q = k.v$

$k.v = -mk+c$

Velocity follows a curve below the sloping line as shown in fig.

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5. The speed-density relationship of a highway is given as $u = 100 - 0.5k$. where, $u =$ speed in km per hour, $k =$ density in vehicles per km. The maximum flow (in vehicles per hour, round off to the nearest integer) is …… CE2 2019

5. **5000**

The speed-density relationship of highway is given as $u = 100 - 0.5k$

u: Speed in km per hour

k: Density in vehicles per km

The maximum flow, $q_{max}$ =?

Capacity, $q = k.u$ = k(100-0.5k) = 100k-0.5k$^2$

For maximum of q, $\frac{dq}{dk} = 0$

$\frac{dq}{dk}$ =100-0.5×2k=0 $\Rightarrow$ 100-k = 0 $\Rightarrow$ k = 100veh/hour

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$q_{max}$ =100×100-0.5(100)$^2$=100×100-0.5(100)$^2$= 5000 veh/hour

OR

Jam density occurs at the vehicles of zero speed.

$k_j$ : Jam density, veh/km

At $u = 0,\ k = k_j \Rightarrow 0 = 100 - 0.5k_j \Rightarrow k_j =$ 200 veh/hour

Free flow of vehicles occur at the zero density

At $k$ =0, $u = v_f \Rightarrow v_f$ =100-0.5×100 $\Rightarrow v_f$ =100 km/hour

$v_f$ : free flow speed, km/hour

Maximum flow, $q_{max} = \frac{v_f}{2} . \frac{k_j}{2} = \frac{v_f . k_j}{4} = \frac{100 \times 200}{4}$ =5000 vehicles/hour

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06. The uniform arrival and uniform service rates observed on an approach road to a signalized intersection are 20 and 50 vehicles/minute, respectively. For this signal, the red time is 30 s, the effective green time is 30 s, and the cycle length is 60 s. Assuming that initially there are no vehicles in the queue, the average delay per vehicle using the approach road during a cycle length (in s, round off to 2 decimal places) is …….. CE2 2019

06. **12.5**

Uniform arrival (normal flow), $q$ =20 vehicles/minutes

Uniform service rate (saturation flow),$S$ =50 vehicles/minute

Red time, $R$ = 30 s

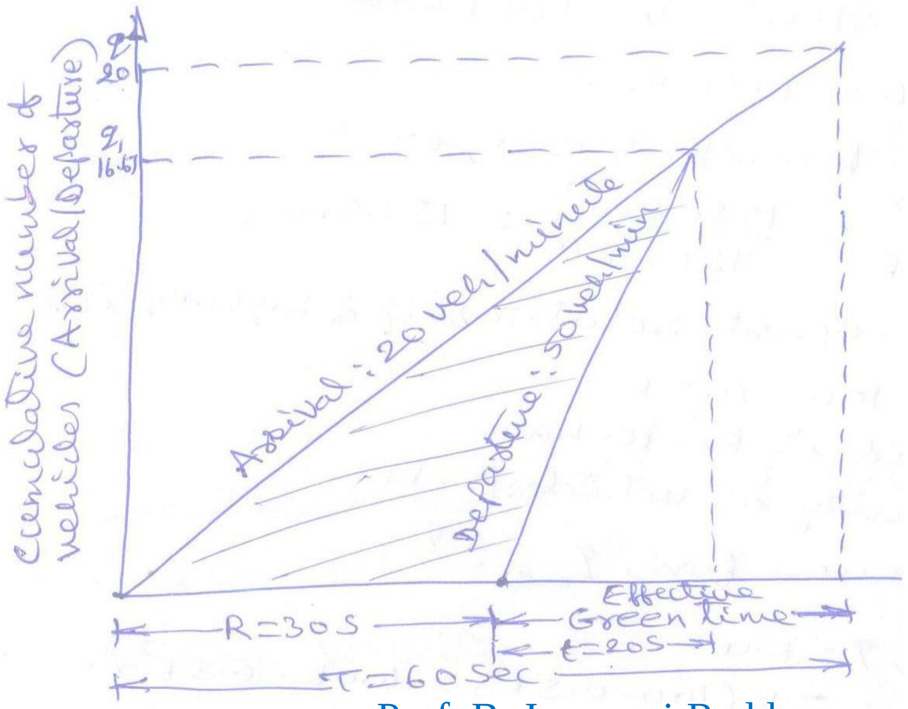
Effective green time, $G$ = 30 s

Cycle length, $C_0$ = 60 s

Average delay per vehicle during a cycle length, $d$ =?

Webster's delay is given by $d = \dfrac{\dfrac{C_o}{2}\left[1-\dfrac{G}{C_0}\right]^2}{\left[1-\dfrac{q}{S}\right]}$ $\qquad d = \dfrac{\dfrac{60}{2}\left[1-\dfrac{30}{60}\right]^2}{\left[1-\dfrac{20}{50}\right]}$ =12.5 sec

OR

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Let $t$ : Time corresponding to the number of arrivals becomes same as that of the number of departures.

$$20(R+t) = 50t \Rightarrow 20(30+t) = 50t \Rightarrow 30t = 600 \Rightarrow t = 20\text{sec}$$

$$\frac{20}{60} = \frac{q_1}{50} \Rightarrow q_1 = 16.67 \text{ veh/minute}$$

$$\text{Average delay per vehicle} = \frac{\text{Area under arrival line-Area under departure live}}{\text{cumulative number of vehicles arrival}}$$

$$= \frac{\frac{1}{2}\times 16.67\times 50 - \frac{1}{2}\times 16.67\times 20}{20}$$

=12.5 sec

7. The speed-density relationship in a mid-block section of a highway follows the Greenshield's model. If the free flow speed is $v_f$ and the jam density is $k_j$, the maximum flow observed on this section is CE2 2019

a. $v_f k_j$ b. $\frac{v_f k_j}{2}$ **c.** $\frac{v_f k_j}{4}$ d. $\frac{v_f k_j}{8}$

7. c

$V_f$ : Free flow speed

$k_j$ : Jam density

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8. Traffic on a highway is moving at a rate of 360 vehicles per hour at a location. If the number of vehicles arriving on this highway follows Poisson distribution, the probability (round off to 2 decimal places) that the headway between successive vehicles lies between 6 and 10 seconds is…… CE1 2019

8. **0.18**

Traffic rate on a highway, $\lambda$ =360 vehicles/hour

$$\lambda = \frac{360}{60 \times 60} = 0.1 \text{ vehicles/sec}$$

n: Number of vehicles arriving on the highway section

Let $x$ be the headway between two successive arrival of vehicles

$$f(x) = \lambda . e^{-\lambda x} = 0.1 e^{-0.1x}$$

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Required probability, $p(6 < x < 10) = \int_{6}^{10} f(x).dx$

$$= \int_{6}^{10} 0.1e^{-0.1x}dx = 0.1\left[\frac{e^{-0.1x}}{-0.1}\right]_{6}^{10} = -\left[e^{-1} - e^{-0.6}\right] = 0.181$$

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10. Average free flow speed and the jam density observed on a road stretch are 60 km/h and 120 vehicles/km, respectively. For a linear speed-density relationship, the maximum flow on the road stretch (in vehicles/h) is……. CE1 2019

10. **1800**

Average free flow speed, $V_f$ =60km/h

Jam density, $K_j$ =120 vehicles/km

Maximum flow on the road, $q$ =?

For linear speed –density relationship,

$$q_{\max} = \frac{v_f . k_j}{4} = \frac{60 \times 120}{4} = 1800 \text{ vehicles/hour}$$

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11. The maximum number of vehicles observed in any five minute period during the peak hour is 160. If the total flow in the peak hour is 1000 vehicles, the five minute peak hour factor (round off to 2 decimal places) is… **0.51 to 0.53** CE1 2019

11. **0.52**

Maximum number of vehicles observed in any 5 minute period during peak hour = 160

Total flow in the peak hour =1000 vehicles

Five minute peak hour factor, PHF=?

$$(PHF)_5 = \frac{\text{Peak flow}}{5\,\text{minute traffice flow}} = \frac{1000}{160 \times \frac{60}{5}} = 0.52$$

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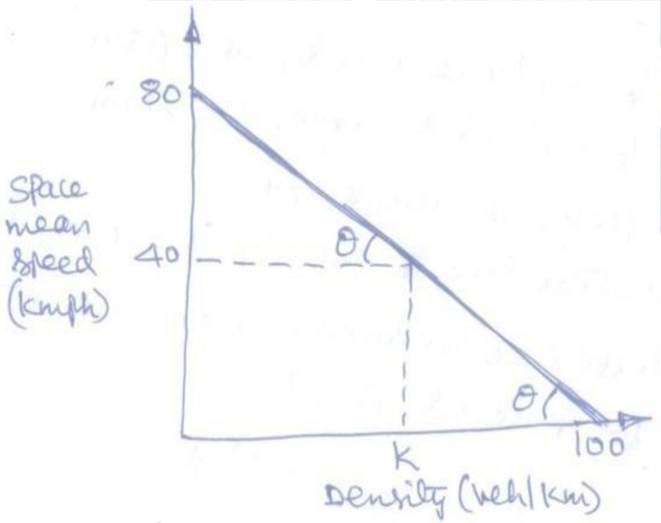
12. The space mean speed (kmph) and density (vehicles/km) of a traffic stream are linearly related. The free flow speed and jam density are 80 kmph and 100 vehicles/km respectively. The traffic flow (in $vehicles/h$, up to one decimal place) corresponding to a speed of 40 kmph is…. CE2 2018

12. 2000

The space mean speed (kmph) and density (vehicles/km) of a traffic stream are linearly related.

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$K$ :Density corresponding to speed 40 kmph. Free mean speed, $V_f$ = 80 kmph.

Jam density, $K_j$ = 100 vehicles/km

$$Tan\theta = \frac{80-40}{k} = \frac{80}{100} \Rightarrow \frac{40}{k} = \frac{80}{100} \Rightarrow k = 50 \text{ vehicles/km}$$

Traffic flow, $q = k.v$ = 50 × 40 = 2000 veh/hour.

**OR**

The linear model law is $V = V_f\left(1-\frac{k}{kj}\right)$

Free mean speed, $V_f$ = 80 kmph

Jam density, $K_j$ = 100 vehicles/km

K:Density corresponding to speed V.

Speed, $V$ = 40 kmph.

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$$40 = 80\left(1 - \frac{k}{100}\right) \Rightarrow \frac{k}{100} = 0.5 \Rightarrow k = 50 \text{ vehicles/km}$$

Traffic flow, $q = k.v = 50 \times 40 = 2000$ vehicles/hour

13. Peak Hour Factor (PHF) is used to represent the proportion of peak sub-hourly traffic flow within the peak hour. If 15-minute sub-hours are considered, the theoretically possible range of PHF will be CE2 2018

a. 0 to 1.0 b.0.25 to 0.75 **c.** 0.25 to 1.0 d. 0.5 to 1.0

13. c

Peak hour factor (PHF) is the hourly volume during maximum volume hour of day divided by the peak 15 minute flow rate within a peak hour.

The possible range of PHF : 0.25 to 1.0

14. A well-designed signalized intersection is one in which the CE1 2018

a. crossing conflicts are increased

**b.** total delay is minimized

c. cycle time is equal to the sum of red and green times in all phases

d. cycle time is equal to the sum of red and yellow times in all phases.

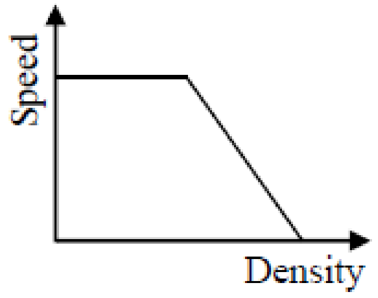
14. b

For evaluating the performance of a signalized intersection, vehicle delay is the most important parameter.

Minimum delay ensures lesser fuel loss, lesser congestion and lesser loss of time of public. Hence, a well designed signalized intersection is the one in which total delay time is minimized.

For a well designed signalized intersection, crossing conflicts should be lesser.

15. The speed-density relationship for a road section is shown in the figure
The shape of the flow-density relationship is CE1 2018




a. piecewise linear
b. parabolic
**c.** initially linear then parabolic
d. initially parabolic then linear

15. c

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Flow = Speed × Density
$= V.K$

For Constant, $V$, flow $\propto$ density $\Rightarrow$ linear

For decreasing, $V$, flow $= [m(k-c)+c]k$
$= mk^2 - mck + c \Rightarrow$ Parabola

The shape of flow density relationship is initially linear and then parabolic.

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16. Two cars P and Q are moving in a racing track continuously for two hours. Assume that no other vehicles are using the track during this time. The expressions relating the distance travelled $d$ (in km) and time $t$ (in hour) for both the vehicles are given as CE2 2017

P: $d = 60t$

Q: $d = 60t^2$

Within the first one hour, the maximum space headway would be

**a.**15 km at 30 minutes b. 15 km at 15 minutes

c.30 km at 30 minutes d. 30 km at 15 minutes

16. a

The expressions relating to the distance traveled d (in km) and t (in hour) for cars is given by

For car P, $d = 60t$

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For car Q, $d = 60t^2$

Distance at any time to between P and Q is given by $d\left(t\right) = 60t^2 - 60t$

For space head to be maximum, $\frac{d}{dt} d(t) = 0$

$120t - 60 = 0 \Rightarrow t = 0.5$ hour

$d\left(0.5\right) = 60 \times 0.5 - 60 \times 0.5^2 = 15$ km

The maximum space head way of 15 km occurs at $t$ = 30 minutes.

17. The safety within a roundabout and the efficiency of a roundabout can be increased, respectively by CE2 2017

a. increasing the entry radius and increasing the exit radius

b. increasing the entry radius and decreasing the exit radius

**c.** Decreasing the entry radius and increasing the exit radius

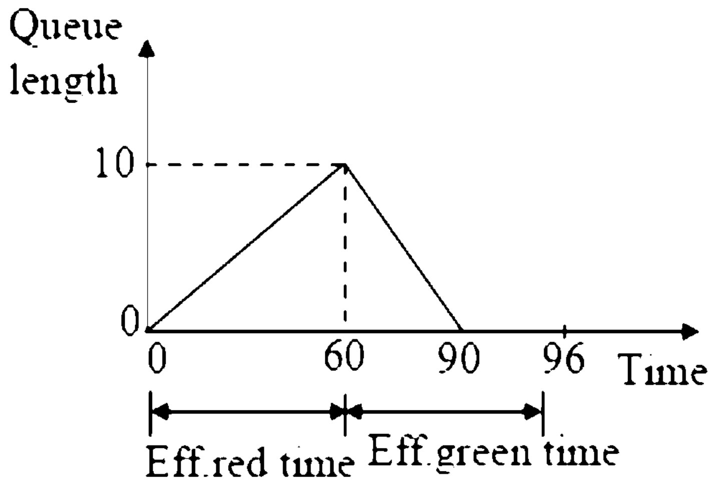
d. Decreasing the entry radius and decreasing the exit radius

17. c

The safety within a round about can be increased by decreasing the entry radius.

The efficiency of a roundabout can be increased by increasing the exit radius.

18. The queue length (in number of vehicles) versus time (in seconds) plot for an approach to a signalized intersection with the cycle length of 96 seconds is shown in the figure (not drawn to scale) CE1 2017




At time $t = 0$, the light has just turned red. The effective green time is 36 seconds, during which vehicles discharge at the saturation flow rate, $s$ (in vph). Vehicles arrive at a uniform rate, $v$ (in vph), throughout the cycle. Which one of the following statements is true?

**a.** $V$ = 600 vph, and for this cycle, the average stopped delay per vehicle = 30 seconds

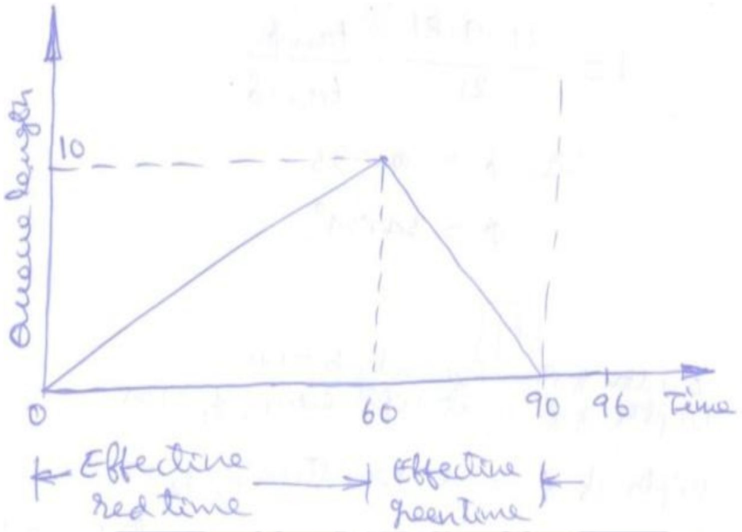
b. $S$ =1800 vph, and for this cycle, the average stopped delay per vehicle = 28.125 seconds

c. $V$ = 600 vph, and for this cycle, the average stopped delay per vehicle = 45 seconds

d. $S$ = 1200 vph, and for this cycle, the average stopped delay per vehicle = 28.125 seconds

18. a

Stopped time delay is defined as the time for a vehicle is stopped in queue while waiting to pass through the intersection. It begins when the vehicle is fully stopped and ends when the vehicles begin to accurate. Average time delay is the average for all vehicles during a specified time period.




$$V = \frac{10}{60} \text{ vehicles/sec}$$

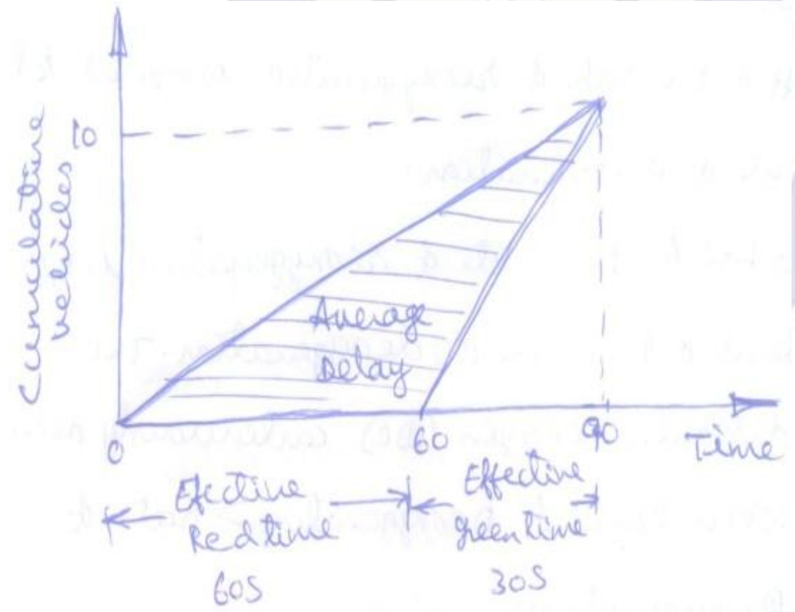
$$V = \frac{10}{60} \times 60 \times 60 = 600 \text{ vehicles/hour}$$

$$S = \frac{10}{30} \text{ vehicles/sec} = \frac{10}{30} \times 60 \times 60 = 1200 \text{ vehicles/hour}$$

The average stopped delay per vehicle $= \frac{0+60}{2} = 30$ sec

(OR)

The average delay for all vehicles passing through the signal is the area between the arrival and departure curves.

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$$\text{Aggregate delay} = \frac{1}{2}\times 90\times 10-\frac{1}{2}\times 30\times 10 = 300 \text{ vehicle-sec}$$

$$\text{Average stopped delay per vehicle} = \frac{300}{10} = 30\,\text{sec}$$

19. Vehicles arriving at an intersection from one of the approach roads follows the Poisson distribution. The mean rate of arrival is 900 vehicles per hour. If a gap is defined as the time difference between two successive vehicle arrivals (with vehicles assumed to be points), the probability (up to four decimal places) that the gap is greater than 8 seconds is …. CE1 2017

19. 0.1354

Using Poisson distribution, the probability that the gap is greater than $t$ seconds is

$$P(T > t) = e^{-\lambda t}$$

$\lambda$ : Mean rate of arrival of vehicles, vehicles per sec

$$= \frac{900}{60 \times 60} = 0.25$$

$$P(t > 8) = e^{-8 \times 0.25} = 0.1354$$

20. 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 10s. 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 CE2 2016

**a.** 34,28 and 28 b. 40, 25 and 25 c. 40, 30 and 30 d. 50, 25 and 25

20. a

The critical flow ratios for a three phase signal are:

$y_1 = 0.30,\quad y_2 = 0.25,\quad y_3 = 0.25$

$$y = y_1 + y_2 + y_3 = 0.3 + 0.25 + 0.25 = 0.8$$

Total lost time in cycle, $L = 10$ sec

Optimum cycle time, $C_0 = \dfrac{1.5L+5}{1-y} = \dfrac{1.5\times10+5}{1-0.8} = 100$ sec

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Green time, $G_1 = \frac{y_1}{y}(C_0 - L) = \frac{0.3}{0.8}(100 - 10)$ = 33.75 s = 34 s

$G_2 = \frac{y_2}{y}(C_0 - L) = \frac{0.25}{0.8}(100 - 10)$ =28.125 s

$G_3$= 28 s

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21. 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

**a.** 15 b. 20 c. 25 d. 30 CE2 2016

21. a

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22. The spot speeds (expressed in km/hr) observed at a road section are 66, 62, 45, 79, 32, 51, 56, 60, 53 and 49. The median speed (expressed in km/hr) is…………… (Note: answer with one decimal accuracy) CE2 2016

22. 54.5

Spot speeds:66, 62, 45, 79, 32, 51, 56, 60, 53

Ascending order of spot speeds:

32, 45, 49, 51, 53, 56, 60, 62, 66, 79

Median= Average of Middle values $= \frac{53+56}{2} = 54.5$ kmph

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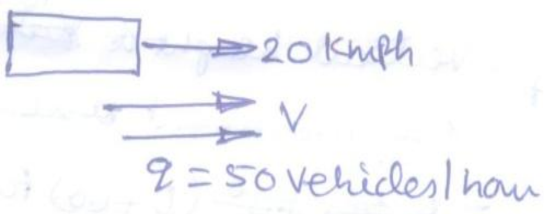
23. While travelling along and against the traffic stream, a moving observer measured the relative flows as 50 vehicles/hr and 200 vehicles/hr, respectively. The average speeds of the moving observer while travelling along and against the stream are 20 km/hr and 30 km/hr, respectively. The density of the traffic stream (expressed in vehicles/km) is…… CE1 2016

23. 3.0

Let $V$: speed of the traffic

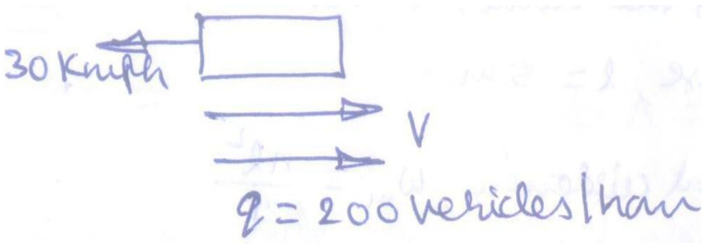
Moving observer along the direction of traffic




$$q = k \times \text{relative speed}$$

$$50 = k\left(v - 20\right) \;\ldots\ldots\text{i}$$

## Moving observer opposite to the direction of traffic:




$q$ = 200 vehicles/hour

$q = k \times \text{relative speed}$

$200 = k\left(v + 30\right)$ …….ii

Solving the equations $i$ and $ii$

$$\frac{200}{50} = \frac{kV + 30k}{kV - 20k}$$

$4KV - 80K = KV + 30K$ $\quad$ $3kV = 110k \Rightarrow V$ = 36.67 kmph

$50 = k(36.67 - 20) \Rightarrow k$ = 3 vehicles/km

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24. In a one-lane one-way homogeneous traffic stream, the observed average headway is 3.0s. The flow (expressed in vehicles/hr) in this traffic stream is …..

CE1 2016

24. 1200

Observed average headway, $Ht = 3.0$ s

The flow of traffic stream, $q = ?$

$$q = \frac{3600}{H_t} = \frac{3600}{3} = 1200 \text{ vehicles/hour}$$

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25. 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). CE2 2015

25. 1750

The relation between speed and density for a traffic stream is given by

$ku = 70 - 0.7k$

$u$ : Speed, km/h

$k$ : Density, vehicles/km

Capacity, $q = u.k \; = (70 - 0.7k)k \; = 70k - 0.7k^2$

For maximum flow, $\dfrac{dq}{dk} = 0$

$70 - 1.4k = 0 \;\; \Rightarrow \;\; k = 50$ Vehicles/km

$q_{max} = 70 \times 50 - 0.7(50)^2$ = 1750 Vehicles/hour.

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26. The following statements are made related to the lengths of turning lanes at signalized intersections. CE2 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)

26. b

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27. Which of the following statements CANNOT be used to describe free flow speed $(u_f)$ of a traffic stream? CE1 2015

a. $u_f$ is the speed when flow is negligible

b. $u_f$ is the speed when density is negligible

c. $u_f$ is affected by geometry and surface conditions of the road

**d.** $u_f$ is the speed at which flow is maximum and density is optimum.

27. d

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28. 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 fourth phase is____ CE2 2014

28. 15.745

Critical lane flow rate for the first three phases are

$$q_1 = 200 \text{ vehicles/hour}$$

$$q_2 = 187 \text{ vehicles/hour}$$

$$q_3 = 210 \text{ vehicles/hour}$$

Saturation flow rate for all phases, $S = 1800$ vehicles/lane

Lost time for each phase $= 4\,\text{sec}$

Total lost time for all phases $= 4 \times 4 = 16\,\text{sec}$

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Length of the cycle, $C_0 = 60$ sec

Effective green time for fourth phase, $G = ?$

$$y_1 = \frac{q_1}{s_1} = \frac{200}{1800} \qquad y_2 = \frac{q_2}{s_2} = \frac{187}{1800} \qquad y_3 = \frac{q_3}{s_3} = \frac{210}{1800}$$

$$C_0 = \frac{1.5L+5}{1-Y} \qquad 60 = \frac{1.5\times16+5}{1-Y} \Rightarrow 1-Y = \frac{29}{30} \Rightarrow Y = 0.517$$

$$Y = y_1 + y_2 + y_3 + y_4$$

$$0.517 = \frac{200}{1800} + \frac{187}{1800} + \frac{210}{1800} + y_4 \qquad y_4 = 0.185$$

$$G = \frac{y_4}{Y}.(C_0 - L) = \frac{0.185}{0.517}.(60-16) = 15.745\text{sec}$$

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29. 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 $k$ in veh/km. The capacity (in veh/h) of this section of the highway would be CE2 2014

a. 1200 **b.** 2400 c. 4800 d. 9600

29. b

Speed density relation is given by $V = 80 - \frac{2}{3}k$

$V$ : Speed of the vehicle, km/h

$k$ : Density of vehicles, vehicles/km

Capacity, $C = V \times k = 80k - \frac{2}{3}k^2$

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For maximum capacity, $\frac{dC}{dk} = 0$

$$\frac{dC}{dk} = 80 - \frac{4}{3}k = 0 \;\Rightarrow k = 60$$

Maximum capacity, $C = 80 \times 60 - \frac{2}{3}(60)^2 = 2400$ vehicles/hour

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30. 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/hr) is CE2 2014

a. 7.5 b. 12 c. 40 **d.** 60

30. d

Distance travelled by the student, $D = 5\,\text{km}$

Total time to reach home, $t = 40\,\text{minutes}$

Stopping time $= 15\,\text{minutes}$

Running time $= 40 - 15 = 25\,\text{minutes}$

Number of overtaking vehicles during ride $= 60$

Number of overtaking vehicles during stopping time $= 45$

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The speed of the vehicle stream, $V = ?$

Speed of the student during ride $= \frac{5}{25} \times 60 = 12$ km/h

$$\left(\frac{\text{Number of vehicles/minute}}{\text{Relative speed of vehicle w.r.t. student}}\right)_{\text{riding}} = \left(\frac{\text{Number of vehicles/minute}}{\text{Relative speed of vehicle w.r.t. student}}\right)_{\text{stopping}}$$

$$\frac{60}{25} \cdot \frac{1}{V-12} = \frac{45}{15} \cdot \frac{1}{V-0}$$

$$20V = 25(V-12)$$

$$5V = 300 \Rightarrow V = 60 \text{ km/h}$$

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31. The average spacing between vehicles in a traffic stream is 50 m, then the density (in veh/km) of the stream is _______ CE2 2014

31. 20

Average spacing between vehicles in traffic stream, $S = 50\,\text{m}$

Density of the vehicles stream, $k = ?$

$$k = \frac{1000}{S} = \frac{1000}{50} = 20\,\text{vehicles/km}$$

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32. An isolated three-phase traffic signal is designed by Webster's method. Theoritical flow ratios for three phases are 0.2, 0.3 and 0.25 respectively, and lost time per phase is 4 seconds. The optimum cycle length (in seconds) is______ CE1 2014

32. 92

Critical flow ratio for three phase $= 0.2 : 03 : 0.25$

Sum of the flow, $Y = y_1 + y_2 + y_3 = 0.2 + 0.3 + 0.25 = 0.75$

Lost time per phase $= 4\,\text{sec}$

Total lost time in a cycle, $L = 4 \times 3 = 12\,\text{sec}$

According to Webster's method, optimum cycle length, $C_0 = \dfrac{1.5L + 5}{1 - Y}$

$$C_0 = \frac{1.5 \times 12 - 5}{1 - 0.75} = 92 \text{ sec}$$

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33. The speed-density $(u-k)$ relationship on a single lane road with unidirectional flow is $u = 70 - 0.7k$, where $u$ is in km/hr and $k$ is in veh/km. The capacity of the road (in veh/hr) is __________ CE1 2014

33. 1750

Speed-density relationship on a single lane road with unidirectional flow is

$$V = 70 - 0.7k$$

$V$ : Speed of the vehicles, km/h

$k$ : Density of vehicles, veh/km

$C$ : Capacity of the road, veh/h

$$C = V.k$$
$$= (70 - 0.7k)k = 70k - 0.7k^2$$

For maximum capacity, $\dfrac{dC}{dk} = 0$

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$$70 - 1.4k = 0 \;\Rightarrow\; k = 50$$

Therefore, maximum capacity, $C = 70 \times 50 - 0.7(50)^2 = 1750$ veh/h

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34. The minimum value of 15 minute peak hour factor on a section of a road is

a. 0.1 b. 0.2 **c.** 0.25 d. 0.33 CE1 2014

34. c

Traffic volume analysis is based on peak rates of flow occurring within the peak hour because substantial short term fluctuations occur during an hour. Peak 15 minute rate of flow is used as a common practice. The relationship between the peak 15 minute flow rate and the full hourly volume is given by the peak hour factor (PHF).

$$PHF = \frac{\text{Hourly volume}}{\text{Peak rate of flow within the hour}} = \frac{V/4}{V_{15}}$$

$V$ : Peak hour volume, vehicles/hour

$V_{15}$ : Volume during the peak 15 minutes flow, vehicles/15 minutes

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Peak hour factors for freeways range between 0.80 and 0.95.
Lower factors are for rural freeways or off peak conditions.
Higher factors are for urban and suburban peak conditions.

$$\text{Maximum value of PHF} = 1.0$$

$$\text{Minimum value of PHF} = 0.25$$

35. For two major roads with divided carriage way 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.

35. b

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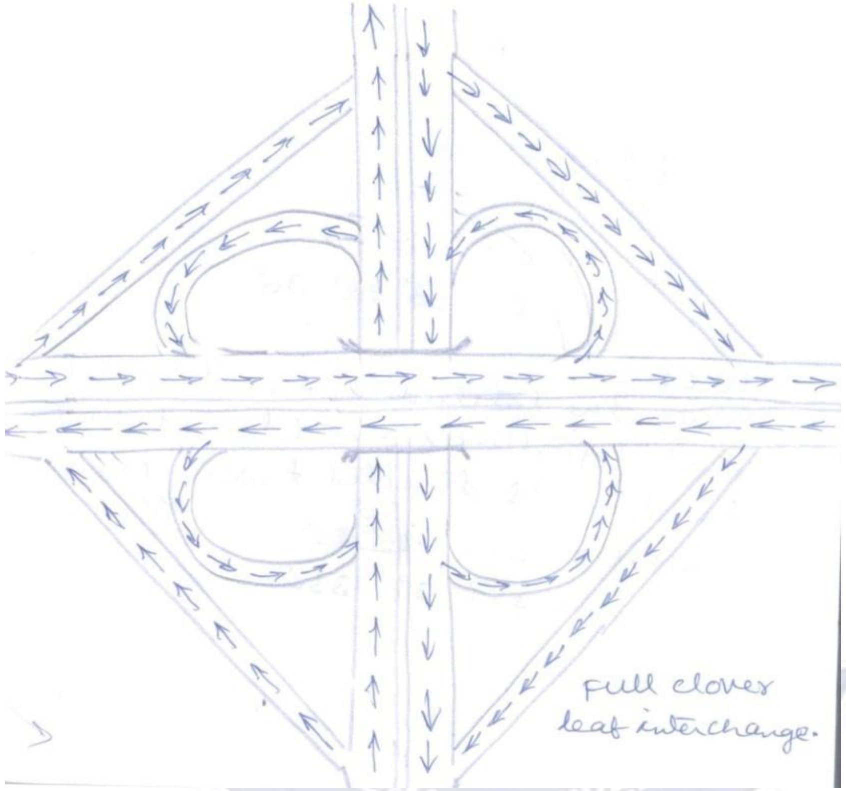


Merging from left is possible
Diverging to left is possible

36. 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 headways greater than 5 seconds in the above observation? GATE 2013

36. **7.91**

Number of vehicles cross the location = 150

Duration of crossing the vehicles, $t$ = 30 minutes

The probability density function of negative exponential distribution is

$$f(t) = \lambda.e^{-\lambda t}, t \geq 0$$

Rate parameter or Mean flow rate, $\lambda = \dfrac{150}{30 \times 60} = \dfrac{1}{12}$

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The probability that the random variable $t$ is greater than a specific value $h$ is

$$p(t \geq h) = e^{-\lambda h}$$

$$p(t \geq 5) = e^{-\frac{1}{12}.5} = 0.6592$$

Number of time headways greater than $h$ = $p(t \geq h)$ × Mean headway

$$= 0.6592 \times 12 = 7.91$$

Prof. B. Jayarami Reddy

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

a. 52 b. 58 **c.** 67 **d.** 75

37. d

Maximum capacity of traffic in two lane urban road with one way

$$q_m = 1800 \text{ vehicles/hour}$$

Average length occupied by the vehicles, $S = 5\text{m}$

Maximum density, $k_m = \dfrac{1000}{5} = 200 \text{ vehicles/km}$

$$q_m = \frac{k_m}{2} \cdot \frac{V_m}{2} \qquad 1800 = \frac{200}{2} \cdot \frac{V_m}{2} \qquad V_m = 36 \text{ kmph}$$

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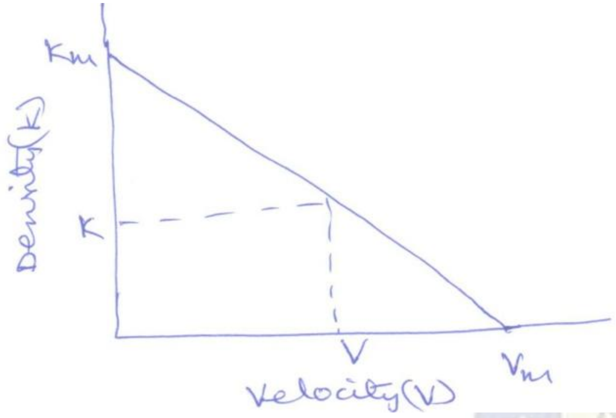
The speed versus density relationship is linear.




From graph

$$\frac{k_m}{V_m} = \frac{k_m - k}{V_m - V} \qquad \frac{200}{36} = \frac{200 - k}{36 - V} \qquad k = 5.55V$$

For normal condition, $q = k.v$

$q$ : Traffic volume = 1000 vehicles/hour

$$1000 = k.\frac{k}{5.55} \qquad k = 74.5 \text{ vehicles/km} \approx 75 \text{ vehicles/km}$$

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