Solution IAT-3 November 2018					
Sub:	TRAFFIC ENGINEERING	Sub Code:	15CV561	Branch:	CIVIL
PART A is compulsory and answer any TWO questions from Part B *Assume any missing data suitably.*					MARKS
	PART A				
1 (a)	Define briefly signal "cycle" and "interval". The average normal flow of traffic on cross roads A and B during design period are 400 and 250 PCU/hr, the saturation flow values on these roads are estimated as 1250 and 1000 PCU/hr respectively. The all red time for pedestrian crossing is 12 sec. design two phase traffic signal by Webster's method. Sketch phase diagram also.				[07]
	Cycle and Interval -2 Optimum cycle time -2 Green time for each cycle +phase diagram -3				
	Cycle: A signal cycle is one complete rotation through all of the indications provided. ***Cycle length:*** Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications. It indicates the time interval between the starting of green for one approach till the next time the green starts. It is denoted by C. ***Interval:*** It indicates the change from one stage to another. There are two types of intervals - change interval and clearance interval. ➢ **Change interval** is also called the yellow time indicates the interval between the green and red signal indications for an approach. ➢ **Clearance interval** is also called all red and is provided after each yellow interval indicating a period during which **all signal faces show red** and is used for clearing off the vehicles in the intersection. ***Green interval:*** It is the green indication for a particular movement or set of movements and is denoted by Gi . This is the actual duration the green light of a traffic signal is turned on. ***Red interval:*** It is the red indication for a particular movement or set of movements and is denoted by Ri . This is the actual duration the red light of a traffic signal is turned on. Assume time lost due to starting delays = 2 sec /phase Total lost time = R+nl= 12+2×2= 16sec. yA = 400/1250 = 0.32 yB = 250/1000 = 0.25 y = 0.32+0.25 = 0.57 C0 = Optimum cycle time = $1.5L+5/(1-y)=1.5\times16+51-0.57 = 67.44$ sec = 68 sec. Effective green time = 68-16= 52 sec Effective green time for A = 0.32/0.57×52=29 sec Effective green time for B = 0.25/0.57×52=23 sec				

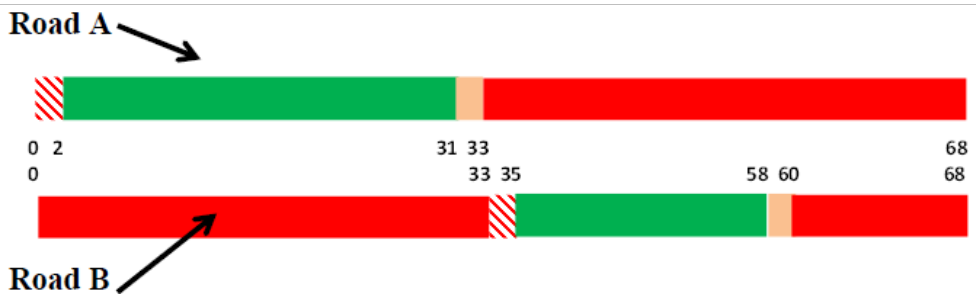
		
(b)	What is TDM? What are the direct and indirect methods of TDM?	[06]
	Definition-1 Listing - 5	
	TDM techniques are aimed at reducing the traffic flows, especially during the peak hour. Direct methods are the methods that can be directly quantified/ visible by the road user itself. Indirect methods are the methods which cannot be directly measured. Among the different techniques enlisted below, except road pricing all are direct methods. The different techniques adopted are 1. Car pooling and other ride-sharing programmes- reduce the volume of vehicles on road and ensures maximum capacity of each vehicle 2. Peripheral parking – to reduce traffic congestion in CBD 3. Chartered buses – to reduce waiting time of commuters 4. Staggering of office hours – to reduce traffic congestion at peak hours 5. Internal shuttle service in CBD – enables commuters to use public transport 6. Parking restraint – encourages commuters to usepublic transport 7. Road pricing -penalising a road user for the congestion created 8. Entry fee – entry fee restricts the commuter from using his own vehicle 9. Priority for buses in traffic – increasing level of service of public transport.	
(c)	Explain with neat sketches different traffic signs. Give three examples under each category	[05]
	Traffic sign and its classification-2 Each one with examples - 3	
	Traffic signs ➢ Traffic signs and road markings are silent speakers to the road users ➢ They give advance information about road conditions ahead. ➢ Road markings also give orders, warning or guidance to drivers or riders ➢ It increases safety in road transport **Types of Traffic signs** 1. Mandatory Signs 2. Cautionary Signs / Warning 3. Informatory Signs **Mandatory Signs / Regulatory Signs** ➢ These signs are used to inform road users of certain laws and regulations to provide safety and free flow of traffic. ➢ These include all signs which give notice of special obligation, prohibition or restrictions with which the road user must comply. ➢ The violation of these signs is a legal offence.	

Figure: Stop sign, give way sign, signs for no entry, sign indicating prohibition for right turn, vehicle width limit sign, speed limit sign

Cautionary Signs

These are used to war the road users of certain hazardous conditions that exist on or adjacent to the roadway. They are in the shape of an equilateral triangle with its apex pointing upwards. They have a white background, red borer and black symbols

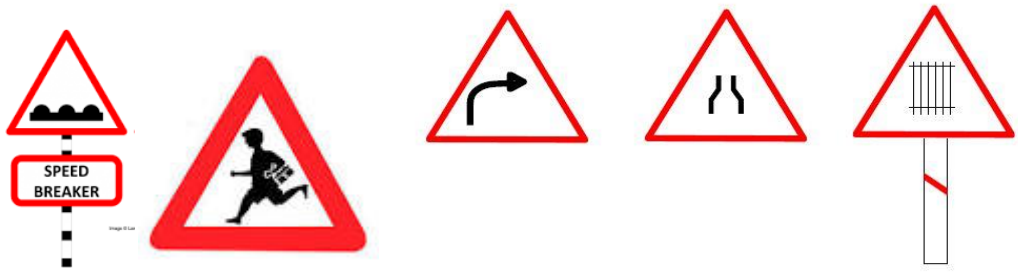


Figure: speed breaker, school, Right hand curve sign board, signs for narrow road, sign indicating railway track ahead)

Informatory Signs: These signs provide information to the driver about the facilities available ahead, and the route and distance to reach the specific destinations

2 (a)	Write short notes on: Rotary intersection, advantages and disadvantages, sketch and indicate various design elements of rotary	[08]
	Rotary intersection, advantages and disadvantages -3 Sketch - 2 Indicate various design elements of rotary -3	
	Rotary intersections or round about are special form of at-grade intersections laid out for the movement of traffic in one direction around a central traffic island. Traffic operations at rotary include diverging, merging and weaving **Advantages of rotary intersection**	

1 Traffic flow is regulated to only one direction of movement, thus eliminating severe conflicts between crossing movements.

1. All the vehicles entering the rotary are gently forced to reduce the speed and continue to move at slower speed. Thus, none of the vehicles need to be stopped, unlike in a signalized intersection.
2. Because of lower speed of negotiation and elimination of severe conflicts, accidents and their severity are much less in rotaries.
3. Rotaries are self governing and do not need practically any control by police or traffic signals.
4. They are ideally suited for moderate traffic, especially with irregular geometry, or intersections with more than three or four approaches.

Disadvantages of rotary intersection

1. All the vehicles are forced to slow down and negotiate the intersection. Therefore, the cumulative delay will be much higher than channelized intersection.
2. Even when there is relatively low traffic, the vehicles are forced to reduce their speed.
3. Rotaries require large area of relatively flat land making them costly at urban areas.
4. The vehicles do not usually stop at a rotary. They accelerate and exit the rotary at relatively high speed. Therefore, they are not suitable when there is high pedestrian movements.

There are 6 design elements of rotary intersection

1)Design speed

- The normal practice is to keep the design speed as **30 and 40 kmph** for urban and rural areas respectively.

2)Entry, exit and island radius

- The radius at the entry depends on various factors like **design speed, super-elevation,** and **coefficient of friction.**
- The **entry radius** of about **20 and 25 meters** is ideal for an **urban and rural** design respectively.
- A general practice is to keep the **exit radius** as **1.5 to 2 times** the **entry radius**.
- The radius of the **central island** which is about **1.3 times that of the entry curve** is adequate for all practical purposes.

3)Entry and exit width:

- The width of the road at entry and exit will be **lower** than the width of the road at the approaches to enable reduction of speed.
- IRC suggests that a **two lane road of 7 m width should be kept as 7 m** for urban roads and **6.5 m for rural roads**.
- Further, a three lane road of **10.5 m is to be reduced to 7 m** and **7.5 m** respectively for urban and rural roads.

4)Weaving width

- The width of the weaving section should be higher than the width at entry (e_1)and exit(e_2)

$$W_{weaving} = \left(\frac{e_1 + e_2}{2}\right) + 3.5m$$

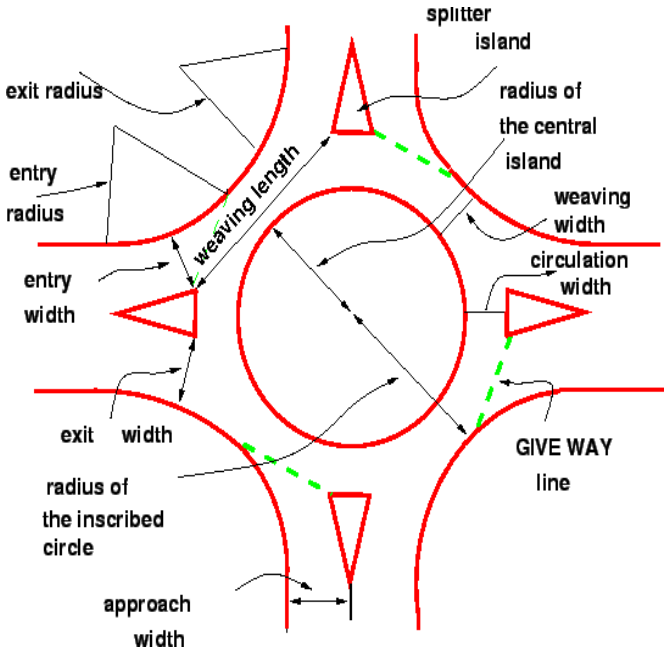
5)Weaving length:

- It is decided based on many factors such as **weaving width, proportion of weaving traffic to the non-weaving traffic** etc
- This can be best achieved by making the **ratio of weaving length to the weaving width very high.**
- A ratio of **4 is the minimum** value suggested by IRC.
- Very large weaving length is also dangerous, as it may encourage speed

6) Capacity

The capacity of rotary is determined by the capacity of each weaving section by using the following empirical formula

$$Q_w = \frac{280w[1 + \frac{e}{w}][1 - \frac{p}{3}]}{1 + \frac{w}{l}}$$



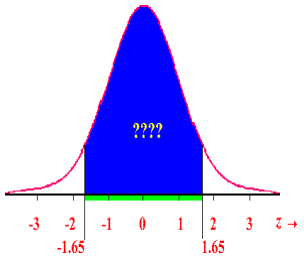
(b)	The spot speeds at a particular location are normally distributed with a mean of 51.71 kmph and standard deviation of 8.3 kmph. What is the probability that (i) the speeds exceed 65 kmph (ii) Speeds lie between 40 kmph and 70 kmph (iii)85th percentile speed. The values from normal distribution tables are ϕ (1.6) = 0.952, ϕ (2.21) = 0.9864, ϕ (1.41) = 0.9207, ϕ (Z) = 0.85 for which Z=1.04.	[08]
	(i) the speeds exceed 65 kmph -3 marks (ii) Speeds lie between 40 kmph and 70 kmph – 3marks (iii) 85th percentile speed – 2marks	
	μ = 51.7 ; and σ = 8.3 a) Probability that speeds exceed 65kph is the area under the normal curve to the right of x = 65 K.P.H **a) Probability of speed exceeding 65 Kmph; so x= 65 kmph** Z = (x – μ)/ σ	

= (65- 51.7)/ 8.3

=1.6

$\phi(1.6)$ from the question = 0.9542

P (x>65) = 1-0.9452 = 0.00548 = 5.48%



b) Probability that speeds lie between 40 and 70 K.P.H

P (40 < x < 70) = $\phi(z_2)$- $\phi(z_1)$

When x = 40 ; z1 = (x – μ)/ σ = (40- 51.7)/ 8.3 = -1.41

When x = 70 ; z2= (x – μ)/ σ = (70- 51.7)/ 8.3 = 2.21

Given in question,

$\phi(z_2) = \phi(2.21)$= 0.9864

$\phi(z_1)= \phi(-1.41) = 1- (\phi(1.41))$ = 1-0.9207 = 0.0793

P (40 < x < 70) = $\phi(z_2)$- $\phi(z_1)$ = 0.9864 – 0.0793 = 0.9071 = 90.71%

c) 85th percentile speed i.e speed below which 85% of vehicles are moving

$\phi(z)$ = 0.85

From the table z = 1.04

Z = (x – μ)/ σ

1.04 = (x- 51.7)/ 8.3

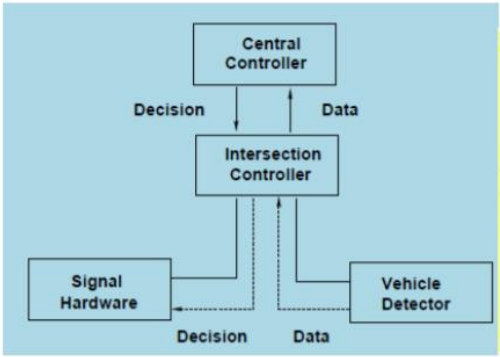
x = 60.83 K.P.H (85th percentile speed)

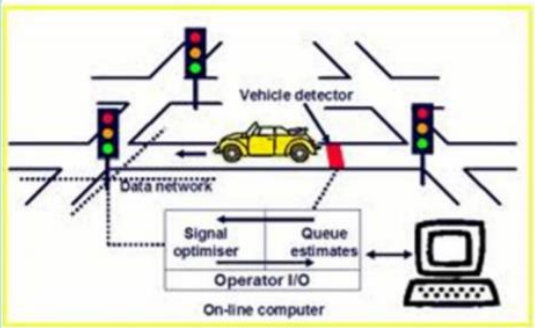
3 (a)	Explain Area traffic control and it's components with neat sketches	[08]
	Explanation with advantages and disadvantages – 3 Sketches with its components – 2+3	

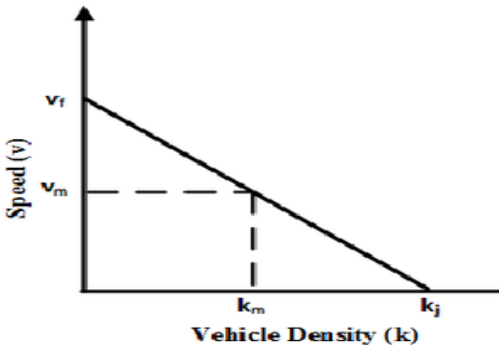
ATC systems are intelligent real-time dynamic traffic control systems which are designed to effectively respond to rapid variations in dynamic traffic conditions.

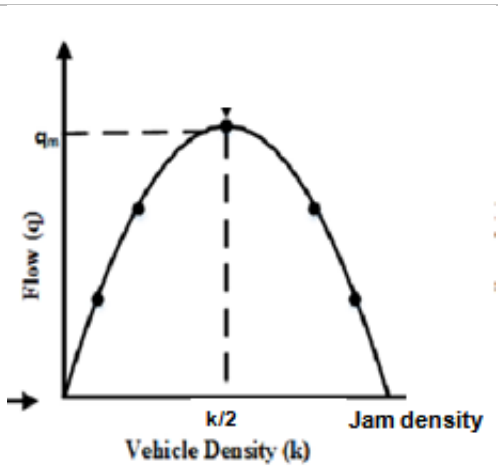
- It is a traffic responsive system that use data from vehicle detectors and optimize traffic signal time in real time.
- The timing plan of traffic controllers changed automatically.
- The technique employs digital computers for achieving the desired objective.

Advantages	Disadvantages
Minimizing journey time for vehicles	Very costly
Reducing accidents	Very complex
Increasing average saving in fuel	Suitable only for lane following traffic





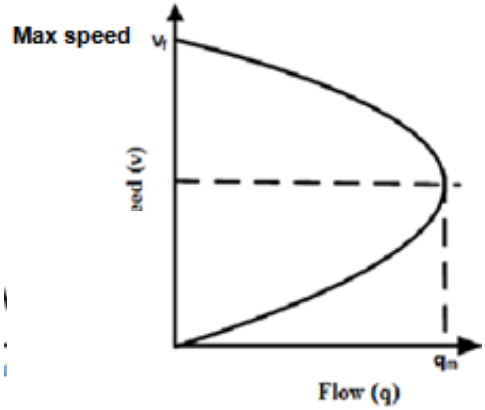
	Major building blocks of ATC *Vehicle Detectors* - VD acts as a nodal point between vehicle and intersection controller *Intersection Controller* **-** It collects the data from vehicle detector and sends it to the central control. Central control processes the data and sends it back to the intersection controller which then implements the signal timings as instructed at the intersection. *Communication Network -* *Application Software -* Application software is a large and complex program involving multiple systems, various procedures for implementation. *Central (Regional) Control System -*It is the main unit of ATC. In this unit collected traffic data is processed to optimize various traffic parameters like-signal timing, phase change, delay Important and major task of ATC system is performed by this unit. It supervises all the units of ATC. Examples of ATC are SCOOT (Split Cycle Offset Optimization Technique), SCAT (Sydney Coordinated Adaptive Traffic)etc.	
(b)	Derive the expression for the fundamental parameters of traffic flow using Green shield model. In a traffic stream, the free flow speed is observed to be 80 km/hr and jam density is estimated as 100 vehicles/ km. Calculate the maximum flow expected on this section	[08]
	Derivation with expression for vf, kj and q -6 Problem -2	
	Greenshield assumed **a linear speed-density** relationship $$v = v_f - \left[\frac{v_f}{k_j}\right].k \qquad (1)$$ Where, v is the mean speed at density k, vf is the free flow speed and kj is the jam density. It indicates that when density becomes zero, speed approaches free flow speed (i.e. v → vf when k → 0).  Substituting equation 1 in the equation 2 q = k x v (2) $$q = v_f.k - \left[\frac{v_f}{k_j}\right]k^2 \qquad (3)$$ The flow density relation is parabolic which can be given by the following graph	



Similarly we can find the relation between **speed and flow.**
For this, put k = q/v in equation 1 and by solving, we get

$$q = k_j.v - \left[\frac{k_j}{v_f}\right] v^2 \qquad (4)$$

The flow velocity relation is also parabolic which can be given by the following graph



<u>Boundary conditions</u>

Boundary conditions that are of interest are jam density, free-flow speed, and maximum flow

i)To find density at maximum flow (differentiate equation 3 with respect to k and equate it to zero)

$$\begin{aligned} \frac{dq}{dk} &= 0 \\ v_f - \frac{v_f}{k_j}.2k &= 0 \\ k &= \frac{k_j}{2} \end{aligned}$$

The density corresponding to maximum flow as k_0

$$k_0 = \frac{k_j}{2}$$

Density corresponding to maximum flow is half the jam density

ii)To find speed at maximum flow (differentiate equation 4 with respect to speed and equate it to zero

$$q = k_j.v - \left[\frac{k_j}{v_f}\right] v^2$$

$dq/dv = k_j - (k_j/v_f)\, 2v = 0$

$v = v_f / 2 = v_o$

$q_{max} = v_{max} \times k_{max}$

$= V_f/2 \times K_j/2$

In the question free flow speed is observed to be 80 km/hr and jam density is estimated as 100 vehicles/ km

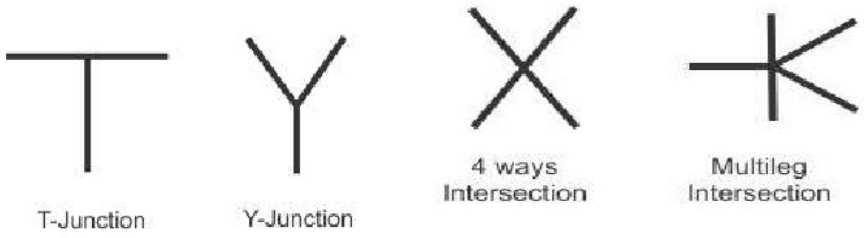
$q_{max} = (80/2) * (100/2)$

=2000 vehicles/hr

4 (a)	Explain i) At grade and grade separated intersections with neat sketches ii) Road markings	[08]
	i) At grade and grade separated intersections with neat sketches – 4marks ii) Road markings – 4 marks	

At grade intersection:

An intersection is the area shared by the joining or crossing of two or more roads. When they join at same level they are known as at grade intersections. T junctions, Y junctions, 4 way, multi way intersections, rotary intersection et joining at same level care few examples of at grade intersction



Grade separated intersections

Grade-separated intersections are provided to separate the traffic in the vertical grade. Different types of grade-separators are **flyovers and interchange**

- ✓ Flyovers can be overpass and underpass
- ✓ Interchanges: Interchange is a system where traffic between two or more roadways flows at different levels in the grade separated junctions. It can be divided in to
  - **Trumpet interchange**: is a three leg interchange. If one of the legs of the interchange meets a highway at some angle but does not cross it, then the interchange is called trumpet interchange.

- **Diamond interchange**: Diamond interchange is a popular form of four-leg interchange found in the urban locations where major and minor roads crosses.
- **Clover leaf interchange**: It is a four leg interchange used when two highways of high volume and speed intersect each other with considerable turning movements. The main advantage of cloverleaf intersection is that it provides complete separation of traffic. In addition, high speed at intersections can be achieved. However, the disadvantage is that large area of land is required. Therefore, cloverleaf interchanges are provided mainly in rural areas.
- **Partial Clover leaf interchange**

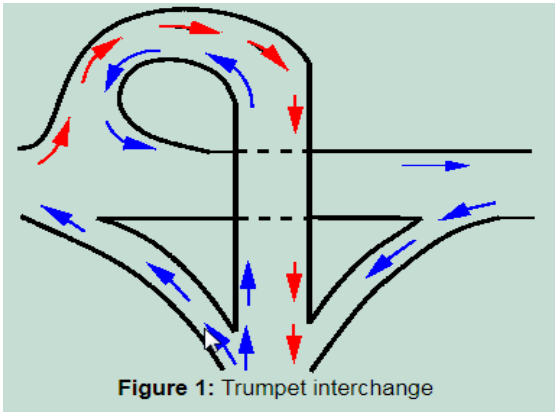


Figure 1: Trumpet interchange

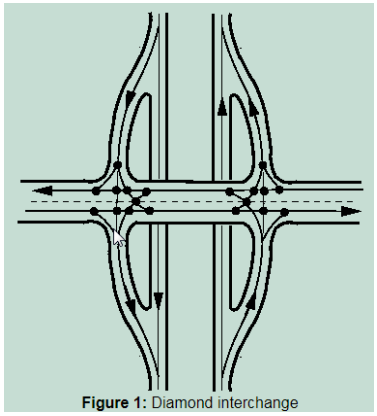
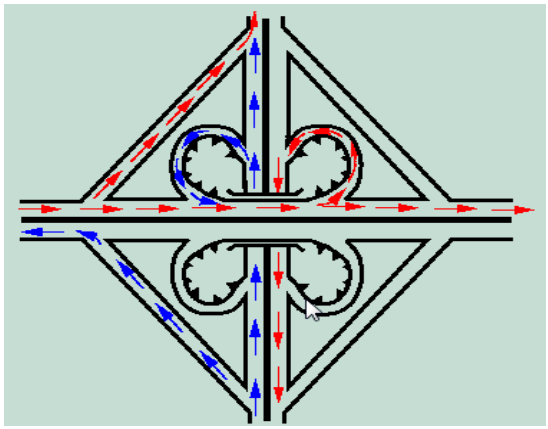
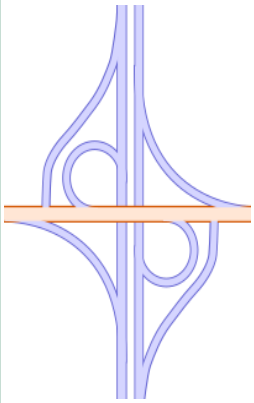


Figure 1: Diamond interchange



Clover leaf



Partial clover leaf

i) Road markings

Road markings are defined as lines, patterns, words or other devices, except signs, set into applied or attached to the carriageway or kerbs or to objects within or adjacent to the carriageway, for controlling, warning, guiding and informing the users.

Longitudinal markings

i. They are of the following types
ii. Centre-line marking
iii. Traffic lane lines
iv. No passing zones
v. Warning lines
vi. Edge lines

Centre line:

- Centre line separates the opposing streams of traffic and facilitates their movements.
- Usually no centre line is provided for roads having width less than 5 m and for roads having more than four lanes.

Traffic lane lines

- The subdivision of wide carriageways into separate lanes on either side of the carriage way helps the driver to go straight and also curbs the meandering tendency of the driver.

No passing zones

- No passing zones are established on summit curves, horizontal curves, and on two lane and three lane where overtaking maneuvers are prohibited because of low sight distance.
- It may be marked by a solid yellow line along the centre or a double yellow line.

Warning lines

- Warning lines warn the drivers about the obstruction approaches.
- They are marked on horizontal and vertical curves where the visibility is greater than prohibitory criteria specified for no overtaking zones.
- They are broken lines with 6 m length and 3 m gap.

Edge lines

- Edge lines indicate edges of rural roads which have no kerbs to delineate the limits upto which the driver can safely venture.
- They should be at least 150 mm from the actual edge of the pavement.
- They are painted in yellow or white.

Transverse markings

- **Stop line:**

  Stop line indicates the position beyond which the vehicles should not proceed when required to stop by control devices like signals or by traffic police.

  They should be placed either parallel to the intersecting roadway or at right angles to the direction of approaching vehicles.

- **Pedestrian crossings**

  Pedestrian crossings are provided at places where the conflict between vehicular and pedestrian traffic is severe.

  At intersections, the pedestrian crossings should be preceded by a stop line at a distance of 2 to 3m for unsignalized intersections and at a distance of one meter for signalized intersections.

	➢ **Directional arrows** Directional arrows should be used to guide the drivers in advance over the correct lane to be taken while approaching busy intersections. Because of the low angle at which the markings are viewed by the drivers, the arrows should be elongated in the direction of traffic for adequate visibility. # Object markings ➢ **Objects within the carriage way:** The obstructions within the carriageway such as traffic islands, raised medians, etc. may be marked by not less than five alternate black and yellow stripes. The stripes should slope forward at an angle of 45◦ with respect to the direction of traffic.. ➢ **Objects adjacent to carriageway** Objects adjacent to the carriageway like subway piers and abutments, culvert head walls etc. should be marked with alternate black and white stripes at a forward angle of 45◦ with respect to the direction of traffic. # Word messages ➢ **Parking:** The marking of the parking space limits on urban roads promotes more efficient use of the parking spaces and tends to prevent encroachment on places like bus stops, fire hydrant zones etc. where parking is undesirable. Such parking space limitations should be indicated with markings that are solid white lines 100 mm wide. ➢ **Hazardous location** Wherever there is a change in the width of the road, or any hazardous location in the road, the driver should be warned about this situation with the help of suitable road markings.	
(b)	Write short notes on i) ITS ii) **S**ignal co-ordination	[08]
	ITS – 4 Signal ordination and its types -4	
	Intelligent Transportation Systems **(ITS)** is the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveler information to increase the safety and efficiency of the surface transportation systems. These systems involve vehicles, drivers, passengers, road operators, and managers all interacting with each other and the environment, and linking with the complex infrastructure systems to improve the safety and capacity of road systems. **ITS user services** Some of the user services offered by ITS are described as follows: 1. **Travel and traffic management**	

The main objective of this group of services is to use real time information on the status of the transportation system to improve its efficiency and productivity and to mitigate the adverse environmental impacts of the system. This includes pre-trip information, enroute information, route guidance, route matching and information, traveller service information etc.

2. **Public transportation operations**

This group of service is concerned with improving the public transportation systems and encouraging their use. This includes services like real time public transit services and its maintainence, enroute information,

3. **Electronic payment:**

This user service allows travellers to pay for transportation services with a common electronic payment medium for different transportation modes and functions. Toll collection, transit fare payment, and parking payment are linked through a multi-modal multi-use electronic system. With an integrated payment system a traveller driving on a toll road, using parking lot would be able to use the same electronic device to pay toll, parking price and the transit fare.

4. **Commercial vehicle operations:** The aim is to improve the efficiency and safety of commercial vehicle operations including freight mobility, automated road side safety inspection, etc.

5. **Advance vehicle control and safety systems:** This user service aims to improve the safety of the transportation system by supplementing drivers' abilities to maintain vigilance and control of the vehicle by enhancing the crash avoidance capabilities of vehicles.

6. **Emergency management:** This includes emergency notification and personal security on the occurrence of an accident as well as emergency vehicle management.

7. **Information management:** This service is aimed to provide the functionality needed to store and archive the huge amounts of data being collected on a continuous basis by different ITS technologies.

8. **Maintenance and construction management:** This user service is aimed to provide the functionality needed for managing the fleets of maintenance vehicles, managing the roadway with regards to construction and maintenance and safe roadway operations.

ITS Architecture

The ITS Architecture provides a common framework for planning, defining, and integrating intelligent transportation systems. It specifies how the different ITS components would interact with each other to help solving transportation problems.

ITS Planning

ITS planning is to integrate ITS into the transportation planning process

b) Signal coordination:

Co-ordinated signal system/ signal coordination is based on the principle of linking adjacent signals so as to secure maximum benefits to the flow of traffic is called co-ordinated control of signals.

There are 4 types of signal coordination system

1. Simultaneous system
2. Alternate system
3. Simple progressive system
4. Flexible progressive

Simultaneous system

- All the signals along a given street will display the same indication to the same traffic stream at the same time.
- Division of cycle time is same at all intersections
- A master controller is employed to keep the series of signals in step

Alternate system

- Consecutive traffic signal installations along a given road show **contrary indications at the same time.**
- This permits the vehicles to travel one block in one half of the cycle time.
- It brings about a certain measure of **speed control** since speeding drivers are stopped at each signal.

Simple progressive system

- In 'simple progressive system' a time schedule is made to permit, as nearly as possible, a continuous operation of groups of vehicles along the main road at a reasonable pre-decided speed.
- Though each signal unit may work as fixed time signals, they have equal signal cycle length and are interlinked so as to operate with the required time off-sets.
- The principle of this simple progressive system is that if a group of vehicles get released during the green phase at a signalized intersection of the main road, by the time the first vehicle of this vehicle group travelling at the recommended speed reaches the next junction, the green phase of this signal would just get started to allow non-stop movement to the next intersection.

Flexible progressive system

- It is possible to automatically vary the length of signal cycle and signal phase at each signalized intersection with the help of sensors to detect vehicle arrival and connecting to a master computer.

This is the most efficient system of all the four types of traffic signal system.