SUMMER – 19 EXAMINATION

Subject Name: Highway Engineering (HEN) **Model Answer** Subject Code: 22302

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
Q.1		**Attempt any FIVE of the following**	**10**
	a) Ans:-	**Classify roads as per Nagpur Plan.** **According to Nagpur plan, roads are classified as:** 1) National Highway (NH) 2) State Highway (SH) 3) Major District Road (MDR) 4) Other District Road (ODR) 5) Village Road (VR)	2M
	b) Ans:-	**Define:** **i) Camber: -** The convexity provided to the surface of the carriage way is called camber **OR** The rise given to the center of carriage way above its edges on straight portion of a road is called camber. **ii) Super-elevation:-** The inward transverse inclination provided to the cross section of the carriage way at horizontal curved portion of a road is called super elevation.	1M 1M
	c) Ans:-	**Enlist types of Gradients.** **Types of Gradient:-** 1) Ruling gradient 2) Limiting gradient 3) Exceptional gradient 4) Average gradient 5) Floating gradient 6) Minimum gradient	½ M each (any four)
	d) Ans:-	**Define:** **i) Road carriageway: -** The portion of roadway constructed for movement of vehicular traffic is called carriageway. **ii) Road shoulder: -** The portion of the roadway between the outer edge of the	1M each

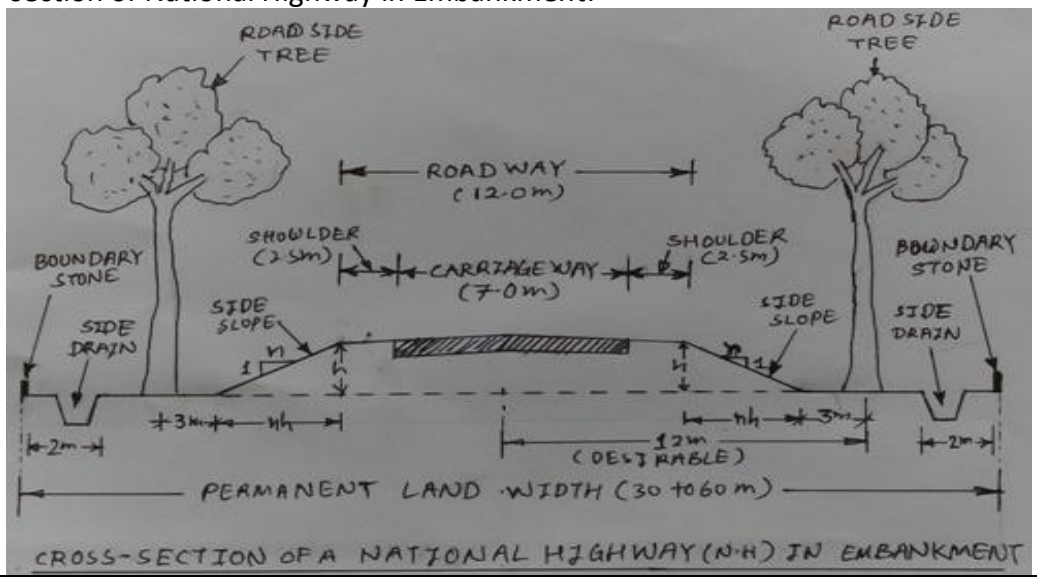
		pavement and inner edge of the side drain in cutting is called shoulder.	
	e) Ans:-	**Define :** **i) Traffic density: -** Traffic density is the number of vehicles occupying a unit length of lane of roadway at a given instant. **ii) Traffic volume: -** It is defined as the survey of number of vehicles and pedestrian crossing section of road per unit during any selected period.	1M each
	f) Ans:-	**State the necessity of Good drainage** **Necessity of good drainage:-** 1) Road drainage is necessary to collect surface water in side drains and to keep road surface in dry condition. 2) It is also required to carry sub surface water away from sub layers in heavy rainfall regions 3) It helps to reduce occurrence of road defects due to rainwater and rise of groundwater 4) It is beneficial to minimize landslides and related undesirable effects. 5) It increases load carrying capacity due to dry condition and maintained density of sub layers 6) It also results a good durable road with lesser maintenance as well.	1M each (Any two)
	g) Ans:-	**State the classification of highway maintenance.** **Classification of highway maintenance:-** 1) Routine repairs 2) Periodic repairs 3) Special repairs 4) Resurfacing 5) Special repairs to monsoon damage 6) Repair to bridge and culverts	½ M (any four)
Q.2		**Attempt any THREE of the following**	**12**
	a) Ans:-	**Define alignment and state the requirement of an ideal road alignment.** **Alignment: -** The position occupied by centerline of a road in plan is called alignment. **Requirements of an ideal road alignment:-** **1) Short: -** In between two terminal station the alignment should be as short as possible. It should provide economy in the cost of construction and maintenance. **2) Easy: -** The alignment should be easy for the operation of vehicles with easy gradients and curves. **3) Safe: -** The alignment should be safe for traffic operation. **4) Economical: -** The alignment should be economical in its cost of construction, maintenance & traffic operation. **5) Utility: -** The alignment should provide maximum utility by connecting important towns and group of villages. **6) Natural aspects: -** The alignment should pass through regions of natural beauty and scenery to have good natural aspects.	**4 M** 1M 1M each (any three)
	b) Ans:-	**State the necessity of providing extra widening on horizontal curves.** **The necessity of providing extra widening on horizontal curves: -** 1) When a vehicle travels on horizontal curves, it occupies more width than that it	**4 M**

		occupies on straight road. This reduces the capacity of the road in respect of accommodating number of vehicles on horizontal curve. To compensate for this effect the width of the road on horizontal curve is increased. 2) This also increases the visibility on the curves. 3) On curves, the vehicles occupy a greater width because the rear wheels follow the inner path as compared to the front wheel. 4) On curves, drivers have difficulty in steering their vehicle to keep to the center line of the road. 5) Drivers have psychological fear to drive close to the edge of the pavements on curves.	1M each (any four)
	c) Ans:-	**Explain the procedure for determining softening point of bitumen.** **Procedure for determining softening point of bitumen:-** 1) Sample material is heated to a temperature between 75^0C to 100^0C above the approximate point until it is completely fluid and is poured in heated rings placed on metal plate. 2) To avoid sticking of the bitumen to metal plate, coating is done to this with a solution of glycerin and dextrin. 3) After cooling the rings in air for 30 minutes, the excess bitumen is trimmed and rings are placed in the support. 4) At this time, the temperature of distilled water is kept at 50^0C. This temperature is maintained for 15 minute after which the balls are placed in position. 5) The temperature of water is raised at a uniform rate of 5^0C per minute with a controlled bottom plate by sinking of balls. At least two observations are made. 6) For material whose softening point is above 80^0C, glycerin is used in heating medium and the starting temperature is 35^0C instead of 5^0C.	**4 M** 4M
	d) Ans:-	**Define PCU and list four factors affecting passenger car unit.** **Passenger car unit: -** In order to convert the different vehicles classes to one class such as passenger car conversion factor, is known as passenger car unit. **Factors affecting passenger car unit:-** 1) It depends upon the factors like environmental and climatic conditions. 2) It depends upon the factors like dimensions, power, speed, acceleration and braking characteristics. 3) It depends upon the factors like roadway characteristics which includes road geometrics, rural or urban roads and types of intersections. 4) It depends upon the factors like different vehicle classes. 5) It depends upon the factors like regulations and control of traffic.	**4 M** 1M 1M each (any three)

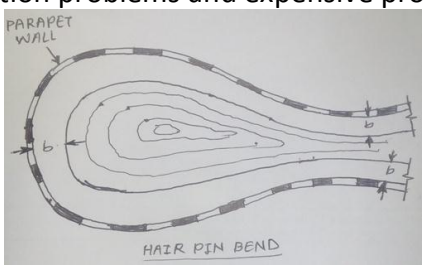
3		**Attempt any THREE of the following :**	**(12)**
	(a) Ans.	**Calculate the safe stopping sight distance for a design speed of 50 Kmph for a two way traffic in a single lane road.** **Assume f = 0.37 and reaction time = 2.5 seconds.** Given data:	**(4 M)**

		V = 50 Kmph t = 2.5 seconds f = 0.37 **SSD = 0.278 V t + (V^2 / 254 f)** = (0.278 x 50 x 2.5) + (50^2 / (254 x 0.37)) = 34.75 + 26.60 **SSD = 61.35 m. for one way traffic.** SSD for Two Way traffic on single lane road = 2 x SSD for one way traffic = 2 x 61.35 m = **122.70 m say 123 m.**	1 M 1 M 2 M
3	**(b)** Ans.	**Explain the procedure for flakiness an elongation test on aggregate.** **Procedure for Flakiness Test:** **1)** The sample of aggregate to be tested is first sieved through a set of sieves and separated into specified size ranges. Now to separate the flaky material, the aggregates which pass through the appropriate elongated slot of the thickness gauge are found. **2)** The width of the appropriate slot would be 0.6 of the average of the size range. If the selected size range of aggregate in a group is 20 – 16 mm (i.e., passing 20 mm and retained on 16 mm sieve), the width of the slot to be selected in thickness gauge would be 18 x 0.6 = 10.8 mm. **3)** The flaky material passing the appropriate slot from each size range of aggregate are added up and let this total weight of flaky particles be W1 gm. **4)** If the total weight of sample taken from the different size ranges is W gm., the flakiness index is given by (W1/W) x 100 percent; in other words Flakiness Index(FI) is the percentage of flaky materials, the widths of which are less than 0.6 of the mean dimensions. **Procedure for Elongation Test:** **1)** The sample of aggregate to be tested is first sieved through a set of sieves and separated into specified size ranges. **2)** The longest side of aggregate particles from each of the size range is then individually passed through the appropriate gauge of the length gauge; the gauge length would be 1.8 times the mean size of the aggregate. **3)** The portion of the elongated aggregate having length greater than the specified gauge from each size range is weighed. **4)** The total weight of the elongated stones is expressed as percentage of the total of the sample taken to obtain the elongation index.	**(4 M)** 2 M (½ M each) 2 M (½ M each)
3	**(c)** Ans.	**Discuss the merits and demerits of bitumen road.** **The merits of bitumen road are as follows:** **1)** It gives joint less smooth surface. **2)** Failure of Bitumen road is gradual. **3)** The quick repair of road is possible. **4)** Curing time is less. **5)** It can be opened to traffic soon as compared to concrete road. **6)** In this road, initial investment is less. **7)** Overall life cycle cost of bitumen road is less. **8)** It gives the lower noise level. **The demerits of bitumen road are as follows:**	**(4 M)** 2 M (any four ½ M each)

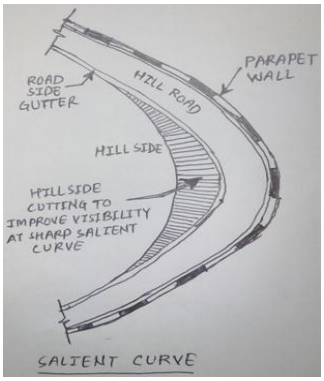
		1) Bitumen roads are less durable. **2)** They have less tensile strength. **3)** They develop hydrocarbon pollution to soil. **4)** Maintenance cost is more than cement concrete road.	2 M (½ M each)
3	**(d)** Ans.	**List any four causes of Accidents.** **Causes of Road Accidents:** The various causes of accidents may be listed as given below: **1) Due to Drivers:** Excessive speed and rash driving, carelessness, violation of rules and regulation, failure to see or understand the traffic situation, sign or signal, temporary effects due to fatigue, sleep or effect of consuming alcohol. **2) Due to Pedestrians:** Violating regulations, carelessness while using the carriageway meant for vehicular traffic. **3) Due to Passengers:** Alighting from or getting into moving vehicles. **4) Due to Vehicle defects:** Failure of brakes, steering system, or lighting system, tyre burst and any other defect in the vehicles. **5) Due to Road Condition:** Slippery or skidding road surface, pot holes, ruts and other damaged conditions of the road surface, temporary obstruction to line of sight (caused by branch of tree or disabled vehicle) resulting in reduction in normal sight distance. **6) Due to Road Design:** Defective geometric design like inadequate sight distance at horizontal or vertical curves, improper curve design, inadequate width of shoulders, improper lighting and improper traffic control devices. **7) Due to Traffic Condition:** Other vehicles of the traffic stream, such as a vehicle moving ahead getting involved in accident, presence of disabled vehicle on the roadway. **8) Due to Weather:** Unfavorable weather conditions like mist, fog, snow, dust, smoke or heavy rainfall which restrict normal visibility and render driving unsafe. **9) Due to Animals:** Stray animals on the road. **10) Other causes:** Incorrect signs or signals, gate of level crossing not closed when required, ribbon development, badly located advertisement boards or service stations etc.	**(4 M)** (any four) 1 M each
4		**Attempt any THREE of the following:**	**(12)**
	(a) Ans.	**Draw following road signs:** **(i) Speed limit** **(ii) No parking** **(iii) Narrow bridge** **(iv) Hair pin bend left** **(1) Speed Limit:** 	**(4 M)** 1 M

		(2) No Parking:  **OR**  **(3) Narrow Bridge:**  **(4) Hair pin bend left:** 	1 M 1 M 1 M
4	**(b)** Ans.	**Draw a neat labeled sketch of National Highway in Embankment.** Cross-section of National Highway in Embankment:  CROSS-SECTION OF A NATIONAL HIGHWAY (N·H) IN EMBANKMENT	**(4 M)** 2 M for figure 1 M for labeling 1 M for dimensions
4	**(c)** Ans.	**Explain the types of hill road curve with neat sketch.** Types of curves provided on hill road are as follow: **(1) Hair pin bend curve:** The curve in a hill road which changes its direction through an angle of 180^{o} or so, down the hill on the same side is known as hair pin bend curve. This type of curve should be located on a hill side having the minimum slope and maximum stability. It must also be safe from view point of landslides and ground water. Hair pin bends with long arms and farther spacing are always preferred.	**(4 M)**

They reduce construction problems and expensive protection works.

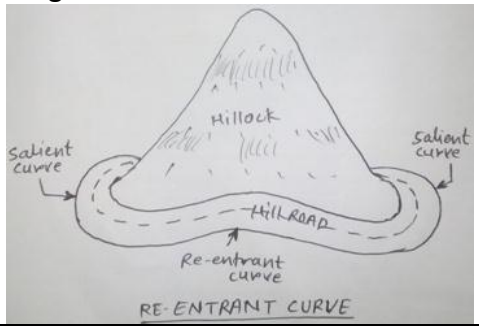


(2) Salient curve: The curves having their convexity on the outer edges of a hill road are called salient curves. The centre of curvature of a salient curve lies towards the hill side. This type of curve occurs in the road length constructed on the ridge of a hill. The bend so formed at the salient curve in a hill road is known as corner bend. Salient curves are very dangerous for fast moving traffic. At such a curve or at corner bend, the portion of projecting hill side is usually cut down to improve the visibility.

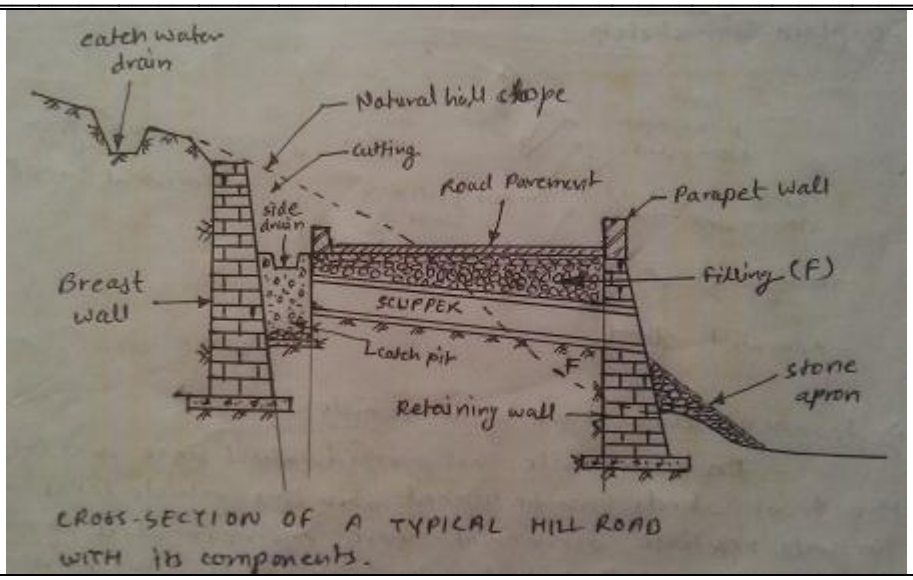
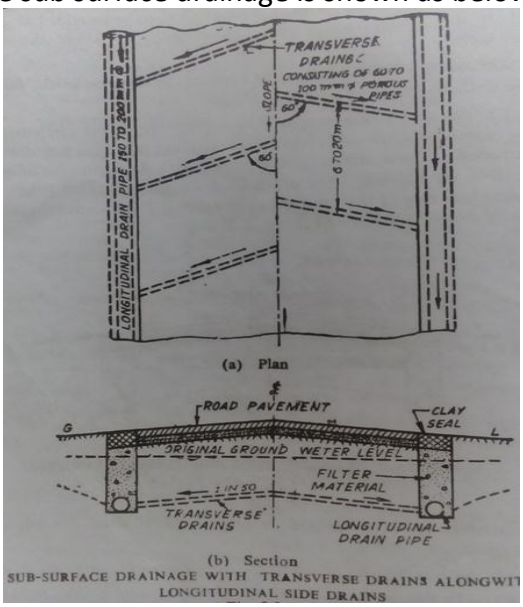
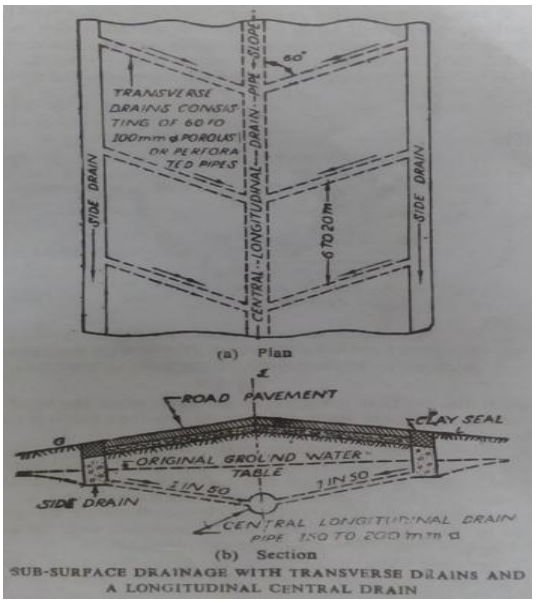


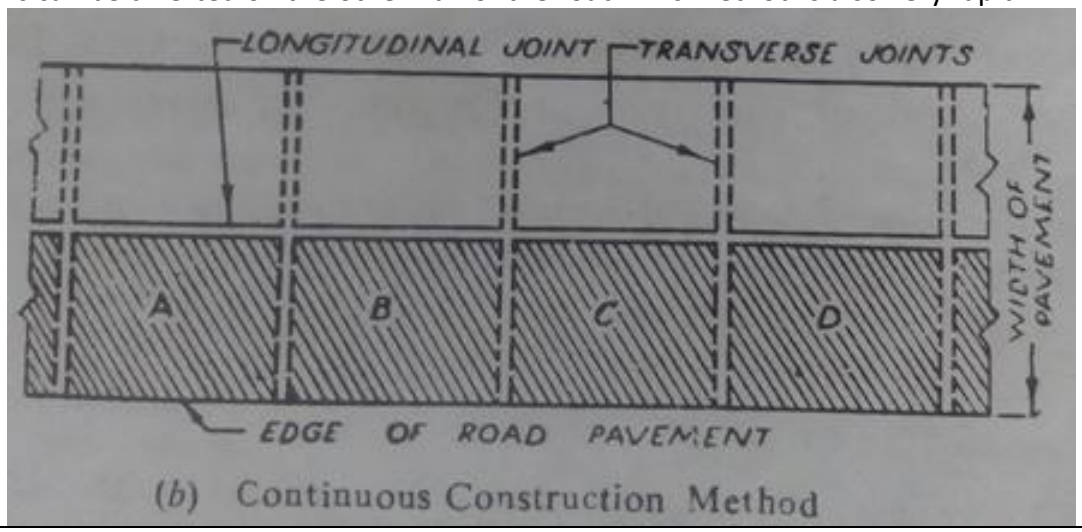
(any two) 2 M each

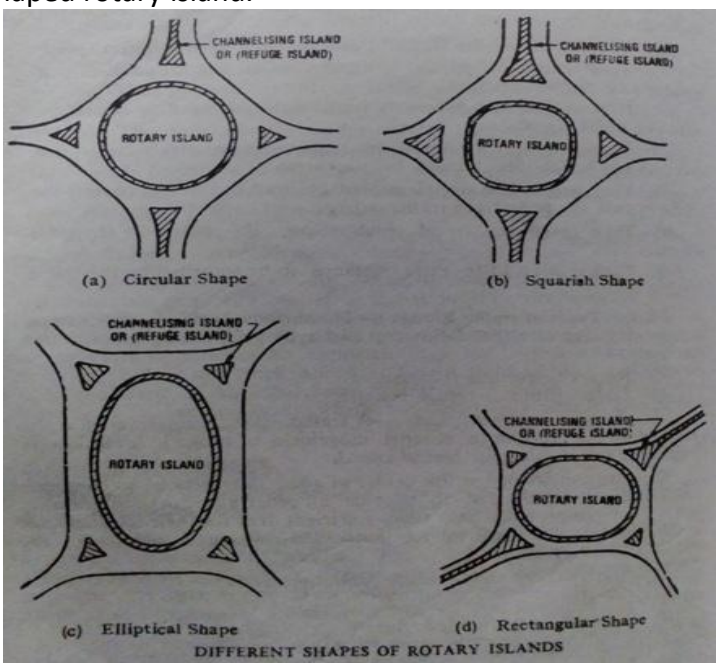
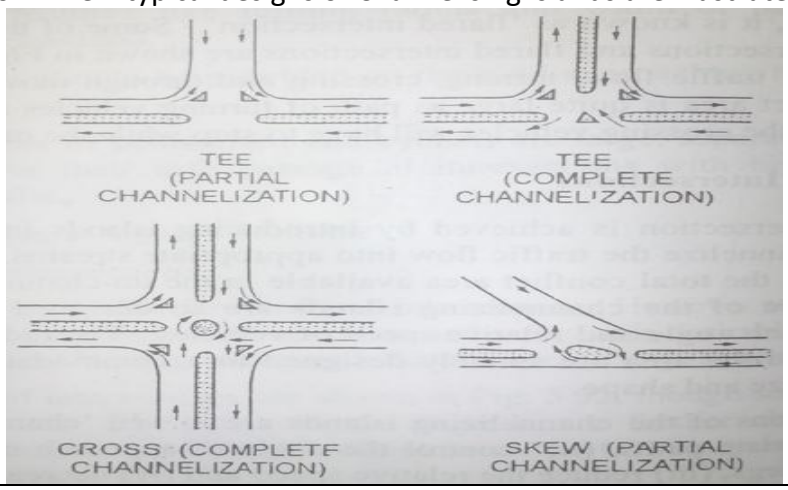
(3) Re-entrant curve: The curves having their convexity on the inner edge of a hill road are called re-entrant curves. The centre of curvature of a re-entrant curve lies away from the hill side. This type of curve occurs in the road length constructed in the valley of a hill. These curves are less dangerous as they provide adequate visibility to the fast moving traffic. At such curves, the parapet wall is provided only for safety of fast moving traffic.



4	(d) Ans.	**Draw a neat sketch of hill road showing its components.** The typical cross section of Hill Road with all component parts is as below:	**(4 M)**

		 CROSS-SECTION OF A TYPICAL HILL ROAD WITH its components.	4 M (2 M for figure and 2 M for labeling)
4	**(e)** Ans.	**Draw a neat sketch of subsurface drainage.** The sub surface drainage is shown as below:  SUB-SURFACE DRAINAGE WITH TRANSVERSE DRAINS ALONGWIT LONGITUDINAL SIDE DRAINS **OR**  SUB-SURFACE DRAINAGE WITH TRANSVERSE DRAINS AND A LONGITUDINAL CENTRAL DRAIN	**(4 M)** 4 M (any one) (2 M for figure and 2 M for labeling)
5		**Attempt any TWO of the following:**	**(12)**
	(a) Ans.	**Design the rate of super elevation for a Horizontal Highway curve of radius 500 metres and speed 100 Kmph. Assume suitable data.** Given data; V = 100 Kmph R = 500 meter For mixed traffic conditions, Super elevation is given by formula for maximum super elevation: $e = V^2 / (225 \times R)$ $= 100^2 / (225 \times 500)$ = 0.089 m per meter of carriage way OR = 0.089 x 100 = 8.9 % > 7 % (Restricted for Plain terrain) Provide maximum super elevation = e = 7 % i.e. = 0.07	**(6 M)** 1 M 1 M 1 M

		Now, Check for coefficient of lateral friction developed for full speed using the Primary or Actual equation. $e + f = V^2 / (127 \times R)$ $0.07 + f = 100^2 / (127 \times 500)$ $0.07 + f = 0.157$ $f = 0.157 - 0.07$ $f = 0.087 < 0.15$ (restricted for design purpose) Hence, the design is safe with a super elevation of e = 0.07 m per meter length carriage way.	1 M 1 M 1 M
5	**(b)** Ans.	**Describe stepwise construction procedure of cement concrete road by continuous bay method.** **Continuous Construction method:** In this method of construction, all the bays or slabs (ABCD) of strip are constructed continuously without any break as shown in figure. In this method, construction joints are, however, provided when the day's work is not ended at the specified joint. In addition to these, construction joints, dummy joints are also provided at 5 m. intervals in the transverse direction to check the planes of weakness and to control cracking. In this method, expansion joints are constructed at about 16 to 20 m. intervals i.e. after every fourth slab. This method is generally preferred as compared to alternate bay method because of its main advantage of construction of half the pavement width at a time. Thus, the essential traffic can be diverted on the other half of the road. This method is also very rapid.  (b) Continuous Construction Method	**(6 M)** 4 M 2 M
5	**(c)** Ans.	**Enlist different types of traffic island and explain any one in brief with neat sketch.** The different types of traffic island are as follow: (1) Rotary or central islands. (2) Channelising or refuse islands. **(1) Rotary or central islands:** A traffic island constructed in the centre of an intersection to compel movement of traffic in a clock-wise direction is called rotary or central island. They are constructed at the centre of road intersection to eliminate points of direct conflict and to provide an orderly and organized traffic flow. They are provided only when sufficient area for their construction is available at the road intersection. Their shape depends upon the type of road intersection. Rotary islands are usually of the following shapes: (i) Circular rotary island. (ii) Squarish with rounded edge rotary island.	**(6 M)** 2 M

		(iii) Elliptical, elongated or oval shaped rotary island. (iv) Rectangular shaped rotary island.  DIFFERENT SHAPES OF ROTARY ISLANDS **(2) Channelising islands:** The traffic islands provided at the entries and exist of traffic rotary are called Channelising or refuge islands. The shape of a Channelising island depends on actual conditions existing at each site of road intersection. A few typical designs of Channelising islands are illustrated below:  	4 M for any one type (2 M for explanation and 2 M for any one figure from it)
6		**Attempt any TWO of the following:**	**(12)**
	(a) Ans.	**Describe stepwise construction procedure for water bound macadam roads.** The construction procedure of W.B.M. road is discussed below: **1. <u>Preparation of subgrade</u> :** The subgrade is prepared to the required grade and camber. **2. <u>Preparation of the base course</u>** : After preparing the subgrade or sub base, the required type of base course is constructed with specified materials in conformity with lines, grade and thickness. **3. <u>Preparation of intermediate and wearing course</u>**: The preparation of intermediate and wearing course of a WBM road is done in following steps: (i) <u>Preparing the surface</u> :- The surface of the newly laid base course on which some traffic has been allowed, is checked and the defective portions are rectified.	**(6 M)** 1 M

		(ii) Providing edging or earthen kerbs :- After preparing the surface brick-on-end edging is provided along the outer edges of the carriage way of the road. (iii) Spreading of coarse aggregate :- The road metal is spread evenly over the prepared base to the specified thickness. (iv) Dry rolling :- After spreading the course aggregate, dry rolling is done by means of a suitable roller. The rolling should be started from edges and gradually shifted towards the centre after properly rolling each strip. (v) Spreading of screenings :- After dry rolling, a blindage layer consisting of stone screenings (12 mm grits) is spread at a slow and uniform rate so as to ensure filling of all voids. (vi) Wet rolling :- After spreading the screenings, the surface is sprinkled over with sufficient quantity of water, swept and rolled. (vii) Application of binding material, watering and rolling :- After the application of screening and wet rolling, the binding material is applied successively in two or more thin layers at a slow and uniform rate. After each application, the surface is freely sprinkled with water and rolled with 6 to 10 tonne roller. (viii) Finishing the surface :- After the final compaction, road surface is allowed to dry overnight. (ix) Setting and drying :- The surface is then allowed to cure for 7 to 9 days. **4. Preparation of shoulders** : During curing, the shoulders are prepared by filling earth to the specified cross slope. These are then properly compacted by rolling or tamping. **5. Open to traffic** : After drying, the road is opened to traffic.	4 M 1 M
6	**(b)** Ans.	**Discuss the types and causes of landslides with neat sketch.** **Types of landslides**: **(1) Fall:** It includes free fall and rolling of rocks and debris down the hill slope. **(2) Slide:** It is the movement of slope forming materials along one or several surfaces down the hill slope. It is caused due to finite shear failure of rocks. **(3) Flow:** It is the movement of the slope forming materials within the displaced mass. The form taken by the moving materials resembles to that of viscous fluid. In this case, the slip surface cannot be located. **(4) Complex land slide:** It includes movement due to combined effect of tow or more types of landslides. **Causes of landslides:** The following are the causes of landslide: 1) Due to increase in water content during rainy season. 2) Due to Hair-cracking due to alternate swelling and shrinkage of the soil mass. 3) Due to increase in load due to traffic or accumulation of snow on the road surface. 4) Due to removal of part of the mass by excavation and increase in slope angle. 5) Due to undermining caused by erosion. 6) Due to shocks and vibration caused by earthquake and nearby blasting or rocks. 7) Due to formation of faults in bedding planes of the strata due to vibrations. 8) Due to fissuring of pre-consolidated mass due to release of lateral pressure while doing cutting of rocks. 9) Due to seepage pressure of percolating ground water. 10) Due to failure of retaining wall or breast wall.	**(6 M)** 2 M (½ M each) 4 M (any eight points) ½ M each
6	**(C)**	**Discuss the causes of failure in flexible and rigid pavement.** **Causes of failure in flexible pavement**: The following are the causes of failure in flexible	**(6 M)**

	Ans.	pavement: 1) Ineffective road surface drainage system such as, (i) inadequate cross slope of the pavement surface or shoulders and (ii) inadequate longitudinal slope of the road side drains, which result in the stagnation of water on the shoulders or on the pavement surface on some road stretches. 2) Blockage or silting up of longitudinal and cross drains resulting in stagnation of water on the road. 3) Inadequate sub-surface drainage system or improper functioning of the drainage/ GSB layer, leading to stagnation of water on the subgrade or within any of the pavement layers and resultant damages to the pavement layers. 4) Environmental factors including heavy rainfall, soil erosion, high water table, snow fall, frost action, etc. 5) Inadequate compaction of embankment, subgrade or any of the pavement layers or settlement of embankment foundation itself, which could result in settlement of the supporting layers of the pavement resulting in damage to the roadway. 6) Defects in construction method and quality control during construction. 7) Defects in the quality of materials used in any of the pavement layers. 8) Increase in the magnitude of wheel loads and the number of load repetitions or passage of excessively overloaded commercial vehicles, exceeding the design values. **Causes of failure in Rigid pavement**: The following are the causes of failure in rigid pavement: 1) Defective drainage system may lead to failures in rigid pavements such as mud pumping, unless preventive measures are taken up at the design and construction stages. 2) Use of nondurable materials which start deteriorating during weathering cycles. 3) Improper alignment of dowel bars may lead to stress concentration and cracking near the joints. 4) Structural inadequacy of the pavement structure consisting of the cement concrete (CC) pavement slab, sub-base and subgrade, with respect the actual loading conditions to which the pavement is being subjected to. 5) Inadequate compaction of embankment or subgrade or settlement of embankment foundation itself, which could result in settlement of the supporting layers of the rigid pavement; these may lead to opening up of the joints or even non-uniform settlement of the pavement slabs resulting in deterioration in riding quality.	3 M (any three) 3 M (any three)