SECTION 1
INTRODUCTION

1. Traffic Engineering Administration and Functions

1.1. Definition

The Institute of Traffic Engineers defines traffic engineering as "that phase of engineering which deals with planning, geometric design and traffic operations of roads and streets and highways, their networks, terminals, abutting lands, relationships with other modes of transportation for the achievement of safe, efficient and convenient movement of persons and goods." (Ref. 1) The definition contained in the Glossary on Traffic Engineering Terms of the PIARC (Ref. 2) is :

"That phase of engineering which deals with the planning and geometric design of streets, highways and abutting lands, and with traffic operation thereon, as their use is related to the safe, convenient and economic transportation of persons and goods."

In addition to the qualifications such as safe, economic, convenient, comfortable and efficient, it may also be appropriate to add the term *"environmentally sustainable"* in the present threat of global warming and greenhouse gases generated by transport system.

The above definitions adequately illustrate the scope of the subject.

1.2. Growth of the Subject of Traffic Engineering

Traffic engineering is a comparatively new branch of engineering and has grown with the increase in traffic in recent years. As vehicular traffic began to increase, the congestion on the streets began to hamper the safe and efficient movement of traffic. More and more accidents were caused, and serious problems of parking and environmental pollution began to be felt. It was, therefore, necessary to give increasing attention to the operational characteristics of highway transportation and study the need for better geometric design, capacity, intersections, traffic regulations, signals, traffic signs, roadway markings, parking facilities, design of bus stands and truck terminals and street lighting. The above specialised needs were sought to be met with by the services of the Traffic Engineer.

Traffic surveys were made in a number of places in the United States, and much of this pioneering work is due to W.P. Eno, through whose endowment the Eno Foundations, Saugatuck is carrying on useful work on traffic research. The now familiar three colour light signals made their appearance in 1918. The Institute of Traffic Engineers was founded in 1931 and with this the profession was officially established and defined (Ref. 3).

Highway Engineering and Traffic Engineering are related subjects, and the latter can be deemed to be an offshoot of the former. In the United States, Traffic Engineering has been now recognized as a specialised branch. A number of universities offer graduate and post-graduate courses in Traffic Engineering. In European countries, Traffic Engineering is now becoming increasingly important and the need for a Traffic Engineering profession has been keenly felt (Ref. 4). In India, Traffic Engineering is still very much an adjunct of Highway Engineering, though the problems facing the urban centres in traffic and transportation are increasingly becoming more and more formidable, justifying the application of specialised techniques and knowledge. It will not be long before that the Traffic Engineer will be recognised for the useful role he has to play in better management of the traffic in our cities and towns. Some Universities in India are now offering post-graduate courses in Traffic Engineering.

1.3. Functions

The functions of a Traffic Engineer include the following :

1.3.1. Collection, analysis and interpretation of data pertaining to traffic. One of the important functions of a traffic engineer is to organise and implement various surveys and studies aimed at collection of data pertaining to traffic characteristics. Such studies include (*i*) origin and destination survey, (*ii*) volume counts, (*iii*) speed, travel time and delay measurements, (*iv*) accident statistics, (*v*) parking characteristics, (*vi*) pedestrian behaviour and use of streets, (*vii*) capacity studies and (*viii*) economic loss caused by inferior traffic facilities.

The data collected by the above studies are analysed by the traffic engineer and interpreted to take advantage of the observed regularities. Accurate understanding of the scientific phenomena behind these regularities enables the traffic engineer to select appropriate solutions to problems.

1.3.2. Traffic and transportation planning. The traffic engineer is concerned with the preparation of traffic and transportation plans to ensure a safe, orderly and fully integrated transportation system. This phase of activity concerns itself with the relation of land use with transportation and study of travel characteristics. Based on the analysis of the results of such a study, mathematical models are formulated to predict how a system will behave under a given set of conditions. Alternative solutions for the development of the street system are then thought out and are evaluated for their comparative merits and demerits. The optimal solution is then selected and implemented.

1.3.3. Traffic design. This part of the traffic engineer's function concerns itself with geometric design of highways and streets, intersection design, schemes for grade separated inter-changes, design of off-street and on-street parking facilities and design of terminal facilities for trucks and buses. In the field of geometric design, the functions of the highway engineer and the traffic engineer overlap and there is need for closer co-operation and consultation between the two.

1.3.4. Measures for operation of traffic. For efficient and safe operation of traffic, the traffic engineer has to take recourse to a number of measures such as :

(*i*) Legislation and enforcement measures for regulating the driver, vehicle and road users like the pedestrians, cyclists and motorcyclists.

(*ii*) Management measures such as one-way streets, prohibited turnings at junctions and tidal flow arrangements, exclusive bus lanes etc. with a view to get the maximum use out of the available street facilities.

(*iii*) Measures for regulation of parking of vehicles.

(*iv*) Traffic control devices such as traffic signs, traffic signals, pavement markings and channelization techniques to guide and secure the safe and efficient flow of traffic.

1.3.5. Administration. One of the functions of the traffic engineer is to organise and administer the various programmes intended to secure safe and efficient traffic in towns and cities. In this field he is closely associated with the legal and administrative framework of the city department dealing with education, legislation and enforcement measures.

1.4. Organisation of the Traffic Engineering Department

With the growth of the vehicular traffic on the roads, it is increasingly realised that the organizational setup designed to deal with the attendant problems of growing traffic has to be a separate unit under competent traffic engineers. The need for such a unit exists at the national, state and city level.

Table 1.1. Organisation of the State Traffic Engineering Unit in U.S.A.

(*Source* : Ref. 5)

In India, the Central Government have the direct responsibility for the construction and maintenance of National Highways. The responsibility requires that data on flow, speed, capacity, cost of Highways be collected in a systematic way, analysed and interpreted. This will facilitate drawing up plans for the orderly and regulated development of the highways and evolve appropriate geometric standards for designing the facilities. This need has been recognised by the Roads Wing of the Ministry of Transport and Shipping and a separate cell under a Chief Engineer established some years ago. However, this cell now is being looked after by the Chief Engineer (Research and Standardisation).

In the United States of America, the pace-setter in Traffic Engineering, the Federal Department of Transportation contains a number of organizations dealing exclusively with highway safety and urban transportation. In U.K., the Department of the Environment has on its staff traffic engineering specialists.

At the State level, a separate traffic engineering unit exists in the United States. Table 1.1 indicates the several functions assumed by the traffic engineering unit at the State level in the United States (Ref. 5).

In U.K., Traffic Engineering units exist at the county level. In India, such units exist only in some States. Recognising this deficiency, the Indian Roads Congress had made recommendations to the various States to set up such specialist units under an officer of the Superintending Engineer's rank (Ref. 6). Many of the State Public Works Departments have already established such cells.

It is on the city streets that concentrated traffic conditions exist, and it is there that there is a great need to organise all activities pertaining to traffic engineering under a single specialist unit. The traffic in the streets has reached chaotic conditions in many cities, leading to frustration, delays, increased vehicle operation costs, greater accident occurrence and degraded environments (Ref. 7). For safe and comfortable traffic, the traffic and transportation requirements of the city have to be assessed and plans have to be formulated to achieve the desired goals. Many metropolitan cities are already taking suitable steps to have comprehensive transportation studies where the traffic engineer has to play a pivotal role. With this background, the need for a separate Traffic Engineering unit in the City Administration set-up is paramount. As early as 1946, the President's Highway Safety Conference on Engineering in U.S.A. (Ref. 8) recommended that :

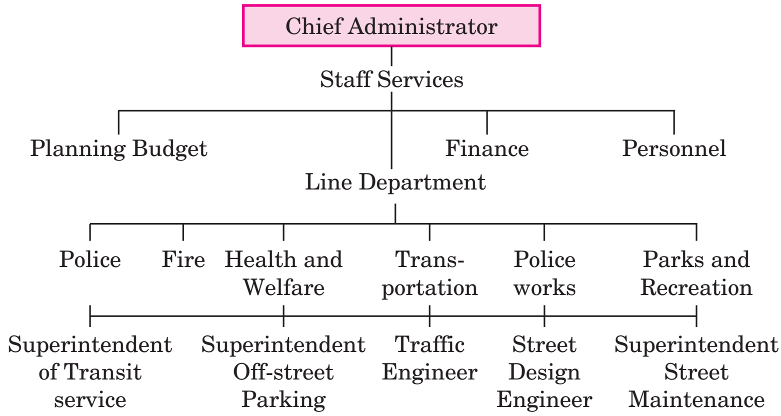
(*i*) In cities having more than 100,000 population, a traffic engineering unit be established comparable in authority and influence to other major divisions.

(*ii*) In cities between 50,000 and 100,000 population, at least one full-time traffic engineer be appointed vested with sufficient authority to adopt appropriate engineering measures for traffic operation and safety.

(*iii*) In cities having less than 50,000 population, an engineer (preferably the director of the department of public works or the city engineer or some member of his staff) could be appointed with sufficient qualifications and experience necessary to perform the functions of traffic engineering.

The above recommendations marked the beginning of effort for vesting the traffic engineer with full responsibilities for traffic matters in the U.S. cities. The following years have seen the fulfilment of these objectives. The recent development is that in large cities or metropolitan areas of over 1,000,000 population, the traffic engineering and other highway functions are brought in under a single transportation department. Traffic engineering is a major division of the organization as indicated in Table 1-2 (Ref. 9).

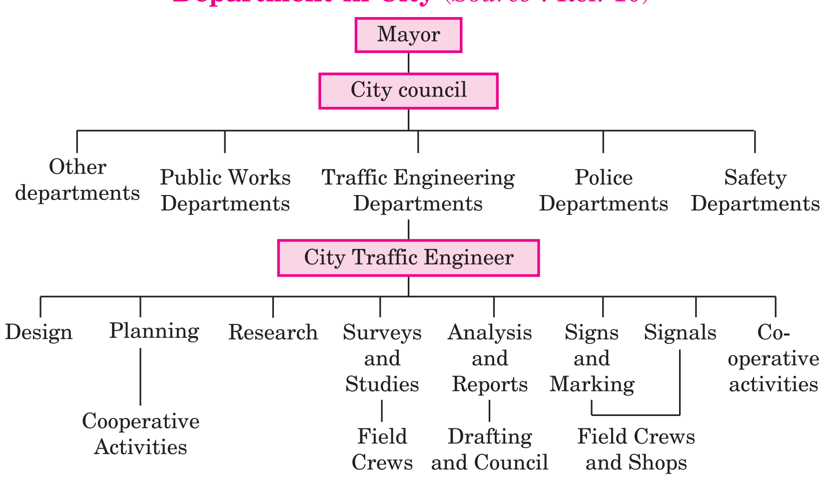
Table 1.2. Traffic Engineering Administration in a Department of Transportation (*Source* : Ref. 9)



The Institute of Traffic Engineers now recommends that the above system be adopted for cities with a population more than 750,000. (Ref. 9). For cities with a population of between 250,000 and 750,000, the Institute recommends a separate major city department, dealing with streets and traffic, and having on its roles several professional engineers and a fairly large supporting staff. For cities between 50,000 and 250,000 a full-time traffic engineer and staff is deemed to be necessary. For cities with a population smaller than 50,000, the Institute reckons that a full-time engineer or staff for traffic functions may not be justified, the city engineer himself assuming responsibility for the overall supervision of traffic engineering activities. In cities having a separate Traffic Engineering Department, the organizational structure and functions can be as shown in Table 1.3 (Ref. 10).

At the city level, the traffic departments in India are managed by high ranking police officers, with traffic engineers playing very minor roles in the organizations (Ref. 11). This is a very unsatisfactory arrangement and needs to be ended soon. Separate Traffic Engineering cells are needed answer to tackle the traffic problems baffling Indian cities.

Table 1.3. Organisational Structure for the Traffic Engineering Department in City (*Source* : Ref. 10)



1.5. Importance of Traffic Engineering under Indian Conditions

Road traffic has been growing a very rapid rate in India during the past three decades. The number of motor vehicles has been growing at a rate around 10 percent per annum (Ref. 13). Table 1.4 gives the actual statistics (Ref. 12). The growth rate of various vehicle classes has been as under (Ref. 13) :

Cars : 7-10 percent
Buses : 5-10 percent
Trucks : 6-15 percent
Two-wheelers : 15-17 percent.

The production of motor vehicles has also been growing at a rapid rate, vide Table 1.5 (Ref. 12 and 15). India has crossed the figure of one million cars per annum recently.

As a result of the steep growth of motor vehicle population, the traffic on the roads has been increasing, both in terms of volume and intensity. The investments on roads have not kept pace with the growth of traffic, with the result there is severe congestion on the roads. Speeds are low and vehicle operating costs are high. Accident rate is usually high.

Traffic engineering measures provide a valuable tool to understand the problems and evolve suitable measures to overcome the deficiencies.

Table 1.4. Total Registered Motor Vehicles in India – 1951-93 (Source : Ref. 12,14) (in Thousands)

Year (as on 31st March)	*All Vehicles*	*Two wheelers*	*Car, jeep and Taxis*	*Buses*	*Goods Vehicles*	*Others**
1951	306	27	159	34	82	4
1956	426	41	203	47	119	16
1961	665	88	310	57	168	42
1966	1099	226	456	73	259	85
1971	1865	576	682	94	343	170
1972	2045	656	740	100	364	185
1973	2109	734	709	95	308	263
1974	2327	838	768	105	323	293
1975	2472	946	766	114	335	311
1976	2700	1057	779	115	351	398
1977	3260	1415	878	119	383	465
1978	3614	1618	919	124	403	550
1979	4059	1888	996	133	444	598
1980	4521	2117	1059	140	473	732
1981	5391	2618	1160	162	554	897
1982	6055	3065	1243	173	613	961
1983	6973	3654	1385	185	675	1074
1984	7949	4351	1455	199	742	1202
1985	9170	5179	1607	223	822	1339
1986	10577	6245	1780	227	863	1462
1987	12618	7739	2007	245	984	1643
1988	14818	9300	2295	269	1114	1840
1989	16920	10965	2486	278	1179	2012
1990	19152	12611	2694	298	1238	2311
1991	21374	14200	2954	331	1356	2533

1992	23507	15661	3205	358	1514	2769
1993	25299	17026	3330	381	1599	2963
1994	26464	17936	3446	390	1791	2901
1995	30295	20831	3841	423	1938	2770
1996	33786	23252	4204	449	2031	3850
1997	37332	25729	4672	484	2343	4104
1998	41368	28642	5138	538	2536	4514
1999	44875	31328	5556	540	2554	4897
2000	48857	34118	6143	562	2715	5319
2001	54991	38556	7058	634	2948	5795
2002	58924	41581	7613	635	2974	6121
2003 (P)	67033	47525	8619	727	3488	6674

Includes Omni buses.

(P) : Provisional

*Others included tractors, trailors, three wheelers (passenger vehicles) and other miscellaneous vehicles which are not separately classified.

Table 1.5. Production of Motor Vehicles in India (1950-93) (Source : Ref. 12 and 15) (in Thousands)

Year (as on 31st Dec)	*Jeeps and Utility Vehicles*	*Car*	*Comme-rcial Vehicles*	*Two Wheelers*				*Three wheel-ers*	*Trac-tors*
				Scoo-ters	*Mopeds*	*Motor cycles*	*Total (Col.5-7)*		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1950	–	2.2	1.9	–	–	–	–	–	–
1955	2.9	10.0	9.3	0.6	–	0.4	1.0	–	–
1960	5.5	19.1	27.5	12.0	0.9	4.0	16.9	0.5	0.1
1965	10.5	24.8	37. 4	20.3	7.4	21.4	49.1	1.9	5.6
1970	9.3	35.2	41.0	58.4	11.7	42.9	113.0	4.2	19.9
1975	8.1	20.1	43.0	101.8	36.2	69.7	207.7	12.2	32.4
1980	15.1	30.5	68.3	209.9	106.1	101.6	417.6	26.5	67.1
1981	17.0	42.1	89.8	202.9	185.4	110.8	499.1	24.8	82.5
1982	19.0	42.7	90.8	250.7	212.6	130.0	593.3	30.6	67.6
1983	21.7	45.1	87.4	273.9	329.1	156.2	759.2	37.7	71.5
1984	22.2	64.0	94.7	297.3	377.0	175.3	849.6	41.8	78.9
1985	26.9	102.5	99.7	422.3	455.3	248.0	1125.6	49.3	78.3
1986	27.8	116.0	93.6	588.1	449.8	314.7	1352.6	53.1	74.7
1987	32.4	148.5	108.1	625.6	475.6	300.6	1401.8	60.2	63.8
1988	35.1	159.9	117.3	658.9	504.2	411.6	1574.7	69.1	102.4
1989	42.4	177.2	117.6	848.5	481.1	420.8	1750.4	83.2	117.2
1990	41.9	176.6	145.6	968.4	428.6	478.5	1875.5	95.5	128.8
1991	30.4	178.9	145.7	778.6	398.1	424.6	1601.3	79.4	152.1
1992	38.2	153.9	128.1	684.3	405.9	387.0	1477.2	66.4	153.2
1993	44.3	199.6	127.8	793.8	451.4	428.5	1673.7	77.5	135.1
2002	169.4	500.3	162.5	937.5	427.5	2906.3	4271.3	212.7	NA
2003	165.9	557.4	203.7	848.4	351.6	3876.2	5076.2	276.7	NA
2004	207.0	782.6	275.0	935.3	332.3	4355.2	5622.8	356.2	NA
2005	249.3	960.4	353.7	987.5	348.4	5193.9	6529.8	374.4	NA
2006	263.0	1045.9	391.1	1020.0	379.6	6201.2	7600.8	434.4	NA

NA : Not Available.

I. MULTIPLE CHOICE QUESTIONS

1. Traffic engineering only includes
(*a*) analysis of traffic characteristics
(*b*) design and application of control devices
(*c*) planning and control of regulatory measures
(*d*) traffic operation
(*e*) all the above.

2. Which set of traffic studies is needed for functional design as well as for 'highway capacity' design?
(*a*) origin and destination studies (*b*) parking and accident studies
(*c*) speed and volume studies (*d*) axle load studies

3. A traffic engineering unit to be established if a city having
(*a*) more than 100,000 populations (*b*) more than 50,000 populations
(*c*) more than 10,000 populations (*d*) none of these

4. Which of the following is known as design capacity?
(*a*) basic capacity (*b*) theoretical capacity
(*c*) possible capacity (*d*) practical capacity

5. For the movement of vehicles at an intersection of two roads, without any interference, the type of grade separator generally preferred to, is
(*a*) delta (*b*) trumpet
(*c*) diamond interchange (*d*) clover leaf.

6. If the ruling gradient on any highway is 3%, the gradient provided on the curve of 300 metre radius, is
(*a*) 2.00% (*b*) 2.25%
(*c*) 2.50% (*d*) 2.75%

7. As per recommendations of I.R.C., traffic volume study is carried out for rural roads for 7 days continuously during
(*a*) harvesting (*b*) lean season
(*c*) harvesting and lean season (*d*) none of these.

8. The minimum ratio of the radii of two circular curves of a compound curve, is kept
(*a*) 1.25 (*b*) 1.5
(*c*) 1.75 (*d*) 2.0

9. Design of horizontal and vertical alignments, super elevation, sight distance and grades, is worst affected by
(*a*) width of the vehicle (*b*) length of the vehicle
(*c*) height of the vehicle (*d*) speed of the vehicle

10. The growth rate of buses in the country is
(*a*) 15-17% (*b*) 7-10%
(*c*) 5-10% (*d*) None of these

11. The number of motor vehicles has been growing at a rate around
(*a*) 10% per annum (*b*) 20% per annum
(*c*) 15% per annum (*d*) None of these

Answers

1. (*e*)	**2.** (*c*)	**3.** (*a*)	**4.** (*a*)	**5.** (*d*)
6. (*d*)	**7.** (*c*)	**8.** (*b*)	**9.** (*d*)	**10.** (*c*)
11. (*a*)				

II. QUESTIONS AND ANSWERS

Q. 1. Define traffic engineering.

Ans. Traffic engineering is the branch of engineering which deals with the improvement of traffic performance of the road networks and terminds focuses on planning, geometric design and traffic operations of roads and streets and highways, their networks, terminals, abutting lands, relationships with other modes of transportation for the achievement of safe, efficient and convenient movement of persons and goods.

Q. 2. What are the functions of traffic engineer?

Ans. A traffic engineer performs following functions:

1. He train and educates staff on criteria and standards of section. He provides engineering guidance to staff and makes engineering recommendations to county officials and other departments.

2. He developes, monitors, and controls the section's budget.

3. He coordinates the section's activities with other sections, departments, and jurisdictions.

4. Maintaines regular, predictable and punctual attendance during regularly scheduled work hours at assigned worksite.

5. He meets travel requirements of the position.

6. Performs the physical requirements of the position; work within the established working conditions of the position.

7. He work a flexible schedule, which may include evenings, weekends, holidays.

Q. 3. What do you mean by traffic congestion?

Ans. Traffic congestion is a condition on transport networks that occurs when the use of transport increases. It is characterized by slower speeds, longer trip times, and increased vehicular queueing. As demand approaches the capacity of a road (or of the intersections along the road), extreme traffic congestion sets in.

Q. 4. What measures a traffic engineer has to take?

Ans. A traffic engineer has to take the following measures:

- Legislation and enforcement measures for regulating the driver, vehicle and road users like the pedestrians, cyclists and motor-cyclists.
- Management measures such as one-way streets, prohibited turning at junctions and tidal flow arrangements, exclusive bus lanes etc. with a view to get the maximum use out of the available street facilities.
- Measures for regulation of parking of vehicles.
- Traffic control devices such as traffic signs, traffic signals, pavement markings and channelization techniques to guide and secure the safe and efficient flow of traffic

Q. 5 What is the importance of traffic engineering?

Ans. Traffic engineering uses engineering techniques to achieve the safe and efficient movement of people and goods. It focuses mainly on research and construction of the immobile infrastructure necessary for this movement, such as roads, railway tracks, bridges, traffic signs and traffic lights. It manages the traffic density by limiting the rate that vehicles enter the highway during peak periods can keep both speeds and lane flows at bottlenecks high. Ramp meters, signals on entrance ramps that control the rate at which vehicles are allowed to enter the mainline facility, provide this function (at the expense of increased delay for those waiting at the ramps).

Q. 6. What the various objectives of traffic engineering?

(*B.E. Exam. 2010*)

Ans. A major objective of traffic engineering is to minimize or eliminate high-loss situations. In particular, the number of rejected messages or failed call attempts should be as close to zero as possible. Another goal of traffic engineering is to balance the QoS (Quality of Service) against the cost of operating and maintaining the network.

It is a method of optimizing the performance of a telecommunications network by dynamically analyzing, predicting and regulating the behavior of data transmitted over that network. Traffic engineering is also known as tele traffic engineering and traffic management. The techniques of traffic engineering can be applied to networks of all kinds, including the PSTN (public switched telephone network), LANs (local area networks), WANs (wide area networks), cellular telephone networks, proprietary business and the Internet.

III. REVIEW QUESTIONS

1. What is the scope of traffic engineering?
2. Briefly explain the growth of traffic engineering.
3. Discuss the important functions of traffic engineering.
4. Describe the road traffic in India.

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2. The Road User and the Vehicle

2.1. Introduction

The traffic engineer has to design and operate the traffic facilities which will be used by pedestrians, cyclists and motorists. A proper understanding of the behaviour of the road user and the vehicle characteristics is necessary for this purpose. The human factors that govern the behaviour of the road user can offer many clues in the design of a traffic facility. A knowledge of how this behaviour is influenced by various external conditions will be useful for the same purpose. The characteristics of the vehicle will determine the design of the geometric elements of the road and in understanding the safety aspects.

2.2. Human Factors Governing Road User Behaviour

2.2.1. The human body as a complex system exhibiting reactions to external stimuli

The aspects of human behaviour having a bearing on traffic can be broadly considered under two groups : (*i*) physiological and (*ii*) psychological. Under the physiological group, the following factors may be considered : (*a*) vision, (*b*) hearing. Under the psychological factors, the perception, intellection, emotion and volition need to be considered. These are discussed in detail below.

2.2.2. Vision

Vision is one of the important factors that affects almost all aspects of highway design and safety. The human eye is the sensory organ that enables one to see and evaluate the size, shape and colour of objects and estimate distances and speeds of bodies. The light rays from the object get refracted through the lens and are brought to focus on the retina. The image formed on the retina is transmitted to the brain through the optic nerve which perceives the object.

The zone of acute vision (visual acuity) is formed by a cone whose angle is 3° about the centre of the retina. This signifies that for very distant vision, the objects should be within this narrow cone for satisfactory perception. However, the vision is still satisfactory when the angle of the cone is upto 10° or 12°. This is important when locating traffic signs and signals.

Peripheral vision deals with the total visual field for the two eyes. Within this field the eyes are able to see objects, but without clear details and colour. For example, a movement or a bright light can alert a driver in the zone of peripheral vision. The angle of peripheral vision is about 160° in the horizontal direction and 115° in the vertical direction. If the detailed attention of the eye is needed, the driver turns his head or eyes so that the object now comes within the cone of clear vision. The cone of peripheral vision also depends upon speed. The angle of the cone falls down from about 110° at 30 K.P.H. speed to about 40° at 100 K.P.H. speed.

Colour vision is important for discerning the traffic lights and colour schemes in traffic signs. But colour blindness need not be of serious concern since drivers can learn other means of recognising signs and signals. For example, the relative position of lights in a signal head being fixed, a driver can without difficulty recognise the proper signals.

The ability of the driver's eyes to adapt to glare due to headlights or to variations in the lighting conditions (entrance to tunnels, exit from tunnels) is an important factor. The age of the driver and the wearing of eye glasses determine the quickness with which he adapts to these changed conditions. The glare recovery time varies from 3 to 6 seconds.

The ability to judge the depth and distance of an object stereo scopically and its speed is important to the road user. To the predestrian waiting for a gap in the stream, the true assessment of the speed of the on coming vehicle and its location is vital. To the driver moving at a speed, the judgment of speeds of other vehicles is needed to facilitate various manoeuvres.

2.2.3. Hearing

Hearing is an aid to the road user which can at times be very vital. The sound of a horn or the sound of the nearing vehicle itself can alert a pedestrian to safety. Elderly persons with falling eyesight can perceive better through hearing than through seeing. Defective hearing is, however, not a very serious handicap.

2.2.4. Perception, intellection, emotion and volition

The important psychological characteristic of road user concerns perception, intellection, emotion and volition, abbreviated as PIEV and the time taken for these processes is known as PIEV time.

Perception is the process of perceiving the sensations received through the eyes, ears, nervous system and the brain. The exact time required for this is dependent upon the individual's psychological and physiological build-up.

Intellection is the identification of the stimuli by the development of new thoughts and ideas. It is slightly different from simple recognition by past experiences, which is part of the normal perception process. When a person perceives certain stimuli, new thoughts and ideas may form leading to better understanding of the stimuli.

Emotion is the personal trait of the individual that governs his decision making process, after the perception and intellection of the stimuli.

Volition is the will to react to a situation.

The reaction time that elapses before a road user perceives a danger and decides to take action is an important design consideration. For example, in the design of sight distances, the perception and brake reaction time comes into the picture. The perception time is the time required for a driver to come to the realisation that brakes must be applied. The brake reaction time is that time lag between the perception of danger and the effective application of the brakes. AASHTO Policy (Ref. 1) is to assume that the total perception and brake reaction time is 2.5 seconds. This total time may be considered to be the PIEV time. The Indian Roads Congress (Ref. 8) adopts the same value.

A detailed discussion about the factors that influence the behaviour of drivers and pedestrians is given in Chapter 18 dealing with Road Accidents.

2.3. Power Performance of Vehicles

2.3.1. A knowledge of the power performance of a vehicle is necessary to determine the vehicle running costs and the geometric design elements like grades.

2.3.2. Resistance to motion of a vehicle

The power developed by the engine (P_p) should be sufficient to overcome all resistance to motion at the desired speed and to accelerate at any desired rate to the desired speed. The following forces have to be overcome for this purpose (Ref. Fig. 2.1) :

1. Rolling resistance. (P_f)   2. Air resistance. (P_a)
3. Grade resistance. (P_i)
4. Inertia forces during acceleration and deceleration. (P_j)
5. Transmission losses.

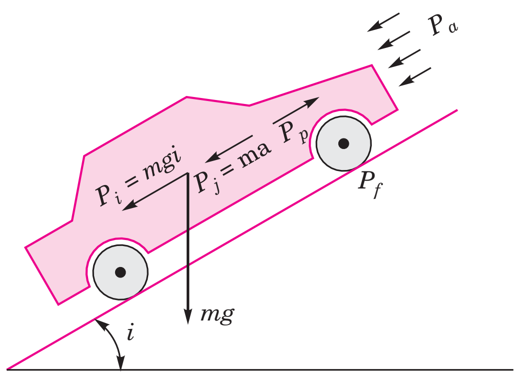

Fig. 2.1. Forces acting on a vehicle.

2.3.3. Rolling resistance

When the vehicle wheels roll over the road surface, the irregularities and the roughness of the surface cause of deformation of the tyres. The road surface itself may undergo deformations. Shocks and impacts are caused by such a motion and these hinder rolling motion of the wheels. The rolling resistance varies with the type of surfacing. The values given in Table 2.1, are typical.

Table 2.1. Values of Coefficient of Rolling Resistance
(*Source :* Ref. 2)

Type of surfacing	*Coefficient of rolling resistance*
(*a*) Cement concrete and asphalt surfacing.	0.01 to 0.02
(*b*) Road with smooth chippings or gravel surface, treated with bituminous binders.	0.02 to 0.025
(c) Chippings or gravel surfacings, not treated with binder, having small pot-holes.	0.03 to 0.04
(*d*) Cobblestone pavement.	0.04 to 0.05
(e) Earth road, smooth, dry and compact.	0.03 to 0.06
(*f*) Ploughed field, saturated and swampy ground, loose sand.	0.15 to 0.30 and over

Research carried out in India has yielded the following values of rolling resistance (Ref. 3), Table 2.2.

The rolling resistance is given by

$$P_f = mfg \quad \text{...(2.1)}$$

where, m = mass of the vehicle in kg

f = co-efficient of rolling resistance

P_f = rolling resistance in N

g = acceleration due to gravity in m/sec^2

Table 2.2. Values of Rolling Resistance Co-efficient from Indian Studies (*Source :* Ref. 3)

	Type of surface	*Rolling resistance co-efficient*
1.	Asphaltic concrete	0.01
2.	Premixed carpet in good condition	0.016
3.	Premixed carpet in bad condition	0.022
4.	Water-bound macadam in good condition	0.025
5.	Water-bound macadam bad condition	0.037
6.	Gravel	0.046
7.	Earth	0.055

The rolling resistance depends on the speed of the vehicles also. Though its value is approximately constant upto a speed of about 50 K.P.H., at higher values of speed the co-efficient increases in value. The following approximate equation accounts for this increase (Ref. 2) :

$$f_v = f_0 \, [1 + 0.01 \, (V - 50)] \quad \text{...(2.2)}$$

where, f_v = co-efficient of rolling resistance at speed V.

V = speed in K.P.H.

f_0 = co-efficient of rolling resistance, assumed constant upto a speed of 50 K.P.H. and can be taken from Table 2.1.

2.3.4. Air resistance

When a vehicle is in motion, air resists it in the following ways :

(*i*) Since air has density, it exerts a reaction pressure against the front of the vehicle when it moves at speed.

(*ii*) The friction of air against the sides of the vehicle body causes resistance.

(*iii*) The eddying of the air stream behind the vehicle, under the body and around the wheels causes power loss.

(*iv*) The flow of air through the vehicle for ventilating and cooling causes resistance to motion.

The following formula can be used to determine the air resistance, P_a (Ref. 3) :

$$P_a = C_a \, . \, Av^2 \quad \text{...(2.3)}$$

where, P_a = air resistance in N

A = projected front area of the vehicle in sq. metres on a plane at right angles to the direction of motion; for Indian vehicles, it can be taken from Table 2.3.

v = speed of the vehicle relative to air in m/sec.

C_a = Co-efficient of air resistance, having values set forth in Table 2.3.
g = Acceleration due to gravity, 9.81 m/sec^2.

Table 2.3. Values of Frontal Area and Co-efficient of Air Resistance (*Source :* Ref. 3, 7)

	Type of Vehicle	*Frontal area (m^2)*	*Mass (kg)*	*Co-efficient of resistance C_a (kg/m^2)*
1.	Premier Padmini car	1.63	1065	0.42
2.	Ambassador car	2.15	1365	0.39
3.	Jeep	2.38	1200	0.37
4.	Tata truck	5.37	6120	0.48
5.	Ashok Leyland truck	5.37	8125	0.48
6.	Maruti car	1.54	880	0.40

2.3.5. Grade resistance

When a vehicle which was moving on a level stretch at a particular speed has to move up an incline, additional work has to be done in keeping the vehicle at the same speed as in the level stretch. The additional work is equal to the work that will be needed to lift the vehicle through a height represented by the inclination. If the horizontal distance is unity (*i.e.*, 1 metre), and the slope is i per cent, the rise will be $\frac{i}{100}$ m. If the mass of the vehicle is m kg, the additional force to move the vehicle up the incline, P_i, is given by,

$$\pm P_i = \frac{m.i.g}{100} \qquad ...(2.4)$$

It may be noted that if the slope becomes downward, i becomes –ve, and P_i also becomes –ve, representing a reduction in the force to move the vehicle.

2.3.6. Inertia forces during acceleration and deceleration

When the speed of a moving vehicle needs to be increased some additional power is needed to accelerate. Similarly if the vehicle has to gather a desired speed from a stopped position, additional force is needed to accelerate. The additional force P_j is given by

Force = Mass × Acceleration

Hence, $$(\pm P_j) = ma = m \,.\, \frac{dv}{dt} \qquad ...(2.5)$$

where, p_j = Force to accelerate, N
m = Mass of the vehicle, kg
a = Average acceleration of the vehicle, m/sec^2 = dv/dt

The value of P_j will be +ve if the vehicle is to accelerate and –ve if the vehicle is to decelerate.

2.3.7. Transmission losses

Losses in power occur to the mode of power transmission (clutch or automatic fluid coupling) from the engine to the gear system and in the gear system itself. The vehicle has a system of gears such that the speed of the vehicle can be altered relative to the engine speed. At the start of the vehicle, high power is needed but at low speed. Similarly, a high engine power is needed while climbing uphill, which is accomplished at a lower road speed than when driving at a level stretch. These manoeuvres are made at the lowest gears. For movement along a good road where the resistance to motion will be small, a high gear will tend to be used. The highest forward gear will generally be 1 : 1, representing direct drive, A further gear reduction is made at the rear axle. The total effect of all the above is to consume about 10 – 15 per cent, of the engine power, which may be as high as 25 per cent in case of trucks in their lowest gear (Ref. 4).

2.3.8. Power requirements of the vehicle

The mechanical power developed by the engine is transmitted to the driving wheels by the transmission system. The torque developed at the flywheel is converted to a torque at the rear axle and the following equation holds good :

Rear-axle torque, $T_a = kT_cG_tG_a$ ...(2.6)

where, T_a = rear-axle torque

k = efficiency of the transmission system, which takes into account the loss of power due to overcoming the resistance of all mechanism between the engine and the driving wheels, and can be taken to be about 0.85 to 0.90

T_c = engine torque at the fly-wheel

G_t = transmission gear ratio

G_a = rear-axle gear ratio.

The rear axle torque imparts a tractive force P_p at the contact of the wheel and the road. This tractive force also known as *tyrerim pull*, is given by the following equation.

$$P_p = \frac{\text{Rear axle torque}}{\text{Radius of the rolling drive tyre}}$$

$$= \frac{kT_e G_t G_a}{r_w} \qquad ...(2.7)$$

r_w is related to the radius of the tyre r_0 by the following formula, Fig. 2.2.

$$r_w = \lambda r_0 \qquad ...(2.8)$$

where, λ = tyre deformation factor will have a value of 0.945 – 0.950 for high pressure air tyres and 0.930 – 0.935 for low-pressure tyres, on hard surfaces (Ref. 2).

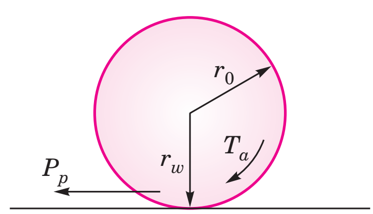

Fig. 2.2. Tractive effort and the driving wheel.

The horse-power corresponding to the tractive effort P_p when the vehicle moves at a speed of v m/sec is

Power output = $P_p v$ ...(2.9)

But $$v = \frac{V \times 1000}{3600} = \frac{V}{3.6}, \; V \text{ being speed in K.P.H.} \qquad ...(2.10)$$

$$\therefore \quad \text{Power output} = \frac{P_p \times V}{3.6} \qquad ...(2.11)$$

Also $$V = \frac{2\pi r_w n}{60\, G_t\, G_a} \quad ...(2.12)$$

where n is the engine speed in R.P.M. Substituting Eq. (2.12) in (2.10)

$$V = \frac{0.377\, r_w\, n}{G_t\, G_a} \quad ...(2.13)$$

Substituting Eq. (2.13) in (2.11),

$$\text{Power output} = \frac{P_v \times 0.377 \times r_w n}{G_t\, G_a}$$

Engine power (in Watts)

$$= \frac{P_v \times 0.377 \times r_w \times n}{G_t \times G_a \times k}$$

where, k = transmission efficiency

Engine horse-power (metric)

$$= \frac{\text{Engine power (in watts)}}{735} \quad ...(2.14)$$

It may be noted that the tractive effort developed at the wheels should be equal to the resistance to be overcome.

P_p = Rolling resistance + Air resistance + Grade resistance + Inertia forces due to acceleration and deceleration

$$= P_f \pm P_a \pm P_i \pm P_j \quad ...(2.15)$$

The following example will illustrate the use of the formulae developed above.

Problem 2.1. A *passenger car weighing 2 tonnes is required to accelerate at a rate of 3 m/sec² in the first gear from a speed of 10 K.P.H. The gradient is + 1 per cent and the road has a black topped surface. The frontal projection area of the car is 2.0 m². The car tyres have radius of 0.33 m. The rear axle gear ratio is 3.82:1 and the first gear ratio is 2.78:1. Calculate the engine horsepower needed and the speed, of the engine. Make suitable assumptions.*

Solution. Tractive force needed,

$= P_p = P_f \pm P_a \pm P_i \pm P_j$

P_f = m.g.f. (Equation 2.1)

Assume f = 0.02

P_f = 2000 × 9.81 × 0.02 = 392.4 N

P_a = $C_a.A.v^2$ (Equation 2.3)

C_a = 0.39 (Table 2.3)

A = 2.15 m²

V = 10 K.M.P.H initially, and increased to 20 K.M.P.H. eventually. So, assume average value of 15 K.M.P.H.

$$P_a = 0.39 \times 2.15 \times \frac{15}{3.6} \times \frac{15}{3.6} = 14.5 \text{ N}$$

Pi = m.g.i. (Equation 2.4)

= 2000 × 9.81 × 1/100 = 196.2 N

$$P_j = m.a = 2000 \times 3 = 6000 \text{ N}$$
$$P_p = 392.4 + 14.5 + 196.2 + 6000 = 6603.1 \text{ N}$$
$$\text{Power output} = P_p \times v = P_p \times \frac{V}{3.6} = 6603.1 \times \frac{10}{3.6}$$

($\therefore$ V = 10 K.M.P.H. initially)

$$= 18341.9 \text{ W} = \frac{18341.9}{735} \text{ hp} = 24.95 \text{ hp.}$$

Assume a transmission efficiency of 0.90, the engine horse-power

$$V = \frac{24.95}{0.9} = 27.72 \text{ hp} = \frac{0.377\, r_w n}{G_t\, G_a} \quad \text{(Equation 2.13)}$$
$$r_w = \lambda r_0$$
$$= 0.935 \times 0.33, \text{ assuming } \lambda = 0.935 = 0.308 \text{ m}$$
$$n = \frac{10 \times 2.78 \times 3.82}{0.377 \times 0.308} = 915 \text{ R.P.M.}$$

2.4. Other Vehicle Characteristics

2.4.1. The other vehicle characteristics that are of concern to the traffic engineer are :

(*i*) Dimensions and weight
(*ii*) Turning capability
(*iii*) Braking system
(*iv*) Acceleration and deceleration.
(*v*) Vehicle lighting system.
(*vi*) Features of the vehicle body.
(*vii*) Tyres etc.

2.4.2. The dimensions and weight of road vehicles and their turning capability have an important influence on the geometric design of roads. They have been discussed in Chapter 11 on Geometric Design.

2.4.3. Ths braking system of a vehicle is important from the point of view of safety. The safe stopping distance is composed of the distance travelled by the vehicle during the perception and brake reaction time and the distance required to stop the vehicle after the brakes are applied. If f is the coefficient of friction between the tyre and the pavement, the braking distance is given by the formula (Ref. 8) :

$$d = \frac{V^2}{254 f} \qquad ...(2.16)$$

where, d = braking distance, metres

V = speed in K.P.H.

f = coefficient of friction between the tyre and the pavement.

Values of f usually adopted in geometric design are discussed in Chapter 11. The braking capability of a vehicle influences the skidding that can take place where brakes are applied suddenly. Because of its close connection with road accidents, skidding is discussed under Chapter 18.

2.4.4. Acceleration characteristics of a vehicle need to be understood when designing the intersection elements (acceleration lane etc.) and overtaking sight distance. Acceleration rate is governed by the vehicle transmission system, weight and horsepower. The acceleration rate also varies with speed, being high at lower speeds and low at higher speeds. The following are the ranges in values of acceleration rates of different types of vehicles :

Medium passenger cars	:	3 – 8 K.P.H. per sec.
Trucks and buses	:	1 – 4 K.P.H. per sec.

2.4.5. When driver applies the brakes, the vehicle decelerates.

The deceleration rate that a driver utilises is generally less than that which a vehicle is capable of developing. Only in an emergency does the driver attempt to fully utilise the maximum deceleration. The maximum deceleration is related to the co-efficient of friction between the tyre and the pavement in the following way :

The force required to decelerate a vehicle is given by :

$$F = md \quad ...(2.17)$$

where, F = force required to decelerate, N

m = mass of the vehicle, kg

d = deceleration in m/sec^2.

Rearranging the terms,

$$d = \frac{F}{m} \quad ...(2.18)$$

But $$\frac{F}{mg} = f.$$

f being the co-efficient of friction.

$$d = f \,.\, g \quad ...(2.19)$$

$$= 9.81\, f \quad ...(2.20)$$

Table 2.4 gives some observed deceleration rates.

Table 2.4. Deceleration Rates from 115 K.P.H.
(*Adapted from* Ref. 5)

	Deceleration	
	(*m/sec*^{2})	(f)
Comfortable to passengers, preferred by driver	2.62	0.27
Undesirable but not alarming to passengers; driver-would rather not use	3.39	0.34
Severe and uncomfortable to passengers; slides objects off seats–driver classifiess as emergency stop.	4.26	0.43

2.4.6. The vehicle lighting system, other features of the body and tyres are discussed in Chapter 18 because of their close connection with road accidents.

2.5. Travelling Vehicle is Suddenly Stopped

When the vehicle which is travelling at a particular speed is suddenly allowed to coast by switching off the engine and putting the gear to neutral, deceleration is caused. From the force equation (Eq. 2.15).

$$P_p = P_f \pm P_a \pm P_i \pm P_j$$

Since $P_p = 0$, and i (gradient) = 0,

$$\therefore \quad P_j = P_a + P_f$$

$$\therefore \quad m\frac{dv}{dt} = C_a.A.v^2 + m.f.g.$$

$$\therefore \qquad \frac{dv}{dt} = \frac{C_v.A.v^2}{m} + f.g \qquad ...(2.21)$$

The following example illustrates the use of the formula.

Problem 2.2. *An Ambassador car travelling at a speed of 60 K.M.P.H. on a level W.B.M. road in good condition is suddenly allowed to coast by switching off the engine and putting the gear in neutral. What is the deceleration caused ?*

Solution. From Eq. 2.21,

$$\frac{dv}{dt} = \frac{C_v.A.v^2}{m} + f.g$$

For an Ambassador car, (Table 2.3)

$$C_a = 0.39 \text{ kg/m}^3$$
$$A = 2.15 \text{ m}^2$$
$$m = 1365 \text{ kg.}$$

For a W.B.M. road,

$$f = 0.025 \text{ (Table 2.2)}$$

$$\therefore \qquad \frac{dv}{dt} = \frac{0.39 \times 2.15}{1365} \times \left(\frac{60}{3.6}\right)^2 + 0.025 \times 9.81$$
$$= 0.17 + 0.25 = 0.42 \text{ m/sec}^2.$$

2.6. Characteristics of Slow Moving Traffic in India

The slow moving traffic in India consists of cycles, cycle rickshaws, bullock carts and horse carts.

An understanding of some of the characteristics of these vehicle types is essential for traffic engineer.

The dimensions of the slow moving vehicles are given in Table below.

Table 2.5. Dimensions of Slow Moving Vehicles
(*Source :* Ref. 6)

S. No.	*Vehicle Type*	*Length (m)*
1.	Cycle	1.91
2.	Cycle rickshaw	2.59
3.	Bullock cart	5.87
4.	Horse cart	4.11

The speeds of the vehicles are given in Table below :

Table 2.6. Mean Speeds of Slow Moving Vehicles
(*Source :* Ref. 6)

S. No.	*Vehicle Type*	*Mean Speed (K.M.P.H.)*	*Standard Deviation (K.M.P.H.)*
1.	Cycles	15.63	2.87
2.	Bullock cart	3.78	0.65
3.	Horse cart	12.24	3.42

The average headway between slow moving vehicles when moving in groups is as below :

Headway between cycles : 2 metres.

Headway between bullock carts : 1 metre.

Headway between horse carts : 8 metres.

The space occupied by cycles, when moving in groups, across the pavement is given below :

Table 2.7. Lateral Space Occupied by Cycle Across the Pavement (*Source :* Ref. 6)

Group size (Number of cycles)	*Lateral space occupied by one cycle (metre)*
1	1
2	0.9
3	0.8
4	0.7
5, 6 and 7	0.6

The speed of a cyclist when crossing an intersection from a stopped position is about 13 km/hr.

I. MULTIPLE CHOICE QUESTIONS

1. The effect of having excess camber is
(*a*) hard steering
(*b*) excessive steering alignment torque
(*c*) too much traction
(*d*) uneven tyre wear

2. In automobiles G.V.W. refers to
(*a*) gross vehicle weight (*b*) gross vehicle width
(*c*) gross vehicle wheel base (*d*) gross vehicle wheel track

3. When two roads with two-lane, two-way traffic cross at an uncontrolled intersection, the total number of potential major conflict points would be
(*a*) 32 (*b*) 24 (*c*) 16 (*d*) 4 (*IES 1999*)

4. When a vehicle is involved in an accident causing injury to any person
(*a*) Take the vehicle to the nearest police station and report the accident
(*b*) Stop the vehicle and report to the police station
(*c*) Take all reasonable steps to secure medical attention to the injured and report to the nearest police station within 24 hours

5. On a road designated as one way
(*a*) parking is prohibited (*b*) overtaking is prohibited
(*c*) should not drive in reverse gear

6. You can overtake a vehicle in front
(*a*) through the right side of that vehicle
(*b*) through the left side
(*c*) through the left side, if the road is wide

7. When a vehicle approaches an unguarded railway level crossing, before crossing it, the driver shall (*a*) stop the vehicle on the left side of the road, get down from the vehicle, go to the railway track, and

(*b*) ensure that no train or trolley is coming from either side

(*c*) sound horn and cross the track as fast as possible

(*d*) Wait till the train passes

8. How can you distinguish a transport vehicle.

(*a*) by looking at the tyre size

(*b*) by colour of the vehicle

(*c*) by looking at the number plate of the vehicle

9. In a road without footpath, the pedestrians

(*a*) should walk on the left side of the road

(*b*) should walk on the right side of the road

(*c*) may walk on either side of the road

10. In traffic moving two lanes in each direction, the car directly ahead of you is waiting to make a right turn. You may

(*a*) pass the vehicle from right side

(*b*) pass the vehicle from left side

(*c*) do not pass the vehicle till the vehicle makes the right turn

11. When passing a procession, body of troops, or men at work, we should

(*a*) proceed at regular speed (*b*) stop

(*c*) proceed at not more than 25 km/hour and carefully

12. Which are the vehicles which have got free passage

(*a*) motor cycles with pillion riders

(*b*) private cars (*c*) emergency vehicles

13. To stop the motor cycles

(*a*) apply the back brake first and after slowing down apply front brake

(*b*) apply front brake first and after slowing down apply back brake

(*c*) apply the front and back brakes simultaneously

14. As you approach a set of traffic lights at an intersection, they change from green to yellow. You must

(*a*) stop before the lights, unless you are so close that sudden braking might cause an accident

(*b*) drive through the intersection without accelerating

(*c*) accelerate to clear the intersection before the lights change to red

15. If you refuse to take a breath test and are convicted for this, you could be disqualified from driving

(*a*) for no more than five years (*b*) for more than five years

(*c*) for at least one year

16. When you apply the brakes, it takes at least 20 metres to bring your car to a stop on a road from 50 km/h. If you double your speed to 100 km/h, what minimum distance will it take to stop your car when you apply the brakes on the same road surface?

(*a*) 30 metres (*b*) 80 metres (*c*) 40 metres (*d*) 20 metres

17. Providing they are not breaking the speed limit, what is the maximum speed for learner drivers who are not in a driving school vehicle fitted with dual brake controls?

(*a*) 60 km/h (*b*) 100 km/h (*c*) 80 km/h

18. When passing a cyclist, what are the required minimum distances that must be adhered to?

(*a*) at least 1.7 meters for any speed limit

(*b*) at least 1 meter when the speed limit is 60 km/h or under and at least 1.5 meters for a speed limit over 60 km/h

(*c*) Any distance as long as it is safe

19. Where there is parallel kerbside parking, are you allowed to double park alongside a parked vehicle?

(*a*) No, not at any time (*b*) Yes, if not obstructing traffic

(*c*) Yes, if delivering goods

20. What is the speed limit at a children's crossing (Koala crossing) when the yellow flashing lights are operating?

(*a*) 40 km/h (*b*) 60 km/h (*c*) 25 km/h

21. You are waiting to turn right from behind the stop line at an intersection. You are faced with a green light and a red right turn arrow. The red arrow light goes out. What should you do?

(*a*) wait behind the stop line until the green light changes to yellow and then move into the intersection and complete the right turn, if it is safe.

(*b*) wait behind the stop line and until the green arrow appears again before you complete the right turn.

(*c*) enter the intersection and wait until it is safe to complete your right turn.

Answers

1. (*d*)	**2.** (*a*)	**3.** (*b*)	**4.** (*c*)	**5.** (*c*)
6. (*a*)	**7.** (*a*)	**8.** (*c*)	**9.** (*b*)	**10.** (*b*)
11. (*c*)	**12.** (*c*)	**13.** (*c*)	**14.** (*a*)	**15.** (*c*)
16. (*b*)	**17.** (*a*)	**18.** (*b*)	**19.** (*a*)	**20.** (*c*)
21. (*b*)				

Explanation

3. (*b*) Point of potential conflicts depends on the number of lanes an intersecting lanes. For two way traffic as a right angled road inter-section the conflict points are it whereas for two way traffic on T-intersection the conflict point are 18 only.

II. SOLVED QUESTIONS AND ANSWERS

Q. 1. What is hearing?

Ans. Hearing is an aid to the road user which can at time be very vital. The sound of a horn or the sound of the nearing vehicle itself can alert a pedestrian to safety.

Q. 2. What do you mean by PIEV time?

Ans. The **PIEV** is important psychological characteristics of road user which concerns perception, intellection, emotion and volition. It is abbreviated as **PIEV**. The time taken for these processes is known as **PIEV** time.

Q. 3. What is perception?

Ans. Perception is the process of perceiving the sensations received through the eyes, ears, nervous system and the brain. The exact time required for this is dependent upon the individuals psychological and physiological build-up.

Q. 4. What is volition?

Ans. Volition is the will to react to a situation.

Q 5. What do you mean by rolling resistances?

Ans. The force that resists the motion when a body rolls on a surface is called the rolling resistance or the rolling friction.

Q. 6. How can the rolling resistance be expressed?

Ans. The *rolling resistance* can be expressed as:

$$F_r = c\ W \qquad ...(1)$$

where, F_r = rolling resistance or rolling friction (N, lb_f)

c = rolling resistance co-efficient – dimensionless (co-efficient of rolling friction – CRF)

$W = mg$ = normal force – weight of the body (N, lb_f)

m = mass of body (kg, lb)

g = acceleration of gravity (9.81 m/s^2, 32.174 ft/s^2)

The rolling resistance can alternatively be expressed as

$$F_r = c_1\ W/r \qquad ...(2)$$

where, c_1 = rolling resistance co-efficient with dimension length (co-efficient of rolling friction) (mm, in)

r = radius of wheel (mm, in)

Q. 7. What is air resistance?

Ans. When a vehicle is in motion, air resists it in the following ways;

(*i*) since air has density, it exerts a reaction pressures against the front to the vehicle.

Q. 8. What are the driving tips for city driving in slow traffic?

Ans. Driving in slow moving city traffic can be quite a workout session. City driving puts lots of stresses on a driver as he has to constantly be mindful of his environment and frequently keep making adjustments to his driving style. The slow moving traffic in India consists of cycles, cycle rickshaws, bullocks carts and horse carts.

Most Indian cars are all manual transmission variants, with automatics making up a very minute population of cars – less than 0.01% of the vehicular density in a large city like New Delhi. In such a scenario, CarToq offers you some tips on how to handle the stresses of city traffic.

Q. 9. Why did the licence weight definition change?

Ans. Changing the definition of licence weight greatly simplified administration for both industry and government agencies.

Q. 10. Why a tyre has some resistance to the motion of a bike as it rolls over the ground.

Ans. Anything on wheels experiences rolling resistance because there is a friction, but anything with the wheel, where the wheel touches the ground, it deforms slightly. It's got a flat section near the ground, and as you roll it over, that flat section moves around the tyre, and so you are constantly having to change the shape of the tyre. So that gives you an extra resistive force, and you notice that, if you leave your bicycle tyres to go flat, it's much harder to pedal than if they are well pumped up and quite firm. That's rolling resistance is what you are feeling.

Q. 11. What is transmission losses?

Ans. Transmission loss is defined as the difference between the power incident on a duct acoustic device (muffler) and that transmitted downstream into an anechoic termination.

Q. 12. Is there any change to how high productivity vehicles are dealt with?

Ans. Vehicles that are used consistently to carry overweight loads have the option of having a special "H vehicle" type RUC licence. This enables them to carry weights up to the maximum under a high productivity vehicle permit at all times. Vehicles that only operate overweight occasionally, or carry varying overweight loads, have the option of purchasing additional RUC licences as required to cover specific journeys.

III. REVIEW QUESTIONS

1. What are the human factors which govern road user behaviour?
2. What do you mean by rolling resistance?
3. Discuss the power requirement of the vehicle?
4. Discuss the characteristics of vehicle.
5. What are the characteristics of slow moving traffic in India?

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