CMR
INSTITUTE OF
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Solutions

Sub: Traffic Engineering **Code:** 10CV667

Sem: VI **Branch:** CIVIL

1. A passenger car weighing 2 tonnes is to accelerate at a rate of 3ms $^{-2}$ in the first gear from a speed of 10 kmph to 20 kmph. The gradient is +1% and the highway has a black topped surface. The frontal exposed area of the car is 2.15m^2. The tyres have a radius of 0.33m. The rear axle gear ratio is 3.82: 1 and the first gear ratio is 2.78:1. Calculate the engine horse power needed and speed of the engine.

2. (a) Define Traffic Engineering. Explain its scope.

Definition of Traffic Engineering:

Traffic engineering is the branch of engineering which deals with the improvement of traffic performances of road by application of scientific principle tools, techniques and findings from traffic studies for safe, rapid, convenient and economic movement of people and goods.

Scope of Traffic Engineering:

It includes the following:

i) Traffic characteristics:

The study of traffic characteristics is the most important pre-requisite for any improvement of traffic facilities. The traffic characteristics include both road

user characteristics and vehicular characteristics. The road users include pedestrians, motorists and cyclists using the road with the different motives.

(ii) Traffic studies and Analysis:

Various studies carried on actual traffic includes speed, volume, capacity, travel patterns, origin and destination, traffic flow characteristics, parking and accident studies

(iii) Traffic operation - control and regulation:

It includes regulations, control and the warrants for application of controls. The regulations may be in the form of laws and ordinances or other traffic regulatory measures such as speed limits. Installation of traffic control devices such as signs, signals, islands are most common means of regulation

(iv) Planning and Analysis:

Traffic planning is a separate phase for major highways, mass transit facilities and parking facilities. Transport planning includes formulation of proposals for safe and efficient movement of goods and people by understanding the nature of problems created by increased vehicle population.

(v) Geometric Design:

All the aspects such as cross-section and surface details, sight distance requirements, horizontal and vertical alignment, manoeuvre areas and intersections and parking facilities are to be suitably designed for better performance.

(vi) Administration and management:

The various phases of traffic engineering are implemented with the help of engineering, enforcement and education or '3 E's'. Enforcement is usually made

6. List and explain the resistances which affect the motion of vehicle.

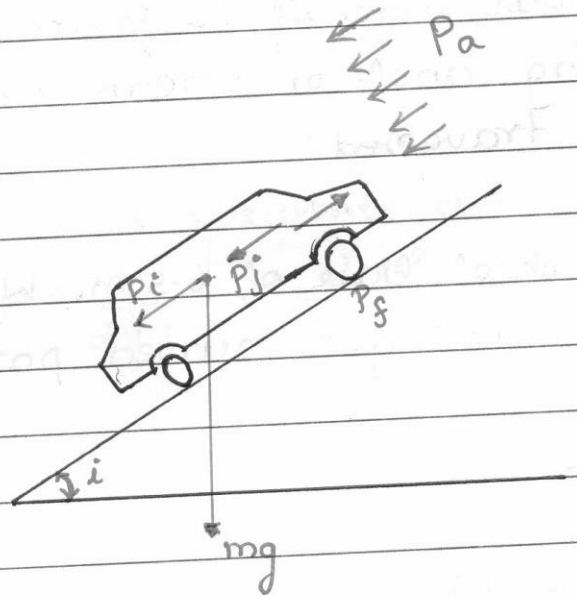
Power performance of vehicles:

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

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.

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



$P_i = mgi$

$P_j = ma$

Forces Acting on a Vehicle.

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① Rolling Resistance :

When the vehicle wheels roll over the road surface, the irregularities and the roughness of the surface cause deformation of the tyres. The road surface may also 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 as shown below

	Type of surfacing	Co-efficient of rolling resistance.
1.	cement concrete and asphalt surfacing	0.01 to 0.02.
2.	Road with smooth chippings or gravel surface, Treated with bituminous binders.	0.02 to 0.025.
3.	Chippings or gravel surfacings, not treated with binder, having small pot-holes.	0.03 to 0.04.
4.	Cobblestone pavement	0.04 to 0.05
5.	Earth road, smooth, dry and compact.	0.03 to 0.06.
6.	Ploughed field, saturated and swampy ground, loose sand.	0.15 to 0.30 and over.

The rolling resistance is given by

$$P_f = mfg$$

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/s^2

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The rolling resistance depends on the speed of the vehicles also. Though its value is approximately constant upto a speed of about 50 kmph., at higher values of speed the co-efficient increases in value. The following equation accounts for this increase

$$f_v = f_0 [1 + 0.01(V-50)]$$

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

V = Speed in kmph.

f_0 = coefficient of rolling resistance, assumed constant upto a speed of 50 kmph and can be taken from the table

	Types 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 in bad condition	0.037.
6.	Gravel	0.046
7.	Earth	0.055

(2) 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 a speed.

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(iii) The friction of air against the sides of the vehicle body causes resistance

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

(v) The flow of air through the vehicles for ventilating and cooling causes resistance to motion

The following formula can be used to determine the air resistance, P_a

$$P_a = C_a \cdot A v^2$$

where P_a = Air resistance in N.

A = Projected front area of the vehicle in m^2 on a plane at right angles to the direction of motion, as given in the table

v = Speed of the vehicle relative to air in m/s.

C_a = Coefficient of air resistance, from table

g = acceleration due to gravity, $9.81 m/s^2$

	Type of vehicle	Frontal Area (m^2)	Mass (kg)	Co-efficient of Resistance (C_a) (kg/m^2)
1.	Premier 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.

(8) Grade Resistance:

When a vehicle 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

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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 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

$$\pm P_i = \frac{m \cdot i \cdot g}{100}$$

Slope - Downward $\Rightarrow$ i = (-ve)

$\therefore P_i$ = -ve $\Rightarrow$ reduction in the force to move the vehicle

④ Inertia forces during acceleration and deceleration

When the speed of the 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, $(\pm) P_j = ma = m \cdot \frac{dv}{dt}$

where, P_j = Force to accelerate, N

m = Mass of the vehicle, kg

a = Average acceleration of the vehicle, m/s^2

$= \frac{dv}{dt}$

P_j = +ve $\Rightarrow$ Acceleration

P_j = -ve $\Rightarrow$ Deceleration

(5) Transmission Losses:

Losses in power occur to the mode of power transmission 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, high engine power is needed while climbing uphill, which is accomplished @ a lower speed than when driving at a level stretch. These manoeuvres are made @ 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 @ 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 25% in case of trucks in their lowest grade.

3. Explain the concept of power requirement of vehicles. Derive an expression to find out the engine horse power needed.

Power Requirements of the Vehicles:

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

Rear-axle-torque, $T_a = K T_c G_t G_a$

where, T_a = rear-axle torque.

K = efficiency of the transmission system,
= 0.85 to 0.90

T_c = Engine torque at the fly wheel.

G_t = Transmission Gear ratio

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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.

The tractive force is given by the following equation.

$$P_p = \frac{\text{Rear Axle Torque}}{\text{Radius of the rolling drive tyre}}$$

$$= \frac{k_t \cdot T_e \cdot G_t \cdot G_a}{r_w}$$

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

$$r_w = \lambda r_0$$

where λ is the tyre deformation factor

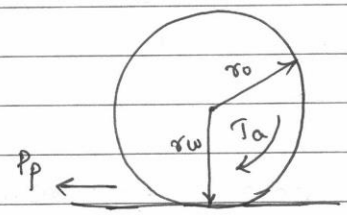
Value on hard surfaces

- For high pressure air tyres - 0.945-0.950
- For low pressure air tyres - 0.930-0.935

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

$$\text{Power output} = P_p v$$

$$\text{But } v = \frac{V}{3.6} \text{ kmph}$$



$$\therefore \text{Power Output} = \frac{P_p \times V}{3.6}$$

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Also, $v = \frac{2\pi r \omega n}{60\, G_t \cdot G_a}$ m/s

where n is the engine speed in R.P.M.

Sub. for v

$$V = \frac{3.6 \times 2\pi r \omega n}{60\, G_t \cdot G_a}$$

$$V = \frac{0.377 \times r\omega \times n}{G_t \cdot G_a}$$

Power output $= P_v \times \frac{0.377 \times r\omega \times n}{G_t \cdot G_a}$

Engine Power (in watts)

$$= \frac{P_v \times 0.377 \times r\omega \times n}{G_t \times G_a \times K}$$

K = Transmission Efficiency

Engine horse-Power (metric)

$$= \frac{\text{Engine Power (in watts)}}{735}$$

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 Accl^n & Deceler^n

$= P_f \pm P_a \pm P_c \pm P_j$

5 (a) A vehicle moving at 40kmph was stopped by applying brake and the length of skid mark was 12.2 m. If the average skid resistance of the pavement is known to be 0.70, determine the brake efficiency of the test vehicle.

$v = \frac{40}{3.6} = 11.11 \text{ ms}^{-1}$

$L = 12.2 \text{ m}$

$f = 0.70$ m

Avg. skid resistance developed.

$f' = \frac{v^2}{2gL} = \frac{11.11^2}{2 \times 9.81 \times 12.2} = 0.516$

Brake Efficiency $= \frac{0.516}{0.70} \times 100$

$= 73.69\%$

Brake Efficiency $= 73.69\%$

2. B) Explain PIEV theory with a neat sketch.

* Psychological

The most important psychological characteristic of road user concerns perception, intellection, emotion and volition, abbreviated as PIEV and the time takes for this process 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 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 to traffic situations depends on the time required to perceive and understand the traffic situation and to take the appropriate action. This depends on many factors such as permanent and temporary physical factors, mental and psychological set up, speed and environmental factor, type of problem and the familiarity. Generally, a value of 2.5 seconds is adopted as PIEV time.

4 (a) Describe the visual aspects of road users affecting highway design.

Vision -

It is one of the important factors that affects almost all aspects of highway design and safety - It includes the acuity of vision, peripheral vision and eye movement, glare vision, glare recovery and depth judgement - Minimum standards for acuity of vision are laid down by licensing authorities - Field of clearest and acute vision is within a cone whose angle is only 3 degrees, ~~through the vision~~ about the centre of retina. This signifies that for very distant vision, the objects should be within the narrow cone for satisfactory perception. and it is important for locating traffic signs & signals.

Peripheral vision is the total visual field for the two eyes, within which the eyes are able to see the objects, but without clear details and colour. The angle of peripheral vision is about 160° in the horizontal direction and 115° in the vertical direction. If the detailed attention is needed, the driver turns his head or eye so that the object now comes within the cone of clear vision. The cone of peripheral vision also depends on speed. The angle of the cone falls down from about 110° @ 30 kmph to 40° @ 100 kmph speed.

Colour vision is important for discerning the traffic lights and colour schemes in traffic signs. The ability of the driver's eyes to adapt to glare due to headlights or to variations in the lighting conditions is an important factor. It depends on the age of the driver and the use of eye glasses. The glare recovery time varies from 3 to 6 seconds. The ability of to judge the depth and distance of an objects stereoscopically and its speed is important to the road user. (pedestrian or a driver)

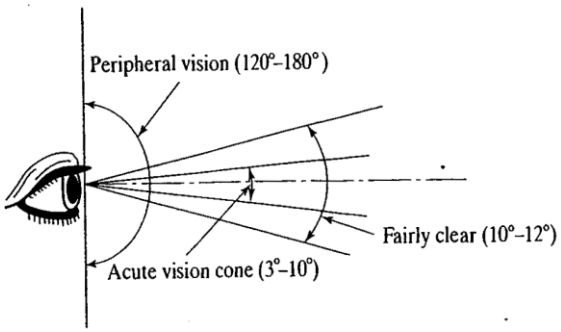
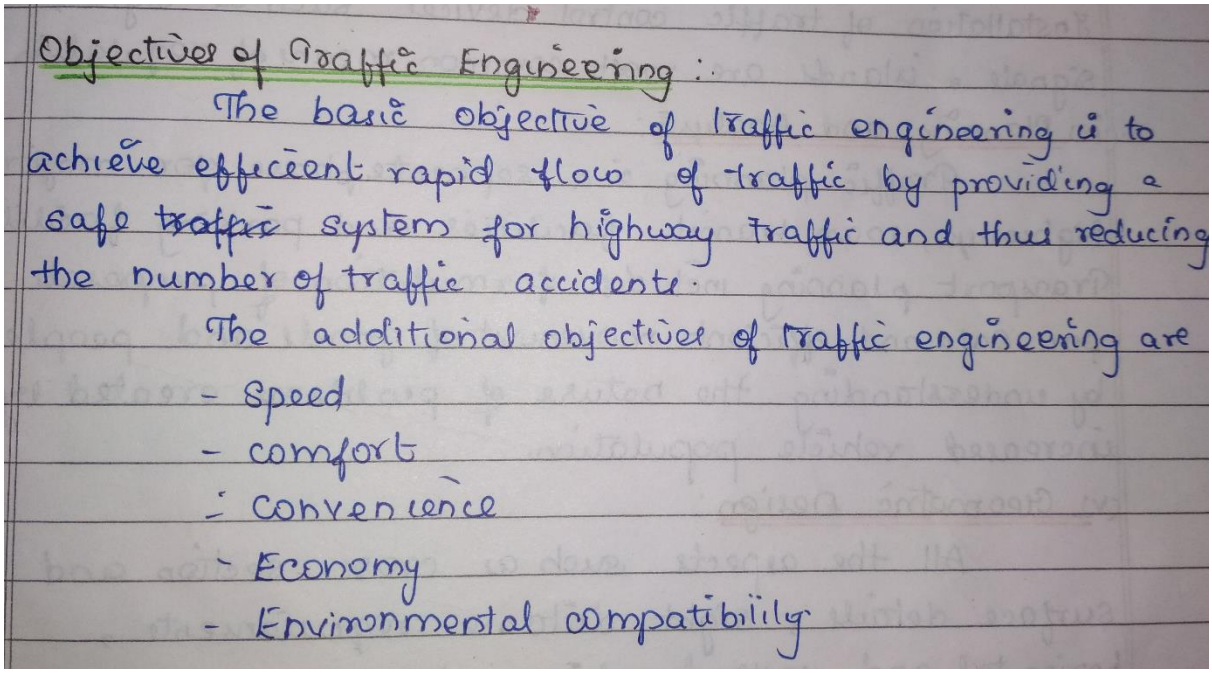


Illustration of field of vision

B) Bring out the objectives of Traffic Engineering.



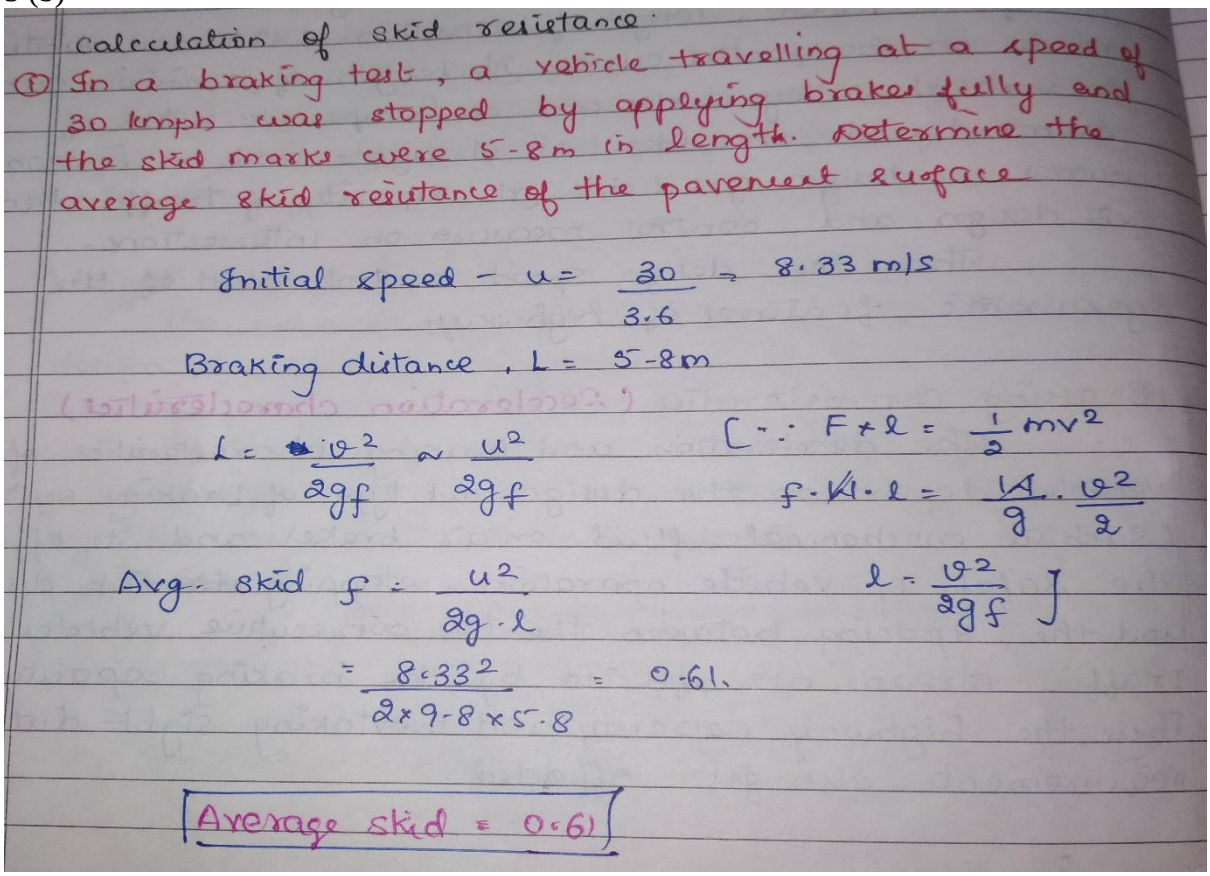
Objectives of Traffic Engineering :

The basic objective of traffic engineering is to achieve efficient rapid flow of traffic by providing a safe traffic system for highway traffic and thus reducing the number of traffic accidents.

The additional objectives of traffic engineering are

- Speed
- comfort
- convenience
- Economy
- Environmental compatibility

5 (b)



Calculation of skid resistance:

① In a braking test, a vehicle travelling at a speed of 30 kmph was stopped by applying brakes fully and the skid marks were 5·8 m in length. Determine the average skid resistance of the pavement surface

Initial speed – $u = \frac{30}{3.6} = 8.33$ m/s

Braking distance, $L = 5.8$ m

$L = \frac{v^2}{2gf} \sim \frac{u^2}{2gf}$

[$\because F \times l = \frac{1}{2}mv^2$

$f \cdot W \cdot l = \frac{W}{g} \cdot \frac{v^2}{2}$

$l = \frac{v^2}{2gf}$]

Avg. skid $f = \frac{u^2}{2g \cdot l}$

$= \frac{8.33^2}{2 \times 9.8 \times 5.8} = 0.61.$

Average skid = 0.61