SHAMBHUNATH INSTITUTE OF ENGINEERING AND TECHNOLOGY, PRAYAGRAJ.

AUTOMOBILE ENGINEERING (RME-702)

B.Tech., Mechanical Engg.

(IV Year, VII Semester) 2019-2020

I- SESSIONAL TEST SOLUTION

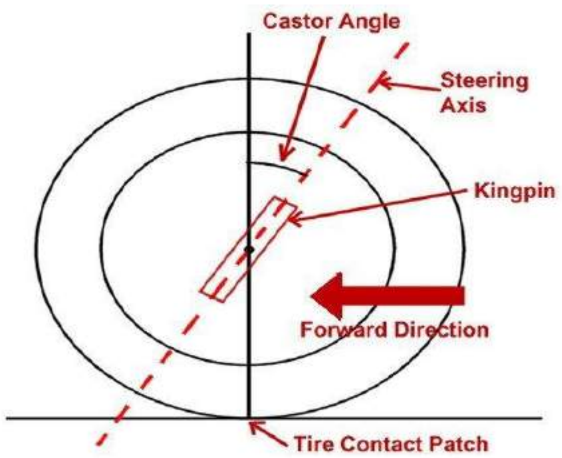
Section A

Answer 1 a) Chassis is the complete vehicle accept the body of the vehicle. Chassis includes frame, suspension system, steering system, braking system, wheels, tyres, transmission system etc. whereas frame is the only one component of the chassis which support the other parts of the chassis.

Answer 1 b) Gear ratio is the ratio of angular speed of driving gearto angular speed of driven gear or it is the ratio of number of teeth on the driven gear to the number of teeth on the driving gear.

$$\text{Gear ratio} = \frac{Angular\ \ speed\ \ of\ driving\ \ gear}{Angular\ \ speed\ \ of\ driven\ \ gear} = \frac{Number\ \ of\ teeth\ on\ driven\ \ gear}{Number\ \ of\ teth\ on\ the\ driving\ \ gear}$$

Answer 1 c)<u>Castor angle: </u>Castor angle is the angle between the kingpin center line and the vertical line passing through the center of the wheel when viewed from the side of the wheel.



Answer 1 d) Two universal joints are used in Hotchkiss drive and one universal joint is used in torque tube joint.

Answer 1 e) The resistance caused by the air in the motion of vehicle is called wind or air resistance. The air resistance depends upon shape and size of the vehicle body, air velocity and its direction and speed of the vehicle. Air resistance is prescribed by the relation.

$$F_a = C_d \times \frac{1}{2}\rho V^2 \times A$$

where V is the vehicle speed neglecting air velocity in m/s, ρ is the air density in kg/m^3, C_d is the drag coefficient and A is the projected frontal area of the vehicle perpendicular to the direction of motion in m^2.

Section B

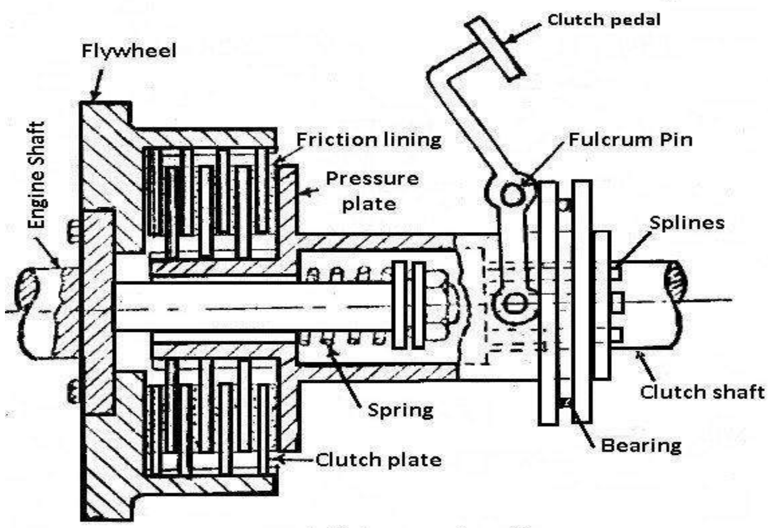
Answer 2 a)Multiplate clutch: When more torque is to be transmitted such as in heavy transport vehicles and racing cars, multi-plate clutch is used in which more contact area is provided in a compact space by increasing the number of friction surfaces.

Construction: It consists of:

Friction plates: Friction plates have friction linings on both sides. However the plates adjacent to the flywheel has friction lining only on the side away from the flywheel. These plates rotate with the flywheel and hence with driving shaft. The friction plates are in two sets. One set slides in grooves on the flywheel while the other set moves on the splines made on the hub of the pressure plate. Further the arrangement is such that the plates with outer and inner splines are set alternately.

Discs or plates: These are supported on splines of the driven shaft. These plates are located in between the friction plates and can slide axially.

Working: When the foot is taken off from the clutch pedal, the set of springs press the disc into contact with the friction plates. There is a tight gripping between the fly wheel the friction plates and the disc and the whole assembly rotates as one units. Hence the power is transmitted from the flywheel (driving shaft) to the driven shaft. The number of friction surfaces increases the capacity of clutch to transmit torque.



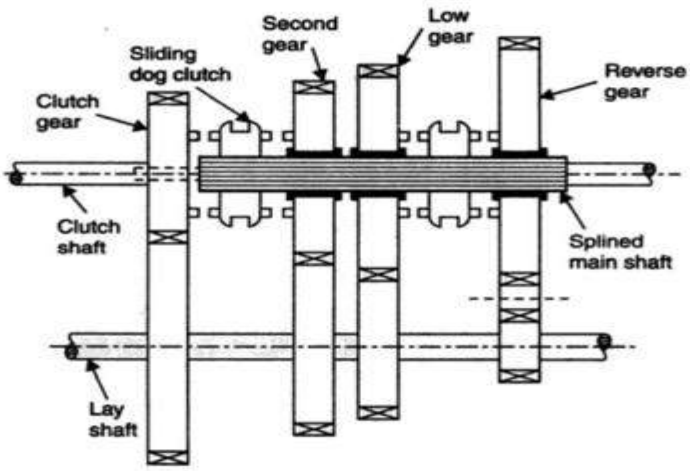
Multiplate Clutch

Answer2b)

Constant mesh gear box :

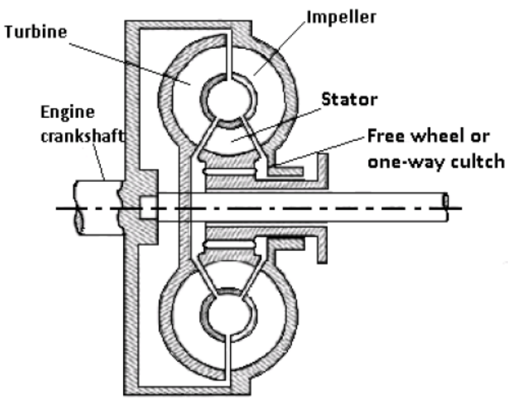
It is that gearbox in which all the gears are in constant mesh with each other (hence the name constant mesh gear box) all the time and this gives a silent or *quiet operation*. Here, helical gears are used to make gear changing easier. The gears on the main shaft which is splined, are *free*. The gears on the counter or layshaft are, however, *fixed*. Two dog clutches are provided on the main shaft-one between the clutch gear and the second gear and the other between the low/first gear and reverse gear. Dog clutch can slide on the main shaft and rotates with it.

When the left-hand dog clutch is made to slide to the left by means of the gearshift lever, it meshes with the clutch gear and the top speed gear is obtained. When the dog clutch meshes with the second gear the second speed gear is obtained. Similarly by sliding the right-hand dog clutch to the left and right, the first speed gear and reverse gear are obtained respectively. However skillful handing is necessary on the part of the driver so that the speed of the locking dogs and respective pinion remain the same to effect a clash-free gear change.



Constant mesh gear box.

Answer 2 c) <u>Torque converter</u>: The torque converter is a hydraulic device used to transmit increased or decreased power from one shaft to another shaft. A variable torque is impressed on the driven member without the use of a gear train or clutch.



Torque converter

Construction and operation:A torque converter essentially consists of pump impeller coupled to the driving shaft, turbine runner coupled to the driven shaft and reaction member or fixed guide vane arranged between the pump impellor and the turbine runner. These units are enclosed in a single casing filled with an oil. The oil flowing from pump impellor to turbine runner exerts a torque on the stationary vane. The vane change the direction of flow of oil, thereby making possible a torque and speed transformation.

Difference between torque converter and food coupling: Torque convertor can convert the magnitude of the torque during transmission whereas fluid coupling transmits the same magnitude of torque from input to output shaft.

Answer 2 d) **Over drive:**The term overdrive refers to the transmission gear that causes the output shaft to turn faster than the input shaft. Over drive is the speed increasing device that allows the propeller shaft rotate faster than the transmission main shaft that is the engine crank shaft.

Over drive is used to save the fuel consumption, decrease the noise and vibrations, decrease frictional losses, for smooth drive and prolonged engine life.

The over drive unit is fitted between the gear box and propeller shaft and it allows the engine to operate at about 70% of propeller speed when the vehicle is operating in the high speed ranges.

Construction: The over drive comprises the following key elements:

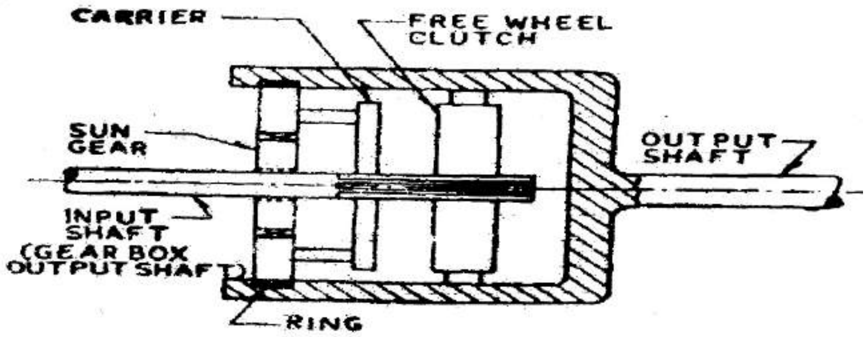
- Input shaft which is the output shaft of the manual gear box.
- Output shaft which communicates with the propeller shaft.
- Epicyclic gear train consisting of a sun gear, three planet gears and a planet carrier.
- Free wheel or over clutch assembly.

The sun gear of the epicyclic train is free to rotate on the gear box output shaft. The carrier and free wheel clutch are mounted on splines provided on the input shaft. The ring gear communicates with output i.e. propeller shaft. The free wheel assembly drives the main shaft below the cut in speed.

Operation: The salient operational aspects of an over drive unit are:

- The overdrive control can be manual but more often it is electrical. There is a solenoid engaging the drive gear.
- The entire operation is carried out by mechanical and electrical control.
- The control handle is pushed into engage over drive and pushed out to lock out over drive.
- When the vehicle speed reaches a predetermined speed N_1usually in the range of 45-50 km/hr. The electrical device operates and completes the preparation of shifting into over drive. At that stage the clutch locks to the outer casing and the sun gear becomes stationary. The planet gear s then driven around the sun gear. In turn, the planet gear drives the annulus ring gear at a speed which is slightly higher than its own speed. The speed at which the over drive can be engaged is called the cut-in-speed.
- Subsequently when the engine speed drops, the over drive will not be dis-engaged at speed N_1. The automatic over drive dis-engagement will occur at a lower speed N_2 called the cut out speed.
- When the sun gear rotates freely on the input shaft, there is direct drive through the free wheel clutch. Further, there will be no overriding of input shaft by the output shaft when

the engine is simply idling. Then the rollers of free wheel clutch do not remain wedged and the vehicle simply free wheels.



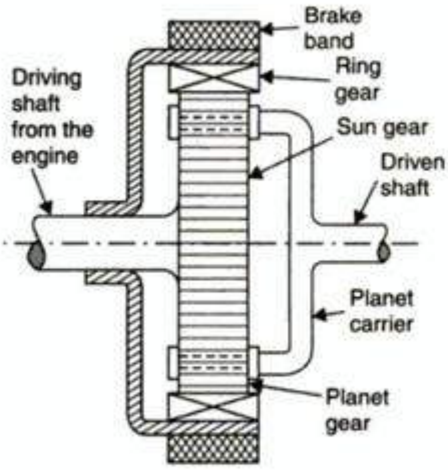
Overdrive

Answer 3 a)<u>**Epicyclic gear:**</u>It consists of a sungear, a ring gear and two or three planet gears with a planet carrier.

- The *sungear* is rotated by the *driving shaft from the engine* and thus moves along with the movement of the engine crankshaft.
- The *planet gears* are in constant mesh with both the sun gear and ring gear or annular wheel and are free to rotate on their axes carried by the carrier frame which in turn is connected to the *driven shaft*.

Working :

- When the ring gear is locked by the brake band, the rotating sun gear causes the planet gears to rotate. Since the ring gear cannot move, the planet gears are forced to climb over it. During this position, the *ring gear acts as track for the planet gears to move over*. The *driven shaft* which is connected to the planet gear carrier is thus *rotated*.
- When the ring gear is *released*, it is free to move in consequence to the rotation of planet gears which rotate around their axis. During this position, there is no movement of planet carries and hence the *driven shaft remains stationary*.



Epicyclic gear set.

A planetary gear box contains a number of such units to obtain various speed reductions.

Fig. shows idler gear fitted in planetary system for reversing direction of rotation.

Fig. shows a typical two-speed epicyclic gear box. It is a two toward speed gear box.

- *Direct gear* is obtained by releasing the brake and engaging the clutch. This locks the sun wheel and the planet carrier.
- *Lower gear* is obtained when brake is applied which locks sun gear S.

Answer 3 b) Differential:

***Differential** is the mechanism by means of which outer wheel runs faster than the inner wheel while taking a turn or moving over upheaval road.*

Differential is a part of the inner axle housing assembly, which includes the differential, rear axles, wheels and bearings. The differential consists of a *system of gears arranged in such a way that connects the propeller shaft with the rear axles.*

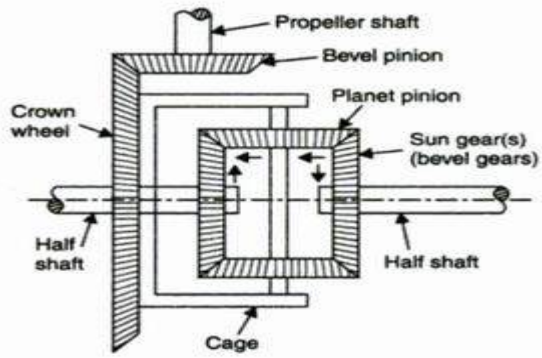
The **purpose** *of the differential is to provide the relative movement to the two rear wheels when the car is taking a turn. The torque transmitted to each wheel is, however, always equal.*

Differentials are *used* in rear drive axle of front-engine, rear-wheel drive vehicles. Differentials are also used in the trans axles on front-engine, front-wheel drive wheels. Also, four-wheel-drive vehicles have differential at both the front and rear wheels. In addition, some four-wheel-drive vehicles have a third differential in the transfer case.

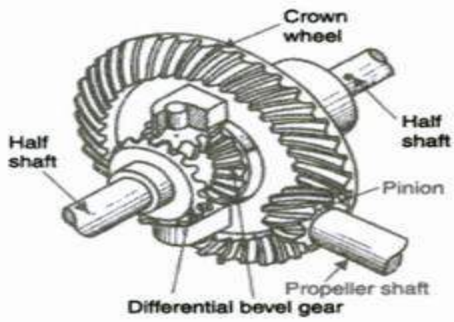
Construction of differential :

Fig shows the various parts of a differential unit. The bevel pinion is fixed to the propeller shaft which rotates the crown wheel. The crown-wheel has another unit called the differential unit. It consists of two bevel gears (sun gears) and two bevel pinions (planet pinions). The bevel gears are in contact with the half shafts of the rear axle.

When the crown wheel is rotating, it rotates the differential unit. The bevel (sun) gears of the differential rotate the two half shafts.



(*i*) Simple differential-simplified diagram



(*ii*) Typical three-dimensional view

Differential.

Operation of differential :

When the car is on a straight road, the ring gear, differential case, differential pinion gears, and two differential side gears all turn as a unit. The two differential pinion gears do not rotate on the pinion shaft. This is because they exert equal force on the two differential side gears. As a result, the side gears turn at the same speed as the ring gear, which causes both drive wheels to turn at the same speed also. However, when the car begins to round a curve, the *differential pinion gears rotate on the pinion shaft*. This *permits the outer wheel to turn faster than the inner wheel.*

Suppose one wheel turns slower than the other as the car rounds a curve. As the differential case rotates, the pinion gears must rotate on their shaft. This occurs because the pinion gears must walk around the slower-turning differential side gear. Therefore, the pinion gears carry additional rotary motion to the faster-turning outer wheel on the turn. The action in a typical turn is shown in Fig. The differential speed is considered to be 100 percent. The rotating action of the pinion gears carries 90 percent of this speed to the slower-rotating inner wheel. It sends 110 percent of the speed to the faster-rotating outer wheel. This is how the differential allows one drive wheel to turn faster than the other.

Whenever the car goes round a turn, the outer drive wheel travels a greater distance than the inner drive wheel. The two pinion gears rotate on their shaft and send more rotary motion to the outer wheel.

- The gear ratio in the differential is usually referred to as the *axle ratio*. However it would be more accurate to call it the *differential ratio*.

Answer 4 a)

Analysis and Design Details

Consider an elementary ring of radius r and thickness dr and subjected to pressure intensity

Axial load δW on the differential element is,

$$\delta W = \text{pressure intensity} \times \text{differential area}$$
$$= p \times 2\pi r\, dr$$

Then, total axial load on the clutch is

$$W = \int_{r_1}^{r_2} p \times 2\pi r\, dr = 2\pi \int_{r_1}^{r_2} pr\, dr$$

and torque transmitted by the clutch is

$$T = \mu \times 2\pi \int_{r_1}^{r_2} pr\, dr \times r$$

$$= 2\pi\mu \int_{r_1}^{r_2} pr^2\, dr$$

where μ is the coefficient friction, and r_1 and r_2 are the inner and outer radii of the friction surfaces.

The above expression can be evaluated by presuming either uniform pressure intensity (p = constant) or uniform rate of wear (pr = constant)

(A) Uniform pressure intensity (p = constant) : This assumption is essentially valid if the surface of friction material is truly plane, i.e., when the clutch is new

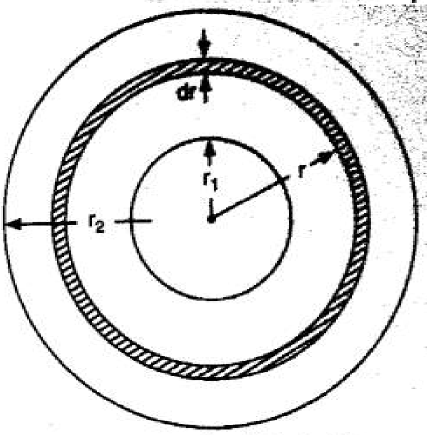


Fig. Single plate clutch

$$W = 2\pi \int_{r_1}^{r_2} pr\, dr = 2\pi p \left| \frac{r^2}{2} \right|_{r_1}^{r_2}$$

$$= \pi p \left(r_2^2 - r_1^2\right)$$

$$T = 2\pi\mu \int_{r_1}^{r_2} pr^2\, dr = 2\pi\mu p \left| \frac{r^3}{3} \right|_{r_1}^{r_2}$$

$$= \frac{2}{3}\pi\mu p \left(r_2^3 - r_1^3\right)$$

$$= \frac{2}{3}\mu \left[\frac{r_2^3 - r_1^3}{r_2^2 - r_1^2}\right] \pi p \left(r_2^2 - r_1^2\right)$$

$$= \frac{2}{3}\mu W \left[\frac{r_2^3 - r_1^3}{r_2^2 - r_1^2}\right] = \mu W R$$

where the term $R = \frac{2}{3}\left[\frac{r_2^3 - r_1^3}{r_2^2 - r_1^2}\right]$ is called the effective mean radius.

(B) Uniform rate of wear (pr = constant) : This assumption is valid for a broken clutch *i.e.,* when the pressure distribution changes and that permits uniform wear.

$$W = 2\pi \int_{r_1}^{r_2} pr\, dr = 2\pi pr \int_{r_1}^{r_2} dr$$

$$= 2\pi pr (r_2 - r_1)$$

$$T = 2\pi \mu \int_{r_1}^{r_2} pr^2\, dr = 2\pi \mu pr \int_{r_1}^{r_2} r dr$$

$$= 2\pi \mu pr \left[\frac{r_2^2 - r_1^2}{2}\right]$$

$$= \frac{\mu}{2} (r_2 + r_1) [2\pi pr (r_2 - r_1)]$$

$$= \mu W \left[\frac{r_2 + r_1}{2}\right] = \mu WR$$

where the term $R = \frac{r_2 + r_1}{2}$ represents the effective mean radius.

Answer 4 b)

Ackermann steering gear :

Refer to Fig. It consists of a cross link CD connected to the short axles AL and BM of the two front wheels through the short arms AC and BD, forming bell crank lowers LAC and MBD, respectively.

When the wheel is running straight [Fig. (*a*)], the cross-link CD is parallel to AB, the short arms AC and BD both make angle α to the horizontal axis of chassis. In order to satisfy the fundamental equation for correct steering, the links AC and BD are suitably proportioned and angle α is the suitably selected.

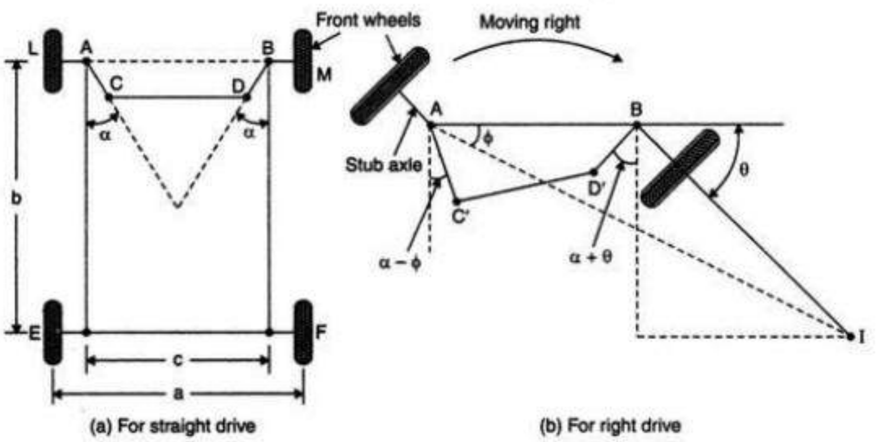


Fig. Ackermann steering gear mechanism.

For correct steering, $\cot \phi - \cos \theta = \frac{c}{b}$

The angles ϕ and θ are shown in Fig. (*b*).

The value of $\frac{c}{b}$ lies between 0.4 and 0.5, generally 0.455. The value of $\cot \phi - \cot \theta$ corresponds to the positions when steering is correct.

In fact there are *three* values of θ which give correct steering of the vehicle : *First,* while turning to 'right' ; *second,* while turning to left and *third* while it is running 'straight'.

Answer 5 a)

. ***Vacuum suspended vacuum brake*** : The vacuum suspended vacuum brake consists of :

(*i*) Control unit provided with a piston and two valves

(*ii*) Vacuum reservoir that connects with the engine inlet manifold

(*iii*) Servo cylinder; one side of which is connected to the vacuum reservoir through control unit while the other side is in direct contact with the inlet manifold

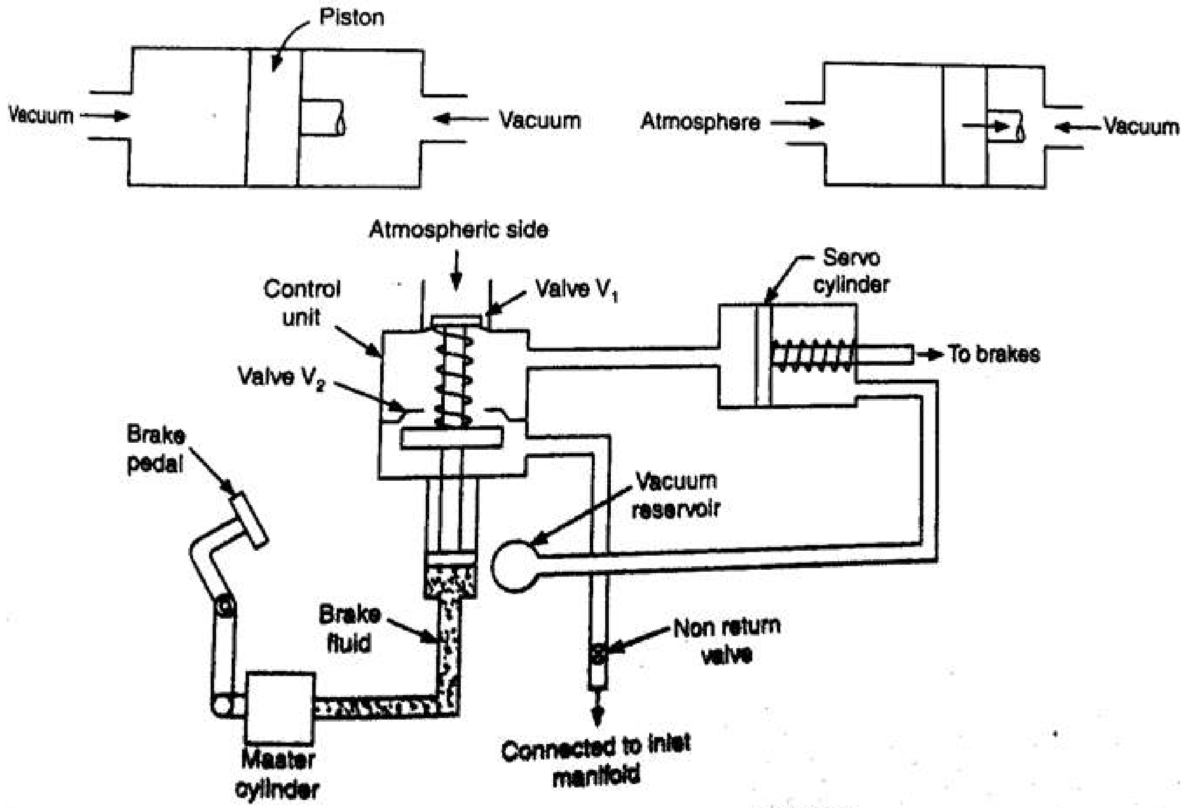


Fig. Vacuum suspended vacuum brake

When the brakes are in the released position, the valve V_1 is closed and the valve V_2 is open. Apparently vacuum acts on both sides of the piston in servo cylinder.

When the brakes are applied, the piston of control unit is pushed up due to force exerted by the pressure of brake fluid. That results into closing of valve V_2 and opening of valve V_1. The left side of the piston in the servo cylinder then opens to atmospheric pressure, while vacuum is acting on the right side. The piston of the servo cylinder moves under the pressure differential. Through suitable linkages, the brake linings come in contact with the drum causing brake action.

With vacuum brakes, the driver's fatigue is considerably reduced as the whole of the braking effort is practically supplied by the engine vacuum.

Answer 5 b)

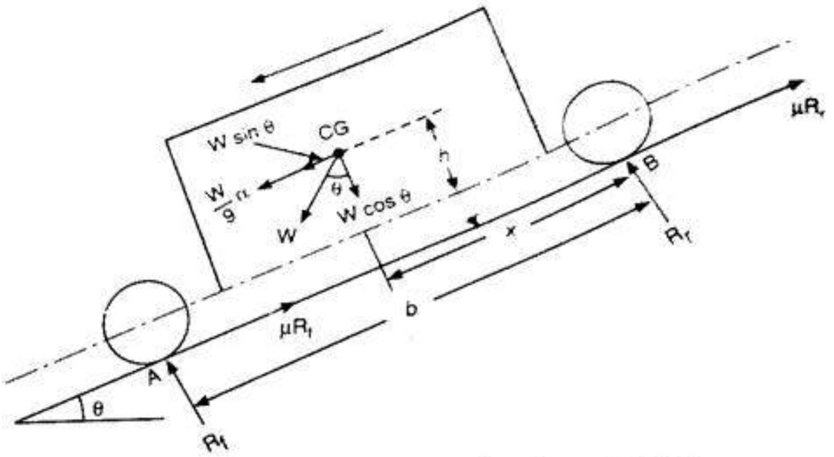


Fig. Forces on vehicle moving down an incline

Refer Fig. 14.4 for the forces and reactions acting on a vehicle moving up an incline with slope angle θ. Let R_f and R_r represent the normal reaction at the front wheel and rear wheel respectively. Then

$$\text{Inertia force} = \frac{W}{g}\alpha$$

$$\text{Braking force at the front wheel} = \mu R_f$$

$$\text{Braking force at the rear wheel} = \mu R_r$$

An analysis needs to be made considering the following cases :

(*i*) *Brakes applied to front wheels only* : When the system is to be in equilibrium, the algebraic sum of the forces and their moment must be equal to zero. When forces are resolved along the road surface and perpendicular to it, we get

$$\mu R_f = W\sin\theta + \frac{W}{g}\alpha \qquad \text{...(i)}$$

$$R_f + R_r = W\cos\theta \qquad \text{...(ii)}$$

Taking moment about B and taking clockwise moment positive, we obtain

$$\frac{W}{g}\alpha \times h + W\sin\theta \times h + W\cos\theta \times x - R_f \times b = 0 \qquad \text{...(iii)}$$

From expressions (*i*) and (*iii*)

$$\frac{W}{g}\alpha h + Wh\sin\theta \times h + Wx\cos\theta - \frac{b}{\mu}\left[W\sin\theta + \frac{W}{g}\alpha\right] = 0$$

or
$$\frac{W}{g}\alpha\left(h - \frac{b}{\mu}\right) + W\sin\theta\left(h - \frac{b}{\mu}\right) + Wx\cos\theta = 0$$

or
$$\frac{W}{g}\alpha\left(\frac{\mu h - b}{\mu}\right) = -W\sin\theta\left(\frac{\mu h - b}{\mu}\right) - Wx\cos\theta$$

or

$$\frac{\alpha}{g} = -\sin\theta - \frac{(x\cos\theta)\mu}{\mu h - b}$$

$$= \frac{\mu x \cos\theta}{b - \mu h} - \sin\theta$$

Substitution of this value for $\frac{\alpha}{g}$ in expression (*i*) gives

$$R_f = \frac{W}{\mu}\sin\theta + \frac{W}{\mu}\frac{\alpha}{g}$$

$$= \frac{W}{\mu}\sin\theta + \frac{W}{\mu}\left(\frac{\mu x\cos\theta}{b - \mu h} - \sin\theta\right)$$

$$= \frac{W x\cos\theta}{b - \mu h}$$

Then from expression (*ii*)

$$R_r = W\cos\theta - R_f$$

$$= W\cos\theta - \frac{W x\cos\theta}{b - \mu h}$$

$$= W\cos\theta\left[1 - \frac{x}{b - \mu h}\right]$$

$$= W\cos\theta\left[\frac{b - \mu h - x}{b - \mu h}\right]$$