UNIT-IV Brakes

A break is a device by means of which artificial frictional resistance is applied to a moving machine Element (member), in order to retard or stop the motion of a machine.

The energy absorbed by brakes is dissipated in the f of heat. This absorbed heat is dissipated in the sur ounding air so that excessive heating of the bra lining does not take place.

⇒ The Capacity of a break depends upon the followi factors:-

1. The unit pressure betn the breaking surface.
2. The Coefficient of friction betn the braking surfa
3. The Peripheral velocity of the brake drum.
4. The Projected area of the friction surfaces.
5. The ability of the breake to dissipate heat equiva to the energy being absorbed.

⇒ The major functional difference betn a clutch an a breake is that a clutch is used to keep the driv and driven member moving together, whereas bra are used to stop a moving member or to contro its speed.

Types of a ~~(brakes)~~ Brakes.

1. Hydraulic brakes, [Pumps or hydrodynamic bra
and fluid agitator.

2. Electric brakes [Generators and Eddy Current
brake.

3. Mechanical brakes.

Mechanical brake

(a) Radial brakes:- The force acting on the brake drum is in radial direction.

External brakes

Internal brakes

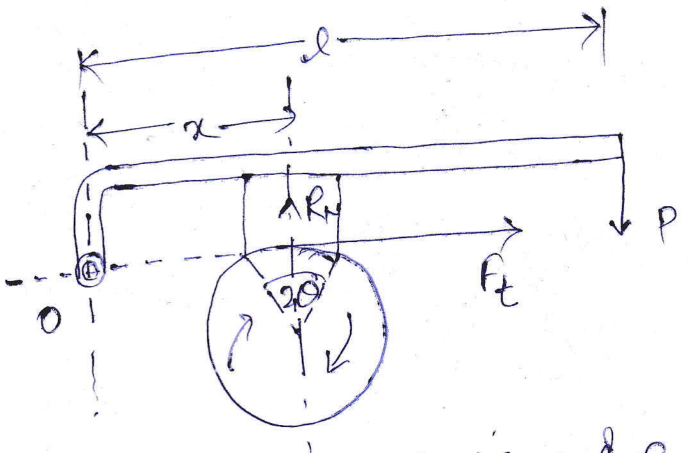
→ According to the shape of the friction element

→ Block brake

→ Shoes brake

→ Band brakes

⇒ Single Block or Shoe brake:-



Clockwise rotation of a brake wheel.

P = Force applied at the e[nd] of the lever

R_N = Normal force pressing the brake block on the wheel.

r = Radius of the wheel.

2θ = Angle of contact surface of the block

μ = Coefficient of friction

F_t = Tangential braking force acting at the contact surface of the block and wheel.

when the angle of Contact is less than 60°, Then the normal Pressure betn the block and the wheel is uniform.

Tangential force (F_t) = μR_N ——— (i)

Braking Torque (T_B) = $F_t \times r$

= $\mu R_N \times r$. ——— (ii)

Case-I. when the line of action of braking tangential force Passing through the fulcrum O of the lever

Taking moment about fulcrum Point 'O'

$\Rightarrow R_N \times x = P \times l$

$$\therefore \boxed{R_N = \frac{P \times l}{x}} \quad \text{——— (iii)}$$

From eqn (ii) & (iii) we get

$T_B = \mu R_N \times r$

$= \mu \frac{P \times l}{x} \times r$ =

$$\boxed{T_B = \frac{\mu P l r}{x}}$$

Case-II when the line of action of the Tangential braking force is Passes through a distance 'a' below the fulcrum Point 'O'

Taking moment about Point 'O' or fulcrum Point i.e

$\Rightarrow R_N \times x + F_t \times a = P \times l$

$\Rightarrow R_N \times x + \mu R_N \times a = P \times l$

$\Rightarrow R_N (x + \mu a) = P \times l$

$\therefore R_N = \left(\dfrac{P \times l}{x + \mu a} \right)$

Now, Braking Torque (TB) $= \mu R_N r$

$= \mu . \dfrac{P \times l}{(x + \mu a)} \times r$

$\therefore \boxed{TB = \dfrac{\mu . P . l . r}{x + \mu . a}}$ For clockwise rotation the wheel.

& $\boxed{TB = \dfrac{\mu . P . l . r}{x - \mu a}}$ For C.C.W of the wheel

Case-III. when F_t passes through a distance 'a' above the fulcrum Point 'O'.

Then ~~moment~~ Taking moment about Point 'O'

$\Rightarrow R_N \times x = P . l + F_t \times a$

$= P \times l + \mu R_N \times a$

$\Rightarrow R_N (x - \mu a) = P l$

$\therefore R_N = \left(\dfrac{P . l}{x - \mu a} \right)$

$\therefore$ Braking torque (TB) $= \mu R_N . r = \mu . \left(\dfrac{P . l}{x - \mu a} \right) . r$

$\therefore \boxed{TB = \dfrac{\mu . P . l . r}{x - \mu a}}$ For clockwise Rotation.

$$R_N = \left(\frac{P \cdot l}{x + \mu a}\right)$$

$\therefore$ Braking torque $(T_B) = \mu R_N \cdot r$

$$= \mu \cdot \left(\frac{P \cdot l}{x + \mu \cdot a}\right) \cdot r$$

$$\therefore \boxed{T_B = \frac{\mu P \cdot l \cdot r}{x + \mu a}}$$ for Anticlock wise rotation

→ The frictional force helps to apply the brakes are said to be Self energizing brake.

When the frictional force is great enough to apply the brake with no external force, then the break is known as to be Self-Locking brake.

The Condition for the brake to be Self locking is

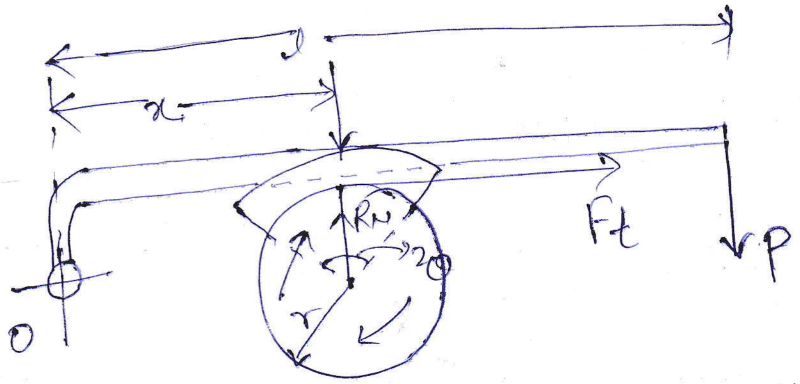
$\boxed{x \leq \mu \cdot a}$, Self locking brake only used in back-stop application

→ The brake should be Self energizing and not the Self locking.

⇒ Pivoted Block and Shoe Brake:-

When the angle of Contact is less than 60°, then it may be assumed that the normal Pressure betn the block and wheel is uniform. But when the angle of Contact is greater than 60°, then the unit Pressure normal to the Surface of Contact is less at the ends than at the Centre.

When $2\theta > 60$. Then



Braking torque for a Pivoted block or shoe brake is

$T_B = F_t \times r$

$= \mu' R_N \times r$

$$\boxed{T_B = \frac{4\mu \sin\theta}{2\theta + \sin 2\theta} \times R_N \times r}$$

μ' = Equivalent Coefficient of friction.

μ = Actual Coefficient of friction.

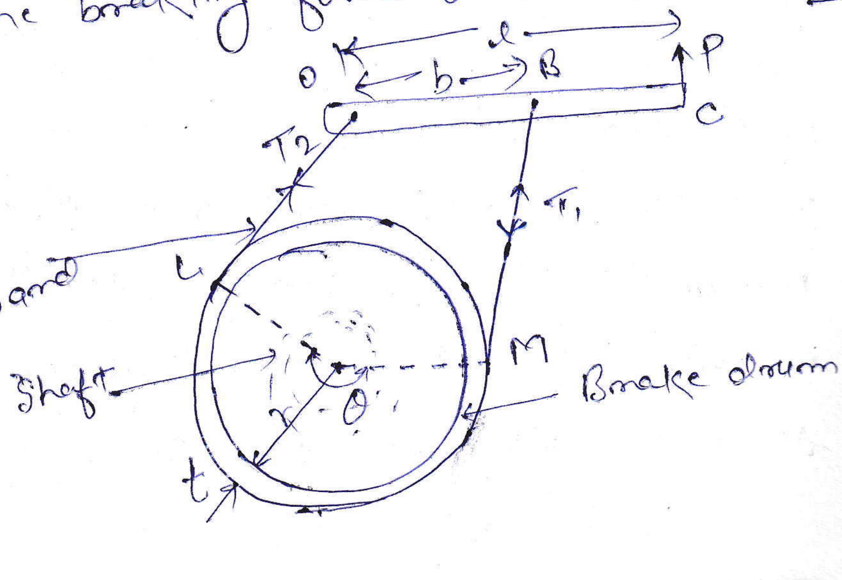
These brakes have more life and may provide a higher braking torque.

→ for Double block or Shoe Brake braking Torque is given below

$$\boxed{T_B = (F_{t_1} + F_{t_2}) \times r}$$

where F_{t1} & F_{t2} are the braking force on the two blocks

→ Simple Band Brake:-



T_1 = Tension in Tight side of the band

T_2 = Tension in Slack side of the band.

θ : Angle of lap (embrace) of the band on the drum.

r_e : Effective radius of the drum $= \left(r + \frac{t}{2}\right)$

$$\boxed{r_e = r + \frac{t}{2}}$$

Limiting ratio of the tensions is given by

$$\Rightarrow \left(\frac{T_1}{T_2}\right) = e^{\mu\theta}$$

$$\Rightarrow \boxed{2.3 \log\left(\frac{T_1}{T_2}\right) = \mu \cdot \theta}$$

Braking force on the drum $= (T_1 - T_2)$

$\therefore$ Braking torque on the drum $(T_B) = (T_1 - T_2)\, r$

when neglect the thickness of the belt

$$\boxed{T_B = (T_1 - T_2) \times r_e}$$ when we consider the thickness of the band.

when the drum rotates in the clockwise direction, then end of the band attached to the fulcrum O will slack side with the tension (T_2).

when the drum rotates in anticlockwise direction the end of the band attached to the fulcrum O will b Tight side with the tension T_1.

Now, Taking moment about Point 'O'

$$\boxed{P \cdot l = T_1 \cdot b}$$ for clockwise rotation of the drum.

$$\boxed{P \cdot l = T_2 \cdot b}$$ For Anticlockwise rotation of the drum.

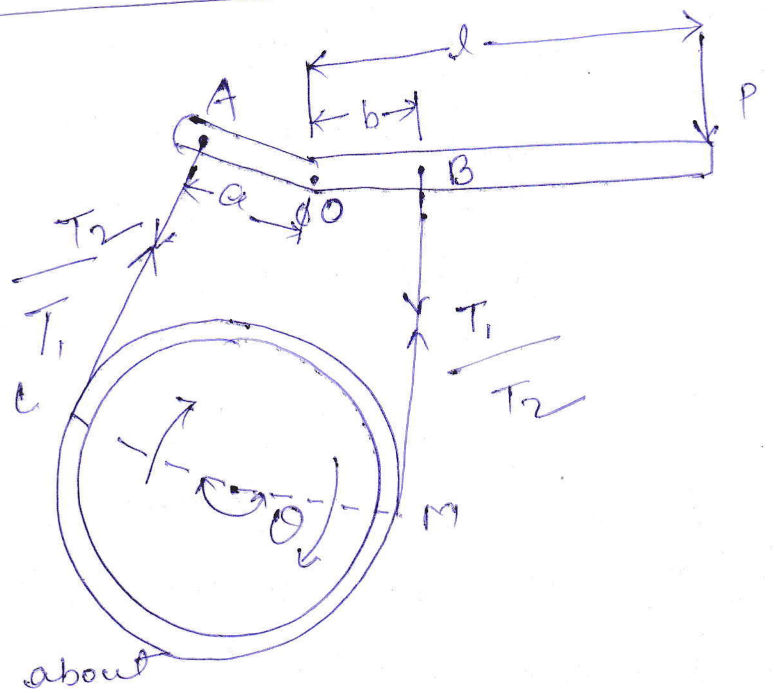
→ When Permissible tensile Stress (σ) for the material of the band is known, then maximum tension in the band is given below.

$$\boxed{T_1 = \sigma \times w \times t}$$

where, w = width of the band

t = Thickness of the band.

⇒ Differential Band Brake:-



Taking moment about fulcrum Point O.

$$\boxed{P \cdot l + T_1 \cdot b = T_2 \cdot a}$$ For clockwise rotation of the drum.

$$\therefore P \cdot l = (T_2 \cdot a - T_1 \cdot b)$$

$$\boxed{P \cdot l + T_2 \cdot b = T_1 \cdot a}$$ For Anticlockwise rotation of the drum.

$$\therefore P \cdot l = (T_1 \cdot a - T_2 \cdot b)$$

when the force P is negative or zero, then brake is self locking.

For differential band brake, for clockwise rotation of the drum, the condition for self locking is

$T_1 . b \geq T_2 . a$

$\therefore \boxed{\frac{T_1}{T_2} \geq \frac{a}{b}}$ or $\boxed{\frac{T_2}{T_1} \leq b/a}$

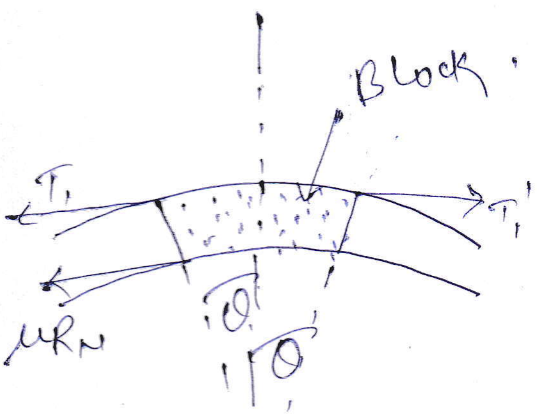
for Anticlockwise direction of the drum. The conditio[n] for self locking is given below.

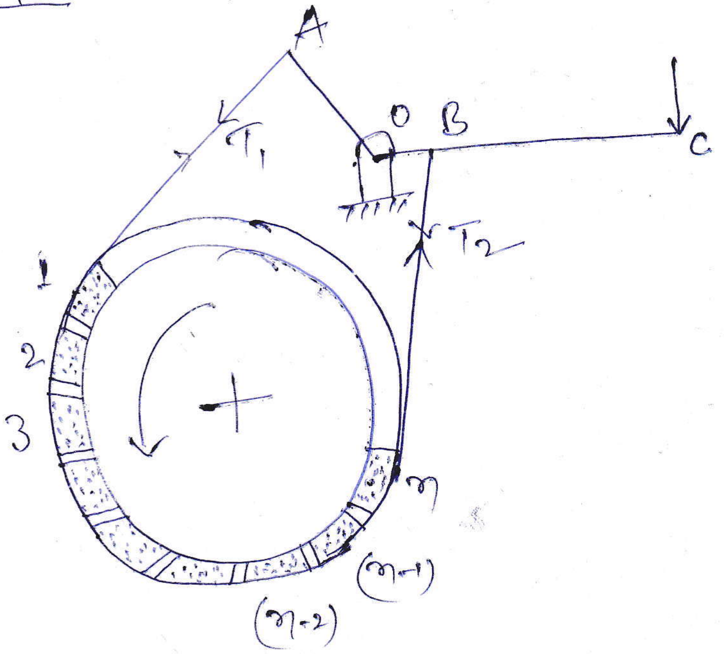
$T_2 . b \geq T_1 . a$

$\therefore \boxed{\frac{T_2}{T_1} \geq \frac{a}{b}}$ or $\boxed{\frac{T_1}{T_2} \leq \frac{b}{a}}$

when the length OB is greater than OA, then the force P must act in the upward direction.

⇒ Band and Block Brake:-





Let T_1 = Tension in the Tight side

T_2 = Tension in the slack side.

μ = Coefficient of friction betⁿ block and drum

T_1' = Tension in the band betⁿ the first and 2ⁿᵈ block.

T_2' = Tension in the band betⁿ 2ⁿᵈ & 3ʳᵈ block

T_3' = " " " " 3ʳᵈ & 4ᵗʰ block

in the above diagram we considered 1st block.

Force resolving in radially, we get

$$(T_1 + T_1') \sin\theta = R_N \quad \text{—— (i)}$$

Force resolving in tangentially, we get

$$(T_1 - T_1') \cos\theta = \mu R_N \quad \text{—— (ii)}$$

Dividing eqⁿ (ii) by (i) we get

$$\Rightarrow \frac{(T_1 - T_1')\cos\theta}{(T_1 + T_1')\sin\theta} = \frac{\mu \cancel{R_N}}{\cancel{R_N}}$$

$$\Rightarrow \frac{(T_1 - T_1')}{(T_1 + T_1')} = \mu \tan\theta$$

$$\Rightarrow (T_1 - T_1') = \mu \tan\theta\,(T_1 + T_1')$$

$$\therefore \boxed{\left(\frac{T_1}{T_1'}\right) = \frac{1+\mu\tan\theta}{1-\mu\tan\theta}}$$

Similarly we find out

$$\frac{T_1'}{T_2'} = \frac{T_2'}{T_3'} = \frac{T_3'}{T_4'} = \cdots = \frac{T_{n-1}}{n_2} = \left(\frac{1+\mu\tan\theta}{1-\mu\tan\theta}\right)$$

$$\therefore \frac{T_1}{T_2} = \frac{T_1}{T_1'} \times \frac{T_1'}{T_2'} \times \frac{T_2'}{T_3'} \times \cdots \times \frac{T_{n-1}}{T_2} = \left(\frac{1+\mu\tan}{1-\mu\tan}\right.$$

$\therefore$ Braking torque on the drum

$$\boxed{T_B = (T_1 - T_2)\, r}$$

(Neglecting the thickness of the band)

$$\boxed{T_B = (T_1 - T_2)\, r_e}$$

⇒ when vehicle moving up an inclined plane

(i) It is a common way of braking the vehicle in which the braking force acts at the rear wheels only.

(ii) It is a very rare way of braking the vehicle, in which the braking force acts at the front wheel one.

(iii) This is the most common way of breaking the vehicle, in which the braking force acts on the both the rear and front wheels.

⇒ Braking of a vehicle :—

The brakes may be applied to

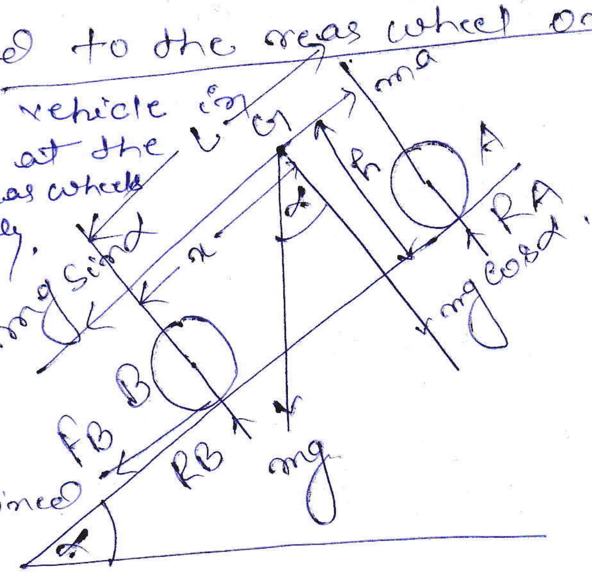
(i) The rear wheel only

(ii) The front wheel only

(iii) All the four wheel.

(i) when the brakes are applied to the rear wheel only

It is a common way of braking the vehicle in which the braking force acts at the rear wheels only.



Let, α = Angle of inclination,

m = Mass of the vehicle in kg or weight mg in newton.

h = Height of C.G from inclined plane.

x = ⊥r distance from rear axle to C.G

L = wheel base

R_A = Normal reaction force at A

R_B = " " " " B.

μ = Coefficient of friction betn tyre and road.

a = Retardation of the vehicle in m/s^2.

F_B = Total braking force acting at rear wheel in due to the application of brakes.

Resolving all forces Parallel and Perpendicular to inclined plane,

$$\boxed{F_B + mg\sin\alpha = ma} \quad \text{——— (i)}$$

$$\boxed{R_A + R_B = mg\cos\alpha} \quad \text{——— (ii)}$$

Taking moment about point C.G is given below

$$\boxed{F_B \times h + R_B \times x = R_A (L - x)} \quad \text{——— (iii)}$$

from eqn (i), & (ii) we put the value of $F_B = \mu R_B$ and $R_A = mg\cos\alpha - R_B$ in the above eqn (iii) we get,

$$\Rightarrow \mu R_B \times h + R_B \times x = (mg\cos\alpha - R_B)(L - x)$$

$$\therefore \boxed{R_B = \frac{mg\cos\alpha (L - x)}{L + \mu h}}$$

Similarly from eqn (ii),

$$\boxed{R_A = \frac{mg\cos\alpha (x + \mu h)}{L + \mu h}}$$

from eqn

$$ma = F_B + mg\sin\alpha$$

$$\therefore a = \frac{F_B}{m} + \frac{\cancel{m} g\sin\alpha}{\cancel{m}}$$

$$= \frac{F_B}{m} + g\sin\alpha = \frac{\mu R_B}{m} + g\sin\alpha$$

$$\boxed{a = \frac{\mu g\cos\alpha (L - x)}{(L + \mu h)} + g\sin\alpha}$$

when $\alpha = 0$, i.e. vehicles moves on horizontal surfa

$$\therefore \boxed{R_B = \frac{mg(L-x)}{L+\mu h}}$$

$$\boxed{a = \frac{\mu g (L-x)}{L+\mu h}}$$

$$\boxed{R_A = \frac{mg(x+\mu h)}{L+\mu h}}$$

If the vehicles move down the plane, Then eqn (i) will change.

$$\Rightarrow ma + mg\sin\alpha = F_B$$

$$\Rightarrow ma = F_B - mg\sin\alpha$$

$$= \mu R_B - mg\sin\alpha$$

$$\therefore a = \frac{\mu R_B}{m} - g\sin\alpha$$

$$\boxed{a = \frac{\mu g\cos\alpha (L-x)}{(L+\mu h)} - g\sin\alpha}$$

(ii) when the brake are applied on front wheel, when vehicles moves up the plane.

Then Braking force F_A acts in downward the inclined plane.

Then, Resolving all forces (free body diagram).

$$\boxed{mg\sin\alpha + F_A = ma} \qquad \text{—— (i)}$$

$$\boxed{R_A + R_B = mg\cos\alpha} \qquad \text{—— (ii)}$$

Taking moment about C.G. is given below

$$\boxed{F_A \times h + R_B \times x = R_A(L-x)} \quad \text{---} \quad (iii)$$

from above eqn we get

$$R_A = \frac{mg \cos\alpha \times x}{(L-\mu h)}$$

$$R_B = mg \cos\alpha \left(\frac{L-\mu h - x}{L-\mu h}\right)$$

&

$$a = \frac{\mu g \cdot \cos\alpha \cdot x}{L-\mu h} + g \sin\alpha.$$

when the vehicles moves on a rough horizontal surface, i.e $\alpha = 0$.

Then,

$$R_A = \frac{mg \times x}{(L-\mu h)}$$

$$R_B = mg \, (L-\mu h - x) / (L-\mu h)$$

&

$$a = \frac{\mu g \cdot x}{L-\mu g h} + g \sin 0^\circ$$

$$\boxed{a = \frac{\mu g \times x}{L-\mu h}}$$

when the vehicles moves down the plane. Then,

$$F_A = mg \sin\alpha + m \cdot a$$

$$\Rightarrow ma = F_A - mg\sin\alpha$$

$$\therefore a = \frac{F_A}{m} - g\sin\alpha$$

$$= \frac{\mu . R_A}{m} - g\sin\alpha$$

$$\boxed{a = \frac{\mu g\cos\alpha \times x}{L - \mu h} - g\sin\alpha}$$

(iii) when the brakes are applied to all the four wheels and vehicles moves up the plane.

The braking force F_A & F_B both are acted downward in direction to inclined plane.

Then Resolving all the forces, which is given below

$$\boxed{F_A + F_B + mg\sin\alpha = ma} \quad \text{—— (i)}$$

$$\boxed{R_A + R_B = mg\cos\alpha} \quad \text{—— (ii)}$$

Taking moment about C.G. Then

$$\boxed{(F_A + F_B) \times h + R_B \times x = R_A \times (L - x)} \quad \text{—— (iii)}$$

from the above all equation, we get

$$R_A = \frac{mg\cos\alpha\,(x + \mu h)}{L}$$

$$R_B = mg\cos\alpha\,\frac{(L - \mu h - x)}{L}$$

from eqn (i),

$$ma = FA + FB + mg\sin\alpha$$
$$= \mu RA + \mu RB + mg\sin\alpha$$
$$= \mu(RA + RB) + mg\sin\alpha$$
$$= \mu . mg\cos\alpha + mg\sin\alpha$$

$$\therefore a = \mu g\cos\alpha + g\sin\alpha$$

$$\boxed{a = g(\mu\cos\alpha + \sin\alpha)}$$

when vehicles moves on the rough horizontal surface, $\alpha = 0$.

$$\therefore RA = \frac{mg(\mu h + x)}{L}$$

$$RB = mg\left(\frac{L - \mu h - x}{L}\right)$$

& $\boxed{a = g\mu}$

when vehicles moves down the inclined plane

$$FA + FB = ma + mg\sin\alpha$$

$$\Rightarrow ma = FA + FB - mg\sin\alpha$$
$$= \mu(RA + RB) - mg\sin\alpha$$
$$= \mu mg\cos\alpha - mg\sin\alpha$$
$$= mg(\mu\cos\alpha - \sin\alpha)$$

$$a = \frac{\cancel{m}g(\mu\cos\alpha - \sin\alpha)}{\cancel{m}}$$

$$\therefore \boxed{a = g(\mu\cos\alpha - \sin\alpha)}$$

⇒ **Dynamometer :-**

A dynamometer is a brake but addition it has to measure the frictional resist ce. It is used for measuring the brake power of a engine.

Dynamometer.

Absorption dynamometer.

The entire energy or power produced by the engine is absorbed by the friction resistances of the brakes and is transformed into heat energy.

Transmission dynam mete

The energy is not wasted in friction is used for doing wor

The energy or power prod ced by the engine is transmitted through the dynamometer to some oth machines where the power developed is suitably meas ed.

⇒ ~~Prony~~ Brake Dynamometer :-
Rope

W : Dead load in N

S : Spring balance reading in N

D : Dia. of the wheel in m

d : Dia. of Rope in m

N : Speed of the engine shaft in r.p.m

Total load on the brakes

$= (W-S)$ N

Distance moved in one revolution

$= \pi(D+d)$ N

∴ Work done per revolution

$= (W-S)\pi(d+D)$ N-m

Now,
Work done per minute

$= (W-S)\pi(d+D)N$ N-m.

∴ Brake Power of the engine

$$B.P = \frac{\text{Work done per min}}{60} = \frac{(W-S)\pi(D+d)N}{60} \text{ watts.}$$

If dia. of rope is neglected. Then

$$\text{Brake Power (B.P)} = \frac{(W-S)\pi DN}{60} \text{ watts.}$$

⇒ Prony Brake Dynamometer:-

Let, W = weight at the outer end of the lever in

L = Horizontal distance of the W from the Centre of the Pulley.

F = Frictional resistance betn Block & Pulley.

R = Radius of the Pulley

N = Speed of the Shaft.

Moment of frictional resistance or Torque on the Shaft

$$T = W \times L = F \times R$$

Work done in one revolution

= torque × Angle turned

$= T \times 2\pi$ N-m

Work done per minute

$W = T \times 2\pi N$ N-m

$$\text{Brake Power (B.P)} = \frac{\text{work done per min}}{60} = \frac{T \times 2\pi N}{60}$$

$$= \frac{WL \times 2\pi N}{60} \text{ watts.}$$

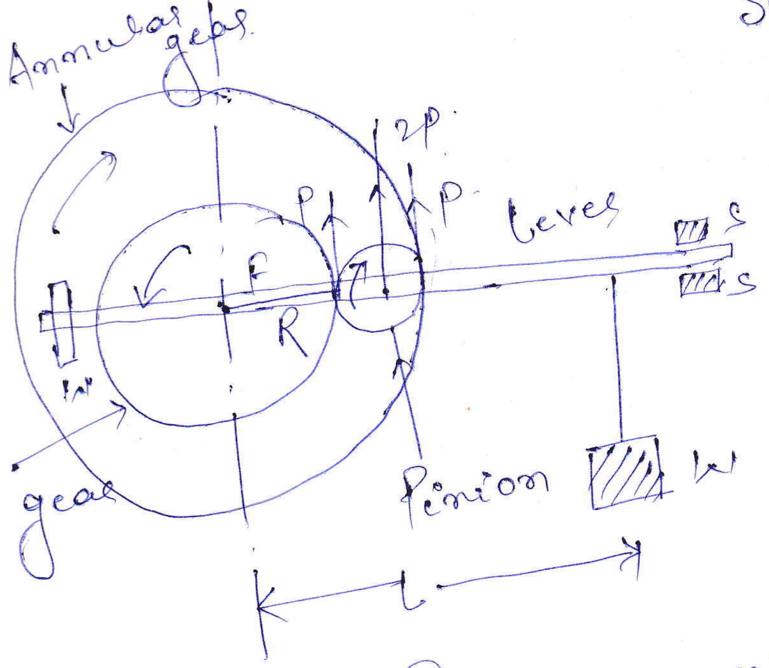
Transmission Dynamometer :-

(i) Epicyclic - train Dynamometer!

(ii) Belt Transmission Dynamometer.

(iii) Torsion Dynamometer.

(i) Epicyclic - train Dynometer.



Spur gear attached to Engine Shaft (driving Shaft) rotates in Clockwise. Annular gear is also attached to the driving Shaft. rotates in A.C.W

For eqm of the lever, Taking moment about the fulcrum Point F.

$\Rightarrow \quad 2P \times a = W \cdot L$

$$\boxed{P = \frac{W \cdot L}{2a}}$$

Let R = Pitch Circle radius of the Spur gear

N = Speed of the Engine Shaft

Torque transmitted, $T = P \times R$.

Power Transmitted $= \dfrac{T \times 2\pi N}{60} = \dfrac{P \cdot R \times 2\pi N}{60}$ Watts.