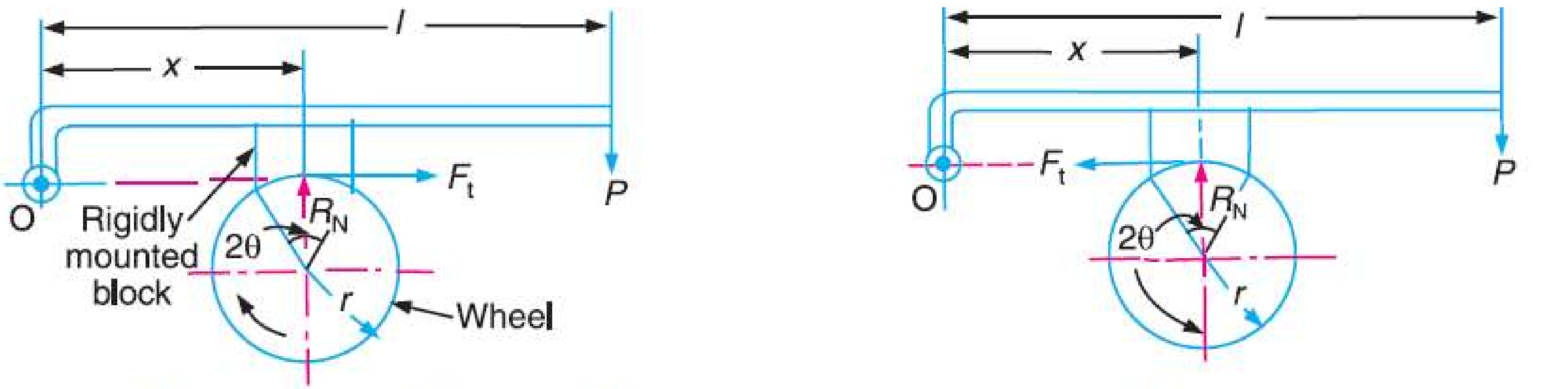
Brakes

- A ***brake*** *is a device by means of which artificial* frictional resistance is applied to a moving machine member, in order to retard or stop the motion of a machine.

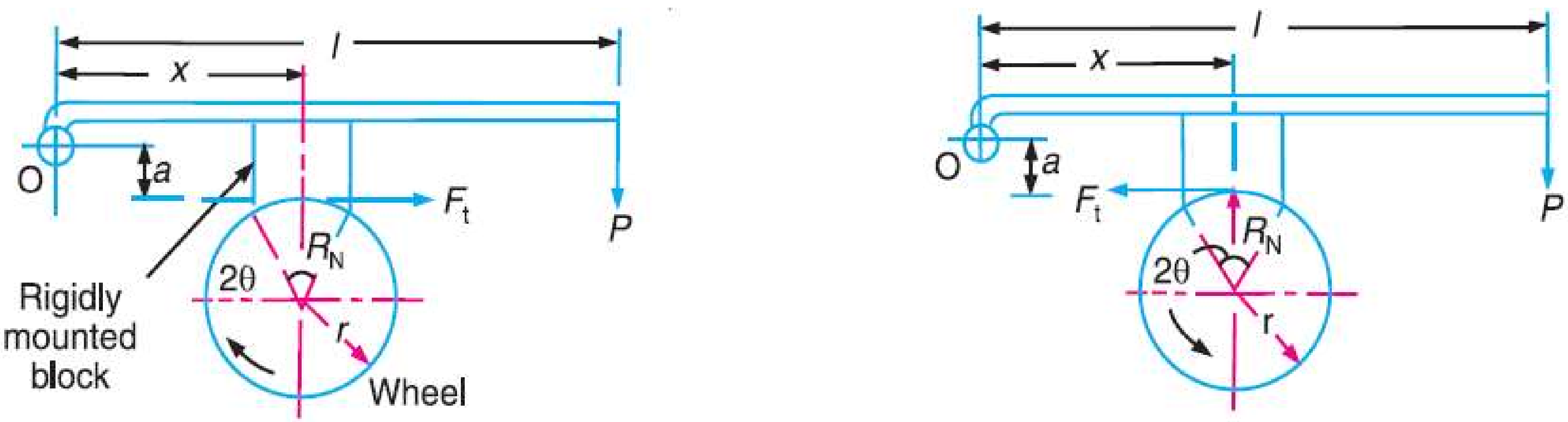
1) **Hydraulic brakes** *e.g. pumps or hydrodynamic brake* and fluid agitator,
2) **Electric brakes** *e.g. generators and eddy current* brakes, and
3) **Mechanical brakes**
   a) **Block brake**
   b) **Band brake**
   c) **Internal or external expanding shoe brake**
   d) **Disc brake**

Single Block or Shoe Brake



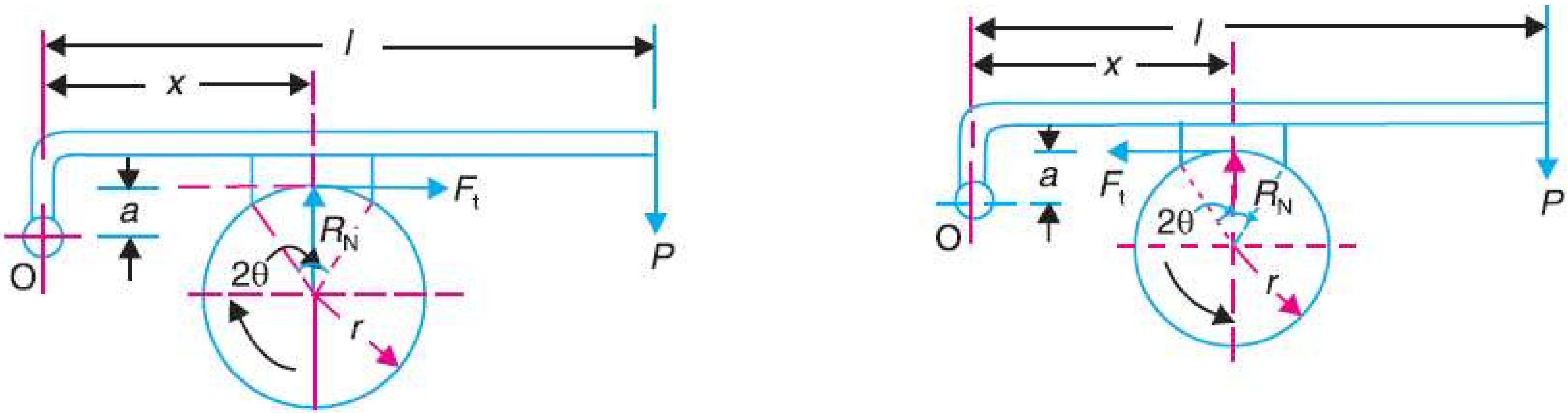
(*a*) Clockwise rotation of brake wheel (*b*) Anticlockwise rotation of brake wheel.

Fig. 19.1. Single block brake. Line of action of tangential force passes through the fulcrum of the lever.



(*a*) Clockwise rotation of brake wheel. (*b*) Anticlockwise rotation of brake wheel.

Fig. 19.2. Single block brake. Line of action of F_t passes below the fulcrum.



(*a*) Clockwise rotation of brake wheel. (*b*) Anticlockwise rotation of brake wheel.

Fig. 19.3. Single block brake. Line of action of F_t passes above the fulcrum.

used on railway trains, bicycles and tram cars

the frictional force helps to apply the brake. Such type of brakes are said to be ***self energizing brakes.*** *When the frictional* force is great enough to apply the brake with no external force, then the brake is said to **be *self-locking brake***

braking torque, $T_B = \mu.R_N.r = \dfrac{\mu.P.l.r}{x - \mu.a}$

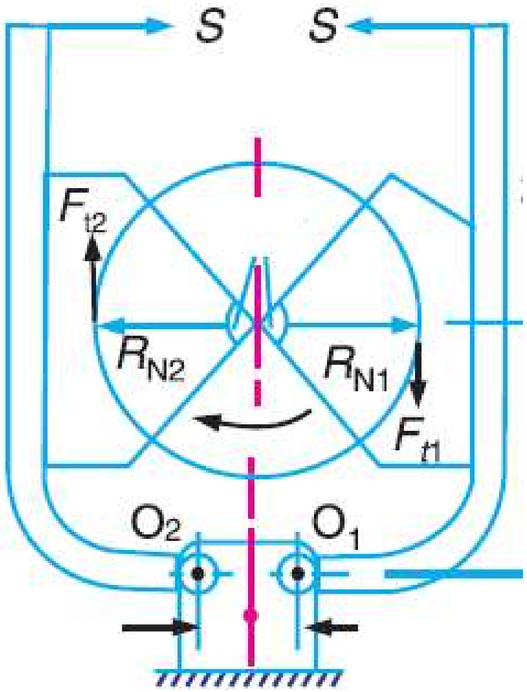
$x \leq \mu.a$, then P will be negative or equal to zero. This means no external force is needed to apply the brake and hence the brake is self locking. Therefore the condition for the brake to be self locking is

$$x \leq \mu.a$$

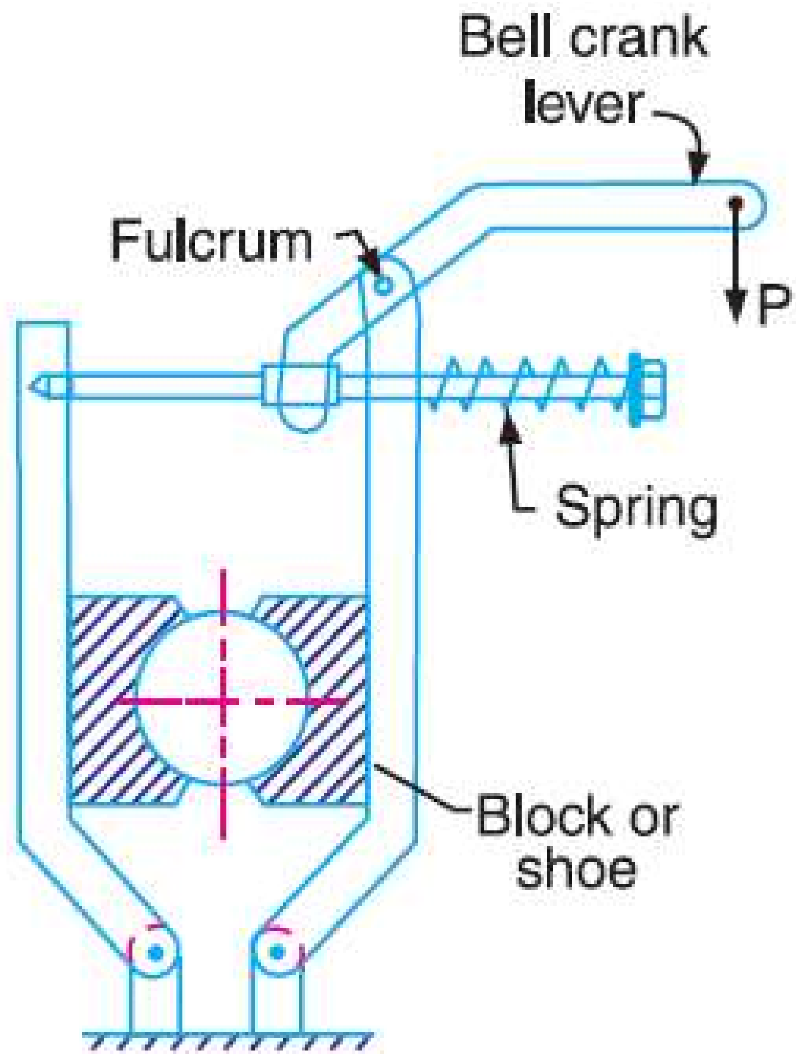
$$R_N \times x = P.l + \mu.R_N.a$$

The frictional force assist the actuating force such brakes are called as **self energizing or self actuating brakes**

Double Block or Shoe Brake



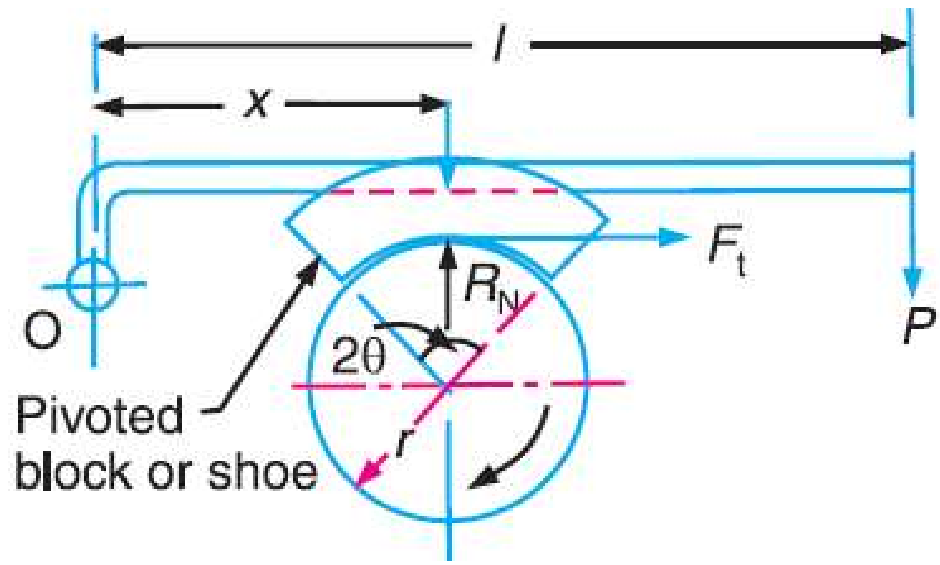
$$T_B = (F_{t1} + F_{t2})\, r$$



Used in electric cranes

Pivoted Block or Shoe Brake

when the angle of contact is less than 60°, normal pressure between the block and the wheel is uniform. But greater than 60°, then the unit pressure normal to the surface of contact is less at the ends than at the centre



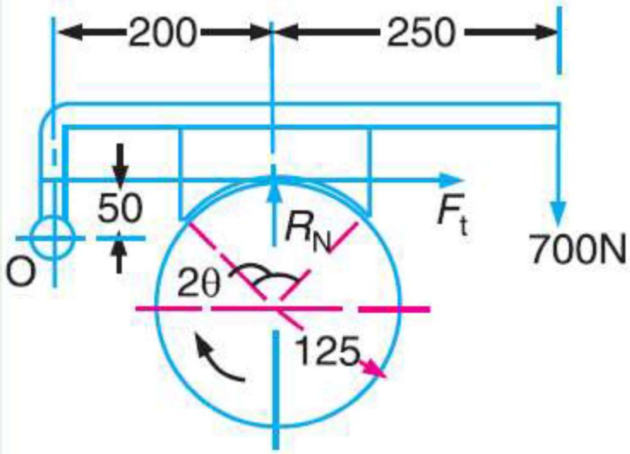
$$T_B = F_t \times r = \mu'.R_N.r$$

where $\mu' = \text{Equivalent coefficient of friction} = \dfrac{4\mu \sin\theta}{2\theta + \sin 2\theta}$, and

$\mu = $ Actual coefficient of friction.

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

Example 19.1. *A single block brake is shown in Fig. 19.5. The diameter of the drum is 250 mm and the angle of contact is 90°. If the operating force of 700 N is applied at the end of a lever and the coefficient of friction between the drum and the lining is 0.35, determine the torque that may be transmitted by the block brake.*

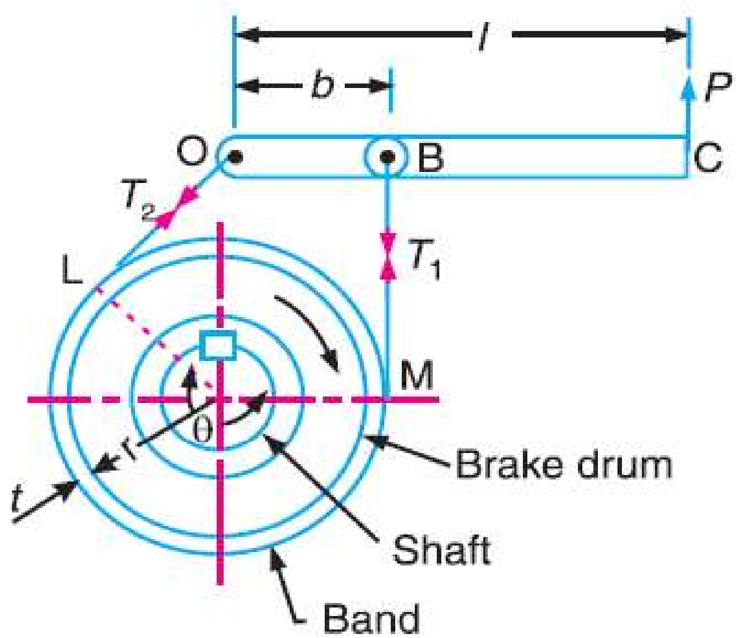


All dimensions in mm.

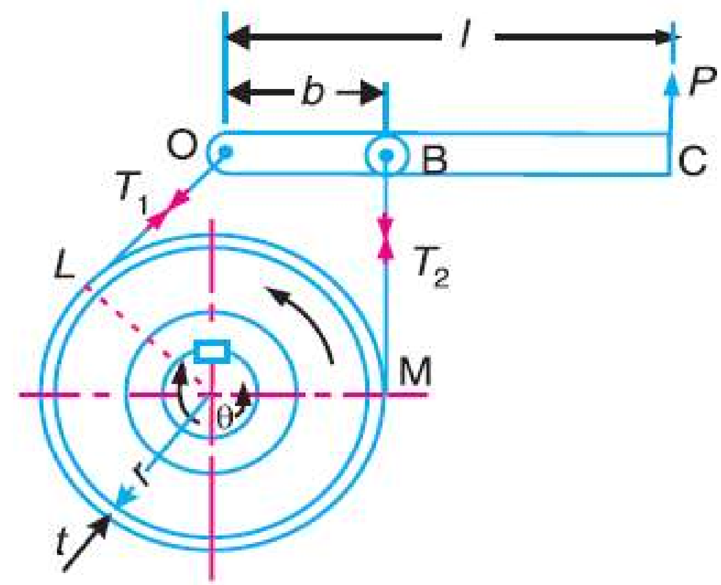
Solution. Given : $d = 250$ mm or $r = 125$ mm ; $2\theta = 90° = \pi/2$ rad ; $P = 700$ N ; $\mu = 0.35$

Band brake

- A band brake consists of a flexible band of leather, one or more ropes, or a steel lined with friction material, which embraces a part of the circumference of the drum



(a) Clockwise rotation of drum.



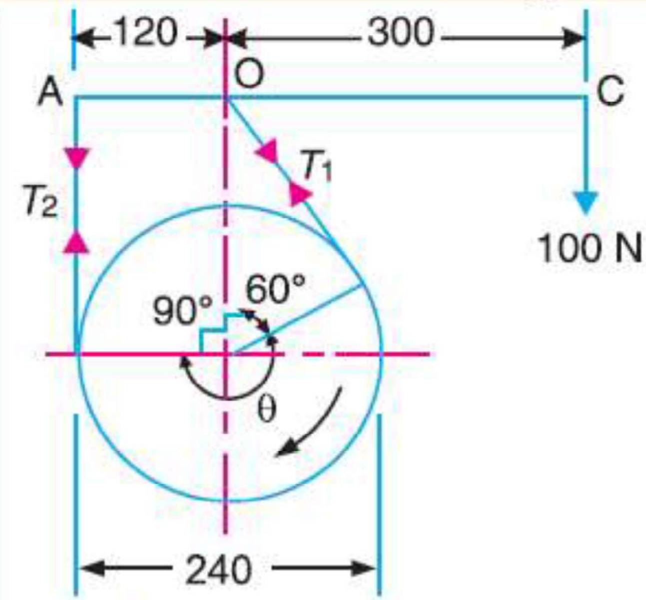
(b) Anticlockwise rotation of drum.

Example 19.6. *A band brake acts on the 3/4th of circumference of a drum of 450 mm diameter which is keyed to the shaft. The band brake provides a braking torque of 225 N-m. One end of the band is attached to a fulcrum pin of the lever and the other end to a pin 100 mm from the fulcrum. If the operating force is applied at 500 mm from the fulcrum and the coefficient of friction is 0.25, find the operating force when the drum rotates in the* (a) *anticlockwise direction, and* (b) *clockwise direction.*

Example 19.7. *The simple band brake, as shown in Fig. 19.12, is applied to a shaft carrying a flywheel of mass 400 kg. The radius of gyration of the flywheel is 450 mm and runs at 300 r.p.m.*

If the coefficient of friction is 0.2 and the brake drum diameter is 240 mm, find :

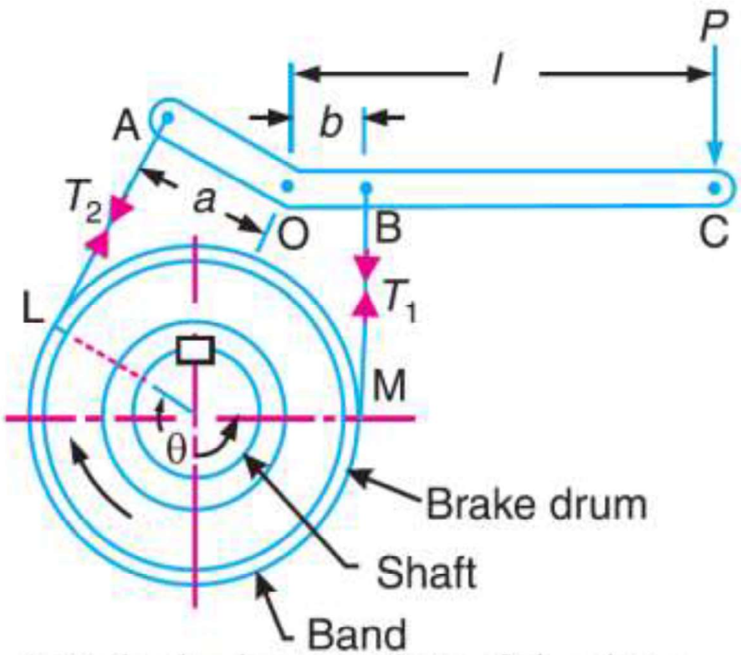
1. *the torque applied due to a hand load of 100 N,*
2. *the number of turns of the wheel before it is brought to rest, and*
3. *the time required to bring it to rest, from the moment of the application of the brake.*



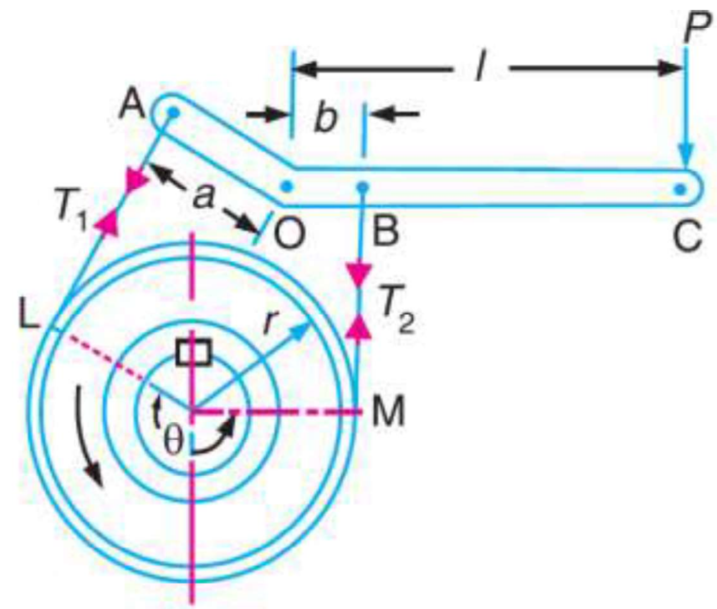
All dimensions in mm.

Solution. Given : $m = 400$ kg ; $k = 450$ mm $= 0.45$ m ; $N = 300$ r.p.m. or $\omega = 2\pi \times 300 / 60 = 31.42$ rad/s ; $\mu = 0.2$; $d = 240$ mm $= 0.24$ m or $r = 0.12$ m

Differential Band Brake



(a) Clockwise rotation of the drum.



(a) Anticlockwise rotation of the drum.

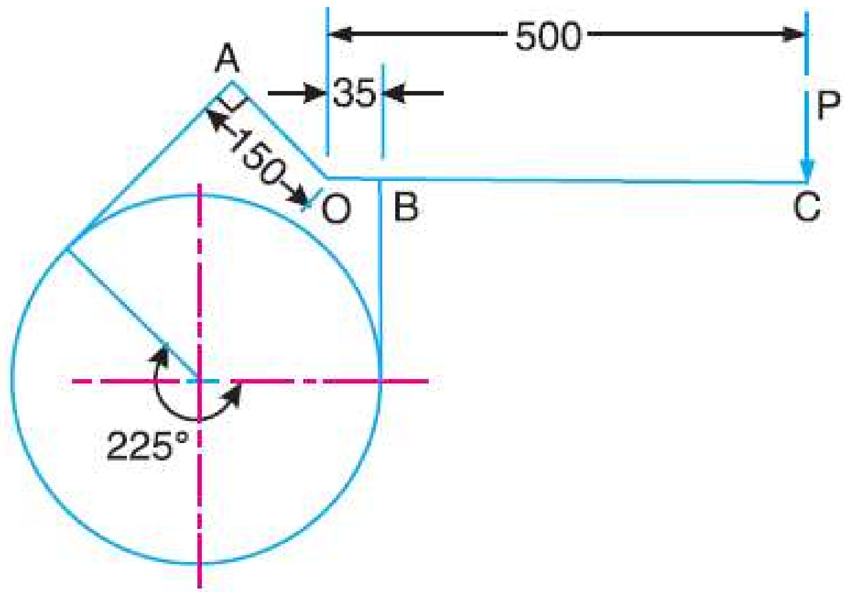
We have also discussed that when the force P is negative or zero, then brake is self locking. Thus for differential band brake and for clockwise rotation of the drum, the condition for self locking is

$$T_2.a \le T_1.b \qquad \text{or} \qquad T_2 / T_1 \le b / a$$

and for anticlockwise rotation of the drum, the condition for self locking is

$$T_1.a \le T_2.b \qquad \text{or} \qquad T_1 / T_2 \le b / a$$

Example 19.10. *A differential band brake, as shown in Fig. 19.17, has an angle of contact of 225°. The band has a compressed woven lining and bears against a cast iron drum of 350 mm diameter. The brake is to sustain a torque of 350 N-m and the coefficient of friction between the band and the drum is 0.3. Find : 1. The necessary force (P) for the clockwise and anticlockwise rotation of the drum; and 2. The value of 'OA' for the brake to be self locking, when the drum rotates clockwise.*



All dimensions in mm.

Band and Block Brake

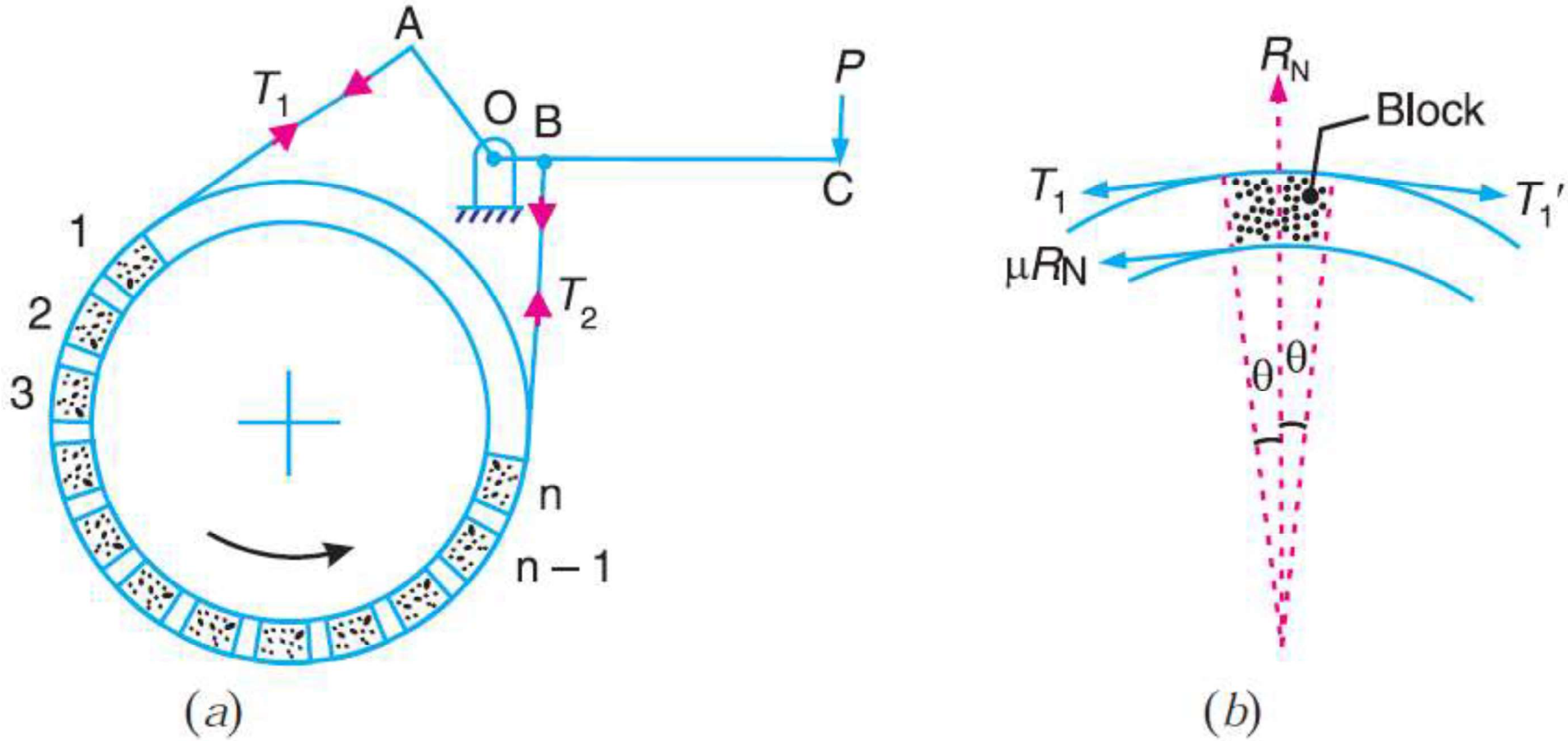


Fig. 19.20. Band and block brake.

T_1 = Tension in the tight side,
T_2 = Tension in the slack side,
μ = Coefficient of friction between the blocks and drum,

'n' number of blocks,

$$\frac{T_1}{T_2} = \left(\frac{1+\mu \tan\theta}{1-\mu \tan\theta}\right)^n$$

Braking torque on the drum of effective radius r_e,

$$T_B = (T_1 - T_2)\, r_e$$
$$= (T_1 - T_2)\, r \qquad \text{... [Neglecting thickness of band]}$$

Example 19.12. *A band and block brake, having 14 blocks each of which subtends an angle of 15° at the centre, is applied to a drum of 1 m effective diameter. The drum and flywheel mounted on the same shaft has a mass of 2000 kg and a combined radius of gyration of 500 mm. The two ends of the band are attached to pins on opposite sides of the brake lever at distances of 30 mm and 120 mm from the fulcrum. If a force of 200 N is applied at a distance of 750 mm from the fulcrum, find:*

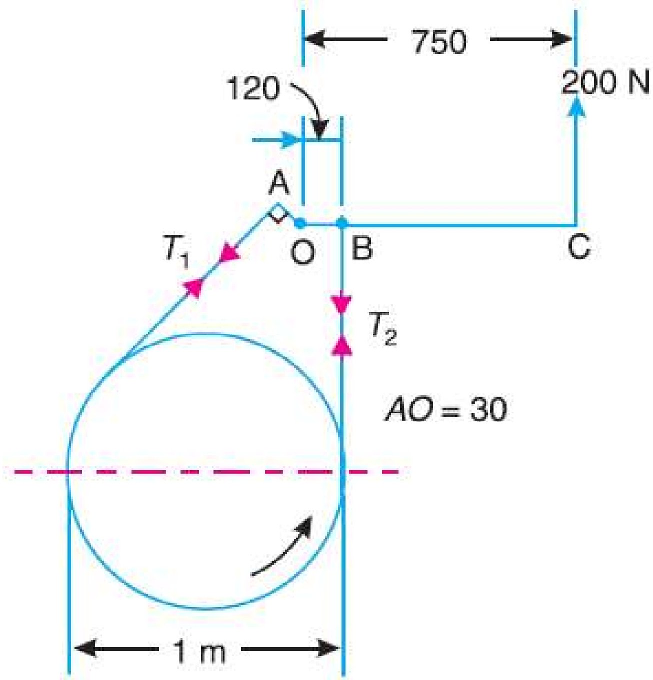
1. maximum braking torque, 2. angular retardation of the drum, and 3. time taken by the system to come to rest from the rated speed of 360 r.p.m.

The coefficient of friction between blocks and drum may be taken as 0.25.

$$\frac{T_1}{T_2} = \left(\frac{1+\mu\tan\theta}{1-\mu\tan\theta}\right)^n$$

$$T_B = (T_1 - T_2)\, r$$

$$T_B = I.\alpha = m.k^2.\alpha$$



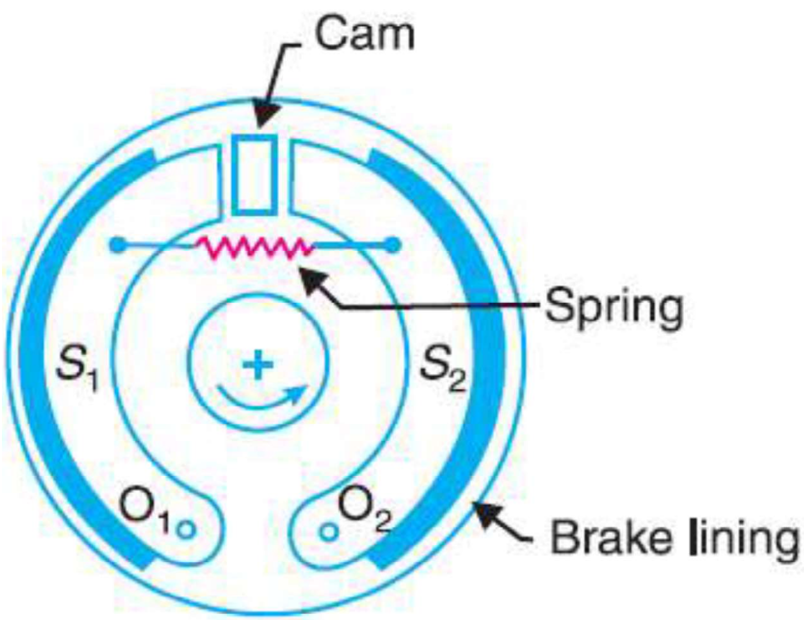
All dimensions in mm

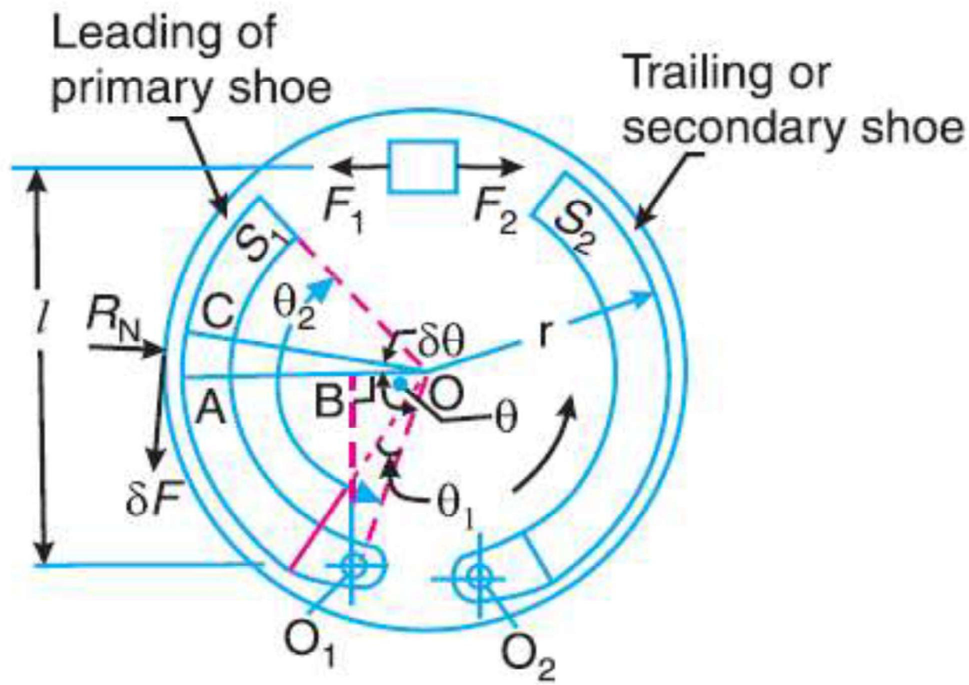
Initial angular speed, $\omega_1 = 2\pi \times 360/60 = 37.7$ rad/s

and final angular speed, $\omega_2 = 0$

We know that $\omega_2 = \omega_1 - \alpha.t$ ... (– ve sign due to retardation)

Internal expanding brake





total braking torque about O for whole of one shoe,

$$T_B = \mu\, p_1 b r^2 (\cos\theta_1 - \cos\theta_2)$$

normal forces about the fulcrum O_1,

$$M_N = \frac{1}{2} p_1 . b . r . OO_1 \left[(\theta_2 - \theta_1) + \frac{1}{2}(\sin 2\theta_1 - \sin 2\theta_2) \right]$$

frictional force about the fulcrum O_1,

$$M_F = \mu\, p_1 b r \left[r(\cos\theta_1 - \cos\theta_2) + \frac{OO_1}{4}(\cos 2\theta_2 - \cos 2\theta_1) \right]$$

Now for leading shoe, taking moments about the fulcrum O_1,

$$F_1 \times l = M_N - M_F$$

and for trailing shoe, taking moments about the fulcrum O_2,

$$F_2 \times l = M_N + M_F$$

Note : If $M_F > M_N$, then the brake becomes self locking.