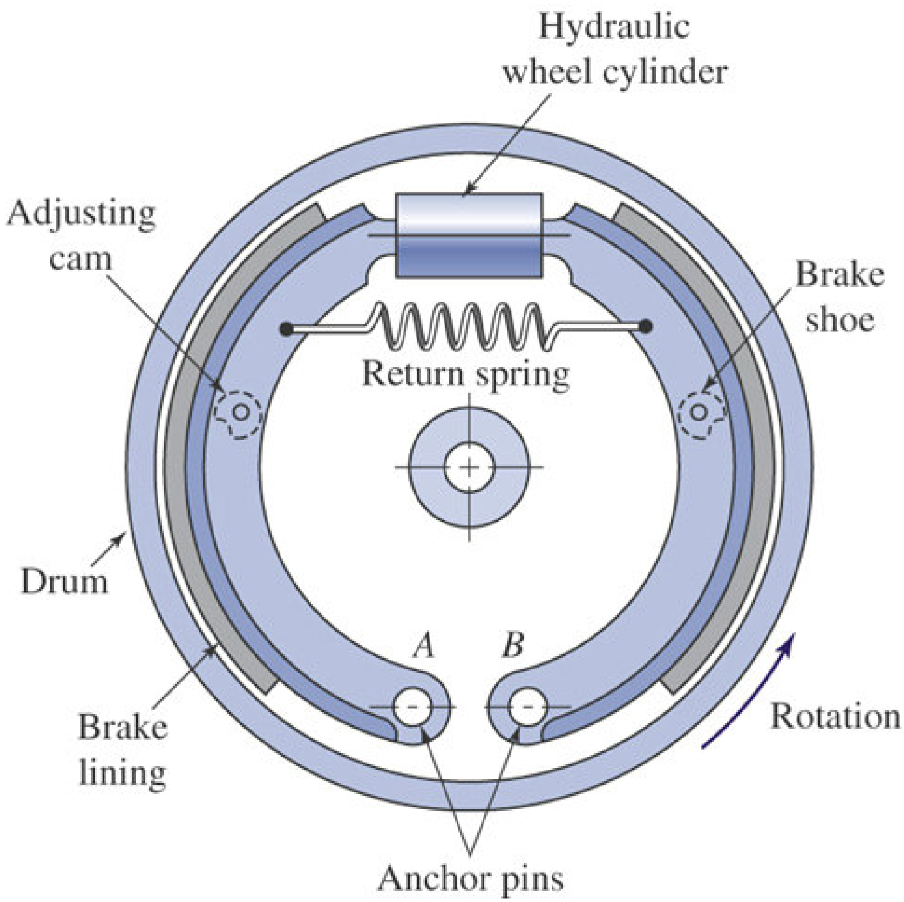
Internal Long-Shoe Drum Brakes



Formerly in wide automotive use; being replaced by caliper disc brakes, which offer better cooling capacity (and many other advantages).

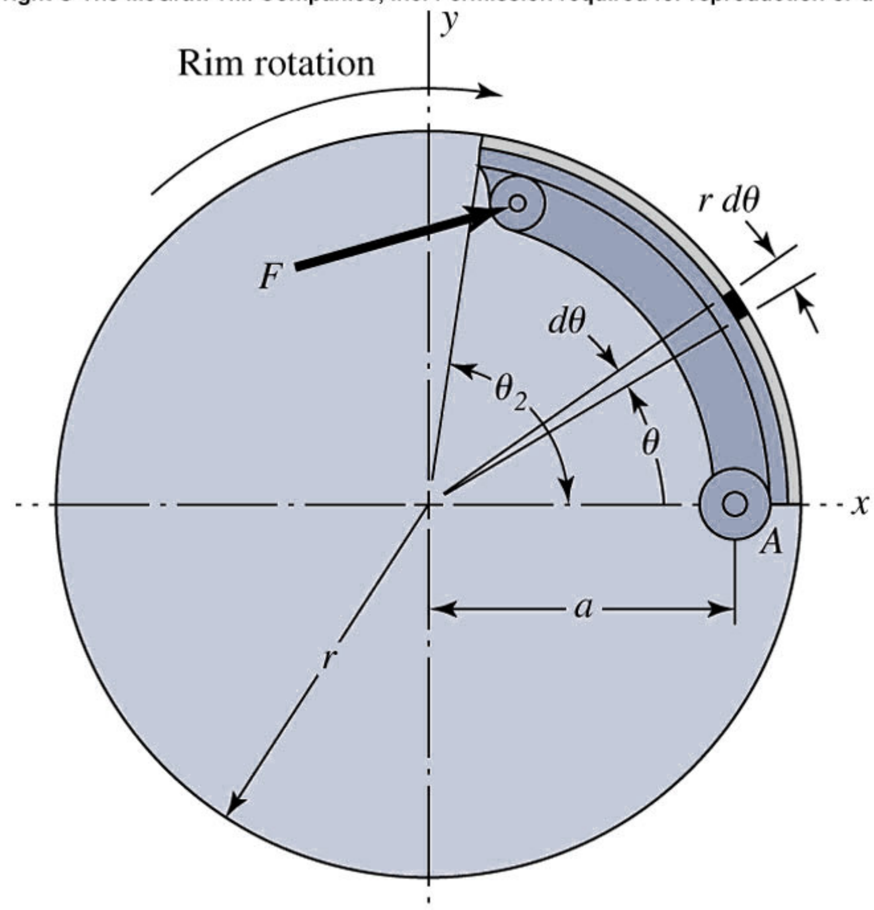
Analysis:

Due to the pivot pin at point A, the movement of the shoe is Restricted at this point.

The normal pressure between The friction lining and brake Drum at any point due to force F is Proportional to the vertical distance from the pivot. The pressure is maximum at Angle θ_2 while it is zero at Point A.

The drum and shoe are Assumed to be rigid and the Centrifugal forces are Negligible.

The coefficient of friction Is considered constant.



Consider an elemental area on the friction lining located at angle θ

The element normal force due to the braking force F is:

$dN = p\ b\ r\ d\theta$

Where p is the normal pressure

b is the width of the friction lining parallel to the drum axis

r is the internal radius of the drum.

Since the pressure is proportional to the vertical distance ($r \sin\theta$)

Then; $p = C_1\ r \sin\theta$

$p = C_2 \sin\theta$

Assume that $p = p_{max}$ when $\theta = \theta_{max}$

and $\theta_{max} = 90^o$ when $\theta_2 > 90^o$

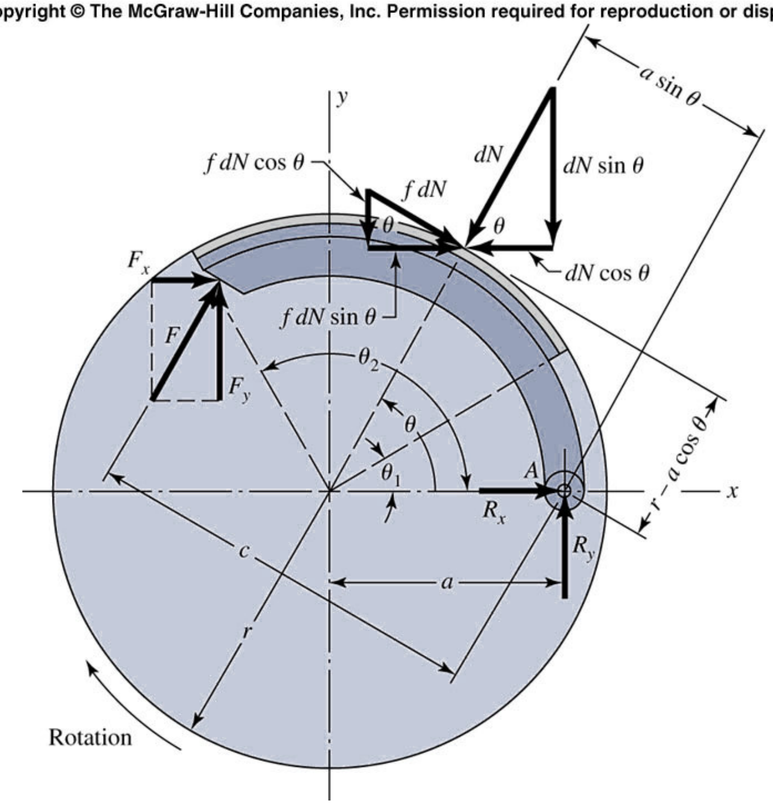
$\theta_{max} = \theta_2$ when $\theta_2 < 90^o$

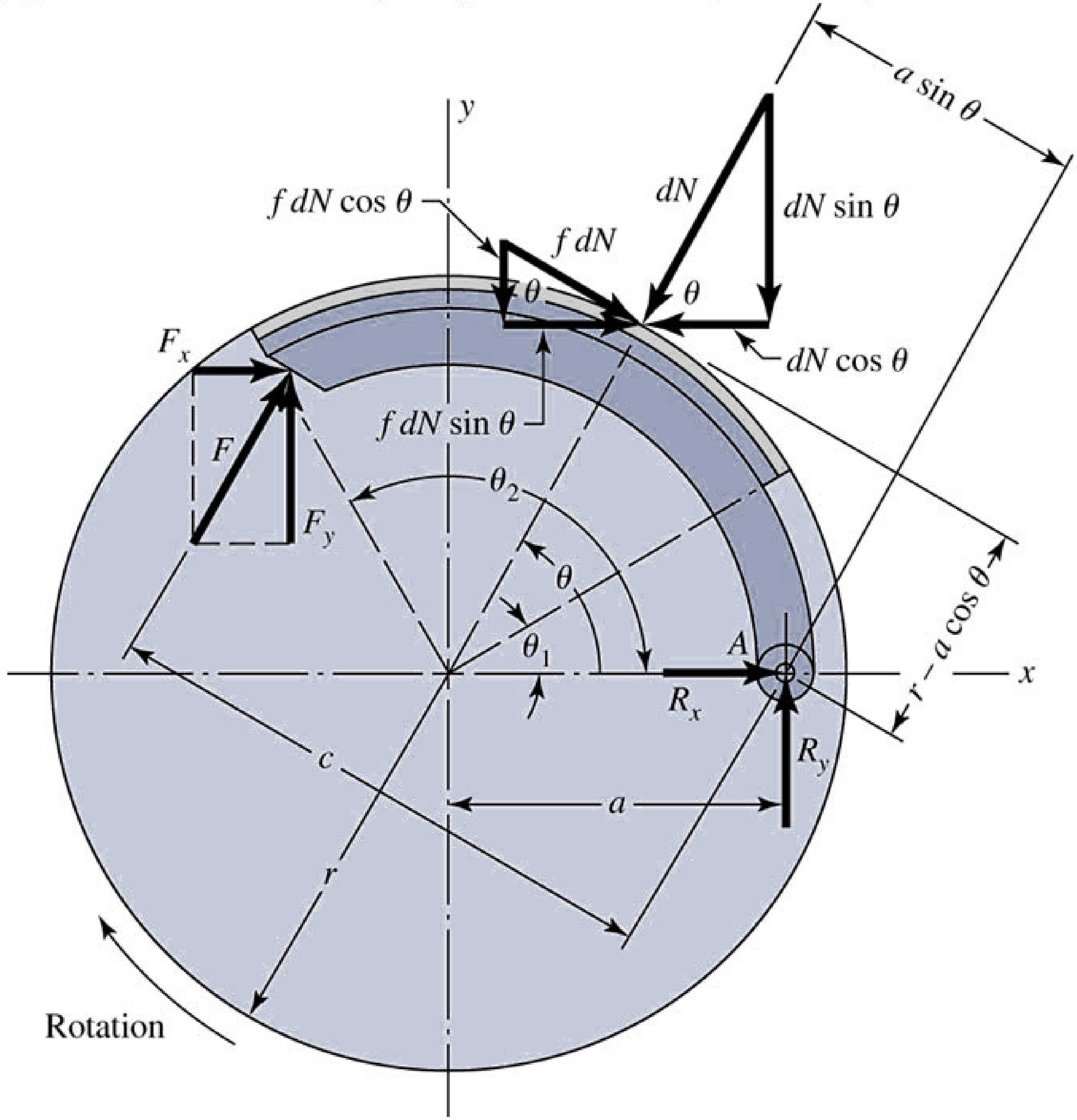
Then:

$P_{max} = C_2\ \sin\theta_{max}$

$$\therefore p = p_{\text{max}}\left(\frac{\sin\theta}{\sin\theta_{\text{max}}}\right)$$

$$\therefore dN = p_{\text{max}}\ b\ r\left(\frac{\sin\theta}{\sin\theta_{\text{max}}}\right)d\theta$$





y
x
a sin θ
dN
dN sin θ
f dN cos θ
f dN
θ
θ
dN cos θ
f dN sin θ
F_x
F
F_y
θ_2
θ
θ_1
A
R_x
R_y
r − a cos θ
c
a
r
Rotation

The moment M_f of the frictional forces f N about the hinge pin at A as shown in figure is:

$$M_f = \int f dN (r - a\cos\theta) = \frac{f p_{max} b r}{\sin\theta_{max}} \int_{\theta_1}^{\theta_2} \sin\theta (r - a\cos\theta) d\theta$$

The moment of the normal forces M_N about the pivot is:

$$M_N = \int dN (a\sin\theta) = \frac{p_{max} b r a}{\sin\theta_{max}} \int_{\theta_1}^{\theta_2} \sin^2\theta \, d\theta$$

From the condition that the summation of the moments about the hinge is zero, Then:

$$F.c = M_N - M_f \quad \text{or} \quad F = \frac{M_N - M_f}{c}$$

The actuating force is: $$F = \frac{M_N - M_f}{c}$$

Notice that the dimension a in the figure should be chosen such that **M_N is greater than M_f** to avoid self locking or self energizing action.

The torque applied to the drum by the brake shoe is the sum of the Frictional forces f dN times the radius of the drum:

$$T = \int frdN = \frac{fp_{\max} br^2}{\sin\theta_{\max}} \int_{\theta_1}^{\theta_2} \sin\theta \, d\theta$$

$$\therefore T = \frac{fp_{\max} br^2 (\cos\theta_1 - \cos\theta_2)}{\sin\theta_{\max}}$$

The hinge-pin reactions are found by taking the summation of the horizontal and vertical forces:

$$R_x = \int dN \cos\theta - \int f dN \sin\theta - F_x$$

$$R_x = \frac{p_{\max} br}{\sin\theta_{\max}} \left(\int_{\theta_1}^{\theta_2} \sin\theta \cos\theta \, d\theta - f \int_{\theta_1}^{\theta_2} \sin^2\theta \, d\theta \right) - F_x$$

$$R_y = \int dN \sin\theta + \int f dN \cos\theta - F_y$$

$$R_y = \frac{p_{\max} br}{\sin\theta_{\max}} \left(f \int_{\theta_1}^{\theta_2} \sin\theta \cos\theta \, d\theta + \int_{\theta_1}^{\theta_2} \sin^2\theta \, d\theta \right) - F_y$$

The direction of the frictional forces is reversed if the rotation Is reversed and

$$F = \frac{M_N + M_f}{c}$$

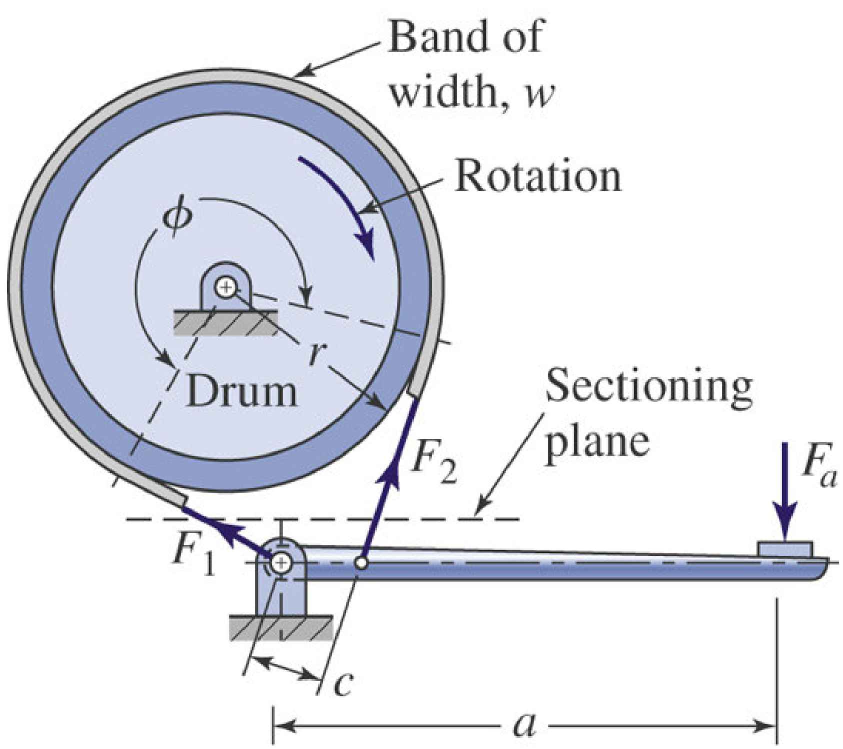
Also, for counterclockwise rotation the signs of the frictional terms in the equations of the pivot reactions change

Note:

$$\int_{\theta_1}^{\theta_2} \sin\theta \cos\theta \, d\theta = \left(\frac{1}{2}\sin^2\theta\right)_{\theta_1}^{\theta_2}$$

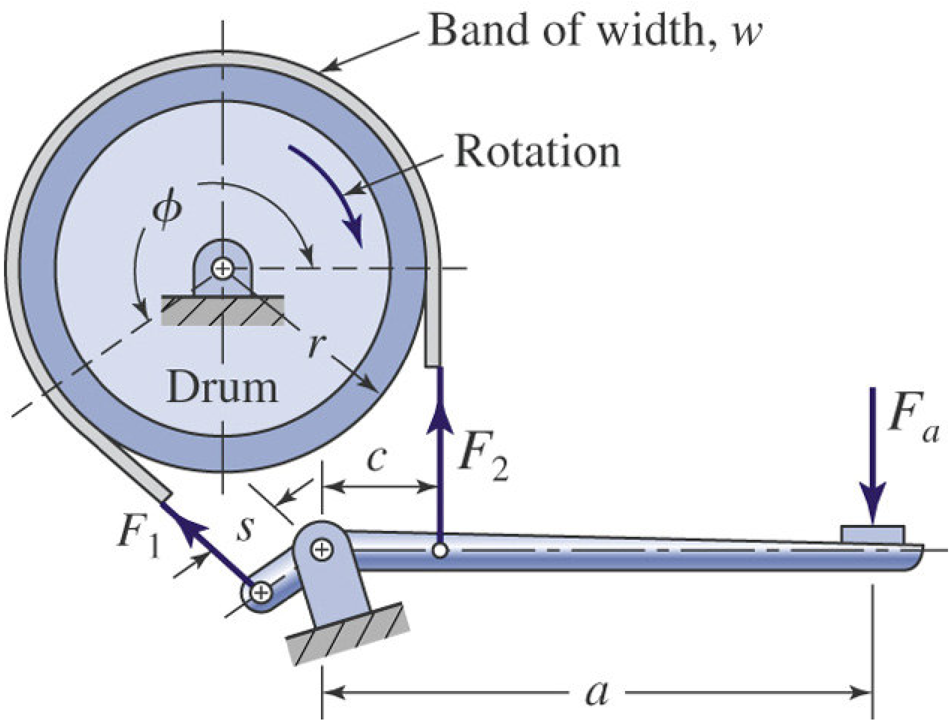
$$\int_{\theta_1}^{\theta_2} \sin^2\theta \, d\theta = \left(\frac{\theta}{2} - \frac{1}{4}\sin 2\theta\right)_{\theta_1}^{\theta_2}$$

Simple Band Brake



Very similar to a belt drive; torque capacity is $T = (F_1 - F_2)r$

Differential Band Brake

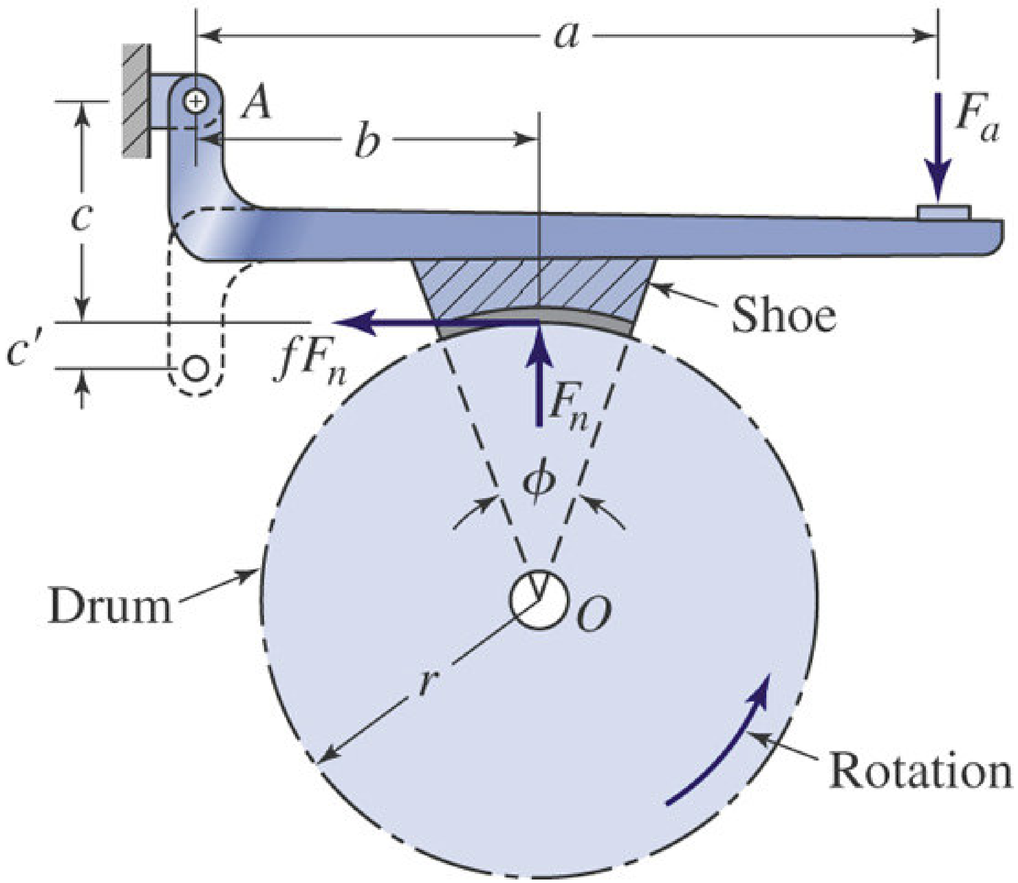


The friction force helps to apply the band: therefore it is "self-energizing."

Can become self-locking:

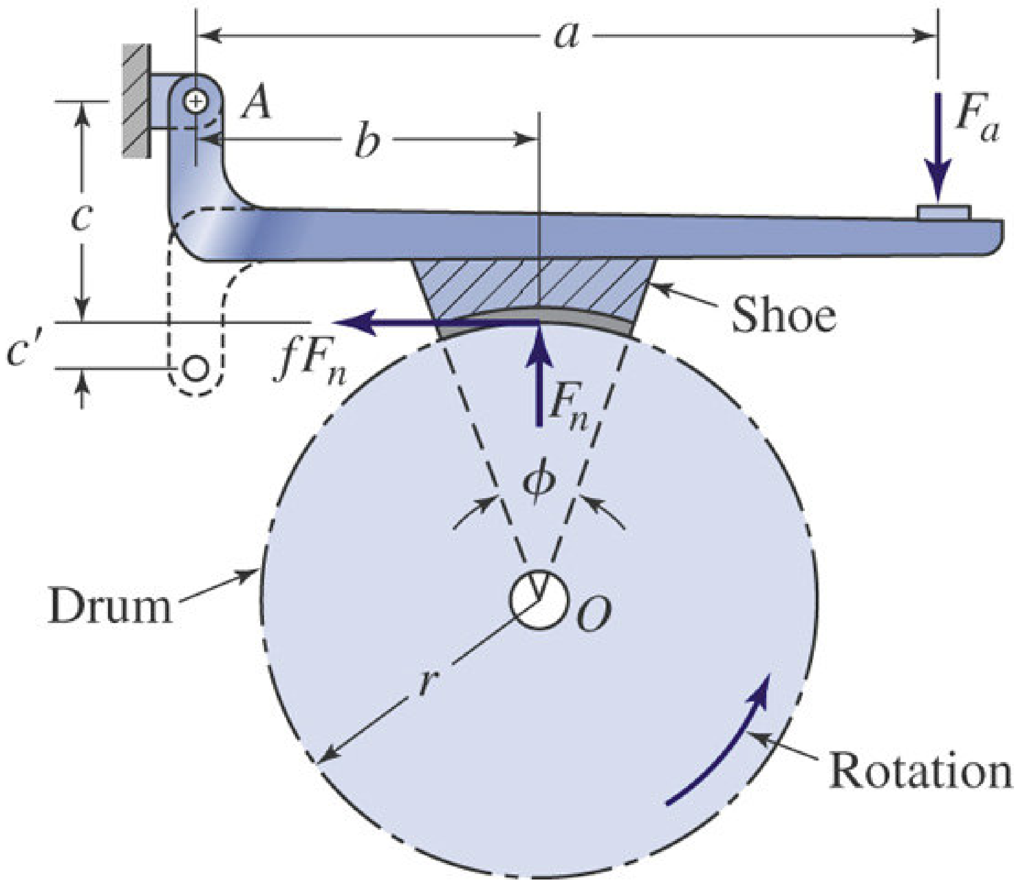
$F_a = (1/a)(cF_2 - sF_1)$

Short-Shoe Drum Brakes



If the shoe is short (less than 45^o contact angle), a uniform pressure distribution may be assumed which simplifies the analysis in comparison to long-shoe brakes.

Self-Energizing & Self-Locking Brakes

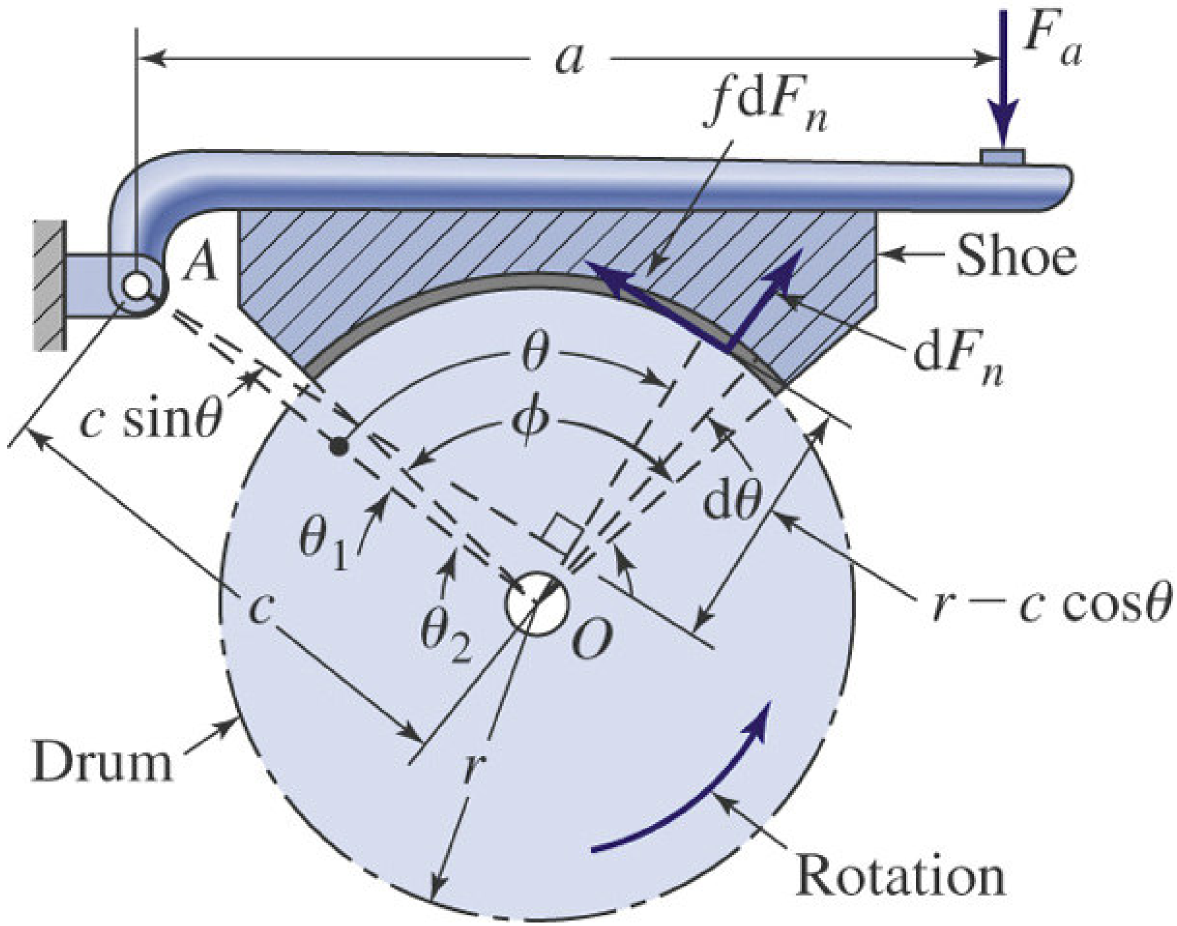


If the rotation is as shown, then

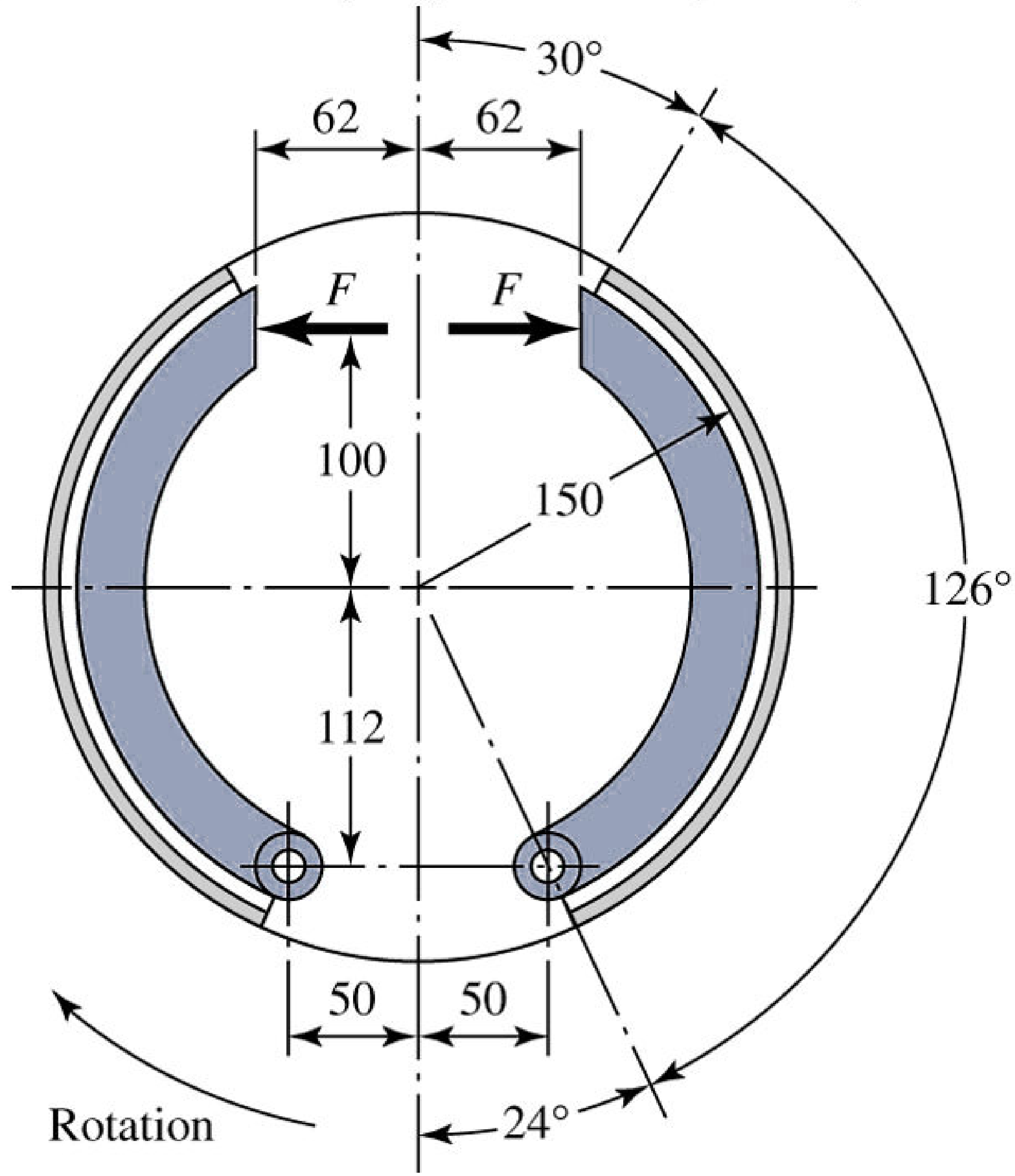
$F_a = (F_n/a)(b - fc)$.

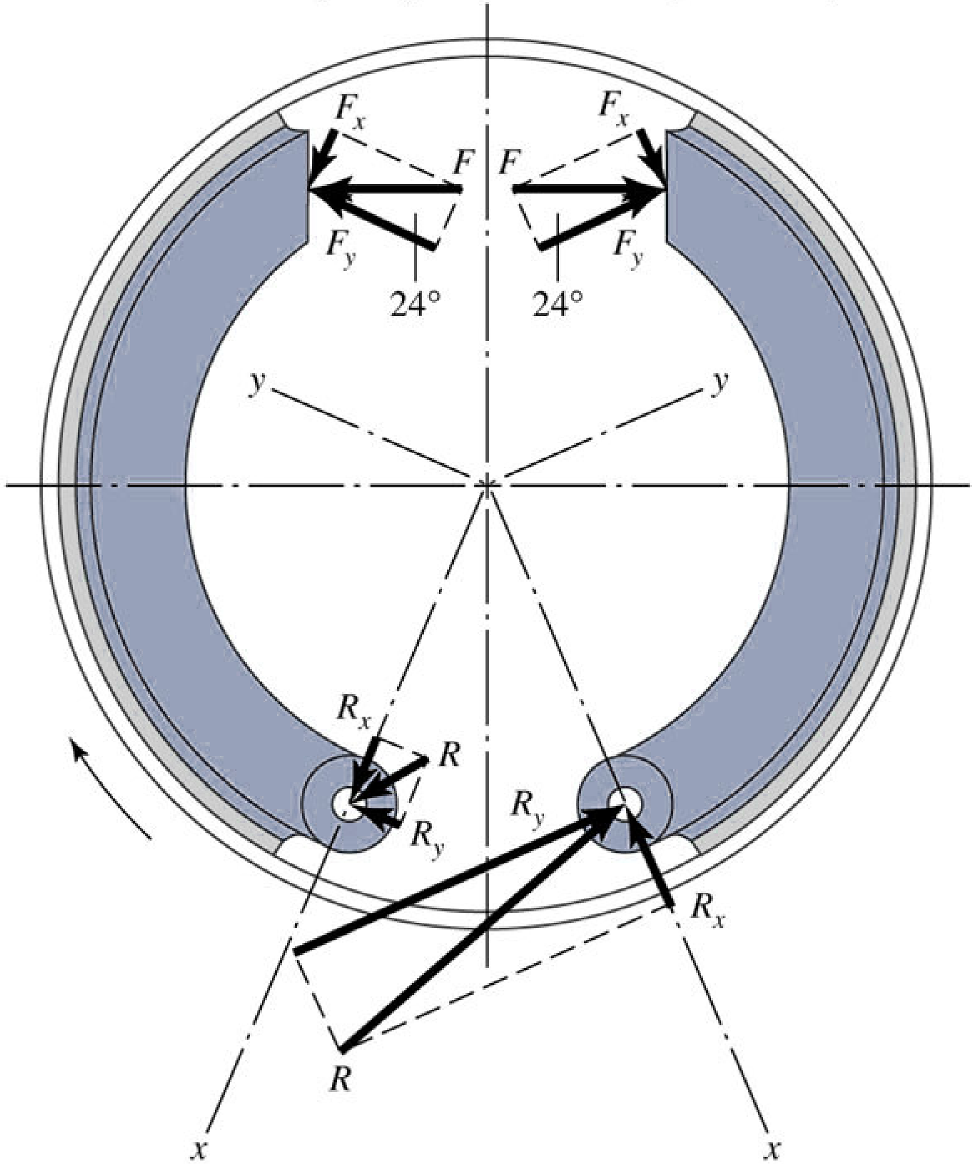
If b <= fc, then the brake is self-locking.

Long-Shoe Drum Brakes



Cannot assume uniform pressure distribution, so the analysis is more involved.


30°
62
62
F
F
100
150
126°
112
50
50
Rotation
24°



F_x
F
F_y
24°
F_x
F
F_y
24°
y
y
R_x
R
R_y
R_y
R_x
R
x
x