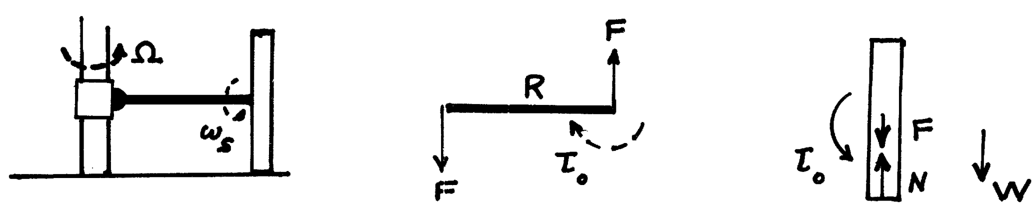
7.4



The axle exerts a torque τ_o on the millstone and a vertical downward force F. The millstone exerts opposite force and torque on the axle. The coupling at the vertical column must also exert a downward force F on the axle.

The axle is in vertical equilibrium, and for rotational equilibrium $RF = \tau_o = \mathcal{L}_o \Omega$

The equations of motion for the millstone are

$N = F + W$

$\tau_o = \mathcal{L}_o \Omega = \frac{1}{2} M b^2 \omega_s \Omega$

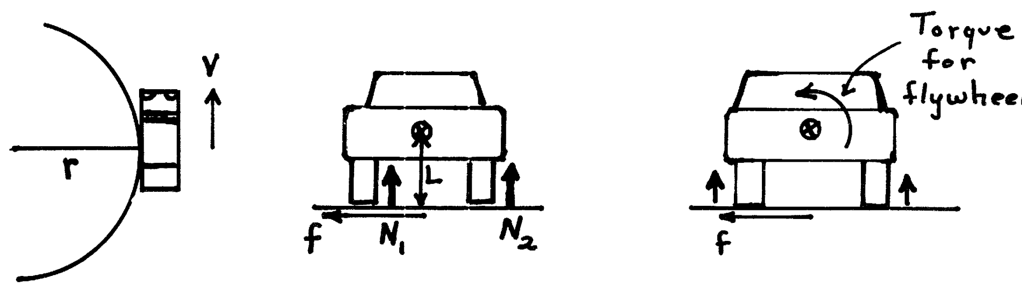
Solving, $F = \tau_o / R = \frac{1}{2} \dfrac{M b^2 \omega_s \Omega}{R}$

For contact at the rim, $\omega_s b = \Omega R$

Then $F = \dfrac{\frac{1}{2} M b^2 \omega_s \Omega}{R} = \frac{1}{2} M b \Omega^2 \longrightarrow N = Mg + F = M\left(g + \frac{1}{2} b \Omega^2\right)$

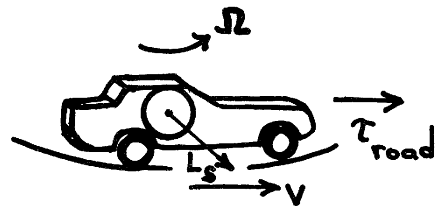
7.5

(a)

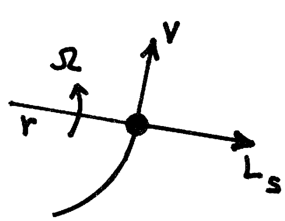


In the absence of the flywheel, the counterclockwise torque due to the normal forces at the wheels must oppose the clockwise torque due to the radial (transverse) friction force, $f = Mv^2/r$. With the flywheel, the normal forces exert no torque; so the flywheel must exert a clockwise torque $= Lf$, where L is the distance from the road to the center of mass. The counterclockwise torque Lf must be just sufficient to make the flywheel precess at the rate the car is turning.

If the flywheel is mounted with its angular momentum sideways, as shown, the torque it exerts on the car will tend to balance the torque due to the road. If the car turns to the right instead of the left, as illustrated, the torques due to the road and due to the flywheel will both change direction.



(b)



The torque due to the road is $\tau = Lf = Mv^2RL$

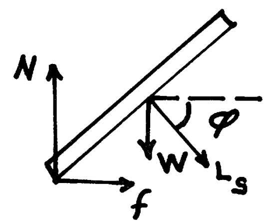
We require

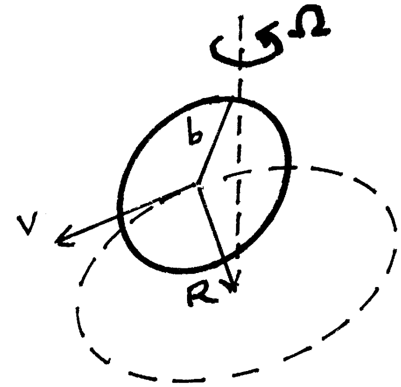
$\tau = L_s \Omega$ Using $\Omega = V/R$,

$$Mv^2 rL = L_s\Omega = \tfrac{1}{2} mR^2\omega \frac{v}{r}$$

$$\text{OR} \quad \omega = 2vML/mR^2$$

7.6





Coin is accelerating, so we must use CM as origin for torque equation.

N = normal force $= Mg$

f = friction force $= Mv^2/R$

L_s = spin angular momentum $= I\omega = \frac{1}{2}Mb^2\frac{v}{b} = \frac{1}{2}Mbv$

Ω = angular speed with which coin rotates about the vertical axis $= v/R$

$\Omega L_s \cos\phi$ = rate of change of angular momentum (in horizontal plane)

Torque equation

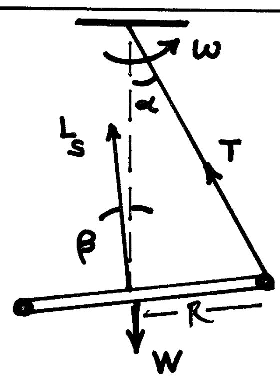
$$Nb\sin\phi - fb\cos\phi = \Omega L_s\cos\phi$$

$$Mgb\sin\phi - \frac{Mv^2}{R}b\cos\phi = \frac{v}{R}\frac{1}{2}Mbv\cos\phi$$

Hence $\tan\phi = \dfrac{3v^2}{2gR}$

7.7

(a)



$$\Delta\vartheta = \omega\Delta t$$

$$\Delta L_s = (I\omega\sin\beta)\Delta\vartheta$$

$$= (I\omega\sin\beta)\omega\Delta t$$