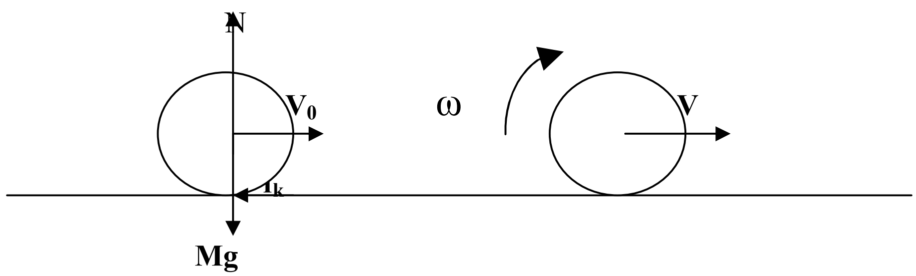
# Bowling Ball Rolling

A uniform bowling ball of radius R and mass M is initially launched so that it is sliding with speed V0 without rolling on an alley with a coefficient of friction $\mu$. How far does the ball go before it starts rolling without slipping, and what is then its speed?

## Sukumar Chandra's Solution *(using kinematics)*




When the ball is slipping, the forces acting on it are:

1) Weight Mg, acting vertically downward through the centre,
2) Normal reaction N, vertically upward through the point of contact
3) Forces of kinetic friction, $f_k = \mu N$, horizontally through the point of contact and opposite to the direction of motion.

The only horizontal force $f_k$, produces horizontal acceleration, a = force/mass = $\mu N/M = \mu g$ [as N = Mg]. This acceleration is directed opposite to the direction of motion of the ball and hence its velocity V at any instant t is given by:

$$V = V_0 - \mu gt. \qquad (1)$$

Further, the only force that produces a torque about the centre is $f_k$. This torque is of magnitude $f_kR$, acting in anticlockwise direction producing an anticlockwise angular acceleration, $\alpha$, of the ball about its center given as $f_kR = I_{cm}\,\alpha$, or $\mu MgR = (2/5)MR^2\,\alpha$, or $\alpha = 5\,\mu g/2R$. This angular acceleration sets the ball rotating with increasing angular velocity in anticlockwise direction whose magnitude $\omega$, at any instant t, is given by

$$\omega = \alpha t. \qquad (2)$$

When the ball starts pure rolling,

$$V = \omega R \qquad (3)$$

is satisfied. Hence using equations (1) , (2) and (3) we get, $V_0 - \mu gt = \alpha tR = 5\,\mu gt/2$, or $\mu gt = 2V_0/7$. Putting this value back in equation (1), we get $V = 5V_0/7$.

Again, using the equation of kinematics, $v^2 = u^2 + 2aD$, we get $(5V_0/7)^2 = V_0^2 - 2\mu gD$ or, $D = 12V_0^2/49\mu g$.