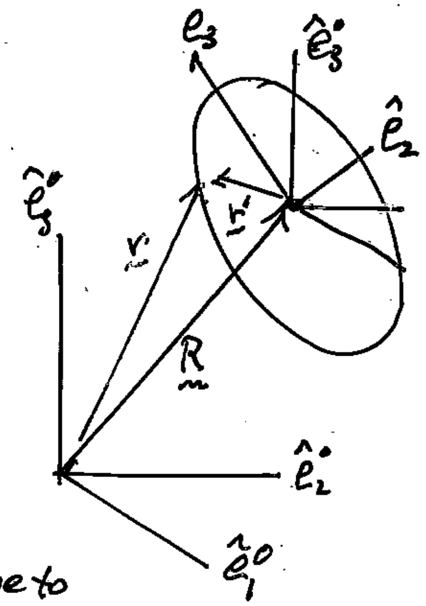
Rigid body $\underset{\sim}{r} = \underset{\sim}{R} + \underset{\sim}{r}'$

No fixed point.



$$\left(\frac{d\underset{\sim}{r}}{dt}\right)_{in} = \dot{R} + \left(\frac{d\underset{\sim}{r}'}{dt}\right)_{in}$$

$$\left(\frac{d\underset{\sim}{r}'}{dt}\right)_{cm} = \sum_1^3 \hat{e}_i^o \frac{d}{dt}(\hat{e}_i^o \cdot \underset{\sim}{r}')$$

Coordinates relative to $\hat{e}_i^o$ - fixed axes

But $\left(\frac{d\underset{\sim}{r}'}{dt}\right)_{cm} = \left(\frac{d\underset{\sim}{r}'}{dt}\right)_{body} + \underset{\sim}{\omega} \times \underset{\sim}{r}'$

$\underset{\sim}{\omega}$ = instantaneous angular velocity

$$\left(\frac{d\underset{\sim}{r}}{dt}\right)_{inertial} = \dot{\underset{\sim}{R}} + \underbrace{\left(\frac{d\underset{\sim}{r}'}{dt}\right)_{body} + (\underset{\sim}{\omega} \times \underset{\sim}{r}')}$$

motion of the centre of mass

rotation around the C.M.

Kinetic Energy $T = \frac{1}{2} M \dot{\underset{\sim}{R}}^2 + T'$

Angular Momentum $\underset{\sim}{L} = (\underset{\sim}{R} \times M\dot{\underset{\sim}{R}}) + \underset{\sim}{L}'$

$$M\ddot{\underset{\sim}{R}} = \underset{\sim}{F}^{(e)} = \sum_p m_p \underset{\sim}{F}_p^{(e)}$$

$$\underset{\sim}{L}' = \sum_p m_p \left(\underset{\sim}{r}_p' \times \left(\frac{d\underset{\sim}{r}_p'}{dt}\right)_{in}\right) = \sum_p m_p \left(\underset{\sim}{r}_p' \times \left(\frac{d\underset{\sim}{r}_p'}{dt}\right)_{cm}\right)$$

$$\left(\frac{d}{dt}\underset{\sim}{L}'\right)_{in} = \left(\frac{d}{dt}\underset{\sim}{L}'\right)_{cm} = \sum_p \left(\underset{\sim}{r}_p' \times \underset{\sim}{\Gamma}_p^{(e)}\right) = \underset{\sim}{\Gamma}^{(e)}$$

torque acting around C.M.