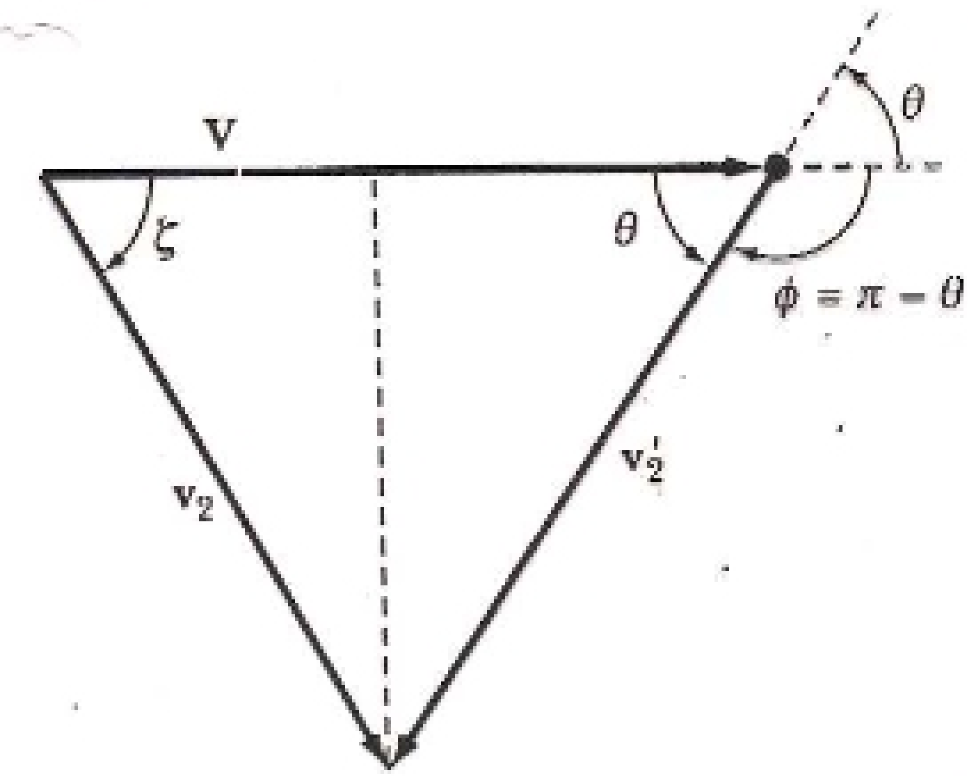

FIGURE 9-12 The final state of recoil mass m_2 in the elastic collision of two particles.

$$\begin{cases} v_2 \sin\zeta = v_2' \sin\theta \\ v_2 \cos\zeta = V - v_2' \cos\theta \end{cases}$$ From figure

$$\Rightarrow \tan\zeta = \frac{\sin\theta}{V/v_2' - \cos\theta}$$

$$v_2' = V \quad \text{so} \quad \tan\zeta = \frac{\sin\theta}{1-\cos\theta} = \cot\frac{\theta}{2}$$

$$\Rightarrow \boxed{2\zeta = \pi - \theta = \phi}$$

$m_1 = m_2 \Rightarrow \theta = 2\psi \Rightarrow \zeta + \psi = \frac{\pi}{2}$

Rocket Science

propellant dm_p

Before $\quad P = (m + dm_p)\, v$

After $\quad P = m(v+dv) + dm_p(v-u)$

Conservation of $P \Rightarrow$

$$m\,dv = u\,dm_p$$

Rocket $dm = -dm_p$

$$\int_{v_0}^{v_1} dv = -u \int_{m_0}^{m_1} \frac{dm}{m}$$

$$v_1 = v_0 + u \ln\left(\frac{m_0}{m_1}\right)$$

In Earth's gravitation field:
(Ascent)

$$v_1 = v_0 + u \ln\left(\frac{m_0}{m_1}\right) - gt$$

$t = \dfrac{m_0 - m_1}{\alpha}$ where $\dfrac{dm}{dt} = -\alpha$ is rate of fuel burning

[Burn fast]

Use large emission speed u

Chemical rockets $\quad T \sim 10\,eV \quad u \sim 10^7\,cm/s$

Nuclear rockets $\quad T \sim MeV \quad u \sim 3 \times 10^9\,cm/s$

Ion drive (accelerators) $\quad \Delta p \sim \Delta m \dfrac{u}{\sqrt{1 - u^2/c^2}}$

Photon rockets $\quad u = c \quad$ (Most efficient use of stored restmass)

Matter/Antimatter fuel ?

Notes for problem 5

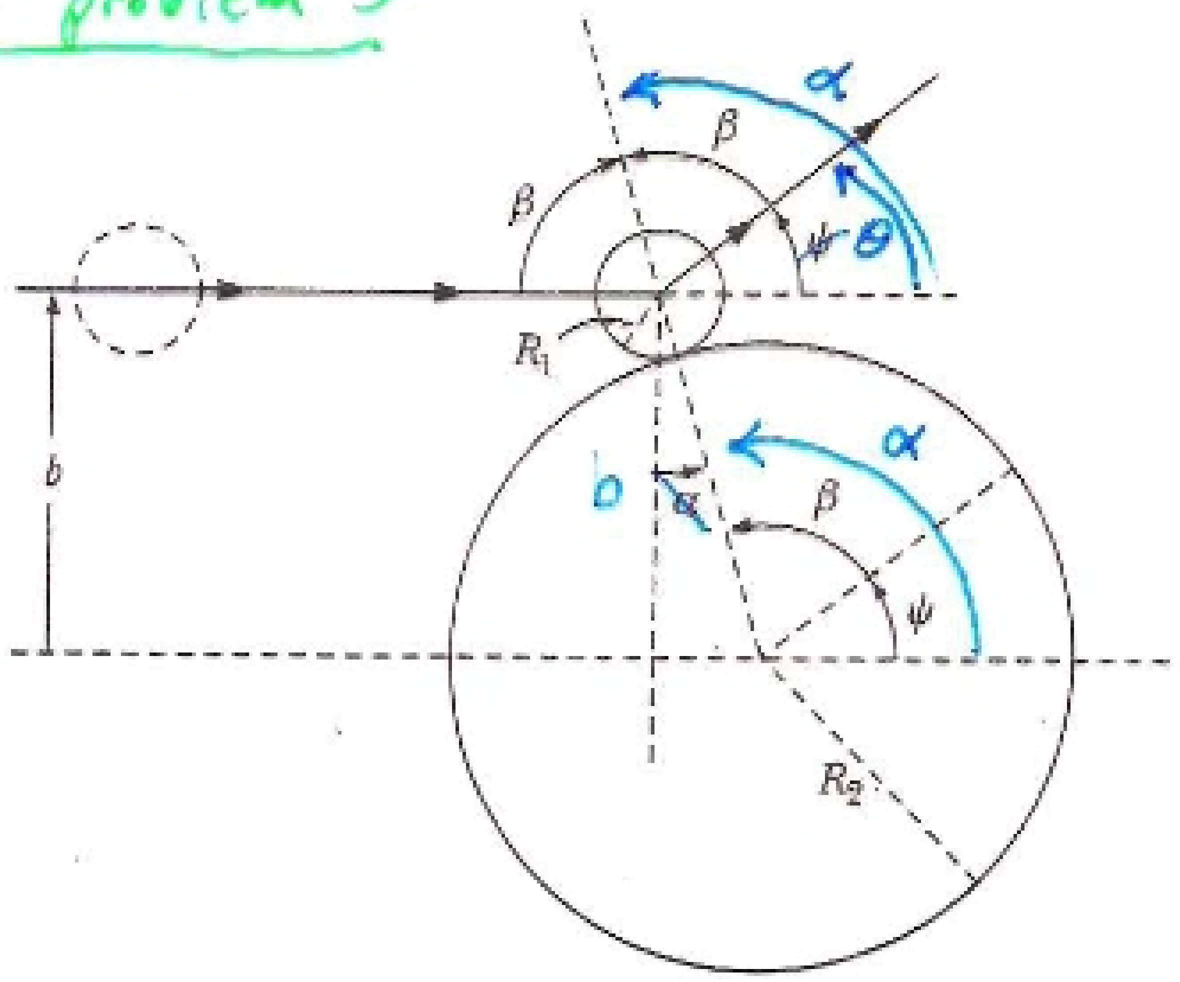

FIGURE 9-23 A molecule of radius R_1 approaches a dust particle of radius R_2 from the left and scatters at angle ψ.

$$\beta = \pi - \alpha$$

$$\theta = \pi - 2\beta = \pi - 2(\pi - \alpha) = 2\alpha - \pi$$