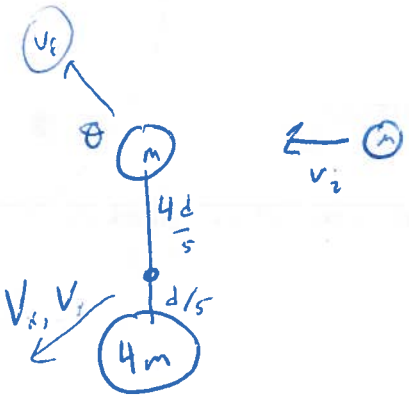


a) A.M. about c of m of barbell (its initial position)

$$m v_i \frac{4d}{5} = m v_f \frac{4d}{5}\cos\theta + m\left(\frac{2\pi}{5T}\frac{4d}{5}\right)\frac{4d}{5} + 4m\left(\frac{2\pi d}{5T}\right)\frac{d}{5}$$

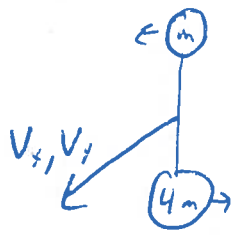
Cancel $\frac{md}{5}$ everywhere

$$4v_i = 4v_f\cos\theta + \frac{2\pi}{T}\frac{16d}{5} + \frac{2\pi}{T}\frac{4d}{5}$$

$$v_i - v_f\cos\theta = \frac{2\pi d}{T}$$

$$T = \frac{2\pi d}{v_i - v_f\cos\theta} \qquad (1)$$

b) K.E. immediately after the collision:



for m: $v_x = V_x + \frac{2\pi}{5T}\frac{4d}{} \qquad v_y = V_y$

for 4m: $v_x = V_x - \frac{2\pi d}{5T} \qquad v_y = V_y$

so $KE = \frac{1}{2}m\left[\left(V_x + \frac{2\pi}{5T}\frac{4d}{}\right)^2 + V_y^2\right] + \frac{1}{2}(4m)\left[\left(V_x - \frac{2\pi d}{5T}\right)^2 + V_y^2\right]$

$$KE = \frac{1}{2}m\left[V_x^2 + V_y^2 + \frac{4\pi d}{5T}V_x + 16\left(\frac{2\pi d}{5T}\right)^2\right] + \frac{1}{2}(4m)\left[V_x^2 + V_y^2 - \frac{4\pi d}{5T}V_x + \left(\frac{2\pi d}{5T}\right)^2\right]$$

$$KE = \frac{1}{2}(5m)\left(V_x^2 + V_y^2\right) + \frac{2}{5}\left(\frac{2\pi d}{T}\right)^2 m$$

c) Cons E:

$$\frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}(5m)\left(V_x^2 + V_y^2\right) + \frac{2}{5}\left(\frac{2\pi d}{T}\right)^2 \quad (2)$$

Cons p_x: $mv_i = mv_f\cos\theta + 5mV_x \rightarrow v_i - v_f\cos\theta = 5V_x$ (3)

cons p_y: $mv_f\sin\theta = 5mV_y \rightarrow V_y = \frac{v_f\sin\theta}{5}$ (4)

Plug (1), (3) and (4) into (2) to eliminate $\frac{2\pi d}{T}$, V_x, V_y

$$\frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}(5m)\left[\left(\frac{v_i - v_f\cos\theta}{5}\right)^2 + \left(\frac{v_f\sin\theta}{5}\right)^2\right] + \frac{2}{5}\left(v_i - v_f\cos\theta\right)^2 m$$

$$5v_i^2 = 5v_f^2 + \left[v_i^2 - 2v_iv_f\cos\theta + v_f^2\cos^2\theta + v_f^2\sin^2\theta\right] + 4\left(v_i^2 - 2v_iv_f\cos\theta + v_f^2\cos^2\theta\right)$$

$$0 = 6v_f^2 - 10v_iv_f\cos\theta + 4v_f^2\cos^2\theta$$

$$v_f\left(3 + 2\cos^2\theta\right) = 5v_i\cos\theta$$

$$v_f = \frac{5v_i\cos\theta}{3 + 2\cos^2\theta}.$$