

We are given that the object  $m_1$  collides with the rod with velocity  $v_0$ , and the rod is floating in free space. Given  $m_1$ ,  $v_0$ ,  $m_2$ ,  $I_0$ , and  $r$ , we are to figure out the final velocity of  $m_1$  after collision  $v_f$ , the velocity of  $m_2$  after collision  $v_{CM}$ , and of course the rotation of the rod after collision  $\omega$ .

We are assuming that this collision elastic.

We have, then, for conservation of linear momentum:

$$m_1 v_0 = m_1 v_f + m_2 v_{CM} \quad (1)$$

Furthermore, we understand that kinetic energy is also conserved here; therefore:

$$\frac{1}{2} m_1 v_0^2 = \left( \frac{1}{2} m_1 v_f^2 \right) + \left( \frac{1}{2} m_2 v_{CM}^2 \right) + \left( \frac{1}{2} I_0 \omega^2 \right) \quad (2)$$

$$\Rightarrow m_1 v_0^2 = (m_1 v_f^2) + (m_2 v_{CM}^2) + (I_0 \omega^2) \quad (3)$$

as the point mass does not have any rotational inertia, and the rod is not rotating at the start.

Lastly, we understand that the angular momentum is also conserved; setting the origin at the centre of mass:

$$v_0(m_1 r^2) = v_f(m_1 r^2) + v_{CM} I_0 \quad (4)$$

Actually setting up to solve the expressions, then:

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var("I m1 v0 m2 r")
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var("vf vcm w")
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solve([m1*v0 == m1*vf+m2*vcm, m1*v0^2==m1*vf^2+m2*vcm^2+I*w^2, v0*m1*r^2 == vf*m1*r^2+vcm*I], vf, vcm, w)
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