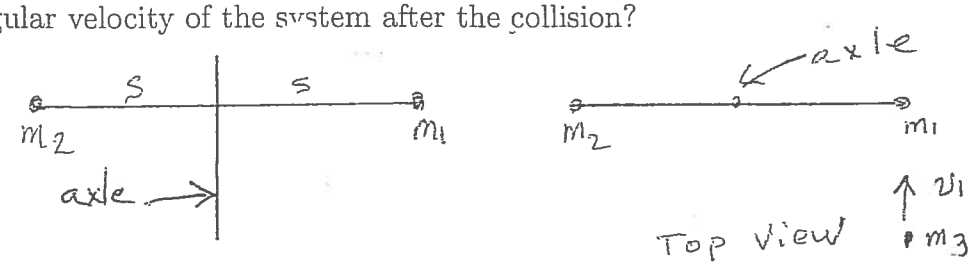
1. (25 points)Derive the expressions for the $\vec{i_r}$ and $\vec{i_\theta}$ components of the velocity and acceleration.

2. (25 points)Two blocks, mass m_1 and m_2, are connected by a massless, rigid rod. The rod is connected to a vertical axle which is free to rotate. Each mass is a distance S from the axle. The system is initially at rest. A small block of mass m_3 strikes one of the blocks and sticks to it. It was travelling horizontally with velocity of magnitude v_1 in the direction shown, perpendicular to the rod. (Ignore gravity.) What will be the angular velocity of the system after the collision?



Free Body Diagrams (If appropriate). Law or Definition

Application

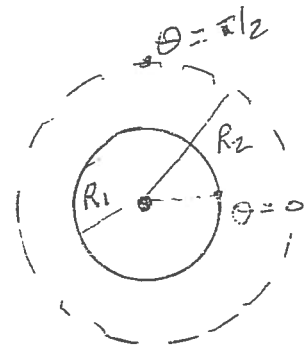
Result

3. (25 points)A small satellite, mass m_s, travels in a circle of radius R_1 about the earth, which is assumed to be fixed. The force exerted by the earth on the satellite is the usual force of gravity which is attractive and has magnitude

$$|\vec{F}| = G\frac{m_e m_s}{r^2}$$

where G is a constant, m_e is the mass of the earth, m_s is the mass of the satellite and r is the distance between the earth and the satellite. How much work would this force do if the satellite were somehow moved from the point $r = R_1$, $\theta = 0$ to the point $r = R_2$, $\theta = \frac{\pi}{2}$ on another circular orbit of radius R_2? Also find the potential energy function for the force of gravity.

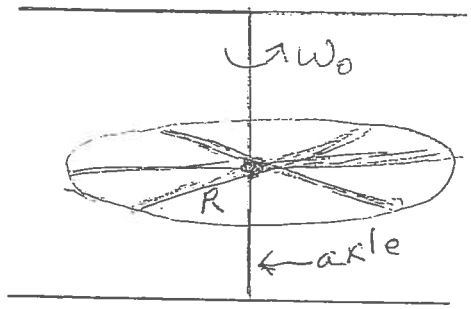
Free Body Diagrams (If appropriate). Law or Definition



Application

Result

4. (25 points)A wagon wheel has mass M, radius R and moment of inertia about its center I. It is free to rotate about a vertical axle. It is set into rotation with an *initial* angular velocity ω_0 at the time $t = 0$. A small, self-propelled object with mass m_s starts at the axle and moves toward the rim along a spoke so that the distance from the axle is $c_1 t$. Find the torque, about the axle, exerted by the object on the wheel.



Free Body Diagrams (If appropriate). Law or Definition

Application

Result