8-1 Two objects have masses of M and 3M, respectively. If both have the same kinetic energy, which one has the larger linear momentum and by what factor? Why?

8-2 If the objects of problems 8-1 have the same linear momentum (magnitude), which will have the larger kinetic energy and by what factor? Why?

8-3 In order to conserve the total vector momentum of a many particle system, why is it necessary to have the external force equal to zero?
In all problems 8-4 through 8-15 assume that $F_{ext} = 0$.

8-4 What is the difference between a totally elastic and a totally inelastic two body collision?

8-5 Show that in a totally elastic head on collision the relative velocity reverses during the collision, that is, relatively velocity after is negative of the relative velocity before the collision.

8-6 You drop a ball of mass 1kg from a height of 2m. The collision with Earth lasts for about $10^{-4}$ seconds and on bouncing the ball rises to a height of 1.5m. Is this collision totally elastic? Justify your answer.
When two objects of mass \( M_1 \) and \( M_2 \) with velocities \( \vec{V}_1 \) and \( \vec{V}_2 \) have a totally elastic head-on collision, the velocities after collision are given by:

\[
\vec{V}_1' = \frac{M_1 - M_2}{M_1 + M_2} \vec{V}_1 + \frac{2M_2}{M_1 + M_2} \vec{V}_2
\]

\[
\vec{V}_2' = \frac{M_2 - M_1}{M_1 + M_2} \vec{V}_2 + \frac{2M_1}{M_1 + M_2} \vec{V}_1
\]

Use these formulae to calculate \( \vec{V}_1' \) and \( \vec{V}_2' \) for the following cases.

i) \( M_1 = M_2, \; \vec{V}_1 = 5 \text{m/s } \hat{x}, \; \vec{V}_2 = 0 \)

ii) \( M_1 << M_2 \) (collision with a wall), \( \vec{V}_1 = 10 \text{m/s } \hat{x}, \; \vec{V}_2 = 0 \)

iii) \( M_1 >> M_2 \) (small object at rest, large object hits it), \( \vec{V}_1 = 10 \text{m/s } \hat{x}, \; \vec{V}_2 = 0 \)

iv) \( M_1 = 10 \text{kg} \quad M_2 = 5 \text{kg} \)
\[
\vec{V}_1 = 2 \text{m/s } \hat{x} \quad \vec{V}_2 = -4 \text{m/s } \hat{x}
\]
8-8 An object of mass $M$ is sitting at rest when it is hit by another object of mass $M$ traveling at $V_1$. The collision is glancing and totally elastic. What is the relationship between their velocity $V_1'$ and $V_2'$ after the collision?

8-9 An object of mass 5kg traveling at $4\text{m/s} \hat{x}$ collides with an object of mass 4kg traveling at $-5\text{m/s} \hat{y}$. After the collision they stick together. What is the magnitude and direction of the velocity after the collision?

8-10 If in Problem 8-7 (iv) the collision was totally inelastic, what would be the velocity after the collision?
8-11 The Earth has a mass which is 81 times the mass of the moon. The Earth-moon distance is $4 \times 10^5$ km. Locate the center of mass of the Earth-moon system.

8-12 The puck $M_1 = 2$ kg has a velocity of $3 \text{m/s} \hat{x}$ when it collides with a puck, $M_2 = 5$ kg which has a velocity of $-6 \text{m/s} \hat{y}$. What are their velocities after the collision?

8-13 A 2 kg block is lying on a smooth horizontal table. A bullet of mass 0.01 kg travelling of $100 \text{m/s} \hat{x}$ is fired into it and gets embedded. If the table is 2 m high, where will the combination land on the ground?
8-14 A person of mass 50kg is standing at the end of a plank of mass 100kg and length 5m, and the plank rests on a horizontal smooth, icy surface. If the person walks from one end to the other, by how much will the plank move? Why?

8-15 (Ballistic Pendulum) Now the mass is hanging from a 1m long string when the bullet is fired. How high will the combination rise before falling back?