Collision Theory
Challenge Problems

Problem 1 Estimate the energy loss in a completely inelastic collision between two identical cars that collide head-on traveling at highway speeds.

Problem 2 You just witnessed a karate master breaking a brick with his hand. Estimate the impulse necessary to break the brick. Estimate an upper limit on the force per area that the hand can safely endure without breaking the hand.

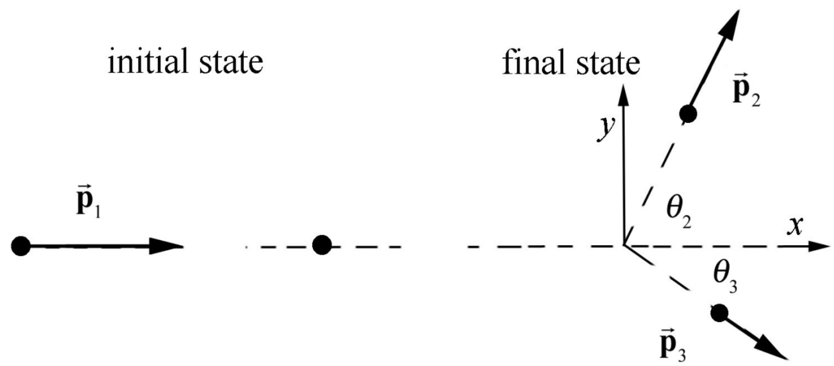
Problem 3 Suppose a golf ball is hurled at a heavy bowling ball initially at rest and bounces elastically from the bowling ball. After the collision, which ball has the greater momentum? Which has the greater kinetic energy?

Problem 4 One Dimensional Collision

A proton makes a head-on collision with an unknown particle at rest. The proton rebounds straight back with $4/9$ of its initial kinetic energy. Find the ratio of the mass of the unknown particle to the mass of the proton, assuming that the collision is elastic.

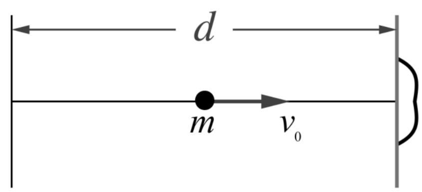
Problem 5 Two-Dimensional Collision

An object with momentum $\vec{\mathbf{p}}_1$ collides with a stationary particle. After the collision, two particles emerge, one with momentum $\vec{\mathbf{p}}_2$ and the other with momentum $\vec{\mathbf{p}}_3$. The direction of the vector $\vec{\mathbf{p}}_2$ makes an angle θ_2 with respect to the direction of the vector $\vec{\mathbf{p}}_1$ and the direction of the vector $\vec{\mathbf{p}}_3$ makes an angle θ_3 with respect to the direction of the vector $\vec{\mathbf{p}}_1$. In terms of $p_1 = |\vec{\mathbf{p}}_1|$, θ_2 and θ_3, what are the magnitudes $p_2 = |\vec{\mathbf{p}}_2|$ and $p_3 = |\vec{\mathbf{p}}_3|$?

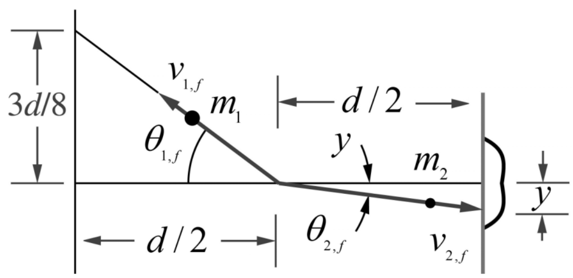


Problem 6 Exploding Hockey Puck

A hockey player shoots a “trick” hockey puck along the ice towards the center of the goal from a position d directly in front of the goal. The initial speed of the puck is v_0 and the puck has a mass m.



Half way to the goal the puck explodes into two fragments. One piece of mass $m_1 = (3/5)m$ comes back towards the player and passes $3d/8$ to the side of the spot it was initially shot from with a speed $v_{1,f} = (5/12)v_0$. The other piece of the puck with mass $m_2 = (2/5)m$ continues on towards the goal with a speed $v_{2,f}$.



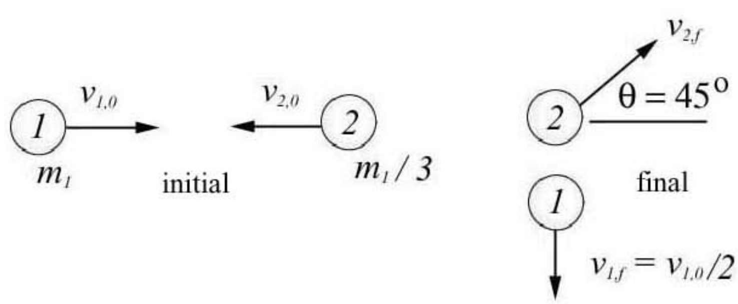
Assume that there is no friction as the puck slides along the ice and that the mass of explosive in the puck is negligible. The goal of this problem is to find the distance, y, that the piece that continues towards the goal misses the center of the goal? Express your answer in terms of d.

a) What concepts will you apply to this problem and briefly explain why.

b) By what distance, y, does the piece that continues towards the goal miss the center of the goal? Express your answer in terms of d.

Problem 7 ***Two- Dimensional Particle Collision***

Particle 1 of mass m_1 is initially moving in the positive x-direction (to the right in the figure) with a speed $v_{1,0}$ and collides with a second particle 2 of mass $m_2 = m_1 / 3$, which is initially moving in the opposite direction (to the left in the figure) with an unknown speed $v_{2,0}$. Assume that the total external force acting on the particles is zero. **You do not know whether or not the collision is elastic.** After the collision particle 1 moves with a speed $v_{1,f} = v_{1,0} / 2$, at an angle $\theta_{1,f} = 90^\circ$ with respect to the positive x-direction (downward in the figure). After the collision, particle 2 moves with an unknown speed $v_{2,f}$, at an angle $\theta_{2,f} = 45^\circ$ with respect to the positive x-direction (upward and to the right in the figure). In this problem you will find $v_{2,0}$ and $v_{2,f}$ in terms of $v_{1,0}$. You also will determine whether or not the collision is elastic. Note: $\sin 45^\circ = \cos 45^\circ = \sqrt{2} / 2$.



a) Find the speed $v_{2,0}$ in terms of $v_{1,0}$.

b) Find the speed $v_{2,f}$ in terms of $v_{1,0}$.

c) Is the mechanical energy conserved in this collision? Justify your answer.

Problem 8 Pendulums and Collisions

A simple pendulum consists of a bob of mass m_1 that is suspended from a pivot by a string of negligible mass. The bob is pulled out and released from a height h_0 as measured from the bob's lowest point directly under the pivot point and then swings downward in a circular orbit (Figure a). At the bottom of the swing, the bob collides with a block of mass m_2 that is initially at rest on a frictionless table. Assume that there is no friction at the pivot point.

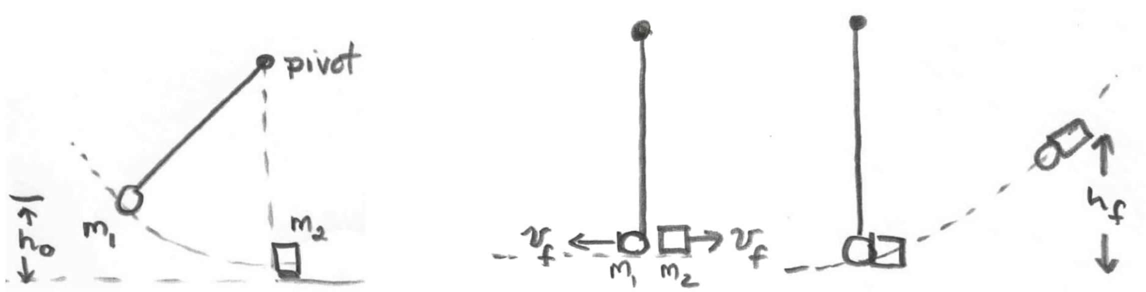
a) What is the speed of the bob immediately before the collision at the bottom of the swing?

b) Assume that the kinetic energy of the bob before the collision is equal to the kinetic energy of the bob and the block after the collision (the collision is elastic). Also assume that the bob and the block move in opposite directions but with the same speed after the collision (Figure b). What is the mass m_2 of the block?

c) Suppose the bob and block stick together after the collision due to some putty that is placed on the block. What is the speed of the combined system immediately after the collision? (Assume now that m_2 is the combined mass of the block and putty.)

d) What is the change in kinetic energy of the block and bob due to the collision in part c)? What is the ratio of the change in kinetic energy to the kinetic energy before the collision?

e) After the collision in part d), the bob and block move together in circular motion. What is the height h_f above the low point of the bob's swing when they both first come to rest after the collision (Figure c)? Ignore any air resistance.



(a) (b) (c)