Name _____

Section _____ Date _____

# Physics 211 PreLab #5: Collisions

## Collisions

Collisions are a constant part of your life, whether you're knocking the "eight-ball" into the corner pocket (nearly elastic collision), smashing a tennis ball with your racket (impulsive collision), or watching bugs smash into your windshield while driving down the interstate (completely inelastic collision). In this lab you will study these three types of collisions in greater detail.

In Investigation 1, you will investigate nearly "elastic" collisions between two carts. In an elastic collision, both total momentum and total kinetic energy are conserved. In the case of two objects of masses $m_1$ and $m_2$ moving in one-dimension with velocities $v_{1i}$ and $v_{2i}$ before the collision, and with velocities $v_{1f}$ and $v_{2f}$ after the collision, the conservation of momentum and kinetic energy can be written,

$$m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f} \qquad \text{(Eq. 1)}$$

and

$$^1/_2\, m_1v^2_{1i} + {}^1/_2\, m_2v^2_{2i} = {}^1/_2\, m_1v^2_{1f} + {}^1/_2\, m_2v^2_{2f} \qquad \text{(Eq. 2)}$$

Equations 1 and 2 can be combined to show that,

$$v_{1i} - v_{2i} = -(v_{1f} - v_{2f})$$
(Eq. 3)

which tells us that the relative speed of two particles is the same before and after an elastic collision, although the direction reverses.

In investigation 1, you will study the nearly elastic collision between two carts when one of the carts is initially at rest (see Figure 1).

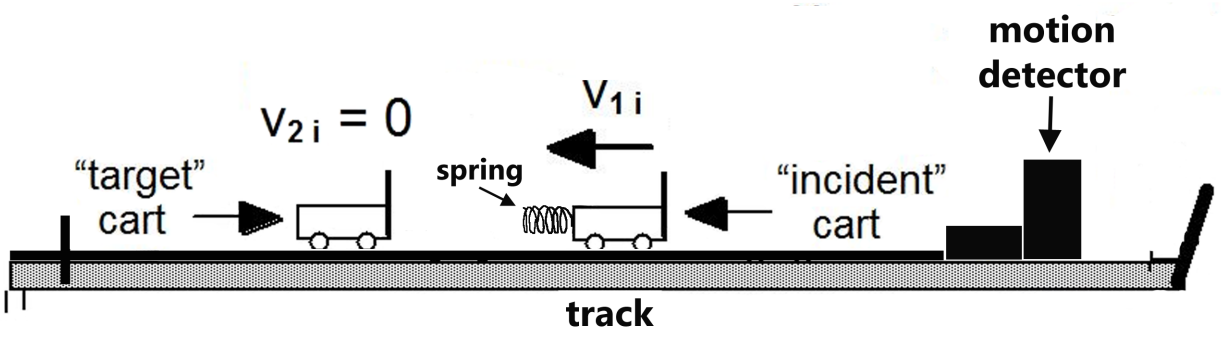



**Figure 1.** Experimental setup for Investigation 1

Answer the following question concerning Investigation 1.

**Q1** - Assume that you push an "incident" cart of mass $m_1$ with an initial velocity $v_{1i}$ so that it collides *completely elastically* with a stationary ($v_{2i}$=0) "target" cart having a mass $m_2$ (see Figure 1). What is the ratio of the final and initial "incident" cart velocities, $v_{1f}/v_{1i}$, in terms of the cart masses $m_1$ and $m_2$?

**Q2** - Object #1 of mass 2 kg makes a perfectly elastic collision with object #2, which is initially at rest. Object #1 then continues to move in its original direction with one-fourth of its original speed. What is the mass of object #2?

In Investigation 2 you will study impulsive collisions. Recall that in an impulsive collision, the impulse associated with the collision, $\mathbf{I} = \int \mathbf{F} dt$ (the integrated area under the force vs. time curve), is equal to the change in momentum $\Delta\mathbf{p}$ that occurs during the collision,

$$\mathbf{I} = \int_{t_1}^{t_2} \mathbf{F}(t)dt = \Delta\mathbf{p} \qquad \text{(Eq. 4)}$$

Recall also that $\Delta\mathbf{p} = \mathbf{F}_{avg}\Delta t$, where $\mathbf{F}_{avg}$ is the average impulsive force and $\Delta t = t_2 - t_1$ is the time duration of the collision. In this investigation, you will verify Eq. 4 by measuring the impulsive force exerted on a cart that is "leashed" to a force probe (see Figure 2).

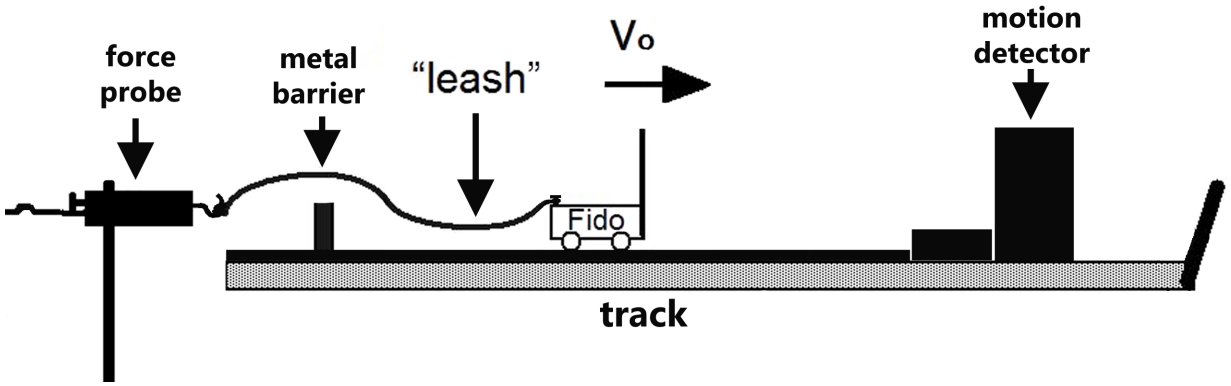
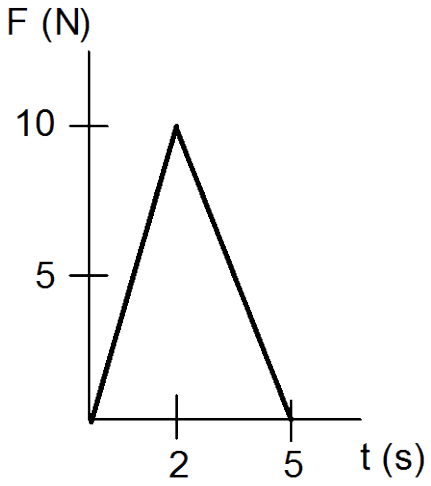



**Figure 2.** Experimental setup for Investigation 2

Answer the following questions regarding Investigation 2.

**Q3** - A 1 kg particle which is initially at rest is subject to an impulsive force whose magnitude varies with time as shown below. What is the net impulse imparted to the particle between t=0 and t=5 s? Also, what is the particle's momentum at t=2 s and at t=5 s?




**Q4** - A 150 gram ball is moving at a speed of 40 m/s when it is struck by a bat that reverses its direction and gives the ball a speed of 60 m/s. What average force was exerted by the bat if it was in contact with the ball for 0.005 seconds?

Finally, in Investigation 3, you will study completely inelastic collisions, i.e., collisions for which the initial particles stick together to form a single composite object with a common velocity, $v_f$. In a completely inelastic collision, total momentum is conserved,

$$m_1 v_{1i} + m_2 v_{2i} = (m_1+m_2) v_f \qquad \text{(Eq. 5)}$$

but kinetic energy is not. In this investigation you will study completely inelastic collisions using two carts with Velcro pads that cause the carts to stick together during a collision (see Figure 3).

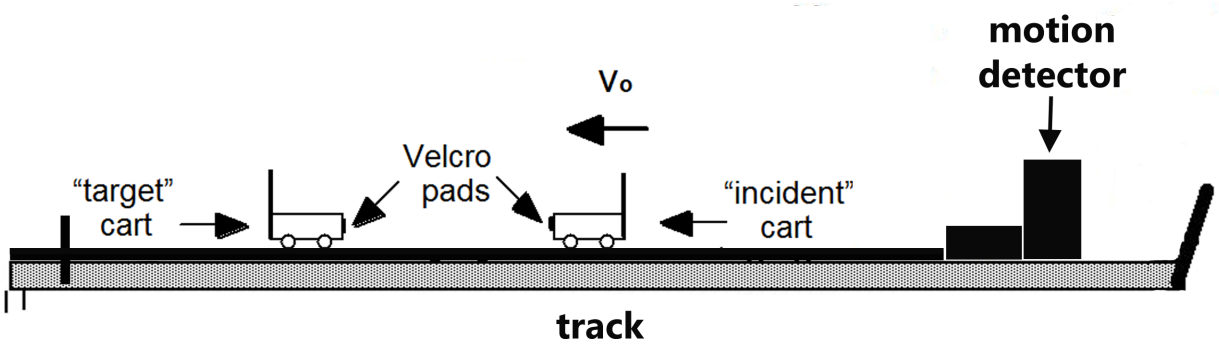



**Figure 3.** Experimental setup for Investigation 3

Answer the following questions regarding Investigation 3.

**Q5** - Assume that you push an "incident" cart with a momentum $m_1v_1$ towards a stationary "target" cart having a mass $m_2$ (see Figure 3). At a time $t_o$ the "incident" cart collides *completely inelastically* with the "target" cart. The resulting total final momentum is $(m_1+m_2)v_2$. What is the fractional change in the total kinetic energy of the two-cart system, $\Delta K.E./K.E._{initial}$, during the collision?

**Q6** - A 6 kg sled is traveling across the ice at a speed of 9 m/s when a 12 kg package is dropped into it from above (assume the package falls completely vertically and sticks to the sled). What is the speed of the sled after this "collision"?