EXPERIMENT 6
Introduction to One-dimensional Collisions

Elastic and Inelastic Collisions

Apparatus

A one-dimensional air track, an air supply, two carts, a photogate timing circuit (including two photogates) and an analytical balance will be used. Figure 1 below is a picture of the air track set up. A photogate, an air track cart and a cart passing through a photogate are shown in Figures 2a, 2b and 2c, respectively.

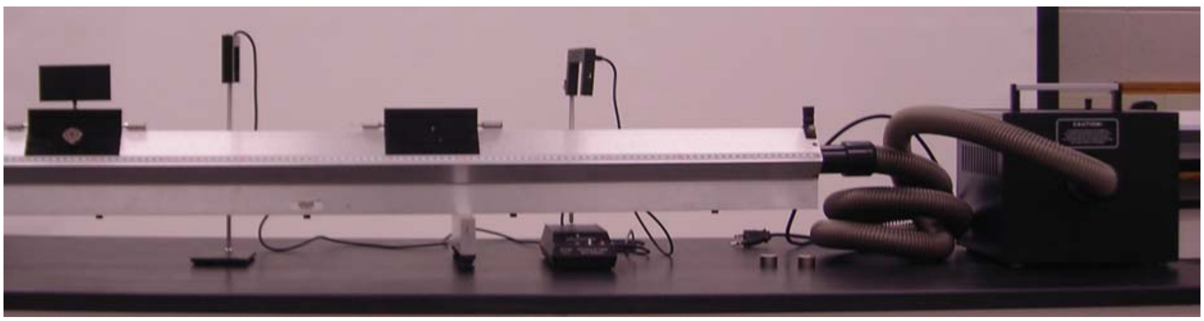
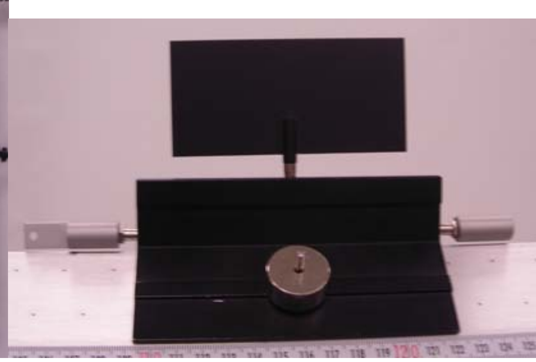


Figure 1



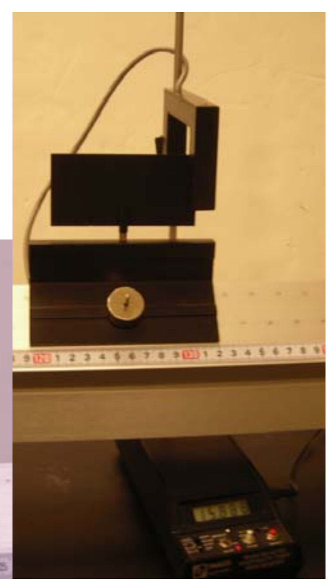


Figure 2a Figure 2b Figure 2c

Theory

The following two experiments deal with two different types of one-dimensional collisions. Below is a discussion of the principles and equations that will be used in analyzing these collisions.

For a single particle, **momentum** is defined as the product of the mass and the velocity of the particle:

$$\boldsymbol{p} = m\boldsymbol{v}. \quad (1)$$

Momentum is a **vector** quantity, making its direction a necessary part of the data. For example for the one-dimensional case the momentum would have a direction in either the +x direction or the -x direction. For a system of more than one particle, the **total momentum** is the vector sum of the individual momenta:

$$\boldsymbol{p} = \boldsymbol{p}_1 + \boldsymbol{p}_2 + \ldots = m\boldsymbol{v}_1 + m\boldsymbol{v}_2 + \ldots \quad (2)$$

So in other words you just add the momentum of each particle together.

One of the most fundamental laws of physics is that the **total momentum** of any system of particles is **conserved**, or constant, as long as the net external force on the system is zero. Assume we have two particles with masses m_1 and m_2 and speeds v_1 and v_2 which collide with each other without any external force acting. Suppose the resulting speeds are v_{1f} and v_{2f} after the collision. **Conservation of momentum** then states that the total momentum before the collision ($\mathbf{p}_{initial} = \mathbf{p}_i$) is equal to the total momentum after the collision ($\mathbf{p}_{final} = \mathbf{p}_f$):

$$\boldsymbol{p}_i = m_1\boldsymbol{v}_{1i} + m_2\boldsymbol{v}_{2i}, \quad , \boldsymbol{p}_f = m_1\boldsymbol{v}_{1f} + m_2\boldsymbol{v}_{2f} \text{ and } \boldsymbol{p}_i = \boldsymbol{p}_f \quad (3)$$

In a given system, the **total energy** is generally the sum of several different forms of energy. **Kinetic energy** is the form associated with motion, and for a single particle

$$KE = \frac{mv^2}{2}. \quad (4)$$

In contrast to momentum, kinetic energy is NOT a vector; for a system of more than one particle the total kinetic energy is simply the sum of the individual kinetic energies of each particle:

$$KE = KE_1 + KE_2 + \ldots \quad (5)$$

Another fundamental law of physics is that the **total energy** of a system is always **conserved**. However within a given system one form of energy may be converted to another, such as in the freely-falling body lab where potential energy was converted to kinetic energy. *Therefore, kinetic energy alone is often not conserved*.

There are two basic kinds of collisions, elastic and inelastic:

In an **elastic collision**, two or more bodies come together, collide, and then move apart again with NO LOSS IN KINETIC ENERGY. An example would be two identical "superballs," colliding and then rebounding off each other with the same speeds they had before the collision. Given the above example conservation of kinetic energy then implies

$$\frac{1}{2}m_1 v_{1i}^2 + \frac{1}{2}m_2 v_{2i}^2 = \frac{1}{2}m_1 v_{1f}^2 + \frac{1}{2}m_2 v_{2f}^2 \quad \text{or} \quad KE_{\text{initial}} = KE_{\text{final}} \tag{6}$$

In an **inelastic** collision, the bodies collide and come apart again, but SOME KINETIC ENERGY IS LOST. That is, some kinetic energy is converted to some other form of energy. An example would be the collision between a baseball and a bat.

If the bodies collide and stick together, the collision is called **completely inelastic**. In this case, MUCH OF THE KINETIC ENERGY IS LOST in the collision. That is, much of the kinetic energy is converted to other forms of energy.

In the following two experiments you will be dealing with a completely inelastic collision in which much of the kinetic energy of the objects is lost, and with a nearly elastic collision in which kinetic energy is conserved. Remember, in both of these collisions total momentum should always be conserved.