611-1320 (40-150) Dynamics Carts

Introduction:

When two objects collide, their subsequent motion is determined by their initial velocities and by the forces acting between the objects during the collision. The physical constraints on those forces lead to two conservation laws which in turn allow the subsequent motion to be predicted either fully or at least in part. What better way to study the Laws of Conservation of Momentum and Energy than with these large-scale, high impact resistant carts? With their sturdy construction and accurately aligned axles, they yield superior data for all quantitative kinematics experiments.

The Dynamics Carts feature a low profile and three widely spaced wheels for stability. Each also has a Velcro™ attachment for studying inelastic collisions and an easily set firing mechanism with two firing positions. The carts can be towed with string or rubber bands to simulate the application of constant forces. They also feature a non-slip vinyl surface for holding additional weight and a safety catch to lock during storage. The carts are stackable and can each support over 60 kg. The 40-150 Dynamics Carts measure 30cm long, 13cm wide, and have a mass of 600 grams.

Other materials needed:

• Weights to place on the carts. Most anything will work such as bricks or lab masses. Masses with a lower center of gravity are better for stability.
• A balance, for weighing the mass of a loaded cart.
• String or rubber bands for towing the carts.
• A small rubber mallet will help to cleanly trigger the firing mechanism. One such as the type used to sound a tuning fork could be used.
• A smooth flat surface to experiment on. This will help to reduce friction.

Operation:

The Dynamics Carts are shipped with the firing pins in the “locked” position. The lock is a safety mechanism useful for experiments that do not require the firing pin, and is useful for storing the Dynamics Carts.

To Release The Safety Lock:

Turn the Dynamics Cart upside down. In between the two wheeled axle is a slider. To release the safety lock, push the slider towards the single wheel end of the Dynamics Cart.

To Release The Firing Pin:

Place the cart with the firing up against a hard solid surface such as a wall. To “cleanly” release the firing is recommended that a small rubber mallet be used to lightly strike the release trigger (see diagram). This will lessen any interference in the experiment. Without a mallet, anything may be used to press down on the release trigger.

To Reset The Firing Pin:

Once released, the firing pin has two small cuts in the top of the shaft. These cuts represent the two firing positions that the pin can be set at. To set the firing pin, push it into the car and upwards, setting one of the cuts onto the catch.

Theory:

When two objects collide, their subsequent motion is determined by their initial velocities and by the forces acting between the objects during the collision. There are physical constraints on those forces that lead to two conservations laws which in turn allow the subsequent motion to be predicted either fully or at least in part. The Law of Conservation of Momentum can be applied to all collisions regardless of the details of the collision. On the other hand details are relevant in the application of the Law of Conservation of Energy because it is necessary to know how much energy of motion (Kinetic Energy - K. E,) is converted to non-recoverable forms of energy such as heat. If that K.E. loss is known, the two conservation laws can together predict subsequent motion.

The Dynamics Cart pair is a good method of demonstration the relevance of momentum and energy conservation to collisions in one dimension between two objects. Each object is a cart carrying known mass. The cart is supported by ball-bearing wheels. Though small, the friction in these wheels does make the carts slow down and the observer must note the cart velocities immediately before and after collision. The friction can be reduced by experimentation a smooth flat surface. Here are special cases of mass and velocity combinations that illustrate the ideas involved without the need for timing equipment.

Conservation Of Momentum:

Conservation of total momentum in a collision follow from Newton's second and third laws of motion. The third law states that for every action there is an equal and opposite reaction. Collisions vary in character. Duration can be short and snap (billiard balls) or long (oil tankers colliding at sea.) The third law implies for all cases that at any instant during that period of contact, the force on one object is exactly equal and opposite to the force on the other. The second law states that the force acting on the object is numerically equal (when appropriate units are used newtons for force and kilogram meters per second for momentum), to the rate change of momentum of the object. If the forces on the objects are equal and opposite (as required by the third law) the rates of change of momentum of those objects must also be equal and opposite at every instant throughout the collision. Whatever momentum is lost by one object is gained by the other. In other words the total momentum of the objects must stay the same.

This conservation can be expressed as an equation relating the velocities before (V_1 and V_2) and after (V_3 and V_4) the collision of objects 1 and 2 of mass M_1 and M_2 respectively. All velocities V will be written as if the objects are moving to the right. A known velocity to the left would be written as a negative number. If the solution to the equation is a negative quantity, the velocity is to the left.

Momentum is the product of mass and velocity, confined to one dimension here.

$$M_1V_1 + M_2V_2 = M_1V_3 + M_2V_4$$

If the starting conditions are known, then M_1, M_2, V_1 and V_2 are known. The equation alone cannot predict V_3 and V_4 but measured values must satisfy this relation.

Conservation of Energy:

Energy can be transferred from one kind to another. Some transformations are reversible, some not. Total energy is a constant but its usefulness decreases through irreversible transformations (the concept of entropy).

The kinetic energy associated with the objects need not remain as kinetic energy of the objects. In most cases some fraction of available K.E. is irreversibly transformed to frictional heating, permanent distortion of the objects, sound, etc.

Elastic Collisions (Conservation of Kinetic Energy):

Elastic collisions are those in which no K.E. is irreversibly transformed to other forms of energy. Instead it is reversibly transformed to a potential energy (here, compression of a spring) and then transformed back to K.E. of the objects as they fly apart. This is seen as a firing pin of a Dynamics Cart is released against a wall or another cart.

Perfectly elastic collisions are almost impossible to achieve. Two dynamics carts bouncing apart with a firing pin extended between them acts as a spring between them. This is an approximation in that a little energy is lost in heating the spring and in sound. The kinetic energy of an object is $1/2MV_2$

Therefore: $1/2M_1V_1^2 + 1/2M_2V_2^2 = 1/2M_1V_3^2 = 1/2M_2V_4^2$

Equations can be combined to give V_3 and V_4 and predict exactly the subsequent motion.

Completely Inelastic Collisions:

Suppose the Dynamics Carts were prevented from rebounding. This is what is demonstrated when the Velcro connects the carts together and the momentum is added.

The equation for momentum conservation still applies. Total velocity (V_T) is:

$$V_T = M_1V_1 + M_2V_2$$

Most collisions lie somewhere between the two extremes of elastic and completely inelastic. The complete range including the two extremes can be analyzed using a modification of equation:

$$e(V_1 - V_2) = V_4 - V_3$$

Experiments:

Case 1:

Both cars facing same direction a known distance apart, one with its firing pin in the released position. Roll both cars, one car into the second on a flat surface. The velocity of the first car must exceed that of the second if a collision is to occur. Where to the cars end up? How far apart?

Case 2:

Release one car with heavy weights from a wall into an empty stationary car facing the opposite directions so that the Velcro will attach. How fast and how far do the connected carts roll forward? Try with the carts facing the same direction, with the second cart's firing pin extended. How fast does the second cart roll after the elastic collision with the car from the wall" How far does it roll?

Case 3:

Bounce the carts together in a head-on-collision;
- With the released firing pin of one impacting the other.
- With different combinations of weights in each.

Where do cars end up? How fast do they roll?

Case 4:

Try out all configurations - with weights; without weights; head-on; facing same direction. Release the firing pins from walls to obtain consistent force. Use the carts with firing pins extended. How fast, how far and in which directions do they roll?

Suggestions:

The Dynamics Carts are durable and can be used for any number of experiments.
- Use with an inclined plane
- Connect the carts with string, springs, or rubber bands
- Quickly double the mass by stacking the two (or more) carts.
- Measure the coefficient of friction

Storage and Maintenance:

The Carts should be stored in a dry place with the lock mechanism on. This will prevent accidental release of the firing pin.

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Warranty and Parts: We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.