611-1300 (40-145) Mini-Dynamics Instructions & Experiments

Warranty & Replacement Parts

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free at **1-800-875-3214** by referring to the part numbers above. We accept Master Card and Visa, school P.O. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse, or normal wear and tear.

How To Teach with Mini-Dynamics

Concepts: Basic notions of velocity, acceleration; uniform acceleration - relation to time, velocity and displacement; Newton's first and second laws; friction. Collision - conservation of momentum and of energy.
Curriculum Fit: PS. Motion and Force. *Unit: Causes of Motion. (Newton's Laws, Momentum & Energy Conservation.)*
Kit contains: 2 high-impact-resistant plastic molded cars; 2 spring-steel bumpers with rounded edges, attached hardware; 2 rubber-stopper assemblies, attached hardware; instructions.

Other Materials Needed:

- **Weights**
- **Incline**

(This can be a board propped on books, hinged desktop, or **611-0035 Inclined Plane** from manufacturer **Science First**®.)

Download instructions and free articles from our website at www.sciencefirst.com

How To Use:

Put different weights in cars' wells. Attach rubber stoppers or spring-steel hex nut on inside of car body. **(You will have to remove wheels to attach accessories. Wheels are designed to snap out without damage.)** Roll cars so they collide. Observe how fast they rebound, and in what direction. With this kit you can demonstrate and calculate:

- **Conservation of momentum**
- **Conservation of energy**
- **Elastic collisions**
- **Inelastic collisions**

Case 1:

Both cars facing same direction a known distance apart with spring-steel bumpers attached. Roll 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 do the cars end up? How far apart?

Case 2:

Roll one car with heavy weights into an empty stationary car facing the same direction, both with spring-steel bumpers attached. How fast and how far does the empty car bounce forward? Try with the same cars rolling forward equally fast. Now collide cars head-on.

Case 3:

Bounce cars together in head-on collision

* with spring steel bumpers attached

* with rubber stoppers attached

* with different combinations of weights in each.

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

Case 4:

Collide cars together on inclines of various heights. (Use a wide book or board propped on books or hinged desk top.) Try out all configurations - with weights; without weights; head-on; facing same direction; with spring-steel; with rubber stoppers.

How fast, how far and in which directions do they roll?

***Suggestion:** Glue ceramic disc magnets to car, experiment with attraction and repulsion.*

Related Products:

611-0035 Inclined Plane - all-aluminum, attached protractor & prop, folds for storage, low-friction pulley on rod, instructions.

611-0040 Halls Car - same construction as Mini-Dynamics Kit. Useful low-cost accessory.

611-1400 Ballistics Car - shows how horizontal & vertical components of acceleration are independent.

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 conservation 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 nonrecoverable forms of energy such as heat. If that K.E. loss is known, the two conservation laws can together predict subsequent motion.

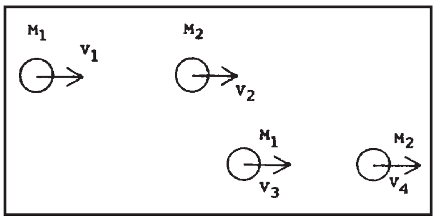
The Dynamics Car pair is a good method of demonstrating the relevance of momentum and energy conservation to collisions in one dimension between two objects. Each object is a car carrying a known mass. The car is supported by ball-bearing wheels. Though small, the friction in these wheels does make the cars slow down and so the observer must note the car velocities immediately **before** and **after** collision. The friction can be greatly reduced only by investing in more expensive air tracks.

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 follows 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 snappy (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 of change of momentum of that 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_i 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 **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.

Perfectly elastic collisions are almost impossible to achieve. Two dynamics cars bouncing apart with a spring between them are 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:

$$1/2M_1V_1^2 + 1/2M_2V_2^2$$
$$= \quad 1/2M_1V_3^2 + 1/2M_2V_4^2$$

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

Completely Inelastic Collisions

The equations for elastic collisions indicate that the relative velocity is reversed when all of the energy stored in the spring is returned.

Suppose the spring were prevented from rebounding. None of the stored energy would be returned. This represents the maximum possible loss of K.E. The cars would not be pushed apart.

Then $V_3 = V_4$.

This is the distinguishing feature of a completely inelastic collision.

The equation for momentum conservation still applies. Final velocity is:

$$V_3=V_4 = \frac{M_1V_1 + M_2V_2}{M_1 + M_2}$$

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:

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

where the fraction **e**, known as coefficient of restitution lies in the range 0 is less than **e** is less than 1. If e is known, from experiment or theory, equations can be solved to predict V_3 and V_4.

Collisions where e is neither 0 nor 1 are known as **inelastic** because not all K.E. is conserved.

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