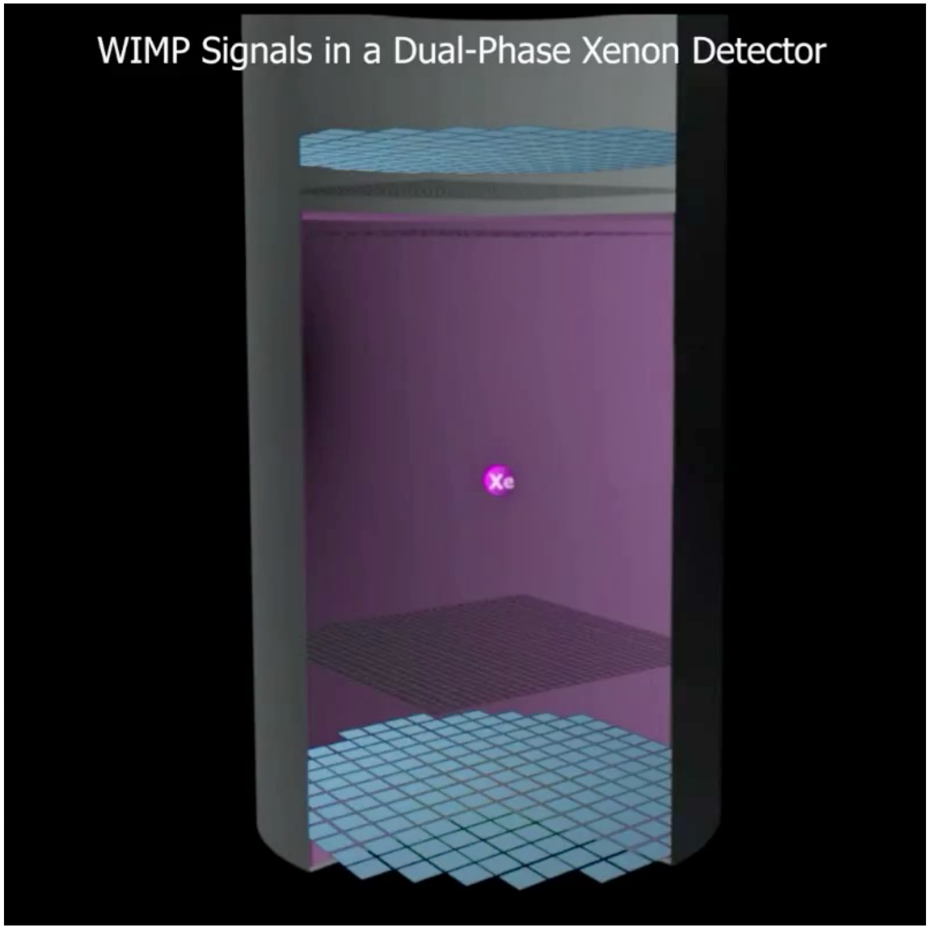
Physics 141.
Lecture 15.



This is where I grew up.
This is where I used to ride my bike.

At the bottom of the Haarlemmermeer.

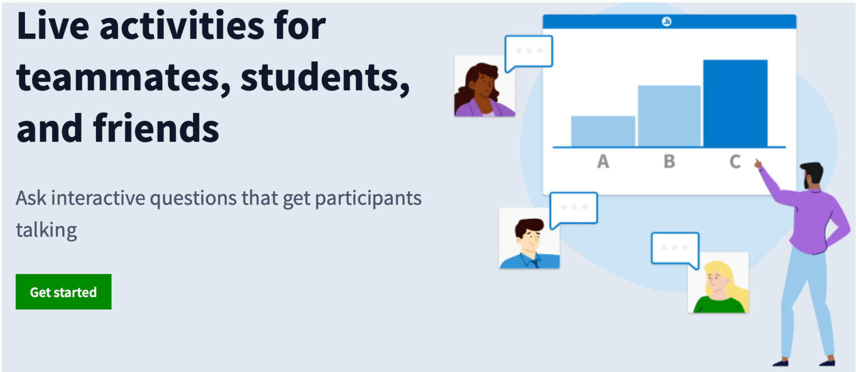
Before 1852.

Physics 141.
Lecture 15.

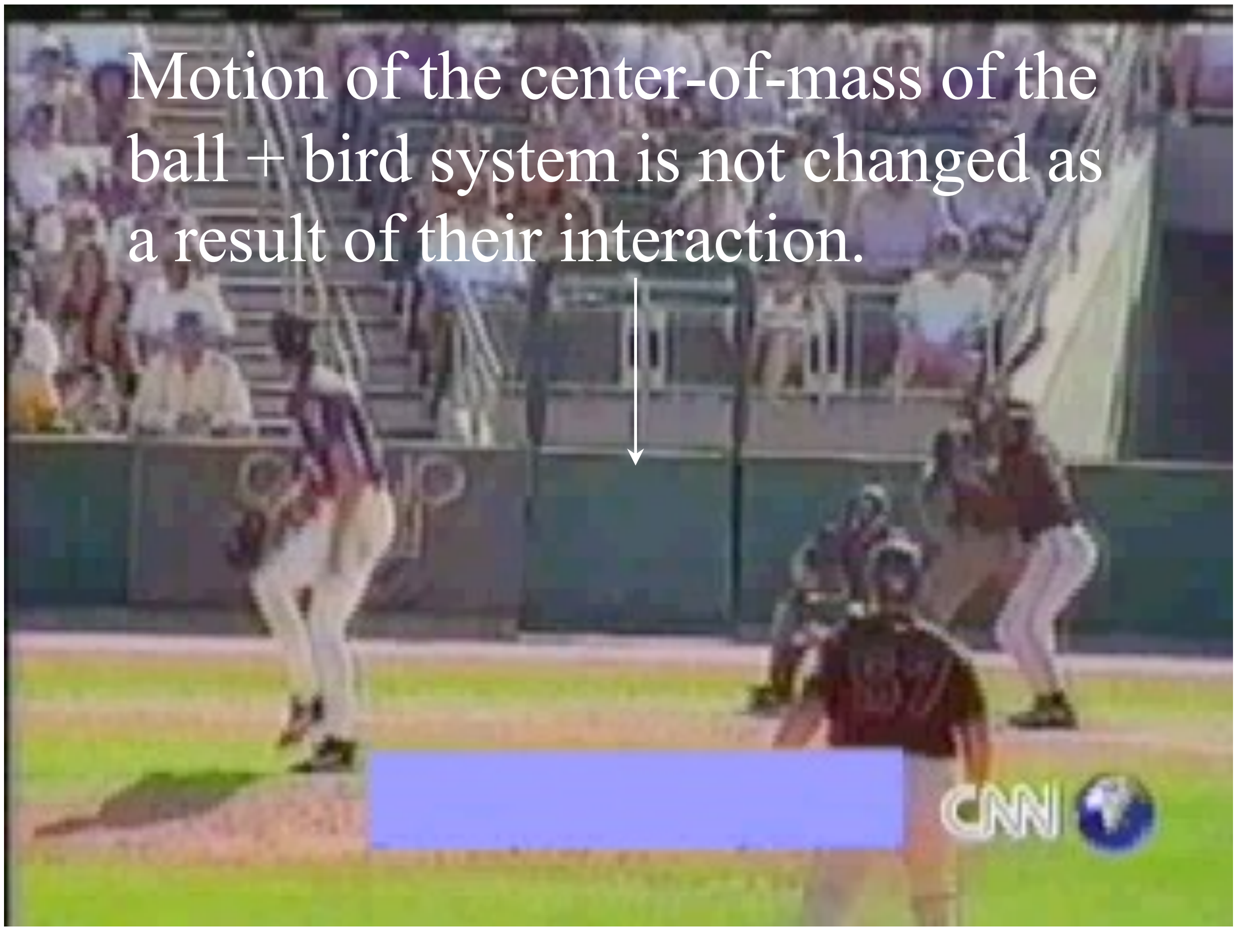
- Course information:
  - Homework set # 6 is due on Friday 10/25.
- Quiz
- Collisions (Chapter 10):
  - Elastic collisions of macroscopic objects.
  - Inelastic collisions of macroscopic objects.

Quiz lecture 15.
PollEv.com/frankwolfs050

- The quiz today will have four questions.
- I will collect your answers electronically using the Poll Everywhere system.
- The answers for each question will be entered in sequence (first 30 s for question 1, followed by 30 s for question 2, etc.).



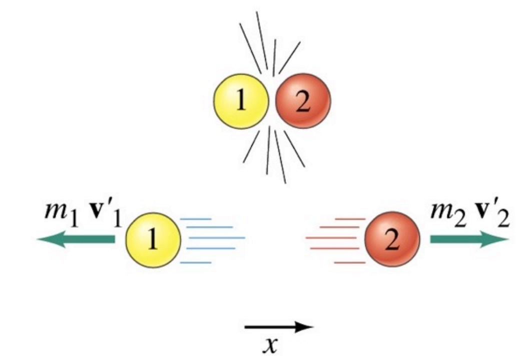
Chapter 10: Exploring collisions. Macroscopic to microscopic.

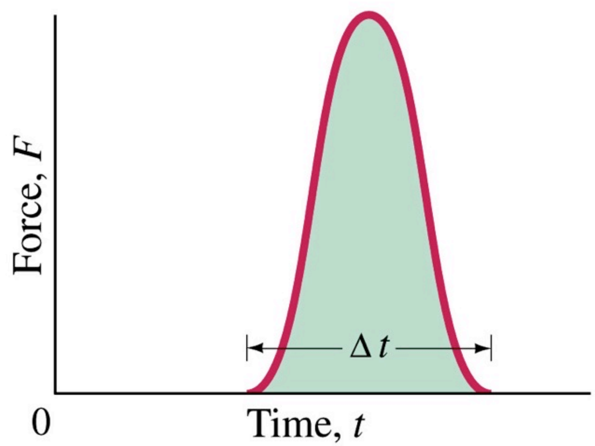


Collisions.
The collision force.

- During a collision, a strong force is exerted on the colliding objects for a short period of time.
- The collision force is usually much stronger then any external force.
- The result of the collision force is a change in the linear momentum of the colliding objects.
- The change in the momentum of one of the objects is equal to

$$\vec{p}_f - \vec{p}_i = \int_{\vec{p}_i}^{\vec{p}_f} d\vec{p} = \int_{t_i}^{t_f} \vec{F}(t)dt$$





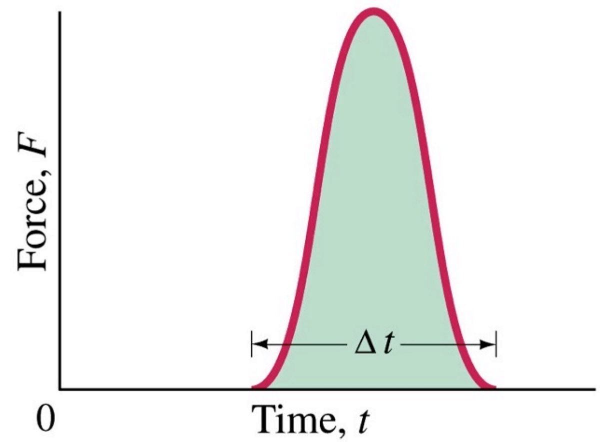
Collisions.
The collision impulse.

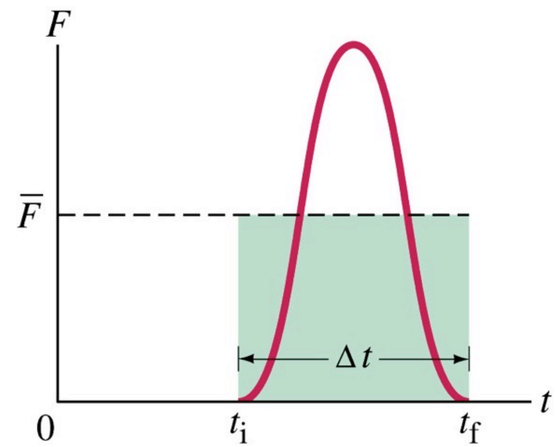
- If we measure the change in the linear momentum of an object, we will obtain information about the integral of the force acting on it:

$$\vec{p}_f - \vec{p}_i = \int_{t_i}^{t_f} \vec{F}(t)dt$$

- The integral of the force is called the collision impulse J:

$$\vec{J} = \int_{\vec{p}_i}^{\vec{p}_f} d\vec{p} = \int_{t_i}^{t_f} \vec{F}(t)dt$$



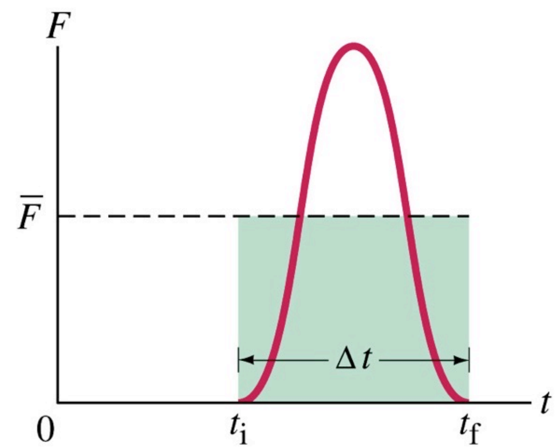


Collisions.
The collision impulse.

- Consider you are involved in a collision: you first move with 55 mph and after the collision you are at rest.
- The change in momentum is thus fixed and the collision impulse is also fixed:

$$\vec{J} = \int_{t_i}^{t_f} \vec{F}(t)dt$$

- What happens to you depends on the magnitude of the force! An increase in time Δt results in a reduction of the force.

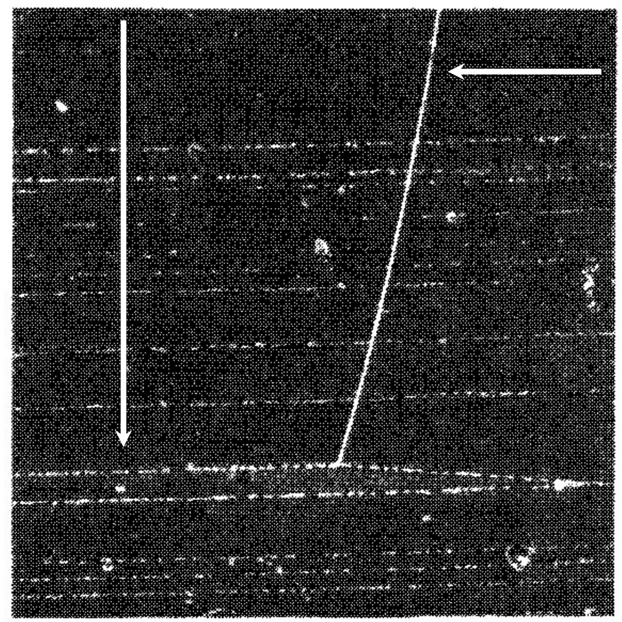


Collisions.
The collision impulse.

- Interactions between sub-atomic particles are usually studied by comparing their momenta before and after an interaction.

- The change in their momenta provides us with information about the collision impulse.

- Determining the force from the collision impulse required a knowledge of the time dependence of the interaction.

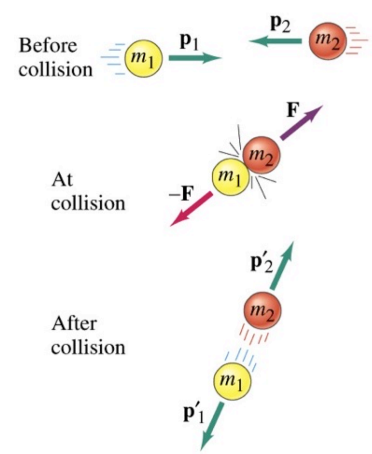


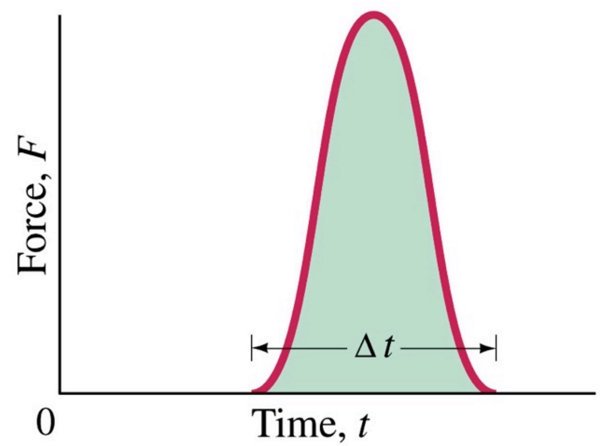
Collision between protons.

Elastic and inelastic collisions.

- If we consider both colliding object, then the collision force becomes an internal force and the total linear momentum of the system must be conserved if there are no external forces acting on the system.

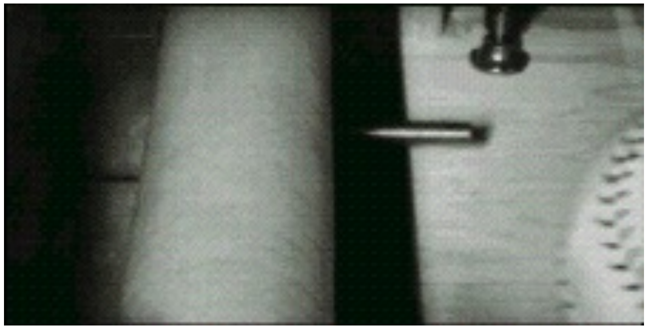
- Collisions are usually divided into two groups:
  - Elastic collisions: **kinetic energy is conserved**.
  - Inelastic collisions: **kinetic energy is NOT conserved**.

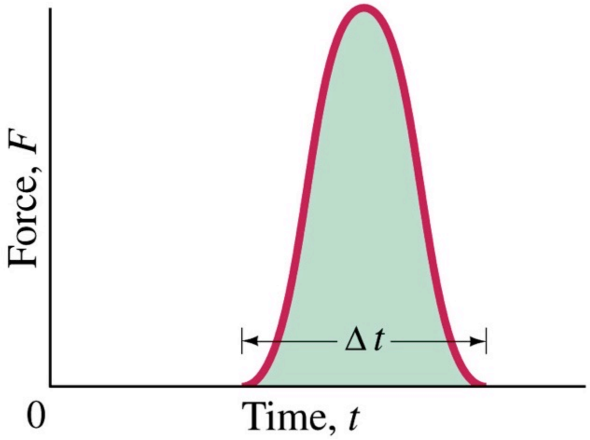




Elastic and inelastic collisions.

- Kinetic energy does not need to be conserved during the time period that the collision force is acting on the system. The kinetic energy may become 0 J for a short period of time.
- During the time period that the collision force is non-zero, some or all of the initial kinetic energy may be converted into potential energy (for example, the potential energy associated with deformation).





3 Minute 00 Second Intermission.

- Since paying attention for 1 hour and 15 minutes is hard when the topic is physics, let's take a 3 minute 00 second intermission.
- You can:
  - Stretch out.
  - Talk to your neighbors.
  - Ask me a quick question.
  - Enjoy the fantastic music.
  - Solve a WeBWorK problem.

Elastic collisions in one dimension.

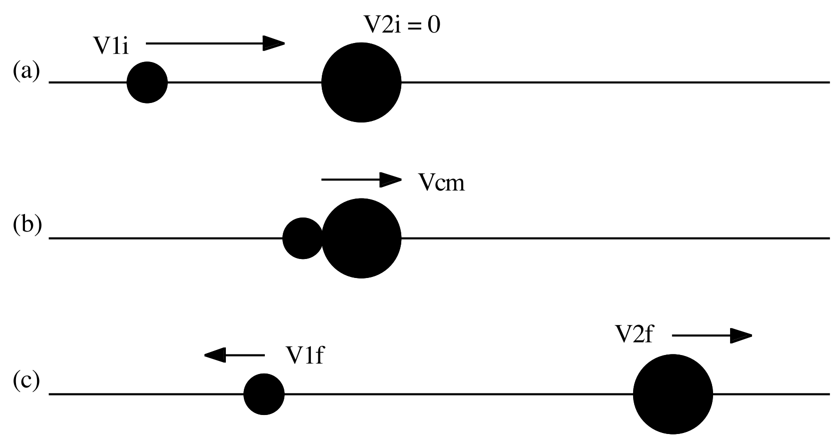
- Consider the elastic collision show in the Figure.
- Conservation of linear momentum requires that

$$m_1 v_{1i} = m_1 v_{1f} + m_2 v_{2f}$$

- Conservation of kinetic energy requires that

$$\frac{1}{2} m_1 v_{1i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$$

- Two equations with two unknown!



Elastic collisions in one dimension.

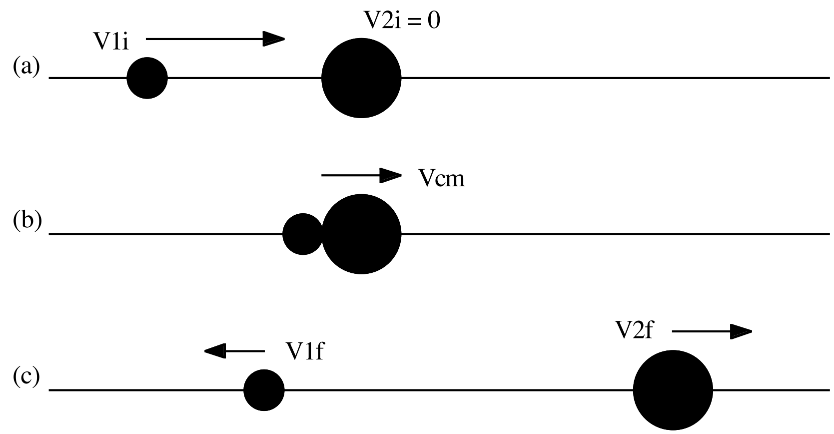
- The solution for the final velocity of mass m_1 is:

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i}$$

- The solution for the final velocity of mass m_2 is:

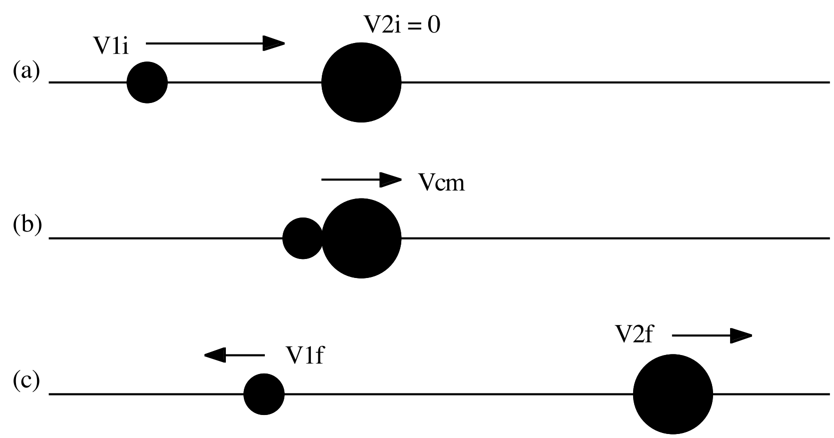
$$v_{2f} = \frac{m_1}{m_2}\left(v_{1i} - v_{1f}\right)$$

$$= \frac{2m_1}{m_1 + m_2} v_{1i}$$



Elastic collisions in one dimension. Special cases.

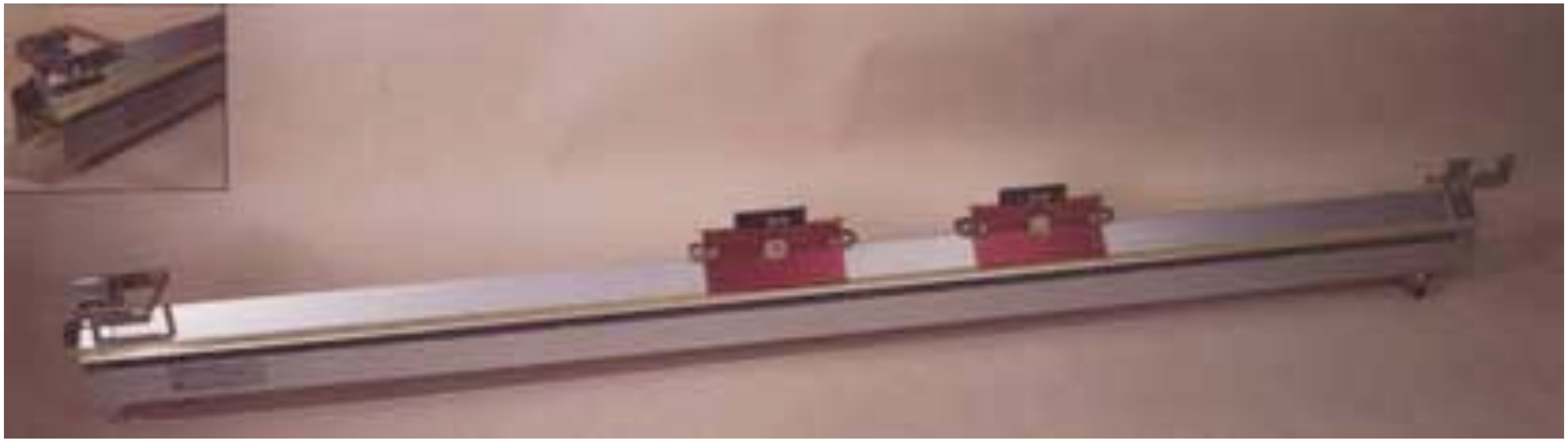
- $m_1 = m_2$:
  - $v_{1f} = 0$ m/s
  - $v_{2f} = v_{1i}$
- $m_2 >> m_1$:
  - $v_{1f} = - v_{1i}$
  - $v_{2f} = (2m_1/m_2)\, v_{1i}$
- $m_1 >> m_2$:
  - $v_{1f} = v_{1i}$
  - $v_{2f} = 2v_{1i}$



Note: the motion of the center of mass is not changed due to the collision.

Elastic collisions in one dimension.

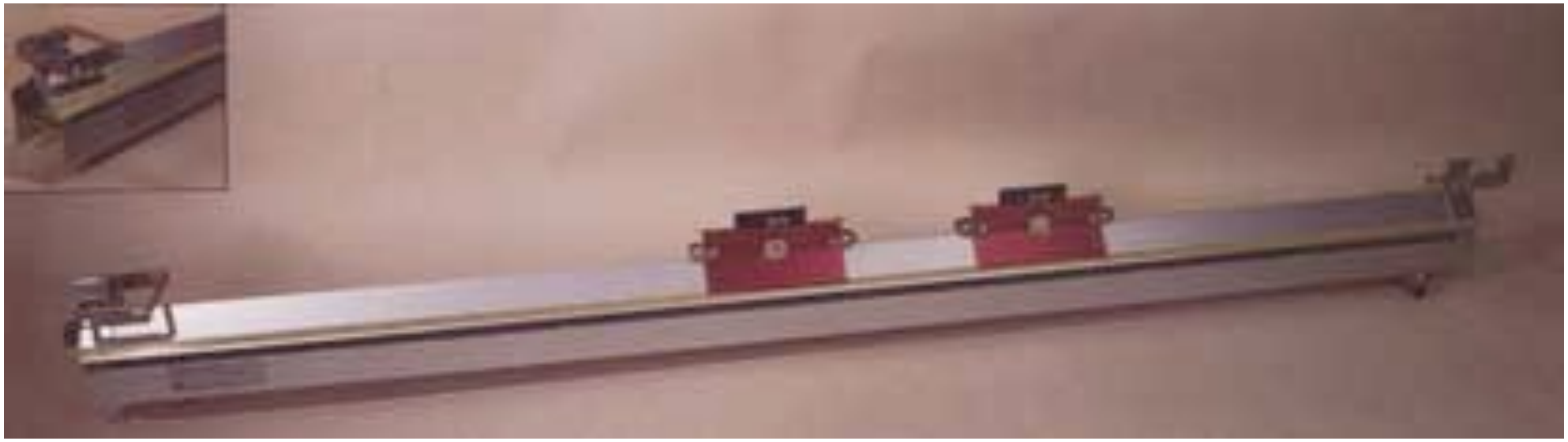
- We can use an air track to study elastic collisions.
- The velocity of the carts can be determined if we measure the length of time required to pass through the photo gates: velocity = length/time, or we can use a photo gate to study the motion.



TEL-Atomic, http://www.telatomic.com/at.html

Elastic collisions in one dimension.

- Let us focus on specific examples where one cart (cart 2) is at rest:
  - $M_1 = M_2$: $v_{1f} = 0$ m/s, $v_{2f} = v_{1i}$
  - $M_1 = 2M_2$: $v_{1f} = (1/3)v_{1i}$, $v_{2f} = (4/3)\ v_{1i}$
  - $2M_1 = M_2$: $v_{1f} = -(1/3)v_{1i}$, $v_{2f} = (2/3)\ v_{1i}$



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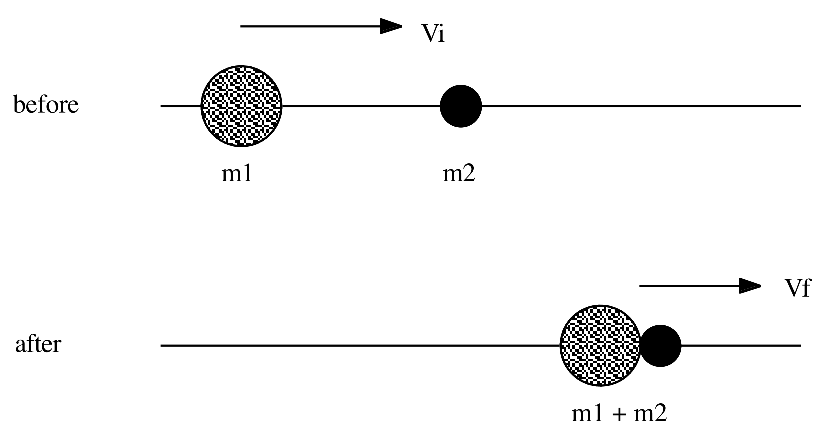
Inelastic collisions in one dimension.

- In inelastic collisions, kinetic energy is not conserved.
- A special type of inelastic collisions are the completely inelastic collisions, where the two objects stick together after the collision.
- Conservation of linear momentum in a completely inelastic collision requires that

$$m_1 v_i = (m_1 + m_2) v_f$$



Inelastic collisions in one dimension.

- The final velocity of the system is equal to

$$v_f = \frac{m_1}{m_1 + m_2} v_i$$

- The final kinetic energy of the system is equal to

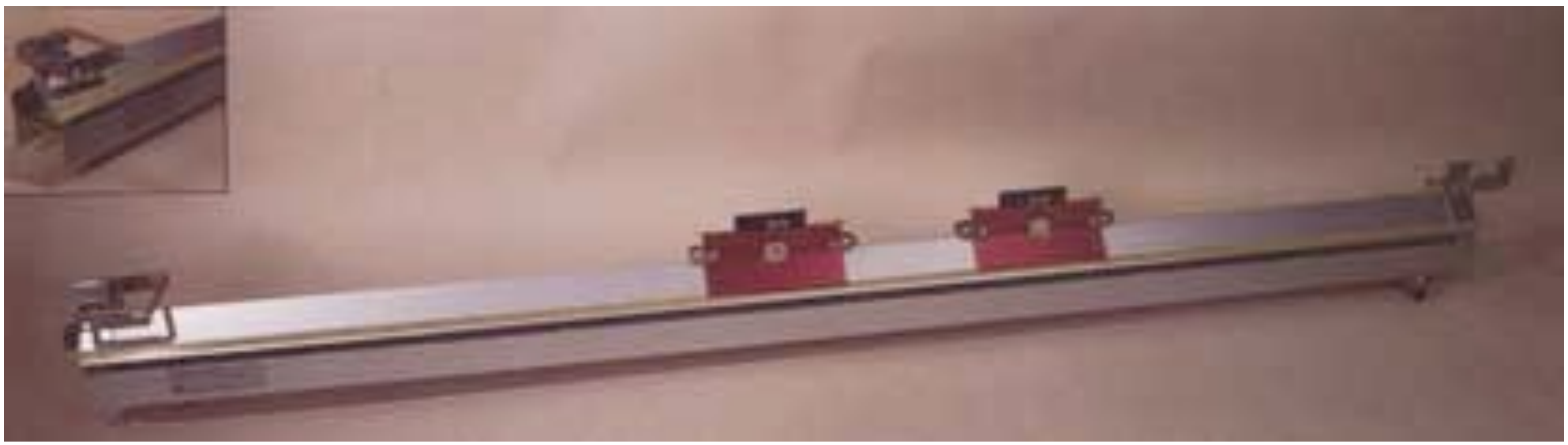
$$k_f = \frac{1}{2}(m_1 + m_2)v_f^2 = \frac{1}{2}(m_1 + m_2)\left(\frac{m_1}{m_1 + m_2} v_i\right)^2 = \frac{m_1}{m_1 + m_2} K_i$$

- Note: not all the kinetic energy can be lost, even in a completely inelastic collision, since the motion of the center of mass must still be present. Only if our reference frame is chosen such that the center-of-mass velocity is zero, will the final kinetic energy in a completely inelastic collision be zero.

Inelastic collisions in one dimension.

- Let us focus on one specific example of a procedure to measure the velocity of a bullet:
  - We shoot a 0.3 g bullet into a cart
  - The final velocity of the cart is measured and conservation of linear momentum can be used to determine the velocity of the bullet:

$$v_i = \frac{m_1 + m_2}{m_1} v_f$$



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Done for today!
This is why I do not fly American Airlines.