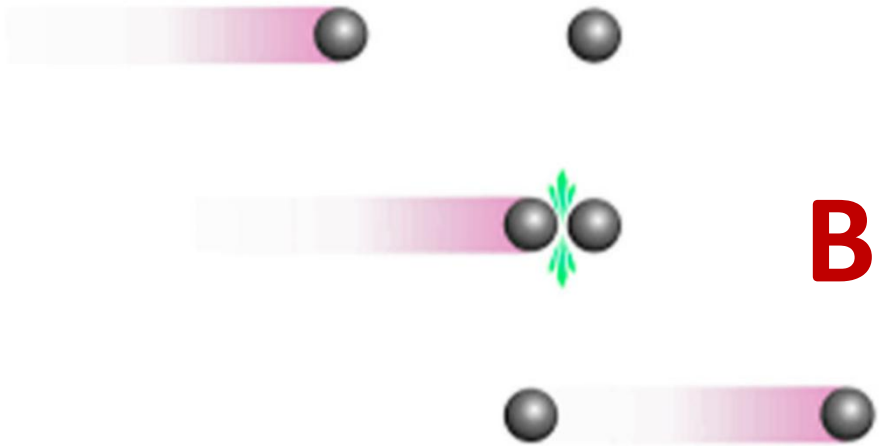
Perfectly Elastic Collision

It's not a thing!



OMG!

Better Than the Best?

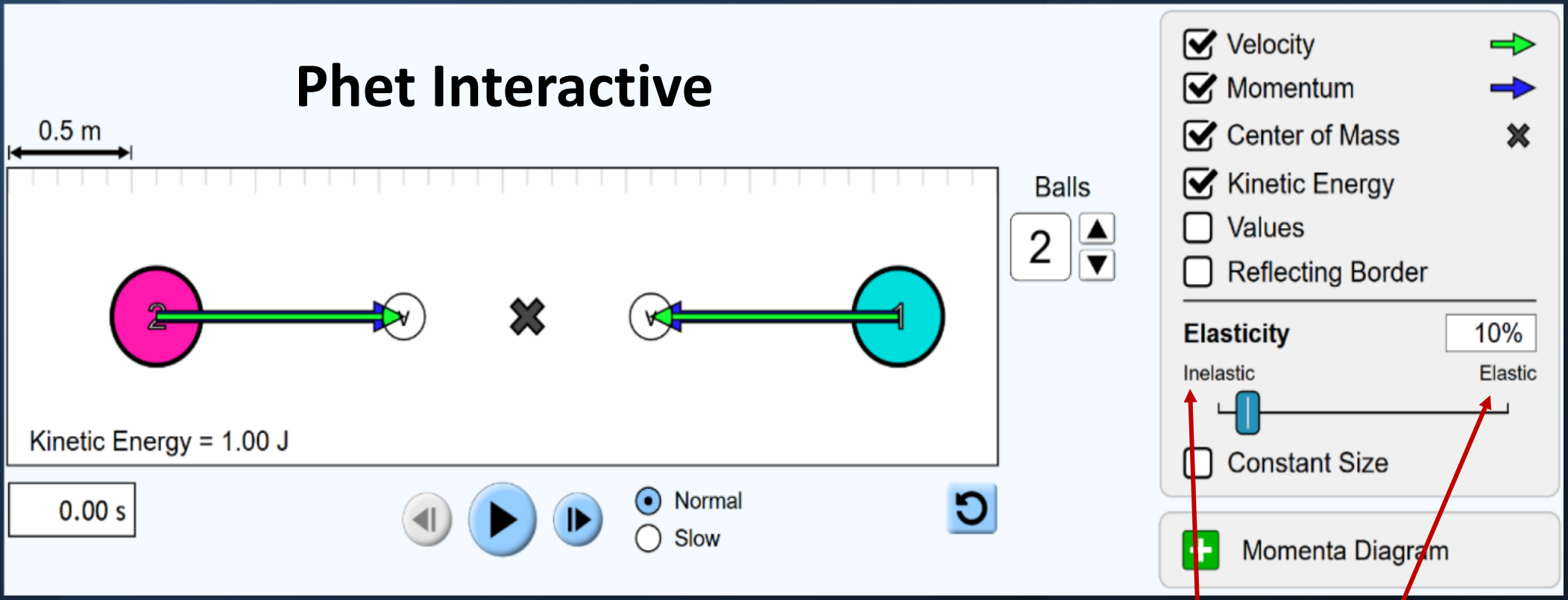
Collision Misconceptions

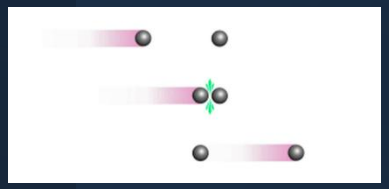
Tom Bright
Physics Educator Symposium on Research and Teaching
15 June 2025

@BrighterPhysics

“Perfectly Elastic Collision”
From where does this come?

Phet Interactive

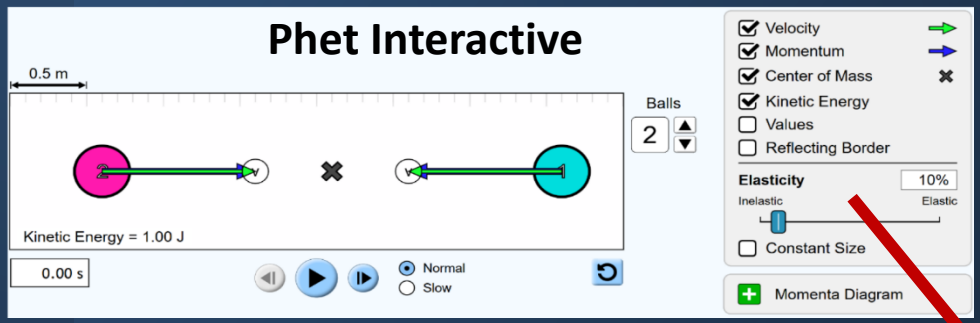




Misleading
Slidebar Limits!

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“Perfectly Elastic Collision”
From where does this come?

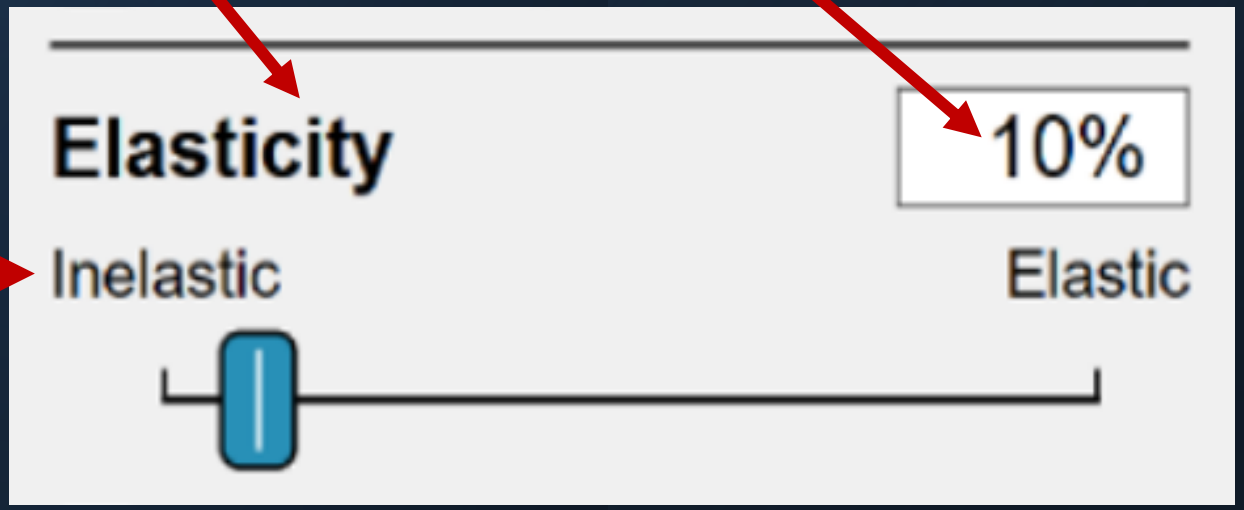


This is NOT

percentage of elastic collision

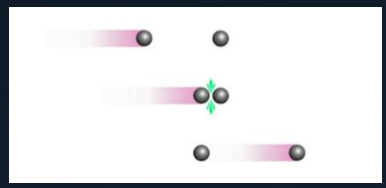
Should be

“Totally Inelastic”



Elasticity:

- **actually the Coefficient of Restitution**
- $= \frac{relative\ velocity\ of\ separation}{relative\ velocity\ of\ approach}$



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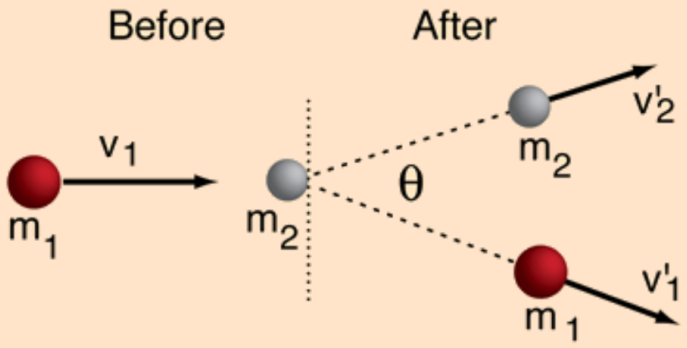
HyperPhysics:

"Perfectly Elastic Collision"
From where does this come?

Elastic and Inelastic Collisions

A perfectly elastic collision is defined as one in which there is no loss of kinetic energy in the collision. An inelastic collision is one in which part of the kinetic energy is changed to some other form of energy in the collision. Any macroscopic collision between objects will convert some of the kinetic energy into internal energy and other forms of energy, so no large scale impacts are perfectly elastic. Momentum is conserved in inelastic collisions, but one cannot track the kinetic energy through the collision since some of it is converted to other forms of energy. Collisions in ideal gases approach perfectly elastic collisions, as do scattering interactions of sub-atomic particles which are deflected by the electromagnetic force. Some large-scale interactions like the slingshot type gravitational interactions between satellites and planets are perfectly elastic.

Collisions between hard spheres may be nearly elastic, so it is useful to calculate the limiting case of an elastic collision. The assumption of conservation of momentum as well as the conservation of kinetic energy makes possible the calculation of the final velocities in two-body collisions.



Elastic collisions, target at rest

HyperPhysics***** Mechanics R Nave

Here elastic and inelastic are defined properly.

But the choice of wording is unfortunate:

- **"perfectly" = "nearly"**
- **both used as adjectives**
- **not part of name**

“Perfectly Elastic Collision”
From where does this come?

Paul Hewett - Conceptual Physics:

Inelastic Collisions

Momentum conservation holds true even when the colliding objects become distorted and generate heat during the collision. Whenever colliding objects become tangled or couple together, a totally **inelastic collision** occurs.



Elastic Collisions

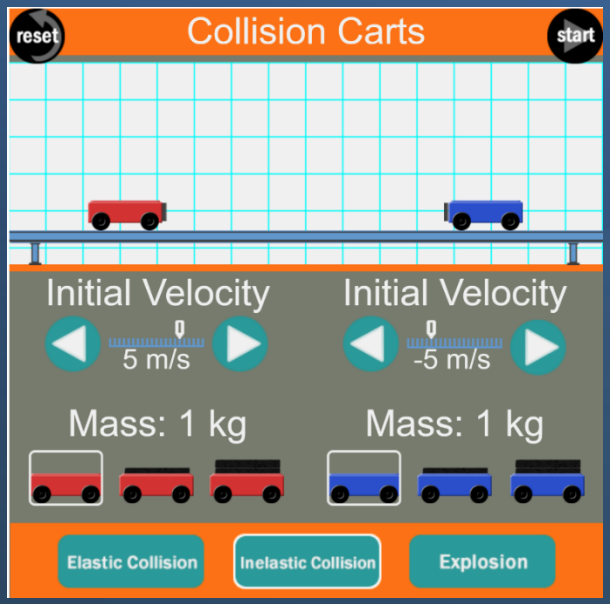
When a moving billiard ball collides head-on with a ball at rest, the first ball comes to rest and the second ball moves away with a velocity equal to the initial velocity of the first ball. We see that momentum is transferred from the first ball to the second ball. When objects collide without being permanently deformed and without generating heat, the collision is said to be an **elastic collision**.



Colliding objects bounce perfectly in perfectly elastic collisions.



Physics Classroom:

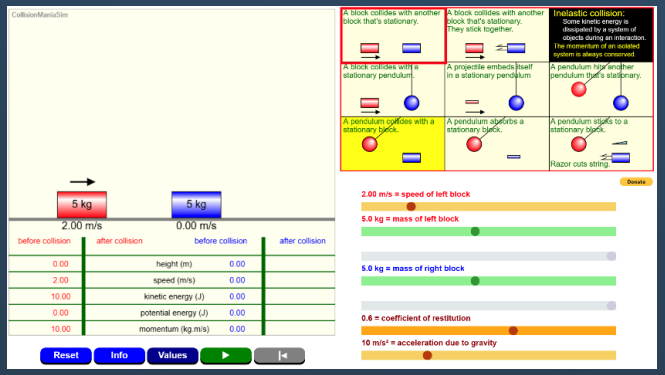


Until recently:

- Binary choice
  - Elastic

    no energy loss
  - Totally Inelastic

    labeled simply “Inelastic”



Only recently added

Collision Mania Sim from Martin Kirby

Properly identifies:

- Elastic
- Inelastic
- Totally Inelastic

- And specifies Coefficient of Restitution

Collisions: The Standard Definitions

- An **elastic collision** is a collision in which the total momentum is conserved, and the total kinetic energy of the system after the collision is the same as the total kinetic energy before the collision.

- An **inelastic collision** is a collision in which the total momentum is conserved, and the total kinetic energy of the system before the collision differs from the total kinetic energy after the collision.

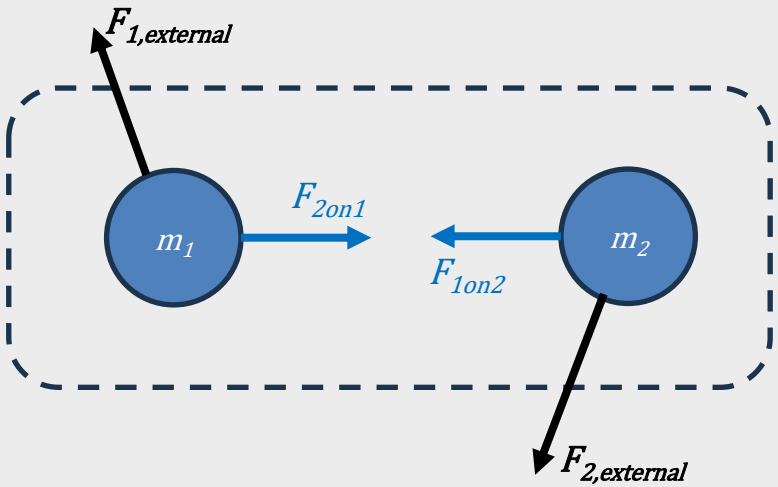
- A **totally inelastic collision** is a special case of an inelastic collision where the colliding masses fuse into one object as a result of the collision.

❖ **Perfectly elastic collision is not a thing!**

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Physics is easy if we are consistent
in how we approach a physical situation:

[Draw a Free-Body Diagram] and [Apply Appropriate Physical Law]



$$+ \quad \vec{F}_{net}\Delta t^{\ddagger} = \Delta\vec{p}$$

If $\vec{F}_{net} = 0$, then momentum of the system is conserved

‡ ***during the time interval*** Δt

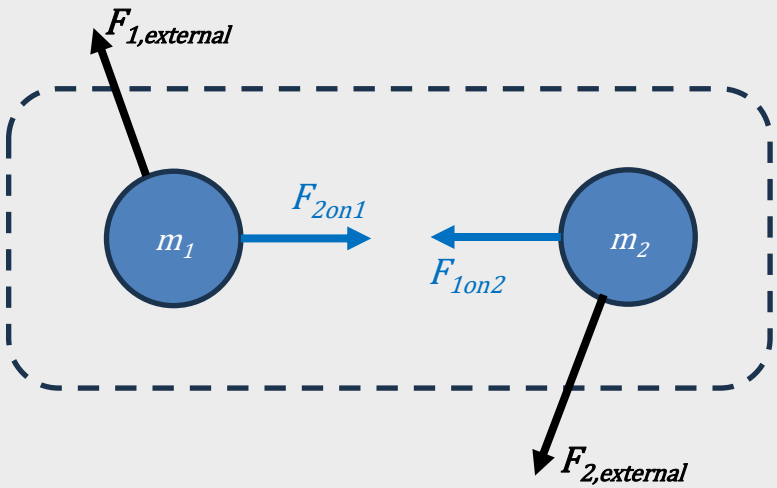
The Free Body Diagram defines:

- **the boundary of the system of two masses**
- **the external forces cutting through the boundary acting on each mass**
- **the internal forces within the boundary acting between the masses**

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Physics is easy if we are consistent in how we approach a physical situation:

[Draw a Free-Body Diagram] and [Apply Appropriate Physical Law]



$+$ $W_{net} = \Delta KE^{\ddagger}$

‡ ***comparing before and after the collision***

If no non-conservative forces act during Δt, then $\Delta KE_{tot} = 0$

– **Elastic Collision**

If non-conservative forces act during Δt, then $\Delta KE_{tot} \neq 0$

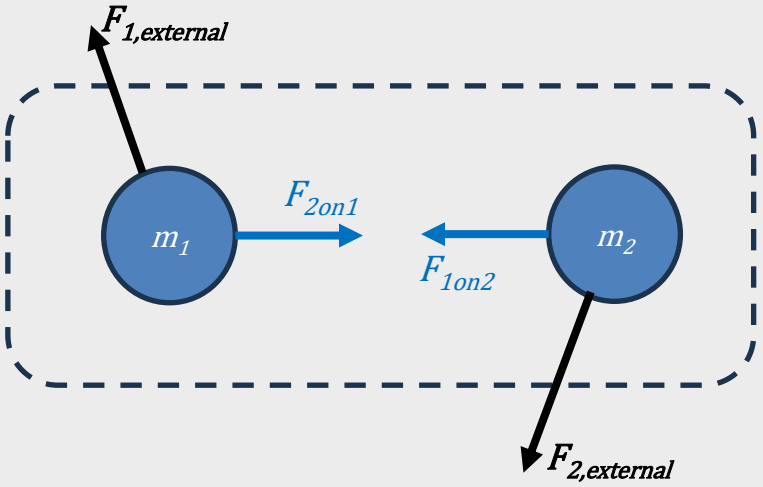
– **Inelastic Collision**

If $KE_{final} = 0$ in the center-of-mass reference frame:

– **Totally Inelastic Collision**

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What if the action-reaction force is long ranged?



$$+ \sum_{\substack{all\ forces \\ on\ 1\ and\ 2}} \int_{t_i}^{t_f} \vec{F} \cdot d\vec{x} = \Delta KE_{i \to f}$$

If no non-conservative forces act, then the sum of integrals is simply $(-\Delta PE)$.

Thus $\boldsymbol{\Delta ME_{tot} = 0}$ for the entire time.

– **Elastic Collision**

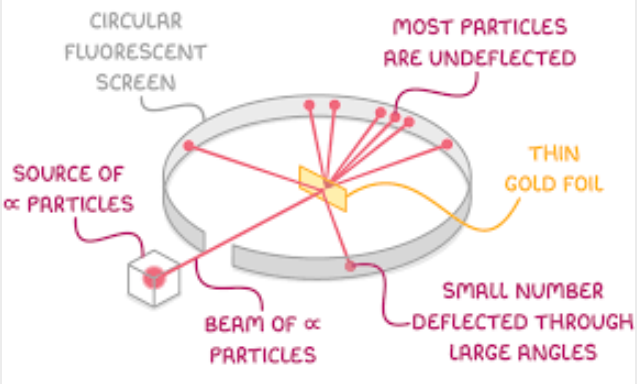
Thus, suppose there are two carts on a frictionless surface.

An ideal spring is attached to one of the carts.

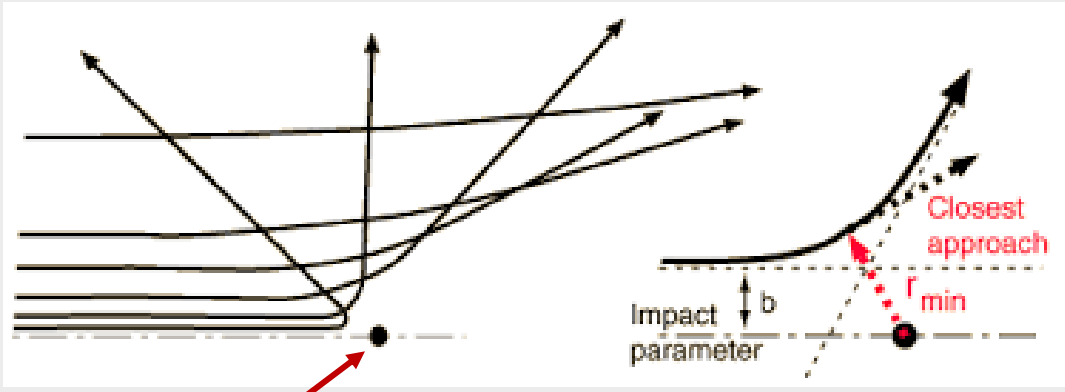
- During the collision, while the spring is compressing and then decompressing, the total kinetic energy is changing, but so is the potential energy.
- The total mechanical energy is the same, before, during, and after the collision.
- **The collision is elastic.**

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Rutherford Scattering
Elastic



Schematic diagram of experiment



Nucleus

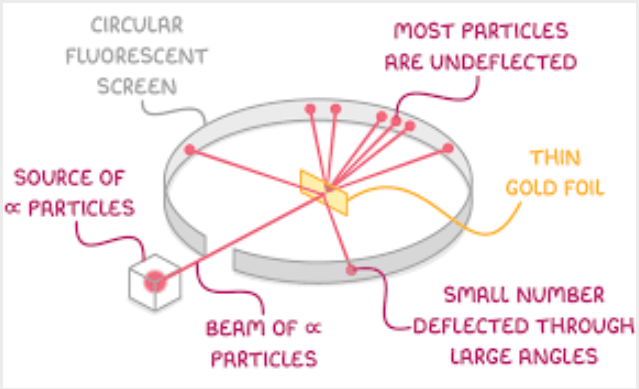
Atomic orbits are 100000 time larger larger

Assuming elastic collisions between the alpha particle and the gold nucleus, the experimental distribution of scattered alpha particles matches the calculated distribution pattern of scattered alpha particles if the nucleus is modeled as a sphere having the size of what we now know is the nuclear size of the gold nucleus.

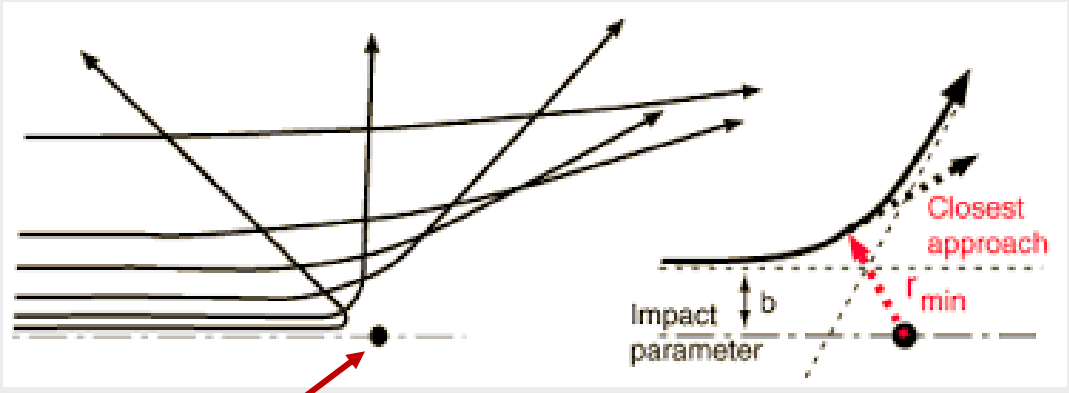
The KE of the alpha particles in the original experiment was such that the alpha particles did not get very close to the nucleus because of the electrostatic repulsion.

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Rutherford Scattering
Inelastic



Schematic diagram of experiment



Nucleus

Atomic orbits are 100000 time larger larger

Imagine increasing the KE of the alpha particles so that they can get much closer to the nucleus, or even overcome the Coulomb Barrier.

In this case, individual nucleons within the gold nucleus may then be excited to a higher energy level. In order to match the experimental alpha particle distribution, this energy loss must be accounted for.

In essence, we now must assume inelastic collisions between the alpha particles and the gold nuclei.

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Idealization vs New Physics

In high school and introductory college Physics, the emphasis is on the ideal at first, and then an introduction of some real-life complexity – but even that is often an idealized complexity. The assumption of speed independent sliding friction for instance.

If done well, students will then have the tools – the ideal – to allow them to investigate deviations from the ideal in a consistent and incremental way.

That is how real Physics is done. It is the deviation from established Physics that gives rise to "new" Physics that can then be investigated leading to a better understanding of the physical universe.

Physics is a set of well established laws and principles that are consistent with the definitions that we use.

At the center is the specification of the system under study. Given this system, we then consistently apply the appropriate laws. From this we then have a consistent set of definitions that we can all use without ambiguity.

Perfectly Elastic Collisions – it ain't a thing!

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Collisions Misconceptions Notes

Collision Misconceptions

Over the last few years, I have been interacting with many physics teachers from around the country in different forums. For whatever reasons, many have issues with the definitions surrounding different types of collisions. To avoid confusion, we must all adhere to the accepted definitions.

With regard to collisions, the standard definitions are:

- An **elastic collision** is a collision in which the total momentum is conserved and the total kinetic energy of the system is the same after the collision is the same as the total kinetic energy before the collision.

- An **inelastic collision** is a collision in which the total momentum is conserved and the total kinetic energy of the system before the collision differs from the total kinetic energy after the collision.

- A **totally inelastic collision** is a special case of an inelastic collision where the colliding masses fuse into one object after the collision.

A totally inelastic collision is often referred to instead as perfectly inelastic or completely inelastic. Also, a totally inelastic collision can be defined in terms of kinetic energy if we view the collision in the rest frame of the center-of-mass. In the center-of-mass rest frame, a collision is totally inelastic if the final kinetic energy of the system is zero. (The total initial kinetic energy goes into deformation and fusing the objects.)

If you are good with these definitions – great! If not, then you should probably read on.

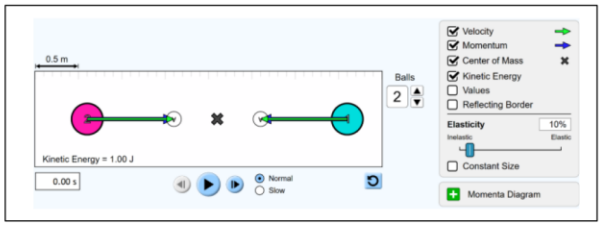
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Collisions Misconceptions Notes

Collision Misconceptions

The term **perfectly elastic** has crept up over the years with the idea that it is an idealization. While it is true that it is an idealization in the macroscopic world, it is not just an idealization in the microscopic realm. In fact, deviations from elasticity in scattering of subatomic particles has led to discovery of new particles, for example the discovery of neutrinos. Other idealizations, such as frictionless surfaces, or zero air resistance, etc., does not necessitate new cumbersome definitions. We simply recognize that it is an idealization and move on.

The use of "perfectly elastic" really took off with the advent of computer simulation software. In the image below taken from a Phet Interactive Simulation, notice that the Elasticity slide bar slides from "Inelastic" (0% elastic) to "Elastic" (100% elastic). Better would probably be



to scale it from "Totally Inelastic" through "Elastic" without a percentage elasticity value to confuse the issue making it seem that it is appropriate to speak of a collision being 75% elastic for instance – it is not! The elasticity, more appropriately called the coefficient of restitution, is the ratio of the relative velocity of separation to the relative velocity of approach. It is easy to understand what it means in the frame of reference of the center-of-mass of the colliding two-mass system. In the c.m. reference frame, an elasticity of 75% would mean that the recoil velocities of the two masses after the collision is 75% of the recoil velocity values they would have if the collision had been elastic. This, I believe, is a large reason for the inappropriate idea of a specific collision being a percentage of an elastic collision.

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Collisions Misconceptions Notes

Collision Misconceptions

There are a number of popular websites that take this to an extreme. On these websites, an "inelastic collision" is one where the objects stick (so totally inelastic), and an "elastic collision" is where the objects essentially just bounce, and the kinetic energy aspect may or may not be discussed.

The problem here is not really just confined to the definition of collision types. At the level of high school and introductory college level, Physics is not as complicated as people tend to think. There are strong unifying concepts that pervades all of Physics and allows for a small set of consistent definitions and concepts.

The concept of a system, defined as the masses within the boundary of a free body diagram, is the same definition for force, momentum, and energy discussions, and then energy, momentum, and force principles can be applied in a consistent manner.

So, since $\Delta\vec{p} = \vec{F}_{net}\Delta t$, momentum is conserved iff there is no net force acting on the system. So, for a system consisting of two colliding projectiles, momentum is conserved horizontally (assuming no air friction) but it is not conserved vertically because of the external force of gravity acting on the system.

We can also consider the nature of the forces acting between the two colliding masses. If there are any non-conservative forces acting between the masses, such as friction, then mechanical energy is not conserved during the collision, and the resulting collision is defined as inelastic.

On the other hand, if all forces acting between the masses are conservative, mechanical energy is conserved, and the resulting collision is defined as elastic.

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Collisions Misconceptions Notes

Collision Misconceptions

Notice that the reference is to mechanical energy that is, or is not, conserved, not kinetic energy. Typically, we consider collisions involving contact forces, springs or Velcro attached to rolling carts for instance, in which case there is a definite beginning and end to the collision. Any potential energy associated with the contact force would have returned to its original value, and we can then say $\Delta KE = 0$ for elastic collisions with contact forces.

So, the term elastic is referring to whether, or not, the contact force is conservative – whether there is a potential energy function associated with the contact force. So, there must be a bounce, but it must be an elastic bounce – one with no loss in energy due to permanent deformation, heat, sound, etc. Yes – it is an ideal, but to the same extent, for example, that Hooke's Law is an ideal for springs. Reversibility is at the heart of what it means to be elastic, just as in Hooke's Law.

With this more general definition based on mechanical energy conservation, we can investigate what happens during a collision, not just comparing before and after. For scattering between subatomic particles, if the energy is not too high, the only interparticle force is the long-range electrostatic force. Even though the total kinetic energy changes, the total mechanical energy is constant, and the collision is truly elastic.

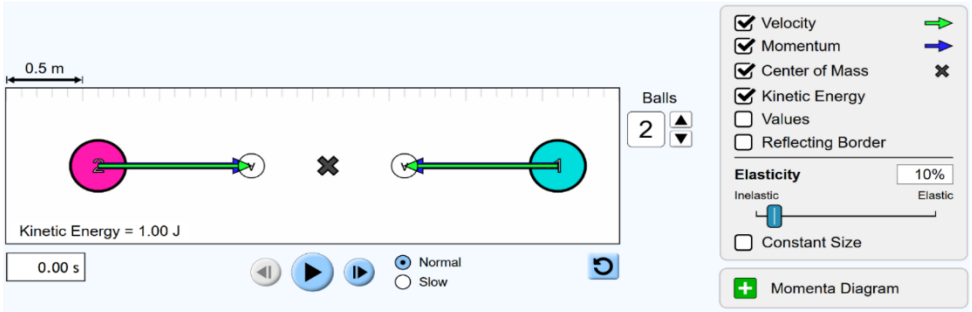
As the energy increases, it is the deviation from that ideal that can give us information about the nature of the strong and weak nuclear forces. This is often how physics knowledge advances – it is the deviation from the expected ideal that provides information on possible new physics.

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“Perfectly Elastic Collision”

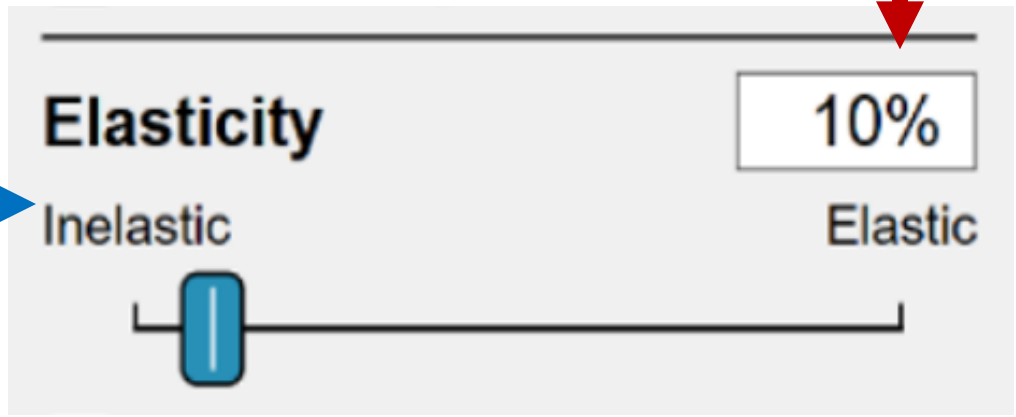
From where does this come?

Phet Interactive



This is NOT the percentage of elastic collision

Should be “Totally Inelastic”



Elasticity:

- **actually the Coefficient of Restitution**
- $= \frac{relative\ velocity\ of\ separation}{relative\ velocity\ of\ approach}$