



Physics Definitions for Arrow Penetration

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Date:

This page defines the core physics concepts used to analyze arrow impact, penetration, and energy loss. These definitions are grounded in classical Newtonian mechanics and apply to arrows as fin-stabilized projectiles interacting with resisting materials such as foam, tissue, and bone.

Mass

Mass is the amount of matter in an object and its resistance to changes in motion.

- Mass does not change with location.
- Mass determines how difficult an object is to accelerate, decelerate, or deflect.

In arrow physics, mass governs how the arrow responds to forces during flight and impact. It directly affects inertia, momentum, and kinetic energy.

Weight

Weight is the force of gravity acting on a mass.

- Weight depends on the strength of gravity.
- Weight changes with location.

In penetration physics, weight is not used because gravity does not stop an arrow during impact. The forces that stop an arrow come from the target, not gravity.

Why Mass Is Used Instead of Weight

Penetration is governed by how an arrow's motion is changed by resisting forces from the target.

- Newton's laws are based on mass, not weight.
- Gravity plays a negligible role during penetration.
- Target resistance, cutting force, friction, and impact forces act on mass.

For this reason, physics-based arrow analysis uses mass rather than weight.

Force

Force is an interaction that changes an object's motion.

Force can:

- Speed an object up
- Slow it down
- Change its direction

During penetration, the target applies resisting force to the arrow. This force comes from cutting, crushing, friction, and material deformation. That resisting force is what slows the arrow and eventually brings it to rest.

Work

Work is done when a force moves an object through a distance.

In penetration:

- The target applies a resisting force
- The arrow continues moving forward
- Work is done as the resisting force acts over penetration distance

Penetration only occurs because force continues acting on the arrow while it moves forward.

Kinetic Energy

Kinetic Energy (KE) is the energy an object has due to motion.

For an arrow:

- Kinetic energy represents its total ability to do work against resistance
- During penetration, kinetic energy is converted into work done on the target

When an arrow comes to rest, all of its kinetic energy has been expended as work against resisting forces.

Momentum

Momentum describes how difficult it is to stop an object over time.

Momentum depends on:

- Mass
- Velocity

Momentum governs how quickly motion changes during impact. It influences stopping time, not stopping distance.

Stopping Distance

Stopping distance is how far an arrow penetrates into a target before coming to rest.

Stopping distance is controlled by:

- The amount of kinetic energy available
- The resisting force applied by the target

In simple terms:

Stopping distance is an energy problem.

Stopping Time

Stopping time is how long it takes for an arrow to slow from impact speed to zero.

Stopping time is controlled by:

- Momentum
- Impulse (force applied over time)

In simple terms:

Stopping time is a momentum problem.

Why Distinction Matters

During penetration:

- **Energy** determines how far the arrow goes
- **Momentum** determines how long the stopping process takes
- **Force** from the target determines how quickly energy is removed

Different targets apply different force profiles. Foam, tissue, bone, blade sharpness, and geometry all change the resisting force acting on the arrow.

Newtonian Mechanics and Arrow Impact

Arrow penetration follows the same physical laws that govern all motion and impact: **Newton's Three Laws of Motion.**

Understanding these laws allows arrow behavior during impact to be analyzed using physics rather than correlation or anecdote.

Newton's First Law — Inertia

An object in motion remains in motion at constant velocity unless acted on by an external force.

After impact, an arrow continues moving forward due to inertia until the target applies a resisting force. Penetration occurs because the arrow resists being stopped while that force acts over distance.

Inertia alone does not cause penetration. Penetration occurs only when resisting force acts on the arrow while it continues moving.

Newton's Second Law — Force and Motion

Newton's Second Law governs how motion changes under force.

During penetration:

- The target applies a resisting force
- That force changes the arrow's velocity
- Momentum and kinetic energy are reduced

From the work–energy relationship, penetration depth is determined by how much kinetic energy the arrow can convert into work against resisting force.

In simple terms:

The arrow penetrates as far as its energy allows against the force of the target.

Newton's Third Law — Action and Reaction

For every force, there is an equal and opposite force.

When an arrow penetrates a target:

- The arrow applies force to the target
- The target applies an equal resisting force to the arrow

This resisting force removes the arrow's kinetic energy and brings it to rest.

Changes in cutting efficiency, blade geometry, sharpness, material hardness, and impact alignment all affect the resisting force applied by the target.

Lower resisting force allows kinetic energy to be converted into penetration over a greater distance.

How the Laws Work Together in Penetration

During arrow impact:

- **First Law:** The arrow continues moving due to inertia
- **Second Law:** The target's resisting force slows the arrow

- **Third Law:** Arrow and target apply equal and opposite forces

Penetration continues until the arrow's kinetic energy has been fully converted into work against resisting force.