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Understanding Penetration: A Newtonian Perspective.

An Introduction to the Physics of Penetration

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Introduction

Penetration happens when a moving object enters a material that resists its motion. Regardless of the object or material, the same laws of physics apply.

This paper explains how Newton's Laws of Motion, momentum, kinetic energy, and the Work-Energy Theorem work together to explain penetration. Together, these principles explain why an object slows down, how it transfers energy into a target, and why it eventually comes to rest.

Moving Object
(Momentum & KE)
→
Impact
→
Target Resists Motion
(3rd Law)
→
Object Slows
(2nd Law)
→
Energy Transfers
(Work-Energy)
→
Penetration Ends

Newton's Laws of Motion

Newton's three laws describe how motion changes during penetration.

Newton's First Law

An object at rest remains at rest, and an object in motion remains in motion unless acted upon by a net external force.

This law tells us that an object's motion does not change by itself. During penetration, the target provides the net external force that changes the object's motion.

Newton's Third Law

For every action, there is an equal and opposite reaction.

As the moving object pushes against the target, the target pushes back with an equal and opposite resisting force. This resisting force opposes the object's motion throughout penetration.

Newton's Second Law

Newton's Second Law explains how that resisting force changes the object's motion.

$$F = ma$$

where

F = Force
m = Mass
a = Acceleration

The greater the resisting force, the greater the object's deceleration. As the object slows, its velocity decreases until it eventually comes to rest.

Momentum

Momentum measures the amount of motion an object has. Momentum depends on both an object's mass and velocity. In general, the greater the momentum, the more difficult the object is to stop.

$$p = mv$$

where

- **p** = Momentum
- **m** = Mass
- **v** = Velocity

During penetration, the resisting force continuously reduces the object's momentum until it reaches zero.

Momentum answers one important question:

How difficult is the moving object to stop?

Kinetic Energy

Kinetic energy is the energy an object has because it is moving.

$$KE = \frac{1}{2}mv^2$$

where

- **KE** = Kinetic Energy
- **m** = Mass
- **v** = Velocity

As the object penetrates, its kinetic energy is transferred by cutting, crushing, stretching, fracturing, and moving material out of the way. Every inch of penetration requires the transfer of kinetic energy.

Kinetic energy answers one important question:

How much energy is available to perform work?

Why Momentum and Kinetic Energy Are Both Important

Momentum and kinetic energy are closely related because both depend on an object's mass and velocity. However, they describe different properties of motion and answer different questions.

Momentum measures the amount of motion an object has, while kinetic energy measures the energy available to perform work.

Neither one replaces the other.

For example, two objects can have similar momentum but different amounts of kinetic energy, or similar kinetic energy but different amounts of momentum. Because they describe different physical properties, both are needed to fully understand penetration.

Together, they provide a more complete Newtonian description of penetration than either quantity alone.

The Work-Energy Theorem

The Work-Energy Theorem connects force, distance, and kinetic energy.

$$W = \Delta KE$$

where

- **W** = Work
- **ΔKE** = Change in Kinetic Energy

Work is defined as a force acting through a distance.

$$W = Fd$$

If the resisting force remains constant,

$$Fd = \Delta KE$$

This relationship shows that penetration requires work. As the object moves through the target, work is performed against the resisting force. That work comes directly from the object's kinetic energy.

Once all of the object's available kinetic energy has been transferred into the target, penetration stops.

These principles are summarized by four fundamental equations. Each equation describes a different part of the penetration process. Together they explain how motion changes, how resisting forces act, and how energy is transferred during penetration.

Summary

Penetration is not explained by a single equation or physical quantity. Instead, it is the result of several physical principles working together.

- **Newton's First Law** explains that an object's motion changes only when acted upon by a net external force.
- **Newton's Third Law** explains why the target pushes back.
- **Newton's Second Law** explains how the resisting force slows the object.
- **Momentum** measures the amount of motion an object has and helps explain how difficult it is to stop.
- **Kinetic Energy** measures the energy available to perform work.
- **The Work-Energy Theorem** explains how that energy is transferred into the target during penetration.

These principles are summarized by four fundamental equations:

$$F = ma$$
$$p = mv$$
$$KE = \frac{1}{2}mv^2$$
$$W = Fd = \Delta KE$$

Together, these equations provide a Newtonian framework for understanding penetration. They explain how any moving object interacts with a resisting material, how its motion changes, and how its energy is transferred until it eventually comes to rest.