A Simple Guide to the Physics of Penetration

This paper is a simplified companion to the full technical paper.
"General Physics Framework for Penetration."

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Abstract

Penetration occurs when a moving object uses its energy to push into a material. As the material pushes back, the object slows down and eventually exhausts its energy. This paper explains penetration through basic physics concepts such as energy, force, drag, shape, and stability. The aim is to clearly demonstrate how any object enters any material and why it stops when its energy is depleted.

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1. Introduction

Penetration may seem complex, but the basic physics behind it is actually simple. Any object that enters a material does so by using its kinetic energy. The material pushes back, and this resistance consumes the object's energy. How deep the object penetrates depends on its initial energy and the resistance the material provides.

This paper explains penetration with simple, easy-to-understand physics. It does not focus on any particular tool or example. Instead, it presents general rules that apply to all objects and materials. These ideas can be useful in science, engineering, and many situations where one object pushes into another.

Acknowledgment of Inspiration

This paper was inspired by discussions with Joel Maxfield, who encouraged a deeper exploration of the basic physics behind penetration. While this paper remains focused on simple first-principles physics, his interest in understanding these ideas helped motivate this work.

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2. Work, Energy, and Penetration

When an object is in motion, it possesses kinetic energy. The basic formula for it is:

$KE = ½mv^2$

Speed is more important than weight because speed is squared in the equation. When an object hits a material, the material pushes back and slows it down. This consumes the object's energy. Work is the energy used to push against a force.

$W = F \cdot d$

Penetration stops when the object uses up all its energy. More initial energy leads to deeper penetration. Greater resistance from the material results in less penetration.

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3. Energy, Momentum, and Slowing Down

Kinetic energy (KE) is the energy an object possesses due to its motion.

$KE = ½mv^2$

Speed increases energy more than weight does. Momentum indicates how difficult it is to slow something down.

$p = mv$

Energy determines how far an object can travel. Momentum determines how gradually that energy is used. When the energy runs out, the motion comes to an end.

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4. Material Resistance

When an object enters a material, the material pushes back, and this is known as resistance.

Harder materials resist more, consuming energy quicker. The material must also move, stretch, or break for the object to pass through, which also requires energy.

Penetration depth measures the amount of energy the object has compared to how much energy the material consumes.

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5. Drag

Drag is a force that pushes against an object as it moves through a material. Faster objects experience more drag and lose energy quickly at the start. Shape also influences drag: smoother shapes encounter less drag, while wider shapes encounter more.

More speed = more drag = more energy used per inch.

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6. Geometry

The shape of an object influences how effectively it penetrates. A narrow front makes initiating entry easier. A smooth shape requires less energy to move through material.

Good shape maintains force in motion and prevents the object from twisting or wasting energy.

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7. Structural Stability

A rigid object penetrates more effectively. If it bends or twists, energy is lost and resistance goes up.

A straight, strong object uses its energy effectively and penetrates more deeply.

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8. Deceleration Curve

Objects slow down rapidly at first because drag is strong at high speeds. As they decelerate, drag decreases, and the object loses energy more gradually. Eventually, the object uses up its last bit of energy and comes to a stop.

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9. Mechanical Advantage

Gentle angles facilitate easier material movement, reducing energy use. Steep angles demand more force and waste additional energy.

A good mechanical advantage indicates that the object efficiently uses energy and penetrates deeper.

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10. Conclusion

Penetration depends on energy, resistance, shape, stability, momentum, and mechanical advantage.

The basic idea is that energy moves things forward, and the material pushes back. When the energy runs out, the motion stops. This applies to all objects and materials.