Karate Through the Eyes of Newton

by Bruce Green

"Sufficiently advanced science is indistinguishable from magic." – Arthur C. Clarke

Introduction

Many people resist discussions of science, but as a part of modern society it can hardly be ignored. Science plays an important part in our understanding of many human activities, including martial arts. The science of physics deals with the laws of matter and energy. Mechanics is the branch of physics that describes how objects move. This article explains the physics of karate techniques, based on Newton's Laws of Motion.

Speed, Mass, and Force

In karate, speed, mass, and force are inseparably connected. (For our purposes, speed and velocity are the same, as are weight and mass). In physics, momentum is the term that connects the concepts of speed, mass, and force. Momentum is evident when a given mass (weight) is accelerated to any velocity (speed). The greater the mass or velocity, the greater the momentum. In karate, greater momentum means more impact force —

When executing karate techniques, we generate speed for two reasons. First, greater speed means better penetration of your opponent's defenses. Second, assuming that mass remains the same, greater speed means more force is generated. This is important because one measure of a karate technique's effectiveness is the force generated by that technique. The breaking of boards and other material represents a test of force.

We also try to use the entire body when executing a technique. Much like a baseball player who tries to get his "body behind the ball" when hitting, we try to put our body behind a technique. For example, by correctly shifting the body forward, we get our body behind the technique and increase the mass involved, thus increasing the force delivered by that technique. The stepping punch is a good example of this concept.

The relationship between force, mass, and speed is described by Newton's Second Law of Motion where force (F) equals mass (m) multiplied by acceleration (a): $F = ma$. In karate this law of physics illustrates the relationship between force, weight (mass), and speed (acceleration).

Focus or kime is another example of getting the entire body behind a technique. Tensing the muscles in the correct sequence is crucial to creating the proper transmission of force. When the muscles are tensed, at the moment of impact, a series of musculoskeletal connections increases the mass (weight) involved in a technique, increasing its force.

If muscles are loose at the moment of impact, they and the surrounding joints will absorb much of the force of impact. This has the effect of disconnecting the mass of the body from the technique. Consequently, momentum is decreased, and the technique loses force.

Energy and Force

Energy can be defined as the capacity for doing work. In karate, energy is expended and work is accomplished when the muscles are used to perform a technique. The use of the muscles is characterized by the two states of energy: potential and kinetic. Energy stored in a compressed spring is potential energy. The energy of a moving body is called kinetic energy.

Potential and kinetic energy are evident in the way we use our muscles in karate. When muscles are contracted or tightened, potential energy is available. Upon release of this tension the energy of motion (kinetic energy) is made available. The more the muscles are contracted, the greater the amount of potential energy. The greater the amount of potential energy, the greater the kinetic energy upon release of the contracted muscles. Finally, the greater the kinetic energy, the greater the force which can be delivered against a target.

For our purposes, force can be defined as the amount of push exerted upon an object. The

relationship between speed and force was explained above. From Newton's Second Law of Motion, we know that force is increased if speed

Photo by William Berg

Breaking requires precise application of force.

is increased. Maximum contraction of the right muscles, followed by rapid release, is critical to developing maximum speed, and thus maximum force, in karate techniques.

Karate techniques convey large impact forces to a target. When this force is delivered using a part of the body with a small surface area, such as the knuckles of the fist or the ball of the foot, considerable pressure (force divided by area) is conveyed to the target. Similarly, when this force is employed against a small target area, enormous pressure is created and is capable of producing shock and breakage.

Motion and Direction

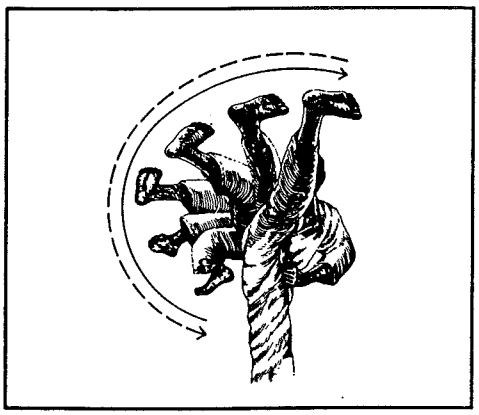
The shortest distance between two points is a straight line. When speed is held constant, a baseball thrown from third base to first base will arrive sooner if thrown in a straight line rather than an arc. This concept is exemplified by a stepping punch where the punching fist travels in a straight line to the target. (This emphasis on the importance of linear motion does not mean that all karate techniques are, or should be, linear.)

A force is conveyed to a target most effectively when it intersects at a right angle. When delivered at an oblique angle, some of the force is deflected away from the target and the technique is weakened. A block is strongest if it meets the technique at a right angle.

In some situations, however, we avoid blocking a technique at right angles (meeting force with force). It may be better to deflect the technique by meeting it at an oblique angle. Proper judgement and experience will determine when to block at perpendicular or oblique angles.

"Snap-back" or quick recoil in techniques, such as snap kicks or back-fist strikes, involves the concept of angular momentum. Angular momentum is a force generated by rotational motion. The whip-like motion in these techniques uses the principle of angular momentum to generate force. In a reverse punch, hip rotation generates angular momentum. This force is then conveyed in a straight line to the target. In some techniques, speed is additive. For example, in a stepping punch, the hips move forward with speed "A". During the stepping motion, the fist moves forward and away from the body with speed "B". Speeds A and B can be added together for the total speed (terminal velocity). The addition of these two speeds increases the momentum and force of the technique. This is why combining bodyshifting with a punch, kick, or block generates so much force.

We often hear that karate is linear in its movements and techniques. This is a crude generalization at best. Many techniques contain a circular motion as a part of a linear motion. The straight punch is a good example. The fist travels in a straight line toward the target, but the forearm and fist rotate at the same time. Forearm and fist rotation is evident when executing many blocks. This rotation of the forearm helps deflect some of the force of an attack. This type of rotational motion also serves to: 1) align and position the body parts involved in performing the technique, 2) better position the striking surface for impact, and 3) increase the length of reach.



Effectiveness of the roundhouse kick depends on quick recoil.

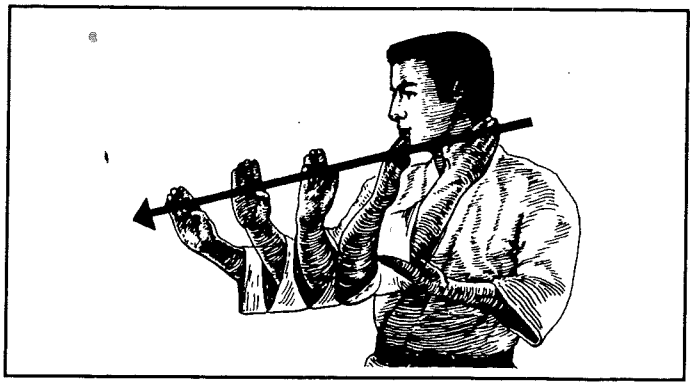
Finally, Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. Application of this concept is most clear-

ly seen with the draw-hand. In blocking and punching, the draw-hand is pulled rapidly back while the other hand moves forward. The draw-hand functions as an equal and opposite reaction. It provides a counter-force during a technique that helps maintain stability and posture.

Stances, Stability, and Geometry

In his book **The Textbook Of Modern Karate,** Okazaki sensei uses the term projection area to explain how stability and stances are related. Projection area is the total area within the boundaries made by foot contact with the floor. Stances with large projection areas, such as front stance and rooted stance, provide strong and stable foundations. Other stances with smaller projection areas, such as back stance, hourglass stance, and cat stance, are not as strong and stable, and are used more for defensive purposes.

Stability is just one reason we need a strong stance. Newton's Third Law (for every action there is an equal and opposite reaction) tells us that a counterforce will occur during the impact phase of a technique. This counterforce is transmitted back against the body that initiated the original force. If the stance is weak, the lower body and legs will absorb the counterforce and the stance may buckle and collapse. A strong stance is critical to the effective transmission of a attack or

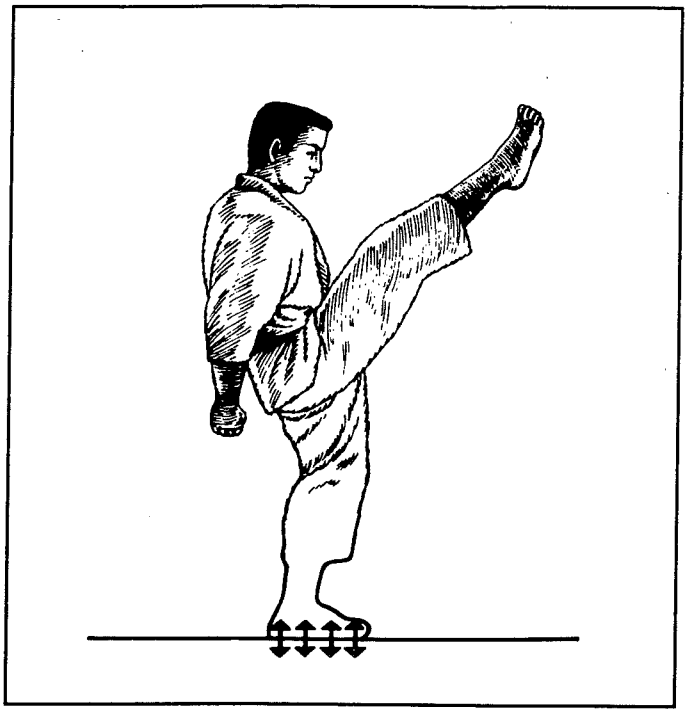


Sword hand strike illustrates rotation within a technique

blocking force and to withstanding the counter-force.

Without body stability and balance, we cannot respond quickly and effectively to a changing situation such as a multiple attack. Posture and a low center of gravity are also important because they relate directly to stability and balance.

As you lean out over your body's center of gravity, you become more unstable. The higher your center of gravity, the more unstable you be-



come as you lean. Without proper attention to these considerations of stance and geometry, instability, loss of balance, and defeat may result.

Conclusion

Karate is known for its devastating techniques. This capacity has been popularized in superhuman terms: the world high-jump record seems meaningless when you see how high martial artists can jump in the movies! In real life, however, karate is still incredibly potent. Science can help us understand the nature of this devastating potency.

This article has related several laws and concepts of physics to karate techniques. These laws and concepts are like the ingredients in a recipe. By themselves, they have little impact. When combined in a good recipe, the results are impressive indeed.

Further refinement of karate-do is quite probable, as techniques are analyzed in an unceasing effort to improve them through a scientific approach. -- **Masatoshi Nakayama**

(Bruce Green is an instructor with the JKA of Boulder, Colorado.)