Physics Behind the Martial Arts
Part Three
by Les Burton*

* Les has a Ph.D. in Physics and over 25 years in the martial arts.

Topics

- **Friction**
- **Pressure**
- **Angular Momentum**
- **Elevator Down concept**
- **Effects of Rotation**

Note: I would recommend that the physics articles be read in order listed as I define terms in earlier physics articles that are assumed in the later physics articles.

Introduction

Martial Arts can be thought of as applied physics to the body for defense or offense against an opponent. In Martial Arts you are applying forces against an opponent and leverage against the body structure. In defense, you would be blocking or immobilizing an opponent. In offense, you would striking or applying joint locks to an opponent. Of course there is overlap, like the old saying that "a good offense is a good defense."

Physics is the branch of science concerned with the nature and properties of matter and energy. The subject matter of physics, distinguished from that of chemistry and biology, includes mechanics, heat, light and other radiation, sound, electricity, magnetism, and the structure of atoms. For Martial Arts, we will be looking at the mechanical part of physics.

In these physics articles, I have tried to explain some of the basic concepts of physics, including a definition of a physics concept and an everyday example. Hope-

fully I also related the physics concept to some Martial Arts examples and applications.

I hope you won't get uptight with the word “physics.” You do not have to follow each concept in detail, unless you wish. You do not have to understand it all. You do not have to read every word at one sitting. Take a quick look. Look at just one concept. Look at the everyday examples. Look at the results of calculations and numbers, not the calculations themselves. Think about how the martial art examples are similar to the everyday examples. This will still allow you to get a feel of the overall concepts. Hopefully, an understanding of the basic concepts of physics will give you a more in-depth understanding of, and how to better apply, your martial art training.

Happy reading.

Friction

The term friction refers to the resistive forces that arise to oppose the motion of a body past another with which it is in contact. When one object slides across another, the very small roughness of the surfaces catch on each other and exert forces.

Friction forces are always opposite to the direction of motion or ever the tendency toward motion. (i.e these frictional forces always try to slow up a moving object or keep an object from moving.) Another way of looking at it, is that frictional forces always do negative work, they take away energy from a system.

Sliding (kinetic) friction is the frictional resistance a body in motion experiences.

Static friction is the frictional resistance a stationary body must overcome in order to be set in motion. Usually static friction is greater than that of sliding. Rolling friction refers to the resistance a circular object experiences as it rolls over a smooth, flat surface: rolling friction is much smaller than those of sliding friction.

Hence, there can be static friction when an object is not moving, but trying to, and kinetic friction, when the object is moving.

In pulling a person, you do not have to completely grab a person in a tight hold, you can use the friction between your hand and the person's arm to help you apply force.

Pressure

Pressure is a measurement of a force on a surface divided by the surface area the force is actually being applied to.

Pressure = force / area

For example, we talk about the air pressure being 15 lb. per square inch. This is a large value. If the air pressure was on one side of a regular door, the force of the air on the door would be over 45,000 lb. The reason we do not notice air pressure is that there is an equal amount of force from air pushing from the inside of our bodies out, as there is force pushing outside of our bodies inward, so that the forces are balanced. This is similar to when a tire is pumped up. We do feel the force of the air on us when it is not balanced inside and out, say during explosive decompression of an airplane high up in the air.

Why strike with only the first two knuckles of your fist? This allows the same force to be applied to the target, but in a smaller area. Thus increasing the pressure of the strike. You probably have had your foot stepped on. This hurts. However, it hurts a lot more (but in a smaller region) if the lady is wearing spike heels when she steps on you.

This is like a book on the table. It has a certain weight (force of gravity) on the table. If you turn it on its end, the weight is the same but the area of the book touching the table is smaller, hence the pressure will be larger.

There is a difference in objectives between eastern martial arts like karate and western styles of empty-hand fighting like boxing. Karate style martial artists use

quick controlled strikes to injure their opponent and at the same time to maintain their balance in case of counter-strikes. In contrast western boxers use less controlled punches with long deliveries and follow-through, that are designed to knock their opponents over. A western style boxer hits with their whole fist or glove, and imparts a large amount of momentum to the entire mass of his opponent, pushing him back.

The karate style martial artist concentrates their blows on a small area of the target and seeks to terminate them about a centimeter inside it. They imparts a large amount of momentum and energy to a small area of the opponent's body, an amount that is capable of breaking tissue and bone. The karate style martial artist may hit with the front two knuckle punch, extended knuckles of the hand, finger tips, elbow, ball of the foot, edge of the foot, or instep. This will increase the pressure of the strike, even though the force of the strike is the same. This increase in pressure will cause more damage to the body of the opponent, not only to the skin, but to deeper organs inside the body. In self defense, we usually wish to cause more damage to our attacker.

The reason boxers starting to use gloves was to reduce the injuries they received during a fight in the ring.

If we assume for a karate punch the contact is your first two knuckles which have an area of about one inch square. Remember that a typical punch generates a force of about 500 Newtons.

Then, pressure = 500 N / square inch = 34,000,000 N / square meter. This is over 33 times that of the pressure of the air on our bodies.

Angular Momentum

Angular momentum is similar to linear momentum but going in a circle.

Remember that for linear momentum

linear momentum = mass • velocity

Then for angular momentum

angular momentum = mass • velocity • radius

The difference is the radius of the circle the object is moving in.

One of the major concepts in physics is the concept of conservation. Here conservation is defined as a system will not gain or loose the thing that is being conserved. We can have conservation of energy, linear momentum, and also angular momentum.

suppose that at one time angular momentum was m • v • r, and then at a later time the angular momentum is still m • v • r.

Hence m • v • r = m • v • r

This is like saying that 4 • 10 = 4 • 10

Now suppose the system changes from the before to after case by decreasing the radius. If angular is momentum to be conserved, the decrease in one term, must be counteracted by an increase in another term. This in general will be the velocity.

Then m • v • r = m • V • $_{r}$

Note the larger velocity and the smaller radius.

This is like saying that 4 • 10 = 8 • 5.

Think of spinning a ball at the end of a string. It has a radius and a certain speed. Now if you stick your finger up to catch the string and cause the string to get smaller as it spins around your finger, the speed of the spinning ball get faster. We would say that angular momentum is still the same, in other words conserved. Angular momentum rotation increases with a smaller circle.

Consider an attacker approaching a defender. the defender can side step the attacker as he grabs the attacker's arm, assisting the attacker in continuing in the direction of his motion momentarily. Blending their masses together, the defender can convert the linear momentum of the attacker into angular momentum of rotation. Now decreasing the radius of rotation of the attacker will increase his speed. If the defender now stops his own rotation, conservation of angular momentum says that the attacker will gain almost all of the momentum of the combined system of bodies. This will cause the attacker to loose his feet and fall to the ground.

Elevator Down concept

The Earth exerts enough force to accelerate objects that are dropped at a rate of 9.8 m/s^2, or 32 $feet/s^2$. This gravitational force is often referred to as "g" in physics equations. If you drop something off a cliff, for each second it falls it will speed up by 9.8 m/s. So, if it falls for five seconds, it will reach a speed of 49 m/s. This is a pretty fast rate of acceleration. If a car accelerated this quickly, it would reach 60 miles per hour (97 km/hr) in less than three seconds!

The Sikal concept of "elevator down" makes use of this. If you just lift up both feet at the same time (do not jump upward), you will accelerate downward at the highest speed possible. This is great for ducking under an opponent's punch or adding momentum and body mass to a strike on a person that is below you or on the ground.

Effects of Rotation

Remember a straight linear punch can generate a force of 500 N and about 50 J of energy. If instead of a linear punch, we use a hook, so that we can use rotational motion at the hips. This will cause the upper half of the body to rotate, the shoulder to extend, and the arm to gain distance so that it can be accelerated through the target, and thereby increase the speed of the strike.

The force of this type of punch will increase to about 700 N and the pressure to about 47,000,000 N / square meter. This is a large increase in force and pressure due to rotation mechanics.

This type of punch can generate about 100 J of energy, This means that adding rotational motion into a linear movement can increase the energy output considerably, allowing for a much more destructive and powerful strike.