Physics Behind the Martial Arts
Part One
by Les Burton*

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Topics

- **English and metric measurements**
- **Definitions**
- **Torque and the Leverage Arm**
- **Newton's Three Laws of Motion**

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. Hopefully 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.

English and metric measurements

In the United States, measurements are usually still made in what is called the English System of measurements (using distance in feet and inches, and weight in pounds). In most of the world, including England now, measurements are in the metric system (SI system) (using distance in kilometers, meters and centimeters, and weight in Newtons). World wide, only three countries, Liberia, Burma, and the United States, do not use the metric system.

For a comparison:
1 inch = 2.54 cm
1 meter = about 39 inches (a little over a yard since 1 yard = 36 inches)
1 Newton = 0.225 pounds or 1 pound = 4.45 Newtons
1 kilometer = 1000 meters = 0.62 miles

When I run, I always like to say I ran 2 kilometers instead of saying I ran 1 mile. Doesn’t 2 sound better than 1? :-)

By the way, abbreviations are as follows:
kilometer = km
meter = m

centimeter = cm
Newton = N
miles = mi
inch = in
pound = lb
hour = hr
second = s
Joule = J

Definitions:

speed, v

The rate at which distance is covered by a moving body with time.
Example: 100 km/hr = 62 mi/hr

velocity, v

The speed and direction of an object. Note that formally velocity includes the direction it is moving in, however this is usually implied. When you execute a punch, you are punching at a person, not away from him. A lot of the time, speed and velocity are used interchangeably.

A rocket ship moving at a speed of 7 mi/s will escape the earth. Note that the rocket will have to be moving in the upward direction. If the rocket is moving downward, it will crash into the earth, not escape it. So direction of motion is important here.

acceleration, a

The change of an object's speed, or direction, or both. It is caused by a force. We talk about the acceleration of a car, or the acceleration of the earth.

When you throw a punch, you must get the punch up to a high speed, usually from rest (not moving). Therefore you will have to accelerate your fist.

A high acceleration will cause damage to the organs and other parts of the body. Hence a large force on the body will cause damage to the body.

mass, m

The quantity of matter in a body. More specifically, it is the measurement of the inertia or sluggishness that a body, in the absence of friction, exhibits in response to any effort made to start it, stop it, or change in any way its state of motion. Mass is not weight, however. An 10 pound object on the Moon would have the same amount of matter, hence have the same mass, as on the Earth. But the 10 pound object on the Moon would have a weight of only 6 pounds.

In the metric system, the unit is the kilogram (kg) or the gram. 1 kg = 1000 grams. On the earth, a 1 kg mass has the weight of 2.2 lb. (9.8 Newtons).

The English unit for mass is the slug. If you hit someone with a mass, you slug him. I guess this is where it got its name. The slug unit is not used very much anymore.

force, F

Force can be defined intuitively as a push or a pull which tends to produce a change of motion. A more formal definition is any influence that can cause a body to be accelerated.

The English unit of force is the pound (lb), and the metric unit for force is the Newton (N).

The weight of an object can be considered the force of the earth puling down on that object.

Note that a typical straight punch generates a force of about 400 to 500 Newtons. This is why you should not practice ending a punch with you arm extended completely. The force you have to produce to stop your fist can hyper-extend your elbow.

When you are on top of a person, you will exert your weight (the force of gravity) on your opponent. Note that your amount of weight the floor is directly holding up is not being exerted on your opponent.

Torque and the Leverage Arm

Torque is the ability to start rotation around some pivot point. Remember that a force is a push or pull that can start an object moving is a straight line. Well, torque will cause an object to start rotating. You can think of torque as rotational force. A rotational force will cause a rotational push and hence generate a rotational acceleration.

When you change a tire on a car, you use a lug wrench to take the lug nut off the wheel. Why not just use your fingers? Well, the short answer is it is too hard to turn the nut with just your hand. But with the lug wrench you can turn it with your hand using the same force. What is the difference? With the lug wrench you have a greater leverage arm and can exert greater rotational effort called torque.

So, a torque is a force with a leverage arm distance from the pivot point.

Torque = Force • leverage arm

Another example is opening a door. If you push near the hinges, a short distance from the hinge (a small leverage arm), it is hard to rotate the door. However, if you push near the door knob, a large distance from the hinges (a large leverage arm), the door is easy to open, even if you use the same amount of force (push).

This concept is applied against an opponent. If you wanted to rotate your opponent, you would not push on the center of his chest because there is no lever arm from your applied force to his rotational center of mass. You would push against the edge of his shoulder to cause him to rotate around his center of mass. For even greater leverage, you could apply your force at his arm, say at the elbow,

Newton's Three Laws of Motion

1st law: (Law of Inertia)An object not moving will continues to not move, or if moving, will continue to move in a straight line and at the same speed, unless it is made to change its speed or direction by a force.

If there is no force, the object will keep on doing what it is doing. We do not see this often on the earth, since there are a lot of hidden forces action on objects all the time, such as forces from rough surfaces (friction), air resistance, etc. The space ship, Voyager I, is now leaving our solar system at a speed of 46,000 miles/ hour. It will keep drifting at this speed and will travel the distance to the nearest star in about 58 thousand years.

In fighting, we apply the concept of inertia, by getting out of the way of a charging person, since his own inertia will make it hard for him to stop. If you do not get out of the way, their inertia will make it hard for your to stop them. You will have to apply a large force to overcome their inertia.

2nd law: If there is a force on an object, the object will either change its direction of motion, or change its speed, or both. The acceleration of a body is directly proportional to the net force acting on the body and inversely proportional to the mass of the body.

Force = mass • acceleration

That is, the more force you apply to an object, the greater the rate of acceleration; but the more mass the object has, the lower the rate of its acceleration.

Forces can be applied to the body to cause compressional tissue damage (opponent’s arm caught directly between your hand and your elbow), or shearing damage (your hand and elbow not on the same line resulting in a possible broken bone).

3rd law: (Law of Action and Reaction) To every action force there is an equal and opposite reaction force. When you push on an object, the object will, in turn, push on you. Note that there must be two objects; the one pushing, and the one being pushed. You can not propel yourself forward by patting yourself on the back.

If you are going to push on an opponent, you need to be braced against something like the ground, or you will be thrown off balance as well as your opponent.

If you have fired a shotgun, you remember the feel of the recoil of the gun back into your shoulder (reaction) as the shotgun pellets fly out of the gun forward (action).

In a like manner, if you keep your arm tense when you strike a person, the shock of hitting will recoil back into you and will lessen the power delivered to your opponent. This is why you should let your arm relax immediately after your strike hits. The recoil will just go into your fist and not travel back into your body.