Physics Behind the Martial Arts
Part One
by Les Burton*

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

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.

Physics Behind the Martial Arts
Part Two
by Les Burton*

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

Topics

- **Center of Mass**
- **Momentum**
- **Impulse**
- **Work**
- **Energy**
- **Power**

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.

Center of Mass

The center of mass of a body is the average position of mass, or the single point associated with a body where all its mass can be considered to be concentrated. It is that point from which it can be suspended in any orientation without tending to rotate. On a person, this is where you can lift that person with one hand.

The average position of weight, or the single point associated with a body where the force of gravity can be considered to act is called the center of gravity. The weight of a body can be considered as a downward force acting on its center of gravity.

In a uniform gravity field, the center of gravity is usually at the same point as the center of mass.

This is the point where an object could be balanced, if on a pivot.

This is also the point that if a force is applied to an object, through this point, the object will not rotate, but only move in a straight line. This point in in the vertical center of the human body and about the hip area. If you wish to move a person off of you, you need to push near their center of mass. If you apply a rotation force to a person, they will tend to rotate about their center of mass.

Momentum

The **linear momentum** of a body is the product of its mass and velocity.

Linear momentum = mass • velocity

Linear momentum is a vector quantity whose direction is that of the body's velocity.

The greater the momentum of a body, the greater its tendency to continue in motion. Thus a baseball hit by a bat (large velocity) is harder to stop (take away the momentum) than a baseball thrown by hand (small velocity), and an iron shot (large mass) is harder to stop than a baseball (small mass) of the same velocity.

Think about which you could stop. A baseball moving at a speed of 100 mi/hr or a car moving at the same speed of 100 mi/hr. The car, having so much more mass, would have a much greater momentum and hence be much harder to stop.

Momentum can also be transfered from one person to another. We could talk about exerting a force and accelerating an object to a velocity, but we can just look at it as transferring momentum. sometimes this is easier.

A large momentum could be a fist (small mass) at a high velocity. However it could be a smaller velocity with the fist backed up by your whole body in the punch (large mass).

An example of the first case could be a jab with the fist at a high velocity.

An example of the second case could be a hook with the whole body behind the punch.

Impulse

Impulse is the force applied to an object times the amount of time the force is applied. If you apply a force to an object, the object will change its speed, Hence it will change its momentum. Therefore, impulse is also equal to change in momentum.

Impulse = Force • time interval = mass • change in velocity

Work

Whenever a force affects the motion of a body, the body undergoes a displacement while the force acts on it. The product of the force and the component of the displacement of the body in the direction of the force is called the work (W), done by the force on the body. Work, as defined by Physicist, is a very narrow and precise definition. Work is force applied in the direction of movement times the distance moved.

Work = Force • distance

In the metric system the unit of work is the Joule (J) and in the British system it is the foot-pound (ft • lb).

Note that if there is no movement, there is no work done.

Work would be done to a nail by applying a force to it, and driving it a distance into a wall.

Note that when you do work, you create energy. Also when you use energy, you do work.

Energy

The ability to do work. The metric unit for energy is the Joule (J).

In mechanics, there are two types of energy, kinetic energy and potential energy. By the way, non-mechanical energies could be sound, electrical, heat, or radioactive.

Kinetic Energy

The Greek word for motion is kinetic. Therefore Kinetic Energy is the ability to do work by the virtue of being in motion.

Kinetic energy, KE, of an object is energy due to both of the mass and velocity (speed) of that object.

KE = 0.5 • mass • velocity • velocity
KE = 0.5 • mass • velocity squared

Note that velocity is used twice in this equation and mass is used only once.

A bowling-ball, moving along the floor, can hit a nail and drive it into the wall, and thus do work. A low mass object, like a balloon would not drive the nail into the wall. A bowling-ball, not moving, or moving very slow, would not drive the nail into the wall.

A punch throw at an opponent has both mass of your fist and velocity. Hence it has kinetic energy. When the punch hits your opponent, that energy can be delivered to your opponent. The typical fist has 0.61% (0.56%) of the male (female) body mass.

In the case of kinetic energy, mass is a factor, but its the square of the object's speed that is a factor. If you triple the object's mass, you triple its kinetic energy, but if you triple its speed, your increase its kinetic energy by a factor of nine times, not just three.

Hence, speed is more important than mass, and a person will want to maximize speed in a strike. In a hand strike, the maximum speed in not at the end of the strike (since the hand has to stop and retract) but about 4/5 of the way out. This is why instructors tell you to try to terminate the punch about a fists length inside your opponent. this will help insure that you are at your maximum speed when you make contact with your opponent.

Note that a typical punch generates about 20 - 50 Joules of mechanical energy and a force of 500 Newtons.

The typical front punch has a maximum speed between 6 m/s and 10 m/s. The typical front kick has a speed between 10 m/s and 15 m/s. The typical mass of the leg can be up to 20% the mass of the body, while the mass of the arm is only 10%. Both from the large mass of the leg compared to the arm and the faster speed of the foot, the energy delivered by the kick is three to six times the energy delivered by a straight punch.

The effective mass of the arm can be increased by stepping forward into the punch. However, this is at the expense of your stability and balance. Hence, increasing the speed of your punch is usually a better way to generate more energy for your punch.

Potential Energy

Potential energy, PE, of an object is energy due to height of an object above the earth. It involves the object's mass, m, height above the earth, h, and the acceleration of gravity of the earth, g.

$$PE = m \bullet g \bullet h$$

A ball, let go above a nail, can fall, hit the nail, and drive it into the floor, and thus do work.

Dropping down on an opponent with your knees would be an example of using your potential energy of your body above your opponent. Note the the more mass you have the more potential energy you have.

It is easier to hit a person when you are mounted on him and can then utilize the potential energy advantage, than it is to hit a person who is mounted on you.

If sparing, you usually need to conserved your energy. Remember to be quick, not fast. That is, move smoothly and without hesitation, instead of moving with jerks, or needing to move fast because you are out of position. Keeping your body at the same height is also important for conserving energy. Every up-and-down movement by only 20 cm (7.8 inches) uses almost as much energy as a punch thrown at a speed of 7 m/s.

Power

The time rate at which work is done is called power. (i.e. Power is the amount of work done per unit time.)

It is a measure of how fast you exert your energy.

Power = energy / time = work / time

The metric unit is the watt (W). The units of the Watt = Joules / second
and in the British system it is the ft-lb/s.

One horsepower is equal to 746 W or 550 ft-lb/s. The definition of horse power comes from experiment. A typical english horse could pull a 550 lb. sled a distance of one foot in a time of one second.

Suppose you go up ten flights of stairs. Since you have lifted your body mass up the ten stories, you have done a certain amount of work and thereby increased your potential energy. Now, this is true if you walk up the stairs or run up them. However, the power used is greater if you run up the stairs since you took less time. Note that you also will feel much more tired if you run.

By the way, our electric power company does not care how fast you use their energy (e.g. the power), but only how much energy is used. Hence you pay for energy not power. Our electricity cost less than 10 cents for 3,000,000 J of energy. A 100 Watt light bulb uses 100 Joules each second. This is less than 10 cents in 24 hours.

The power of a strike is how fast we can deliver energy to the target. due to the inertia of your opponent, a high power strike allows more energy to be delivered to a relatively stationary target. a low power strike will tend to push your opponent backwards.

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. 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.

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.

Physics Behind the Martial Arts
Part Four
by Les Burton*

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

Topics

Physics Analysis of Martial Arts: Board Breaking

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.

Physics Analysis of Martial Arts: Board Breaking

For completeness, and for those who enjoy seeing every step, I have including the math here with the physics equations. You do not have to follow each step in detail, unless you wish. Looking only at the results will still allow you to get the overall concepts.

A well-executed karate strike delivers to its target several kilowatts (thousands of watts) of power over several milliseconds (one thousands of a second), quite enough to break blocks of wood and concrete. For a linear punch, the hand of the practitioner of karate can develop a peak velocity of 6 m/s to 10 m/s ((18.7 ft/s and 32.15 ft/s)) and has a mass of 0.65% (0.56%) of the male (female) body mass. For a faster strike, the overhand strike, the hand can have a speed of 10 m/s to 14 m/s.

For a 70 kg (155 lb.) male, the hand would have a mass of 0.46 kg and the forearm would have 1.14 kg of mass.

For the hand alone, at 10 m/s, the

$$KE = 0.5 \cdot m \cdot v \cdot v$$
$$KE = 0.5 \cdot 0.46 \text{ kg} \cdot 10 \text{ m/s} \cdot 10 \text{ m/s}$$
$$KE = 23 \text{ Joules.}$$

And at a speed of 14 m/s, the hand would deliver 45 Joules of energy.

The force needed to break the ribs of a person corresponds to the energy needed to break a one inch thick pine board one foot by one foot square. The energy needed is about 30 Joules. It would seem that an overhand strike can break the board, but that a linear punch can not.

The average forearm has a mass of 1.63% (1.38%) of the male (female) body mass. Using proper bone alignment of fist and forearm, a part of the mass of the foreman can be considered added to the fist. This enables more energy to be delivered in the linear punch. (This analysis is much more difficult for the hammer strike, since the fist is moving in an arc, the forearm is not moving as fast as the end point of the arc, the fist. Also the forearm is not in line behind the fist when it hits.)

For our 70 kg male, At 10m/s, the energy from the forearm alone will be 57 Joules, adding this value to the fist and we get a total of 80 Joules of energy.

Since the total mass of the forearm may not contribute, the total energy will be less, say about 40 or 50 Joules. However, this is well over the 30 Joules needed to break the board.

Note: This information should only be used to increase your knowledge of the martial arts. It is not meant to be used without the supervision of a qualified instructor.

It should be noted that the energy needed to break the hand is considerably more than that needed to break the pine board (or a rib). Therefore, when done with proper technique, we do not need to worry about the hand. However, I have seen cases where improper technique such as wrong bone alignment can cause a sprained or broken wrist.

Another thing that can happen is that the person, trying to break the board gets cold feet and does not follow through with the punch allowing the board to stop the hand, without breaking the board. This will deliver a large change in momentum to the hand, the hand going from high speed to zero in a fraction of a second. I have seen this case a number of times. If the person is going slow enough, it will only hurt or bruise, but it can and has resulted in a broken knuckle.

Newton's 3rd Law says that if you exert a force on the board by your hand, then the reaction to that would be the force the board exerts on the hand.

We can use the concept of Impulse to calculate the force on the hand by the board.

Force • time interval = mass • change in velocity

Solving for the force we get

Force = (mass • change in velocity) / time interval

Assume the mass of the fist for a male of 70 kg, and the change in speed to be from 10 m/s to 9.8 m/s, and the time interval to be one hundredth of a second.

Force = (0.46 kg) (0.2 m/s) / 0.01 s
Force = 9.2 Newtons

This value of force is not enough to cause damage to the hand.

However, if the board does not break, then the change in speed will be from 10 m/s to zero.

Then
Force = (0.46 kg) (10 m/s) / 0.01 s
Force = 460 Newtons

This is a factor of 50 times, a tremendous increase.

Even if these numbers are not completely accurate for a given case, they show relative results that should be in the ballpark.