# The Physics of Karate

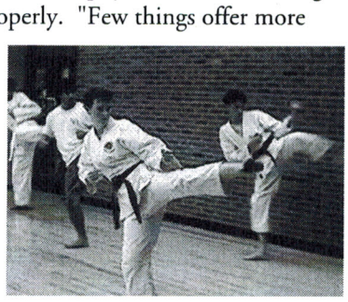
**Outcomes:**

1. Analyze natural and technological systems to interpret and explain their structure and dynamics (116-7).
2. Describe the functioning of a natural technology based on principles of momentum (116-5).
3. Apply Newton's Laws of motion to explain the interaction of forces between two objects (325-8).
4. Apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions (326-3).
5. Interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables (214-5).
6. Compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (214-3).
7. Use appropriate language and conventions when describing events related to momentum and energy (114-9).

## Introduction

What kind of person would intentionally bring their hand or foot crashing down onto a slab of wood or concrete? A daredevil? A Hollywood stuntperson? As it turns out, that kind of person is simply someone who understands the physics of karate - someone like you!

Karate means "open or empty hand", and began as a form of weaponless combat in 17th century Japan. In recent years it has become popular in our culture, as a form of fitness, self-defense and self-expression. Karate participants - called Karateka - often break concrete or wooden boards as a demonstration of the strength developed through training. Surprisingly there are no tricks involved in accomplishing such a feat. What is involved is a physics-based knowledge of how to do it properly. "Few things offer more visceral proof of the power of physics than a karate chop. Punch a brick with your bare hand, untutored in the martial arts, and you may break a finger. Punch it with the proper force, momentum and positioning and you'll break the brick instead" (Rist, 2000).



## Theory

### *Force, Speed and Area*

Karateka agree that the secret to karate lies in the force, speed and focus of the strike. The more quickly a board is hit, the harder the strike. Maximum hand velocity is actually achieved when the arm reaches 75-80% of extension. Since the hand cannot move forward a distance greater than the length of the arm, it must have a velocity of 0 at full arm's extension. To get the hardest hit, contact must be made with the object before this slowdown begins. Thus a good karate chop has no follow-through (as would a good tennis or golf swing). The hand is typically in contact with the object for fewer than five milliseconds.

How fast can a karate punch actually move? Experiments done with a strobe light on karateka throwing punches found that beginners can throw a punch at about 6.1 m/s (20 feet/sec), while black

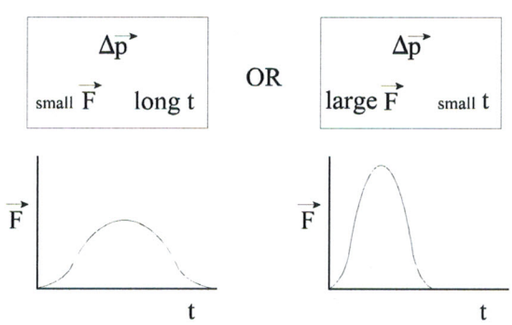
belts could chop at 14 m/s (46 feet/sec). At the latter speed a black belt can deliver about 2800 N to the object being hit. (Splitting a typical concrete slab requires only about 1900 N). A concrete slab could probably support a force of 2800 N if it were not concentrated into such a small area. Minimizing the striking surface of the hand, and therefore the area of the target being hit, maximizes the amount of force and energy transferred per unit area. To understand why speed and focus are so important, the principles of momentum and impulse must also be considered.

### *Momentum and Impulse*

Momentum ( $\vec{p}$) is defined as an object's mass x velocity. Change in momentum, ( $\Delta\vec{p}$) is defined as impulse (symbol $\vec{\mathcal{J}}$ ), and is given by force x time. According to Newton's third law momentum is a conserved quantity. The third law states that for every action force on an object in a given time, there is an equal and opposite reaction force by that object for the same amount of time. Thus, any momentum lost by the first object is exactly gained by the second object. Momentum is transferred from one object to the other. Using,

$$\vec{\mathcal{J}} = \Delta\vec{p} = \vec{F}t$$

we can see that if $\Delta\vec{p}$ remains fixed, then force and time are inversely proportional. This means that if force increases, than time decreases and vice versa. It follows that a fixed amount of momentum can then be transferred with a small force for a long time or with a large force for a short time.




The quicker the karateka can make the chop, the larger the force transferred to the target. According to Newton's second law ( $\vec{F} = m\vec{a}$ ) the part of the object struck with this force will begin to accelerate or oscillate. Breakage occurs if the small area hit accelerates enough relative to the stationary ends of the object. The object will experience strain and begin to crack from the bottom up.

What about the strain experienced by the hand or foot? Fortunately bone can withstand about forty times more force than concrete. Hands and feet can withstand even more than that due to the skin, muscles and ligaments which absorb much of the impact. Despite possessing these "natural shock absorbers", breaking wood, concrete or bricks should not be attempted without proper training. Such training would include toughening up the hand and knowing exactly how and where to hit the object with maximum speed. Over time the knife edge of the hand, called the "shuto", develops a callous which acts to absorb the collision force. As well, experts know to only hit things that can actually be broken. Sihak Henry Cho, a grand master at the Karate Institute in Manhattan sums it up nicely: "Being good at karate is a lot like being good at telling a joke. It's not what you break; it's how you break it" (Rist, 2000).

## Questions

1. Why is it important to hit a concrete slab quickly when attempting to break it?
2. Karate black belts often advise beginners before their first attempt at breaking, not to try to break the board, but to aim for the floor underneath the board. How would this advice help?
3. Research: Karate practitioners usually yell "Kiai" when striking an object. Research the meaning of this term?

**PHYSICS 2204**
**STSE- The Physics Of Karate**

Student Name:_____

**PART A: MULTIPLE CHOICE:** Place the correct answer in the space provided on the answer sheet.

1. What does "karate" mean?

(A) Closed or full hand
(B) Hard kick
(C) Soft kick
(D) Open or empty hand

2. Where did karate begin?

(A) Canada
(B) China
(C) Japan
(D) Twain

3. What name is given to people who study karate?

(A) Karateka
(B) Kung fu fighter
(C) Ninja
(D) Samurai

4. Which of the following can be used to explain the secret of karate?

(A) Area
(B) Force
(C) Speed
(D) All of the above

5. What percentage of arm extension will achieve maximum hand velocity?

(A) 20 - 30%
(B) 50 - 60%
(C) 75 - 80%
(D) 85 - 90%

6. A good karate chop will have no follow through like tennis or baseball:

(A) True
(B) False

7. How long is the hand in contact with the board?

(A) Exactly 5 milliseconds
(B) Fewer than 5 milliseconds
(C) More than 5 milliseconds
(D) The article does not indicate the time

8. What force is required to break a concrete slab?

(A) 6.1 N
(B) 14 N
(C) 1900 N
(D) 2800 N

9. How fast is a karate punch?

| | Beginner | Black Belt |
|---|---|---|
| (A) | 6.1 m/s | 6.1 m/s |
| (B) | 6.1 m/s | 14/ m/s |
| (C) | 14 m/s | 6.1 m/s |
| (D) | 14 m/s | 14 m/s |

10. What is change in momentum defined as?

(A) Impulse
(B) Force
(C) Time
(D) Work

11. According to the Impulse- Momentum Theorem, what occurs by making quick chops at a target?

(A) Decrease in force
(B) Increase time
(C) Increase in force
(D) No change in time

12. How much force can bone withstand?

(A) 4 times more than concrete
(B) 14 times more than concrete
(C) 24 times more than concrete
(D) 40 times more than concrete

13. You should not attempt breaking wood, bricks or concrete without proper training?

(A) True
(B) False

**PART B: LONG ANSWER QUESTIONS**

1. Why is it important to hit a concrete slab quickly when attempting to break it?

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3. Research: Karate practitioners usually yell "Kiai" when striking an object. Research the meaning of this term

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