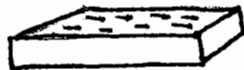


Karate

The Science of Breaking Boards

by C. Brin

Why is everyone always picking on me?
What did I ever do to these karate folks?

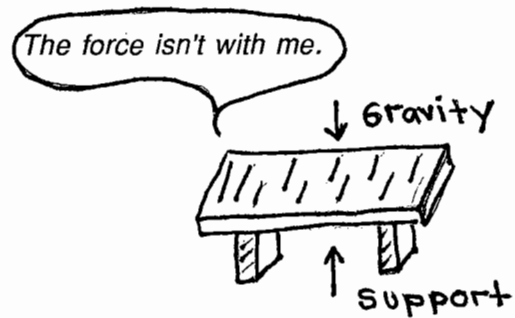


In the beginning

the board isn't moving.

So the sum of all forces
acting on the board is zero.

Gravity's downward pull equals
the upward support of the blocks.



The basic laws describing how things
move date back to English scientist
Sir Isaac Newton (1642 - 1727).
Newton's 1st law is:

**"An object at rest will stay at rest
unless a force acts upon it."**

Scientists call this inertia.

Inertia is the tendency to resist any
change in motion.

A board at rest tends to stay at rest.
A karate chop has to overcome the
board's inertia.

Excuse me, I'm resting.



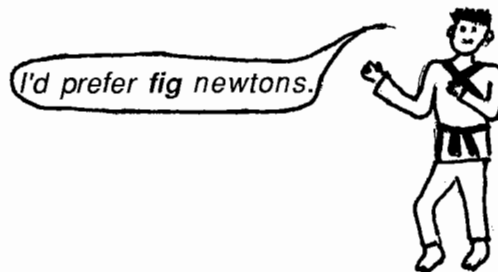
A force is a push or a pull.

Forces can move things.

Karate Kid uses his arm to exert a
pushing force.

The strength of a force is measured in
units called **Newtons**.

Splitting a 1 and 1/2 inch thick concrete slab
requires a force of about 1,900 Newtons.



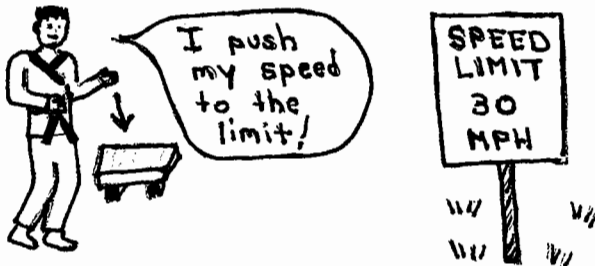
How do we get a force large enough to break a board?

Karate Kid has to move his arm very quickly, over a distance from his torso to the board.

Speed is defined as the distance divided by time:

$$\text{Average speed} = \text{total distance} / \text{time}$$

Michael Feld and Ronald McNair clocked a karate master's chop at a speed of 46 feet per second, or 31 mph, yielding a force of 2,800 Newtons.



Speed in a particular direction is called **velocity**.

Karate Kid doesn't punch at a constant velocity. His fist starts at zero, and speeds up.

A change in velocity is called **acceleration**. When you put your foot on the gas, the car accelerates.

$$\text{Acceleration} = \text{change in velocity} / \text{time}$$

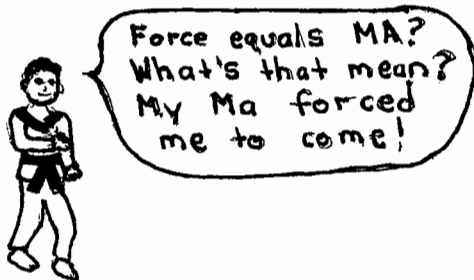


Isaac Newton has more to say:
Newton's second law says:

"The larger the acceleration, and the larger the mass, the larger the resulting force."

$$\text{Force} = \text{mass times acceleration}$$

often written as: $F = m \times a$



Mass is the amount of matter.

How much does an arm weigh?

Karate kid tenses his muscles just before impact. This links his arm to the rest of his body, so he can use his entire body to increase mass.

The more mass, the more force.



What about acceleration?
 Karate Kid needs to increase the velocity of his chop.
 He can do this by increasing the distance his arm travels. Why?
 More distance gives him more time to accelerate to high velocity.

**The more acceleration,
 the more force.**

The force is with you, Luke.



I'm a Jedi master, not a karate master!



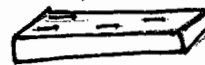
Physicists have another word to describe motion:

Momentum is the 'oomph' of impact.

Momentum is mass times velocity

For instance, a bowling ball has more momentum than a tennis ball. It transfers a lot more 'oomph', and would cause more pain upon impact.

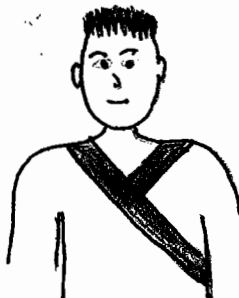
You missed me, you missed me....



Karate Kid needs to transfer momentum to the board.

To do this, he needs a large force over a small time.
 The karate chop takes place in the blink of an eye.

I missed it. I must have blinked.



Other karate students work to stabilize the board. If the board moves backward, it will absorb the force of the impact, rather than breaking.

*Does anyone want to know my life story?
 I started as a tiny seed, grew into a tall pine tree....*



It's not enough to apply force. Karate kid also needs to impact the board with as little of his hand as possible.

$$\text{Pressure} = \text{force} / \text{surface area}$$

The smaller the surface area,
the larger the pressure.

I can't stand the pressure, I'm breaking up.

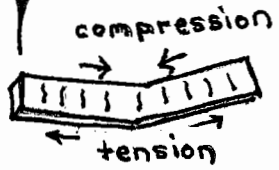


Pressure on the board leads to two types of stress:

A stretching force is tension.
A squeezing force is compression.

When the force surpasses the **tensile strength** of wood or concrete, the board breaks.

I'm very tense.
I'm under a lot of stress.



Less pressure is required, if the board is broken along the grain.

Wood consists of long, fiber-like molecules of **cellulose**. These long chains of carbon, hydrogen and oxygen form fibers which give wood its grain.

You can see this by tearing a piece of newspaper. Compare the ease of tearing up and down, with ripping side to side.

Excuse me,
but I haven't read the paper yet!



There's another part to Newton's first law:

"An object in motion will stay in motion, unless a force acts upon it."

For instance, a ball will continue rolling, until the force of friction slows it down.

In this case, Karate Kid's arm will continue moving until it meets the board, and transfers momentum.

I want to keep moving.

I want to stay still.



Finally, Newton's Third law states:

"For every action, there is an equal and opposite reaction."

In other words, if you push on a board, the board pushes back just as hard on you.

Hal I knew I'd get back at him somehow.



So, we have all the **ingredients** of a successful karate chop:

A board oriented along the grain, and held securely.

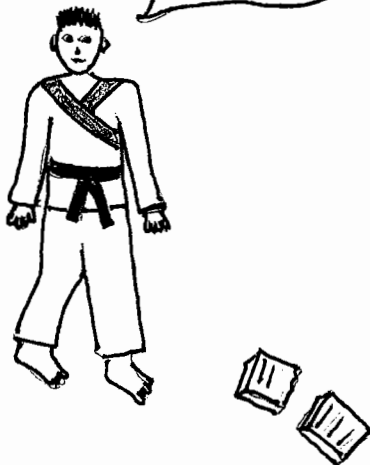
Sufficient body mass, an arm moving with enough velocity, focused on a small surface area, to yield a force which can surpass the tensile strength of the board.

Mix them all together, and what do you get?



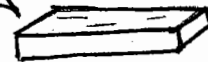
And the result is:

Azaa!



**Success!
A broken board.**

Now, finally, I get to tell my side of the story....



I started life as a tiny seed, inside a pine cone, so full of hope. As I sprouted and reached toward the sky, my dreams grew bigger and bigger.

I wished to become a house, a ship to sail distant seas. But then, the sawmill (horrors!), sawn into slices.

Stacked in Home Depot.

Sold at a discount.

Chopped to smithereens by some karate kid.....

*Wait, there's more to tell...
Hey, is there going to be a sequel?*