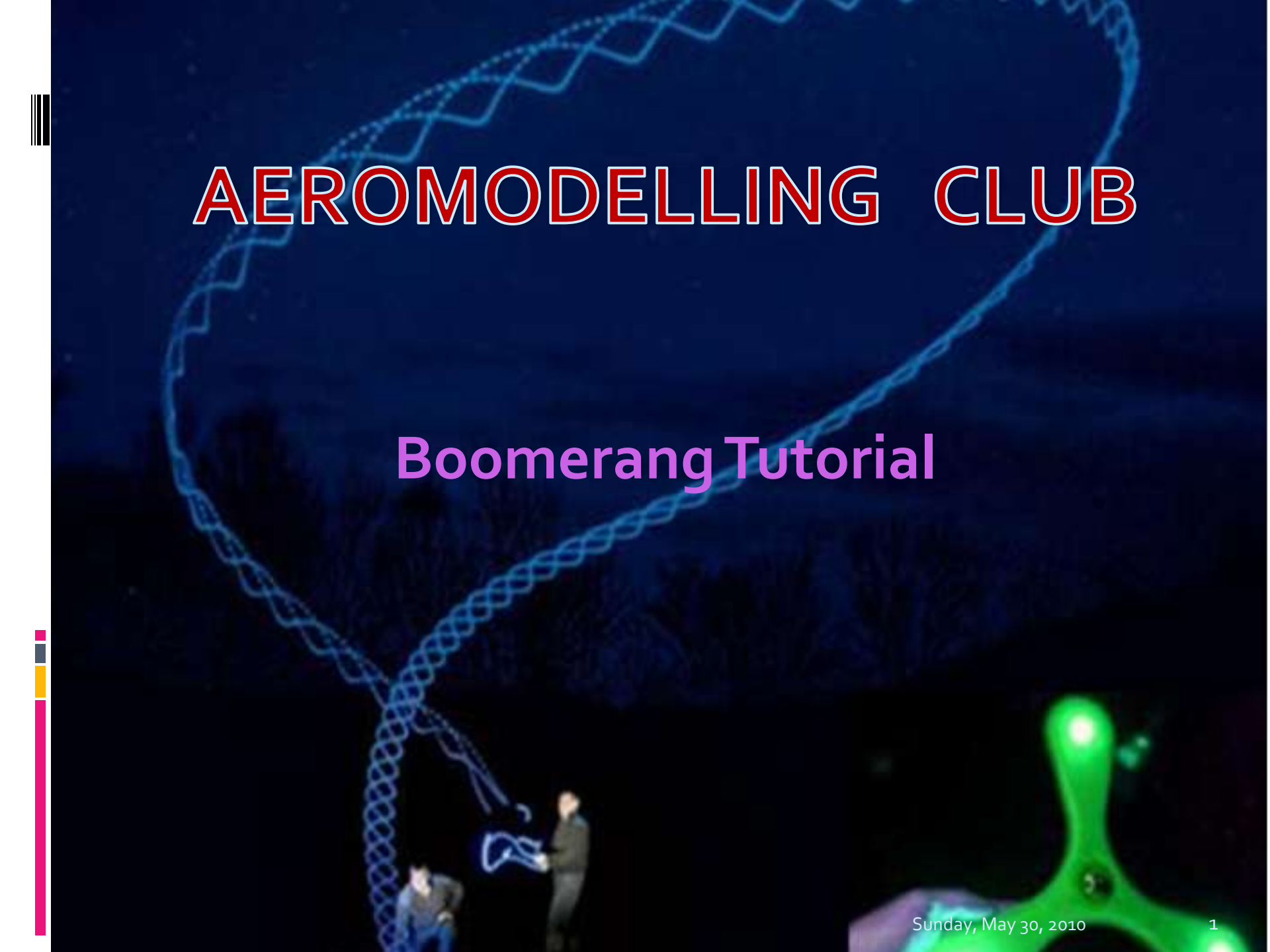
AEROMODELLING CLUB

Boomerang Tutorial



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What is boomerang?

It is a bent or curved piece of tough wood (or any other material), which can be thrown so as to return back to the thrower.

It is a scientific marvel as it envisions the aerodynamic as well as aviation principles coupled with theorems of Physics which were surprisingly utilized thousands of years before they were even invented.

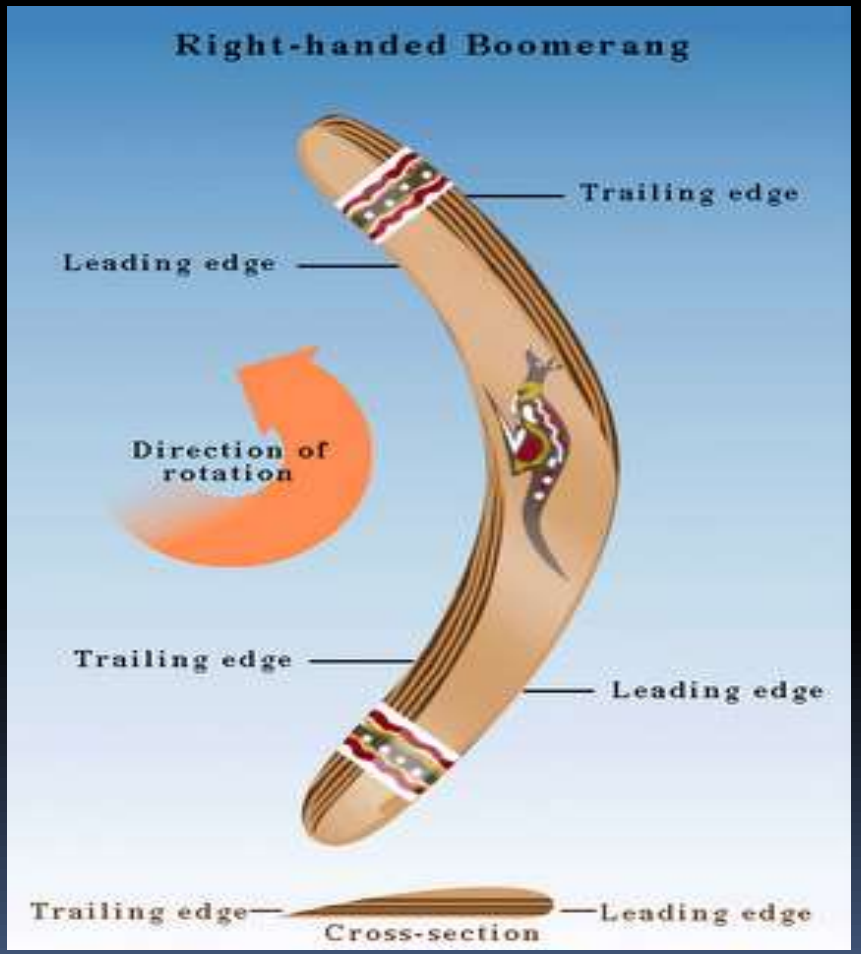
History of boomerang

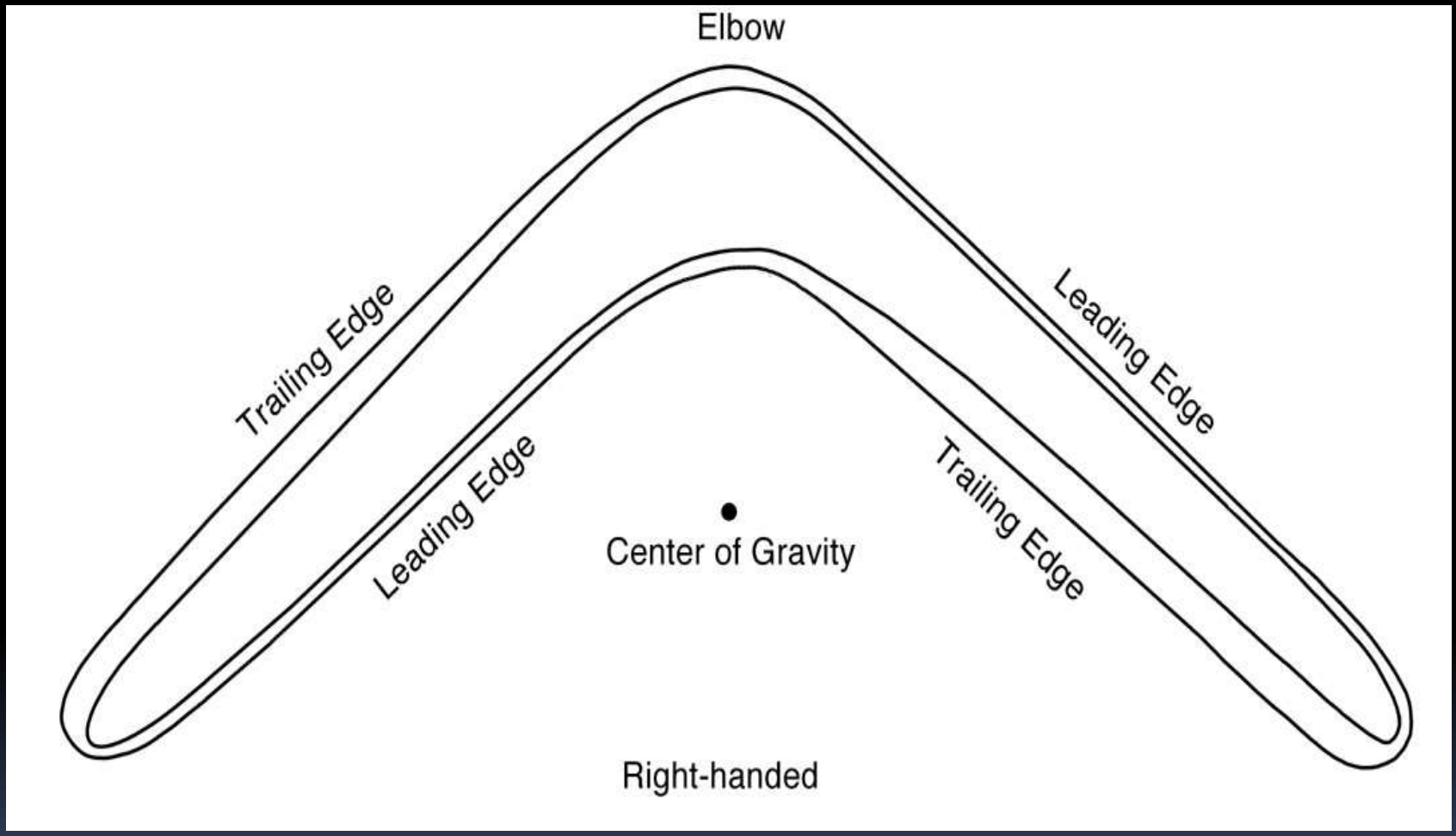
- With a history of being 30,000 years old, it is believed to be the oldest flying object.
- Prominently used by Australian aborigines as hunting sticks (kylies) which were non-returnable.
- Now over years it had been developed as a recreational object

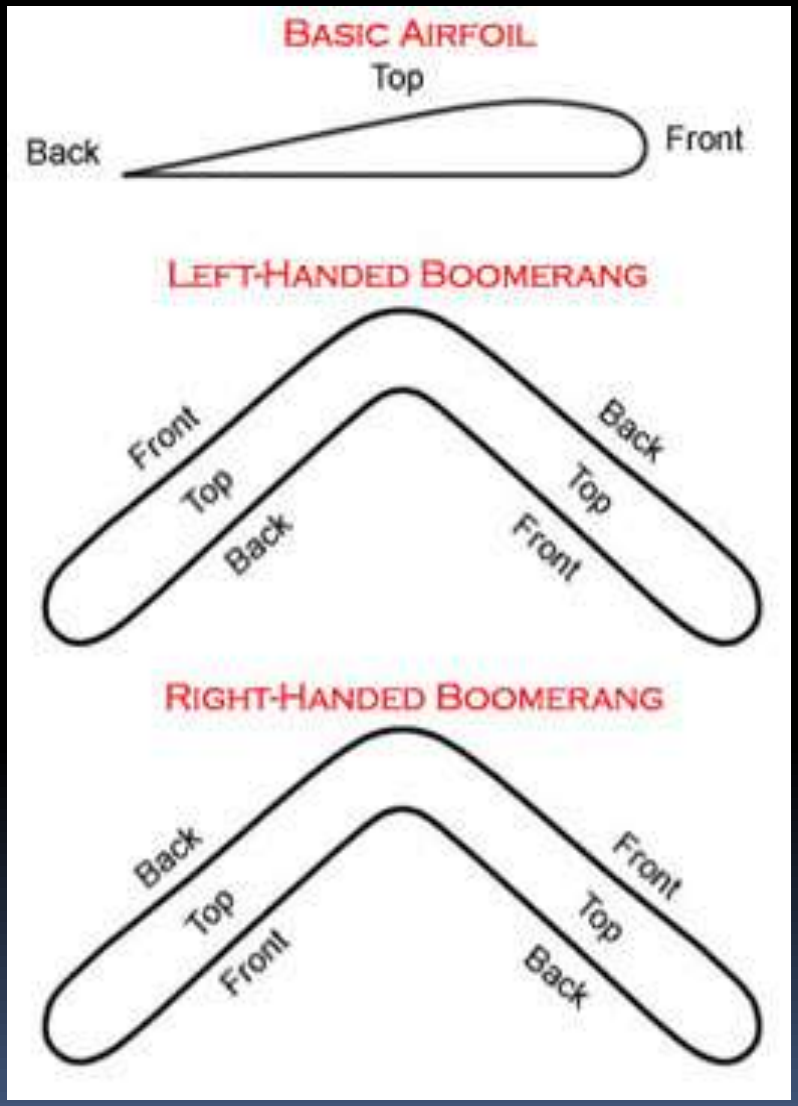
kylies

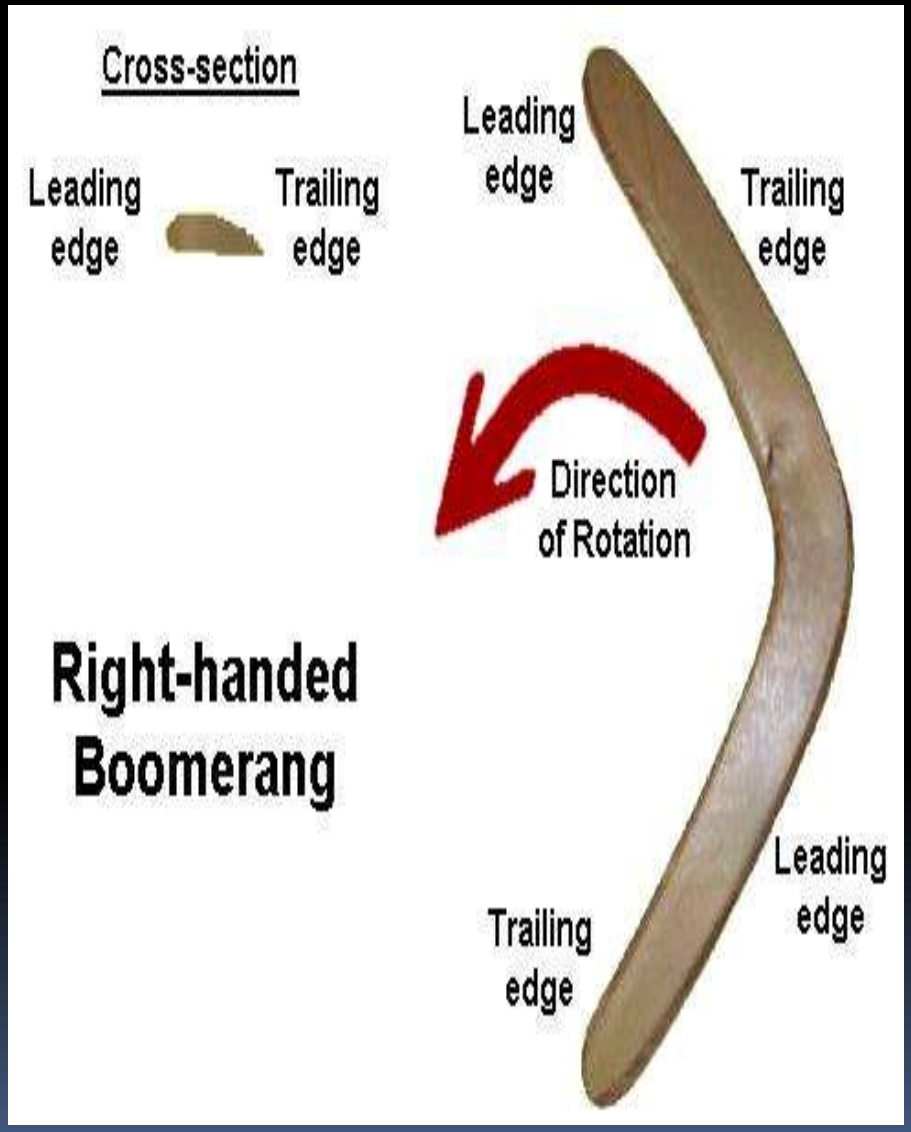
Features of boomerang

- Boomerang has a leading edge and a trailing edge
- Returning boomerangs consists of two or more arms connected at an angle
- Each arm is shaped as an airfoil




Elbow
Trailing Edge
Leading Edge
Leading Edge
Trailing Edge
Center of Gravity
Right-handed

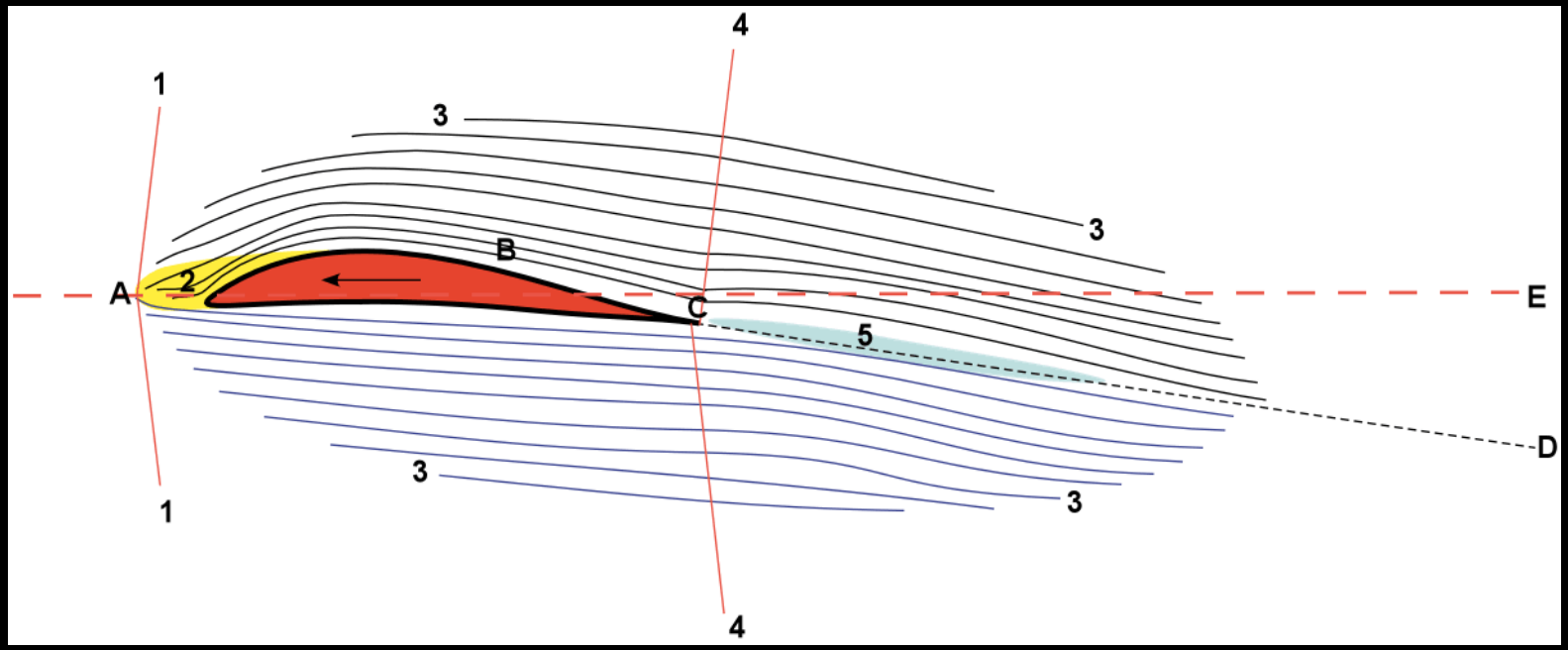

BASIC AIRFOIL
Top
Back
Front
LEFT-HANDED BOOMERANG
Front
Top
Back
Back
Top
Front
RIGHT-HANDED BOOMERANG
Back
Top
Front
Front
Top
Back


Cross-section
Leading edge
Trailing edge
Leading edge
Trailing edge
Direction of Rotation
Right-handed Boomerang
Trailing edge
Leading edge

Aerodynamics of boomerang

How does a boomerang float in the air?

The same aviation principle. The wing of an airplane is designed in such a way that at the topside the wind speed is much more greater than at the bottom side. The result- Because of the very high velocity of wind at the topside of the wing, the pressure is small and at the same time since the velocity of wind at the bottom side of the wing is much less, the pressure is great which pushes the wing up.

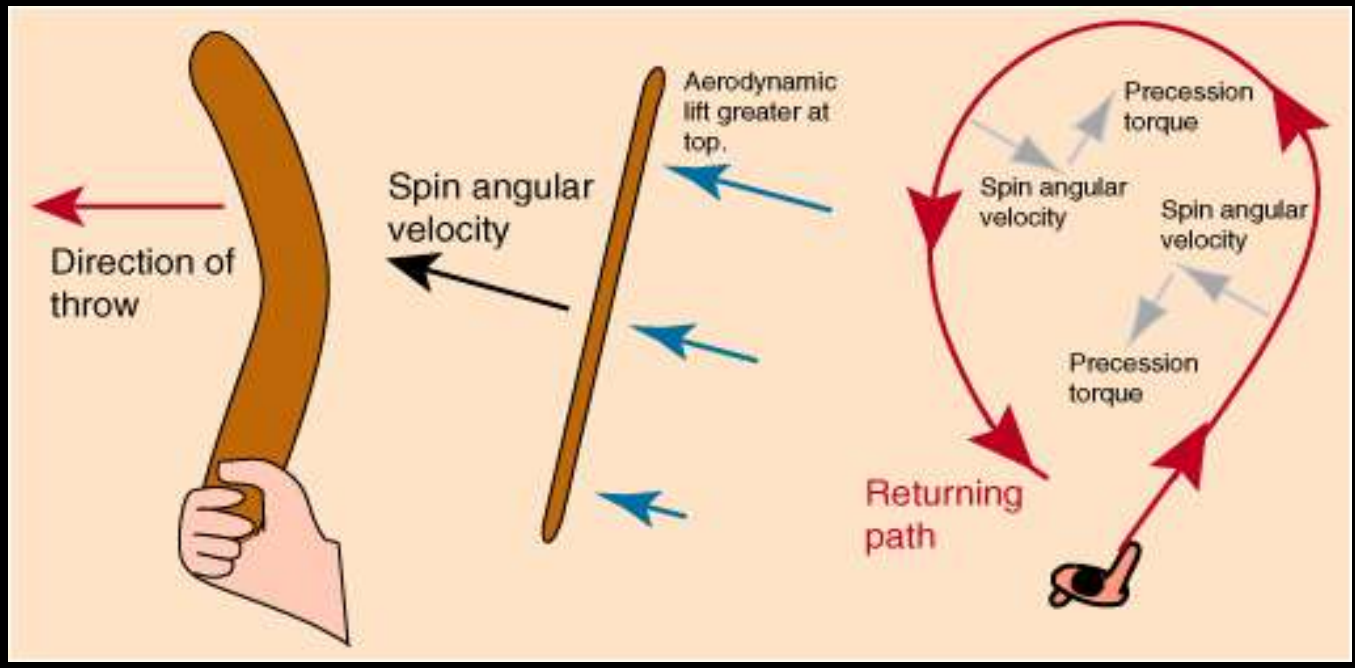


- 1. Leading shock wave front. Fluid doesn't "feel" airfoil and airfoil doesn't feel fluid on left 1-A-1 line.
  2. Fluid pillow: the area of increased dynamic pressure. The streams generation starts here.
  3. Streams. The envelope of the streams corresponds to theBoundary area. It is assumed that stream having less than 5 percent of stream maximum speed can be neglected. The threshold option permits to hide very slow streams in trailing edge, which do not affect airfoil lift, but are responsible for energy dissipation only.
  4. Trailing edge of shock wave. Streams separate from trailing edge of airfoil near 4-C-4 line. The separation relaxes stress, which generates the trailing edge shock wave. No lift force is generated on right side of this line. The right (CD) area corresponds to stream tension relaxation and the region of their inertive energy dissipation.
  5. Reduced pressure air bubble increases airfoil drag, but has no effects on the lift force. It starts at a separation point and follows the airfoil, sucking fluid from the nearest streams. The bubble corresponds the turbulent region.

Boomerang basically acts on The Bernoulli's principle

How does a boomerang return to the thrower?

When you throw a boomerang you not only impart great speed but also a certain amount of spin. The spin at the top is more than at the bottom. Because the design enables the top of the wing to move forward and at the same time spin forward as well, for the same reason, the bottom portion spins not very fast but it surges forward and effects the lift.



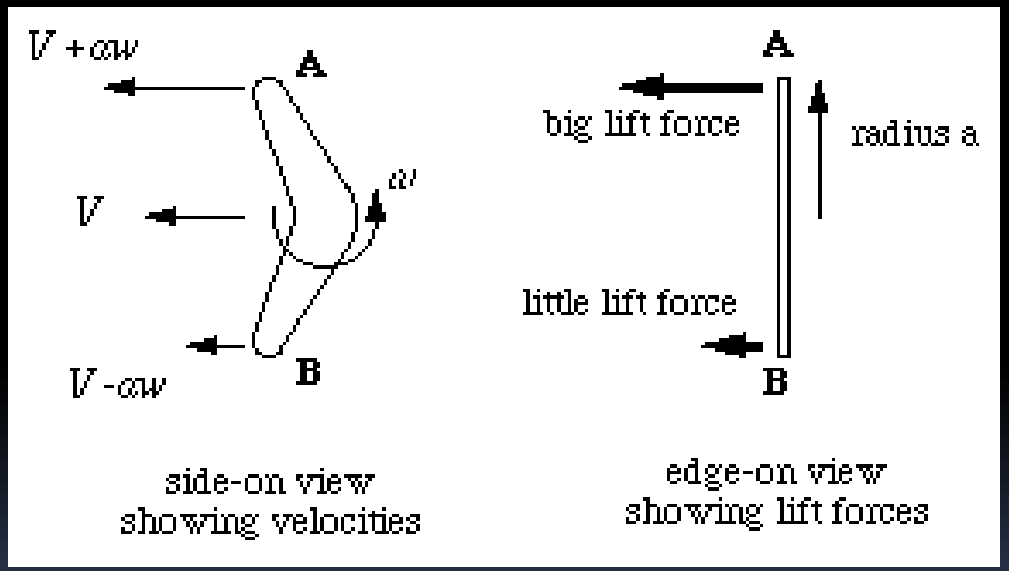
Topside spins forward – backside spins backward. Result? When the boomerang loses momentum the spin creates a gyroscopic precession, which propels it to turn to the left enabling it to fly back in a circle to whoever threw it.

Physics of boomerang

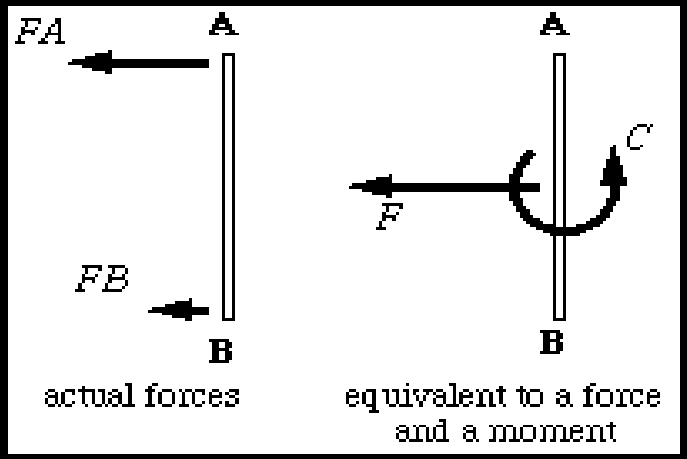
- A boomerang does funny things because it is in fact a gyroscope. Aerodynamic forces generate a twisting moment which cause the "gyroscope" to *precess* and to move on a circular path.
- However, to understand what precession is, you simply need to observe that as well as spinning quickly round its own axis, the boomerang slowly changes the direction in which it is pointing.

- Examining the forces acting on a boomerang of radius a. The centre of the boomerang is moving at a constant forward speed V and the boomerang is spinning with angular velocity ω, as shown in the diagram.

The "top" end **A** is therefore moving faster than with speed "$V+a\omega$", and the "bottom" end **B** is moving slower with speed "$V-a\omega$".



A wing generates more lift when it is moving faster so point **A** is generating more lift than point **B**.



The two forces F_A and F_B can be represented by a single force and a single couple C. With this simple representation of the forces acting on the boomerang we can give two reasons why it moves on a circular path:

1. A constant centripetal force F produces circular motion with velocity on a radius such that:

$$F = mV^2/R \qquad (1)$$

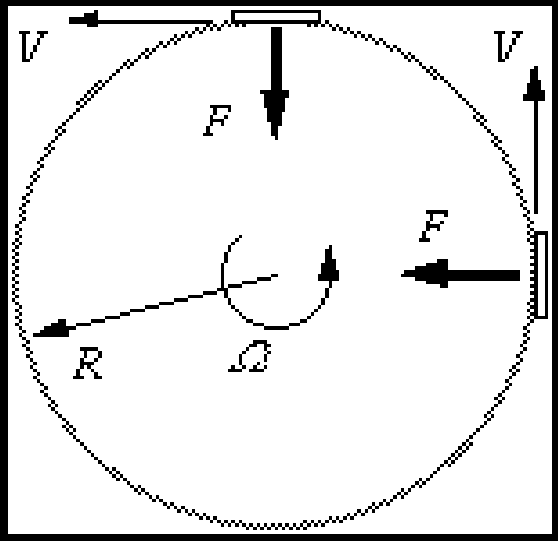
where m is the mass of the boomerang.

2. A constant couple *C* acting on a gyroscope spinning at angular velocity ω causes steady precession at rate Ω such that:

$$C = J\omega\Omega \qquad (2)$$

where *m* is the mass of the boomerang and *J* is its moment of inertia.

If the rate of precession Ω exactly corresponds to the angular velocity of circular motion, then the boomerang rotates at exactly the correct rate to stay tangential to the flight path as shown. This gives an equation relating V to Ω,



$$V = R\Omega \qquad (3)$$

A wing of area A moving at speed v in air with density ρ generates an aerodynamic lift force L. It can be shown that L is proportional to the air density, the wing area and the square of the wing speed.

The precise relationship is expressed using the proportionality constant C_L, which is known as the *lift coefficient*, and takes the following form:

$$L = \tfrac{1}{2} \rho v^2 C_L A \qquad (4)$$

It can also be shown by integrating the lift force over the area of a cross-shaped boomerang that the net lift force and aerodynamic couple are given by

$$F = \tfrac{1}{4} \rho (V^2 + (a\omega^2)) C_L A_S \qquad (5)$$

and

$$C = \tfrac{1}{4} \rho V^2 a\omega C_L A_S \qquad (6)$$

For

$J = \frac{1}{2}ma^2$

, and co

where V, ω and a are the velocity, spin speed and radius of the boomerang as before, and $A_S = \pi a^2$ (the swept area of the boomerang).

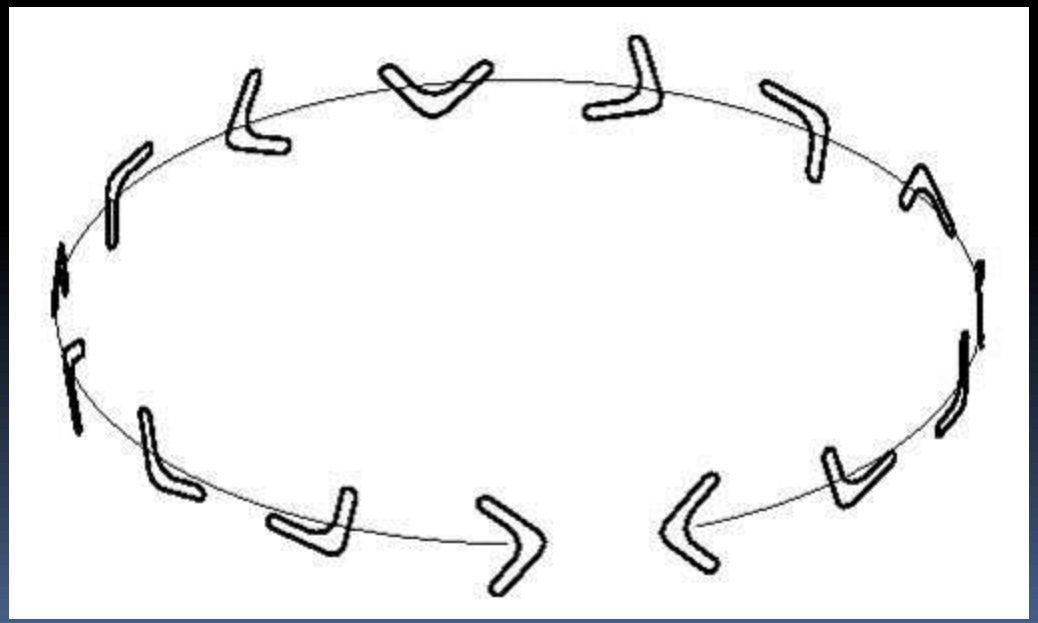
From equations 2, 3 and 6, we find that the radius R of the circular flight path is independent of spin speed ω and forward velocity V, and that it is a constant for a given boomerang:

$$R = (4J) / (\rho C_L \pi a^4) \qquad (7)$$

- For the case of a boomerang with $J=1/3\ ma^2$, and equations 1, 5 and 7 can be arranged to give

$$a\omega = (\sqrt{2})\,V \qquad (8)$$

which defines the "flick-of-the-wrist" needed to make the boomerang fly properly.



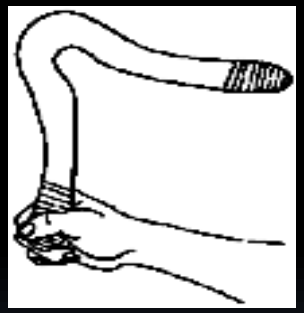
Material used

- Boomerangs are made with materials such as wood (mostly birch or poplar), from hard woods like teak or rosewood exceptionally crafted to get the body weight and balance. Today, plastics, reinforced fiberglass, polypropylene, PVC, ABS (Acrylonitrite Butadien Styrol), Paxolin (made of layers of paper bonded with phenolic resin) etc are also used. However, a precision crafted boomerang made from birch wood still steals the thunder!

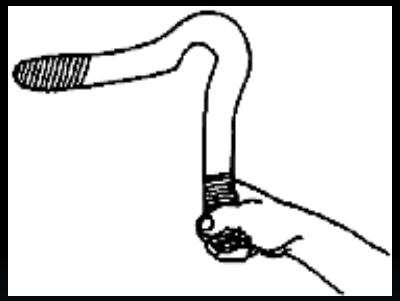
Throwing technique

❶ Where To Grip

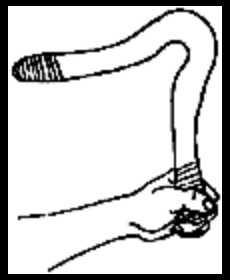
- Right-handers must use right-handed boomerangs and vice-versa



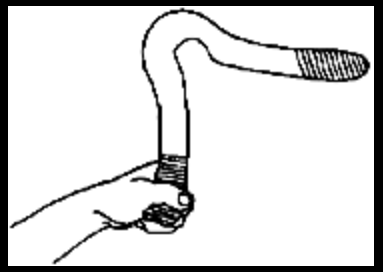
Right-handed Dingle Arm Grip



Right-handed LIft Arm Grip



Left-handed
Dingle Arm Grip



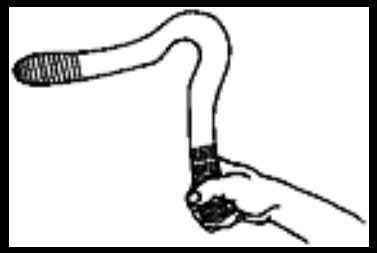
Left-handed
Lift Arm Grip

- You must always grip the boomerang so that the curved side is toward you and the flat side should face away from you. (In flight, the curved side is the top and the flat side is the bottom.) You can grip the boomerang by either the dingle arm or the lift arm.

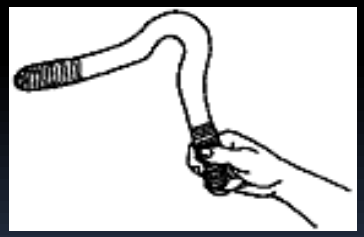
❷ How To Grip

Choose a grip that is comfortable for you

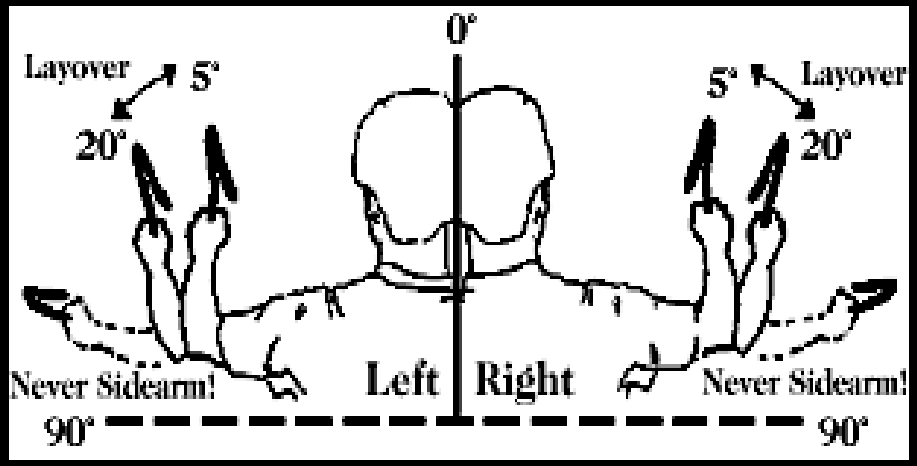
- Pinch Grip: Make your hand into a hitchhiking sign, and then pinch the boomerang tightly between your thumb and first finger.



- Pencil Grip: Support the boomerang with your thumb, first finger, and middle finger as shown. The first finger hooks around the edge of the boomerang.



❸ Layover

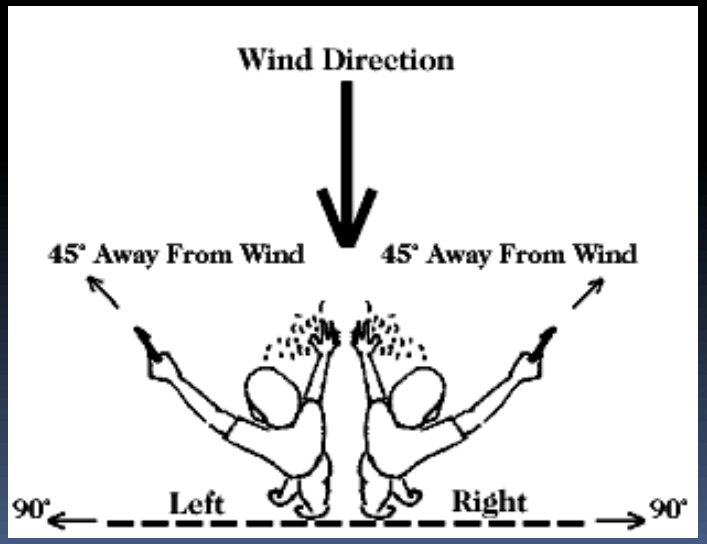


- Boomerangs are thrown overhand, not sidearm! The boomerang should be released vertically (perpendicular to the ground).The layover from vertical should be no more than 5-20°. Upon release, the boomerang should cartwheel forward, end over end, in a nearly vertical plane.

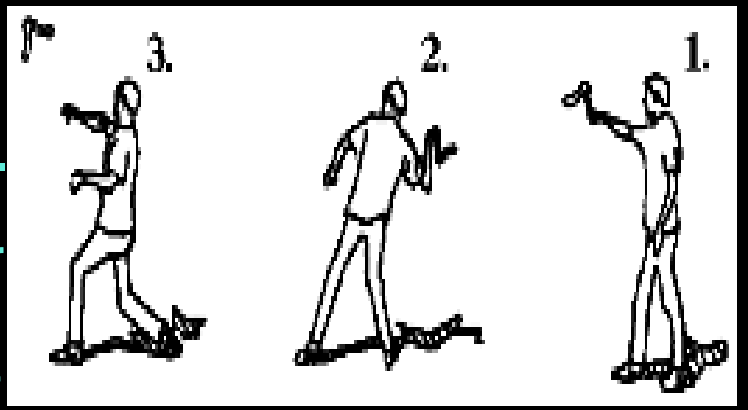
- It is extremely important to avoid using too much layover. If the boomerang is thrown with too much layover and released too horizontally, it will spin like a frisbee, suddenly climb high into the air, and then dive straight into the ground. Boomerangs may break when thrown in this way.

4 Direction Of Throw

Face the wind directly. Then turn to the right about 45°away from wind if you are right handed and vice-versa

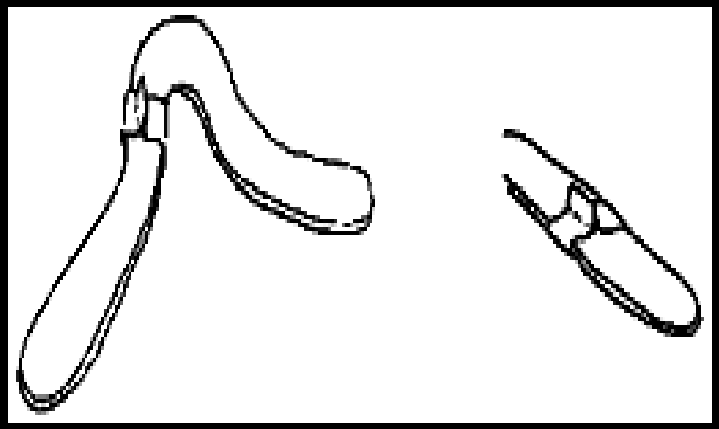


5 Throw!

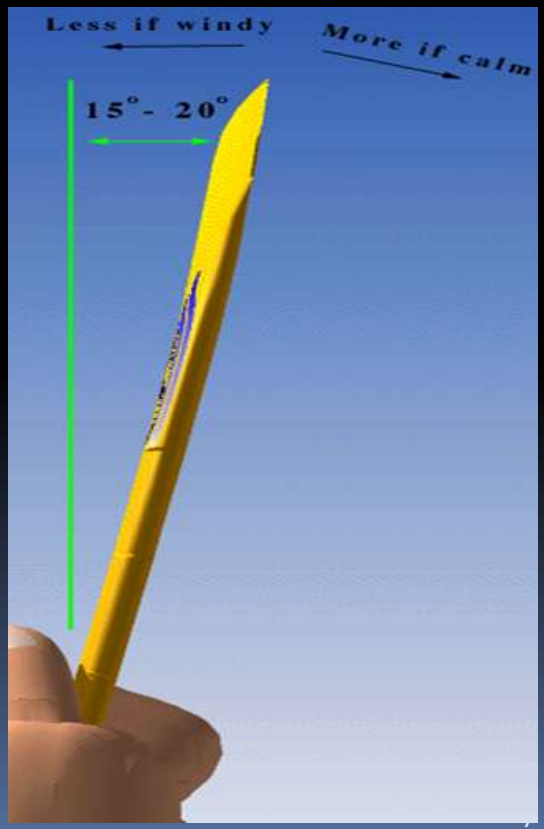


1. Aim a little above the horizon.
2. Cock your arm back over your shoulder, with your wrist bent backwards. Follow through with a smooth body motion and a strong snap of the wrist. The snap will create spin, and spin is more important than power. Grip tightly throughout the throw and release. The boomerang will pull itself out of your grip.
3. Be sure that the boomerang is released in a nearly vertical plane. Do not throw horizontally (sidearm).

Throwing in Wind



In windy conditions (over 5 MPH), boomerangs tend to fly over your head and past you.

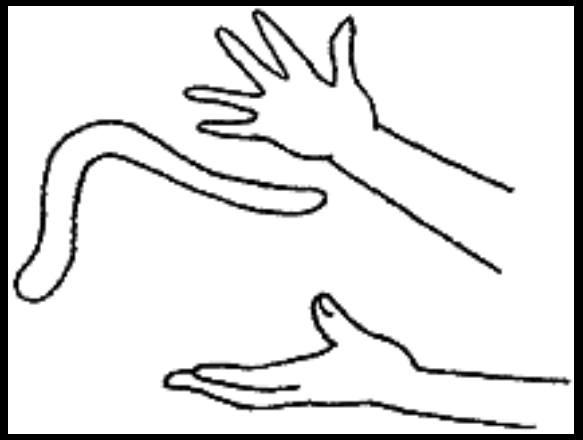


Four things should be followed:

1. Try throwing softer.
2. Throw with less layover
3. Throw higher.

Usually a combination of two serves good.

6 Catching



After you are familiar with the flight pattern of your boomerang, you can attempt catching.

However, never try to catch plummeting boomerangs, or boomerangs that are returning rapidly, or higher than chest level. The trick in catching is to make a "boomerang sandwich." Hold one hand above and one below, with palms parallel to the boomerang. As the boomerang floats between them, slap your hands together.

7 Summary

1. Hold boomerang facing the wind, nearly vertical with flat side away from you. Then turn about 45° to the right if you are right-handed, or about 45° to the left if you are left-handed.
2. Cock arm back, with wrist bent backwards, aim.
3. Throw with snap of the wrist, releasing the boomerang in a vertical plane at a point just above the horizon.

Throwing in wind (Details)

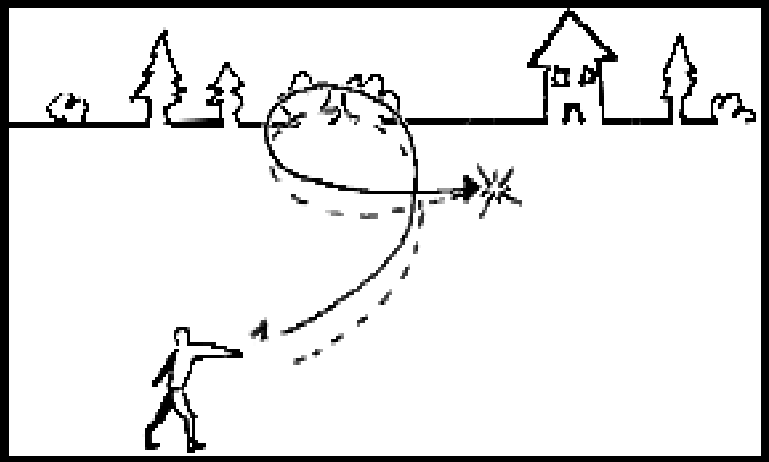
- There are four basic ways to deal with wind:

1. East throw, or "surfing throw" : Impart lot of spin with snap of wrist without providing much forward velocity which will be eventually provided by wind. Also release it higher with more layover than usual. Its least effective among all four.
2. Humpback throw : Throw with vertical release, high altitude and hard throw. It works because boomerang loses forward velocity as it tries to crash into ground.
3. Drag producing additions that slow the boomerang down thus preventing it from flying past your head. You can do so by drilling holes, more and closer to tips or by placing taped flaps whose location should be experimented accordingly.
4. Adding weight by placing coins with tape accordingly.

- **Conclusion:** When throwing in wind it is helpful to understand that boomerangs don't come back very accurately. And when you do flap, weight, or throw the boomerang just right, and it comes back accurately, it is very satisfying.

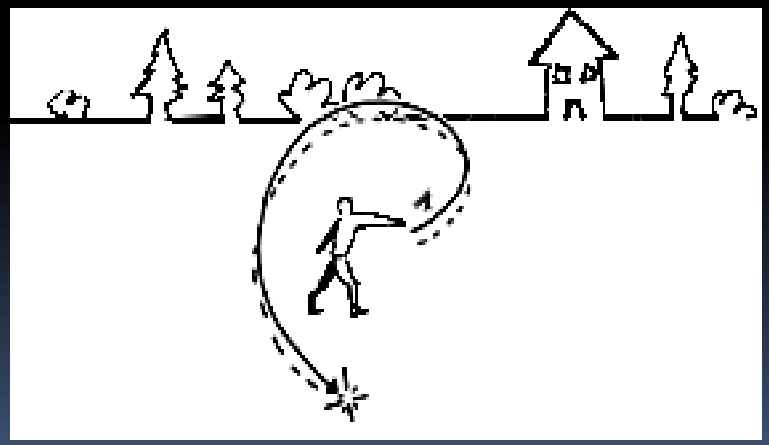
The key to learning how to throw in wind, is to go out and throw in wind! Simple as that. Try flaps, weights, humpbacks and surfing. The best solution is probably a combination of one or more these techniques.

Flight problems & solutions



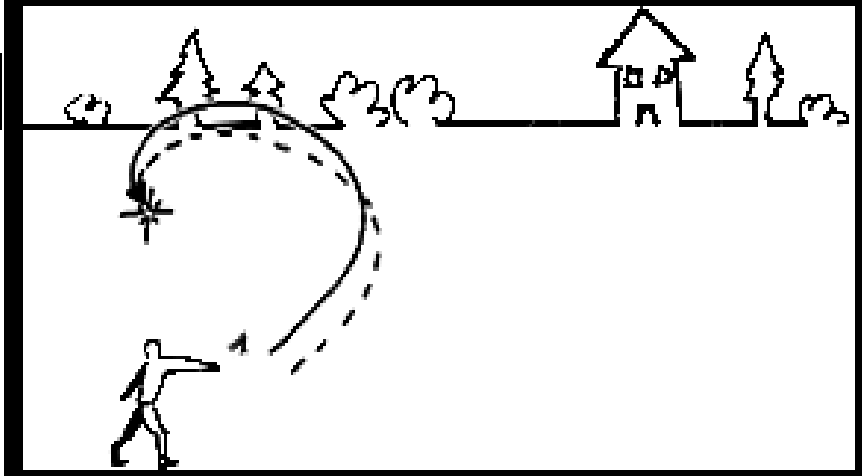
TOO FAR AWAY FROM THE WIND

- **Problem:** Boomerang circles but lands in front of you.
- **Solution:** Throw more directly into the wind.

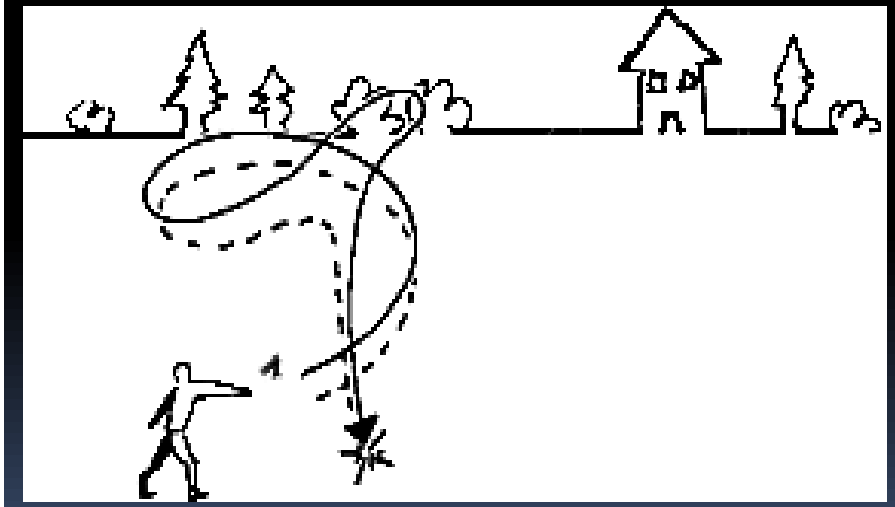


TOO MUCH INTO THE WIND

- **Problem:** Boomerang circles but lands in back of you.
- **Solution:** Throw more away from the wind.



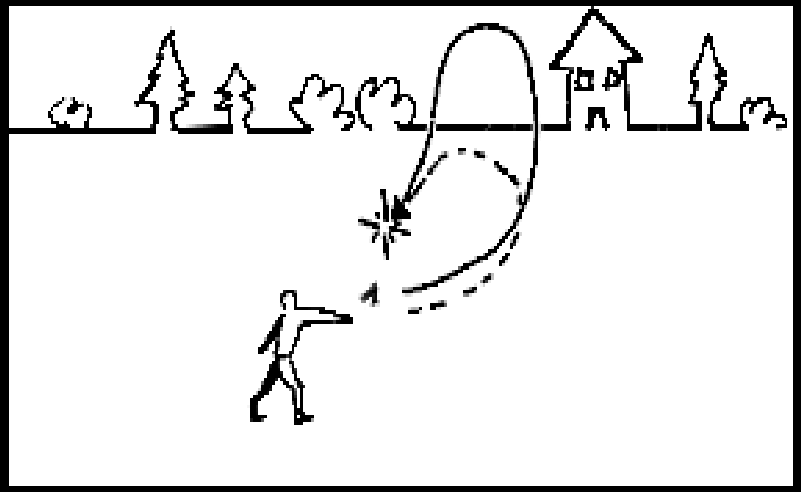
TOO SOFT



TOO HARD

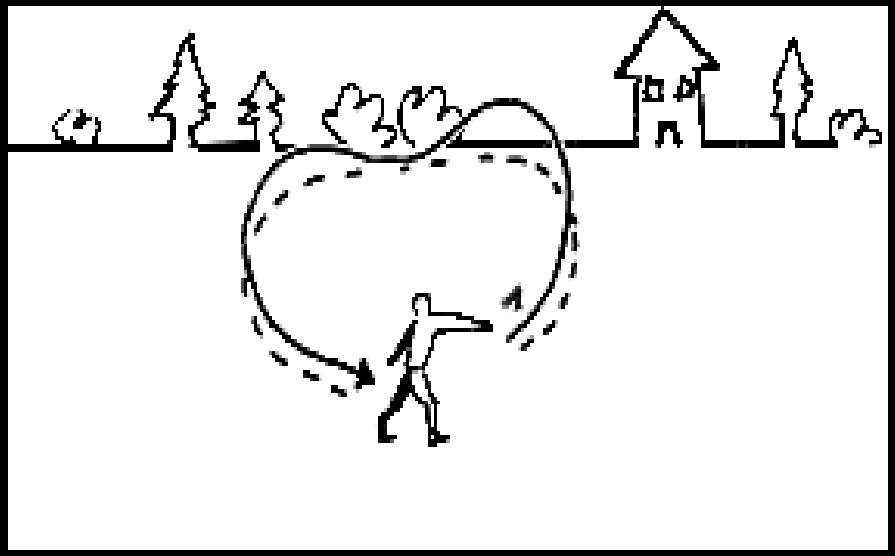
- **Problem:** Boomerang circles but returns short.
- **Solution:** Throw harder, or use more spin.

- **Problem:** Boomerang flies high over your head and past you.
- **Solution:** Throw easier, or release the boomerang in a more vertical position.



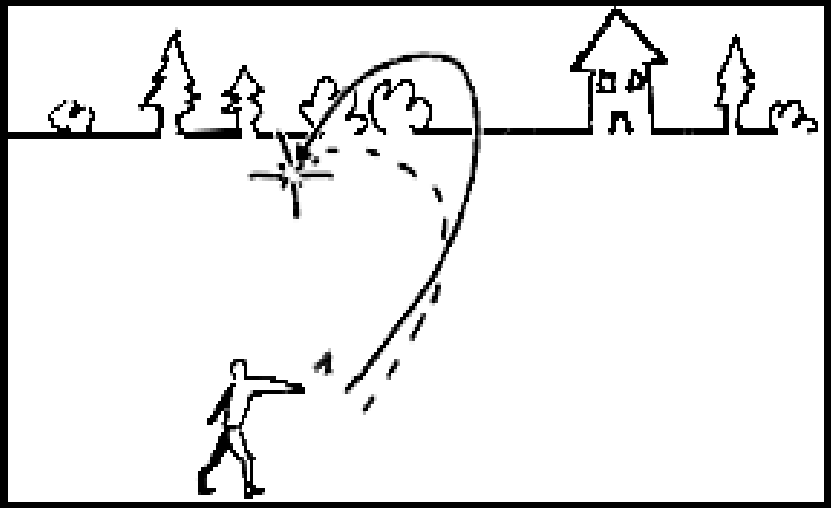
TOO MUCH LAYOVER

- **Problem:** Boomerang climbs straight up and then dives to the ground. This is **THE** most common problem.
- **Solution:** Boomerang was released too horizontally (sidearm). It should be nearly vertical when released.



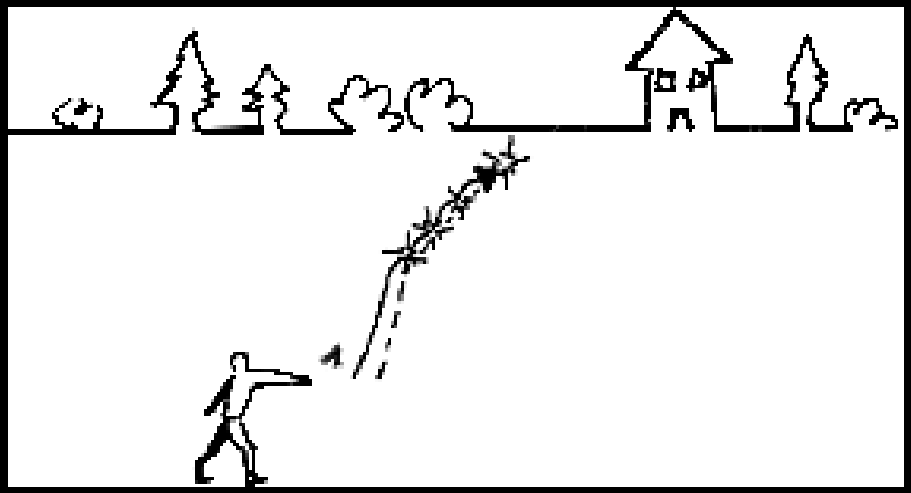
TOO LITTLE LAYOVER

- **Problem:** Boomerang dips in flight, and may hit the ground.
- **Solution:** Boomerang was thrown with too little layover. Throw with a little more layover.



TOO HIGH

- **Problem:** After being thrown into the air, boomerang fails to circle and crashes to the ground.
- **Solution:** Boomerang was thrown too high. Throw boomerang lower. Aim at a point just above the horizon.



FLAT SIDE FACING IN

- **Problem:** Boomerang fails to climb into the air, hits the ground and cartwheels.
- **Solution:** 1. Boomerang was gripped with the flat side towards you. Turn the flat side away.

OR

2. You threw the wrong-handed boomerang. Throw the correct left-handed/right-handed boomerang.

Some innovative shapes and designs

Sources

- Wikipedia
- Google images
- Google
- Bing
- Yahoo

THANK YOU