I. Scope of Seminar: A basic introduction to the fundamentals of sea kayak design without mathematics, or "Sea Kayak Design 101." Useful for boat buying decisions, but also to become a savvier paddler.

II. Origins of Sea Kayaking

- A. Greenland
  1. No one knows the precise origin of kayaks, but has existed for centuries among the Inuit people of Greenland, from before the time the first Europeans came (1600-1700s). Some archaeological evidence indicating kayaks are 4,000 years old.
  2. Kayaking is still an important part of Greenland's culture, although it was in danger of vanishing in the early 20th century after the introduction of power boats. Kayaking now experiencing a renaissance in Greenland.
  3. West Greenland kayaks probably closest to the modern design.
  4. Greenland paddlers are still among the greatest in the world. Most of the roll, rescue, and paddle techniques we use today come from the Inuit.
  5. Purpose of kayaking for Inuit: Primary method of subsistence hunting of caribou, seals, sea otters, and whales. Very dangerous. Data in the late 1800s indicated in south Greenland, about 24 males died each year during kayak hunting out of a total population of 5600.
  6. Basic construction:
     - a) Seal-skin over drift-wood
     - b) Wood bent into shape after steaming over fire
     - c) Joints lashed together with seal sinew
     - d) Seams of seal skin sewn with seal sinew, and sealed with seal blubber.

Traditional West Greenland Kayak and Gear

  7. Size: Kayaks sized to the person who will paddle it, with the standard length being 3 arm-spans long (measured from finger tip to finger tip of the outstretched arms). The width of the boat is width of the paddler's hips plus two times the width of the hand measured across the knuckles.
  8. Implements:
     - a) Short, wooden, unfeathered paddles with very small blades tipped with bone
     - b) Tuiliq: Ancient clothing article combining a paddle jacket, pogies, and spray skirt into one piece. Made from seal skin.

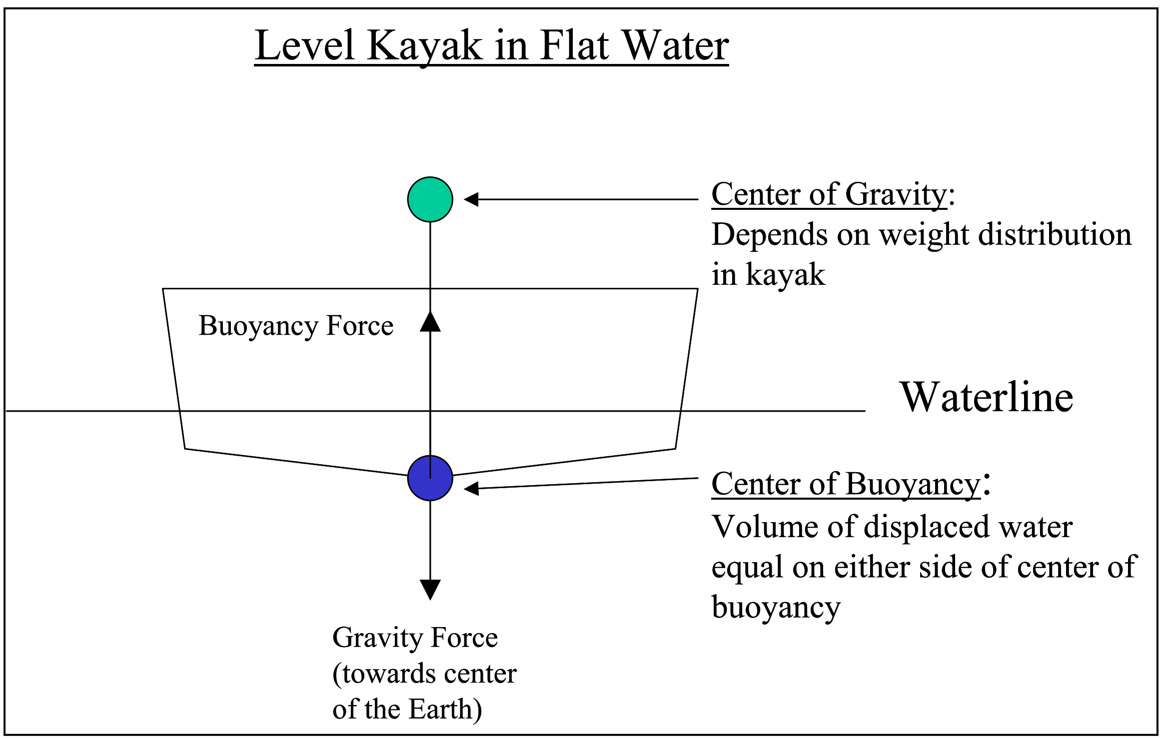
c) Harpoon
d) Throwing Board
e) Air Bladders for tying to harpoon to slow down prey

B. Aleutian Islands of Alaska
1. Adapted different technology to suit different environment
2. Quite different shapes; usually paddled with single bladed paddle
3. Also wood frame, but often with sea lion skin
4. Baidarkas: Kayaks capable of carrying two or three people. Often the other passengers did not paddle.

III. Basic Seamanship Concepts and Definitions

A. Buoyancy: A force acting on a body immersed in a fluid of a magnitude equal to the weight of the displaced fluid. The direction of the buoyancy force is normal (perpendicular) to the water's surface.

B. Stability
1. Rise of Stability:
a) Center of Buoyancy: Line through which the buoyancy form acts. The center of buoyancy is located where the displaced water on either side has equal volume.
b) Center of Gravity: Line through which the gravity force acts.
c) The following diagrams illustrate how buoyancy and gravity gives rise to kayak stability and instability:



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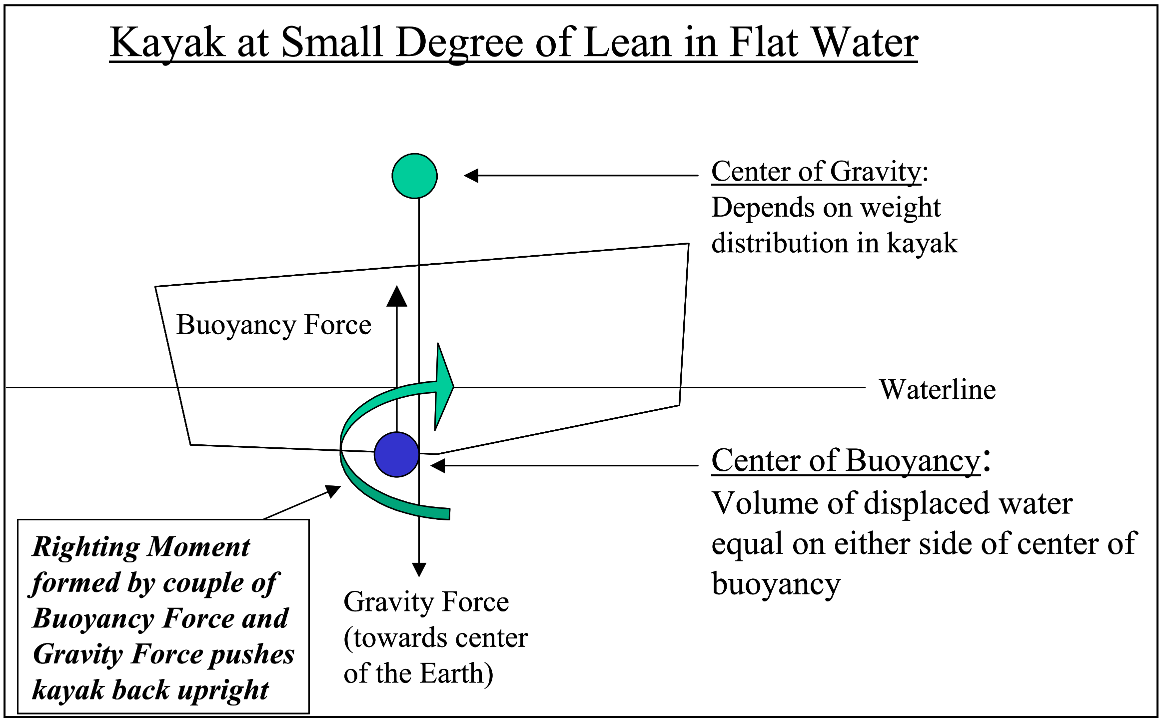

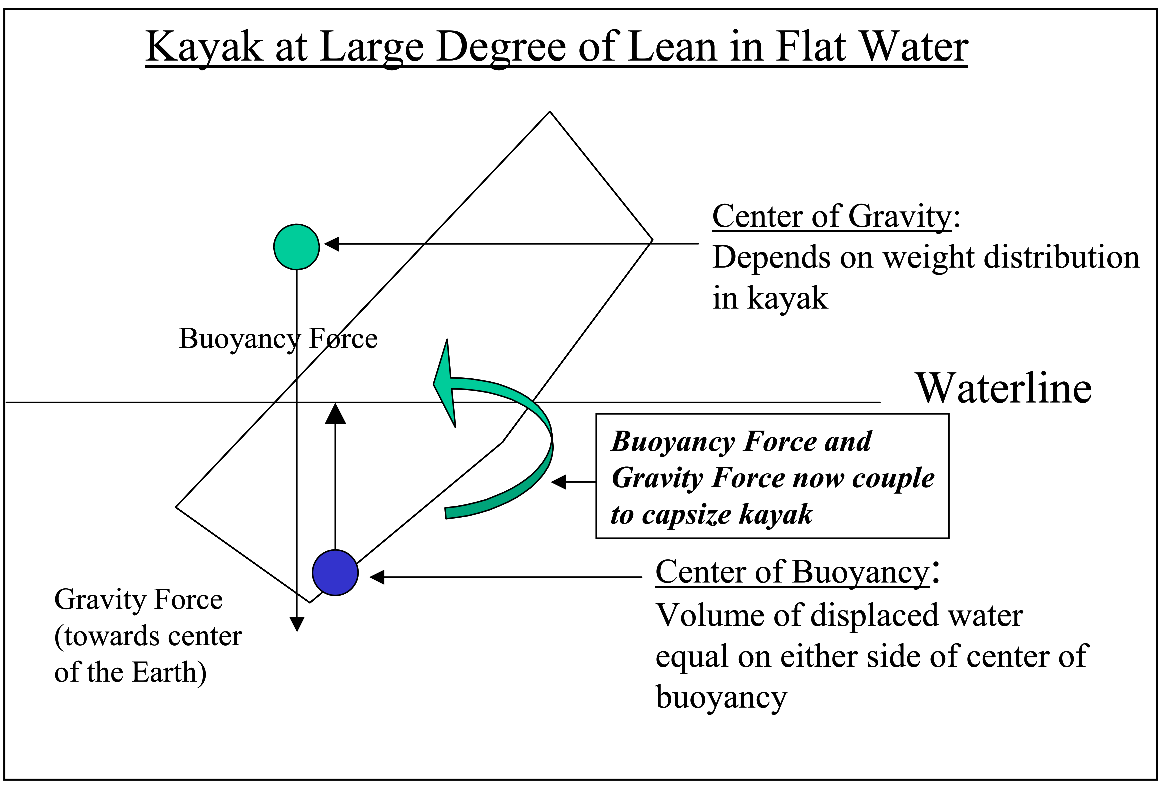

2. Primary Stability: Resistance of kayak to small degrees of lean (also called Initial Stability). Primary stability can be thought of as the slope of

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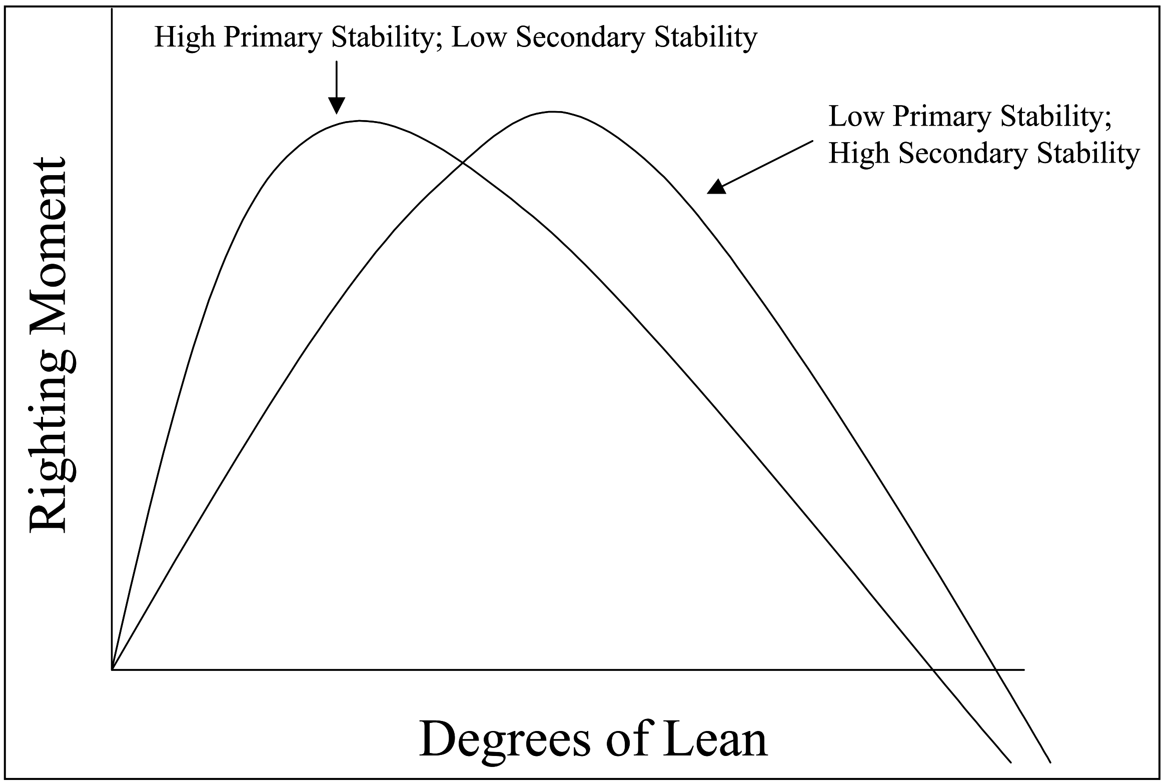
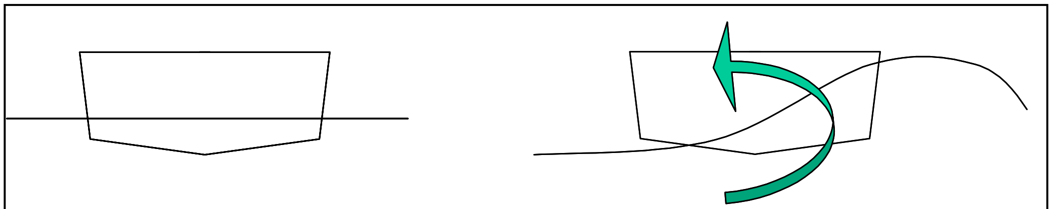
a stability curve (righting moment vs. degrees of heel) at just above 0 degrees.

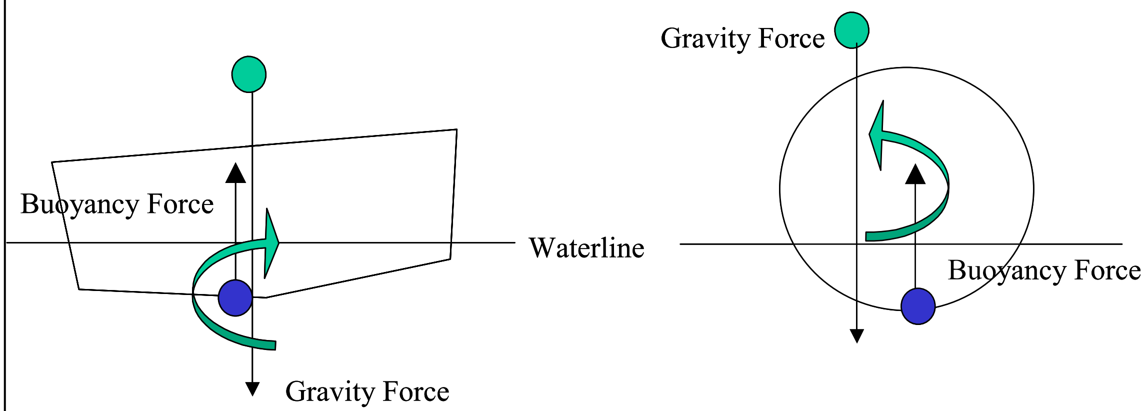
3. Secondary Stability: Stability of the kayak at large degrees of lean. Secondary stability can be thought of as the maximum degree of heel before which the kayak becomes unstable.
4. Primary Stability vs. Secondary Stability: A kayak which has high primary stability in flat water will tend to roll when sideways on a wave, whereas a kayak with low primary stability will have more of a tendency to stay upright. Therefore, there is a tradeoff between primary stability and secondary stability. Too much primary stability can be a bad thing for advanced kayakers too, because it makes the boat difficult to lean (for carved turns, or for bracing into waves).





A kayak which is initially stable in flat water (resists small leans) will have a tendency to roll when hit by a large wave abeam

Opposite Extremes: Flat Hull vs. Round Hull



A flat hull has high primary stability. A completely round hull has no primary stability because the Center of Buoyancy is the same regardless of lean.

C. Tracking: The tendency of a kayak to hold a straight course.
D. Weathercocking: Tendency of a kayak to turn into the wind, like a weathervane.
E. Parts of a boat
   1. Bow: Forward section of the boat
   2. Stern: Aft section of the boat
   3. Hull: The bottom of a kayak
   4. Deck: Closed-in area over the kayak
   5. Gunwale: Seam where the hull and deck meet
   6. Cockpit: The opening in the deck where the paddler sits
   7. Coaming: The curved lip around the edge of the cockpit
   8. Bulkhead: Sealed compartment in a kayak
   9. Keel: Strip or extrusion along bottom of boat to prevent side-slipping.
   10. Rudder: Foot-controlled steering device on touring kayaks
   11. Skeg: Fixed rudder

IV. Design Elements and their Importance
A. Materials
   1. Plastic
      a) Linear or cross-link polyethylene plastic: Linear is lighter, stiffer and recyclable, but has less impact resistance
      b) Roto-molded method of construction
      c) Plastic is heaviest (70 lbs for typical plastic touring boat) but cheapest material
      d) Very durable, but vulnerable to UV
      e) Difficult to repair
   2. Fiberglass

a) Show fiberglass material: Glass fabric cloth encased in resin (often epoxy) and covered in gelcoat for UV protection and cosmetic reasons
b) Hand-layup and vacuum bagging methods of construction
c) 15% lighter (typically 55-60 lbs) and 40% more expensive than plastic
d) More vulnerable to impact and cracking than plastic, but easy to repair, stiffer, and will generally last longer

3. Kevlar
    a) Kevlar (bullet proof vest) cloth encased in same resins as fiberglass
    b) Same methods of manufacture as fiberglass
    c) About 25% lighter than fiberglass (typically 40-45 lbs) and 30% more expensive than fiberglass
    d) As easy to repair as fiberglass and as stiff, but more impact resistant
4. Carbon/graphite: Most expensive, and even lighter than kevlar
5. Wood
    a) Plywood or cedar strip
    b) Primarily used in kit boats and homemade boats
    c) Can be as light as Kevlar
    d) Often coated in fiberglass cloth for protection
6. Canvas
7. Nylon

B. Length
1. Length Overall vs. Waterline Length
2. Length affects:
    a) Hull Speed: Maximum sustainable speed in a kayak; arises from the wave created in front of a moving boat, and the need for a kayak to climb out of the trough of its own wave the faster it goes. Approximately equal to 1.34 times the square root of the waterline length in feet. In reality, paddlers are only limited by hull speed if they have short boats.
        (1) 13 ft. waterline: 4.8 knots hull speed
        (2) 17 ft. waterline: 5.5 knots hull speed; 15% greater
        (3) 20 ft. waterline (double kayak): 6.0 knots hull speed!

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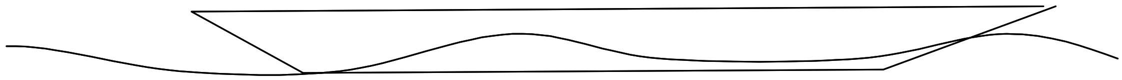
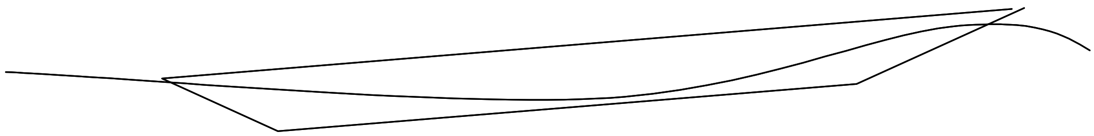


A boat moving at slow speeds creates a series of waves with short wavelenths



A boat moving at higher speeds will create longer waves. At a critical speed, called the Hull Speed, the length of the wave will equal the length of the boat, and to go faster, the boat must work against gravity to climb out of the trough of its own wave. Powerboats can exceed Hull Speed by climbing out of the trough and skimming (hydroplaing) on top of the water, but human powered boats cannot.

b) Weight: Longer kayaks tend to be heavier
c) Storage Volume: Longer kayaks tend to have greater storage volume for gear
d) Tracking: Longer kayaks tend to track better

C. Beam
1. Beam Overall vs. Waterline Beam
2. A wide kayak will usually be more stable than a narrower one.
3. A narrow craft will be faster than a wide one and easier to lean (for carved turns and to lean into a wave), but will compromise primary stability.

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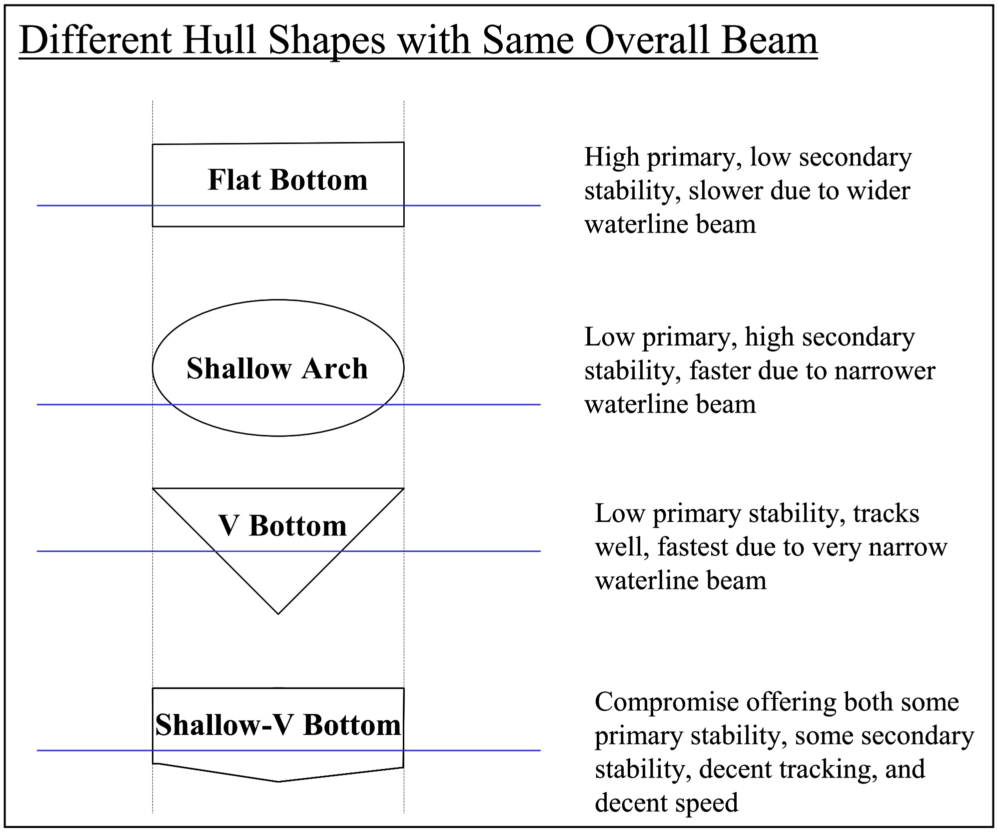
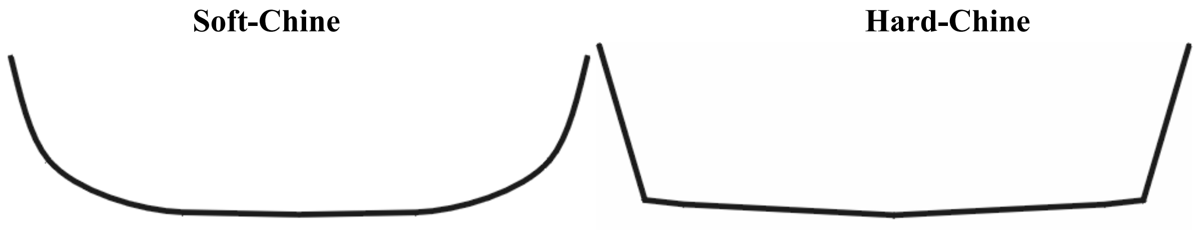
D. Hull-Shape

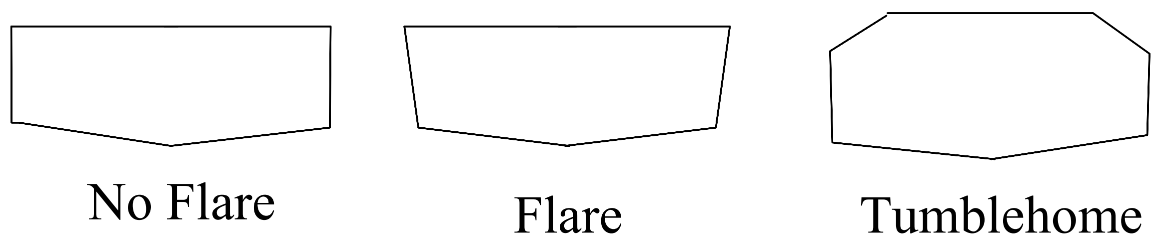


1. Often different parts of the same boat will have different hull shape; e.g., the bow may be a deep-V (for speed and tracking) while the mid-section may be shallow-V (for primary stability).

E. Related to Hull Shape - Chine: Shape of transition between bottom of kayak and sides of kayak hull
1. Hard-chine: Abrupt, nearly right-angle transition.
2. Soft-chine: Smoother, more rounded transition
3. Multi-chine: Multiple chines with less acute angles
4. Main differences:
    a) Carved turns: Hard chines are more efficient at carving leaned turns. Chine acts as a keel on a leaned turn.
    b) Speed: Soft chines and multi-chines have less wetted surface area for the same waterline length, and are thus approximately 3% faster at cruising speeds



F. Flare: Angle of a kayak's side outward from waterline towards gunwales.
  1. Outward Flare: Kayaks with flared sides have greater secondary stability, but less initial stability, and are easier to lean into a wave or lean for a turn.
  2. Tumblehome: Many wider kayaks have tumblehome, meaning the sides actually curve inward as they come up creating narrower beam on the deck. This enables the paddler to more easily reach the water while still having the stability of a wider kayak.



G. Rocker: The degree of upward curvature of the hull -bow to stern- along the keel line determines the amount of rocker in a kayak. More rocker increases the maneuverability of the hull, but reduces the amount of waterline in the water. This results in a less efficient hull and a loss of directional stability. A kayak with no rocker will track very well, but can be more difficult to maneuver.

H. Symmetry: Overall shape of boat from bow to stern
  1. Symmetrical: Bow and stern have same shape. Generally the most maneuverable shape.
  2. Swede-form: Greater volume in stern. A swede form kayak has a cleaner, longer slender entry giving easy touring speed and maneuverability.
  3. Fish-form: Greater volume in bow. Fish form kayaks may have a slightly blunter entry but will have a more slender exit through the water which increases tracking, even in adverse conditions

I. Depth: Vertical measurement from the hull's lowest point to its highest. Large depth means a roomier kayak with more storage space for a given length, but it also means more of a tendency to weathercock because of the larger exposed volume above the water.

J. Taper: Entry lines of a kayaks bow and stern
  1. Full: Gives extra volume for storage and riding over a wave
  2. Pointed: For fine, fast cruisers; knife through the water

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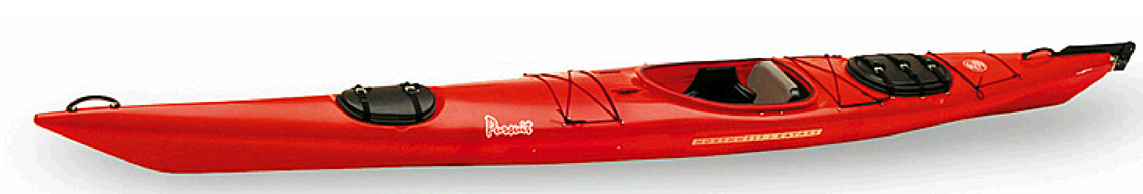
V. Examples

A. Necky Kayaks Looksha IV

1. 17’ x 22” (overall, without rudder)
2. Fish-form
3. Multi-chined (“double-hard chine”) midsection
4. Ample rocker in bow and stern
5. Molded skeg
6. Low-profile deck
7. Dolphin bow (deep-V, upturned, low volume)

B. Northwest Kayaks Pursuit

1. 16’10.5” x 22” (overall, without rudder)
2. Swede-form
3. Shallow-V bottom hull
4. High depth deck fore of the cockpit
5. Hard-chined midsection
6. Rounded, full V bow
7. Little stern rocker or bow rocker



VI. Paddle Design

A. Materials

1. Shafts and blades sometimes different material
2. Aluminum: Cheap and durable, but heavy
3. Fiberglass saturated in plastic resin: More expensive, lighter, and durable
4. Carbon/Graphite saturated in plastic resin: Lightest, most expensive
5. Wood: Relatively lightweight, durable, and high flotation (good for rolls)

B. Feather Angle:

1. Feathered: Less resistance in a head-wind
2. Unfeathered: More resistance, but reduces wrist-strain for some

C. Relative merits of blade size

1. Larger blades: More power, higher acceleration

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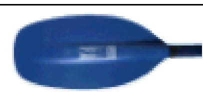
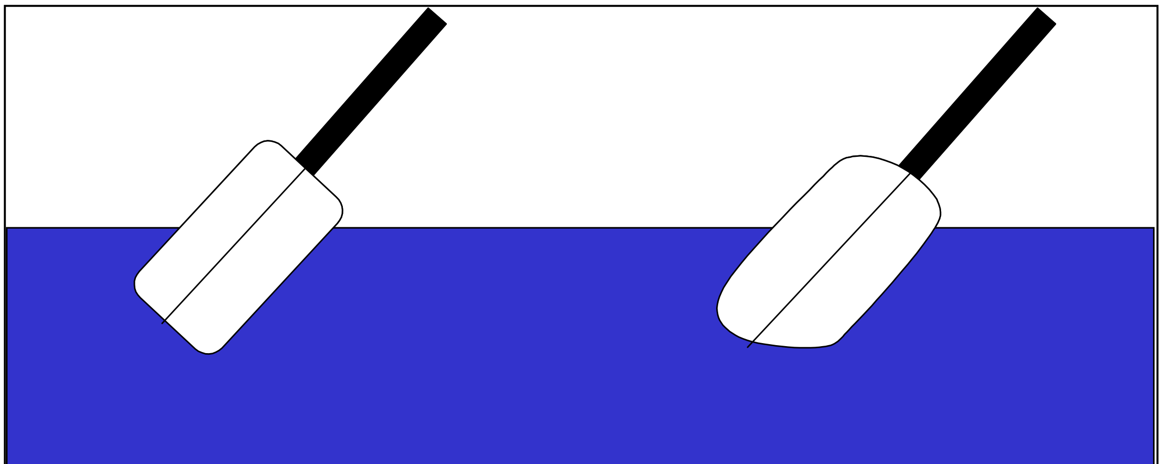
2. Smaller blades: Less power, but allows for a faster, more aerobic stroke

D. Symmetry

1. Symmetrical: Easier and cheaper to produce, but produces uneven forces when immersed on the water, requiring a harder grip.
2. Asymmetrical: Harder to produce, but reduces twisting due to the profile on entry into the water, producing a smoother stroke when adopting a low-angle touring stroke.

Symmetrical Paddle	Asymmetrical Paddle
	
(from Lightning Paddles website)	



<u>Symmetrical Paddle</u>:
Uneven forces on either side of blade when using a low-angle touring stroke; causes paddle to twist

<u>Assymmetrical Paddle</u>:
Forces more even on either side of the blade when using low angle touring stroke; results in smoother stroke

3. Blade Cross-Section:
   a) Flat Blade: A good choice for beginners and recreational paddlers. Flat blades provide easy stroking, but lack grip on the water that more advanced paddlers prefer. Also tend to flutter.
   b) Spoon Blade: Generates a powerful stroke for increased speed and control. Recommended for experienced paddlers.
   c) Dihedral Blade: Dihedral Blade: Designed to give direction to the flow of water off the blade, providing a powerful, smooth stroke.
   d) Wing Blade: Designed to generate lift, like and airplane wing. Designed for speed and straight-line paddling. Takes considerable training to use properly.

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Flat Blade Above

Dihedral Blade Above

Spoon Blade Above

Wing Blade Above