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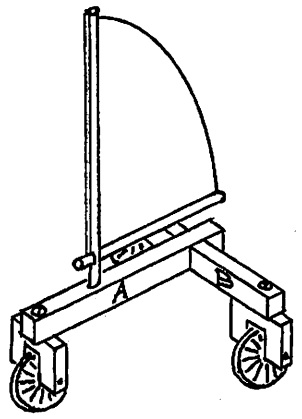
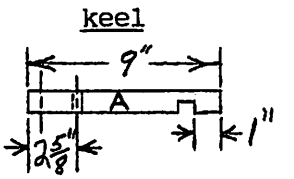
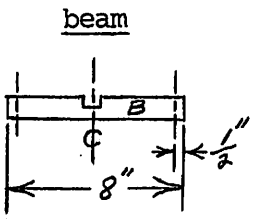
The sail cart - Sails have been attached to boats, runners, and wheels for centuries, using the wind's energy to propel them. Because the wind's direction is always changing and people usually have a specific destination in mind, steering or controlling the final direction of travel using the wind has always been a problem whether on water, ice, or land. In physics, of course, different directions are viewed as a good vector problem. For students interested in the sport of sailing, it's an opportunity to increase their understanding of sailing by studying the physics involved. The wheeled (land) sail cart suggested here can be of some help in this study. Of course, without a rudder, it will be "sailing" with just a sail. Its design is simple but produces good results. For a "wind" source, I prefer the exhaust of a Shop-Vac (vacuum cleaner) over a fan. It provides plenty of force and with its nozzle, is easier to direct.

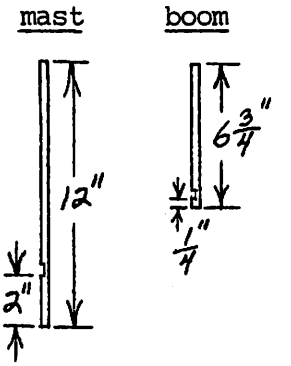
Diagram and materials: (Actual size and shape of sail is on the back.)







3/4" x 1 1/16" pine stick (2)
3/8"dia. dowel (2)
alum. flashing, 10"x6½"
#2 x ¼" screw (6)
¼"x 20 x 1½" RH bolt (3)
very low-friction pulley wheels - Pasco? (3)



Construction: (a) Make up the two pine sticks and carefully cut the notches for a tight fit; glue them together. Drill the three holes on the ends for the ¼" dia. bolts. Drill the 3/8" dia. hole 7/8" deep for the mast dowel.

(b) Make up the two dowels and carefully cut the notches for a tight fit; glue them together at exactly 90° .

(c) Cut out the sail made from alum. flashing using the pattern provided, and drill the holes for the #2 screws. Bend (bow) the sail a little (like the top of an airplane wing) before you screw it to the mast and boom. Lay the sail on the mast and boom dowels and mark the screwholes on the dowels; drill the screwholes. Fasten the sail to the dowels.

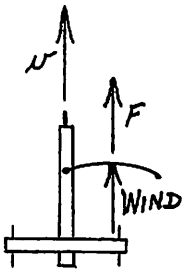
(d) Attach the pulley wheels to the sticks with the bolts; align the wheels properly and tighten the bolts with a screwdriver.

(e) The mast must fit tightly in the keel stick but must remain slightly movable so its position can be changed in the study. It must not swivel freely. If the dowel's diameter is too big, carefully sand it down. If the drilled hole is too big, add some masking tape to the dowel until the right tightness is reached.

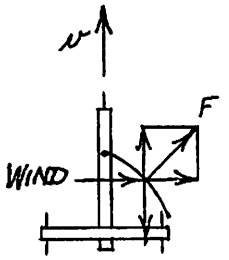
As always, feel free to change any part or all of this design even if it simply worked well enough for me.

Presentation: The sail has three basic positions (sets?) for propulsion and vector analysis. (trims?)

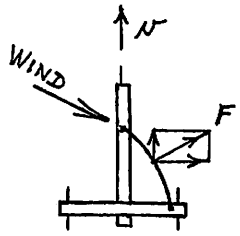
(a) tailwind (downwind) - running



(b) crosswind (windward) - reaching



(c) headwind (upwind) - beating



Begin with the Vac's nozzle (the "wind") pointed as a 0° tailwind against the sail as in (a). Rotate the nozzle 90° and the beam (sail) clockwise 45° until the 90° crosswind (b) is achieved. Continue to rotate the nozzle until the headwind (c) position is achieved. In this position, the sail is acting more like the foil of an airplane wing or the sail is producing a "lift" effect. If you can maintain the same distance between the nozzle and the sail, you should notice a decrease in the cart's speed. In true sailing, this is where the rudder comes in, to tack or change the direction (course) of the cart (boat?), thus regaining a better relative position with the wind (nozzle) to get more speed. Practice and experiment; have fun with it. Good luck!

Extra: While writing up this exercise, I was reminded of an old middle school poem I studied over 60 years ago, "The Winds of Fate" by Ella Wheeler Wilcox. It seemed relevant and something for students to think about.

One ship drives east, the other drives west,
With the self same winds that blow;
'Tis the set of the sails, and not the gales,
That determine which way they go.

Like the winds of the sea are the winds of fate,
As the voyage along through life;
'Tis the set of the soul that decides the goal,
and not the calm or the strife.

A special thank you to Dr. and Mrs. David Wagenknecht, retired English teachers at Boston University, who found the poem on the internet.