Sailing Vessel Design
Due September 15, 2003

Problem Set 1

In this problem you will determine some parameters for preliminary design of a sloop rigged sail boat with auxiliary engine.

To define some aspects of the shape, we consider an (x,y,z) coordinate system with the origin on the waterplane. x is forward, y is to starboard and z is downward. This is not a universally used coordinate system, but will be used here to define some of the boat's geometry.

Here are some physical values which may be of use to you.
Acceleration of gravity = g = 9.81 m/s^2 = 32.18 ft/s^2
Mass density of seawater = 1025 kg/m^3
Weight density of seawater = 10055 N/m^3
Weight density of lead containing 2% antimony = 107910 N/m^3
Mass density of lead containing 2% antimony = 11000 kg/m^3
1 N = 0.2248 pounds 1 pound = 4.449 Newtons
1 meter = 3.2808 feet 1 kg under gravity weights 2.2046 pounds

Consider a boat whose waterline extends from x = -5 m to x = 5 m, so it is 10 m long.

The waterline half beam, y (in m) is given by $y = 0.123(5-x)(x+5)^{½}$, where x is the numerical value in meters.

The submerged depth of the canoe body (in m) is $z = 0.02(5-x)(x+5)$ where x is the numerical value in meters.

1. Show that the maximum waterline beam is 3 m.

The block coefficient is defined to be equal to the submerged volume divided by the product of the waterline length, maximum beam and maximum draft.

2. For the canoe body of the boat considered here, the block coefficient is 0.40. It has a prismatic coefficient of Cp= 0.55. The Section area coefficient is the same at all sections and equal to Cm= 0.72. Determine the submerged canoe body displacement (volume).

3. Suppose the center of area of each section is at 40% of draft, down from the waterplane (z= 0). Determine both the VCB and the LCB of the canoe body.

4. Determine the LCF of the Boat

The keel has a trapezoidal planform with a span of 2 m below the hull. The chord at the root is twice the chord at the tip. It has a thickness fraction of 0.15 on each horizontal section. Initially choose a root chord of 2 m and a tip chord of 1 m. Place the leading edge of the root chord at 1 m forward of amidship, and consider the vertical position of the root chord to be equal to the canoe body draft at amidship. The fully submerged rudder is a simple rectangular planform foil with a chord of 0.4 m, a span of 1.2 m and a thickness fraction of 0.13. The rudder is position so that its trailing edge is at the end of the waterline (x= -5 m), so the vertical position of its root chord is equal to the draft at x= -4.8 m. The section shapes for both the keel and the rudder have area coefficients of 0.7, and the center of area is at 35% of the chord length from the leading edge.

4. Determine the displacements of the rudder, the keel and the entire appended boat. Note that we would adjust the keel size as the design progresses.

The structural weights (given in kg which is Newtons/gravity) and centers of gravity (meters below the design waterline of the various parts are in the following list. The weight for the keel is for structural elements only. The lower portion of the keel will be lead whose amount is to be determined subsequently. The weight of 250 kg for the rig and sails is for a mast height of 15 m. You will be designing a sailplan subsequently and the weight of rig and sails will be proportional to the square of the height of the mast. So if the rig height is designed to be 16 m, its weight (with sails) would be estimated as 250 x $(16/15)^2$. The freeboard at the mast is 1.2 m.

	Weight (kg)	VCG (m)
Hull	1250 kg	-0.1 m
Deck	500 kg	-1.1 m
Rudder	30 kg	0.4 m
Keel Structure	140 kg	1.3 m
Rig and Sails	250 kg (for 15 m mast)	-7.2 m
Deck Hardware	100 kg	-1.1 m
Interior components	250 kg	-0.4 m
Engine and propulsion	250 kg	-0.2 m
People	400 kg	-1.2 m
Miscellaneous items	250 kg	-0.7 m

5. The remaining additional weight will be lead. Determine how much 2% antimony lead will be needed. Will this fit in the keel if 5% of the keel volume is initially used up by its structural components?

If the lead will fit in the keel with room to spare, there will be empty space inside the keel shell above the lead. If all the lead will not fit in the keel fin, the remainder will go into the boat as ballast. The height of the CG of any internal ballast will be at z = 0.4 m.

6. Determine the location of the CG of the entire boat.

7. We have set the center of area of each hull section as 40% of its draft. Determine the center of buoyancy (VCB and LCB) of the entire boat, including the appendages.

8. Determine the metacentric height, GM.

The rig is a fractionally rigged sloop. The mast is 15 m high above the freeboard which is 1.2 m at the mast. The height of the foretriangle is 13 m. The base of the foretriangle is 4.3 m. The tack of the mainsail is 1 m above the deck and the luff of the mainsail is 13.8 m. The length of the foot of the mainsail is 5 m.

9. Using the small angle stability formula, determine the Dellenbaugh angle for the boat, using the conventional formula based on the triangular area of the mainsail and the foretriangle.

10. Using actual sail areas for a rig as described in class, what would be the value of the Dellenbaugh angle.