Physics II
Boat Test Study Guide
Answers

Name: ______________________________

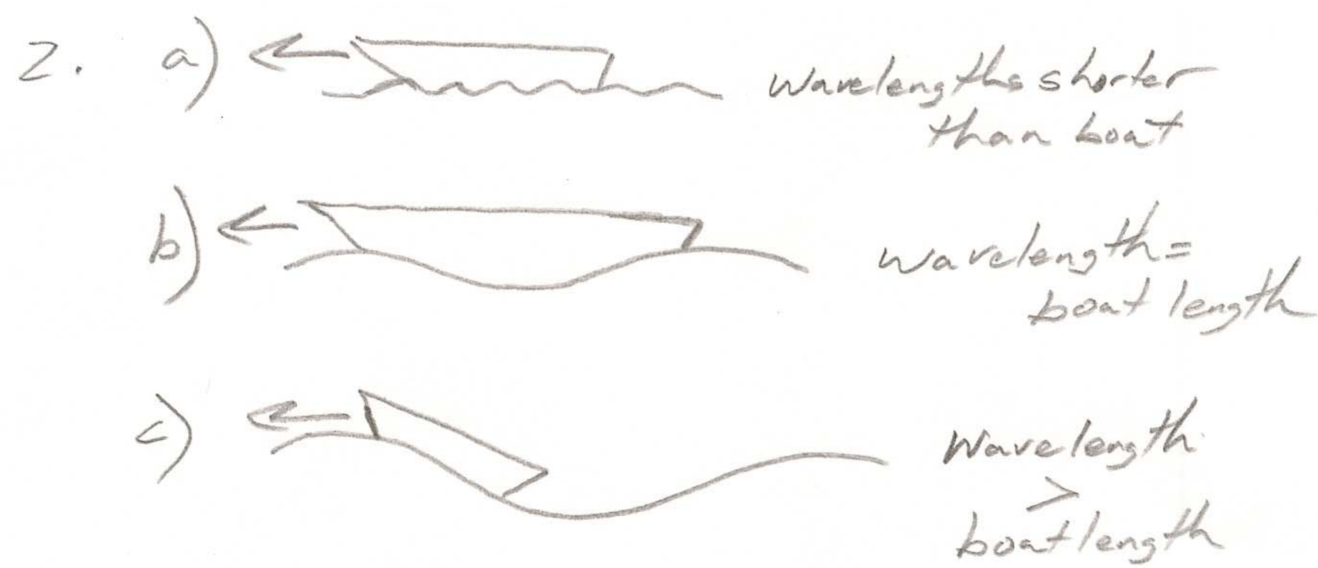
The actual test will have very similar questions. The essence of each question will be the same, though specific values, diagrams, and the order of answer choices will change. Several of these questions come from warm-up discussions. If you were absent when we discussed those questions, you may ask another student for help, or you can look up the answers on the internet.

1. What types of boats have planing hulls? What is the function of a planing hull, and why is it advantageous?

Speed boats have planing hulls. The purpose of a planing hull is to lift a boat out of the water as it accelerates. This decreases the force of drag by decreasing the boat's cross-sectional area that is exposed to the oncoming water.

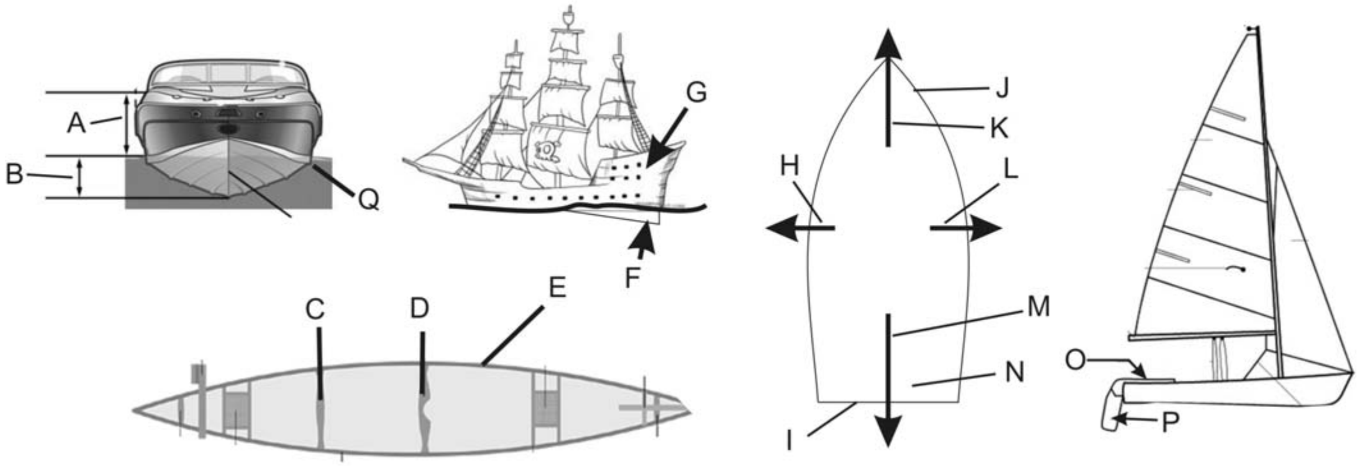
2. Draw three side view pictures of the same boat traveling through the water. In the pictures, show the boat traveling…

   a. far below its hull speed   b. at its hull speed   c. faster than its hull speed

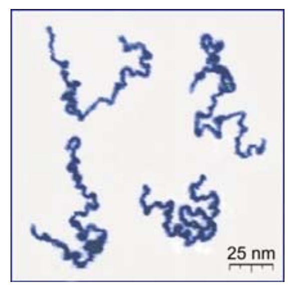


3. Match these boat terms to their corresponding letters in the diagrams…

E gunwale	A freeboard	K fore	M aft	J bow	N stern	H port
L starboard	Q chine	O tiller	P rudder	G poop	C thwart	I transom
D yoke	B draft	F keel				



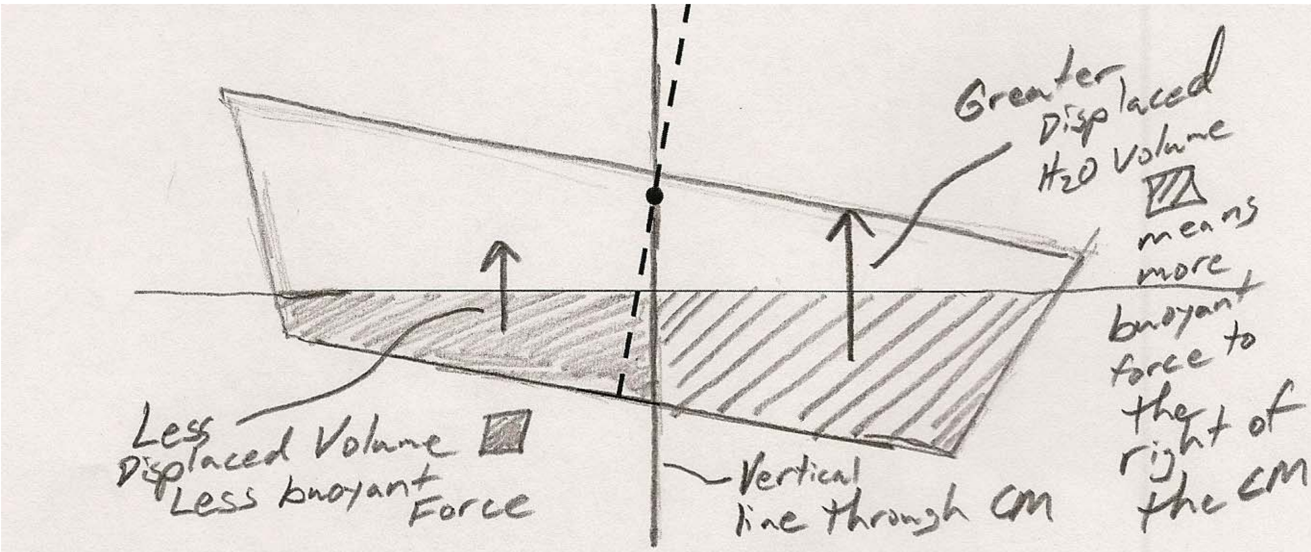
4. Why does shrinkwrap shrink when it is heated?



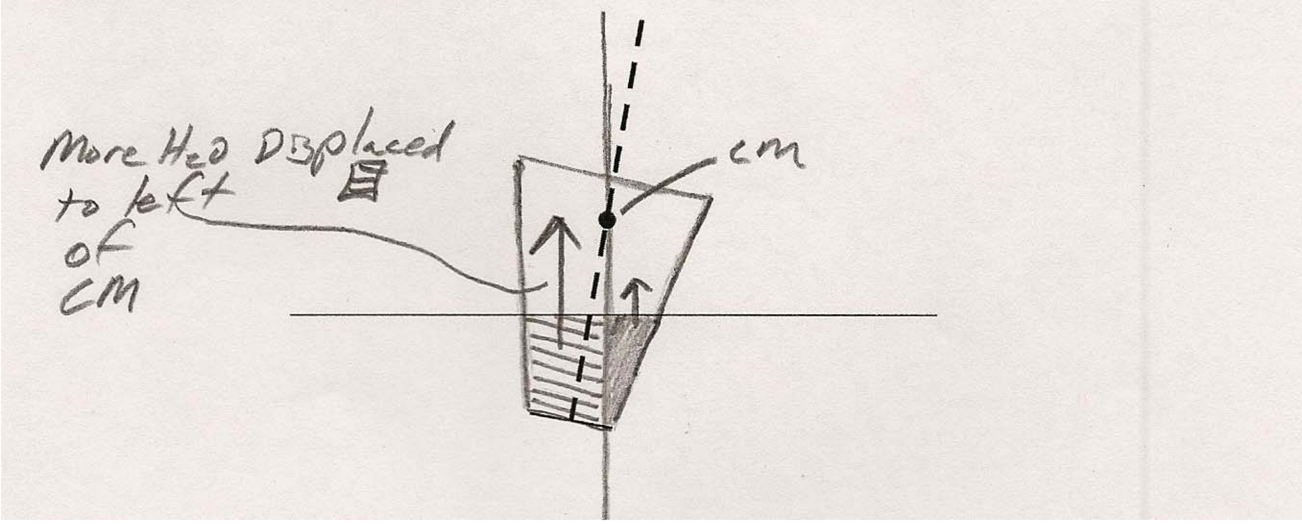
Shrinkwrap molecules are polymers (strings of atoms). Even though they are made of many atoms, in their natural state those strings are relatively short, because they are kinked and tangled (see microscope image on right). Shrink wrap is prepared by heating those polymers, stretching them, and then cooling them in a stretched orientation. Cooling the polymers while they are stretched causes them to remain frozen in this unnatural, stretched condition. When the shrinkwrap is heated, the polymers are allowed to "spring back" to their shorter tangled orientation. So the shrinkwrap shrinks.

5. In both of the diagrams below, the dotted line can be thought of as the mast of a tipping boat. The line runs directly upward from the center of the boat's floor. In the picture, the dotted line is not vertical because the boat is tilting. The solid segment at the bottom of the dotted line represents a portion at the center of the boat's tilted floor. The dot represents the boat's CM. Another solid line shows the water line. As only one small segment of each boat's hull is shown, your task will be to draw-in the remainder of each boat's hull.

a. On the first diagram, complete a hull cross-section <u>that will right itself</u> given the current tilt and the current placement of the CM. Then explain why the hull with right itself. Your hull must have mirror symmetry across the dotted line.



b. On the second diagram, follow the rules from part A, but draw a hull whose current state will cause it to continue to tilt. In this case, explain why the hull continues to tilt.

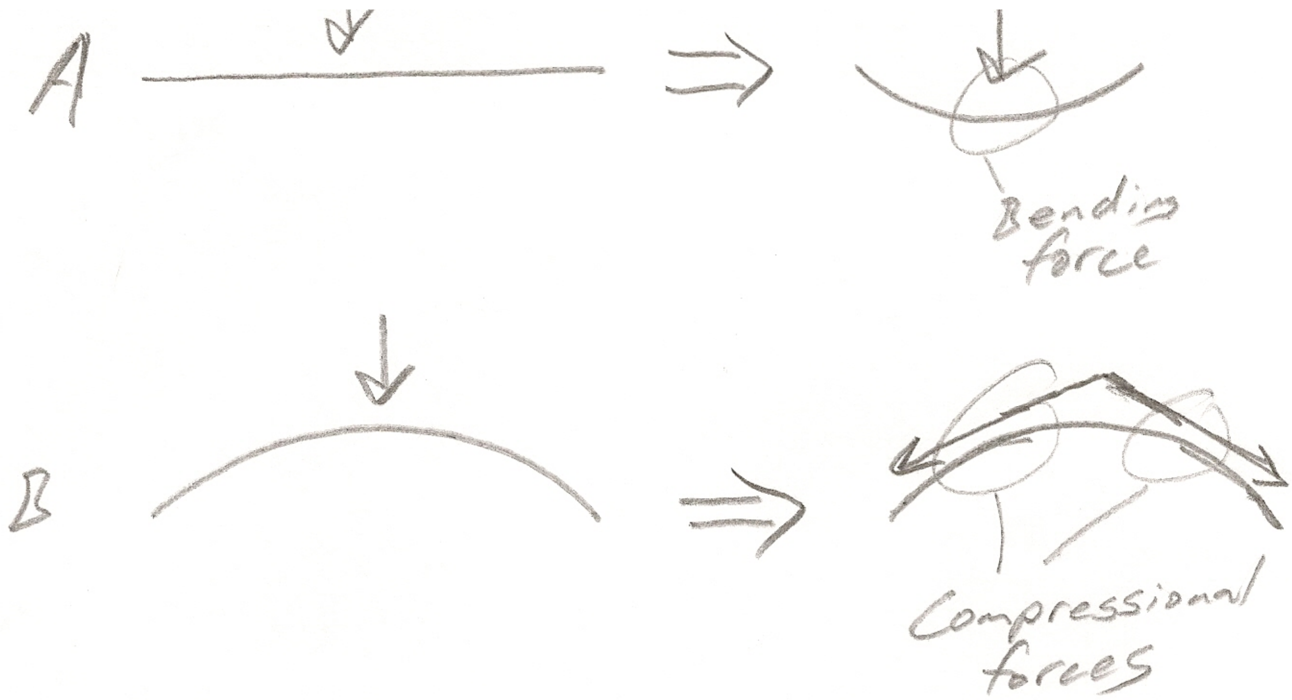


6. Two boats are made using the same type of thin plywood. One boat is box-shaped, with walls that are all flat. The other has walls that are convex. When both boats are placed in water and loaded with significant weight, the convex-walled boat is less likely to have its walls deformed by the surrounding water pressure. Why?

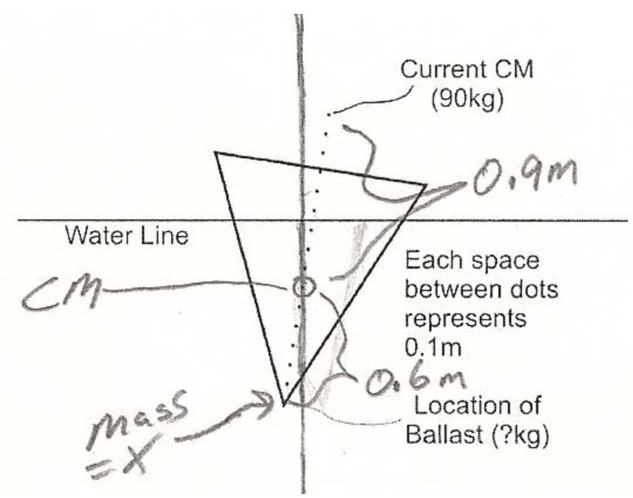
Thin plywood is easily bent. Bending plywood becomes even easier as the plywood piece gets longer. Plywood is not as easily compressed.

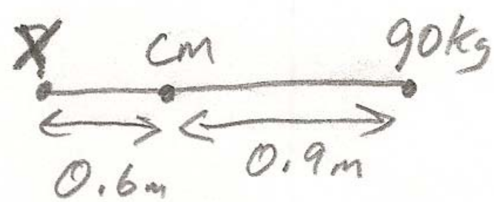
Diagram A shows how an outside force can easily bend a straight piece of plywood.

Diagram B shows what happens when a similar force is applied to a convex piece of plywood. As the force is applied, it gets resolved into vectors running somewhat parallel to the plywood's length. Since they run along the plywood's length, these vectors apply compressional force, rather than bending force, to the plywood. Plywood is much better at resisting compression than it is at resisting bending.



7. A boat and its standing passenger have a net mass of 90kg. The collective CM of the boat + passenger is shown in the diagram below. The water line and a cross-section of the boat's hull are also shown. In its current situation, the boat is unstable. Assuming that any mass of ballast can be placed at the bottom center of the boat's floor (at the point of the triangle), approximately how many kilograms of ballast must be added in that location in order to remove the boat's current tendency to tip? Note that the spaces between dots each represent 0.1m, so that the dotted center line can be used as a measuring stick. Show/explain your work. [It is realistically impossible to place all of this new mass at the very bottom of the boat, but assume that it can be done in this problem.]





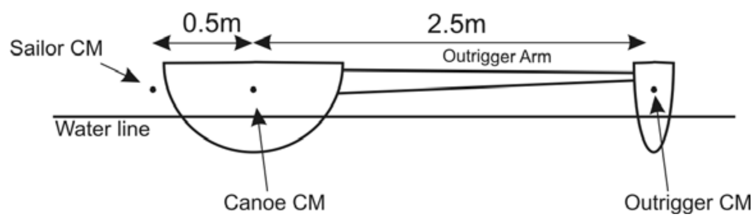
$0.6m(x) = 0.9m(90kg)$

$x = 135kg$

Bonus. A tipsy sailor is confined to a small, tippy canoe with a semicircular cross-section. It is lucky that the canoe is equipped with an outrigger, because the sailor has flopped over the side of the canoe. The location of her CM is shown. The sailor's mass is 60kg. The canoe's mass is 30kg. The outrigger's mass is 15kg. Other dimensions are shown in the diagram. Assume that the outrigger arm has negligible mass.

a. Where is the net center of mass of the entire system (sailor + canoe + outrigger), relative to the canoe's CM? **0.0714m to the right of the canoe's CM**

b. When the sailor is in the position shown, how many liters of water is the outrigger displacing? **3 liters**



8. Candace has a boat that does not "track" straight. Its constant wobbling left and right is slowing down the boat. Explain how Candace can fix her boat by adding a keel. Explain why adding a keel can help in terms of the boat's CM and CP.

Candace should add a keel behind her boat's CM. The keel should be big enough or far enough back to move her boat's CP behind its CM. As we saw with rockets, a freely rotating body will move noseward through a fluid if its CP is tailward of its CM.

9. a. A knot is approximately _**1.15**_ mph

b. Why does a knot have that particular magnitude?

A boat with a velocity of one knot directly Northward or Southward will travel one minute of latitude in an hour. 1.15is the number of miles per hour a boat must go in order to do this.

c. Where did the word "knot" come from?

At one time, boat speed was measured by throwing a "chip log" overboard. The chip log was attached to a string, and the string was wound around a spool that spun easily. When the chip log was thrown overboard, it sank enough to be held stationary, relative to the water. The boat's speed was determined by measuring the length of string came off of the spool in a given amount of time. In order to measure the length of string, **knots** were tied in the string at relative intervals.

10. State Archimedes' Principle

The buoyant force acting on an object is equal to the weight of fluid displaced by that object.

11. You are given the task of designing a box-shaped boat capable of carrying a load of **<u>300kg,</u>** <u>not including the mass of the boat itself</u>. The boat will be made of thin rectangular sheets with a mass/area ratio of **<u>15kg/m²</u>**. When it is fully loaded, your boat should have no more than **<u>0.1m</u>** of draft and at least **<u>0.3m</u>** of freeboard.

a. Provide the dimensions of an acceptable boat, in meters. L = **<u>2.03m</u>** , W =**<u>2.03m</u>** H = **<u>0.4m</u>**

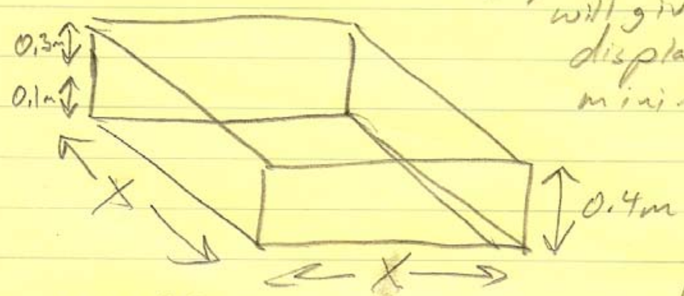
b. What is the total mass of your boat when it is fully loaded? **410.5kg (solution not shown, but it's easy)**

c. What is your boat's draft when fully loaded? **0.1m**

d. How much freeboard does your boat have when it is fully loaded? **0.3m**

11.

Square bottom will give most displacement and minimize draft



mass per m^2 of wall

wall areas

$$\text{Boat Mass} = 15\,\text{kg/m}^2\left[x^2 + 4(0.4\text{m}\,x)\right]$$

$$\text{Boat Mass} = 15x^2\,\text{kg/m}^2 + 24x\,\text{kg/m}$$

$$\text{Total Mass} = 15x^2\,\text{kg/m}^2 + 24x\,\text{kg/m} + 300\,\text{kg}$$

$$\text{Archimedes} \rightarrow \text{Total Mass} = \text{Displaced } H_2O \text{ Mass} =$$

$$m = V\rho \longrightarrow x^2(0.1\text{m})(1000\,\text{kg/m}^3)$$

$$15x^2\,\text{kg/m}^2 + 24x\,\text{kg/m} + 300\,\text{kg} = 100\,\text{kg}\,x^2/\text{m}^2$$

$$85x^2\,\text{kg/m}^2 - 24x\,\text{kg/m} - 300\,\text{kg} = 0$$

$$\frac{24 \pm \sqrt{24^2 - [4(85)(-300)]}}{2(85)}$$

$$\frac{24 + \sqrt{576 + 102{,}000}}{170} = 2.03\text{m}$$

12. Suppose your boat (above) is fully loaded, and it is dragged forward very slowly through the water by the force provided by a falling 1kg mass. As your boat is being dragged, its terminal velocity is 0.1m/s. During this process, your boat is oriented so that its width is exposed to the oncoming water.

a. What is your boat's drag coefficient?

b. At best, your answer is a close approximation. Why can't you give an exact answer?

(Draft)(width)

a) $\text{Drag} = \frac{1}{2} C_d A \rho v^2 = 1\text{kg}(9.8\text{m/s}^2) = 9.8\text{N}$

$9.8\text{N} = \frac{1}{2}(C_d)\left[(0.1\text{m})(2.03\text{m})\right]\left(1000\text{kg/m}^3\right)\left(0.1\text{m/s}\right)^2$

$C_d = 9.66$

b) This assumes that the cross-sectional area is the draft times the width. When the boat is moving, water may pile up in front of the boat, increasing A. The boat may also plane, decreasing A. For a very low velocity, however, this is probably an accurate determination of Cd