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MET 330 Fluid Mechanics
Dr. Orlando Ayala
Spring 2018
Test 1

Take home – Due Tuesday February 06th 2018 before class time.

READ FIRST

1. RELAX!!!! DO NOT OVERTHINK THE PROBLEMS!!!! There is nothing hidden. The test was designed for you to pass and get the maximum number of points, while learning at the same time. HINT: THINK BEFORE TRYING TO USE/FIND EQUATIONS (OR EVEN FIND SIMILAR PROBLEMS)
2. The total points on this test are one hundred (100). FOR THE "WORKFORCE" SYLLABUS STUDENTS: Ten (10) points are from your HW assignments, and ten (10) other points are based on the basis of technical writing. The other eighty (80) points will come from the problem solutions. FOR THE "OTHER" SYLLABUS STUDENTS: Ten (10) other points are based on the basis of technical writing. The other eighty (90) points will come from the problem solutions. For the technical writing I will follow the attached rubric.
3. There are 3 problems. Each problem will be worth (80/3) points for "Workforce" syllabus students and (90/3) for the "Other" syllabus students.
4. What you turn in should be only your own work. You cannot discuss the exam with anyone, except me. Call me, skype me, text me, email me, come to my office, if you have any question.
5. I do not read minds. You should be explicit and organized in your answers. Use drawings/figures. If you make a mistake, do not erase it. Rather use that opportunity to explain why you think it is a mistake and show the way to correct the problem.
6. You have to turn in your test ON TIME and ONLY through BLACKBOARD. You must submit only one file and it has to be a pdf file. For the ePortfolio (which is optional) you are supposed to upload this artifact to your Google drive. I will provide more instructions later.
7. Do not start at the last minute so you can handle anything that could happen. Late tests will not be accepted. Test submitted through email will not be accepted either.
8. Cheating is completely wrong. The ODU Student Honor Pledge reads: "I pledge to support the honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism." By attending Old Dominion University you have accepted the responsibility to abide by this code. This is an institutional policy approved by the Board of Visitors. It is important to remind you the following part of the Honor Code:

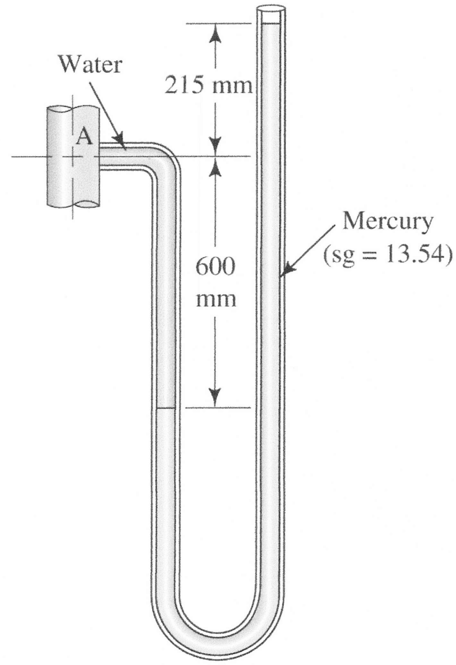
IX. PROHIBITED CONDUCT

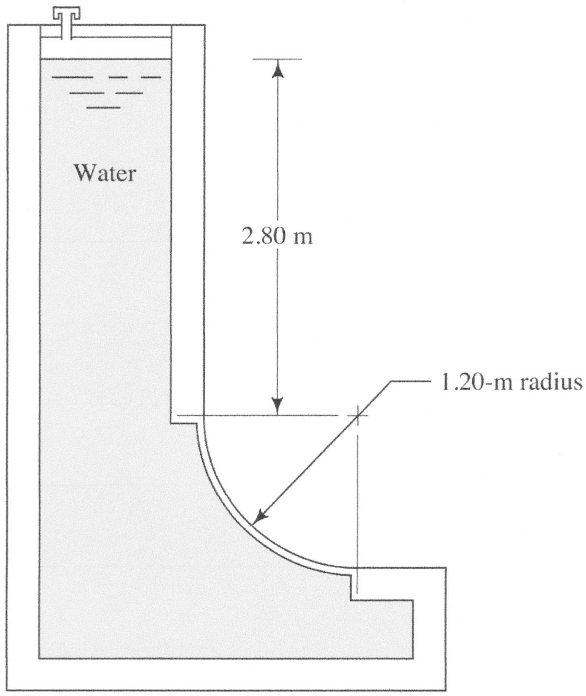
A. Academic Integrity violations, including:

1. *Cheating*: Using unauthorized assistance, materials, study aids, or other information in any academic exercise (Examples of cheating include, but are not limited to, the following: using unapproved resources or assistance to complete an assignment, paper, project, quiz or exam; collaborating in violation of a faculty member's instructions; and submitting the same, or substantially the same, paper to more than one course for academic credit without first obtaining the approval of faculty).

With that said, you are NOT authorized to use any online source of any type, unless is ODU related.

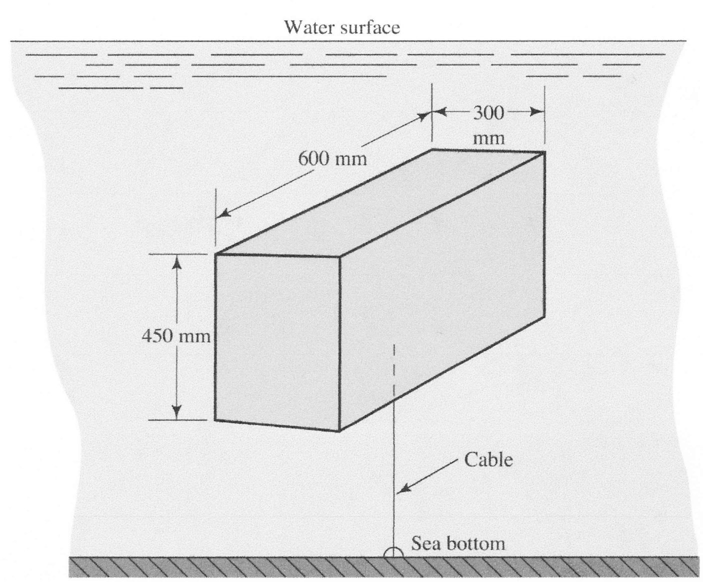
1) In the set up of the manometer shown right, the pressure at A is 102.4 kPa(gage). What would be the pressure at A if the Mercury/Water interface in the left leg and the Mercury surface on the right leg are at the same height?





2) In the set up shown left, the magnitude of the vertical force due to the pressure acting upon the curved surface is 54 kN. What would be resultant force exerted by the fluid on that surface if the water level drops to a point where the vertical force becomes half of the force magnitude in the original set up (27kN). Also, find the resultan force direction and the location of the new vertical and horizontal forces.

3) The package shown in the figure on the right weighs 258 N and it is hold near the sea bottom by a cable. The sea water specific weight is 10.05kN/m^3. If the cable breaks, the package will move to the water surface. The package will float once it reaches the surface. Would the package be stable while floating in its current orientation?

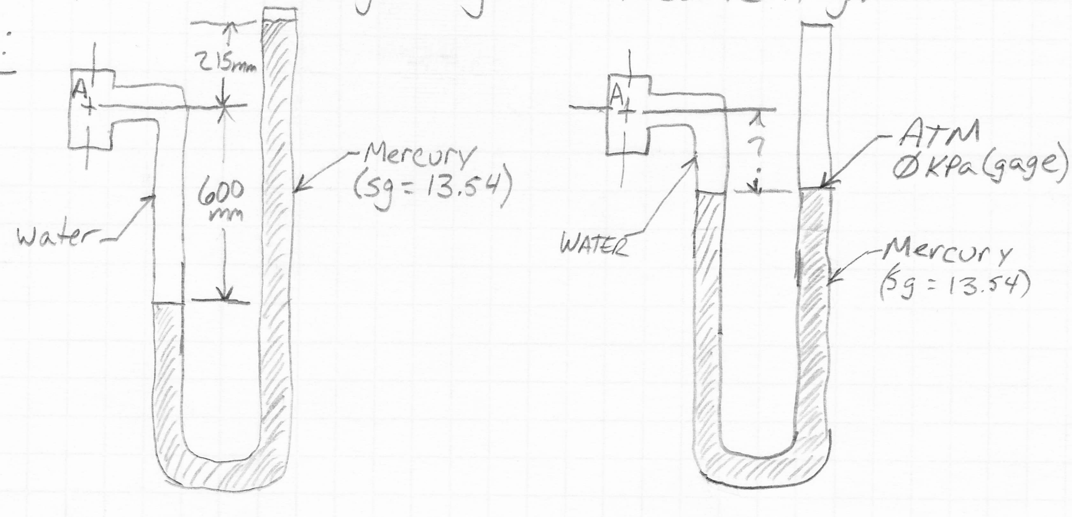


P#1 | TEST#1 | MET 330 | STEVEN BLEA | A

PROBLEM #1

PURPOSE: Compute the difference in pressure at point A required if mercury in left and right leg are at same height.

DRAWING:



Sources: Mott R. and Untener J. Applied Fluid Mechanics. 7th ed. pearson 2014

DESIGN CONSIDERATIONS: 1) Process is isothermal 2) Fluids are incompessible 3) Tube is open to atmosphere

DATA and Variables: sg (Mercury) = 13.54; Distances shown in Drawings

PROCEDURE: This problem will be solved using the equation:

$$\Delta P = \gamma * h$$

when Mercury level in both left and right leg are the same height, the pressure at the Mercury/water interface will be Ø kPa (gage) since the right side of the tube is open to atm.

we will need to figure the required change in fluid level of the Mercury to level out, then figure the distance from point A to the Mercury/water interface. The pressure at point A will be atmosphere minus the weight of the column of water from point A to the interface.

CALCULATIONS: Before calculating we need to convert the units

$$600\,mm \times \left(\frac{1\,m}{1000\,mm}\right) = 0.6\,m$$

$$215\,mm \times \left(\frac{1\,m}{1000\,mm}\right) = 0.215\,m$$

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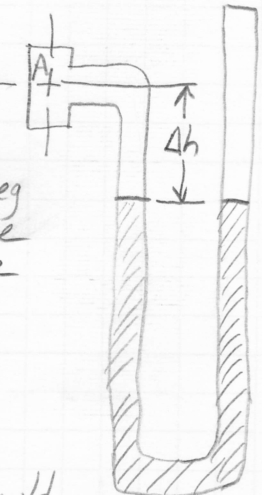
CALCULATIONS CONT :



*for Mercury to be level in both sides the right leg would have to drop and the left leg would have to rise by the same amout.

initial distance from point A to Mercury/wate interface was 0.6m

so $\Delta h = 0.6m - 0.4075m$

$\Delta h = 0.1925m$

$\Delta h_{initial} = 0.815m$

To equalize, left leg would have to rise by $\frac{0.815m}{2} = 0.4075m$

Since the pressure at the interface is equal to ATM (Ø kPa gage) the pressure at A must be atmospheric pressure minus the pressure created by the weight of the column of water from point A to the interface.

$P_A + \gamma_{water} * 0.1925m = Ø\ kPa(gage)$ or $1Ø1\ kPa(absolute)$

from table in back of book $\gamma_{water} = 9.81\ kN/m^3$

$P_A = Ø\ kPa(gage) - 9.81 \frac{kN}{m^3} + 0.1925m = -1.888\ kPa(gage)$

$P_A = 101\ kPa\ (abs) - 9.81 \frac{kN}{m^3} * 0.1925m = 99.112\ kPa\ (abs)$

$P_A = 99.112\ kPa\ (abs)$ or $-1.89\ kPa(gage)$

SUMMARY: The pressure at point A in the manometer is 99.112 kPa(abs) (or -1.89 kPa (gage))

MATERIALS: WATER, MERCURY, MANOMETER

ANALYSIS: The pressure at point A was atmospheric pressure minus the pressure created by the column of water from mercury/water interface and point A.

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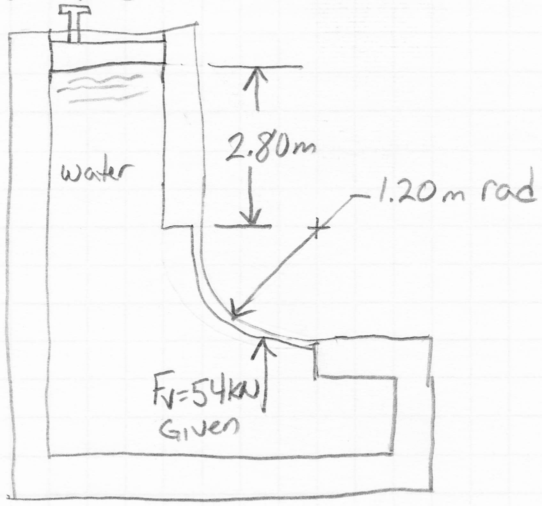
PROBLEM #2

PURPOSE: Calculate the resultant force exerted by the fluid drops to a point where the vertical force becomes half of the force of magnitude in original setup. Also find new vertical and horizontal resultant forces

DRAWING:



SOURCES:

Mott R. and Untener J. Applied Fluid Mechanics 7th ed. Pearson. 2014

DESIGN CONSIDERATIONS:

1) Structure is rigid
2) incompessible fluid
3) Process is isothermal

DATA AND VARIABLES: Dimensions given,

$\gamma_{water} = 9.81 \frac{KN}{m^3}$ from book, we also need to find the width of the surface by using the given data for vertical for of 54 KN.

PROCEDURE: To solve this problem, where the fluid is below the surface, we first assume there is fictional column of fluid above the surface.

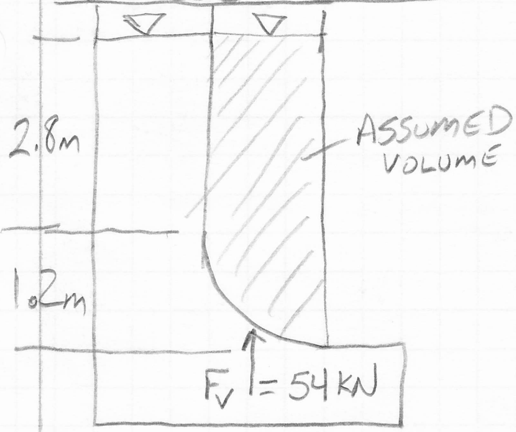
The vertical force on the curve surface is the weight of the fictional column of fluid above the surface.

$F_V = W = \gamma * V$ F_V is given as 54 KN

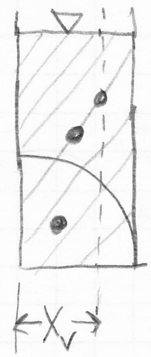
The volume of the fictional column is a composite of two separate volumes. One rectangular and one circular.

$F_V = \gamma\,(V_{rec} - V_{1/4\,circle})$

PROCEDURE CONT.:



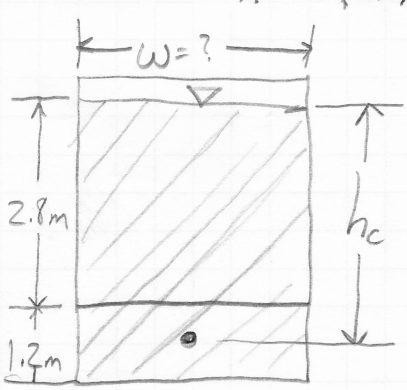
For the location of the vertical force we need to find the centroid of the assumed composite area.



For the horizontal force due to the pressure we will use the equation for a vertical surface:

$$F_h = \gamma * h_c * A$$

A = Area
h_c = Centroid of area



Calculations: Since we already have the force in the vertical direction we can use that to find the unknown dimension for the width.

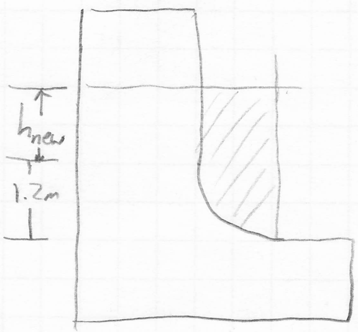
$$F_V = \gamma \left(V_{rec} - V_{1/4\,circle}\right) \Rightarrow 54\,KN = \gamma \left(V_{rec} - V_{1/4\,circle}\right)$$

$$54\,KN = 9.81\,\frac{KN}{m^3}\left(\left(2.8m + 1.2m\right) * 1.2m - \frac{\pi * 1.2^2}{4}\right) * W$$

$$54\,KN = 9.81\,\frac{KN}{m^3}\left(4.8m^2 - 1.131m^2\right) * W$$

$$54\,KN = 35.993\,\frac{KN}{m} \Rightarrow \boxed{W = 1.50\,m}$$

CALCULATIONS CONT: We can now use this data to find the height of the surface of the water when it drops to a level that exerts a force of 27 KN



$$27\,KN = 9.81\frac{KN}{m^3} * \left[(h_{new} + 1.2) * 1.2m - \frac{\pi * 1.2^2}{4}\right] * 1.5m$$

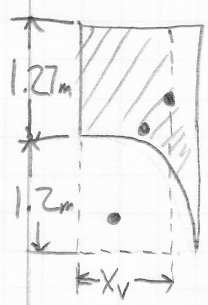
$$1.8349 = \left[1.2m(h_{new}) + 1.44 - 1.131\right]$$

$$h_{new} = \frac{1.52586m^2}{1.2m} = \boxed{1.27m}$$

we can now find the location of the centroid of the composite area:

$$A * X_v = A_{rec} * X_{rec} - A_{1/4\,circle} * X_{1/4\,circle}$$

$$X_v = \frac{[(1.27m + 1.2m) * 1.2m] * \frac{1.2m}{2} - \frac{\pi * 1.2^2}{4} m^2 * (0.424 * 1.2m)}{[(1.27m + 1.2m) * 1.2m] - \frac{\pi * 1.2^2}{4} m^2}$$



$$X_v = \frac{1.20296}{1.8330} = \boxed{0.656m}$$

we now need to calculate horizontal force:

$$F_h = \gamma * h_c * A$$

$$F_h = 9.81\frac{KN}{m^3} * \left(1.27m + \frac{1.2m}{2}\right) * (1.2m * 1.5m)$$

$$F_h = 9.81\frac{KN}{m^3} * (3.366m^3) = \boxed{33.02\,KN}$$

The horizontal force is located:

$$h_p = h_c + \frac{I_c}{h_c * A}$$

$$h_p = \left(1.27m + \frac{1.2m}{2}\right) + \left(\frac{(1.5 * 1.2^3)/(12m^3)}{\left(1.27m + \frac{1.2}{2}m * (1.2m * 1.5m)\right)}\right) = 1.87m + \frac{0.216}{3.366}$$

$$\boxed{h_p = 1.934m}$$

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CALCULATIONS:

To find the resultant force we can use the equation

$$F_r = \sqrt{F_v^2 + F_h^2} = \sqrt{(27\,KN)^2 + (33.02\,KN)^2}$$

$$\boxed{F_r = 42.65\,KN}$$

direction of resultant force:

$$\theta = \tan^{-1}\frac{F_v}{F_h} = \tan^{-1}\frac{27}{33.02}$$

$$\boxed{\theta = 39.3^\circ}$$

SUMMARY: The resultant force on the curved surface is 42.65 KN. with a direction of 39.3°

The location of the new vertical force (X_1) is 0.0656m and the horizontal force (h_p) is 1.934 m

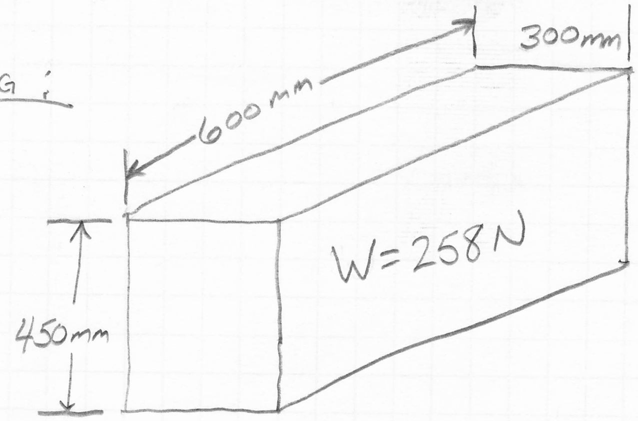
MATERIALS: A rigid container and water

ANALYSIS: With the vertical force given we did not have to solve for that variable. Instead we used the given vertical force to solve for the unknown dimension of the container. Once the unknown dimension was found we then used that data to calculate the remaining values required.

PROBLEM #3

PURPOSE: Verify whether or not the package shown will be stable or not.

DRAWING:



SOURCES: Mott R. And Untener J. Applied Fluid Mechanics 7th ed pearson 2014

DESIGN CONSIDERATIONS: 1) Isothermal process 2) Incompressible fluid

DATA AND VARIABLES: Dimensions of package are shown in drawing above.

PROCEDURE: We first need to calculate the force of the entire package. We then need to use that data to calculate the resting position of the floating object. Once we know the position, we can then determine if the package would be stable while floating.

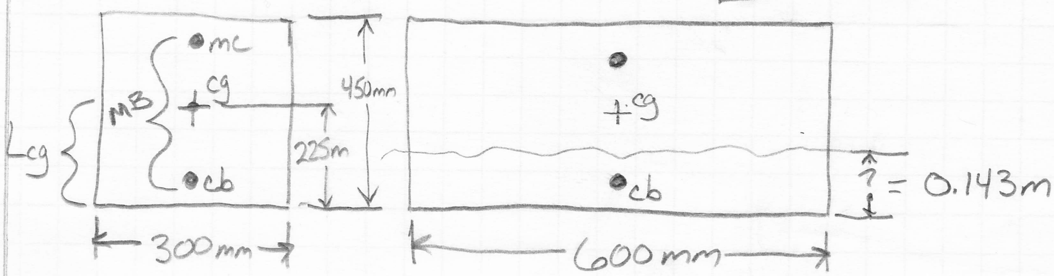
In order for the package to be stable the metacenter must be above the center of gravity which we will find.

The center of buoyancy (cb) is located at the centroid of the package.

The metacenter (mc) is located above the (cb) by distance (MB)

For the package to be stable, the point "mc" should be above the point cg:

$$L_{cb} + MB > L_{cg}$$



PROCEDURE: we know the distance to center of gravity and the width and length of the package. we can use this data to calculate the center of buoyancy and MB.

CALCULATIONS: Distances and Dimensions should be in meters

$450mm * \left(\frac{1m}{1000mm}\right) = 0.45m$ $600mm * \left(\frac{1m}{1000mm}\right) = 0.6m$

$300mm * \left(\frac{1m}{1000mm}\right) = 0.3m$

we need to calculate the buoyancy force of the entire package.

$$F_b = W + F_e \Rightarrow F_e = F_b - W$$

$$F_b = \gamma_{sw} * V_d = \left(10.05\frac{kN}{m^3}\right)(0.45m * 0.3m * 0.6m) = 0.814\ kN$$

$F_b = 814N$ so $F_e = 814N - 258N = \underline{556N}$

we need to find the displacement so the package will be at equilibrium at the surface

so, F_b at surface is 258N

the length and width are fixed. we can use this to find the height of the portion in the water.

$$F_b = \gamma_{sw} * V_d = \left(10.05\frac{kN}{m^3}\right)(0.3m * 0.6m * h_{submerged}) = 258N$$

$$0.3m * 0.6m * h_{submerged} = \frac{0.258kN}{10.05\ kN/m^3}$$

$$\boxed{h_{submerged} = 0.143\ m}$$

we can now calculate the total area as well as the submerged area

Total Area: $A_{tot} = 0.3m * 0.45m = \underline{0.135m^2}$

Submerged area is: $A_{submerged} = 0.3m * 0.143m = 0.043\ m^2$

CALCULATIONS: we need to now find the centroid of both total and submerged areas

centroid of whole area: $Y_{cg} = \frac{A \cdot y}{A_{total}} = \frac{0.3m * 0.45m * \frac{0.45m}{2}}{0.135m^2} = 0.225m$

centroid of submerged area: $Y_{cb} = \frac{A y_1}{A_{submerged}} = \frac{0.143m * 0.3m * \frac{0.143m}{2}}{0.043m^2}$

$$\boxed{Y_{cb} = 0.071m}$$

displaced volume of package:

$V_d = A_{sub} * B = 0.043m^2 * 0.6m = 0.0258m^3$

B = Length of package

Now we need to calculate the moment of inertia of the package along the X-axis:

$$\boxed{I = \frac{BH^3}{12} = \frac{0.6m * 0.3m^3}{12} = 0.00135m^4}$$

We now need to calculate MB which is the distance between cb and mc.

$$\boxed{MB = \frac{I}{V_d} = \frac{0.00135m^4}{0.0258m^3} = 0.052m}$$

So the center distance from the base of the boat is $Y_{mc} = Y_{cb} + MB = 0.071m + 0.052m$

$$\boxed{Y_{mc} = 0.123m}$$

$Y_{cg} = 0.225m$ so, $Y_{mc} < Y_{cg}$

The package will not be stable when it floats to the surface

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SUMMARY: Given the dimensions and weight of the package it would not be stable once the cable broke and it floated to the surface of the seawater

MATERIALS: 1) package 2) water 3) Broken cable

ANALYSIS: At first it seems as though, given the rectangular shape of the package that it would be stable when it floated to the surface. After analyzing the data we see that the buoyancy of the size of the package is so great that the package floats out of the water much too high due to the given weight. If the package was smaller or weighed more it might then be stable in the water.