MET 335

Module 4 – Stability of a Floating Vessel

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Purpose, Theory, and Procedure

1. **Experiment Title**
    a. Stability of a Floating Vessel
2. **Purpose**
    a. To experimentally determine the location of the metacenter of a floating vessel and compare that finding to the calculated theoretical value. I will also work to understand the concept of buoyancy and how the stability of the vessel can be affected.
3. **Theoretical Considerations**
    a. Two important points to determine stability:
        i. The center of gravity (G) – the center of mass of the entire vessel
        ii. The center of buoyancy (B) – the center of volume of immersed position
    b. M (metacenter) > G (center of gravity) = stable
    c. M (metacenter) < G (center of gravity) = unstable
    d. $\omega = weight\ of\ adjustable\ weight$
    e. $W = Total\ weight\ of\ floating\ assembly$
    f. $I = \frac{1}{12} lb^3$
    g. $V = \frac{W}{\gamma}$
    h. $BM = \frac{I}{V}$
    i. $GM = \left(\frac{\omega}{W}\right) \bullet \left(\frac{\delta x_1}{\delta \theta}\right)$
    j. Depth of immersion must be calculated.
    k. Farthest position of the adjustable weight in lateral displacement may not be recorded.
    l. Total mass of floating assembly is found by adding record total mass of pontoon without weights and the mass of the adjustable weight.
    m. $\gamma_{water} = 1000 \frac{kg}{m^3}$

4. Drawing or Sketch

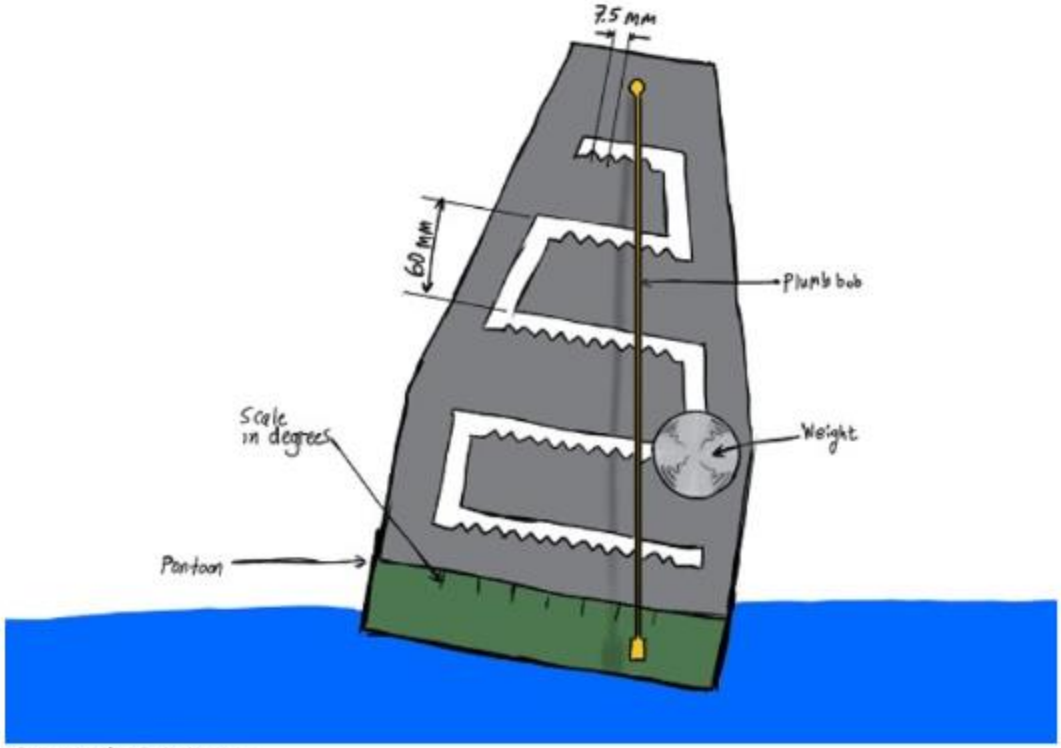
a. 

Figure 1 - Floating Pontoon

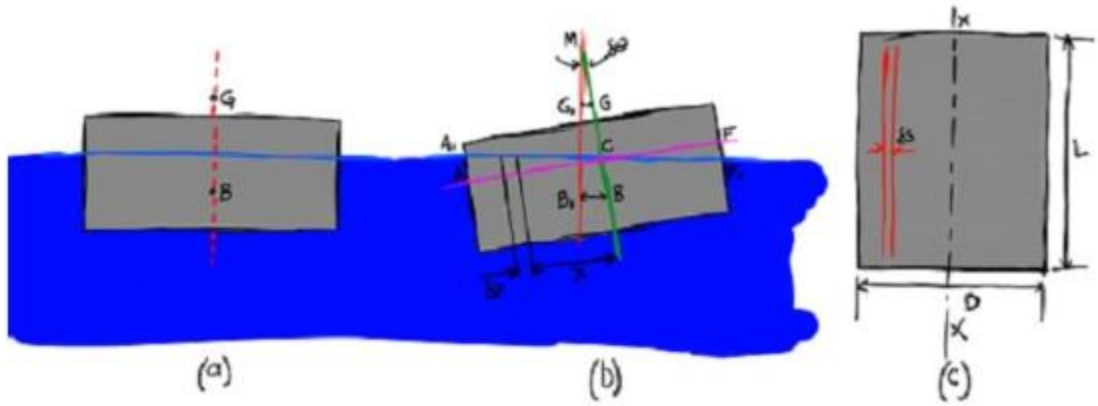


Figure 2 - Derivation of Stability of Floating Pontoon

b.

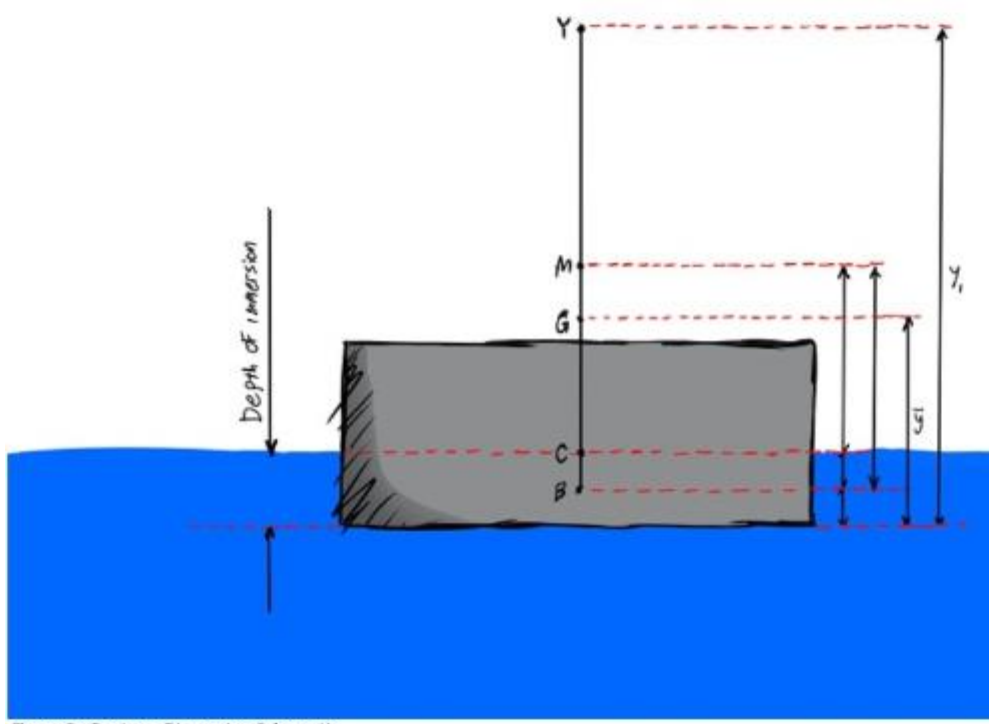


Figure 3 - Pontoon Dimension Schematic

c.

5. **Verbal Description**
    a. A rectangular pontoon floats in water and includes a plastic sail that has 5 rows of V-slots of equally spaced length on sail. These equally spaced V slots are 7.5mm apart. This apparatus consists of two machined cylinder that can be screwed together if desired. These cylinders fit into the V-slots on the sail and can be used to change the height of the center of gravity and the angle of the tilts on the pontoon. How we measure the angle of tilt is by using a plumb bob that is suspended from the center of the sail.
6. **Step-by-Step Procedure**
    a. Identified six components used for the lab
        i. Sail
        ii. Water tank
        iii. Assembly
        iv. Adjustable weight
        v. Plumb bob
        vi. Pontoon
    b. Recorded total mass of the assembly (total mass of pontoon without weights + mass of adjustable weight)
        i. Value: 2733g
    c. Recorded mass of the adjustable weight
        i. Value: 388g
    d. Recorded pontoon breadth and length
        i. Breadth: 202mm
        ii. Length: 360mm
    e. Recorded vertical height of adjustable weight
        i. 87mm
    f. Recorded the angle of tilt at -75mm
        i. -10.5°
    g. Recorded the angle of tilt at -60mm
        i. -8.5°
    h. Recorded the angle of tilt at -45mm
        i. -6.5°
    i. Recorded the angle of tilt at -30mm
        i. -4.5°
    j. Recorded the angle of tilt at -15mm
        i. -2.5°
    k. Recorded the angle of tilt at 0mm
        i. 0°
    l. Recorded the angle of tilt at 15mm
        i. 2.5°
    m. Recorded the angle of tilt at 30mm

    i. 4.5°

n. Recorded the angle of tilt at 45mm
    i. 6.5°
o. Recorded the angle of tilt at 60mm
    i. 8.5°
p. Recorded the angle of tilt at 75mm
    i. 10.5°
q. Moved the adjustable weight to a recorded height of 207mm
r. Recorded the angle of tilt at -45mm
    i. -9°
s. Recorded the angle of tilt at -30mm
    i. -6°
t. Recorded the angle of tilt at -15mm
    i. -3.25°
u. Recorded the angle of tilt at 0mm
    i. 0°
v. Recorded the angle of tilt at 15mm
    i. 3.25°
w. Recorded the angle of tilt at 30mm
    i. 6°
x. Recorded the angle of tilt at 45mm
    i. 9°
y. Moved the adjustable weight to a recorded height of 327mm
z. Recorded the angle of tilt at -15mm
    i. -5°
aa. Recorded the angle of tilt at 0mm
    i. 0°
bb. Recorded the angle of tilt at 15mm
    i. 5°
cc. Successfully completed lab

Recorded Data Table(s)

Total mass of floating assembly: 2733(g)

Mass of adjustable weight: 388(g)

Breadth of position (B): 202(mm)

Length of pontoon (L): 360(mm)

Depth of immersion: 370 (mm)

Height of adjustable weight, y: (mm)	Angles of list (degrees) for adjustable weight lateral displacement from sail center line x_1 (mm)										
	-75	**-60**	**-45**	**-30**	**-15**	**0**	**15**	**30**	**45**	**60**	**75**
87	**-10.5°**	**-8.5°**	**-6.5°**	**-4.5°**	**-2.5°**	**0**	**2.5°**	**4.5°**	**6.5°**	**8.5°**	**10.5°**
207	**-**	**-**	**-9°**	**-6°**	**-3.25°**	**0**	**3.25°**	**6°**	**9°**	**-**	**-**
327	**-**	**-**	**-**	**-**	**-5°**	**0**	**5°**	**-**	**-**	**-**	**-**

Sample Calculations

$$V = \frac{W}{\gamma} = \frac{2733g}{1000\frac{kg}{m^3}} = \frac{2.733kg}{1000\frac{kg}{m^3}} = \boxed{0.0027m^3}$$

$$0.027m^3 = 202mm \bullet 360mm \bullet depth\,of\ immersion$$

$$0.027m^3 = .202m \bullet .36m \bullet depth\,of\ immersion$$

$$\frac{0.027m^3}{.202m \bullet .36m} = 0.37m = \boxed{370mm}$$

$$GM = \left(\frac{388}{2733}\right) \bullet (0.144) = 0.0204 * 1000 = \boxed{20.44mm}$$

$$\bar{y} = y_1 \frac{\omega}{W} + A = (87mm)(\frac{388g}{2733g}) + 40.7mm = \boxed{53.05mm}$$

$$CG(87) = 53.05 - 370 = \boxed{-316.95mm}$$

$$CM(207) = (29.53mm) + (-299.91mm) = \boxed{-270.38mm}$$

$$Depth\,of\ center\ of\ buoyancy = (370/2) = \boxed{185mm}$$

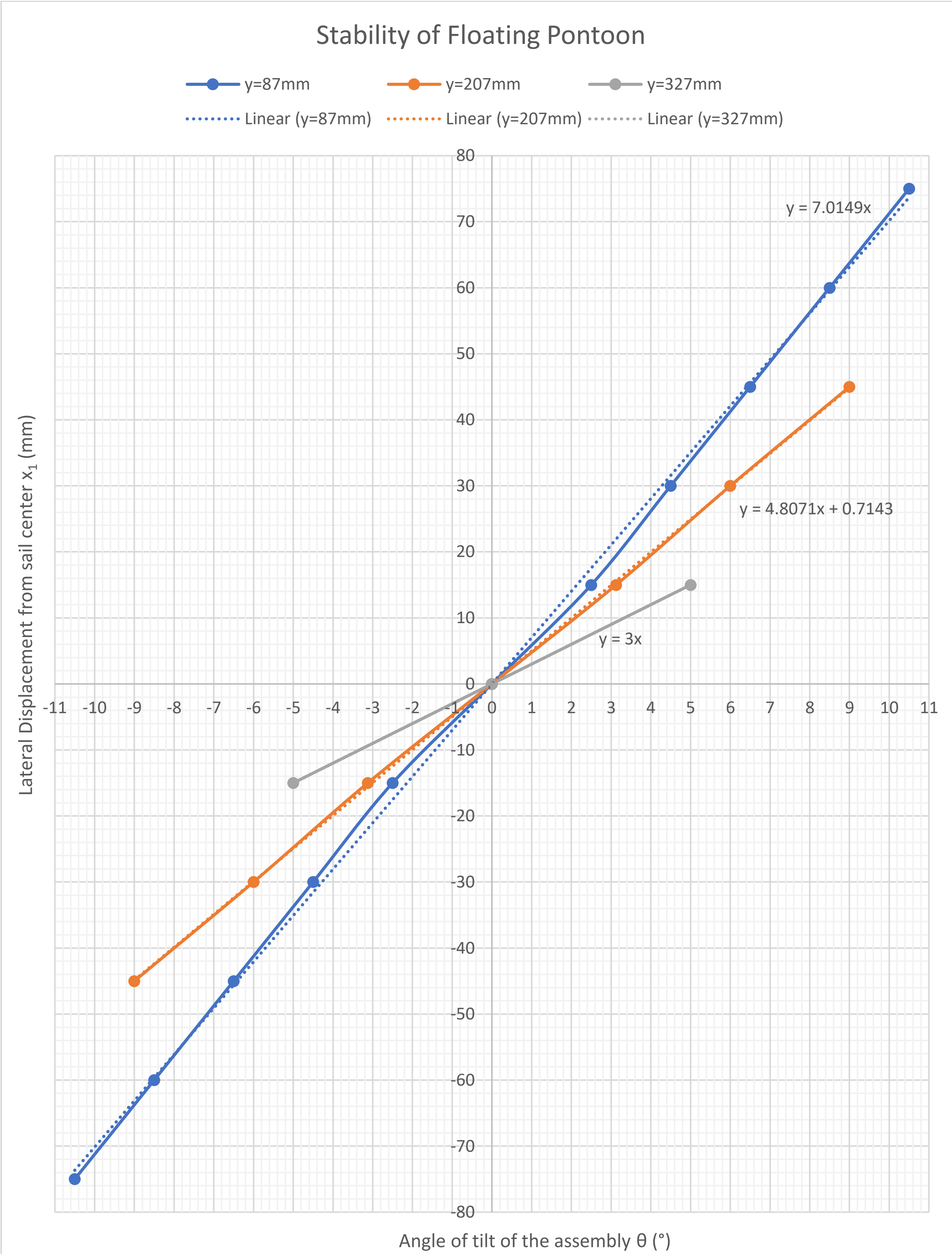
$$BM(327) = CM + depth\,of\ center\ of\ buoyancy = -235.60mm + 185mm = \boxed{-50.60mm}$$

$$Average\,BM = \frac{(-111.51mm + -85.38mm + -50.60mm)}{3} = \boxed{-82.50mm}$$

Calculated Data Table(s)

Description:	Value:	Unit:
Total mass of floating assembly:	2733	g
Mass of adjustable weight:	388	g
Breadth of position (B):	202	mm
Length of pontoon (L):	360	mm
Depth of immersion:	370	mm
Volume of Water Displaced (V)	0.0027	m^3
Inverse slope of y=87mm	0.144x-0.065	mm/rad
Inverse slope of y=207mm	0.208x-0.149	mm/rad
Inverse slope of y=327mm	0.333x	mm/rad
GM y=87mm	20.44	mm
GM y=207mm	29.53	mm
GM y=327mm	47.28	mm
$\bar{y}(87) =$	53.05	mm
$\bar{y}(207) =$	70.09	mm
$\bar{y}(327) =$	87.12	mm
CG(87)	-316.95	mm
CG(207)	-299.91	mm
CG(327)	-282.88	mm
CM(87)	-296.51	mm
CM(207)	-270.38	mm
CM(327)	-235.60	mm
Depth of center of buoyancy	185	mm
BM(87)	-111.51	mm
BM(207)	-85.38	mm
BM(327)	-50.60	mm
BM Average	-82.50	mm

Graph(s)



Stability of Floating Pontoon
y=87mm
y=207mm
y=327mm
Linear (y=87mm)
Linear (y=207mm)
Linear (y=327mm)
y = 7.0149x
y = 4.8071x + 0.7143
y = 3x
Lateral Displacement from sail center x1 (mm)
Angle of tilt of the assembly θ (°)
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
11

Discussion of Results and Conclusions

From the graph above, my first conclusion is that the there is a direct correlation between the increase in height of the adjustable weight and the slope of the curve it creates. We see that in the three curves on the graph. The blue line being 87mm and having a slope of 7.0149, the orange line being 207mm and having a slope of 4.8071, and the grey line being 327mm and having a slope of 3. So as the height of the adjustable weight increases, the lower the slope gets.

As far as my results go, I believe there was a mishap somewhere and I think it started when finding the inverse of the using that specific term in the equation 4. While the GM values and the ybar values all seem reasonable, the CG, CM, and BM values all seem a little off because of the negative value. While the negative value may be true because the value is "under" the surface of the water, it still makes me a little nervous that something went wrong in my calculations and has caused a domino effect and made everything else wrong as well.

Lastly, my last discussion point is that the angle of tilt also has a direct correlation with the height of the adjustable weight. The higher the weight, the higher the angle of tilt. We see this in the graph when the weight is at 327mm and the angle of tilt for -15mm displacement along the center sail was 5 degrees. For reference, at 87mm, the angle of tilt was only 2.5 degrees. This leads me into another conclusion and that is while one may think that if I doubled the height of the adjustable sail, my angle of tilt would double. That's not true here as we can see from the graphical results. The height almost has to quadruple before the angle of tilt doubles.