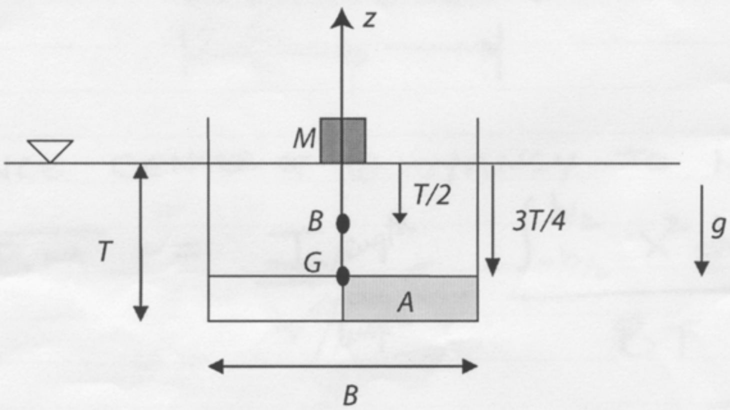
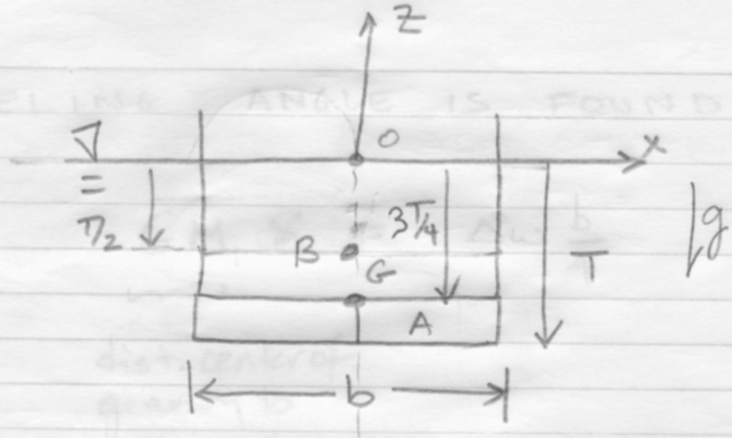
Example Problem:

You are called on the scene when a double hull tanker unfortunately runs into a migrating whale shark (while very gentle these sharks are very large). This collision has created a small crack in the outer hull allowing water to flood the lower compartment. A pump with mass, *M*, is on deck at the centerline of the vessel. A cross sectional view of the vessel is shown below:



1) Determine the vertical position of the metacentric height.
2) The empty compartment A is flooded with water and the tanker assumes a small heel angle, δ. Determine the angle in terms of the given quantities.
3) In order to stabilize the tanker to a level position the captain decides to shift the pump horizontally on deck and asks you to determine the necessary horizontal shift for the heel angle to vanish.
4) In order not to run aground coming into port the captain must know the new draft of the vessel following the adjustment in part c and again asks you to calculate it for him.



N.B.: ALL CALCULATIONS ASSUME A UNIT WIDTH INTO THE PAPER

GIVENS

(A) $\overline{KB} = T/2$

(1) DISTANCE CENTER OF BUOYANCY TO METACENTER:

$$\overline{BM} = \frac{I/\text{length}}{\forall/\text{length}} = \frac{\int_{-b/2}^{b/2} x^2\,dx}{BT} = \frac{b^2}{12T}$$

DISTANCE C.B. TO ORIGIN $\overline{BO} = T/2$

DISTANCE HEIGHT OF METACENTER ON Z-AXIS

$$\overline{ZM} = \overline{BM} - \overline{BO} = \boxed{\frac{b^2}{12T} - \frac{T}{2}}$$

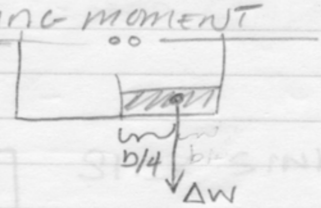
(2) FILLING COMPARTMENT IS EQUIVALENT TO TWO SIMULTANEOUS EFFECTS:

A) LOSS OF BUOYANCY:

$$\Delta W = \rho \frac{b}{2}\frac{T}{4} = \rho \frac{bT}{8}$$ = WEIGHT OF WATER IN AREA "A"

B) APPLICATION OF HEELING MOMENT

$$M_{heel} = \Delta W \frac{b}{4}$$



$$\forall_1 = \forall_0 - \Delta W = \frac{7}{8}\rho bT$$ ← NEW BUOYANCY VOLUME

HEELING ANGLE IS FOUND

$$W'\overline{GM_1}\,\delta = \Delta w \frac{b}{4}$$ ← eqn from "incline" tests

$\overline{GM_1}$: dist. center of gravity to new metacenter

W' new displaced weight $\rho g \forall_1$

For small δ

$$\delta = \frac{\rho b^2 T L}{32\overline{GM_1}\cdot W'} = \frac{\rho b^2 T L}{32(\overline{GM_1})\cdot \frac{7}{8}\rho b T L}$$

$$\therefore \boxed{\delta = \frac{b}{28(\overline{GM_1})}}$$

NEW VESSEL CONFIGURATION: ADDED WEIGHT OF WATER IS COMPENSATED BY ADDITIONAL BUOYANCY IN ORDER FOR VESSEL TO REACH EQULIBRIUM.

$$\rho g \forall_1 = \rho g \forall_0 + \Delta w g$$

- $\rho g \forall_1$: new displaced volume
- $\rho g \forall_0$: original weight of vessel
- $\Delta w g$: additional weight of water in "A"

$$\text{so: } \forall_1 = \forall_0 + \frac{bT}{8} = bT + \frac{bT}{8}$$

$$\forall_1 = bT_1$$

$$\forall_1 = \frac{9bT}{8}$$

PART D: $\therefore \boxed{T_1 = \frac{9T}{8}}$ SHIP SINKS $\frac{T}{8}$ DEEPER WITH FLOODED COMPARTMENT

NEW POSITION OF BUOYANCY CENTER FOR A "LEVEL" VESSEL RELATIVE TO THE KEEL:

$$CB \Rightarrow \quad \overline{KB_1} = \frac{T_1}{2} = \frac{9}{16}T$$

C.G. STAYS CONSTANT.

$$\overline{KG} = \frac{T}{4}$$

DISTANCE BTWN NEW CB & METACENTER

$$\overline{BM} = \frac{I_w}{\forall_1} = \frac{b^3/12}{9bT/8} = \frac{2}{27}\frac{b^2}{T}$$

METACENTRIC HEIGHT:

$$\overline{GM_1} = \overline{KM} - \overline{KG}$$

$$= \overline{KB} + \overline{BM} - \overline{KG}$$

$$\overline{GM_1} = \frac{9}{16}T + \frac{2b^2}{27T} - \frac{T}{4}$$ → can now plug into eqn for θ!

(C) PUMP MUST BE SHIFTED SUCH THAT IT CREATES A MOMENT TO OFFSET THE MOMENT DUE TO THE FLOODED COMPARTMENT

$$M\Delta x = A w \frac{b}{4}$$

($M\Delta x$: moment from weight; $Aw\frac{b}{4}$: moment from flooded compartment)

Example Problem:

$$\text{so } \Delta x = \frac{A w\, b/4}{M}$$

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