STABILITY FORMULAE

SOME BASIC FORMULAS

Area of Waterplane = L x B x C_W

…. L = Length of vessel

…. B = Breadth of vessel

...C_W = Co-efficient of Waterplane

Volume of Displacement = L x B x d x C_B

…. d = depth of vessel

….C_B = Block co-efficient

Volume (V) = L x B x d

Displacement (W) = L x B x d x R.D

... R.D = Relative density of water

TRANSVERSE STABILITY

Rectangular Waterplanes

$$BM = \frac{I}{V} \quad \text{where} \quad I = \frac{LB^3}{12}$$

…. V = Volume of vessel

Depth of centre of buoyancy below water line:

$$= \frac{1}{3}\left(\frac{d}{2} + \frac{V}{A}\right)$$

LONGITUDINAL STABILITY

a) Rectangular Waterplanes

$$I_L = \frac{L^3B}{12} \quad \text{and} \quad BM_L = \frac{I_L}{V}$$

b) Box Shapes

$$BM_L = \frac{L^2}{12d}$$

LIST

$$GG_{1(Horizontal)} = \frac{w \times d}{W}$$

….d = distance moved horizontal
….w = weight
….W = Final Displacement

$$GG_{1(Vertical)} = \frac{w \times d}{W}$$

….d = distance moved vertical
….w = weight
….W = Final Displacement

$$TAN\theta = \frac{GG_1}{GM}$$

….GM = Metacentric height

$$TAN\theta = \frac{\text{Listing Moments}}{W \times GM}$$

….GM = Use Fluid GM
…. W = Final Displacement

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DRY DOCKING

$$P = \frac{trim \times MCTC}{lcf}$$

...lcf = Distance of COF from where vessel touches blocks first

...P = Upward force acts on ship where block first touches

$$P = \frac{C.O.T \times MCTC}{lcf}$$ …..In case of declivity of Dock

$$\text{Virtual loss of GM} = \frac{P \times KG}{W}$$

$$\text{Virtual loss of GM} = \frac{P \times KM}{(W - P)}$$ if P – force is very small

After taking the blocks (F & A):

P = Change in TMD (cms) x TPC or

P = Reduction in water level x TPC

….TMD = True mean draft

$$\text{Change in Draft (rise) (cms)} = \frac{P}{TPC}$$ …always subtract from draft

$$TMD = \text{Draft Aft} - \left(\frac{LCF}{LBP} \times \text{Trim} \right)$$

….subtract if vessel is by the stern

….add if vessel is by the head

DRY DOCKING
HYDROSTATIC TABLES AND VESSEL 'A' TYPE PROBLEMS

Proceed as follows :

1. Find **mean draft** from the present given drafts.
2. From this mean draft, look in tables for **LCF**
3. Using that LCF, calculate **TMD**
4. From the TMD, look in tables and find **MCTC, LCF and DISPLACEMENT**
5. Calculate now **P-Force**
6. For Displacement (W) at Critical Instant, find **W-P**
7. From this new (W), look in tables for **KM_T**
8. Now find **Virtual loss of GM** and use **new KM_T** but **old Displacement (W)**
9. Find now **initial GM**, using the **new KM_T**
10. Apply Virtual loss of GM in it and find the **EFFECTIVE GM**.

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FREE SURFACE EFFECT / MOMENT

$$FSE = \frac{l.b^3.R.D}{12W}$$

$$FSM = \frac{l.b^3.R.D}{12}$$

….R.D = Density of liquid in tank

$$FSE = \frac{FSM}{W}$$

$$\text{Corrected FSM} = \text{Tabulated FSM} \times \frac{\text{Actual R.D}}{\text{Assumed R.D}}$$

$$\text{New FSM} = \text{Original FSM} \times \frac{1}{n^2}$$

….n = number of tanks which are subdivided

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DYNAMICAL STABILITY

Dynamical Stability = W x Area under the curve

STATICAL STABILITY

Statical Stability = W x GZ

KN CURVES

$GZ = KN - KG.SIN\theta$

INCLINING EXPERIMENT

$$GM = \frac{w \times d}{W} \times \frac{\text{Length of Plumbline}}{\text{Deflection}}$$

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RIGHTING MOMENT

SMALL ANGLES OF HEEL (UPTO 10^O HEEL):

$$GZ = GM \times SIN\theta$$

LARGE ANGLES OF HEEL (WALL SIDED FORMULA):

$$GZ = SIN\theta \left(GM + \frac{1}{2}.BM.TAN^2\theta \right)$$

WIND HEELING MOMENT:

$$\text{Total Wind heeling moment} = \frac{F.A.d}{1000}$$

$$\text{GZ (at angle of heel)} = \frac{F.A.d}{1000W}$$

….d = Distance of centre of buoyancy to centre of windage area

….F = Steady wind force of 48.5 kg/m^2

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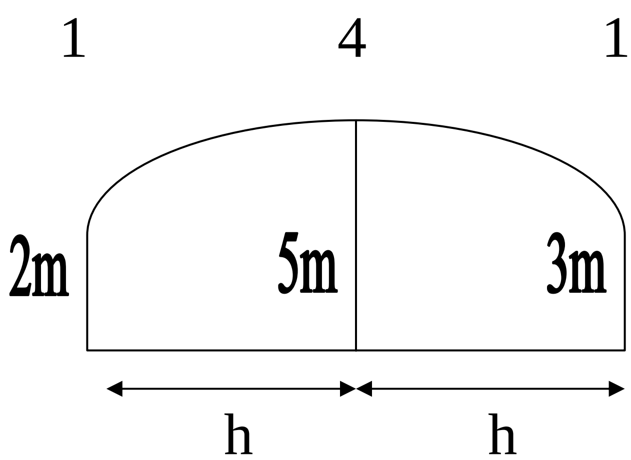
SIMPSON'S RULES

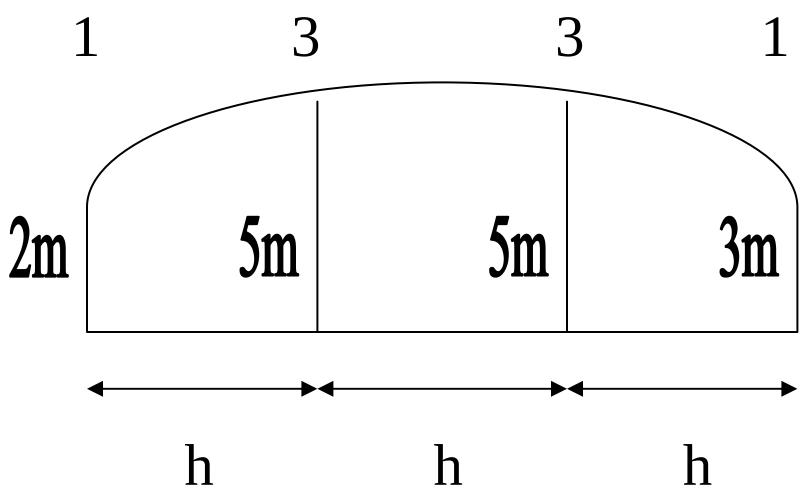
SIMPSON'S FIRST RULE:



$$\text{Area} = \frac{h}{3} \times (a + 4b + 2c + 4d + 2e + 4f + g)$$

Remember : 1 4 1

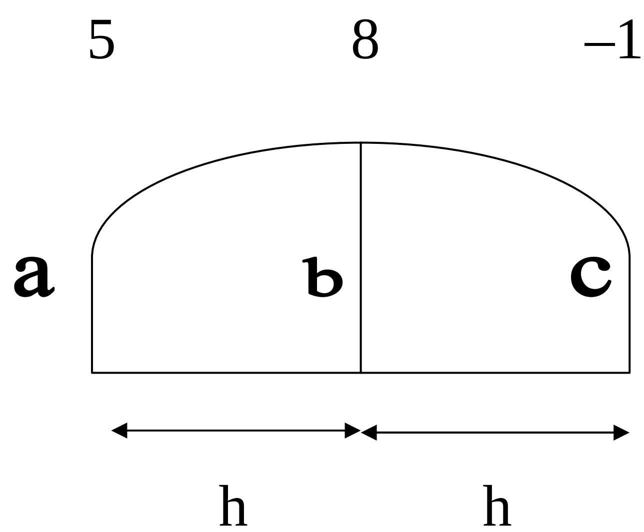
SIMPSON'S SECOND RULE:



$$\text{Area} = \frac{3}{8} \times h \times \text{sum of products}$$

Remember : 1 3 3 1

SIMPSON'S THIRD RULE:



Area = $\frac{h}{12}$ x (5a + 8b – c)

Remember : 5 8 –1

NB:
Divide the value of ' h (in degrees) ' by ' 57.3 ' while calculating the area.

NB:
In the 3rd rule of Simpson, we are only looking for a particular piece between the area i.e., from one co-ordinate to other and this is mainly used by surveyors for calculating sludge in bunker tank etc. Also for knowing the full area, we use Simpson's first rule.

GM CONDITIONS

GM AT LOLL:

$$GM = \frac{2(\text{Initial GM})}{\cos\theta}$$

….answer will be –ive but write +ive sign

WHEN GM IS NEGATIVE:

$$\tan(\text{Heel}) = \sqrt{\frac{-2GM}{BM}}$$

WHEN GM IS NIL:

$$\tan(\text{Heel}) = \sqrt[3]{\frac{2wd}{BMW}}$$

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TURNING CIRCLE

$$\text{TAN(Heel)} = \frac{v^2 BG}{gGMr}$$

….v = velocity of ship(m/s)
….r = radius of turning circle
….g = Acceleration due to Gravity (9.81 m/s)

$$T = \frac{2\pi K}{\sqrt{GMg}}$$

….T = Period of Rolls (seconds)
….K = Radius of Gyration
….π = 3.142857143 (constant)

$$K = \sqrt{\frac{I}{W}}$$

….I = Weight Moment of Inertia about Rolling axis (tonne - metres^2)

Hence we get,

$$T = 2\pi\sqrt{\frac{I}{WGMg}}$$

$$\text{Actual New Draft} = \left[\text{Initial draft} + \frac{B}{2}\tan\theta\right]\cos\theta$$

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AIR DRAFT

CALCULATING LENGTH OF THE IMMAGINARY MAST WHICH IS EXACTLY ABOVE THE 'CF':

Correction to Aft Mast

$$= \frac{\text{Dist. of center mast from Aft Mast}}{\text{Dist. between the two masts}} \times \text{Diff. of ht between masts}$$

….subtract this value from the ht of Aft mast

or

Correction to Fwd Mast

$$= \frac{\text{Dist. of center mast from Fwd Mast}}{\text{Dist. between the two masts}} \times \text{Diff. of ht between masts}$$

….add this value from the ht of Fwd mast

FOR FINDING DRAFT FWD AND AFT

$$\frac{\text{Trim between masts}}{\text{Distance between masts}} = \frac{\text{Trim of vessel}}{\text{LBP}}$$

…..(from this, calculate 'trim of vessel' and proceed as follows)

$$\text{Trim Effect Aft} = l_a \times \frac{\text{Trim}}{L}$$

$$\text{Trim Effect Fwd} = l_f \times \frac{\text{Trim}}{L}$$

GRAIN

$$\text{Weight of Grain} = \frac{\text{Volume}}{\text{S.F}}$$

$$\text{Weight of H.M} = \frac{\text{Volumetric H.M}}{\text{S.F}}$$

$$\text{Approx. Angle of heel} = \frac{\text{Total H.M}}{\text{Max.H.M}} \times 12^o$$

…. Max.H.M can be found in the Tables of Maximum permissible Grain heeling moment against 'W' and KG

$$GG_1 (\lambda o) = \frac{w \times d}{W}$$

….w = weight of Grain liable to shift while rolling
….d = horizontal distance of Grain shift

$$\lambda o = \frac{\text{Total volumetric H.M (in } m^4)}{\text{S.F} \times W}$$

$\lambda_{40} = GG_1(\lambda o) \times 0.80$ ….80% of λo (GG_1)

NB:
If value for cargo is given for centroid then follow as normal but if value given for 'Kg' of cargo then,

Multiply H.M value for fully filled compartment by 1.06 and
Multiply H.M value for partially filled compartment by 1.12

TRIM

HYDROSTATIC TABLES AND VESSEL ‘A’ TYPE PROBLEMS

Proceed as follows :

1. Find **mean draft** from the present given drafts.
2. From this mean draft, look in tables for **LCF**
3. Using that LCF, calculate **TMD**
4. From the TMD, look in tables and find **MCTC, LCB and DISPLACEMENT**
5. Calculate now **INITIAL LCG**
6. Now Calculate **FINAL ‘W’ and FINAL LCG by MOMENTS**
7. With this FINAL ‘W’, go in tables and look find **TMD, LCB, LCF and MCTC**
8. Calculate **TRIM**
9. After this calculate **TRIM EFFECTS (F & A)**
10. Now apply this TRIM EFFECT to **find FINAL DRAFTS.**

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TRIM

Trimming Moment = w x d (d = distance from COF)

Area of Waterplane = L x B x C_w

Volume of Displacement = L x B x D x C_B

$$TPC_{sw} = \frac{1.025A}{100}$$

$$FWA = \frac{W}{40\ TPC}$$

$$DWA = \frac{FWA\ (1.025 - R.D)}{0.025}$$

$$MCTC = \frac{WGM_L}{100L}$$

$$TPC_{DW} = \frac{R.D}{1.025} \times TPC_{SW}$$

$$MCTC_{DW} = \frac{R.D}{1.025} \times MCTC_{SW}$$

$$Displacement_{(DW)} = \frac{RD}{1.025} \times Displacement_{(sw)}$$

$$Sinkage\ (cms) = \frac{w}{TPC}$$

$$COT = \frac{\text{Trimming Moments}}{\text{MCTC}}$$

$$\text{COD Aft} = \frac{l_a}{L} \times COT$$

COD Fwd = COT – COD Aft

WHEN THE VESSEL IS EVEN KEEL

LCG = LCB

FOR A BOXED SHAPED VESSEL

$$BM = \frac{B^2}{12d}$$

$$KB = \frac{\text{draft}}{2}$$

FOR A BOX SHAPED VESSEL WHEN DISPLACEMENT CONSTANT

$$\frac{\text{New Draft}}{\text{Old Draft}} = \frac{\text{Old Density}}{\text{New Density}}$$

FOR A SHIP SHAPED VESSEL WHEN DRAFT CONSTANT

$$\frac{\text{New Displacement}}{\text{Old Displacement}} = \frac{\text{New Density}}{\text{Old Density}}$$

TO KEEP THE AFT DRAFT CONSTANT

$$d = \frac{L \times MCTC}{l_a \times TPC}$$ ….keeping the aft draft constant

$$d = \frac{L \times MCTC}{l_f \times TPC}$$ ….keeping the fwd draft constant

d = Distance from the CF
l_a = Distance from the AP
l_f = Distance from the FP

TO PRODUCE A REQUIRED TRIM

$$\text{Change in Draft (cms)} = \left(\frac{l.}{L} \times \frac{w \times d}{MCTC} \right) \pm \frac{w\ .}{TPC}$$

(– ive for Draft Aft)
(+ ive for Draft Fwd)
(l_a for aft and l_f for fwd)

$$\text{Trim (cms)} = \frac{W\,(LCB - LCG)}{MCTC}$$

(Values for LCB, LCG and MCTC should be final)

COT WITH CHANGE OF DENSITY

$$COT = \frac{W(RD_1 - RD_2)(LCF - LCB)}{RD_1 \times MCTC_2}$$

$$LCG_{INITIAL} = LCB \pm \left(\frac{\text{Trim (cms)} \times MCTC}{W} \right)$$

….(– ive for stern trim)
….(+ ive for head trim)

$$\text{TRIM EFFECT AFT} = \frac{l_a}{L} \times \text{Trim}$$

$$\text{TRIM EFFECT FWD} = \frac{l_f}{L} \times \text{Trim}$$

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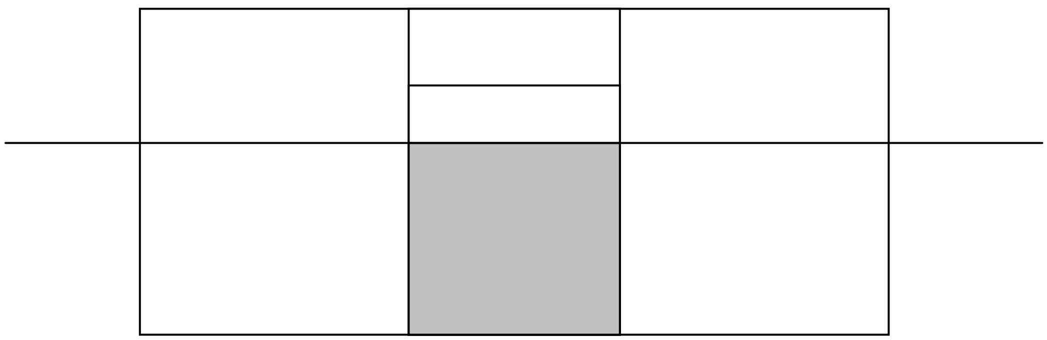
BILGING

WHEN HEIGHT OF COMPARTMENT IS GIVEN AND ABOVE WATER LEVEL
CALCULATE SINKAGE BY RECOVERABLE BUOYANCY METHOD:



$$\text{Sinkage} = \frac{\text{Buoyancy still to be recover}}{L \times B}$$

Buoyancy still to be recover = Lost buoyancy – Recoverable Buoyancy

Volume of Lost Buoyancy = l x b x draft

Recoverable Buoyancy = (L – l) x B x (Depth – Draft)

To find the Final Draft, add the Sinkage to Tank's height

WHEN IN QUESTION PERMEABILITY OF THE CARGO IS GIVEN
CALCULATE THE EFFECTIVE LENGTH OF THE TANK:

$$\text{Permeability } (\mu) = \frac{\text{Broken Stowage}}{\text{Stowage Factor}}$$

Broken Stowage = Actual Stowage – Solid Stowage

$$\text{Solid Stowage} = \frac{1}{\text{R.D of liquid in tank}}$$

Effective Length = Tank's length $_{\text{ORIGINAL}}$ x Permeability (μ)

NB
After calculating 'Effective length' always use this length for tank's length.

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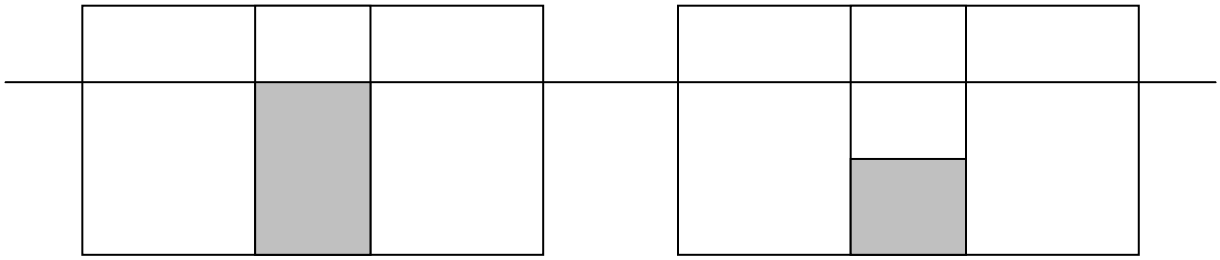
BILGING

MIDSHIP COMPARTMENT



NON WATER TIGHT WATER TIGHT

$$\text{Sinkage} = \frac{v}{A - a}$$ …If NON WATER TIGHT

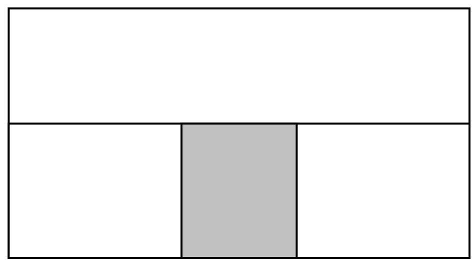
$$\text{Sinkage} = \frac{v}{A}$$ …If WATER TIGHT

$$BM = \frac{LB^3}{12V}$$ …If WATER TIGHT

$$BM = \frac{(L - l)B^3}{12V}$$ …If NON WATER TIGHT

BILGING

SIDE COMPARTMENT



PLAN VIEW OF A SHIP

$$\text{Sinkage} = \frac{v}{A - a}$$ …If NON WATER TIGHT

$$\text{Sinkage} = \frac{v}{A}$$ …If WATER TIGHT

$$\tan\theta = \frac{BB_1}{GM}$$ ….θ = List

$$BB_1 = \frac{a \times d}{\text{Final } A}$$ ….d = Distance from center of tank to ship's center line

….Final A = A – a

$$BM = \frac{I_{OZ}}{V}$$

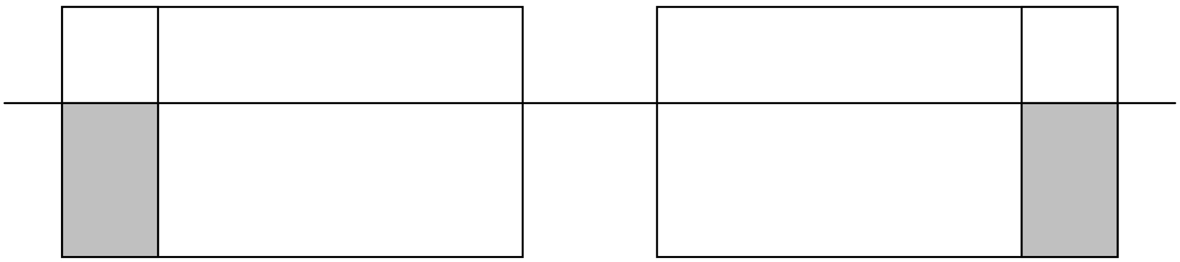
$$I_{OZ} = I_{AB} - Ad^2$$ ….$d = \frac{B}{2} + BB_1$

….A = A – a

$$I_{AB} = \frac{LB^3}{3} - \frac{lb^3}{3}$$

BILGING

END COMPARTMENT



AFT COMP. BILGED
NON WATER TIGHT

FWD COMP. BILGED
NON WATER TIGHT

$$\text{Sinkage} = \frac{v}{A - a}$$ …If NON WATER TIGHT

$$\text{Sinkage} = \frac{v}{A}$$ …If WATER TIGHT

If 'KG' is not given, then $GM_L = BM_L$

$$BM = \frac{L^3B}{12V}$$ …If WATER TIGHT

$$BM = \frac{(L - l)^3B}{12V}$$ …If NON WATER TIGHT

$$COT = \frac{w \times d}{MCTC}$$

….w = l x b x dft x R.D

….d = $\frac{L}{2}$ ..(Non water tight case)

….d = tank's center to CF ..(Water tight case)

$$MCTC = \frac{WGM_L}{100L}$$

$$COD\ Aft = \frac{l_a}{L} \times COT$$

$$\ldots l_a = \left(\frac{L - l}{2}\right) + \text{tank's length}$$

(For measuring the CF from AP) ..(Non water tight case)

$$\ldots l_a = \frac{L}{2}$$

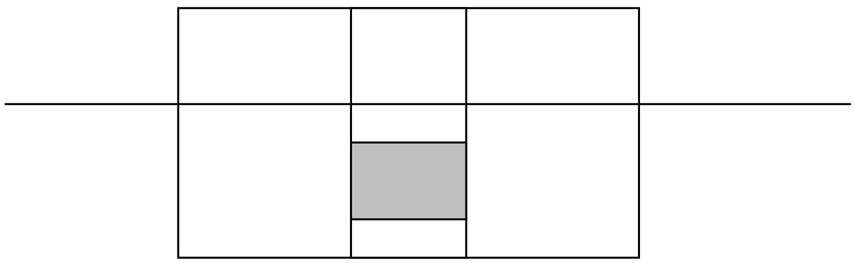
(CF hasn't changed and is amidships) ..(Water tight case)

When Fwd compartment is bilged (and non water tight), then just use

$$\ldots l_a = \left(\frac{L - l}{2}\right)$$

(Again for measuring the CF from AP) ..(Non water tight case)

<u>IN CASE OF WATER TIGHT COMPARTMENT BELOW WATER LINE AND BELOW THE TANK THERE IS AN EMPTY COMPARTMENT</u>



a) Deal as normal water tight case
b) Use volume of the tank only which is filled with water but not the portion beneath it.
c) But for KB of tank, use from K to center of tank

<u>NB</u>

<u>IN WATER TIGHT CASE</u>

- BM remains the same before and after
- KB is different before and after bilging
  - KB_1 is half of Original Draft
  - KB_2 is found by moments

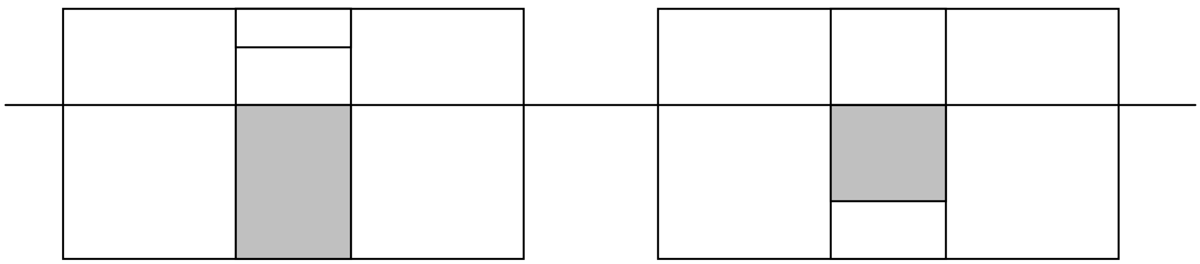
<u>IN NON WATER TIGHT CASE</u>

- BM is different before and after bilging

  BM_1 is $\frac{LB^3}{12V}$ and BM_2 is $\frac{(L - l)B^3}{12V}$

- KB is different before and after bilging
  - KB_1 is half of Initial Draft
  - KB_2 is half of New Draft

PLEASE NOTE THE FOLLOWING CONDITIONS



WATER TIGHT CASE

NON WATER TIGHT CASE

Calculate:

a) Sinkage by non w/t method

b) KB_2 by Moments

NB:

In all cases of WATER TIGHT COMPARTMENT, calculate KB by the MOMENTS METHOD& use ‘New Draft’ in calculating this KB when calculating volume.

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