

Q.2. **BILGING (Box-shaped vessel)**

© Consider a box-shaped vessel 100m long and 12m wide, floating at an even keel draft of 6m in SW. It has an empty amidship compartment 10m long and 8m wide, on the centreline of the ship.

Total/Initial WPA: $L \times B$

Area of bilging/WPA lost: $L \times b$

* Case 1A: Midship compartment has watertight flat far above the waterline.
If this compartment is bilged, calculate the new draft

⇒ Volume of lost buoyancy = $L \times b \times d$

Intact WPA: Initial WPA - WPA lost = $LB - lb$

$$\text{Sinkage} = \frac{\text{vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{L \times b \times d}{LB - lb}$$

Hence, New draft: Initial draft + sinkage.

Diagram

* Case 2A: Midship compartment has watertight flat 1m above the keel.
If the compartment is bilged below this watertight flat, calculate the new draft

⇒ Volume of lost buoyancy = $L \times b \times h$

Intact WPA = LB

$$\text{Sinkage} = \frac{\text{vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{L \times b \times h}{LB}$$

Hence, New draft: Initial draft + sinkage.

* Case 3A: Midship compartment has watertight flat 1m above the keel.
If the compartment is bilged above this watertight flat, calculate the new draft.

⇒ Volume of lost buoyancy = $L \times b \times (d - h)$

Intact WPA = $LB - lb$

$$\text{Sinkage} = \frac{\text{vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{L \times b \times (d - h)}{LB - lb}$$

New draft = Initial draft + sinkage.

- * Case 4A: Midship compartment has watertight flat 6m above the keel.
If the compartment is bilged. calculate the new draft

⇒ $\text{volume of lost buoyancy} = l \times b \times d$

$\text{Intact WPA} = LB$

$\text{Sinkage} = \frac{\text{vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{l \times b \times d}{LB}$

$\text{New draft} = \text{Initial draft} + \text{sinkage}$

- * Case 5A: Midship compartment has watertight flat 6.5m above the keel.
If this compartment is bilged. calculate the new draft

⇒ ① → Since, WT flat is above the waterline/draft.

If this compartment is bilged, water will be filled upto the waterline/draft

So, $\text{volume of lost buoyancy} = l \times b \times d = 10 \times 8 \times 6 = 480 \text{ m}^3$

② Assume, sinkage due to bilging, is 0.5

In that case, $\text{sinkage} = 0.5 \text{ m}$

$\text{volume of buoyancy regained} = S \times (LB - lb)$

$= 0.5 \times \{ (120 \times 10) - (10 \times 8) \}$

$= 0.5 (1200 - 80)$

$= 560 \text{ m}^3$

- ③ * Since, the ship cannot regain more buoyancy than what she lost
Hence, sinkage will be less than 0.5

And, WT flat remains above the waterline even after bilging.

- ④ * So, the calculation will be same as case 1A.

$\text{Volume of lost buoyancy} = l \times b \times d$

$\text{Intact WPA} = LB - lb$

$\text{Sinkage} = \frac{\text{vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{l \times b \times d}{LB - lb}$

$\text{New draft} = \text{Initial draft} + \text{sinkage}$

- * Case 6A: Midship compartment has watertight flat 6.2m above the keel. If this compartment is bilged. Find the new draft.

⇒ ① Reference to case 5A,

$$\text{Vol. of buoyancy lost} = L \times b \times d = 10 \times 8 \times 6 = 480 \text{ m}^3$$

$$\text{② Sinkage} = h - d = 6.2 - 6.0 = 0.2 \text{ m}$$

$$\begin{aligned} \text{Vol. of buoyancy regained} &= S \times (LB - lb) \\ &= 0.2 (1200 - 80) \\ &= 224 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{③ Vol yet to regain} &= \text{Vol. of buoyancy lost} - \text{Vol. of buoyancy regained} \\ &= 480 - 224 \\ &= 256 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{During this, Intact WPA} &= LB \\ &= 120 \times 10 \end{aligned}$$

$$= 1200 \text{ m}^2$$

$$\begin{aligned} \text{④ Further sinkage} &= \frac{\text{Vol. yet to regain}}{\text{Intact WPA}} \\ &= \frac{256}{1200} = 0.213 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{⑤ New draft} &= \text{Initial draft} + \text{sinkage} + \text{further sinkage} \\ &\Rightarrow 6.0 + 0.2 + 0.213 = 6.413 \text{ m} \end{aligned}$$

PERMEABILITY

Permeability is the percentage ratio of space available for the entry of water into a compartment, to the total volume of compartment.

- For an empty compartment, $p = 100\%$.
- For a full compartment, $p = 0\%$.

- * Case 1B: same condition as 1A, given that $p = 35\%$.

$$\text{Volume of lost buoyancy} = 35\% \text{ of } L \times b \times d = 35\% (10 \times 8 \times 6) = 168 \text{ m}^3$$

$$\text{Intact WPA} = LB - 35\% \text{ of } lb = 1200 - (80 \times \frac{35}{100})$$

$$\Rightarrow 1200 - 28 = 1172 \text{ m}^2$$

$$\begin{aligned} \text{Sinkage} &= \frac{\text{Vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{35\% \text{ of } L \times b \times d}{LB - 35\% \text{ of } lb} = \frac{168}{1172} = 0.143 \text{ m} \end{aligned}$$

$$\text{New draft} = \text{Initial draft} + \text{sinkage}$$

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* Case 2B: Condition is same as 2A, given that space below the WT flat is full of SW ballast.

⇒ Since, the compartment is full of SW & even after bilged, the compartment will get filled by SW only.

Permeability, $p = 0.1$.

Hence, Sinkage = 0

New draft = Initial draft

Note: If the bilged compartment had an RD different from that of water outside, this shortcut can not be used

* Case 3B: Condition is same as 3A, given that $p = 40\%$.

Volume of lost buoyancy = 40% of $L \times b \times (d-h)$

Intact WPA = $LB - 40\%$ of lb

Sinkage = $\frac{\text{Vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{40\% \text{ of } L \times b \times (d-h)}{LB - 40\% \text{ of } lb}$

New draft: Initial draft + sinkage.

* Case 4B: Condition is same as 4A, given that $p = 30\%$.

Volume of lost buoyancy = 30% of $L \times b \times d$

Intact WPA = LB

Sinkage = $\frac{\text{Vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{30\% \text{ of } L \times b \times d}{LB}$

New draft = Initial draft + sinkage

* Case 5B: Midship compartment has watertight flat 6.2m above the keel. If this compartment is bilged, given $p = 25\%$. Calculate the new draft

① Reference to case 5A

Vol. of buoyancy lost: 25% of $L \times b \times d$

$$= \frac{25}{100} (10 \times 8 \times 6)$$

$$= 120 \text{ m}^3$$

② Assume sinkage = 0.2 m

$$\begin{aligned}\text{Volume of buoyancy regained} &= S \times \{LB - (25\% \text{ of } lb)\} \\ &= 0.2 \times \{1200 - (25\% \text{ of } 80)\} \\ &= 0.2 \times (1200 - 20) \\ &= 236 \text{ m}^3\end{aligned}$$

③ Ship can not regain more buoyancy than what she lost

Hence, sinkage will be less than 0.2 m.

WT flat remains above the waterline even after bilging.

④ So, the calculation will be same as LB

$$\text{Volume of lost buoyancy} = 25\% \text{ of } L \times B \times d$$

$$\text{Intact WPA} = LB - 25\% \text{ of } lb$$

$$\text{Sinkage} = \frac{\text{Vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{25\% \text{ of } L \times B \times d}{LB - 25\% \text{ of } lb}$$

New draft: Initial draft + sinkage.

* Case 6B: Midship compartment has watertight flat 6.1 m above the keel.

If this compartment is bilged, given $p = 80\%$. Calculate the new draft.

① Reference to case 5A, vol. of buoyancy lost = 80% of $L \times B \times d$

$$= \frac{80}{100} (10 \times 8 \times 6) = 384 \text{ m}^3$$

② Sinkage = $h - d = 6.1 - 6.0 = 0.1 \text{ m}$

$$\text{Vol. of buoyancy regained} = S \times (LB - 80\% \text{ of } lb)$$

$$= 0.1 \times (1200 - 80\% \text{ of } 80) = 113.6 \text{ m}^3$$

③ Volume yet to regain = vol. of lost buoyancy - vol. of buoyancy regained

$$= 384 - 113.6$$

$$= 274 \text{ m}^3$$

During this, Intact WPA = LB

$$= 120 \times 10$$

$$= 1200 \text{ m}^2$$

④ Further sinkage = $\frac{\text{Vol. yet to regain}}{\text{Intact WPA}}$

$$= \frac{274}{1200} = 0.225 \text{ m}$$

⑤ New draft = Initial draft + sinkage + further sinkage

$$= 6.0 + 0.1 + 0.225 = 6.325 \text{ m}$$

BILGING - MIDSHIP COMPARTMENT

05/05/2026

NOV 2025, NOV 2024,
AUG 2024, FEB 2024,
NOV 2018

A box shaped vessel 40m long and 20m wide and 5.0m deep is floating in D.W of R.D 1.005 with even keel draft of 3.0m with KG 4.2m. A midship compartment extending from side to side 15m long with permeability 80% is bilged. calculate the GM after bilging

Solⁿ:-

After bilging (case 1B)

$$\begin{aligned}\text{Volume of lost buoyancy} &= 80\% \text{ of } l \times b \times d \\ &= \frac{80}{100} (15 \times 20 \times 3) \\ &= 720 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Intact WPA} &= \text{Initial WPA} - \text{WPA lost} = LB - 80\% \text{ of } lb \\ &= (40 \times 20) - 80\% \text{ of } (15 \times 20) \\ &= 800 - 80\% \text{ of } 300 \\ &= 800 - 240 \\ &= 560 \text{ m}^2\end{aligned}$$

$$\text{Sinkage} = \frac{\text{vol. of lost buoyancy}}{\text{Intact WPA}} = \frac{720}{560} = 1.286 \text{ m}$$

$$\begin{aligned}\text{New draft} &= \text{Initial draft} + \text{sinkage} \\ &= 3.000 + 1.286 \\ &= 4.286 \text{ m}\end{aligned}$$

$$KB = \text{draft}/2 = 4.286/2 = 2.143 \text{ m}$$

$$\begin{aligned}BM_T &= \frac{I(\text{intact})}{V} \\ &= \frac{I(\text{initial}) - I(\text{lost})}{V}\end{aligned}$$

$$= \frac{\frac{LB^3}{12} - 80\% \text{ of } \frac{lb^3}{12}}{V}$$

$$= \frac{\frac{40 \times 20^3}{12} - 80\% \text{ of } \frac{15 \times 20^3}{12}}{40 \times 20 \times 3}$$

$$= \frac{26666.667 - 8000}{2400}$$

$$= \frac{26666.667 - 8000}{2400}$$

$$= 7.778 \text{ m}$$

05/05/

$$\begin{aligned} KM_T &= KB + BM_T \\ &= 2.143 + 7.778 \\ &= 9.921 \text{ m} \end{aligned}$$

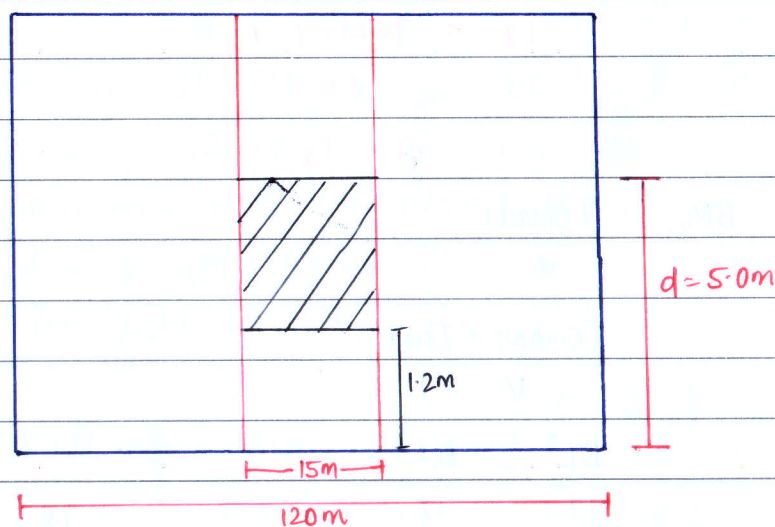
$$\begin{aligned} GM &= KM - KG \\ &= 9.921 - 4.2 \\ &= 5.721 \text{ m} \end{aligned}$$

Answer: GM after bilging: 5.721 m

AUG 2024

A vessel 120m long and 20m wide is floating in SW of RD 1.018 with an even keel draft of 5.0m. A mid-ship compartment extending from side to side, 15m long, with its aft bulkhead at midship is bilged. It has a DB tank 1.2m below the hold. The hold with permeability 40% is bilged. Calculate the forward and aft drafts.

Soln:



Case 3B: Compartment is bilged above the watertight flat

$$\begin{aligned} \text{Volume of lost buoyancy} &= 40\% \text{ of } l \times b \times (d - h) \\ &= 40\% \text{ of } 15 \times 20 \times (5 - 1.2) \\ &= 40\% \text{ of } 15 \times 20 \times 3.8 \\ &= 40\% \text{ of } 1140 \\ &= 456 \text{ m}^3 \end{aligned}$$

$$\begin{aligned}
 \text{Intact WPA} &= \text{Initial WPA} - \text{WPA lost} = LB - 40\% \text{ of } lb \\
 &= (120 \times 20) - 40\% \text{ of } (15 \times 20) \\
 &= 2400 - 40\% \text{ of } 300 \\
 &= 2400 - 120 \\
 &= 2280 \text{ m}^2
 \end{aligned}$$

$$\text{Sinkage} = \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}} = \frac{456}{2280} = 0.2 \text{ m}$$

$$\begin{aligned}
 \text{New draft} &= \text{Initial draft} + \text{Sinkage} \\
 &= 5.0 + 0.2 \\
 &= 5.2 \text{ m}
 \end{aligned}$$

To find draft, we have to find Total trim(t), T_a & T_f

$$\text{Total trim}(t) = \frac{w \times d}{\text{MCTC} \times 100}$$

$$\text{where, } w = \text{volume} \times \text{density}, \quad \text{MCTC} = \frac{W \times GML}{100L}$$

$$d = \text{distance}(h) \text{ (Final LCF} - \text{compartment LCF)}$$

$$T_a = \frac{\text{Trim} \times \text{LCF}}{\text{LBP}}$$

$$T_f = T - T_a$$

$$\textcircled{1} \quad BM_L = \frac{I(\text{intact})}{V}$$

$$= \frac{I(\text{initial}) - I(\text{lost})}{V}$$

$$= \frac{\frac{BL^3}{12} - \frac{bl^3}{12}}{V}$$

$$= \frac{\frac{20 \times 120^3}{12} - \frac{20 \times 15^3}{12}}{120 \times 20 \times 5}$$

$$= \frac{2880000 - 5625}{12000}$$

$$= 239.531 \text{ m}$$

$$\begin{aligned}
 W &= L \times B \times d \times \text{density} \\
 &= 120 \times 20 \times 5 \times 1.018 \\
 &= 12216 \text{ t}
 \end{aligned}$$

Note: If KG is not given in question, we can use BM_L to find MCTC

$$MCTC = \frac{W \times GML (BM_L)}{100L}$$

$$MCTC = \frac{12216 \times 239.531}{100 \times 120}$$

$$MCTC = 243.843 \text{ tm}$$

(ii)

$$w = p.f. \text{ of } l \times b \times (d-h) \times \text{density}$$

$$w = \{40\% \text{ of } 15 \times 20 \times 3.8\} \times 1.018$$

$$w = 456 \times 1.018$$

$$w = 464.208 \text{ t}$$

(iii)

New COF w.r.t midship: Intact WPA $\times$ = $(L \times B \times LCF_{\text{of int}}) - (L \times b \times LCF_{\text{of compartment}})$

Compartment is bilged above the WT flat. Buoyancy lost. No buoyancy regained. Hence, LCF will change

Remarks	WPA	LCF w.r.t AP	Moment
Initial	$120 \times 20 = 2400$	60	144000
Lost	$40\% \text{ of } 15 \times 20 = 120$	$60 - 7.5 = 52.5$	(-) 6300
	2280		137700

$$\text{Final LCF} = \frac{137700}{2280} = 60.395 \text{ m}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

$$d = h = 60.395 - 52.5$$

$$d = h = 7.895 \text{ m}$$

(iv)

$$\text{Total trim} = w \times d$$

$$\frac{MCTC \times 100}{LBP}$$

$$T = \frac{464.208 \times 7.895}{243.843 \times 100}$$

$$T = 0.150 \text{ m}$$

$$T_a = \frac{\text{Total trim} \times LCF}{LBP} = \frac{0.150 \times 60.395}{120} = 0.075 \text{ m}$$

$$T_f = T - T_a = 0.150 - 0.075 = 0.075 \text{ m}$$

	Fwd	Aft
New draft	5.2	5.2

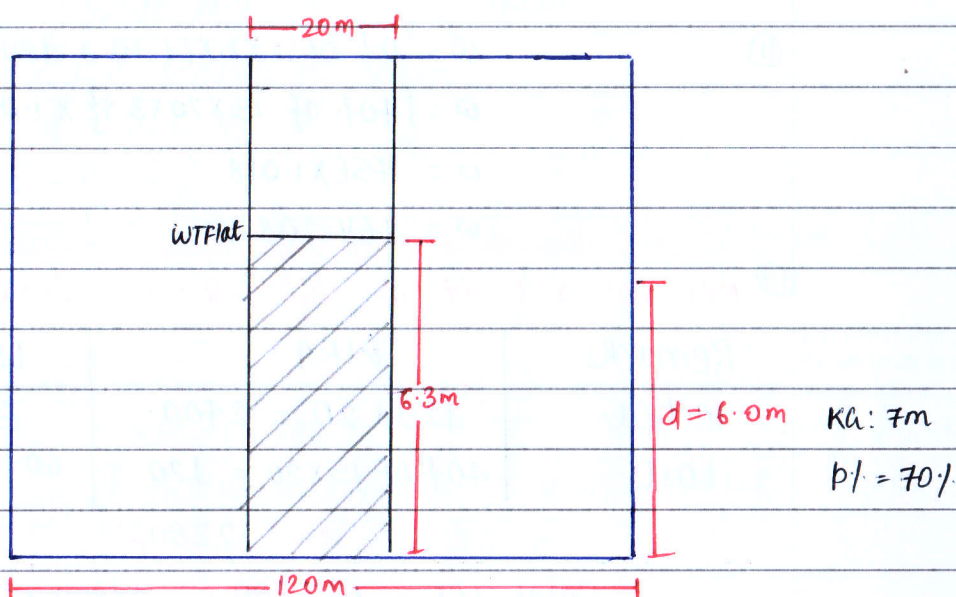
$T_f \& T_a$	(-) 0.075	(+) 0.075
Final draft	5.125 m	5.275 m

Ans

AUG 2023,
MAY 2018, MAY 2018

A box-shaped vessel of length 120m, breadth 25m is floating at an even Keel draft of 6m, K_G of the vessel is 7m. It has a mid-ship compartment of 20m in length extending from side to side with its forward bulkhead amidship. The permeability is 70%. The compartment contains a watertight flat at height of 6.3m above the keel. Calculate the draft forward and aft & $G M_T$ if that compartment is bilged below the watertight flat.

Soln:-



Case 5B or 6B

$$\begin{aligned}\text{Volume of buoyancy lost} &= 70\% \text{ of } l \times b \times d \\ &= 70\% \text{ of } 20 \times 25 \times 6 \\ &= 70\% \text{ of } 3000 \\ &= 2100 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Assumed sinkage} &= h - d \\ &= 6.3 - 6.0 = 0.3 \text{ m}\end{aligned}$$

$$\begin{aligned}\text{Volume of buoyancy regained} &= S \times \{LB - 70\% \text{ of } lb\} \\ &= 0.3 \times \{(120 \times 25) - 70\% \text{ of } (20 \times 25)\} \\ &= 0.3 \times \{3000 - 70\% \text{ of } 500\} \\ &= 0.3 \times \{3000 - 350\} \\ &= 0.3 \times 2650 \\ &= 795 \text{ m}^3\end{aligned}$$

This is case 6B

$$\begin{aligned}\text{Volume yet to regain} &= \text{Vol of buoyancy lost} - \text{Vol of buoyancy regained} \\ &= 2100 - 795 \\ &= 1305 \text{ m}^3\end{aligned}$$

During this, Intact WPA = LB

$$= 120 \times 25$$

$$= 3000 \text{ m}^2$$

Further sinkage = $\frac{\text{Volume yet to regain}}{\text{Intact WPA}}$

$$= \frac{1305}{3000}$$

$$= 0.435 \text{ m}$$

New draft: Initial draft + sinkage + further sinkage

$$= 6.0 + 0.3 + 0.435$$

$$= 6.735$$

⇒ To Find GM_T

$$GM_T = KM_T - KG$$



→ Given in ques

$$KM_T = KB + BM_T$$

① Final KB is not half of draft

Note: If there is a WT flat which restrict the vertical extent of damage upto the height of WT flat, in such case, we need to calculate the KB by taking the moment

$$\text{Final KB} = \frac{\{\text{New volume of vessel} \times \text{New KB of vessel}\} - \{\text{p.f. of vol. of compartment} \times \text{KB of compartment}\}}{\text{Initial volume of vessel}}$$

$$= \frac{\{(120 \times 25 \times 6.735) \times (6.735/2)\} - \{70\% \text{ of } (20 \times 25 \times 6.3) \times (6.3/2)\}}{120 \times 25 \times 6}$$

$$= \frac{\{20205 \times 3.368\} - \{70\% \text{ of } 3150 \times 3.15\}}{18000}$$

$$= \frac{68050.44 - 6945.75}{18000}$$

$$= 3.395 \text{ m}$$

$$= 3.395 \text{ m}$$

$$= 3.395 \text{ m}$$

$$= 3.395 \text{ m}$$

$$\textcircled{II} \quad BM_T = \frac{LB^3}{12V} = \frac{120 \times 25^3}{12(120 \times 25 \times 6)} = 8.681 \text{ m}$$

(iii)

$$KM_T = KB + BM_T$$

$$KM_T = 3.395 + 8.681$$

$$KM_T = 12.076 \text{ m}$$

$$GM_T = KM_T - KG$$

$$GM_T = 12.076 - 7$$

$$GM_T = 5.076 \text{ m} \quad \text{Ans}$$

⇒ To find draft forward and aft

$$\text{Total trim (t)} = \frac{w \times d}{MCTC \times 100}$$

$$\textcircled{i} \quad w = (70\% \text{ of } L \times b \times d) \times 1.025$$

$$w = 2100 \times 1.025$$

$$w = 2152.5 \text{ t}$$

$$\textcircled{ii} \quad d = \text{distance (h)}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

$$d = h = 60 - 50 = 10 \text{ m}$$

(iii)

$$MCTC = \frac{w \times GM_L}{100L} \longrightarrow GM_L = \frac{KM_L - KG}{1}$$

$$KM_L = KB + BM_L$$

$$BM_L = \frac{BL^3}{12V}$$

$$KB = 3.395 \text{ m}$$

$$BM_L = \frac{25 \times 120^3}{12(120 \times 25 \times 6)}$$

$$W = L \times B \times d \times \text{density}$$

$$W = 120 \times 25 \times 6 \times 1.025$$

$$W = 18450 \text{ t}$$

$$BM_L = 200 \text{ m}$$

$$KM_L = KB + BM_L$$

$$KM_L = 3.395 + 200$$

$$KM_L = 203.395 \text{ m}$$

$$GM_L = KM_L - KG$$

$$GM_L = 203.395 - 7.0$$

$$GM_L = 196.395 \text{ m}$$

Buoyancy lost =
Buoyancy regained
LCF will not change

$$MCTC = \frac{W \times Q \times M_L}{100L}$$

$$MCTC = \frac{18450 \times 196.395}{100 \times 120}$$

$$MCTC = 301.957 \text{ tm}$$

$$(iv) \text{ Total trim}(T) = \frac{w \times d}{MCTC \times 100}$$

$$T = \frac{2152.5 \times 10}{301.957 \times 100}$$

$$T = 0.713 \text{ t}$$

$$T_a = \frac{\text{Total trim} \times LCF}{LBP}$$

$$T_a = \frac{0.713 \times 60}{120}$$

$$T_a = 0.357 \text{ m}$$

$$T_f = T - T_a$$

$$T_f = 0.713 - 0.357$$

$$T_f = 0.356 \text{ m}$$

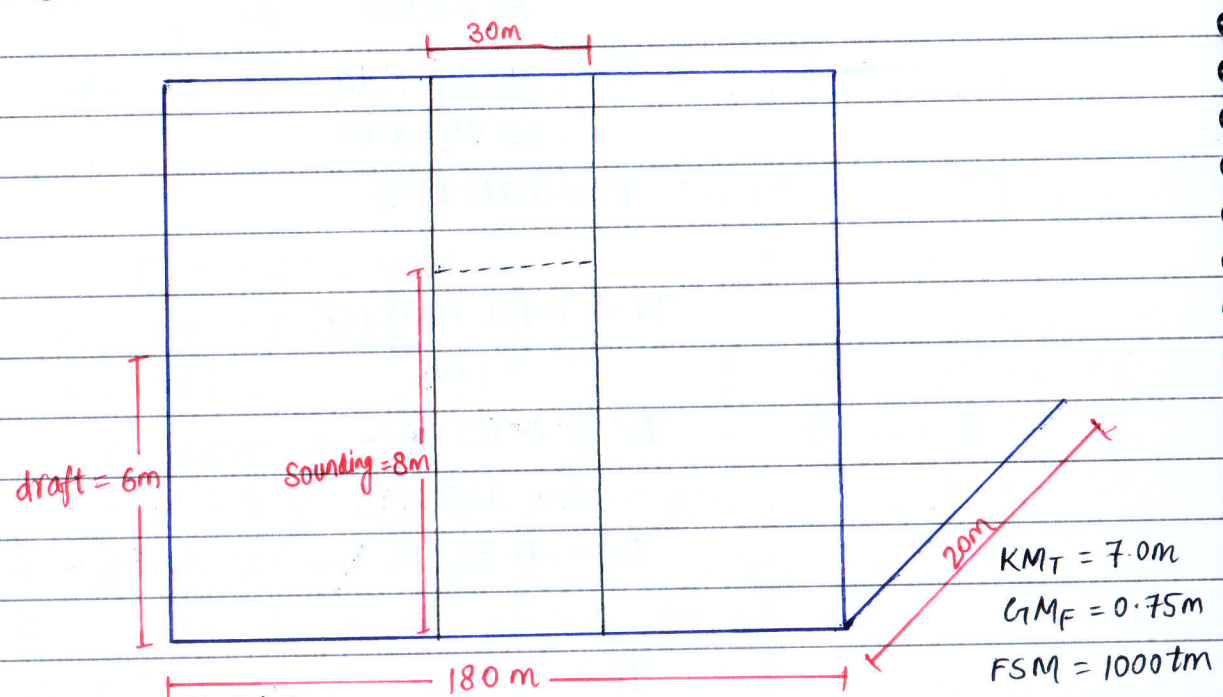
Draft	Fwd	Aft
New draft	6.735	6.735
$T_f \& T_a$	(-) 0.356	(+) 0.357
Final draft	<u>6.379 m</u>	<u>7.092 m</u>

Ans

NOV 2021

A box shaped vessel 180x20m is floating in water of R.D 1.015. The vessel has a mid-ship tank of 30m length extending for the full width and height of the vessel. The tank, which is slack, contains seawater to a sounding of 8.0m. The draught, KM_T , GM_F and the FSM of the vessel then are 6.0m even keel, 7m, 0.75m and 1000tm respectively. Calculate her draughts F&A and GM_T after this tank is bilged by a damage below the waterline.

Soln:-



⇒ To find draft F&A
Initial displacement = $l \times b \times h \times \text{density}$
 $= 180 \times 20 \times 6 \times 1.015$
 $= 21924t$

Displacement lost = $l \times b \times h \times \text{density}$
 $= 30 \times 20 \times 8 \times 1.025$
 $= 4920t$

Displacement after bilging = Initial displacement - Displacement lost
 $= 21924 - 4920$
 $= 17004t$

To find draft after bilging
Displacement = $L \times B \times d \times \text{density}$
 $17004 = 180 \times 20 \times d \times 1.015$
 $d = 4.654m$

Case 1A: Volume of buoyancy lost = $L \times b \times d$
 $= 30 \times 20 \times 4.654$
 $= 2792.4 \text{ m}^3$

Intact WPA = Initial WPA - WPA lost = $LB - lb$
 $= (180 \times 20) - (30 \times 20)$
 $= 3600 - 600$
 $= 3000 \text{ m}^2$

Sinkage = $\frac{\text{Volume of buoyancy lost}}{\text{Intact WPA}}$
 $= \frac{2792.4}{3000} = 0.931 \text{ m}$

New draft = Initial draft + sinkage
 $= 4.654 + 0.931$
 $= 5.585 \text{ m}$
Ans

$\Rightarrow$ To find GM_T : $GM_T = KM_T - KG$

$KM_T = KB + BM_T$

$KB = \text{draft} / 2 = 5.585 / 2 = 2.793 \text{ m}$

$BM_T = \frac{I_{(\text{intact})}}{V} = \frac{I_{(\text{initial})} - I_{(\text{lost})}}{V}$

$= \frac{LB^3 - lb^3}{12V}$

$= \frac{180 \times 20^3 - 30 \times 20^3}{12(180 \times 20 \times 4.654)}$

$= \frac{1440000 - 240000}{201052.8}$

$= \frac{1200000}{201052.8}$

$= 5.969 \text{ m}$

$= 5.969 \text{ m}$

$KM_T = KB + BM_T$

$= 2.793 + 5.969$

$= 8.762 \text{ m}$

$KG = ?$

* To find Initial KG

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

$FSC = \frac{1000}{180 \times 20 \times 6 \times 1.015} = 0.046 \text{ m}$

$GM(S) - FSC = GM(F)$

$GM(S) = GM(F) + FSC$

$GM(S) = 0.75 + 0.046$

$GM(S) = 0.796 \text{ m}$

$$GM(S) = KM - KG$$

$$KG = KM - GM(S)$$

$$\text{Initial } KG = 7.0 - 0.796$$

$$\text{Initial } KG = 6.204m$$

* To find Final KG

Remarks	Weight	KG	Moment
Initial	21924	6.204	136016.496
Tank	(-) 4920	$8/2 = 4$	(-) 19680.000

$$\text{Final } W : 17004 t$$

$$\text{Final v. moment: } 116336.496$$

$$\text{Final } KG = \frac{\text{Final v. moment}}{\text{Final } W}$$

$$= \frac{116336.496}{17004}$$

$$= 6.842m$$

$$GM_T = KM_T - KG$$

$$GM_T = 8.762 - 6.842$$

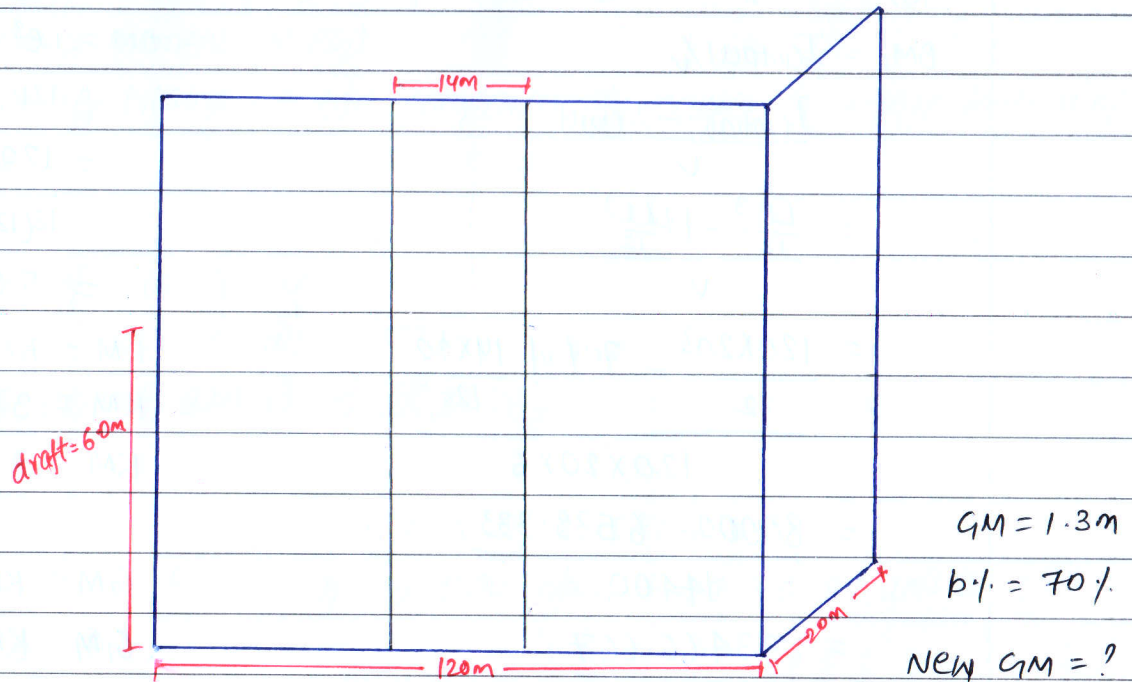
$$GM_T = 1.919m$$

Ans

FEB 2020

A box shaped vessel length 120m breadth 20m draft 6m GM 1.3m has a centreline midship compartment 14m long full of homogenous cargo (permeability 70%). Find new GM after the compartment is bilged and equilibrium is attained.

Soln:-



Case 1B

$$\begin{aligned}\text{Volume of buoyancy lost} &= 70\% \text{ of } l \times b \times d \\ &= 70\% \text{ of } 14 \times 20 \times 6 \\ &= 70\% \text{ of } 1680 \\ &= 1176 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Intact WPA} &= \text{Initial WPA} - \text{WPA lost} = LB - 70\% \text{ of } lb \\ &= (120 \times 20) - \{70\% \text{ of } (14 \times 20)\} \\ &= 2400 - 70\% \text{ of } 280 \\ &= 2400 - 196 \\ &= 2204 \text{ m}^2\end{aligned}$$

$$\text{Sinkage} = \frac{\text{volume of buoyancy lost}}{\text{Intact WPA}}$$

$$= \frac{1176}{2204} = 0.534 \text{ m}$$

$$\begin{aligned}\text{New draft} &= \text{Initial draft} + \text{Sinkage} \\ &= 6.000 + 0.534 \\ &= 6.534 \text{ m}\end{aligned}$$

⇒ To find GM_T

$$GM_T = KM_T - KG$$

$$KM_T = KB + BM_T$$

$$KB = \text{draft}/2 = 6.534/2 = 3.267\text{m}$$

$$BM_T = I_{\text{intact}}/V$$

$$= \frac{I_{\text{intact}} - I_{\text{lost}}}{V}$$

$$= \frac{\frac{LB^3}{12} - p \cdot \frac{lb^3}{12}}{V}$$

$$= \frac{120 \times 20^3}{12} - 70\% \text{ of } \frac{14 \times 20^3}{12}$$

$$120 \times 20 \times 6$$

$$= \frac{80000 - 6533.333}{14400}$$

$$= 73466.667$$

$$14400$$

$$= 5.102\text{m}$$

$$KM_T = KB + BM_T$$

$$KM_T = 3.267 + 5.102$$

$$KM_T = 8.369\text{m}$$

$$KB = \text{draft}/2 = 6/2 = 3\text{m}$$

$$BM = \frac{LB^3}{12V}$$

$$= \frac{120 \times 20^3}{12(120 \times 20 \times 6)}$$

$$= 5.556\text{m}$$

$$KM = KB + BM$$

$$KM = 3 + 5.556$$

$$KM = 8.556\text{m}$$

$$GM = KM - KG$$

$$KG = KM - GM$$

$$KG = 8.556 - 1.3$$

$$KG = 7.256\text{m}$$

$$GM_T = KM_T - KG$$

$$GM_T = 8.369 - 7.256$$

$$GM_T = 1.113\text{m}$$

Ans

BILGING - END COMPARTMENT

___/___/___

- The bilging of an end compartment causes the COB of the ship to be longitudinally displaced away from the bilged compartment.
- COG of the ship remain unaffected.
- The longitudinal separation of the COB and the COG (i.e. BG) results in a trimming moment ($W \cdot BG$)
- Therefore, bilging an end compartment causes a change in trim of the ship.

* Theorem of parallel axis

MOI about centroid : I^*_{GG}

MOI about axis : I^*_{ZZ}

$$I^*_{ZZ} = I^*_{GG} + Ay^2$$

where, A = Area of rectangle

y = distance b/w axis GG and the axis ZZ

Case 1:

If $L = 10m$, $B = 6m$, $y = 12m$, $I^*_{ZZ} = ?$

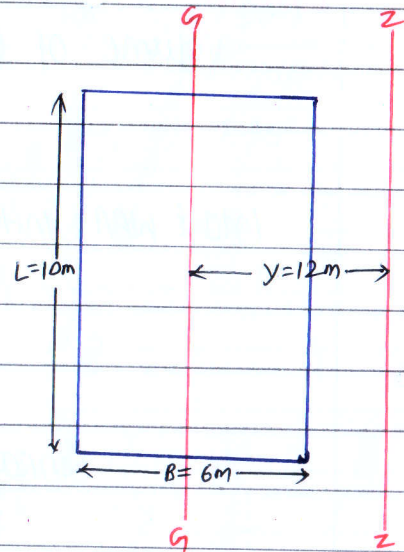
$$I^*_{ZZ} = I^*_{GG} + Ay^2$$

$$I^*_{ZZ} = \frac{LB^3}{12} + LB(y^2)$$

$$I^*_{ZZ} = \frac{10 \times 6^3}{12} + (10 \times 6)12^2$$

$$I^*_{ZZ} = 180 + 8640$$

$$I^*_{ZZ} = 8820 m^4$$



Case 2:

If $L = 8m$, $B = 4m$, $y = 1.5m$, $I^*_{ZZ} = ?$

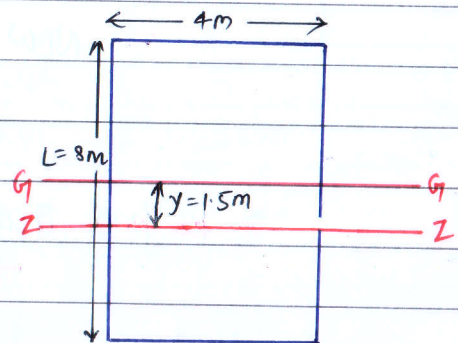
$$I^*_{ZZ} = I^*_{GG} + Ay^2$$

$$I^*_{ZZ} = \frac{BL^3}{12} + LB(y^2)$$

$$I^*_{ZZ} = \frac{4 \times 8^3}{12} + (4 \times 8)1.5^2$$

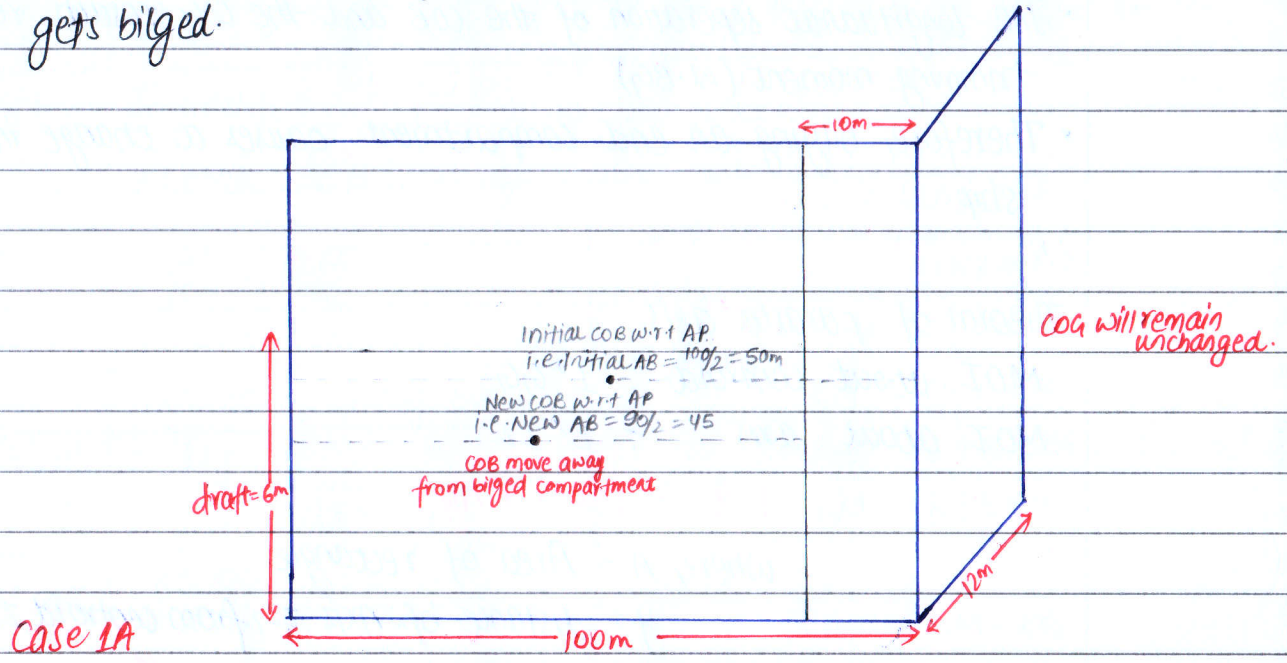
$$I^*_{ZZ} = 170.667 + 72$$

$$I^*_{ZZ} = 242.667 m^4$$



Sample Ques:- A box-shaped vessel 100m long and 12m wide floats at an even keel draft of 6m in SW. The compartment at the forward end, 10m long and 12m broad is empty. Find the new draft fwd and aft if this compartment gets bilged.

Soln:-



Case 1A

$$\begin{aligned} \text{Volume of lost buoyancy} &: L \times b \times d \\ &= 100 \times 12 \times 6 \\ &= 720 m^3 \end{aligned}$$

$$\begin{aligned} \text{Intact WPA} &= \text{Initial WPA} - \text{WPA lost} = LB - lb \\ &= (100 \times 12) - (10 \times 12) \\ &= 1200 - 120 \\ &= 1080 m^3 \end{aligned}$$

$$\begin{aligned} \text{Sinkage} &= \frac{\text{volume of lost buoyancy}}{\text{Intact WPA}} \\ &= \frac{720}{1080} = 0.667m \end{aligned}$$

$$\begin{aligned} \text{New draft} &: \text{Initial draft} + \text{sinkage} \\ &= 6.0 + 0.667 \\ &= 6.667m \end{aligned}$$

⇒ To find draft forward and aft

$$\text{Total trim (t)} = \frac{w \times d}{MCTC \times 100}$$

$$\textcircled{i} \quad w = L \times b \times d \times \text{density}$$

$$w = 720 \times 1.025$$

$$w = 738 \text{ t}$$

$$\textcircled{ii} \quad d = \text{distance (m)}$$

$$d = h = \frac{\text{Final LCF} - \text{compartment LCF}}{(\text{W.B.} + \text{AP})} \quad (\text{W.B.} + \text{AP})$$

$$d = h = 45 - 95$$

$$d = h = -50 \text{ m (by head)}$$

$100 \times 12 = 1200$	50	60000
$10 \times 12 = 120$	95	(-) 11400
<u>1080</u>		48600

$$\text{Final LCF} = \frac{48600}{1080} = 45 \text{ m}$$

$$\textcircled{iii} \quad \text{MCTC} = \frac{W \times GML}{100L} \longrightarrow GML = KML - KG$$

$$KML = KB + BML$$

Since KG is not given, we use BML instead of GML

$$BML = \frac{I_{\text{centroid}}}{V}$$

$$W = L \times B \times d \times \text{density}$$

$$W = 100 \times 12 \times 6 \times 1.025$$

$$W = 7380 \text{ t}$$

$$BML = \frac{BL^3}{12V}$$

$$BML = \frac{12(90^3)}{12(100 \times 12 \times 6)}$$

$$BML = 101.25 \text{ m}$$

$$\text{MCTC} = \frac{W \times GML(BML)}{100L}$$

$$\text{MCTC} = \frac{7380 \times 101.25}{100 \times 100}$$

$$\text{MCTC} = 74.723 \text{ tm}$$

$$\textcircled{iv} \quad \text{Total trim} = \frac{w \times d}{\text{MCTC} \times 100}$$

$$T = \frac{738 \times 50}{74.723 \times 100}$$

$$T = 4.938 \text{ m by head}$$

$$T_a = \frac{\text{Total trim} \times \text{Final LCF}}{\text{LBP}} = \frac{4.938 \times 45}{100} = 2.222 \text{ m}$$

$$T_f = T - T_a = 4.938 - 2.222 = 2.716 \text{ m}$$

	Fwd	Aft
New draft	6.667	6.667
Tf & Ta	(+) 2.716	(-) 2.222
Final new draft	9.383 m	4.445 m Ans

Example ques:- Same as previous with $p = 40\%$.

Case 1A

$$\begin{aligned}\text{Volume of lost buoyancy} &: 40\% \text{ of } l \times b \times d \\ &= 40\% \text{ of } (10 \times 12 \times 6) \\ &= 40\% \text{ of } 720 \\ &= 288 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Intact WPA} &= \text{Initial WPA} - \text{WPA lost} = LB - 40\% \text{ of } lb \\ &= (100 \times 12) - \{40\% \text{ of } 10 \times 12\} \\ &= 1200 - (40\% \text{ of } 120) \\ &= 1200 - 48 \\ &= 1152 \text{ m}^2\end{aligned}$$

$$\text{Sinkage} = \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}}$$

$$\text{Sinkage} = \frac{288}{1152} = 0.25 \text{ m}$$

$$\begin{aligned}\text{New draft} &= \text{Initial draft} + \text{sinkage} \\ \text{new draft} &= 6.0 + 0.25 \\ &= 6.25 \text{ m}\end{aligned}$$

⇒ To find draft forward and aft

$$\text{Total trim} = \frac{w \times d}{MCTC \times 100}$$

$$\begin{aligned}\textcircled{1} \quad w &= (40\% \text{ of } l \times b \times d) \times \text{density} \\ w &= (40\% \text{ of } 10 \times 12 \times 6) \times 1.025 \\ w &= (40\% \text{ of } 720) \times 1.025 \\ w &= 288 \times 1.025 \\ w &= 295.2 \text{ t}\end{aligned}$$

② $d = \text{distance}$

$$d = \text{Final LCF}_{\text{w.r.t AP}} - \text{compartment LCF}_{\text{w.r.t AP}}$$

Remark	WPA	LCF w.r.t AP	Moment
Total	$100 \times 12 = 1200$	50	60000
lost	$40\% \text{ of } 10 \times 12 = 48$	95	(-) 4560
	<u>1152</u>		<u>55440</u>

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Area}}$$

$$= \frac{55440}{1152}$$

$$= 48.125 \text{ m}$$

$$d = \text{Final LCF} - \text{compartment LCF}$$

$$d = 48.125 - 95$$

$$d = -46.875 \text{ m by head}$$

$$\textcircled{\text{III}} \text{ MCTC} = \frac{W \times GML(BML)}{100L}$$

$$\bullet W = L \times B \times d \times \text{density}$$

$$W = 100 \times 12 \times 6 \times 1.025$$

$$W = 7380 \text{ t}$$

$$\bullet \text{ For BML,}$$

$$FF' = \frac{\text{Moment of intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of lost WPA}}{\text{Total WPA} - \text{lost WPA}}$$

where, Moment = Area $\times$ dist w.r.t COF i.e. midship

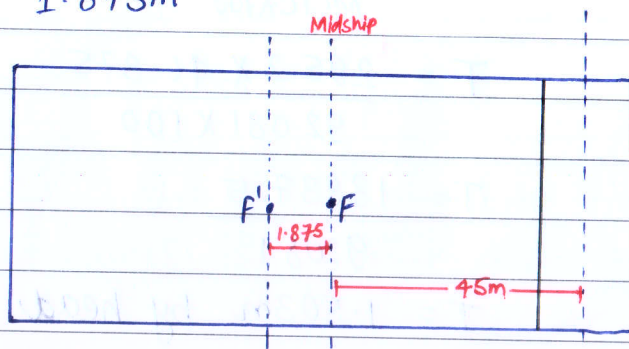
$$FF' = \frac{(LB \times \text{dist. w.r.t COF}) - \{(p.f. \text{ of } lb) \times \text{dist w.r.t COF}\}}{LB - p.f. \text{ of } lb}$$

$$FF' = \frac{\{(100 \times 12) \times 0\} - \{(40.f. \text{ of } 10 \times 12) \times 45\}}{(100 \times 12) - (40.f. \text{ of } 10 \times 12)}$$

$$FF' = \frac{0 - 2160}{1200 - 48}$$

$$FF' = -2160/1152$$

$$FF' = 1.875 \text{ m}$$



$$BM_L = \frac{I_{\text{COF of Intact WPA}}}{\text{(about new COF) Initial volume}}$$

$$BM_L = \frac{I^* \text{ COF of Total WPA} - I^* \text{ COF of Lost WPA}}{\text{Initial volume}}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + BL(y^2) \right\} - p.f. \text{ of } \left\{ \frac{bd^3}{12} + bd(y^2) \right\}}{\text{Initial volume}}$$

where, y = distance b/w axis GG & axis ZZ

$$BM_L = \frac{\left\{ \frac{12 \times 100^3}{12} + (12 \times 100)(1.875)^2 \right\} - 40\% \text{ of } \left\{ \frac{12 \times 10^3}{12} + (12 \times 10)(46.875)^2 \right\}}{100 \times 12 \times 6}$$

$$BM_L = \frac{\{1000000 + 4218.75\} - 40\% \text{ of } \{1000 + 2636710.88\}}{7200}$$

$$BM_L = \frac{1004218.75 - 40\% \text{ of } 264671.875}{7200}$$

$$BM_L = \frac{1004218.75 - 105868.75}{7200}$$

$$BM_L = \frac{898350}{7200}$$

$$BM_L = 124.771 \text{ m}$$

$$MCTC = \frac{W \times BM_L}{100L}$$

$$MCTC = \frac{7380 \times 124.771}{100 \times 100}$$

$$MCTC = 92.081 \text{ tm}$$

$$(IV) \text{ Total trim (T)} = \frac{W \times d}{MCTC \times 100}$$

$$T = \frac{295.2 \times 46.875}{92.081 \times 100}$$

$$T = \frac{13837.5}{9208.1}$$

$$T = 1.503 \text{ m by head. (b/c of minus sign of d)}$$

$$T_a = \frac{\text{Total trim} \times \text{LCF}}{\text{LBP}}$$

$$T_a = \frac{1.503 \times 48.125}{100}$$

$$T_a = 0.723\text{m}$$

$$T_f = T - T_a$$

$$T_f = 1.503 - 0.723$$

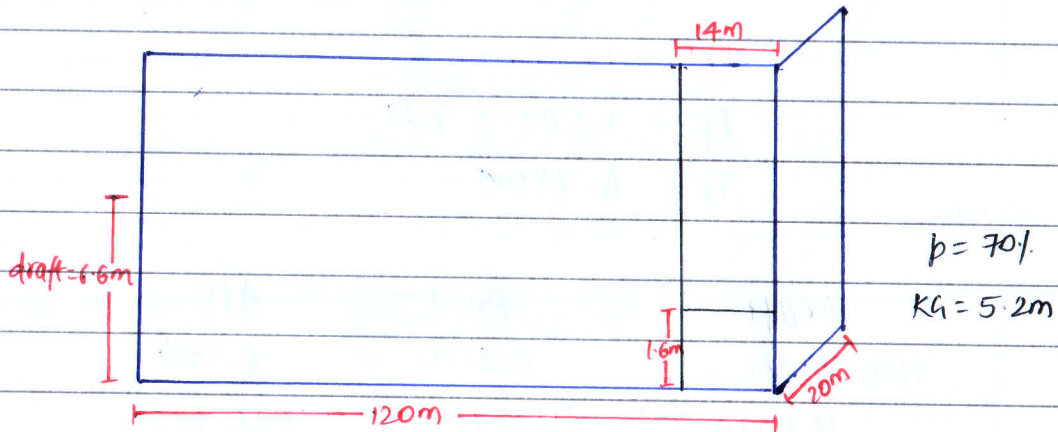
$$T_f = 0.780\text{m}$$

	Fwd	Aft
New Draft	6.250	6.250
Tf & Ta	(+) 0.780	(-) 0.723
Final draft	<u>7.030m</u>	<u>5.527m</u> Ans

NOV 2023 AM

A box shaped vessel 120x20m even keel draft of 6.6m, has a forward end compartment 14m long extending the full width above the DB tank which is 1.6m high. The compartment is filled with homogenous cargo ($p = 70\%$). The compartment is bilged above the DB tank. Find the drafts if the initial K_G is 5.2m.

Soln:



Case 3B

$$\begin{aligned}
 \text{Volume of lost buoyancy} &= 70\% \text{ of } l \times b \times d - h \\
 &= 70\% \text{ of } 14 \times 20 \times (6.6 - 1.6) \\
 &= 70\% \text{ of } 14 \times 20 \times 5 \\
 &= 70\% \text{ of } 1400 \\
 &= 980 \text{ m}^3
 \end{aligned}$$

$$\begin{aligned}
 \text{Intact WPA} &= \text{Initial WPA} - \text{lost WPA} = LB - 70\% \text{ of } lb \\
 &= (120 \times 20) - 70\% \text{ of } (14 \times 20) \\
 &= 2400 - 70\% \text{ of } 280 \\
 &= 2400 - 196 \\
 &= 2204 \text{ m}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Sinkage} &= \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}} \\
 &= \frac{980}{2204} \\
 &= 0.445 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{New draft} &= \text{Initial draft} + \text{Sinkage} \\
 &= 6.6 + 0.445 \\
 &= 7.045 \text{ m}
 \end{aligned}$$

⇒ To find draft forward & aft

$$\text{Total trim (t)} = \frac{w \times d}{\text{MCTC} \times 100}$$

① $w = (\text{p.l. of } L \times B \times d - h) \times \text{density}$

$$w = \{70\% \text{ of } 14 \times 20 \times (6.6 - 1.6)\} \times 1.025$$

$$w = 980 \times 1.025$$

$$w = 1004.5 \text{ t}$$

② $d = \text{distance}(h)$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$120 \times 20 = 2400$	60	144000
Lost	$70\% \text{ of } 14 \times 20 = 196$	113	(-) 22148
	<u>2204</u>		<u>121852</u>

$$\text{Final LCF} = \frac{\text{Moment}}{\text{WPA}}$$

$$= \frac{121852}{2204}$$

$$= 55.287 \text{ m}$$

$$d = \text{Final LCF} - \text{compartment LCF}$$

$$d = 55.287 - 113$$

$$d = -57.713 \text{ m by head}$$

③ $\text{MCTC} = \frac{W \times \text{GML}}{100L}$

• $W = L \times B \times d \times \text{density}$

$$W = 120 \times 20 \times 6.6 \times 1.025$$

$$W = 16236 \text{ t}$$

• GML

$$\text{GML} = \text{KML} - \text{KG}$$

$$\downarrow$$

$$\text{KML} = \text{KB} + \text{BML}$$

Find KB by moment

$$\text{Final KB} = \frac{\{\text{New vol. of vessel} \times \text{new KB of vessel}\} - \{\text{p.l. of vol. of compartment} \times \text{KB of compartment}\}}{\text{Initial volume of vessel}}$$

$$\text{Final KB} = \frac{\{(120 \times 20 \times 7.045) \times (7.045/2)\} - \{(70\% \text{ of } 14 \times 20 \times (7.045 - 1.6)) \times (\frac{5.445}{2} + 1.6)\}}{120 \times 20 \times 6.6}$$

$$\text{Final KB} = \frac{\{16908 \times 3.523\} - \{1067.22 \times 4.323\}}{15840}$$

$$\text{Final KB} = \frac{59566.884 - 4613.592}{15840}$$

$$\text{Final KB} = \frac{54953.292}{15840}$$

$$\text{Final KB} = 3.469 \text{ m}$$

Now, Find BM_L

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of Lost WPA}}{\text{Total WPA} - \text{Lost WPA}}$$

where, Moment = Area $\times$ dist w.r.t COF i.e. midship

$$FF' = \frac{(LB \times \text{dist w.r.t COF}) - \{(P\% \text{ of } LB) \times \text{dist w.r.t COF}\}}{LB - P\% \text{ of } LB}$$

$$FF' = \frac{\{(120 \times 20) \times 0\} - \{(70\% \text{ of } 14 \times 20) \times 53\}}{(120 \times 20) - (70\% \text{ of } 14 \times 20)}$$

$$FF' = \frac{0 - (196 \times 53)}{2400 - 196}$$

$$FF' = \frac{-10388}{2204}$$

$$FF' = -4.713 \text{ m}$$

$$BM_L = \frac{I^* \text{ COF Intact WPA}}{\text{Initial volume}}$$

(about new COF)

$$BM_L = \frac{I^* \text{ COF of Total WPA} - I^* \text{ COF of Lost WPA}}{\text{Initial volume.}}$$

$$BM_L = \left\{ \frac{BL^3}{12} + BL(y^2) \right\} - \text{p.f. of } \left\{ \frac{bl^3}{12} + bl(y^2) \right\}$$

Initial volume

$$BM_L = \left\{ \frac{20 \times 120^3}{12} + (20 \times 120)(4.713)^2 \right\} - 70\% \text{ of } \left\{ \frac{20 \times 14^3}{12} + (20 \times 14)(53+4.713)^2 \right\}$$

120X20X6.6

$$BM_L = \frac{\{2880000 + 53309.686\} - 70\% \text{ of } \{4573.333 + 932621.303\}}{15840}$$

$$BM_L = \frac{2933309.686 - 70\% \text{ of } 937194.636}{15840}$$

$$BM_L = \frac{2933309.686 - 656036.245}{15840}$$

$$BM_L = \frac{2277273.441}{15840}$$

$$BM_L = 143.767m$$

$$KM_L = KB + BM_L$$

$$KM_L = 3.469 + 143.767$$

$$KM_L = 147.236m$$

$$GM_L = KM_L - KG$$

$$GM_L = 147.236 - 5.2$$

$$GM_L = 142.036m$$

$$MCTC = \frac{W \times GM_L}{100L}$$

$$MCTC = \frac{16236 \times 142.036}{100 \times 120}$$

$$MCTC = \frac{2306096.496}{12000}$$

$$MCTC = 192.175 tm$$

(IV)

$$\text{Total trim}(t) = \frac{w \times d}{MCTC \times 100}$$

$$T_c = \frac{1004.5 \times 57.713}{192.175 \times 100}$$

$$T_c = \frac{57972.709}{19217.471}$$

$$T_c = 3.017 \text{ m}$$

$$T_a = \frac{\text{Total trim} \times \text{Final LCF}}{\text{LBP}}$$

$$T_a = \frac{3.017 \times 55.287}{120}$$

$$T_a = 1.390 \text{ m}$$

$$T_f = T - T_a$$

$$T_f = 3.017 - 1.390$$

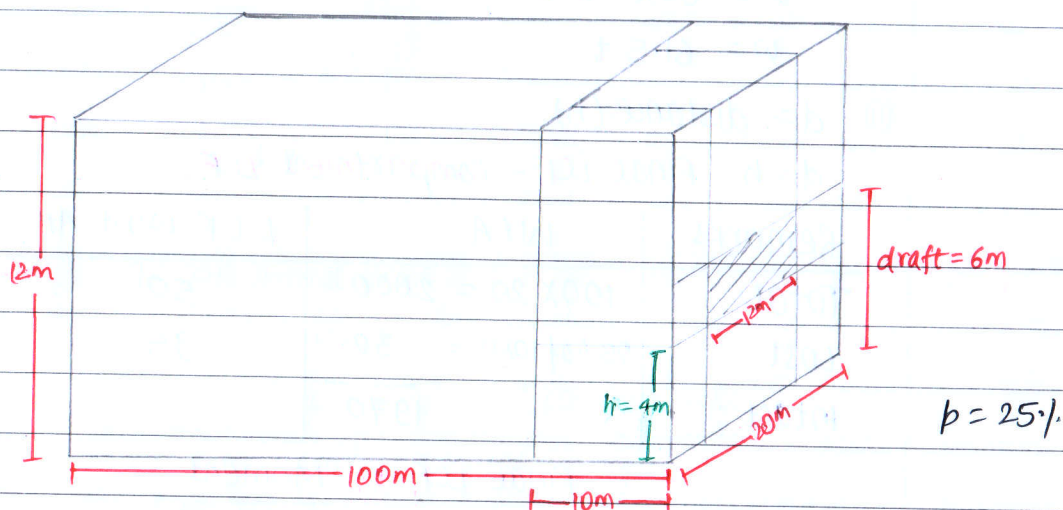
$$T_f = 1.627 \text{ m}$$

	Fwd	Aft
New draft	7.045	7.045
T_f & T_a	(+) 1.627	(-) 1.390
Final draft	8.672 m	5.655 m <u>Ans</u>

FEB 2024
PAPER 1

A box shaped vessel 100m long, 20m wide, 12m deep is floating in salt water on an even keel draft of 6m. A forward centre compartment is 10m long, 12m wide and extends from the outer bottom to a watertight flat, 4m above the keel. The compartment contains cargo of permeability 25%. Find new draft if this compartment is bilged.

Soln:-



Case 3B

$$\begin{aligned}\text{Volume of lost buoyancy} &= 25\% \text{ of } l \times b \times (d - h) \\ &= 25\% \text{ of } 10 \times 12 \times (6 - 4) \\ &= 0.25 \times 10 \times 12 \times 2 \\ &= 60 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Intact WPA} &= \text{Initial WPA} - \text{WPA lost} = LB - p \cdot lb \\ &= (100 \times 20) - 25\% \text{ of } (10 \times 12) \\ &= 2000 - 25\% \text{ of } 120 \\ &= 2000 - 30 \\ &= 1970 \text{ m}^2\end{aligned}$$

$$\text{Sinkage} = \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}}$$

$$\text{Sinkage} = \frac{60}{1970}$$

$$\text{Sinkage} = 0.030 \text{ m}$$

$$\begin{aligned}\text{New draft} &= \text{Initial draft} + \text{sinkage} \\ &= 6.0 + 0.030 \\ &= 6.030 \text{ m}\end{aligned}$$

⇒ To find draft forward and aft

$$\text{Total trim}(t) \text{ or Trim caused}(tc) = \frac{W \times d}{MCTC \times 100}$$

① $w = \{p.l. \text{ of } L \times B \times (d-h)\} \times \text{density}$

$$w = \{25\% \text{ of } 10 \times 12 \times (6-4)\} \times 1.025$$

$$w = 60 \times 1.025$$

$$w = 61.5 \text{ t}$$

② $d = \text{distance}(h)$

$$d = h = \text{Final LCF} - \text{Compartment LCF}$$

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$100 \times 20 = 2000$	50	100000
Lost	$25\% \text{ of } 10 \times 12 = 30$	95	(-) 2850
Intact:	1970		97150

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Intact WPA}}$$

$$\text{Final LCF} = \frac{97150}{1970}$$

$$\text{Final LCF} = 49.315 \text{ m}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

$$d = h = 49.315 - 95$$

$$d = h = -45.685 \text{ m}$$

③ $MCTC = \frac{W \times GML(BML)}{100L}$

• $W = L \times B \times d \times \text{density}$

$$W = 100 \times 20 \times 6 \times 1.025$$

$$W = 12300 \text{ t}$$

• To find BM_L

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$\text{Intact WPA}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of lost WPA}}{\text{Total WPA} - \text{Lost WPA}}$$

$$\text{Total WPA} - \text{Lost WPA}$$

$$FF' = \frac{(LB \times \text{dist w.r.t COF}) - (p.f. \text{ of } lb \times \text{dist w.r.t COF})}{LB - p.f. \text{ of } lb}$$

$$= \frac{\{(100 \times 20) \times 0\} - \{(25\% \text{ of } 10 \times 12) \times 45\}}{100 - 25\% \text{ of } 10}$$

$$= \frac{0 - (30 \times 45)}{2000 - 30}$$

$$= \frac{1350}{1970}$$

$$= -0.685m$$

$$BM_L = \frac{I^* \text{ COF Intact WPA}}{\text{(about new COF) Initial volume}}$$

$$BM_L = \frac{I^* \text{ COF Total WPA} - I^* \text{ COF Int WPA}}{\text{Initial volume}}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + BL(y^2) \right\} - p.f. \left\{ \frac{bL^3}{12} + bL(y^2) \right\}}{L \times B \times d}$$

$$BM_L = \frac{\left\{ \frac{20 \times 100^3}{12} + (20 \times 100)(0.685)^2 \right\} - 25\% \left\{ \frac{12 \times 10^3}{12} + (12 \times 10)(45 + 0.685)^2 \right\}}{100 \times 20 \times 6}$$

$$BM_L = \frac{\{1666666.667 + 938.45\} - 25\% \{1000 + 250454.307\}}{12000}$$

$$BM_L = \frac{1667605.117 - 25\% \text{ of } 251454.307}{12000}$$

$$BM_L = \frac{1667605.117 - 62863.577}{12000}$$

$$BM_L = \frac{1604741.54}{12000}$$

$$BM_L = 133.728m$$

$$MCTC = \frac{W \times BM_L}{100L}$$

$$MCTC = \frac{12300 \times 133.728}{100 \times 100}$$

$$MCTC = 164.485tm$$

(IV)

$$\text{Total trim}(t) = \frac{w \cdot d}{MCTC \times 100}$$

$$t = \frac{61.5 \times 45.685}{164.485 \times 100}$$

$$t = \frac{2809.627}{16448.544}$$

$$t = 0.171 \text{ m}$$

$$T_a = \frac{\text{Total trim} \times \text{Final LCF}}{LBP}$$

$$T_a = \frac{0.171 \times 49.315}{100}$$

$$T_a = 0.084 \text{ m}$$

$$T_f = T - T_a$$

$$T_f = 0.171 - 0.084$$

$$T_f = 0.087 \text{ m}$$

	Fwd	Aft
New draft	6.030	6.030
$T_f \times T_a$	(+) 0.087	(-) 0.084
Final draft	6.117 m	5.946 m Ans

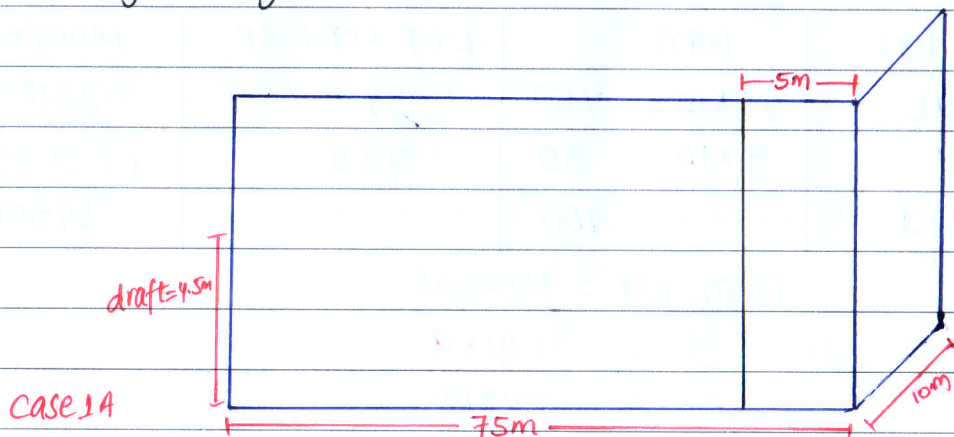
NOV 2023 PM,

OCT 2022, FEB 2018,

AUG 2014

Soln:-

A box shaped vessel 75m x 10m x 6m is floating in SW on an even keel draft of 4.5m. Find the new drafts Fwd & Aft if the forward compartment 5m long is bilged.



Case 1A

$$\begin{aligned} \text{Volume of lost buoyancy} &= l \times b \times d \\ &= 5 \times 10 \times 4.5 \\ &= 225 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Intact WPA} &= \text{Initial WPA} - \text{lost WPA} = LB - lb \\ &= (75 \times 10) - (5 \times 10) \\ &= 750 - 50 \\ &= 700 \text{ m}^2 \end{aligned}$$

$$\text{Sinkage} = \frac{\text{volume of lost buoyancy}}{\text{Intact WPA}}$$

$$= \frac{225}{700}$$

$$= 0.321 \text{ m}$$

$$\text{New draft} = \text{Initial draft} + \text{sinkage}$$

$$= 4.5 + 0.321$$

$$= 4.821 \text{ m}$$

⇒ To find draft fwd and aft

$$\text{Total trim (t)} = \frac{w \cdot d}{MCTC \times 100}$$

$$\textcircled{1} \quad w = l \times b \times d \times \text{density}$$

$$w = 5 \times 10 \times 4.5 \times 1.025$$

$$w = 230.625 \text{ t}$$

② $d = \text{distance}(h)$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

To find Final LCF

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$75 \times 10 = 750$	37.5	28125
Lost	$5 \times 10 = 50$	72.5	(-) 3625
Intact	<u>700</u>		<u>24500</u>

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Area}}$$

$$= \frac{24500}{700}$$

$$= 35\text{m}$$

$$d = \text{Final LCF} - \text{compartment LCF}$$

$$d = 35 - 72.5$$

$$d = -37.5\text{m by head}$$

③

$$\text{MCTC} = \frac{W \times GML}{100L}$$

$$\bullet W = L \times B \times d \times \text{density}$$

$$W = 75 \times 10 \times 4.5 \times 1.025$$

$$W = 3459.375\text{t}$$

- KG is not given in question, we will use BM_L instead of GM_L
For BM_L ,

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of lost WPA}}{\text{Total WPA} - \text{lost WPA}}$$

$$FF' = \frac{(LB \times \text{dist w.r.t COF}) - (lb \times \text{dist w.r.t COF})}{LB - lb}$$

$$FF' = \frac{\{(75 \times 10) \times 0\} - \{(5 \times 10) \times 35\}}{(75 \times 10) - (5 \times 10)}$$

$$FF' = \frac{0 - (50 \times 35)}{750 - 50}$$

$$FF' = \frac{1750}{700}$$

$$FF' = 2.5 \text{ m by head}$$

$$BM_L = \frac{I^* \text{ COF Intact WPA}}{\text{(about new COF) Initial vol}}$$

$$= \frac{I^* \text{ COF total WPA} - I^* \text{ COF lost WPA}}{\text{Initial volume}}$$

$$= \frac{\left\{ \frac{BL^3}{12} + BL(y^2) \right\} - \left\{ \frac{bl^3}{12} + bl(y^2) \right\}}{L \times B \times d}$$

$$= \frac{\left\{ \frac{10 \times 75^3}{12} + (10 \times 75)(2.5)^2 \right\} - \left\{ \frac{10 \times 5^3}{12} + (10 \times 5)(37.5)^2 \right\}}{75 \times 10 \times 4.5}$$

$$= \frac{\{351562.5 + 4687.5\} - \{104.167 + 70312.5\}}{3375}$$

$$= \frac{356250 - 70416.667}{3375}$$

$$= \frac{285833.333}{3375}$$

$$= 84.691 \text{ m}$$

$$MCTC = \frac{W \times BM_L}{100L}$$

$$MCTC = \frac{3459.375 \times 84.691}{100 \times 75}$$

$$MCTC = 39.064 \text{ tm}$$

(IV)

$$\text{Total trim} = \frac{W \cdot d}{MCTC \times 100}$$

$$T = \frac{230.625 \times 37.5}{39.064 \times 100}$$

$$T = \frac{8648.438}{3906.372}$$

//_

$$T = 2.214m$$

$$T_a = \frac{\text{Total trim} \times \text{Final LCF}}{LBP}$$

$$T_a = \frac{2.214 \times 35}{75}$$

$$T_a = 1.033m$$

$$T_f = T - T_a$$

$$T_f = 2.214 - 1.033$$

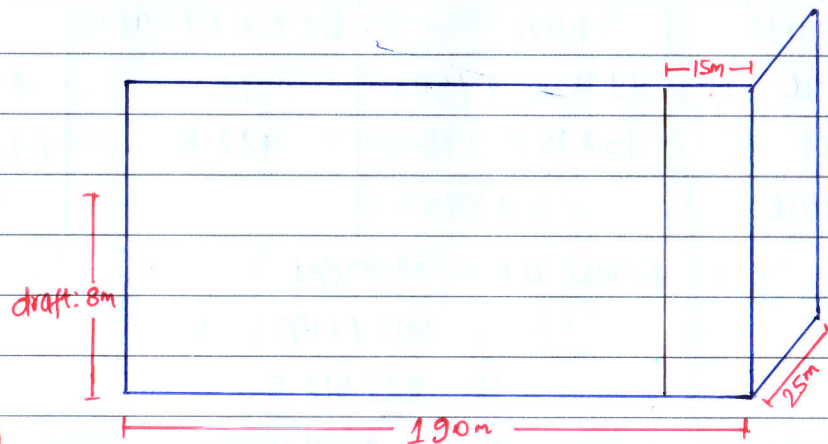
$$T_f = 1.181m$$

	Forward	Aft
New draft	4.821	4.821
T_f & T_a	(+) 1.181	(-) 1.033
Final draft	6.002m	3.788m Ans

JAN 2022

A box shaped vessel 190m x 25m at even keel draft of 8m, KG 4.34m has a compartment at the fore end 15mts in length extending full width of vessel. Calculate draft F & A after that compartment is bilged.

Soln:-



KG: 4.34m

Case 1A

$$\begin{aligned} \text{Volume of lost buoyancy} &= l \times b \times d \\ &= 15 \times 25 \times 8 \\ &= 3000 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Intact WPA} &= \text{Initial WPA} - \text{WPA lost} = LB - lb \\ &= (190 \times 25) - (15 \times 25) \\ &= 4750 - 375 \\ &= 4375 \text{ m}^2 \end{aligned}$$

$$\text{Sinkage} = \frac{\text{volume of lost buoyancy}}{\text{Intact WPA}}$$

$$= \frac{3000}{4375}$$

$$= 0.686 \text{ m}$$

$$\begin{aligned} \text{New draft} &= \text{Initial draft} + \text{sinkage} \\ &= 8.000 + 0.686 \\ &= 8.686 \text{ m} \end{aligned}$$

⇒ To calculate draft fwd & aft

$$\text{Total trim} = \frac{w \cdot d}{MCTC \times 100}$$

$$\begin{aligned} \textcircled{1} \quad w &= l \times b \times d \times \text{density} \\ w &= 15 \times 25 \times 8 \times 1.025 \\ w &= 3075 \text{ t} \end{aligned}$$

⑪ $d = \text{distance (h)}$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

To find final LCF

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$190 \times 25 = 4750$	95	451250
Lost	$15 \times 25 = 375$	182.5	(-) 68437.5
Intact	<u>4375</u>		<u>382812.5</u>

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Intact WPA}}$$

$$= \frac{382812.5}{4375}$$

$$= 87.5 \text{ m}$$

$$= 87.5 \text{ m}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

$$d = h = 87.5 - 182.5$$

$$d = h = -95 \text{ m by head}$$

⑫

$$\text{MCTC} = \frac{W \times GML}{100L}$$

$$W = L \times B \times d \times \text{density}$$

$$W = 190 \times 25 \times 8 \times 1.025$$

$$W = 38950 \text{ t}$$

$$GML = KML - KG$$

$$KML = KB + BML$$

$$\rightarrow KB = \frac{\text{New draft}}{2} = \frac{8.686}{2} = 4.343 \text{ m}$$

$\rightarrow$ TO calculate BML

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of lost WPA}}{\text{Total WPA} - \text{lost WPA}}$$

$$FF' = \frac{(LB \times \text{dist. w.r.t COF}) - (lb \times \text{dist. w.r.t COF})}{LB - lb}$$

$$FF' = \frac{(4750 \times 0) - (375 \times 87.5)}{4750 - 375}$$

$$FF' = \frac{4750 \times 0 - 375 \times 87.5}{4750 - 375}$$

$$FF' = \frac{4750 \times 0 - 375 \times 87.5}{4750 - 375}$$

$$FF' = \frac{4750 \times 0 - 375 \times 87.5}{4750 - 375}$$

$$FF' = \frac{4750 \times 0 - 375 \times 87.5}{4750 - 375}$$

$$FF' = \frac{-32812.5}{4375}$$

FF' = 7.5m by head (away from bilged area)

$$BM_L = \frac{I^* \text{COF Intact WPA}}{\text{Initial volume}}$$

$$BM_L = \frac{I^* \text{COF Total WPA} - I^* \text{COF Lost WPA}}{\text{Initial volume}}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + BL(y)^2 \right\} - \left\{ \frac{bl^3}{12} + bl(y)^2 \right\}}{L \times B \times d}$$

$$BM_L = \frac{\left\{ \frac{25 \times 190^3}{12} + (25 \times 190)(7.5)^2 \right\} - \left\{ \frac{25 \times 15^3}{12} + (25 \times 15)(\frac{7.5+87.5}{95})^2 \right\}}{190 \times 25 \times 8}$$

$$BM_L = \frac{\{14289583.33 + 267187.5\} - \{7031.25 + 3384375\}}{38000}$$

$$BM_L = \frac{14556770.83 - 3391406.25}{38000}$$

$$BM_L = \frac{11165364.58}{38000}$$

$$BM_L = 293.825m$$

$$KM_L = KB + BM_L$$

$$KM_L = 4.343 + 293.825$$

$$KM_L = 298.168m$$

$$GM_L = KM_L - KG$$

$$GM_L = 298.168 - 4.34$$

$$GM_L = 293.828m$$

$$MCTC = \frac{W \times GM_L}{100L}$$

$$= \frac{38950 \times 293.828}{100 \times 190}$$

$$= 602.347tm$$

(IV)

$$\text{Total trim} = \frac{w \cdot d}{MCTC \times 100}$$

$$t = \frac{3075 \times 95}{602.347 \times 100}$$

$$t = \frac{292125}{60234.74}$$

$$t = 4.850 \text{ m}$$

$$T_a = \frac{\text{Total trim} \times \text{Final LCF}}{\text{LBP}}$$

$$T_a = \frac{4.850 \times 87.5}{190}$$

$$T_a = 2.233 \text{ m}$$

$$T_f = T - T_a$$

$$T_f = 4.850 - 2.233$$

$$T_f = 2.617 \text{ m}$$

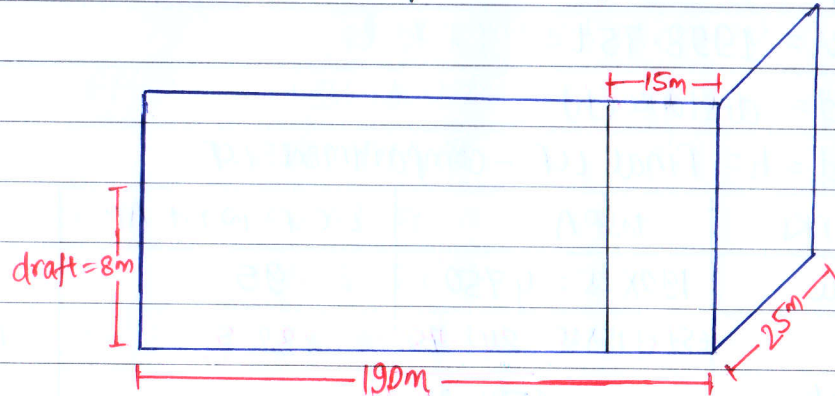
	forward	Aft
New draft	8.686	8.686
T_f & T_a	(+) 2.617	(-) 2.233
Final draft	<u>11.303 m</u>	<u>6.453 m</u> Ans

APRIL 2021

Similar only p.t.
changed:
NOV 2020,
MAY 2019

Soln:-

A box shaped vessel 190m long & 25m wide at even keel draft of 8m, $KG = 5.5m$ has a fwd compartment 15m in length with a permeability of 65%. Calculate draft F&A if that compartment is bilged.



$KG : 5.5m$

p.f. : 65%

$$\begin{aligned}\text{Volume of lost buoyancy} &= \text{p.f. of } l \times b \times d \\ &= 65\% \text{ of } 15 \times 25 \times 8 \\ &= 65\% \text{ of } 3000 \\ &= 1950 m^3\end{aligned}$$

$$\begin{aligned}\text{Intact WPA} &= \text{Total WPA} - \text{WPA lost} = LB - 65\% \text{ of } lb \\ &= (190 \times 25) - 65\% \text{ of } (15 \times 25) \\ &= 4750 - 65\% \text{ of } 375 \\ &= 4750 - 243.75 \\ &= 4506.25 m^2\end{aligned}$$

$$\text{Sinkage} = \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}}$$

$$\text{Sinkage} = \frac{1950}{4506.25}$$

$$\text{Sinkage} = 0.433 m$$

New draft : initial draft + sinkage

$$\text{New draft} = 8 + 0.433$$

$$\text{New draft} = 8.433 m$$

⇒ To find draft fwd & aft

$$\text{Total Trim (T)} = \frac{w \times d}{MCTC \times 100}$$

$$\textcircled{i} \quad w = \{65\% \text{ of } L \times B \times d\} \times \text{density}$$

$$w = \{65\% \text{ of } 15 \times 25 \times 8\} \times 1.025$$

$$w = 1950 \times 1.025$$

$$w = 1998.75 \text{ t}$$

$$\textcircled{ii} \quad d = \text{distance (h)}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$190 \times 25 = 4750$	95	451250
Lost	$65\% \text{ of } 15 \times 25 = 243.75$	182.5	$(-) 44484.375$
Intact	4506.25		406765.625

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Intact WPA}}$$

$$\text{Final LCF} = \frac{406765.625}{4506.25}$$

$$\text{Final LCF} = 90.267 \text{ m}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

$$d = h = 90.267 - 182.5$$

$$d = h = -92.233 \text{ m}$$

$$\textcircled{iii} \quad \text{MCTC} = \frac{W \times GML}{100L}$$

$$\bullet W = L \times B \times d \times \text{density}$$

$$W = 190 \times 25 \times 8 \times 1.025$$

$$W = 38950 \text{ t}$$

$$\bullet \text{ For } GML$$

$$GML = KML - KG$$

$$\downarrow$$

$$KML = KB + BML$$

$$\rightarrow KB = \frac{\text{New draft}}{2} = \frac{8.433}{2} = 4.217 \text{ m}$$

$$\rightarrow \text{For } BML$$

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$\text{Intact WPA}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of Lost WPA}}{\text{Total WPA} - \text{Lost WPA}}$$

$$\text{Total WPA} - \text{Lost WPA}$$

$$FF' = \frac{\{LB \times \text{dist. w.r.t COF}\} - \{p.l. \text{ of } lb \times \text{dist. w.r.t COF}\}}{LB - p.l. \text{ of } lb}$$

$$FF' = \frac{\{(190 \times 25) \times 0\} - \{65\% \text{ of } 15 \times 25\} \times 87.5}{190 \times 25 - 65\% \text{ of } (15 \times 25)}$$

$$FF' = \frac{0 - 21328.125}{4750 - 243.75}$$

$$FF' = \frac{-21328.125}{4506.25}$$

$$FF' = 4.733 \text{ m}$$

$$BM_L \text{ (about new COF)} = \frac{I^* \text{ COF Intact WPA}}{\text{Initial volume}}$$

$$BM_L = \frac{I^* \text{ COF Total WPA} - I^* \text{ COF lost WPA}}{\text{Initial volume}}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + BL(y^2) \right\} - p.l. \left\{ \frac{bL^3}{12} + bL(y^2) \right\}}{L \times B \times d}$$

$$BM_L = \frac{\left\{ \frac{25 \times 190^3}{12} + (25 \times 190)(4.733)^2 \right\} - 65\% \left\{ \frac{25 \times 15^3}{12} + (25 \times 15)(87.5)^2 \right\}}{190 \times 25 \times 8}$$

$$BM_L = \frac{\{14289583.33 + 106406.123\} - 65\% \text{ of } \{7031.25 + 3190097.358\}}{38000}$$

$$BM_L = \frac{14395989.45 - 2078133.595}{38000}$$

$$BM_L = \frac{12317855.85}{38000}$$

$$BM_L = 324.154 \text{ m}$$

$$KM_L = KB + BM_L$$

$$KM_L = 4.217 + 324.154$$

$$KM_L = 328.371 \text{ m}$$

$$GM_L = KM_L - KG$$

$$GM_L = 328.371 - 5.5$$

$$GM_L = 322.871 \text{ m}$$

$$MCTC = \frac{W \times GML}{100L}$$

$$MCTC = \frac{38950 \times 322.87}{100 \times 190}$$

$$MCTC = 661.886m$$

(iv)
$$\text{Total trim}(t) = \frac{w \cdot d}{MCTC \times 100}$$

$$t = \frac{1998.75 \times 92.233}{661.886 \times 100}$$

$$t = \frac{184350.709}{66188.555}$$

$$t = 2.785m$$

$$T_a = \frac{\text{Total trim} \times \text{Final LCF}}{LBP}$$

$$T_a = \frac{2.785 \times 90.267}{190}$$

$$T_a = 1.323m$$

$$T_f = T - T_a$$

$$T_f = 2.785 - 1.323$$

$$T_f = 1.462m$$

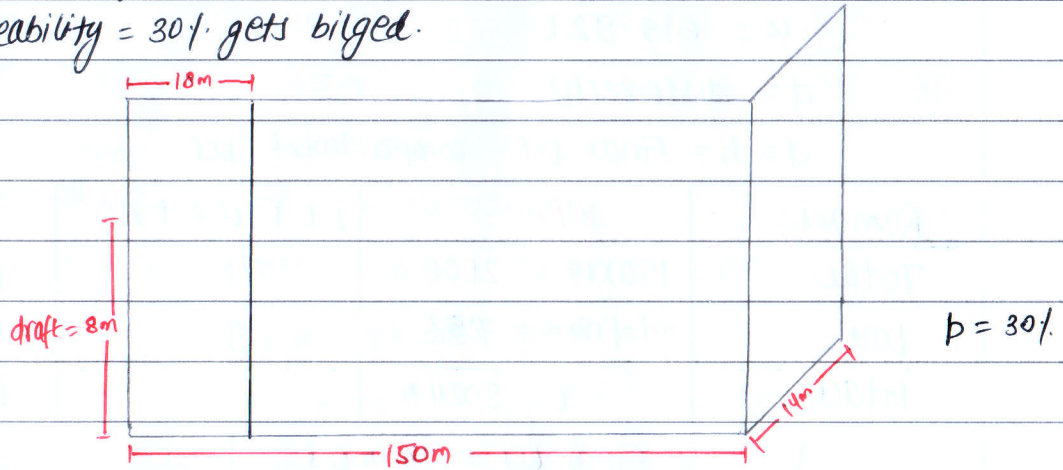
	Forward	Aft
New draft	8.433	8.433
T _f & T _a	(+) 1.462	(-) 1.323
Final draft	9.895m	7.110m

Ans

AUG 2021

A vessel 150m long and 14m wide is box shaped and afloat in SW at an even keel draft of 8m. The after-most compartment, 18m long & 14m wide, is full of cargo. Find the new drafts fwd & aft if this compartment, having permeability = 30% gets bilged.

Soln:-



$$\begin{aligned}\text{Volume of lost buoyancy: } p \cdot l \cdot b \cdot d \\ &= 30\% \text{ of } 18 \times 14 \times 8 \\ &= 30\% \text{ of } 2016 \\ &= 604.8 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Intact WPA} &= \text{Initial WPA} - \text{Lost WPA} = LB - p \cdot l \cdot b \\ &= (150 \times 14) - 30\% \text{ of } 18 \times 14 \\ &= 2100 - 30\% \text{ of } 252 \\ &= 2100 - 75.6 \\ &= 2024.4 \text{ m}^2\end{aligned}$$

$$\begin{aligned}\text{Sinkage} &= \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}} \\ &= \frac{604.8}{2024.4} \\ &= 0.299 \text{ m}\end{aligned}$$

$$\begin{aligned}\text{New draft} &= \text{Initial draft} + \text{Sinkage} \\ &= 8.00 + 0.299 \\ &= 8.299 \text{ m}\end{aligned}$$

⇒ To find draft forward & aft

$$\text{Total trim}(t) = \frac{w \cdot d}{MCTC \times 100}$$

$$① \quad w = \{p.f. \text{ of } l \times b \times d\} \times \text{density}$$

$$w = \{30\% \text{ of } 18 \times 14 \times 8\} \times 1.025$$

$$w = 604.8 \times 1.025$$

$$w = 619.92t$$

$$② \quad d = \text{distance}(h)$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

Remarks	WPA	L.C.F w.r.t AP	Moments
Total	$150 \times 14 = 2100$	75	157500
Lost	$30\% \text{ of } 18 \times 14 = 75.6$	9	(-) 680.4
Intact	<u>2024.4</u>		<u>156819.6</u>

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Intact WPA}}$$

$$= \frac{156819.6}{2024.4}$$

$$= 77.465m$$

$$d = h = 77.465 - 9$$

$$= 68.465m$$

③

$$\text{MCTC} = \frac{W \times GML}{100L}$$

$$\bullet W = L \times B \times d \times \text{density}$$

$$W = 150 \times 14 \times 8 \times 1.025$$

$$W = 17220t$$

• To find BM_L

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of total WPA} - \text{Moment of lost WPA}}{\text{Total WPA} - \text{lost WPA}}$$

$$FF' = \frac{\{LB \times \text{dist w.r.t coF}\} - \{l \times lb \times \text{dist. w.r.t coF}\}}{LB - l \times lb}$$

$$FF' = \frac{\{(150 \times 14) \times 0\} - \{30\% \text{ of } 18 \times 14\} \times 66}{(150 \times 14) - \{30\% \text{ of } (18 \times 14)\}}$$

$$FF' = \frac{\{(150 \times 14) \times 0\} - \{30\% \text{ of } 18 \times 14\} \times 66}{(150 \times 14) - \{30\% \text{ of } (18 \times 14)\}}$$

$$FF' = \frac{\{(150 \times 14) \times 0\} - \{30\% \text{ of } 18 \times 14\} \times 66}{(150 \times 14) - \{30\% \text{ of } (18 \times 14)\}}$$

$$FF' = \frac{0 - 4989.6}{2100 - 75.6}$$

$$FF' = \frac{4989.6}{2024.4}$$

$$FF' = 2.465m$$

$$BM_L = \frac{I^* \text{ COF Intact WPA}}{\text{(about new COF) Initial volume}}$$

$$BM_L = \frac{I^* \text{ COF Total WPA} - I^* \text{ COF lost WPA}}{\text{Initial volume}}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + BL(y^2) \right\} - p \left\{ \frac{bL^3}{12} + bL(y^2) \right\}}{\text{Initial volume}}$$

$$BM_L = \frac{\left\{ \frac{14 \times 150^3}{12} + (14 \times 150)(2.465)^2 \right\} - \left\{ \frac{14 \times 18^3}{12} + (14 \times 18)(\frac{66 + 2.465}{68.465})^2 \right\}}{150 \times 14 \times 8}$$

$$BM_L = \frac{\{ 3937500 + 12760.073 \} - 30 \cdot \{ 6804 + 1181238.969 \}}{16800}$$

$$BM_L = \frac{3950260.073 - 30 \cdot 1188042.969}{16800}$$

$$BM_L = \frac{3950260.073 - 356412.891}{16800}$$

$$BM_L = \frac{3593847.182}{16800}$$

$$BM_L = 213.919m$$

$$MCTC = \frac{W \times BM_L}{100L}$$

$$MCTC = \frac{17220 \times 213.919}{100 \times 150}$$

$$MCTC = \frac{3683693.362}{15000}$$

$$MCTC = 245.580tm$$

//_

$$\textcircled{\text{IV}} \quad \text{Total Trim} = \frac{w \cdot d}{MCTC \times 100}$$

$$t = \frac{619.92 \times 68.465}{245.580 \times 100}$$

$$t = \frac{42442.823}{24557.956}$$

$$t = 1.728 \text{ m}$$

$$T_a = \frac{\text{total trim} \times \text{Final LCF}}{\text{LBP}}$$

$$T_a = \frac{1.728 \times 77.465}{150}$$

$$T_a = 0.892 \text{ m}$$

$$T_f = t - t_a$$

$$T_f = 1.728 - 0.892$$

$$T_f = 0.836 \text{ m}$$

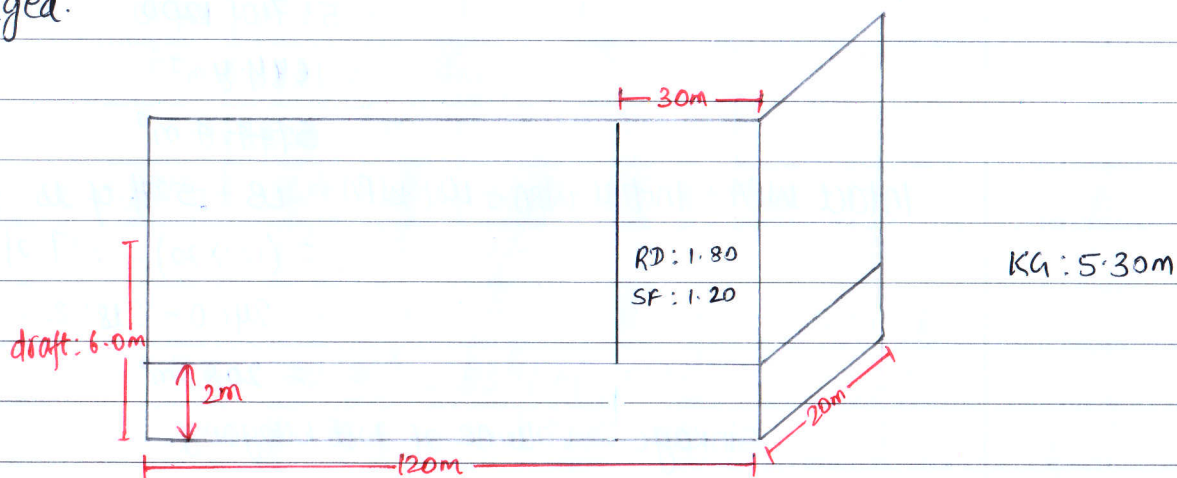
	Forward	Aft
New draft	8.299	8.299
T_f & T_a	0.836	0.892
Final draft	<u>7.463 m</u>	<u>9.191 m</u> <u>Ans</u>

AUG 2019

A box-shaped vessel is 120m long and 20m broad. It has a double bottom tank 2m high running for the full length and breadth of the vessel. There is a forward compartment 30m long above the D.B tank extending for the full width of the vessel. This compartment contains cargo of R.D. 1.80 and of SF 1.20 for the full height of the compartment. Vessel's KG is 5.30m. Vessel is floating at an even keel draft 6.0m.

Find vessel's GM, after the D.B tank as well as the forward compartment is bilged.

Soln:-



→ Find permeability

$$RD: 1.80$$

that means, 1.80t of cargo should occupy $1m^3$

$$\text{so, 1t of cargo will occupy} = 1 \div 1.80 \\ = 0.556 m^3$$

$$\text{But } SF = 1.20$$

that mean, 1t of cargo will actually occupy $= 1.20 m^3$

$$BS = 1.20 - 0.556 \\ = 0.644$$

$$\text{Permeability} = \frac{BS}{SF} \times 100$$

$$= \frac{0.644}{1.20} \times 100$$

$$= 53.7\%$$

Volume of lost buoyancy:-

CASE 2A

① For DB tank: $L \times b \times h$

$$= 120 \times 20 \times 2$$

$$= 4800 \text{ m}^3$$

CASE 3B

② of compartment = b.l. of $L \times b \times (d-h)$

$$= 53.71 \text{ of } \{30 \times 20 \times (6-2)\}$$

$$= 53.71 \text{ of } 30 \times 20 \times 4$$

$$= 53.71 \text{ of } 2400$$

$$= 1288.8 \text{ m}^3$$

$$6088.8 \text{ m}^3$$

$$\text{Intact WPA} = \text{Initial WPA} - \text{Lost WPA} = LB - 53.71 \text{ of } LB$$

$$= (120 \times 20) - 53.71 \text{ of } (30 \times 20) - 0$$

$$= 2400 - 322.2 - 0$$

$$= 2077.8 \text{ m}^2$$

$$\text{Sinkage} = \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}}$$

$$= \frac{6088.8}{2077.8}$$

$$2.930 \text{ m}$$

$$= 2.930 \text{ m}$$

$$\text{New draft} = \text{Initial draft} + \text{sinkage}$$

$$= 6.0 + 2.930$$

$$= 8.930 \text{ m}$$

⇒ To find GM_T

$$GM_T = KM_T - KG$$



$$KM_T = KB + BM_T$$

① Find KB by moment

Remarks	Volume	KB	Moment
Total (new)	$120 \times 20 \times 8.93 = 21432$	$\frac{8.930}{2} = 4.465$	95693.88
Compartment	$53.71 \times (30 \times 20 \times 6.930) = 2232.85$	$\frac{6.930}{2} + 2 = 5.465$	(-) 12202.525
DB tank	$120 \times 20 \times 2 = 4800$	$\frac{2}{2} = 1$	(-) 4800
	14399.15		78691.355

$$\begin{aligned}\text{Final KB} &= \frac{\text{Moment}}{\text{Volume}} \\ &= \frac{78691.355}{14399.15} \\ &= 5.465\text{m}\end{aligned}$$

⑪ Find BM_T

$$BM_T = \frac{I_{\text{intra}}^*}{V}$$

$$BM_T = \frac{I_{\text{TOTAL}}^* - I_{\text{lost}}}{V}$$

$$BM_T = \frac{\frac{LB^3}{12} - \frac{\text{p.l. of lb}^3}{12}}{V}$$

$$BM_T = \frac{\frac{120 \times 20^3}{12} - 53.7\% \text{ of } \frac{30 \times 20^3}{12}}{120 \times 20 \times 6}$$

$$BM_T = \frac{80000 - 10740}{14400}$$

$$BM_T = \frac{69260}{14400}$$

$$BM_T = 4.810\text{m}$$

$$KM_T = KB + BM_T$$

$$KM_T = 5.465 + 4.810$$

$$KM_T = 10.275\text{m}$$

$$GM_T = KM_T - KG$$

$$GM_T = 10.275 - 5.30$$

$$GM_T = 4.975\text{m}$$

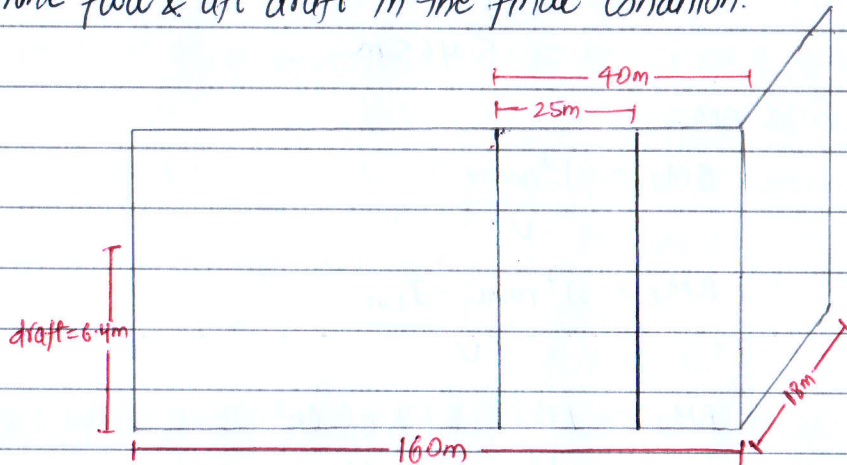
BILGING - INTERMEDIATE COMPARTMENT

//_

AUG 2025 PM,
AUG 2025 AM,
NOV 2024, FEB 2023,
MAY 2022, MARCH 2022,
AUG 2018

A box shaped vessel 160m x 18m floats in SW at an even keel draft of 6.4m. A forward hold of length 25m whose aft bulkhead is 40m aft of FP and is bilged. If the permeability of the hold is 80% and K_G of vessel was 4.7m. Determine fwd & aft draft in the final condition.

Soln:-



SW
 $p = 80\%$
 $K_G = 4.7m$

$$\begin{aligned} \text{Volume of lost buoyancy} &= p\% \text{ of } l \times b \times d \\ &= 80\% \text{ of } 25 \times 18 \times 6.4 \\ &= 80\% \text{ of } 2880 \\ &= 2304 m^3 \end{aligned}$$

$$\begin{aligned} \text{Intact WPA} &= \text{Total WPA} - \text{WPA lost} = LB - p\% \text{ of } lb \\ &= (160 \times 18) - 80\% \text{ of } (25 \times 18) \\ &= 2880 - 80\% \text{ of } 450 \\ &= 2880 - 360 \\ &= 2520 m^2 \end{aligned}$$

$$\begin{aligned} \text{Sinkage} &= \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}} \\ &= \frac{2304}{2520} \\ &= 0.914 m \end{aligned}$$

$$\begin{aligned} \text{New draft} &= \text{Initial draft} + \text{sinkage} \\ &= 6.40 + 0.914 \\ &= 7.314 m \end{aligned}$$

⇒ To find draft fwd & aft

$$\text{Total trim}(t) = \frac{w.d}{MCTC \times 100}$$

$$\begin{aligned}
 \textcircled{i} \quad w &= \{ \text{p/ of } l \times b \times d \} \times \text{density} \\
 &= \{ 80\% \text{ of } 25 \times 18 \times 6.4 \} \times 1.025 \\
 &= 80\% \text{ of } 2880 \times 1.025 \\
 &= 2361.6 \text{ t}
 \end{aligned}$$

$$\begin{aligned}
 \textcircled{ii} \quad d &= \text{distance}(h) \\
 d &= h = \text{Final LCF} - \text{compartment LCF}
 \end{aligned}$$

To find Final LCF

Remarks	WPA	LCF w.r.t AP	Moment
Total	$160 \times 18 = 2880$	80	230400
Lost	$80\% \text{ of } 25 \times 18 = 360$	132.5	(-) 47700
Intact	<u>2520</u>		<u>182700</u>

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Intact WPA}}$$

$$= \frac{182700}{2520}$$

$$= 72.5 \text{ m}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

$$d = h = 72.5 - 132.5$$

$$d = h = -60 \text{ m by head.}$$

$$\textcircled{iii} \quad \text{MCTC} = \frac{W \times GML}{100L}$$

$$\text{where, } GML = KML - KG$$

$$\downarrow \\
 KML = KB + BML$$

$$\bullet \quad KB = \frac{\text{New draft}}{2} = \frac{7.314}{2} = 3.657 \text{ m}$$

$$\bullet \quad BML$$

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of Lost WPA}}{\text{Total WPA} - \text{WPA lost}}$$

$$FF' = \frac{(LB \times \text{dist w.r.t COF}) - (\text{p/ of lb} \times \text{dist w.r.t COF})}{LB - \text{p/ of lb}}$$

$$FF' = \frac{\{(160 \times 18) \times 0\} - \{(80\% \text{ of } 25 \times 18) \times 52.5\}}{(160 \times 18) - 80\% \text{ of } 25 \times 18}$$

$$FF' = \frac{0 - 18900}{2880 - 360}$$

$$FF' = \frac{-18900}{2520}$$

$$FF' = 7.5m$$

$$BM_L = \frac{I^* \text{COF Intact WPA}}{\text{(about new COF) Initial vol.}}$$

$$BM_L = \frac{I^* \text{COF total WPA} - I^* \text{COF lost WPA}}{L \times B \times d}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + BL(y)^2 \right\} - p \cdot \left\{ \frac{bl^3}{12} + bl(y^2) \right\}}{L \times B \times d}$$

18432

$$BM_L = \frac{\left\{ \frac{18 \times 160^3}{12} + (18 \times 160)(7.5)^2 \right\} - 80\% \left\{ \frac{18 \times 25^3}{12} + (18 \times 25)(\frac{7.5+52.5}{=60})^2 \right\}}{160 \times 18 \times 6.4}$$

$$BM_L = \frac{\{6144000 + 162000\} - 80\% \{23437.5 + 1620000\}}{18432}$$

$$BM_L = \frac{6306000 - 1314750}{18432}$$

$$BM_L = \frac{4991250}{18432}$$

$$BM_L = 270.793m$$

$$KM_L = KB + BM_L$$

$$KM_L = 3.657 + 270.793$$

$$KM_L = 274.45m$$

$$GM_L = KM_L - KG$$

$$GM_L = 274.45 - 4.7$$

$$GM_L = 269.75m$$

$$W = L \times B \times d \times \text{density}$$

$$W = 160 \times 18 \times 6.4 \times 1.025$$

$$W = 18892.8 \text{ t}$$

$$\text{MCTC} = \frac{W \times \text{GML}}{100L}$$

$$\text{MCTC} = \frac{18892.8 \times 269.75}{100 \times 160}$$

$$\text{MCTC} = 318.521 \text{ tm}$$

$$\text{Total trim (t)} = \frac{w \cdot d}{\text{MCTC} \times 100}$$

$$t = \frac{2361.6 \times 60}{318.521 \times 100}$$

$$t = \frac{141696}{31852.1}$$

$$t = 4.449 \text{ m}$$

$$T_a = \frac{\text{total trim} \times \text{Final LCF}}{\text{LBP}}$$

$$T_a = \frac{4.449 \times 72.5}{160}$$

$$T_a = 2.016 \text{ m}$$

$$T_f = T - T_a$$

$$T_f = 4.449 - 2.016$$

$$T_f = 2.433 \text{ m}$$

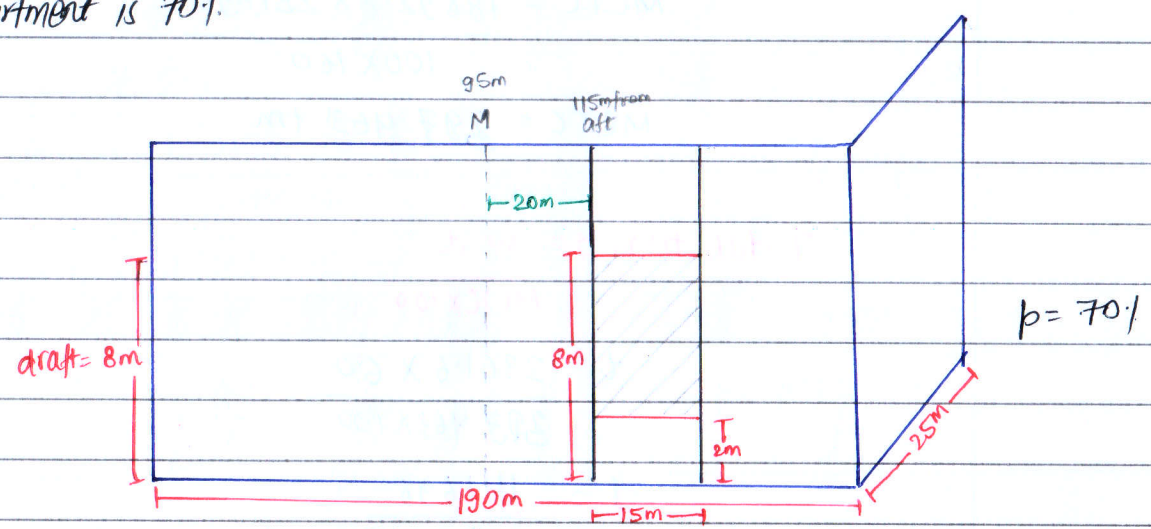
	Forward	Aft
New draft	7.314	7.314
T _f & T _a	(+) 2.433	(-) 2.016
Final draft	9.747m	5.298m

Ans

MAY 2025, SEP 2022

A box-shaped vessel 190m X 25m is floating at an even keel draft of 8m. There is a watertight compartment 8m deep with watertight flat at 2m. The length of the compartment is 15m and its aft bulkhead is 20m forward of midship. Find the draft of the vessel if the watertight compartment gets bilged above the flat. The permeability of cargo in the watertight compartment is 70%.

Soln:-



$$\begin{aligned}\text{Volume of lost buoyancy} &= p\% \text{ of } l \times b \times (d-h) \\ &= 70\% \text{ of } 15 \times 25 \times (8-2) \\ &= 70\% \text{ of } 15 \times 25 \times 6 \\ &= 70\% \text{ of } 2250 \\ &= 1575 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Intact WPA} &= \text{Total WPA} - \text{Lost WPA} = LB \\ &= 190 \times 25 \\ &= 4750 \text{ m}^2\end{aligned}$$

$$\begin{aligned}\text{Sinkage} &= \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}} \\ &= \frac{1575}{4750} \\ &= 0.332 \text{ m}\end{aligned}$$

$$\begin{aligned}\text{New draft} &= \text{Initial draft} + \text{Sinkage} \\ &= 8.00 + 0.332 \\ &= 8.332 \text{ m}\end{aligned}$$

⇒ To find draft forward & aft

$$\text{Total Trim}(t) = \frac{w \times d}{MCTC \times 100}$$

① $w = \{l \times b \times (d-h)\} \times \text{density}$

$$w = 1575 \times 1.025$$

$$w = 1614.375t$$

② $d = \text{distance}(h)$

$$d = h = \text{Final LCF} - \text{Compartment LCF}$$

To find Final LCF

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$190 \times 25 = 4750$	95	—
Lost	0	0	0
Intact			

$$\text{Final LCF} = 95m$$

$$d = h = 95 - 122.5$$

$$= -27.5m \text{ by head.}$$

③

$$MCTC = \frac{W \times GML}{100L}$$

• $W = L \times B \times d \times \text{density}$

$$W = 190 \times 25 \times 8 \times 1.025$$

$$W = 38950t$$

• Since K_G is not given, we will find BM_L

To find BM_L ,

$$BM_L = \frac{BL^3}{12V}$$

$$= \frac{25 \times 190^3}{12(190 \times 25 \times 8)}$$

$$= 376.042m$$

$$MCTC = \frac{W \times BM_L}{100L}$$

$$MCTC = \frac{38950 \times 376.042}{100 \times 190}$$

$$MCTC = 770.885tm$$

(IV)

$$\text{Total time} = \frac{w \times d}{MCTC \times 100}$$

$$t = \frac{1614.375 \times 27.5}{770.885 \times 100}$$

$$t = \frac{44395.313}{77088.542}$$

$$t = 0.576 \text{ m}$$

$$T_a = \frac{\text{total time} \times LCF}{LBP}$$

$$T_a = \frac{0.576 \times 95}{190}$$

$$T_a = 0.288 \text{ m}$$

$$T_f = t - t_a$$

$$T_f = 0.576 - 0.288$$

$$T_f = 0.288 \text{ m}$$

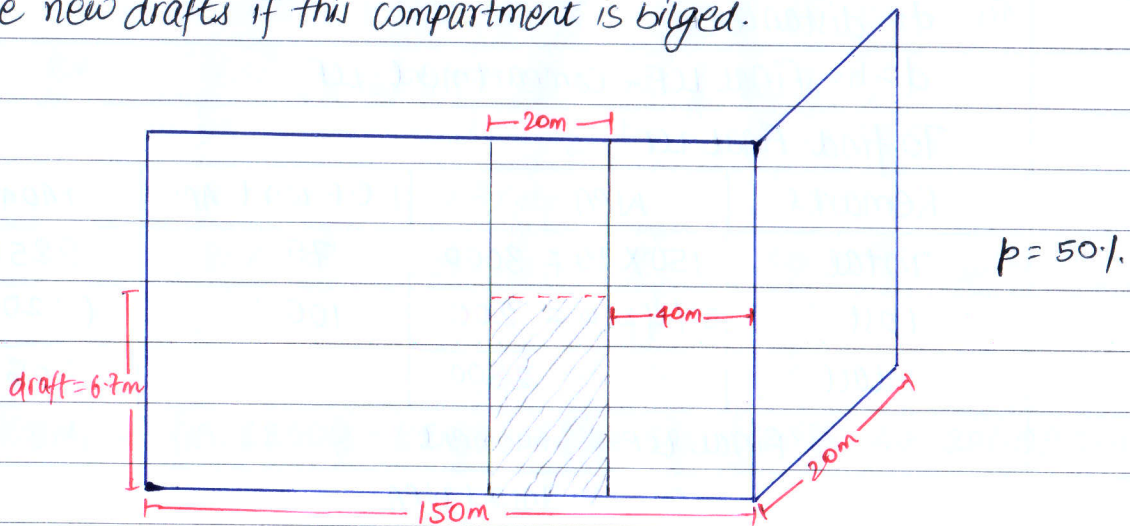
	Forward	Aft
New draft	8.332m	8.332m
$T_f \times T_a$	(+) 0.288m	(-) 0.288m
Final draft	8.620m	8.044m

Ans

FEB 2025 PM,
MAY 2024 PAPER 2

A box-shaped vessel (150m x 20m) is floating in SW at a draft of 6.7m. A 20m long compartment whose fwd bulkhead is 40m from the fwd end of the vessel is loaded with cargo of a permeability of 50%. Calculate the new drafts if this compartment is bilged.

Soln:-



$$\begin{aligned}\text{Volume of lost buoyancy} &= p\% \text{ of } L \times B \times d \\ &= 50\% \text{ of } 20 \times 20 \times 6.7 \\ &= 50\% \text{ of } 2680 \\ &= 1340 \text{ m}^3\end{aligned}$$

$$\begin{aligned}\text{Intact WPA} &= \text{Total WPA} - \text{lost WPA} = LB - p\% \text{ of } LB \\ &= (150 \times 20) - 50\% \text{ of } (20 \times 20) \\ &= 3000 - 50\% \text{ of } 400 \\ &= 3000 - 200 \\ &= 2800 \text{ m}^2\end{aligned}$$

$$\text{Sinkage} = \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}} = \frac{1340}{2800} = 0.479 \text{ m}$$

$$\begin{aligned}\text{New draft} &= \text{Initial draft} + \text{sinkage} \\ &= 6.7 + 0.479 \\ &= 7.179 \text{ m}\end{aligned}$$

⇒ To find draft forward and aft

$$\text{Total trim} = \frac{w \times d}{MCTC \times 100}$$

P.T.O

$$\textcircled{i} \quad w = \{p.l. of l \times b \times d\} \times \text{density}$$

$$w = 1340 \times 1.025$$

$$w = 1373.5 t$$

$$\textcircled{ii} \quad d = \text{distance (m)}$$

$$d = h = \text{Final LCF} - \text{Compartment LCF}$$

To find Final LCF

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$150 \times 20 = 3000$	75	225000
Lost	$50\% \text{ of } 20 \times 20 = 200$	100	(-) 20000
Intact	2800		205000

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Intact WPA}}$$

$$= \frac{205000}{2800}$$

$$= 73.214 m$$

$$d = h = 73.214 - 100$$

$$= -26.786 m \text{ by head}$$

$\textcircled{iii}$

$$MCTC = \frac{W \times GML}{100L}$$

- Since, K_A is not given, we will use BML
- $W = L \times B \times d \times \text{density} = 150 \times 20 \times 6.7 \times 1.025 = 20602.5 t$
- To find BML

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of Lost WPA}}{\text{Total WPA} - \text{Lost WPA}}$$

$$FF' = \frac{\{LB \times \text{dist w.r.t COF}\} - \{(p.l. of lb) \times \text{dist. w.r.t COF}\}}{\text{Total WPA} - \text{Lost WPA}}$$

$$FF' = \frac{\{(150 \times 20) \times 0\} - \{(50\% \text{ of } 20 \times 20) \times 25\}}{(150 \times 20) - (50\% \text{ of } 20 \times 20)}$$

$$FF' = \frac{0 - (200 \times 25)}{3000 - 200}$$

$$FF' = 5000/2800$$

$$FF' = 1.786 m$$

$$BM_L = \frac{I^*_{\text{COF Intact WPA}}}{\text{(about its new COF) Initial vol.}}$$

$$BM_L = \frac{I^*_{\text{COF Total WPA}} - I^*_{\text{COF lost WPA}}}{\text{Initial vol.}}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + (BL)(y)^2 \right\} - p.l. \left\{ \frac{bd^3}{12} + bd(y)^2 \right\}}{L \times B \times d}$$

$$BM_L = \frac{\left\{ \frac{20 \times 150^3}{12} + (20 \times 150)(1.786)^2 \right\} - 50\% \left\{ \frac{20 \times 20^3}{12} + (20 \times 20)(1.786 + 25)^2 \right\}}{150 \times 20 \times 6.7}$$

$$BM_L = \frac{\{ 5625000 + 9569.388 \} - 50\% \{ 13333.333 + 286995.918 \}}{20100}$$

$$BM_L = \frac{5634569.388 - 50\% \text{ of } 300329.251}{20100}$$

$$BM_L = \frac{5634569.388 - 150164.626}{20100}$$

$$BM_L = \frac{5484404.762}{20100}$$

$$BM_L = 272.856 \text{ m}$$

$$MCTC = \frac{W \times BM_L}{100L}$$

$$MCTC = \frac{20602.5 \times 272.856}{100 \times 150}$$

$$MCTC = 374.768 \text{ tm}$$

$$\textcircled{IV} \text{ Trim} = \frac{w \times d}{MCTC \times 100} = \frac{1373.5 \times 26.786}{374.768 \times 100} = 0.982 \text{ m}$$

$$T_a = \frac{\text{Trim} \times LCF}{LBP} = \frac{0.982 \times 73.214}{150} = 0.479 \text{ m}$$

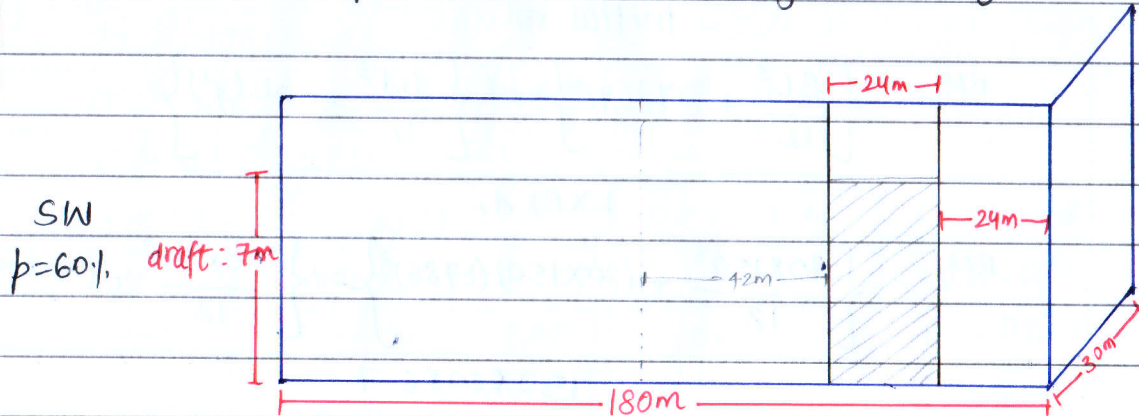
$$T_f = T - T_a = 0.982 - 0.479 = 0.503 \text{ m}$$

	Forward	Aft
New draft	7.179	7.179
Tf & Ta	(+) 0.503	(-) 0.479
Final draft	7.682 m	6.700 m Ans

MAY 2024 PAPER 1

A box shaped vessel 180m long and 30m wide is in SW with an even keel draft of 7m. A compartment of length 24m whose forward bulkhead is 24m from the FP, permeability 60% is bilged. Find new drafts

Soln:-



$$\begin{aligned} \text{Volume of lost buoyancy} &= p\% \text{ of } l \times b \times d \\ &= 60\% \text{ of } 24 \times 30 \times 7 \\ &= 60\% \text{ of } 5040 \\ &= 3024 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Intact WPA} &= \text{Total WPA} - \text{lost WPA} = LB - p\% \text{ of } lb \\ &= (180 \times 30) - 60\% \text{ of } (24 \times 30) \\ &= 5400 - 60\% \text{ of } 720 \\ &= 5400 - 432 \\ &= 4968 \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \text{Sinkage} &= \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}} \\ &= \frac{3024}{4968} \\ &= 0.609 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{New draft} &= \text{Initial draft} + \text{sinkage} \\ &= 7 + 0.609 \\ &= 7.609 \text{ m} \end{aligned}$$

⇒ To find drafts forward and aft

$$\begin{aligned} \text{Trim} &= \frac{wx d}{MCTC \times 100} \end{aligned}$$

$$\textcircled{i} \quad w = \{ \text{p.f. of } l \times b \times d \} \times \text{density}$$

$$w = 3024 \times 1.025$$

$$w = 3099.6 \text{ t}$$

$$\textcircled{ii} \quad d = \text{distance (h)}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

To find Final LCF

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$180 \times 30 = 5400$	90	486000
Lost	$60\% \text{ of } 24 \times 30 = 432$	144	(-) 62208
Intact	4968		423792

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Intact WPA}}$$

$$= \frac{423792}{4968} = 85.304 \text{ m}$$

$$d = h = 85.304 - 144$$

$$= -58.696 \text{ m by head}$$

$$\textcircled{iii} \quad \text{MCTC} = \frac{W \times GML(BML)}{100L}$$

We will use BML , bcz KG is not given in question

$$\bullet \quad W = L \times B \times d \times \text{density}$$

$$= 180 \times 30 \times 7 \times 1.025$$

$$= 38745 \text{ t}$$

• To find BML

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of Lost WPA}}{\text{Total WPA} - \text{Lost WPA}}$$

$$FF' = \frac{\{ LB \times \text{dist w.r.t cor} \} - \{ \text{p.f. of } lb \times \text{dist. w.r.t cor} \}}{LB - \text{p.f. of } lb}$$

$$FF' = \frac{\{ (180 \times 30) \times 0 \} - \{ (60\% \text{ of } 24 \times 30) \times 54 \}}{(180 \times 30) - (60\% \text{ of } 24 \times 30)}$$

$$FF' = \frac{0 - 23328}{5400 - 432}$$

$$BM_L = \frac{I^*_{\text{COF Initial WPA}}}{\text{Initial vol}}$$

(about its new cor)

$$BM_L = \frac{I^*_{\text{COF Total WPA}} - I^*_{\text{COF lost WPA}}}{\text{Initial vol}}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + BL(y)^2 \right\} - \text{p.t. of } \left\{ \frac{bl^3}{12} + bl(y)^2 \right\}}{L \times B \times d}$$

$$BM_L = \frac{\left\{ \frac{30 \times 180^3}{12} + (30 \times 180)(4.696)^2 \right\} - 60\% \text{ of } \left\{ \frac{30 \times 24^3}{12} + (30 \times 24)(4.696 + 5)^2 \right\}}{180 \times 30 \times 7}$$

$$BM_L = \frac{\{14580000 + 119083.046\} - 60\% \text{ of } \{34560 + 2480558.7\}}{37800}$$

$$BM_L = \frac{14699083.05 - 60\% \text{ of } 2515118.7}{37800}$$

$$BM_L = \frac{14699083.05 - 1509071.22}{37800}$$

$$BM_L = 348.942 \text{ m}$$

$$MCTC = \frac{W \times BM_L}{100L}$$

$$MCTC = \frac{38745 \times 348.942}{100 \times 180} = 751.098 \text{ tm}$$

(iv) $\text{Total trim} = \frac{w \times d}{MCTC \times 100}$

$$t = \frac{3099.6 \times 58.696}{751.098 \times 100} = 2.422 \text{ m}$$

$$T_a = \frac{\text{Total trim} \times \text{Final LBP}}{\text{LBP}} = \frac{2.422 \times 85.304}{180} = 1.148 \text{ m}$$

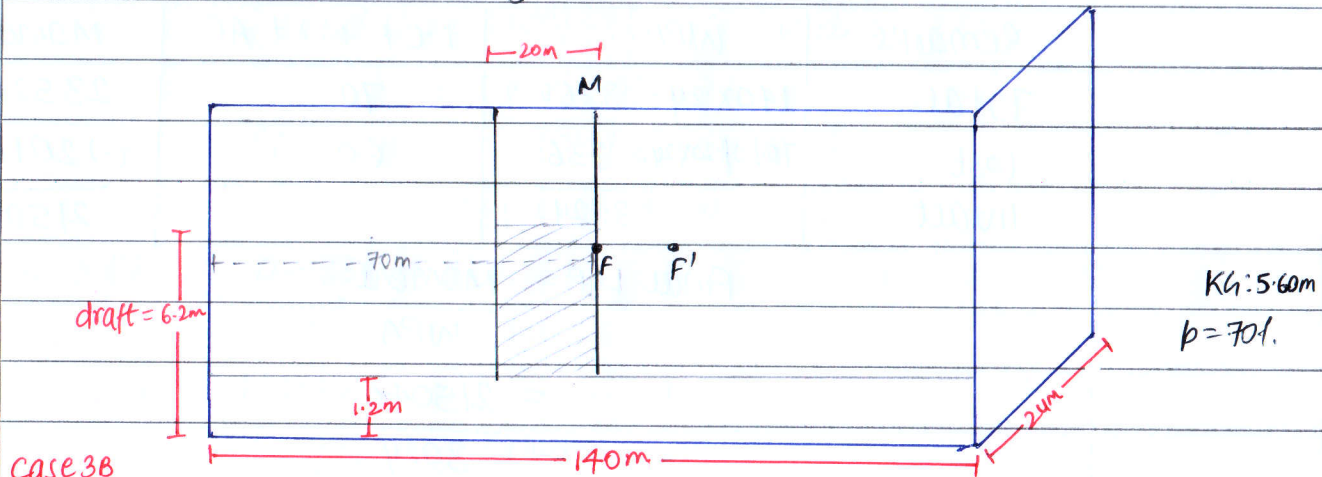
$$T_f = T - T_a = 2.422 - 1.148 = 1.274 \text{ m}$$

	Forward	Aft
New draft	7.609 m	7.609 m
T _f & T _a	(+) 1.274 m	(-) 1.148 m
Final draft	8.883 m	6.461 m <u>Ans</u>

MAY 2023

A box shaped barge 140m long, 24m broad, KG 5.60m, is floating at even keel draft of 6.2m has double bottom tank, 1.2m deep, throughout her length. A compartment 20m in length situated above the double bottom extending from side to side with its forward bulkhead amidships has permeability of 70%. calculate the drafts if that compartment is bilged above the double bottom.

Soln:-



Case 3B

$$\begin{aligned}
 \text{Volume of lost buoyancy} &= p\% \text{ of } l \times b \times (d - h) \\
 &= 70\% \text{ of } 20 \times 24 \times (6.2 - 1.2) \\
 &= 70\% \text{ of } 20 \times 24 \times 5 \\
 &= 70\% \text{ of } 2400 \\
 &= 1680 \text{ m}^3
 \end{aligned}$$

$$\begin{aligned}
 \text{Intact WPA} &= \text{Total WPA} - \text{lost WPA} = LB - p\% \text{ of } LB \\
 &= (140 \times 24) - 70\% \text{ of } (20 \times 24) \\
 &= 3360 - 336 \\
 &= 3024 \text{ m}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Sinkage} &= \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}} \\
 &= \frac{1680}{3024} = 0.556 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{New draft} &= \text{Initial draft} - \text{final draft} \\
 &= 6.2 + 0.556 \\
 &= 6.756 \text{ m}
 \end{aligned}$$

⇒ To find draft fwd & aft

$$\text{Trim} = \frac{W \times d}{MCTC \times 100}$$

$$\textcircled{i} \quad w = \{ \text{pt. of } L \times B \times (d-h) \} \times \text{density}$$

$$w = 1680 \times 1.025$$

$$w = 1722 \text{ t}$$

$$\textcircled{ii} \quad d = \text{distance (h)}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

To find Final LCF

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$140 \times 24 = 3360$	70	235200
lost	$70\% \text{ of } 20 \times 24 = 336$	60	(-) 20160
Intact	<u>3024</u>		<u>215040</u>

$$\text{Final LCF} = \frac{\text{Moment}}{\text{WPA}}$$

$$= \frac{215040}{3024}$$

$$= 71.111 \text{ m}$$

$$d = h = 71.111 - 60$$

$$= 11.111 \text{ m}$$

$$\textcircled{iii} \quad \text{MCTC} = \frac{W \times GML}{100L}$$

$$GML = KML - KG$$

$$\downarrow$$

$$KML = KB + BML$$

$$\begin{aligned} \bullet W &= L \times B \times d \times \text{density} \\ &= 140 \times 24 \times 6.2 \times 1.025 \\ &= 21352.8 \text{ t} \end{aligned}$$

• To find KB (by moment)

Remarks	Volume	KB	Moment
Total (new)	$140 \times 24 \times 6.756 = 22700.16$	$6.756/2 = 3.378$	76681.140
Compartment	$70\% (20 \times 24 \times 5.556) = 18660.816$	$5.556/2 + 1.2 = 3.978$	(-) 7426.194
	<u>20833.344</u>		<u>69254.946</u>

$$\text{Final KB} = \frac{69254.946}{20833.344}$$

$$= 3.324 \text{ m}$$

• To find BM_L

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of lost WPA}}{\text{Total WPA} - \text{lost WPA}}$$

where, Moment = Area $\times$ dist. w.r.t coF

$$FF' = \frac{\{LB \times \text{dist. w.r.t coF}\} - \{p.f. \text{ of } lb \times \text{dist. w.r.t coF}\}}{LB - p.f. \text{ of } lb}$$

$$FF' = \frac{\{(140 \times 24) \times 0\} - \{70\% \text{ of } 20 \times 24 \times 10\}}{(140 \times 24) - (70\% \text{ of } 20 \times 24)}$$

$$FF' = \frac{0 - 3360}{3360 - 336}$$

$$FF' = 1.111m$$

$$BM_L = \frac{I^* \text{ COF Intact WPA}}{\text{Initial vol.}}$$

(about its new coF)

$$BM_L = \frac{I^* \text{ COF Total WPA} - I^* \text{ COF lost WPA}}{\text{Initial vol.}}$$

$$BM_L = \frac{\left\{ \frac{BL^3}{12} + BL(y^2) \right\} - p.f. \left\{ \frac{bl^3}{12} + bl(y)^2 \right\}}{L \times B \times d}$$

$$BM_L = \frac{\left\{ \frac{24 \times 140^3}{12} + (24 \times 140)(1.111)^2 \right\} - 70\% \text{ of } \left\{ \frac{24 \times 20^3}{12} + (24 \times 20)(\frac{1.111 + 10}{1.111})^2 \right\}}{140 \times 24 \times 6.2}$$

$$BM_L = \frac{\{5488000 + 4147.319\} - 70\% \text{ of } \{16000 + 59258.074\}}{20832}$$

$$BM_L = \frac{5492147.319 - 52680.652}{20832}$$

$$BM_L = \frac{5439466.667}{20832}$$

$$BM_L = 261.111m$$

$$KM_L = KB + BM_L$$

$$KM_L = 3.324 + 261.111$$

$$KM_L = 264.435m$$

$$GML = KML - KG$$

$$GML = 264.435 - 5.60$$

$$GML = 258.835m$$

$$MCTC = \frac{W \times GML}{100L}$$

$$MCTC = \frac{21352.8 \times 258.835}{100 \times 140}$$

$$MCTC = 394.775tm$$

(iv)

$$\text{Total trim}(t) = \frac{w \cdot d}{MCTC \times 100}$$

$$t = \frac{1722 \times 11.111}{394.775 \times 100}$$

$$t = \frac{19133.142}{39477.531}$$

$$t = 0.485m$$

$$Ta = \frac{\text{Total trim} \times \text{Final LCF}}{LBP}$$

$$Ta = \frac{0.485 \times 71.111}{140}$$

$$Ta = 0.246m$$

$$Tf = T - Ta$$

$$Tf = 0.485 - 0.246$$

$$Tf = 0.239m$$

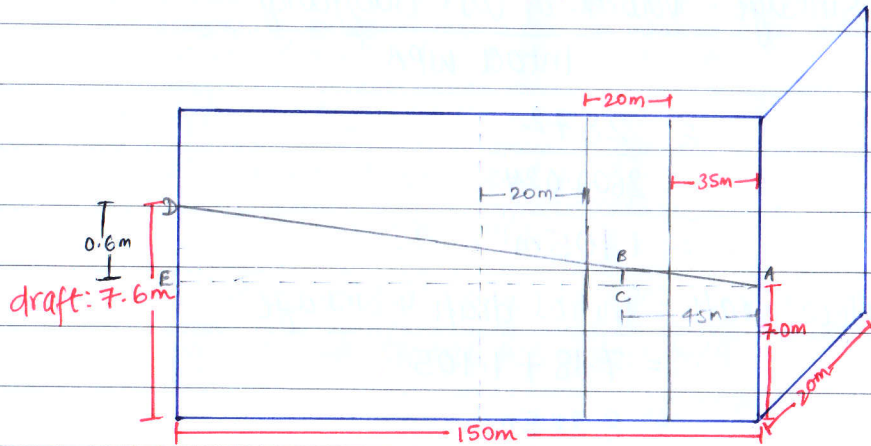
	Forward	Aft
New draft	6.756	6.756
Tf & Ta	(-) 0.239	(+) 0.246
Final draft	6.517m	7.002m

Ans

NOV 2019

A box shaped vessel 150m long and 20m wide is in SW with a draft of 7m fwd and 7.6m aft. A compartment on ships centerline is 20m long whose forward bulkhead is 35m from the forward perpendicular is bilged. Find the new draft

Soln:-



- To find draft at middle of bilged compartment

Consider similar triangle $\triangle ABC$ & $\triangle ADE$

$$\frac{AE}{AC} = \frac{DE}{BC}$$

$$\frac{150}{45} = \frac{0.6}{BC}$$

$$BC = \frac{0.6 \times 45}{150}$$

$$BC = 0.18m$$

$$\text{draft at middle of bilged compartment: } 7.0 + 0.18 = 7.18m$$

$$\begin{aligned} \text{Volume of lost buoyancy} &= L \times b \times d \\ &= 20 \times 20 \times 7.18 \\ &= 2872 m^3 \end{aligned}$$

To find Total WPA, we need AD

$$AD^2 = DE^2 + AE^2$$

$$AD = \sqrt{DE^2 + AE^2}$$

$$AD = \sqrt{(0.6)^2 + (150)^2}$$

$$AD = \sqrt{0.36 + 22500}$$

$$AD = 150.0012m$$

$$\begin{aligned}
 \text{Intact WPA} &= \text{Total WPA} - \text{WPA lost} = L_B - L_b \\
 &= (150 \cdot 0012 \times 20) - (20 \times 20) \\
 &= 3000 \cdot 024 - 400 \\
 &= 2600 \cdot 024 \text{ m}^2
 \end{aligned}$$

$$\text{Sinkage} = \frac{\text{Volume of lost buoyancy}}{\text{Intact WPA}}$$

$$\begin{aligned}
 &= \frac{2872}{2600 \cdot 024} \\
 &= 1 \cdot 105 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{New draft} &= \text{Initial draft} + \text{sinkage} \\
 &= 7 \cdot 18 + 1 \cdot 105 \\
 &= 8 \cdot 285 \text{ m}
 \end{aligned}$$

⇒ To find draft fwd and aft

$$\text{Trim} = \frac{w \cdot d}{MCTC \times 100}$$

$$\begin{aligned}
 \text{① } w &= L \times b \times d \times \text{density} \\
 &= 20 \times 20 \times 7 \cdot 18 \times 1 \cdot 025 \\
 &= 2943 \cdot 8 \text{ t}
 \end{aligned}$$

$$\text{② } d = \text{distance (m)}$$

$$d = h = \text{Final LCF} - \text{compartment LCF}$$

Remarks	WPA	L.C.F w.r.t AP	Moment
Total	$150 \cdot 0012 \times 20 = 3000 \cdot 024$	75	225001.8
lost	$20 \times 20 = 400$	105	(-) 42000
Intact	$2600 \cdot 024$		183001.8

$$\text{Final LCF} = \frac{\text{Moment}}{\text{Intact WPA}}$$

$$\begin{aligned}
 &= \frac{183001 \cdot 8}{2600 \cdot 024} \\
 &= 70 \cdot 385 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 d = h &= 70 \cdot 385 - 105 \\
 &= -34 \cdot 615 \text{ m}
 \end{aligned}$$

(iii)

$$MCTC = \frac{W \times GML}{100L}$$

Since KG is not given in ques, we will use BML

$$W = L \times B \times d \times \text{density}$$

$$W = 150 \times 20 \times 7.3 \times 1.025$$

$$W = 22447.5 \text{ t}$$

To find BML

$$FF' = \frac{\text{Moment of Intact WPA}}{\text{Intact WPA}}$$

$$FF' = \frac{\text{Moment of Total WPA} - \text{Moment of lost WPA}}{\text{Total WPA} - \text{lost WPA}}$$

where Moment = Area $\times$ dist. w.r.t COF

$$FF' = \frac{\{LB \times \text{dist w.r.t COF}\} - \{lb \times \text{dist w.r.t COF}\}}{LB - lb}$$

$$FF' = \frac{\{(150 \cdot 0012 \times 20) \times 0\} - \{(20 \times 20) \times 30\}}{(150 \cdot 0012 \times 20) - (20 \times 20)}$$

$$FF' = \frac{0 - 12000}{3000.024 - 400}$$

$$FF' = \frac{-12000}{2600.024}$$

$$FF' = 4.615m$$

$$BML_{\text{(about its new COF)}} = \frac{I^* \text{ COF Intact WPA}}{\text{Initial volume}}$$

$$BML = \frac{I^* \text{ COF Total WPA} - I^* \text{ COF lost WPA}}{\text{Initial volume}}$$

$$BML = \frac{\left\{ \frac{BL^3}{12} + BL(y^2) \right\} - \left\{ \frac{bl^3}{12} + bl(y^2) \right\}}{L \times B \times d}$$

$$BML = \frac{\left\{ \frac{20 \times 150.0012^3}{12} + (20 \times 150.0012)(4.615)^2 \right\} - \left\{ \frac{20 \times 20^3}{12} + (20 \times 20)(\frac{4.615 + 30}{34.615})^2 \right\}}{150 \times 20 \times 7.3}$$

$$BM_L = \frac{\{5625135.001 + 63895.186\} - \{13333.333 + 479279.29\}}{21900}$$

$$BM_L = \frac{5689030.187 - 492612.623}{21900}$$

$$BM_L = \frac{5196417.564}{21900}$$

$$BM_L = 237.279m$$

$$MCTC = \frac{W \times BM_L}{100L}$$

$$MCTC = \frac{22447.5 \times 237.279}{100 \times 150}$$

$$MCTC = 355.088tm$$

(iv) $\text{Trim caused (t)} = \frac{w \times d}{MCTC \times 100}$

$$t = \frac{2943.8 \times 34.615}{355088 \times 100}$$

$$t = 2.870m$$

$$T_a = \frac{\text{Trim} \times \text{Final LCF}}{LBP}$$

$$= \frac{2.870 \times 70.385}{150}$$

$$= 1.347m$$

$$T_f = T - T_a$$

$$= 2.870 - 1.347$$

$$= 1.523m$$

	Forward	Aft
Initial draft	7.000	7.600
Sinkage	(+) 1.105	(+) 1.105
Tf & Ta	(+) 1.523	(-) 1.347
Final draft	9.628m	7.358 Ans