$$\text{Final AG} = \frac{955932 + 62X}{13714.5} = 71.872$$

X = 479.90 t = quantity to load in No: 1
and (932.5-X) = 452.6 t to load in No: 4

Example 7B

M.v. VIJAY is in SW, drawing 6 m fwd and 6.8 m aft. From what location may 1200 t cargo be discharged if it is desired to keep the draft aft constant at 6.8 m? State the final draft fwd.

Fwd 6.0 m aft 6.8 m, trim 0.8 m by stern
Mean draft 6.4 m for which AF = 71.172 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{71.172(0.8)}{140} = 0.407 \text{ m}$$

Initial hydraft = 6.80 - 0.407 = 6.393 m

Draft	W (t)	MCTC tm	AB (m)
6.393	13014.1	176.337	71.915

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\overline{BG} = \frac{80(176.337)}{13014.1} = 1.084 \text{ m}$$

Since trim is by stern, AG < AB.
AG = AB - $\overline{BG}$ = 71.915 - 1.084 = 70.831 m

AG of ship in given condition = 70.831 m

Final W = 13014.1 - 1200 = 11814.1 t

W (t)	Draft	MCTC tm	AB (m)	AF (m)
11814.1	5.863	171.805	71.972	71.550

Final draft aft = 6.8, hydraft = 5.863 m
So trim by stern (final AG < final AB),
and final Ta = 6.800 - 5.863 = 0.937 m.

$$Ta = \frac{AF}{L} \times Tc \quad \text{or} \quad Tc = \frac{L \times Ta}{AF}$$

$$Tc = \frac{140 \times 0.937}{71.55} = 1.833 \text{ m.}$$

Final draft fwd = 6.8 - 1.833 = 4.967 m.

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\text{Final } \overline{BG} = \frac{183.3(171.805)}{11814.1} = 2.666 \text{ metres}$$

Final AG = final AB - final $\overline{BG}$
Final AG = 71.972 - 2.666 = 69.236 m.

Remarks	Weight	AG (m)	Moment abt A
Ship	13014.1	70.831	921802
Disch	1200	X	-1200X
Final	11814.1		921802-1200X

$$\text{Final AG} = \frac{921802 - 1200X}{11814.1} = 69.236$$

X = 86.53 m = AG of wt to be discharged.

Rough check by method 'A' (chapter 26):

$$Ta = \text{mean rise} \quad \text{or} \quad \frac{AF}{L} \times \frac{dw}{MCTC} = \frac{w}{TPC}$$

$$\frac{71.172}{140} \times \frac{d}{176.4} = \frac{1}{22.64} \quad \text{or} \quad d = 15.326 \text{ m}$$

AG of cargo = d + AF = 86.5 m approx.

Example 8B

M.v.VIJAY is in SW drawing 3.8 m fwd and 4.2 m aft. 800 t of deck cargo is to be loaded. In order to keep a damaged part of the hull above water, it is decided that the sailing draft fwd should be 3.8 m. Find where this cargo may be loaded & state the final draft aft.

Fwd 3.8 m aft 4.2 m, trim 0.4 m by stern
Mean draft 4.0 m for which AF = 72.127 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{72.127(0.4)}{140} = 0.206 \text{ m}$$

Initial hydraft = 4.20 - 0.206 = 3.994 m

Draft	W (t)	MCTC tm	AB (m)
3.994	7695.1	157.746	72.008

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\overline{BG} = \frac{40(157.746)}{7695.1} = 0.820 \text{ m}$$

Since trim is by stern, AG < AB.
AG = AB - $\overline{BG}$ = 72.008 - 0.820 = 71.188 m

AG of ship in given condition = 71.188 m

Final W = 7695.1 + 800 = 8495.1 t

W (t)	Draft	MCTC tm	AB (m)	AF (m)
8495.1	4.363	160.984	72.014	72.064

Final draft fwd = 3.8, hydraft = 4.363 m
So trim by stern (final AG < final AB),
and final Tf = 4.363 - 3.800 = 0.563 m.

$$Tf = \frac{\text{fwd length}}{L} \times Tc \quad \text{or} \quad Tc = \frac{L \times Tf}{140 - AF}$$

$$Tc = \frac{140 \times 0.563}{67.936} = 1.160 \text{ m.}$$

Final draft aft = 3.8 + 1.160 = 4.960 m.

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\text{Final } \overline{BG} = \frac{116.0(160.984)}{8495.1} = 2.198 \text{ metres}$$

Final AG = final AB - final $\overline{BG}$
Final AG = 72.014 - 2.198 = 69.816 m.

Remarks	Weight	AG (m)	Moment abt A
Ship	7695.1	71.188	547799
loaded	800	X	+800X
Final	8495.1		547799 +800X

$$\text{Final AG} = \frac{547799 + 800X}{8495.1} = 69.816$$

X = 56.618 m = AG of cargo to be loaded.

Rough check by method 'A' (chapter 26):

$$Tf = \text{mean sinkage or } \frac{(140 - AF)\,dw}{L \times MCTC} = \frac{w}{TPC}$$

$$\frac{67.873}{140} \times \frac{d}{157.8} = \frac{1}{21.6} \quad \text{or} \quad d = 14.402 \text{ m}$$

AG of cargo = AF - d = 57.725 m approx.

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Example 9B

M.v.VIJAY is in SW at 3.6 & 6.4 m F & A. Cargo is to be loaded in No:2, AG 102 m, until the draft aft becomes 5.6 m. Find the amount to load & the final draft fwd

Note: This is an unique problem. Because w is not given, final W is not directly known. Final hydraft is not given. Hence the final hydrostatic particulars are not readily available. Using the initial hydrostatic particulars, the approximate value of w can be found by method 'A' (chapter 26). An accurate calculation is then made, assuming that the approximate calculated value of w is loaded. Then minor changes to the result can be made to bring the draft aft to exactly 5.6 m.

To find approx w: (see chapter 26)

Draft aft + sinkage - Ta = new draft aft
So 6.4 + mean sinkage - Ta = 5.6

Since both sinkage & trim will be in cm,

$$640 + \frac{w}{TPC} - \frac{AF}{L} \times \frac{dw}{MCTC} = 560$$

$$\text{or } \frac{AF}{L} \times \frac{dw}{MCTC} - \frac{w}{TPC} = 80$$

Mean draft	MCTC tm	AF (m)	TPC
5.000 m	165.700	71.913	22.06

$$\frac{71.913}{140} \times \frac{w(102 - 71.913)}{165.7} - \frac{w}{22.06} = 80$$

$$w = 1668.8 \text{ t approx.}$$

Assuming that the cargo loaded is exactly 1668.8 t, to find the precise drafts fwd & aft:

Fwd 3.6 m aft 6.4 m, trim 2.8 m by stern
Mean draft 5.0 m for which AF = 71.913 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{71.913(2.8)}{140} = 1.438 \text{ m}$$

Initial hydraft = 6.40 - 1.438 = 4.962 m

Draft	W (t)	MCTC tm	AB (m)
4.962	9807.4	165.434	72.014

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\overline{BG} = \frac{280(165.434)}{9807.4} = 4.273 \text{ m}$$

Since trim is by stern, AG < AB.
$AG = AB - \overline{BG} = 72.014 - 4.723 = 67.291$ m

AG of ship in given condition = 67.291 m

Remarks	Weight	AG (m)	Moment
Ship	9807.4	67.291	659950
Loaded	1668.8	102	170218
Final	11476.2		830168

New AG = 830168 ÷ 11476.2 = 72.338 m

From table, for W = 11476.2 t:

Draft	MCTC tm	AB (m)	AF (m)	TPC
5.713	170.689	71.983	71.623	22.339

New AG > new AB. So new Tc by the head.
New $\overline{BG}$ = 72.338 - 71.983 = 0.355 metres.

$$Tc = \frac{W.\overline{BG}}{MCTC} = \frac{11476.2 \times 0.355}{170.689} = 23.9 \text{ cm}$$

$$Ta = \frac{AF}{L} \times Tc = \frac{71.623}{140} \times 0.239 = 0.122 \text{ m}$$

$$Tf = Tc - Ta = 0.239 - 0.122 = 0.117 \text{ m}$$

	Fwd	Aft
New hydraft	5.713 m	5.713 m
Tf or Ta	+0.117 m	-0.122 m
New drafts	5.830 m	5.591 m

Note 1: It is found that after loading 1668.8 t at AG 102 m, the draft aft is 5.591 m instead of 5.6 m. In actual practice, this is acceptable to ship's officers because:
a) 9 mm would not be noticeable visually
b) It is not feasible to load cargo at AG = exactly 102 m.

Note 2: Calculation by method A is very quick & would suffice in actual practice

Note 3: To obtain a theoretically exact draft of 5.6 m draft aft, a small change has to be made in the figure of 1668.8 t

By loading 1668.8 t in No:2, the draft aft has decreased 0.9 cm more than necessary. So a small quantity discharged, say 'Y' tonnes, from No:2 would give an exact result. Since TPC & MCTC are being used, the calculation in cm is:-

$$559.1 - \text{rise} + Ta = 560$$

$$559.1 - \frac{Y}{TPC} + \frac{AF \times dY}{L \times MCTC} = 560$$

$$\frac{71.623}{140} \times \frac{Y(102 - 71.623)}{170.689} - \frac{Y}{22.339} = 0.9$$

Y = 19.4 t. Actual cargo to load in No:2 hold = 1668.8 - 19.4 = 1649.4 tonnes.

Note: Since Y is only 19.4 t, the hydrostatic particulars would not change appreciably. So a simple calculation by method A would suffice to obtain the final drafts fwd and aft.

$$\text{Mean rise} = \frac{19.4}{22.339} = 0.900 \text{ cm} = 0.009 \text{ m.}$$

$$Tc = \frac{dw}{MCTC} = \frac{30.377(19.4)}{170.689} = 3.5 \text{ cm}$$

$$Ta = \frac{AF}{L} \times Tc = \frac{71.623}{140} \times 0.035 = 0.018 \text{ m}$$

$$Tf = Tc - Ta = 0.035 - 0.018 = 0.017 \text{ m}$$

	Fwd	Aft
New drafts	5.830 m	5.591 m
Mean rise	0.009 m	0.009 m
	5.821 m	5.582 m
Tf or Ta	-0.017 m	+0.018 m
Final drafts	5.804 m	5.600 m

Example 10B

M.v.VIJAY is in FW drawing 3.2 m fwd and 5.8 m aft. 1350 t of cargo is loaded in No:3 LH, AG 85 m. Find the final drafts fwd and aft in FW.

Fwd 3.2 m aft 5.8 m, trim 2.6 m by stern
Mean draft 4.5 m for which AF = 72.035 m

$$Corr = \frac{AF}{L} \times trim = \frac{72.035(2.6)}{140} = 1.338 \text{ m}$$

Initial FW hydraft = 5.8 - 1.338 = 4.462

Draft	W (t)	MCTC tm	AB (m)	AF (m)
SW4.462	8711.5	161.734	72.016	72.043
FW4.462	8499.0	157.789	72.016	72.043

Note: FW data is obtained by modifying the SW values as explained in chapters 17 and 18 in Ship Stability I.

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{trim \times MCTC}{W}$$

$$\overline{BG} = \frac{260(157.789)}{8499} = 4.827 \text{ m}$$

Since trim is by stern, AG < AB.

$AG = AB - \overline{BG} = 72.016 - 4.827 = 67.189$ m

Remarks	Weight	AG (m)	Moment
Ship	8499.0	67.189	571039
Loaded	1350.0	85	114750
Final	9849.0		685789

New AG = 685789 ÷ 9849 = 69.630 m.

Assuming same draft in SW & FW, for the sake of entering the hydrostatic table:
W in SW = W in FW(1.025) = 10095.2 t

Draft	W (t)	MCTC tm	AB (m)	AF (m)
SW 5.092	10095.2	166.346	72.013	71.880
FW 5.092	9849	162.289	72.013	71.880

Note: FW data is obtained by modifying the SW values as explained in chapters 17 and 18 in Ship Stability I.

Final AB = 72.013 m. Final AG = 69.630 m
AG < AB, so Tc is by stern, $\overline{BG}$ = 2.383 m

$$Tc = \frac{W.\overline{BG}}{MCTC} = \frac{9849 \times 2.383}{162.289} = 144.6 \text{ cm}$$

$$Ta = \frac{AF}{L} \times Tc = \frac{71.880(1.446)}{140} = 0.742 \text{ m}$$

$$Tf = Tc - Ta = 1.446 - 0.742 = 0.704 \text{ m}$$

	Fwd	Aft
Final FW hydraft	5.092 m	5.092 m
Tf or Ta	-0.704 m	+0.742 m
Final FW drafts	4.388 m	5.834 m

Example 11B

M.v.VIJAY is in DW of RD 1.013 at drafts of 4.2 m fwd & 3.6 m aft. Find the final drafts fwd & aft, in the same DW, after carrying out the following operations:
100 t pumped out of the FP tank AG 135 m
400 t HFO received in No:4 DBT, AG 60 m.
500 t cargo loaded in No:4 LH, AG 50 m.

Fwd 4.2 m aft 3.6 m, trim 0.6 m by head
Mean draft 3.9 m for which AF = 72.134 m

$$Corr = \frac{AF}{L} \times trim = \frac{72.134(0.6)}{140} = 0.309 \text{ m}$$

Initial DW hydraft = 3.6 + 0.309 = 3.909

Draft	W (t)	MCTC tm	AB (m)	AF (m)
SW3.909	7511.9	156.981	72.003	72.133
DW3.909	7424.0	155.143	72.003	72.133

Note: DW data is obtained by modifying the SW values for the same draft.

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\overline{BG} = \frac{60(155.143)}{7424} = 1.254 \text{ m}$$

Since trim is by head, AG > AB.
$AG = AB + \overline{BG} = 72.003 + 1.254 = 73.257$ m

Remarks	Weight	AG (m)	Moment
Ship	7424	73.257	543860
SW	-100	135	-13500
HFO	+400	60	+24000
Cargo	+500	50	+25000
Final	8224		579360

Final AG = 579360 ÷ 8224 = 70.447 m.

Assuming same draft in SW & DW, for the sake of entering the hydrostatic table:

W in SW = W in DW(1.025/1.013) = 8321.4t

	Draft	W (t)	MCTC tm	AB (m)	AF (m)
SW	4.283	8321.4	160.305	72.013	72.081
DW	4.283	8224	158.428	72.013	72.081

Note: DW data is obtained by modifying the SW values for the same draft.

Final AG < final AB so final Tc by stern
Final $\overline{BG}$ = 72.013 - 70.447 = 1.566 m

$$Tc = \frac{W.\overline{BG}}{MCTC} = \frac{8224 \times 1.566}{158.428} = 81.3 \text{ cm}$$

$$Ta = \frac{AF}{L} \times Tc = \frac{72.081}{140} \times 0.813 = 0.419 \text{ m}$$

$$Tf = Tc - Ta = 0.813 - 0.419 = 0.394 \text{ m}$$

		Fwd	Aft
Final hydraft		4.283 m	4.283 m
Tf or Ta		-0.394 m	+0.419 m
Final drafts		3.889 m	4.702 m

Exercise 23

Trim problems - Type B

1 M.v.VIJAY draws 4.5 m fwd & 6.5 m aft in SW. Find the new drafts if 100 t ballast is transferred from the after peak tank, AG 3.5 m, to the fore peak tank, AG 136.5 m.

2 M.v.VIJAY is in DW RD 1.015 drawing 6 m fwd & 5 m aft. Find the new drafts if 400 t cargo is transferred from No:1 LH AG 120 m, to No:3 LH AG 80 m.

3 M.v.VIJAY is in SW at drafts of 5.8 m fwd & 5 m aft. AG is 73.251 m. Find the new drafts if 600 t cargo is discharged from No:1 TD, AG 124 m.

4 M.v.VIJAY is in SW, drawing 3.6 m fwd & 4.8 m aft. AG is 69.651 m. Find the new drafts fwd & aft if the following operations are carried out:
2000 t cargo loaded in No:4, AG 60 m.
1000 t discharged from No:5, AG 20 m.
120 t SW run into AP tank, AG 3 m.

5 The drafts of m.v.VIJAY in SW are 4 m fwd & 3.6 m aft. AG is 72.854 m. Find the final drafts if the following operations take place:
1400 t cargo loaded in No:2, AG 98 m.
2100 t cargo loaded in No:5, AG 22 m.
120 t FW transferred from APT AG 3 m, to FPT AG 135 m.

6 M.v.VIJAY is drawing 5 m fwd & aft in SW. Find the new drafts if 1550 t of cargo is loaded in No:4 LH, AG 50 m.

7 The drafts fwd & aft of m.v.VIJAY in SW are 5 m & 6.8 m. 1900 t cargo is loaded in No:3, AG 84 m. Find the new drafts fwd & aft.

8 M.v.VIJAY arrives at a SW port drawing 4 m fwd & 5.9 m aft. Find the new drafts if 1600 t cargo is discharged from No:4, AG 60 m.

9 M.v.VIJAY draws 3.3 m fwd & 6.3 m aft in a SW port. 2000 t of cargo is to be loaded. Space is available in No:2, AG 100 m, and in No:4, AG 60 m. Distribute this cargo in order to finish trimmed 1.5 m by the stern. State the final drafts fwd & aft.

10 M.v.VIJAY is in FW, drawing 4.8 m fwd & 4 m aft. 1800 t cargo is yet to be loaded. Space is available in No:2, AG 105 m, and in No:5, AG 20 m. Find how much to put in each space to finish trimmed 1 m by the stern. State the final drafts fwd & aft.

11 The fwd & aft drafts of m.v. VIJAY in SW are 3.9 m & 4.9 m. Find how much cargo may go in No:1, AG 120 m, & in No:4, AG 55 m, to finish on an even keel draft of 5.8 m.

12 M.v.VIJAY floats in DW of RD 1.010 at an even keel draft of 6.6 m. Find how much cargo may be discharged from No:1, AG 118 m, and No:5, AG 16 m, to finish on an even keel draft of 6 m, in the same dock.

13 M.v. VIJAY floats in SW, at drafts of 3.1 m fwd & 5.6 m aft. At what location must 500 t cargo be loaded if the after draft should remain at 5.6 m? State also, the final draft fwd.

14 M.v.VIJAY is in DW (RD 1.015) drawing 4.3 m fwd & 4 m aft. At what location should 800 t cargo be loaded if the final draft fwd is to be 4.3 m? State the final draft aft.

15 M.v. VIJAY is in FW, at an even keel draft of 4.9 m. Find the location from which 1200 t of cargo may be discharged in order to finish at a draft of 4.9 m fwd. State, also, the final draft aft.

16 M.v.VIJAY is in DW (RD 1.018) drawing 4.6 m fwd and 4 m aft. Find the location from which to discharge 1650 t cargo in order to finish with 4 m draft aft. State the final draft fwd.

17 M.v.VIJAY is in SW, drawing 3.5 m fwd & 4.9 m aft. What quantity of cargo may be loaded in No:4 LH, AG 58 m, if the final draft aft is to be 6 m? State the final draft fwd.

18 M.v.VIJAY is in DW (RD 1.013) drawing 5.2 m fwd and 6 m aft. 800 t of cargo is to be discharged. What should be the AG, of this cargo, if the final draft forward is to be 4.8 m? Also state the final draft aft.

19 M.v.VIJAY arrives at a saltwater port drawing 3.7 m fwd & 4.5 m aft. 4000 t of cargo is to be loaded, of which:

1000 t must go into No:2, AG 100 m,
1000 t must go into No:4, AG 56 m,
1000 t must go into No:3, AG 80 m.

How much cargo must be put into No:1, AG 120 m, and into No:5, AG 18 m, to finish trimmed 1 m by the stern. State the final drafts fwd and aft.

20 M.v.VIJAY arrives in DW (RD 1.016) at drafts of 6.8 m fwd & 7.0 m aft. Part of her bulk cargo is to be discharged as follows:

500 tonnes from No:1, AG 122 m,
500 tonnes from No:5, AG 18 m,
500 tonnes from No:3, AG 80 m.

A further amount of 1500 t is to be discharged, part from No:2, AG 100 m, & part from No:4, AG 56 m. Calculate the quantity to discharge from Nos:2 and 4, if the final trim is to be 0.8 metre by the stern. State the final drafts fwd and aft.

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CHAPTER 28

TRIM PROBLEMS

TYPE C

These problems are very similar to those of type B, except that all distances are expressed from amidships (H) instead of from the after perpendicular (A). These have the disadvantage that, each time, distances and moments have to be identified as forward of, or abaft, amidships. However, problems of type C have the advantage that the values used are much smaller than in problems of type B where the after perpendicular is used for reference.

Problems of type C are included here because the hydrostatic tables issued by some shipyards give distances from amidships only. The basic theory, and order of work, is very similar to that of type B. For working problems of type C, the hydrostatic table of m.v. VICTORY may be used. This is given as Appendix II at the end of this book.

Example 1C

M.v. VICTORY is afloat in SW at an even keel draft of 13 m. 300 t is shifted aft by 80 m. Find the new drafts fwd & aft.

From hydrostatic table, for 13 m draft, MCTC = 1159.1 tm and HF = 0.27 m aft.

$$Tc = \frac{TM}{MCTC} = \frac{300 \times 80}{1159.1} = 20.7 \text{ cm by stern.}$$

$$Ta = \frac{AF}{L}(Tc) = \frac{(L/2 - 0.27)0.207}{236} = 0.103 \text{ m}$$

$$Tf = Tc - Ta = 0.207 - 0.103 = 0.104 \text{ m}$$

	fwd	aft
Final hydraft	13.000 m	13.000 m
Tf or Ta	-0.104 m	+0.103 m
Final drafts	12.896 m	13.103 m

Example 2C

M.v.VICTORY is afloat in SW at drafts of 12.8 m fwd and 14.8 m aft. HG is 1.669 m fwd. Find the new drafts fwd and aft if 3000 t of cargo is loaded in No:3 LH, HG 52 m fwd.

Fwd 12.8 m aft 14.8 m, trim 2 m by stern
For mean draft 13.8 m, HF = 0.98 m aft.

$$\text{Correctn} = \frac{HF}{L} \times \text{trim} = \frac{0.98(2)}{236} = 0.008 \text{ m}$$

Note: Trim is by stern and HF is aft. So correction to mean draft is positive. Refer to chapter 18 in Ship Stability I.

Initial hydraft =13.8 + 0.008= 13.808 m.

For 13.808 m hydraft, W = 90541.8 tonnes
Final W = 90541.8 + 3000 = 93541.8 t

From table, particulars for final W are:

W (t)	draft	MCTC tm	HB fwd	HF aft
93541.8	14.231	1198.303	4.116	1.313

Remarks	Weight	HG (m)	moment abt H
Ship	90541.8	1.669 fwd	151114 fwd
Cargo	+3000	52 fwd	156000 fwd
Final	93541.8		307114 fwd

Final HG = 307114/93541.8 = 3.283 m fwd.

Final HG 3.283 fwd, final HB 4.116 fwd.
COG is abaft COB so final trim by stern.
Final $\overline{BG}$ = 4.116 - 3.283 = 0.833 metres.

$$Tc = \frac{W.\overline{BG}}{MCTC} = \frac{93541.8 \times 0.83}{1198.303} = 65 \text{ cm}$$

AF = L/2 - HF = 118 - 1.313 = 116.687 m.

$$Ta = \frac{AF \times Tc}{L} = \frac{116.687 \times 0.65}{236} = 0.321 \text{ m.}$$

$$Tf = Tc - Ta = 0.650 - 0.321 = 0.329 \text{ m.}$$

	fwd	aft
Final hydraft	14.231 m	14.231 m
Tf or Ta	-0.329 m	+0.321 m
Final drafts	13.902 m	14.552 m

Example 3C

M.v.VICTORY is afloat in SW at drafts of 10 m fwd & 13.8 m aft. HG is 0.46 m aft. Find the new drafts fwd & aft after the following operations:

10,000 t of cargo loaded at HG 72 m fwd
6,000 t of cargo loaded at HG 52 m aft
1,500 t SW pumped out from HG 110 m fwd

Fwd 10 m aft 13.8 m, trim 3.8 m by stern
For mean draft 11.9 m, HF = 0.86 m fwd.

$$\text{Corrctn} = \frac{HF(\text{trim})}{L} = \frac{0.86(3.8)}{236} = 0.014 \text{ m}$$

Trim by stern & HF fwd so correction (-)

Initial hydraft =11.9 - 0.014 = 11.886 m by which the initial W = 77054.4 tonnes.

Remarks	Weight	HG (m)		moment abt H	
Ship	77054.4	0.46	aft	35,445	aft
Cargo	+10000	72	fwd	720,000	fwd
Cargo	+ 6000	52	aft	312,000	aft
SW	- 1500	110	fwd	165,000	aft
Final	91554.4			207,555	fwd

Final HG = 207555/91554.4 = 2.267 m fwd

From table, particulars for final W are:

W (t)	draft	MCTC tm	HB fwd	HF aft
91554.4	13.951	1189.773	4.230	1.101

Final HG 2.267 fwd, final HB 4.230 fwd. COG is abaft COB so final trim by stern. Final $\overline{BG}$ = 4.230 - 2.267 = 1.963 metres.

$$Tc = \frac{W.\overline{BG}}{MCTC} = \frac{91554.4 \times 1.963}{1189.773} = 151.1 \text{ cm.}$$

AF = L/2 - HF = 118 - 1.101 = 116.899 m.

$$Ta = \frac{AF(Tc)}{L} = \frac{116.899 \times 1.511}{236} = 0.748 \text{ m.}$$

Tf = Tc - Ta = 1.511 - 0.748 = 0.763 m.

	fwd	aft
Final hydraft	13.951 m	13.951 m
Tf or Ta	-0.763 m	+0.748 m
Final drafts	13.188 m	14.699 m

Example 4C

M.v. VICTORY is in SW drawing 12.2 m fwd and 16.2 m aft. 5000 t cargo is loaded into No:4 LH, HG 31 m fwd. Find the new drafts fwd and aft.

Fwd 12.2 m aft 16.2 m, trim 4 m by stern
For mean draft 14.2 m, HF = 1.29 m aft.

$$\text{Corrctn} = \frac{HF}{L} \times \text{trim} = \frac{1.29 \times 4}{236} = 0.022 \text{ m}$$

Trim by stern & HF aft so correction (+)

Initial hydraft =14.2 + 0.022= 14.222 m.

Draft	W (t)	MCTC	HB fwd
14.222	93480.5	1198.049	4.120

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\overline{BG} = \frac{400(1198.049)}{93480.5} = 5.126 \text{ m}$$

Since trim is by stern, COG is abaft COB
Initial HG = 5.126 - 4.120 = 1.006 m aft

Remarks	Weight	HG (m)	Moment abt H
Ship	93480.5	1.006 aft	94041 aft
Cargo	+5000	31.00 fwd	155000 fwd
Final	98480.5		60959 fwd

Final HG = 60959 ÷ 98480.5 = 0.619 m fwd

From Appendix II, for final W 98480.5 t:

Draft	MCTC tm	HB fwd	HF aft
14.923	1218.510	3.825	1.794

Finally HG = 0.619 fwd & HB = 3.825 fwd. COG abaft COB, so final trim is by stern Final $\overline{BG}$ = 3.825 - 0.619 = 3.206 metres.

$$\text{Final Tc} = \frac{W.\overline{BG}}{MCTC} = \frac{98480.5(3.206)}{1218.51} = 259.1 \text{ (cm)}$$

AF = L/2 - HF = 118 - 1.794 = 116.206 m.

$$Ta = \frac{AF}{L} \times Tc = \frac{116.206 \times 2.591}{236} = 1.276 \text{ m}$$

Tf = Tc - Ta = 2.591 - 1.276 = 1.315 m

	Fwd	Aft
Final hydraft	14.923 m	14.923 m
Tf or Ta	-1.315 m	+1.276 m
Final drafts	13.608 m	16.199 m

Example 5C

M.v.VICTORY is afloat in SW drawing 11 m fwd & 14.4 m aft. 8000 t of cargo is yet to be loaded. Space is available in No:2 HG 72 m fwd, and in No:7, HG 31 m aft. Find how much to put in each space to finish loading 1.5 m by the stern. State the final drafts fwd and aft.

Fwd 11 m aft 14.4 m, trim 3.4 m by stern For mean draft 12.7 m, HF = 0.02 m fwd.

Note: The student is advised to look into the hydrostatic table and obtain the HF by himself, in this case, as HF for 12.6 m draft is fwd whereas for 12.8 m, it is aft.

$$\text{Corrn} = \frac{HF}{L} \times \text{trim} = \frac{0.02(3.4)}{236} = <0.001 \text{ m}$$

Initial hydraft = mean draft = 12.700 m.

Draft	W (t)	MCTC	HB fwd
12.700	82733	1148.950	4.750

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \text{ or } \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\overline{BG} = \frac{340(1148.950)}{82733} = 4.722 \text{ m}$$

Since trim is by stern, COG is abaft COB Initial HG = 4.750 - 4.722 = 0.028 m fwd

Final W = 82733 + 8000 = 90733 tonnes, for which particulars from Appendix II:-

Draft	MCTC tm	HB fwd	HF aft
13.835	1186.184	4.276	1.008

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \text{ or } \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\overline{BG} = \frac{150(1186.184)}{90733} = 1.961 \text{ m}$$

Final trim by stern, so COG is abaft COB Final HG = 4.726 - 1.961 = 2.315 m fwd.

Let cargo to load in No:2 = X tonnes. So cargo to load in No:7 = 8000 - X tonnes.

Remarks	Weight	HG (m)	Moment abt H
Ship	82733	0.028 fwd	2317 fwd
No:2	X	72 fwd	72X fwd
No:7	8000-X	31 aft	24800-31X aft

Final moment = (2317+72X) - (24800-31X)
(Since final HG is fwd final mom is fwd)

Final HG = final moment/final W = 2.315

[(2317+72X) - (24800-31X)]/90733 = 2.315

X = 4424.5 t = cargo to load in No:2 LH
& (8000 - X) = 3575.5 t cargo in No:7 LH

AF = L/2 - HF = 118 - 1.008 = 116.992 m.

$Ta = \frac{AF}{L} \times Tc = \frac{116.992 \times 1.500}{236} = 0.744$ m

Tf = Tc - Ta = 1.500 - 0.744 = 0.756 m

	Fwd	Aft
Final hydraft	13.835 m	13.835 m
Tf or Ta	-0.756 m	+0.744 m
Final drafts	13.079 m	14.579 m

Example 6C

M.v.VICTORY is afloat in SW drawing 11 m fwd & 13 m aft. She is to sail on an even keel draft of 13.6 m. Find how much cargo to put in No:3, HG 52 m fwd, and in No:7, HG 32 m aft.

Fwd 11 m aft 13 m, trim 2 m by the stern
For mean draft 12.0 m, HF = 0.74 m fwd.

$Corrctn = \frac{HF}{L} \times trim = \frac{0.74 \times 2}{236} = 0.006$ m

Trim by stern & HF fwd so correction (-)

Initial hydraft =12.0 - 0.006= 11.994 m.

Draft	W (t)	MCTC tm	HB fwd	HF fwd
11.994	77803.4	1123.757	5.022	0.747

$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC}$ or $\overline{BG} = \frac{trim \times MCTC}{W}$

$\overline{BG} = \frac{200(1123.757)}{77803.4} = 2.889$ m

Initial trim by stern:- COG is abaft COB
Initial HG = 5.022 - 2.889 = 2.133 m fwd

Draft	W (t)	MCTC tm	HB fwd	HF aft
13.60	89070	1178.800	4.380	0.810

Can load = 89070.0 - 77803.4 = 11266.6 t

Even keel:- final HG = HB = 4.380 m fwd.

Let cargo to load in No:3 = X tonnes. So cargo to load in No:7 = (11266.6 - X) t.

Remarks	Weight	HG (m)	Moment abt H
Ship	77803.4	2.133 fwd	165955 fwd
No:3	X	52 fwd	52X fwd
No:7	11266.6-X	32 aft	360531-32X aft

Final mom = (165955+52X) - (360531-32X)
(Since final HG is fwd final mom is fwd)

Final HG = final moment/final W = 4.380

[165955+52X - (360531-32X)]/89070 = 4.38

X = 6960.7 t = cargo to load in No:3 LH
11266.6 - X = 4305.9 t cargo in No:7 LH

Example 7C

M.v. VICTORY is in SW drawing 14 m fwd & 14.8 m aft. From what location must 2500 tonnes cargo be discharged if the draft aft is to remain constant? State the final drafts fwd & aft.

Fwd 14 m aft 14.8 m, trim 0.8 m by stern
For mean draft 14.4 m, HF = 1.44 m aft.

Corrctn $= \frac{HF(trim)}{L} = \frac{1.44(0.8)}{236} = 0.005$ m

Trim by stern & HF aft so correction (+)

Initial hydraft =14.4 + 0.005= 14.405 m.

Draft	W (t)	MCTC	HB fwd
14.405	94782.7	1203.448	4.038

Trim in cm $= \frac{W.\overline{BG}}{MCTC}$ or $\overline{BG} = \frac{trim \times MCTC}{W}$

$$\overline{BG} = \frac{80(1203.448)}{94782.7} = 1.106 \text{ m}$$

Initial trim by stern:- COG is abaft COB
Initial HG = 4.038 - 1.106 = 3.022 m fwd

Final W = 94782.7 - 2500 = 92282.7 t

W (t)	draft	MCTC	HB fwd	HF aft
92282.7	14.053	1192.927	4.189	1.180

Ta = final draft aft - final hydraft
Ta = 14.800 - 14.053 = 0.747 metre

Ta $= \frac{AF}{L}(Tc)$ or Tc $= \frac{236(0.747)}{118 - 1.18} = 1.509$ m

Final draft fwd = 14.8 - 1.509 = 13.291m

Trim in cm $= \frac{W.\overline{BG}}{MCTC}$ or $\overline{BG} = \frac{trim \times MCTC}{W}$

$$\overline{BG} = \frac{150.9(1192.927)}{92282.7} = 1.951 \text{ m}$$

Final trim by stern, so COG is abaft COB
Final HG = 4.189 - 1.951 = 2.238 m fwd.

Let HG of cargo to discharge = X m fwd.

Remarks	Weight	HG (m)	Moment abt H
Ship	94782.7	3.022 fwd	286433 fwd
Cargo	-2500	X fwd	2500X aft
Final	92282.7		286433-2500X fwd

(Since final HG is fwd final mom is fwd)

Final HG = final moment/final W = 2.238

$\frac{286433-2500X}{92282.7} = 2.238$ or X = 31.962 m fwd

HG of cargo to discharge = 31.962 m fwd.

Note: If the value of X was found to be negative, the assumed direction of COG, from H, would have to be changed. The value obtained would still hold good.

Rough check by method A

Mean rise = Ta or $\frac{w}{TPC} = \frac{AF\ (dw)}{L(MCTC)}$

Using initial hydrostatic particulars:

$d = \frac{L(MCTC)}{AF(TPC)} = \frac{236 \times 1203.448}{(118-1.44)71.193} = 34.226$ m

HG of cargo = 34.226 - 1.440 = 32.786 m.

Example 8C

M.v. VICTORY is in SW drawing 11.8 m fwd and 12.2 m aft. 3000 t cargo is to be loaded. To effect some shipside repairs, the fwd draft has to be maintained at 11.8 m. Find where this cargo should be loaded and state the final draft aft.

Fwd 11.8 aft 12.2 m, trim 0.4 m by stern
For mean draft 12.0 m, HF = 0.74 m fwd.

Corrctn = $\frac{HF(trim)}{L} = \frac{0.74(0.4)}{236} = 0.001$ m

Trim by stern & HF fwd so correction (-)
Initial hydraft = 12 - 0.001 = 11.999 m.

Draft	W (t)	MCTC tm	HB fwd	HF fwd
11.999	77838.1	1123.960	5.020	0.741

Trim in cm = $\frac{W.\overline{BG}}{MCTC}$ or $\overline{BG} = \frac{trim \times MCTC}{W}$

$\overline{BG} = \frac{40(1123.96)}{77838.1} = 0.578$ m

Initial trim by stern:- COG is abaft COB
Initial HG = 5.020 - 0.578 = 4.442 m fwd

Final W = 77838.1 + 3000 = 80838.1 t

W (t)	draft	MCTC	HB fwd	HF fwd
80838.1	12.429	1139.441	4.858	0.291

Since final trim is by the stern,

Tf = final hydraft - final draft forward
= 12.429 - 11.800 = 0.629 metre.

$\frac{\text{Fwd length (Tc)}}{L}$ = Tf or Tc = $\frac{236\ (0.629)}{118 - 0.291}$

Tc = Final trim = 1.261 m by the stern

Final draft aft = 11.8 + 1.261 = 13.061m

Trim in cm = $\frac{W.\overline{BG}}{MCTC}$ or $\overline{BG} = \frac{trim \times MCTC}{W}$

$\overline{BG} = \frac{126.1(1139.441)}{80838.1} = 1.777$ m

Final trim by stern, so COG is abaft COB
Final HG = 4.858 - 1.777 = 3.081 m fwd.

Let HG of cargo to be loaded be X m fwd.

Remarks	Weight	HG (m)	Moment abt H
Ship	77838.1	4.442 fwd	345757 fwd
Cargo	+3000	X fwd	3000X fwd
Final	80838.1		345757+3000X fwd

Final HG = final moment/final W = 3.081

$\frac{345757+3000X}{80838.1} = 3.081$, X = -32.232 m fwd

HG of cargo to be loaded = 32.232 m aft.

Note: HG of the cargo was intentionally assumed to be X m fwd, just to illustrate the meaning of the negative sign obtained at the end of the calculation.

Rough check by method A

Mean sinkage = Ta or $\frac{w}{TPC}$ = $\frac{\text{fwd length (dw)}}{L \times MCTC}$

$\frac{3000}{69.4} = \frac{(118-0.74)3000d}{236 \times 1123.296}$ or d = 32.595 aft

HG of cargo = 32.595 - 0.74 = 31.855 aft

Example 9C

M.v.VICTORY is alongside a loading berth with a conveyor chute loading into No:2 LH, HG 72 m fwd. The present drafts are

10 m fwd & 13 m aft. Find how much cargo to put in No:2 in order to bring the aft draft to 12 m. State the final draft fwd

Note: Because w is not given, the final W is not directly known and neither is the final hydraft given. Hence the final hydrostatic particulars are not readily available. Using the initial hydrostatic data, an approximate value of w is obtained by method A. This value is assumed to be loaded and the precise results calculated. Then minor changes are effected, as necessary, to obtain the precise quantity to load.

Fwd 10 m aft 13 m, trim 3 m by the stern
For mean draft 11.5 m, HF = 1.345 m fwd

$$\text{Corrctn} = \frac{HF(\text{trim})}{L} = \frac{1.345(3)}{236} = 0.017 \text{ m}$$

Trim by stern & HF fwd so correction (-)
Initial hydraft =11.5 - 0.017 = 11.483 m

Draft	W (t)	MCTC	HB fwd	HF fwd
11.483	74266.1	1102.945	5.201	1.366

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \text{ or } \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$$\overline{BG} = \frac{300(1102.945)}{74266.1} = 4.455 \text{ m}$$

Initial trim by stern:- COG is abaft COB
Initial HG = 5.201 - 4.455 = 0.746 m fwd

To find approximate w by method A:

Old draft + sinkage - Ta = new draft aft

$$1300 + \frac{w}{TPC} - \frac{AF(dw)}{L(MCTC)} = 1200$$

$$\frac{w}{69} - \frac{(118 + 1.366)(72 - 1.366)w}{236 \times 1102.945} = -100$$

w = 5587 tonnes (approximately).

Assuming that exactly 5587 t is loaded:-

Remarks	Weight	HG (m)	Moment abt H
Ship	74266.1	0.746 fwd	55403 fwd
Cargo	+5587	72 fwd	402264 fwd
Final	79853.1		457667 fwd

Final HG = 457667 ÷ 79853.1 = 5.731 fwd.

W (t)	draft	MCTC	HB fwd	HF fwd
79853.1	12.288	1134.433	4.909	0.437

Since COG is fwd of COB, trim is by head and final $\overline{BG}$ = 5.731 - 4.909 = 0.822 m.

$$Tc = \frac{W.\overline{BG}}{MCTC} = \frac{79853.1 \times 0.822}{1134.433} = 57.9 \text{ cm.}$$

$$Ta = \frac{AF(Tc)}{L} = \frac{(118 + 0.437)0.579}{236} = 0.291$$

$$Tf = Tc - Ta = 0.579 - 0.291 = 0.288 \text{ m}$$

	Fwd	Aft
New hydraft	12.288 m	12.288 m
Tf or Ta	+0.288 m	-0.291 m
New drafts	12.576 m	11.997 m

Note: It is found that after loading 5587 t in No:2, the draft aft is calculated to be 11.997 m instead of 12.000 m. This is acceptable in practice because

(a) 0.003 m difference is not noticeable at the draft marks and
(b) the HG of cargo loaded cannot be made exactly 72 m fwd.

However, for the sake of theory, a minor adjustment, using the final hydrostatic data, would give an accurate result. To create a difference of 0.003 m in draft, method A will suffice.

Draft aft - mean rise + Ta = final draft

$$1199.7 - \frac{w}{TPC} + \frac{AF \times dw}{L(MCTC)} = 1200$$

$$-\frac{w}{69.63} + \frac{(118 - 0.437)(72 - 0.437)w}{236 \times 1134.433} = -0.3$$

w = 17.3 t to discharge.

Cargo to load = 5587 - 17.3 = 5569.7 t

Since 17.3 t is a very small quantity, the hydrostatic particulars would not change appreciably. So a simple calculation by method A would suffice to get the final draft fwd & also verify that the final draft aft is 12.000 m exactly.

$$\text{Mean rise} = \frac{w}{TPC} = \frac{17.3}{69.63} = 0.2 \text{ cm} = 0.002 \text{ m}$$

$$Tc = \frac{dw}{MCTC} = \frac{(72 - 0.437)\ 17.3}{1134.433} = 1.1 \text{ cm.}$$

$$Ta = \frac{AF(Tc)}{L} = \frac{(118+0.437)0.011}{236} = 0.005 \text{ m}$$

Tf = Tc - Ta = 0.011 - 0.005 = 0.006 m

	Fwd	Aft
New draft	12.576 m	11.997 m
Mean rise	0.002 m	0.002 m
	12.574 m	11.995 m
Tf or Ta	-0.006 m	+0.005 m
Final drafts	12.568 m	12.000 m

Example 10C

M.v. Victory in FW draws 11.4 m fwd & 11 m aft. Find the final FW drafts if 8000t cargo is loaded in No:7 LH, HG 32 m aft.

Fwd 11.4 m aft 11 m, trim 0.4 m by head.
For mean draft 11.2 m, HF = 1.172 m fwd.

$$\text{Corrn.} = \frac{HF(\text{trim})}{L} = \frac{1.172(0.4)}{236} = 0.003 \text{ m}$$

Trim by head & HF fwd so correction (+)
Initial hydraft =11.2 + 0.003 = 11.203 m

	Draft	W (t)	MCTC	HB fwd	HF fwd
SW	11.203	72335.7	1091.423	5.299	1.716
FW	11.203	70571.4	1064.803	5.299	1.716

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

$\overline{BG}$ = [40 x 1064.803] ÷ 70571.4 = 0.604 m

Initial trim by head:- COG is fwd of COB
Initial HG = 5.299 + 0.604 = 5.903 m fwd

Remarks	Weight	HG (m)	Moment abt H
Ship	70571.4	5.093 fwd	416583 fwd
Cargo	+8000	32 aft	256000 aft
Final	78571.4		160583 fwd

Final HG = 160583 ÷ 78571.4 = 2.044m fwd

	W (t)	draft	MCTC	HB fwd	HF fwd
SW	80535.7	12.386	1137.905	4.875	0.335
FW	78571.4	12.386	1110.151	4.875	0.335

Final COG is abaft COB so Tc is by stern and final $\overline{BG}$ = 4.875 - 2.044 = 2.831 m.

$$Tc = \frac{W.\overline{BG}}{MCTC} = \frac{78571.4 \times 2.831}{1110.151} = 200.4 \text{ cm.}$$

$$Ta = \frac{AF(Tc)}{L} = \frac{(118+0.335)2.004}{236} = 1.005 \text{ m}$$

$$Tf = Tc - Ta = 2.004 - 1.005 = 0.999 \text{ m}$$

	Fwd	Aft
Final hydraft	12.386 m	12.386 m
Tf or Ta	-0.999 m	+1.005 m
Final drafts	11.387 m	13.391 m

Example 11C

M.v.Victory is in DW of RD 1.012 drawing 13 m fwd and 13.6 m aft. Find the final drafts fwd & aft in the same dock if the following operations are carried out:

5000 t cargo loaded in No:4, HG 30 m fwd
1000 t HFO received in No:5, HG 60 m aft
500 t SW transferred from the FP tank HG 110 m fwd, to the AP tank, HG 114 m aft.

Fwd 13 m aft 13.6 m, trim 0.6 m by stern
For mean draft 13.3 m, HF = 0.55 m aft.

$$Corrctn = \frac{HF(trim)}{L} = \frac{0.55(0.6)}{236} = 0.001 \text{ m}$$

Trim by stern & HF aft so correction (+)
Initial hydraft =13.3 + 0.001 = 13.301 m

	Draft	W (t)	MCTC	HB fwd
SW	13.301	86958.6	1169.083	4.500
DW	13.301	85855.7	1154.255	4.500

$$\text{Trim in cm} = \frac{W.\overline{BG}}{MCTC} \quad \text{or} \quad \overline{BG} = \frac{\text{trim} \times MCTC}{W}$$

BG = [60 x 1154.255] ÷ 85855.7 = 0.807 m

Initial trim by stern:- COG is abaft COB
Initial HG = 4.500 - 0.807 = 3.693 m fwd

Remarks	Weight	HG (m)	Moment abt H
Ship	85855.7	3.693 fwd	317065 fwd
Cargo	+5000	30 fwd	15000 fwd
HFO	+1000	60 m aft	60000 aft
SW transferred	500 x	224 aft	112000 aft
Final	91855.7		160065 fwd

Final HG = 160065 ÷ 91855.7 = 1.743m fwd

	W (t)	draft	MCTC	HB fwd	HF aft
SW	93035.7	14.159	1196.162	4.146	1.260
DW	91855.7	14.159	1180.991	4.146	1.260

Final COG is abaft COB so Tc is by stern and final $\overline{BG}$ = 4.146 - 1.743 = 2.403 m.

$$Tc = \frac{W.\overline{BG}}{MCTC} = \frac{91855.7 \times 2.403}{1180.991} = 186.9 \text{ cm.}$$

$$Ta = \frac{AF(Tc)}{L} = \frac{(118-1.260)1.869}{236} = 0.925 \text{ m}$$

$$Tf = Tc - Ta = 1.869 - 0.925 = 0.944 \text{ m}$$

	Fwd	Aft
Final hydraft	14.159 m	14.159 m
Tf or Ta	-0.944 m	+0.925 m
Final drafts	13.215 m	15.084 m

Exercise 24
Trim problems type C

1 M.v.VICTORY draws 12.5 m fwd & 14.5 m aft in SW. Find the new drafts fwd & aft if 500 t ballast is transferred from the AP tank, HG 114 m aft, to the FP tank, HG 110 m fwd.

2 M.v.VICTORY draws 13.8 m fwd and 16 m aft in DW of RD 1.010. Find the new drafts if 1500 t HFO is shifted from No:5 hopper tank, HG 58 m aft, to the fwd deep tank, HG 104 m fwd.

3 M.v.VICTORY is in SW, drawing 12.2 m fwd & 14.6 m aft. HG is 1.248 m fwd. Find the drafts fwd and aft if 4820 t cargo is loaded in No:3, HG 52 m fwd.

4 M.v.VICTORY draws 13.7 m fwd and 13 m aft in SW. HG is 5.42 m fwd. Find the drafts after the following:-
8000 t disch from No:3 LH HG 52 m fwd
5000 t disch from No:5 LH HG 10 m fwd
2000 t disch from No:9 LH HG 72 m aft
1000 t SW taken into FPT HG 110 m fwd

5 The drafts of m.v. VICTORY in SW are 11 m fwd & 11.5 m aft. HG of ship is 4.531 m fwd. Find the new drafts fwd and aft after loading the following:
6000 t in No:2 hold, HG 72 m fwd
5000 t in No:4 hold, HG 30 m fwd
5000 t in No:6 hold, HG 10 m aft
10000 t in No:8 hold, HG 52 m aft.

6 M.v. VICTORY is in SW drawing 11.45 m fwd & aft. Find the drafts if 11000 t cargo is loaded in No:6, HG 10 m aft.

7 The drafts of m.v. VICTORY are 13 m & 14.8 m fwd & aft in SW. Find the new drafts if 9500 t cargo is discharged from No:7 hold, HG 32 m aft.

8 M.v.VICTORY arrives port drawing 12 m fwd & 12.4 m aft in SW. Find the new drafts if 4200 t cargo is discharged from No:3 hold, HG 52 m fwd.

9 M.v.VICTORY draws 13 m fwd & 14 m aft in SW. 7000 t is yet to be loaded. Conveyors are ready to load in No:3, HG 52 m fwd, & in No:7, HG 32 m aft. Find how much ore to load in each of these two holds to finish with a trim of 0.40 m by the stern. State the final drafts fwd and aft.

10 M.v. VICTORY is in FW, drawing 14.8 m fwd & 14 m aft. 6000 t of cargo is to be discharged, part from No:3 HG 52 m fwd and part from No:8 HG 52 m aft. Calculate the quantities to discharge & the final FW drafts if the trim on completion is to be 1 m by the stern.

11 The drafts of m.v. VICTORY in SW are 12 m fwd & 13.2 m aft. How much cargo may be put in No:1 hold, HG 92 m fwd, and in No:9 hold, HG 72 m aft, in order to complete loading on an even keel draft of 14.8 m?

12 M.v. VICTORY is in DW RD 1.012 at an even keel draft of 14.6 m. How much cargo may be discharged from No:3 LH, HG 52 m fwd, & from No:7 HG 31 m aft, in order to finish at 13.6 m draft, even keel, in the same dock?

13 M.v. VICTORY is in SW drawing 11.1 m fwd and 13.6 m aft. At what location may 1000 t of cargo be loaded if the draft aft is to remain at 13.6 m? State the final draft fwd.

14 M.v.VICTORY is in DW RD 1.018 drawing 12.5 m fwd and 11.9 m aft. Where may 4000 t cargo be loaded if the draft fwd is to remain at 12.5 m? State the final draft aft.

15 M.v.VICTORY is in FW at 12.9 m draft, even keel. Find the location from which 3000 t cargo may be discharged in order to finish with 12.9 m draft aft. State the final draft fwd.

16 M.v.VICTORY is in DW RD 1.010 drawing 12.4 m fwd and 12.6 m aft. Find where 2800 t may be loaded if the ship is to sail with 12.4 m draft fwd. State the final draft aft.

17 M.v. VICTORY is in SW with drafts of 11.8 m fwd & 12 m aft. How much cargo may be loaded into No:7, HG 32 m aft, in order to finish at 13 m draft aft? State the final draft fwd.

18 M.v.VICTORY is afloat in DW RD 1.017 at drafts of 13.7 m fwd and 14 m aft. How much ore is to be discharged from No:2, HG 72 m fwd, if the final draft fwd is to be 12 m? What would be the final draft aft?

19 M.v. VICTORY arrives at a SW port at 14.6 m even keel. Cargo is to be discharged in stream to lighten the ship

sufficiently to enter the docks at an even keel draft of 11.6 m. The master decides to discharge 4500 t of cargo from each of hold Nos:3 (HG 52 m fwd) 5 (HG 10 m fwd) and 7 (HG 31 m aft). Find the quantities to discharge from Nos:1 (HG 92 m fwd) & 9 (HG 72 m aft)

20 M.v.VICTORY arrives in DW of RD 1.009 drawing 14.6 m fwd & 14.8 m aft. Ore is to be discharged as follows:

6000 t from No:4, HG 30 m fwd,
8000 t from No:6, HG 10 m aft.

A further 6000 t is to be discharged, part from No:2 (HG 72 m fwd) and part from No:8 (HG 52 m aft). Find how much to discharge from each of these two spaces if the final trim is to be one metre by the stern. State the final DW drafts fwd and aft.

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CHAPTER 29

COMBINED

LIST AND TRIM

Sometimes, it may become necessary to cause a change of both, list and trim, by shifting fuel oil, FW, SW ballast or, as a last resort, by shifting cargo. In such cases, the problem could be split into two parts and each part may then be calculated separately, and in any order. In this book, change of list has been tackled first and then, change of trim. Having studied the earlier chapters on list and trim, the student should find the calculations here, quite simple.

Example 1

A ship of W 8000 t, KM 8 m, KG 7.2 m and MCTC 150 tm, is listed 6° to port and trimmed 0.2 m by the head. It is desired to bring the ship upright & trimmed 1 m by the stern by shifting heavy fuel oil between No:2 DB tanks port and starboard and No:6 DB tanks port & starboard. The COG of each tank is 8 m off the centre line of the ship. The distance between the centres of Nos:2 & 6 tanks is 80 m. No:2 DBT port and starboard have 300 t HFO each while No:6 DBT port & starboard are empty. Find how much transfer of HFO should take place between the tanks and the final distribution.
(Neglect free surface correction).

To correct list

$\tan\theta = ILM \div W.GM$ or $ILM = W.GM.\tan\theta$

$ILM = 8000(0.8)\tan 6° = 672.667$ tm port.

To upright the vessel it is necessary to cause LM of similar value to starboard.

$dw = 672.667$ or $w = 672.667 \div 16 = 42$ t.

Required to shift 42 t HFO to starboard.

To change trim

Present: 0.2 m by head. Desired: 1 m by stern. So Tc = 1.2 m = 120 cm by stern.

$$Tc = \frac{dw}{MCTC} \quad \text{or} \quad w = \frac{MCTC(Tc)}{d}$$

$w = 150(120) \div 80 = 225$ t HFO to go aft.

Distribution in tonnes
Initial: 2P 300, 2S 300, 6P Nil, 6S Nil.
Final : 2P 75, 2S 300, 6P 183, 6S 42.

Example 2

M.v.VIJAY, in SW drawing 4 m fwd & 6.6 m aft, is listed 7° to port. KG = 8 m. How much HFO must be transferred between tank Nos:2 P & S and 7 P & S to bring the ship upright and trimmed 1.2 m by the stern? The COG of the tanks are transversely 11 m apart & longitudinally 92 m. (Neglect free surface correction.)

Fwd 4 m, aft 6.6 m, trim 2.6 m by stern.
Mean draft 5.3 m for which AF = 71.800 m

$$Corr = \frac{AF}{L}(trim) = \frac{71.800(2.6)}{140} = 1.333 \text{ m}$$

Initial hydraft = 6.6 - 1.333 = 5.267 m.

Draft	W (t)	MCTC tm	KMT m
5.267	10481.7	167.569	8.530

To correct list

Tan θ = ILM ÷ W.GM or ILM = W.GM.Tan θ

ILM = 10481.7 (0.53) tan 7° = 682.105 tm

To upright the vessel it is necessary to cause LM of similar value to starboard.

dw = 682.105 or w = 682.105 ÷ 11 = 62 t.

Required to shift 62 t HFO to starboard.

To change trim

Present: 2.6 m by stern. Desired: 1.2 m by stern. So Tc = 1.4 m = 140 cm by head

$$Tc = \frac{dw}{MCTC} \text{ or } w = \frac{MCTC(Tc)}{d} = \frac{167.569(140)}{92}$$

Required to shift 255 t HFO aft to fwd.

Example 3

M.v. VICTORY is in DW, RD 1.015, drawing 12 m fwd & 14 m aft. KG is 12.6 m. The ship is listed 5° to starboard. Find how much oil transfer is required between the following tanks to bring the ship upright and trimmed 1 m by the stern: No:2 P and S (HG 61 m fwd) and No:5 P and S (HG 59 m aft). The COG of each tank is 16 m off the centre line of the ship. (Neglect free surface correction.)

Fwd 12 m, aft 14 m, trim 2 m by stern.
For mean draft 13.0 m, HF = 0.270 m aft.

$$Corr = \frac{HF}{L} \times trim = \frac{0.270 \times 2}{236} = 0.002 \text{ m}$$

Hydraft = 13 + 0.002 = 13.002 m.

	Draft	W (t)	MCTC tm	KMT m
SW	13.002	84853.1	1159.167	13.180
DW	13.002	84025.2	1147.858	13.180

GM = 13.180 - 12.600 = 0.580 metre.

To correct list

Tan θ = ILM ÷ W.GM or ILM = W.GM.Tan θ

ILM = 84025.2 (0.58) tan 5° = 4263.7 tm.

To upright the vessel it is necessary to cause LM of similar value to port.

dw = 4263.7 or w = 4263.7 ÷ 32 = 133.2 t

Required to shift 133.2 t HFO to port.

To change trim

Present: 2.0 m by stern. Desired: 1.0 m by stern. So Tc = 1.0 m = 100 cm by head

$$Tc = \frac{dw}{MCTC} \text{ or } w = \frac{MCTC(Tc)}{d} = \frac{100(1147.858)}{120}$$

Required to shift 956.5 t HFO forwards.

Exercise 25
Combined list & trim

1 A ship of W 15000 t, KM 9 m, KG 8 m, MCTC 200 tm, is listed 6° to port and trimmed 3 m by the stern. What oil transfer must take place between Nos:3 P & S and Nos:8 P & S to bring the V/L upright & trimmed 2 m by the stern? The COG of the tanks are transversely 10 m apart and longitudinally, 100 m. (Neglect free surface correction.)

2 A tanker of W 50000 t, MCTC 650 tm, KM 11 m, KG 10.1 m, is listed 7° to port and trimmed 5 m by the stern. Find the transfer of oil that must take place between Nos:10 P & S and Nos:2 P & S to bring the ship upright and trimmed 3 m by the stern. The COG of the tanks are transversely 14 m apart and longitudinally 140 m apart. (Neglect FSC.)

3 M.v.VIJAY is upright in SW drawing 5.6 m fwd & 6.8 m aft. KG 7.16 m. Find how much oil transfer must take place between Nos:2 P & S and Nos:7 P & S, in order to list the ship 5° to port and bring her on an even keel. The COG of the tanks are transversely 10 m apart and longitudinally, 90 m. (Neglect free surface correction.)

4 M.v.VICTORY is in DW RD 1.009, drawing 13.6 m fwd & 12.6 m aft. KG 12.647 m. The ship is listed 8° to starboard. Find the oil transfer to be made between the following tanks to bring the ship upright and trimmed 0.5 m by the stern: Nos:2 P & S (HG 61 m fwd) &

Nos:5 P & S (HG 59 m aft). The COG of each tank is 16 m off the centre line. (Neglect free surface correction.)

5 M.v. VIJAY is in DW, RD 1.017, drawing 7 m fwd & 6 m aft, listing 5° to port. KG is 7.4 m. How much FW must be transferred between the peak tanks (COG 132 m apart) and HFO between Nos: 2 P and S (COG 10 m apart) to upright the ship and trim her one metre by the stern? (Ignore FSC.)

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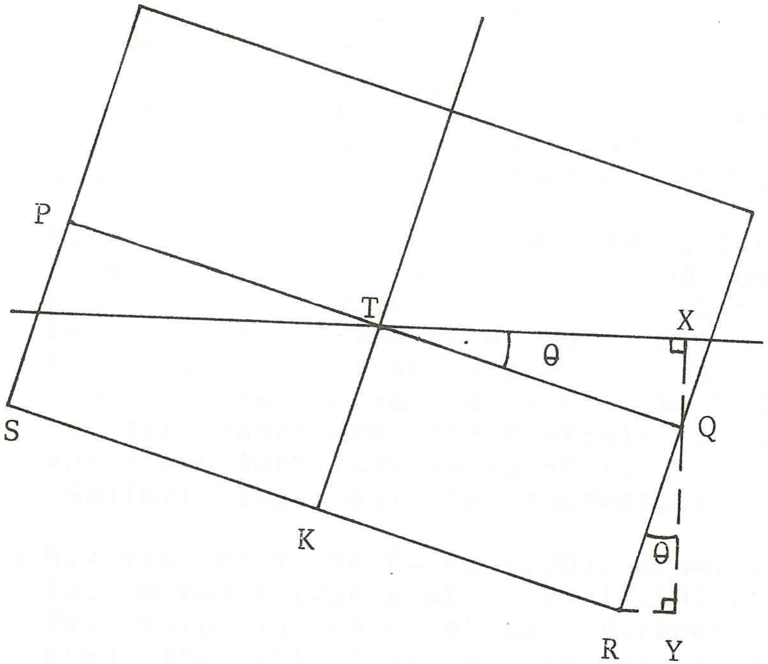
CHAPTER 30

DRAFT INCREASE

DUE TO LIST

Draft is the depth of the lowest part of the ship below the waterline. When the vessel lists, the draft increases. Calculation of this increase can be done by simple trigonometry.

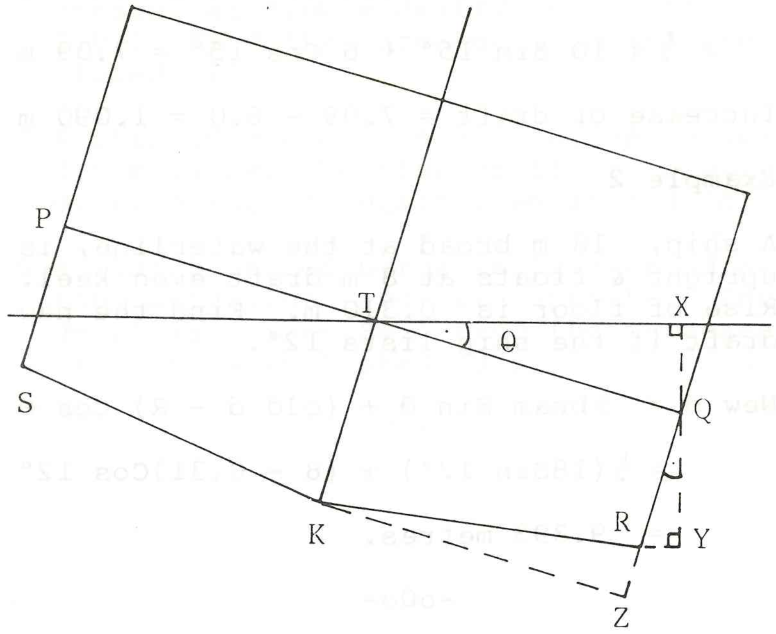
Box-shaped vessel



New d = XY = XQ+QY = TQ Sin θ + QR Cos θ
= ½beam Sin θ + old draft Cos θ

Ship-shapes

The midship section of a ship resembles that of a box-shaped vessel except that the ship usually has a rise of floor. Rise of floor is the vertical distance between the keel and the bilge when the ship is upright. When pumping out a tank rise of floor helps drain the liquid towards the suction pipe which is situated near the centre line of the ship.



New d = XY = XQ+QY = TQ Sin θ + QR Cos θ
= TQ Sin θ + (QZ - RZ) Cos θ

New d = ½ beam Sin θ + (old d - R) Cos θ
(where R = rise of floor of ship).

Note: Where there is no rise of floor, zero may be substituted in the foregoing formula which then becomes the same as the earlier formula.

Example 1

A box-shaped vessel 10 m broad floats upright & on an even keel draft of 6 m. Find the increase in draft if the vessel lists 15°.

New draft = ($\frac{1}{2}$beam Sin θ) + old d.Cos θ

$= \frac{1}{2} \times 10 \text{ Sin } 15° + 6 \text{ Cos } 15° = 7.09 \text{ m}$

Increase of draft = 7.09 - 6.0 = 1.090 m

Example 2

A ship, 18 m broad at the waterline, is upright & floats at 8 m draft even keel. Rise of floor is 0.310 m. Find the new draft if the ship lists 12°.

New d = $\frac{1}{2}$beam Sin θ + (old d - R) Cos θ

$= \frac{1}{2}(18 \text{Sin } 12°) + (8 - 0.31)\text{Cos } 12°$

= 9.393 metres.

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Exercise 26
Draft increase due to list

1 A box shaped vessel, 100 x 20 x 8 m, floats upright at 5 m draft. Find the new draft if the vessel lists 16°.

2 A ship, 32 m broad at the waterline, is upright and draws 12.3 m. The rise of floor is 0.34 m. Find the new draft at 15° list.

3 A box-shaped vessel, 27 m broad, is upright at 9.00 m draft, in DW of RD 1.016. Find the increase in draft when listed 12°.

4 A ship 18 m broad is upright and draws 8.6 m in FW. The rise of floor is 0.15 m. Find the new draft when listed 18°.

5 A flat bottomed barge is 12 m broad at the waterline and is upright. The draft is 5 m in SW. Find the increase in draft when listed 13°.

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CHAPTER 31

DRYDOCKING

AND GROUNDING

When a ship enters a graving type dry dock, she should be in stable equilibrium, upright and trimmed slightly by the stern. As far as possible, all tanks should be either empty or pressed up so as to reduce FSE to the barest minimum possible under the circumstances.

When the gate is closed and pumping out commences, the water level in the dock will drop gradually. Side shores consisting of large baulks of timber will be positioned loosely between the ship's sides and the sides of the dock, by shore personnel, at intervals of about five metres.

As the lower end of the stern frame nears the blocks, the rate of pumping will be reduced suitably while the ship is correctly positioned and aligned over the keel blocks. After the stern takes to the blocks, pumping out is continued. As the forward end near the blocks, the side shores are wedged up tight, working from the after end towards forward, so that, by the time the bow also takes to the blocks, all the side shores would be tight thereby aligning the ship correctly over the keel blocks and preventing her from capsizing.

Until the stern has taken to the blocks, the ship is floating freely. Whatever trim, GM, etc. that she had while entering the dock will be unaffected until the stern touches the keel blocks. After the stern has taken to the blocks, part of the weight of the ship gets transferred to the blocks, say 'P' tonnes. This is equivalent to the discharge of weight from the location of the stern frame - both KG and AG of the discharged weight are zero metres. This results in:

(a) Decrease in the hydraft of the ship.
(b) Decrease in the trim by the stern.
(c) Virtual rise of COG of the ship and consequent virtual loss of GM.

The value of 'P' at the stern frame increases as the water level drops, until the bow also takes to the blocks. Thereafter, P acts along the entire keel and not only at the stern frame.

The interval, from the instant the stern takes to the blocks till the instant the bow also takes to the blocks, is called the critical period. This is because, during this period, the ship suffers steadily increasing virtual loss of GM, without the benefit of the side shores. The most dangerous time is at the end of the critical period, called the critical instant, when P, acting at the stern frame only, is maximum while the side shores are all not yet wedged tight.

Calculation of P

(1) During the critical period:
During the critical period, the force P

acts only at the after perpendicular of the ship. So its distance from the COF is the AF of the ship.

$$\text{Trim (cm)} = \frac{TM}{MCTC} = \frac{P.AF}{MCTC} \quad \text{or} \quad P = \frac{\text{trim} \times MCTC}{AF}$$

(2) After the critical period:
After the ship has taken to the blocks at both ends, further drop in the level of water would cause further transfer of weight to the keel blocks but this would act all along the ship's length and not only at the stern frame. This increase of P, after the critical period, may be calculated by multiplying the drop in water level after the critical period by the TPC. The results obtained by this method are approximate as TPC of a ship is not constant but changes with draft.

(3) At any time:
Obtain the ship's displacement while entering the drydock - W1. At any time during the drydocking process, whether during the critical period or afterwards, obtain the hydraft and thence the displacement - W2. Then, at that time, P = W1 - W2 tonnes. The results obtained by this method are fairly accurate.

Virtual loss of GM

The virtual loss of GM, at any time during the process of drydocking, may be calculated by either of two formulae:

Formula................. A...or... B

$$\text{Virtual loss of GM (in metres)} = \frac{P.KG}{W - P} \qquad \frac{P.KM}{W}$$

In both these formulae, the values of W and KG are those that the ship had while entering the drydock. Whenever sufficient data is available, the KM used should be that for the reduced displacement, (W - P). If sufficient data is not available, then the value of KM in formula B may be taken to be that with which the ship entered the drydock. Both formulae give fairly close results.

Formula A assumes that P is a transfer of weight to the keel blocks equivalent to the discharge of weight from the keel resulting in a virtual increase of KG. It is derived from the $GG_1\uparrow$ formula.

Formula B assumes that P is a transfer of buoyancy to the keel blocks resulting in a decrease of KM while the weight and KG remain constant.

While calculating the moment of statical stability (righting moment), at small angles of inclination during the drydocking process, by multiplying by GM.Sin θ, the displacement used after formula A should be (W - P) and after formula B, the original W. The GM used in both cases should be the virtual GM.

The virtual loss of GM, as calculated by the foregoing formulae, is approximate only. Therefore, the only practical solution, available to the Master/Chief Officer, is to ensure that the residual virtual GM at the critical instant, arrived at by using these formulae, is sufficiently large to accommodate the possible inaccuracy.

The calculation need only be done using either formula A or formula B. For illustration purposes, each example has been worked twice in this book, once with formula A and again with formula B.

Free surface correction

During the critical period FSC increases and may be calculated by the formula: FSC = FSM ÷ (W − P), where FSM is in tm.

Once the ship is wedged up tight in drydock, without any possibility of roll, FSE ceases to exist. Hence, after the critical period is over, FSE may be ignored. However, if the ship is aground she may roll due to wave action even though she may be sitting overall on the sea-bed. In such a case, FSE cannot be ignored - FSC must be applied.

Example 1

M.v. VIJAY enters a SW drydock drawing 3 m fwd & 5.2 m aft. KG 9 m, FSM 1200 tm. Calculate the virtual GM & the moment of statical stability at 0.5° heel, when she is just about to take to blocks fwd.

Fwd 3.0 m aft 5.2 m, trim 2.2 m by stern
Mean draft 4.1 m for which AF = 72.113 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{72.113(2.2)}{140} = 1.133 \text{ m}$$

Initial hydraft = 5.20 − 1.133 = 4.067 m

Draft	W (t)	MCTC tm	AF (m)
4.067	7853.1	158.403	72.118

To find P & GM at critical instant:

$$\underset{(cm)}{\text{Trim}} = \frac{TM}{MCTC} = \frac{P.AF}{MCTC} \quad \text{or} \quad P = \frac{\text{trim} \times MCTC}{AF}$$

P = 220(158.403) ÷ 72.118 = 483.2 tonnes

(W − P) = 7853.1 − 483.2 = 7369.9 t, for which KM from hydro. table = 9.887 m

GM = KM − KG = 9.887 − 9.000 = 0.887 m
FSC = FSM/(W − P)=1200/7369.9 = 0.163 m
GM fluid .... = 0.724 m

	Formula A		Formula B
Virtual loss of GM) =	$\frac{P.KG}{W - P}$		$\frac{P.KM}{W}$
=	$\frac{483.2(9)}{7369.9}$	or	$\frac{483.2(9.887)}{7853.1}$

Virtual loss of GM = 0.590 m or 0.608 m.
GM fluid .... = 0.724 m 0.724 m.
Virtual GM ...... = 0.134 m or 0.116 m.

	Formula A		Formula B
RM @ 0.5° =	(W − P)GM.Sin θ	or	W.GM.Sin θ
=	8.618 tm	or	7.950 tm

Example 2

M.v.VIJAY has W = 7277 t in SW, KG = 9.1 m. Find the maximum trim with which she may enter drydock, if the virtual GM at the critical instant is to be not less than 0.25 metre.

W (t)	MCTC tm	AF (m)	KM (m)
7277	156.0	72.141	9.950

Initial GM solid = 9.95 - 9.10 = 0.850 m
Minimum desired virtual GM = 0.250 m
Permitted virtual loss of GM = 0.600 m

Formula A or Formula B

$$\text{Virtual loss of GM} = \frac{P.KG}{W - P} \quad \text{or} \quad \frac{P.KM}{W}$$

$$0.6 = \frac{P\,(9.1)}{W - P} \quad \text{or} \quad \frac{P\,(9.95)}{7277}$$

Maximum P = 450.1 t or 438.8 t.

$$\text{Maximum trim} = \frac{P.AF}{MCTC} \quad \text{or} \quad \frac{P.AF}{MCTC}$$

$$= \frac{450.1(72.141)}{156} \quad \text{or} \quad \frac{438.8(72.141)}{156}$$

Maximum trim = 208.1 cm or 202.9 cm.

Note: Due to the nature of the problem, the value of P is available only towards the end of the calculation. Hence the KM used is for the original displacement (W) not for the reduced displacement (W - P). In reality, the KM for (W - P) would be more than the KM used above and hence the maximum safe trim would be more than the value calculated above. The error is thus on the safer side.

Example 3

M.v.VIJAY is at anchor drawing 4.9 m fwd & 6.7 m aft in SW. KG 7 m, FSM 1100 tm. During low water, the depth of water around the ship is expected to drop to 5.5 m. Assuming that the sea-bed is horizontal, find the virtual GM at LW.

Fwd 4.9 m aft 6.7 m, trim 1.8 m by stern
Mean draft 5.8 m for which AF = 71.586 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{71.586(1.8)}{140} = 0.920 \text{ m}$$

Initial hydraft = 6.70 - 0.920 = 5.780 m

Note: An interesting case develops here. At LW, when the depth of water becomes 5.5 m, if the ship is sitting overall on the sea-bed, then the hydraft of the ship would be 5.5 m, for which the displacement (W - P), and KM, can be obtained from the hydrostatic table. On the other hand, if at LW the ship is not sitting overall on the sea-bed, the aft draft would have reduced from 6.7 m to 5.5 m as a result of mean rise and the after proportion of trim (Ta). In such a case, the hydraft at LW would be <5.5 m. The correct situation can be assessed by a simple calculation.

Draft	W (t)	MCTC tm	AF (m)
5.780	11627.1	171.160	71.595

To sit overall, P = (trim x MCTC) ÷ AF

= 180(171.16) ÷ 71.595 = 430.3 t

(W - P) = (11627.1 - 430.3) = 11196.8 t, for which hydraft as per table = 5.588 m

The hydraft when sitting overall on the sea-bed will be 5.588 m. In other words, the depth of water at which the ship would sit overall on the sea-bed is 5.588 m. The depth at LW is 5.5 m. So at LW, the ship is sitting overall and the hydraft then is 5.5 m, for which the displacement = 11000 t and KM = 8.417 m.

At LW, P = 11627.1 - 11000 = 627.1 t
GM solid = 8.417 - 7.0 = 1.417 m
FSC = FSM ÷ (W - P) = 0.100 m
GM fluid .... = 1.317 m

$$\text{Virtual loss of GM} = \underset{\text{Formula A}}{\frac{P.KG}{W - P}} \qquad \underset{\text{Formula B}}{\frac{P.KM}{W}}$$

$$= \frac{627.1(7)}{11000} \text{ or } \frac{627.1(8.417)}{11627.1}$$

Virtual loss of GM = 0.399 m or 0.454 m.
GM fluid .... = 1.317 m 1.317 m.
Virtual GM .... = 0.918 m or 0.863 m.

Example 4

M.v. VIJAY enters a SW drydock drawing 3.6 m fwd and 5.8 m aft. KG 8.2 m, FSM 1000 tm. Find the virtual GM when the water level has dropped by 1 m after the stern has taken to the blocks.

Fwd 3.6 m aft 5.8 m, trim 2.2 m by stern
Mean draft 4.7 m for which AF = 71.992 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{71.992(2.2)}{140} = 1.131 \text{ m}$$

Initial hydraft = 5.80 - 1.131 = 4.669 m

Note: When the stern takes to the blocks the depth of water above the blocks will be 5.8 m. After a fall of 1 m in level, if the ship is sitting overall on the blocks, the hydraft will be 4.8 m. If, however, after the 1 m drop in level, the bow is still afloat, the hydraft will be <4.8 m. The actual situation can be ascertained by a simple calculation.

Draft	W (t)	TPC t	MCTC tm	AF (m)
4.669	9164.1	21.918	163.252	71.998

To sit overall, P = (trim x MCTC) ÷ AF

= 220(163.252) ÷ 71.998 = 498.8 t

(W - P) = (9164.1 - 498.8) = 8665.3 t,
for which hydraft as per table = 4.441 m

The depth of water above the blocks, at the given time, is 4.8 m. Therefore, the ship is still in the critical period. The draft aft has reduced from 5.8 m to 4.8 m as a result of mean rise and the after proportion of trim (Ta).

Decrease of draft aft = mean rise + Ta

$$100 = \frac{P}{TPC} + \frac{AF \times Tc}{L}$$

$$100 = \frac{P}{21.918} + \frac{P(71.998)}{163.252}\frac{(71.998)}{(140)}$$

P = 367.1 t. (W - P) = 8797 t for which, from the hydrostatic table, KM = 9.086 m

GM solid = 9.086 - 8.200 ..... = 0.886 m
FSC = FSM ÷ (W - P) .... = 0.114 m
GM fluid at required time .... = 0.772 m

$$\text{Virtual loss of GM} = \underset{\text{Formula A}}{\frac{P.KG}{W - P}} \qquad \underset{\text{Formula B}}{\frac{P.KM}{W}}$$

$$= \frac{367.1(8.2)}{8797} \text{ or } \frac{367.1(9.086)}{9164.1}$$

Virtual loss of GM = 0.342 m or 0.364 m.
GM fluid .... = 0.772 m 0.772 m.
Virtual GM .... = 0.430 m or 0.408 m.

Example 5

M.v.VIJAY has W = 6849 t in SW, KG = 9.6 m, FSM = 900 tm. Find the maximum trim with which she may enter a drydock, if the GM at the critical instant is to be not less than 0.3 metre.

Note: This example is similar to example 2 but for one difference. Here, FSM has been given and has to be allowed for in the calculation.

W t	Draft	TPC t	MCTC	AF (m)	KM (m)
6849	3.60	21.36	154.1	72.141	10.274

Initial GM = 10.274 - 9.600 = 0.674 m
Virtual GM @ critical instant = 0.300 m
Permitted total loss of GM = 0.374 m

Total loss of GM = FSC + loss due to P

Therefore $0.374 = \frac{FSM}{W - P}$ + drydocking loss

By formula A: $0.374 = \frac{900}{6849-P} + \frac{P.KG}{W - P}$

$0.374 = \frac{900}{6849-P} + \frac{P(9.6)}{6849-P}$ so **P = 166.6 t**

Trim = 166.6(72.141) ÷ 154.1 = **78.0 cm**

By formula B: $0.374 = \frac{900}{6849-P} + \frac{P.KM}{W}$

$0.374 = \frac{900}{6849-P} + \frac{P(10.274)}{6849}$ so **P = 159.6 t**

Trim = 159.6(72.141) ÷ 154.1 = **74.7 cm**

Example 6

While drawing 3 m fwd and 7 m aft in SW, m.v. VIJAY runs aground lightly on a sandy coast. External soundings indicate that the depth of water near the after perpendicular is 2 m greater than near the fwd perpendicular. If KG is 8.1 m & FSM is 1200 tm, find (a) the drop in water level at which the ship would sit overall on the sea-bed; (b) the virtual GM when the ship sits overall on the sea-bed; (c) The drop in water level at which the ship would become unstable.

Note: When sitting overall on the sea-bed, the trim would be 2 m by the stern.

Fwd 3.0 m aft 7.0 m, trim 4.0 m by stern
Mean draft 5.0 m for which AF = 71.913 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{71.913(4.0)}{140} = 2.055 \text{ m}$$

Initial hydraft = 7.00 - 2.055 = 4.945 m

Draft	W (t)	MCTC tm	AF (m)	KM (m)
4.945	9770.0	165.315	71.929	8.725

Initial trim 4 m by stern. Final trim 2 m by the stern. So Tc = 2 m by the head.

Tc = P.AF/MCTC or P = Tc (MCTC)/AF

P = 200(165.315) ÷ 71.929 = 459.7 tonnes

(W - P)	Draft	AF m	KM m
9310.3	4.736	71.984	8.881

Hydraft when sitting overall = 4.736 m & trim = 2 m by the stern. Draft aft = ?

Ta = AF(Tc)/L = 71.984(2)/140 = 1.028 m.
Draft aft = 4.736 + 1.028 = 5.764 metres

Draft aft when sitting overall = 5.764 m
Draft aft when aground lightly = 7.000 m
Drop to sit overall = **ans (a)** = 1.236 m

Tabular verification of above:-

	Draft of ship aft (m)	fwd	Depth of water aft (m)	fwd
Initial:	7.000	3.000	7.000	5.000
Final :	5.764	3.764	5.764	3.764
Remarks:	Final trim by stern = 2 m		Rise of bottom 2m at fwd end.	

New GM solid = 8.881 - 8.100 = 0.781 m
FSC = FSM/(W-P) = 1200/9310.30 = 0.129 m
Fluid GM when sitting overall = 0.652 m

Virtual loss of GM) = $\frac{P.KG}{W - P}$ (Formula A) or $\frac{P.KM}{W}$ (Formula B)

$= \frac{459.7(8.1)}{9310.3}$ or $\frac{459.7(8.881)}{9770}$

Virtual loss of GM = 0.400 m or 0.418 m.
GM fluid .... = 0.652 m 0.652 m.
Virtual GM **ans (b)** = **0.252 m or 0.234 m.**

Initial GM = Initial KM - KG = 0.625 m, the loss of which will result in zero GM

Total loss of GM = FSC + loss due to P

Therefore 0.625 = $\frac{FSM}{W - P}$ + drydocking loss

By formula A: $0.625 = \frac{1200}{9770-P} + \frac{P.KG}{W - P}$

$0.625 = \frac{1200}{9770-P} + \frac{P(8.1)}{9770-P}$ so P = 562.3 t

GM will be 0 when disp = W-P = 9207.7 t.

W (t)	Draft	AF (m)
9207.7	4.689	71.994

Ta = AF(Tc)/L = 71.994(2)/140 = 1.028 m.

Draft aft = 4.689 + 1.028 = 5.717 metres

Draft aft when GM becomes zero = 5.717 m
Draft aft when aground lightly = 7.000 m
Drop in level for 0 GM **ans (c)** = **1.283 m**

By formula B: $0.625 = \frac{1200}{9770-P} + \frac{P.KM}{W}$

$0.625 = \frac{1200}{9770-P} + \frac{P(8.725)}{9770}$ so P = 554.1 t

GM will be 0 when disp = W-P = 9215.9 t.

W (t)	Draft	AF (m)
9215.9	4.693	71.993

Ta = AF(Tc)/L = 71.993(2)/140 = 1.028 m.
Draft aft = 4.693 + 1.028 = 5.721 metres

Draft aft when GM becomes zero = 5.721 m
Draft aft when aground lightly = 7.000 m
Drop in level for 0 GM **ans (c)** = 1.279 m

(See note at the end of example 2).

Example 7

M.v. VIJAY enters a SW drydock drawing 3 m fwd & 5.8 m aft. KG = 8.6 m, FSM = 800 tm. Find the new GM: (a) on taking to blocks overall and (b) after the water level drops by one metre thereafter.

Fwd 3.0 m aft 5.8 m, trim 2.8 m by stern
Mean draft 4.4 m for which AF = 72.056 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{72.056(2.8)}{140} = 1.441 \text{ m}$$

Initial hydraft = 5.80 - 1.441 = 4.359 m

Draft	W (t)	MCTC tm	AF (m)
4.359	8486.8	160.952	72.065

Tc = P.AF/MCTC or P = Tc (MCTC)/AF
P = 280(160.952) ÷ 72.065 = 625.4 tonnes

W - P = 7861.4 t, for which KM = 9.570 m

New GM = new KM-KG = 9.57-8.6 = 0.970 m
FSC = FSM/(W - P) = 800/7861.4 = 0.102 m
GM fluid when sitting overall = 0.868 m

$$\text{Virtual loss of GM} = \frac{P.KG}{W-P} \text{ (Formula A)} \quad \text{or} \quad \frac{P.KM}{W} \text{ (Formula B)}$$

$$= \frac{625.4(8.60)}{7861.4} \text{ or } \frac{625.4(9.57)}{8486.8}$$

Virtual loss of GM = 0.684 m or 0.705 m.
GM fluid .... = 0.868 m 0.868 m.
Virtual GM **ans (a)** = 0.184 m or 0.163 m.

Note: After the critical period is over, the side shores would be in position and there is no possibilty of roll. FSE can then be ignored.

On taking to blocks overall, the displacement is 7861.4 t, for which the hydraft is 4.071 m. After a further drop of 1 m in water level, hydraft = 3.071 m for which W = 5729.1 t & KM = 11.314 m. Then GM solid = 11.314 - 8.600 = 2.714 m and P = 8486.8 - 5729.1 = 2757.7 t.

$$\text{Virtual loss of GM} = \frac{P.KG}{W-P} \text{ (Formula A)} \quad \text{or} \quad \frac{P.KM}{W} \text{ (Formula B)}$$

$$= \frac{2757.7(8.6)}{5729.1} \text{ or } \frac{2757.7(11.314)}{8486.8}$$

Virtual loss of GM: 4.140 m or 3.676 m
GM solid ....: 2.714 m 2.714 m
Virtual GM **ans (b)**: -1.426 m or -0.962 m

Example 8

M.v. VIJAY, drawing 5 m fwd & 6 m aft in SW, has KG = 7.6 m and FSM = 950 tm. She runs aground lightly on a reef at the fwd perpendicular. Internal soundings indicate that the hull is still watertight. If the tide is expected to fall by 0.5 m, find at LW: (a) the upthrust exerted on the hull by the reef, (b) the drafts fwd & aft and (c) the virtual GM.

Fwd 5.0 m aft 6.0 m, trim 1.0 m by stern
Mean draft 5.5 m for which AF = 71.714 m

$$\text{Corr} = \frac{AF}{L} \times \text{trim} = \frac{71.714(1.0)}{140} = 0.512 \text{ m}$$

Initial hydraft = 6.00 - 0.512 = 5.488 m

Draft	W (t)	TPC t	MCTC tm	AF (m)
5.488	10973.2	22.255	169.116	71.719

The draft fwd would decrease by 50 cm as a result of the upthrust P exerted by the reef at the fwd perpendicular.

Decrease of fwd draft = mean rise + Tf

50 = P/TPC + Tc(length forward of COF)/L

$$50 = \frac{P}{TPC} + \frac{P(L - AF)}{MCTC} \times \frac{(L - AF)}{L}$$

$$50 = \frac{P}{22.255} + \frac{P(68.281)(68.281)}{(169.116)(140)}$$

Upthrust P at LW = 206.7 t = **answer (a)**.

$$Tc = \frac{P(L - AF)}{MCTC} = \frac{206.7(68.281)}{169.116} = 83.5 \text{ cm}$$

Trim @ LW = original trim + Tc = 1.835 m

Draft fwd = 5.000 - 0.5 = 4.500 m at LW
aft = 4.5 + 1.835 = 6.335 m **ans(b)**

W - P = 10766.5 t for which KM = 8.463 m
KG of ship.................. = 7.600 m
GM solid at low water .... = 0.863 m
FSC = FSM/(W - P)= 950/10766.5 = 0.088 m
GM fluid at low water........ = 0.775 m

$$\text{Virtual loss of GM} = \underset{\text{Formula A}}{\frac{P.KG}{W - P}} \quad \underset{\text{Formula B}}{\frac{P.KM}{W}}$$

$$= \frac{206.7(7.6)}{10766.5} \text{ or } \frac{206.7(8.463)}{10973.2}$$

Virtual loss of GM = 0.146 m or 0.159 m.
GM fluid at LW ... = 0.775 m 0.775 m.
Virtual GM **ans** (c) = 0.629 m or 0.616 m.

Example 9

M.v.VIJAY draws 6 m fwd & 8 m aft in SW. KG 7.04 m and FSM 1060 tm. She grounds lightly on a reef 30 m astern of the fwd perpendicular. The hull is still intact. The water level is expected to fall by 0.6 m. At LW, find: (a) the upthrust on the hull by the reef, (b) the drafts fwd and aft and (c) the virtual GM.

Note: This is similar to example 8 with the exception that the point of grounding is not at the forward perpendicular but 30 m astern of it.

Fwd 6.0 m aft 8.0 m, trim 2.0 m by stern
Mean draft 7.0 m for which AF = 70.602 m

Correction = 70.602(2.000)/140 = 1.009 m
Initial hydraft = 8.00 - 1.009 = 6.991 m

Draft	W (t)	TPC t	MCTC tm	AF (m)
6.991	14381.3	22.926	182.592	70.611

At R, the point of grounding, the decrease of draft, by tidal fall, = 60 cm.
Let the distance of R from the COF = RF.
RF = AR - AF = 110 - 70.611 = 39.389 m.

Reduction of draft at R = mean rise + Tr where Tr is the proportion of Tc, the trim caused, at point R.

$$60 = \frac{P}{TPC} + \frac{P(RF)}{MCTC} \times \frac{(RF)}{L}$$

$$60 = \frac{P}{22.296} + \frac{P(39.389)^2}{182.592(140)} \text{ or } P = 575.2 \text{ t}$$ **answer (a)**

(W - P)	Draft	KM m
13806.1	6.740	8.083

$$Tc = \frac{P \times RF}{MCTC} = \frac{575.2(39.389)}{182.592} = 124.1 \text{ cm}$$

Trim @ LW = original trim + Tc = 3.241 m

$$Ta = \frac{AF(trim)}{L} = \frac{70.611\ (3.241)}{140} = 1.635 \text{ m}$$

Tf = trim - Ta = 3.241 - 1.635 = 1.606 m

Draft fwd = 6.74 - 1.606 = 5.134 m at LW
aft = 6.74 + 1.635 = 8.375 m **ans b**

GM solid at LW = 8.083 - 7.040 = 1.043 m
FSC = FSM/(W - P)=1060/13806.1 = 0.077 m
GM fluid at low water........ = 0.966 m

$$\text{Virtual loss of GM} = \frac{P.KG}{W - P} \ (\text{Formula A}) \qquad \frac{P.KM}{W} \ (\text{Formula B})$$

$$= \frac{575.2(7.04)}{13806.1} \text{ or } \frac{575.2(8.083)}{14381.3}$$

Virtual loss of GM = 0.293 m or 0.323 m.
GM fluid at LW... = 0.966 m 0.966 m.
Virtual GM **ans (c)** = 0.673 m or 0.643 m.

Example 10

M.v.VIJAY is in a SW anchorage drawing 5.4 m fwd & 6 m aft. KG 7.2 m, FSM 1100 tm. At LW, the ship rests on an uncharted rock and it is found that the drafts are then 6 m fwd & 5 m aft. Find (a) the upthrust exerted on the hull by the rock; (b) the distance, to the nearest metre, of the rock from the after perpendicular (c) the virtual GM and (d) the rise of tide required for the ship to refloat, assuming that she is aground at only one point surrounded by deep water.

Fwd 5.4 m aft 6.0 m, trim 0.6 m by stern
Mean draft 5.7 m for which AF = 71.629 m

$$Corr = \frac{AF}{L} \times trim = \frac{71.629(0.6)}{140} = 0.307 \text{ m}$$

Initial hydraft = 6.00 - 0.307 = 5.693 m for which the displacement W = 11431.8 t

Fwd 6.0 m aft 5.0 m, trim 1.0 m by head
Mean draft 5.5 m for which AF = 71.714 m

Correction = 71.714(1.000)/140 = 0.512 m

At LW, hydraft = 5.000 + 0.512 = 5.512 m

Draft	W - P	MCTC tm	AF (m)	KM m
5.512	11026.8	169.284	71.709	8.412

P = 11431.8 - 11026.8 = 405 t **answer (a)**

Original trim = 60 cm by stern. Trim at LW = 100 cm by head. Tc = 160 cm by head Hence rock is astern of COF. Let FR be the distance of the rock astern of COF.

Tc = P(FR)/MCTC or 160 = 405(FR)/169.284
FR = 66.878. AF = 71.709. So AR = 4.831

Distance of rock from the after perpendicular, to the nearest m, = 5 m **ans** (b).

GM solid at LW = 8.412 - 7.200 = 1.212 m
FSC = FSM/(W - P)=1100/11026.8 = 0.100 m
GM fluid at low water......... = 1.112 m

	Formula A	Formula B
Virtual) loss of GM) =	$\frac{P.KG}{W - P}$	$\frac{P.KM}{W}$
=	$\frac{405(7.2)}{11026.8}$ or	$\frac{405(8.412)}{11431.8}$

Virtual loss of GM = 0.264 m or 0.298 m.
GM fluid at LW ... = 1.112 m 1.112 m.
Virtual GM **ans** (c) = 0.848 m or 0.814 m.

Let Tr be the proportion of trim at R.

Before grounding:

$$Tr = \frac{FR(trim)}{L} = \frac{66.878(0.600)}{140} = 0.287 \text{ m.}$$

Since trim was by stern, draft at R was > initial hydraft of 5.693 m by 0.287 m.
Draft at R = 5.693 + 0.287 = 5.980 m.

After grounding

$$Tr = \frac{FR(trim)}{L} = \frac{66.878(1.000)}{140} = 0.478 \text{ m.}$$

Since trim is by head, draft at R is < the LW hydraft of 5.512 m by 0.478 metre
Draft at R = 5.512 - 0.478 = 5.034 m.

After grounding, draft at R = 5.034 m
To float freely, draft at R = 5.980 m
Required tidal rise **answer** (d) = 0.946 m

FLOATING DRYDOCKS

From the shipmaster's point of view, a floating drydock has one big advantage over a graving type drydock: the drydock itself can be made to have a trim in order to offset any adverse trim that the ship may have. Suppose the ship is trimmed one metre by the head. The drydock can be made to trim 2 m by the head so that, when the ship's stern takes to the keel blocks, the relative trim is one metre by the stern. Therefter, the ballast tanks of the drydock can be pumped out at a predetermined sequence to ensure that the stern frame of the ship always remains in contact with the keel blocks while the relative trim is gradually reduced. Once the bow also has taken to the blocks (relative trim zero) pumping out of the drydock can be completed, bringing the ship's keel above, & parallel to, the water surface.

If the ship is trimmed 3 m by the stern, the drydock can be made to trim 2 m by the stern so that the relative trim is only one metre by the stern, and so on.

-oOo-

Exercise 27
Drydocking and grounding

1 M.v.VIJAY enters a SW drydock drawing 6 m fwd & 8 m aft. KG 6 m. When she is just about to take to the blocks fwd, calculate (a) the virtual GM and (b) the moment of statical stability at 0.5° heel.

2 Rework Q1 given that FSM = 1180 tm.

3 M.v.VIJAY has W = 10333 t, KG = 8 m. What is the maximum trim by the stern with which she may enter a SW drydock if the virtual GM at the critical instant is to be not less than 0.3 m?

4 Rework Q3 given that FSM = 970 tm.

5 M.v.VIJAY is at anchor in SW, drawing 7 m fwd & aft. KG 6.2 m. During low water, the depth of water around the ship is expected to drop to 6 m. Find the virtual GM at LW, assuming that the sea-bed is even and horizontal.

6 Rework Q5 given that FSM = 1400 tm.

7 While drawing 4.8 m fwd & 8 m aft in SW, m.v.VIJAY runs aground lightly on a sandy shoal, during a falling tide. Hand lead soundings indicate that the depth of water near the after perpendicular is one metre more than at the forward perpendicular. If KG = 7.5 m, calculate (a) the drop in water level at which the ship will sit overall on the sea-bed; (b) the virtual GM when just sitting overall and (c) the drop in water level at which the ship would become unstable.

8 Rework Q7 given that FSM = 1300 tm.

9 M.v.VIJAY enters a SW drydock drawing 3.4 m fwd & 5.8 m aft. KG 8 m. Find the virtual GM when the level of water has fallen one metre after the stern has taken to the blocks.

10 Rework Q9 given that FSM = 880 tm. (If, during drydocking, the critical period is over, FSC may be ignored.)

11 M.v.VIJAY enters a SW drydock drawing 3.5 m fwd & 5.5 m aft. KG 7.1 m. Find the virtual GM after the water level has fallen to 4 m above the blocks.

12 Rework Q11 given that FSM = 820 tm. (If, during drydocking, the critical period is over, FSC may be ignored.)

13 M.v. VIJAY, drawing 5.6 m fwd & 8.4 m aft in SW, KG 7.2 m, runs aground lightly on a shoal during a falling tide. At low water, the drafts are found to be 6 m fwd & 7.4 m aft. Find the virtual GM at low water.

14 Rework Q13 given that FSM = 1400 tm.

15 M.v. VIJAY, floating at 5.2 m fwd & 7 m aft in SW, KG 7.4 m & FSM 1250 tm, runs aground lightly on a coral reef. Soon after grounding, the drafts are found to be 4.4 m fwd and 7.4 m aft. Find (a) the upthrust exerted on the hull by the reef and (b) the point,

to the nearest metre, where it acts. Find also (c) the virtual GM soon after grounding and (d) the rise of tide required for the ship to refloat assuming that the reef is acting only at one point surrounded by deep water.

16 M.v. VIJAY, afloat in SW at 4.6 m fwd & 5.4 m aft, KG 7.8 m, FSM 1180 tm, runs aground lightly at the foward perpendicular. The stern is in deep water. The tide is expected to fall by one metre. Find, at low water, (a) the upthrust exerted on the hull by the shoal; (b) the drafts fwd and aft and (c) the virtual GM.

17 M.v.VIJAY floats at drafts of 5 m fwd & 7 m aft, KG 7.64 m, FSM 1086 tm, in a SW anchorage. During ebb tide, she sits on an uncharted rock 20 m abaft the fwd perpendicular. The hull is still intact. The tide is expected to fall another 0.5 m. Find at low water (a) the force exerted on the hull by the rock; (b) the drafts fwd and aft and (c) the virtual GM.

18 M.v.VIJAY enters a FW drydock drawing 3.6 m fwd and 4.8 m aft. KG 8 m, FSM 960 tm. Find the virtual GM @ (a) the critical instant (b) after a further drop of one metre in water level.

19 M.v. VIJAY is in DW of RD 1.017. W is 9013 t, KG 8.02 m & FSM 810 tm. What is the maximum trim with which she may enter a drydock, of RD 1.017, if the virtual GM @ the critical instant is to be not less than 0.3 m?

20 M.v. VIJAY is to be refloated in a SW drydock after a prolonged stay for structural repairs. Her displacement, KG & AG after repairs are calculated to be 8576 t, 8.1 m and 68 m. FSM is 900 tm. Calculate the virtual GM and the depth of water, above the blocks, when the bow just lifts off the blocks.

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CHAPTER 32

BILGING OF

AMIDSHIPS COMPARTMENTS

A compartment is said to be bilged when it is holed below the waterline, the hole being large enough for water to pass freely in and out. Minor leaks are excluded as they can be tackled by the ship's pumps.

Bilging causes a loss of buoyancy. A compartment, which was displacing water before, does not do so after bilging. So the ship's draft increases until the loss of buoyancy is regained by the extra sinkage of intact spaces. By this line of thought, the displacement and KG remain unaffected by bilging. Though the draft of the ship increases, resulting in change of hydrostatic particulars, the volume of displacement is the same because the volume of buoyancy lost equals the volume of buoyancy regained. The increase of draft, denoted by 'S' metres, may be calculated as follows:-

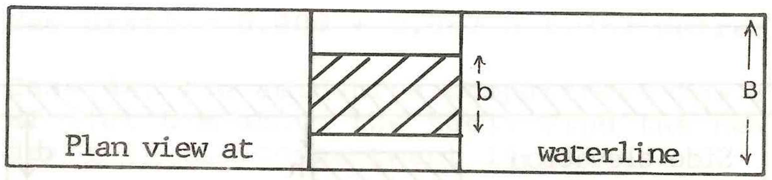
$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}}$$

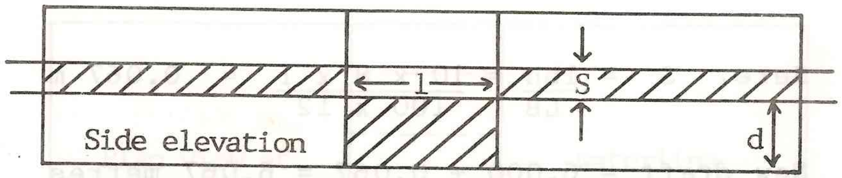
This chapter deals only with bilging of the amidships compartment of box-shaped vessels, resulting in parallel sinkage without causing any trim or list.

Water-tight flats restrict the entry of water into a bilged compartment. The volume of lost buoyancy, and hence the resultant sinkage, is less when the bilged compartment has a water-tight flat below the waterline. A good example of a water-tight flat is the tank top of the double bottom tanks of a cargo ship. The following cases show the calculation of sinkage caused by bilging an amidships compartment. The advantage of having a WT flat is apparent by the limited amount of calculated sinkage.

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

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





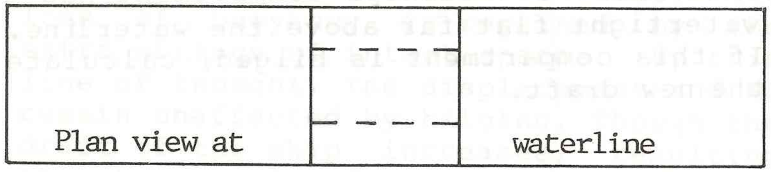
Note: Since the water-tight flat is far up, it will remain above the waterline after bilging. Its presence, therefore, makes no difference to the calculation.

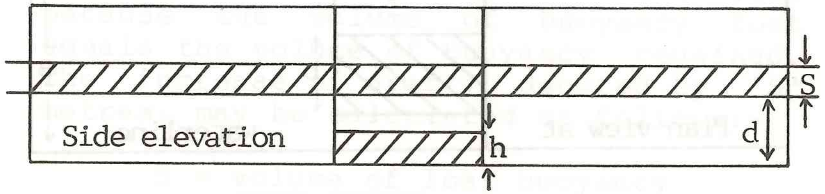
$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}}$$

Here, $S = \dfrac{lbd}{LB - lb} = \dfrac{10 \times 8 \times 6}{1200 - 80} = 0.429$ m

New draft = 6.000 + 0.429 = 6.429 metres

Case 2A: The amidships compartment has a WT flat 1 m above the keel. Find the new draft if the compartment is bilged below this flat. (Note: The bilged compartment is similar to the DB tank of a ship.)

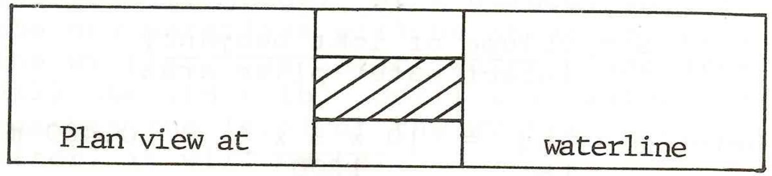


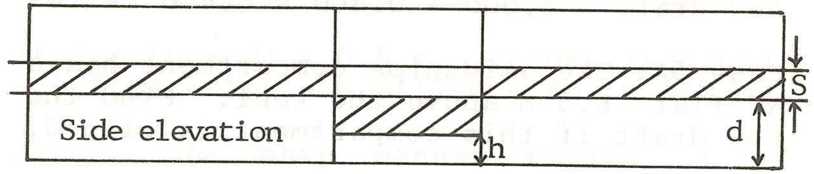


Here, $S = \dfrac{lbh}{LB} = \dfrac{10 \times 8 \times 1}{100 \times 12} = 0.067$ m

New draft = 6.000 + 0.067 = 6.067 metres

Case 3A: The amidships compartment has a WT flat 1 m above the keel. Find the new draft if the compartment is bilged above this flat.



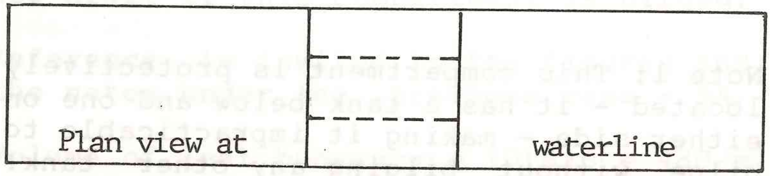


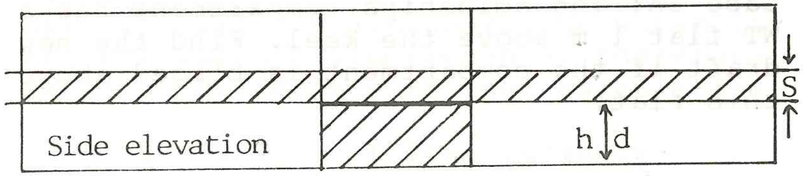
$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}}$$

Here, $S = \dfrac{lb(d-h)}{LB - lb} = \dfrac{10 \times 8 \times 5}{1200 - 80} = 0.357$ m

New draft = 6.000 + 0.357 = 6.357 metres

Case 4A: The amidships compartment has a WT flat 6 m above the keel. Find the new draft if the compartment is bilged.



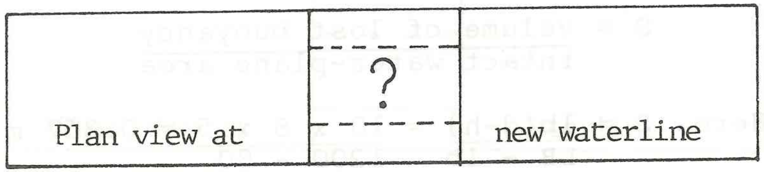


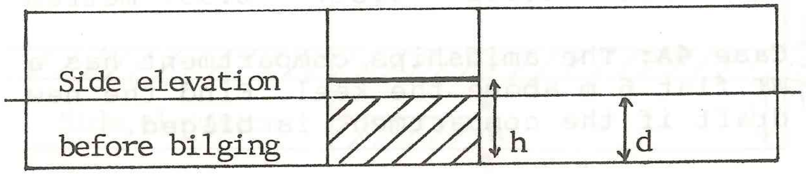
$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}}$$

$$\text{Here, } S = \frac{lbd}{LB} = \frac{10 \times 8 \times 6}{1200} = 0.400 \text{ m}$$

New draft = 6.000 + 0.400 = 6.400 metres

Case 5A: The amidships compartment has a WT flat 6.5 m above the keel. Find the new draft if this compartment is bilged.





Note 1: This compartment is protectively located - it has a tank below and one on either side - making it impracticable to bilge without bilging any other tank!

For theoretical purposes, assume that a very large pipeline leading out to sea has burst inside the compartment.

Note 2: Since the WT flat is very near the waterline before bilging, it is not possible to judge, at a glance, whether the new waterline will be above or below the WT flat. The intact water-plane area will be (LB - lb) until the waterline reaches the level of the WT flat; thereafter, it will be LB.

Vol of buoyancy lost = 10(8)6 = 480 m^3.

If S = (h - d) = 0.5 m, volume regained = 0.5(LB - lb) = 0.5(1200 - 80) = 560 m^3

Since the ship cannot regain more buoyancy than what she lost, S < 0.5 m. The WT flat remains above the waterline even after bilging. The calculation is now similar to that of case 1A.

$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}}$$

$$\text{Here, } S = \frac{480}{LB - lb} = \frac{480}{1200 - 80} = 0.429 \text{ m}$$

New draft = 6.000 + 0.429 = 6.429 metres

Case 6A: The amidships compartment has a WT flat 6.2 m above the keel. Find the new draft if this compartment is bilged.

Reference is invited to the figures and the notes under the previous case - 5A.

Volume of lost buoyancy = 10(8)6 = 480 m^3

If S = (h - d) = 0.2 m, volume regained = 0.2(LB - lb) = 0.2(1200 - 80) = 224 m^3

Vol yet to regain = 480 - 224 = 256 m^3 during which the intact WP area = LB.

Further sinkage = 256 ÷ 1200 = 0.213 m.

New draft = 6.0 + 0.2 + 0.213 = 6.413 m.

Exercise 28

Bilging amidships compartment (empty)

A box-shaped vessel, 120 m long and 14 m wide, is afloat at 8 m draft even keel. Find the new draft if a central compartment 12 m long is bilged as under:

(As b is not given, assume b = B = 14 m)

1 It has a WT flat 11 m above the keel.

2 It has a WT flat 1.2 m above the keel, & the compartment is bilged below it.

3 It has a WT flat 1.5 m above the keel, & the compartment is bilged above it.

4 It has a WT flat 1.0 m above the keel. The compartment is bilged above and below this flat.

5 It has a WT flat 8.0 m above the keel.

6 It has a WT flat 8.9 m above the keel.

7 It has a WT flat 8.5 m above the keel.

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PERMEABILITY

So far, the compartments bilged in this chapter were empty. If, however, they had cargo in them, that cargo would occupy space and only the balance space would be available for occupation by water in the event of bilging. In other words, cargo would restrict the space available for water, thereby reducing the volume of buoyancy lost due to bilging.

Permeability is the percentage ratio of the space available for the entry of water into a compartment, to the total volume of the compartment. The letter 'p' is used here to denote permeability. For an empty compartment, p = 100% and for a compartment so full that water could not enter at all, if bilging occured, p = 0%. For any compartment, p may be calculated by the formula: p % = (BS ÷ SF)100, where SF is the stowage factor in cubic metres per tonne & BS is the broken stowage per tonne of cargo.

Example: A compartment is full of coal in bulk (SF 1.3 m^3/t). If RD of coal is 1.1, find p % of the compartment.

RD = 1.1 so density = 1.1 t/m^3, meaning that 1.1 t of coal should occupy 1 m^3, or 1 t of coal should occupy 1 ÷ 1.1 = 0.909 m^3. But SF = 1.3 m^3/t meaning that 1 t of coal actually occupies 1.3 m^3. So broken stowage per tonne = 1.3 - 0.909 = 0.391 m^3.

p% = (BS/SF)100 = (0.391/1.3)100 = 30.1%

Where the cargo in a compartment is heterogenous, it is not possible to calculate the permeability to any degree of accuracy. In such a case, it is suggested that 60% may be used as a rough approximation at sea.

Permeability, once known or estimated, can be put to practical use as follows:

Consider the same box-shaped vessel and the six cases referred to earlier in this chapter, where L = 100 m, B = 12 m, d = 6 m, l = 10 m and b = 8 m.

Case 1B: The amidships compartment has a WT flat far above the waterline. Find the new draft if this compartment is bilged, given that p = 35%.

$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}}$$

Note: Only 35% of (lbd) is available for entry of water as a result of bilging. The area of cargo also contributes to the intact water-plane area. So the area of lost buoyancy = 35% of (lb).

$$S = \frac{lbd(p/100)}{LB - lb(p/100)} = \frac{10(8)6(35/100)}{1200-80(35/100)} = 0.143\text{m}$$

New draft = 6.000 + 0.143 = 6.143 metres

Case 2B: The amidships compartment has a WT flat 1 m above the keel. The space below the WT flat, full of SW ballast, gets bilged. Find the new draft. (Note: The bilged compartment is similar to the DB tank of a cargo ship.)

Since the bilged compartment was full of SW, p = 0%; S = zero; new draft = 6.0 m.

Note: This is a short cut method which cannot be used if the contents of the bilged compartment had an RD different from that of the water outside. For a solution suitable for all problems of this kind see example 5 few pages hence.

Case 3B: The amidships compartment has a WT flat 1 m above the keel. If the space above this flat, having p = 40%, gets bilged, find the new draft.

$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}}$$

$$= \frac{lb(d-h)(p/100)}{LB - lb(p/100)} = \frac{10(8)5(40/100)}{1200-80(40/100)} = 0.137$$

New draft = 6.000 + 0.137 = 6.137 metres

Case 4B: The amidships compartment has a WT flat 6 m above the keel. Find the new draft if this compartment gets bilged, given that permeability = 30%.

$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}}$$

$$S = \frac{lbd(p/100)}{LB} = \frac{10(8)6(30/100)}{1200} = 0.120\text{m}$$

New draft = 6.000 + 0.120 = 6.120 metres

Case 5B: The amidships compartment has a WT flat 6.2 m above the keel. Find the new draft if this compartment is bilged, given that p = 25%.

Volume of buoyancy lost = lbd (p ÷ 100)

= 10(8)6(25/100) = 120 m^3.

If S = (h-d) = 0.2 m, volume regained = 0.2[LB-lb(p/100)] = 0.2[1200-80(25/100)]

If S = 0.2 m, volume regained = 236 m^3.

Since the ship cannot regain more buoyancy than what she lost, S < 0.2 m. The WT flat remains above the waterline even after bilging. The calculation is now similar to that of case 1B.

$$S = \frac{120}{LB-lb(p/100)} = \frac{120}{1200-80(25/100)} = 0.102 \text{ m}$$

New draft = 6.000 + 0.102 = 6.102 metres

Case 6B: The amidships compartment has a WT flat 6.1 m above the keel. Find the new draft if this compartment is bilged, given that p = 80%.

Volume of buoyancy lost = lbd (p ÷ 100)

= 10(8)6(80/100) = 384 m^3.

If S = (h-d) = 0.1 m, volume regained = 0.1[LB-lb(p/100)] = 0.1[1200-80(80/100)]

If S = 0.1 m, volume regained = 113.6 m^3

Vol yet to regain = 384-113.6 = 270.4 m^3 during which the intact WP area = LB.

Further sinkage = 270.4 ÷ 1200 = 0.225 m

New draft = 6.0 + 0.10 + 0.225 = 6.325 m

Exercise 29
Bilging amidships compartment (loaded)

Rework exercise 28 given that the bilged amidships compartment has the permeability given against each question below:-

(1) p = 20% (2) Full of SW (3) p = 30%

(4) p = 50% (5) p = 40% (6) p = 65%

(7) p = 80%.

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EFFECT OF BILGING ON STABILITY

Since bilging causes a loss of buoyancy, resulting in an increase of draft, the KM of the ship would change. KG remains unaffected by bilging.

Example 1: A box-shaped vessel 150 x 18 m floats in SW at 5 m draft even keel. KG = 4 m. An empty amidships compartment 25 m long and 18 m broad gets bilged. Find the GM before and after bilging.

Before bilging

$$BM = \frac{I}{V} = \frac{LB^3}{12V} = \frac{150(18 \times 18 \times 18)}{12\ (150 \times 18 \times 5)} = 5.4 \text{ m}$$

KM = KB + BM = 2.500 + 5.400 = 7.900 m
GM = KM - KG = 7.900 - 4.000 = 3.900 m

After bilging

$$S = \frac{\text{vol of lost buoyancy}}{\text{intact WP area}} = \frac{25(18)5}{150(18)-25(18)}$$

S = 2250 ÷ (2700-450) = 2250/2250 = 1 m.

New draft = 5.000 + 1.000 = 6.000 metres

BM = I*CL intact WP area ÷ vol of displ.

$$BM = \frac{LB^3 - lb^3}{12V} = \frac{150(18^3)-25(18^3)}{12(150 \times 18 \times 5)} = 4.5 \text{ m}$$

Note: Volume of displacement is constant

$V = 150 \times 18 \times 5 = 13500 \text{ m}^3.$
or $V = 125 \times 18 \times 6 = 13500 \text{ m}^3.$

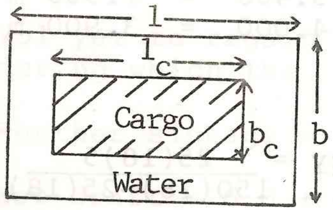
KM = KB + BM = 3.000 + 4.500 = 7.500 m
GM = KM - KG = 7.500 - 4.000 = 3.500 m

Example 2: Rework example 1 given that permeability = 30%.

The calculation of GM before bilging is the same as in example 1 & = 3.9 metres.

$$S = \frac{\text{buoyancy vol lost}}{\text{intact WP area}} = \frac{2250\ (30/100)}{2700-450(30/100)}$$

S = 0.263 m. After bilging, the area of the cargo contributes to the intact water-plane area. So the calculation of I of the intact WP area about the centre line should include the area of cargo in the compartment for which the following assumption is suggested:



The cargo is assumed to be centred over the compartment with its sides parallel to the boundaries, as shown in the figure.

Area of the bilged compartment = lb.
Area of water in compartment = lb(p/100)

$$\text{Area of cargo} = lb - \frac{lbp}{100} = \frac{lb(100 - p)}{100}$$

$$= l\sqrt{\frac{(100 - p)}{100}} \times b\sqrt{\frac{(100 - p)}{100}}$$

Length of cargo = lc = $l\sqrt{(100 - p)/100}$

Breadth of cargo = bc = $b\sqrt{(100 - p)/100}$

Here lc = $25\sqrt{0.7}$ and bc = $18\sqrt{0.7}$
So lc = 20.917 m and bc = 15.060 m

$$\text{I*CL intact WP area} = \frac{LB^3}{12} - \frac{lb^3}{12} + \frac{lc(bc^3)}{12}$$

$$= [150(18^3)-25(18^3)+20.917(15.06^3)]/12$$

I*CL intact WP area = 66703.784 m^4.

BM = I/V = 66703.784/13500 = 4.941 m
In this cse, KB = new draft/2 = 2.632 m
KM after bilging .... = 7.573 m
KG .... = 4.000 m
GM after bilging .... = 3.573 m

Example 3: A box-shaped vessel 220 x 36 m is afloat in SW at an even keel draft of 10 m. KG = 12 m. An empty DB tank 1.8 m high, 20 m long & 18 m wide, situated centrally, is bilged. Find the GM.

$$S = \frac{\text{buoyancy vol lost}}{\text{intact WP area}} = \frac{20(18)1.8}{220 \times 36} = \frac{648}{7920}$$

New draft = 10.0 + 0.082 = 10.082 metres

$$BM = \frac{I*CL}{V} = \frac{LB^3}{12V} = \frac{220\ (36^3)}{12(79200)} = 10.800\ m$$

Note: Here new KB is NOT half new draft.

Taking moments of volume about the keel:
Final V(final KB) = original V(its KB) - v lost (its KB) + v regained (its KB).

79200(KB) =79200(5)-648(0.9)+648(10.041)

Note: KB of vol regained = old draft + $\frac{S}{2}$

New KB = 5.075 metres.

KM = KB + BM = 5.075 + 10.800 = 15.875 m
GM = KM - KG = 15.875 - 12.000 = 3.875 m

Example 4: A box-shaped vessel 160 x 22 m floats at 6 m SW draft. Its DB tanks are 1 m high. A hold amidships 26 m long and 22 m wide gets bilged. Find the GM if permeability = 40% and KG = 9 m.

$$S = \frac{\text{volume lost}}{\text{intact WP area}} = \frac{26(22)5(40/100)}{160(22)-26(40/100)22}$$

Sinkage = 1144/3291.2 = 0.348 metres
New draft = 6.000 + 0.348 = 6.348 metres

$$lc = l\sqrt{(100 - p)/100} = 26\sqrt{0.6} = 20.140\ m$$

$$bc = b\sqrt{(100 - p)/100} = 22\sqrt{0.6} = 17.041\ m$$

$$I*CL \text{ intact WP area} = \frac{LB^3}{12} - \frac{lb^3}{12} + \frac{lc(bc^3)}{12}$$

$$= [160(22^3)-26(22^3)+20.14(17.041^3)]/12$$

I*CL intact WP area = 127208.122 m^4.

$$BM = \frac{I*CL}{V} = \frac{127208.122}{21120} = 6.023\ \text{metres.}$$

Note: Here new KB is NOT half new draft.

Taking moments of volume about the keel:
Final V(final KB) = original V(its KB) - v lost (its KB) + v regained (its KB).

21120(KB)=21120(3)-1144(3.5)+1144(6.174)

Note: KB of vol regained = old draft + $\frac{S}{2}$

New KB = 3.145 metres.

KM = KB + BM = 3.145 + 6.023 = 9.168 m
GM = KM - KG = 9.168 - 9.000 = 0.168 m

Example 5:

A box-shaped vessel 100 m long and 25 m wide floats at 5 m SW draft. KG = 10 m. A DB tank amidships 20 m long, 25 m wide and 1.8 m high, full of SW, gets bilged. Find the GM before and after bilging.

Before bilging KB = d/2 = 2.5 m

$$BM = \frac{I}{V} = \frac{LB^3}{12V} = \frac{100\ (25^3)}{12(12500)} = 10.417\ m$$

KM = KB + BM = 2.500 + 10.417 = 12.917 m
GM = KM - KG = 12.917 - 10.00 = 2.917 m

Note: After bilging, the SW in the DB is no longer part of the ship. First assume that the SW was pumped out and calculate the new draft, KG & W. Then, using this new data, the empty DB tank may be bilged and the usual calculation made.

W =LBd(1.025)=100(25)5(1.025)= 12812.5 t
w =lbh(1.025)=20(25)1.8(1.025) = 922.5 t

Remarks	Weight	KG	Moment
Ship	12812.5	10.0	128125.00
SW	- 922.5	00.9	830.25
Final	11890		127294.75

Final KG = 127294.75 ÷ 11890 = 10.706 m.

New draft = 11890/(100)25(1.025) = 4.640

After pumping out

W = 11890 t, V = 11600 m^3, d = 4.640 m
KB = 2.320 m, KG = 10.706 m.

After bilging

$$S = \frac{\text{volume of lost buoyancy}}{\text{intact water-plane area}} = \frac{900}{2500} = 0.36$$

New draft = 4.640 + 0.360 = 5.000 metres

Note: Here new KB is NOT half new draft.

Taking moments of volume about the keel:
Final V(final KB) = original V(its KB) - v lost (its KB) + v regained (its KB).

11600(KB)=11600(2.32)-900(0.9)+900(4.82)

Note: KB of vol regained = old draft+S/2

New KB = 2.624 metres. I*CL is unchanged

BM = I/V = 130208.333 ÷ 11600 = 11.225 m

KM = KB + BM = 2.624 + 11.225 = 13.849 m
GM = KM - KG = 13.849 - 10.706 = 3.143 m

Exercise 30
Bilging amidships compartment (KM)

1 A box-shaped vessel 110 m long & 16 m wide floats in SW at 4 m even keel draft. An empty central compartment 16 m long & 10 m wide is bilged. Find the KM before and after bilging.

2 A box-shaped vessel 140 m long & 20 m wide floats in FW at 7 m even keel draft. KG = 8 m. An empty central compartment, 24 m long and 20 m wide, gets bilged. Find the GM before and after bilging.

3 A box-shaped vessel 150 m long & 25 m wide floats in SW at 6 m even keel draft. KG = 10 m. An empty amidships compartment on the centre line, 25 m long & 18 m wide, has a WT flat 2 m high. Find the GM before and after it is bilged below this WT flat.

4 A box-shaped vessel 200 m long & 26 m wide floats in SW at 8 m even keel draft. KG = 9 m. An empty amidships compartment, 28 m long and 26 m wide, has a WT flat 1.6 m above the keel. Find the GM before and after it is bilged above this flat.

5 A box-shaped vessel 210 m long and 25 m wide floats in SW at 10 m draft fwd and aft. KG is 10.6 m. An empty amidships compartment 30 m long and 25 m wide has a watertight flat 10.5 m above the keel. Find the GM if this compartment is bilged.

6 Rework question 3 given that the compartment, before bilging, was half full of HFO of RD 0.95. No other tanks on the ship were slack. (FSC to be allowed where applicable.)

7 Rework question 2 given that p = 40%.

8 Rework question 4 given that the compartment was full of coal of SF 1.25 & RD 1.3, other data unchanged.

9 Ship as in question 1. The bilged compartment originally had SW ballast in it to a sounding of 6 m. KG = 6 m. All other particulars as before. Find the GM before and after bilging.

10 Rework question 5, if p = 50%.

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A N S W E R S

Exercise 15 (page 8): (1) 11.681 m; 3.681 m (2) 3.333m (3) 8.167m (4) SW 10 m; FW 9.954 m (5) 0.71m (6) 2.375° or 2°22.5' (7) 4.899 m @ 5m draft (8) 10.666m (9)(a) 2.95 m (b) 5.60 m (10) 1.6m (11) 4.852m (12) 5.198m (13) 0.75 m & 3.5m (14) 0.583 & 1.5m (15) No! GM -0.024 m

Exercise 16 (page 18): (1) 20m^2 (2) 251.083m^2 (3) By Rule 1: 64.8 m^2 and by Rule 2: 64.65m^2 (4) By Rules 1 & 2: 149.75 m^2; by Rules 1 & 3 149.701 m^2 (5) (a) 1849.625 m^2 (b) 0.727 (c) 18.959 t/cm (6) By Rules 1 and 2: 299.438 m^2; by Rules 1 and 3: 299.2 m^2 (7) (i) 4 m^2 (ii) 6.28 litres (8) (a) 10.839 t/cm (b) 0.691 (9)(a) 1483.2 m^2 (b) 11.2cm (10) 1053.113 m^2.

Exercise 17 (page 22) (1)2324.583m^3 23.83t/cm (2) 2127.5m^3 (3) Rules 1 & 3: 7332.2t; Rules 1 & 2: 7317.6t (4) 58.4t (5) 35303.7t 58.55t/cm

Exercise 18 (page 33): (1) 1057.5 m^2; AF 40 m (2) (a) 62.8 m^2 (b) 3.227 m (c) 593.942 t. (3) By Rule 1: 198.533 m^2, 7.546 m; By Rule 2 198.550 m^2; 7.549 m (4) 2.322 m; 5227.5 t (5) 12113.3 t; KB 3.173 m (6) 299.288 m^2; GC 12.028 m from forward (7) 3.253 m; 11845.6 t (8) 31282.1 t; 2.552 m (9) COF 18.974 m from aft (10) 1886.667 m^2; AF 89.668 m (11) 1866m^2 HF 0.383 m aft (12) 616.4 m^2; AF 43.091 m (13) 2233.875 m^3; GC 11.179 m from aft (14) 4363.9 t; AB 47.255 m (15) By Rules 1 and 2: 12.983 m^2; GC 3.751 m from bottom and 1.308 m from port (16) 43.5 m^2; GC 1.638m from bottom (17) 30.5 t; GC 5.705 m from aft (18) Rules 1 & 3: 299.325 m^2; GC 12.028 m from fwd; Rules 1 & 2 as in Q6: 299.288 m^2; 12.028 m from fwd (19) 1820.438 m^2; as per Q5/Ex16: 1849.625 m^2 (20)(a) 1.181% low (b) 0.435% low.

Exercise 19 (page 42): (1) 19.11° or 19° 06' (2) -0.200 metre (3) 141 t (4) 5.158 metres (5) No! Angle of loll = 37.8° or 37° 48' (6) Less than 0.2113 or more than 0.7887.

Exercise 20 (page 57): (1) 1.440 m (2) 20° (3) 4.7m @ 31° (4) 0 - 86° (5) 190800tm @ 35°

Exercise 21 (page 65): (1) 2.53 metres at 40° (2) 0.95 metre at 49° (3) 6.17 metres @ 42.5° (4) 33° and 80° (5) 30°.

Exercise 22 (page 79): (1) F:4.104 A:5.104 m (2) 126.9 tonnes (3) F:8.304 A: 9.468m (4) F:10.126 A:10.426m (5) F:8.480 A:10.320m (6) F: 9.783 A:10.183m (7) F:8.262 A: 9.431m (8) 735.1 tonnes in No:1, 82.4 tonnes in No:4 (9) Hydrostatic draft 9.10 m; 943.2 t in No:1 806.8 tonnes in No:4 hold; F:8.550 A:10.550 m (10) HF 3 metres aft (11) HF 2 metres fwd (12) 12.630 m fwd of COF; F:7.704 m A:8.400 m (13) 13.85m fwd of COF (14) 24.82m abaft COF F:9.600 A:10.965 m (15) 161t; F:6.141 A:6.7m (16) 388.5t No:2, 331.5t No:4; F:7.793 A:9.0m (17) 506.3 t from No:2 and 743.70 t from No:4 (18) 62.50 tonnes; F:8.677 A:9.677 metres (19) 271.2 tonnes; F:8.142 A:8.600 metres (20) 199.9t from AP to FP; F:8.822 A:9.122 m.

Exercise 23 (page 105) (1) F:4.884 A:6.097 m (2) F:5.534 A:5.490 m (3) F:4.620 A:5.688 m (4) F:4.711 A:4.678 m (5) F:4.059 A:6.822 m (6) F:4.730 A:6.710 m (7) F:6.532 A:6.905 m (8) F:3.823 A:4.583 m (9) F:4.929 A:6.429 m 1183.4 t in No:2, 816.6t in No:4 (10) 760.4 t in No:2, 1039.6 t in No:5; F:4.764 A:5.764 m

(11) 1060.20 t in No:1, 2068.40 t in No:4 (12) 727.80 t from No:1, 616.20 t from No:5 (13) AG of cargo 85.553 m; F:3.543 A:5.600 m (14) AG of cargo 56.817 m; F:4.300 A:4.765 m (15) AG of cargo 56.883 m; F:4.900 A:3.742 m (16) AG of cargo 86.211 m; F:3.103 A:4.000 m (17) 1245.800 t of cargo; F:3.569 A:6.000 m (18) AG of cargo 73.050 m; F:4.800 A:5.675 m (19) 284.5 tonnes in No:1 hold, 715.5 tonnes in No:5 hold; Final drafts F:5.412 A:6.412 m (20) 674.3 t from No:2, 825.7 t from No:4; Final drafts F:5.174 m A:5.974 m.

Exercise 24 (page 128) (1) F:12.979 A:14.026m (2) F:14.827 A:15.003m (3) F:13.977 A:14.196m (4) F:10.784 A:11.912m (5) F:14.797 A:15.086m (6) F:10.949 A:11.949m (7) F:12.930 A:12.189m (8) F:10.436 A:12.779m (9) F:14.286 A:14.686m No:3 3388.5t, No:7 3611.5t (10) 4934.3t from No:3, 1065.7 t from No:8; F:13.025 A:14.025 m (11) 7589.4 t in No:1, 7985.6 t in No:9 hold (12) 2508.9 t from No:3, 4504 t from No:7 (13) Cargo HG 31.333m fwd, F:11.382 A:13.600m (14) Cargo HG 32.329m aft, F:12.500 A:13.054m (15) Cargo HG 32.424m fwd, F:12.024 A:12.900m (16) Cargo HG 33.071m aft, F:12.400 A:13.408m (17) 3482 t; Final drafts F:11.801 A:13.000m (18) 3706 t; Final drafts F:12.000 A:14.632m (19) 2445.7 t from No:1, 5153.30 t from No:9 (20) 2328.40 t from No:2, 3671.6 t from No:8; Final drafts F:11.321 m A:12.321 m.

Exercise 25 (page 136): (1) 157.70 t to stbd, 200 t fwd (2) 394.7 t to stbd, 928.6 t fwd. (3) 112.3 t to port, 232.7 t fwd (4) 198.9 t to port, 1430.30 t aft (5) 82.60 t to stbd, 266.6 t fwd.

Exercise 26 (page 141): (1) 7.563 metres. (2) 15.964m (3) 2.610m (4) 10.818m (5) 1.222m

Exercise 27 (page 164):
Answers first by formula A then by formula B:

(1)(a) 1.856 or 1.789 m (b) 224.5 or 224.5 tm
(2)(a) 1.771 or 1.704 m (b) 214.3 or 213.9 tm
(3) 143 cm or 138 cm (4) 92.5 cm or 88.3 cm
(5) 0.868 or 0.730 m (6) 0.753 m or 0.615 m
(7)(a) 1.357 m (b) 0.369 or 0.354 m (c) 1.567 or more. (8)(a) 1.357 m (b) 0.264 or 0.249 m (c) 1.490 m or more (9) 0.844 m or 0.810 m
(10) 0.741 or 0.707 m (11) 1.618 or 1.428 m
(12) FSC 0.106 m - ignored: shores in place.
(13) 0.531 m or 0.506 m (14) 0.429 or 0.404 m
(15)(a) 484.9 t (b) 114 m fwd of A (c) 0.467 or 0.445 m (d) 0.579 m (16)(a) 407.7 tonnes (b) F:3.600 m A:6.076 m (c) 0.564 or 0.535 m
(17)(a) 352.4 tonnes (b) F:4.359 m A:7.349 m (c) 0.328 or 0.316 m (18)(a) 1.188 or 1.145 m (b) -0.023 m or -0.016 m after neglecting FSC
(19) 2.571 or 2.459m (20)(a) 0.742 or 0.694 m (b) 4.180m (hydraft at the critical instant).

Exercise 28 (page 174): (1) 8.889m (2) 8.120m (3) 8.722 m (4) 8.889m (5) 8.800m (6) 8.889 m (7) 8.850 m.

Exercise 29 (page 179): (1) 8.163m (2) 8.000m (3) 8.201 m (4) 8.421m (5) 8.320m (6) 8.556 m, (7) 8.680 m.

Exercise 30 (page 185):
(1) (a) 7.333 metres (b) 7.344 metres
(2) (a) 0.262 metres (b) 0.170 metres
(3) (a) 1.681 metres (b) 1.886 metres
(4) (a) 2.042 m (b) 1.473m (5) 0.433 metres
(6) (a) 1.181 m fluid (b) 1.815 m (no FSC)
(7) (a) 0.262 metres (b) -0.003 metres
(8) (a) 2.042 metres (b) 1.575 metres
(9) (a) 1.144 m fluid (b) 1.382 m (no FSC)
(10) Final GM (after bilging) = -0.008 metre.

Appendix I

HYDROSTATIC TABLE OF M.V. 'VIJAY'

DRAFT	W t in SW	TPC t cm^{-1}	MCTC tm cm^{-1}	AB m	AF m	KB m	KM_T m	KM_L m
3.0	5580	20.88	146.9	71.956	72.127	1.605	11.470	397.9
3.2	6000	21.07	149.6	71.968	72.141	1.710	11.030	375.8
3.4	6423	21.22	152.1	71.979	72.141	1.823	10.630	356.1
3.6	6849	21.36	154.1	71.990	72.141	1.931	10.274	339.1
3.8	7277	21.48	156.0	71.998	72.141	2.039	9.950	323.6
4.0	7708	21.60	157.8	72.008	72.127	2.147	9.660	309.9
4.2	8141	21.70	159.6	72.012	72.099	2.256	9.406	296.7
4.4	8576	21.80	161.3	72.015	72.056	2.367	9.182	285.0
4.6	9013	21.89	162.7	72.017	72.013	2.473	8.992	274.1
4.8	9451	21.97	164.3	72.016	71.970	2.576	8.828	263.9
5.0	9891	22.06	165.7	72.014	71.913	2.685	8.686	254.3
5.2	10333	22.14	167.1	72.011	71.842	2.789	8.566	245.4
5.4	10777	22.22	168.5	72.003	71.757	2.892	8.460	237.5
5.6	11223	22.30	169.9	71.990	71.671	2.998	8.374	229.9
5.8	11672	22.37	171.3	71.977	71.586	3.102	8.298	223.0
6.0	12122	22.45	172.9	71.960	71.472	3.205	8.234	217.2
6.2	12575	22.54	174.6	71.939	71.329	3.309	8.180	211.6
6.4	13030	22.64	176.4	71.914	71.172	3.413	8.136	206.6
6.6	13486	22.73	178.2	71.887	71.001	3.516	8.100	202.4
6.8	13943	22.83	180.3	71.856	70.802	3.620	8.076	198.4
7.0	14402	22.93	182.7	71.819	70.602	3.725	8.054	194.6

W	displacement	Load W	19943 t	LOA	150.00 m
A	after perpendicular	Light W	6000 t	LBP	140.00 m
K	keel	DWT	13943 t	GRT	10,000 Tons
SW	salt water of RD 1.025			NRT	5576 Tons

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Appendix II

Hydrostatic particulars of m.v. VICTORY

d	W sw	TPC	MCTC	HB	HF	KB	KM_T	KM_L
11.00	70941	68.58	1083.0	5.37F	1.96F	5.64	13.24	366
11.20	72315	68.74	1091.3	5.30F	1.72F	5.75	13.22	362
11.40	73693	68.91	1099.5	5.23F	1.47F	5.85	13.20	358
11.60	75074	69.07	1107.8	5.16F	1.22F	5.95	13.18	354
11.80	76458	69.24	1115.9	5.09F	0.98F	6.06	13.17	351
12.00	77845	69.40	1124.0	5.02F	0.74F	6.16	13.16	347
12.20	79237	69.56	1131.3	4.94F	0.53F	6.26	13.16	343
12.40	80633	69.72	1138.4	4.87F	0.32F	6.37	13.16	340
12.60	82032	69.88	1145.5	4.79F	0.12F	6.47	13.16	336
12.80	83434	70.03	1152.4	4.71F	0.08A	6.58	13.17	333
13.00	84839	70.19	1159.1	4.62F	0.27A	6.68	13.18	329
13.20	86246	70.34	1165.8	4.54F	0.46A	6.79	13.19	326
13.40	87657	70.49	1172.3	4.46F	0.64A	6.89	13.21	323
13.60	89070	70.63	1178.8	4.38F	0.81A	7.00	13.22	320
13.80	90485	70.78	1185.1	4.29F	0.98A	7.10	13.25	316
14.00	91904	70.92	1191.3	4.21F	1.14A	7.21	13.27	313
14.20	93324	71.06	1197.4	4.13F	1.29A	7.31	13.30	310
14.40	94747	71.19	1203.3	4.04F	1.44A	7.42	13.33	308
14.60	96173	71.32	1209.2	3.96F	1.58A	7.52	13.36	305
14.80	97600	71.45	1215.0	3.88F	1.72A	7.63	13.39	302
15.00	99030	71.57	1220.7	3.79F	1.84A	7.73	13.43	299

d = draft in metres, K = keel, H = amidships.

LOA 245 m, LBP 236 m, GRT 42000 T, NRT 28000 T

Light W 14000 t, Load W 98000 t, Deadweight 84000 t