65. *M.V. 'Hindship' is floating at a draft of F 5.62 m, A 6.78 m. A wt. of 220 tonnes is then shifted from No. 3 TD to a position 112.5 metres ford of AP. Calculate the final drafts F & A.*

Original drafts	F 5.62 m A 6.78 m M 6.20 m	trim 1.16 m by stern

LCF for mean draft 6.20 m = 72.333 m

After draft = 6.780 m

Corrn. to After draft from table 'A' = (–) 0.586 m

Hydrostatic draft = 6.194 m

For Hydrostatic draft 6.194 m. LCF = 72.338 m

MCTC = 175.600 mt

Lcg of No. 3 TD = 80.79 m ford of AP

Cargo shifted to = 112.50 m ford of AP

Distance cargo shifted = 112.50 – 80.79 = 31.71 m ford

Moment of shift = 220 × 31.71 = 6976 mt ford

$$\text{Total trim caused by shift} = \frac{\text{Moment}}{\text{MCTC} \times 100} = \frac{6976}{175.6 \times 100}$$

= 0.397 m by Head

$$\text{After trim} = \frac{\text{Total trim} \times \text{LCF}}{\text{LBP}} = \frac{0.397 \times 72.338}{143.16} = 0.201 \text{ m}$$

Ford trim = Total trim – After trim = 0.397 – 0.201 = 0.196 m

	F	A
Original draft	5.620	6.780
trim due to shift	(+) 0.196	(–) 0.201
Final drafts	**F 5.816 m**	**A 6.579 m**

NB. 1) It should be noted that the trim calculated is the change in trim due to shift of cargo and not the total trim of the vessel, as is done in earlier trim problems. Change in trim is therefore applied to the original drafts F & A and **not** to the Hydrostatic drafts.

2) This question can also be worked by finding the initial LCG of the ship as shown in the next problem. Since however the displacement remains unchanged in this problem, the Hydrostatic particulars also remain unchanged and therefore the method shown above is simpler.

66. *M. V. 'Hindship' floating at a draft of F 5.70 m, A 7.60 m, discharges the entire cargo from No. 4 TD which was full. The stowage factor of the cargo in No. 4 TD was 2/3 cubic metre per tonne. Calculate the drafts F & A, after discharge.*

Original drafts F 5.70 m, A 7.60 m } trim 1.90 m by stern.
M 6.65 m

LCF for mean draft 6.65 m	=	71.955 m
After draft	=	7.600 m
Corrn. to After draft from table 'A'	=	(–) 0.955 m
Hydrostatic draft	=	6.645 m
For Hydrostatic draft 6.645 m, displacement	=	13486 t
LCB	=	72.882 m
MCTC	=	179.77 mt

$$\text{Total trim } t = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$1.90 = \frac{72.882 - LCG}{179.77 \times 100} \times 13486$$

$$1.90 \times 179.77 \times 100 = (72.882 - LCG) \times 13486$$

$$= 72.882 \times 13486 - 13486 \times LCG$$

$$13486 \times LCG = (72.882 \times 13486) - (1.90 \times 179.77 \times 100)$$

$$LCG = \frac{(72.882 \times 13486) - (1.90 \times 179.77 \times 100)}{13486} = 70.349 \text{ m}$$

$$\text{Weight of cargo discharged} = \frac{\text{Volume}}{\text{S.F.}} = \frac{507.7}{2/3} = \frac{507.7 \times 3}{2} = 761.6 \text{ tonnes}$$

	Weights (t)	*LCG* (m)	*L. Moments* (mt)
Original displ.	13486	70.349	948726.6
No. 4 TD	(–) 761.6	57.44	(–) 43746.3
	Final Wt. 12724.4	Final L. Moment =	904980.3

$$\text{Final LCG} = \frac{904980.3}{12724.4} = 71.121 \text{ m}$$

For final displ. 12724.4 t	LCB	=	72.927 m
	Hyd. draft	=	6.311 m
	MCTC	=	176.7 mt
	LCF	=	72.246 m

$$\text{Total trim } t = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$= \frac{72.927 - 71.121}{176.7 \times 100} \times 12724.4$$

$$\text{Total trim } t = 1.301 \text{ m.}$$

$$t_a = \frac{t \times LCF}{LBP} = \frac{1.301 \times 72.246}{143.16}$$

$$= 0.657 \text{ m.}$$

$$t_f = t - t_a = 1.301 - 0.657 = 0.644$$

	F	A
Hydrostatic draft	6.311	6.311
trim	(–) 0.644	(+) 0.657
Final Drafts	**F 5.667 m**	**A 6.968 m**

67. *M.V. 'Hindship' at a draft of F 7.66 m, A 7.82 m, loads 220 t in No. 2 TD and consumes 30 t of FW from the TD drinking water tank (P). Calculate the final drafts F & A.*

Original drafts F 7.66 m, A 7.82 m } trim 0.16 m by stern
M 7.74 m

LCF for mean draft 7.74 m	=	70.840 m
Corrn. to After draft (Table 'A')	=	0.079 m
After draft	=	7.820 m
Hydrostatic draft	=	7.741 m

For hydrostatic draft 7.741 m,

Displacement	=	16023 t
MCTC	=	193.774 mt
LCB	=	72.655 m

$$\text{Total trim } t = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$(LCB - LCG) = \frac{t \times MCTC \times 100}{\text{Displacement}} = \frac{0.16 \times 193.774 \times 100}{16023}$$

$$= 0.193 \text{ m}$$

LCB = 72.655 m

Original LCG = 72.462 m

	Weights (t)	LCG (m)	L. Moments (mt)
Original displacement	16023	72.462	1161058.6
Loaded 2 TD	(+) 220	103.91	(+) 22860.2
FW consumed	(–) 30	5.86	(–) 175.8
Final displacement	16213	Final L. Moments	1183743.0

$$\text{Final LCG} = \frac{1183743}{16213} = 73.012 \text{ m}$$

For displacement 16213 t,

Hydrostatic draft	=	7.822 m
MCTC	=	194.907 mt
LCB	=	72.635 m
LCF	=	70.760 m

$$\text{Total trim } t = \frac{(LCB - LCG)}{MCTC \times 100} \times \text{Displacement}$$

$$= \frac{(72.635 - 73.012)}{194.907 \times 100} \times 16213$$

= (–) 0.314 m (Note – ve sign indicates trim by the head)

$$t_a = \frac{t \times LCF}{LBP} = \frac{0.314 \times 70.76}{143.16} = (-)\ 0.155 \text{ m}$$

$$t_f = t - t_a = -0.314 - (-0.155) = (-)\ 0.159 \text{ m}$$

Draft (Fwd) = Hydrostatic draft – t_f

= 7.822 – (–0.159 m) = 7.981 m

Draft (Aft) = Hydrostatic draft + t_a

= 7.822 + (–0.155 m) = 7.667 m

Final drafts F 7.981 m. A 7.667 m.

EFFECT ON DRAFT FORE & AFT DUE TO LOADING/ DISCHARGING/SHIFTING IN DIFFERENT DENSITIES

(Before attempting problems on this topic, the student is advised to carefully recapitulate Qns. 3 and 4).

68. *M.V. 'Hindship' in a river port of water of RD 1.014 is at a displacement of 10230 t, GM (Fluid) 0.82 m, FSC 0.077 m, LCG 71.62 m. She loads 470 t, LCG 60.20 m Kg 9.8 m. 150 t of water ballast is run into No. 1 DB tank. Find her final drafts F & A and GM (Fluid).*

Initial displacement = 10230 t

Equivalent weight in SW = $\frac{10230 \times 1.025}{1.014}$ = 10340.9 t

GM (Fluid) = 0.820 m

FSC = 0.077 m

GM (Solid) = 0.897 m

KM for displ. 10230 t in density 1.014 = 8.744 m

KG = 7.847 m

Initial FSM = 0.077 × 10230 = 787.7 mt

FSM in 1 DB tank = 419 × 1.014 = 424.9 mt

Final FSM = 1212.6 mt

	Weights (t)	*KG* (m)	*V. Moments* (mt)	*LCG* (m)	*L. Moments* (mt)
Original displ.	10230	7.847	80274.8	71.62	732672.6
Loads	(+) 470	9.80	(+) 4660.0	60.20	(+) 28294.0
No. 1 DB tank	(+) 150	1.14	(+) 171.0	124.63	(+) 18694.5

Final Wt. = 10850 Final V. Mmts. = 85051.8 Final L. Mmts. = 779661.1

Final KG : $\frac{85051.8}{10850}$ = 7.839 m

Final LCG : $\frac{779661.1}{10850}$ = 71.858 m

Final FSC : $\frac{1212.6}{10850}$ = 0.112 m.

For displacement 10850 t in density 1.014, equivalent Weight in SW

= $\frac{10850 \times 1.025}{1.014}$ = 10967.7 t

Hydrostatic draft = 5.532 m (From hydrostatic tables for displ. 10967.7 t)

MCTC = 168.692 mt (MCTC for displ. 10967.7 = 170.522

$\frac{170.522 \times 1.014}{1.025}$ = 168.692)

LCB = 72.996 m (From hydrostatic tables for displ. 10967.7 t)

LCF = 72.704 m (" " ")

KM = 8.607 m (" " ")

Total trim 't' = $\frac{(LCB - LCG)}{MCTC \times 100}$ × Displacement

= $\frac{(72.996 - 71.858)}{168.692 \times 100}$ × 10850 = 0.732 m.

t_a = $\frac{t \times LCF}{LBP}$ = $\frac{0.732 \times 72.704}{143.16}$ = 0.372 m.

t_f = $t - t_a$ = 0.732 − 0.372 = 0.360 m.

	F	A
Final Hydrostatic draft	5.532 m	5.532 m
trim	(–) 0.360 m	(+) 0.372 m
Final draft	**5.172 m**	**5.904 m**

Final KM = 8.607 m

Final KG = 7.839 m

Final GM (Solid) = 0.768 m

FSC = 0.112 m

Final GM (Fluid) = 0.656 m

69. *M. V. 'Hindship' at a draft of F 5.38 m, A 6.17 m, has GM (Fluid) 0.83 m and FSC 0.092 m. She discharges 430 t from No. 3 TD, VCg 10.2, LCg 78.5 m and loads 250 t in No. 5 LTD. 300 t of fuel oil was received equally distributed in No. 2 DB tanks P & S. Calculate her final drafts F & A and GM (Fluid).*

Original draft F 5.38 m, A 6.17 m } trim 0.79 m by stern.
M 5.775 m

LCF for mean draft 5.775 m	=	72.601 m
After draft	=	6.170 m
Corrn. from table 'A'	=	0.400 m
Original hydrostatic draft	=	5.770 m
Original displacement	=	11501.7 t
LCB	=	72.981 m
MCTC	=	172.19 mt
KM	=	8.513 m
Original GM (Fluid)	=	0.830 m
FSC	=	0.092 m
Original GM (Solid)	=	0.922 m
Original KM	=	8.513 m
Original KG	=	7.591 m

$$t = \frac{(LCB - LCG)}{MCTC \times 100} \times \text{Displacement}$$

$$0.79 = \frac{(LCB - LCG)}{172.19 \times 100} \times 11501.7$$

$$(LCB - LCG) = \frac{0.79 \times 172.19 \times 100}{11501.7} = 1.183 \text{ m}$$

LCB	=	72.981 m
Original LCG	=	71.798 m

	Weight (t)	KG (m)	V. Moments (mt)	LCG (m)	L. Moments (mt)
Original displ.	11501.7	7.591	87309.4	71.798	825799.1
Disch. No. 3 TD	(–) 430.0	10.2	(–) 4386.0	78.5	(–) 33755.0
Loads No. 5 LTD	(+) 250.0	10.69	(+) 2672.5	17.24	(+) 4310.0
Fuel Oil					
No. 2 DB Tk.	(+) 300.0	0.65	(+) 195.0	102.2	(+) 30660.0

Final Wt. 11621.7 Final V. Mmts. 85790.9 Final L. Mmts. 827014.1

$$\text{Final KG} = \frac{85790.9}{11621.7} = 7.382 \text{ m}$$

$$\text{Final LCG} = \frac{827014.1}{11621.7} = 71.161 \text{ m}$$

Original FSM = 0.092 × 11501.7	=	1058.2 mt
FSM in No. 2 (P & S) = 1436 × 0.95	=	1364.2 mt
Final FSM	=	2422.4 mt
Final FSC = $\frac{2422.4}{11621.7}$	=	0.208 m
For final displ. 11621.7 t Hydrodraft	=	5.823 m
MCTC	=	172.587 mt
LCB	=	72.977 m
LCF	=	72.577 m
KM	=	8.495 m
Final KG	=	7.382 m
Final GM (Solid)	=	1.113 m
FSC	=	0.208 m
Final GM (Fluid)	=	**0.905 m**

$$\text{Total trim 't'} = \frac{(LCB - LCG)}{MCTC \times 100} \times \text{Displ.} = \frac{(72.977 - 71.161)}{172.587 \times 100} \times 1621.7$$

$$= 1.223 \text{ m}$$

$$\text{After trim, } t_a = \frac{t \times LCF}{LBP} = \frac{1.223 \times 72.577}{143.16} = 0.620 \text{ m}$$

$t_f = t - t_a = 1.223 - 0.620 = 0.603$ m

Hydro. draft	5.823	5.823
trim	(–) 0.603	(+) 0.620
Final draft	**F = 5.220 m**	**A = 6.443 m**

70. *M. V. 'Hindship' berthed in a dock where RD of water is 1.007, at a draft of 7.87 m, A 8.32 m, KG 7.45 m, FSM 970 mt. She discharged 410 t of cargo from 2 TD. A 60 t case is shifted from deck, Kg 14.7 m, Lcg 58.6 m. to No 2 Hold. 110 t of water Kg 2.77 m, Lcg 16.23 m, was received in No. 8 (P x S) tanks, filling them completely. Calculate the draft F & A at which she should sail from the deck. Also calculate her sailing GM (Fluid) if additional FSE was created in No. 3 DB tank (centre) which contained HFO.*

Initial draft F 7.87 m, A 8.32 m } trim = 0.45 m by stern.
M 8.095 m LCF = 70.507 m

Corrn. to After draft from table 'A'	= 0.222 m
After draft	= 8.320 m
Hydrostatic draft	= 8.098 m
For hydro, draft 8.098 m in δ 1.007, displ.	= 16574.4 t
MCTC	= 195.281 mt
LCB	= 72.561 m

$$t = \frac{(LCB - LCG)}{MCTC \times 100} \times \text{Displacement}$$

$$(LCB - LCG) = \frac{t \times MCTC \times 100}{\text{Displ.}} = \frac{0.45 \times 195.281 \times 100}{16574.4} = 0.530 \text{ m}$$

LCB = 72.561 m
LCG = 72.031 m

	Weight (t)	*KG* (m)	*V. Moments* (mt)	*LCG* (m)	*L. Moments* (mt)
Initial displacement	16574.4	7.45	123479.3	72.031	1193870.6
Discharge 2 TD	(–) 410	10.72	(–) 4395.2	103.91	(–) 42603.1
Shifted	60	↓ 9.72	(–) 583.2	44.54	(+) 2672.4
No. 8 (P & S)	(+) 110	2.77	(+) 304.7	16.23	(+) 1785.3
	Final Wt. 16274.4		Final V. Mmts. 118805.6		Final L. Mmts. 1155725.2

Original FSM		=	970 mt
No. 8 (P & S)	= 23 × 1.0	= (–)	23 mt

No. 3 (C)	= 1181 × 0.95	=	(+) 1122 mt
Final FSM		=	2069 mt
Final FSC	= $\frac{2069}{16274.4}$	=	0.127 m
Final KG	= $\frac{118805.6}{16274.4}$	=	7.300 m
Final LCG	= $\frac{1155725.2}{16274.4}$	=	71.015 m

For displacment 16274.4 in δ 1.007, Hydro. draft = 7.971 m

MCTC	=	193.529 m
LCB	=	72.596 m
LCF	=	70.622 m
KM	=	8.249 m
Final KG	=	7.300 m
Final GM (Solid)	=	0.949 m
Final FSC	=	0.127 m
Final GM (Fluid)	**=**	**0.822 m**

$$\text{Total trim 't'} = \frac{(LCB - LCG)}{MCTC \times 100} \times \text{Displacement}$$

$$= \frac{(72.597 - 71.015)}{193.529 \times 100} \times 16274.4 = 1.330 \text{ m}$$

$$t_a = \frac{t \times LCF}{LBP} = \frac{1.33 \times 70.622}{143.16} = 0.656 \text{ m}$$

$$t_a = t - t_a = 1.330 - 0.656 = 0.674 \text{ m}$$

	F	A
Final hydrostatic draft	7.971	7.971
trim	(–) 0.674	(+) 0.656
Final draft	**F 7.297 m**	**A 8.627 m**

N.B. It should be noed that the Hydrostatic Particulars of M. V. 'Hindship' are given for the EVEN KEEL condition. Thus, if the CB and the CG are brought in the same vertical line at any particular Hydrostatic draft, there will be no trimming moment and the ship will be on an even keel. This argument is used in solving the problems on this topic.

71. *M. V. 'Hindhsip' is floating at a draft of F 7.2 m, A 7.8 m.*

(a) Find, where with respect to AP 200 tonnes of cargo is to be loaded to bring her on an even keel.

(b) If instead of loading as in (a), the even keel condition was to be achieved by shifting cargo from No. 5 Hold to No. 3 Hold, find the amount of cargo to be shifted.

(a) Initial drafts F 7.2 m, A 7.8 m } trim = 0.6 m by stern.
M 7.5 m

LCF for mean draft 7.5 m	=	71.086 m
After draft	=	7.800 m
Corrn. to After draft from table 'A'	=	(–) 0.298 m
Hydrostatic draft	=	7.502 m
For hydrostatic draft 7.502 m. LCB	=	72.714 m
MCTC	=	190.4 mt
Displacement	=	15464 t

$$\text{Total trim} = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

Let x be the original LCG of the ship.

$$\text{Then } 0.6 = \frac{72.714 - x}{190.4 \times 100} \times 15464$$

$$\therefore 0.6 \times 19040 = 15464 \times 72.714 - 15464\,x$$

$$= 1124449.3 - 15464\,x$$

$$x = \frac{1113025.3}{15464} = 71.975 \text{ m}$$

Original LCG	=	71.975 m.
Original displacement	=	15464 tonnes
To load	=	200 tonnes
Final displacement	=	15664 tonnes
LCB for final displacement	=	72.693 m
To be on an even keel, LCB	=	LCG.

Let y be the Lcg of the weight to be loaded

	Weights (t)	*LCG* (m)	*L. Moments* (mt)
Original displacement	15464	71.975	1113025.3
Loaded	200	y	200 y
Final displacement	15664	Final L. Moment	1113025.3 + 200 y.

$$\text{Final LCG} = \frac{1113025.3 + 200\text{ y}}{15664} = 72.693 \text{ (LCG = LCB)}$$

$$200\text{ y} = 15664 \times 72.693 - 1113025.3$$

$$\text{y} = \frac{25637.852}{200} = 128.19 \text{ m}$$

Cargo is to be loaded 128.19 m ford of AP.

(b)	Lcg of No. 3 Hold	=	80.63 m
	Lcg of No. 5 Hold	=	17.31 m
	Distance through which cargo is to be shifted	=	63.32 m
	As in (a) above, Original displacement	=	15464 t
	Original LCB	=	72.714 m
	Original LCG	=	71.975 m

For even keel condition, LCG should equal LCB.

GG_1 required in the ford direction = 72.714 − 71.975 = 0.739 m

$$GG_1 = \frac{\text{w} \times \text{d}}{\text{W}} = \frac{\text{w} \times 63.32}{15464} = 0.739$$

w = 180.478 tonnes

Cargo to be shifted = 180.5 tonnes

72. *M. V. 'Hindship' in Condition No. 10, has to load 800 tonnes of cargo. Space is available in No. 1 TD, 125 metres ford of AP and in No. 3 TD, 80 metres ford of AP. Find the amount of cargo to load in each space to finish the ship on an even keel. State also the final drafts F & A.*

Displacement in Condition No. 10	=	16133 tonnes
Cargo to be loaded	=	800 tonnes
Final displacement	=	16933 tonnes
LCB for displacement 16933 t	=	72.553 m

To achieve even keel condition, LCG should also be 72.553 m, ford of AP. Let 'x' tonnes be loaded in No. 1 and $(800 - x)$ tonnes in No. 3.

	Weigths (t)	*LCG* (m)	*L. Moments* (mt)
Displacement in Condition No. 10	16133	70.289	1133972
No. 1 TD	(+) x	125	(+) $125x$
No. 3 TD	(+) $(800-x)$	80	$(+)64000-80x$

Final Wt = 16933 Final L. Moments = $1197972 + 45x$

$$\text{Final LCG} = \frac{1197972 + 45x}{16933} = 72.553.$$

$$45x = (16933 \times 72.553) - 1197972$$

$$x = \frac{30568}{45} = 679.3 \text{ tonnes.}$$

Cargo to be loaded in No. 1 TD = 679.3 tonnes

Cargo to be loaded in No. 3 TD = 800 – 679.3 = 120.7 tonnes.

Hydrostatic draft for displacement 16933 t = 8.124 m

Since the V/L is on an even keel. **The drafs F & A = 8.124 m**

73. *M.V. 'Hindship' sails in Condition No. 6. On the voyage, she is expected to consume 230 tonnes of fuel from No. 3 DB tank and No. 7 DB tanks. Find the amount to be consumed from each tank to arrive on an even keel.*

Displacement in Condition No. 6	=	19617 t
Fuel consumed	=	230 t
Displacement on arrival	=	19387 t
LCB for displacement 19387 t	=	72.243 m

Let x tonnes be consumed from No. 7 DB tanks and $(230 - x)$ tonnes from No. 3 DB tank.

	Weights (t)	*LCG* (m)	*L. Moments* (mt)
Displacement in Condition No. 6	19617	71.813	1408746
No. 7 DB tank	(–) x	22.97	(–) $22.97x$
No. 3 DB tank	(–) $(230-x)$	80.63	(–) $(18544.9-80.63x)$

Final Weight = 19387 Final L. Moment = $1390201.1 + 57.66x$

$$\text{Final LCG} = \frac{1390201.1 + 57.66x}{19387} = 72.243 \text{ (LCG = LCB)}$$

$$57.66x = (19387 \times 72.243) - 1390201.1$$

$$x = \frac{10373.9}{57.66} = 179.92 \text{ t}$$

Fuel to be consumed from No. 7 DB tanks = 179.92 t

Fuel to be consumed from No. 3 DB tanks = 230–179.92 = 50.08 t

74. *M. V. 'Hindship' arrives in Condition No. 7 and discharges the entire cargo from No. 4 TD. Given, change in LCB due to ballasting is negligible, find the amount of ballast to be run into the A. Pk tank to bring her on an even keel. Also calculate the drafts F & A after ballasting.*

	Weights (t)	*LCG* (m)	*L. Moments* (mt)
Displacement in Condition NO. 7	18529.3	72.340	1340415
No. 4 TD	(–) 296.2	57.680	(–) 17085

Final Wt. = 18233.1 Final L. Moment = 1323330

$$LCG = \frac{1323330}{18233.1} = 72.578 \text{ m}$$

LCB for displacement 18233.1 = 72.394 m

Let 'x' tonnes of ballast be run into A. Pk.

	Weights (t)	*LCG* (m)	*L. Moments* (mt)
Displacement	18233.1	72.578	1323330
Ballast in A Pk	(+) x	3.58	(+) $3.58x$

Final Wt. = 18233.1 + x Final L. Moment 1323330 + $3.58x$

$$\text{Final LCG} = \frac{1323330 + 3.58x}{18233.1 + x} = 72.394 \text{ m}$$

$$1323330 + 3.58x = (18233.1 \times 72.394) + 72.394x$$

$$68.814x = 3363$$

$$x = \frac{3363}{68.814} = 48.87 \text{ t}$$

Ballast to be run into A Pk = 48.87 tonnes (approx).

Though the change in LCB is stated to be negligible, there will in fact be some small change. Therefore the above figure of 48.87 tonnes is approximate.

Displacement after ballasting = 18233.1 + 48.87

= 18281.97 t

Hydrostatic draft for 18281.97 = 8.684 m

Drafts F & A = 8.684 m

75. *M. V. 'Hindship' loading in dock water, RD 1.018 is on an even keel draft of 8.4 m, with a GM (Solid) of 0.45 m. She is to sail on an even keel at her summer draft in SW. Space has been allocated for the following parcels :-*

400 t in No. 2	Kg 11 m	LCg 107 m
350 t in No. 4	Kg 98 m	LCg 53 m
650 t in No. 5 TD	Kg 10 m	LCg 18 m

The remaining cargo is to be loaded in No. 1, Kg 5.5 m, LCg 122 m and No. 5 Hold Kg 6 m, LCg 15 m. Calculate the amount to be loaded in each of these spaces and the final GM (Fluid) of the vessel, if her FSM was 2500 mt.

KM for draft 8.4 m = 8.292 m

Initial GM (Solid) = 0.450 m

Initial KG = 7.842 m

Displacement in SW at draft 8.4 m = 17598 t

$$\text{Displacement at that draft in water RD 1.018} = \frac{17598 \times 1.018}{1.025} = 17477.8\text{t}$$

Displ. at summer draft in SW = 19617.0 t

Total cargo to load = 2139.2 t

Weight of cargo for which space has been allotted = 1400 t

Wt. of cargo to be loaded in No. 1 and 5 Hold = 739.2 t

Let x tonnes be loaded in No. 1 and (739.2 – x) t in No. 5 Hold.

As she is on an even keel, initial LCG = LCB for draft 8.4 m, i.e. 72.473 m.

As she should finish on an even keel,

Final LCG = LCB for draft 9.233 m = 72.212

	Weights (t)	*LCG* (m)	*L. Moments* (mt)
Initial displacement	17477.8	72.473	1266668.5
No. 2	400.0	107.0	42800.0
No. 4	350.0	53.0	18550.0
No. 5 TD	650.0	18.0	11700.0
No. 1 H	x	122.0	122 x
No. 5 H	739.2–x	15.0	11088–15 x

Final Wt. 19617.0 Final L. Mmts. 1350806.5 + 107 x

$$\text{Final LCG} = 72.212 = \frac{1350806.5 + 107x}{19617}$$

$$x = \frac{(19617 \times 72.212) - 1350806.5}{107} = 614.7\text{t}$$

Cargo to be loaded in No. 1 = 614.7 t

Cargo to be loaded in No. 5 H = 739.2 − 614.7 = 124.5 t

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Initial displacement	17477.8	7.842	137060.9
No. 2	400.0	11.0	4400.0
No. 4	350.0	9.8	3430.0
No. 5 TD	650.0	10.0	6500.0
No. 1	614.7	5.5	3380.9
No. 5 H	124.5	6.0	747.0
Final Wt.	19617.0	Final V. Moment	155518.8

Final KM = 8.435 m

$$\text{Final KG} = \frac{155518}{19617} = 7.928 \text{ m}$$

GM (Solid) = 0.507 m

$$\text{FSC} = \frac{2500}{19617} = 0.127 \text{ m}$$

Final GM (Fluid) = 0.380 m

76. *M.V. 'Hindship' in Condition No. 2, has to load 220 tonnes of cargo. Where should this be loaded to keep her after draft unchanged?*

Displacement in Condition No. 2	= 7799 tonnes
Cargo to load	= 220 tonnes
Final displacement	= 8019 tonnes
For displacement 8019 t. Hydrostatic draft	= 4.191 m
MCTC	= 160.621 mt
LCB	= 73.014 m
LCF	= 73.104 m

Hydrostatic draft = 4.191 m

After draft reqd. = 6.012 m

(Same as in Condition No. 2)

∴ After trim reqd. = 1.821 m

$$\text{Total trim reqd.} = \frac{\text{LBP} \times t_a}{\text{LCF}} = \frac{143.16 \times 1.821}{73.104} = 3.566 \text{ m}$$

Since the trim reqd. is by the stern, LCB is > LCG.

$$\text{Total trim } t = \frac{(\text{LCB} - \text{LCG}) \times \text{Displacement}}{\text{MCTC} \times 100}$$

$$3.566 = \frac{(\text{LCB} - \text{LCG}) \times 8019}{160.621 \times 100}$$

$$(\text{LCB} - \text{LCG}) = \frac{3.566 \times 160.621 \times 100}{8019}$$

(LCB − LCG) = 7.143 m

LCG = 73.014 − 7.143 = 65.871 m

This is the Final LCG required to provide the above trim.

	Weights (t)	LCG (m)	L. Moments (mt)
Original displacement	7799	65.344	509617
Cargo loaded	(+) 220	x	(+) 220 x

Final Wt. = 8019 Final Moments = 509617 + 220 x

$$\text{Final LCG} = \frac{509617 + 220x}{8019} = 65.871$$

$$220x = (8019 \times 65.871) - 509617$$

$$= 18602.54$$

$$x = \frac{18602.54}{220} = 84.557 \text{ m}$$

Cargo to be loaded 84.557 m ford of AP.

77. *M.V. 'Hindship' in SW at a draft of 7.25 m ford and 8.10 m aft, has to load 170 t of cargo. Where with respect to AP should this cargo be loaded so that her ford draft would remain the same in water of RD 1.015.*

Initial draft F 7.250 m, A 8.100 m } trim = 0.85 m by stern.
M 7.675 m LCF = 70.904 m

Corrn. to After draft from table 'A' = 0.421 m

After draft = 8.100 m

Initial hydrostatic draft = 7.679 m

For hydrostatic draft 7.679 m, Displ. = 15877.9 t

MCTC = 192.91 mt

LCB = 72.671 m

LCF = 70.90 m

$$\text{Initial trim 't'} = \frac{(LCB - LCG)}{MCTC \times 100} \times \text{Displacement}$$

$$\therefore (LCB - LCG) = \frac{t \times MCTC \times 100}{\text{Displacement}} = \frac{0.85 \times 192.91 \times 100}{15877.9}$$

$$= 1.033 \text{ m}$$

LCB = 72.671 m

Initial LCG = 71.638 m

Initial displacement = 15877.9 t

To be loaded = 170.0 t

Final displacement = 16047.9 t

For displacement 16047.9 t in δ 1.015, equivalent weight in SW

$$= 16047.9 \times \frac{1.025}{1.015} = 16206 \text{ t}$$

For displacement 16047.9 t in δ 1.015, Hydro. draft = 7.819 m

MCTC = 192.965 mt

LCB = 72.636 m

LCF = 70.762 m

Ford draft reqd. = 7.250 m

Final hydrostatic draft = 7.819 m

F. trim required = 0.569 m

$$\text{F. Trim} = \frac{\text{T. Trim} \times \text{Ford Length}}{\text{Total Lenght}}$$

$$\therefore \text{T. Trim} = \frac{\text{F. Trim} \times \text{T. Length}}{\text{Ford Length}}$$

Ford length = LBP − LCF = 143.16 − 70.762 = 72.398 m

$$\therefore \text{T. Trim 't'} = \frac{0.569 \times 143.16}{72.398} = 1.125 \text{ m}$$

$$\text{'t'} = \frac{(\text{LCB} - \text{LCG})}{\text{MCTC} \times 100} \times \text{Displacement}$$

$$\therefore \text{LCB} - \text{LCG} = \frac{t \times \text{MCTC} \times 100}{\text{Displacement}}$$

$$= \frac{1.125 \times 192.965 \times 100}{16047.9} = 1.353 \text{ m}$$

Final LCB = 72.636 m

∴ Final LCG reqd. = 71.283 m

	Weights (t)	*LCG* (m)	*L. Moments* (mt)
Initial displacement	15877.9	71.638	1137461
Loaded	(+) 170.0	x	(+) 170 x
Final displacement	16047.9	Final L. Mmts. =	1137461 + 170 x

$$\text{Final LCG} = 71.283 = \frac{1137461 + 170\,x}{16047.9}$$

$$\therefore x = \frac{71.283 \times 16047.9 - 1137461}{170} = 38.126 \text{ m}$$

Cargo to be loaded 38.126 m ford of AP.

TO ACHIEVE A DESIRED TRIM

78. *M. V. 'Hindship' in Condition No. 8 has to discharge 300 tonnes, prior to sailing. Calculate the position with respect to AP, from where, this weight is to be discharged to enable her to sail trimmed 1.5 metres by the stern. Also find the sailing drafts F & A.*

Displacement in Condition No. 8	=	16133 tonnes
To discharge	=	300 tonnes
Final displacement	=	15833 tonnes
For displacement 15833 t Hydrostatic draft	=	7.660 m
MCTC	=	192.638 mt
LCB	=	72.675 m
LCF	=	70.919 m

$$\text{Total trim} = \frac{\text{LCB} - \text{LCG}}{\text{MCTC} \times 100} \times \text{Displacement}$$

Desired total trim = 1.5 metres

$$\therefore 1.5 = \frac{(\text{LCB} - \text{LCG})}{192.638 \times 100} \times 15833$$

$$1.5 \times 192.638 \times 100 = (\text{LCB} - \text{LCG}) \times 15833$$

$$(\text{LCB} - \text{LCG}) = \frac{1.5 \times 192.638 \times 100}{15833}$$

$$= 1.825 \text{ m}$$

Final LCG reqd. to produce the above trim = 72.675 − 1.825

= 70.850 m

	Weights (t)	LCG (m)	L. Moments (mt)
Original displacement	16133	70.045	1130041
Wt. discharged	(–) 300	x	(–) 300 x
Final Wt.	15833	Final L. Mmts. =	1130041 – 300 x

$$\text{Final LCG} = \frac{1130041 - 300x}{15833} = 70.85$$

$$300x = 1130041 - (15833 \times 70.85)$$

$$300x = 8273$$

$$x = \frac{8273}{300} = 27.577 \text{ m ford of AP}$$

Position from where 300 tonnes is to be discharged = 27.577 m ford of AP

To find Sailing drafts F & A

$$\text{After trim } t_a = \frac{t \times LCF}{LBP} = \frac{1.5 \times 70.919}{143.16}$$

$$t_a = 0.743 \text{ m}$$

$$t_f = t - t_a$$

$$= 1.5 - 0.743 = 0.757 \text{ m}$$

	F	A
Final Hydrostatic draft	7.660	7.660
trim	(–) 0.757	(+) 0.743
Final drafts =	**F 6.903 m**	**A 8.403 m**

79. *M.V. 'Hindship' in dock water of density 1.007 t/m³ is at a draft of F 7.62 m, A 7.94 m. She has to load 450 t of cargo. Calculate the position with respect to AP, where this weight should be loaded so that she would be trimmed 1 m by the stern on completion*

Initial draft F 7.62 m, A 7.94 m } trim 0.32 m by stern.
M 7.78 m

LCF for mean draft 7.78 m	=	70.800 m
Corrn. to after draft	=	0.158 m
After draft	=	7.940 m
Hydrostatic draft	=	7.782 m

For hydrostatic draft 7.782 m displacement in density 1.007

$$= \frac{16118.90 \times 1.007}{1.025} = 15835.8 \text{ t}$$

MCTC = 190.935 mt

LCB = 72.645 m

$$\text{Total trim} = 0.32 = \frac{(LCB - LCG)}{190.935 \times 100} \times 15835.8$$

$$\therefore (LCB - LCG) = \frac{0.32 \times 190.935 \times 100}{15835.8} = 0.386 \text{ m}$$

Original LCB	=	72.645 m
∴ Original LCG	=	72.259 m
Original displacement	=	15835.8 t
To load	=	450.0 t
Final displacement	=	16285.8 t

$$\text{Equivalent weight in SW} = \frac{16285.8 \times 1.025}{1.007} = 16576.9 \text{ t}$$

For displacement 16285.8 t in density 1.007,

LCB = 72.594 m

MCTC = 193.596 mt

$$\text{Reqd. trim} = 1.0 = \frac{(LCB - LCG)}{193.596 \times 100} \times 16285.8$$

$$\therefore (LCB - LCG) = \frac{1.0 \times 193.596 \times 100}{16285.8} = 1.189 \text{ m}$$

LCB = 72.594 m

∴ Final LCG required = 71.405 m

	Weight (t)	LCG (m)	L. Moments (mt)
Initial displacement	15835.8	72.259	1144279
To load	(+) 450.0	x	(+) 450 x
Final Wt.	16285.8	Final L. Mmts.	1144279 + 450 x

$$\text{Final LCG} = 71.405 = \frac{1144279 + 450x}{16285.8}$$

$$x = \frac{(71.405 \times 16285.8) - 1144279}{450} = 41.352 \text{ m}$$

The Wt. should be loaded 41.352 m ford of AP.

TO ACHIEVE A DESIRED DRAFT AT ONE END

80 *M.V. 'Hindship' in Condition No. 3, sustained damage aft. To effect repairs, it is required to reduce the after draft to 4.5 m by loading 518 tonnes in the fore part of the vessel. Find how far abaft the fore perpendicular, this weight should be loaded?*

Displacement in Condition No. 3 = 7087.3 tonnes

To load = 518.0 tonnes

Final displacement = 7605.3 tonnes

For displacement 7605.3 t Hydrostatic draft = 4.00 m

MCTC = 158.9 mt

LCB = 73.010 m

LCF = 73.131 m

After draft required = 4.50 m

Hydrostatic draft = 4.00 m

After trim required = 0.50 m

$$\text{Total trim required } \frac{t_a \times LBP}{LCF} = \frac{0.5 \times 143.16}{73.131} = 0.979 \text{ m (by stern.)}$$

$$\text{total trim } t = \frac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$$

$$LCB - LCG = \frac{\text{total trim} \times MCTC \times 100}{\text{Displacement}}$$

$$= \frac{0.979 \times 158.9 \times 100}{7605.3} = 2.045 \text{ m}$$

LCB in Final condition = 73.010 m

LCB − LCG = 2.045 m

Final LCG required = 70.965 m

	Weights (t)	LCG (m)	L. Moments (mt)
Original displacement	7087.3	67.679	479662
To load	518.0	x	518 x
Final Wt.	7605.3	Final Mmts.	479662 + 518 x

$$\text{Final LCG} = 70.965 = \frac{479662 + 518x}{7605.3}$$

$$518x = (7605.3 \times 70.965) - 479662$$

$$= 60132$$

$$x = \frac{60132}{518} = 115.923 \text{ m from AP.}$$

LBP of Ship = 143.16 m

Distance from FP = 143.16 − 115.923 = 27.237 m

81. *M. V. 'Hindship' in Fresh Water is at a draft of F 6.32 m, A 7.18 m. Calculate the position with respect to AP, from where 140 t should be discharged to reduce her ford draft by 32 cms.*

Initial drafts F 6.32 m, A 7.18 m } trim 0.86 m by stern.
M 6.75 m

LCF for mean draft 6.75 m = 71.856 m

Corrn. to After draft = 0.431 m

After draft = 7.180 m

Hydrostatic draft in FW = 6.749 m

$$\text{For draft 6.749 m, displacement in FW} = \frac{13723.5 \times 1.000}{1.025}$$

= 13388.8 t

MCTC = 176.454 mt

LCB = 72.866 m

$$\text{Present trim} = 0.86 = \frac{(LCB - LCG)}{176.454 \times 100} \times 13388.8$$

$$\therefore (LCB - LCG) = \frac{0.86 \times 176.454 \times 100}{13388.8} = 1.133 \text{ m}$$

LCB = 72.866 m

∴ Initial LCG = 71.733 m

Initial displacement = 13388.8 t

To discharge = 140.0 t

Final displacement = 13248.8 t

$$\text{Equivalent weight in SW} = \frac{13248.8 \times 1.025}{1.000} = 13580 \text{ t}$$

For displacement 13248.8 t in FW,

Hydrostatic draft = 6.686 m

MCTC = 175.810 mt

LCB = 72.876 m

LCF = 71.919 m

Ford draft required = 6.000 m

Hydrostatic draft = 6.686 m

∴ Ford trim required = 0.686 m

Ford length = LBP − LCF = 143.16 − 71.919 = 71.241 m

$$\text{Ford trim} = \frac{\text{Total trim} \times \text{Ford length}}{\text{Total length}}$$

$$\therefore \text{Total trim} = \frac{\text{Ford trim} \times \text{Total length}}{\text{Ford length}}$$

$$= \frac{0.686 \times 143.16}{71.241} = 1.379 \text{ m}$$

$$1.379 = \frac{(\text{LCB} - \text{LCG})}{\text{MCTC} \times 100} \times \text{Displacement}$$

$$\therefore (\text{LCB} - \text{LCG}) = \frac{t \times \text{MCTC} \times 100}{\text{Displacement}} = \frac{1.379 \times 175.81 \times 100}{13248.8}$$

= 1.830 m

LCB = 72.876 m

∴ Final LCG required = 71.046 m

	Weight (t)	*LCG* (m)	*L. Moments* (mt)
Original displacement	13388.8	71.733	960418.8
To discharge	(−) 140.0	x	(−) 140 x
Final Wt.	13248.8	Final L. Moment	960418.8 − 140 x

$$\text{Final LCG} = 71.046 = \frac{960418.8 - 140x}{13248.8}$$

$$\therefore x = \frac{(71.046 \times 13248.8) - 960418.8}{(-)\ 140} = 136.747 \text{ m}$$

Weight to be discharged 136.747 m ford of AP.

CHANGE OF TRIM DUE TO CHANGE OF DENSITY

The student is already aware that the hydrostatic draft of the vessel changes when she proceeds from water of one density to water of another density. He should further note that the trim of the vessel also alters with the change of density. As can be seen from the following problem the change in trim is caused due to the change in the value LCB, as the hydrostatic draft changes with change of density. Since the value of LCB changes, the trim obtained by the formula $'t' = \frac{(\text{LCB} - \text{LCG})}{\text{MCTC} \times 100} \times W$, also changes.

82. *M.V. 'Hindship' is at an even keel draft of 9.35 m in dock water of RD 1.004. Calculate her drafts F & A on reaching the sea. Assume fuel and fresh water consumption negligible.*

Displacement in SW at a draft 9.35 m = 19902.25 t

$$\text{Displacement at that draft in } \delta\ 1.004 = \frac{19902.25 \times 1.004}{1.025} = 19494.5 \text{ t}$$

Initial LCG = LCB (As she is on an even keel) = 72.175 m

For displacement 19494.5 t in SW, Hydrostatic draft = 9.183 m

MCTC = 214.264 mt

LCB = 72.229 m

LCF = 69.625 m

$$\text{Final trim 't'} = \frac{(\text{LCB} - \text{LCG})}{\text{MCTC} \times 100} \times \text{Displacement}$$

$$= \frac{(72.229 - 72.175)}{214.264 \times 100} \times 19494.5 = 0.049 \text{ m}$$

$$t_a = \frac{t \times \text{LCF}}{\text{LBP}} = \frac{0.049 \times 69.625}{143.16} = 0.024 \text{ m}$$

$$t_f = t - t_a = 0.049 - 0.024 = 0.025 \text{ m}$$

		F	A
Hydrostatic draft in SW	=	9.183 m	9.183 m
Trim	=	(−) 0.025 m	(+) 0.024 m
Final drafts F & A		**F 9.158 m**	**A 9.207 m**

USE OF TRIM TABLES

Trim tables are provided indicating change in draft. Forward and Aft at different mean drafts, when tanks are filled to their capacity and for addition of 100 t weight, at different positions with respect to **midships.**

These tables may be used for determination of approximate drafts after loading, discharging or shifting weights which are not large.

It should be noted that more accurate results are obtained by calculations as indicated in the earlier problems.

83. *M.V. 'Hindship' floating at a draft of F 5.45 m, A 6.53 m, fills up No. 1 DB tank with water ballast, discharges 120 t of cargo from No. 2 TD, 99.5 m ford of AP and shifts a 70 t parcel of cargo from No. 2 TD to No. 4 TD. Using the trim tables, determine the final lrafts F & A.*

	F (m)	A (m)	M (m)
Original drafts	5.450	6.530	5.990
Interpolating for mean draft 5.99 m.			
from tank's trim tables for 161.50 t WB in No. 1 DB tank.			
Change in draft	(+) 0.310	(–) 0.174	
	5.760	**6.356**	
Cg. of No. 2 TD = 99.5 m ford of AP.			
Midships = 71.58 m ford of AP.			
∴ Cargo discharged from 27.92 m ford of midships.			
Change in draft due to discharging 120 t from 27.92 m ford of midships	(–) 0.144	(–) 0.041	
Note : Signs are reversed as weight was discharged, and values obtained for 100 t are multiplied by $\frac{120}{100}$			
	5.616	**6.397**	

	F	A
	5.616	**6.397**
Shift of cargo from No. 2 TD to No. 4 TD is equivalent to discharging that cargo from No. 2 TD and then loading it at No. 4 TD.		
Then change in drafts due to this operation is therefore determined in two stages as indicated below.		
Change in draft due to discharging 70 t from No. 2 TD, 32.33 m ford of midships.	(–) 0.093	(+) 0.032
	5.523	**6.429**
Change in draft due to loading 70 t in No. 4 TD, 14.14 m aft of midships.	(+) 0.001	(+) 0.062

Final drafts **F 5.524 m A 6.491 m**

84. *M.V. 'Hindship' in Condition No. 3 is listed 3^0 to starboard. It is desired to increase her trim to 3 metres by the stern and to bring her upright by transferring water ballast from No. 2 DB tanks to No. 4 DB tanks P and S only. Calculate the final distribution of water ballast in No. 2 and No. 4 DB tanks to achieve this, with No. 4 Port filled to capacity. Assume Cgs of No. 2 and No. 4 (P & S) tanks are 6.7 metres from the centre line.*

Displacement in Condition No. 3	=	7087.3 t
MCTC	=	156.7 mt
GM (Fluid)	=	2.586 m
Present trim	=	2.406 m by stern
Required trim	=	3.000 m by stern
Change of trim required	=	0.594 m by stern

Let x tonnes be transferred from No. 2 to No. 4 tanks in order to increase her trim by 0.594 m.

Trimming Moment required = 0.594 × 100 × 156.7 mt.

Distance between Lcg of No. 2 and No. 4 tanks.

= 102.20 − 58.14 = 44.06 m

Trimming Moment required = wt. × distance shifted

$\therefore\ 0.594 \times 100 \times 156.7 = x \times 44.06$

$$x = \frac{0.594 \times 100 \times 156.7}{44.06} = 211.26 \text{ t}$$

WB to be transferred from No. 2 to No. 4 = 211.26 t

GG_1 causing present list of 3^0 = GM tan θ

= 2.586 × tan 3°

= 0.1355 m

Moment causing 3^0 list to starboard = GG_1 × W

= 0.1355 × 7087.3

= 960.329 mt

To bring her upright, an equal moment should be caused to port by transferring ballast from starboard to port through a distance (6.7 + 6.7) = 13.4 m.

Let 'y' tonnes be transferred from S to P.

Then 960.329 = y × 13.4

$$y = \frac{960.329}{13.4} = 71.68 \text{ t}$$

Water ballast to be transferred from S to P = 71.68 t

Ballast to transfer from No. 2 to No. 4 to increase her trim to 3 metres = 211.26 t

Ballast to transfer from No. 2 S to No. 4 P to bring her upright = 71.68 t

Further quantity to transfer from No. 2 to No. 4 (P to P or S to S) = 139.58 t

Full capacity of No. 4 Port = 127.4 × 1.025 = 130.59 t

Ballast to be transferred from No. 2 S to No. 4 P = 71.68 t

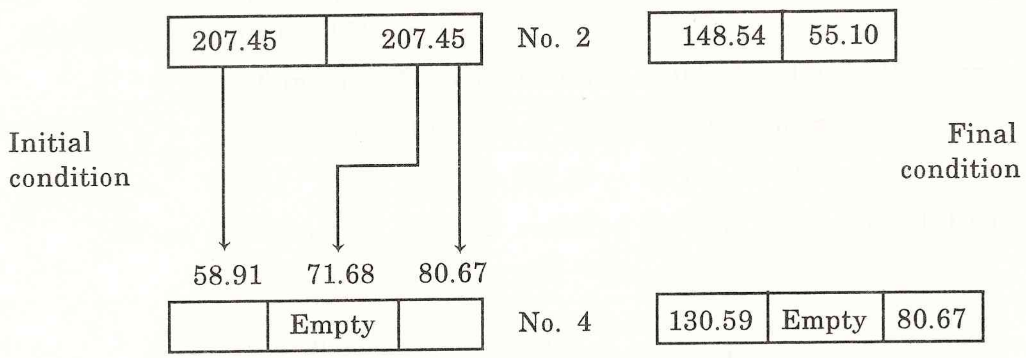
Ballast to be transferred from No. 2 P to No. 4 P, to fill it to its capacity = 58.91 t

Ballast to be transferred from No. 2 S to No. 4 S = 139.58 − 58.91 = 80.67 t

Total ballast removed from No. 2 S = 80.67 + 71.68 = 152.35 t

Ballast remaining in No. 2 S = 207.45 − 152.35 = 55.10 t

Ballast remaining in No. 2 P = 207.45 − 58.91 = 148.54 t



Note : When ballast is transferred, the FSC will change, causing a reduction in her GM, but this does not feature in the calculation above, because we know that when port moment equals starboard moment, the ship will be upright, regardless of the amount of +ve GM.

85. *M. V. 'Hindship' loading in river water of RD 1.012 is at a draft of F 5.16 m A 6.02 m. She then pumps out the entire ballast in No. 1 and 4 (P, C & S) DB tanks, which were filled in earlier at the same berth. No. 3 (P & S) and No. 5 DB tanks which were empty are filled with H.F.O. Calculate to the nearest tonne the maximum quantity of cargo that can be loaded, so that the vessel will be at her Summer draft on reaching the open sea. Allow fuel and water consumption as follows, 50 tonnes in port and 70 tonnes for river passage.*

Also calculate to the nearest .01 m, the even keel sailing draft at the loading berth, in river water.

Original drafts F 5.16 m, A 6.02 m } trim 0.86 m by the stern

M 5.59 m LCF = 72.679 m

After draft = 6.020 m

Corrn. to After draft from table 'A' = (−) 0.436 m

Hydrostatic draft = 5.584 m

Displacement in SW at Hydrostatic draft of 5.584 m = 11084.32 t

∴ Present underwater volume = $\frac{W}{\delta} = \frac{11084.32}{1.025}$ = 10813.97 m^3

∴ Present displ. in water of RD 1.012 = 10813.97 × 1.012 = 10943.74 t

Total ballast pumped out = v × δ_1.

No. 1	157.6 m^3		
No. 4 (P & S)	254.8 m^3		
No. 4 (C)	257.4 m^3		
	669.8 × 1.012	=	(−) 677.84 t
			10265.90 t

Total H.F.O. received = $v_1 \delta_2$.

No. 3 (P & S)	221 m^3		
No. 5	48.8 m^3		
	269.8 m^3 × 0.95	=	(+) 256.31 t
			10522.21 t

		10522.21 t
Fuel and water to be consumed (70 + 50)	=	(–) 120.00 t
Displacement after above operations	=	10402.21 t
Summer displacement	=	19617.00 t
Cargo that can be loaded		9214.79 t

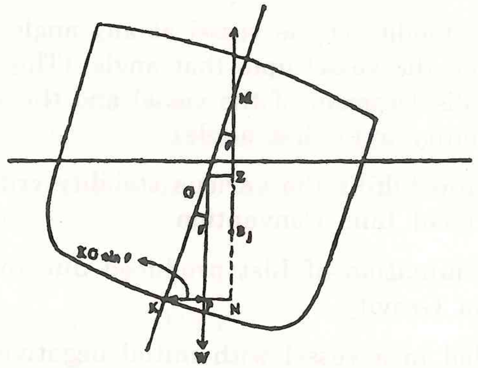
Maximum cargo that can be loaded = 9215 t

Summer displacement	=	19617 t
Fuel & water for river passage	=	(+) 70 t
Displacement on sailing	=	19687 t
Hydro. draft in SW for displacement 19687 t	=	9.262 m
River water allowance = $\frac{202 \times 13}{25}$	=	0.105 m
Sailing draft in river water	=	9.367 m

Even keel sailing draft = 9.37 m

CURVES OF STABILITY

CROSS CURVES OF STABILITY (KN CURVES)



The student is already familiar with the Righting Lever GZ, which is measured from the centre of gravity. It can be seen from the above figure that KN is the righting lever as measured from the keel. The values of KN will vary with heel and displacement.

Cross Curves of Stability are a set of curves of KN values plotted against a scale of displacements for various angles of heel. These curves facilitate obtaining of KN values, at any displacement, for the particular angles of heel for which the curves are drawn. The student should verify this for himself by inspecting the Cross Curves available in the Trim & Stability particulars of M.V. 'Hindship' or any other ship.

Very often, KN values are also given in a tabular form in addition to the curves, as in the case of M. V. 'Hindship'. The main use of KN values is to obtain GZ values at any displacement for different angles of heel. From the above figure it can be seen that the GZ at any angle of heel may be obtained by the expression GZ = KN — KG sin θ. From the GZ values obtained at the different angles of heel, it is possible to construct the curve of statical stability for that condition.

CURVE OF STATICAL STABILITY

This is a curve of GZ values plotted against a scale of heel for a particular displacement and a particular KG. Such curves are available in the Trim & Stability particulars of all ships for the various conditions. From this curve it is possible to ascertain the following :

a) Initial metacentric height.

b) The angle of contraflexure (i.e. the angle of heel upto which the rate of increase of GZ with heel is increasing. Though the GZ may increase further, the rate of increase of GZ begins to decrease at this angle).

c) The maximum GZ value of the vessel and the angle of heel at which it occurs.

d) The angle of vanishing stability and the range of stability.

e) The dynamical stability of the vessel at any angle of heel i.e. the work done in inclining the vessel upto that angle. (This can be found as the product of the displacement of the vessel and the area under the curve of statical stability upto that angle).

f) Whether the ship fulfills the various stability criteria specified in the International Load Line Convention.

g) Accurate determination of List produced due to transverse shift of ship's centre of Gravity.

h) The angle of loll in a vessel with initial negative metacentric height.

The student's attention to drawn to items 7 and 8 of the General Instructions. When determining GZ values from KN, the corrected KG (KG + FSC) is to be used.

86. *M. V. 'Hindship' in Condition No. 5, shifted some weight vertically upwards, so that her KG increased by 0.22 m*

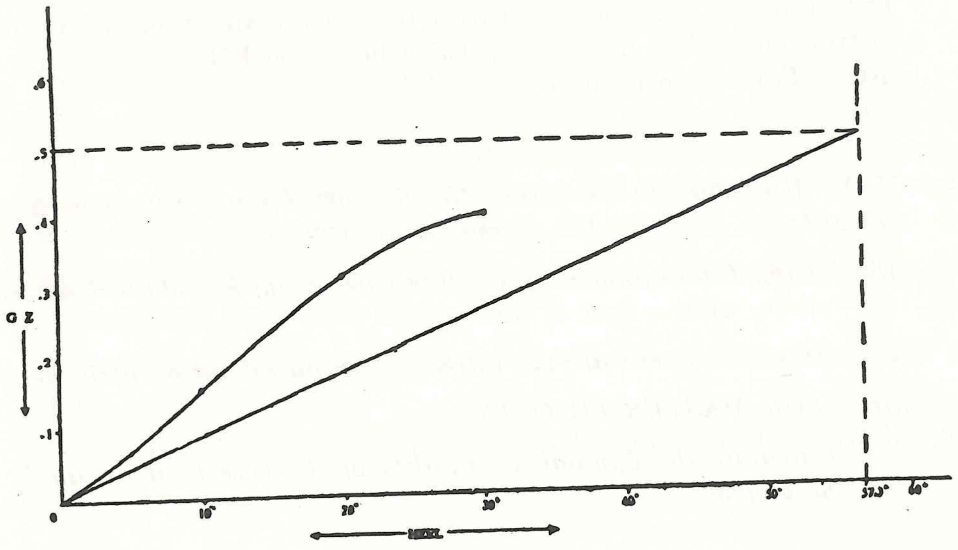
(i) Using GZ ordinates at 10^0 intervals, draw her statical stability curve, upto a heel of 30^0.

(ii) From the curve drawn, estimate her initial metacentric height.

(iii) (FOR MASTER FG ONLY)

Calculate the dynamical stability of the vessel, at an angle of heel of 30^0.

(i) Heel	Original GZ	Upward GG_1	sin θ	Corn. to GZ = GG_1 sin θ	Corrected GZ = Original GZ–Corn.	SM	Product for Area
0^0	0.00	0.22	0.0	0.0	0.0	1	0.0
10^0	0.191	0.22	0.174	0.038	0.153	3	0.459
20^0	0.383	0.22	0.342	0.075	0.308	3	0.924
30^0	0.500	0.22	0.500	0.110	0.390	1	0.390
						SUM :	1.773



(ii) **Estimated Initial GM = 0.50 m**

(iii) Area under the curve of statical stability upto 30° heel

$$= 1.773 \times \frac{3}{8} \times \frac{10}{57.3}$$

$$= 0.116 \text{ m radians}$$

Dynamical stability = Area × W $= 0.116 \times 18{,}529.3$

$= 2150$ tm

Dynamical Stability at 30° heel = 2150 tm

87. *M.V. 'Hindship' displacing 18,529 tonnes, KG 7.539 m, FSC 0.084 m.*

(i) Find her GM (Fluid).

(ii) Draw the statical stability curve for this condition.

(iii) From the curve find

(a) The maximum GZ and the angle of heel at which it occurs.

(b) The angle of vanishing stability.

(c) The change in the range of stability, when an upsetting moment of 4500 tonnes metre is caused.

(d) The list produces by the above upsetting moment.

(iv) State Whether the ship fulfills criterion A of the Minimum Stability Requirements of the International Load Line Convention

(i)

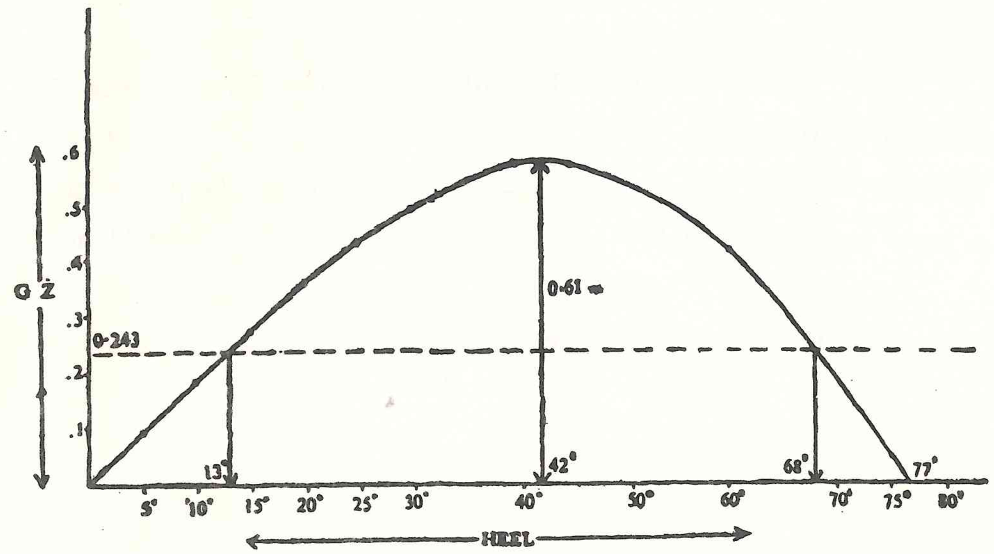
KM for displacement of 18529 t	=	8.349 m
KG	=	7.539 m
GM (Solid)	=	0.810 m
FSC	=	0.084 m
GM (Fluid)	=	**0.726 m**

(ii) To find corrected KG in order to determine GZ value from KN.

KG	=	7.539 m
FSC	=	(+) 0.084 m
Corrected KG	=	7.623 m

GZ = KN — (Corrected KG × sin θ)

θ	0°	5°	10°	15°	20°	25°	30°	40°	45°	60°	75°
Sin θ	0	0.087	0.174	0.259	0.342	0.423	0.500	0.643	0.707	0.866	0.966
KN	0	0.760	1.517	2.252	2.990	3.629	4.312	5.498	5.978	7.027	7.416
−KG sin θ	0	0.663	1.326	1.974	2.607	3.225	3.812	4.902	5.389	6.602	7.364
GZ	0	0.097	0.191	0.278	0.383	0.404	0.500	0.596	0.589	0.425	0.052
S.M.	1	4	2	4	2	4	1	SUM			
PRODUCT	0.0	0.388	0.382	1.112	0.766	1.616	0.500	4.764			



(iii) (a) **Maximum GZ = 0.61 m at 42° angle of heel**

(b) **Angle of Vanishing Stability = 77°**

(c) Upsetting lever = $\frac{\text{Upsetting moment}}{\text{Displacement}} = \frac{4500}{18529} = 0.243$ m

New range of stability = 13° to 68° = 55°

Reduction in the range of stability = 77° − 55° = 22°

(d) **List produced by the upsetting moment = 13°**

(iv) Area under the Curve upto 30° $= 4.764 \times \frac{1}{3} \times \frac{5}{57.3}$

$= 0.139$ metre radians.

Since this area is greater than 0.055 metre radians, the ship satisfies criterion A of the Minimum Stabilty Requirements of the International Load Line Convention.

88. *M.V. 'Hindship' in Condition No. 9, pumps out, 100 tonnes of ballast each from No. 2 (P) and No. 2 (S), DB tanks,*

(i) *Calculate her righting levers at 10° intervals upto an angle of heel of 40°.*

(ii) *(MASTER F.G. ONLY) — Calculate her dynamical stability at an angle of heel of 40°.*

(iii) *Also state, whether the ship fulfills criteria A, B and C of the minimum stability requirements of the International Load Line Regulations, given angle of flooding as 42°.*

	Weight (t)	*KG* (m)	*V. Moments* (mt)
Displacement Condition No. 9	15727.8	7.334	115352
Ballast pumped out	(–) 200	0.65	(–) 130
Final Wt.	15527.8	Final Moments	115222

$$\text{Final KG} = \frac{115222}{15527.8} = 7.420 \text{ m}$$

Original FS moment = 1552 mt

FS moment of No. 2, (P & S) (1436 × 1.025) = 1472 mt

Final FS moment = 3024 mt

$$\text{Final FSC} = \frac{3024}{15527.8} = 0.195 \text{ m}$$

To find corrected KG to determine GZ values from KN

KG = 7.420 m

FSC = (+)0.195 m

Corrected KG = 7.615 m

θ	0°	10°	20°	30°	40°	
Sin θ	0.0	0.174	0.342	0.500	0.643	
KN	0.0	1.500	2.965	4.414	5.723	
– KG sin θ	0.0	1.325	2.604	3.808	4.896	
GZ	0.0	0.175	0.361	0.606	0.827	
SM	1	4	2	4	1	SUM
PRODUCT FOR AREA	0.0	0.700	0.722	2.424	0.827	4.673
*S.M.			– 1	8	5	SUM
PRODUCT FOR AREA			– 0.361	4.848	4.135	8.622

(ii) Area under the Curve upto 40° $= 4.673 \times \frac{1}{3} \times \frac{10}{57.3}$

$= 0.27184$ m radians

MASTER (FG) ONLY.

Dynamical Stability at 40° heel $= 0.27184 \times 15527.8$

$= 4221.07$ tm

Dynamical Stability at 40° heel = 4221.1 tm

* Common interval, 10° and the ordinates being the GZ values.

(iii) Area under the Curve between 30⁰ & 40⁰ heel.

$$= 8.622 \times \frac{1}{12} \times \frac{10}{57.3} = 0.12539 \text{ m radians}$$

Area under the Curve upto 30^0 = 0.27184 − 0.12539

= 0.14645 m radians

Area under the Curve upto 30^0 = 0.14645 m radians, which is greater than 0.055

Criterion 'A' is therefore satisfied.

Area under the curve upto 40^0 = 0.27184 m radians, which is greater than 0.09

Criterion 'B' is therefore satisfied.

Area under the Curve between 30^0 & 40^0 = 0.12539 m radians, which is greater than 0.03

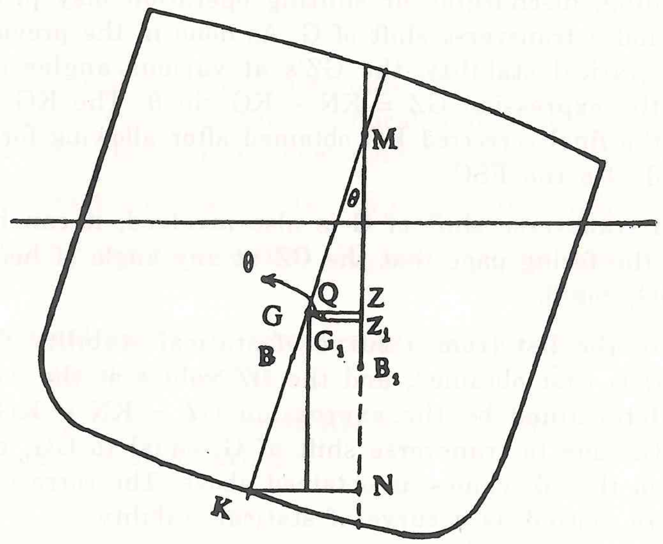
Criterion 'C' is therefore satisfied.

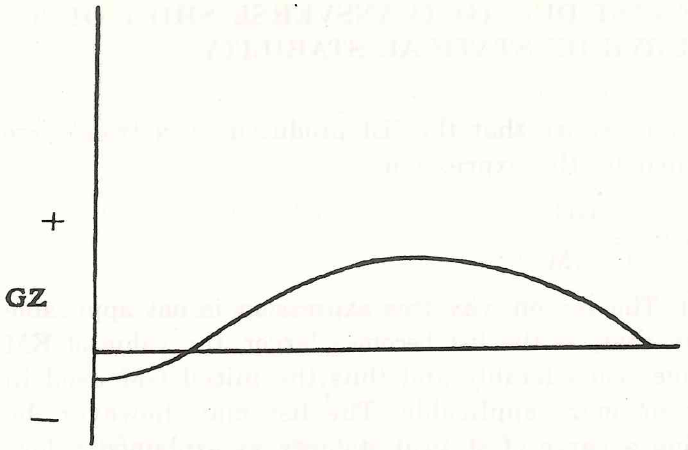
DETERMINATION OF LIST DUE TO TRANSVERSE SHIFT OF 'G' FROM CURVE OF STATICAL STABILITY

The student is already aware that the list produced by a transverse shift of 'G' can be obtained by the expression

$$\tan\theta = \frac{GG_1}{GM},$$

provided the list is small. The reason why this expression is not applicable at larger angles of heel is, that, as the list becomes larger, the value of KM and, therefore, GM changes considerably and thus the initial GM used in the above expression is no more applicable. The list may, however, be determined accurately from a curve of statical stability as explained below.





Statical stability curve for the side on which the Vessel is heeled, with heel on the X axis and GZ on the Y axis.

Any loading, discharging or shifting operation may produce both a vertical shift and a transverse shift of G. As done in the previous problems on curves of statical stability, the GZ's at various angles of heel were obtained, by the expression GZ = KN − KG sin θ. The KG used in this expression is the final corrected KG obtained after allowing for any vertical shift of G and also the FSC.

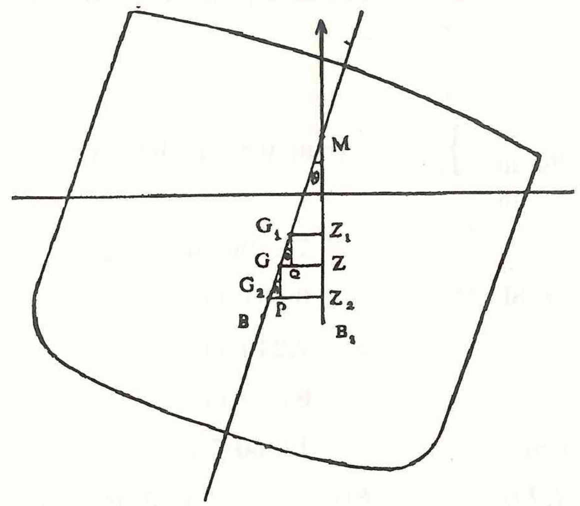
Where a transverse shift of G is also involved, it can be seen from the figure on the facing page that the GZ at any angle of heel reduces by an amount GG_1 cos θ.

To obtain the list from a curve of statical stability the final KG (corrected KG) is first obtained, and the GZ values at the various angles of heel are determined by the expression GZ = KN − KG sin θ. The reduction in GZ due to transverse shift of G, equal to GG_1 cos θ is then subtracted from the GZ values as obtained above. The corrected GZ values so obtained are plotted as a curve of statical stability.

The list is then read off, where the curve attains zero value, as at earlier angles the vessel has a −ve GZ (capsizing lever) while at larger angles, she has a +ve GZ (Righting lever), as can be seen from the curves in the following problems.

It should be noted that the curve drawn is only for the side to which she is listed. Though the GZ values are negative initially, it is important to note that this is not due to a −ve GM. As the G shifts transversely, the vessel lists till the new Centre of Buoyancy once again comes in the same vertical line as the Centre of Gravity. At this list, she attains static equilibrium.

DETERMINATION OF LIST WHEN GZ VALUES ARE GIVEN



For upward shift of G

$GQ = GG_1 \times \sin\theta$

$G_1Z_1 = GZ - GQ = GZ - GG_1 \sin\theta$

For downward shift of G

$G_2Z_2 = GZ + GG_2 \sin\theta$

In a theoretical problem where only GZ values at different angles of heel are given, where after some vertical and transverse shift of G has occurred, the GZ values for the new condition may be obtained as follows:

1. Subtract transverse GG_1 cos θ from the given values of GZ.
2. Add or subtract vertical GG_1 sin θ (+) for downward shift of G.
   (−) for upward shift of G.

The statical stability curve may now be plotted and the list determined, as indicated earlier.

This method is resorted to as KN and KG values are not available to use the method indicated earlier.

89. *M. V. 'Hindship' is at a draft of F 6.38 m, A 7.24 m, KG 8.06 m, FSM 1172 mt. 100 t of ballast is run into No. 3 (P) DB tank, Cg 8.0 m from CL. Draw the curve of statical stability and from it, determine the angle of list.*

Initial drafts	F 6.38 m	}	trim 0.86 m by stern
	A 7.24 m		
	M 6.81 m		

LCF for draft 6.81 m = 71.796 m

Correction to Aft draft from table 'A' = 0.431 m

After draft = 7.240 m

Hydrostatic draft = 6.809 m

Displacement for draft 6.809 m = 13860.7 t

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Displacement	13860.7	8.06	111717.2
No. 3 DB tank (P)	(+) 100	0.67	(+) 67.0
Final Wt.	13960.7	Final V. Moments	111784.2

$$\text{Final KG} = \frac{111784.2}{13960.7} = 8.007 \text{ m}$$

Original FSM = 1172 mt

No. 3 P = 227 × 1.025 = 232.68 mt

Final FSM = 1404.68 mt

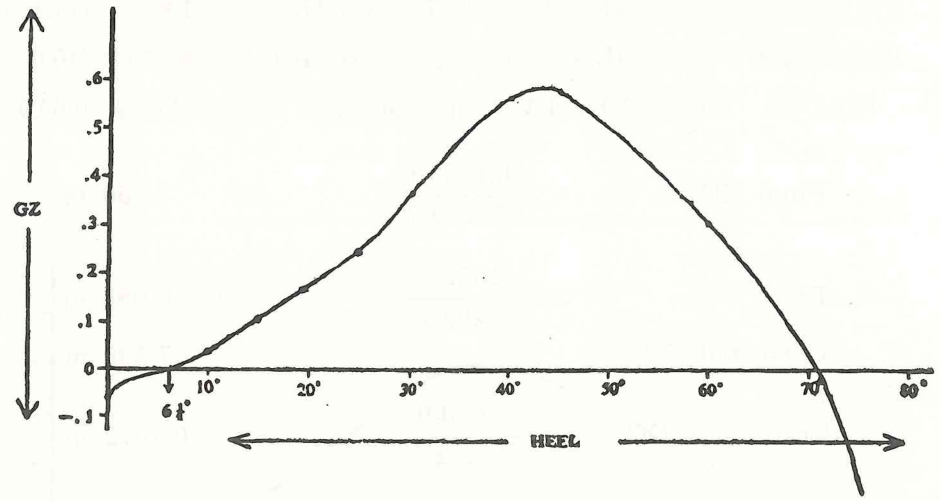
$$\text{Final FSC} = \frac{1404.68}{13960.7} = (+)0.101 \text{ m}$$

Corrected KG = 8.108 m

$$\text{Transverse } GG_1 = \frac{100 \times 8}{13960.7} = 0.0573 \text{ m}$$

θ	0^0	5^0	10^0	15^0	20^0	25^0	30^0	40^0	45^0	60^0	75^0
Sin θ	0.000	0.087	0.174	0.259	0.342	0.423	0.500	0.643	0.707	0.866	0.966
cos θ	1.000	0.996	0.985	0.966	0.940	0.906	0.866	0.766	0.707	0.500	0.259
KN	0.000	0.755	1.506	2.232	2.982	3.723	4.471	5.819	6.350	7.353	7.619
–KG sin θ	0.000	0.705	1.411	2.100	2.773	3.430	4.054	5.213	5.732	7.022	7.832
Uncorrected GZ	0.000	0.050	0.095	0.132	0.209	0.293	0.417	0.606	0.618	0.331	(–)0.213
Transverse GG_1 cos θ	0.057	0.057	0.056	0.055	0.054	0.052	0.050	0.044	0.041	0.029	0.015
Corrected GZ	(–)0.057	(–)0.007	0.039	0.077	0.155	0.241	0.367	0.562	0.577	0.302	(–)0.228

STATICAL STABILITY CURVE FOR PORT HEEL



Angle of List as inidicated by the curve = 6¼° to Port.

The curve inidicates that the GZ values are negative upto a heel of 6¼°, and positive thereafter. In other words, capsizing levers operate upto a heel of 6¼° and righting levers are present thereafter. The ship will attain static equilibrium at the angle of heel at which neither capsizing nor righting levers are present, which in this case occurs at 6¼°

Note : In practice, on board a ship, when the accurate list is required to be determined, it is not necessary to draw the entire curve of statical stability. A part of the curve till GZ values become positive would suffice.

90 *M. V. 'Hindship' in Condition No. 5 loads and discharges as follows:*

Discharges 250 t from No. 1 TD, cg 6 m to starboard of CL. Discharges 50 t from No. 3 TD, Kg 11.15 m, cg 1.3 m to port of CL. Fills up No. 8 DB tank (S) cg 1.8 m from CL, with FW.

A parcel of cargo weighing 40 t is shifted 6.2 m vertically downwards and 16 m transversely to port. Draw the curve of statical stability for this condition and determine the resultant list.

	Weights	*KG*	*V. Moments*	*Dist. from CL*	*T. Moments*	
	(t)	(m)	(mt)	(m)	(mt)	
Condition No. 5	18529.3	7.539	139700	0	0	
Disch. No. 1 TD	(–)250.0	11.17	(–)2792.5	6	1500	(P)
Disch. No. 3 TD	(–)50.0	11.15	(–) 557.5	1.3	65	(S)
FW in No. 8 (S)	(+)63.4	2.77	(+) 175.6	1.8	114.1	(S)
Shifted 40 t.	40.0	6.2	(–) 248.0	16	640.0	(P)

Final Wt. 18292.7 Final V. Mmts. 136277.6 Final T. Mmts. 1960.9 (P)

$$\text{Final KG} = \frac{136277.6}{18292.7} = 7.450 \text{ m}$$

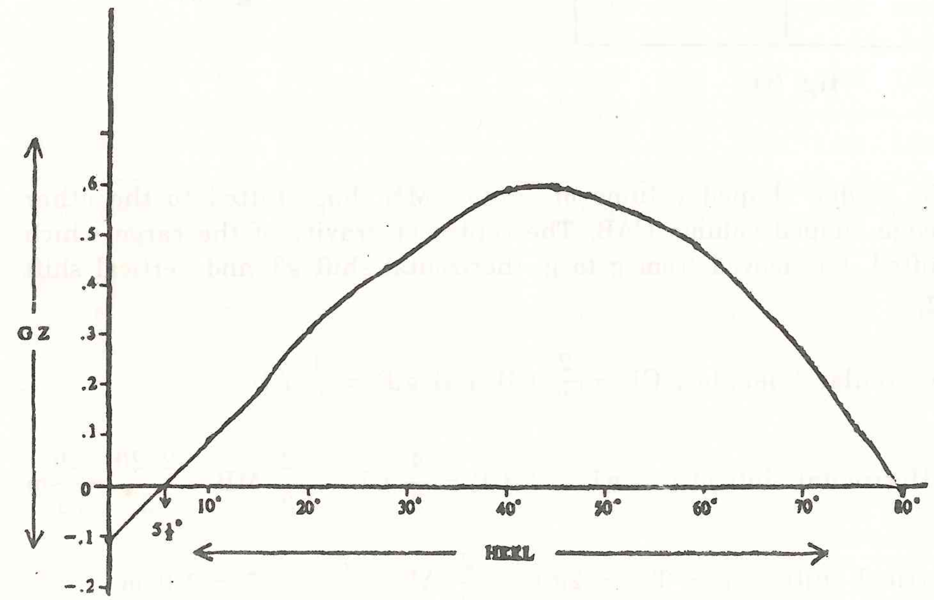
$$\text{FSC} = \frac{1552}{18292.7} = (+)\ 0.085 \text{ m}$$

$$\text{Corrected KG} = 7.535 \text{ m}$$

$$\text{Transverse } GG_1 = \frac{1960.9}{18292.7} = 0.1072 \text{ m}$$

θ	0⁰	5⁰	10⁰	15⁰	20⁰	25⁰	30⁰	40⁰	45⁰	60⁰	75⁰
sin θ	0.000	0.087	0.174	0.259	0.342	0.423	0.500	0.643	0.707	0.866	0.966
cos θ	1.000	0.996	0.985	0.966	0.940	0.906	0.866	0.766	0.707	0.500	0.259
KN	0.000	0.759	1.513	2.249	2.990	3.636	4.320	5.517	5.997	7.044	7.426
—KG sin θ	0.000	0.656	1.311	1.952	2.577	3.187	3.768	4.845	5.327	6.525	7.279
Uncorrected GZ	0.000	0.103	0.202	0.297	0.413	0.449	0.552	0.672	0.670	0.519	0.147
Transverse GG_1 cos θ	0.107	0.107	0.106	0.104	0.101	0.097	0.093	0.082	0.076	0.054	0.028
Corrected GZ	(–)0.107	(–)0.004	0.096	0.193	0.312	0.352	0.459	0.590	0.594	0.465	0.119

STATICAL STABILITY CURVE FOR PORT HEEL



Angle of List obtained form Curve = 5½⁰(P)

91. *M. V. 'Hindship' floating at a hydrostatic draft of 8.785 m, KG 7.807 m, FS Moment 1552 mt has homogeneous cargo stowing at 1.78 cubic metres per tonne in No. 3 Hold. Consider No. 3 Hold to be cuboidal, (length and breadth of the hold remain constant over the entire height) of length 21 m and breadth 20 m. The cargo in this compartment shifts, raising the surface on the starboard side by 1.5 m and lowering the surface on the port side by the same amount. Draw the curve of statical stability and hence determine her list.*

Discuss briefly the effect of this shift of cargo on the stability of the vessel.

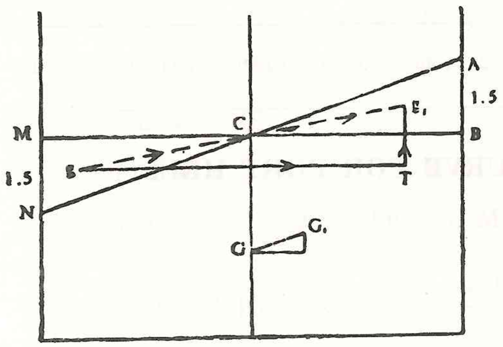


fig (i)

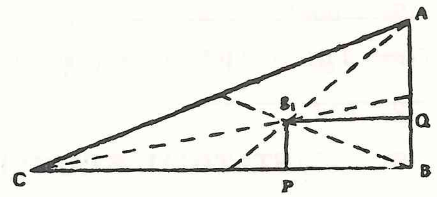


fig (ii)

The wedge shaped volume of cargo CMN, has shifted to the other wedge shaped volume CAB. The centre of gravity of the cargo which shifted, has moved from g to g_1 (horizontal shift gT and vertical shift Tg_1)

By similar triangles, $CP = \frac{2}{3}CB$ and $g_1P = \frac{1}{3}AB$

$\therefore$ Horizontal shift of g = gT = $2 \times CP = \frac{4}{3}CB = \frac{2}{3}MB = \frac{2 \times 20}{3} = \frac{40}{3}$m

Vertical shift of g = $Tg_1 = 2g_1P = \frac{2}{3}AB = \frac{2}{3} \times 1.5 = 1.0$ m

For hydrostatic draft 8.785 m   Displacement = 18528.7 t

Volume of cargo shifted = $\frac{10}{2} \times 1.5 \times 21$ = 157.5 cu m

Wt. of cargo shifted = $\frac{157.5}{1.78}$ = 88.5 t

Transverse GG_1 = $\frac{w \times d}{W} = \frac{88.5 \times 40}{18528.7 \times 3}$ = 0.0637 m

Vertical GG_1 = $\frac{88.5 \times 1}{18528.7}$ = 0.00477 = 0.005 m

Original KG = 7.807 m

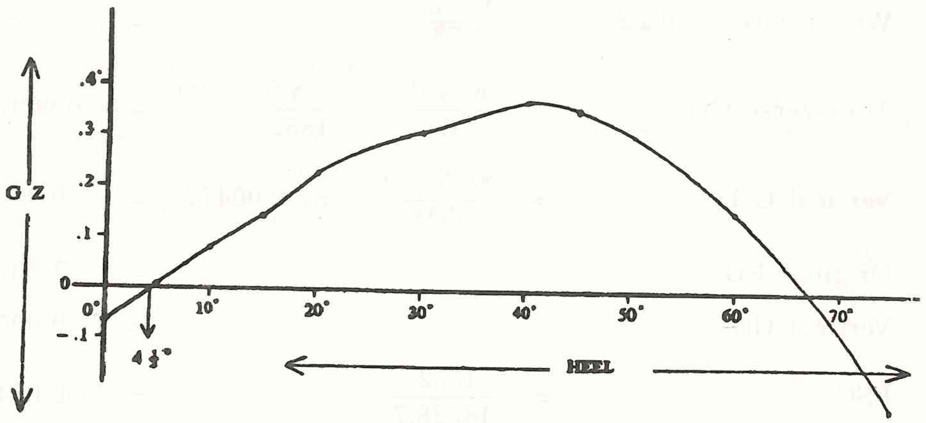
Vertical GG_1 = (+)0.005 m

FSC = $\frac{1552}{18528.7}$ = (+)0.084 m

Corrected KG = 7.896 m

θ	0°	5°	10°	15°	20°	25°	30°	40°	45°	60°	75°
sin θ	0.000	0.087	0.174	0.259	0.342	0.423	0.500	0.643	0.707	0.866	0.966
cos θ	1.000	0.996	0.985	0.966	0.940	0.906	0.866	0.766	0.707	0.500	0.259
KN	0.000	0.760	1.517	2.252	2.990	3.629	4.312	5.498	5.978	7.027	7.416
-KG sin θ	0.000	0.687	1.374	2.045	2.700	3.340	3.948	5.077	5.582	6.838	7.628
Uncorrected GZ	0.000	0.073	0.143	0.207	0.290	0.289	0.364	0.421	0.396	0.189	(–)0.212
Transverse GG_1 cos θ	0.064	0.063	0.063	0.062	0.060	0.058	0.055	0.049	0.045	0.032	0.016
Corrected GZ	(–)0.064	0.010	0.080	0.145	0.230	0.231	0.309	0.372	0.351	0.157	(–)0.228

STATICAL STABILITY CURVE FOR STARBOARD HEEL



Angle of list = 4½° to starboard

Effect of shift of cargo on Stability

(i) A permanent list of 4½° to starboard is caused.

(ii) The righting levers at all angles of heel are reduced.

(iii) As a result of (ii) above, the maximum righting lever becomes smaller.

(iv) Also because of (ii) above, the angle of vanishing stability and the range of stability are both reduced.

92. *M.V. 'Hindship' is in Condition No. 7 in water of RD 1.025. Rough weather causes 400 tonnes of cargo to shift horizontally through a distance of 8.5 metres and vertically downwards through a distance of 3 meters. Draw the curve of Statical Stability upto a heel of 40°, after the shift of cargo has taken place. From the Curve estimate the resulting angle of list.*

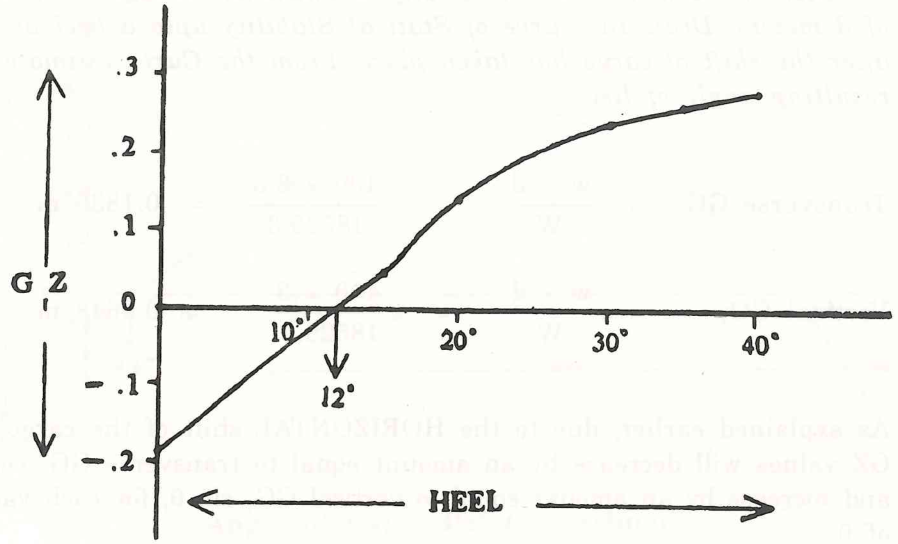
$$\text{Transverse } GG_1 = \frac{w \times d}{W} = \frac{400 \times 8.5}{18529.3} = 0.1835 \text{ m}$$

$$\text{Vertical } GG_1 = \frac{w \times d}{W} = \frac{400 \times 3}{18529.3} = 0.0648 \text{ m}$$

As explained earlier, due to the HORIZONTAL shift of the cargo, all GZ values will decrease by an amount equal to transverse $GG_1 \cos \theta$, and increase by an amount equal to vertical $GG_1 \sin \theta$, for each values of θ.

θ	0°	5°	10°	15°	20°	25°	30°	35°	40°
sin θ	0.000	0.087	0.174	0.259	0.342	0.423	0.500	0.574	0.643
cos θ	1.000	0.996	0.985	0.966	0.940	0.906	0.866	0.819	0.766
Original GZ	0.000	0.073	0.144	0.208	0.291	0.291	0.366	0.371	0.374
(–) Transverse $GG_1 \cos \theta$	0.184	0.183	0.181	0.177	0.172	0.166	0.159	0.150	0.140
GZ Corrected for transverse shift of G	(–)0.184	(–)0.110	(–)0.037	0.031	0.119	0.125	0.207	0.221	0.234
(+) Vertical $GG_1 \sin \theta$	0.000	0.006	0.011	0.017	0.022	0.027	0.032	0.037	0.042
Final GZ	(–)0.184	(–)0.104	(–)0.026	0.048	0.141	0.152	0.239	0.258	0.276

STATICAL STABILITY CURVE FOR THE HEELED SIDE



Resulting Angle of list 12°

MINIMUM STABILITY REQUIREMENTS OF THE INTERNATIONAL LOAD LINE REGULATIONS

Note :- The minimum stability requirements stipulated by the Load Line Convention 1966, are usually available in the trim and stability particulars of all ships.

These are :-

(A) The area under the curve of statical stability shall not be less than

(i) 0.055 metre radians upto an angle of heel of 30°

(ii) 0.09 metre radians upto an angle of heel of 40° or the lesser angle at which any openings which cannot be closed weathertight are immersed.

(iii) 0.03 metre radians between the angles of heel of 30° and 40° or the lesser angle referred to in (ii).

(B) The GZ value shall be atleast 0.2 metres at an angle of heel ≥ 30°.

(C) The maximum GZ shall occur at an angle of heel of not less than 30°.

(D) The initial metacentric height shall not be less than 0.15 metres.

93. *M.V. 'Hindship' is at a draft of F 7.98 m, A 8.59 m, KG 7.059 m, FSC 0.089 m. Using the table of Cross Curves of Stability Particulars, calculate her righting levers upto 75° heel. Assuming the angle of heel at which flooding occurs is 44°, state whether she satisfies each stability requirement of the International Load Line Rules.*

Original draft	F 7.98 m	} trim 0.61 m	
	A 8.59 m		
	M 8.285 m		
LCF for M. draft 8.285 m		=	70.336 m
After draft		=	8.59 m
Correction to After draft from table 'A'		=	0.30 m
Hydrostatic draft		=	8.29 m
KM for Hydrostatic draft 8.29 m		=	8.280 m
	KG	=	7.059 m
	GM (Solid)	=	1.221 m
	FSC	=	8.089 m
	GM (Fluid)	=	1.132 m

Criterion (F) is satisfied as Initial GM is greater than 0.15 m

To find Corrected KG

KG	=	7.059 m
FSC	=	(+) 0.089 m
Corrected KG	=	7.148 m

θ	0°	5°	10°	15°	20°	25°	30°	40°	45°	60°	75°
sin θ	0.0	0.087	0.174	0.259	0.342	0.423	0.50	0.643	0.707	0.866	0.966
KN	0.0	0.755	1.504	2.234	2.982	3.663	4.351	5.593	6.075	7.114	7.466
-KG sin θ	0.0	0.622	1.244	1.851	2.445	3.024	3.574	4.596	5.054	6.190	6.905
GZ	0.0	0.133	0.260	0.383	0.537	0.639	0.777	0.997	1.021	0.924	0.561
SM	1	4	2	4	2	4	1		SUM		
Product	0.0	0.532	0.520	1.532	1.074	2.556	0.777		6.991		
*SM	1		4		2		4	1	SUM		
Product	0.0		1.040		1.074		3.108	0.997	6.219		

* Common interval, 10° and the ordinates being the GZ values.

Area under the Curve upto 30° $= 6.991 \times \frac{1}{3} \times \frac{5}{57.3}$

= 0.2034 metre radians, which is greater than 0.055

Criterion (A) is therefore satisfied.

Area under the Curve upto 40° $= 6.219 \times \frac{1}{3} \times \frac{10}{57.3}$

= 0.3618 metre radians, which is greater than 0.09

Criterion (B) is therefore satisfied.

Area under the Curve between 30° & 40°

= 0.3618 − 0.2034 = 0.1584 metre radians, which is greater than 0.03.

Criterion (C) is therefore satisfied.

The maximum GZ occurs at an angle of heel > 30° and is more than 0.2 metres.

Criterion (E) is therefore satisfied.

Each requirement of the International Load Line Convention regarding Criterion of Stability is therefore satisfied.

Note : Though accurate results are obtained by using 5° intervals upto 30°, sufficiently reliable results would be obtained by using 10° intervals.

CURVES SHOWING MINIMUM INITIAL 'GM' REQUIRED TO COMPLY WITH THE MINIMUM STABILITY REQUIREMENTS OF THE INTERNATIONAL LOAD LINE CONVENTION 1966

Such curves may be provided as a part of the Trim & Stability Particulars at some ships : From the last problem the student will appreciate that the calculations involved in ensuring that the vessel satisfies the minimum stability requirements, is rather time consuming. Separate curves indicating the minimum GM which would satisfy each of the minimum requirements are developed in the shipyard and plotted with draft/displacement on one axis and the minimum GM, on the other axis as shown in the diagram on page 161.

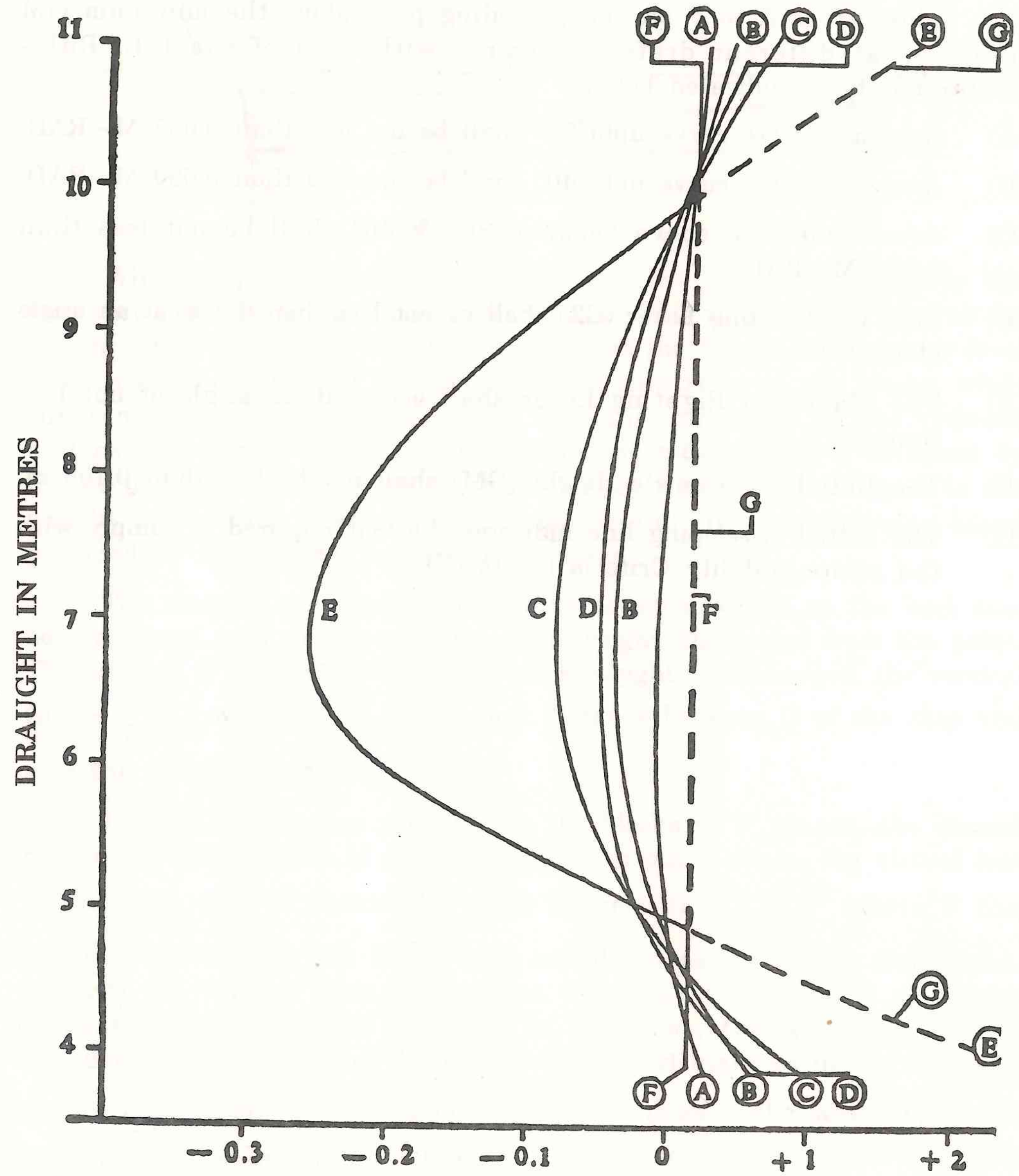
As can be seen from the set of curves, if the ship's GM is greater than the values represented by each curve, the ship would satisfy all the minimum stability requirements. Therefore, it is evident that, all the requirements are satisfied provided the GM value at any particular draft/ displacement is greater than the values represented by the dotted enveloping line.

Though it would appear from the above, that GM is the only parameter to be considered regarding the ship's stability, the student should realize that GM values required to satisfy each stability requirement, have been developed using the minimum criteria as regards statical stability curves. The fundamental importance of the statical stability curve for any condition should not therefore be ever underrated.

The ship's officer should be aware that the KM available to him in the "Hydrostatic particulars" of the ship, is for the UPRIGHT CONDITION. In most ships, as in the case of M.V. 'Hindship', the KM provided, is also for the EVEN KEEL CONDITION. Should the vessel be trimmed, the shape of her waterplane will change causing a corresponding change in the KM, and therefore in the GM. This effect will be very pronounced, in case of ships with fine lines, as the after water plane is considerably fuller than the forward one. In such ships the GM is likely to reduce considerably, when trimmed by the head.

Some ships may be provided with important hydrostatic particulars for different trims. Where such particulars are available, the ship's officer should utilize the data for the actual condition the ship is in, and this will provide him with more realistic results. However, if the hydrostatic particulars of his ship are available only for the Even keel condition, he would do well, to ensure that the calculated GM, of the vessel is large enough, to allow for any change in the KM, caused due to the trim.

When the ship is at sea, and pitching heavily, the change in KM will be very pronounced, particularly in ships with finer forward lines. In such ships, if the GM is not adequate, it may be noticed, that when pitched heavily by the head, the GM becomes very small, or even negative, thereby causing the ship, to roll to dangerously large angles.



MINIMUM GM REQUIRED TO COMPLY WITH L.L. RULES CRITERIA

CURVES SHOWING THE MINIMUM INITIAL GM REQUIRED TO COMPLY WITH THE STABILITY CRITERIA AS PER LOAD LINE RULES

The curves A to F on the preceding page show the minimum GM required at different drafts to comply with each of the L.L. Rules requirements as indicated below :

A) Area under GZ curve upto 30° shall be not less than 0.055 M—RAD.

B) Area under GZ curve upto 40° shall be not less than 0.090 M—RAD.

C) Area under GZ curve between 30° & 40° shall be not less than 0.030 M—RAD.

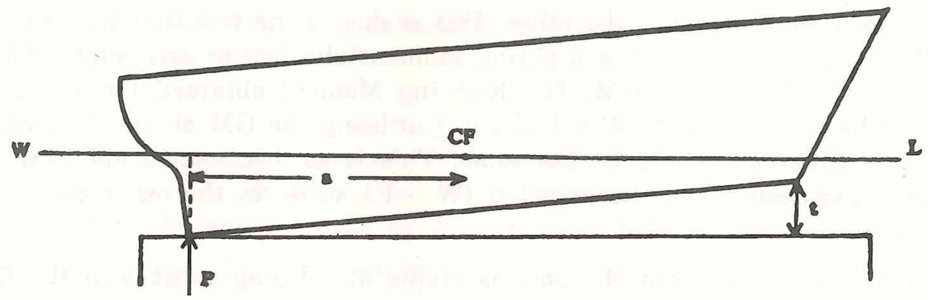
D) That the Righting Lever (GZ) shall be not less than 0.2 m at an angle of heel 30°.

E) The Maximum Righting Lever shall occur at an angle of not less than 30°.

F) The Initial Metacentric Height (GM) shall not be less than 0.150 m.

G) The dotted enveloping line indicates the GM required to comply with the entire stability Criteria (A) to (F).

DRY DOCKING



When a ship is floating, the weight of the ship is balanced by the buoyancy provided by the underwater volume. This would be so, even at the instant when one end of the ship just touches the blocks. If the water level falls thereafter, a part of the weight of the ship rests on the blocks, while the remainder is supported by the buoyancy provided by the reduced underwater volume. Thus, at any instant the total weight is balanced by (i) the upward reaction from the block on the keel (which is equal to the weight of the ship resting on the blocks) and (ii) the buoyancy being provided by the reduced underwater volume.

The reaction provided by the blocks acting upwards on the keel may be considered as a negative weight, or a weight discharged from the point. The student is already aware that when a weight is discharged, the vertical $GG_1 = \frac{w \times d}{W-w}$ where 'd' is the vertical distance between G of the ship and g of the weight discharged.

Thus if the reaction provided by the blocks is 'P' tonnes, the virtual rise in the ships centre of grativy (GG_1) or in other words, the virtual loss in the GM, can be obtained by the expression, $\frac{P \times KG}{W-P}$, where P the upthrust provided by the blocks may considered as the weight discharged, and KG the vertical distance between the ship's G and the g of weight discharged is equivalent to 'd' as in this case, the weight has been considered discharged from the keel level. This virtual loss in the GM may also be found from the expression $\frac{P \times KM.}{W}$ The proof of the latter expression is beyond the scope of the syllabus for Master (FG).

Though the loss in GM and therefore the residual GM calculated separately using the two expressions would give slightly different results, it should not be inferred that the slight difference is due to one expression being more accurate than the other. This is due to the fact that the criterion of the ship's stability is the Righting Moment she has at any angle of heel and not just the initial GM. The Righting Moment obtained for any angle of heel by the expression W x GM sin θ utilizing the GM obtained by either of the expressions would be the same. This is so, because in one case the virtual displacement of the vessel is (W – P), while in the other case, it is W itself.

It is essential that the ship is stable at all stages between the first end of the ship taking blocks and the entire keel resting on the blocks. Once the entire keel takes the blocks, the stability of the ship, is not a matter of great concern. However, when only one end of the vessel is resting on the blocks, should she become unstable, she will heel over, damaging her bottom and the blocks. To ensure that she is stable throughout the period between one end touching the blocks and the entire keel resting on the blocks, it is sufficient to ensure that she is stable at the instant before the second end of the ship takes the blocks. It is obvious that, if she is stable at that instant when the second end of the ship takes the blocks, she must have been stable at all prior occasions for the reason that as the level of water falls the force P increases and therefore the virtual GM of the vessel decreases throughout this period.

To calculate the loss of GM at the instant, she takes the blocks all over, it is necessary to know the value of force P. This can be easily obtained as the total trim she had on entering the dock is nullified when her entire keel rests on level blocks. The trimming moment that she had on entering the dock is equal to trim in cms 't' × MCTC. To reduce that trim to zero, an equal and opposite trimming moment was provided by the upward force P acting at the end of the ship which first took the blocks. The trimming moment provided by any force = The force × it's fore and aft distance from the CF.

Since the trim has been reduced to zero, the initial trimming moment and the trimming moment provided by the force 'P' would be equal i.e. P × a = t × MCTC where 'a' is the fore and aft distance between the CF and the end of the ship which took the block first. In the above expression, P is the only unknown, which can be determined and then used in the expressions mentioned earlier, to ascertain the virtual loss of GM at that instant.

Note : During drydocking, the KM and FSC of the vessel may change with the fall in water level. However, in the following problems, they may be considered constant over the range of drafts involved, as otherwise, the calculations will be beyond the scope of the Master (FG) syllabus.

94. *M.V. 'Hindship' displacing 9540 tonnes and trimmed 0.78 m by the stern is to be drydocked for bottom inspection. The hull has remained watertight and no flooding has occured. KG 7.826 m, FSC 0.164 m.*

(i) Obtain her KM, MCTC and position of LCF.

Assuming that these values and the FSC remain constant over the range of drafts involved, and that the vessel takes the blocks fore and aft at the fore and after perpendiculars respectively, calculate the following :-

(ii) The GM (Fluid) of the vessel before entering dry dock.

(iii) The virtual GM of the vessel when her keel takes the blocks all along the length of the vessel.

(iv) The ford and after draft, at which the virtual GM of the vessel becomes zero.

(v) The fall in water level, between the vessel taking blocks all over and her virtual GM becoming zero.

(i)	KM	=	8.970 m
	MCTC	=	166.0 mt
	LCF	=	72.949 m

(ii) KM = 8.970 m

KG = 7.826 m

GM (Solid) = 1.144 m

FSC = 0.164 m

GM (Fluid) = 0.980 m

GM (Fluid) before entering dry dock = 0.980 m

(iii) Calculation of virtual loss of GM on taking blocks all over.

P × a = t × MCTC (where t = trim in cms.

$$P = \frac{t \times MCTC}{a}$$ and a = dist. between CF & AP)

$$P = \frac{78 \times 166}{72.949} = 177.5 \text{ tonnes}$$

Note : Alternative methods have been shown for working sections (iii), (iv) and (v). When sufficient information is available in the question, either method may be used, but the student should follow any one method, throughout the problem. It is however advisable for the students to learn both the methods, as sometimes, the information given in the question is sufficient for one of the methods only.

Method 1

$$\text{Virtual loss of GM} = \frac{P \times KG}{W - P} = \frac{177.5 \times 7.826}{9362.5}$$

Virtual loss of GM = 0.148 m

Original GM = 0.980 m.

Virtual GM on taking blocks all over = 0.832 m

Method 2

$$\text{Virtual loss of GM} = \frac{P \times KM}{W} = \frac{177.5 \times 8.970}{9540}$$

Virtual loss of GM = 0.167 m

Original GM = 0.980 m

Virtual GM on taking blocks all over = 0.813 m

(iv) For the virtual GM to become zero, the virtual loss of GM should exactly equal the original GM.

Method 1:

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

$$0.980 = \frac{P \times 7.826}{9540 - P}$$

$$P \times 7.826 = 0.980 \times (9540 - P)$$

$$P\,(7.826 + 0.980) = 0.980 \times 9540$$

$$P \times 8.806 = 9349.2$$

$$P = \frac{9349.2}{8.806} = 1061.7 \text{ t}$$

Method 2:

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

$$0.980 = \frac{P \times 8.97}{9540}$$

$$P = \frac{0.980 \times 9540}{8.97}$$

$$P = 1042.3 \text{ t}$$

Since P is the upthrust provided by the blocks, the virtual weight of the vessel is reduced by an equal amount. Therefore the virtual displacement of the vessel, when her GM becomes zero, is (Original displacement – P).

Method 1 (Contd.)	**Method 2** (Contd.)
Virtual displacement when GM becomes zero	Virtual displacement when GM becomes zero
= 9540 – 1061.7	= 9540 – 1042.3
= 8478.3 t	= 8497.7 t
Hydrostatic draft for 8478.3 t	Hydrostatic draft for 8497.7 t
= 4.402 m	= 4.411 m
Since she is already on level blocks, the hydrostatic draft = draft F & A	Since she is already on level blocks, the hydrostatic draft = draft F & A.
F & A draft = 4.402 m	**F & A draft = 4.411 m**

v) Virtual displacement on taking blocks all over = 9540–177.5 = 9362.5 t

Hydrostatic draft for displacement of 9362.5 t = 4.806 m	Hydrostatic draft for displacement of 9362.5 t = 4.806 m
Fall in W.L. between V/L taking blocks all over and her virtual GM becoming zero	Fall in W.L. between V/L taking blocks all over and her virtual GM becoming zero
= 4.806 – 4.402 = 0.404 m	= 4.806 – 4.411 = 0.395 m
Fall in W.L. = 0.404 m	**Fall in W.L. = 0.395 m**

95. *M.V. 'Hindship' floating at a displacement of 18,820 tonnes, KG 7.728 m, FSC 0.092 m, is to be drydocked. Find her MCTC, LCF and KM.*

a) Assuming that these values remain constant over the range of drafts involved and that the vessel takes the blocks fore and aft at the fore and after perpendiculars respectively, calculate the maximum trim by the stern allowable to ensure a virtual GM of at least 0.3 m on taking the blocks fore and aft.

b) At the maximum permissible trim, find

(i) Her drafts F & A, on entering dry dock.

(ii) The draft Forward, at which the head would take the blocks.

(iii) The fall in water level between taking blocks Aft and taking blocks For'd.

For displacement of 18820 t

MCTC	210.47 mt
LCF	69.836 m
KM	8.371 m
Hydrostatic Draft	8.905 m

KM	=	8.371 m
KG	=	7.728 m
GM (Solid)	=	0.643 m
FSC	=	0.092 m
GM (Fluid)	=	0.551 m
Residual GM required	=	0.300 m
Loss of GM permissible	=	0.251 m

Method 1

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

$$\therefore 0.251 = \frac{P \times 8.371}{18820}$$

$$P = \frac{0.251 \times 18820}{8.371}$$

$$P = 564.3 \text{ tonnes}$$

$$P \times a = t \times MCTC$$

$$t = \frac{P \times a}{MCTC}$$

$$= \frac{564.3 \times 69.836}{210.47}$$

$$\text{trim} = 187.2 \text{ cms.}$$

Maximum permissible trim : 1.872 m

Method 2

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

$$\therefore 0.251 = \frac{P \times 7.728}{18820 - P}$$

$$18820 \times 0.251 = P\,(7.728 + 0.251)$$

$$P = \frac{18820 \times 0.251}{(7.728 + 0.251)} = \frac{4723.82}{7.979}$$

$$P = 592 \text{ tonnes}$$

$$P \times A = t \times MCTC$$

$$t = \frac{P \times a}{MCTC}$$

$$= \frac{592 \times 69.836}{210.47}$$

$$\text{trim} = 196.4 \text{ cms.}$$

Maximum permissible trim : 1.964 m

Method 1 (Contd.)

(b) (i) $t_a = \frac{t \times LCF}{LBP}$

$$= \frac{1.872 \times 69.836}{143.16}$$

$$t_a = 0.913 \text{ m}$$

$$t_f = t - t_a$$

$$= 1.872 - 0.913$$

$$t_f = 0.959 \text{ m}$$

Original hydrostatic draft.

	F	A
	8.905 m	8.905 m
trim	(–) 0.959 m	(+) 0.913 m

Drafts on entering dry dock
F 7.946, A 9.818 m

Method 2 (Contd.)

(i) $t_a = \frac{t \times LCF}{LBP}$

$$= \frac{1.964 \times 69.836}{143.16}$$

$$t_a = 0.958 \text{ m.}$$

$$t_f = t -$$

$$= 1.964 - 0.958$$

$$t_f = 1.006 \text{ m}$$

Original hydrostatic draft.

	F	A
	8.905 m	8.905 m
trim	(–) 1.006 m	(+) 0.958 m

Drafts on entering dry dock
F 7.899 m, A 9.863 m

Method 1 (Contd.)

(b) (ii) Original displacement = 18820 t

Upthrust 'P' on taking blocks F & A = 564.3 t

∴ Virtual displacement on taking block For'd = 18255.7 t

Hydrostatic draft for displacement 18255.7 t = 8.672 m

Method 2 (Contd.)

Original displacement = 18820 t

Upthrust 'P' on taking blocks F & A = 592 t

∴ Virtual displacement on taking blocks For'd =18228 t

Hydrostatic draft for displacement 18228 t = 8.661 m

Since the vessel will be on an even keel, on taking the blocks F & A, the For'd and the After draft, will be equal to the Hydrostatic draft.

Method 1: **Draft Ford, at which the head will touch the blocks = 8.672 m**

Method 2: **Draft Ford at which the head will touch the blocks = 8.661 m**

(b) (iii) Stern will take the blocks, when the **depth of water** over the blocks equals the **original draft Aft.**

The head will take the blocks, when the **depth of water** over the blocks equals the **draft at which the head touches the block,** as calculated above.

Method 1:

Original draft Aft as per b (i) = 9.818 m

Draft at which head takes the blocks, as per b (ii) =8.672 m

Fall in water level = 1.146 m

Method 2:

Original draft Aft as per b (i) = 9.863 m

Draft at which head takes the blocks, as per b (ii) = 8.661 m

Fall in water level = 1.202 m

96. *M.V. 'Hindship' at a draft of F 3.82 m, A 5.46 m in water of density 1.015 is being drydocked, KG 8.38 m, FSC 0.12 m. Assuming the KM, MCTC, LCF and FSC remain unchanged over the range of drafts involved, calculate (i) the virtual GM of the vessel on taking blocks all over (ii) the fore and after drafts at which her virtual GM becomes nil.*

F 3.82 m
A 5.46 m } trim 1.64 m by stern
M 4.64 m

LCF for mean draft of 4.64 m	=	73.008 m
Corrn. from table 'A'	=	0.836 m
After draft	=	5.460 m
Hydrostatic draft	=	4.624 m

Hydrostatic particulars in water of density 1.015

$$\text{Displacement} = \frac{8962.56 \times 1.015}{1.025} = 8875.1 \text{ m}$$

$$\text{MCTC} = \frac{163.992 \times 1.015}{1.025} = 162.392 \text{ m}$$

LCF = 73.012 m

KM = 9.176 m

KM	=	9.176 m
KG	=	8.380 m
GM (Solid)	=	0.796 m
FSC	=	0.120 m
GM (Fluid)	=	0.676 m

Virtual loss of GM on taking the blocks all over

$$P \times a = t \times \text{MCTC}$$

$$P = \frac{t \times \text{MCTC}}{a} = \frac{162.392 \times 164}{73.012} = 364.766 \text{ t}$$

Method 1

(i) Virtual loss of GM $= \dfrac{P \times KG}{W - P}$

$= \dfrac{364.8 \times 8.38}{(8875.1 - 364.8)}$

Virtual loss of GM = 0.359 m

Original GM = 0.676 m

Virtual GM on taking blocks all over = 0.317 m

Method 2

Virtual Loss of GM $= \dfrac{P \times KM}{W}$

$= \dfrac{364.8 \times 9.176}{8875.1}$

Virtual loss of GM = 0.377 m

Original GM = 0.676 m

Virtual GM on taking blocks all over = 0.299 m

(ii) For virtual GM to become zero, Virtual loss of GM must equal the original GM.

Method 1:

Virtual loss of GM $= \dfrac{P \times KG}{W - P}$

$0.676 = \dfrac{P \times 8.38}{W - P}$

$0.676\ W - 0.676\ P = 8.38\ P$

$8.38\ P + 0.676\ P = 0.676 \times 8875.1$

$P = \dfrac{0.676 \times 8875.1}{9.056}$

$P = 662.5$ t

Virtual displ. when GM becomes zero = 8875.1 − 662.5

= 8212.6 t

Equivalent weight in SW

$\dfrac{8212.6 \times 1.025}{1.015} = 8293.5$ t

Hydrostatic draft = 4.317 m

Since she is already on level blocks, hydrostatic draft = draft F & A

F & A draft = 4.317 m

Method 2:

Virtual loss of GM $= \dfrac{P \times KM}{W}$

$0.676 = \dfrac{P \times 9.176}{8875.1}$

$P = \dfrac{8875.1 \times 0.676}{9.176}$

$P = 653.8$ t

Virtual displ. when GM becomes zero = 8875.1 − 653.8

= 8221.3 t

Equivalent weight in SW

$\dfrac{8221.3 \times 1.025}{1.015} = 8302.3$ t

Hydrostatic draft = 4.321 m

Since she is already on level blocks, hydrostatic draft = F & A

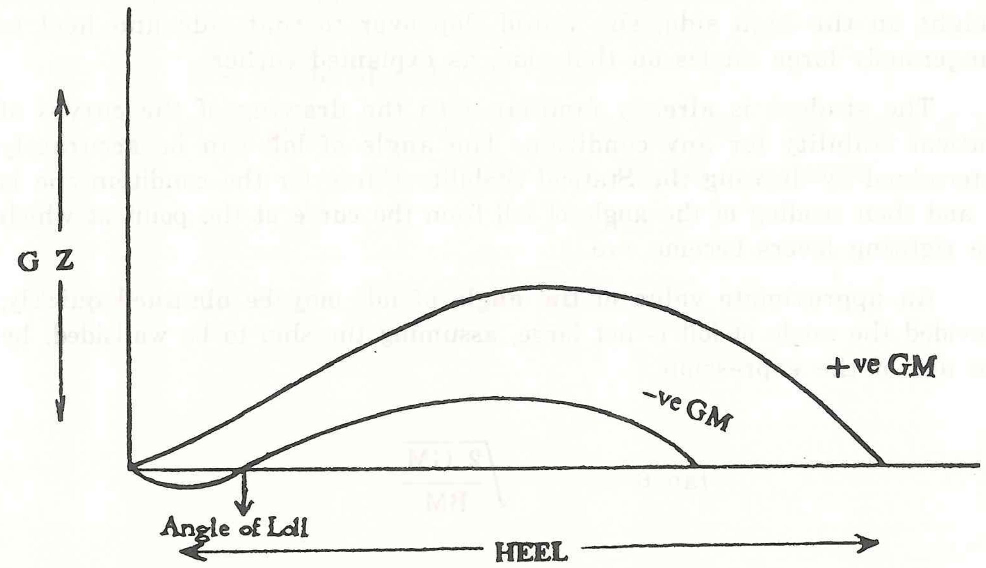
F & A draft = 4.321 m

ANGLE OF LOLL

A vessel with an initial negative metacentric height is unstable in the upright condition and therefore heels over as she has a capsizing lever when inclined slightly. On heeling, the centre of buoyancy moves out from the centre line till, at a particular angle of heel the centre of buoyancy and the centre of gravity are in the same vertical line. The angle of heel at which this occurs is called the angle of loll. In still water, the vessel will remain heeled to that angle. It should be realized that no righting levers are present upto the angle of loll on either port or starboard sides. Thus she may incline to her angle of loll either to port side or to starboard side.

Though she may attain positive stability and therefore have righting levers at larger angles of heel, when rolling in a seaway, it should be realized that the righting levers would be fairly small. Even a small heeling moment will therefore cause the vessel to heel over to dangerously large angles.

The following sketch illustrates the statical stability curve of a vessel with a +ve GM and of the same vessel with initial −ve GM.



As can be seen from the sketch, the vessel with an initial −ve metacentric height has capsizing levers till her angle of loll. The maximum GZ value, the angle of vanishing stability, the range of +ve stability and the dynamical stability at any angle of heel are all very much less than those for the same vessel with +ve GM.

Should a vessel develop a −ve GM, at sea, due to unforeseen circumstances, it should be realized that she will roll to very large angles of heel and not just between the angle of loll on either side. This is so because, as she rolls from one side to the other, since there are no righting levers operating between the angles of loll on either side to oppose the roll, she builds up a large amount of kinetic energy. Since her statical stability curve is shallow, the area under that curve and, therefore, the dynamical stability upto any angle of heel is very small. The momentum of the roll cannot therefore be overcome till very large angles of heel are reached. This can result in shift of cargo causing further deterioration in the situation.

To correct such a condition it is necessary to remedy the basic cause i.e. G being too high. The G may be lowered by reducing free surface effect in various tanks or by trimming down weights or by ballasting at a low level.

When ballasting, care should be taken to ballast a divided tank, commencing with the low side. When that tank is full, the high side tank should be filled to even out the weight distribution. If on the contrary the high side tank was ballasted initially, as would have been done to correct a list due to excess weight on the lowside, it would lead to dangerous consequences including capsizing. This could happen because, on adding weight on the high side, she would flop over to that side and heel to dangerously large angles on that side, as explained earlier.

The student is already familiar with the drawing of the curves of statical stability for any condition. The angle of loll can be accurately determined by drawing the Statical Stability Curve for the condition she is in and then reading of the angle of loll from the curve at the point at which the righting levers become +ve.

An approximate value of the angle of loll may be obtained quickly, provided the angle of loll is not large, assuming the ship to be wallsided, by the use of the expression :

$$\tan\theta = \sqrt{\frac{2\ GM}{BM}}$$

97. *M.V. 'Hindship' is floating at a displacement of 16875.5 tonnes, KG 8.158 m, FS Moment 1798 mt. Assuming her to be wallsided, calculate her angle of loll. Also calculate her GM at the angle of loll.*

$$FSC = \frac{1798}{16875.5} = 0.107 \text{ m.}$$

For Displacement 16875.5 t

KB	=	4.304 m
BM	=	3.956 m
KM	=	8.260 m
KG	=	8.158 m
GM (Solid)	=	0.102 m
FSC	=	0.107 m
GM (Fluid)	=	0.005 m (negative)

$$\tan \text{ angle of loll} = \sqrt{\frac{2GM}{BM}} = \sqrt{\frac{2 \times 0.005}{3.956}}$$

θ = Angle of Loll = **2°53'**

GM at the Angle of Loll = 2 × Initial GM × sec. angle of loll

= 2 × 0.005 × sec 2°53'

= 0.010 m

GM at the Angle of Loll = 0.010 m

98. *M.V. 'Hindship' floating at a draft of F 5.73 m, A 6.42 m, is at an angle of loll of 4°, FS Moment 1563 mt. Assuming the ship to be wallsided, calculate her KG.*

Draft F 5.73 m, A 6.42 m } trim 0.69 m by stern.

M 6.075 m LCF = 72.422 m

After draft	=	6.420 m
Corrn. from table 'A'	=	(–) 0.349 m
Hydrostatic draft	=	6.071 m
For hydrostatic draft 6.071 m, displacement	=	12179.8 tonnes
KM	=	8.419 m
KB	=	3.241 m
BM	=	5.178 m

$$\tan \text{Angle of Loll} = \sqrt{\frac{2GM}{BM}}$$

$$\tan^2 \text{Angle of Loll} = \frac{2GM}{BM}$$

$$\text{Initial GM} = \frac{BM \times \tan^2 \text{angle of Loll}}{2}$$

$$= \frac{5.178 \times \tan^2 4°}{2}$$

$$= 0.013 \text{ m (negative)}$$

$$FSC = \frac{1563}{12179.8} = 0.128 \text{ m}$$

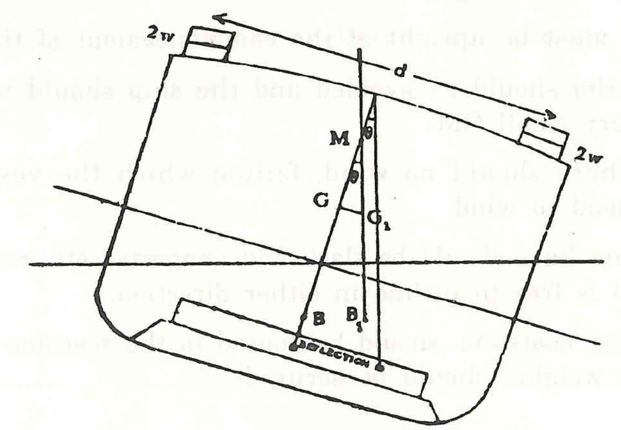
GM (Solid)	=	0.115 m (positive)
KM	=	8.419 m
KG	=	**8.304 m**

INCLINING EXPERIMENT

The KG for any condition may be obtained, provided its value is known accurately for a specified condition. The International Load Line Regulations, therefore require every ship to be supplied, with her KG and GM in the LIGHT condition, as determined by an inclining experiment. This is normally carried out by the shipyard, when the ship is as near completion as possible. The experiment may also have to be carried out if large structural alterations are made subsequently.

Two or three long pendulums, are generally rigged, one forward, one midships, and one aft. The pendulum bobs are immersed in troughs of oil, to damp their motion. Graduated battens are set up beneath each pendulum to measure their deflection when the vessel heels. Four equal weights together amounting to about 1/500th of the light weight of the ship are placed on deck, two on each side, at measured equal distances, off the centre line. Since KM changes with heel, the weights are chosen so as to give small enough angles of heel when they are shifted across the deck. If the angles of heel were large, the KM would change significantly and the heels produced will not be proportional to the heeling moment provided. On the other hand, if the weights were too small, the heels produced would also be very small, and any small error in the reading of the deflections, would introduce a significant error in the calculation of GM.

The pendulum positions are noted against each batten. One weight is shifted from port to starboard and the deflections of the pendulums are noted. The second weight from the port side is also, then shifted to starboard and the deflections of the pendulums are again noted. The two weights are then returned to the port side, to check that the pendulums return to the initial positions. This entire procedure is then repeated with the two weights from the starboard side. In some shipyards, the heel produced is measured or verified by an instrument called a 'stabilograph.'



When a weight of 'w' tonnes is shifted transversely through a distance 'd' metres the transverse $GG_1 = \frac{w \times d}{W}$. From the figure, it can be seen that $GG_1 = GM \times \tan\theta$

$$\therefore GM \tan\theta = \frac{w \times d}{W}$$

$$\Rightarrow GM = \frac{w \times d}{W \times \tan\theta}$$

As can be seen from the figure, $\tan\theta = \frac{\text{deflection of pendulum}}{\text{length of pendulum}}$

It must be remembered, that 'W' used in the calculations is the displacement of the ship at the time of the inclining experiment, **including the inclining weights.**

When more than one weight is used and as is often the case, the weights are not equal, the method used in calculating the GM varies from shipyard to shipyard. In the case of M.V. 'Hindship' the GM is calculated separately for each shift of weight, using the deflection of each pendulum. The GMs so obtained for the various operations are then averaged to give the GM (Fluid) of the ship in that condition.

The KM for displacement 'W' is obtained from the vessel's hydrostatic data. The corrected KG in that condition is then obtained by subtracting GM (Fluid) from the KM. The FSC if any, is subtracted, to obtain her KG in that condition. By taking moments about the keel, allowance is then made for any weights on board, including the inclining weights, which do not form part of the light ship, to obtain the KG in the LIGHT condition.

Preparations / Precautions

1. The ship must be upright at the commencement of the experiment.
2. A large trim should be avoided and the ship should not be inclined with a very small GM.
3. Ideally, there should no wind, failing which the vessel should be moored head to wind.
4. All mooring lines should be slack and gangways etc. removed, so that the vessel is free to incline in either direction.
5. All derricks, boats etc. should be housed in the seagoing condition, and any loose weights should be secured.

6. The ship should be as near completion as possible. An accurate list should be made of weights to be removed, those to go on board, and those to be shifted, together with their kgs, so that proper allowances can be made for these weights, in the calculation of light KG.
7. All tanks should preferably be full or empty.
8. A careful note should be made of all tank soundings, to allow for the weight of liquid in them, as well as for any free surface effect.
9. Only the minimum number of persons should remain on board and they should remain on the centre line, when deflections are noted.
10. The density of water, and the drafts of the ship forward midships (P & S), and aft, should be noted carefully.

99. *M.V. 'Hindship' was floating with all compartments empty except as follows :-*

No. 2 (P & S) DB tanks full with water ballast

No. 1 DB tank contained 100 tonnes of H.F.O.

An inclining Experiment was conducted in this condition. A weight of 10 tonnes Kg 10.2 m, shifted transversely through a distance of 17.6 m, caused a deflection of 8.3 cms in a plumb line 8.5 m in length. Calculate the GM (solid) and the KG of the light ship.

Light Displacement of M.V. 'Hindship'	=	5499.8 tonnes
Water ballast in No. 2 (P & S) = 404.8 x 1.025	=	414.92 tonnes
H.F.O. in No. 1 DB tank	=	100.00 tonnes
Inclining weight	=	10.00 tonnes
Displacement at the time of Inclining Experiment	=	6024.72 tonnes
KM for displacement of 6024.72 t	=	11.113 m

$$GM\ (Fluid) = \frac{w \times d}{W \times \tan\theta} = \frac{w \times d}{W \times \frac{deflection}{length}}$$

$$= \frac{10 \times 17.6}{6024.72 \times \frac{0.083}{8.5}} = 2.992\ m$$

Corrected KG, when heeled = 11.113 − 2.992 = 8.121 m

$$FSC\ for\ No.\ 1\ tank = \frac{419 \times 0.95}{6024.72} = 0.066\ m$$

KG, when heeled = 8.055 m

	Weights (t)	*KG* (m)	*Moments* (mt)
Total Displacement	6024.72	8.055	48529.1
No. 2 DB tanks	(–) 414.92	0.65	(–) 269.7
No. 1 DB tank	(–) 100.0	1.14	(–) 114.0
Inclining Wt.	(–) 10.0	10.2	(–) 102.0
Light Wt.	5499.8	Lt. Moments	48043.4

$$\textbf{Light KG} = \frac{48043.4}{5499.8} = \textbf{8.735 m}$$

KM for light displacement = 11.651 m

Light GM (Solid) = 2.916 m

100. *M.V. 'Hindship' in Condition No. 7 struck a rock piercing her outer bottom in way of No. 4 P, C & S and No. 5 P & S DB tanks. Calculate the drafts F & A at which she will float and her GM (Fluid) after bilging.*

Since No. 4 (P & S) DB tanks already contain S.W. to their full capacity, no further amount of water is added in these tanks on bilging. Thus they do not enter into the calculations.

Wt. of water entering No. 4 (C) DB tank = 257.4 × 1.025 = 263.8 t

Capacity of No. 5 (P) = 83.5 m^3

$$Vol.\ of\ D.O.\ oil\ in\ it = \frac{17.7}{0.88} = 20.1\ m^3$$

Wt. of water entering No. 5 (P) = 63.4 × 1.025 = 65 t

Capacity of No. 5 (S) = 48.8 m^3

$$Vol.\ of\ H.F.O.\ in\ it = \frac{38.0}{0.95} = 40.0\ m^3$$

Wt. of water entering No. 5 (S) = 8.8 × 1.025 = 9 t

	Weights (t)	*KG* (m)	*V. Moments* (mt)	*LCG* (m)	*L. Moments* (mt)
Cond. No. 7	18529.3	7.807	144653	72.340	1340415
No. 4 (C)	263.8	0.63	166.2	57.58	15189.6
No. 5 (P)	65.0	0.85	55.3	38.24	2485.6
No. 5 (S)	9.0	0.87	7.8	39.73	357.6
Final Wt.	18867.1	F.V. Mmts.	144882.3	F.L. Mmts.	1358447.8

$$LCG = \frac{1358447.8}{18867.1} = 72.001\ m$$

$$KG = \frac{144882.3}{18867.1} = 7.679\ m$$

To find FSC after bilging,

Original F.S. Moment = 1552 mt

F.S.M. of No. 5 (P & S) = (–) 242 mt

Final F.S. Moment = 1310 mt

$$Final\ FSC = \frac{1310}{18867.1} = 0.069\ m$$

KM for displacement 18867.1 t	=	8.374 m
KG	=	7.679 m
GM (Solid)	=	0.695 m
FSC	=	0.069 m
GM (Fluid)	=	**0.626 m**

For displacement 18867.1 t, Hydrostatic draft	=	8.924 m
MCTC	=	210.74 m
LCB	=	72.312 m
LCF	=	69.822 m

$$\text{Total trim } t = \frac{LCB - LCG}{MCTC \times 100} \times W = \frac{72.312 - 72.001}{210.74 \times 100} \times 18867.1 = 0.278 \text{ m}$$

$$t_a = \frac{t \times LCF}{LBP} = \frac{0.278 \times 69.822}{143.16} = 0.136 \text{ m}$$

$$t_f = t - t_a = 0.278 - 0.136 = 0.142 \text{ m}$$

	F	A
Hydrostatic Draft	8.924 m	8.924 m
trim	(–) 0.142 m	(+) 0.136 m
Final Draft	**F : 8.782 m**	**A : 9.060 m**

Note :- 1. The problem has been solved by the added weight method.

2. The vessel will have the above drafts and GM immediately after bilging, if the oil in No. 5 (P & S) DB tanks is not displaced by water. Over some period of time, water is likely to replace the oil, when, theoretically, these values will change. However, since the amount of oil involved is very small, the changes will be negligible.

101. *M.V. 'Hindship' floating at a Hydrostatic draft of 8.8 m has, zero GM. Calculate the list produced if a weight of 2 tonnes already on board is shifted transversely through a horizontal distance of 2.45 metres. Assume the ship to be wall sided.*

For hydrostatic draft of 8.8 m, displacement	=	18565 tonnes
KM	=	8.352 m
KB	=	4.674 m
BM	=	3.678 m

$$\tan \text{list} = \sqrt[3]{\frac{2 \times w \times d}{W \times BM}} = \sqrt[3]{\frac{2 \times 2 \times 2.45}{18565 \times 3.678}}$$

$$\tan \text{list} = 0.0523$$

Angle of list = 3°

102. *Calculate the Moment of Inertia of the water plane of M.V. 'Hindship' at an even keel of 7.70 m.*

$$BM = I/V$$

$$I = BM \times V$$

$$= BM \times \frac{\text{Displacement}}{1.025}$$

For draft 7.70 m	Displacement	=	15927 tonnes
	KM	=	8.239 m
	KB	=	4.092 m
	BM	=	4.147 m

$$I = \frac{4.147 \times 15927}{1.025} = 64437 \text{ m}^4$$

Moment of Inertia = 64437 m⁴

STABILITY FORMULAE

Area of waterplane = $L \times B \times C_w$

Volume of displacement = $L \times B \times d \times C_b$

Displacement = Volume of displacement × density

For box shaped vessels

(Density remaining constant) $\frac{\text{New displacement}}{\text{Old displacement}} = \frac{\text{New draft}}{\text{Old draft}}$

For box shaped vessels

(Displacement remaining constant) $\frac{\text{New draft}}{\text{Old draft}} = \frac{\text{Old density}}{\text{New density}}$

For all vessels

(Draft remaining constant) $\frac{\text{New displacement}}{\text{Old displacement}} = \frac{\text{New density}}{\text{Old density}}$

$$TPC = \frac{1.025\ A}{100}$$

$$\text{FWA (in mms)} = \frac{W}{4\ TPC}$$

$$\text{Dockwater allowance} = \frac{\text{FWA} \times \text{(Difference of densities)}}{(1.025 - 1.000)}$$

$$GG_1 = \frac{w \times d}{\text{Final W}}$$

$$\text{Final KG} = \frac{\text{Final Vertical Moment}}{\text{Final Weight}}$$

$$\text{Final LCG} = \frac{\text{Final Longitudinal Moment}}{\text{Final Weight}}$$

$$GM = KM - KG$$

$$GM_L = KM_L - KG$$

$\tan \text{list} = \frac{GG_1}{GM}$ (for small angles of heel only)

$GZ = GM \times \sin\theta$ (for small angles of heel only)

Wall Sided Formula : $GZ = (GM + \frac{1}{2} BM \tan^2\theta) \times \sin\theta$

$GN = KN - KG \sin\theta$

New GZ = Old GZ $\pm$ Vertical $GG_1 \sin\theta$

New GZ = Old GZ $-$ Horizontal $GG_1 \cos\theta$

Righting Moment or Moment of Statical Stability = $W \times GZ$

Dynamical Stability = Area under the curve of statical stability $\times$ W

Dynamical Stability = $2 \times W \times \text{Hav}\,\theta\,(GM + BM\ \text{Hav}\,\theta.\ \sec\theta)$

F.S. Moment = $I \times \delta$

F.S. Correction $= \dfrac{\text{F.S. Moment}}{\text{Displacement}}$

F.S.C. for rectangular tanks $= \dfrac{lb^3}{12V} \times \dfrac{\delta_t}{\delta_r} \times \dfrac{1}{n^2}$

For rectangular waterplane I $= \dfrac{LB^3}{12}$

BM $= \dfrac{I}{V}$

For box shaped vessels BM $= \dfrac{B^2}{12d}$

For box shaped vessels KB $= \dfrac{d}{2}$

For vessels of triangular cross-section BM $= \dfrac{B^t}{6d}$

For vessels of triangular cross-section KB $= \dfrac{2}{3}d$

For rectangular waterplanes $I_L = \dfrac{BL^3}{12}$

$BM_L = \dfrac{I_L}{V}$

For box shaped vessels $BM_L = \dfrac{L^2}{12d}$

For vessels of triangular cross-section $BM_L = \dfrac{L^2}{6d}$

Simpsons Rules

Rule 1. for odd numbers.

Simpson's multipliers 1, 4, 2, 4, 2, ... 4, 1.

Common multiplier $\dfrac{h}{3}$

Rule 2. for (4 + 3n)

Simpsons multipliers 1, 3, 3, 2, 3, 3, ... 2, 3, 3, 1.

Common multiplier $\dfrac{3h}{8}$

Rule 3.

Simpsons multipliers 5, 8, -1

Common multipliers $\dfrac{h}{12}$

Moment of Area or volume, for Rule 3,

Simpsons multipliers 3, 10, -1

Common multiplier $\dfrac{h^2}{24}$

Centre of Gravity of Area or Volume $= \dfrac{\text{Moment of Area or Volume}}{\text{Area or Volume}}$

Mean Sinkage or Rise in cms. $= \dfrac{W}{TPC}$

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

Trimming Moment $= w \times d$ (from CF)

Total change of trim $= \dfrac{\text{Trimming Moment}}{\text{MCTC}}$

After trim = total trim $\times \dfrac{I}{L}$ (½ total trim when CF is amidships)

Ford trim = total trim $-$ after trim

Correction to mean draft to obtain true mean draft

Corrn. : $= \dfrac{\text{distance (between CF \& midships)} \times \text{trim}}{\text{Length}}$

Inclining Experiment

$$GM = \frac{w \times d}{W \times \tan\theta} = \frac{GG_1 \times \text{Length of pendulum}}{\text{deflection}}$$

Increase in draft due to list

New draft = (old draft − rise of floor) × cos θ + ½ Beam sin θ

Effect of trim on tank sounding :

difference between ford & after soundings $= \frac{I \times t}{L}$

Dry Docking

$$P = \frac{t \times MCTC}{a}$$

P = original displacement − virtual displacement

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

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

Bilging

Permeability $= \frac{\text{Broken Stowage} \times 100}{\text{Stowage factor}}$ %

Mean Sinkage $= \frac{\text{Volume of lost buoyancy}}{\text{Intact waterplane area}} = \frac{V}{(A - a)}$

Sinkage with permeability $= \frac{p \times v}{(A - pa)}$

trim $= \frac{\text{trimming moment}}{\text{MCTC in bilged condition}}$

Total Pressure or Thrust = A × δ × head × 9.81 KN

Depth of CP below WL $= \frac{I_{WL}}{A \times \text{head}}$

Theorem of Parallel Axis

$$I_{xx} = I_{CG} + Ah^2$$

tan angle of loll $= \sqrt{\frac{2GM}{BM}}$ (For wallsided V/Ls)

Positive GM at angle of Loll = 2 × initial GM × sec. loll (for wallsided V/Ls).

List with Zero GM

tan list $= \sqrt[3]{\frac{2 \times w \times d}{W \times BM}}$ (For wallsided V/Ls)

FURTHER FORMULAE USED IN THIS BOOK

Corrected KG = KG + FSC

GM (Solid) = KM − KG

GM (Fluid) = GM (Solid) − FSC

tan list $= \frac{GG_1}{GM\ (Fluid)}$ (for small angles of heel)

GZ = KN − Corrected KG × sin θ

Hydrostatic draft = draft aft ± Corrn. from table 'A'

total trim 't' $= \frac{LCB - LCG}{MCTC \times 100} \times$ Displacement

$t_a = \frac{t \times LCF}{LBP}$

$t_f = t - t_a$

Draft After = Hydrostatic draft + t_a

Draft Forward = Hydrostatic draft − t_f

TEST YOURSELF

2nd Mate (FG), 1st Mate (FG), Master (FG).

1. M.V. 'Hindship' arrives port in Condition No. 7. One of the locomotives, weighing 76 tonnes is to be discharged, using the ship's jumbo derrick, the head of which is 25 metres above keel. Find her GM (Fluid)

   i) when the locomotive is hanging on the derrick 0.5 metre above the deck.

   ii) when the locomotive has been discharged.

   (i) 0.413 m, ii) 0.478 m.

2. M.V. 'Hindship' displacing 13530 t in water of density 1.015 t/m^3, KG 7.344 m, FSC 0.076m, shifts a weight of 30 tonnes from 3 metres off the centre line on the port side to 4.5 m off the centre line on the starboard side. Calculate the resultant list.

   (1°06' to starboard)

3. M.V. 'Hindship' arrives port in Condition No. 11. She then loads and discharges as follows :-

Compartment	*Disch.* (t)	*Load* (t)	*Kg.* (m)	*V. Moments* (mt)
Locomotives on Deck	760		13.83	10510
2 TD	400		10.70	4280
4 TD	200		10.40	2080
2 TD		300	10.70	3210
4 TD		150	10.40	1560

   Assuming the FSC in the final condition was 0.107 m and bunker consumption was negligible, calculate the GM (Fluid), after the above operations.

   (0.765 m)

4. M.V. 'Hindship' loads to her Summer mark, in Fresh Water and proceeds down river to another port consuming 30 tonnes of bunkers and water. At this port, she loads some cargo and is again at her Summer draft in water of RD 1.016. Find the number of tonnes of cargo loaded at the second port.

   (336.2 t)

5. M.V. 'Hindship' floating at a mean draft of 5.5 m, Kg 7.53 m, FSC in the final condition 0.104 m, has to load 1200 tonnes of cargo in No. 2 Hold and No. 2 TD. Find the amount of cargo to be loaded in each space to complete the ship with a GM (Fluid) of 1 m.

(No. 2 Hold = 1098.9 t)
(No. 2 TD = 101.1 t)

6. M.V. 'Hindship' displacing 16398 t, KG 7.15 m, FSC 0.08 m discharged 280 t, Kg 6.20 m, Cg 1.4 m off the CL to stbd. and loaded 280 t, Kg 6.20 m, Cg 3.5 m to starboard off CL. A 70 t parcel of cargo was shifted horizontally from 3.6 m port of CL to 1.2 m port of CL. Calculate the resultant list.

(2°36' to starboard)

7. M.V. 'Hindship' in Condition No. 4, discharges the entire cargo from No. 1 TD and No. 3 TD. The entire HFO from the settling and service tank P & S is shifted to No. 4 DB tank centre. Find the final KG and GM (Fluid).

(KG 6.932 m, GM (Fluid) 1.235 m)

8. M.V. 'Hindship' arrives at a port in water of RD 1.012 with drafts F 6.15 m, A 7.22 m. Her sailing draft in water of RD 1.025 was F 5.33 m, A 5.98 m. Calculate the weight of cargo discharged at that port, if 85 tonnes of fuel and fresh water were consumed in the port.

(2083.3 t)

9. M.V. 'Hindship' floating at a mean draft of 7.12 m in water of RD 1.008, KG 6.12 m. loads 900 t of cargo in 3 TD, 2 m off CL to Port and 200 t in No. 4 TD, 2.5 m to stbd. of CL. An 80 t lift is discharged from deck Kg 14.1 m, Cg 4 m to port of CL. Calculate her final mean draft and angle of list if the FSC in the final condition was 0.12 m.

(7.566 m, 2°07' to Port)

10. M.V. 'Hindship' floating in water RD 1.025 at a draft of F 7.23 m, A 7.93 m loads 940 t and sails to another port consuming 130 t of fuel and FW. Find her arrival hydrostatic draft at the second port in water of RD 1.009.

(8.036 m)

11. M.V. 'Hindship' loading in FW is at a hydrostatic draft of 7.30 m, KG 7.90 m. 1300 tonnes of cargo is to be loaded. What should be the Kg of the cargo to be loaded so that her final GM is 0.5 m. (i) in SW. (ii) in FW.

(5.927 m, 5.976 m)

12. M.V. 'Hindship' displacing 12,400 t in water of RD 1.010 has a GM (Fluid) of 0.68 m, FSM 1530 mt. She loads 620 t in No. 2 Hold, kg 5.02 m. No. 2 DB tanks P & S which contained 50 t each SW ballast was pumped out. A 150 t parcel of cargo was shifted from No. 2 Hold to No. 3 TD. Calculate her final GM (Fluid).

(0.661 m)

13. M.V. 'Hindship' is in Condition No. 2. Find her GM (Fluid) after the following operations are carried out :-

Loads	1 TD	601 tonnes	
Loads	3 Hold	1520 tonnes	Kg 1.70 m
Loads	5 Hold	420 tonnes	

Pumps out F. Pk. Tank
Pumps out No. 4 DB tanks (P & S)
FSC in the final condition is 0.155 m.

(2.118 m)

14. M.V. 'Hindship' loading in dock water of RD 1.010, is floating at a mean draft of 8.9 m. Calculate the amount of cargo she can load prior to sailing into a Winter Zone, if 120 tonnes of bunkers is yet to be received and 45 tonnes of FW and fuel is expected to be consumed before sailing.

(543.3 t)

15. M.V. 'Hindship' is floating at a draft of F 8.68 m, A 8.88 m. in water of density 1.010 tonnes/m³. LCG 72.129 m. It is desired to obtain an LCG of 71.9 m by discharging 400 t of cargo. Calculate the position from where the weight should be discharged.

(82.348 m ford. of AP)

16. M.V. 'Hindship' is Condition No. 7 pumps out 60 tonnes of ballast each from No. 4 DB tanks P and S. The entire diesel oil is No. 5 DB tank P is consumed in shifting to the dock. Calculate her GM (Fluid) on arriving in the dock where the RD of water is 1.007.

(0.397 m)

17. M.V. 'Hindship' is floating at a draft of F 7.40 m, A 6.60 m, in dock water of RD 1.016. Calculate her (i) hydrostatic draft, (ii) displacement, (iii) dead weight.

(i) 7.00 m, (ii) 14273.4 t, (iii) 8673.6 t

18. M.V. 'Hindship' floating in water of RD 1.025, at an even keel draft of 3.9 m. Calculate the hydrostatic draft at which she will float, in water of RD 1.011 at the same displacement :- (i) using FWA, calculated for the draft in question. (ii) without the use of FWA.

(i) 3.948 m, (ii) 3.948 m

19. M.V. 'Hindship' berthed in dock where RD of the water is 1.007 at a draft of F 7.87 m. A 8.32 m, KG 7.45 m, FSM 970 mt. She discharges 41.0 t of cargo from 2 TD. A 60 t case is shifted from deck Kg 14.7 m to No. 2 Hold. 110 t of water was received in No. 8 P and S tanks Kg 2.77 m, filling them completely. Calculate her GM (Fluid), if additional FSE was created in No. 3 DB tank (C) containing HFO.

(0.822 m)

20. M.V. 'Hindship' loading in dockwater of density 1.008 kg/m³ is to sail into a Summer Zone. She is floating with her starboard plimsol 2 cms above water line and port plimsol 6 cms below water line. Calculate the amount cargo that can be loaded before she commences her voyage.

(284.12 t)

21. M.V. 'Hindship' in Condition No. 5 receives 100 tonnes of D.O. in No. 7 port DB tank, Cg 5 metres off the centre line. Calculate the resulting list.

(2°2' to Port)

22. M.V. 'Hindship' floating on an even keel in dock water of RD 1.017 with her starboard plimsol 15 cms above water and port plimsol 11.6 cms above water is to sail from the dock with a maximum even keel draft of 9.2 m. Calculate (i) The maximum amount of cargo that can be loaded. (ii) her draft on reaching the sea.

(241.1 t, 9.137 m)

23. M.V. 'Hindship' is floating at a draft of F 7.2 m, A 7.8 m (a) Find, where with respect to AP 200 tonnes of cargo is to be loaded to bring her on an even keel. (b) if instead of loading as in (a), the even keel condition was to be achieved by shifting cargo from No. 5 Hold to No. 3 Hold, find the amount of cargo to be shifted.

(a) 128.19 m ford of AP, (b) 180.5 t

24. M.V. 'Hindship' floating at a displacement of 19150 tonnes, KG 6.65 m, FSC 0.042 m, has yet to load 2 locomotives weighing 76 tonnes each, with her own gear. The first locomotive is placed on deck (quay side), Cg 13.83 m above the base and 6 meters from CL. The derrick then plumbs the quay with it's head 21.5 m above the base and 13 m from CL and lifts the second locomotive to be placed on deck, on the other side. Calculate the maximum list during operation.

(2°38')

25. M.V. 'Hindship' in Condition No. 7 discharges the entire cargo in No. 2 TD, and fills in the bulbous bow with 186.6 tonnes of water ballast, Kg 3.52 m, Lcg 139.6 m ford of AP. Assume theoretically that the deck cargo of locomotive was shifted to No. 2 TD. A negligible quantity of water was inadvertantly pumped out from No. 4 P & S DB tanks, causing them to become slack. Calculate her GM (Fluid) and drafts F & A in the final condition.

(0.723 m, F 8.225 m, A 8.617 m)

26. M.V. 'Hindship' in Condition No. 9, pumps out, 100 tonnes of ballast each from No. 2 (P) and No. 2 (S), DB tanks.

(i) Calculate her righting levers at 10° intervals upto an angle of heel of 40°.

(ii) (MASTER F.G. ONLY) — Calculate her dynamical stability at an angle of heel of 40°.

(iii) Also state, whether the ship fulfills criteria A, B and C of the minimum stability requirements of the International Load Line Regulations, given angle of flooding as 42°.

[(i) 0.175, 0.361, 0.608 0.827. (ii) 4228.4 tm. (iii) satisfies]

27. Find the Moment of Stability of M.V. 'Hindship' at an angle of heel of 7°, when displacing 16133 t, KG 7.57 m, FSC 0.085 m.

(1968.23 mt)

28. M.V. 'Hindship' in Condition No. 2, has to load 220 tonnes of cargo, where should this be loaded to keep her after draft unchanged?

(84.557 m ford of AP)

29. M.V. 'Hindship' is at an even keel draft of 9.35 m in dock water of RD 1.004. Calculate her drafts F & A on reaching the sea. Assume fuel and fresh water consumption negligible.

(F 9.158 m, A 9.207 m)

30. M.V. 'Hindship' is at a draft of F 6.38 m, A 7.24 m, KG 8.06 m, FSM 1172 mt. 100 t of ballast is run into No. 3 (P) DB tank Cg 8.0 m from CL. Draw the curve of statical stability and from it, determine the angle of list.

(6¼° to Port)

31. M.V. 'Hindship' at a displacement of 13750 t, KG 7.32 m, FS Moment 1146 mt, is listed 2½° to starboard and has yet to load 380 tonnes of cargo. Space is available in No. 3 TD, 1.5 metres to starboard of centre line, and in No. 5 UTD, 6.2 metres to port of CL. Find the amount of cargo to be loaded in each space, so that the ship will be upright on completion.

(Port side 142.79 t) (Starboard side 237.21 t)

32. M.V. 'Hindship' at a draft of F 5.38 m, A 6.17 m, has GM (Fluid) 0.83 m and FSC 0.092 m. She discharges 430 t from No. 3 TD, VCg 10.2 m, LCg 78.5 m and loads 250 t in No. 5 LTD. 300 t of fuel oil was received equally distributed in No. 2 DB tanks P & S. Calculate her final drafts F & A and GM (Fluid).

(F 5.220 m, A 6.443 m, 0.905 m)

33. M.V. 'Hindship' loading in river water of RD 1.012 is at a draft of F 5.16 m, A 6.02 m. She then pumps out the entire ballast in No. 1 and 4 (P, C & S) DB tanks, which were filled in earlier at the same berth. No. 3 (P & S) and No. 5 DB tanks which were empty are filled with H.F.O. Calculate to the nearest tonne the maximum quantity of cargo that can be loaded, so that the vessel will be at her summer draft on reaching the open sea. Allow fuel and water consumption as follows, 50 tonnes in port and 70 tonnes for river passage.

Also calculate to the nearest .01 m, the even keel sailing draft at the loading berth, in river water.

(9215 t, 9.37 m)

34. M.V. 'Hindship' loading in dock water, RD 1.018 is on an even keel draft of 8.4 m, with a GM (Solid) of 0.45 m. She is to sail on an even keel at her summer draft in SW. Space has been allocated for the following parcels :-

400 t in No. 2	Kg 11 m	LCg 107 m
350 t in No. 4	Kg 9.8 m	LCg 53 m
650 t in No. 5 TD	Kg 10 m	LCg 18 m

The remaining cargo is to be loaded in No. 1, Kg 5.5 m, LCg 122 m and No. 5 Hold Kg 6 m, LCg 15 m. Calculate the amount to be loaded in each of these spaces and the final GM (Fluid) of the vessel, if her FSM was 2500 mt.

(No. 1 : 614.7 t, No. 5 : 124.5 t, 0.380 m)

35. M.V. 'Hindship' in dock water of density 1.007 t/m³ is at a draft of 7.62 m, A 7.94 m. She has to load 450 t of cargo. Calculate the position with respect to AP, where this weight should be loaded so that she would be trimmed 1 m by the stern on completion.

(41.352 m ford. of AP)

36. M.V. 'Hindship' floating at a displacement of 13750 tonnes, KG 6.2 m, FSC 0.12 m is listed 1½° starboard. Find the amount of cargo to be loaded in No. 4 TD, 6 m off the centre line to bring the vessel upright.

(117.9 tonnes)

37. M.V. 'Hindship' in Fresh Water is at a draft of F 6.32 m, A 7.18 m. Calculate the position with respect to AP, from where 140 t should be discharged to reduce her ford. draft by 32 cms.

(136.747 m ford. of AP)

38. M.V. 'Hindship' arrives in Condition No. 7 and discharges the entire cargo from No. 4 TD. Given change in LCB due to ballasting is negligible, find the amount of ballast to be run into the A. Pk tank to bring her on an even keel. Also calculate the drafts F & A after ballasting.

(48.87 t, F & A drafts 8.684 m)

39. M.V. 'Hindship' in Condition No. 5, shifted some weight vertically upwards, so that her KG increased by 0.22 m.

(i) Using GZ ordinates at 10° intervals, draw her statical stability curve, upto a heel of 30°.

(ii) From the curve drawn, estimate her initial metacentric height.

(iii) (FOR MASTER FG ONLY)
Calculate the dynamical stability of the vessel, at an angle of heel of 30°.

(GM 0.50 m, D.S. 2150 tm)

40. M.V. 'Hindship' floating at a draft of F 5.70 m, A 7.60 m, discharges the entire cargo from No. 4 TD which was full. The stowage factor of the cargo in No. 4 TD was 2/3 cubic meter per tonne. Calculate the drafts F & A, after discharge.

(F 5.667 m, A 6.968 m)

41. M.V. 'Hindship' is in Condition No. 8 has to discharge 300 tonnes prior to sailing. Calculate the position with respect of AP, from where, this weight is to be discharged to enable her to sail trimmed 1.5 metres by the stern. Also find the sailing drafts F & A.

(27.577 m ford of AP, F 6.903 m, A 8.403 m)

42. M.V. 'Hindship' berthed in a dock where RD of water is 1.007, at a draft of F 7.87 m, A 8.32 m, KG 7.45 m, FSM 970 mt. She discharged 410 t of cargo from 2 TD. A 60 t case is shifted from deck, Kg 14.7 m, LCg 58.6 m. to No. 2 Hold. 110 t of water Kg 2.77 m, LCg 16.23 m was received in No. 8 (P & S) tanks, filling them completely. Calculate the draft F & A at which she would sail from the dock. Also calculate her sailing GM (Fluid) if additional FSE was created in No. 3 DB tank (centre) which contained HFO.

(0.822 m, F 7.297 m, A 8.627 m)

43. M.V. 'Hindship' is in Condition No. 7 in water of RD 1.025, Rough weather causes 400 tonnes of cargo to shift horizontally through a distance of 8.5 meters and vertically downwards through a distance of 3 meters. Draw the Curve of Statical Stability upto a heel of 40°, after the shift of cargo has taken place. From the Curve estimate the resulting angle of list.

(12°)

44. M.V. 'Hindship' in SW at a draft of 7.25 m ford and 8.10 m aft, has to load 170 t of cargo. Where with respect to AP should this cargo be loaded so that her ford draft would remain the same in water of RD 1.015.

(38.126 m ford of AP)

45. M.V. 'Hindship' is at a draft of F 8.778 m, A 8.792 m, LCG 72.34 m ford of AP. She discharges 206 tonnes of cargo from No. 5 L TD. Calculate the drafts F and A.

(F 8.961 m, A 8.451 m)

46. M.V. 'Hindship' displacing 18,529 tonnes, KG 7.539 m, FSC 0.084 m.

(i) Find her GM (Fluid).

(ii) Draw the statical stability curve for this condition.

(iii) From the curve find

(a) The maximum GZ and the angle of heel at which is occurs.

(b) The angle of vanishing stability.

(c) The change in the range of stability, when an upsetting moment of 4500 tonnes metre is caused.

(d) The list produced by the above upsetting moment.

(iv) State whether the ship fulfills criterion A of the Minimum Stability Requirements of the International Load Line Convention.

(i) 0.726 m, (ii) (a) 0.61 m, (b) 77°, (c) 22°, (d) 13°, (iv) satisfies.

47. M.V. 'Hindship' in Condition No. 10, has to load 800 tonnes of cargo. Space is available in No. 1 TD, 125 metres ford of AP and in No. 3 TD, 80 metres ford of AP. Find the amount of cargo to load in each space to finish the ship on an even keel. State also the final drafts F & A.

1 TD : 679.3 t. 3 TD : 120.7 t. Drafts F & A 8.124 m

48. M.V. 'Hindship' in Condition No. 3, sustained damage aft. To effect repairs, it is required to reduce the after draft to 4.5 meters by loading 518 tonnes in the fore part of the vessel. Find how far abaft the fore perpendicular, this weight should be loaded.

(27.237 m from FP)

49. M.V. 'Hindship' floating at a displacement of 18820 tonnes, KG 7.728 m, FSC 0.092 m, is to be drydocked. Find her MCTC, LCF and KM.

(a) Assuming that these values remain constant over the range of drafts involved and that the vessel takes the blocks fore and aft at the fore and after perpendiculars respectively, calculate the maximum trim by the stern allowable to ensure a virtual GM of at least 0.3 m on taking the blocks fore and after.

(b) At the maximum permissible trim, find

(i) Her drafts F & A, on entering dry dock.

(ii) The draft Forward, at which the head would take the blocks,

(iii) The fall in water level between taking blocks Aft and taking blocks For'd.

(a) 1.872 m or 1.964 m

(b) (i) F 7.946 m A 9.818 m

or

F 7.899 m A 9.863 m

(ii) 8.672 m or 8.661 m

(iii) 1.146 m or 1.202 m

50. M.V. 'Hindship' is at a draft of F 7.98 m, A 8.59 m, KG 7.059 m, FSC 0.089 m. Using the table of Cross curves of Stability Particulars, calculate her righting levers upto 75° heel. Assuming the angle of heel at which flooding occurs is 44, state whether she satisfies each stability requirement of the International Load Line Rules.

(Satisfies all Criteria)

51. M.V. 'Hindship' in Condition No. 7 struck a rock piercing her outer bottom in way of No. 4 P, C & S and No. 5 P & S D.B. tanks. Calculate the drafts F & A at which she will float and her GM (Fluid) after bilging.

(0.626 m, F 8.782 m, A 9.060 m)

52. M.V. 'Hindship' floating at a draft of F 5.73 m, A 6.42 m, is at an angle of loll of 4°, FS Moment 1563 mt. Assuming the ship to be wallsided, calculate her KG.

(8.304 m)

53. M.V. 'Hindship' was floating with all compartments empty as follows:- No. 2 (P & S) DB tanks full with water ballast, No. 1 DB tank contained 100 tonnes of H.F.O. An inclining experiment was conducted in this condition. A weight of 10 tonnes KG 10.2 m, shifted transversely through a distance of 17.6 m, caused a deflection of 8.3 cms in a plumb line 8.5 m in length. Calculate the GM (Solid) and the KG of the light ship.

KG : 8.735 m, GM : 2.916 m

54. M.V. 'Hindship' displacing 9540 tonnes and trimmed 0.78 m by the stern is to be drydocked for bottom inspection. The hull has remained watertight and no flooding has occured. KG 7.826 m. FSC 0.164 m.

(i) Obtain her KM, MCTC and position of LCF.

Assuming that these values and the FSC remain constant over the range of drafts involved, and that the vessel takes the blocks fore and aft at the fore and after perpendiculars respectively, calculate the following :-

(ii) The GM (Fluid) of the vessel before entering dry dock.

(iii) The virtual GM of the vessel when her keel takes the block all along the length of the vessel.

(iv) The ford and after draft, at which the virtual GM of the vessel becomes zero.

(v) The fall in water level, between the vessel taking blocks all over and her virtual GM becoming zero.

(i) KM 8.970 m, MCTC 166.0 mt, LCF 72.949 m,

(ii) 0.980 m,

(iii) 0.832 m or 0.813 m,

(iv) F & A drafts 4.402 m or 4.411 m,

(v) 0.404 m or 0.395 m.