PROBLEMS IN STABILITY ON M.V. 'HINDSHIP'

Capt. T.K. Joseph
EXTRA MASTER
Former Principal
LBS College of Advanced
Maritime Studies and Research
Former Capt. Suptd. T.S. Rajendra

Capt. S.S.S. Rewari
EXTRA MASTER
Former Principal
LBS College of Advanced
Maritime Studies and Research
Former Capt. Suptd. T.S. Rajendra

ARI

Applied Research International
B-1, Hauz Khas, New Delhi-110016 India
Tel. : 6969825, 6859627
Fax : 6858331

Published in India by :
Applied Research International
(Media Division) Delhi

First Edition 1978
Second Edition, revised and enlarged 1980
Reset 1997

***Price* Rs. 240.00**

Typesetted and Printed by
GAURAV ENTERPRISES
C-56, Hari Nagar Clock Tower, New Delhi-110064
Tel. : 5402407

PREFACE

Till recently, there was some disparity between the stability and trim calculations which a ship's officer faced on board ship, in practice, and those presented to him in text books. The problems set in the M.O.T. examinations now, involve the use of the trim and stability particulars of a ship.

In this book therefore we have endeavoured to provide practical problems based on the trim and stability particulars of M.V. 'Hindship'. The aim of this book is to help ship's officers in preparing for their certificates of competency examinations. It should also provide a guide for their practical stability work on ships.

Fair proficiency in the theory of stability for the respective grades is assumed. Brief notes and comments have been included in the text wherever thought necessary for clear understanding. The book is divided into 3 sections covering the syllabii for 2nd Mate F.G., 1st Mate F.G. and Master F.G. respectively.

Each problem has been carefully designed so that it teaches something new which illustrates and amplifies the theory and brings into sharp focus, the fine points without which the student may find himself unsure.

We have been able to restrict the total number of problems in this book by avoiding repetition of identical problems. This should enable the students, who are hard pressed for time to learn the subject matter in the shortest possible period.

To promote step-by-step learning, and to ensure that, at each step, the student grasps the principles and processes used in the solutions, the problems have been graded with care. The special feature of this book is that every problem has been worked out. This book is in no way a condensation of ordinary text material. it is intended to be a comprehensive book of stability and trim calculations.

For the purpose of revision, particularly so before the examination, the student is advised to work out the problems from the section titled 'Test Yourself'. The problems in that section have been arranged in random order to test the student's proficiency in solving the various types of problems.

We have exercised care to eliminate any arithmetical or printing errors. If however, any errors are detected, we would be thankful if they are communicated to us.

We are very grateful to all our colleagues in the profession for their encouragement which has helped us in this endeavour. We are particularly indebted to our students both past and present whose searching questions and quest for knowledge have helped us in producing this book.

T.K. Joseph, S.S.S. Rewari

PREFACE TO SECOND EDITION

The book has been revised to increase its usefulness to the merchant navy officers, both when studying for their certificate of Competency examinations and for their practical work on board ships. To highlight the important aspects of safety, further theory, illustrations and problems have been added.

T.K.J., S.S.S.R.

CONTENTS

Mate Home Trade students should solve problems 1 to 32 and 44 to 52.

Master Home Trade students should solve problems 1 to 70, 85, 86(i), 87(i) & (ii) and 93.

INTRODUCTION

Prior to 1968, ships were provided with information of a general nature relating to stability. As per the latest International Load Line Rules, the stability information to be supplied to ships has been standardised and made more comprehensive. Present-day ships are therefore provided with this information in a format basically similar to the **Booklet of Trim and Stability Particulars of M.V. 'Hindship'.** The information relating to the stability of the vessel to be provided for the master may be briefly summarised as follows:-

(i) General particulars of the ship including tonnages, dimensions, summer draft etc.

(ii) A profile of the ship showing all compartments, tanks, store rooms, passenger/crew spaces etc.

(iii) Capacity and Cg (longitudinally and vertically) of all compartments.

(iv) Estimated weights of
   (a) Passengers and their effects,
   (b) Crew and their effects,
   together with their Cgs (both longitudinally and vertically).

(v) The estimated weight, disposition and Cg of the maximum amount of deck cargo the ship may be expected to carry.

(vi) Curves or tables showing the Load Line mark with corresponding freeboards and displacement, TPC and deadweight for a range of drafts between the light water line and the deepest load line.

(vii) Curves or tables showing the hydrostatic particulars of the ship including KM and MCTC for a range of drafts between the light waterline and the deepest load line.

(viii) The free surface effect of each tank in which liquids may be carried.

(ix) Cross Curves of Stability indicating the assumed axis from which righting levers are measured.

(x) (a) A profile diagram of the ship showing the disposition of all components of the deadweight.
   (b) A statement showing the lightweight, disposition and total weight of all components of the deadweight, the displacement, the corresponding KG, LCG, KM and GM.
   (c) A statical stability curve corrected for any free surface effect.

The above (a), (b) and (c) shall be provided separately for the following conditions :

(1) **Light condition :** If the ship has permanent ballast, both (i) with such ballast (ii) without such ballast.

(2) **Ballast Condition :** both (i) on departure (ii) on arrival.

(3) **Loaded to her summer load line** with homogeneous cargo filling all spaces available for cargo both (i) on departure (ii) on arrival.

(4) **Service Loaded Conditions :** both (i) on departure (ii) on arrival.

(xi) Where any special procedures are necessary to maintain adequate stability, a statement of instructions as to the appropriate procedure.

(xii) A copy of the report of the inclining test and the calculation therefrom of the light condition particulars.

If the reader refers to the **Booklet of Trim and Stability Particulars of M.V. 'Hindship'** (or in fact any ship) he should be in a position to locate any of the items mentioned above. In this book, we have endeavoured to demonstrate the use of the stability and trim information now provided to ships, in solving practical problems faced by ship's officers.

It was the practice to do calculations pertaining to Trim, GM, Heel etc. of ships assuming that various parameters, such as TPC, MCTC, LCF, KM etc. remain unchanged irrespective of change in the displacement or draft of the ship. This assumption is not correct. It has therefore become necessary now, to revise the mode of working trim and stability calculations to obtain realistic results. The use of certain well known formulae has been restricted in this book and certain other methods of stability calculations have been introduced to correctly utilise the information available in the stability particulars now supplied to ships.

To obtain maximum benefit and to ensure that the principles involved in the calculations have been fully understood, it is suggested that the student should attempt to solve each problem without reference to the solution. If the final result is in error, he should study each step of the solution carefully, and then rework the problem on his own.

DEFINITIONS PERTAINING TO HYDROSTATIC PARTICULARS

DENSITY of a substance is its mass per unit volume, normally expressed as tonnes per cubic metre in ship calculations.

RELATIVE DENSITY of a substance is the ratio between the density of that substance and the density of fresh water.

DISPLACEMENT of the ship is the weight of the ship and its contents or the weight of water displaced by the ship in that condition.

Displacement = Underwater volume of the ship × the density of the water in which she is floating.

It should be noted that the volume of displacement is the underwater volume of the ship. When a ship proceeds from water of one density to water of another density, the volume of displacement changes, whereas the displacement remains unchanged.

HYDROSTATIC DRAFT OR TRUE MEAN DRAFT is the draft at the centre of floatation. When the ship is on an even keel the drafts forward and aft, the mean draft and the hydrostatic draft are the same.

TPC (Tonnes Per Centimetre Immersion) at any draft is the weight in tonnes which should be loaded or discharged to change the vessel's mean draft by one centimetre, in saltwater.

$$TPC = \frac{1.025 \times \text{Area of ship's water plane}}{100}$$

MCTC or MCT 1 cm (Moment to change trim by one centimetre) is the moment required to change the total trim of the vessel by one centimetre.

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

CB (Centre of Buoyancy) is the geometric centre of the underwater volume of the ship. The entire buoyancy provided by the displaced water may be considered to act vertically upwards through this point.

LCB (Longitudinal Centre Buoyancy) is the longitudinal separation between the After Perpendicular and the centre of buoyancy.

VCB (Vertical Centre of Buoyancy) is the vertical separation between the keel and the centre of buoyancy.

CF (Centre of Floatation) is the centroid of the ship's water plane area.

LCF (Longitudinal Centre of Floatation) is the longitudinal separation between the After Perpendicular and the Centre of Floatation.

M (Transverse Metacentre) is the point of intersection of the vertical line through the Centre of Buoyancy in the upright condition and the vertical line through the Centre of Buoyancy in a slightly inclined condition.

KM is the vertical separation between the keel and the metacentre.

M_L (Longitudinal Metacentre) is the point of intersection of the vertical line through the Centre of Buoyancy in an even keel condition and the vertical line through the Centre of Buoyancy in a slightly trimmed condition.

KM_L is the vertical separation between the keel and the longitudinal metacentre.

NOTE : In stability calculations in various text books, the different hydrostatic particulars like TPC, MCTC, LCF, KM etc. are assumed constant despite change in displacement/draft, to facilitate easier solution. This assumption is incorrect and **cannot** be used while actually calculating stability/trim on board ships. It must therefore, be borne in mind that all the hydrostatic particulars of the ship change with draft/displacement. The calculations in this book have taken this important fact into account.

It should also be noted that though the displacement remains unchanged, yet some of the hydrostatic particulars change with the density of water in which the ship is floating. Even when the density and the displacement are constant, some of them like KM also change with HEEL and TRIM, as the shape of waterplane alters when these parameters change. This fact has been taken into consideration in problems on LIST/HEEL, where the value of KM is assumed constant only for very small angles of heel.

GENERAL INSTRUCTIONS

When using the Trim and Stability data for M.V. 'Hindship', the following should be taken into account **unless** otherwise stated :-

1. Relative densities of liquids shall be taken as follows :-

Salt Water	1.025	Fresh Water	1.00
Heavy Fuel Oil	0.95	Diesel Oil	0.88
Lub. Oil	0.90	Cylinder Oil	0.92

2. GZ curves, hydrostatic curves and displacement scale are for inspection only. For actual calculations, the tables on pages 21-22 and 7-8 respectively should be used. Interpolated values shall be considered correct for in between displacement/drafts.
3. Draft marks are to be assumed as being at the fore and aft perpendiculars.
4. KG means the KG without allowing for free surface correction.
5. GM (Solid) means GM without allowing for free surface correction.
6. GM (Fluid) means GM (Solid) – FSC.
7. FSC is to be applied to the GM and not to the KG, except when determining GZ values from KN.
8. When determining GZ from KN, corrected KG means KG + FSC.
9. Kg. of liquid in any tank is to be presumed as for full tank.
10. Moment of inertia for calculations of FSC is to be obtained from page 19 and the FSC is to be worked out as indicated on pages 18 to 20.
11. Hydrostatic draft means the draft at the centre of floatation.
12. All information taken from pages 8 and 9 relates to hydrostatic draft. However, when the trim of the ship is not given, the mean draft may be considered to be the same as the hydrostatic draft.
13. A tank shall be considered full when filled to its 100% capacity.
14. When a large change of displacement is involved, the hydrostatic data is to be obtained corresponding to the final draft/displacement.
15. Trim is to be calculated as indicated at the commencement of the chapter on trim in this book.
16. On pages 21 and 22, where righting arm (KN) values are given under columns 'A' and 'B', the values given under column 'B' alone should be used.
17. Weights added or removed from any compartment are to be assumed at, or from the respective centres of gravity of the compartment (both vertical and longitudinal).
18. For calculations involving capacities of cargo compartments, the grain capacities are to be used.

FAMILIARIZATION WITH THE BOOKLET OF TRIM & STABILITY PARTICULARS OF M.V. 'HINDSHIP'

Prior to proceeding to the actual PROBLEMS, the student should familiarize himself with the **content** and **layout** of the M.V. 'Hindship' trim and stability booklet. For this, the following exercise will be useful.

1. Find the LBP and Moulded Breadth of M.V. 'Hindship'.
2. Locate the criteria of minimum stability requirements as per Load Line Rules.
3. Find the Displacement, TPC, MCTC, LCB, LCF, VCB, KM and KM_L at a draft of 4.2 m.
4. Find the capacity of No. 2TD.
5. Find the Lcg. and Kg. of No. 3 Hold.
6. Find the Capacity, Kg. and Lcg. of No. 4 DB tank (C).
7. Find the weight of ballast in the A Pk. tank, when full.
8. Find the moment of inertia of No. 12 DB tank (S).
9. Find the KN value at a displacement of 13,500 t, when heeled 40^0.
10. Find the draft, freeboard, displacement and deadweight at the Winter Load Line.
11. Find the FWA of the ship.
12. In Condition No. 5, find the following :-
    - (i) Weight of cargo in No. 5 TD.
    - (ii) Longitudinal moment of No. 5 DB tank (S).
    - (iii) Total free surface moment of the ship.
    - (iv) Displacement.
    - (v) Vertical Moment of the ship.
    - (vi) Kg. of oil in Storage & Settling tanks.
    - (vii) Weight of the mail cargo.
    - (viii) Position of LCB.
    - (ix) Hydrostatic draft.
    - (x) Total trim.
    - (xi) KG.
    - (xii) FSC.
    - (xiii) Righting Lever at 10^0 heel.
    - (xiv) Area under GZ curve upto 40^0.
    - (xv) Maximum GZ and the angle at which it occurs.

ANSWERS

1.	(a) 143.16 m. (b) 20.00 m.	Page 3. 'Hindship' Booklet
2.		Page 5. " "
3.	(a) 8038 t. (b) 21.72 t. (c) 160.7 mt. (d) 73.014 m. (e) 73.103 m. (f) 2.256 m. (g) 9.610 m. (h) 290.1 m.	Page 7. " "
4.	1854.9 cu. metres	Page 10. " "
5.	(a) 80.63 m. (b) 5.0 m.	Page 10. " "
6.	(a) 2574 cu. m. (b) 0.63 m. (c) 57.58 m.	Page 14. " "
7.	117.8 × 1.025 = 120.745 t.	Page 16. " "
8.	17 m^4.	Page 19. " "
9.	5.845 m.	Page 22. " "
10	(a) 9.041 m. (b) 2.81 m. (c) 19151 t. (d) 13651 t.	Page 26. " "
11.	202 mm.	Page 26. " "
12.	(i) 715.8 t (ii) 1510 mt. (iii) 1552 mt. (iv) 18529.3 t (v) 139700 mt. (vi) 6.46 m. (vii) 5.1 t. (viii) 72.356 m. (ix) 8.785 m. (x) 0.201 m. (xi) 7.539 m. (xii) (–) 0.084 m. (xiii) 0.191 m. (xiv) 0.237 m. radians (xv) 0.650 m at 41.5^0.	

NOTE :

When utilizing data given for conditions 1 to 11, the values as given for the **condition** are to be used though calculations may not agree exactly with them, e.g.

(i) Condition No. 11, the vertical moment of 235 tonnes of refrigerated cargo, at a Kg of 10.36 is indicated as 2435 mt. instead of (235 × 10.36) = 2434.6 mt. The value 2435 is to be used.

(ii) In the same condition No. 3 DB tank (P) (C) & (S) is said to contain 442.5 t of WB. Calculations ($431.7m^3$ × 1.025 = 442.5 t) show that the tanks are full to 100% capacity. Yet a FS moment of 120 mt. has been indicated against these tanks. The tank is to be considered slack with a FS moment of 120 mt.

(iii) In the same condition, the L. Moment is indicated as 1108044 mt, while displacement of 15460.2 × LCG, 71.671 gives 1108048 mt. The value 1108044 is to be used.

DETERMINATION OF HYDROSTATIC PARTICULARS

1. *Find the Hydrostatic particulars (Hydrostatic draft, TPC, MCTC, LCB, LCF, VCB, KM and KM_L) of M.V. 'Hindship' at a displacement of 9540 tonnes.*

Displacement	Hydrostatic draft	TPC	MCTC	LCB	LCF	VCB	KM	KM_L
9.348	4.80	21.99	165.4	73.018	72.974	2.576	9.032	257.3
9540?								
9.788	5.00	22.08	166.8	73.016	72.917	2.684	8.890	247.7
440	0.2	0.09	1.4	0.002	0.057	0.108	0.142	9.6

For diff. in displacement of 440 t. diff. in hydrostatic draft = 0.2

For diff. in displacement of (9,540–9,348) = 192 t. diff. in hydrostatic draft

$$= \frac{0.2 \times 192}{440} = 0.087$$

Interpolating as above, we have :-

diff. in Hydrostatic draft $= \frac{0.2 \times 192}{440} = 0.087$ Hyd. draft = 4.80 + 0.087 = **4.887 m**

" " TPC $= \frac{0.09 \times 192}{440} = 0.039$ TPC = 21.99 + 0.039 = **22.029 t**

" " MCTC $= \frac{1.4 \times 192}{440} = 0.611$ MCTC = 165.4 + 0.611 = **166.011 mt**

" " LCB $= \frac{0.002 \times 192}{440} = 0.001$ LCB = 73.018 − 0.001 = **73.017 m**

" " LCF $= \frac{0.057 \times 192}{440} = 0.025$ LCF = 72.974 − 0.025 = **72.949 m**

" " VCB $= \frac{0.108 \times 192}{440} = 0.047$ VCB = 2.576 + 0.047 = **2.623 m**

" " KM $= \frac{0.142 \times 192}{440} = 0.062$ KM = 9.032 − 0.062 = **8.970 m**

" " KM_L $= \frac{9.6 \times 192}{440} = 4.189$ KM_L = 257.3 − 4.189 = **253.111 m**

2. *Find the Hydrostatic particulars of M.V. 'Hindship' floating at the hydrostatic draft of 7.66 m.*

Hydrodraft	Displ.	TPC	MCTC	LCB	LCF	VCB	KM	KM_L
7.60	15693	23.29	191.8	72.690	70.979	4.040	8.238	178.9
7.66?								
7.80	16161	23.41	194.6	72.641	70.780	4.144	8.240	176.6
0.20	468	0.12	2.8	0.049	0.199	0.104	0.002	2.3

Interpolating between the above values :-

diff. in displacement $= \frac{468 \times 0.06}{0.20} = 140.4$ Displ. = 15693 + 140.4 = **15833.4 t**

" " TPC $= \frac{0.12 \times 0.06}{0.20} = 0.036$ TPC = 23.29 + 0.036 = **23.326 t**

" " MCTC $= \frac{2.8 \times 0.06}{0.20} = 0.84$ MCTC = 191.8 + 0.84 = **192.64 mt**

" " LCB $= \frac{0.049 \times 0.06}{0.20} = 0.015$ LCB = 72.690 − 0.015 = **72.675 m**

" " LCF $= \frac{0.199 \times 0.06}{0.20} = 0.060$ LCF = 70.979 − 0.060 = **70.919 m**

" " VCB $= \frac{0.104 \times 0.06}{0.20} = 0.031$ VCB = 4.040 + 0.031 = **4.071 m**

" " KM $= \frac{0.002 \times 0.06}{0.20} = 0.001$ KM = 8.238 + 0.001 = **8.239 m**

" " KM_L $= \frac{2.3 \times 0.06}{0.20} = 0.690$ KM_L = 178.9 − 0.690 = **178.210 m**

DETERMINATION OF HYDROSTATIC PARTICULARS IN WATER OF DENSITIES OTHER THAN SALT WATER

3. *Find the hydrostatic particulars of M.V. 'Hindship' at a hydrostatic draft of 5.60 m in water R. D. 1.015.*

It should be noted that the hydrostatic particulars supplied are for the vessel floating in salt water. When the vessel is floating in water of any other density, some of the tabulated particulars will alter as shown below.

DISPLACEMENT

The displacement at a particular draft i.e. a particular underwater volume obviously **varies** directly as the density of the water. THUS DISPLACEMENT IS DIRECTLY PROPORTIONAL TO DENSITY OF WATER.

$$\text{Displ.} = 11120 \times \frac{1.015}{1.025} = \mathbf{11011.5\ t}$$

TPC

For an immersion of 1 cm., at a particular draft, the volume of water displaced remaining the same, the TPC WOULD ALSO VARY DIRECTLY AS THE DENSITY OF THE WATER.

$$\text{TPC} = 22.32 \times \frac{1.015}{1.025} = \mathbf{22.10\ t}$$

MCTC

Though the density of water has altered, since the KM_L which is equal to $KB + BM_L$ depends on the underwater shape and volume of the vessel as well as the shape of the waterplane, the KM_L for a particular draft remains unchanged irrespective of the change in the density of water. Therefore, if the KG is unaltered, the GM_L would remain the same. The length of the vessel at that water line also remains unchanged.

Therefore, in the expression, $\text{MCTC} = \frac{W \times GM_L}{100\ L}$,

the only parameter that changes when the density is altered, is the displacement W, which varies directly as the density of water. Thus MCTC at a particular draft VARIES DIRECTLY AS DISPLACEMENT i.e. DIRECTLY AS THE DENSITY.

$$\text{MCTC} = 171.0 \times \frac{1.015}{1.025} = \mathbf{169.33\ mt}$$

LCB

LCB depends on the underwater volume and its shape, which are unaltered.

LCB = **72.992 m** (UNCHANGED)

LCF

LCF depends on the shape of the water plane which remains unchanged.

LCF = **72.675 m** (UNCHANGED)

VCB

VCB depends on the shape of the underwater volume, which remains unchanged.

VCB = **2.998 m** (UNCHANGED)

KM

KM = KB + BM, depends on the underwater volume and shape as well as the shape of the vessel's waterplane. Since these have not altered,

KM = **8.578 m** (UNCHANGED)

KM_L

As stated for MCTC, the KM_L will remain unaltered

KM_L = **223.3 m** (UNCHANGED)

4. *Find the hydrostatic particulars of M.V. 'Hindship' at a displacement of 12,200 tonnes in water of RD 1.010.*

HYDROSTATIC DRAFT

Since the hydrostatic particulars supplied are for SW, the displacement of 12,200 t in water of RD 1.010 should be converted to its corresponding underwater volume and thence to the displacement in SW for that underwater volume, to obtain the hydrostatic draft from the table.

For a displacement of 12,200 t in water RD 1.010, underwater volume

$$V = \frac{W}{\delta} = \frac{12{,}200}{1.010}$$

Displacement in SW for that underwater volume

$$= V \times \delta_1 = \frac{12{,}200}{1.010} \times 1.025 = 12381.2 \text{ t}$$

Hydrostatic draft for displacement 12381.2 t

$$\text{in SW} = 6.00 + \frac{0.2 \times 362.2}{453}$$

Hydrostatic Draft = 6.00 + 0.16 = **6.16 m**

NOTE :- It should be clearly understood that the actual displacement of the ship i.e. its weight remains 12,200 t as given in the Qn. Her displacement at that draft in SW was found only to facilitate obtaining the data from the table which is tabulated for the vessel in SW.

TPC

$$\text{TPC (in SW)} = \frac{1.025\ A}{100}$$ where A is the waterplane area at that draft.

The TPC required is for a waterplane area corresponding to the draft is SW for displacement of 12381.2 t.

$$\text{TPC for displ. 12381.2 t in SW} = 22.47 + .09 \times \frac{362.2}{453}$$

$$= 22.47 + .07 = 22.54 \text{ t}$$

As in Qn. 3, TPC at that draft in water δ 1.010

$$= 22.54 \times \frac{1.010}{1.025} = \mathbf{22.21\ t}$$

MCTC

As explained in Qn. 3, the MCTC at a particular draft varies directly as the displacement at that draft, that is directly as the density. MCTC for a draft corresponding to a SW displacement of

$$12381.2 \text{ t} = 174.0 + 1.7 \times \frac{362.2}{453} = 174.0 + 1.36$$

$$= 175.36 \text{ mt}$$

∴ MCTC at that draft, for a displacement of 12,200 t.

$$= 175.36 \times \frac{1.010}{1.025} = \mathbf{172.79\ mt}$$

LCB

The LCB depends on the underwater volume and it's shape. It will therefore correspond to a draft in SW for a displacement of 12381.2 t.

$$\text{LCB} = 72.962 - \frac{0.021 \times 362.2}{453} = 72.962 - 0.017 = \mathbf{72.945\ m}$$

LCF

LCF depends on the shape of the waterplane. It will therefore correspond to a draft in SW for a displacement of 12381.2 t.

$$\text{LCF} = 72.476 - \frac{0.143 \times 362.2}{453} = 72.476 - 0.114 = \mathbf{72.362\ m}$$

VCB

VCB depends on the shape of the underwater volume. It will therefore correspond to a draft in SW for a displacement of 12381.2 t.

$$\text{VCB} = 3.204 + \frac{0.104 \times 362.2}{453} = 3.204 + 0.083 = \mathbf{3.287\ m}$$

KM

KM depends on the underwater volume and the shape of the waterplane. It will therefore correspond to a draft in SW for a displacement of 12381.2 t.

$$\text{KM} = 8.438 - \frac{0.054 \times 362.2}{453} = 8.438 - 0.043 = \mathbf{8.395\ m}$$

KM_L

KM_L also depends on the underwater volume and the shape of the waterplane. It will therefore correspond to a draft in SW for a displacement of 12381.2 t.

$$KM_L = 210.6 - \frac{5.6 \times 362.2}{453} = 210.6 - 4.48 = \mathbf{206.12\ m}$$

Alternatively, once the hydrostatic draft of 6.16 m was obtained, the remaining hydrostatic particulars could have been interpolated for the hydrostatic draft of 6.16 m. instead of interpolating for the SW displ. of 12381.2 t. This method would also give the same results.

Note : In general, hydrostatic data supplied to ships provide the various values at 1 cm intervals, thereby reducing the interpolation required.

5. *M.V. 'Hindship' floating at a hydrostatic draft of 7.12 m loads 900 tonnes of cargo in 3 TD. Calculate her final hydrostatic draft and state whether this loading will trim her by the head or by the stern.*

For draft 7.12 m displacement = 14576.2 t

Initial displacement	=	14576.2 t
Cargo loaded	=	900.0 t
Final displacement	=	15476.2 t

For displacement 15476.2 t draft = 7.507 m

Final hydrostatic draft = 7.507 m

For the hydrostatic draft of 7.507 m, LCF from AP = 71.08 m. (from Hydrostatic particulars table)

From table of CAPACITIES & Cgs of DRY CARGO SPACES,

Lcg of 3 TD = 80.79 m from AP

Since the weight has been loaded forward of CF, she will **trim by the HEAD**

6. *At 8 A.M., on 27th January, M.V. 'Hindship' was at a hydrostatic draft on 7.30 m. At 8 A.M. the next day, she was at a hydrostatic draft of 7.975 m. Find the amount of cargo loaded during the day, if No. 2 DB tanks (P & S), which were full with water ballast were pumped out and the Port Tween Deck Drinking Water tank was filled with fresh water, during the interval.*

Intial displacement for draft 7.30 m	=	14993.5 t
Ballast pumped out from No. 2 (P & S) = capacity × density = 404.8 × 1.025	=	(–) 414.9 t
	=	14578.6 t
FW received in Port TD Drinking water tank = capacity × density = 49.7 × 1.0	=	(+) 49.7 t
Displ. after above operations	=	14628.3 t
Final displacementt at 7.975 m draft	=	16575.8 t

Cargo loaded during the day = 1947.47 t

CALCULATION OF HYDROSTATIC DRAFT FROM DRAFTS FORD AND AFT

A. For a vessel with no trim, the drafts ford and aft is the mean draft as well as the hydrostatic draft.

B. For a vessel which is trimmed, obtain the arithmetical mean draft. Determine the position of LCF for this mean draft.

C. Calculate the Hydrostatic draft as below :-

Hydrostatic draft = draft aft (±) correction from table 'A', available in this book prior to chapter on Trim, as well as in the 'Hindship' Stability Particular Booklet.

Note :- (i) Correction is –ve when trimmed by the stern, +ve when trimmed by the head,

(ii) Correction is unaffected by density of water, in which ship is floating.

D. From the hydrostatic tables, any required hydrostatic particulars can be determined against hydrostatic draft.

7. M.V. 'Hindship' is floating at a draft of F 5.65 m, A 7.45 m. Calculate (i) her hydrostatic draft and (ii) her displacement.

Initial Drafts : F 5.65 m, A 7.45 m } trim 1.80 by stern
M 6.55 m

For mean draft 6.55 m LCF = 72.048 m. ford of AP

Corrn. to After draft (from table 'A') = 0.906 m

Hydrostatic draft = After draft ± corrn. from table 'A'

Hydrostatic draft = 7.45 – 0.906 = 6.544 m (–ve, since V/L is trimmed by stern).

Displacement for hydrostatic draft 6.544 m = 13255.3t

8. *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) Original drafts F 7.40 m, A 6.60 m } trim 0.80 m by head
M 7.00 m

LCF for mean draft 7.00 m	=	71.606 m
Corrn. to After draft from table 'A'	=	(+) 0.40 m
After draft	=	6.60 m

Hydrostatic draft = 7.00 m

(ii) For hydrostatic draft 7.00 m, displacement in SW = 14299 t

$$\text{Displacement at that draft in water of RD 1.016} = \frac{14299 \times 1.016}{1.025}$$

Displacement in RD 1.016 = 14173.4 t

(iii) Light displacement (from Condition No. 1) = 5499.8 t

Deadweight = 14173.4 – 5499.8

Deadweight = 8673.6 t

9. *M. V. 'Hindship' arrives at a port, where the density of water is 1.014 tm^{-3} at an even keel draft of 6.72 m. She sails at a draft of F 7.2 m, A 7.3 m, 120 t of FW was received and 40 t of fuel and FW were consumed in port. Calculate the weight of cargo loaded at that port.*

Sailing draft F 7.20 m, A 7.30 m } trim 0.10 by stern.
M 7.25 m

LCF for mean draft 7.25 m	=	71.343 m
After draft	=	7.300 m
*Corrn. to After draft from table 'A'	=	0.050 m
Sailing hydrostatic draft	=	7.250 m
SW displ. for arrival hydro. draft 6.72 m.	=	13657.2 t
Displ. at that draft in δ 1.014 = 13657.2 × $\frac{1.014}{1.025}$	=	13510.6 t
SW displ. for sailing hydro. draft 7.250 m	=	14877.3 t
Displ. at that draft in δ 1.014 = 14877.3 × $\frac{1.011}{1.025}$	=	14717.6 t

Arrival displacement	=	13510.6 t
FW received	=	(+) 120.0 t
Fuel & FW consumed	=	(–) 40.0 t
Displ. after above operations	=	13590.6 t
Sailing displacement	=	14717.6 t
Cargo loaded in port	**=**	**1127.0 t**

* As explained in the definition of hydrostatic draft, where the trim is nil, the correction to the after draft to obtain the hydrostatic draft is zero. The correction from table 'A' for a trim of 0.1 m is therefore interpolated between zero and 0.2 values.

10. *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.*

Arrival draft F 6.15 m, A 7.22 m } trim 1.07 m by stern.
M 6.685 m

LCF for mean draft 6.685 m	=	71.92 m
After draft	=	7.22 m
Corrn. to After draft from table 'A'	=	0.537 m
Arrival hydrostatic draft	=	6.683 m
Displacement in SW for hydrostatic draft 6.683 m	=	13572.7 t
Displacement at that draft in δ 1.012 = 13572.7 × $\frac{1.012}{1.025}$	=	13400.6 t

Departure Draft F 5.33 m, A 5.98 m } trim 0.65 m by stern.
M 5.655 m

LCF for mean draft 5.655 m	=	72.652 m
After draft	=	5.98 m
Corrn. to After draft from table 'A'	=	0.33 m
Departure hydrostatic draft	=	5.65 m
Displacement in SW for hydrostatic draft 5.65 m	=	11232.3 t
Arrival Displacement	=	13400.6 t
Departure Displacement	=	11232.3 t
Reduction in displacement	=	2168.3 t
Fuel and water consumed	=	85.0 t
Weight of cargo discharged	**=**	**2083.0 t**

KG BY MOMENTS AND FINAL GM

In considering a ship's stability, the GM is an important criterion. GM is the vertical separation between the centre of gravity and the metacentre of the ship, that is KM – KG.

As indicated in the earlier problems, the KM for any displacement is available from the hydrostatic tables.

The KG of the vessel is usually obtained by the principle of moments. The moments are taken about the keel of the vessel. The vertical moment of the ship's displacement is obtained by the product of the displacement and the KG (not the KG corrected for free surface effect). Thereafter, such calculation may involve three operations, i.e. loading, discharging and shifting.

Moments of weights loaded are added and those of weights discharged, subtracted. When a weight is shifted, the change in the moment about the keel is obtained by the product of the weight shifted and the vertical distance through which it is shifted. This quantity is **added** when weights are shifted **upwards** and **subtracted** when weights are shifted **downwards.**

$$\text{Final KG} = \frac{\text{Final Moment}}{\text{Final Displacement}}$$

Free surface of liquid in any compartment causes a virtual rise in the centre of gravity and, therefore, a corresponding virtual loss in the GM of the vessel. Therefore, this correction (FSC) is subtracted from GM (Solid) to obtain GM (Fluid). Conversely GM (Solid) can be obtained by adding the FSC to GM (Fluid). The FSC is customarily applied to the GM and not to the KG.

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

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

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

	Weights *Disch.* (t)	Weights *Load* (t)	Kg (m)	V. Moments *Disch.* (mt)	V. Moments *Load* (mt)
Ship in condition 11		15460.2	7.726		119451
Locomotives	760		13.83	10510	
2 TD	400		10.70	4280	
4 TD	200		10.40	2080	
2 TD		300.0	10.70		3210
4 TD		150.0	10.40		1560
	1360	15910.2		16870	124221

Final V. Moments = 124221 – 16870 = 107351 mt

Final Wt. = 15910.2 – 1360 = 14550.2 t

$$\text{Final KG} = \frac{\text{Final moment}}{\text{Final Wt.}} = \frac{107351}{14550.2} = 7.378 \text{ m}$$

KM for displacement of 14550.2 t	=	8.250 m
Final KG	=	7.378 m
GM (Solid)	=	0.872 m
FSC	=	(–) 0.107 m
GM (Fluid)	**=**	**0.765 m**

When weights are shifted and the KG of the ship is to be calculated by moments, the moment of shift is obtained by the product of the weight shifted and the vertical distance through which it is shifted. The moment is **ADDED** if the shift is **UPWARDS** and **SUBTRACTED** if the shift is **DOWNWARDS. REMEMBER THAT SHIFTING A WEIGHT DOES NOT ALTER THE DISPLACEMENT OF THE VESSEL.**

12. *M. V. 'Hindship' is at Bombay in Condition No. 4. A consignment of cargo weighing 500 tonnes is shifted from 3 Hold to the Upper Deck, Kg 13.28 m. Find the final GM (Solid and Fluid).*

Upper Deck Kg = 13.28 m

3 Hold Kg = 5.00 m

Distance shifted 'd' = 8.28 m (upwards) ↑

		KG (m)	*V. Moments* (mt)
Initial displacement	= 19617.0 tonnes	7.272	142648
Wt. shifted	= 500.0 tonnes	↑ 8.28	(+) 4140
Final displacement	= 19617.0 tonnes		
Final V. moment			= 146788

$$\text{Final KG} = \frac{\text{Final moment}}{\text{Final displacement}} = \frac{146788}{19617} = 7.483 \text{ m}$$

Alternative method to final KG

$$GG_1 = \frac{w \times d}{W} = \frac{500 \times 8.28}{19617} = 0.211 \text{ m}$$

Original KG = 7.272 m

↑ GG_1 (+) = 0.211 m

Final KG = 7.483 m

KM for Condition No. 4 = 8.435 m

Final KG = 7.483 m

GM (Solid) = 0.952 m

FSC for Cond. No. 4 (–) 0.070 m

GM (Fluid) = 0.882 m

13. *M.V. 'Hindship' floating in Condition No. 2 loads 400 tonnes of cargo in No. 1 TD and on the voyage consumes the entire oil in No. 2 DB tanks P & S. Calculate GM (Solid & Fluid). As change of displacement is negligible, assume FSC constant.*

	Wt. (t)	*KG* (m)	*V. Moment* (mt)
Initial displacement	7799.0	6.942	54137
Cargo loaded	(+) 400.0	11.170	(+) 4468
	8199.0		58605
Oil consumed	(–) 384.6	0.65	(–) 249.99
Final Wt.	7814.4	Final V. Moment	58355.01

$$\text{Final KG} \quad \frac{58355.01}{7814.4} = 7.468 \text{ m}$$

KM = 9.745 m (The KM changes with change of displacement.

KG = 7.468 m In this case however, since displacement has

GM (Solid) = 2.277 m hardly changed, KM given for the condition has been used).

FSC (–) 0.233 m (obtained from particulars of Condition No. 2)

GM (Fluid) = 2.044 m

14. *M.V. 'Hindship' floating in condition No. 5, discharges the entire cargo from No. 1 TD, No. 5. Poop Deck and refrigerated cargo spaces. No. 4 DB tank (C) is filled with water ballast. FSC in final condition is 0.0895 m. Calculate her GM (Fluid).*

	Wt (t)	*KG* (m)	*V. Moment* (mt)
Condition No. 5	18529.3	7.539	139700
No. 1 TD	(–) 681.7	11.17	(–) 7615
No. 5 Poop Deck	(–) 542.6	13.76	(–) 7466
Ref. Cargo	(–) 235.0	10.36	(–) 2435
No. 4(C) (257.4 × 1.025)	(+) 263.8	0.63	(+) 166.2
Final displacement	17333.8	Final moment	122350.2

$$\text{Final KG} = \frac{122350.2}{17333.8} = 7.0585 \text{ m}$$

KM for displacement of 17333.8 t = 8.280 m

KG = 7.0585 m

GM (Solid) = 1.2215 m

FSC in Final condition = (–) 0.0895 m

GM (Fluid) = 1.132 m

15. *M.V. 'Hindship' floating 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. Assuming theoretically that the deck cargo of locomotives was shifted to No. 2 TD and No. 4 (P & S) DB tanks slackened, increasing the FSC by 0.035 m, calculate the final GM (Fluid) of the ship.*

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Condition No. 7	18529.3	7.807	144653
2 TD	(–) 1058.4	10.720	(–) 11346
B. Bow	(+) 186.6	3.52	(+) 656.8
Shift of Locos	760.0	*3.11	(–) 2363.6
(Does not alter displacement)			
Final Wt. =	17657.5	Final Moment =	131600.2

*Kg of Locos = 13.83 m

Kg of No. 2 TD = 10.72 m

Shift of Wt. Downwards = 3.11 m

$$\text{Final KG} = \frac{\text{Final moment}}{\text{Final Wt.}} = \frac{131600.2}{17657.5} = 7.453 \text{ m}$$

KM for displacement of 17657.5 t = 8.295 m

KG = 7.453 m

GM (Solid) = 0.842 m

Final FSC = 0.084 + 0.035 = (–) 0.119 m

GM (Fluid) = 0.723 m

16. *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

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Cond. No. 2	7799.0	6.942	54137
Loads 1 TD	(+) 601	11.17	(+) 6713.2
Loads 3 Hold	(+) 1520	1.70	(+) 2584
Loads 5 Hold	(+) 420	6.91	(+) 2902.2
	10,340.0		66,336.4
Pumped out F. Pk.	(–) 106.1	6.31	(–) 669.5
Pumped out 4 (P & S)	(–) 261.2	0.68	(–) 177.6
	Final Wt = 9972.7	Final moments =	65,489.3

Final KG $= \dfrac{65,489.3}{9972.7} =$ 6.567 m

KM for displacement of 9972.7 t = 8.840 m

KG = 6.567 m

GM (Solid) = 2.273 m

FSC for final condition = (–) 0.155 m

GM (Fluid) = 2.118 m

FREE SURFACE CORRECTION

As stated earlier, a virtual rise in the CG and a consequent virtual loss of GM occurs whenever there is a free surface of liquid in any compartment in the ship. This loss is not present if the tank is either completely full or completely empty, as there is no free surface of liquid in either of the conditions. The virtual loss in GM is obtained by the expression

$$\frac{i}{V} \times \frac{\delta t}{\delta s}$$

Where i = moment of inertia of the free surface area.

V = underwater volume of the ship.

δt = density of liquid in the tank.

δs = density of water in which the ship is floating.

The numerator (i × δt) is referred to as the Free Surface Moment and the denominator (V × δs) is the displacement of the ship. The denominator being the ship's displacement, is independent of the density of water in which the ship is floating. The moments of inertia for the various tanks are available on page 19 of the Booklet of Trim and Stability Particulars of M.V. 'Hindship'.

The moment of inertia of each slack tank is multiplied by the density of liquid in that tank to obtain the free surface moment. The total free surface moment divided by the displacement, as shown on page 20 of the above booklet gives the virtual loss in GM or FSC. For a particular displacement, FSC is independent of the density of water in which the ship floats.

17. *M.V. 'Hindship' at a displacement of 18420 tonnes, has a free surface moment of 1972 mt.*

(a) Calculate the free surface correction.

(b) If at the same displacement, the FS moment was 1104 mt. calculate the FSC.

(a) FSC $= \dfrac{\text{FS Moment}}{\text{Displacement}} = \dfrac{1972}{18420} =$ **0.107 m**

(b) FSC $= \dfrac{\text{FS Moment}}{\text{Displacement}} = \dfrac{1104}{18420} =$ **0.060 m**

18. *M.V. 'Hindship' at a displacement of 14240 tonnes, had a FSC of 0.087 m. Find the FSC after having discharged 3210 tonnes of cargo, assuming the tank soundings remained unchanged.*

FS moment	=	FSC × displacement
	=	0.087 × 14240 = 1238.88 mt
Final displacement	=	14240 – 3210 = 11030 tonnes
FSC after discharge	=	$\frac{\text{FS Moment}}{\text{Displacement}} = \frac{1238.88}{11030}$
		= 0.112 m

Final FSC = 0.112 m

19. *M. V. 'Hindship' floating at a displacement of 8420 tonnes, has a free surface moment of 1542 mt. Find her GM (Fluid) if KG = 7.651 m.*

FSC = $\frac{\text{Free surface moment}}{\text{Displacement}}$	=	$\frac{1542}{8420}$
	=	0.183 m
KM for displacement 8420 tonnes	=	9.413 m
KG	=	7.651 m
GM (Solid)	=	1.762 m
FSC	=	0.183 m
GM (Fluid)	**=**	**1.579 m**

20. *M.V. 'Hindship' floating at a mean draft of 7.50 m. KG 7.726 m has the following tanks slack.*

No. 3 DB tanks P, C & S.	containing Water Ballast
No. 5 DB tank Port.	containing DO
No. 5 DB tank Stbd.	containing HFO
Tween deck FW tank Stbd.	containing FW

(a) Find her GM (Fluid)

(b) If the displacement of the ship is 10,280 t with the same tanks slack, calculate the FSC.

(a) For draft 7.5 m, displacement = 15459.5 t

" " KM = 8.238 m

		Moment of Inertia (m^4)		*Density*		*FS moment* (mt)
No. 3 P & S (SW) 2 × 227	=	454	×	1.025	=	465.35
No. 3 Centre (SW)	=	1181	×	1.025	=	1210.53
No. 5 Port (DO)	=	172	×	0.88	=	151.36
No. 5 Stbd. (HFO)	=	95	×	0.95	=	90.25
TD FW Tank (FW)	=	42	×	1.0	=	42.00
				Total FS Moment	=	1959.49

$$FSC = \frac{\text{FS Moment}}{\text{Displacement}} = \frac{1959.49}{15459.5} = 0.127 \text{ m}$$

KM	=	8.238 m
KG	=	7.726 m
GM (Solid)	=	0.512 m
FSC	=	0.127 m
GM (Fluid)	=	**0.385 m**

(b) $$FSC = \frac{\text{FS Moment}}{\text{Displacement}} = \frac{1959.49}{10,280} = 0.191 \text{ m}$$

FSC = 0.191 m

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

	Weights (t)		*KG* (m)	*V. Moments* (mt)
Condition No. 4 displ.	19617		7.272	142648
No. 1 TD	(–) 681.7		11.170	(–) 7615
No. 3 TD	(–) 887.7		10.370	(–) 9205
Shift of HFO	131	{6.09 – 0.63 = 5.46}	5.46	(–) 715
Final Wt.	= 18047.6		Final Moment =	125113

$$\textbf{Final KG} = \frac{125113}{18047.6} = \textbf{6.932 m}$$

Original FS Moment	=	1372 mt
FS Moment of settling & Service tanks		(–) 15 mt
FS Moments of No. 4 centre		
= 1408 × 0.95	=	(+) 1337.6 mt
Final FS Moment	=	2694.6 mt

$$\text{Final FSC} = \frac{2694.6}{18047.6} = 0.149 \text{ m}$$

KM for displacement 18047.6	=	8.316 m
KG	=	6.932 m
GM (Solid)	=	1.384 m
FSC	=	0.149 m
GM (Fluid)	**=**	**1.235 m**

22. *M.V. 'Hindship' at a draft of F 5.38 m, A 6.17 m, GM (Fluid) 0.83 m. FSC 0.092 m discharges 430 t from No. 3 TD Vcg 10.2 m, 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 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	=	6.17 m
Corrn. from table 'A'	=	(–) 0.40 m
Original hydrostatic draft	=	5.77 m
Original displacement	=	11501.7 t
KM	=	8.513 m
Original GM (Fluid)	=	0.830 m
FSC	=	0.092 m
GM (Solid)	=	0.922 m
KM	=	8.513 m
Original KG	=	7.591 m

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Original displacement	11501.7	7.591	87309.4
Disch. from 3 TD	(–) 430	10.2	(–) 4386.0
Loaded in No. 5 LTD	(+) 250	10.69	(+) 2672.5
Fuel oil in 2 DB tank	(+) 300	0.65	(+) 195.0
Final Weight	11621.7	Final V. Moments	85790.9

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

Original FSM	=	0.092 × 11501.7	=	1058.2 mt
FSM in 2 (P&S)	=	1436 × 0.95	=	(+) 1364.2 mt
Final FSM			=	2422.4 mt
Final FSC	=	$\frac{2422.4}{11621.7}$	=	0.208 m
KM for displacement 11621.7 t			=	8.495 m
Final KG			=	7.382 m
		Final GM (Solid)	=	1.113 m
		FSC	=	0.208 m
		Final GM (Fluid)	**=**	**0.905 m**

23. *M.V. 'Hindship' at a river port in water of RD 1.014 has a displacement of 10,230 t. GM (Fluid) 0.82 m. FSC 0.077 m. She loads 470 t. of cargo Kg 9.8 m. 150 t. of water ballast is run into No. 1 DB tank. Find her final GM (Fluid).*

For displacement 10,230 t in density 1.014

$$\text{equivalent weight in salt water} = \frac{10{,}230 \times 1.025}{1.014} = 10340.9 \text{ t},$$

GM (Fluid)	=	0.820 m
FSC	=	0.077 m
GM (Solid)	=	0.897 m

The underwater volume for displacement 10340.9 t: in SW is equal to that for 10230 t in water of density 1.014. We therefore obtain the KM for 10340.9 t from the tables as explained in question 4.

KM for displacement 10340.9 t in SW	=	8.744 m
KG = KM − GM (Solid) = 8.744 − 0.897	=	7.847 m

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Original displacement	10230	7.847	80274.8
Loaded	(+) 470	9.8	(+) 4606.0
Ballast in 1 DB	(+) 150	1.14	(+) 171.0
Final Weight	10850	Final V. Moments	85051.8

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

Initial FSM = 0.077 × 10230	=	787.7 mt
FSM in 1 DB tank = 419 × 1.014	=	424.9 mt
Final FSM	=	1212.6 m
Final FSC = $\frac{1212.6}{10850}$	=	0.112 m

For displacement 10850 t. in density 1.014, equivalent weight in SW

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

KM for displacement 10967.7 t in SW	=	8.607 m
Final KG	=	7.839 m
Final GM (Solid)	=	0.768 m
FSC	=	0.112 m
Final GM (Fluid)	**=**	**0.656 m**

24. *M.V. 'Hindship' in Condition No. 7 pumps out 60 tonnes of ballast each from No. 4 DB tanks P and S. The entire diesel oil in 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.*

	Weights (t)	*KG* (m)	*V.Moments* (mt)
Initial displacement	18529.3	7.807	144653
No. 4 DB Tk. P & S	(–) 120.0	0.68	(–) 82
No. 5 DB Tk. P	(–) 17.7	0.21	(–) 4
Final Weight	18391.6	Final V. Moment =	144567

$$\text{Final KG} = \frac{144567}{18391.6} = 7.861 \text{ m}$$

Initial FSM	=	1552 mt
FSM of No. 4 P & S = 542 × 1.025	=	(+) 556 mt
FSM of No. 5 P	=	(–) 152 mt
Final FSM	=	1956 mt

$$\text{Final FSC} = \frac{\text{Final FSM}}{\text{Final Displ.}} = \frac{1956}{18391.6} = 0.106 \text{ m}$$

For displ. 18391.6 t in δ 1.007, equivalent weight in SW

$$= 18391.6 \times \frac{1.025}{1.007} = 18720.3 \text{ t}$$

From tables, KM for displ. 18720.3 t	=	8.364 m
Final KG	=	7.861 m
Final GM (Solid)	=	0.503 m
FSC	=	0.106 m
Final GM (Fluid)	**=**	**0.397 m**

25. *M.V. 'Hindship' displacing 12,400 t in water of RD 1.010, has a GM (Fluid) of 0.58 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).*

For displ. 12,400 t in δ 1.010, equivalent weight in SW

$$= 12400 \times \frac{1.025}{1.010} = 12584 \text{ t}$$

From tables, KM for displacement 12584 t = 8.373 m

Initial GM (Fluid) = 0.580 m

$$FSC = \frac{1530}{12400} = 0.123 \text{ m}$$

Initial GM (Solid) = 0.703 m = 0.703 m

Initial KG = 7.670 m

	Weights (t)	KG (m)	V. Moments (mt)
Initial displacement	12400	7.67	95108
No. 2 LH	(+) 620	5.02	(+) 3112.4
No. 2 DB Tk, P & S	(–) 100	0.65	(–) 65.0
Shifted	150	5.30 ↑	(+) 808.5
Final Weight	12920	Final V. Moment	98964

$$\text{Final KG} = \frac{98964}{12920} = 7.660 \text{ m}$$

Initial FSM = 1530 mt

No. 2 DB tank P & S = 1436 × 1.025 = 1472 mt

Final FSM = 58 mt

$$\text{Final FSC} = \frac{58}{12920} = 0.004 \text{ m}$$

For displ. 12920 t in RD 1.010, equivalent weight in SW

$$= 12920 \times \frac{1.025}{1.010} = 13112 \text{ t}$$

From tables, KM for displacement 13112 t = 8.325 m

Final KG = 7.660 m

Final GM (Solid) = 0.665 m

FSC = 0.004 m

Final GM (Fluid) = 0.661 m

26. *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 410 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.*

Initial draft F 7.87 m, A 8.32 m } trim 0.45 m by stern; M 8.095 m

LCF for mean draft 8.095 m = 70.507 m

After draft = 8.320 m

Corrn. to Aft draft from table 'A' = 0.222 m

Hydrostatic draft = 8.098 m

Displacement at 8.098 m draft in density 1.007

$$= \frac{16870.7 \times 1.007}{1.025} = 16574.4 \text{ t}$$

	Weights (t)	KG (m)	V. Moments (mt)
Initial displ.	16574.4	7.45	123479.3
Discharged from 2 TD	(–) 410	10.72	(–) 4395.2
Shifted	60	↓ 9.72	(–) 583.2
Water received in No. 8 (P&S)	(+) 110	2.77	(+) 304.7
Final Wt.	16274.4	Final V. Moments	118805.6

$$\text{Final KG} = \frac{118805.6}{16274.4} = 7.300 \text{ m}$$

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

$$\text{Final FSC} = \frac{2069}{16274.4} = 0.127 \text{ m}$$

For displacement 16274.4 t in density 1.007, equivalent

$$\text{weight in SW} = \frac{16274.4 \times 1.025}{1.007} = 16565.3 \text{ t}$$

KM for above displacement	=	8.249 m
KG	=	7.300 m
GM (Solid)	=	0.949 m
FSC	=	0.127 m
Final GM (Fluid)	**=**	**0.822 m**

27. *M. V. 'Hindship' at a displacement of 7087.3 t, KG 7.45 m, FSC 0.103 m, is in water of density 1.012 t/m³.*

No. 2 Hold and No. 5 Hold which were empty are fully loaded with cargo stowing at 0.75 m³/t and 1.08 m³/t respectively. The After Peak tank which was empty, is filled with water of density 1.005 t/m³. Calculate her GM (Fluid) in the final condition.

$$\text{Cargo loaded in 2 Hold} = \frac{3586.7}{0.75} = 4782.3 \text{ t}$$

$$\text{Cargo loaded in 5 Hold} = \frac{684.0}{1.08} = 633.3 \text{ t}$$

Ballast in A. Pk. Tank = 117.8 × 1.005 = 118.4 t

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Original displ.	7087.3	7.45	52799
Loaded in No. 2 Hold	(+) 4782.3	4.98	(+) 23816
Loaded in No. 5 Hold	(+) 633.3	6.91	(+) 4375
Ballast in A. Pk.	(+) 118.4	8.81	(+) 1043
Final Wt.	12621.3	Final V. Moments	82033

$$\text{Final KG} = \frac{82033}{12621.3} = 6.500 \text{ m}$$

Original FSM = 0.103 × 7087.3 = 730 mt

For displacement 12621.3 t in density 1.012,

$$\text{equivalent weight in SW} = \frac{12621.3 \times 1.025}{1.012} = 12783.4 \text{ t}$$

KM for above displacement	=	8.354 m
Final KG	=	6.500 m
GM (Solid)	=	1.854 m

$$\text{Final FSC} = \frac{730}{12621.3} = 0.058 \text{ m}$$

GM (Fluid) = 1.796 m

28. *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.*

(i) Displ. for hydrostatic draft 7.30 m in SW = 14993.5 t

Displ. at that draft in FW $= \frac{14993.5 \times 1.0}{1.025}$ = 14627.8 t

Cargo to be loaded = 1300 t

Final displacement = 15927.8 t

KM in SW for displacement 15927.8 t = 8.239 m

GM required = 0.500 m

Final KG required = 7.739 m

	Weight (t)	*KG* (m)	*V. Moments* (mt)
Initial displacement	14627.8	7.9	115559.6
Loaded	(+)1300	x	(+) 1300x
Final Wt.	15927.8	Final V. Moments.	115559.6+1300x

$$\text{Final KG} = \frac{115559.6 + 1300x}{15927.8} = 7.739 \text{ m}$$

$$x = \frac{(7.739 \times 15927.8) - 115559.6}{1300} = 5.927 \text{ m}$$

Kg of weight to be loaded = 5.927 m

(ii) For displacement 15927.8 t in FW, equivalent weight in

$$\text{SW} = \frac{15927.8 \times 1.025}{1.000} = 16326 \text{ t}$$

KM for displ. 16326 t = 8.243 m

GM required = 0.500 m

Final KG required = 7.743 m

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Initial displacement	14627.8	7.9	115559.6
Loaded	(+) 1300	x	(+) 1300x
Final Wt.	15927.8	Final V. Moments	115559.6 + 1300x

$$\text{Final KG} = \frac{115559.6 + 1300x}{15927.8} = 7.743 \text{ m}$$

$$x = \frac{(7.743 \times 15927.8) - 115559.6}{1300} = 5.976 \text{ m}$$

Kg of weight to be loaded = 5.976 m

29. *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.*

Since the trim of the vessel is not given, the mean draft may be considered as the hydrostatic draft.

Displacement for hydrostatic draft 5.5 m	=	10897 tonnes
To load	=	1200 tonnes
Final Displacement	=	12097 tonnes
GM (Fluid) required	=	1.000 m
FSC	=	0.104 m
GM (Solid) reqd	=	1.104 m
KM for Displacement of 12097 t	=	8.429 m
KG required	=	7.325 m

Let 'x' tonnes be loaded in No. 2 Hold (Kg = 4.98 m)

Then cargo loaded in No. 2 TD = (1200 − x), (Kg 10.72 m)

	Weights (t)	*KG* (m)	*V. Moment* (mt)
Initial displacement	10897	7.53	82054.4
No. 2 Hold	x	4.98	$4.98x$
No. 2 TD	$1200-x$	10.72	$12864-10.72x$
Final Weights :	12097	Final Moments:	$94918.4-5.74x$

$$\text{Final KG} = 7.325 = \frac{94918.4 - 5.74x}{12097}$$

$$12097 \times 7.325 = 94918.4 - 5.74x$$

$$5.74x = 94918.4 - 88610.5 = 6307.9$$

$$x = \frac{6307.9}{5.74} = 1098.9 \text{ tonnes}$$

Cargo to load in No. 2 Hold = 1098.9 tonnes

Cargo to load in No. 2 TD = 1200 − 1098.9 = 101.1 tonnes

Cargo to load No. 2 Hold = 1098.9 tonnes

" " No. 2 TD = 101.1 tonnes

30. *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 the 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.

		Weights (t)	*KG* (m)	*V. Moments* (mt)
(i)	Condition No. 7	18529.3	7.807	144653
	*Shifted	76.0	11.17	(+) 849
	Final Wt.	18529.3	Final Moment =	145502

(*When a wt. is lifted by the derrick the virtual Cg of the wt. is at the derrick head, irrespective of the ht. through which the wt. has been lifted.)

Final KG = $\frac{145502}{18529.3}$		=	7.852 m
KM (unchanged)		=	8.349 m
KG		=	7.852 m
GM (Solid)		=	0.497 m
FSC (unchanged)	(–)	=	0.084 m
GM (Fluid)		=	**0.413 m**

(ii)

	Weights (t)	KG (m)	V. Moments (mt)
Condition No. 7	18529.3	7.807	144653
Discharged	(–) 76	13.83	(–) 1051
Final Wt.	18453.3	Final Moment	143602

$$\text{Final KG} = \frac{143602}{18453.3} = 7.782 \text{ m}$$

KM for Final displacement = 8.344 m

Final KG = 7.782 m

GM (Solid) = 0.562 m

Original FSM = 1552 mt

$$\text{Final FSC} = \frac{1552}{18453.3} \quad (-) = 0.084 \text{ m}$$

GM (Fluid) = 0.478 m

FORE & AFT SHIFT OF G

When finding moment about AP, moments of weights LOADED are ADDED and those of weights DISCHARGED are SUBTRACTED.

When weights are shifted in the fore & aft direction, the moment of the shift is obtained by the product of the wt. shifted and the horizontal distance through which it is shifted. The moment is ADDED if the wt. is shifted FOR'D and is SUBTRACTED if the wt. is shifted AFT, on the same principle as for moments of weights shifted vertically, when considering moments about the keel.

31. *M. V. 'Hindship', when floating in Condition No. 2, transfers the water ballast in the Fore Peak tank to the A Peak tank. Find the horizontal shift of the ship's centre of gravity.*

LCG of ship in Condition No. 2 = 65.344 m

Lcg of Fore Peak Tank = 137.187 m

Lcg of Aft Peak Tank = 3.58 m

∴ The distance, ballast was shifted = 137.18 – 3.58 = 133.60 m

	Weights (t)	LCG (m)	L. Moments (mt)
Initial Displ	7799	65.344	509617
Shifted	106.1	133.6	(–) 14175
Final Weight	7799	Final Moments	495442

$$\text{Final LCG} = \frac{\text{Final L. Moments}}{\text{Final Weight}} = \frac{495442}{7799} = 63.526 \text{ m}$$

Final LCG = 63.526 m ford of AP

Initial LCG = 65.344 m ford of AP

Horizontal Shift of G = 1.818 m ford of AP

Shift of G = 1.818 m towards Stern

32. *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.*

Original draft	F 8.68 m, A 8.88 m	trim 0.2 m by stern.
	M 8.78 m	LCF = 69.927 m
Aft Draft		= 8.880 m
Corrn. to Aft draft from table 'A'		= 0.098 m
Hydrostatic draft		= 8.782 m
Displ. in SW for hydrostatic draft 8.782 m.		= 18521.4 t

Hence displ. at that draft in density 1.010 = $\frac{18521.4 \times 1.010}{1.025}$ = 18250.4t

	Weight (t)	*LCG* (m)	*L. Moments* (mt)
Original displ.	18250.4	72.129	1316383
Disch.	(–) 400	x	(–) $400x$
Final displ.	17850.4	Final L. Moments	$1316383 - 400x$

$$\text{Final LCG} = 71.9 = \frac{1316383 - 400x}{17850.4}$$

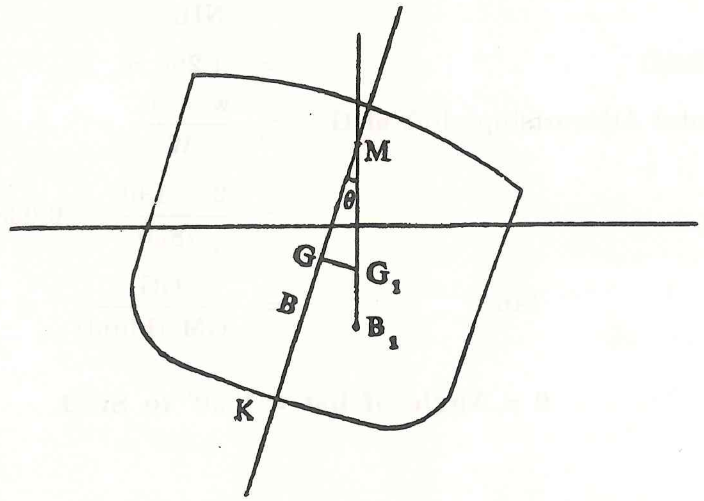
$$x = \frac{(71.9 \times 17850.4) - 1316383}{-400} = 82.348 \text{ m.}$$

400 t to be discharged from 82.348 m ford of AP.

When only one weight is loaded, discharged or shifted, the shift of G, i.e. GG_1 may be calculated by the expressions $GG_1 = \frac{w \times d}{W + w}$, $\frac{w \times d}{W - w}$ or $\frac{w \times d}{W}$ respectively, where "W" is the original displacement and "w" the weight loaded dischargd or shifted. For loading and discharging 'd' is the athwartship distance between g of the weight and G of the ship. In the case of shifting, 'd' is the athwartship distance through which the weight is shifted. For an upright ship, G is on the centre line.

When more than one weight is involved, it would be more convenient to calculate GG_1 by moments about the centre line.

The resultant moment about the centre line obtained as the algebraic sum of moments to port and moments to starboard, divided by the final displacement gives the athwartship GG_1.



From the above figure it can be seen that the list may be calculated by the expression

$$\tan \theta = \frac{GG_1}{GM\ (\text{Fluid})}$$

The above formula can be used without appreciable loss of accuracy for very small angles of list only, for reasons already stated under section 'DEFINITIONS'. Lists of larger angles can be correctly determined from the curves of statical stability as indicated later under the First Mates (FG) section.

33. *M. V. 'Hindship' displacing 7720 tonnes KG 8.42 m, no FSC, loads 130 tonnes, Kg 10.52 m and cg 2 m off the centre line to starboard. Calculate the resultant list.*

	Weights (t)	*KG* (m)	*V. Moment* (mt)
Initial displacement	7720	8.42	65002.4
Loaded	(+) 130	10.52	(+) 1367.6
Final Wt.	7850	Final Moment	66370

Final KG $= \dfrac{66370}{7850} = 8.455$ m

KM for displacement of 7850 t = 9.720 m

GM (Solid) = 1.265 m

FSC = NIL

GM (Fluid) = 1.265 m

Horizontal Athwartship shift of G $= \dfrac{w \times d}{W}$

$$= \frac{2 \times 130}{7850} = 0.03312 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.03312}{1.264}$$

θ = Angle of list = 1°30' to Stbd.

34. *M.V. 'Hindship' is in Condition No. 2 Find the shift of her CG if 100 tonnes of cargo is shifted transversely over a distance of 10 metres. Also find the resulting list.*

Transverse $GG_1 = \dfrac{w \times d}{W} = \dfrac{100 \times 10}{7799} = 0.128$ m

$GG_1 = 0.128$ m

GM (Fluid) for Condition No. 2 = 2.57 m

$$\tan\theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.128}{2.57}$$

θ = Angle of List = 2°51'

35. *M.V. 'Hindship' floating at a draft of F 5.70 m, A 7.60 m, KG 6.12 m, loads 400 t of cargo in 3 TD, 2 m off the centre line to port. Calculate her angle of list. No FSC.*

Original draft 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

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Initial displacement	13486	6.12	82534
Loaded	(+) 400	10.37	(+) 4148
Final Wt.	13886	Final V. Moments	86682

$$\text{Final KG} = \frac{86682}{13886} = 6.242 \text{ m}$$

KM for displacement of 13886 t	=	8.278 m
GM (Solid)	=	2.036 m
FSC	=	NIL
GM (Fluid)	=	2.036 m

$$\text{Transverse } GG_1 = \frac{w \times d}{W} = \frac{400 \times 2}{13886} = 0.0576 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.0576}{2.036}$$

θ = Angle of List = 1° 37' to Port.

36. *M.V. 'Hindship' in Condition No. 5, receives 100 tonnes of DO in No. 7. Port DB tank, Cg 5 metres off the centre line. Calculate the resulting list.*

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Condition No. 5 displ.	18529.3	7.539	139700
No. 7 Port	(+) 100.0	2.620	(+) 262
Final Wt.	18629.3	Final V. Moments	139962

$$\text{Final KG} = \frac{\text{Final Moment}}{\text{Final Wt.}} = \frac{139962}{18629.3} = 7.513 \text{ m}$$

$$\text{Volume of DO in No. 7 Port} = \frac{\text{wt.}}{\text{density}} = \frac{100}{0.88} = 113.63 \text{ m}^3$$

Since the total capacity of No. 7 Port is 114.6 m^3, the tank is SLACK.

Original Free Surface Moment	=	1552 mt
FSM of No. 7 Port = (50 × 0.88)	=	44 mt
Final FSM	=	1596 mt

$$\text{Final FSC} = \frac{1596}{18629.3} = 0.086 \text{ m}$$

KM for displacement 18629.3 t	=	8.357 m
KG	=	7.513 m
GM (Solid)	=	0.844 m
FSC	=	0.086 m
GM (Fluid)	=	0.758 m

$$\text{Transverse } GG_1 = \frac{w \times d}{W + w} = \frac{100 \times 5}{18629.3} = 0.02684 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.02684}{0.758}$$

θ = Angle of List = 2°2' to Port.

37. *M.V. 'Hindship', displacing 13530 t. in water of density 1.015 t/m³, KG 7.344 m, FSC 0.076 m, 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.*

Underwater volume in δ 1.015 $= \frac{\text{Displ.}}{\delta} = \frac{13530}{1.015} = 13330\ m^3$.

Displacment in SW for underwater volume 13330 m^3

$= V \times \delta_1 = 13330 \times 1.025 = 13663.3$ t

KM for displacement 13663.3 t = 8.289 m

KG = 7.344 m

GM (Solid) = 0.945 m

FSC = 0.076 m

GM (Fluid) = 0.869 m

$$\text{Transverse } GG_1 = \frac{w \times d}{W} = \frac{30 \times 7.5}{13,530} = 0.01662 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM\ (\text{Fluid})} = \frac{0.01662}{0.869} = 0.01912$$

θ = Angle of List = 1°06' to starboard

38. *M.V. 'Hindship' in Condition No. 8, consumes the entire HFO from No. 5. DB tank (S), cg 4 metres from the centre line. Find the resultant list.*

	Weights (t)	*KG* (m)	*V. Moments* (mt)
Condition No. 8	16133	7.263	117177
No. 5 (S)	(–) 46.4	0.870	(–) 40
Final Wt.	16086.6	Final V. Moments	117137

FS Moment in Condition No. 8 = 1372 mt

Change in FS Moment = Nil

Final FS Moment = 1372 mt

$$\text{FSC in final condition} = \frac{1372}{16086.6} = 0.085 \text{ m}$$

$$\text{Final KG} = \frac{\text{Final Moment}}{\text{Final Wt.}} = \frac{117137}{16086.6} = 7.282 \text{ m}$$

KM for displacement 16086.6 t = 8.240 m

GM (Solid) = 0.958 m

FSC = 0.085 m

GM (Fluid) = 0.873 m

$$\text{Transverse } GG_1 = \frac{w \times d}{W-w} = \frac{4 \times 46.4}{16086.6} = 0.01153 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM\ (\text{Fluid})} = \frac{0.01153}{0.873} = 0.0132$$

θ = Angle of List = 0°45' to Port.

39. *M. V. 'Hindship' floating at a hydrostatic draft of 6.10 m is listed $2\frac{1}{4}^0$ to port, GM (Fluid) 0.491 m. To bring her upright, where with respect to the centre line, should 100 tonnes be*

(a) *loaded,*

(b) *discharged.*

(c) *If the list was to be corrected by shifting 100 tonnes transversely, through what distance should the wt. be moved.*

Displacement for hydrostatic draft of 6.10 m = 12245.5 t

$$\tan \theta = \frac{GG_1}{GM\ (Fluid)}$$

$\therefore$ GG_1 causing list = GM (Fluid) × tan θ = 0.491 × tan $2\frac{1}{4}^0$

= 0.019292

Moment to port causing list = GG_1 × W = 0.019292 × 12245.5

= 236.24 mt.

To correct the list, an equal moment should be caused to starboard.

Since Moment = wt. × dist.

(a) dist. from CL at which wt. should be loaded

$$= \frac{Moment}{wt.} = \frac{236.24}{100} = \textbf{2.362 m to starboard}$$

(b) Similarly, the dist. from CL at which the wt. should be discharged

$$= \frac{Moment}{wt.} = \frac{236.24}{100} = \textbf{2.362 m to port}$$

(c) Distance through which the wt. should be shifted transversely

$$= \frac{Moment}{wt.} = \frac{236.24}{100} = \textbf{2.362 m towards starboard}$$

Note : The GM (Fluid) would change when weights are loaded or discharged, as KM and FSC would alter. The change would be negligible in this case, and has therefore been ignored.

40. *A wt. of 20 tonnes, when moved transversely through a distance of 18 metres, causes M.V. 'Hindship' floating at a mean draft of 5.92 m, to list 2.6^0. Calculate her GM (Solid), given FSC 0.082 m.*

For draft 5.92 m. displacement = 11839 t

" " " KM = 8.464 m

$$\text{Transverse } GG_1 = \frac{w \times d}{W} = \frac{20 \times 18}{11839} = 0.0304 \text{ m}$$

$$\text{GM (Fluid)} = \frac{GG_1}{\tan \theta} = \frac{0.0304}{\tan 2.6^0} = 0.670 \text{ m}$$

FSC = 0.082 m

GM (Solid) = 0.752 m

41. *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 stbd. of 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.*

Since 280 t were discharged and 280 t loaded at the same Kg and the third parcel of cargo was shifted horizontally only, the ship's KG will remain unchanged. The FSC also remains unchanged as the displacement and FSM have not altered.

To find the transverse GG_1 :-

	Weights (t)	*Dist. from CL* (m)	*Transverse moments* (mt)
Discharged	280	1.4 (S)	392 (P)
Loaded	280	3.5 (S)	980 (S)
Shifted	70	2.4 to (S)	168 (S)
Resultant Moment		=	756 (S)

$$\text{Transverse } GG_1 = \frac{756}{16398} = 0.0461 \text{ m}$$

KM for displ. 16398 t	=	8.245 m
KG	=	7.15 m
GM (Solid)	=	1.095 m
FSC	=	0.080 m
GM (Fluid)	=	1.015 m

$$\tan\theta = \frac{GG_1}{GM\ (Fluid)} = \frac{0.0461}{1.015} = 0.0454 \text{ m}$$

θ = Angle of List = 2°36' to starboard

42. *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 starboard 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.*

Displ. in SW for M. draft 7.12 m = 14576.2 t

$$\text{Displ. at that draft in } \delta\ 1.008 = 14576.2 \times \frac{1.008}{1.025} = 14334.4 \text{ t}$$

	Weights (t)	*KG* (m)	*V. Moments* (mt)	*Dist. from CL* (m)	*Trans. Moments* (mt)
Ship	14334.4	6.12	87726.5	0.0	-
Loads No. 3 TD	+ 900	10.37	(+) 9333.0	2.0 (P)	1800 (P)
Loads No. 4 TD	+ 200	10.76	(+) 2152.0	2.5 (S)	500 (S)
Disch. from Dk.	(–)80	14.1	(–) 1128.0	4.0 (P)	320 (S)
Final Displ.	15354.4	Final V. Moment	98083.5	Final T. Moment	980 (P)

Equivalent displ. in SW for displ. 15354.4 t in δ 1.008

$$= 15354.4 \times \frac{1.025}{1.008} = 15613.4 \text{ t}$$

KM for displ. 15354.4 t in δ 1.008 = 8.238 m

$$\text{Final KG} = \frac{98083.5}{15354.4} = 6.388 \text{ m}$$

GM (Solid) = 1.850 m

FSC = 0.120 m

GM (Fluid) = 1.730 m

$$\text{Transverse } GG_1 = \frac{980}{15354.4} = 0.06383 \text{ m}$$

$$\tan\theta = \frac{GG_1}{GM \text{ (Fluid)}} = \frac{0.0638}{1.73}$$

θ = Angle of List = 2°07' to P

For displ. 15613.4 t in SW, hydrostatic draft from tables = 7.566 m

Final Mean Draft = 7.566 m

RIGHTING MOMENT

The Righting Lever GZ is the perpendicular distance between the ship's Centre of Gravity and the vertical line through the Centre of Buoyancy in an inclined position.

The Righting Moment or Moment of Statical Stability of a vessel at any angle of heel is the moment with which she tends to return to the original upright condition, when heeled to that angle by an external force.

For very small angles of heel, GZ = GM × sin θ.

At larger angles of heel, GZ must be obtained as

KN – corrected KG × sin θ

Righting Moment = W × GZ.

43. Calculate the Righting Moment of M.V. 'Hindship' at an angle of heel of 10° in Condition No. 4.

Righting Moment = W × GZ

GZ for 10° heel in Condition No. 4 = 0.262 m.

Therefore Righting Moment = 19617 × 0.262.

RM = 5139.65 mt.

RELATIONSHIP BETWEEN DENSITY, DRAFT & DISPLACEMENT

The Student is advised to refer to definitions of Displacement, Volume of Displacement, Density and Relative Density, given earlier in this book.

LAW OF FLOATATION : Every body floating in a fluid, displaces a volume of that fluid equal in mass to the mass of that body.

Therefore, in the case of a ship, her Displacement = Weight of water displaced.

The weight of any substance = It's volume × It's density. Thus the Weight of the ship = Volume of water displaced by the ship × Density of that water.

$$W = V \times \delta$$

When a ship proceeds from water of one density to water of another density, her displacement does not alter. Therefore from the above expression, it can be seen that W remaining constant, V, the underwater volume and therefore the draft must increase if the density of water decreases, and conversely the underwater volume and the draft must decrease if the density increases.

It should also be noted that the displacement of a ship floating **at the same draft** in water of **different densities,** will not be the same as the underwater volumes would be the same, but the densities would be different.

The Freshwater Allowance of a ship is the number of millimeters by which the mean draft of the ship changes when she proceeds from Salt Water to Fresh Water or from Fresh Water to Salt Water, when floating at the Load water line.

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

The FWA given in the Load Line Certificate is valid only for drafts corresponding to waterlines between W & TF marks. For drafts less than winter draft the FWA for the concerned draft may be calculated by the above expression using W and TPC for salt water at that draft.

Dock Water Allowance for densities between those of FW and SW may be obtained by simple proportion.

$$\text{Thus, Dock Water Allowance} = \frac{\text{FWA} \times \text{(Difference in densities)}}{(1.025 - 1.000)}$$

Calculations in this section may also be done using first principles of volume, density and weight.

44. *M. V. 'Hindship' floating at her Summer draft, in salt water, proceeds to water of density 1.007 tonnes/m^3. Calculate her freeboard.*

FWA = 202 mm.

$$\text{Dock water allowance} = \frac{202 \times (1025 - 1007)}{(1025 - 1000)}$$

$$= \frac{202 \times 18}{25} = 145 \text{ mm.}$$

$= 0.145$ m

Summer freeboard = 2.626 m

Dockwater allowance = 0.145 m

$\therefore$ **Freeboard in water of density 1.007 = 2.481 m**

45. *M. V. 'Hindship', is floating in water of SG 1.012, with a freeboard of 4.42 m. Calculate her displacement.*

Summer draft	= 9.233 m
Summer freeboard	= 2.626 m
Distance between keel & deck line	= 11.859 m
Present freeboard	= 4.420 m
$\therefore$ Present draft in dockwater	= 7.439 m

Displacement in salt water for 7.439 m, draft = 15317 tonnes

$\therefore$ Underwater volume, V, at that draft $= \frac{15317}{1.025}\ m^3$

$\therefore$ Displacement at the same draft in dockwater (1.012) = $V \times \delta_1$

$$= \frac{15317}{1.025} \times 1.012$$

= 15123.1 tonnes

46. *M. V. 'Hindship' is 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) Displacement at 3.9 m draft = 7389.5 tonnes

TPC " " = 21.56 tonnes

$$\text{FWA (in mm)} = \frac{W}{4\ \text{TPC}} = \frac{7389.5}{4 \times 21.56}$$

= 85.7 mm

$$\text{Dockwater allowance} = \frac{\text{FWA} \times \text{diff. in densities}}{25}$$

$$= \frac{85.7 \times 14}{25}$$

= 48 mm = 0.048 m

Original draft = 3.900 m

Dockwater allowance = 0.048 m

∴ **Hydrostatic draft in dock water = 3.948 m**

(ii) Displacement at 3.9 m draft = 7389.5 t

Underwater volume, for the above displacement,

$$\text{in water of RD 1.011} = \frac{W}{\delta} = \frac{7389.5}{1.011} = 7309.09\ m^3$$

If drafts could be read off from the hydrostatic tables, against underwater volumes, we could obtain the required mean draft, directly. Since however, the hydrostatic tables are tabulated for SW displacements against drafts, we have to convert the underwater volume to its corresponding displacement in SW.

Displ. in SW for vol. 7309.09 m^3 = $V \times \delta_1$ = 7309.09 × 1.025
= 7491.82 t

From hydrostatic tables, hydrostatic draft for the above displ.
= 3.948 m.

∴ **Hydrostatic draft in dock water = 3.948 m**

47. *M.V. 'Hindship' floating in water RD 1.025 at a draft of F 7.23 m, A 7.93. 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 RD 1.009.*

Original drafts	F 7.23 m A 7.93 m M 7.58 m		trim 0.7 m by stern.
LCF for mean draft 7.58 m		=	71.000 m
After draft		=	7.930 m
Corrn. to After draft from table 'A'		=	(–) 0.348 m
Original hydrostatic draft		=	7.582 m
Original displacement		=	15651 t
Cargo loaded		=	(+) 940 t
Fuel & FW consumed		=	(–) 130 t
Final displacement		=	16461 t

Underwater Volume for displacement of 16461 in density 1.009

$$= \frac{16461}{1.009} = 16314.1 \text{ m}^3$$

Displacement in salt water for the above underwater volume

$$= 16314.1 \times 1.025 = 16722 \text{ t}$$

Hydrostatic draft for SW displacement of 16722 t = 8.036 m

Final Hydrostatic draft = 8.036 m

48. *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.*

Since the draft of the vessel is now less than the winter draft, the SW draft will be still lesser. The FWA of the ship is therefore not applicable. The problem is therefore worked from first principles.

Displacement in SW at the draft of 8.9 m = 18808 t

$$\text{Underwater volume at that draft} = \frac{W}{\delta} = \frac{18808}{1.025} = 18349.2 \text{ m}^3$$

∴ Displacement for the above underwater volume in water of RD 1.010

$= V \times \delta = 18349.2 \times 1.010$	=	18532.7 t
Winter displacement	=	19151.0 t
Increase in displacement allowable	=	618.3 t
Net wt. to be received = 120 – 45	=	75.0 t

∴ Wt. of Cargo that can be loaded = 543.3 tonnes

49. *M.V. 'Hindship' loading in dockwater of density 1008 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 of cargo that can be loaded before she commences her voyage.*

Starboard Plimsol		2 cms above W.L.
Port Plimsol		6 cms below W.L.
		4 cms below W.L.
Mean level of Plimsol = $\frac{4}{2}$	=	2 cms below W.L.
	=	0.020 m
Dockwater allowance	=	$\frac{202\times17}{25}$ = 137.4 mm
	=	0.137 m
Summer draft	=	9.233 m
Immersion of Plimsol (+)	=	0.020 m
Present draft in dockwater	=	9.253 m
Dockwater allow. (–)	=	0.137 m
Present S.W. draft	=	9.116 m
Displacement for draft 9.116 m	=	19332.88 t
Summer displacement	=	19617.00 t
∴ **Cargo that can be loaded**	=	**284.12 tonnes**

50. *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.*

Starboard Plimsol		15 cms above W.L.
Port Plimsol		11.6 cms abve W.L.
		26.6 cms above W.L.
Mean Level of Plimsol	=	$\frac{26.6}{2}$ = 13.3 cms above W.L.
Summer draft	=	9.233 m
Mean Level of Plimsol (–)	=	0.133 m above W.L.
∴ Present hydrostatic draft	=	9.100 m

(i) Salt water displacement for 9.1 m draft = 19294 t

Dock water displacement for that draft = $\frac{19294\times1.017}{1.025}$ = 19143.4 t

Salt water displacement for maximum permissible draft (9.20 m) = 19537 t

Dockwater displacement for that draft = $\frac{19537\times1.017}{1.025}$ = 19384.5 t

Maximum amount of cargo that can be loaded = 19384.5 – 19143.4 = 241.1 t

Maximum amount of cargo that can be loaded = 241.1 t

(ii) Saltwater Draft for final displacement of 19384.5 t = 9.137 m.

SW draft in the final condition = 9.137 m

51. *M.V. 'Hindship' loading in dockwater of RD 1.008 has a freeboard of 2.43 metres on the port side and 2.28 metres on the starboard side. Calculate the amount of cargo she may load or must discharge prior to sailing at the tropical draft in SW.*

Starbd. freeboard	=	2.28 m
Port freeboard	=	2.43 m
		4.71 m
Mean freeboard $= \frac{4.71}{2}$	=	2.355 m

To find the dist. between keel & dk. line.

Add the draft and its corresponding freeboard.

Summer draft	=	9.233 m
Summer freeboard	=	2.626 m
Dist. between keel & dk. line	=	11.859 m
Present freeboard	=	2.355 m
Present draft in water RD 1.008	=	9.504 m
Dock water Allowance	=	$\frac{\text{F.W.A.} \times \text{diff. in densities}}{25}$
$= \frac{202 \times 17}{25}$	=	137.4 mm = 0.137 m
Present draft in S.W.	=	9.504 − 0.137
	=	9.367 m
Displacement for draft 9.367 m	=	19943.6 t
Tropical displacement	=	20085 t
∴ **Cargo that can be loaded**	=	**141.4 tonnes**

52. *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.*

Underwater volume at Summer draft	=	$\frac{\text{Displacement}}{\text{Density}}$
$= \frac{19617}{1.025}$	=	19138.5 m^3
Displacement at Summer draft in FW	=	Volume × δ
	=	19138.5 × 1.000
	=	19138.5 tonnes
Displacement at Summer draft in water of density 1.016	=	V × δ_1
	=	19138.5 × 1.016
	=	19444.7 tonnes
∴ Wt. added on ship	=	19444.7 − 19138.5
	=	306.2 t
Bunkers and water consumed	=	30.0 t
∴ **Cargo loaded at 2nd Port**	=	**336.2 tonnes**

53. *Calculate the block coefficient and water plane coefficient of M.V. 'Hindship' at her summer draft, assuming the maximum breadth of water plane at that draft to be the moulded breadth. Compare your answers with those obtained from the Hydrostatic Curves.*

Length of the water plane at Summer draft is the LBP

(a) Block Coeff. Cb $= \dfrac{\text{Volume of displacement}}{L \times B \times \text{draft}}$

Volume of disp. $= \dfrac{19617}{1.025} = 19138.5 \text{ m}^3$

$\therefore$ Cb $= \dfrac{19138.5}{143.16 \times 20 \times 9.233} = 0.72395$

Cb = **0.724**

From Hydrostatic Curves, Cb = **0.723**

(b) Water plane Coefft. Cw $= \dfrac{\text{Area of water plane}}{L \times B}$

Area of W.P. $= \dfrac{\text{TPC} \times 100}{1.025}$

$= \dfrac{24.28 \times 100}{1.025} = 2368.7 \text{ m}^2$

Cw $= \dfrac{2368.7}{143.16 \times 20} = 0.82731$

Cw = **0.827**

From Hydrostatic Curves, Cw = **0.830**

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

KM for displ. 13750 t = 8.285 m

KG = 6.200 m

GM (Solid) = 2.085 m

FSC = 0.120 m

GM (Fluid) = 1.965 m

GG_1 causing 1½° list = GM (Fluid) × tan θ = 1.965×tan 1½°

= 0.0515 m

Moment causing list to (S) = 0.0515 × 13750 = 707.5 mt

$\therefore$ Equating moments P & S to bring her upright

$x \times 6 = 707.5$

$x = \dfrac{707.5}{6} = 117.9$ t

Amount of cargo to be loaded = 117.9 tonnes

Note : A doubt may arise, as to why the final KG has not figured in the working. The student should understand that the final KG is immaterial in this type of problem, because when the moment to port equals the moment to starbd, the ship must be upright provide the GM is positive.

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

Discharges 150 tonnes from No. 1 TD cg 6 m, to stbd. of CL.

Discharges 50 tonnes from No. 3 TD Kg 11.15 m, cg 1.3 m to port of CL.

Fills up No. 8 DB tank (S) cg 2.4 m from CL with FW. A parcel of cargo weighing 40 tonnes is shifted 6.2 metres vertically downwards and 1.8 m transversely to starboard. Calculate the resultant list.

	Weights (t)	*KG* (m)	*V.Moments* (mt)	*Dist. from CL* (m)	*Transverse Moments* (mt)	
Condition No. 5 displ.	18529.3	7.539	13970	0	0	
Disch. from No. 1 TD	(–)150.0	11.17	(–) 1675.5	6	900	(P)
Disch. from No. 3 TD	(–) 50	11.15	(–) 557.5	1.3	65	(S)
Receives FW No. 8 (S)	(+) 63.4	2.77	(+) 175.6	2.4	152.2	(S)
Shifted 40 t	40	↓6.2	(–) 248.0	1.8	72.0	(S)
	Final Wt.= 18392.7		Final V.M. = 137394.6		Final T.M. = 610.8	(P)

$$\text{Final KG} = \frac{137394.6}{18392.7} = 7.470 \text{ m}$$

KM for displ. 18392.7 t = 8.340 m

Final GM (Solid) = 0.870 m

$$\text{FSC} = \frac{1552}{18392.7} = 0.084 \text{ m}$$

Final GM (Fluid) = 0.786 m

$$\text{Transverse } GG_1 = \frac{610.8}{18392.7} = 0.03321 \text{ m}$$

$$\tan\theta = \frac{GG_1}{\text{GM (Fluid)}} = \frac{0.03321}{0.786}$$

θ = Angle of List = 2°25'. to port.

56. *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 metre to starbd. 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.*

$$\text{FSC} = \frac{\text{FS Moment}}{\text{Displacement}} = \frac{1146}{13750} = 0.083 \text{ m}$$

KM for displacement of 13750 t = 8.285 m

KG = 7.320 m

GM (Solid) = 0.965 m

FSC = 0.083 m

GM (Fluid) = 0.882 m

GG_1 causing list of 2½° to starboard = GM (Fluid) × tan θ

= 0.882 × tan 2½°

= 0.03851 mt

Moment causing list to starboard = $GG_1 \times W$

= 0.03851 × 13750

= 529.51 mt.

Let 'x' tonnes be loaded on the port side and

(380–x) " " " starboard side

Equating moment to port & starboard to bring the V/L upright.

$$x \times 6.2 = (380-x) \times 1.5 + 529.51$$

$$6.2\,x + 1.5\,x = 570 + 529.51$$

$$7.7\,x = 1099.51$$

$$x = \frac{1099.51}{7.7} = 142.79 \text{ tonnes}$$

Cargo to be loaded on port side = 142.79 t.

Cargo to be loaded on starbd side = 380 – 142.79 = 237.21 t.

57. *M.V. 'Hindship' in Condition No. 7 is listed 3° to port No. 7 DB tank starboard is then filled with DO, cg. 3.8 m from CL. Calculate the final list.*

GG_1 causing list of 3° to port = GM (Fluid) × tan θ = 0.458 × tan 3°
= 0.024 m.

Moment causing list = GG_1 × W = 0.024 × 18529.3 = 447.7 mt.

Wt. of DO added in No. 7 (S)
(101.9 × 0.88) = 89.672 t.

Moment to starboard caused by DO added (w × d) = 89.672 × 3.8
= 340.75 mt.

Resultant Moment to port = 444.7 − 340.75 = 103.95 mt.

	Weights (t)	KG (m)	V.Moments (mt)
Condition No. 7 displacement	18529.3	7.807	144653
D.O. added	89.67	2.59	232.25
Final Wt.	18618.97	Final Moment	144885.25

$$\text{Final KG} \quad \frac{144885.25}{18618.97} = 7.782 \text{ m.}$$

$$\text{Final FSC} \quad \frac{\text{FS Moment}}{\text{Final displ.}} = \frac{1552}{18618.97} = 0.083 \text{ m}$$

KM for displacement 18618.97 t. = 8.356 m
KG = 7.782 m
GM (Solid) = 0.574 m
FSC = 0.083 m
GM (Fluid) = 0.491 m

Transverse GG_1 in final condition

$$= \frac{\text{Resultant Moment}}{\text{Displacement}} = \frac{103.95}{18618.97} = 0.0056 \text{ m}$$

$$\tan\theta = \frac{GG_1}{\text{GM (Fluid)}} = \frac{0.0056}{0.491}$$

θ = Angle of List = 0°39.3' to Port.

58. *M.V. 'Hindship' at a hydrostatic draft of 5.76 m in FW is listed 0°50' to port. KG 7.68 m, FSC 0.09 m. A parcel of cargo weighing 80 t. is shifted from 1 m to port of CL to 4.5 m off the CL to port. Calculate the final list.*

Disp. in SW for hydro. draft. 5.76 m = 11479.2 t

$$\text{Displ. at that draft in FW} = 11479.2 \times \frac{1.000}{1.025} = 11199.2 \text{ t}$$

KM for draft 5.76 m = 8.517 m
KG = 7.680 m
GM (Solid) = 0.837 m
FSC = 0.090 m
GM (Fluid) = 0.747 m

Initial transverse GG_1 = GM (F_L) × tan θ = 0.747 × tan 0°50'

Initial listing moment = GG_1 × W = 0.747 × 0.0146 × 11199.2
= 122 mt (P)

Listing moment due to shift of cargo = 80 × 3.5 = 280 mt (P)

Final listing moment = 402 mt (P)

$$\text{Transverse } GG_1 = \frac{402}{11199.2} = 0.0359 \text{ m}$$

$$\tan\theta = \frac{GG_1}{\text{GM (Fluid)}} = \frac{0.0359}{0.747}$$

θ = Angle of List = 2°45' to Port.

59. *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 metres 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 the operation.*

The maximum list will occur when one locomotive has been loaded on deck on the quay side and the second locomotive has been lifted by the derrick swung over the quay.

To find KG and transverse GG_1 in the above condition

	Weights	*KG*	*V. Moments*	*Dist. from CL*	*Trans. Moments*
	(t)	(m)	(mt)	(m)	(mt)
Ship	19150	6.65	127347.5	0	—
1st Loco.	76	13.83	1051.1	6.0	456.0
2nd Loco.	76	21.50	1634.0	13.0	988.8
Final Wt.	19302	Final V. Moments	130032.6	F. T. Moments	1444.8

Final KG $= \dfrac{1300326}{19302} = 6.737$ m

Final Trans. $GG_1 = \dfrac{1444}{19302} = 0.0748$ m

Original FSM = FSC × Original Displacement = 0.042 × 19150 = 804.3 mt.

FSC in Final Condition $= \dfrac{\text{FSM}}{\text{Final Displ.}} = \dfrac{804.3}{19302} = 0.042$ m

KM for displ. 19302 t. = 8.409 m

KG = 6.737 m

GM (Solid) = 1.672 m

FSC = 0.042 m

GM (Fluid) = 1.630 m

$\tan\theta = \dfrac{GG_1}{\text{GM (Fluid)}} = \dfrac{0.0748}{1.630}$

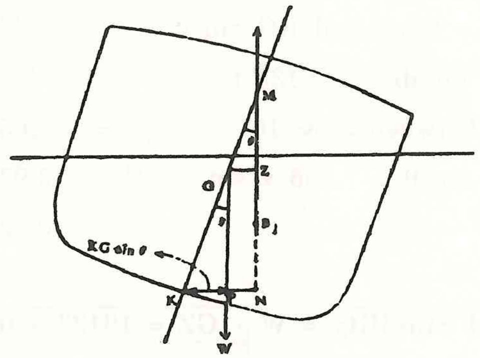
θ = Angle of list = 2°38'

Maximum List during the operation = 2°38'

The student should recall that at very small angles of heel, GZ may be obtained as GM × sin θ

At larger angles of heel, GZ must be obtained as

KN − Corrected KG × sin θ



As can be seen from the figure, GZ = PN = KN − KP

= KN − KG sin θ

From the figure, it appears that GZ could be obtained as GM sin θ for any angle of heel. It cannot be done in practice, as the GM changes with angle of heel. The change in GM is caused, due to change in the position of M with heel. Since this change is negligible for small angles of heel, GM may be considered constant at such angles of heel.

The hydrostatic table provides the KM for the upright condition only and not for different angles of heel, but the KN is available for various a ngles of heel. Therefore GZ can be obtained very correctly fom expression KN − KG sin θ, for any angle of heel.

The stability particulars provided on ships give KN values at different displacements at convenient intervals of heel. For intermediate values of displacement and heel, KN values may be interpolated linearly without appreciable loss of accuracy.

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

KG	=	7.570 m
FSC	=	0.085 m
Corrected KG	=	7.655 m

GZ = KN − Corrected KG sin θ

KN at 7° heel for displ. 16133 t (interpolating between 5° & 10°)	=	1.055 m
Corrected KG sin θ = 7.655 × sin 7°	=	0.933 m
∴ GZ	=	0.122 m

Moment of Statical Stability = W × GZ = 16133 × 0.122 = 1968.23 mt.

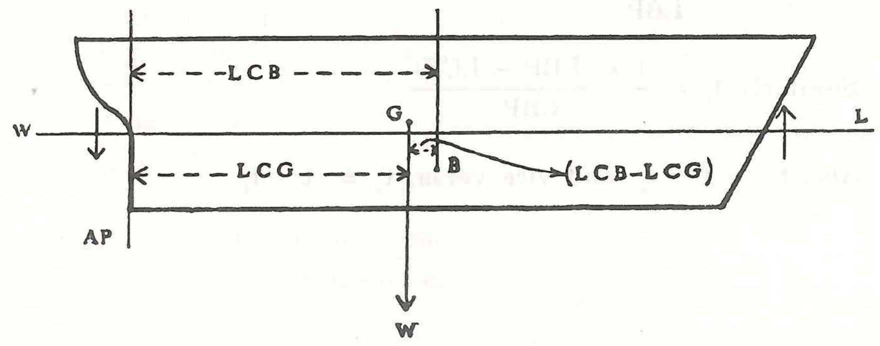
TRIM

TRIM is the difference between the ford draft and the after draft.

CENTRE OF FLOATATION : (CF) is the centroid of the ship's water plane area. The ship trims about this point.

CALCULATION OF TRIM : Since the hydrostatic particulars of the vessel are available, the trim of the vessel can be calculated more accurately by the method explained below.

When a ship is in equilibrium, the buoyancy provided by the displaced water is exactly equal to the ship's weight. When the Centre of Buoyancy and the Centre of Gravity are in the same vertical line, these forces produce no couple and therefore no trim is caused.

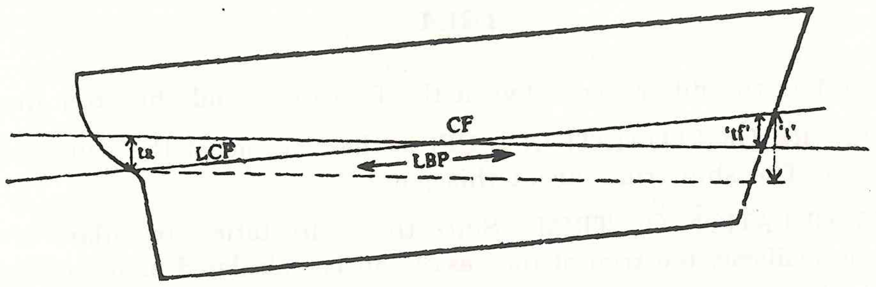


When the centre of buoyancy and the centre of gravity are not in the same vertical line, as shown in the figure, these two equal and opposite forces set up a couple tending to trim the vessel. The moment of this couple i.e. Trimming Moment, is obtained by the product of one of the forces and the lever between the forces i.e. (LCB − LCG) × displacement. The Trimming Moment divided by the MCTC gives the trim in centimetres which is then divided by 100 to give the trim in metres.

Thus, Total trim 't' metres = $\dfrac{(LCB - LCG)}{MCTC \times 100} \times$ displacement.

As can be seen from the figure the trim obtained would be **by the stern.**

If the LCB was less than LCG the above formula would result in a negative trim indicating **trim by the head.**



As shown in the above figure, the after trim would bear a ratio to the LCF as the total trim bears to the length of the ship, i.e.

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

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

Similarly $t_f = \dfrac{t \times (LBP - LCF)}{LBP}$

Also $t_f = t - t_a$ and vice versa, $t_a = t - t_f$.

NOTES TO CALCULATE TRIM OF VESSEL AFTER LOADING/DISCHARGING/SHIFTING

1. For a vessel with no trim, the arithmetical mean draft is the same as the hydrostatic draft.

   For a vessel which is trimmed, obtain the arithmetical mean draft. Determine the position of LCF from AP, for this mean draft.

2. Calculate the hydrostatic draft as below :-

   Hydrostatic draft = draft Aft ± correction from table 'A'

   Note :- Correction is –ve when trimmed by stern

   +ve when trimmed by head

3. From the hydrostatic tables, determine against the hydrostatic draft; the corresponding displacement (if not given).

4. List the various weights involved in arriving at the final displacement, viz, original displacement, weights loaded, discharged or shifted, together with their LCG. Calculate the final longitudinal moment and final displacement.

5. Find the LCG from AP as follows :-

   $$\text{LCG from AP} = \frac{\text{Final Long. moments}}{\text{Final displacement}}$$

6. Determine against final displacement, the values of Hydrostatic draft, MCTC, LCB and LCF.

7. Total trim 't' (metre) $= \dfrac{LCB - LCG}{MCTC \times 100} \times \text{Displacement}$

8. Trim aft 't_a' (metre) $= \dfrac{\text{'t'} \times LCF}{LBP}$

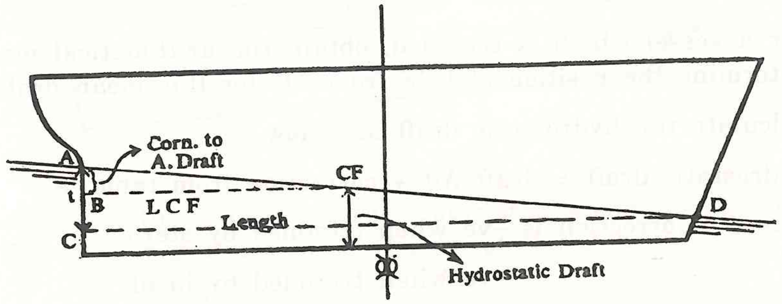
9. Trim forward 't_f' (metre) = 't' – 't_a'

   Draft aft = Hydrostatic draft + 't_a'

   Draft fwd = Hydrostatic draft – 't_f'

TABLE 'A'

The hydrostatic draft of a ship is her true mean draft, that is, the draft at the Centre Floatation.



In the case illustrated above, the vessel is trimmed by the stern. Her hydrostatic draft is after draft – the correction AB. It can also be seen from the similar triangles ACD and ABF, that

$$\frac{\text{AB (corrn.)}}{\text{BCF (LCF)}} = \frac{\text{AC (trim)}}{\text{CD (Length)}}$$

$$\Rightarrow \text{corrn.} \times \text{length} = \text{trim} \times \text{LCF}$$

Since Length of the ship is constant, the corrn. will very directly as LCF and also directly as the trim.

The values of the correction for M.V. 'Hinship' have been worked out using the above deduction for various values of trim and possible values of LCF. These corrections have been provided as table 'A', to facilitate obtaining the correction to the after draft.

The student should be able to visualise that when the vessel is trimmed by the head, the hydrostatic draft will be After Draft + the correction.

As can be seen from the above expression, the correction to the after draft is independent of the density of water in which the vessel may be floating.

Such a table does not normally form part of the stability information supplied to ships. It should however be quite easy for the ship's officer to make such a table for his own ship. The possible values of LCF are available from the hydrostatic tables. For example, in the case of M.V. 'Hindship' it is 73.145 m to 69.127 m.

For values of LCF at convenient intervals extending over the entire range of it's possible values, the correction to the After draft may be worked out for trims ranging between zero trim and the maximum probable trim; at say 20 cms intervals, using the expression :-

$$\text{Corrn.} = \frac{\text{Trim} \times \text{LCF}}{\text{Length}}$$

TABLE 'A'

CORRECTION TO AFTER DRAFT TO OBTAIN HYDROSTATIC DRAFT

Posn. of LCF From AP Trim (m)	69	70	71	72	73	74
0.20	.096	.098	.099	.100	.102	.103
40	.193	.195	.198	.201	.204	.207
60	.289	.293	.298	.302	.306	.310
80	.386	.391	.397	.402	.408	.414
1.00	.482	.489	.496	.503	.510	.517
20	.578	.587	.595	.604	.612	.620
40	.675	.685	.694	.704	.714	.724
60	.771	.782	.794	.805	.816	.827
80	.868	.880	.893	.905	.918	.930
2.00	.964	.978	.992	1.006	1.020	1.034
20	1.060	1.076	1.091	1.106	1.122	1.137
40	1.157	1.174	1.190	1.207	1.224	1.241
60	1.253	1.271	1.289	1.308	1.326	1.344
80	1.350	1.369	1.389	1.408	1.428	1.447
3.00	1.446	1.467	1.488	1.509	1.530	1.551
20	1.542	1.565	1.587	1.609	1.632	1.654
40	1.639	1.662	1.686	1.710	1.734	1.757
60	1.735	1.760	1.785	1.811	1.836	1.860
80	1.832	1.858	1.885	1.911	1.938	1.964
4.00	1.928	1.956	1.984	2.012	2.040	2.068
20	2.024	2.054	2.083	2.112	2.142	2.171
40	2.121	2.151	2.182	2.213	2.244	2.274
60	2.217	2.249	2.281	2.313	2.346	2.378

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

61. *M.V. 'Hindship' floating at a draft of F 5.65 m, and A 7.45 m, LCG 70.47 m, ford of AP, loads 500 tonnes of cargo, 100.5 m ford of AP. Calculate (i) her final displacement, (ii) final hydrostatic draft and (iii) final drafts F & A.*

Initial drafts F 5.65 m, A 7.45 m } trim = 1.80 m by stern.

M 6.55 m LCF = 72.048 m ford of AP

Corrn. to After draft (From table 'A') = 0.906 m

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

= 7.45 − 0.906 = 6.544 m (−ve since V/L is trimmed by stern)

Displacement for Hydrostatic draft : 6.544 m = 13255.3 tonnes

Cargo loaded = 500.0 tonnes

Final displacement = **13755.3 tonnes**

Final Hydrostatic draft = **6.763 m**

For displacement 13755.3 t:

MCTC = 181.0 m

LCB = 72.864 m ford of AP.

LCF = 71.843 m " "

	Weights (t)	LCG (m)	L. Moments (mt)
Original displacement	13255.3	70.47	934100
Cargo loaded	500	100.50	50250
Final Wt	13755.3	Final L. Moments	984350

$$\text{Final LCG} = \frac{\text{Final L. Moments}}{\text{Final Wt.}} = \frac{984350}{13755.3} = 71.562 \text{ m ford of AP.}$$

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

$$= \frac{72.864 - 71.562}{181 \times 100} \times 13755.3 = 0.989 \text{ m by stern}$$

Note :- The Couple produced by the weight acting downwards through G, and the buoyancy acting upwards through B will trim the vessel by the stern, in this case as her LCG is abaft her LCB.

$$\text{trim aft 't}_a\text{'} = \frac{\text{total trim} \times \text{LCF}}{\text{LBP}} = \frac{0.989 \times 71.843}{143.16}$$

$$t_a = 0.496 \text{ m}$$

$$\text{trim ford 't}_f\text{'} = \text{total trim} - \text{trim aft} = 0.989 - 0.496$$

$$t_f = 0.493 \text{ m}$$

	F	A
Hydrostatic draft	6.763 m	6.763 m
Trim	(−) 0.493 m	(+) 0.496 m
Final drafts	**F 6.270 m**	**A 7.259 m**

Note :-
1) The total trim calculated is the entire trim and **not** the change of trim, caused by loading 500 tonnes.
2) Since the Hydrostatic particulars of M.V. 'Hindship' are given for the even keel condition, the Hydrostatic draft obtained from the tables for the final displacement is that for the even keel condition. Therefore t_a and t_f are applied to the Hydrostatic draft to obtain the drafts F & A.

62. *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 LTD. Calculate the drafts F and A.*

Initial drafts F 8.778 m, A 8.792 m } trim 0.014 m by stern.
M 8.785 m LCF : 69.923 m ford of AP

Corrn. to After draft (From table 'A') = 0.007 m

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

= 8.792 − 0.007 = 8.785 m

Displacement for hydrostatic draft 8.785	=	18529 tonnes
Cargo discharged	=	206 tonnes
Final displacement	=	18323 tonnes
For displacement 18323 t, Hydrostatic draft	=	8.70 m
MCTC	=	207.50 mt
LCB	=	72.382 m
LCF	=	69.989 m

	Weights (t)	*LCG* (m)	*L. Moments* (mt)
Original displacement	18529	72.34	1340388
Cargo discharged	(–) 206	17.24	(–) 3551
Final Wt.	18323	Final Moment	1336837

$$\text{Final LCG} = \frac{\text{Final Moment}}{\text{Final Wt.}} = \frac{1336837}{18323}$$

$$= 72.96 \text{ m.}$$

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

$$= \frac{(72.382 - 72.960)}{207.5 \times 100} \times 18323$$

$$t = -0.510 \text{ m}$$

The negative trim indicates that the vessel is trimmed by the head, which is also substantiated by the fact that LCG is ford of LCB.

$$t_a = \frac{t \times \text{LCF}}{\text{LBP}} = \frac{0.510 \times 69.989}{143.16}$$

$$t_a = 0.249 \text{ m}$$

$$t_f = t - t_a = 0.510 - 0.249 = 0.261 \text{ m}$$

	F	A
Hydrostatic draft	8.700 m	8.700 m
trim	(+) 0.261 m	(–) 0.249 m
Final drafts	**F 8.961 m**	**A 8.451 m**

63. *M. V. 'Hindshp' arrives port in Condition No. 5, and discharges the entire cargo from No. 1 TD, No. 5 Poop Deck and Refrigerated Cargo Spaces. No. 4 DB tank (centre) is filled with water ballast. Calculate her GM (Fluid) and drafts F & A.*

	Weights (t)	*KG* (m)	*V. Moments* (mt)	*LCG* (m)	*L. Moments* (mt)
Displ. in Condition No. 5	18529.3	7.539	139700	72.129	1336498
No. 1 TD	(–) 681.7	11.17	(–) 7615	124.67	(–) 84988
No. 5 Poop Dk.	(–) 542.6	13.76	(–) 7466	14.78	(–) 8020
Ref. Cargo	(–) 235.0	10.36	(–) 2435	60.17	(–) 14140
No. 4 (C) (257.4 × 1.025)	(+) 263.8	0.63	(+) 166	57.58	(+) 15189
	Final Wt = 17333.8		Final V Mmts. 122350		Final L. Mmts. 1244539

Final KG $= \frac{122350}{17333.8}$ = 7.0585 m

Final FSC $= \frac{1552}{17333.8}$ = 0.0895 m

KM for displ. 17333.8 t	= 8.280 m
KG	= 7.0585 m
GM (Solid)	= 1.2215 m
FSC	= 0.0895 m
GM (Fluid)	**= 1.132 m**

Fina LCG $= \frac{1244539}{17333.8}$ = 71.798 m

For displ. 17333.8 t. Hydrostatic draft	= 8.290 m
MCTC	= 201.5 mt
LCB	= 72.505 m
LCF	= 70.332 m

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

$= \frac{72.505 - 71.798}{201.5 \times 100} \times 17333.8$

Total trim 't' = 0.608 m by stern

$t_a = \frac{t \times \text{LCF}}{\text{LBP}} = \frac{0.608 \times 70.332}{143.16} = 0.299$ m

$t_f = t - t_a = 0.608 - 0.299 = 0.309$ m

	F	A
Final Hydrostatic draft	8.290	8.290
Trim	(–) .309	(+) .299
Final drafts	**F 7.981 m**	**A 8.589 m**

64. *M.V. 'Hindhsip' 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 locomotives 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.*

	Weights (t)	*KG* (m)	*V. Moments* (mt)	*LCG* (m)	*L. Moments* (mt)
Displ. in Condition No. 7	18529.3	7.807	144653	72.340	1340415
No. 2 TD	(–) 1058.4	10.72	(–) 11346	103.91	(–) 109978
Bulbous Bow	(+) 186.6	3.52	(+) 657	139.60	(+) 26049
Shift of Locos	760.0	3.11	(–) 2364	19.87	(+) 15101

(13.83 – 10.72 = 3.11) (103.91 – 84.04 = 19.87 F)

Final Wt. 17657.5 Final L. Moments : 1271587

Final V. Moments : 131600

Final KG $= \dfrac{131600}{17657.5} = 7.453$ m

Final LCG $= \dfrac{1271587}{17657.5} = 72.014$ m

To find final FSC

Original FS Moment = 1552 mt

FSM of No. 4 (P & S)

(542 × 1.025) = 556 mt

Final FS Moments = 2108 mt

Final FSC $= \dfrac{\text{FS Moment}}{\text{Displacement}} = \dfrac{2108}{17657.5} = 0.119$ m

KM for displacement 17657.5 t = 8.295 m

KG = 7.453 m

GM (Solid) = 0.842 m

FSC = 0.119 m

GM (Fluid) = 0.723 m

For displ. 17657.5 t

Hydrostatic draft	= 8.425 m
MCTC	= 203.5 mt
LCB	= 72.466 m
LCF	= 70.217 m
Final LCG	= 72.014 m

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

$= \dfrac{72.466 - 72.014}{203.5 \times 100} \times 17657.5 = 0.392$ m

$t_a = \dfrac{t \times \text{LCF}}{\text{LBP}} = \dfrac{0.392 \times 70.217}{143.16} = 0.192$ m

$t_f = t - t_a = 0.392 - 0.192 = 0.200$ m

	F	A
Hydrostatic draft	8.425	8.425
trim	(–) 0.200	(+) 0.192
Final drafts	**F 8.225 m**	**A 8.617 m**