SELECTION OF EXAMINATION QUESTIONS

FIRST CLASS

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1. A ship 120 m long has draughts of 6.6 m forward and 6.9 m aft. The TPC is 20, MCTI cm 101 tonne m and the centre of flotation 3.5 m aft of midships. Calculate the maximum position aft at which 240 tonne may be added so that the after draught does not exceed 7.2 m.

2. A vessel, when floating at a draught of 3.6 m has a displacement of 8172 tonne, KB 1.91 m and LCB 0.15 m aft of midships. From the following information, calculate the displacement, KB and position of the LCB for the vessel when floating at a draught of 1.2 m.

Draught (m)	TPC	LCF from midships
1.2	23.0	1.37 F
2.4	24.2	0.76 A
3.6	25.0	0.92 A

3. An oil tanker has LBP 142 m, beam 18.8 m and draught 8 m. It displaces 17 000 tonne in sea water of 1.025 t/m³. The face pitch ratio of the propeller is 0.673 and the diameter 4.8 m. The results of the speed trial show that the true slip may be regarded as constant over a range of speeds of 9 to 12 knots and is 35%. The wake fraction may be calculated from the equation:

$$w = 0.5C_b - 0.05$$

If the vessel uses 20 tonne of fuel per day at 12 knots, and the consumption varies as (speed)³, find the consumption per day at 100 rev/min.

4. A ship of 5000 tonne displacement has a KM of 6.4 m. When 5 tonne are moved 15 m across the ship a pendulum 6 m long has a deflection of 12 cm. A double bottom tank 7.5 m long, 9 m wide and 1.2 m deep is half-full of sea water.
Calculate the KG of the light ship.

5. A propeller has a pitch ratio of 0.95. When turning at 120 rev/min the real slip is 30%, the wake fraction 0.28 and the ship speed 16 knots. The thrust is found to be 400 kN, the torque 270 kN m and the QPC 0.67. Calculate:

(a) the propeller diameter
(b) the shaft power
(c) the propeller efficiency
(d) the thrust deduction factor.

6. A pontoon has a constant cross-section as shown in Fig. 120. The metacentric height is 2.5 m. Find the height of the centre of gravity above the keel.

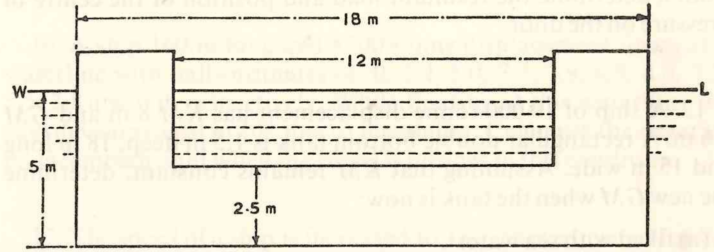


Fig. 120

7. (a) Derive the Admiralty Coefficient formula and show how this may be modified to suit a fast ship.
(b) A ship of 14 000 tonne displacement requires 23 000 kW shaft power to drive it at 24 knots. Using the modified Admiralty Coefficient formula, calculate the shaft power required for a similar ship of 12 000 tonne displacement at 21 knots.

8. A ship 80 m long has equally-spaced immersed cross-sectional areas of 0, 11.5, 27, 38.5, 44, 45, 44.5, 39, 26.5, 14.5 and 0 m² respectively. Calculate:

(a) displacement
(b) distance of centre of buoyancy from midships
(c) prismatic coefficient.

9. The following data refer to two similar ships

	L	S	V	ep_n	f_{SW}
Ship A	160	4000	18	6400	0.420
Ship B	140				0.425

Calculate ep_n for ship B at the corresponding speed.

10. A ship of 11 200 tonne displacement has a double bottom tank containing oil, whose centre of gravity is 16.5 m forward and 6.6 m below the centre of gravity of the ship. When the oil is used the ship's centre of gravity moves 380 mm. Calculate:

(a) the mass of oil used
(b) the angle which the centre of gravity moves relative to the horizontal.

11. A watertight door is 1.2 m high and 0.75 m wide, with a 0.6 m sill. The bulkhead is flooded with sea water to a depth of 3 m on one side and 1.5 m on the other side. Draw the load diagram and from it determine the resultant load and position of the centre of pressure on the door.

12. A ship of 10 000 tonne displacement has *KM* 8 m and *GM* 0.6 m. A rectangular double bottom tank is 1.5 m deep, 18 m long and 15 m wide. Assuming that *KM* remains constant, determine the new *GM* when the tank is now:

(a) filled with sea water
(b) half-filled with sea water.

13. A propeller 6 m diameter has a pitch ratio of 0.9, BAR 0.48 and, when turning at 110 rev/min, has a real slip of 25% and wake fraction 0.30. If the propeller delivers a thrust of 300 kN and the propeller efficiency is 0.65, calculate:

(a) blade area
(b) ship speed
(c) thrust power
(d) shaft power
(e) torque.

14. When a ship is 800 nautical miles from port its speed is reduced by 20%, thereby reducing the daily fuel consumption by 42 tonne and arriving in port with 50 tonne on board. If the fuel consumption in t/h is given by the expression $(0.136 + 0.001\ V^3)$ where V is the speed in knots, estimate:

(a) the reduced consumption per day
(b) the amount of fuel on board when the speed was reduced

(c) the percentage decrease in consumption for the latter part of the voyage
(d) the percentage increase in time for this latter period.

15. An oil tanker 160 m long and 22 m beam floats at a draught of 9 m in sea water. C_w is 0.865.

The midship section is in the form of a rectangle with 1.2 m radius at the bilges. A midship tank 10.5 m long has twin longitudinal bulkheads and contains oil of 1.4 m^3/t to a depth of 11.5 m. The tank is holed to the sea for the whole of its transverse section. Find the new draught.

16. A ship 160 m long and 8700 tonne displacement floats at a waterline with half-ordinates of: 0, 2.4, 5.0, 7.3, 7.9, 8.0, 8.0, 7.7, 5.5, 2.8 and 0 m respectively. While floating at this waterline, the ship develops a list of 10° due to instability. Calculate the negative metacentric height when the vessel is upright in this condition.

17. The speed of a ship is increased to 18% above normal for 7.5 hours, then reduced to 9% below normal for 10 hours. The speed is then reduced for the remainder of the day so that the consumption for the day is the normal amount. Find the percentage difference between the distance travelled in that day and the normal distance travelled per day.

18. A double bottom tank containing sea water is 6 m long, 12 m wide and 1 m deep. The inlet pipe from the pump has its centre 75 mm above the outer bottom. The pump has a pressure of 70 kN/m^2 and is left running indefinitely. Calculate the load on the tank top:

(a) if there is no outlet
(b) if the overflow pipe extends 5 m above the tank top.

19. A ship 120 m long displaces 12 000 tonne. The following data are available from trial results:

V (knots	10	11	12	13	14	15
sp (kW)	880	1155	1520	2010	2670	3600

(a) Draw the curve of Admiralty Coefficients on a base of speed
(b) Estimate the shaft power required for a similar ship 140 m long at 14 knots.

20. A box barge 60 m long and 10 m wide floats at a level keel draught of 3 m. Its centre of gravity is 2.5 m above the keel. Determine the end draughts if an empty, fore end compartment 9 m long is laid open to the sea.

21. A vessel of constant triangular cross-section floats apex down at a draught of 4 m, the width of the waterplane being 8 m, when its keel just touches a layer of mud having relative density twice that of the water. The tide now falls 2 m. Calculate the depth to which the vessel sinks in the mud.

22. The following information relates to a model propeller of 400 mm pitch:

Rev/min		400	450	500	550	600
Thrust	N	175	260	365	480	610
Torque	Nm	16.8	22.4	28.2	34.3	40.5

(a) Plot curves of thrust and torque against rev/min
(b) When the speed of advance of the model is 150 m/min and slip 0.20, calculate the efficiency.

23. A ship of 8100 tonne displacement floats upright in sea water. KG = 7.5 m and GM = 0.45 m. A tank, whose centre of gravity is 0.5 m above the keel and 4 m from the centreline, contains 100 tonne of water ballast. Neglecting free surface effect, calculate the angle of heel when the ballast is pumped out.

24. The ½ ordinates of a waterplane 120 m long are 0.7, 3.3, 5.5, 7.2, 7.5, 7.5, 7.5, 6.8, 4.6, 2.2 and 0 m respectively. The ship displaces 11 000 tonne. Calculate the transverse BM.

25. A box barge 85 m long, 18 m beam and 6 m draught floats in sea water of 1.025 t/m³. A midship compartment 18 m long contains cargo stowing at 1.8 m³/t and having a density of 1.600 t/m³. There is a watertight flat 6 m above the keel. Calculate the new draught if this compartment is bilged below the flat.

26. The ½ ordinates of a waterplane 90 m long are as follows:

Station	AP	½	1	2	3	4	5	6	7	7½	FP
½ ordinate	0.6	2.7	4.6	6.0	6.3	6.3	6.3	5.7	4.8	2.0	0 m

Calculate the area of the waterplane and the distance of the centre of flotation from midships.

27. A ship of 6600 tonne displacement has KG 3.6 m and KM 4.3 m. A mass of 50 tonne is now lifted from the quay by one of the ship's derricks whose head is 18 m above the keel. The ship heels to a maximum of 9.5° while the mass is being transferred. Calculate the outreach of the derrick from the ship's centreline.

28. A ship 120 m long displaces 10 500 tonne and has a wetted surface area of 3000 m². At 15 knots the shaft power is 4100 kW, propulsive coefficient 0.6 and 55% of the thrust is available to overcome frictional resistance.

Calculate the shaft power required for a similar ship 140 m long at the corresponding speed. f = 0.42 and n = 1.825.

29. A box-shaped vessel 30 m long and 9 m wide floats in water of 1.025 t/m³ at a draught of 0.75 m when empty. The vessel moves from water of 1.000 t/m³ to water of 1.025 t/m³ in a partially laden state and, on reaching the sea water, it is found that the mean draught is reduced by 3.2 cm. Calculate the mass of cargo on board.

30. A ship of 5000 tonne displacement has a double bottom tank 12 m long. The ½ breadths of the top of the tank are 5, 4 and 2 m respectively. The tank has a watertight centreline division. Calculate the free surface effect if the tank is partially full of fresh water *on one side only*.

* 31. The following data apply to a ship operating at a speed of 15 knots:

Shaft power = 3050 kW
Propeller speed = 1.58 rev/s
Propeller thrust = 360 kN
Apparent slip = 0

Calculate the propeller pitch, real slip and the propulsive coefficient if the Taylor wake fraction and thrust deduction factor are 0.31 and 0.20 respectively.

32. The force acting normal to the plane of a rudder at angle α is given by:

$$F_n = 577\,A\,v^2 \sin\alpha \quad \text{N}$$

where A = area of rudder = 22 m^2

and v = water speed in m/s.

When the rudder is turned to 35°, the centre of effort is 1.1 m from the centreline of stock. Allowing 20% for race effect, calculate the diameter of the stock if the maximum ship speed is 15 knots and the maximum allowable stress is 70 MN/m^2.

If the effective diameter is reduced by corrosion and wear to 330 mm, calculate the speed at which the vessel must travel so that the above stress is not exceeded.

33. A ship 100 m long and 15 m beam floats at a mean draught of 3.5 m. The semi-ordinates of the waterplane at equal intervals are: 0, 3.0, 5.5, 7.3, 7.5, 7.5, 7.5, 7.05, 6.10, 3.25 and 0 m respectively. The section amidships is constant and parallel for 20 m and the submerged cross-sectional area is 50 m^2 at this section.

Calculate the new mean draught when a midship compartment 15 m long is opened to the sea. Assume the vessel to be wall-sided in the region of the waterplane.

34. A ship 85 m long displaces 8100 tonne when floating in sea water at draughts of 5.25 m forward and 5.55 m aft. TPC 9.0, GM_L 96 m, LCF 2 m aft of midships. It is decided to introduce water ballast to completely submerge the propeller and a draught aft of 5.85 m is required. A ballast tank 33 m aft of midships is available. Find the least amount of water required and the final draught forward.

35. A solid block of wood has a square cross-section of side S and length L greater than S. Calculate the relative density of the wood if it floats with its sides vertical in fresh water.

36. A ship travelling at 15.5 knots has a propeller of 5.5 m pitch turning at 95 rev/min. The thrust of the propeller is 380 kN and the delivered power 3540 kW. If the real slip is 20% and the thrust deduction factor 0.198, calculate the QPC and the wake fraction.

37. (a) Describe briefly the inclining experiment and explain how the results are used.

(b) A ship of 8500 tonne displacement has a double bottom tank 11 m wide extending for the full breadth of the ship, having a free surface of sea water. If the apparent loss in metacentric height due to slack water is 14 cm, find the length of the tank.

38. (a) Derive an expression for the change in draught of a vessel moving from sea water into river water.

(b) A ship of 8000 tonne displacement has TPC 17 when at a level keel draught of 7 m in sea water of 1.024 t/m^3. The vessel then moves into water of 1.008 t/m^3. The maximum draught at which the vessel may enter dock is 6.85 m. Calculate how much ballast must be discharged.

39 (a). What is meant by the Admiralty Coefficient and the Fuel Coefficient?

(b) A ship of 14 900 tonne displacement has a shaft power of 4460 kW at 14.55 knots. The shaft power is reduced to 4120 kW and the fuel consumption at the same displacement is 541 kg/h. Calculate the fuel coefficient for the ship.

40. A ship of 12 000 tonne displacement has a rudder 15 m^2 in area, whose centre is 5 m below the waterline. The metacentric height of the ship is 0.3 m and the centre of buoyancy is 3.3 m below the waterline. When travelling at 20 knots the rudder is turned through 30°. Find the initial angle of heel if the force F_n perpendicular to the plane of the rudder is given by:

$$F_n = 577\,A\,v^2 \sin\alpha \quad \text{N}$$

Allow 20% for the race effect.

41. A ship 120 m long has a light displacement of 4000 tonne and LCG in this condition 2.5 m aft of midships.

The following items are then added:

Cargo	10 000 tonne Lcg	3.0 m forward of midships
Fuel	1500 tonne Lcg	2.0 m aft of midships
Water	400 tonne Lcg	8.0 m aft of midships
Stores	100 tonne Lcg	10.0 m forward of midships

Using the following hydrostatic data, calculate the final draughts:

Draught (m)	Displacement (t)	MCT1 cm (t m)	LCB from midships (m)	LCF from midships (m)
8.50	16 650	183	1.94F	1.20A
8.00	15 350	175	2.10F	0.06F

42. A box barge 30 m long and 9 m beam floats at a draught of 3 m. The centre of gravity lies on the centreline and KG is 3.50 m. A mass of 10 tonne, which is already on board, is now moved 6 m across the ship.

(a) Estimate the angle to which the vessel will heel, using the formula:

$$GZ = \sin\theta\,(GM + \tfrac{1}{2}BM\tan^2\theta)$$

(b) Compare the above result with the angle of heel obtained by the metacentric formula.

43. The fuel consumption of a ship at 17 knots is 47 tonne/day. The speed is reduced and the consumption is reduced to 22 tonne/day. At the lower speed, however, the consumption per unit power is 13.2% greater than at 17 knots. Find the reduced speed and the percentage saving on a voyage of 3000 nautical miles.

44. A ship of 14 000 tonne displacement is 135 m long and floats at draughts of 7.30 m forward and 8.05 m aft. GM_L is 127 m, TPC 18 and LCF 3.0 m aft of midships. Calculate the new draughts when 180 tonne of cargo are added 40 m forward of midships.

45. A propeller has a pitch of 5.5 m. When turning at 93 rev/min the apparent slip is found to be − S% and the real slip + S%, the wake speed being 10% of the ship's speed. Calculate the speed of the ship, the apparent slip and the real slip.

46. The ½ ordinates of a waterplane at 15 m intervals, commencing from aft, are 1, 7, 10.5, 11, 11, 10.5, 8, 4 and 0 m. Calculate:

(a) TPC

(b) distance of the centre of flotation from midships

(c) second moment of area of the waterplane about a transverse axis through the centre of flotation.

Note:—Second moment of area about any axis y − y which is parallel to an axis N − A through the centroid and distance x from it, is given by:

$$I_{yy} = I_{NA} + Ax^2$$

47. A ship travelling at 12 knots has a metacentric height of 0.25 m. The distance between the centre of gravity and the centre of lateral resistance is 2.7 m. If the vessel turns in a circle of 600 m radius, calculate the angle to which it will heel.

48. The following data are available for a twin screw vessel:

V	(knots)	15	16	17	18
ep_n	(kW)	3000	3750	4700	5650
QPC		0.73	0.73	0.72	0.71

Calculate the service speed if the brake power for each engine is 3500 kW. The transmission losses are 3% and the allowances for weather and appendages 30%.

49. A ship 120 m long displaces 8000 tonne, GM_L is 102 m, TPC 17.5 and LCF 2 m aft of midships. It arrives in port with draughts of 6.3 m forward and 6.6 m aft.

During the voyage the following changes in loading have taken place:

Fuel used	200 tonne	18 m forward of midships
Water used	100 tonne	3 m aft of midships
Stores used	10 tonne	9 m aft of midships
Ballast added	300 tonne	24 m forward of midships

Calculate the *original* draughts.

50. A propeller has a pitch of 5.5 m. When turning at 80 rev/min the ship speed is 13.2 knots, speed of advance 11 knots, propeller efficiency 70% and delivered power 3000 kW. Calculate:

(a) real slip
(b) wake fraction
(c) propeller thrust.

* 51. A watertight bulkhead 6.0 m deep is supported by vertical inverted angle stiffeners 255 mm x 100 mm x 12.5 mm, spaced 0.6 m apart. The ends of the stiffeners in contact with the tank top are welded all round, and the thickness of weld at its throat is 5 mm.

Calculate the shear stress in the weld metal at the tank top when the bulkhead is covered on one side, by water of density 1025 kg/m³, to a depth of 4.85 m.

52. A ship of 5000 tonne displacement has three rectangular double bottom tanks; A 12 m long and 16 m wide; B 14 m long and 15 m wide; C 14 m long and 16 m wide.

Calculate the free surface effect for any one tank and state in which order the tanks should be filled when making use of them for stability correction.

53. A box barge 75 m long and 8.5 m beam floats at draughts of 2.13 m forward and 3.05 m aft.

An empty compartment is now flooded and the vessel finally lies at a draught of 3.00 m level keel. Calculate the length and Lcg of the flooded compartment.

54. A vessel has a maximum allowable draught of 8.5 m in fresh water and 8.25 m in sea water of 1.026 t/m³, the TPC in the sea water being 27.5. The vessel is loaded in river water of 1.012 t/m³ to a draught of 8.44 m. If it now moves into sea water, is it necessary to pump out any ballast, and if so, how much?

55. A bulkead is in the form of a trapezoid 13 m wide at the deck, 10 m wide at the tank top and 7.5 m deep.

Calculate the load on the bulkead and the position of the centre of pressure if it is flooded to a depth of 5 m with sea water on one side only.

56. A double bottom tank is 23 m long. The half breadths of the top of the tank are 5.5, 4.6, 4.3, 3.7 and 3.0 m respectively. When the ship displaces 5350 tonne, the loss in metacentric height due to free surface is 0.2 m. Calculate the density of the liquid in the tank.

57. A vessel of constant rectangular cross-section is 100 m long and floats at a draught of 5 m. It has a mid-length compartment 10 m long extending right across the vessel, but sub-divided by a horizontal watertight flat 3 m above the keel. GM is 0.8 m.

Calculate the new draught and metacentric height if the compartment is bilged below the flat.

58 (a). If resistance $\propto$ S V² and S $\propto \Delta^{\frac{2}{3}}$, derive the Admiralty Coefficient formula.

(b). A ship 160 m long, 22 m beam and 9.2 m draught has a block coefficient of 0.765. The pitch of the propeller is 4 m and when it turns at 96 rev/min the true slip is 33%, the wake fraction 0.335 and shaft power 2900 kW. Calculate the Admiralty Coefficient and the shaft power at 15 knots.

59. A ship model 6 m long has a total resistance of 40 N when towed at 3.6 knots in fresh water.

The ship itself is 180 m long and displaces 20 400 tonne. The wetted surface area may be calculated from the formula

$$S = 2.57\sqrt{\Delta L}.$$

Calculate ep_n for the ship at its corresponding speed in sea water. $f(\text{model})_{FW} = 0.492$; $f(\text{ship})_{SW} = 0.421$; $n = 1.825$.

60 (a). Why is an inclining experiment carried out? Write a short account of the method adopted.

(b) An inclining experiment was carried out on a ship of 8000 tonne displacement. The inclining ballast was moved transversely through 12 m and the deflections of a pendulum 5.5 m long, measured from the centreline, were as follows:

3 tonne port to starboard	64 mm S
3 tonne port to starboard	116 mm S
Ballast restored	3 mm S
3 tonne starboard to port	54 mm P
3 tonne starboard to port	113 mm P

Calculate the metacentric height of the vessel.

61. A ship of 8000 tonne displacement, 110 m long, floats in sea water of 1.024 t/m³ at draughts of 6 m forward and 6.3 m aft. The TPC is 16, LCB 0.6 m aft of midships, LCF 3 m aft of midships and MCT1 cm 65 tonne m. The vessel now moves into fresh water of 1.000 t/m³. Calculate the distance a mass of 50 tonne must be moved to bring the vessel to an even keel and determine the final draught.

62. A rectangular watertight bulkhead 9 m high and 14.5 m wide has sea water on both sides, the height of water on one side being four times that on the other side. The resultant centre of pressure is 7 m from the top of the bulkead. Calculate:

(a) the depths of water
(b) the resultant load on the bulkhead.

* 63. The following values refer to a vessel 143 m in length which is to have a service speed of 14 knots:

Service speed (knots)	13.0	14.1	15.2	16.3
Effective power naked ep_n (kW)	1690	2060	2670	3400

If allowances for the above ep_n for trial and service conditions are 13 per cent and 33 per cent respectively, and the ratio of service indicated power to maximum available indicated power is 0.9, calculate using the data below:

(a) the indicated power (i p) of the engine to be fitted.
(b) the service and trial speed of the vessel if the total available ep were used.

The vessel has the following data:

Quasi-propulsive coefficient (QPC) = 0.72
Shaft losses = 3.5 per cent
Mechanical efficiency of the engine to be fitted = 87 per cent.

64. A ship of 15 000 tonne displacement has righting levers of 0, 0.38, 1.0, 1.41 and 1.2 m at angles of heel of 0°, 15°, 30°, 45° and 60° respectively and an assumed *KG* of 7.0 m. The vessel is loaded to this displacement but the *KG* is found to be 6.80 m and *GM* 1.50 m.

(a) Draw the amended stability curve
(b) Estimate the dynamical stability at 60°.

65. On increasing the speed of a vessel by 1.5 knots it is found that the daily consumption of fuel is increased by 25 tonne and the percentage increase in fuel consumption for a voyage of 2250 nautical miles is 20. Estimate:
(a) the original daily fuel consumption
(b) the original speed of the ship.

66. The end bulkhead of the wing tank of an oil tanker has the following widths at 3 m intervals, commencing at the deck: 6.0, 6.0, 5.3, 3.6 and 0.6 m. Calculate the load on the bulkhead and the position of the centre of pressure if the tank is full of oil *rd* 0.8.

* 67. The following data for a ship has been produced from propulsion experiments on a model:

Ship speed (knot)	12.50	13.25	14.00
Effective power (kW)	1440	1800	2230
QPC	0.705	0.713	0.708
Propeller efficiency	0.565	0.584	0.585
Taylor wake fraction	0.391	0.362	0.356

Determine the speed of the ship and propeller thrust when the delivered power is 2385 kW.

68. A box barge 45 m long and 15 m wide floats at a level keel draught of 2 m in sea water, the load being uniformly distributed over the full length. Two masses, each of 30 tonne, are added at 10 m from each end and 50 tonne is evenly distributed between them. Sketch the shear force diagram and give the maximum shear force.

* 69. The power delivered to a propeller is 3540 kW at a ship speed of 15.5 knots. The propeller rotates at 1.58 rev/s, develops a thrust of 378 kN and has a pitch of 4.87 m.

If the thrust deduction fraction is 0.24, real slip 30 per cent and transmission losses are 3 per cent, calculate:

(a) the effective power,
(b) the Taylor wake fraction,
(c) the propulsive coefficient,
(d) the quasi-propulsive coefficient, assuming the appendage and weather allowance is 15 per cent.

70. A ship of 14 000 tonne displacement is 125 m long and floats at draughts of 7.9 m forward and 8.5 m aft. The TPC is 19, GM_L 120 m and LCF 3 m forward of midships. It is required to bring the vessel to an even keel draught of 8.5 m. Calculate the mass which should be added and the distance of the centre of the mass from midships.

71. A ship of 4000 tonne displacement has a mass of 50 tonne on board, on the centreline of the tank top. A derrick, whose head is 18 m above the cg of the mass, is used to lift it. Find the shift in the ship's centre of gravity from its original position when the mass is:
(a) lifted just clear of the tank top
(b) raised to the derrick head
(c) placed on the deck 12 m above the tank top
(d) swung outboard 14 m.

* 72. A rectangular bulkhead 8 m wide has water of density 1000 kg/ m³ to a depth of 7 m on one side and on the other side oil of density 850 kg/ m³ to a depth of 4 m. Calculate:

(a) the resultant pressure on the bulkhead
(b) the position of the resultant centre of pressure.

* 73. A ship of 91.5 m length between perpendiculars contains ballast water in a forward compartment and has the following equidistant half areas of immersed sections commencing at the after perpendicular (AP).

Section	0(AP)	1	2	3	4	5	6	7	8	9	10(FP)
Half-area of immersed sections (m²)	0.4	7.6	21.4	33.5	40.8	45.5	48.4	52.0	51.1	34.4	0

If, prior to ballasting, the ship's displacement was 5750 tonne and the position of the longitudinal centre of buoyancy (LCB) was 4.6 m forward of midships, calculate:

(a) the mass of water of density 1025 kg/ m³ added as ballast,
(b) the distance of the centre of gravity of the ballast water contained in the forward compartment from midships.

74. A ship of 7500 tonne displacement has a double bottom tank 14 m long, 12 m wide and 1.2 m deep full of sea water. The centre of gravity is 6.7 m above the keel and the metacentric height 0.45 m.

Calculate the new *GM* if half of the water is pumped out of the tank. Assume that *KM* remains constant.

75. A ship 120 m long displaces 9100 tonne. It loads in fresh water of 1.000 t/ m³ to a level keel draught of 6.70 m. It then moves into sea water of 1.024 t/ m³. TPC in sea water 16.8, MCT1 cm 122 tonne m, LCF 0.6 aft of midships, LCB 2.25 m forward of midships. Calculate the end draughts in the sea water.

76. A box-shaped vessel is 20 m long and 10 m wide. The weight of the vessel is uniformly distributed throughout the length and the draught is 2.5 m. The vessel contains ten evenly-spaced double bottom tanks, each having a depth of 1 m.

Draw the shear force diagrams:

(a) with No. 1 and No. 10 tanks filled
(b) with No. 3 and No. 8 tanks filled
(c) with No. 5 and No. 6 tanks filled.

Which ballast condition is to be preferred from the strength point of view?

* 77. For a box-shaped barge of 216 tonne displacement, 32 m in length, 5.5 m breadth and floating in water of density 1025 kg/ m³, the *KG* is 1.8 m. An item of machinery of mass 81 tonne is loaded amidships and to maintain a positive metacentric height, 54 tonne of solid ballast is taken aboard and evenly distributed over the bottom of the barge so that the average *Kg* of the ballast is 0.15 m. If in the final condition the *GM* is 0.13 m, calculate the *Kg* of the machinery.

78. The maximum allowable draught of a ship in fresh water of 1.000 t/ m³ is 9.50 m and in sea water of 1.025 t/ m³ is 9.27 m.

The vessel is loaded to a draught of 9.50 m in a river, but when it proceeds to sea it is found that 202 tonne of water ballast must be pumped out to prevent the maximum draught being exceeded. If the TPC in the sea water is 23, calculate the density of the river water.

* 79. The following data are recorded from tests carried out on a model propeller 0.3 m diameter rotating at 8 rev/s in water of density 1000 kg/ m³.

Speed of advance *va* (m/s)	1.22	1.46	1.70	1.94
Thrust (N)	93.7	72.3	49.7	24.3
Torque (Nm)	3.90	3.23	2.50	1.61

Draw graphs of thrust and delivered power against speed of advance *va*.

A geometrically similar propeller 4.8 m diameter operates in water of 1025 kg/ m³. If the propeller absorbs 3000 kW delivered power and satisfies the law of comparison, determine for the propeller:

(a) the thrust power,
(b) the efficiency.

Note: For geometrically similar propellers the thrust power and delivered power vary directly as $(\text{diameter})^{3.5}$.

* 80. A ship 128 m in length, 16.75 m in breadth, has the following hydrostatic data:

Draught (m)	1.22	2.44	3.66	4.88	6.10
Waterplane area coefficient	0.78	0.82	0.85	0.88	0.90
Position of longitudinal centre of flotation (LCF) from midships (m)	1.30 for'd	1.21 for'd	0.93 for'd	0.50 for'd	0.06 aft

Calculate:

(a) the displacement in water of density 1025 kg/m³ of a layer of shipbody between the waterplanes at 1.22 m and 6.10 m draught.

(b) for the layer

(i) the position of the longitudinal centre of buoyancy,

(ii) the position of the vertical centre of buoyancy.

SOLUTIONS TO FIRST CLASS EXAMINATION QUESTIONS

1.
$$\text{Bodily sinkage} = \frac{240}{20}$$
$$= 12\,\text{cm}$$
$$\text{New draught aft} = 6.9 + 0.12$$
$$= 7.02\,\text{m}$$

i.e. the after draught may be increased by a further 0.18 m and this becomes the change in trim aft.

$$\text{Change in trim aft} = \text{total change in trim} \times \frac{56.5}{120}$$
$$18 = t \times \frac{56.5}{120}$$
$$t = 18 \times \frac{120}{56.5}$$
$$= 38.23\,\text{cm}$$

But
$$t = \frac{m \times d}{\text{MCT 1 cm}}$$
$$d = \frac{38.23 \times 101}{240}$$
$$= 16.09\text{ m aft of the centre of flotation}$$
$$= 19.59\text{ m aft of midships}$$

2.

draught	TPC	SM	product for displacement	lever*	product for vertical moment
1.2	23.0	1	23.0	1	23.0
2.4	24.2	4	96.8	2	193.6
3.6	25.0	1	25.0	3	75.0
			144.8		291.6

*Using a lever of 1 at 1.2 m draught produces a vertical moment about the *keel*.

M

$$\text{Displacement 1.2 m to 3.6 m} = \frac{1.2}{3} \times 144.8 \times 100$$
$$= 5792 \text{ tonne}$$

$$\text{Displacement 0 m to 3.6 m} = 8172 \text{ tonne}$$

$$\therefore \text{Displacement 0 m to 1.2 m} = 2380 \text{ tonne}$$

Vertical moment 1.2 m to 3.6 m

$$= \frac{1.2}{3} \times 1.2 \times 291.6 \times 100$$

$$= 14\,000 \text{ tonne m}$$

$$\text{Vertical moment 0 m to 3.6 m} = 8172 \times 1.91$$
$$= 15\,610 \text{ tonne m}$$

$\therefore$ Vertical moment 0 m to 1.2 m

$$= 1610 \text{ tonne m}$$

$$KB \text{ at 1.2 m draught} = \frac{1610}{2380}$$

$$= 0.676 \text{ m}$$

draught	TPC	LCF*	TPC × LCF	SM	product for longitudinal moment
1.2	23.0	− 1.37	− 31.5	1	− 31.5
2.4	24.2	+ 0.76	+ 18.39	4	+ 73.56
3.6	25.0	+ 0.92	+ 23.0	1	+ 23.0
					+ 65.06

* Taking forward as negative and aft as positive.

Longitudinal moment 1.2 m to 3.6 m

$$= \frac{1.2}{3} \times 65.06 \times 100$$

$$= +2602.4 \text{ tonne m}$$

Longitudinal moment 0 m to 3.6 m

$$= 8172 \times 0.15$$
$$= +1225.8 \text{ tonne m}$$

$\therefore$ Longitudinal moment 0 m to 1.2 m

$$= -1376.6 \text{ tonne m}$$

$$\text{LCB at 1.2 m draught} = -\frac{1376.6}{2380}$$

$$= 0.578 \text{ m forward of midships}$$

i.e. at 1.2 m draught, the displacement is 2380 t, *KB* 0.676 m and the LCB 0.578 m forward of midships.

3. $$\text{Block coefficient } C_b = \frac{17\,000}{1.025 \times 142 \times 18.8 \times 8}$$

$$= 0.776$$

$$w = 0.5 \times 0.776 - 0.05$$
$$= 0.338$$

$$\text{Pitch} = 4.8 \times 0.673$$
$$= 3.23 \text{ m}$$

$$\text{Theoretical speed} = \frac{3.23 \times 100 \times 60}{1852}$$

$$= 10.46 \text{ knots}$$

$$\text{Speed of advance} = 10.46 \times 0.65$$
$$= 6.80 \text{ knots}$$

$$\text{Ship speed} = \frac{6.80}{1 - 0.338}$$

$$= 10.27 \text{ knots}$$

$$\text{New fuel consumption} = 20 \times \left(\frac{10.27}{12}\right)^3$$

$$= 12.54 \text{ tonne per day}$$

4. $$\text{Effective } GM = \frac{5 \times 15 \times 6}{5000 \times 0.12}$$

$$= 0.75 \text{ m}$$

$$\text{Free surface effect} = \frac{1.025}{1.025} \times \frac{7.5 \times 9^3 \times 1.025}{12 \times 5000}$$

$$= 0.093 \text{ m}$$

Hence, actual $GM = 0.7 + 0.093$
$= 0.843$ m
$KM = 6.40$ m
$\therefore$ $KG = 5.557$ m

Mass of water in tank $= 1.025 \times 7.5 \times 9 \times 0.6$
$= 41.51$ tonne

Taking moments about the keel:

$$\text{Light ship } KG_1 = \frac{5000 \times 5.557 - 41.51 \times 0.3}{500 - 41.51}$$
$$= 5.601 \text{ m}$$

5. $$w = \frac{V - Va}{V}$$

Speed of advance $Va = 16(1 - 0.28)$
$= 11.52$ knots

$$\text{Real slip } s = \frac{V_t - Va}{V_t}$$

$$\text{Theoretical speed } V_t = \frac{11.52}{1 - 0.30}$$
$$= 16.46 \text{ knots}$$

But $$V_t = \frac{P \times N \times 60}{1852}$$

$$\text{Pitch } P = \frac{16.46 \times 1852}{120 \times 60}$$
$$= 4.23 \text{ m}$$

$$\text{Pitch ratio } p = \frac{P}{D}$$

(a) $$\therefore \text{Diameter } D = \frac{4.23}{0.95}$$
$$= 4.45 \text{ m}$$

(b) $$\text{Shaft power sp} = 2\pi \times \frac{120}{60} \times 270$$
$$= 3393 \text{ kW}$$

(*Note.* This is the power at the after end of the shaft and hence is strictly the delivered power.)

(c) $$\text{Thrust power tp} = 400 \times 11.52 \times \frac{1852}{3600}$$
$$= 2370 \text{ kW}$$

$$\text{Propeller efficiency} = \frac{2370}{3393} \times 100$$
$$= 69.84\%$$

(d) $$\text{ep} = 3393 \times 0.67$$
$$= 2273.3$$

But $$\text{ep} = R_t \times v$$

$$R_t = \frac{2273.3 \times 3600}{16 \times 1852}$$
$$= 276.2 \text{ kN}$$

$$R_t = T(1 - t)$$

$$1 - t = \frac{276.2}{400}$$
$$= 0.69$$

Thrust deduction factor $t = 0.31$

6.

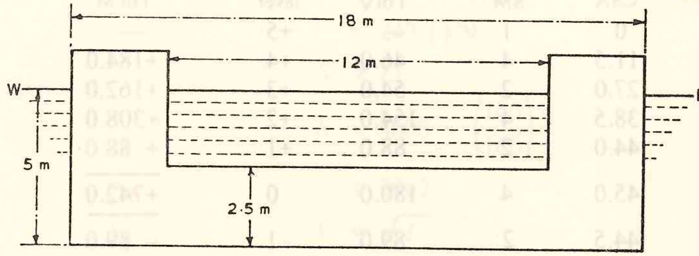


Fig. 121

$$KB = \frac{12 \times 2.5 \times 1.25 + 2 \times 3 \times 5 \times 2.5}{12 \times 2.5 + 2 \times 3 \times 5}$$
$$= 1.875 \text{ m}$$

$$I = \frac{1}{12} L(18^3 - 12^3)$$
$$= \frac{1}{12} \times 4104L$$

$$\nabla = L(12 \times 2.5 + 2 \times 3 \times 5)$$
$$= 60L$$

$$BM = \frac{4104\,L}{12 \times 60\,L}$$

$$= 5.70 \text{ m}$$

$$KM = 1.875 + 5.70$$
$$= 7.575 \text{ m}$$

$$GM = 2.50 \text{ m}$$

$$\therefore \quad KG = 5.075 \text{ m}$$

7(a). Derive $\quad \text{sp} = \dfrac{\Delta^{\frac{2}{3}} V^3}{C}$

and hence $\quad \dfrac{\text{sp}_1}{\text{sp}_2} = \left(\dfrac{\Delta_1}{\Delta_2}\right)^{\frac{2}{3}} \left(\dfrac{V_1}{V_2}\right)^4$

(b) $\quad \text{sp}_2 = 23\,000 \times \left(\dfrac{12\,000}{14\,000}\right)^{\frac{2}{3}} \times \left(\dfrac{21}{24}\right)^4$

$$= 12\,166 \text{ kW}$$

8.

CSA	SM	f of ∇	lever	f of M
0	1	—	+5	—
11.5	4	46.0	+4	+184.0
27.0	2	54.0	+3	+162.0
38.5	4	154.0	+2	+308.0
44.0	2	88.0	+1	+ 88.0
				+742.0
45.0	4	180.0	0	
44.5	2	89.0	−1	− 89.0
39.0	4	156.0	−2	−312.0
26.5	2	53.0	−3	−159.0
14.5	4	58.0	−4	−232.0
0	1	—	−5	—
		878.0		−792.0

$$h = 8 \text{ m}$$

(a) $\quad \text{Displacement} = \dfrac{8}{3} \times 878 \times 1.025$

$$= 2400 \text{ tonne}$$

(b) $\quad \text{LCB from midships} = \dfrac{8\,(742 - 792)}{878}$

$$= -0.455 \text{ m}$$
$$= 0.455 \text{ m forward}$$

(c) $\quad \text{Prismatic coefficient} = \dfrac{8 \times 878}{3 \times 80 \times 45}$

$$= 0.650$$

9. Ship A

$$ep_n = R_t \times v$$

$$R_t = \frac{6400 \times 3600}{18 \times 1852}$$

$$= 691.1 \text{ kN}$$

$$R_f = f S V^n$$
$$= 0.42 \times 4000 \times 18^{1\cdot825}$$
$$= 328.2 \text{ kN}$$

$$R_r = 691.1 - 328.2$$
$$= 362.9 \text{ kN}$$

Ship B

$$R_r \propto L^3$$

$$\therefore \quad R_r = 362.9 \times \left(\frac{140}{160}\right)^3$$

$$= 243.1 \text{ kN}$$

$$S \propto L^2$$

$$\therefore \quad S = 4000 \times \left(\frac{140}{160}\right)^2$$

$$= 3062$$

$$V \propto \sqrt{L}$$

$$\therefore \quad V = 18\sqrt{\frac{140}{160}}$$

$$= 16.84$$

$$R_f = 0.425 \times 3062 \times 16.84^{1\cdot825}$$
$$= 225.1 \text{ kN}$$

$$R_t = 225.1 + 243.1$$
$$= 468.2 \text{ kN}$$

$$ep_n = \frac{468.2 \times 16.84 \times 1852}{3600}$$

$$= 4055 \text{ kN}$$

10.

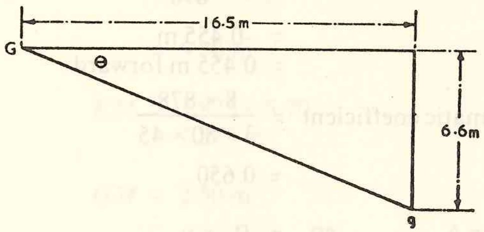


Fig. 122

$$Gg = \sqrt{16.5^2 + 6.6^2}$$

$$= \sqrt{315.81}$$
$$= 17.77 \text{ m}$$

This is the distance from the centre of gravity of the tank to the original centre of gravity of the ship.

(a) Let m = mass of oil used

Then shift in centre of gravity $= \dfrac{m \times Gg}{\text{final displacement}}$

$$0.380 = \frac{m \times 17.77}{11\,200 - m}$$

$$m = \frac{11\,200 \times 0.38}{17.77 + 0.38}$$

$$= 234.5 \text{ tonne}$$

(b) $$\tan\theta = \frac{6.6}{16.5}$$

$$= 0.40$$

Angle of shift $\theta = 21° \, 48'$

11.

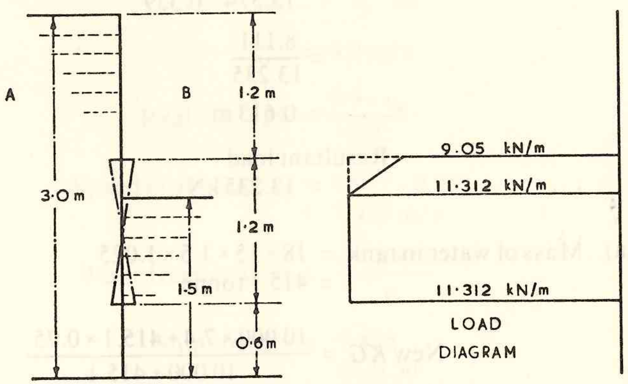


Fig. 123

Load / m at top of door from side A
$= 1.025 \times 9.81 \times 1.2 \times 0.75$
$= 9.050$ kN

Load / m 0.3 m from top of door side A
$= 1.025 \times 9.81 \times 1.5 \times 0.75$
$= 11.312$ kN

Load / m at bottom of door from side A
$= 1.025 \times 9.81 \times 2.4 \times 0.75$
$= 18.099$ kN

Load / m at bottom of door from side B
$= 1.025 \times 9.81 \times 0.9 \times 0.75$
$= 6.787$ kN

∴ nett load / m at bottom of door
$= 18.099 - 6.787$
$= 11.312$ kN

Thus the load diagram is in the form shown by Fig. 123.

The area of this diagram represents the load, while the centroid represents the position of the centre of pressure.

Taking moments about the top of the door:

Centre of pressure from top

$$= \frac{11.312 \times 1.2 \times 0.6 - (11.312 - 9.05) \times 0.3 \times \tfrac{1}{2} \times 0.10}{11.312 \times 1.2 - (11.312 - 9.05) \times 0.3 \times \tfrac{1}{2}}$$

$$= \frac{8.145 - 0.0339}{13.574 - 0.339}$$

$$= \frac{8.111}{13.235}$$

$$= 0.613 \text{ m}$$

Resultant load

$$= 13.235 \text{ kN}$$

12(a). Mass of water in tank $= 18 \times 15 \times 1.5 \times 1.025$

$= 415.1$ tonne

$$\text{New } KG = \frac{10\,000 \times 7.4 + 415.1 \times 0.75}{10\,000 + 415.1}$$

$$= \frac{74\,000 + 311}{10\,415.1}$$

$$= 7.135 \text{ m}$$

New $GM = 8.00 - 7.135$ m

$= 0.865$ m

(b) Mass of water in tank $= \dfrac{415.1}{2}$

$= 207.55$ tonne

$$\text{New } KG = \frac{74\,000 + 207.55 \times 0.375}{10\,000 + 207.55}$$

$$= 7.257 \text{ m}$$

$$\text{Free surface effect} = \frac{1.025 \times 18 \times 15^3 \times 1.025}{1.025 \times 12 \times 10\,207.55}$$

$$= 0.508 \text{ m}$$

New $GM = 8.00 - 7.257 - 0.508$

$= 0.235$ m

13(a). Blade area $= 0.48 \times \dfrac{\pi}{4} \times 6^2$

$= 13.57 \text{ m}^2$

(b) Theoretical speed $v_t = \dfrac{6 \times 0.9 \times 110}{60}$

$= 9.9$ m/s

Real slip $0.25 = \dfrac{9.9 - v_a}{9.9}$

Speed of advance $v_a = 9.9(1 - 0.25)$

$= 7.425$ m/s

Wake fraction $0.30 = \dfrac{v - 7.425}{v}$

Ship speed $v = \dfrac{7.425}{1 - 0.30}$

$= 10.61$ m/s

$= 10.61 \times \dfrac{3600}{1852}$

$= 20.62$ knots

(c) Thrust power tp $= 300 \times 7.425$

$= 2227.5$ kW

(d) Shaft power sp $= \dfrac{2227.5}{0.65}$

$= 3427$ kW

(e) sp $= 2\pi n Q$

Torque $Q = \dfrac{3427 \times 60}{2\pi \times 110}$

$= 297$ kN m

14. Let C = normal cons/h at V knots

C_1 = cons/h at reduced speed of 0.8 V knots

Then $C_1 = C - \dfrac{42}{24}$ tonne/h

Now $C = 0.136 + 0.001\,V^3$

$$C - \frac{42}{24} = 0.136 + 0.001\,(0.8V)^3$$

Subtracting: $\frac{42}{24} = 0.001V^3 - 0.001(0.512V^3)$

$= 0.001V^3(1 - 0.512)$

$V^3 = \frac{42}{24 \times 0.001 \times 0.488}$

$V = 15.31$ knots

Reduced speed $= 0.8 \times 15.31$
$= 12.25$ knots

$C = 0.136 + 0.001 \times 15.31^3$
$= 3.722$ tonne/h

Normal cons/day $= 3.722 \times 24$
$= 89.33$ tonne

(a) Reduced cons/day $= 89.33 - 42$
$= 47.33$ tonne

(b) Time taken to travel 800 nautical miles at normal speed

$= \frac{800}{15.31}$

$= 52.26$ h

Time taken at reduced speed $= \frac{800}{12.25}$

$= 65.30$ h

Fuel consumption for 800 nautical miles at reduced speed

$= 47.33 \times \frac{65.30}{24}$

$= 128.8$ tonne

Fuel on board when speed reduced
$= 128.8 + 50$
$= 178.8$ tonne

(c) Normal cons for 800 nm $= 89.33 \times \frac{52.26}{24}$

$= 194.5$ tonne

% reduction in consumption $= \frac{194.5 - 128.8}{194.5} \times 100$

$= \frac{65.7}{194.5} \times 100$

$= 33.78\%$

(d) % increase in time $= \frac{65.30 - 52.26}{52.26} \times 100$

$= \frac{13.04}{52.26} \times 100$

$= 24.95\%$

15. Complete waterplane area
$= 160 \times 22 \times 0.865$
$= 3045.8\ m^2$

Intact waterplane area $= 3045.8 - 10.5 \times 22$
$= 2814.8\ m^2$

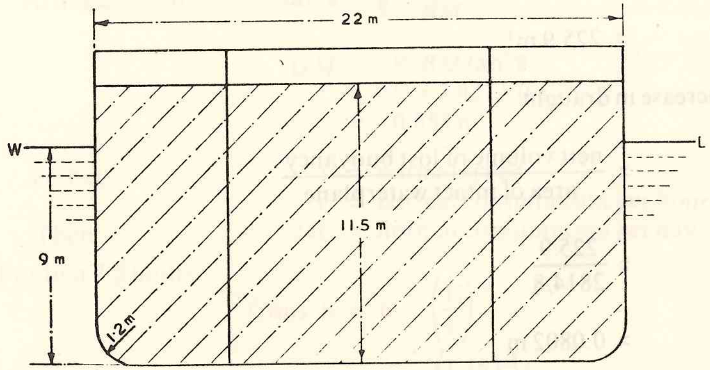


Fig. 124

It may be assumed that the whole of the mass of the oil is taken from the ship and that all the buoyancy of the compartment is lost.

Cross-sectional area of oil

$= \frac{1}{2}\pi \times 1.2^2 + (22 - 2.4) \times 1.2 + 22(11.5 - 1.2)$

$= 2.26 + 23.52 + 226.6$

$= 252.38\ m^2$

Immersed cross-sectional area

$= 252.38 - 22 \times 2.5$

$= 197.38\ m^2$

Mass of oil in compartment

$$= \frac{252.38 \times 10.5}{1.4}$$

$= 1892.85$ tonne

Mass of buoyancy lost

$= 197.38 \times 10.5 \times 1.025$

$= 2124.30$ tonne

Nett loss in buoyancy

$= 2124.30 - 1892.85$

$= 231.55$ tonne

Equivalent volume

$$= \frac{231.55}{1.025}$$

$= 225.9\ m^3$

Increase in draught

$$= \frac{\text{nett volume of lost buoyancy}}{\text{area of intact waterplane}}$$

$$= \frac{225.9}{2814.8}$$

$= 0.0802$ m

New draught

$= 9.08$ m

16.

½ ord	½ ord³	SM	product
0	0	1	—
2.4	13.82	4	55.28
5.0	125.00	2	250.00
7.3	389.02	4	1556.08
7.9	493.04	2	986.08
8.0	512.00	4	2048.00
8.0	512.00	2	1024.00
7.7	456.53	4	1826.12
5.5	166.38	2	332.76
2.8	21.95	4	87.80
0	0	1	—
			8166.12

$h = 16$ m

$$I = \frac{2}{9} \times 16 \times 8166.12$$

$= 29\,035\ m^4$

$$BM = \frac{29\,035}{8700} \times 1.025$$

$= 3.421$ m

At angle of loll $\tan\theta = \sqrt{\dfrac{-2GM}{BM}}$

$GM = -\frac{1}{2} BM \tan^2\theta$

$= -\frac{1}{2} \times 3.421 \times 0.1763^2$

$= -0.053$ m

17. Let V = normal speed

C = normal consumption per *hour*

Then $24C$ = normal consumption per day.

For first 7.5 hours:

$$\text{Cons/h} = C \times \left(\frac{V_1}{V}\right)^3$$

$$= C \times \left(\frac{1.18V}{V}\right)^3$$

$= 1.643C$

$$\text{Cons for 7.5 hours} = 7.5 \times 1.643C$$
$$= 12.32C$$

For next 10 hours:

$$\text{Cons/h} = C \times \left(\frac{0.91V}{V}\right)^3$$
$$= 0.7536C$$
$$\text{Cons for 10 hours} = 7.536C$$

i.e. cons for 17.5 hours $= 12.32C + 7.536C$
$$= 19.856C$$

$$\text{Cons for remaining 6.5 hours} = 24C - 19.856C$$
$$= 4.144C$$

$$\text{Cons/h} = \frac{4.144C}{6.5}$$
$$= 0.637C$$

$$\text{Reduced speed } V_3 = V\sqrt[3]{\frac{0.637C}{C}}$$
$$= 0.86V$$

Normal distance travelled/day $= 24V$

New distance travelled/day $= 1.18V \times 7.5 + 0.91V \times 10 + 0.86V \times 6.5$
$$= 23.54V$$

$$\% \text{ reduction in distance/day} = \frac{24V - 23.54V}{24V} \times 100$$
$$= 1.92\%$$

18.

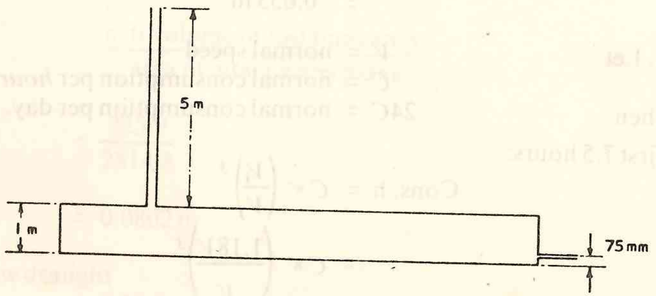


Fig. 125

(a) Pressure at tank top = pressure exerted by pump — pressure due to head of water

$$= 70 - 1.025 \times 9.81 \times (1 - 0.075)$$
$$= 60.70 \text{ kN/m}^2$$

$$\text{Load on tank top} = 60.70 \times 6 \times 12$$
$$= 4370 \text{ kN}$$
$$= 4.37 \text{ MN}$$

(b) With 70 kN/m² pressure:

$$\text{maximum head above inlet} = \frac{70}{1.025 \times 9.81}$$
$$= 6.968 \text{ m}$$

Maximum head above tank top
$$= 6.968 - 0.925$$
$$= 6.043 \text{ m}$$

Hence the water will overflow and the maximum head above the tank top is therefore 5 m.

$$\text{Load on tank top} = 1.025 \times 9.81 \times 6 \times 12 \times 5$$
$$= 3616 \text{ kN}$$
$$= 3.616 \text{ MN}$$

19(a).

V	V^3	$\Delta^{\frac{2}{3}}$	sp	Ad. Coeff.
10	1000	524.1	880	595.5
11	1331	524.1	1155	604.0
12	1728	524.1	1520	595.8
13	2197	524.1	2010	572.9
14	2744	524.1	2670	538.6
15	3375	524.1	3600	491.3

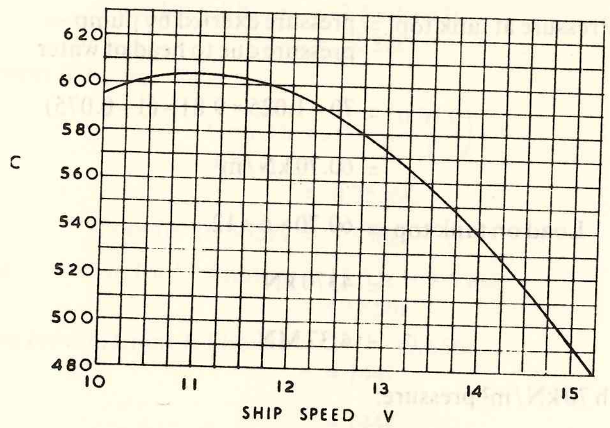


Fig. 126

(b) Corresponding speed of 120 m ship to 14 knots for 140 m ship.

$$= 14\sqrt{\frac{120}{140}}$$

$$= 12.96 \text{ knots}$$

From graph at 12.96 knots, the Admiralty Coefficient is 574.6

$$\Delta \propto L^3$$

$$\therefore \quad \Delta = 12\,000 \times \left(\frac{140}{120}\right)^3$$

$$= 19\,056 \text{ tonne}$$

Hence shaft power $= \dfrac{19\,056^{\frac{2}{3}} \times 12.96^3}{574.6}$

$$= 2703 \text{ kW}$$

20.

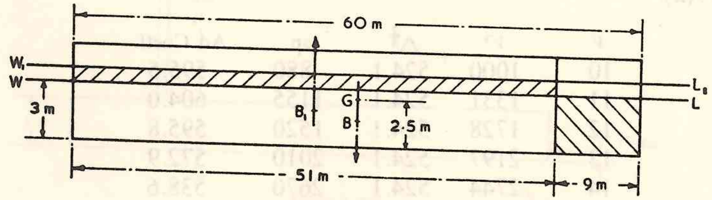


Fig. 127

Increase in mean draught $= \dfrac{9 \times 10 \times 3}{51 \times 10}$

$= 0.529$

New mean draught $d_1 = 3 + 0.529$

$= 3.529$

$$KB_1 = \frac{3.529}{2}$$

$$= 1.765$$

$$I_F = \tfrac{1}{12} \times 51^3 \times 10$$

$$\nabla = 60 \times 10 \times 3$$

$$BM_L = \frac{51^3 \times 10}{12 \times 60 \times 10 \times 3}$$

$$= 61.41 \text{ m}$$

$$GM_L = 1.765 + 61.41 - 2.50$$

$$= 60.675 \text{ m}$$

$$BB_1 = \frac{9}{2}$$

$$= 4.5 \text{ m}$$

Change in trim $= \dfrac{\Delta \times 4.5}{\Delta \times 60.675} \times 60$

$= 4.45$ m by the head

Change forward $= +\dfrac{4.45}{60} \times \left(\dfrac{60}{2} + 4.5\right)$

$= +2.559$ m

Change aft $= -\dfrac{4.45}{60}\left(\dfrac{60}{2} - 4.5\right)$

$= -1.891$ m

New draught forward $= 3.259 + 2.559$

$= 5.818$ m

New draught aft $= 3.259 - 1.891$

$= 1.368$ m

21.

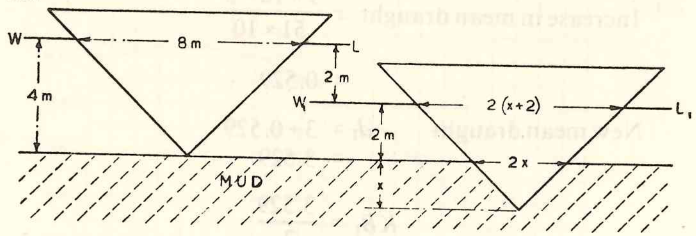


Fig. 128

Let L = length of vessel in m

ρ = density of water in tonne/m³

2ρ = density of mud in tonne/m³

x = depth to which vessel sinks in mud

$$\text{Original displacement} = \rho \times L \times \frac{8 \times 4}{2}$$

$$= 16\rho L \text{ tonne}$$

This displacement remains constant.

$$\text{Displacement of part in mud} = 2\rho \times L \times \frac{2x \times x}{2}$$

$$= 2\rho L x^2$$

$$\text{Displacement of part in water} = \rho \times L \times 2\left(\frac{2x + 2x + 4}{2}\right)$$

$$= \rho L (4x + 4)$$

Hence
$$16\rho L = 2\rho L x^2 + 4\rho L x + 4\rho L$$

$$16 = 2x^2 + 4x + 4$$

$$2x^2 + 4x - 12 = 0$$

from which
$$x = 1.646 \text{ m}$$

i.e. vessel sinks 1.646 m into the mud.

22(a).

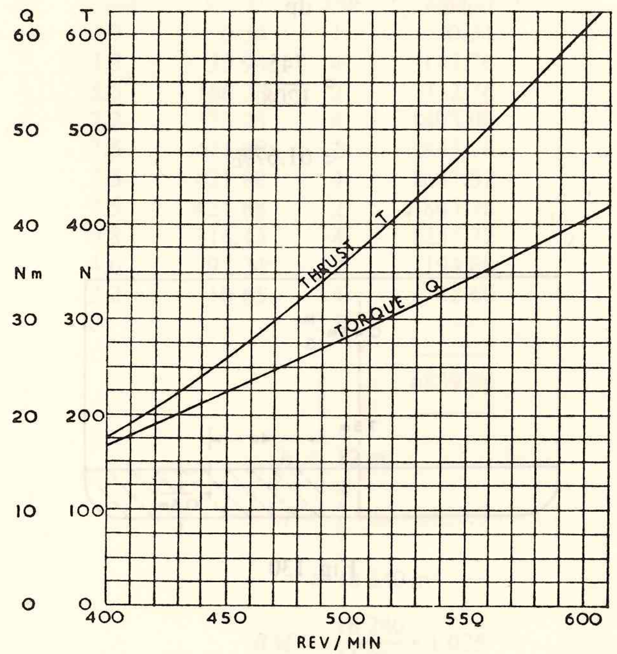


Fig. 129

(b)
$$v_t = P \times N$$

$$v_a = 0.8\, v_t$$

$$150 = 0.8 \times 0.4 \times N$$

$$\text{Rev/min } N = 469$$

At 469 rev/min, T = 298 N and Q = 24.6 N m

$$\text{Thrust power tp} = 298 \times \frac{150}{60}$$

$$= 745 \text{ W}$$

$$\text{Delivered power dp} = 24.6 \times 2\pi \times \frac{469}{60}$$

$$= 1208 \text{ W}$$

$$\text{Propeller efficiency} = \frac{tp}{dp}$$

$$= \frac{745}{1208}$$

$$= 61.67\%$$

23.

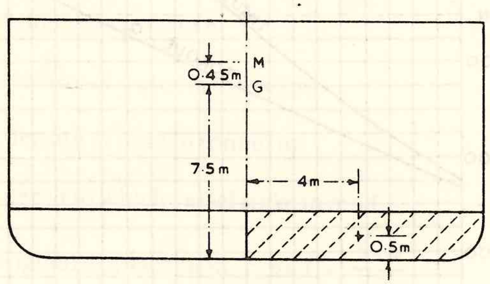


Fig. 130

$$\text{New } KG = \frac{8100 \times 7.5 - 100 \times 0.5}{8100 - 100}$$

$$= \frac{60\,750 - 50}{8000}$$

$$= 7.588 \text{ m}$$

$$\text{New } GM = 7.5 + 0.45 - 7.588$$

$$= 0.362 \text{ m}$$

$$\text{Heeling moment} = 100 \times 4$$

$$\tan\theta = \frac{100 \times 4}{8000 \times 0.362}$$

$$= 0.1381$$

$$\text{Angle of heel } \theta = 7° 52'$$

24.

½ ord	½ ord³	SM	product
0.7	0.34	1	0.34
3.3	35.94	4	143.76
5.5	166.38	2	332.76
7.2	373.25	4	1493.00
7.5	421.88	2	843.76
7.5	421.88	4	1687.52
7.5	421.88	2	843.76
6.8	314.43	4	1257.72
4.6	97.34	2	194.68
2.2	10.65	4	42.60
0	—	1	—
			6839.90

$$h = 12 \text{ m}$$

$$I = \frac{2}{9} \times 12 \times 6839.9$$

$$= 18\,240 \text{ m}^4$$

$$BM = \frac{18\,240}{11\,000} \times 1.025$$

$$= 1.70 \text{ m}$$

25. 1 tonne of stowed cargo occupies 1.8 m³

1 tonne of solid cargo occupies $\frac{1}{1.6}$ or 0.625 m³

Hence in every 1.8 m³ of space 0.625 m³ is occupied by cargo and the remaining 1.175 m³ is available for water.

$$\text{Permeability} = \frac{1.175}{1.8}$$

$$= 0.653$$

$$\text{Volume of lost buoyancy} = 18 \times 18 \times 6 \times 0.653$$

$$\text{Area of intact waterplane} = 85 \times 18$$

$$\text{Increase in draught} = \frac{18 \times 18 \times 6 \times 0.653}{85 \times 18}$$

$$= 0.830 \text{ m}$$

$$\text{New draught} = 6 + 0.830$$

$$= 6.830 \text{ m}$$

26.

Station	½ ord	SM	product	lever	product
AP	0.6	½	0.3	+ 4	+ 1.2
½	2.7	2	5.4	+ 3½	+ 18.9
1	4.6	1½	6.9	+ 3	+ 20.7
2	6.0	4	24.0	+ 2	+ 48.0
3	6.3	2	12.6	+ 1	+ 12.6
4	6.3	4	25.2	0	+ 101.4
5	6.3	2	12.6	− 1	− 12.6
6	5.7	4	22.8	− 2	− 45.6
7	4.8	1½	7.2	− 3	− 21.6
7½	2.0	2	4.0	− 3½	− 14.0
FP	0	½	—	− 4	—
			121.0		− 93.8

$$\text{Common interval} = \frac{90}{8}$$

$$\text{Area} = \frac{2}{3} \times \frac{90}{8} \times 121.0$$

$$= 907.5 \text{ m}^2$$

$$\text{LCF from midships} = \frac{90}{8} \times \left(\frac{101.4 - 93.8}{121.0}\right)$$

$$= 0.707 \text{ m aft}$$

27.

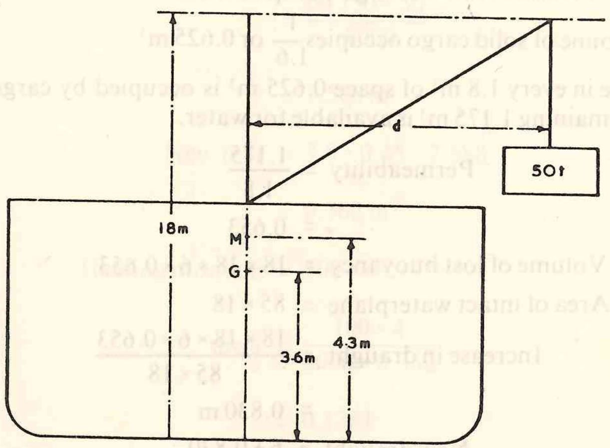


Fig. 131

$$\text{New } KG = \frac{6600 \times 3.6 + 50 \times 18}{6600 + 50}$$

$$= \frac{23\,760 + 900}{6650}$$

$$= 3.708 \text{ m}$$

$$\text{New } GM = 4.30 - 3.708$$

$$= 0.592 \text{ m}$$

$$\tan\theta = \frac{m \times d}{\Delta \times GM}$$

$$d = \frac{6650 \times 0.592 \times \tan 9.5°}{50}$$

$$\text{Outreach of derrick} = 13.18 \text{ m}$$

28. 120 m ship:

$$\text{Shaft power} = 4100 \text{ kW}$$

$$\text{Effective power} = 4100 \times 0.6$$

$$= 2460 \text{ kW}$$

$$= R_t \times v$$

$$R_t = \frac{2460 \times 3600}{15 \times 1852}$$

$$= 318.8 \text{ kN}$$

$$R_f = 0.55\, R_t$$

$$\therefore \quad R_r = 0.45\, R_t$$

$$= 143.46 \text{ kN}$$

140 m ship:

$$R_r \propto L^3$$

$$R_r = 143.46 \times \left(\frac{140}{120}\right)^3$$

$$= 227.81 \text{ kN}$$

$$S \propto L^2$$

$$\therefore \quad S = 3000 \times \left(\frac{140}{120}\right)^2$$

$$= 4083 \text{ m}^2$$

$$V \propto \sqrt{L}$$

$$\therefore \quad V = 15 \times \sqrt{\frac{140}{120}}$$

$$= 16.20 \text{ knots}$$

$$R_f = 0.42 \times 4083 \times 16.20^{1 \cdot 825}$$

$$= 276.44 \text{ kN}$$

$$R_t = 276.44 + 227.81$$

$$= 504.25 \text{ kN}$$

$$\text{ep} = \frac{504.25 \times 16.2 \times 1852}{3600}$$

$$= 4202 \text{ kW}$$

$$\text{sp} = \frac{\text{ep}}{\text{pc}}$$

$$= \frac{4202}{0.6}$$

$$= 7003 \text{ kW}$$

29. Original displacement $= 30 \times 9 \times 0.75 \times 1.025$

$$= 207.5 \text{ tonne}$$

$$\text{Change in mean draught} = \frac{\Delta \times 100}{A_w}\left(\frac{\rho_S - \rho_R}{\rho_S \times \rho_R}\right) \text{cm}$$

$$3.2 = \frac{\Delta \times 100}{30 \times 9}\left(\frac{1.025 - 1.000}{1.025 \times 1.000}\right)$$

$$\Delta = \frac{3.2 \times 30 \times 9 \times 1.025}{100 \times 0.025}$$

$$= 354.2 \text{ tonne}$$

$$\text{Cargo added} = 354.2 - 207.5$$

$$= 146.7 \text{ tonne}$$

30.

½ breadth	SM	f of a	(½b)²	SM	f of m	(½b)³	SM	f of i
5	1	5	25	1	25	125	1	125
4	4	16	16	4	64	64	4	256
2	1	2	4	1	4	8	1	8
		23			93			389

$$\text{Area of tank surface } a = \frac{6}{3} \times 23$$

$$= 46 \text{ m}^2$$

$$\text{Centroid from centreline} = \frac{93}{2 \times 23}$$

$$= 2.022 \text{ m}$$

Second moment of area about centreline

$$= \frac{6}{9} \times 389$$

$$= 259.33 \text{ m}^4$$

Second moment of area about centroid

$$i = 259.33 - 46 \times 2.022^2$$

$$= 71.26 \text{ m}^4$$

$$\text{Free surface effect} = \frac{\rho_1 i}{\rho \nabla}$$

$$= \frac{1.000 \times 71.26}{1.025 \times 5000} \times 1.025$$

$$= 0.0142 \text{ m}$$

31. $\text{Ship speed} = 15 \times \frac{1852}{3600}$

$$= 7.717 \text{ m/s}$$

$$\text{Apparent slip} = \frac{v_t - v}{v_t}$$

$$O = v_t - v$$

$$\therefore \quad v_t = v$$

$$= 7.717 \text{ m/s}$$

$$\text{Propeller pitch } P = \frac{7.717}{1.58}$$

$$= 4.884 \text{ m}$$

$$w_t = \frac{v - v_a}{v}$$

$$v_a = 7.717(1 - 0.31)$$

$$= 5.325 \text{ m/s}$$

$$\text{Real slip} = \frac{7.717 - 5.325}{7.717}$$

$$= 0.31$$

$$R_t = T(1 - t)$$

$$= 360(1 - 0.20)$$

$$= 288 \text{ kN}$$

$$\text{ep} = 288 \times 7.717$$

$$= 2222.5 \text{ kW}$$

$$\text{Propulsive coefficient} = \frac{2222.5}{3050}$$

$$= 0.729$$

32. Torque = force × lever

$$= F_n \times b$$

$$= 577 \times 22 \times \left(1.2 \times 15 \times \frac{1852}{3600}\right)^2 \times \sin 35° \times 1.1$$

$$= 686\,780 \text{ N m}$$

But $\dfrac{T}{J} = \dfrac{q}{r}$

And $J = \dfrac{\pi}{2} r^4$

$$\therefore \quad \frac{686\,780}{\frac{\pi}{2} r^4} = \frac{70 \times 10^6}{r}$$

$$r^3 = \frac{686\,780 \times 2}{70 \times 10^6 \pi}$$

$$r = 0.184 \text{ m}$$

Diameter of stock

$$= 368 \text{ mm}$$

If the diameter is reduced to 330 mm:

$$\frac{T}{\frac{\pi}{2} \times 0.165^4} = \frac{70 \times 10^6}{0.165}$$

$$T = \frac{70 \times 10^6 \times \pi \times 0.165^3}{2}$$

$$= 493\,920 \text{ N m}$$

$$493\,920 = 577 \times 22 \times \left(1.2 \times V \times \frac{1852}{3600}\right) \times 0.5736 \times 1.1$$

$$V^2 = \frac{493\,920 \times 3600^2}{577 \times 22 \times 1.2^2 \times 1852^2 \times 0.5736 \times 1.1}$$

$$\text{Ship speed } V = 12.72 \text{ knots}$$

33.

½ ord	SM	product
0	1	—
3.0	4	12.0
5.5	2	11.0
7.3	4	29.2
7.5	2	15.0
7.5	4	30.0
7.5	2	15.0
7.05	4	28.2
6.10	2	12.2
3.25	4	13.0
0	1	—
		165.6

$$h = 10 \text{ m}$$

$$\text{Waterplane area} = \tfrac{2}{3} \times 10 \times 165.6$$

$$= 1104 \text{ m}^2$$

$$\text{Intact waterplane area} = 1104 - 15 \times 15$$

$$= 879 \text{ m}^2$$

$$\text{Immersed cross-sectional area} = 50\ \text{m}^2$$

$$\text{Volume of lost buoyancy} = 15 \times 50$$

$$= 750\ \text{m}^2$$

$$\text{Increase in draught} = \frac{750}{879}$$

$$= 0.853\ \text{m}$$

$$\text{New draught} = 4.353\ \text{m}$$

34. Let m = mass of ballast required

$$\text{MCT1 cm} = \frac{\Delta \times GM_L}{100\,L}$$

$$= \frac{8100 \times 96}{100 \times 85}$$

$$= 91.48\ \text{tonne m}$$

$$\text{Trimming moment} = m(33-2)$$

$$= 31\,m$$

$$\text{Change of trim } t = \frac{31\,m}{91.48}\ \text{cm by the stern}$$

$$\text{Change aft} = +\frac{t}{85}\left(\frac{85}{2}-2\right)$$

$$= 0.476t\ \text{cm}$$

$$\text{Bodily sinkage} = \frac{m}{9.0}\ \text{cm}$$

$$\text{New draught aft} = \text{old draught aft} + \frac{m}{900} + \frac{0.476t}{100}$$

$$5.85 = 5.55 + 0.00111m + \frac{0.476}{100} \times \frac{31m}{91.48}$$

$$0.30 = 0.002726\,m$$

$$\text{Ballast required } m = 110\ \text{tonne}$$

$$\text{Bodily sinkage} = \frac{110}{9}$$

$$= 12.22\ \text{cm}$$

$$\text{Change in trim} = \frac{31 \times 110}{91.48}$$

$$= 37.28\ \text{cm by the stern}$$

$$\text{Change forward} = -\frac{37.28}{85}\left(\frac{85}{2}+2\right)$$

$$= -19.51\ \text{cm}$$

$$\text{New draught forward} = 5.25 + 0.122 - 0.195$$

$$= 5.177\ \text{m}$$

35.

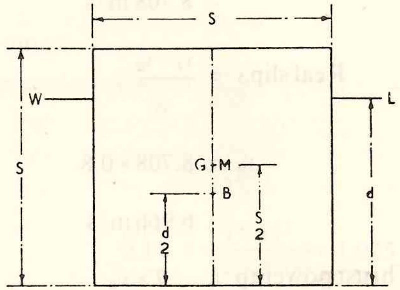


Fig. 132

Let x = relative density of wood

Then draught $d = Sx$

The limit of stability occurs when G and M coincide.

$$KG = \frac{S}{2}$$

$$KB = \frac{d}{2}$$

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

Since $KG = KM$

$$\frac{S}{2} = \frac{d}{2} + \frac{S^2}{12d}$$

$$\frac{S}{2} = \frac{Sx}{2} + \frac{S^2}{12Sx}$$

$$\frac{1}{2} = \frac{x}{2} + \frac{1}{12x}$$

Multiplying by 12:

$$6x = 6x^2 + 1$$

$$6x^2 - 6x + 1 = 0$$

$$x = \frac{6 \pm \sqrt{36-24}}{12}$$

$$\text{Relative density } x = 0.212 \text{ or } 0.788$$

It may be seen on referring to the metacentric diagram that the block will be *unstable* between these limits. Thus the relative density must be below 0.212 or between 0.788 and 1.0.

36. $$\text{Theoretical speed } v_t = 5.5 \times \frac{95}{60}$$

$$= 8.708 \text{ m/s}$$

$$\text{Real slip } s = \frac{v_t - v_a}{v_t}$$

$$v_a = 8.708 \times 0.8$$

$$= 6.966 \text{ m/s}$$

$$\text{Thrust power tp} = T \times v_a$$

$$= 380 \times 6.966$$

$$= 2647 \text{ kW}$$

$$R_t = T(1-t)$$

$$= 380\,(1 - 0.198)$$

$$= 304.8 \text{ kN}$$

$$\text{ep} = R_t \times v$$

$$= 304.8 \times 15.5 \times \frac{1852}{3600}$$

$$= 2430 \text{ kW}$$

$$\text{QPC} = \frac{\text{ep}}{\text{dp}}$$

$$= \frac{2430}{3540}$$

$$= 0.686$$

$$\text{Wake fraction} = \frac{V - V_a}{V}$$

$$= \frac{15.5 - \left(6.966 \times \frac{3600}{1852}\right)}{15.5}$$

$$= 0.126$$

37.(a) Description

(b) $$\text{Free surface effect} = \frac{\rho_1\, i}{\rho \nabla}$$

$$= \frac{l b^3}{12 \nabla}$$

$$0.14 = \frac{l \times 11^3}{12 \times 8500} \times 1.025$$

$$l = \frac{0.14 \times 12 \times 8500}{1331 \times 1.025}$$

$$= 10.47 \text{ m}$$

38.(a) Derivation of formula.

(b) Change in draught due to density

$$= \frac{8000 \times 100}{\text{TPC} \times 100} \times 1.024 \left(\frac{1.024 - 1.008}{1.008 \times 1.024}\right)$$

$$= 7.47 \text{ cm increase}$$

$$\text{New mean draught} = 7.075 \text{ m}$$

Max. allowable draught

$$= 6.85 \text{ m}$$

Required reduction in draught

$$= 0.225 \text{ m}$$

Mass of ballast discharged

$$= 22.5 \times 17 \times \frac{1.008}{1.024}$$

$$= 376.5 \text{ tonne}$$

39.(a) Admiralty Coefficient $= \dfrac{\Delta^{\frac{2}{3}} V^3}{sp}$

Fuel Coefficient $= \dfrac{\Delta^{\frac{2}{3}} V^3}{\text{fuel cons/day}}$

(b) With constant displacement and Admiralty Coefficient:

$$sp \propto V^3$$

$$\frac{4460}{4120} = \left(\frac{14.55}{V_1}\right)^3$$

$$V_1 = 14.55\sqrt[3]{\frac{4120}{4460}}$$

$$= 14.17 \text{ knots}$$

At 14.17 knots fuel cons = 541 kg/h

$$= 541 \times 24 \times 10^{-3}$$

$$= 12.98 \text{ tonne/day}$$

$$\text{Fuel coefficient} = \frac{14\,900^{\frac{2}{3}} \times 14.17^3}{12.98}$$

$$= 132\,700$$

40. Normal rudder force F_n

$$= 577\, A\, v^2 \sin\alpha \quad \text{N}$$

Transverse force F_t

$$= 577\, A\, v^2 \sin\alpha \cos\alpha \quad \text{N}$$

$$= 577 \times 15 \left(1.2 \times 20 \times \frac{1852}{3600}\right)^2 \times 0.5 \times 0.866$$

$$= 571.29 \text{ kN}$$

Heeling moment $= 571.29 \times (5 - 3.3) \cos\theta$

$= 971.2 \cos\theta$ kN m

Righting moment

$$= \Delta g\, GZ$$

$$= \Delta g\, GM \sin\theta$$

Steady heel will be produced when the heeling moment is equal to the righting moment.

$$12\,000 \times 9.81 \times 0.3 \sin\theta = 971.2 \cos\theta$$

$$\tan\theta = \frac{971.2}{12\,000 \times 9.81 \times 0.3}$$

$$= 0.0275$$

Angle of heel $\theta = 1° 36'$

41.

Item	mass	Lcg	moment forward	moment aft
Cargo	10 000	3.0	30 000	3 000
Fuel	1 500	2.0		3 200
Water	400	8.0		
Stores	100	10.0	1 000	10 000
Lightship	4 000	2.5		
Displacement	16 000		31 000	16 200

Excess moment forward $= 31\,000 - 16\,200$

$= 14\,800$ tonne m

$$\text{LCG from midships} = \frac{14\,800}{16\,000}$$

$= 0.925$ m forward

From hydrostatic data at 16 000 tonne displacement: $d = 8.25$ m; MCT1 cm = 179 t m; LCB = 2.02 m F; LCF = 0.57 m A.

Trimming lever $= 2.02 - 0.925$

$= 1.095$ m aft

$$\text{Trim} = \frac{16\,000 \times 1.095}{179}$$

$= 97.88$ cm by the stern

$$\text{Change forward} = -\frac{97.88}{120}\left(\frac{120}{2} + 0.57\right)$$

$= -49.40$ cm

$$\text{Change aft} = +\frac{97.88}{120}\left(\frac{120}{2} - 0.57\right)$$

$= 48.48$ cm

Draught forward $= 8.250 - 0.494$

$= 7.756$ m

$$\text{Draught aft} = 8.250 + 0.485$$
$$= 8.735 \text{ m}$$

42. $$KB = \frac{3.0}{2}$$
$$= 1.5 \text{ m}$$
$$BM = \frac{9^2}{12 \times 3}$$
$$= 2.25 \text{ m}$$
$$GM = 1.5 + 2.25 - 3.5$$
$$= 0.25 \text{ m}$$
$$\text{Displacement } \Delta = 30 \times 9 \times 3 \times 1.025$$
$$= 830.25 \text{ tonne}$$
$$\text{Righting moment} = \Delta \times GZ$$
$$\text{Heeling moment} = 10 \times 6$$

(a) $$\therefore \quad 10 \times 6 = 830.25\, GZ$$
$$= 830.25 \sin\theta\,(GM + \tfrac{1}{2} BM \tan^2\theta)$$
$$= 830.25 \sin\theta\,(0.25 + \frac{2.25}{2} \tan^2\theta)$$
$$0.07227 = \sin\theta\,(0.25 + .125 \tan^2\theta)$$

This expression may be solved graphically.

θ	$\tan\theta$	$\tan^2\theta$	$1.125\tan^2\theta$	$\sin\theta$	GZ
5°	0.0875	0.00766	0.00861	0.0872	0.0226
10°	0.1763	0.03108	0.03497	0.1736	0.0495
15°	0.2680	0.07182	0.08080	0.2588	0.0856
20°	0.3640	0.13250	0.14906	0.3420	0.1365

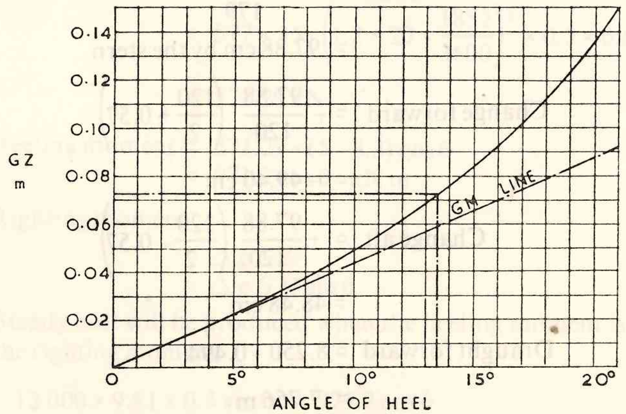


Fig. 133

$$\text{From graph when } GZ = 0.07227$$
$$\text{Angle of heel } \theta = 13° \, 30'$$
$$GZ = GM \sin\theta$$
$$0.07227 = 0.25 \sin\theta$$
$$\sin\theta = \frac{0.07227}{0.25}$$
$$= 0.28908$$
$$\text{Angle of heel } \theta = 16° \, 48'$$

43. Let V = reduced speed in knots

Normally at V knots the consumption per day would be:

$$47 \times \left(\frac{V}{17}\right)^3 \text{ tonne}$$

$$\text{Actual cons/day:} \quad 22 = 1.132 \times 47 \times \left(\frac{V}{17}\right)^3$$
$$V^3 = \frac{22 \times 17^3}{1.132 \times 47}$$
$$\text{Reduced speed } V = 12.66 \text{ knots}$$
$$\text{At 17 knots, time taken} = \frac{3000}{17 \times 24}$$
$$= 7.353 \text{ days}$$
$$\text{and voyage consumption} = 7.353 \times 47$$
$$= 345.6 \text{ tonne}$$
$$\text{At 12.66 knots, time taken} = \frac{3000}{12.66 \times 24}$$
$$= 9.872 \text{ days}$$
$$\text{and voyage consumption} = 9.872 \times 22$$
$$= 217.2 \text{ tonne}$$
$$\text{Difference in consumption} = \frac{345.6 - 217.2}{345.6} \times 100$$
$$= 37.15\%$$

44. Bodily sinkage $= \dfrac{180}{18}$

$= 10$ cm

Trimming moment $= 180 \times (40 + 3)$

$$\text{MCT1 cm} = \frac{14\,000 \times 127}{100 \times 135}$$

$$\text{Change in trim} = \frac{180 \times 43 \times 100 \times 135}{14\,000 \times 127}$$

$= 58.76$ cm by the head

$$\text{Change forward} = +\frac{58.76}{135}\left(\frac{135}{2} + 3\right)$$

$= +\ 30.68$ cm

$$\text{Change aft} = -\frac{58.76}{135}\left(\frac{135}{2} - 3\right)$$

$= -\ 28.08$

New draught forward $= 7.30 + 0.10 + 0.307$
$= 7.707$ m

New draught aft $= 8.05 + 0.10 - 0.281$
$= 7.869$ m

45. Theoretical speed $V_t = \dfrac{5.5 \times 93 \times 60}{1852}$

$= 16.57$ knots

Let ship speed $= V$

Then $$-S = \frac{V_t - V}{V_t}$$

$$-S\,V_t = V_t - V \qquad \ldots(1)$$

and $$+S = \frac{V_t - 0.9V}{V_t}$$

$$+S\,V_t = V_t - 0.9V \qquad \ldots(2)$$

Adding (1) and (2) $\quad 0 = 2V_t - 1.9V$

$$V = \frac{2 \times 16.57}{1.9}$$

Ship speed $V = 17.44$ knots

Substituting for V:

$$-S = \frac{16.57 - 17.44}{16.57}$$

$= -0.0525$

i.e. apparent slip $= -\ 5.25\%$
and real slip $= +\ 5.25\%$

46.

½ ord	SM	product	lever	product	lever	product
1	1	1	+4	+ 4	+4	+ 16
7	4	28	+3	+ 84	+3	+252
10.5	2	21	+2	+ 42	+2	+ 84
11	4	44	+1	+ 44	+1	+ 44
11	2	22	0	+174	0	0
10.5	4	42	−1	− 42	−1	+ 42
8	2	16	−2	− 32	−2	+ 64
4	4	16	−3	− 48	−3	+144
0	1	—	−4	—	−4	—
		190		−122		+646

$h = 15$ m

(a) Waterplane area $A = \frac{2}{3} \times 15 \times 190$
$= 1900$ m²

TPC $= 1900 \times 0.01025$
$= 19.475$

(b) LCF from midships $\bar{x} = \dfrac{15(174 - 122)}{190}$
$= 4.11$ m aft

(c) Second moment about midships
$= \frac{2}{3} \times 15^3 \times 646$
$= 1\,453\,500$ m⁴

$A\bar{x}^2 = 1900 \times 4.11^2$
$= 32\,095$ m⁴

Second moment about centroid

$$= 1\,453\,500 - 32\,095$$

$$= 1\,421\,405 \text{ m}^4$$

47. Centrifugal force $= \dfrac{\Delta v^2}{r}$

$$= \frac{\Delta}{600}\left(\frac{12 \times 1852}{3600}\right)^2$$

$$= 0.06\,352\,\Delta$$

Heeling moment $= \text{CF} \times GL \cos\theta$

$$= 0.06\,352\,\Delta \times 2.7 \cos\theta$$

Righting moment $= \Delta g\, GM \sin\theta$

$$= 0.25 \times 9.81\,\Delta \sin\theta$$

$$0.25 \times 9.81\,\Delta \sin\theta = 0.06\,352 \times 2.7\,\Delta \cos\theta$$

$$\tan\theta = \frac{0.06\,352 \times 2.7}{0.25 \times 9.81}$$

$$= 0.06\,993$$

Angle of heel $\theta = 4°$

48.

V	ep_n	$ep = ep_n \times 1.3$	QPC	dp
15	3000	3900	0.73	5342
16	3750	4875	0.73	6678
17	4700	6110	0.72	8486
18	5650	7345	0.71	10 345

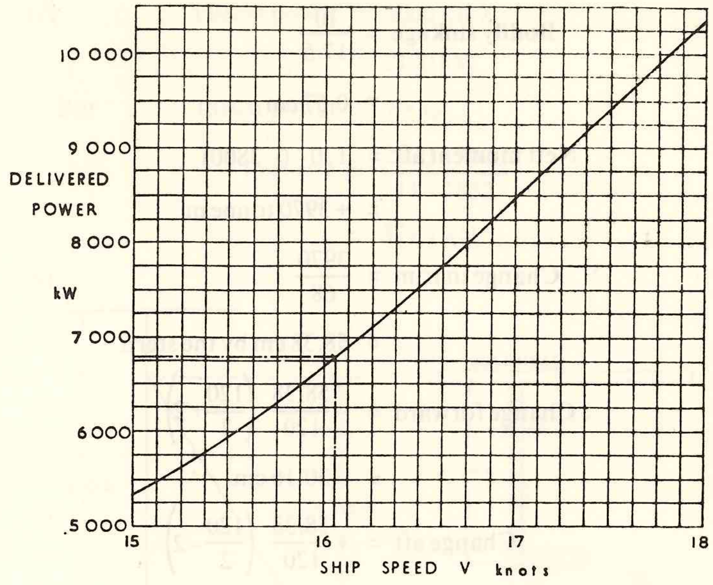


Fig. 134

Total brake power $= 2 \times 3500$
$= 7000$ kW

Total delivered power $= 7000\,(1 - 0.03)$
$= 6790$ kW

From graph: service speed = 16.06 knots

49. MCT 1 cm $= \dfrac{8000 \times 102}{100 \times 120}$

$= 68$ tonne m

Note: The distances must be measured from the LCF.

	mass	distance from F	moment forward	moment aft
Fuel used	+200	20 F	+4000	
Water used	+100	1 A		+100
Stores used	+ 10	7 A		+ 70
Ballast added	−300	26 F	−7800	
	+ 10		−3800	+170

$$\text{Bodily sinkage} = \frac{10}{17.5}$$

$$= 0.57\,\text{cm}$$

$$\text{Nett moment aft} = 170 - (-3800)$$

$$= +3970\,\text{tonne m}$$

$$\text{Change in trim} = \frac{3970}{68}$$

$$= 58.38\,\text{cm by the stern}$$

$$\text{Change forward} = -\frac{58.38}{120}\left(\frac{120}{2}+2\right)$$

$$= -30.16\,\text{cm}$$

$$\text{Change aft} = +\frac{58.38}{120}\left(\frac{120}{2}-2\right)$$

$$= +28.22\,\text{cm}$$

$$\text{Original draught forward} = 6.30 + 0.006 - 0.302$$

$$= 6.004\,\text{m}$$

$$\text{Original draught aft} = 6.60 + 0.006 + 0.282$$

$$= 6.888\,\text{m}$$

50.

$$V_t = \frac{5.5 \times 80 \times 60}{1852}$$

$$= 14.25\,\text{knots}$$

(a)

$$\text{Real slip} = \frac{14.25 - 11}{14.25}$$

$$= 0.2281$$

$$\text{or } 22.81\%$$

(b)

$$\text{Wake fraction} = \frac{13.2 - 11}{13.2}$$

$$= 0.167$$

(c)

$$\text{Thrust power} = 3000 \times 0.7$$

$$= 2100\,\text{kW}$$

But

$$\text{thrust power} = T \times v_a$$

$$\therefore \quad \text{Thrust } T = \frac{2100 \times 3600}{11 \times 1852}$$

$$= 371.1\,\text{kN}$$

51.

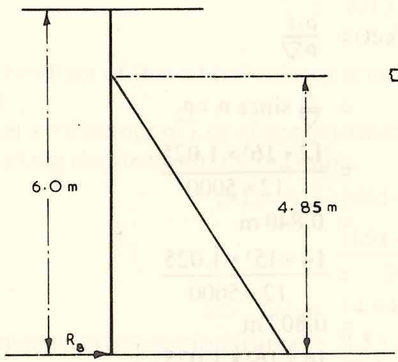


Fig. 135(a)

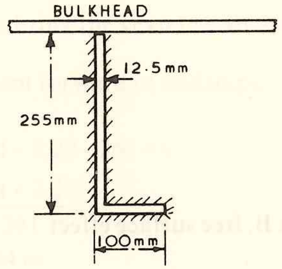


Fig. 135(b)

$$\text{Load on stiffener} = \rho g A H$$

$$= 1.025 \times 9.81 \times 4.85 \times 0.6 \times \frac{4.85}{2}$$

$$= 70.96\,\text{kN}$$

$$\text{Centre of pressure from surface} = \frac{2}{3} \times 4.85$$

$$= 3.233\,\text{m}$$

$$\text{Centre of pressure from top} = 3.233 + 1.15$$

$$= 4.383\,\text{m}$$

Taking moments about the top

$$R_B = 70.96 \times \frac{4.385}{6}$$

$$= 51.86\,\text{kN}$$

This is also the shear force at the bottom of the stiffener.

$$\text{Length of weld metal} = 255 + 255 + 100 + 100 - 12.5$$
$$= 697.5\text{ mm}$$
$$\text{Area of weld metal} = 697.5 \times 5$$
$$= 3487.5\text{ mm}^2$$
$$\text{Shear stress in weld} = \frac{51.86 \times 10^3}{3487.5 \times 10^{-6}}$$
$$= 14.87 \times 10^6\text{ N/m}^2$$
$$= 14.87\text{ MN/m}^2$$

52. $$\text{Tank A, free surface effect} = \frac{\rho_1 i}{\rho \nabla}$$
$$= \frac{i}{\nabla} \text{ since } \rho_1 = \rho_2$$
$$= \frac{12 \times 16^3 \times 1.025}{12 \times 5000}$$
$$= 0.840\text{ m}$$
$$\text{Tank B, free surface effect} = \frac{14 \times 15^3 \times 1.025}{12 \times 5000}$$
$$= 0.807\text{ m}$$
$$\text{Tank C, free surface effect} = \frac{14 \times 16^3 \times 1.025}{12 \times 5000}$$
$$= 0.980\text{ m}$$

The tank with the lowest free surface effect is filled first and thus they should be filled in the order B, A, C.

Note: Since the difference in free surface effect depends upon the product ($l \times b^3$), this value could have been calculated for each tank instead of the complete free surface effect.

53.

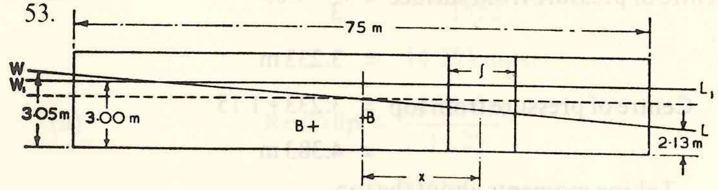


Fig. 136

$$\text{Original mean draught} = \frac{3.05 + 2.13}{2}$$
$$= 2.59\text{ m}$$
$$\text{Volume of displacement} = 75 \times 8.5 \times 2.59$$
$$= 1651\text{ m}^3$$

$$\text{LCB from midships} = \frac{37.5 \times \frac{0.46}{2} \times \frac{4}{3} \times 37.5}{75 \times 2.59}$$
$$= 2.22\text{ m aft}$$
$$\text{Final volume of displacement} = 75 \times 8.5 \times 3.0$$
$$= 1912\text{ m}^3$$

LCB at midships

Increase in volume of displacement
$$= 1912 - 1651$$
$$= 261\text{ m}^3$$

The effect of this added volume is to bring the vessel to an even keel.

Let x = distance of Lcg of compartment forward of midships

Taking moments about midships:
$$1912 \times 0 = 1651 \times 2.22 - 261 \times x$$
$$x = \frac{1651 \times 2.22}{261}$$
$$= 14.04\text{ m}$$
$$\text{Immersed cross-sectional area} = 8.5 \times 3$$
$$= 25.5\text{ m}^2$$
$$\therefore \text{Length of compartment} = \frac{261}{25.5}$$
$$= 10.24\text{ m}$$

54. $$\text{TPC} = A_W \times 0.01\,026$$
$$A_W = \frac{27.5}{0.01\,026}\text{ m}^2$$
$$\text{Change in draught} = \frac{\Delta \times 100}{A_W}\left(\frac{\rho_S - \rho_R}{\rho_R \times \rho_S}\right)\text{ cm}$$
$$25 = \frac{\Delta \times 100 \times 0.01\,026}{27.5}\left(\frac{1.026 - 1.000}{1.000 \times 1.026}\right)$$
$$= \frac{\Delta \times 0.026}{27.5}$$
$$\Delta = \frac{25 \times 27.5}{0.026}$$
$$= 26\,442\text{ tonne}$$

If, with this displacement, the vessel moves into the river water, then:

$$\text{Change in draught} = \frac{26\,442 \times 1.026}{27.5}\left(\frac{1.026 - 1.012}{1.012 \times 1.026}\right)$$
$$= 13.30\ \text{cm}$$

Thus the maximum allowable draught in the river water

$$= 8.25 + 0.133$$
$$= 8.383\ \text{m}$$

$$\text{Actual draught} = 8.44\ \text{m}$$

$$\therefore \quad \text{Excess draught} = 0.057\ \text{m}$$

$$\text{TPC in river water} = 27.5 \times \frac{1.012}{1.026}$$
$$= 27.12$$

$$\therefore \quad \text{Excess mass} = 5.7 \times 27.12$$
$$= 154.6\ \text{tonne}$$

55.

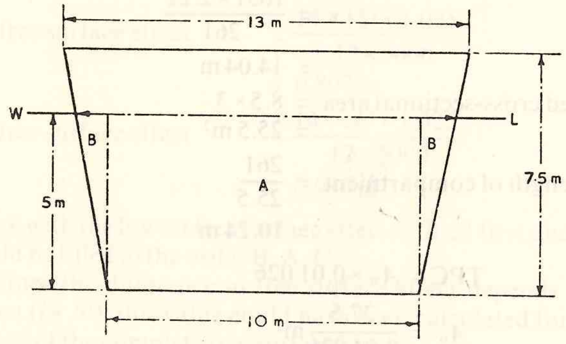


Fig. 137

$$\text{Breadth at water level} = 10 + \frac{3}{7.5} \times 5$$
$$= 12\ \text{m}$$

Divide into a rectangle A and two triangles B.

$$\text{Load on A} = \rho g A H$$
$$= 1.025 \times 9.81 \times 10 \times 5 \times 2.5$$
$$= 1256.91\ \text{kN}$$

$$\text{Centre of pressure from WL} = \tfrac{2}{3} \times 5$$
$$= 3.33\ \text{m}$$

$$\text{Load on B} = 1.025 \times 9.81 \times \tfrac{1}{2} \times 5 \times \frac{5}{3} \times 2$$
$$= 83.79\ \text{kN}$$

$$\text{Centre of pressure from WL} = \tfrac{1}{2} \times 5$$
$$= 2.5\ \text{m}$$

$$\text{Total load} = 1256.91 + 83.79$$
$$= 1340.7\ \text{kN}$$

Taking moments about the waterline:

$$\text{Centre of pressure from WL} = \frac{1256.91 \times 3.33 + 83.79 \times 2.5}{1256.91 + 83.79}$$
$$= \frac{4189.7 + 209.5}{1340.7}$$
$$= 3.281\ \text{m}$$

$\therefore$ Centre of pressure is 5.781 m from the top of the bulkhead.

56.

½ ord	½ ord³	SM	product
5.5	166.38	1	166.38
4.6	97.34	4	389.36
4.3	79.51	2	159.02
3.7	50.65	4	202.60
3.0	27.00	1	27.00
			944.36

$$h = \frac{23}{4}$$
$$= 5.75\ \text{m}$$

Second moment of area about centreline

$$= \tfrac{2}{9} \times 5.75 \times 944.36$$
$$= 1206.7\ \text{m}^4$$

$$\text{Free surface effect} = \frac{\rho_l i}{\rho \nabla}$$

$$0.2 = \frac{\rho_l \times 1206.7 \times 1.025}{1.025 \times 5350}$$

$$\text{Density of liquid } \rho_l = \frac{0.2 \times 5350}{1206.7}$$
$$= 0.887\ \text{t/m}^3$$

57.

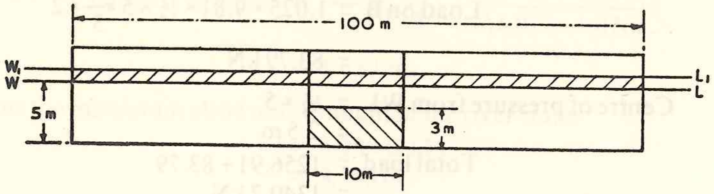


Fig. 138

Before bilging: $KB = \frac{5}{2}$

$= 2.5\text{ m}$

$BM = \frac{B^2}{12 \times 5}$

$KG = 2.5 + \frac{B^2}{60} - 0.8$

$= 1.7 + \frac{B^2}{60}$

After bilging:

Increase in draught $= \frac{10 \times B \times 3}{100 \times B}$

$= 0.3\text{ m}$

New draught $= 5.3\text{ m}$

$$KB_1 = \frac{100 \times 5.3 \times \frac{5.3}{2} - 10 \times 3 \times \frac{3}{2}}{100 \times 5.3 - 10 \times 3}$$

$$= \frac{1404.5 - 45}{100 \times 50}$$

$= 2.719\text{ m}$

$$B_1M_1 = \frac{100 + B^3}{12 \times 100 \times B \times 5}$$

$$= \frac{B^2}{60}$$

New metacentric height $GM_1 = KB_1 + B_1M_1 - KG$

$$= 2.719 + \frac{B^2}{60} - \left(1.7 + \frac{B^2}{60}\right)$$

$= 1.019\text{ m}$

58. (a) Show that $C = \frac{\Delta^{\frac{2}{3}} V^3}{\text{sp}}$

(b) Displacement $= 160 \times 22 \times 9.2 \times 0.765 \times 1.025$

$= 25\,393$ tonne

Theoretical speed $V_t = \frac{4.0 \times 96 \times 60}{1852}$

$= 12.44$ knots

Real slip $0.33 = \frac{12.44 - V_a}{12.44}$

$V_a = 12.44\,(1 - 0.33)$

$= 8.335$ knots

Wake fraction $0.335 = \frac{V - V_a}{V}$

$0.665V = V_a$

$V = \frac{8.335}{0.665}$

$= 12.53$ knots

Admiralty Coefficient $= \frac{25\,393^{\frac{2}{3}} \times 12.53^3}{2900}$

$= 585.9$

At 15 knots: shaft power $= 2900 \times \left(\frac{15}{12.53}\right)^3$

$= 4976\text{ kW}$

59. Wetted surface area of ship

$= 2.57\sqrt{24\,000 \times 180}$

$= 5341\text{ m}^2$

Wetted surface area of model

$= 5241 \times \left(\frac{6}{180}\right)^2$

$= 5.934\text{ m}^2$

Model:

$$R_t = 40\text{ N in FW}$$

$$R_f = 0.492 \times 5.934 \times 3.6^{1.825} = 30.24\text{ N in FW}$$

$$R_r = 40 - 30.24 = 9.76\text{ N in FW} = 9.76 \times 1.025 = 10.004\text{ N in SW}$$

Ship:

$$R_r \propto L^3$$

$$\therefore \quad R_r = 10.004 \times \left(\frac{180}{6}\right)^3 = 270\,110\text{ N}$$

$$V \propto \sqrt{L}$$

$$\therefore \quad V = 3.6\sqrt{\frac{180}{6}} = 19.72\text{ knots}$$

$$R_f = 0.421 \times 5341 \times 19.72^{1.825} = 518\,930\text{ N}$$

$$R_t = 518\,930 + 270\,110 = 789\,040\text{ N}$$

$$ep_n = 789\,040 \times 19.72 \times \frac{1852}{3600} \times 10^{-3} = 8005\text{ kW}$$

60. (a) Description

(b)

	mass	deflection	deviation
	3 tonne	64 mm S	64 mm
	3 tonne	116 mm S	52 mm
	6 tonne	3 mm S	113 mm
	3 tonne	54 mm P	57 mm
	3 tonne	113 mm P	59 mm
	6)18 tonne		6)345 mm
Mean	3 tonne		57.5 mm

$$\tan\theta = \frac{57.5}{5.5 \times 1000}$$

$$GM = \frac{m \times d}{\Delta \times \tan\theta} = \frac{3 \times 12 \times 5500}{8000 \times 57.5} = 0.430\text{ m}$$

61. Change in mean draught

$$= \frac{\Delta \times 100}{A_w}\left(\frac{\rho_S - \rho_R}{\rho_R \times \rho_S}\right)\text{ cm}$$

$$= \frac{8000 \times 100 \times 1.024}{16 \times 100}\left(\frac{1.024 - 1.000}{1.000 \times 1.024}\right)$$

$$= 12\text{ cm increase}$$

Shift in centre of buoyancy

$$= \frac{\rho_S - \rho_R}{\rho_S} \times FB$$

$$= \frac{1.024 - 1.000}{1.024} \times (3.0 - 0.6)$$

$$BB_1 = 0.05625\text{ m aft}$$

$$\text{Change in trim} = \frac{8000 \times 0.05\,625}{65} = 6.92\text{ cm by the head}$$

$$\text{New trim} = 30 - 6.92 = 23.08\text{ cm}$$

$$\text{Moment required} = 23.08 \times 65$$

$$\therefore \text{Distance moved by mass} = \frac{23.08 \times 65}{50} = 30.00\text{ m}$$

Total change in trim = 30 cm by the head

$$\text{Change forward} = +\frac{30}{110}\left(\frac{110}{2}+3\right)$$

$$= +15.8\text{ cm}$$

$$\text{Final level keel draught} = 6.00 + 0.12 + 0.158$$
$$= 6.278\text{ m}$$

62.

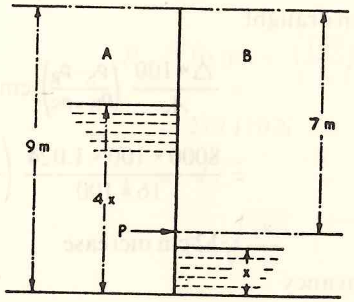


Fig. 139

Let x = height of water on side B

$4x$ = height of water on side A

$$\text{Load on side A} = \rho g A H$$
$$= 1.025 \times 9.81 \times 4x \times 14.5 \times 2x$$
$$= 145.8 \times 8x^2$$

Centre of pressure on side A

$$= \tfrac{2}{3} \times 4x \text{ from surface}$$
$$= \tfrac{1}{3} \times 4x \text{ from bottom}$$

$$\text{Load on side B} = 1.025 \times 9.81 \times x \times 14.5 \times 0.5x$$
$$= 145.8 \times 0.5x^2$$

Centre of pressure on side B

$$= \tfrac{1}{3} \times x \text{ from bottom}$$

Taking moments about the *bottom* of the bulkhead:

$$2(145.8 \times 8x^2 - 145.8 \times 0.5x^2) =$$
$$145.8 \times 8x^2 \times \frac{4x}{3} - 145.8 \times 0.5x^2 \times \frac{x}{3}$$

Dividing by $148.5x^2$:

$$2(8 - 0.5) = \frac{32x}{3} - \frac{0.5x}{3}$$

$$x = \frac{2 \times 7.5 \times 3}{31.5}$$
$$= 1.429\text{ m}$$

Height on side B = 1.429 m

Height on side A = 5.716 m

$$\text{Resultant load} = 145.8x^2(8 - 0.5)$$
$$= 2233\text{ kN}$$
$$= 2.233\text{ MN}$$

63. There are several methods of approach with this question. Probably the most straightforward is to plot curves of ep (trial) and ep (service).

V	13.0	14.1	15.2	16.3
ep_n	1690	2060	2670	3400
ep_t	1909.7	2327.8	3017.1	3842
ep_s	2247.7	2739.8	3551.1	4522

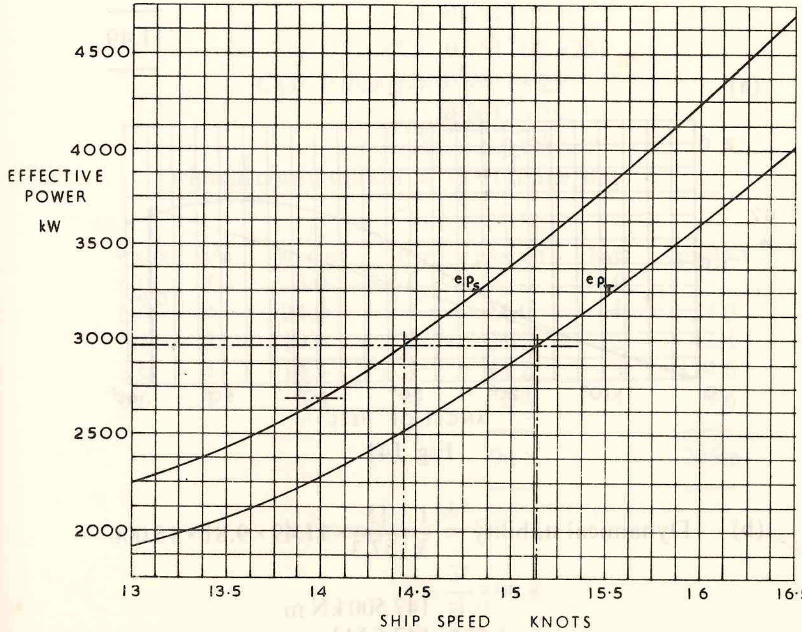


Fig. 140

At 14 knots, ep (service) = 2675 kW

$$\text{ep (max)} = \frac{2675}{0.9} = 2970\text{ kW}$$

(a) Required
$$\text{ip} = \frac{2970}{0.72 \times 0.965 \times 0.87} = 4920\text{ kW}$$

(b) At ep 2970 kW, from graph:

Service speed = 14.46 knot

Trial speed = 15.14 knot

64. $GG_1 = 0.20$ m

θ	sin θ	$GG_1 \sin\theta$	GZ	G_1Z	SM	product
0	0	0	0	0	1	0
15°	0.259	0.0518	0.38	0.43	4	1.72
30°	0.500	0.100	1.00	1.10	2	2.20
45°	0.707	0.1414	1.41	1.55	4	6.20
60°	0.866	0.1732	1.20	1.37	1	1.37
						11.49

(a)

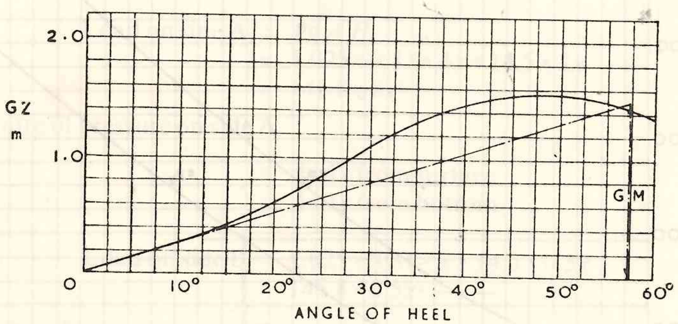


Fig. 141

(b) Dynamical stability
$$= \frac{1}{3} \times \frac{15}{57.3} \times 11.49 \times 9.81 \times 15\,000$$
$$= 147\,500\text{ kN m}$$
$$= 147.5\text{ MJ}$$

65. Let V = original speed

C = original cons/day

K = original cons for the voyage

Cons/day ∝ speed³

$$\therefore \quad \frac{C}{C+25} = \left(\frac{V}{V+1.5}\right)^3$$

Voyage cons ∝ speed²

$$\frac{K}{1.2K} = \left(\frac{V}{V+1.5}\right)^2$$

$$\sqrt{\frac{1}{1.2}} = \frac{V}{V+1.5}$$

$$V + 1.5 = \sqrt{1.2}V = 1.095\,V$$

$$V = \frac{1.5}{0.095}$$

∴ Original speed = 15.79 knots

$$\frac{C}{C+25} = \left(\frac{15.79}{15.79+1.5}\right)^3 = 0.7617$$

$$C = 0.7617\,(C + 25)$$

$$C\,(1 - 0.7617) = 0.7617 \times 25$$

$$C = \frac{0.7617 \times 25}{0.2383}$$

∴ Original consumption = 79.91 tonne/day

66.

Width	SM	product	lever	product	lever	product
6.0	1	6.0	0	—	0	—
6.0	4	24.0	1	24.0	1	24.0
5.3	2	10.6	2	21.2	2	42.4
3.6	4	14.4	3	43.2	3	129.6
0.6	1	0.6	4	2.4	4	9.6
				90.8		205.6

$$\text{1st moment} = \frac{h^2}{3}\Sigma m = \frac{3^2}{3} \times 90.8 = 272.4\text{ m}^3$$

$$\text{Load on bulkhead} = \rho g \times \text{1st moment}$$
$$= 0.80 \times 9.81 \times 272.4$$
$$= 2138 \text{ kN}$$
$$= 2.138 \text{ MN}$$

$$\text{Centre of pressure} = \frac{\text{2nd moment}}{\text{1st moment}}$$
$$= \frac{h\Sigma_I}{\Sigma_m}$$
$$= \frac{3 \times 205.6}{90.8}$$
$$= 6.79 \text{ m from top of bulkhead}$$

67.

V (knot)	12.50	13.25	14.00
ep (kW)	1440	1800	2230
QPC	0.705	0.713	0.708
dp (kW)	2042	2525	3150

$$\text{dp} = \frac{\text{ep}}{\text{QPC}}$$

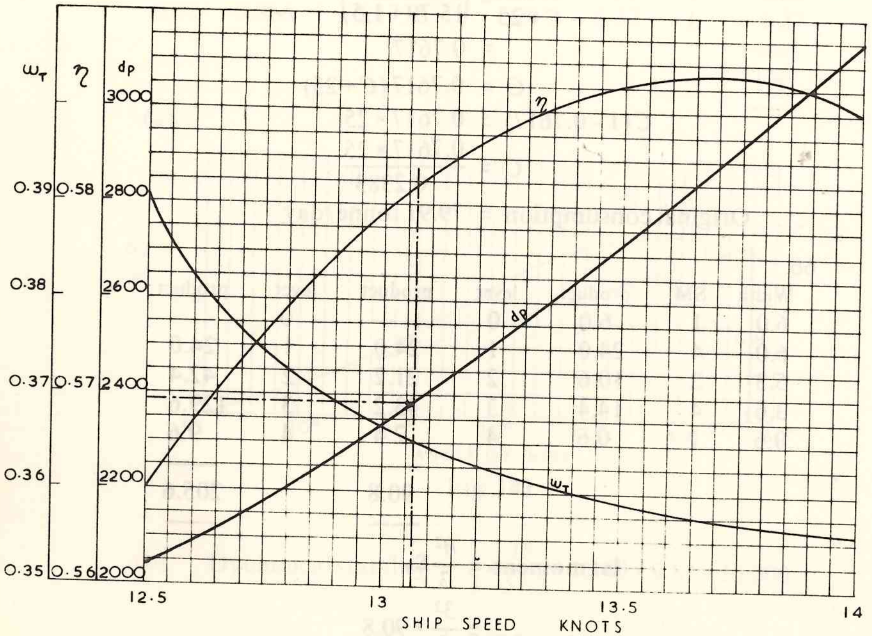


Fig. 142

From graph, when dp is 2385 kW,

$$\text{Ship speed} = 13.06 \text{ knot}$$

At this speed, $w_t = 0.365$ and propeller efficiency = 0.581

$$\text{Thrust power} \quad \text{tp} = 2385 \times 0.581$$
$$= 1385 \text{ kW}$$
$$\text{Ship speed} = 13.06 \times \frac{1852}{3600}$$
$$= 6.72 \text{ m/s}$$
$$0.365 = \frac{6.72 - v_a}{6.72}$$
$$v_a = 6.72(1 - 0.365)$$
$$= 4.266 \text{ m/s}$$
$$\text{tp} = T \times v_a$$
$$\text{Propeller thrust} \quad T = \frac{1385}{4.266}$$
$$= 325 \text{ kN}$$

68.

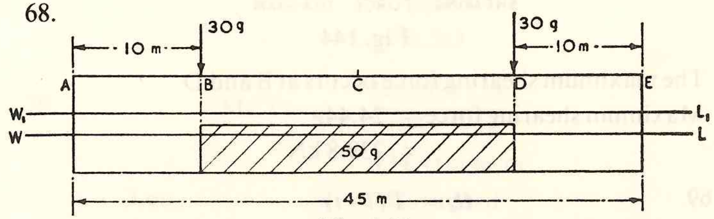


Fig. 143

Since initially the load is uniformly distributed along the vessel's length there will be no shearing force.

After the addition of the masses there will be shearing forces due to the difference in loading along the length of the vessel.

Uniformly distributed load, B to D.

$$= \frac{50g}{25}$$
$$= 2g \text{ kN/m}$$

Additional buoyancy required

$$= \left(\frac{30 + 30 + 50}{45}\right) g$$
$$= 2.444g$$

Shearing force at A $= 0$

Shearing force at left hand of B

$$= 2.444g \times 10$$
$$= 24.44g$$

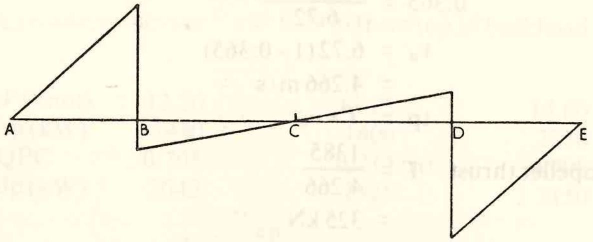
Shearing force at right hand of B

$$= 24.44g - 30g$$
$$= -5.56g$$

Shearing force at C $= 2.444g \times 22.5 - 30g - 2.0g \times 12.5$

$$= 55g - 30g - 25g$$
$$= 0$$

Since the vessel is symmetrically loaded, these values will be repeated, but of opposite sign.



SHEARING FORCE DIAGRAM

Fig. 144

The maximum shearing force occurs at B and D.

Maximum shearing force $= 24.44g$

$$= 239.8 \text{ kN}$$

69. $R_t = T(1 - t)$

$$= 378(1 - 0.24)$$
$$= 287.3 \text{ kN}$$

Ship speed $= 15.5 \times \dfrac{1852}{3600}$

$$= 7.974 \text{ m/s}$$

Effective power ep $= 287.3 \times 7.974$

$$= 2291 \text{ kW}$$

$$v_t = 4.87 \times 1.58$$
$$= 7.695 \text{ m/s}$$

$$0.30 = \frac{7.695 - v_a}{7.695}$$

$$v_a = 7.695(1 - 0.30)$$
$$= 5.386 \text{ m/s}$$

Taylor wake fraction $w_T = \dfrac{7.974 - 5.386}{7.974}$

$$= 0.324$$

Shaft power $\text{sp} = \dfrac{3540}{0.97}$

$$= 3649.5 \text{ kW}$$

Propulsive coefficient $= \dfrac{\text{ep}}{\text{sp}}$

$$= \frac{2291}{3649.5}$$
$$= 0.628$$

$$\text{ep} = \text{ep}_n + \text{appendage allowance}$$

$$\text{ep}_n = \frac{2291}{1.15}$$
$$= 1992 \text{ kW}$$

Quasi-Propulsive Coefficient QPC $= \dfrac{\text{ep}_n}{\text{dp}}$

$$= \frac{1992}{3540}$$
$$= 0.563$$

70. MCT1 cm $= \dfrac{14\,000 \times 120}{100 \times 125}$

$$= 134.4 \text{ tonne m}$$

Let m = mass added

d = distance of mass from F

Change in trim required $= (8.5 - 7.9)\,100$

$$= 60 \text{ cm}$$

Since the after draught remains constant, the change in trim aft must be equal to the bodily sinkage.

Change in trim aft $= \dfrac{60}{125}\left(\dfrac{125}{2} + 3\right)$

$$= 31.44 \text{ cm}$$

Bodily sinkage $= \dfrac{m}{19}$

$$\therefore \quad \frac{m}{19} = 31.44$$

$$m = 31.44 \times 19$$
$$= 597.36 \text{ tonne}$$

But change in trim $60 = \dfrac{m \times d}{\text{MCT 1 cm}}$

$$d = \frac{60 \times 134.4}{597.36}$$

$$= 13.50 \text{ m forward}$$

Thus 597.36 tonne must be added 16.50 m forward of midships.

71. When a mass is suspended from a derrick head, its centre of gravity may be taken at the derrick head.

(a) $GG_1 = \dfrac{50 \times 18}{4000}$

$= 0.225$ m up

(b) The mass has been moved the same distance:

i.e. $GG_1 = 0.225$ m up

(c) $GG_1 = \dfrac{50 \times 12}{4000}$

$= 0.15$ m up

(d) $GG_1 = \dfrac{50 \times 14}{4000}$

$= 0.175$ m outboard

72.

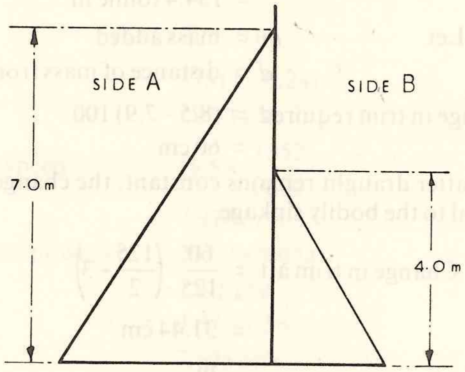


Fig. 145

$$\text{Load on side A} = \rho g A H$$

$$= 1.00 \times 9.81 \times 7 \times 8 \times \frac{7}{2}$$

$$= 1922.76 \text{ kN}$$

Centre of pressure from bottom $= \dfrac{7}{3}$ m

$$\text{Load on side B} = 0.850 \times 9.81 \times 4 \times 8 \times \frac{4}{2}$$

$$= 533.66 \text{ kN}$$

Centre of pressure from bottom $= \dfrac{4}{3}$ m

(a) Resultant load $= 1922.76 - 533.66$

$= 1389.1$ kN

(b) Take moments about the bottom of the bulkhead:

$$\text{Resultant centre of pressure} = \frac{1922.76 \times \frac{7}{3} - 533.66 \times \frac{4}{3}}{1389.1}$$

$$= \frac{4486.44 - 711.54}{1389.1}$$

$$= 2.718 \text{ m from bottom}$$

73.

Section	½ area	SM	Product for volume	lever	Product for moment
AP	0.4	1	0.4	+ 5	+ 2.0
1	7.6	4	30.4	+ 4	+ 121.6
2	21.4	2	42.8	+ 3	+ 128.4
3	33.5	4	134.0	+ 2	+ 268.0
4	40.8	2	81.6	+ 1	+ 81.6
5	45.5	4	182.0	0	+ 601.6
6	48.4	2	96.8	− 1	− 96.8
7	52.0	4	208.0	− 2	− 416.0
8	51.1	2	102.2	− 3	− 306.6
9	34.4	4	137.6	− 4	− 550.4
FP	0	1	—	− 5	—
			1015.8		− 1369.8

(a) New Displacement $= \dfrac{2}{3} \times 9.15 \times 1015.8 \times 1.025$

$= 6351.3$ tonne

Original Displacement $= 5750.0$ tonne

$\therefore$ Mass of water added $= 601.3$ tonne

(b) Moment of buoyancy about midships

$$= \frac{2}{3} \times 9.15^2 \times (1369.8 - 601.6) \times 1.025$$

$$= 43\,949 \text{ tonne m forward}$$

Original moment of buoyancy $= 5750.0 \times 4.6$

$$= 26\,450 \text{ tonne m forward}$$

$\therefore$ Moment of ballast about midships

$$= 43\,949 - 26\,450$$

$$= 17\,499 \text{ tonne m forward}$$

Centre of gravity of ballast from midships

$$= \frac{17\,499}{601.6}$$

$$= 29.09 \text{ m forward}$$

74. Mass of water pumped out $= 14 \times 12 \times 0.6 \times 1.025$
$= 103.3$ tonne

The centre of gravity of this water is 0.9 m above the keel. Taking moments about the keel:

$$\text{New } KG = \frac{7500 \times 6.7 - 103.3 \times 0.9}{7500 - 103.3}$$

$$= \frac{50\,250 - 93.0}{7396.7}$$

$$= 6.781 \text{ m}$$

$$\text{Free surface effect} = \frac{i}{\nabla}$$

$$= \frac{14 \times 12^3 \times 1.025}{12 \times 7396.7}$$

$$= 0.279 \text{ m}$$

Original $KM = 6.70 + 0.45$
$= 7.15$ m

New $GM = 7.15 - 6.781 - 0.279$
$= 0.090$ m

75. Change in mean draught

$$= \frac{\Delta \times 100}{A_w} \left(\frac{\rho_S - \rho_R}{\rho_R \times \rho_S} \right) \text{cm}$$

$$= \frac{9100 \times 100 \times 1.024}{16.8 \times 100} \left(\frac{1.024 - 1.000}{1.000 \times 1.024} \right)$$

$$= \frac{9100 \times 0.024}{16.8}$$

$$= 13.0 \text{ cm reduction}$$

Shift in centre of buoyancy

$$= \frac{\rho_S - \rho_R}{\rho_R} FB$$

$$= \frac{1.024 - 1.000}{1.000} \times (0.6 + 2.25)$$

$$= 0.0684 \text{ m}$$

$$\text{Change in trim} = \frac{9100 \times 0.0684}{122}$$

$$= 5.10 \text{ cm by the stern}$$

$$\text{Change forward} = -\frac{5.10}{120} \left(\frac{120}{2} + 0.6 \right)$$

$$= -2.6 \text{ cm}$$

$$\text{Change aft} = \frac{5.10}{120} \left(\frac{120}{2} - 0.6 \right)$$

$$= +2.5 \text{ cm}$$

New draught forward $= 6.70 - 0.13 - 0.026$
$= 6.544$ m

New draught aft $= 6.70 - 0.13 + 0.025$
$= 6.595$ m

76.

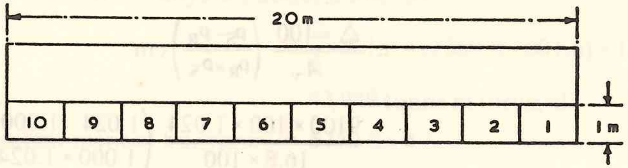


Fig. 146

$$\text{Mass added/tank} = 2 \times 10 \times 1 \times 1.025 = 20.50 \text{ tonne}$$

$$\text{Total mass added} = 41.0 \text{ tonne}$$

$$\text{mass/m} = \frac{20.5}{2} = 10.25 \text{ tonne}$$

$$\text{Weight/m} = 10.25g \quad \text{kN}$$

$$\text{Buoyancy required/m} = \frac{41.0g}{20} = 2.05g$$

Hence, in way of ballast,

$$\text{Excess load/m} = 10.25g - 2.05g = 8.20g \quad \text{kN}$$

(a) With No. 1 and No. 10 tanks filled:

S.F. at aft end of vessel $= 0$

S.F. at fore end of No. 10 $= -8.20g \times 2 = -16.40g$ kN

S.F. at midships $= -16.40g + 2.05g \times 8 = 0$

S.F. at aft end of No. 1 $= +2.05g \times 8 = +16.40g$

S.F. at fore end of vessel $= +16.40g - 8.20g \times 2 = 0$

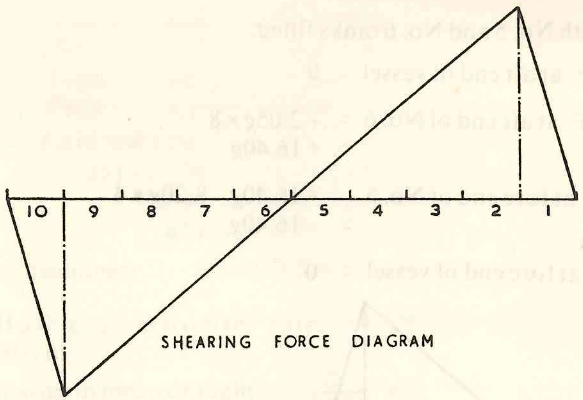


Fig. 147

(b) With No. 3 and No. 8 tanks filled:

S.F. at aft end of vessel $= 0$

S.F. at aft end of No. 8 $= +2.05g \times 4 = +8.20g$

S.F. at fore end of No. 8 $= +8.20g - 8.20g \times 2 = -8.20g$

S.F. at midships $= -8.20g + 2.05g \times 4 = 0$

S.F. at aft end of No. 3 $= +2.05g \times 4 = +8.20g$

S.F. at fore end of No. 3 $= +8.20g - 8.20g \times 2 = -8.20g$

S.F. at fore end of vessel $= 0$

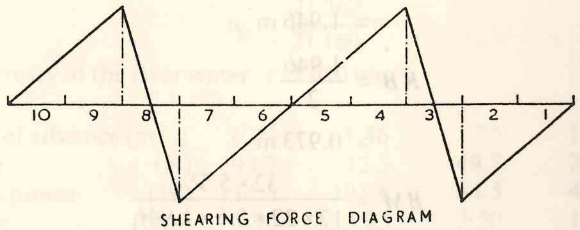


Fig. 148

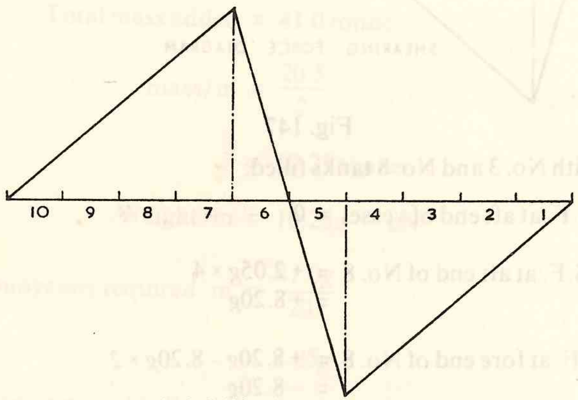
(c) With No. 5 and No. 6 tanks filled:

S.F. at aft end of vessel $= 0$

S.F. at aft end of No. 6 $= +2.05g \times 8$
$= +16.40g$

S.F. at fore end of No. 5 $= +16.40g - 8.20g \times 4$
$= -16.40g$

S.F. at fore end of vessel $= 0$



SHEARING FORCE DIAGRAM

Fig. 149

The maximum shearing force in case (b) is half of the maximum values in cases (a) and (c). Thus (b) is the best loaded condition.

77. Final displacement $= 216 + 81 + 54$
$= 351$ tonne
$= L \times B \times d \times \rho$

$$\text{New draught} = \frac{351}{32 \times 5.5 \times 1.025}$$
$$= 1.946 \text{ m}$$

$$KB = \frac{1.946}{2}$$
$$= 0.973 \text{ m}$$

$$BM = \frac{32 \times 5.5^3}{12 \times 32 \times 5.5 \times 1.946}$$
$$= 1.295 \text{ m}$$

$KM = 0.973 + 1.295$
$= 2.268$ m

Final $GM = 0.130$ m

$\therefore$ Final $KG = 2.138$ m

Let $x = Kg$ of machinery

$351 \times 2.138 = 216 \times 1.8 + 81x + 54 \times 0.15$
$750.44 = 388.8 + 81x + 8.1$
$81x = 353.54$

Kg of machinery $x = 4.365$ m

78. If a ship moves from sea water of 1.025 t/m³ into fresh water of 1.000 t/m³,

$$\text{change in mean draught} = \frac{\Delta}{40\,\text{TPC}} \text{ cm}$$

$$\therefore \quad 23 = \frac{\Delta}{40 \times 23}$$

$$\Delta = 23 \times 40 \times 23$$

21 160 tonne

The draught in the river water is the same as the allowable draught in the fresh water, but the displacement is 202 tonne greater, i.e. 21 362 tonne.

Let ρ_R = density of river water

Volume of displacement in fresh water

$$= \frac{21\,160}{1.000} \text{ m}^3$$

Volume of displacement in river water

$$= \frac{21\,362}{\rho_R} \text{ m}^3$$

But volume in fresh water = volume in river water

$$\frac{21\,160}{1.000} = \frac{21\,362}{\rho_R}$$

$$\rho_R = \frac{21\,362}{21\,160}$$

Density of the river water $= 1.010$ t/m³

79.

Speed of advance (m/s)	1.22	1.46	1.70	1.94
Thrust (N)	93.7	72.3	49.7	24.3
Thrust power (W)	114.3	105.6	84.5	47.1
Torque (Nm)	3.90	3.23	2.50	1.61
Delivered power (W)	196.1	162.4	125.7	80.9

$$\text{Thrust power} = \text{thrust} \times \text{speed of advance}$$
$$\text{Delivered power} = \text{torque} \times 2\pi \times \text{rev/s}$$

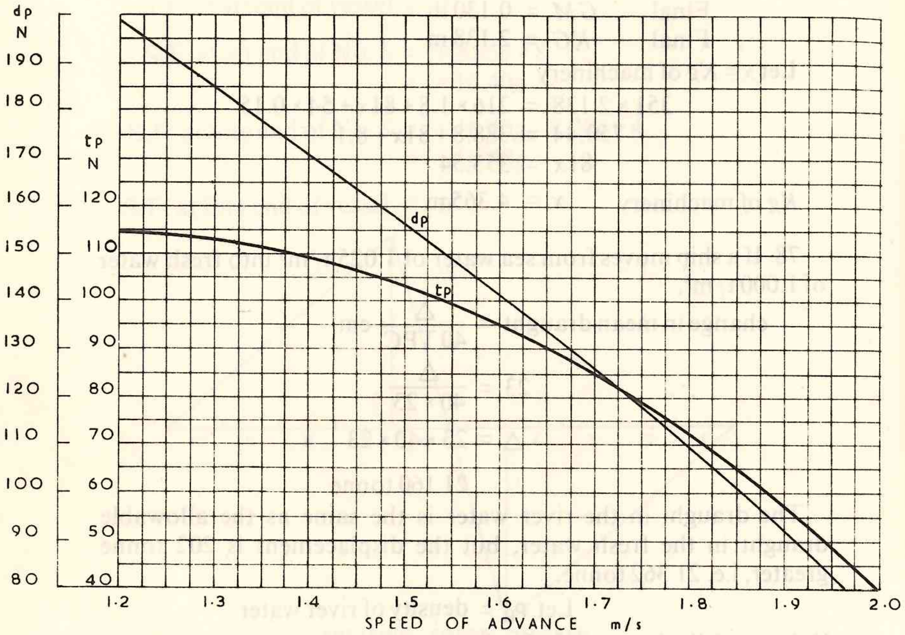


Fig. 150

For ship dp 3000 kW in sea water

$$\text{Equivalent for model} \quad dp = 3000 \times \left(\frac{0.3}{4.8}\right)^{3.5} \times \frac{1.00}{1.025}$$
$$= 178.6\ \text{W}$$

From graph at this dp: $v_a = 1.348$ m/s
and at this speed: tp = 111.1 W

$$\text{(a)} \quad \text{For ship} \quad tp = 111.1 \times \left(\frac{4.8}{0.3}\right)^{3.5} \times \frac{1.025}{1.00}$$
$$= 1866\ \text{kW}$$

$$\text{(b) Propeller efficiency} = \frac{1866}{3000} \times 100$$
$$= 62.2\%$$

80.

Draught	C_W	SM	Product for volume	(1) lever	Product for vert. moment	LCF	Product for (2) longl. moment
1.22	0.78	1	0.78	1	0.78	+ 1.30	+ 1.014
2.44	0.82	4	3.28	2	6.56	+ 1.21	+ 3.969
3.66	0.85	2	1.70	3	5.10	+ 0.93	+ 1.581
4.88	0.88	4	3.52	4	14.08	+ 0.50	+ 1.760
6.10	0.90	1	0.90	5	4.50	- 0.06	- 0.054
			10.18		31.02		8.270

(1) Levers taken from the keel

(2) Product of volume column and LCF

$$\text{(a) Displacement of layer} = \frac{1.22}{3} \times 10.18 \times 128 \times 16.75 \times 1.025$$
$$= 9097.8\ \text{tonne}$$

$$\text{(b) (i) Longitudinal moment} = \frac{1.22}{3} \times 8.27 \times 128 \times 16.75$$

$$\text{LCB of layer from midships} = \frac{\frac{1.22}{3} \times 8.27 \times 128 \times 16.75}{\frac{1.22}{3} \times 10.18 \times 128 \times 16.75}$$
$$= \frac{8.27}{10.18}$$
$$= 0.812\ \text{m forward}$$

$$\text{(ii) Vertical moment} = \frac{1.22^2}{3} \times 31.02 \times 128 \times 16.75$$

$$\text{VCB of layer from keel} = \frac{\frac{1.22^2}{3} \times 31.02 \times 128 \times 16.75}{\frac{1.22}{3} \times 10.18 \times 128 \times 16.75}$$
$$= \frac{1.22 \times 31.02}{10.18}$$
$$= 3.717\ \text{m}$$

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