

Design procedure

Properties of Irregular shapes

a) Properties of irregular shapes:

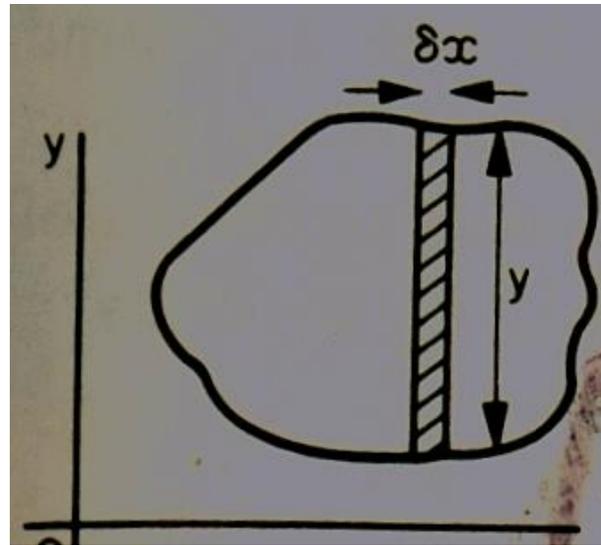
The Geometry of the ship has been defined, it is necessary to anticipate what properties of these shapes are going to be useful and find out how to calculate them.

(i) Plane shapes (Two dimensional shapes)

Water planes, transverse sections, flat decks, bulk heads, the curve of areas and expansion of curved surfaces are some of the plane shapes whose properties are of interest. The area of a plane surface shape in the plane OXY defined in Cartesian co-ordinates is

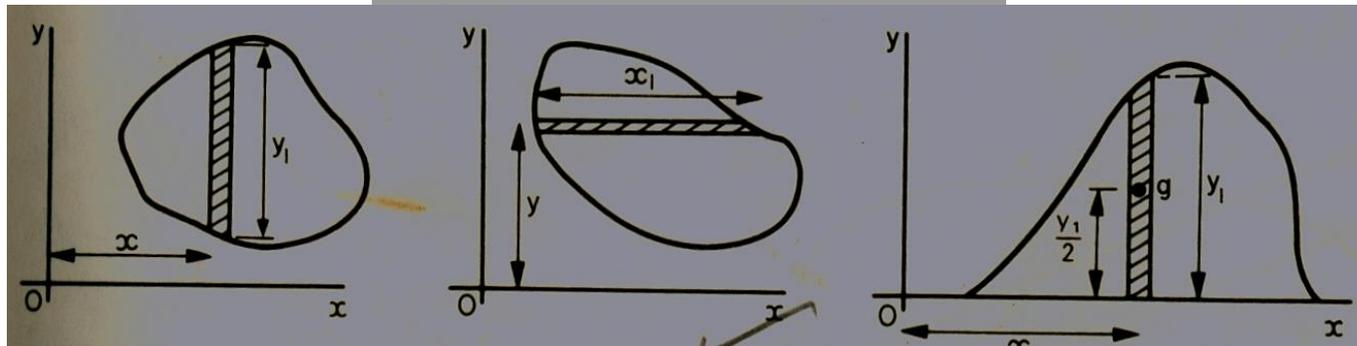
$$A = \int y \, dx$$

In which all strips of length y and width $/x$ are summed over the total extent of x . Because y is rarely, with ship shapes a precise mathematical function of x the integration must be carried out by an approximate method.



There are first moments of area about each axis (x_1 and y_1 are lengths and x and y are co-ordinates)

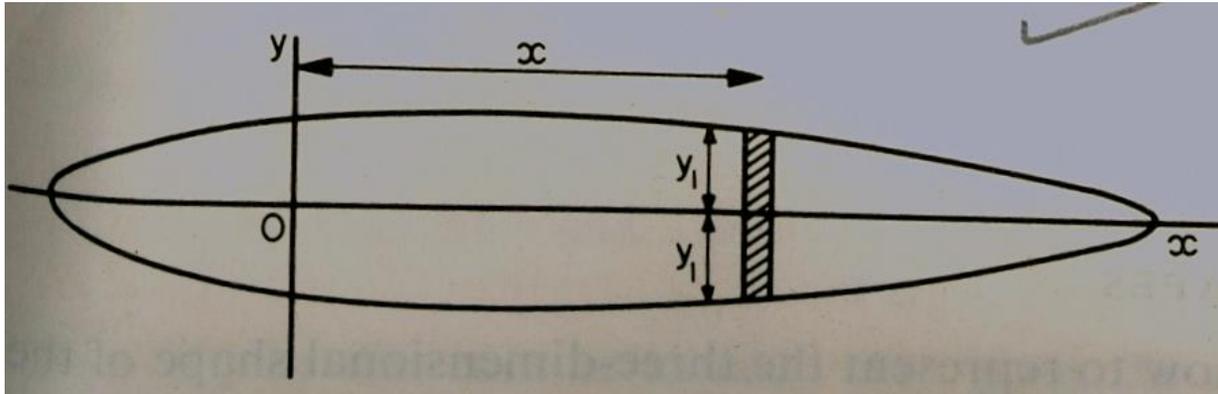
$$X = M_{yy} = \int xy_1 dx \quad \text{and} \quad \int x_1 y dy = M_{xx} = y$$



Dividing each expression by the area gives the co-ordinates of the centre of area (x, y)

$$x = \frac{1}{A} \int x y_1 dx \quad y = \frac{1}{A} \int y x_1 dy$$

For a plane figure placed symmetrically about the x- axis such as a water plane $M_{xx} = \int x^2 y dy = 0$ and the distance of the centre of area called in the particular case of water plane, the centre of Floatation (CF) from the y axis is given by

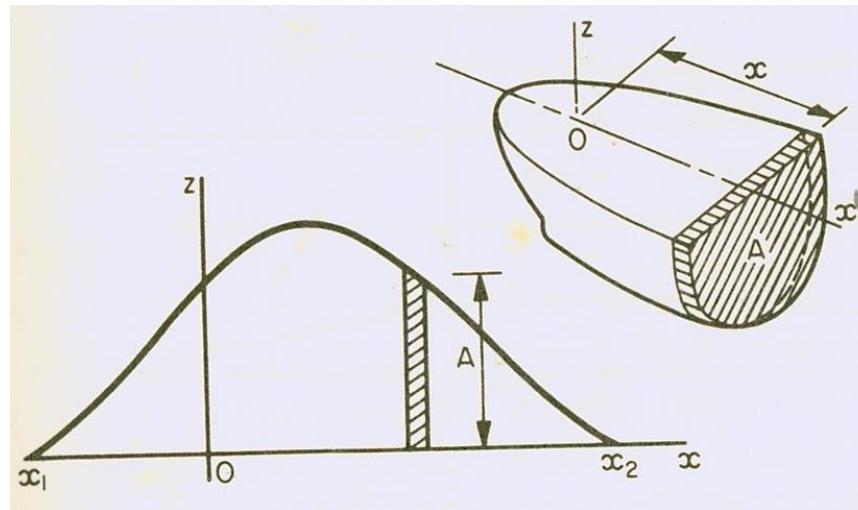


(ii) Three dimensional shapes:

The ships under water form can be represented by three–dimensional shape. The volume of displacement is given by

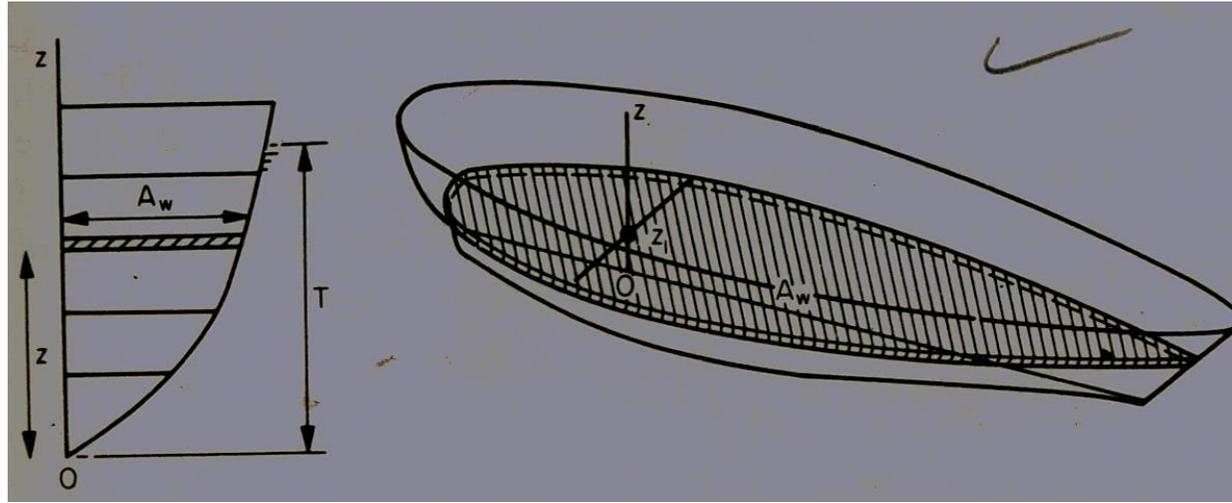
$$\nabla = \int_{x_1}^{x_2} A \, dx$$

It is the sum of all such slices of cross-sectional area A over the total extent of “ x ”.



The shape of the ship can be equally represented by a curve of water plane areas on a vertical axis, the breadth of the curve at any height, Z above the keel representing the area of the water plane at that draught. The volume of displacement is again sum of all slices of cross – sectional area A_w over the total extent of Z from zero to draught.

$$\nabla = \int_0^d A_w dz$$



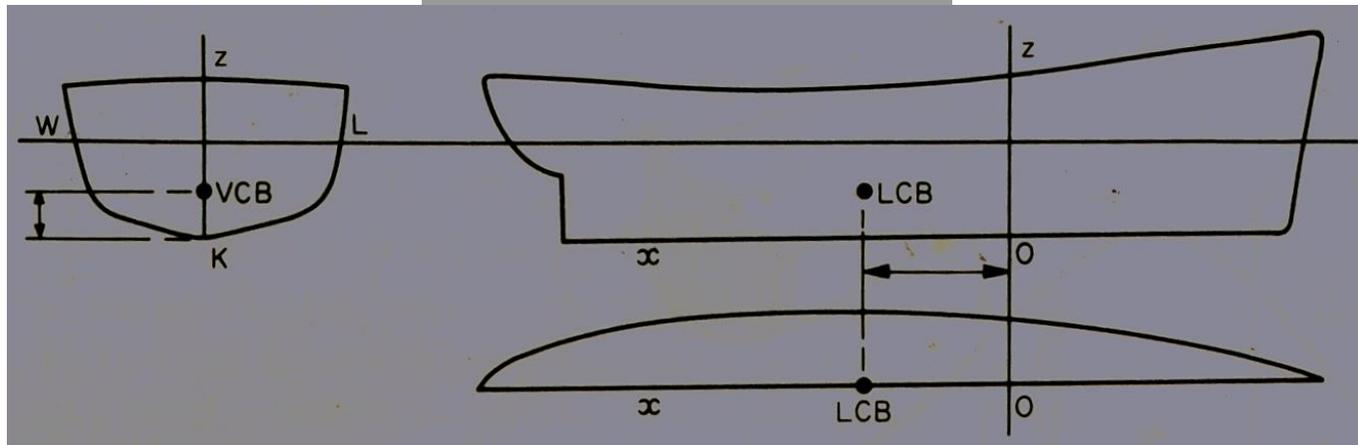
The first moments of volume in the longitudinal direction about OZ and in the vertical direction about the keel is given by

$$ML = \int A X dx \text{ and } Mv = \int_0^d A_w Z dz$$

Dividing by the volume in each case gives the co-ordinates of the centre of volume. The centre of volume of fluid displaced by a ship is known as the centre of buoyancy. Its projection in the plan and in sections is known as the Longitudinal Centre of Buoyancy (L.C.B.) and the Vertical Centre of Buoyancy (V.C.B.)

$$\text{L.C.B. from OY} = \frac{1}{\nabla} \int A X dx$$

$$\text{V.C.B. above the keel} = \frac{1}{\nabla} \int A_w Z dz$$



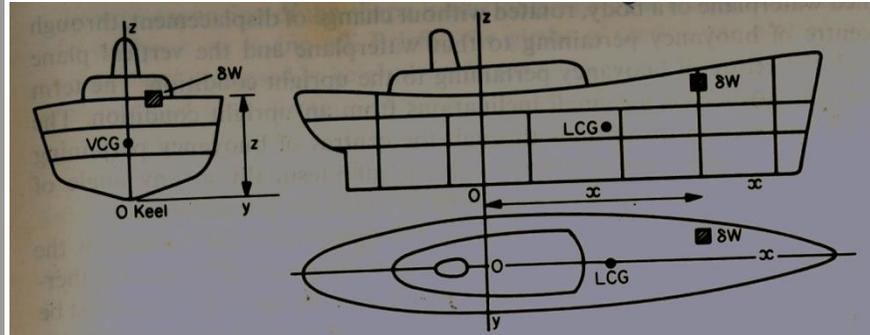
Should the ship not be symmetrical below the water line, the centre of buoyancy will not lie in the middle line plane. The centre of buoyancy of a floating body is the centre of volume of the displaced fluid in which the body is floating. The first moment of volume about the centre of volume is zero.

The weight of a body is the total of the weights of all of its constituent parts. First moment of the weights about particular axes divided by the total weight, define the co-ordinates of the centre of weight or centre of gravity (C.G) relative to those axes.

Projections of the centre of gravity of a ship in plan and in section are known as the Longitudinal Centre of Gravity (L.C.G.) and Vertical Centre of Gravity (V.C.G.)

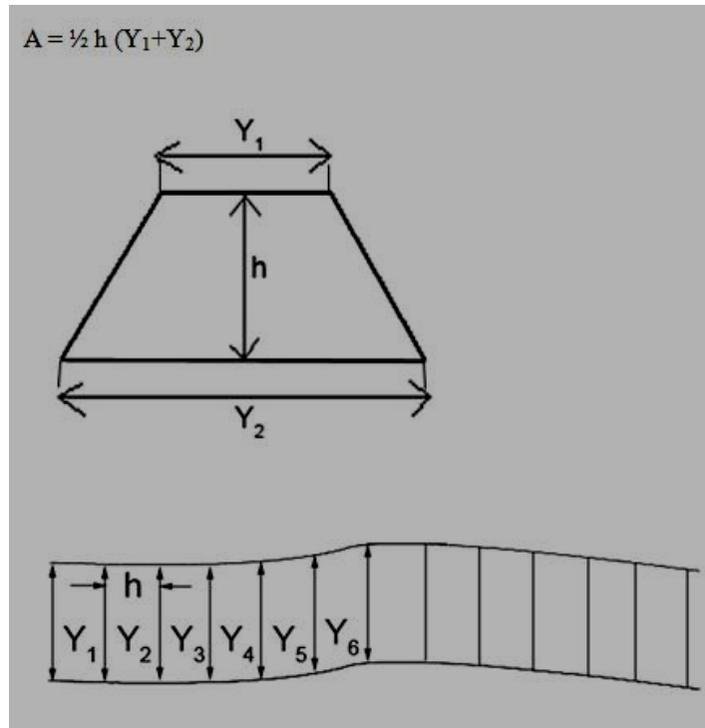
$$\text{L.C.G. from OY} = \frac{1}{W} \int X dw$$

$$\text{V.C.G. above keel} = \frac{1}{W} \int Z dw$$



The trapezoidal rule

A trapezoid is a plane four sided figure having two sides parallel. If the lengths of these sides are Y_1 and Y_2 and they are h apart, the area of the trapezoid is given by



A curvilinear figure can be divided into number of approximate trapezoids by covering it with 'n' equally spaced ordinates 'h' apart, the breadths at the ordinates in order being $Y_1, Y_2, Y_3 \dots \dots \dots Y_n$. Commencing with the left hand trapezoid, the areas of each trapezoid are given by

$$a_1 = \frac{1}{2} h (Y_1 + Y_2) \quad a_2 = \frac{1}{2} h (Y_2 + Y_3)$$

$$a_3 = \frac{1}{2} h (Y_3 + Y_4) \dots \dots \dots a_n$$

By addition the total area A of the figure is given by

$$A = \frac{1}{2} h (Y_1 + 2Y_2 + 2Y_3 + 2Y_4 + 2Y_5 + \dots \dots \dots + Y_n) \text{ OR}$$

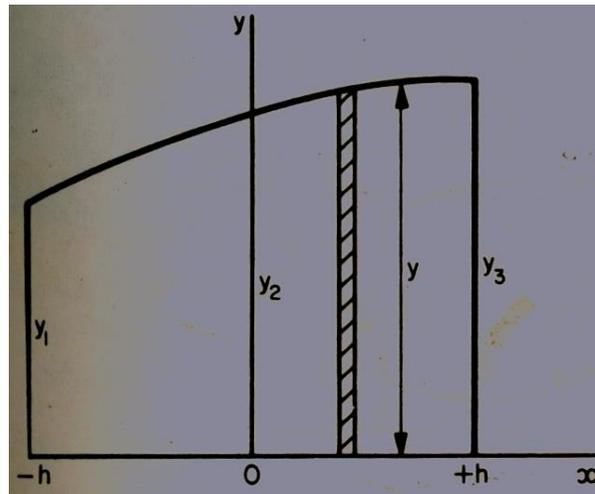
$$A = h \left(\frac{Y_1 + Y_2 + Y_3 + Y_4 + Y_5 + \dots \dots \dots + Y_n}{2} \right)$$

This is termed as TRAPEZOIDAL RULE. The more numerous the ordinates, the most accurate will be the answer. Thus to evaluate the expression of the shape is divided into evenly spaced section 'h' apart, the ordinates measured and substituted in the rule given above. If the ordinates represent cross-sectional areas of solid, then the integration gives the volume of that solid.

$$V = \int A \, dx$$

Simpson's 1st rule

These rules are widely applied in Naval Architecture. They are a special case of the Newton's cotes rule. Let us deduce a rule for integrating a curve Y over the extent of x . It will be convenient to choose the origin to be in the middle of the base $2h$ long having ordinates Y_1 , Y_2 and Y_3 . The choice of origin in no way affects the result.



Assume that the curve can be represented by an equation of the third order.

$$Y = a_0 + a_1x + a_2x^2 + a_3x^3$$

The area under the curve is given by

$$A = \int_{-h}^h y \, dx = \int_{-h}^h (a_0 + a_1x + a_2x^2 + a_3x^3) \, dx$$

$$\left[a_0x + a_1 \frac{x^2}{2} + a_2 \frac{x^3}{3} + a_3 \frac{x^4}{4} \right]_{-h}^h$$

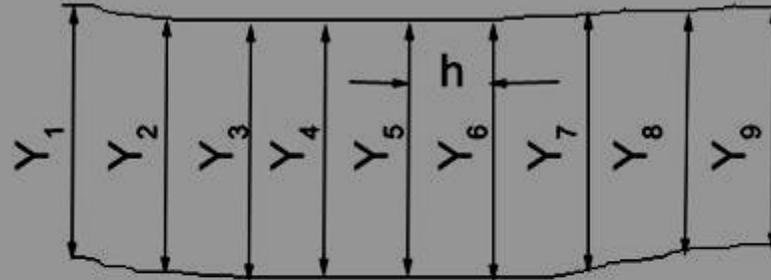
$$= a_0h + a_1 \frac{h^2}{2} + a_2 \frac{h^3}{3} + a_3 \frac{h^4}{4} + a_0h - a_1 \frac{h^2}{2} + a_2 \frac{h^3}{3} - a_3 \frac{h^4}{4}$$

$$2a_0h + \frac{2}{3} a_2h^3$$

$$2a_0h + \frac{2}{3} a_2h^3 \text{ -----equation (1)}$$

Assume now that the area can be given by the expression

$$A = LY_1 + MY_2 + NY_3 \text{ -----equation (2)}$$



Substitute $Y_1 = -h$

$$Y_2 = 0$$

$$Y_3 = +h$$

$$Y = a_0 + a_1x + a_2x^2 + a_3x^3$$

$$\text{Now } Y_1 = a_c + a_1(-h) + a_2(-h)^2 + a_3(-h)^3$$

$$Y_1 = a_c - a_1h + a_2h^2 - a_3h^3$$

$$Y_2 = a_c$$

$$Y_3 = a_c + a_1h + a_2h^2 + a_3h^3$$

Substituting in equation (2)

$$A = LY_1 + MY_2 + NY_3$$

$$= L(a_c - a_1h + a_2h^2 - a_3h^3) + M(a_c) + N(a_c + a_1h + a_2h^2 + a_3h^3)$$

$$= La_c - La_1h + La_2h^2 - La_3h^3 + Ma_c + Na_c + Na_1h + Na_2h^2 + Na_3h^3$$

$$= (L+M+N)a_c - (L-N)a_1h + (L+N)a_2h^2 - (L-N)a_3h^3 \text{ -----equation (iii)}$$

Equating co-efficient of a in equation (1) and (3)

$$L+M+N = 2h$$

$$L-N = 0$$

$$L+N = \frac{2}{3}h$$

$$L = N = \frac{1}{3}h$$

$$4$$

$$M = \frac{---}{3}h$$

$$3$$

The area can be represented by equation (ii) therefore, provided that the co-efficient are those deduced and

$$A = \frac{1}{3}hy_1 + \frac{4}{3}hy_2 + \frac{1}{3}hy_3 = \frac{1}{3}h(y_1 + 4y_2 + y_3)$$

$$1$$

$$A = \frac{---}{3}h(Y_1 + 4Y_2 + Y_3)$$

$$A_1 = \frac{h}{3} (Y_1 + 4Y_2 + Y_3)$$

Within 3 and 5 ordinates

$$A_2 = \frac{h}{3} (Y_3 + 4Y_4 + Y_5)$$

Within 5 and 7 ordinates

$$A_3 = \frac{h}{3} (Y_5 + 4Y_6 + Y_7) \text{ and so on}$$

The total area is given by

$$A = \frac{h}{3} (Y_1 + 4Y_2 + 2Y_3 + 4Y_4 + 2Y_5 + 4Y_6 + 2Y_7 + 4Y_8 + \dots + Y_n) \text{ OR}$$

$$\text{ie } \frac{h}{3} \left(\frac{Y_1}{2} + 2Y_2 + Y_3 + 2Y_4 + Y_5 + 2Y_6 + Y_7 + 2Y_8 + \dots + \frac{Y_n}{2} \right)$$

This is the generalized form of the first rule applied to areas. The common multiplier is $1/3 \times$ the common interval "h" and the individual multipliers are 1,4,2,4,2,4,2,4,1

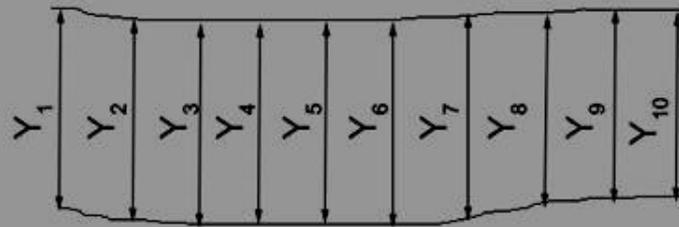
The rule is one for evaluating an integral. It is equally applicable to any integration using Cartesian or polar coordinates.

It is suitable for 3, 5, 7, 9, 11, 13 ... etc ordinates

Simpson's IInd rule

Simpson's rules for four evenly spaced ordinates becomes

$$A = \frac{3}{8} h (Y_1 + 3Y_2 + 3Y_3 + Y_4)$$



In general

$$A = \frac{3}{8} h (Y_1 + 3Y_2 + 3Y_3 + 2Y_4 + 3Y_5 + 3Y_6 + 2Y_7 + 3Y_8 + 3Y_9 + 2Y_{10} + \dots + Y_n)$$

Thus the common multiplier in this case is 3/8 times the common interval and the individual multipliers 1, 3, 3, 2, 3, 3, 2, 3, 3, 1. It is suitable for 4, 7, 10, 13, 16, 19, 22 etc., ordinates.

Displacement

a) Definition

The amount of water displaced or put aside by a freely floating ship is termed as displacement. Archimedes principle states that the body wholly or partially immersed in a fluid loses weight, equal in amount to the weight of the fluid it displaces.

This applies whether the body is heavier, lighter or equal in weight to an equal volume of fluid in which it is immersed. For a ship to float freely in water the weight of the ship must equal to the weight of the amount (volume) of water it displaces. The amount of water displaced expressed in cubic feet is called the volume of displacement. The corresponding weight of this water is known as the weight of displacement or displacement and is usually expressed in tons.

A cubic feet of sea water weights 64 lb

35 cubic feet of sea water weights one ton.

A cubic feet of fresh water weights 62.4 lb

36 cubic feet of fresh water weights 1 ton.

$$\text{Displacement in Sea Water (tons)} = \frac{\text{Volume of Displacement in cubic feet}}{35}$$

$$\text{Displacement in Fresh Water (tons)} = \frac{\text{Volume of Displacement in ft}^3}{36}$$

This is because of the actual weight of any given material is affected by its density.

Sea water – 1025 kg/m³

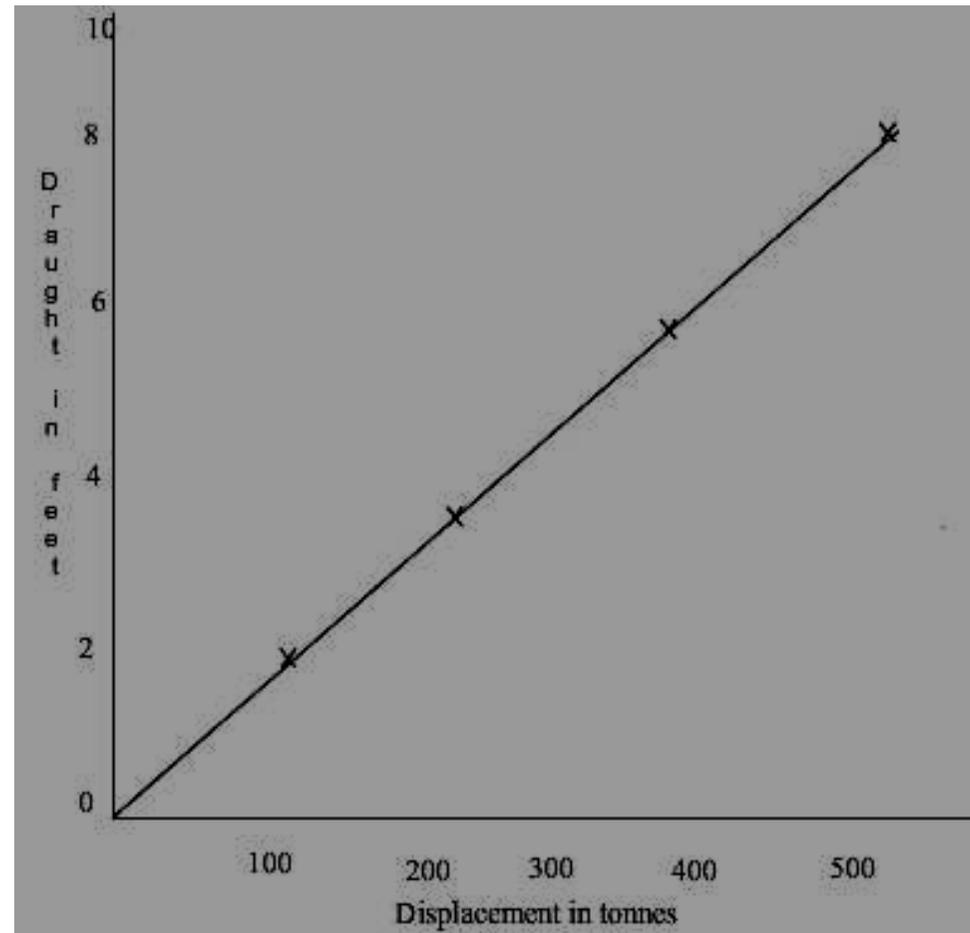
Fresh water – 1000 kg/m³

For this reason, a vessel draft alters in going from fresh water to sea water and vice versa.

The displacement of a box shaped vessel is easily obtained by multiplying the volume of displacement by the density of water in which the body floats.

In metric system Displacement = Volume of displacement x density

b) Displacement curve



Displacement curve can plot as displacement in X-axis and draught in Y-axis. Displacement curve for a vessel of a box form 100 ft long, 20 ft beam and floating in sea water at a draught of 10 ft. The displacements may be calculated at series of draughts of say 2,4,6,8 and 10 ft and set off against the vertical scale of draught. The

displacement curve in case of a box-shaped vessel is a straight line may then be drawn through the points obtained and the displacement at any intermediate draught can thus be found.

Displacement at draught of

c) Light weight and Dead weight

Light weight: This is generally defined as the weight of the ship complete and ready for sea but with no fuel, feed, water, fresh-water, store provisions, ballast, other than permanent ballast – passengers and baggage or cargo on board.

Dead weight: It is the actual amount of weight in tons that the ship can carry when loaded to the maximum draft permitted by international law. It is also defined as the total dead weight of a ship is the difference between the load displacement and the light weight. The latter comprises the net steel, wood and outfit and propelling machinery consequently the total dead weight includes 1) Cargo 2) Fuel 3) Feed and fresh water 4) Stores and provisions 5) passengers and baggage.

Displacement = Light weight + Dead weight

d) Calculation of displacement of a ship floating at a given water line Method (1)

- The bottom of the ship is assumed to be flat and the load water line is parallel to it.
- The immersed depth of a ship is divided into equal number of intervals by water planes parallel to load water plane.
 - The area of each water plane is found out by applying Simpson's rule
- The areas are treated by Simpson's multiplier. The sum of the product is multiplied by 1/3 of the common interval, if the first rule is applied and the result will be the volume of displacement.

Method (II)

- The immersed portion of the ship is divided by transverse vertical planes or sections into number of equal intervals suitable for the application of Simpson's rule.
 - The areas of these up to load water line are calculated applying Simpson's rule.
 - These areas are put through Simpson's multipliers.
 - The final result will give the loaded displacement (volume)