Chapter 5 Transverse Stability

Consider a ship floating upright as shown in Figure 5.1. The centres of gravity and buoyancy are on the centre line. The resultant force acting on the ship is zero, and the resultant moment about the centre of gravity is zero.

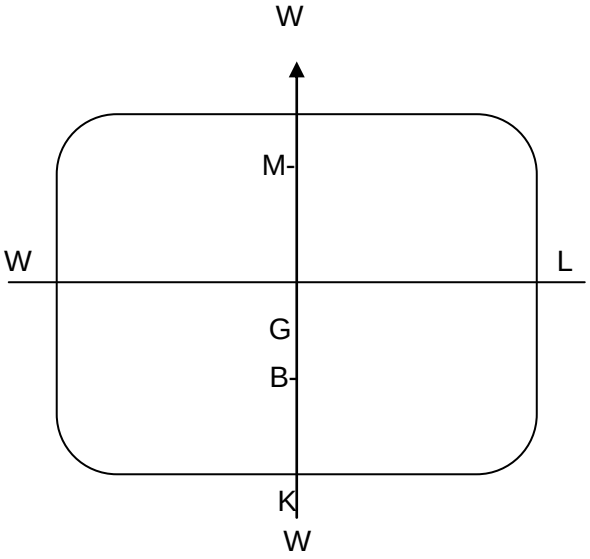


Figure. 5.1

Now let a weight already on board the ship be shifted transversely such that G moves to G_1 as in Figure 5.2. This will produce a listing moment of W X GG_1 and the ship will start to list until G_I and the centre of buoyancy are in the same vertical line as in Figure 5.3.

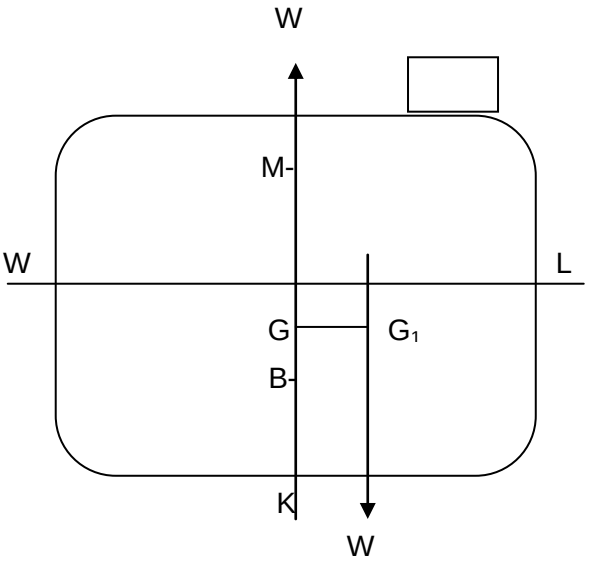


Figure. 5.2

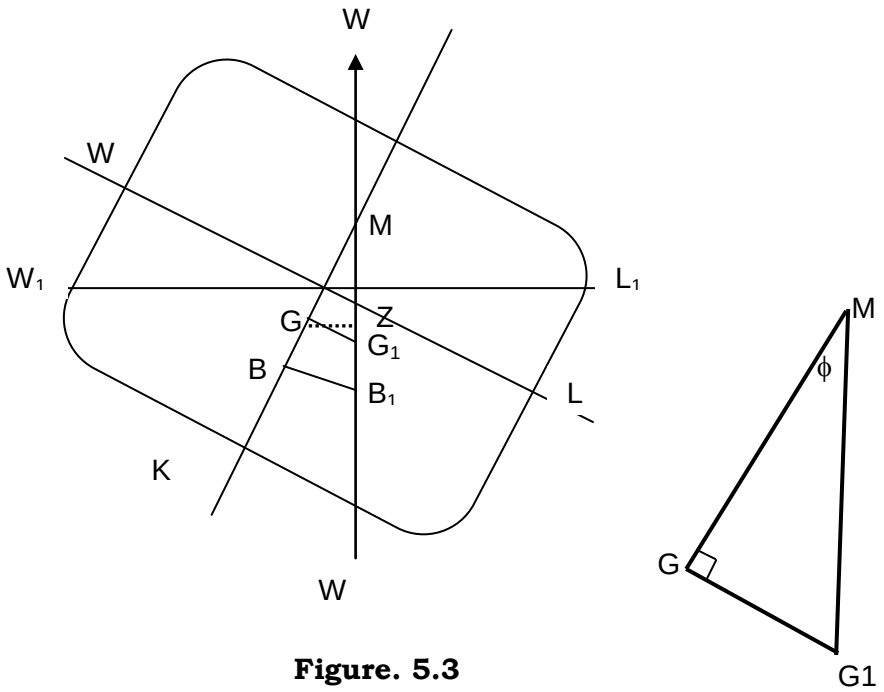


Figure. 5.3

In this position G_1 will also lie vertically under M so long as the angle *of* list is small. Therefore, if the final positions of the metacentre and the centre of gravity are known, the final list can be found, using trigonometry, in the triangle GG_1M which is right-angled at G.

In triangle GG_1M: $GG1 = \frac{w \times d}{W}$

$$\text{Tan } \phi^\circ = \frac{GG1}{GM}$$

$$\text{Tan } \phi^\circ = \frac{w \times d}{W \times GM}$$

The formula can be restated as:

$$\text{Tan } \phi^\circ = \frac{\text{listing moment}}{W \times GM}$$

It can be seen that GM plays a big role in determining angle of list. The bigger GM, the less the angle of list and vice-versa.

The final position of the centre of gravity and hence GM is found by taking moments about the keel and about the centre line as discussed in Chapter 4.

Note. It will be found more convenient in calculations, when taking moments, to consider the ship to be upright throughout the operation.

Example I

A ship of 6,000 tonnes displacement has KM = 7.3 m, and KG = 6.7 m, and is floating upright. A weight of 60 tonnes already on board is shifted 12 m transversely.
Find the resultant list.

Figure 5.4(a) shows the initial position of G before the weight was shifted and Figure 5.4(b) shows the final position of G after the weight has been shifted.

When the weight is shifted transversely the ship's centre of gravity will also shift transversely, from G to G_1. The ship will then list ϕ degrees to bring G_1 vertically under M the metacentre

GM = KM - KG = 0.6m
Listing Moment = 60 x 12 tonne-m

$$\text{Tan } \phi^\circ = \frac{60 \times 12}{6000 \times 0.6}$$

Tan ϕ° = 0.2
Ans. List = 11° 18 ½ '

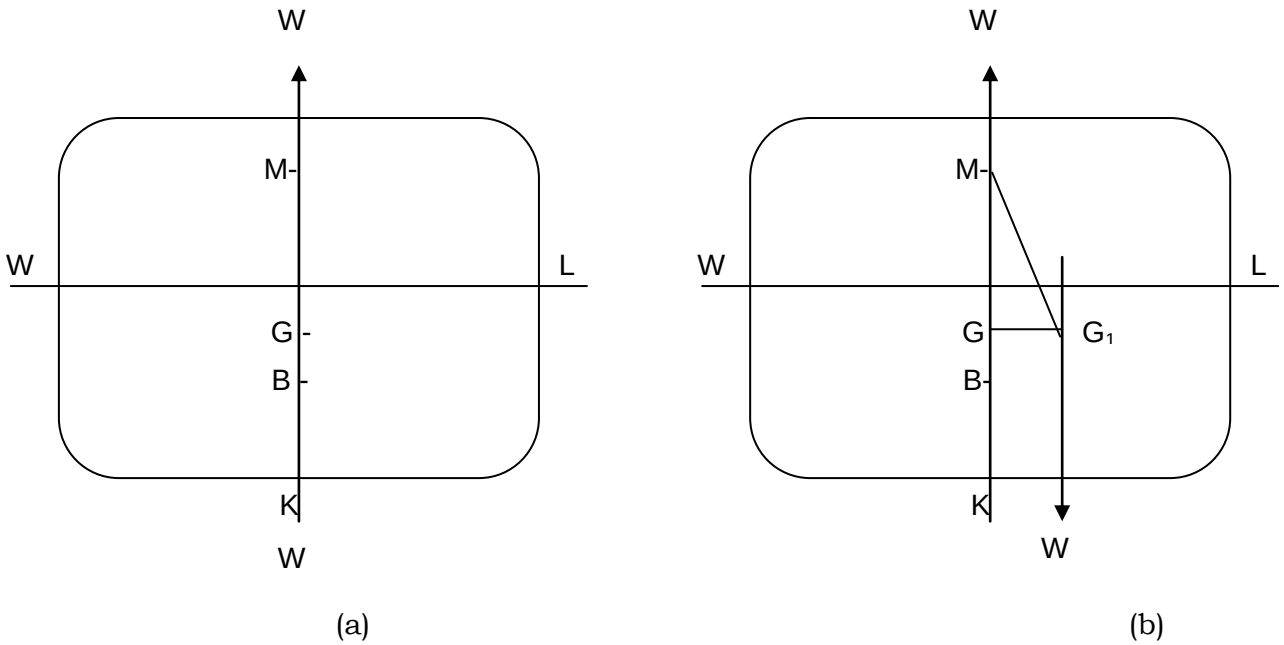


Figure. 5.4

Example 2

A ship of 8,000 tonnes displacement has KM = 8.7 m, and KG = 7.6 m The following weights are then loaded and discharged:

- Load 250 tonnes cargo KG 6.1 m and centre of gravity 7.6 m to starboard of the centre line.
- Load 300 tonnes fuel oil KG 0.6 m and centre of gravity 6.1 m to port of the centre line.

- Discharge 50 tonnes of ballast KG 1.2 m and centre of gravity 4.6 m to port of the centre line.

Find the final list.

Note. In this type of problem find the final KG by taking moments about the keel, and the final listing moment by taking moments about the centre line.

(1) Moments about the keel

Weight	KG	Moment about keel
8000	7.6	60800
250	6.1	1525
300	0.6	180
-50	1.2	-60
8500		62445

Final KG = $\frac{\text{Final moment}}{\text{Final displacement}}$

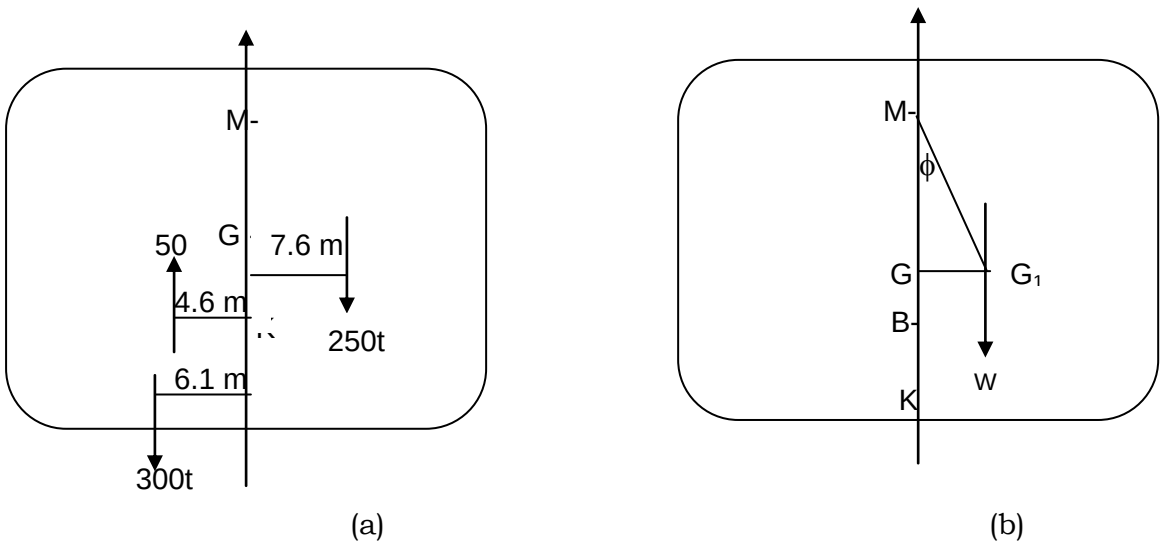
= $\frac{62.445}{8500}$

Final KG = 7.34 m

KM = 8.7 m.

Final KG = 7.34 m.

Final GM = 1.36 m.



(a) (b)

Figure 5.5

Moments about the centre line

W	*.d*	*Listing moment (tonne-m)*	
		to port	*to*

			starboard
250 -50 300	7.6 4.6 6.1	 -230 1830	1900 -
		1600	1900
Net listing moment			300

Since the final position of the centre of gravity must lie vertically under M, it follows that the ship will list ϕ degrees to starboard.

$$\text{Tan } \phi^\circ = \frac{\text{Listing Moment}}{W \times GM}$$

$$= \frac{300}{8500 \times 1.36}$$

$$\therefore \quad \phi = 1^\circ 29\ ½'$$

Ans. Final list = 1°29 ½' to starboard

Example 4

A ship of 13,750 tonnes displacement, GM = 0.75 m, is listed 2.5 degrees to starboard and has yet to load 250 tonnes of cargo. There is space available in each side of No.3 'tween deck (centre of gravity, 6.1 m out from the centre line). Find how much cargo to load on each side if the ship is to be upright on completion of loading.

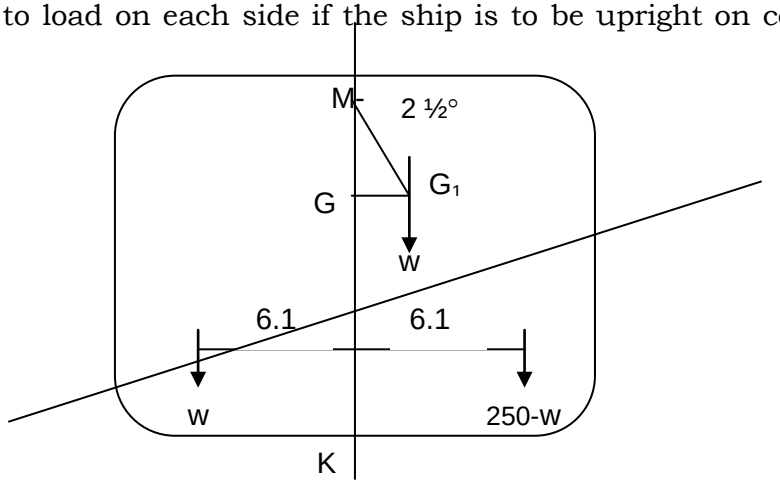


Figure 5.6

$$\text{Tan } \phi = \frac{\text{listing mmt}}{W \times GM}$$

1. Find listing moment that is initialy listing the ship to starboard;

listing moment = W x GM x tan ϕ = 13750 x 0.75 x tan 2.5 = 450.25 tonne-m S clockwise

2. Load 'w' tonnes to port and (250-w tonnes) to starboard.

Net moment of the new load (anticlockwise) must counterbalance the original moment (clockwise):

[New moment to port]– [New moment to starboard] = 450.25
[w x 6.1] – [(250 - w) x 6.1] = 450.25
w = 161.9 tonne to port
88.1 tonne to starboard

Example 5

A ship of 9,900 tonnes displacement has KM = 7.3 m and KG = 6.4 m. She has yet to load two 50 tonne boxes with her own gear and the first box ls to be placed on deck on the inshore side (KG 9 m and centre of gravity 6 m out from the centre line). When the derrick plumbs the quay its head is 15 m above the keel and 12m out from the centre line. Calculate maximum list during operation.
Note: The maximum list is obviously occur when the first box is in place on the deck and the second box is suspended over the quay as shown in Figure 5.7.

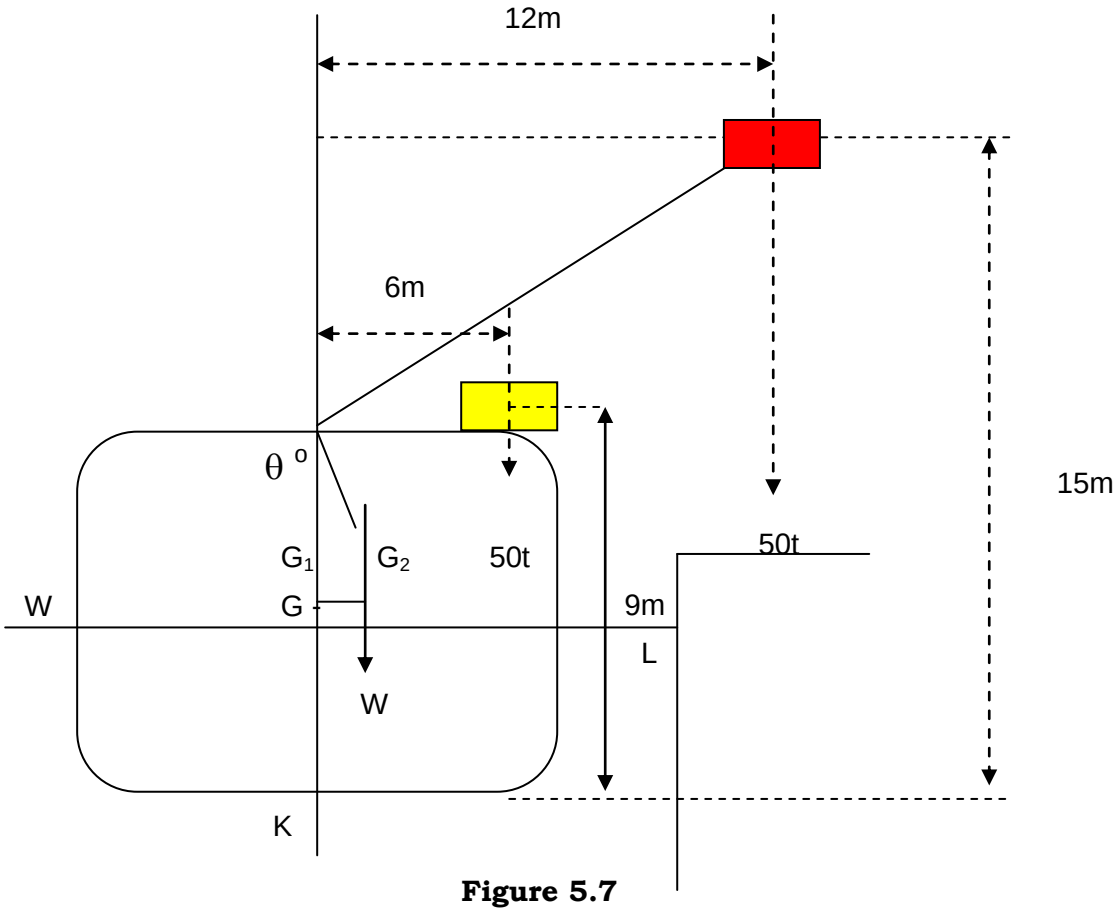


Figure 5.7

(1) Moments about the keel

weight	*KG*	*Moment*
9900	6.4	63,360

50 50	9.0 15.0	450 750
1000 0		64,560

Final KG = Final moment

Final displacement

= 64,560
10000

= 6.456m

(2) Moments about the centre line

W	*.d*	*Listing moment*	
		to port	*to starboard*
50 50	12 6	- -	600 300
			900

i.e. listing moment = 900 tonnes metres

(3)

New GM = 7.3- 6.456
= 0.844 m.

tan ϕ = Listing moment
W x GM

= 900
10000 x 0.844

Ans. Maximum list = 6° 6’

Exercise 5

1. A ship of 6,000 tonnes displacement has KM = 7.3 m, and KG = 6.7 m, and is floating at a list of 11.3 degrees to starboard. Find how much water to be transferred from starboard to port tanks, a distance of 5 meters to bring the ship to upright.

2. A ship of 5,000 tonnes displacement has KG 4.2 m, KM 4.5m and is listed 5 degrees to port. Assuming that KM remains constant, find the final list if 80 tonne of bunker is loaded in No 2 starboard tank whose centre of gravity is 1 meter above the keel and 4 metre out from the centre line. (6 deg 3 min)

3. A ship of 4,515 tonnes displacement is upright and has KG 5.4 m and KM 5.8 m It is required to list the ship 2 degrees to starboard and a weight of 15 tonnes is to be shifted transversely for this purpose. Find the distance through which it must be shifted. (4.2m)

4. A ship of 7,800 tonnes displacement has a mean draft of 6.8 m and is to be loaded to a mean draft of 7 metres. GM 0.7 m, TPC 20 tonnes. The ship is at present listed 4 degrees to starboard. How much more cargo can be shipped in the port and starboard 'tween decks, centres of gravity 6 m and 5 m respectively from the centre line, for the ship to complete loading and finish upright. (216.5 tonnes Port, 183.5 tonnes Stb)

5. A ship of 1,500 tonnes displacement has KG 2.7 m, and KM 3.1 m and is floating upright in salt water. Find final list if a weight of 10 tonnes is shifted transversely across the deck through a distance of 10 metres. (9.5 deg)

6. A weight of 12 tonnes when moved transversely across the deck through a distance of 12 m, causes a ship of 4,000 tonnes displacement to list 3.8 degrees to starboard. If KM 6 m, find the KG. (5.46m)

7. A quantity of grain, estimated at 100 tonnes, shifts 10 m horizontally and 1.5 m vertically in a ship of 9,000 tonnes displacement. If the ship's original GM was 0.5 m, find the resulting list. (13 deg)

8. A ship of *7,500* tonnes displacement has KM 8.6 m, KG 7.8 m and 20 m beam. A quantity of deck cargo is lost from the starboard side (KG 12 m and centre of gravity 6 m in from the rail). If the resulting list is 3 degrees 20 minutes to port, find how much deck cargo was lost. (XX.X tonnes)

9. A ship of 12,500 tonnes displacement, KM 7 m, KG 6.4 m, has a 3 degree list to starboard and has yet to load 500 tonnes of cargo. There is space available in the 'tween decks, centres of gravity 6 m each side of the centre line. Find how much cargo to load on each side if the ship is to complete loading upright. (282.75 tonnes P)

10. A ship is listed 2.5 degrees to port. The displacement is 8,500 tonnes KM 5.5 m, and KG 4.6 m. The ship has yet to load a locomotive of 90 tonnes mass on deck on the starboard side (centre of gravity 7.5 m from the centre line), and a tender of 40 tonnes. Find how far from the centre line the tender must be placed if the ship is to complete loading upright, and also find the final GM. (KG of the deck cargo is 7 m.)

11. A ship of 9,500 tonnes displacement is listed 3.5 degrees to starboard and has KM 9.5 m and KG 9.3 m. She loads 300 tonnes of bunkers in No.3 double-bottom tank port side (KG 0.6 m and centre of gravity 6 m from the centre line), and discharges two parcels of cargo each of 50 tonnes from the port side of No.2 Shelter Deck (KG 11 m and centre of gravity 5 m from the centre line). Find the final list. (14 deg)

12. A ship of 6,500 tonnes displacement is floating upright and has GM 0.15 m. A weight of 50 tonnes. already on board, is moved 1.5 m vertically downwards and 5m transversely to starboard. Find the list. (13 deg)

13. A ship of 5,600 tonnes displacement is floating upright and has KG 5.5 m, and GM 0.5 m. A weight of 30 tonnes is lifted from the port side of No.2 'tween deck to the starboard side of No.2 shelter deck (10 m horizontally and 3 m vertically). Find the weight of water to be transferred in No.3 double-bottom tank from starboard to port to keep the ship upright. The distance between the centres of gravity of the tanks is 6 metres.