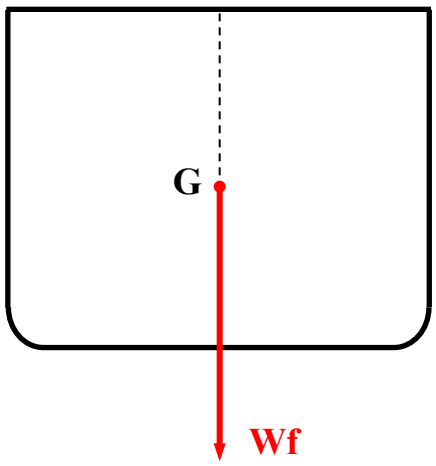
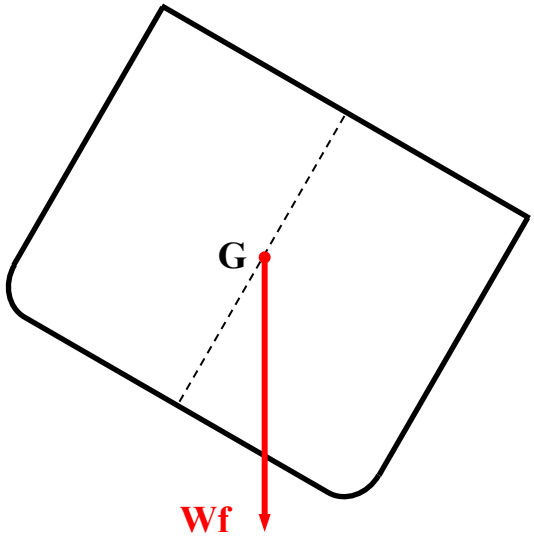
CENTRE OF GRAVITY (G)

Is the point through which the total weight force (Wf) of the ship can be considered to act vertically downwards. It's position will depend upon the distribution of the weight of the vessel and everything on board.

The position of G will not move as the ship heels (provided that weights are not caused to move within the ship). ***It always acts vertically downwards!***

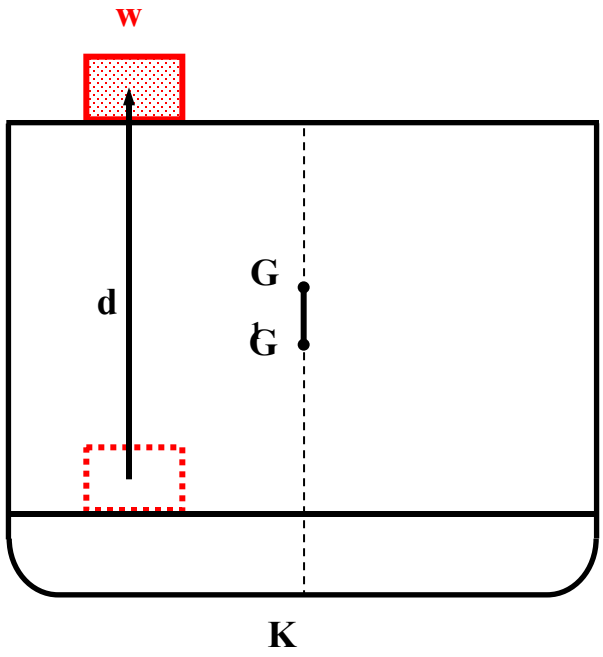




When weights are ***shifted*** on board, ***loaded*** or ***discharged*** G will move. Whenever G is caused to move the 'shift of G' must be calculated.

Effect of shifting a weight already on board

Whenever a weight already on board is shifted G will move ***parallel*** to and in the ***same direction*** as the shift of the centre of gravity of the weight (g).



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

'w' is the weight shifted.
'd' is the distance through which the weight is shifted.
'W' (Δ) is the ship's displacement

The vertical position of G is expressed in terms of metres above the keel (KG).

SAQ

A ship displaces 5000 t and has an initial KG of 4.5 m. Calculate the final KG if a weight of 20 t is moved vertically upwards from the lower hold (Kg 2.0 m) to the upper deck (Kg 6.5 m)

Answer

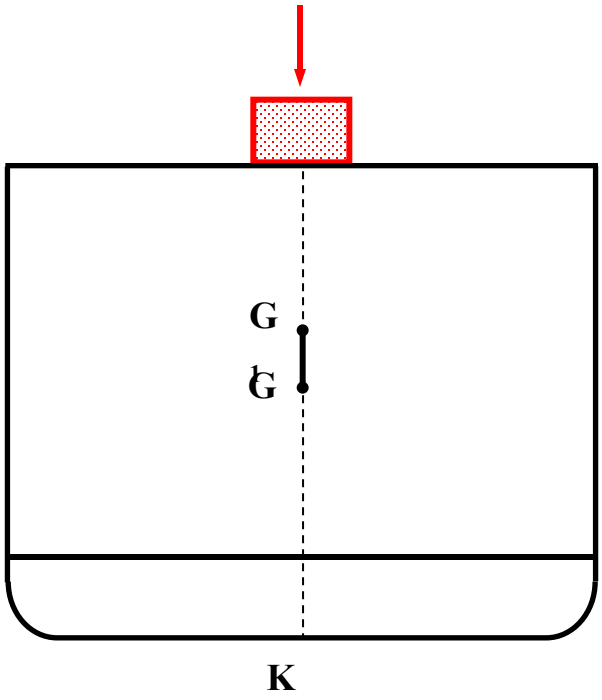
$$GG_1 = \frac{w \times d}{W} = \frac{20 \times (6.5 - 2.0)}{5000} = 0.018 \text{ m}$$

Initial KG	***= 4.500 m***
GG_1	***= 0.018 m***
FINAL KG	***= 4.518 m***

KG has increased which would make the ship less stable.

Effect of loading a weight

Whenever a weight is loaded G will move directly ***towards*** the centre of gravity of the loaded weight (g).



$$GG_1 = \frac{w \times d}{W + w}$$

'w' is the weight loaded.
'd' is the distance between G of the ship and g of the loaded weight.
'W' (Δ) is the ship's initial displacement.

SAQ

A ship displaces 12500 t and has an initial KG of 6.5 m. Calculate the final KG if 1000 t of cargo is loaded into the lower hold at Kg 3.0 m.

Answer

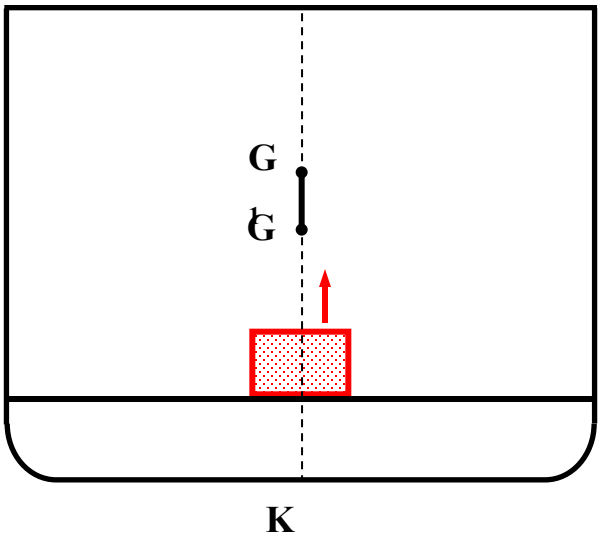
$$GG_1 = \frac{w \times d}{W + w} = \frac{1000 \times (6.5 - 3.0)}{12500 + 1000} = 0.259 \text{ m}$$

Initial KG	***= 6.500 m***
GG_1	***= 0.259 m***
FINAL KG	***= 6.241 m***

KG has decreased which would make the ship more stable.

Effect of discharging a weight

Whenever a weight is discharged G will move directly ***away*** from the centre of gravity of the discharged weight (g).



$$GG_1 = \frac{w \times d}{W - w}$$

'w' is the weight discharged.
'd' is the distance between G of the ship and g of the discharged weight.
'W' (Δ) is the ship's initial displacement.

SAQ

A ship displaces 18000 t and has an initial KG of 5.30 m. Calculate the final KG if 10000 t of cargo is discharged from the lower hold (Kg 3.0 m).

Answer

$$GG_1 = \frac{w \times d}{W - w} = \frac{10000 \times (5.3 - 3.0)}{18000 - 10000} = 2.875 \text{ m}$$

Initial KG	***= 5.300 m***
GG_1	***= 2.875 m***
FINAL KG	***= 8.175 m***

KG has increased which makes the ship less stable.

It would be very tedious to do a calculation for every single weight that was either shifted, loaded or discharged from the ship.

In practice 'moments about the keel' are used to determine the final KG of the ship.

MOMENTS (t-m) = WEIGHT (t) × DISTANCE (m)

Moments about the keel

Example

A ship displaces 10000 t and has a KG of 4.5 m.

The following cargo is worked:

Load: 120 t at Kg 6.0 m;

730 t at Kg 3.2 m.

Discharge: 68 t from Kg 2.0 m;

100 t from Kg 6.2 m.

Shift: 86 t from Kg 2.2 m to Kg 6.0 m.

Calculate the final KG.

$$\text{FINAL KG} = \frac{\text{SUM OF THE MOMENTS}}{\text{FINAL DISPLACEMENT}}$$

	WEIGHT (t)	KG (m)	MOMENTS (t-m)
Ship (+)	10000.00	4.50	45000.00
Load (+)	120.00	6.00	720.00
Load (+)	730.00	3.20	2336.00
Discharge (-)	-68.00	2.00	-136.00
Discharge (-)	-100.00	6.20	-620.00
* Discharge (-)	-86.00	2.20	-189.20
*Load (+)	86.00	6.00	516.00
FINAL	10682.00	4.459	47626.80
* Represents the weight shifted.			

SAQ

A ship displaces 14200 t and has a KG of 6.22 m.

The following cargo is worked:

Load: ***168 t at Kg 7.20 m;***

Discharge: ***348 t from Kg 4.62 m;***

266 t from Kg 5.36 m.

Shift: ***188 t from Kg 8.00 m to Kg 3.60 m.***

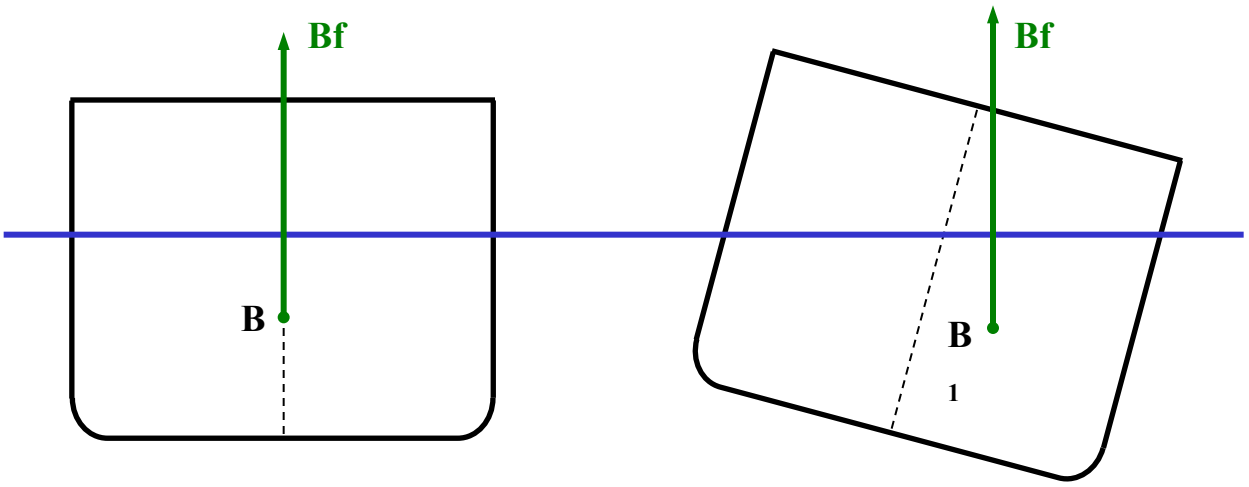
Calculate the final KG.

Answer

	WEIGHT (t)	KG (m)	MOMENTS (t-m)
Ship (+)	14200.00	6.22	88324.00
Load (+)	168.00	7.20	1209.60
Discharge (-)	-348.00	4.62	-1607.76
Discharge (-)	-266.00	5.36	-1425.76
* Discharge (-)	-188.00	8.00	-1504.00
*Load (+)	188.00	3.60	676.80
FINAL	13754.00	6.229	85672.88
* Represents the weight shifted.			

CENTRE OF BUOYANCY(B)

Is the geometric centre of the underwater volume of the ship. It is the point through which the total force of buoyancy (Bf) is considered to act vertically upwards.
It's position will constantly move as the ship moves in a seaway.



The position of B has nothing to do with the disposition of weights within the ship.

The centre of gravity (G) is assumed to remain in the same place (provided weights do not shift within the ship) as the ship heels but ***the centre of buoyancy constantly moves as the ship pitches, rolls and heaves***.

For a box-shaped vessel on even keel KB is half the draught.