Outcome 2
LESSON 7
Transverse Statical Stability

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TRANSVERSE STATICAL STABILITY

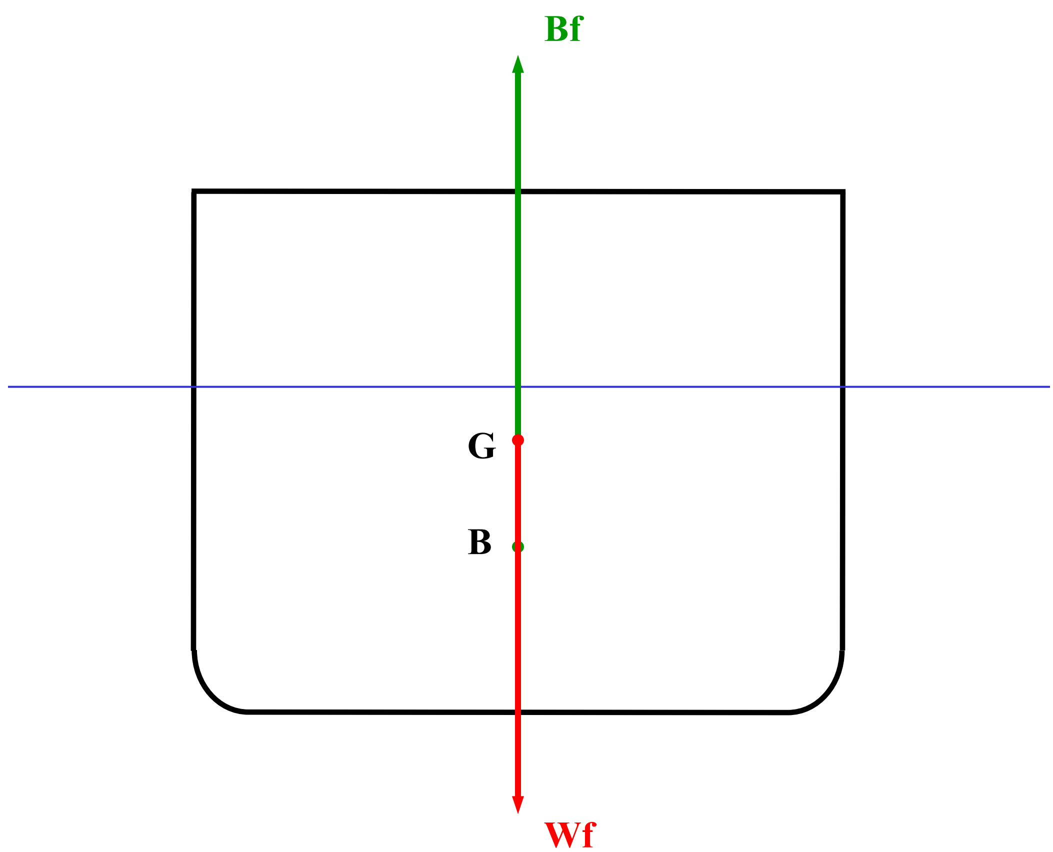
'Transverse statical stability' is a term used to describe the ability of a ship to return to the upright when it has been ***forcibly heeled*** by an ***external force*** to some angle and is ***momentarily at rest*** in ***still water***.

It is the relative positions of the centre of gravity (G) and the centre of buoyancy (B) as the ship is heeled to a particular angle that determines how stable a ship is.

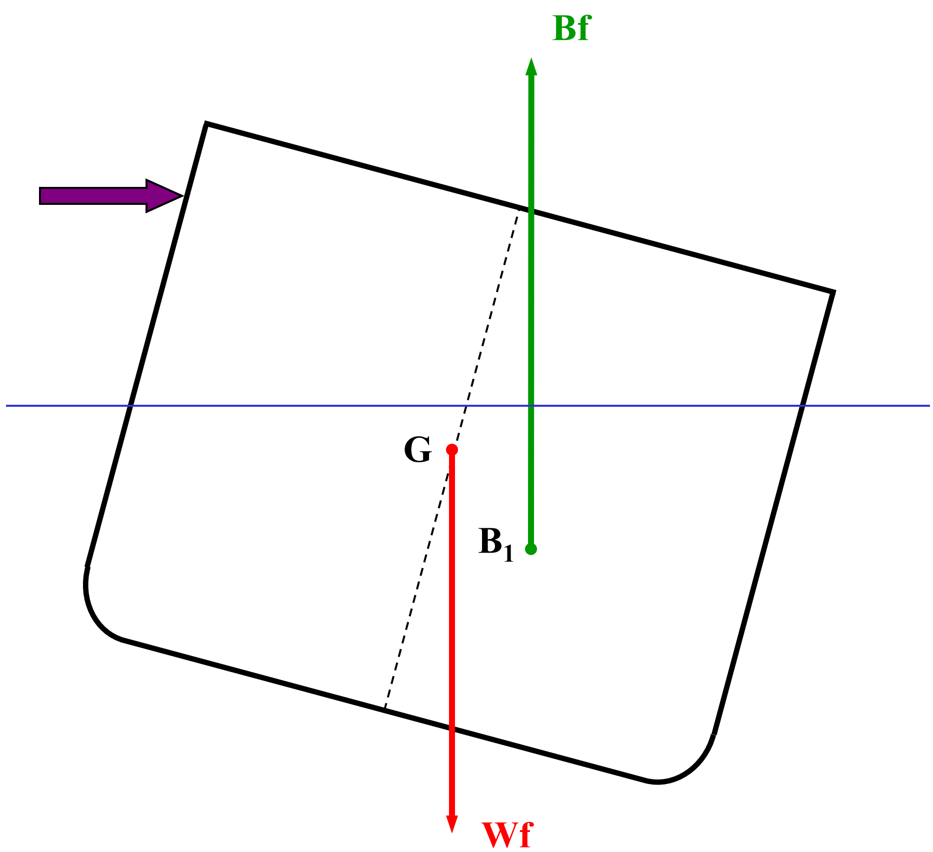
Centre of Gravity (G) – Is defined as the point through which the total weight force (Wf) of the ship can be considered to act vertically downwards. Its position depends on the distribution of the ship's structure and all weights loaded on board.

Centre of Buoyancy (B) – Is defined as being at the geometric centre of the underwater volume of the ship and is the point through which the total buoyancy force (Bf) can be considered to act vertically upwards. Its position constantly changes as the ship heels, heaves and pitches at sea.

When the ship is upright the lines of action of both the weight force (Wf) and buoyancy force (Bf) act through the points G and B as shown.



If the ship is heeled by an ***external force*** to some angle the relative positions of G and B change causing the lines of action of Wf and Bf to become ***horizontally*** separated.

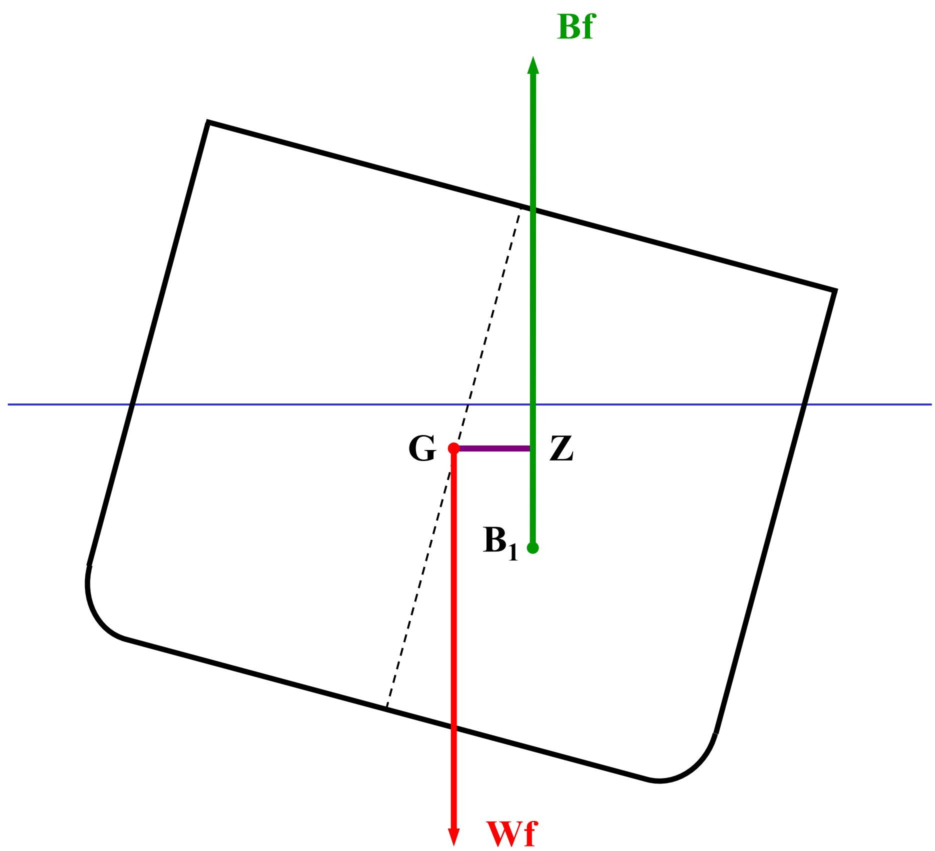


<u>SAQ</u>

Will this ship heel further or return to the upright if the external force is removed?

Answer

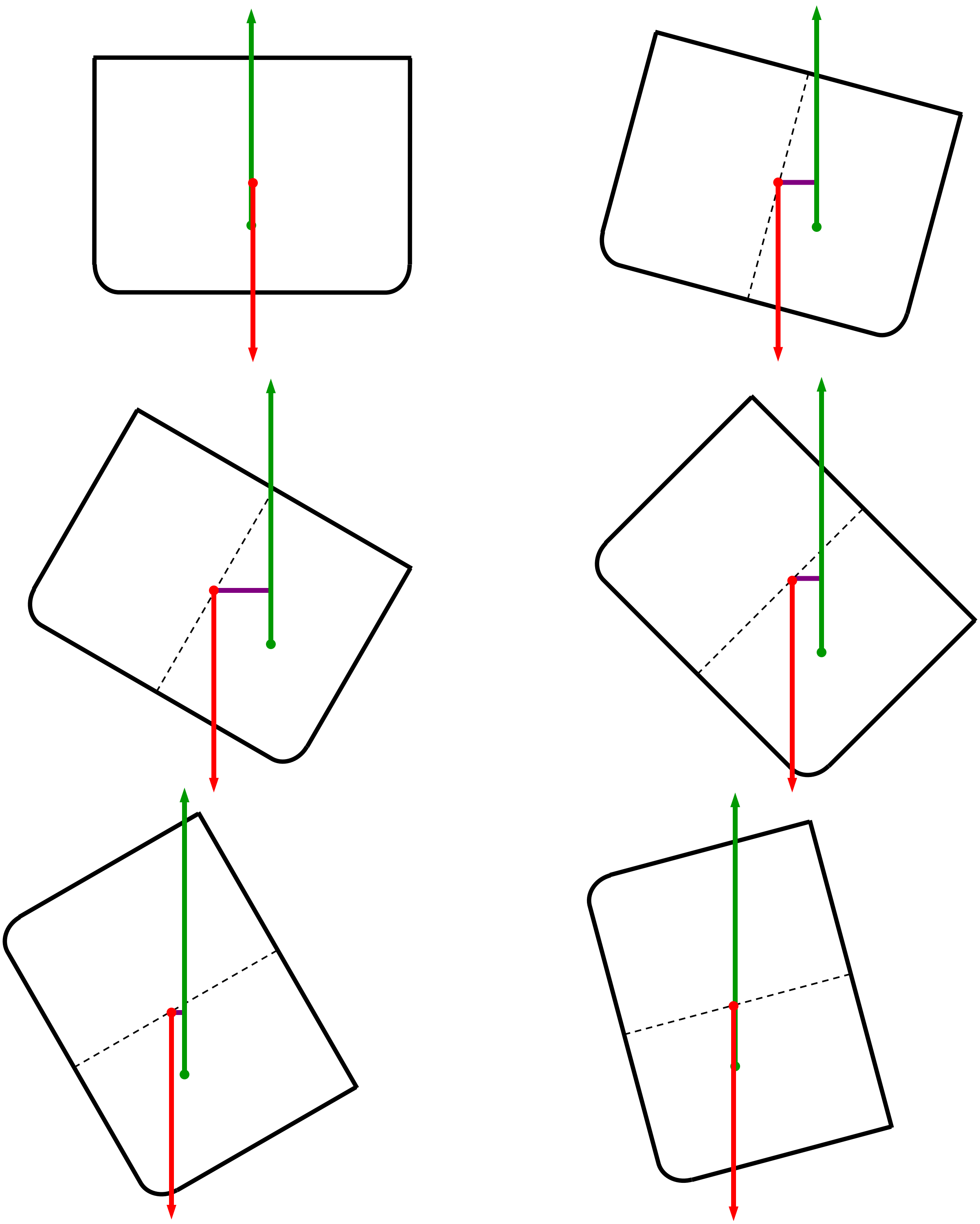
The ship will return to the upright.



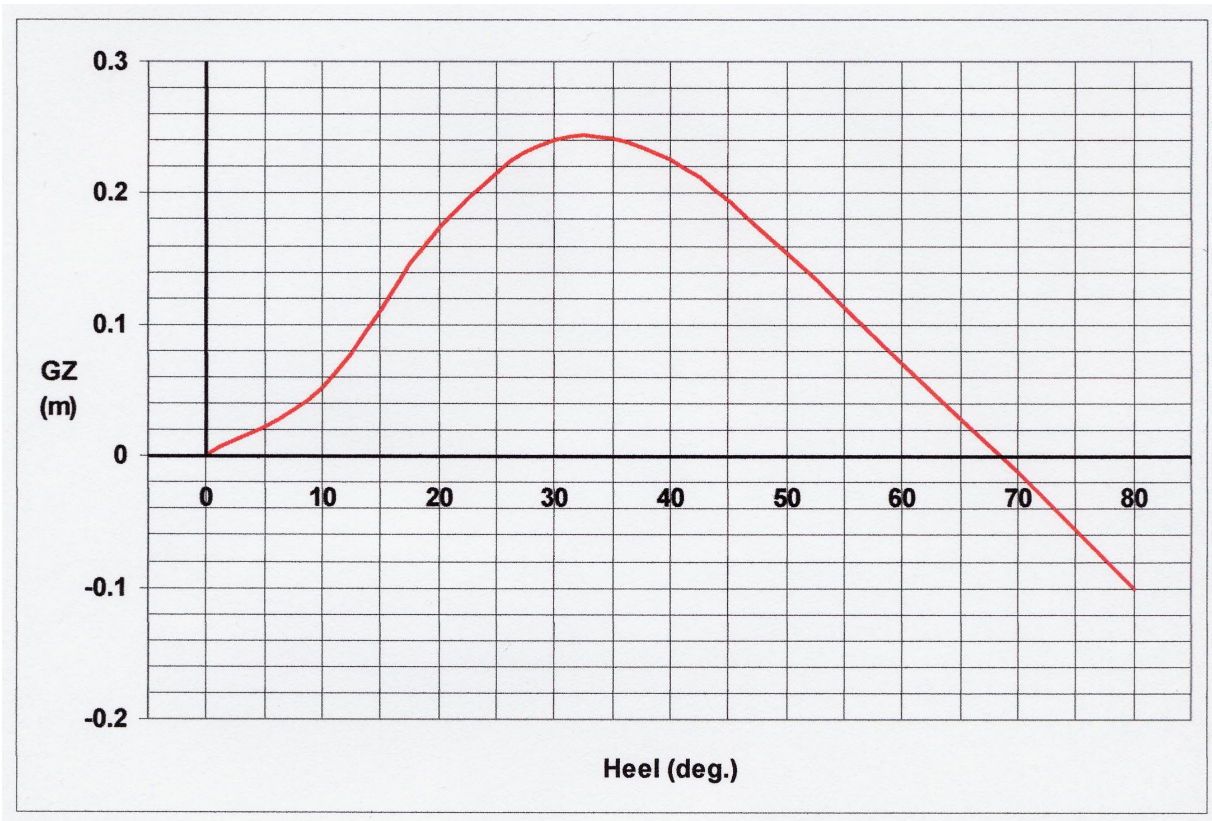
The horizontal separation of the lines of action of Wf and Bf is such that a ***righting lever (GZ)*** now exists.

Righting lever (GZ) is defined as the horizontal distance between the centre of gravity (G) and the vertical line of action of the buoyancy force (Bf) acting through the centre of buoyancy (B) when the ship is heeled.

Righting lever (GZ) increases to some maximum value and then decreases as the ship progressively heels further.



The righting levers for specified angles of heel are represented on a ***curve of statical stability***, commonly known as a ***GZ curve*** as shown.

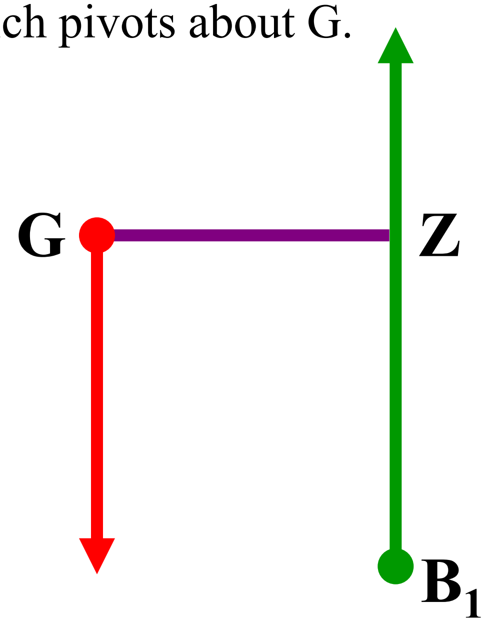


Righting moment

The ***righting moment*** at any given angle of heel is found by:

RIGHTING MOMENT = GZ × DISPLACEMENT

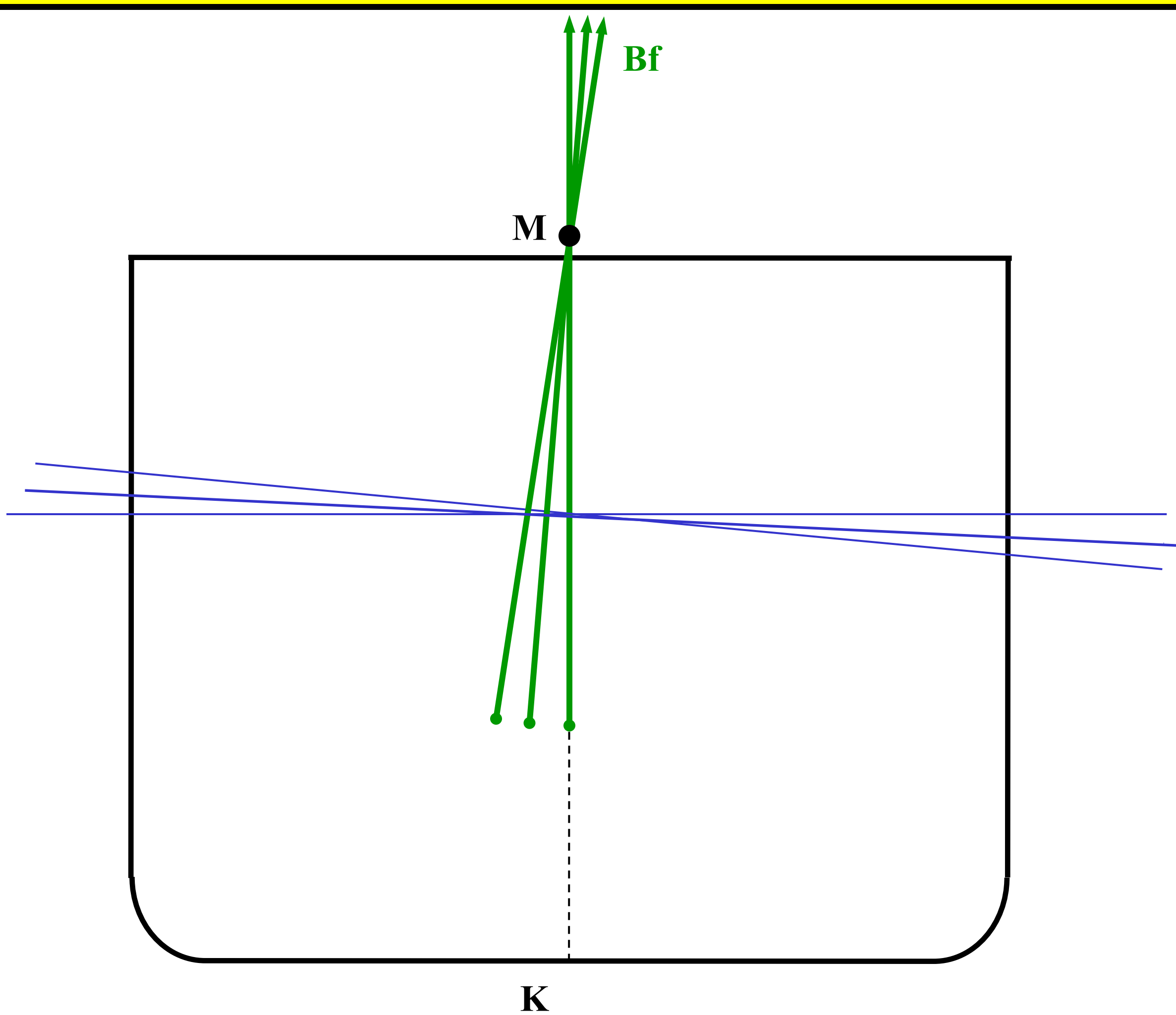
which results from the buoyancy force (Bf), which is equal to the ship's displacement (Wf), acting on the end of the lever GZ which pivots about G.



The ***righting moment*** at any angle of heel represents the instantaneous value of the 'work available' to right the ship in 'still water' conditions.

Initial Transverse Metacentre (M)

Is defined as the point of intersection of the lines of action of buoyancy force (Bf) when the ship is in the initial upright condition and subsequently heeled conditions. It only applies at small angles of heel from the upright (up to 10° heel approximately).

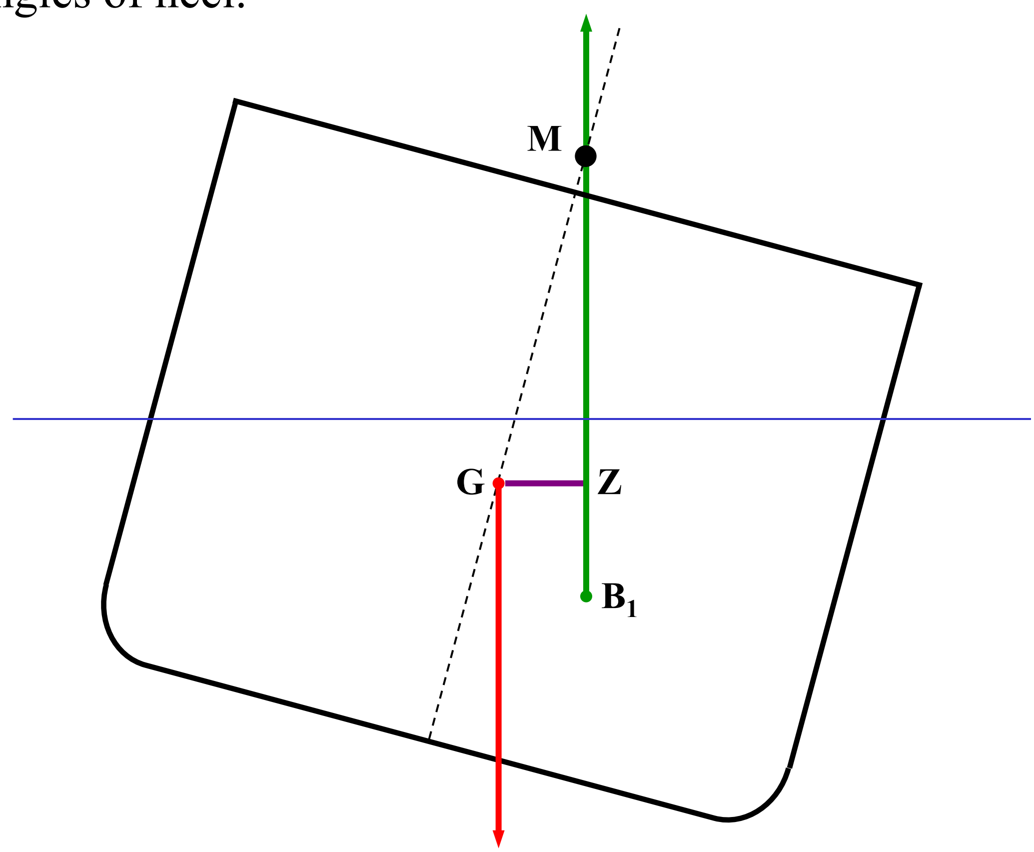


It's height is quoted in relation to the keel - KM.

Metacentric Height (GM)

Is the vertical distance between the ship's centre of gravity (G) and the metacentre (M).

The GM is very important in determining the initial stability of the ship i.e. the stability of the ship at small angles of heel.

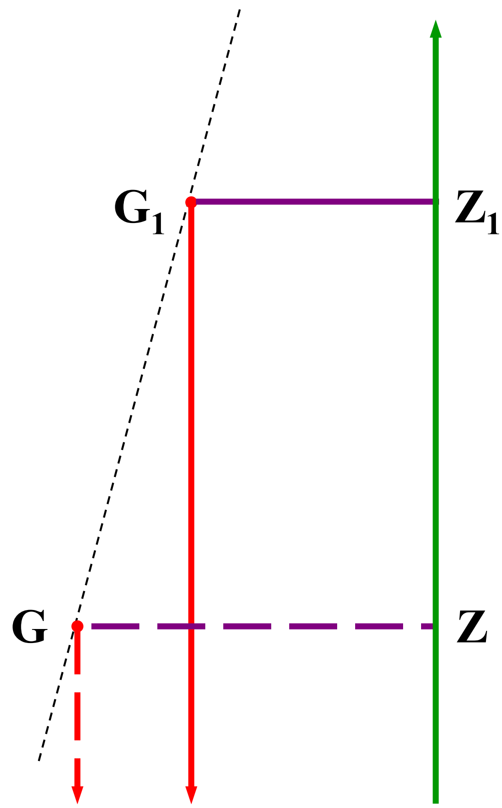


SAQ

If the centre of gravity (G) of the ship shown was higher, would the ship be more or less stable?

Answer

The ship would be less stable. Consider the same ship with G now at G_1.

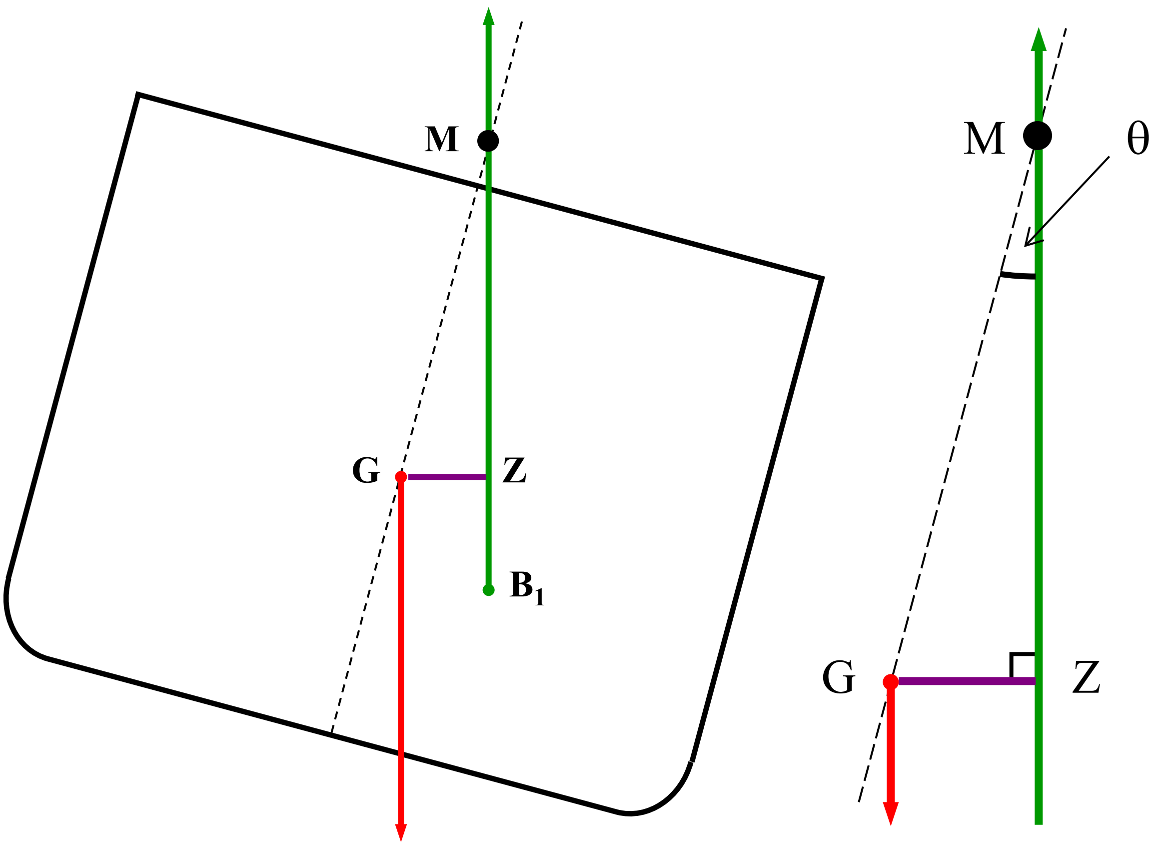


Righting lever (GZ) has ***reduced*** to G_1Z_1 as a result of the upward movement of the centre of gravity (G).

Therefore, ***available righting moment*** will also be ***reduced.***

Similarly, if G was ***lowered*** the ***righting lever*** (GZ) (and ***available righting moment***) would be ***increased.***

Calculating the righting moment at *small* angles of heel



In triangle GZM: $\sin\theta = \frac{OPP}{HYP} = \frac{GZ}{GM}$

Therefore: $\boxed{GZ = GM \times \sin\theta}$

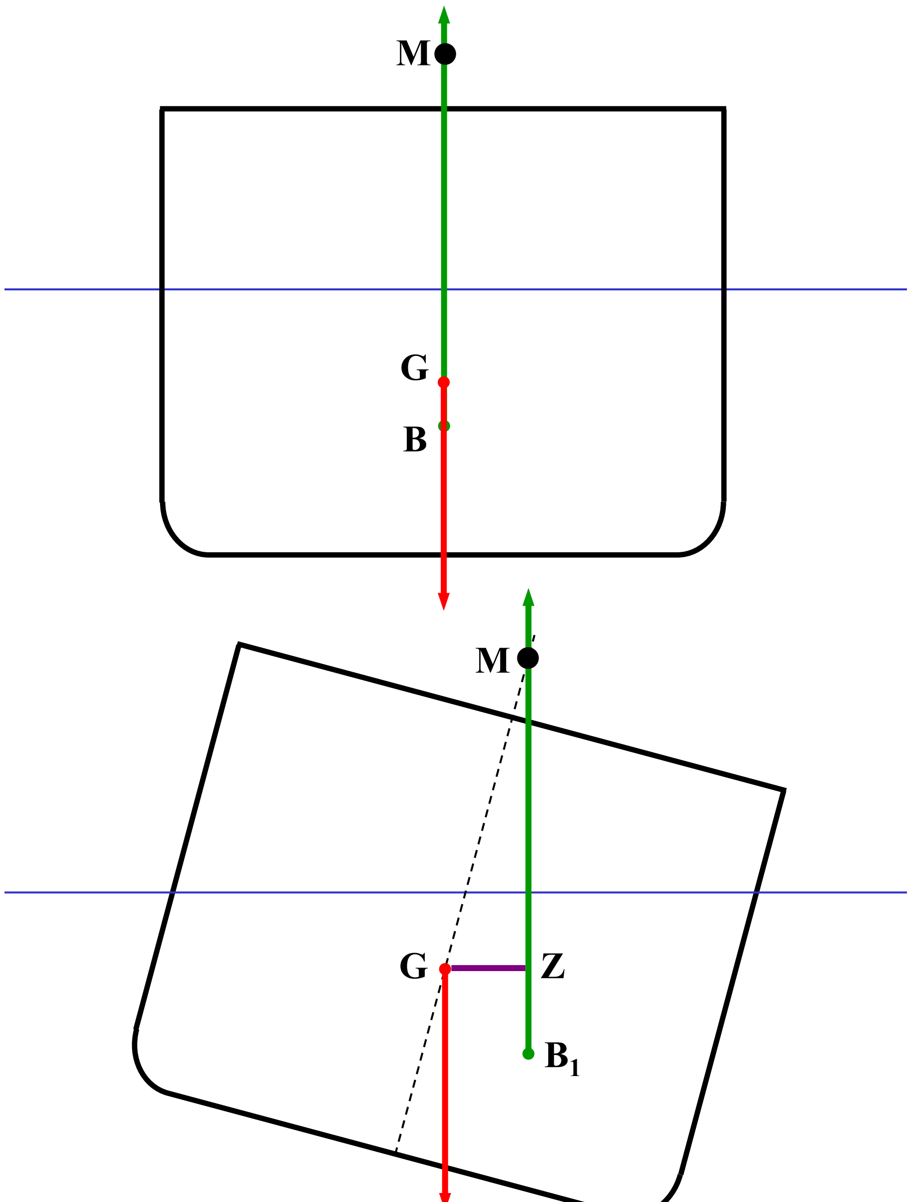
Having found GZ: $\boxed{RM = GZ \times DISPLACEMENT}$

Note

The formula for GZ can only be used at ***small*** angles of heel.

Stable condition

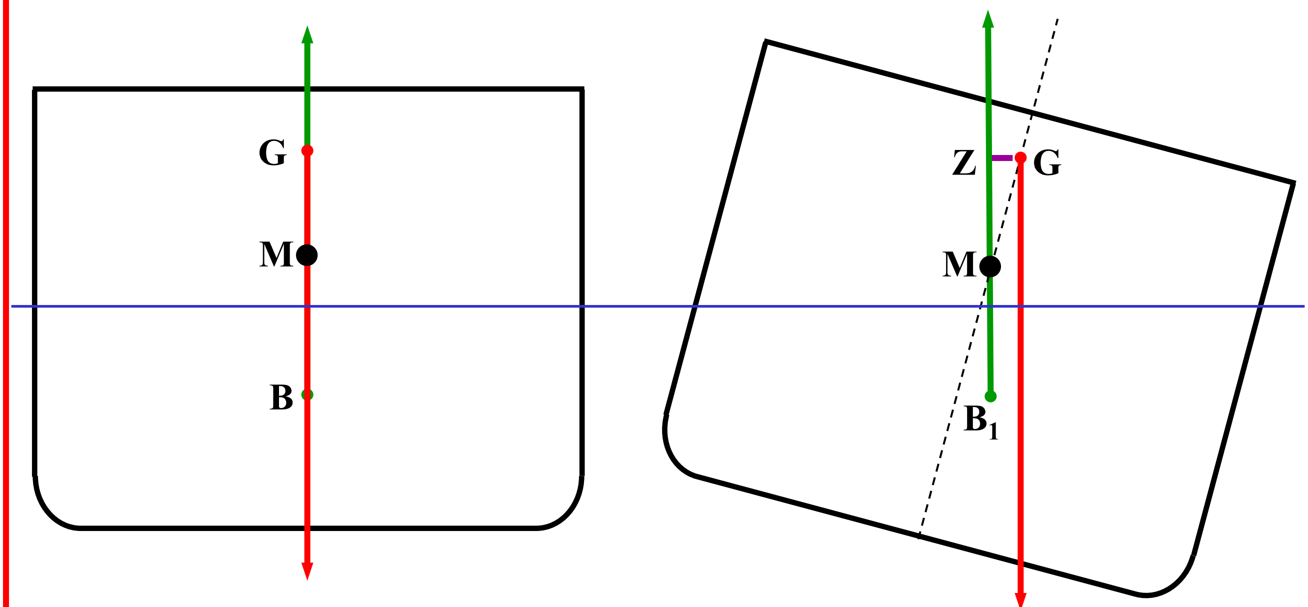
A ship is in a ***stable condition*** if, when heeled by an external force to a small angle, it returns to the upright when the force is removed.



In this condition the ship has a ***positive initial GM.***

Unstable condition and angle of loll

A ship is in an ***unstable condition*** if, when heeled by an external force to a small angle, it continues to heel further when the force is removed. ***GZ acts as a capsizing lever***.



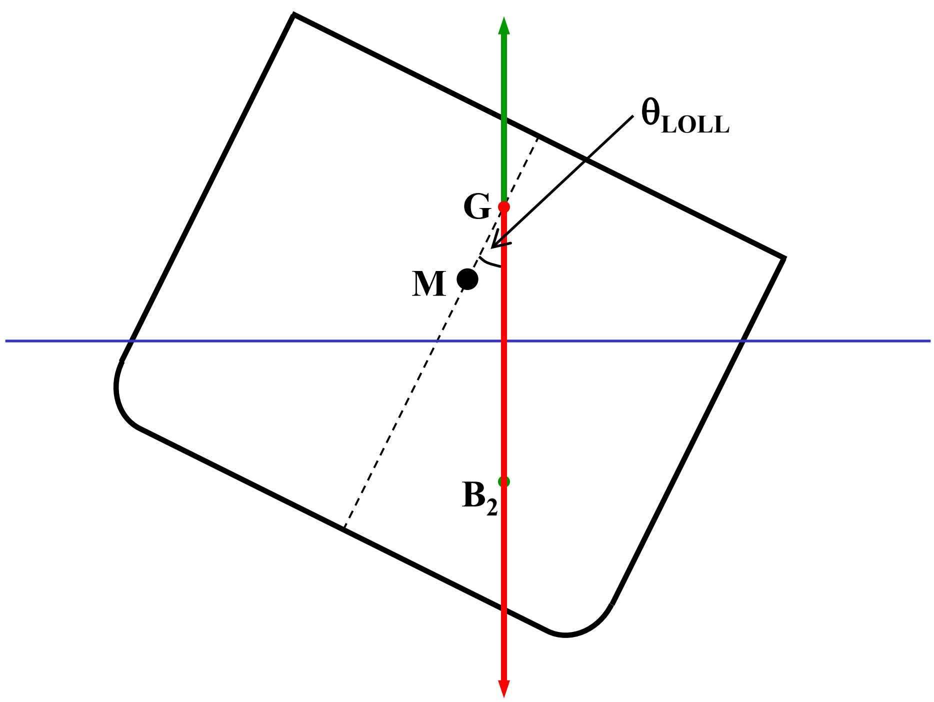
In this condition the ship has a ***negative initial GM.***

SAQ

Will this ship capsize?

Answer

Possibly. As the ship heels further over the centre of buoyancy (B) will move outward as the underwater volume changes shape. Provided that the centre of buoyancy can move sufficiently outboard to attain a new position vertically below G the capsizing lever will disappear and the ship will come to rest at an angle of loll. If the centre of gravity was very high then the ship would capsize.

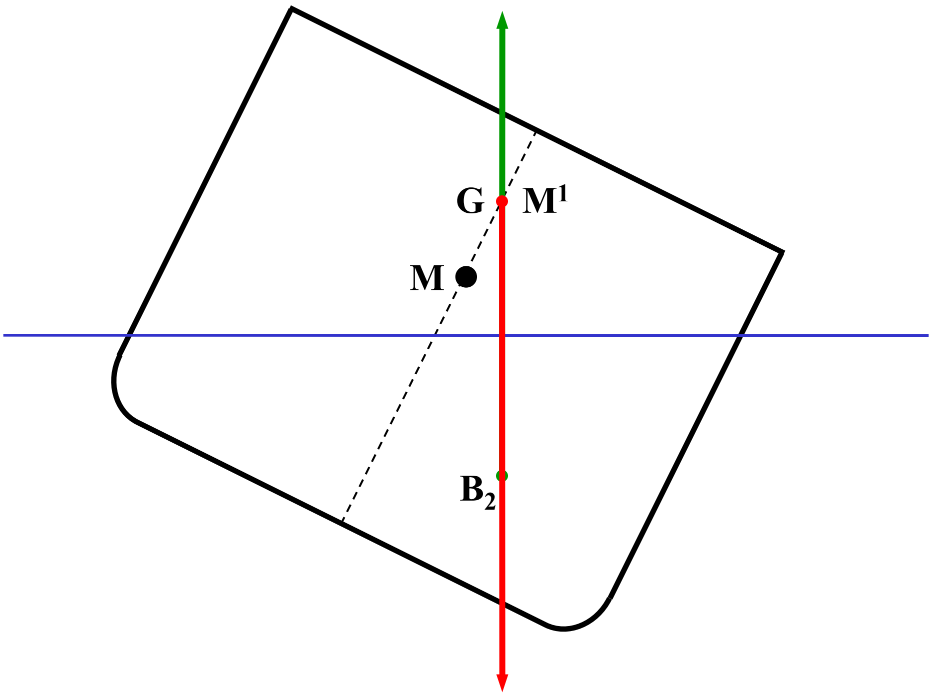


SAQ

When the vessel comes to rest at an angle of loll will it be lying at a small or a large angle?

Answer

If the metacentre (M) is considered, it is now no longer at M. It has moved to a position on the same vertical as G and may be considered to be at the same position as G. It is now termed a 'pro-metacentre' or a 'moving metacentre' (M^1). Therefore the ship must now be lying at a 'large' angle of heel from a stability point of view (within small angles of heel the line of action of Bf acts through M).

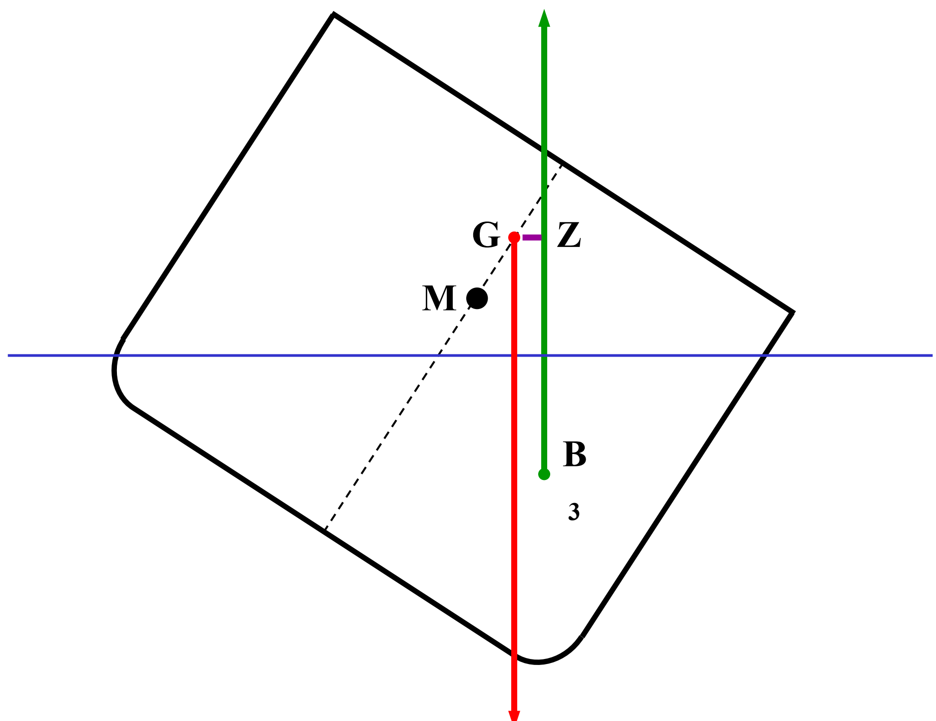


SAQ

If the ship is heeled beyond the angle of loll what will happen?

Answer

The centre of buoyancy (B) will move outboard of the centre of gravity (G) and a positive righting lever (GZ) will take effect to right the ship back to the angle of loll.

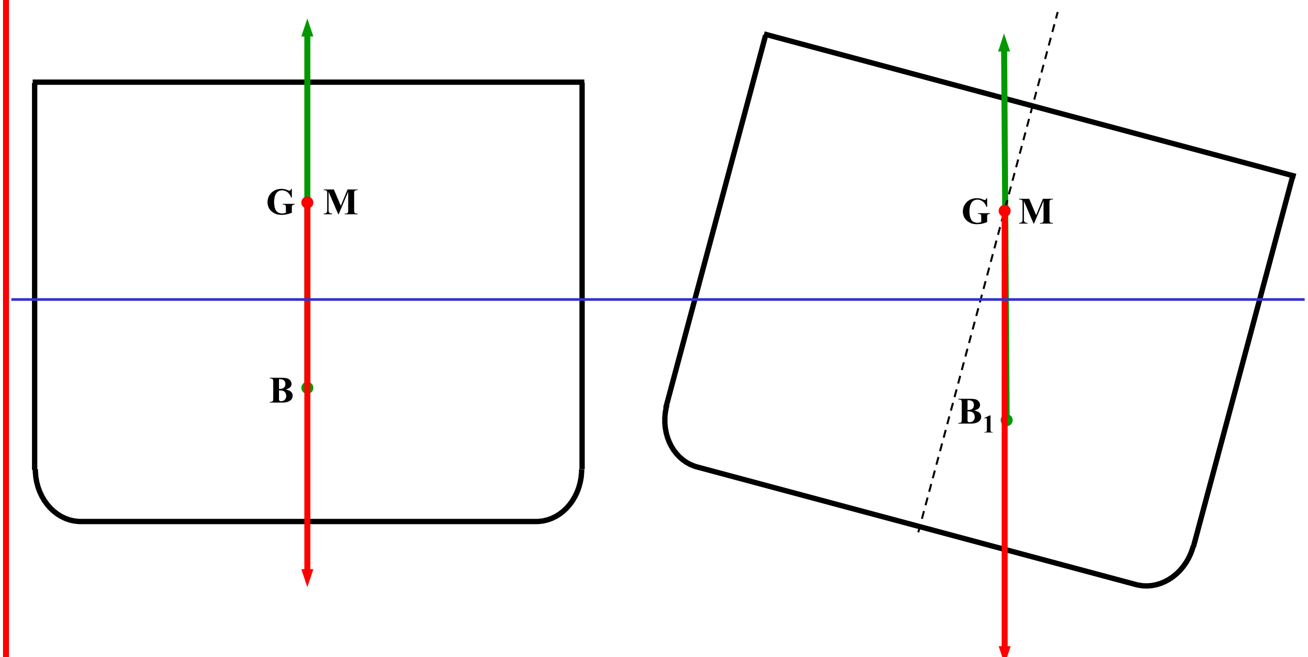


Note

A ship lying at an angle of loll is in a potentially dangerous situation. If the wind/waves were to cause the ship to roll through the vertical it would, ***in theory***, come to rest at the same angle of loll on the other side. However, the momentum of the ship as it rolls over may be sufficient to cause it to capsize. In any event cargo shift would be likely which would worsen the situation further.

Neutral condition (GM = 0)

A ship is in a ***neutral condition*** if, when heeled by an external force, it comes to rest at an ***indeterminate*** angle of heel within small angles. ***GZ remains at zero within small angles of heel.***



In this condition the ship has ***no GM***, i.e. the centre of gravity (G) is in the same place as the transverse metacentre (M).

SAQ

What will happen if the ship is heeled beyond small angles?

Answer

Eventually the centre of buoyancy (B) will move outboard of the centre of gravity (G) and righting levers will become positive to right the ship back to some indeterminate small angle.