SUSPENDED WEIGHTS

Introduction

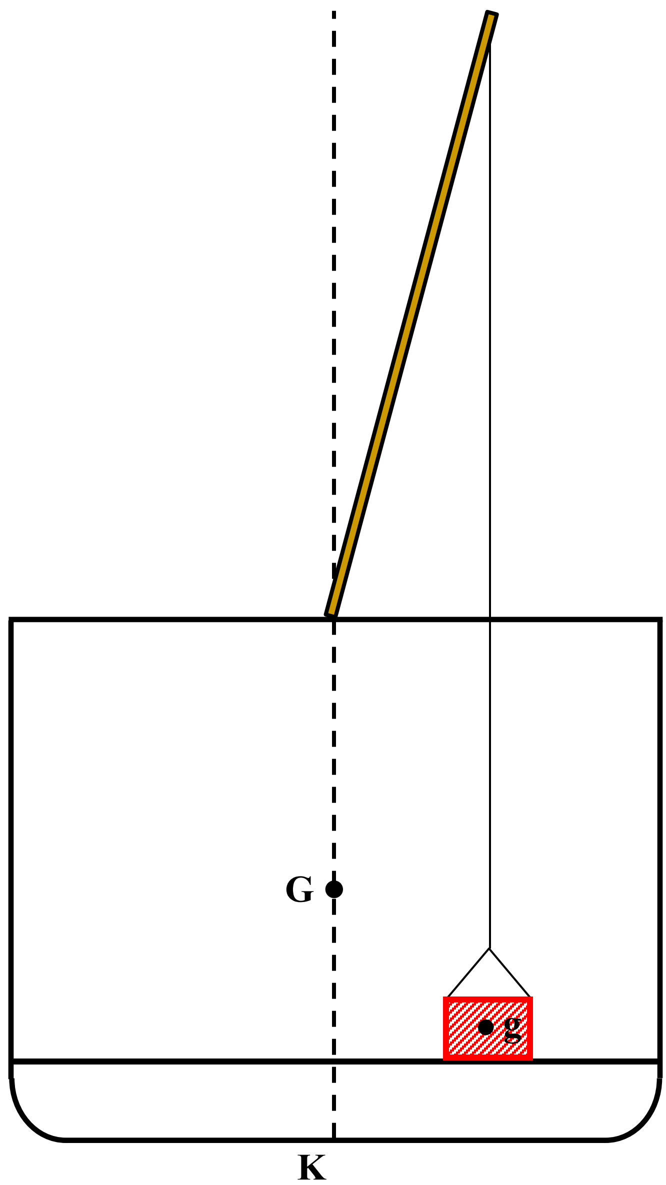
When a weight is suspended from a ship's crane or derrick it's effective centre of gravity will be ***at the point of suspension*** of the weight, being at the derrick or crane head.

This means that as soon as the weight is picked up, either from the quay or from somewhere on board, there will be an immediate transfer of the weight to the derrick (or crane) head with a resulting upward vertical movement of the ship's centre of gravity, G. This causes a corresponding reduction in metacentric height, GM. If the weight being lifted is substantial, as in the case of a heavy lift, the considerable upward movement of G cannot be ignored, requiring the ***maximum permissible KG***, or ***minimum permissible GM***, during the lifting operation to be calculated.

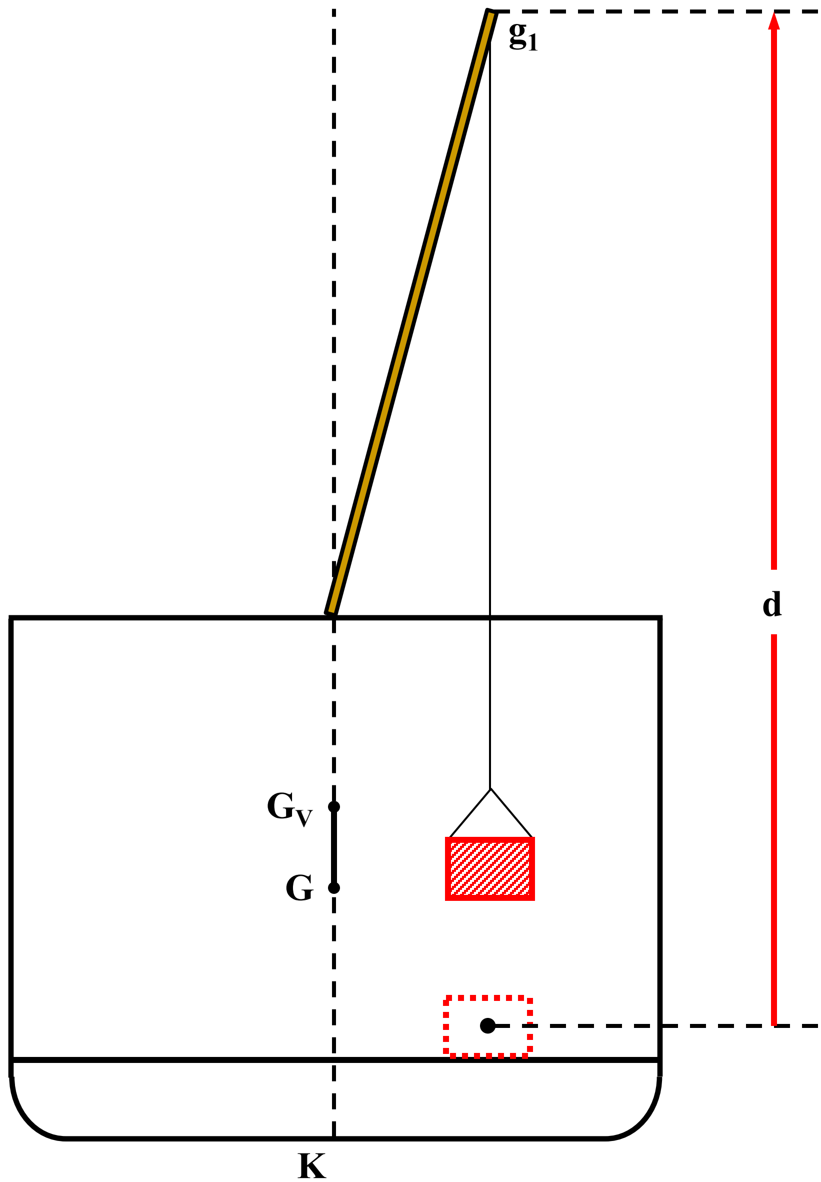
When the weight is plumbed over the side a larger than normal list will also occur and certain precautions will have to be taken to ensure that the maximum list is restricted to an acceptable limit.

Effect on KG of lifting a weight using ship's gear

Consider the situation where a weight ***already on board*** is to be lifted from a position in the lower hold using the ship's own derrick. Initial KG is shown.



As soon as the weight is lifted clear of the tank top the centre of gravity of the weight moves vertically up to it's point of suspension at $\mathbf{g_1}$. This results in a corresponding vertical movement of **G** to $\mathbf{G_V}$, causing an ***increase*** in KG.



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

where ***'d'*** is the distance through which the weight is effectively shifted upwards from it's initial stowage position to the derrick head.

<u>Example</u>

A ship has a displacement of 10516 t, KG 8.20 m and KM 9.00 m. A weight of 86 t in the lower hold, Kg 3.40 m, is lifted by the ship's heavy lift derrick, the head of which is 22.00 m above the keel.

(a) ***Calculate the GM when the weight is suspended.***

(b) ***Calculate the final GM when the weight is restowed in the tween deck at Kg 8.50 m.***

Solution

(a)

$$GG_V = \frac{w \times d}{W} = \frac{86 \times (22.00 - 3.40)}{10516} = 0.152\ m$$

Initial KG	*8.200 m*
GG_V	*0.152 m*
KG when weight suspended	*8.352 m*
KM	*9.000 m*
GM when weight suspended	*0.648 m*

This is the minimum GM during the lifting operation.

(b) ***To calculate the final GM when the weight has been shifted treat as a normal single weight problem - simply shift the weight from it's initial stowage position (Kg 3.40 m) to it's final stowage position (Kg 8.50 m) i.e. ignore the derrick.***

$$GG_V = \frac{w \times d}{W} = \frac{86 \times (8.50 - 3.40)}{10516} = 0.042\ m$$

Initial KG	*8.200 m*
GG_V	*0.042 m*
Final KG	*8.242 m*
KM	*9.000 m*
FINAL GM	*0.758 m*

The previous example was very simple as there was no horizontal shift of G involved as would be the case when loading or discharging a weight.

When loading or discharging weights using ship's lifting gear the following must be considered:

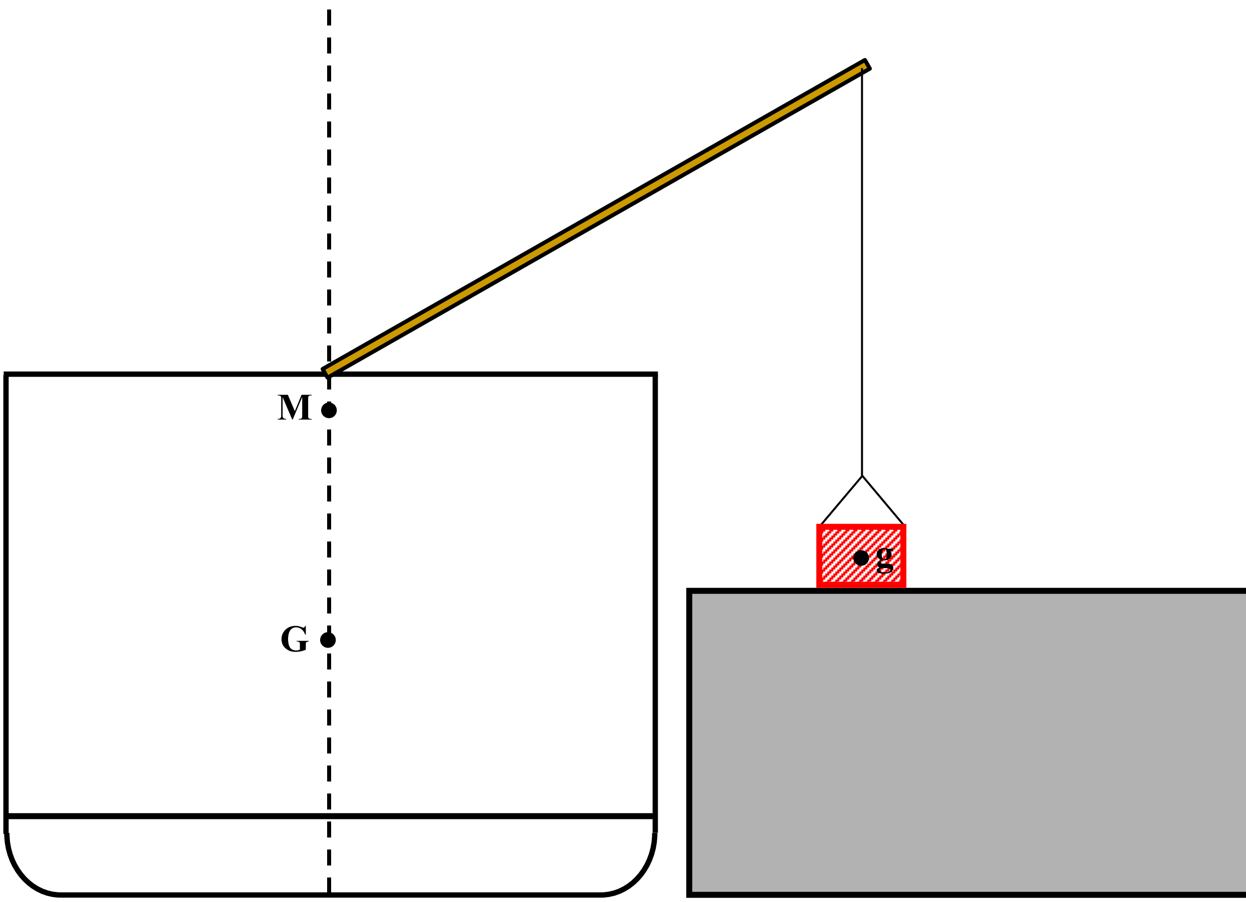
(1) ***the <u>increase in KG/decrease in GM</u> when the weight is suspended at the derrick/crane head;***

(2) ***the <u>maximum angle of list</u> that will occur when the derrick or crane is plumbed over the ship's side.***

Loading a weight using ship's lifting gear

Consider the movement of the ship's centre of gravity (G) when a weight is lifted off the quay on one side of the ship and stowed in the lower hold on the centre-line. (For the purpose of this explanation the ship is ***not*** shown to list.)

1. Derrick plumbed over the weight.



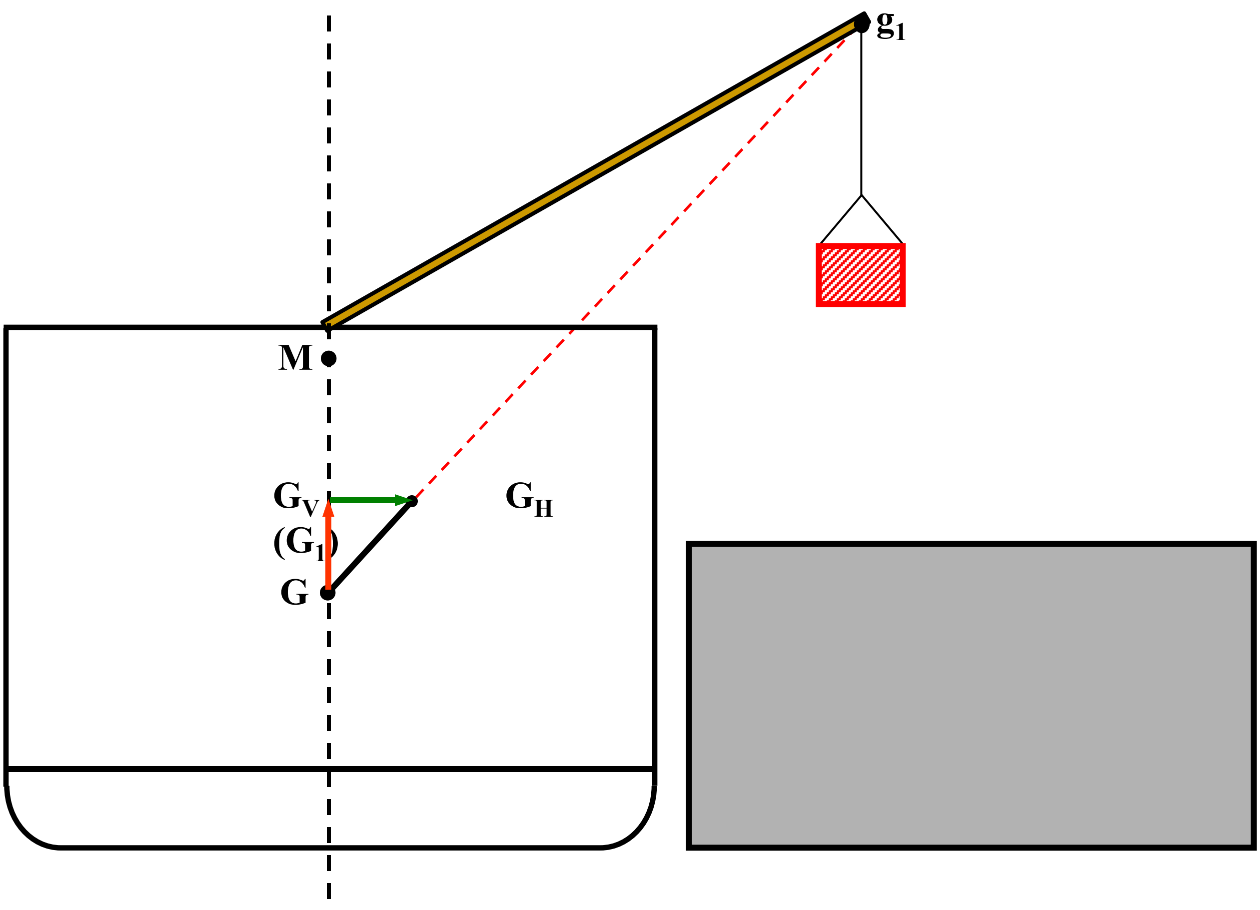
2. ***Derrick picks the weight up off the quay.***

G moves to G_1, directly towards the centre of gravity of the loaded weight - the point of suspension (g_1).

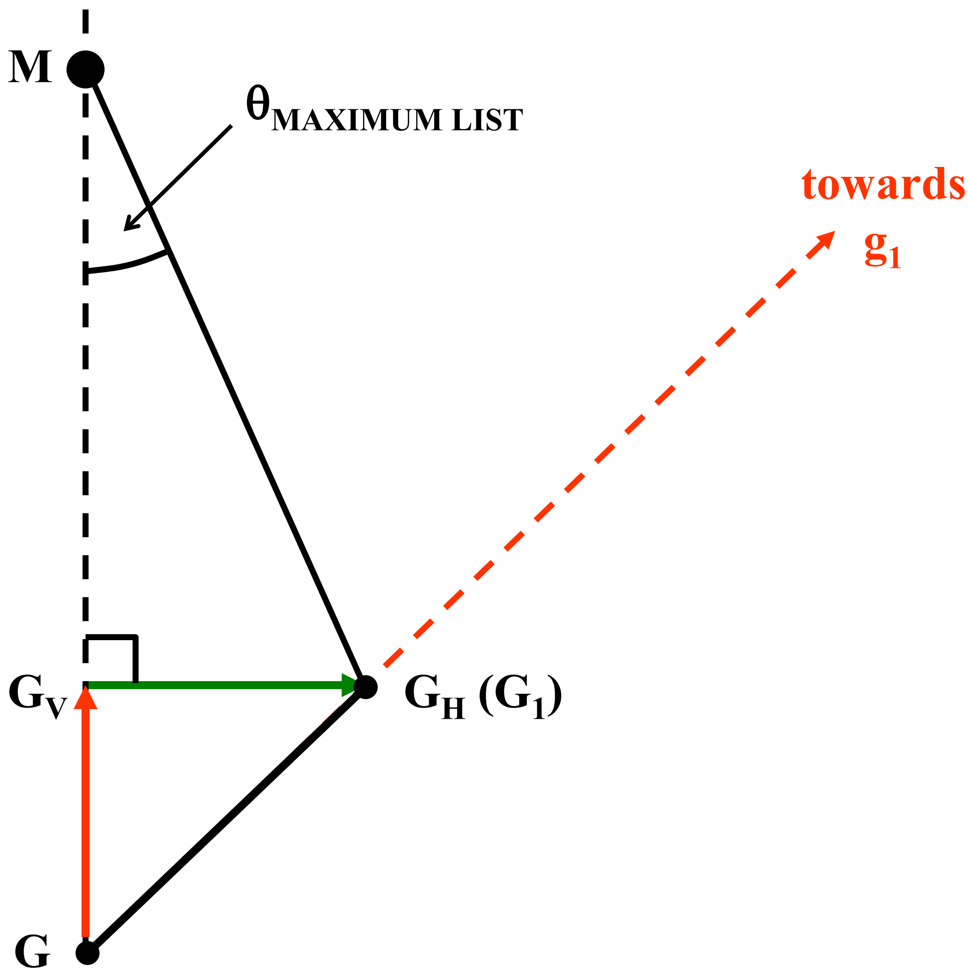
The movement GG_1 has two components:

GG_V: which causes an increase in KG/decrease in GM.

GG_H: which causes the ship to list.



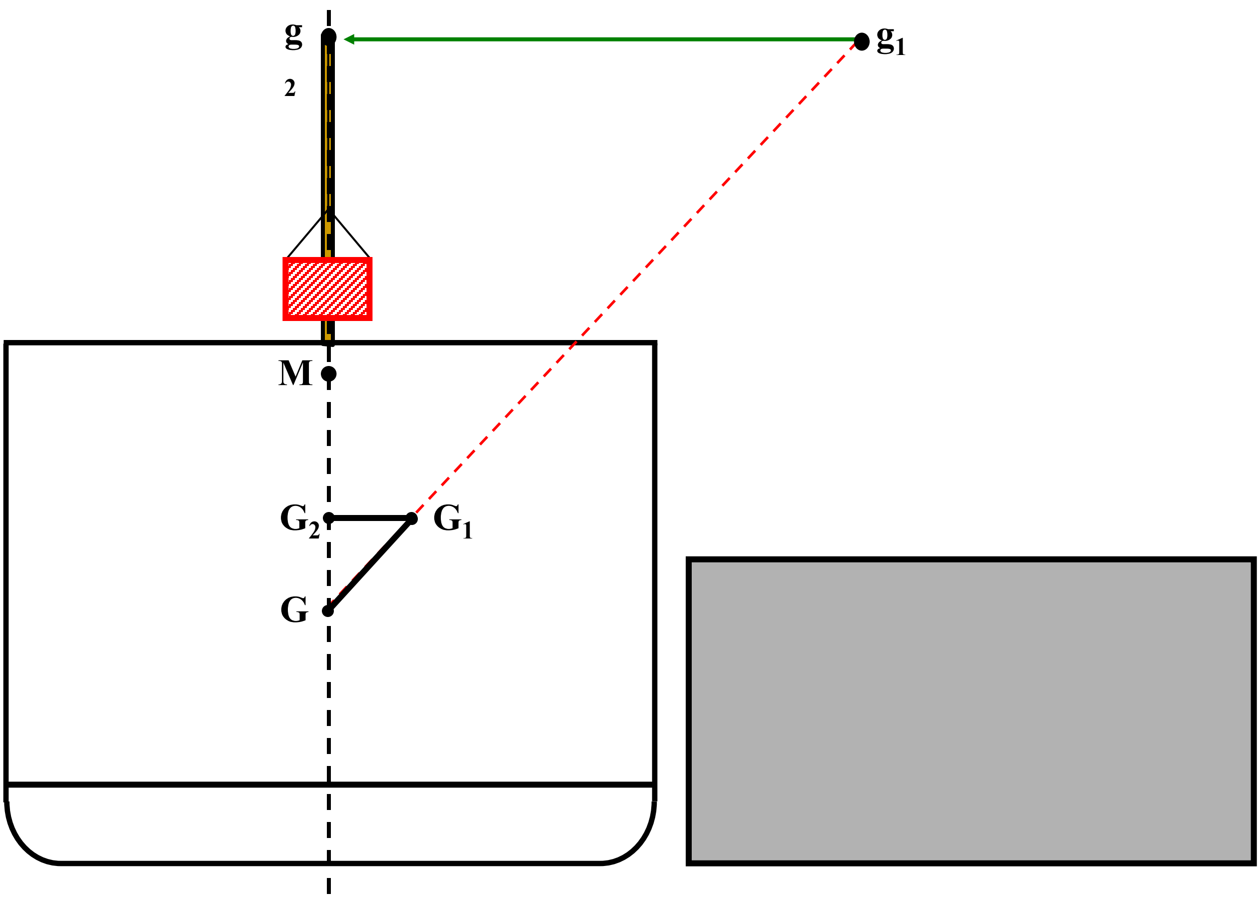
It is at this stage that the ***maximum list*** would occur which coincides with the moment when the ***GM has it's minimum value***. Consider the list triangle below:



$$\text{Tan } \theta_{MAX.\ LIST} = \frac{GG_H}{GM_{MIN.}}$$

3. ***Derrick swings inboard to plumb stowage position on the centre-line.***

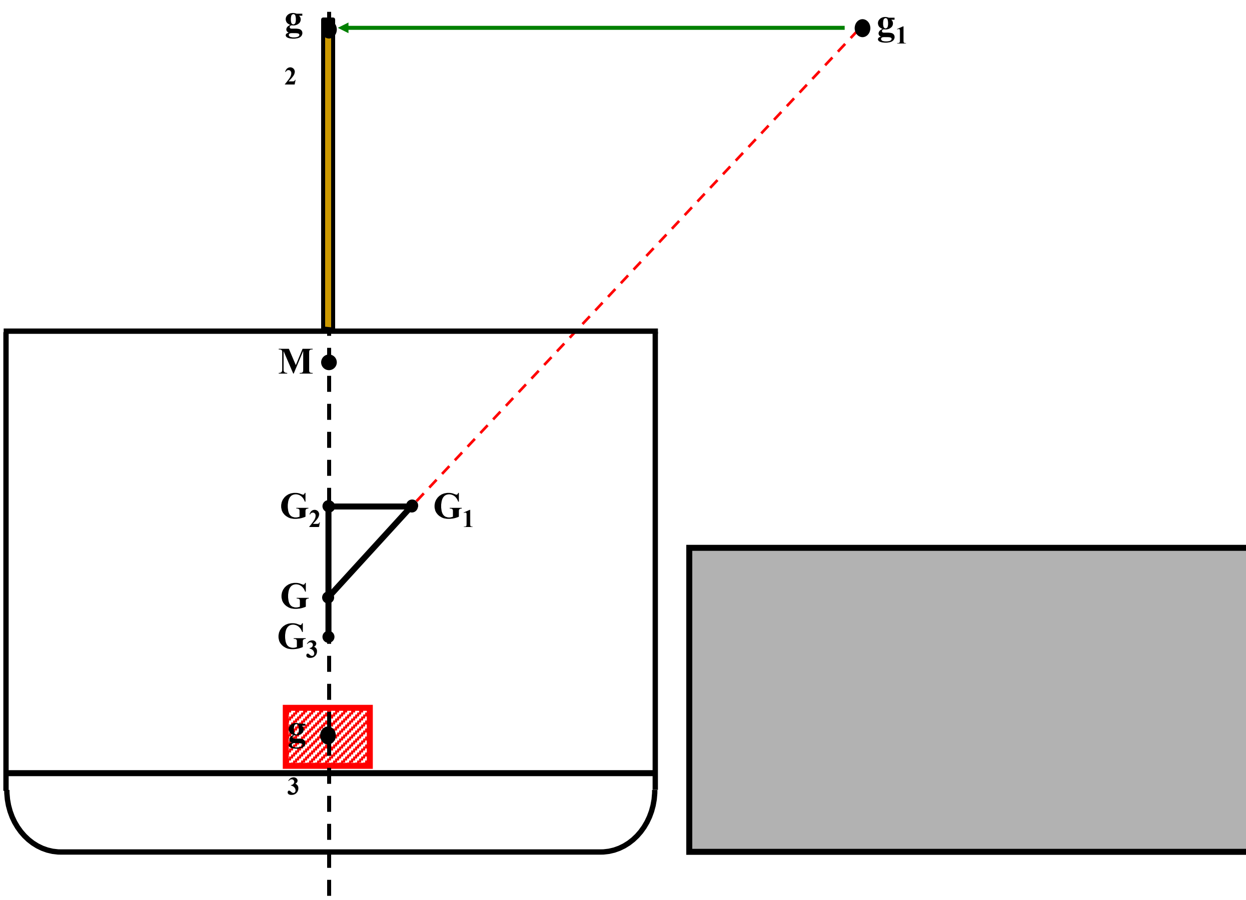
G_1 moves to G_2 as the weight is swung inboard from g_1 to g_2. Ship becomes upright.



4. ***Weight landed in the lower hold.***

The weight is removed from the derrick head at g_2 as it is landed in the lower hold and finally acts at g_3. G_2 moves to G_3.

Note that the weight is loaded ***below*** the initial centre of gravity of the ship, hence the final position of G, G_3 must be ***lower***. KG is ***reduced*** overall.



The following example illustrates a typical list question involving a heavy lift being loaded. The calculation may done by one of two methods:

(1) Formula method.
(2) Taking moments about the keel and the centreline.

Both methods are shown, however, the moments method is much simpler and will be adopted for all other examples in this section.

<u>Example</u>

A ship displaces 8850 t, KG 7.15 m and KM 7.98 m. A weight of 40 t is to be loaded from the quay which is 15.0 m to starboard of the ship's centreline. If the head of the derrick is 27.0 m above the keel when topped to it's maximum extent for the lifting operation, calculate:

(a) ***the GM when the weight is suspended;***

(b) ***the maximum angle of list;***

(c) ***the final angle of list if the weight is placed on deck at Kg 10.40 m, 5.0 m off the centreline to starboard.***

(d) ***the weight of ballast to transfer between two double bottom tanks, <u>each</u> having its centre of gravity 4.0 m off the centreline, to bring the ship upright.***

(Assume KM remains constant)

Solution (Method 1)

(a) To calculate the GM when the weight is suspended.

Load the weight at the derrick head.

$$GG_V = \frac{w \times d}{W+w} \qquad GG_V = \frac{40 \times (27.00 - 7.15)}{8850 + 40} = 0.089 \text{ m}$$

Initial KG	***7.150 m***
GG_V	***0.089 m***
Maximum KG	***7.239 m***
KM	***7.980 m***
MINIMUM GM	***0.741 m (GM when the weight is suspended)***

(b) Calculate the distance that G is off the centreline when the weight is suspended over the quay (GG_H).

$$GG_H = \frac{w \times d}{W+w} \qquad GG_H = \frac{40 \times 15}{8850 + 40} = 0.067 \text{ m}$$

$$\tan \theta_{MAX.\ LIST} = \frac{GG_H}{GM_{MIN.}} \qquad \tan \theta_{MAX.\ LIST} = \frac{0.067}{0.741} = 0.09042$$

Maximum list = 5.2º Stbd.

(c) ***Calculate the final angle of list when the weight is placed on deck.***
(Simply load the weight on deck, ignoring the derrick as in a normal single weight problem.)

$$GG_V = \frac{w \times d}{W+w} \qquad GG_V = \frac{40 \times (10.40 - 7.15)}{8850 + 40} = 0.015\ m$$

Initial KG	*7.150 m*
GG_V	*0.015 m*
Final KG	*7.165 m*
KM	*7.980 m*
Final GM	*0.815 m*

$$GG_H = \frac{w \times d}{W+w} \qquad GG_H = \frac{40 \times 5}{8850 + 40} = 0.022\ m$$

$$\tan \theta_{LIST} = \frac{GG_H}{GM_{FINAL.}} \qquad \tan \theta_{LIST} = \frac{0.022}{0.815} = 0.02700$$

Final list = 1.5º Stbd.

(d) Calculate weight of ballast to transfer from Stbd. DB tank to Port DB tank.

In the final condition G is off the centreline by 0.022 m (GG_H.)

$$GG_H = \frac{w \times d}{W} \qquad 0.022 = \frac{w \times 8}{8890} \qquad w = \frac{0.022 \times 8890}{8} = \underline{24.5\ t}$$

<u>Transfer 24.5 t</u>

Solution (Method 2)

(a) ***To calculate the GM when the weight is suspended.***

Load the weight at the derrick head. Take moments about the keel.

weight (t)	Kg (m)	moments (t-m)
8850.0	7.15	63277.5
40.0	27.00	1080.0
8890.0	7.239	64357.5

KM	7.980
KG	7.239
GM	0.741

GM when weight suspended 0.741 m (Minimum GM)

(b) ***Take moments about the centreline to determine GG_H.***

	Dist off	Port	Stbd
weight (t)	CL (m)	moments (t-m)	moments (t-m)
8850.0	0.00	0.0	0.0
40.0	15.00		600.0
8890.0	0.067	0.0	600.0

$$Tan\ \theta_{MAX.\ LIST} = \frac{GG_H}{GM_{MIN.}} \qquad Tan\ \theta_{MAX.\ LIST} = \frac{0.067}{0.741} = 0.09042$$

Maximum list = 5.2º Stbd.

(c) Calculate the final angle of list when the weight is placed on deck.

Take moments about the keel.

weight (t)	Kg (m)	moments (t-m)
8850.0	7.15	63277.5
40.0	10.40	416.0
8890.0	7.165	63693.5

KM	7.980
KG	7.165
GM	0.815

Take moments about the centreline to determine GG_H.

	Dist off	Port	Stbd
weight (t)	CL (m)	moments (t-m)	moments (t-m)
8850.0	0.00	0.0	0.0
40.0	5.00		200.0
8890.0	0.022	0.0	200.0

$$\tan\theta_{LIST} = \frac{GG_H}{GM_{FINAL.}} \qquad \tan\theta_{LIST} = \frac{0.022}{0.815} = 0.02700$$

Final list = 1.5º Stbd.

(d) Calculate weight of ballast to transfer from Stbd. DB tank to Port DB tank.

In the final condition G is off the centreline by 0.022 m (GG_H.)

$$GG_H = \frac{w \times d}{W} \qquad 0.022 = \frac{w \times 8}{8890} \qquad w = \frac{0.022 \times 8890}{8} = \underline{24.5\ t}$$

<u>Transfer 24.5 t</u>

To calculate the maximum permissible KG required prior to loading or discharging a weight to ensure that a certain list limit is not exceeded.

The key point here is to firstly identify the situation during the lifting operation which will create the maximum list. Drawing a diagram will help.

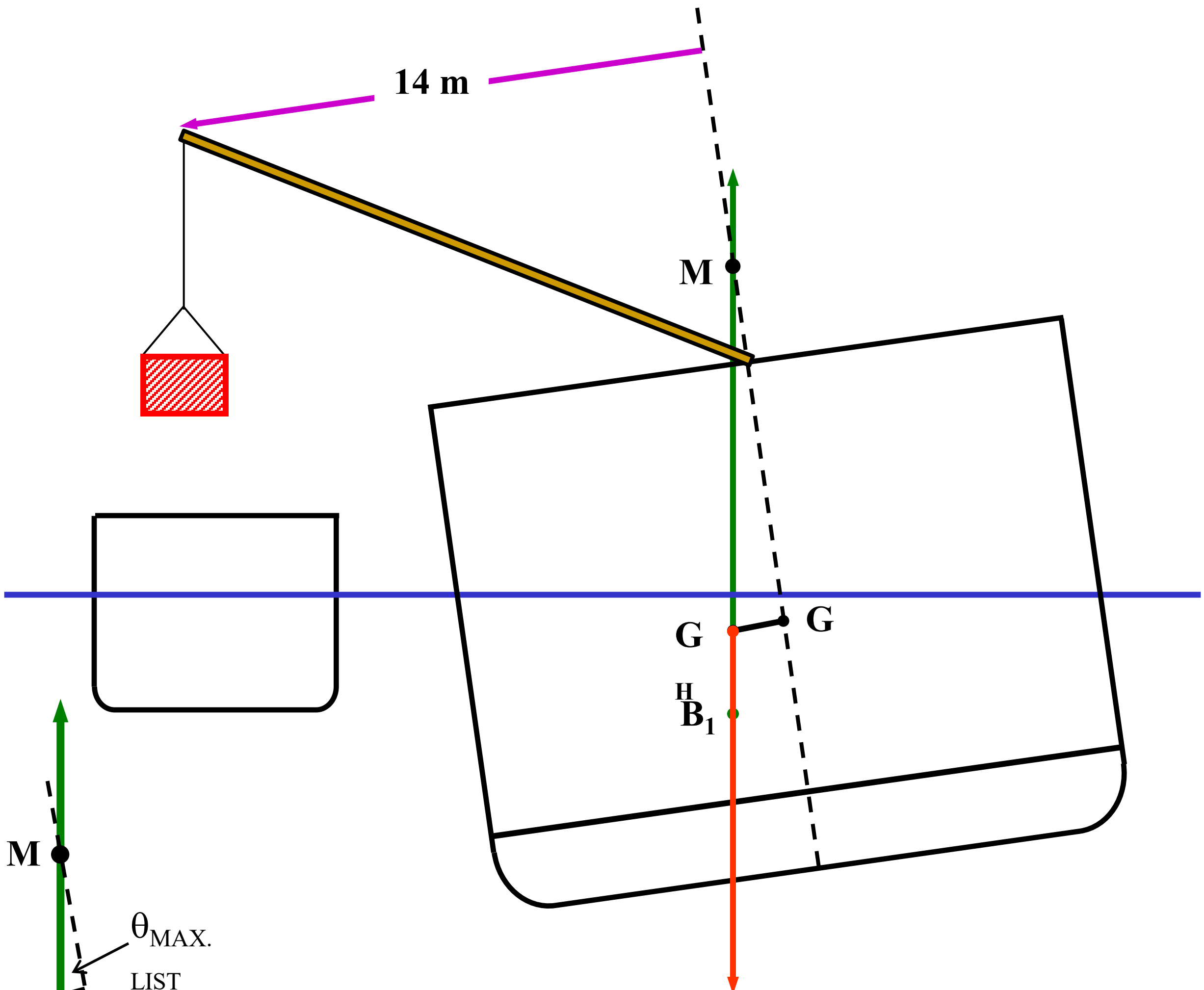
Consider the following example.

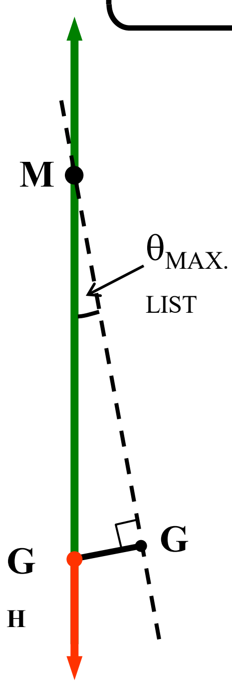
Example

A ship displacing 16200 t is upright and has a 90 t weight on deck at Kg 13.0 m, 6.00 m to port of the centre-line. This weight is to be discharged into a lighter on the port side, 14.00 m from the centre-line using the ship's heavy lift derrick. If the angle of list is not to exceed 8º at any time during the operation, calculate the maximum allowable KG prior to discharge given that KM is 9.60 m.

Solution

Maximum list will occur when the weight is suspended at the derrick head and the derrick is plumbed over the port side.





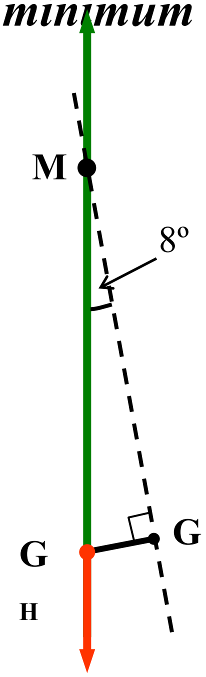
GM will have it's minimum value.

$$\textbf{Tan } \theta_{\text{MAX. LIST}} = \frac{GG_H}{GM_{MIN.}}$$

Calculate the distance that G will be off the centre-line (GG_H) when the ship is at it's maximum angle of list.

$$GG_H = \frac{w \times d}{W} \qquad GG_H = \frac{90 \times (14 - 6)}{16200} = 0.044\ m$$

Maximum allowed list is 8º. GG_H is 0.044 m. This allows the minimum GM to be calculated.



$$\tan \theta_{MAX.\ LIST} = \frac{GG_H}{GM_{MIN}}$$

$$\tan 8^o = \frac{0.044}{GM_{MIN}}$$

$$\text{Therefore:} \quad GM_{MIN} = \frac{0.044}{\tan 8^o} = 0.313\ m$$

A minimum GM of 0.313 m is required when the weight is plumbed over the side at Kg 27.0 m.

KM	***9.600 m***
Minimum GM	***0.313 m***
Maximum KG	***9.287 m***

Having calculated the maximum allowed KG when the weight is suspended from the derrick head (Kg 27.0 m), shift the weight back to it's original stowage position on deck (Kg 13.0) to calculate the maximum initial KG required for the operation.

Take moments about the keel.

weight (t)	Kg (m)	moments (t-m)
16200	9.287	150449.4
-90.0	27.00	-2430.0
90.0	13.00	1170.0
16200.0	9.209	149189.4

The initial KG must not be greater than 9.209 m in order to limit the list to 8º.