**US418**

**Problem statement** -In this use case, the proposed problem is to determine the unloaded center of mass of each ship according to its characteristics. Along with this problem we had to take into account three main criteria:

1. Make a sketch of the vessel's geometric figure.
2. Identify/choose a reference for the calculation.
3. Determine the center of mass for the different vessels (consider that the  
   vessel is all made of the same material).

**Problem resolution** – For us to solve this problem, it was necessary to divide the question into five steps to reach the intended objective, that is, the calculation of the center of mass of the ship in question. The five steps of the process were:

* Ship dimensions.
* Sketch of the geometric figures used for the problem and their measurements.
* Calculation of the volume of the areas and allocation of the ship's density.
* Calculation of the mass referring to each area of the ship.
* Calculation of the center of mass.

**Ship dimensions**

The dimensions of the ships we used for the calculations were as follows:

**Container Ship**

Length – 390 meters

Width – 50 meters

Height – 30 meters

**Oil Tanker**

Length – 250 meters

Width – 44 meters

Height – 25 meters

**Bulk Carrier**

Length – 362 meters

Width – 65 meters

Height – 56 meters

**Sketch of geometric figures and their measurements**

The ship we chose to use as a reference in the sketch of the geometric figures was the container ship, which contains the turret in the center of the ship. Bear in mind that the oil tanker has the turret on the left side of the ship (Stern of the ship) and the bulk carrier on the right side of the ship (ship’s bow).

The way we divided the ship was very simple, basically, it was assumed that the two bows of the ship would be two right triangles, that the rest of the ship's structure would be a rectangle and that it would contain another rectangle that corresponded to the ship's tower such as the following sketch shows:

a

b

A4

a

a

A1

A3

b

b

b

A2

a

Note: The geometry assigned to the container ship is identical to the other ships.

Dimensões das áreas dos navios:

**Container Ship**

**A1 and A3:**

a = 30 m

b = 30 m

**A2:**

a = 330 m

b = 30 m

**A4:**

a = 20 m

b = 5 m

**Oil Tanker**

**A1 and A3:**

a = 25 m

b = 25 m

**A2:**

a = 200 m

b = 25 m

**A4:**

a = 20 m

b = 5 m

**Bulk Carrier**

**A1 and A3:**

a = 56 m

b = 56 m

**A2:**

a = 250 m

b = 56 m

**A4:**

a = 20 m

b = 5 m

**Calculation of the volume of the areas and allocation of the ship's density**

In our solution, it was assumed that the entire ship was made of the same material. The material chosen was steel of density 7,8 kg/ m³.

**Container Ship**

**V (A1 e A3) =** Ab x Height => 30 x 30 = 900 m³

**V (A2) =** Length x Width x Height => 330 x 50 x 30 = 495 000 m³

**V (A4) =** Length x Width x Height => 20 x 50 x 5 = 5000 m³

**Oil Tanker**

**V (A1 e A3) =** Ab x Height => 25 x 25 = 625 m³

**V (A2) =** Length x Width x Height => 200 x 44 x 25 = 220 000 m³

**V (A4) =** Length x Width x Height => 20 x 44 x 5 = 4400 m³

**Bulk Carrier**

**V (A1 e A3) =** Ab x Height => 56 x 56 = 3136 m³

**V (A2) =** Length x Width x Height => 250 x 65 x 56 = 910 000 m³

**V (A4) =** Length x Width x Height => 20 x 65 x 5 = 6500 m³

**Mass calculation**

The formula that was used to calculate the mass for each area of the ship was as follows:

**mass = density x volume**

**Container Ship**

**m (A1 and A3) =** 7,8 x 900 = 7020 kg

**m (A2) =** 7,8 x 495 000 = 3 861 000 kg

**m (A4) =** 7,8 x 5000 = 39 000 kg

**Oil Tanker**

**m (A1 and A3) =** 7,8 x 625 = 4875 kg

**m (A2) =** 7,8 x 220 000 = 1 716 000 kg

**m (A4) =** 7,8 x 4400 = 34 320 kg

**Bulk Carrier**

**m (A1 and A3) =** 7,8 x 3136 = 24 461 kg

**m (A2) =** 7,8 x 910 000 = 7 098 000 kg

**m (A4) =** 7,8 x 6500 = 50 700 kg

**Calculation of the center of mass**

Auxiliary Calculations

During the process of calculating the center of mass, it was necessary to calculate the center of mass in X and Y for the two triangular areas (A1 and A3), for which the following formulas were used:

**Container Ship**

X = b / 3 = > 30 / 3 = 10m

Y = Height / 3 => 30 / 3 = 10m

**Oil Tanker**

X = b / 3 = > 25 / 3 = 8,33m

Y = Height / 3 => 25 / 3 = 8,33m

**Bulk Carrier**

X = b / 3 = > 56 / 3 = 18,67m

Y = Height / 3 => 56 / 3 = 18,67m

Note: Bearing in mind that the triangles meet with their axes inverted, these 10 meters in “Y”(Cargo ship) means that from the upper base, corresponding to our length “a”, 10 m is removed from the maximum height (30 m), assuming thus the value of 20 m in Y with respect to the calculation of the center of mass. This reasoning is attributed to the remaining ships.

To calculate the ship's center of mass without cargo, the following formulas were used:

**Xcm** = m(A1) x X1 + m(A2) x X2 + m(A3) x X3 + m(A4) x X4

m(A1) + m(A2) + m(A3) + m(A4)

**Ycm** = m(A1) x Y1 + m(A2) x Y2 + m(A3) x Y3 + m(A4) x Y4

m(A1) + m(A2) + m(A3) + m(A4)

**Container Ship**

Xcm = 7,020 x 10 + 3861 x 195 + 7,020 x 380 + 23,4 x 195 / 7,020 + 3861 + 7,020 + 23,4

= > Xcm = 195,00 m

Ycm = 7,020 x 20 + 3861 x 15 + 7,020 x 20 + 39 x 32,5 / 7,020 + 3861 + 7,020 + 23,4

=> Ycm = 15,19 m

**Oil Tanker**

Xcm = 4,875 x 8,33 + 1716 x 125 + 4,875 x 241,6 + 34,32 x 20 / 4,875 + 1716 + 4,875 + 34,32

= > Xcm = 122,95 m

Ycm = 4,875 x 16,67+ 1716 x 12,5 + 4,875 x 16,67 + 34,32 x 27,5 / 4,875 + 1716 + 4,875 + 34,32

=> Ycm = 12,82 m

**Bulk Carrier**

Xcm = 24,461 x 18,67 + 7098 x 181 + 24,461 x 343,3 + 50,7 x 330 / 24,461 + 7098 + 24,461 + 50,7

= > Xcm = 182,05 m

Ycm = 24,461 x 37,33 + 7098 x 28 + 24,461 x 37,33 + 50,7 x 58,5 / 24,461 + 7098 + 24,461 + 50,7

=> Ycm = 28,28 m

Note: The mass values have all been deducted from tons so that the calculation values are pleasant to work with.

**Conclusion**

Our group believes that the results obtained are quite satisfactory and expected, since the mass of the body A2, of both ships, corresponds to the largest area of ​​the ship, thus containing the center of mass in it.

Finally, with regard to the deviation of the center of mass both at the "x" coordinate level (in the case of the oil tanker and bulk carrier) and at the "y" coordinate level (container ship) is expected due to the positioning of a body (A4) that causes it to move from the center of mass of the larger body.