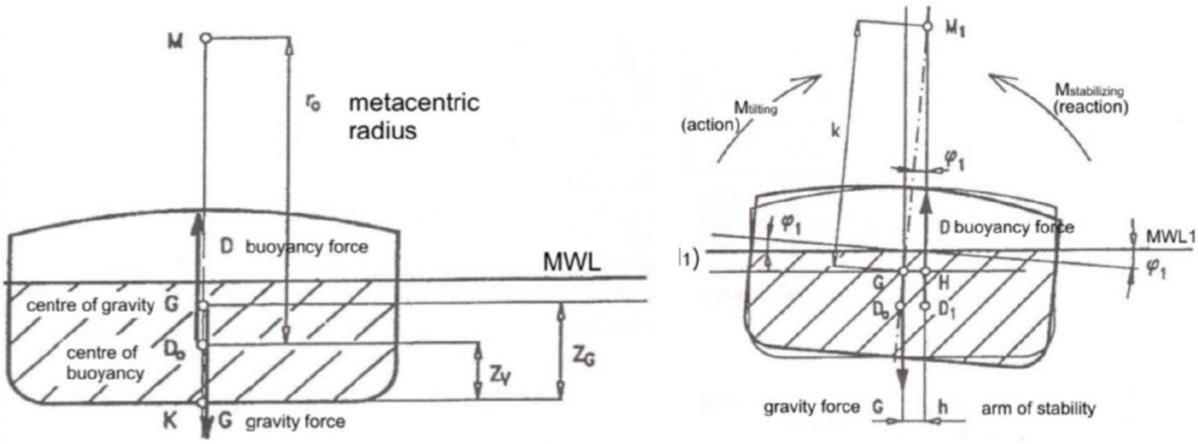
Theory – see the lecture No. 3 – Wessels theory

Lateral stability:

Lateral stability at small inclinations up to 8° to 15°. G is the centre of gravity of the ship and it does not change during inclination. The force (weight) of the whole ship acts on this point $G = V.\gamma = V.\rho.g$. The centre of buoyancy of the submerged part is point D_0 and displacement force acts on it. If the ship is inclined from the horizontal position a/ to position b/ the angle of heel is φ_1, point D_0 inclines from its original position to D_1, which is the centre of buoyancy of the submerged part of the hull MWL_1.



A ship is stable when buoyancy *D* and the weight of the ship *G* exert an inclining moment and return the ship to its original horizontal position. The value of lateral stability (or the effect of the moment of stability) is expressed by arm h (the arm of stability: the larger it is, the more stable it is) and also the height of the intersection of the carrier of buoyancy force *D* with the vertical axis of the ship above the centre of gravity G (M_1). As stated above, this is an imaginary centre point of the inclined ship called the **metacentric point M_1** (metacentre: the higher it is, the more stable it is). In practice, **metacentric height** $k = M_1G$ is used for static stability, which is the distance of the metacentre from the centre of gravity of the ship. i.e. the ship is stable when M_1 lies above the centre of gravity of the ship G (i.e. $k>0$).

The size of stabilizing moment

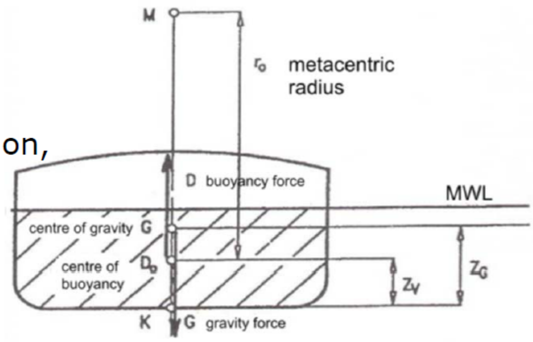
$$M_{stabilizing} = D \cdot h$$

$$M_{stabilizing} = D \cdot k \cdot \sin\varphi$$

From the cross section we derive

$$\overline{MG} = \overline{MD_0} + \overline{D_0K} - \overline{GK}$$

$$k = r_0 + z_v - z_G$$



Attwood's formula for the metacentric position, the **metacentric radius**

$r_0 = \dfrac{I_x}{V}$;

the units are [m] = [m^4] / [m^3].

I_x is area moment of inertia at the water plane at the longitudinal axis of symmetry x, V is the volume of the submerged part of the hull.

It is generally true that safe stability requires a large metacentric height. However, a ship with a high metacentre has **hard stability** (it vigorously reacts to maneuvering, has hard jerking movements which are unfavourable). **Soft stability** is found in sea ships with a metacentric height of k = 0.6 to 0.8 m. An indicator of hard or soft stability is the duration of inclination of the ship. If the inclination of a ship from one side to the other is less than 10seconds, this is a very fast inclination and it has hard stability. These kinds of movements place great stress on the large and heavy driving machinery onboard.

For example:

River cargo ships: k = 2 – 3 m

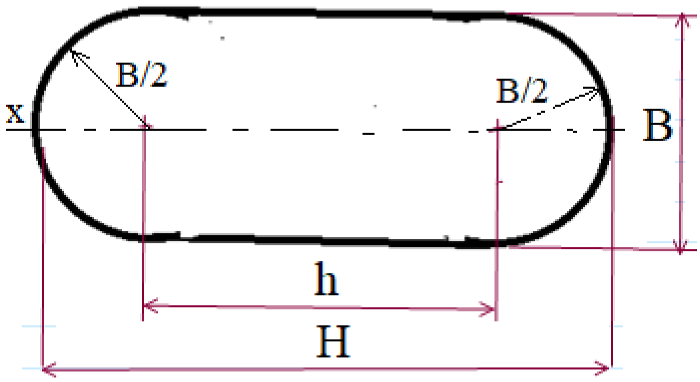
Barges: k = 2 – 15 m

Passenger ships: 0.5 – 2 m

Minimal value in practice: k= 0.25 m

Task:

Determine the lateral stability of a ferry. The shape of this ship is approximately rectangular with semicircular fronts - width B and length H.



The mass of ship and cargo is *m*

For simplicity, assume a prismatic shape of ship, i.e. the ship's sides are vertical.

1. Area monent of inertia at the longitudal axis of a ship *x:*

$$I_x = \frac{B^3}{19}\,(16.h + 3.\pi.B)$$

2. Metacentric radius – see the theory

3. Centre of buoyancy force z_v :

Area at a surface level: $A = B.h + \pi\frac{B^2}{4}$

Volume of submerged part: cargo mass m ⇒ volume of water displaced V

Due to the assumption of a prismatic shape of a ship – z_v is approximately a half of the submerged depth

$$V = A\,.2\,.z_V \;\Rightarrow\; z_V$$

4. Metacentric height *k* – see the theory

k = ?

The input values to the stutents tasks

When the student's number is ***StN*** :

mass	*m = 50 + (StN * 0,2)*	[tonnes]
width	*B = 6 + (StN * 0.1)* [m]	
length	*H = 20 + (StN * 0.1)*	[m]
centre of gravity	z_G= *3 + (StN * 0.01)*	[m]
centre of buoyance	z_v = *0,4 + (StN * 0.01)*	[m]