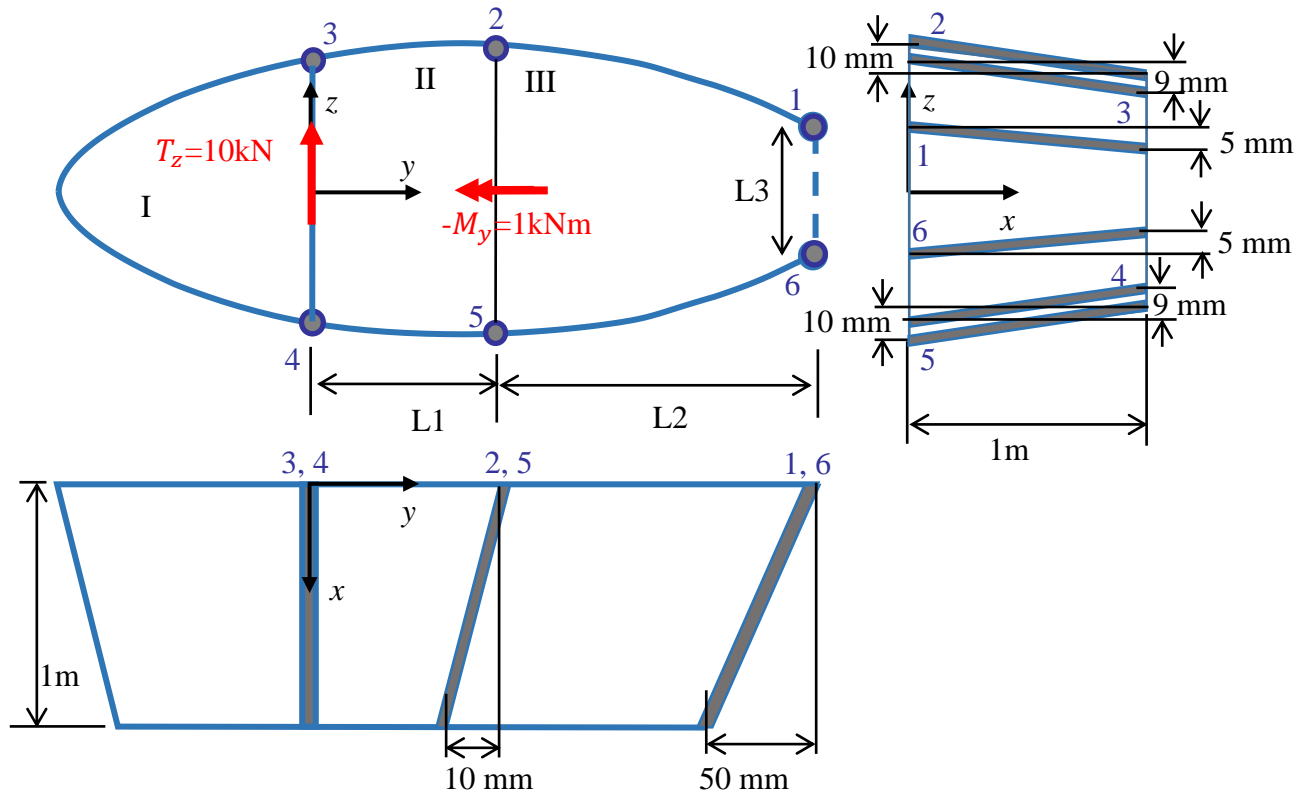


Question n° 1



Wall	Length (mm)	Thickness (mm)	Shear modulus (GPa)
12, 56	580	0.3	22
23, 45	160	0.3	22
34(400	0.3	22
34I	175	0.5	45
25	180	0.5	45

Boom	Section (mm ²)	Cell	Area (mm ²)
1, 6	700	I	21 000
2, 5	800	II	28 500
3, 4	700	III	97 100

Distance	Length (mm)
L1	150
L2	550
L3	150

The tapered wing cross-section depicted here above has two closed cells “I” and “II”. The cell “III” is not closed (wall 61 is absent). The section is already idealized with its properties reported in the four Tables here above.

We consider the following assumptions

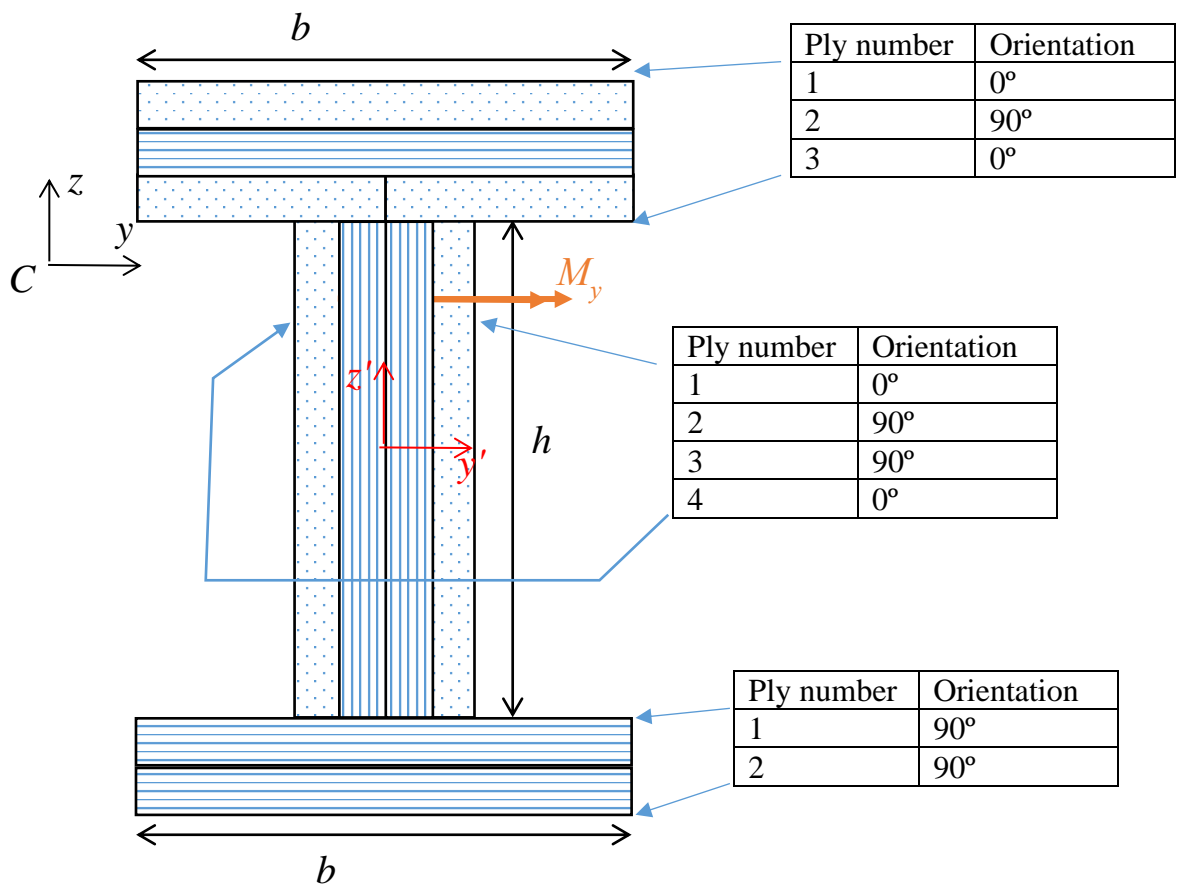
- The booms carry the direct stress (due to bending) only;
- The skin panels sustain the shear stress only;

- The cross-section has a single symmetry;
- Twist and shear centres are assumed to coincide.

You are requested to compute

1. The location of the bending inertia centre;
2. The second moments of area I_{yy} , I_{yz} and I_{zz} ;
3. The direct stress in each boom;
4. The shear flow in each wall;
5. The cross-section twist rate;
6. The shear stress in each wall.

Question n° 2



Material properties	Values
Matrix Young's modulus E_m	3 GPa
Matrix Poisson coefficient ν_m	0.3
Fibre Young's modulus E_f	250 GPa
Fibre Poisson coefficient ν_f	0.2
Fibre volume fraction ν_f	50 %

Geometrical properties	Values
Ply thickness t	0.2 mm
Web height h	30 mm
Flange width b	20 mm

A stringer is made of a composite laminate as illustrated in the Figure here above. Each ply is made of a unidirectional composite (continuous isotropic fibres embedded in an isotropic matrix), with a fibre volume fraction v_f . Each ply has a uniform thickness t and an orientation (the orientation of the carbon fibres) related to the x-axis. Material and geometrical properties are reported in the Tables here above.

You are requested to evaluate

- 1) The homogenised properties of the plies of different orientations ($E_x^{0^\circ}, E_y^{0^\circ}, E_z^{0^\circ}, \nu_{xy}^{0^\circ}, \nu_{yx}^{0^\circ}, \nu_{xz}^{0^\circ}, \nu_{zx}^{0^\circ}, \mu_{xy}^{0^\circ}, E_x^{90^\circ}, E_y^{90^\circ}, E_z^{90^\circ}, \nu_{xy}^{90^\circ}, \nu_{yx}^{90^\circ}, \nu_{yz}^{90^\circ}, \nu_{zy}^{90^\circ}, \mu_{xy}^{90^\circ}$); The answers are numerical values and refer to the plies of the flange.

Using the **theory of thin walls** and neglecting the Poisson effect (you do not have to use the A, B D-matrix laminate theory), you are also requested to evaluate

- 2) Using the symbolic notations (in terms of $E_x^{0^\circ}, \dots, t, h, b$), the location (C_y, C_z) of the inertia centre C governing the bending behaviour in the referential $O'y'z'$ **linked to the mid height of the web**; Be careful that the plies have different orientations (**hence different material properties**);
- 3) The numerical values of the answer to point 2);
- 4) Using the symbolic notations (in terms of $E_x^{0^\circ}, \dots, t, h, b, C_y, C_z$), the values of the modified second moments of area, EI_{yy}, EI_{zz} , and EI_{yz} , governing the bending behaviour;
- 5) Using the symbolic notations (in terms of $E_x^{0^\circ}, \dots, t, h, b, EI_{yy}, EI_{zz}, EI_{yz}, C_y, C_z$), the location of the shear centre; **Choose wisely the reference point to write the equilibrium equation.**
- 6) The numerical values of the answer to points 4) and 5);
- 7) Using the symbolic notations (in terms of $E_x^{0^\circ}, \dots, t, h, b, C_y, C_z, EI_{yy}, EI_{zz}, EI_{yz}, M_y$), the values of the stress in the different plies when the stringer is subject to a bending moment M_y ;
- 8) The numerical values of the maximum stress in the different plies for $M_y=100$ N m.