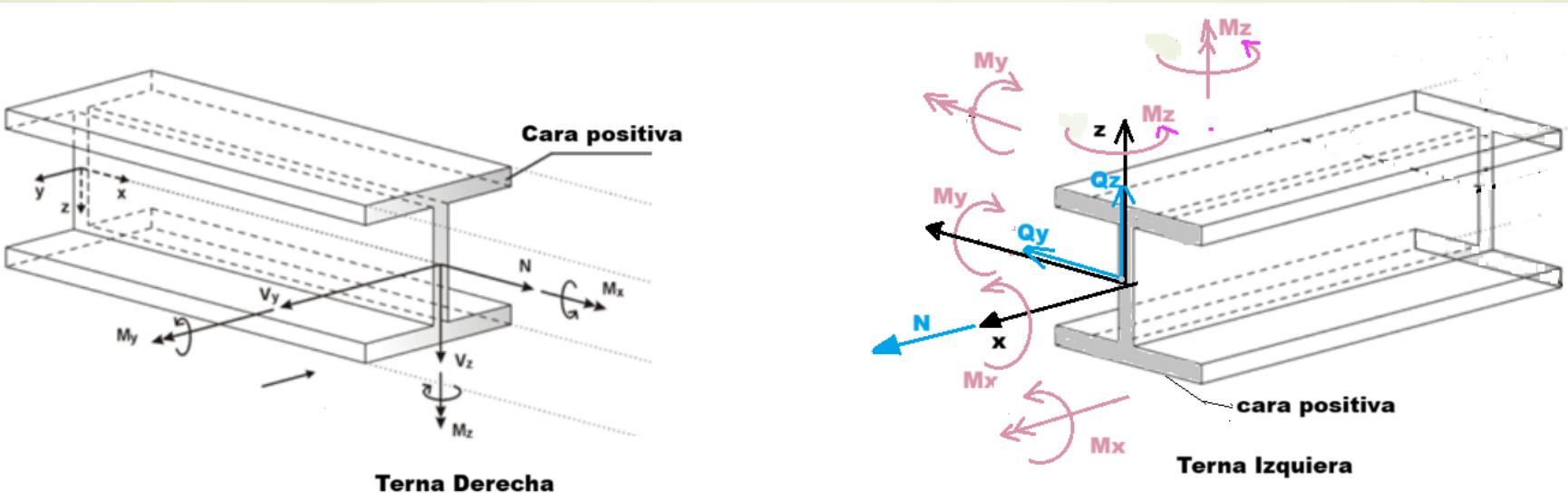


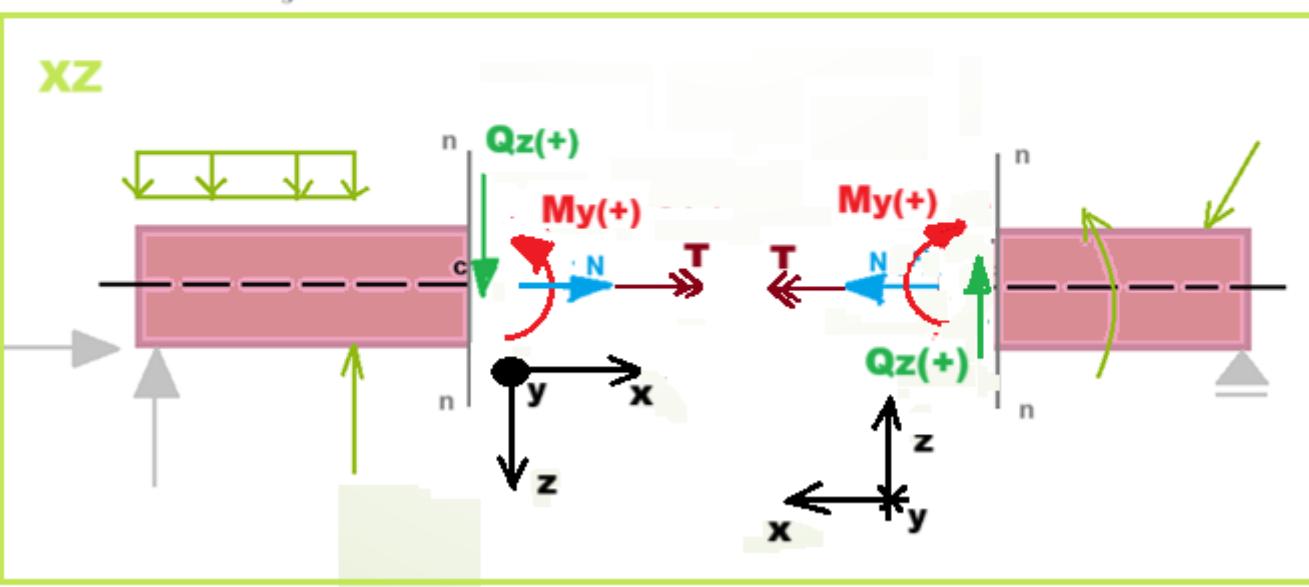
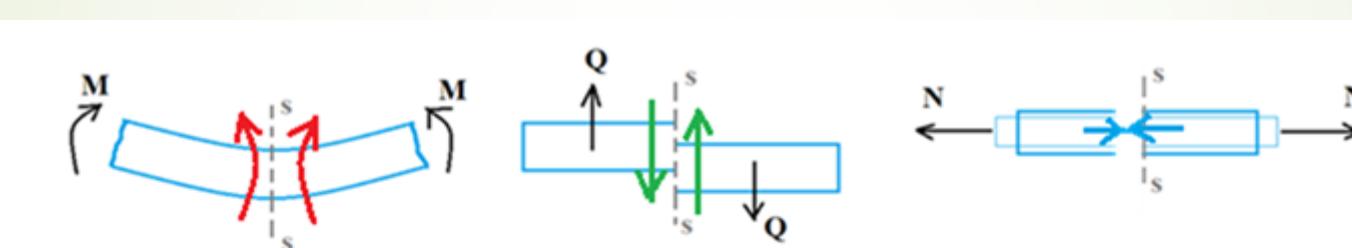


ESFUERZOS INTERNOS EN EL ESPACIO



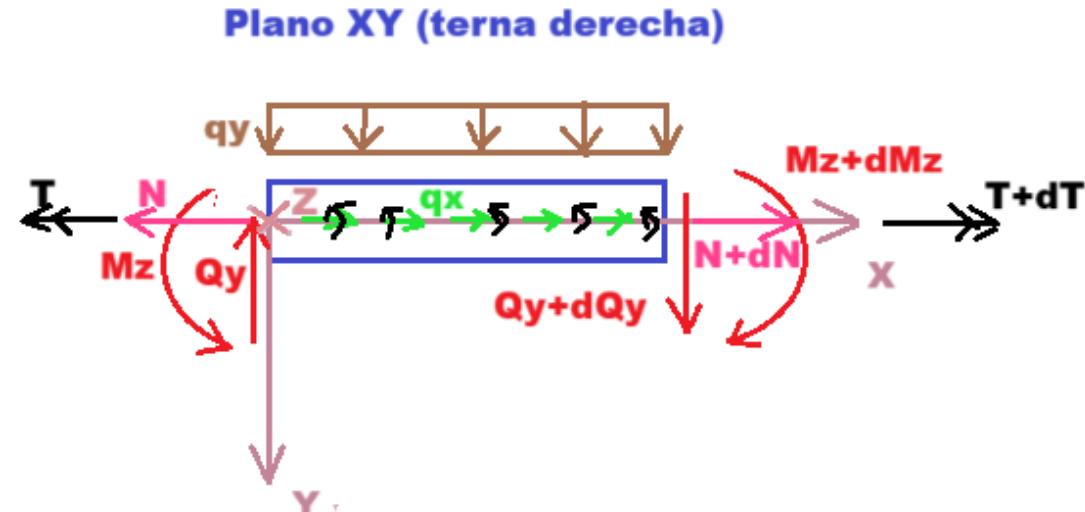
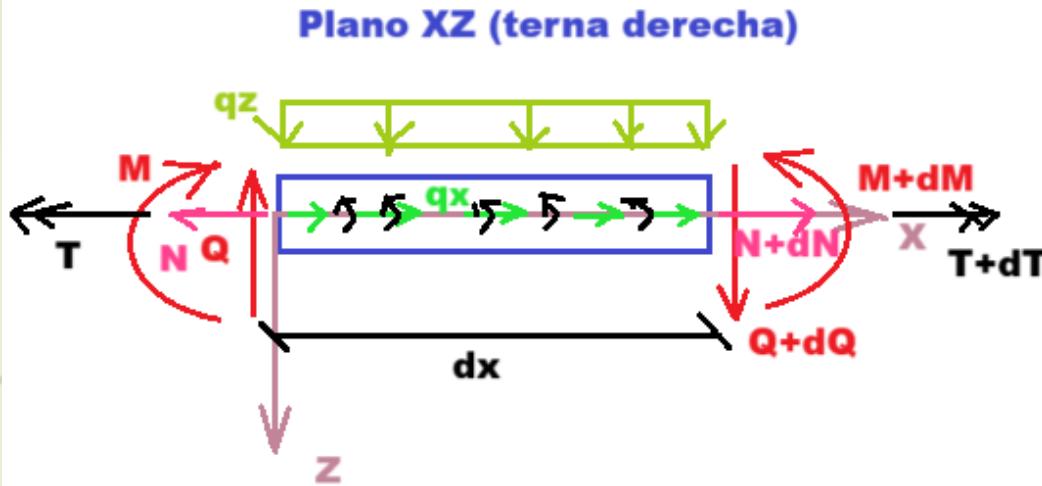
$$R = \begin{bmatrix} N \\ Q_y \\ Q_z \end{bmatrix}$$

$$M = \begin{bmatrix} M_T \\ M_Z \\ M_Y \end{bmatrix}$$



Convención de signos plano XZ

Relaciones diferenciales



$$\sum F_x = 0$$

$$-N + q_x \, dx + N + dN = 0$$

$$\sum F_y = 0$$

$$-Q_y + q_y \, dx + Q_y + dQ_y = 0$$

$$\sum M_x = 0$$

$$T + m_x \, dx - T - dT = 0$$

$$\sum M_y = 0$$

$$M_x + Q_z \, dx - q_z \frac{dx^2}{2} - M_y - dM_y = 0$$

$$\sum M_z = 0$$

$$-M_z + Q_y \, dx - q_y \frac{dx^2}{2} + M_z + dM_z = 0$$

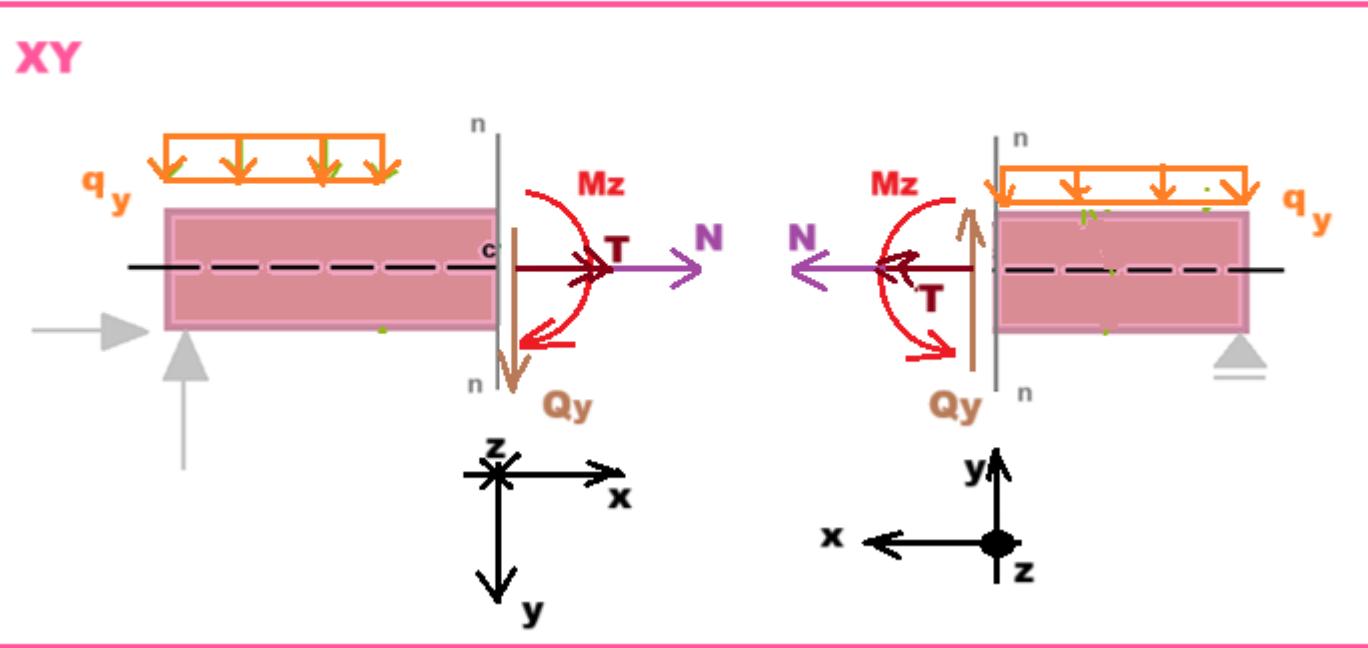
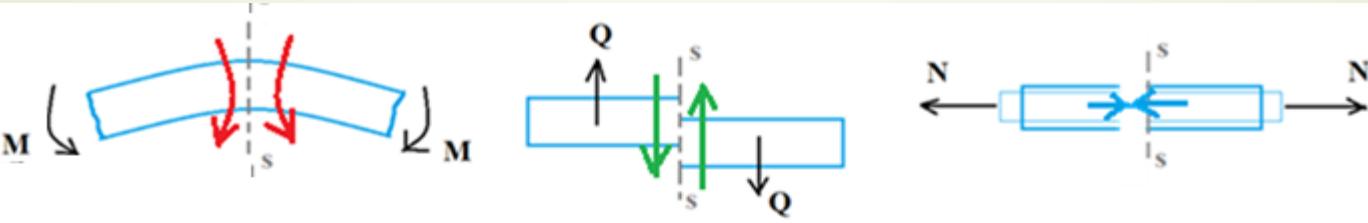
$$-q_x = \frac{dN}{dx}$$

$$-q_y = \frac{dQ_y}{dx}$$

$$m_x = \frac{dT}{dx}$$

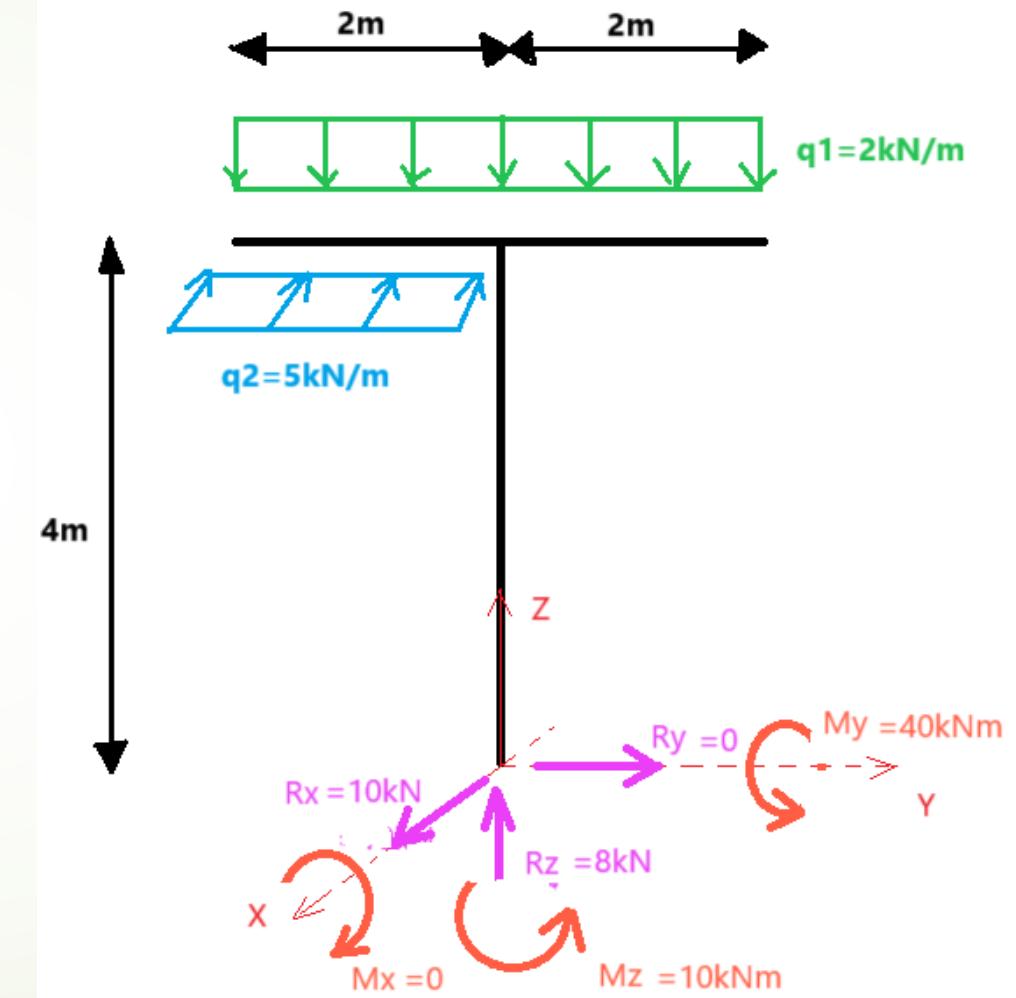
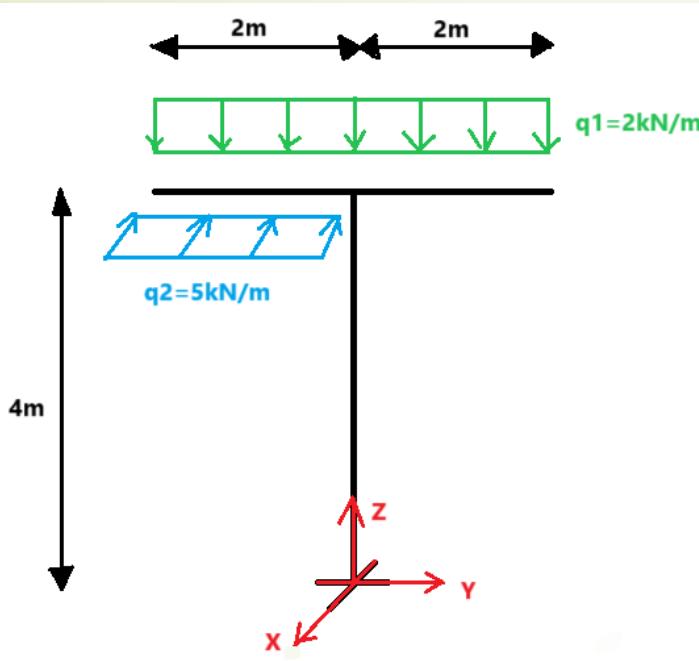
$$Q_z = \frac{dM_y}{dx}$$

$$-Q_y = \frac{dM_z}{dx}$$



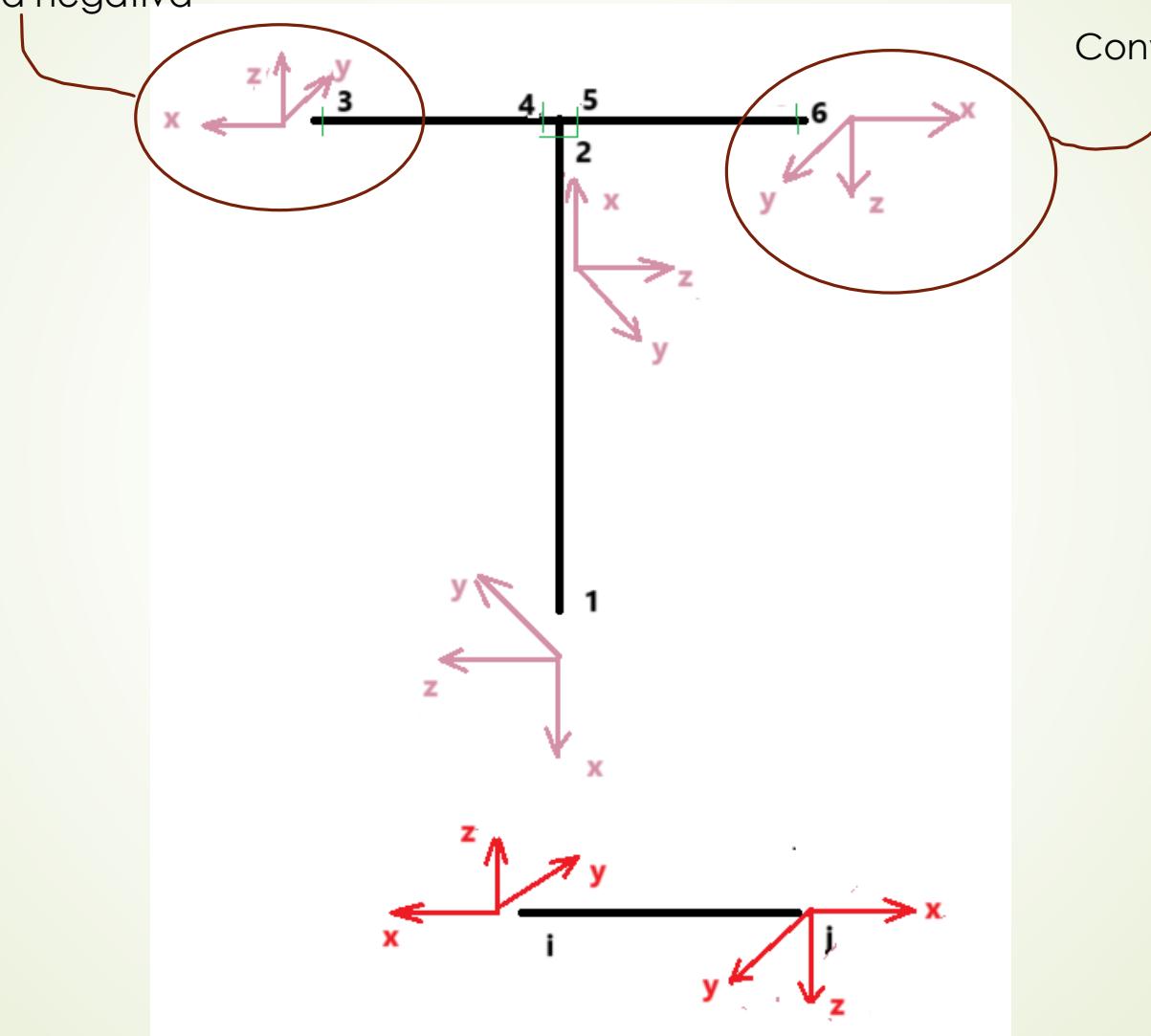
Convención de signos plano XY

Se definen los ejes globales para determinar reacciones.



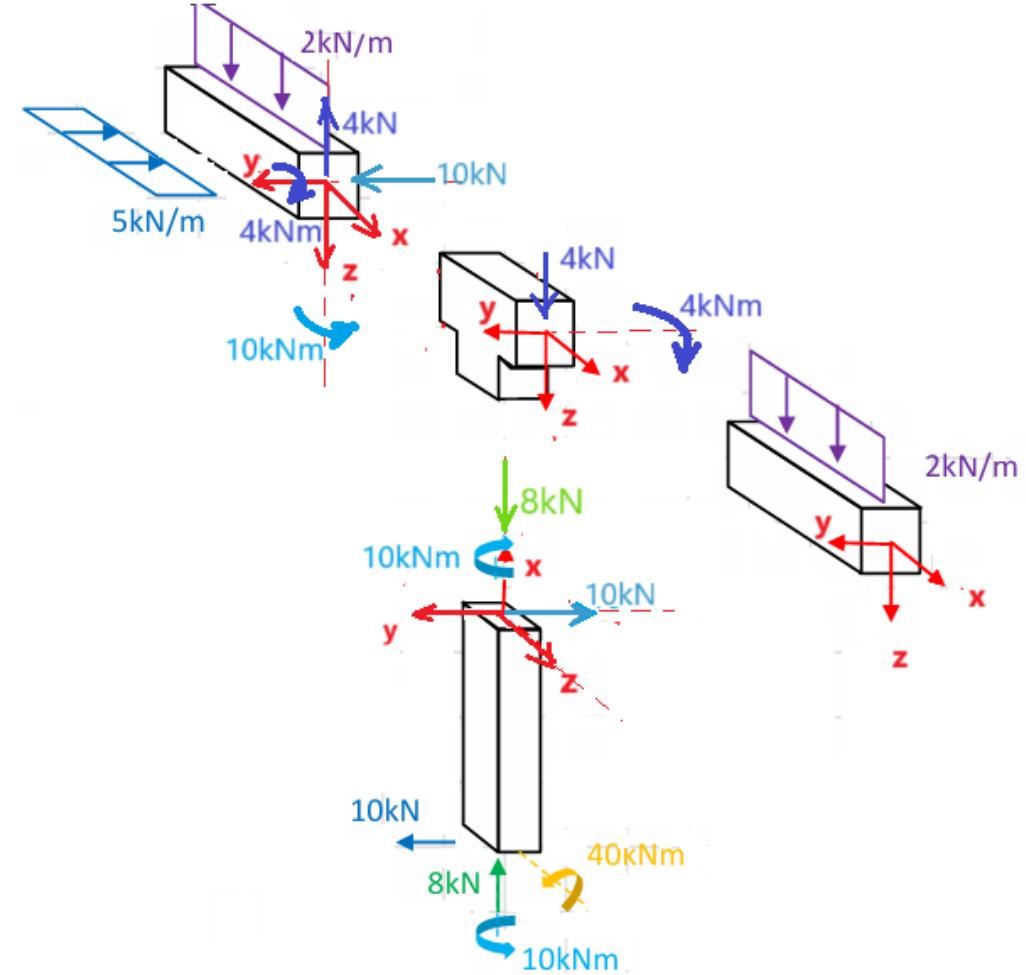
Se definen los ejes locales y secciones para determinar esfuerzos internos.

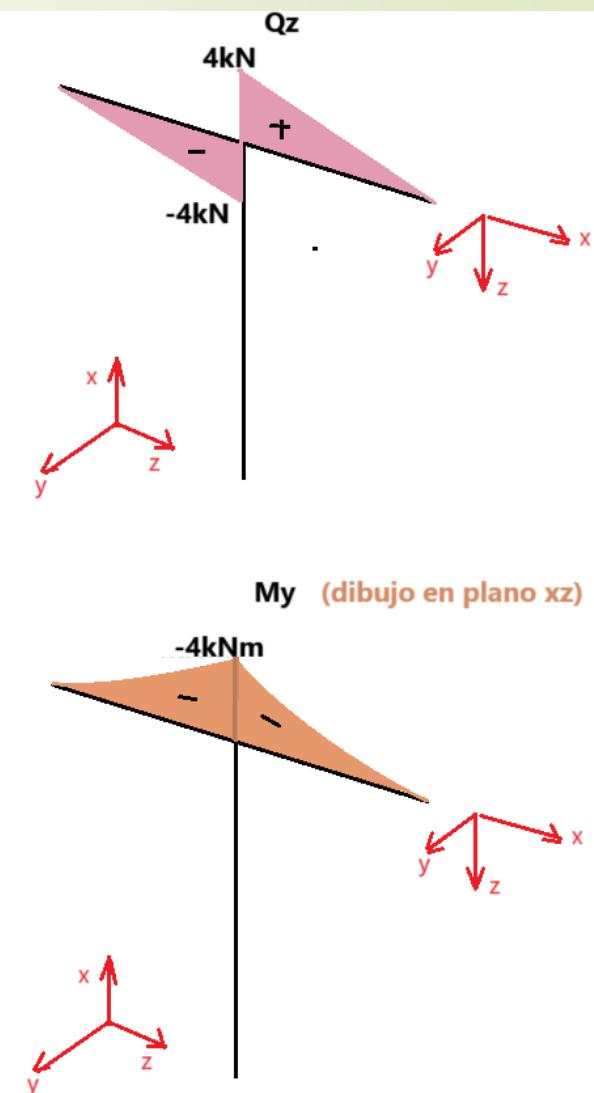
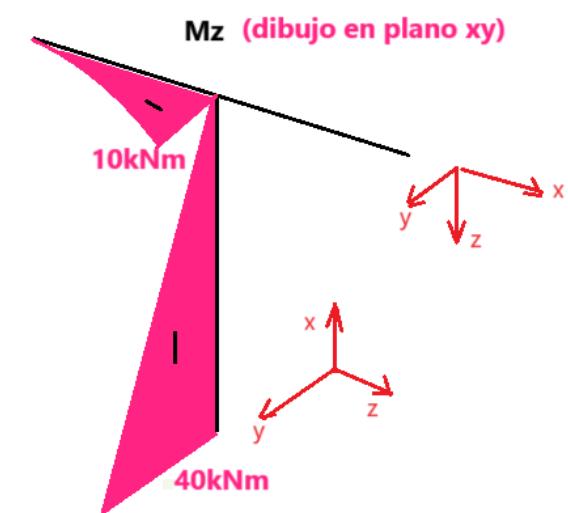
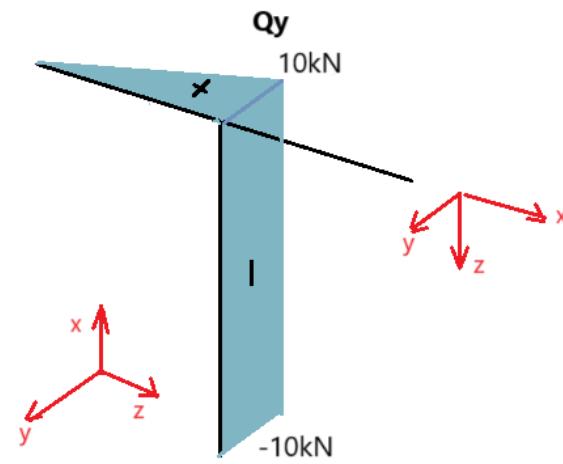
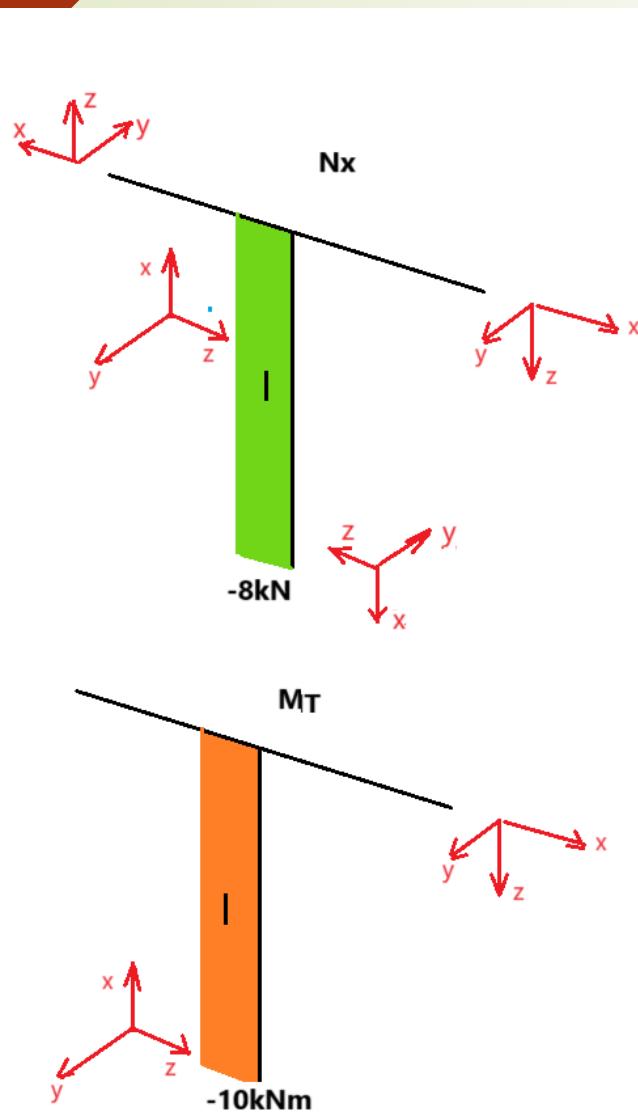
Convención cara negativa



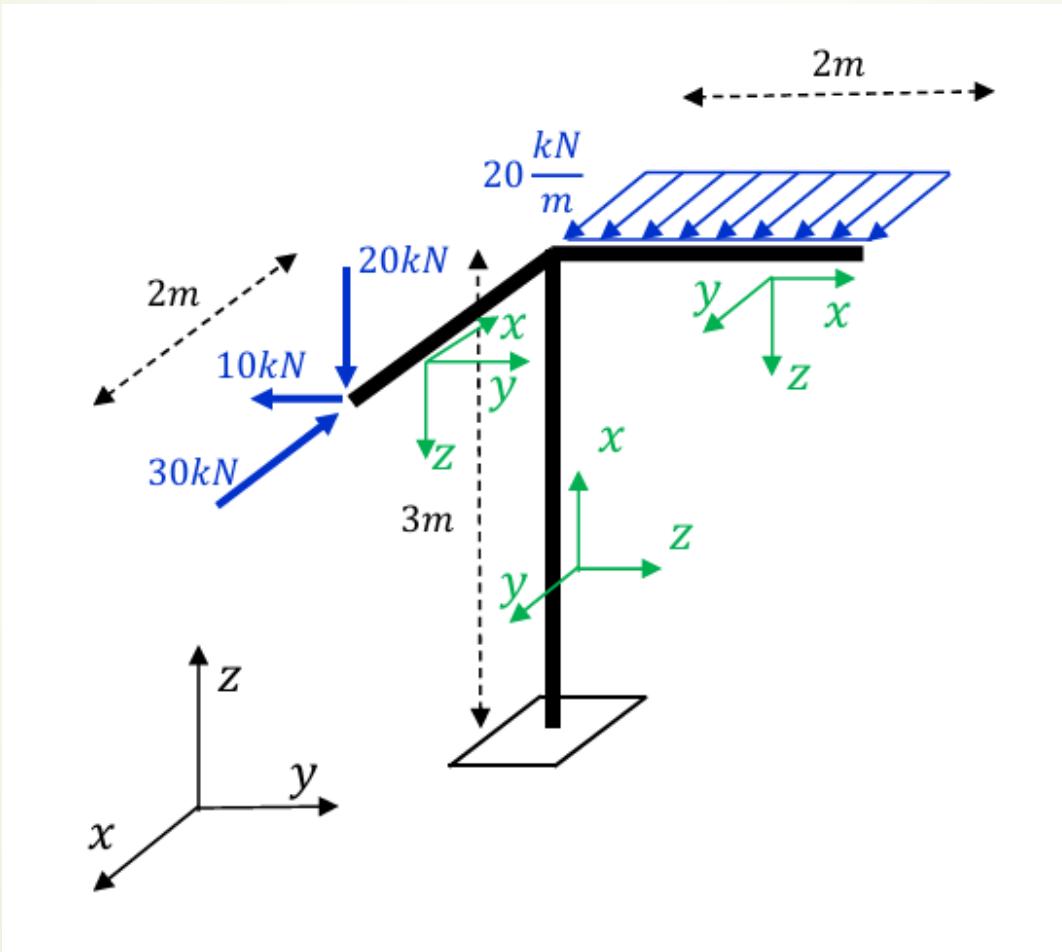
Esfuerzos característicos

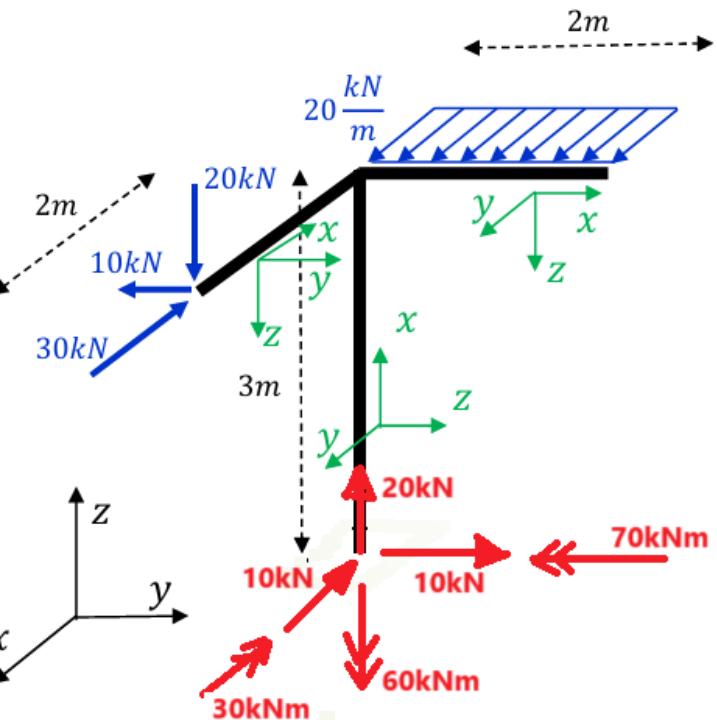
| | 1 | 2 | 3 | 4 | 5 | 6 |
|-------|--------|--------|---|--------|-------|---|
| N_x | -8kN | -8kN | 0 | 0 | 0 | 0 |
| Q_y | -10kN | -10kN | 0 | 10kN | 0 | 0 |
| Q_z | 0 | 0 | 0 | -4kN | 4kN | 0 |
| M_x | -10kNm | -10kNm | 0 | 0 | 0 | 0 |
| M_y | 0 | 0 | 0 | -4kNm | -4kNm | 0 |
| M_z | -40kNm | | 0 | -10kNm | 0 | 0 |





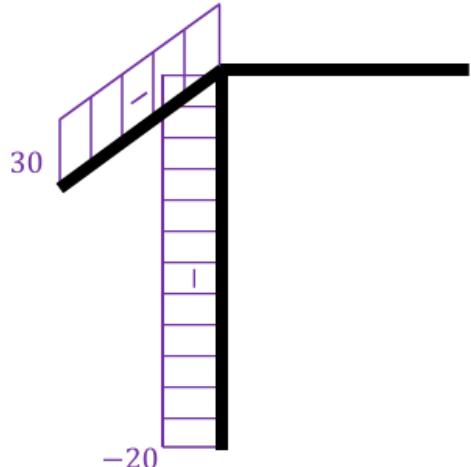
Ejemplo: Determinar los esfuerzos internos en la estructura 3D.



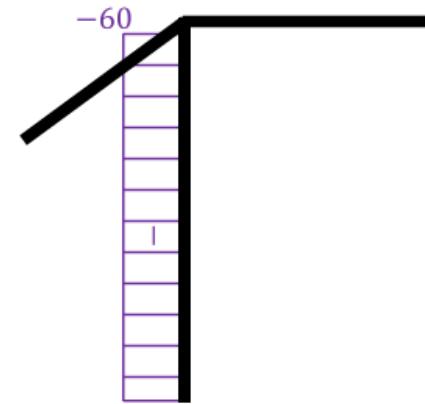


$$\frac{dN(x)}{dx} = -q_x(x)$$

$$\frac{dM_t(x)}{dx} = -m_t(x)$$

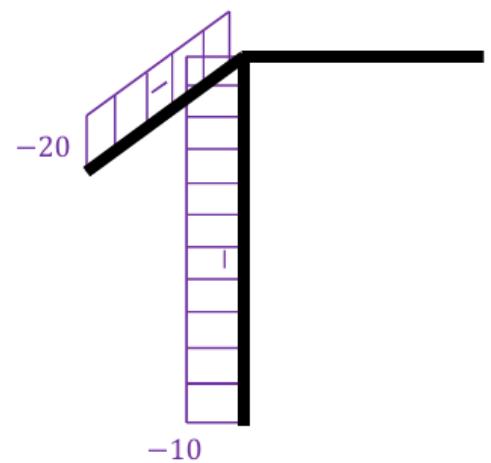


N [kN]
(cualquier plano)



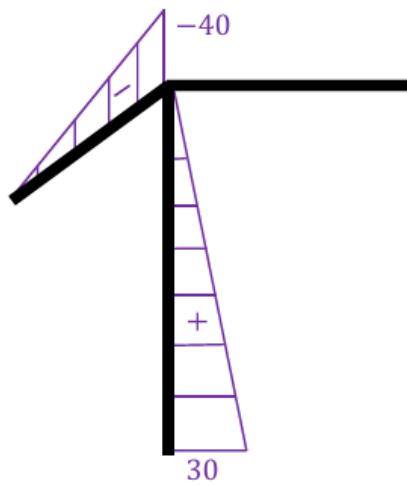
M_t [kNm]
(cualquier plano)

$$\frac{dQ_z(x)}{dx} = -q_z(x)$$



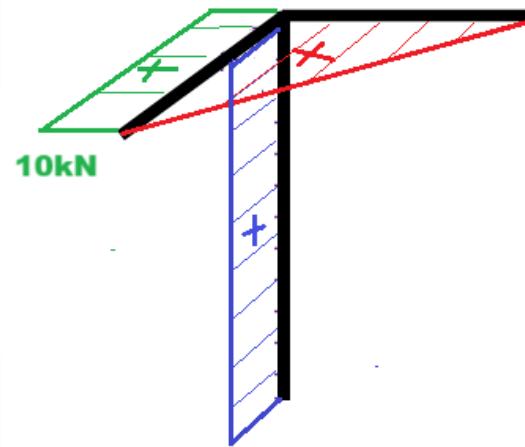
Q_z [kN]
(plano xz)

$$\frac{dM_y(x)}{dx} = Q_z(x)$$



M_y [kNm]
(plano xz)

$$\frac{dQ_y(x)}{dx} = -q_y(x)$$



Q_y [kN]
(plano xy)



M_z [kNm]
(plano xy)

$$\frac{dM_z(x)}{dx} = -Q_y(x)$$

