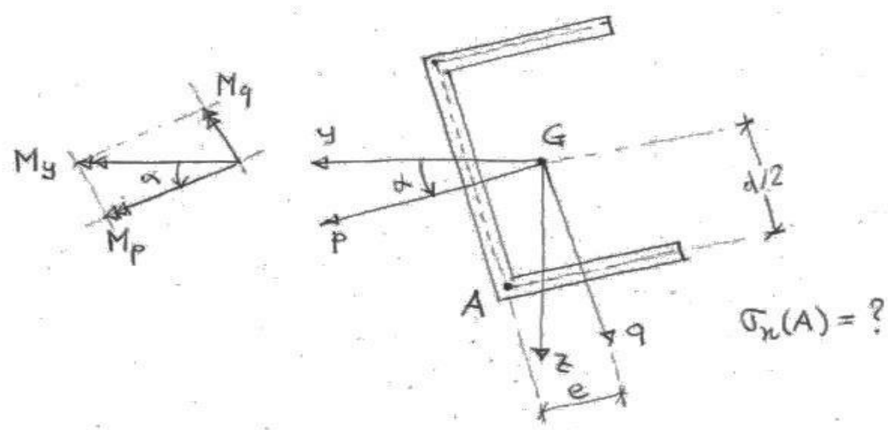
# Unit IV- Unsymmetrical Bending

## Unsymmetrical Bending (2/3)

- The first case is trivial, and can be solved by using:
  - Decomposition of the bending moment:

$$M_p = M_y \boxed{\cos(\alpha)}$$

$$M_q = -M_y \boxed{\sin(\alpha)}$$

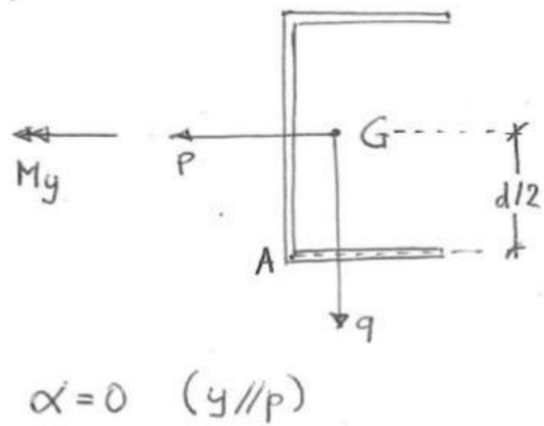



  - Superposition of effects: $\sigma_x(A) = \frac{M_p}{I_{pp}} \cdot \frac{d}{2} - \frac{M_q}{I_{qq}} \cdot e$

$$= M_y \left( \frac{d/2}{I_{pp}} \cos(\alpha) + \frac{e}{I_{pp}} \sin(\alpha) \right)$$

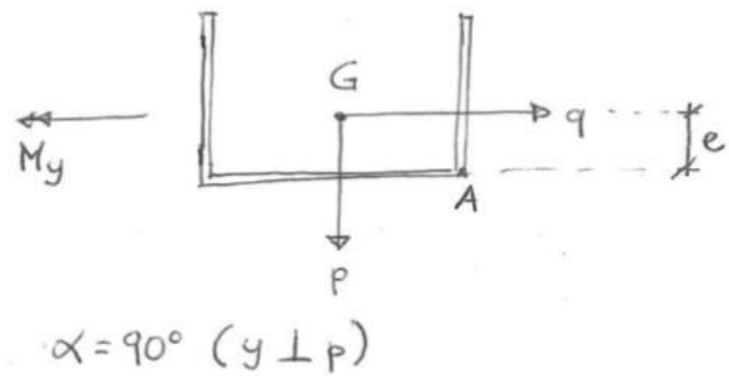
# Unsymmetrical Bending (3/3)

- Particular cases…




$$\sigma_x(A) = \frac{M_y}{I_{pp}} \cdot \frac{d}{2}$$

Bending about the strong axis




$$\sigma_x(A) = \frac{M_y}{I_{qq}} \cdot e$$

Bending about the weak axis

# Product Moment of Area (1/3)

- Let's introduce a new quantity, $I_{yz}$, called

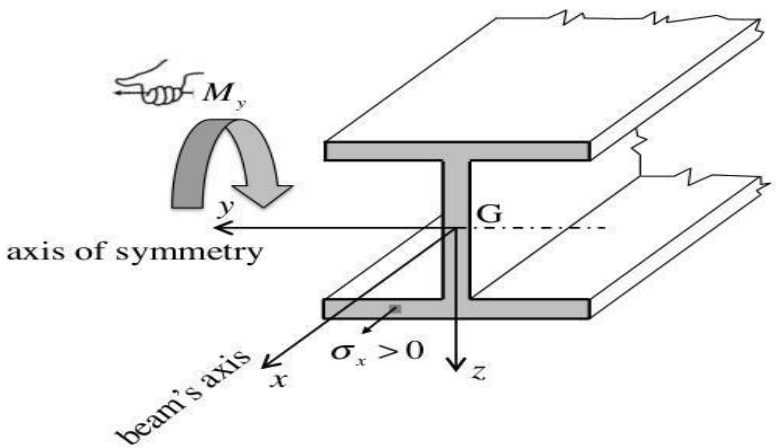
  "Product Moment of Area"

  - Defined as:

$$I_{yz} = \int_A y\,z\,\mathrm{d}A$$

- If and only if $I_{yz}$ =0, a bending moment acting on one of these two axes will cause the beam to bend about the same axis only, not about the orthogonal axis (symmetric bending)
  - I.e. a vertical transverse load will not induce any lateral sway and a lateral transverse will not cause any vertical movement

# Symmetrical Bending (4/4)




- The simplest case when the bending moment $M_y$ acts about the axis *y*, orthogonal to the axis of symmetry *z*
- Therefore, the beam bends in the vertical plan $G_{xz}$
- The direct stress $\sigma_x$ is given by:

**Eq. (1)**

$$\sigma_x = \frac{M_y z}{I_{yy}}$$