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Aircraft Structures
(GATE Aerospace) by
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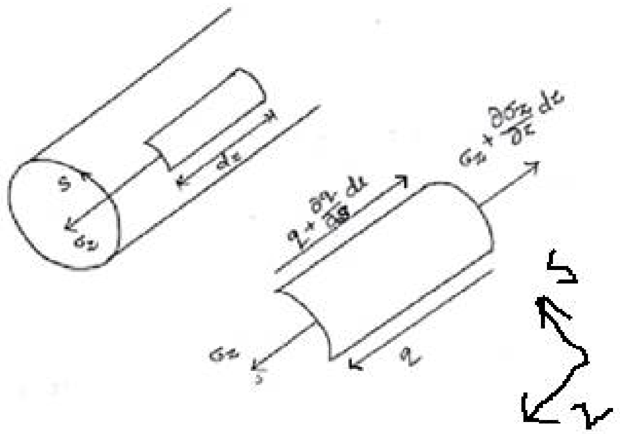
Shear flow due to non-uniform bending of thin walled structures

We know non uniform bending

$$\sigma_z = \frac{(I_{xx}M_y - I_{xx}M_x)}{(I_{xx}I_{yy} - {I_{xy}}^2)}x + \frac{(I_{yy}M_x - I_{xy}M_y)}{(I_{xx}I_{yy} - {I_{xy}}^2)}y$$

Consider a thin walled beam of an arbitrary resection as shown in fig, it is subjected to a non-uniform bending, if σ_z is bending stress and q is the shear flow developed due to uniform bending.



Consider the force equilibrium of an element of length dz act with dt as shown in fig.

$$\sigma_z.ds.t - \left(\sigma_z + \frac{\partial \sigma_z}{\partial z}dz\right).ds.t + q.dz - \left(q + \frac{\partial q}{\partial s}ds\right).dz = 0$$

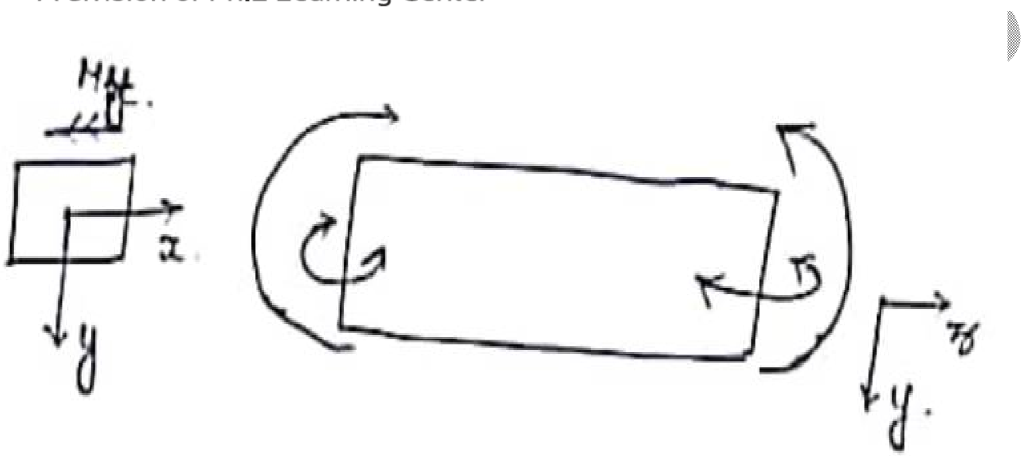
$$-\frac{\partial \sigma_z}{\partial z}dsdz.t - \frac{\partial q}{\partial s}dzds = 0$$

$$\frac{\partial q}{\partial s} + t\frac{\partial \sigma}{\partial z} = 0,$$

$$\frac{\partial q}{\partial s} = -\ t\frac{\partial \sigma}{\partial z}$$

$$\frac{\partial q}{\partial s} = -t\left[\frac{I_{xx}\frac{\partial M_y}{\partial z} - I_{xy}\frac{\partial M_x}{\partial z}}{I_{xx}I_{yy} - {I_{xy}}^2}\right]x - t\left[\frac{I_{yy}\frac{\partial M_x}{\partial z} - I_{xy}\frac{\partial M_y}{\partial z}}{I_{xx}I_{yy} - {I_{xy}}^2}\right]y$$

$V_x = \frac{\partial M_y}{\partial z}$ and $V_y = \frac{\partial M_x}{\partial z}$



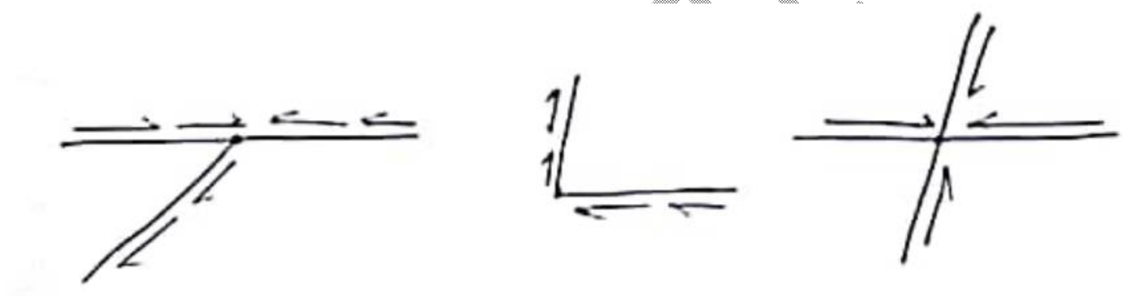
$$\frac{\partial q}{\partial s} = -t\frac{(I_{xx}V_x - I_{xy}V_y)}{(I_{xx}I_{yy} - I_{xy}{}^2)}x - t\frac{(I_{yy}V_y - I_{xy}V_x)}{(I_{xx}I_{yy} - I_{xy}{}^2)}y$$

$$q_{s2} - q_{s1} = \int_{s_1}^{s_2} \frac{\partial q}{\partial s} ds$$

Note: - for thin walled section at the free end (open end) shear flow is considered as zero (Boundary condition)

Shear Centre

- Shear centre is a point, if transverse loading is applied through this point, and then there will be no twist of the section. It will be only undergoing bending.
- It is also the point of twist or centre of the twist or centre of flexure.
- Shear centre is cross section property and it is independence of loading.
- For any section, if there is a junction, the junction itself will be a shear centre.



- For doubly symmetric section, shear centre and centroid is same.
- For single symmetric section, shear centre lies on axis of symmetry.

Problem 1.)

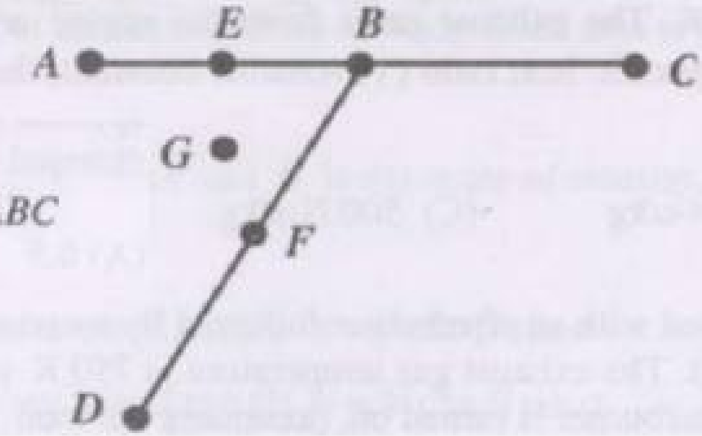
For the thin walled beam cross section as shown in the figure, the shear centre lies at

(A) Mid point of *AB*, i.e. at point *E*

(C) Junction point *B*

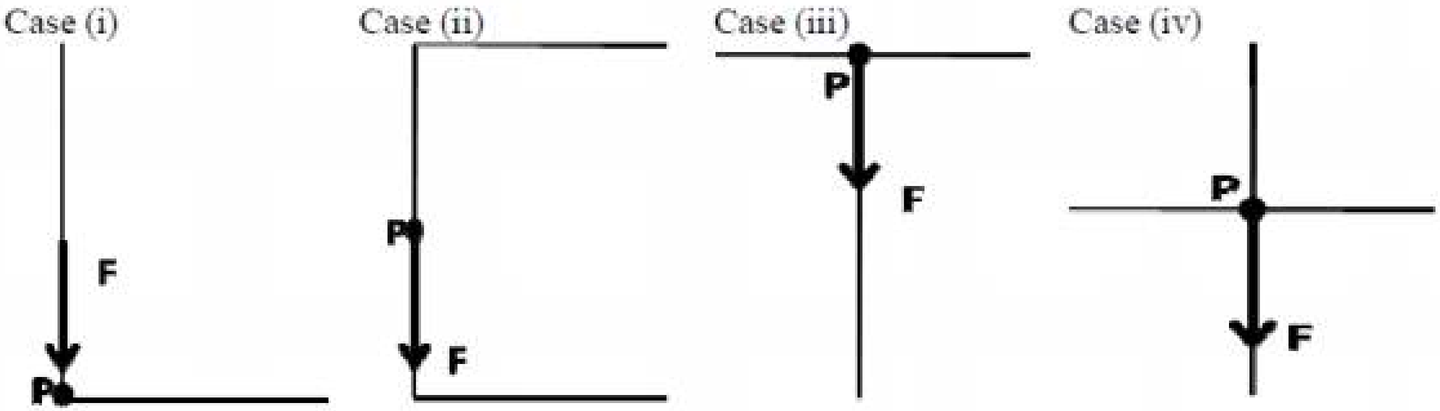
(B) Mid point of *BD*, i.e. at point *F*

(D) at a point *G* lying within the area *ABC*



Problem 2.)

Consider four thin-walled beams of different open cross-sections, as shown in the cases (i-iv). A shear force of magnitude 'F' acts vertically downward at the location 'P' in all the beams. In which of the following case, does the shear force induce bending and twisting?



(A) (i)
(B) (ii)
(C) (iii)
(D) (iv)

Problem 3.)

The cross-section of a long thin-walled member is as shown in the figure. When subjected to pure twist, point A

(A) does not move horizontally or axially, but moves vertically

(B) does not move axially, but moves both vertically and horizontally

(C) does not move horizontally, vertically or axially

(D) does not move vertically or axially, but moves horizontally

Problem 4.)

Which of the following statement(s) is / are true about the shear centre of a cross-section:
P: It is that point in the cross-section through which shear loads produce no twisting.
Q: This point is also the centre of twist of sections subjected to pure torsion.
R: The normal stress at this point is always zero.

(A) P, Q and R (B) P only (C) P and Q only (D) P and R only

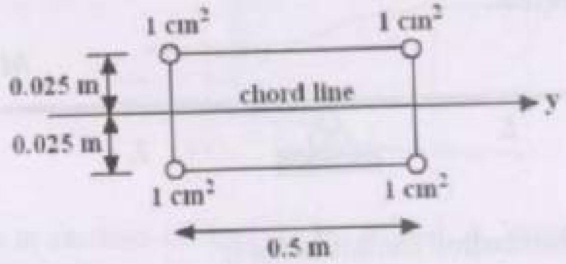
Problem 5.)

Which of the following statements about the neutral axis of a beam with unsymmetrical cross section is true:

(A) The product of second moment of area about the neutral axis is always zero.
(B) The normal stress along the neutral axis is always zero.
(C) The shear stress along the neutral axis is always zero.
(D) The product of second moment of area about the neutral axis and the normal stress about the neutral axis are always zero.

Problem 6.)

A wing root cross section is idealized using lumped areas (booms) as shown below.



The wing root bending moment in steady level flight is $M_y = 10$ N-m. If the airplane flies at a load factor $n = 3.5$, the maximum bending stress at the root is

(A) 1×10^6 N/m^2

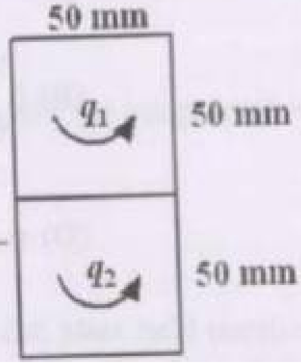
(B) 3.5×10^6 N/m^2

(C) 7×10^6 N/m^2

(D) 0.286×10^6 N/m^2

Problem7.)

A 2-celled tube with wall thickness 0.5 mm is subjected to a torque of 10 N-m. The resulting shear flows in the two cells are q_1 and q_2 as shown below.



The torque balance equation (Bredt-Batho formula) for this section leads to

(A) $q_1 - q_2 = 2000$ N/m

(B) $q_1 + 2q_2 = 2000$ N/m

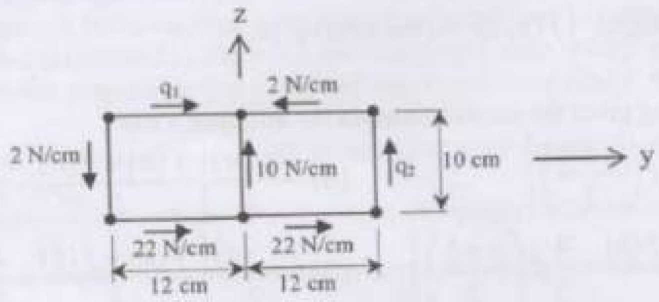
(C) $q_1 + q_2 = 2000$ N/m

(D) $2q_1 + q_2 = 2000$ N/m

Problem 8.)

Statement for Linked Answer Questions 84 and 85:

An idealized thin walled two cell symmetric box beam is as shown. The shear flows in the walls are due to the applied shear forces $V_y = 480$ N, $V_z = 300$ N, and a torque M, all acting at the shear center.



Q.84 The shear flows q_1 and q_2 are

(A) $q_1 = -2$ N/cm, $q_2 = +22$ N/cm

(B) $q_1 = +2$ N/cm, $q_2 = +22$ N/cm

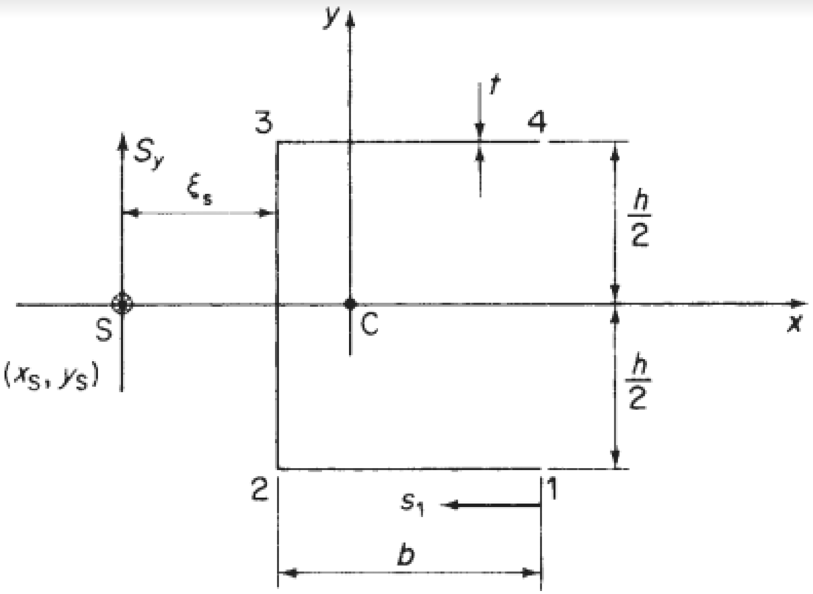
(C) $q_1 = +2$ N/cm, $q_2 = -22$ N/cm

(D) $q_1 = -2$ N/cm, $q_2 = -22$ N/cm

Q.85 The torque M is

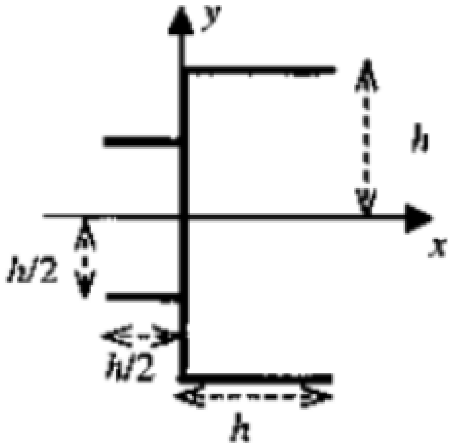
(A) 3360 N.cm (B) 5760 N.cm (C) 6960 N.cm (D) 8160 N.cm

Problem9.)



Problem10.)

The given thin wall section of uniform thickness, t, is symmetric about x-axis. Moment of inertia is given to be $I_{xx} = \frac{35}{12} th^3$. Shear center for this section is located at



(A) $x = -\frac{3}{8}h$ (B) $x = -\frac{9}{28}h$ (C) $x = -\frac{35}{36}h$ (D) $x = -\frac{17}{35}h$