AE 4001 Sem 1

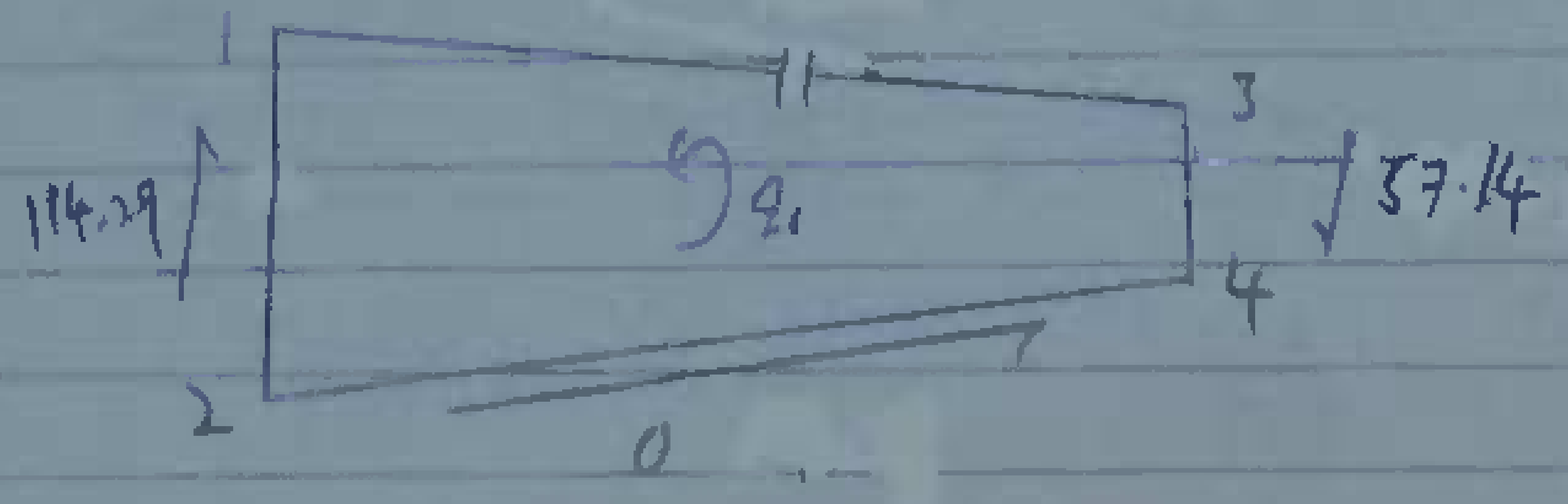
Date No.

$S_y = 20000\,N$

Boom	y_i (mm)	B_i (mm²)	$\Delta y_i \cdot B_i$	$\Delta q_{b,i}$	Section	q_b N/mm
1	75mm	100	562500	-114.29	1-2	-114.29 (cut)
2	-75mm	100	562500	+114.29	2-4	0
3	25	150	93750	-57.14	4-3	-57.14
4	-25	~~150~~	93750	+57.14	3-1	0

$I_{xx} = \sum B y^2 = 1312500$

in open section

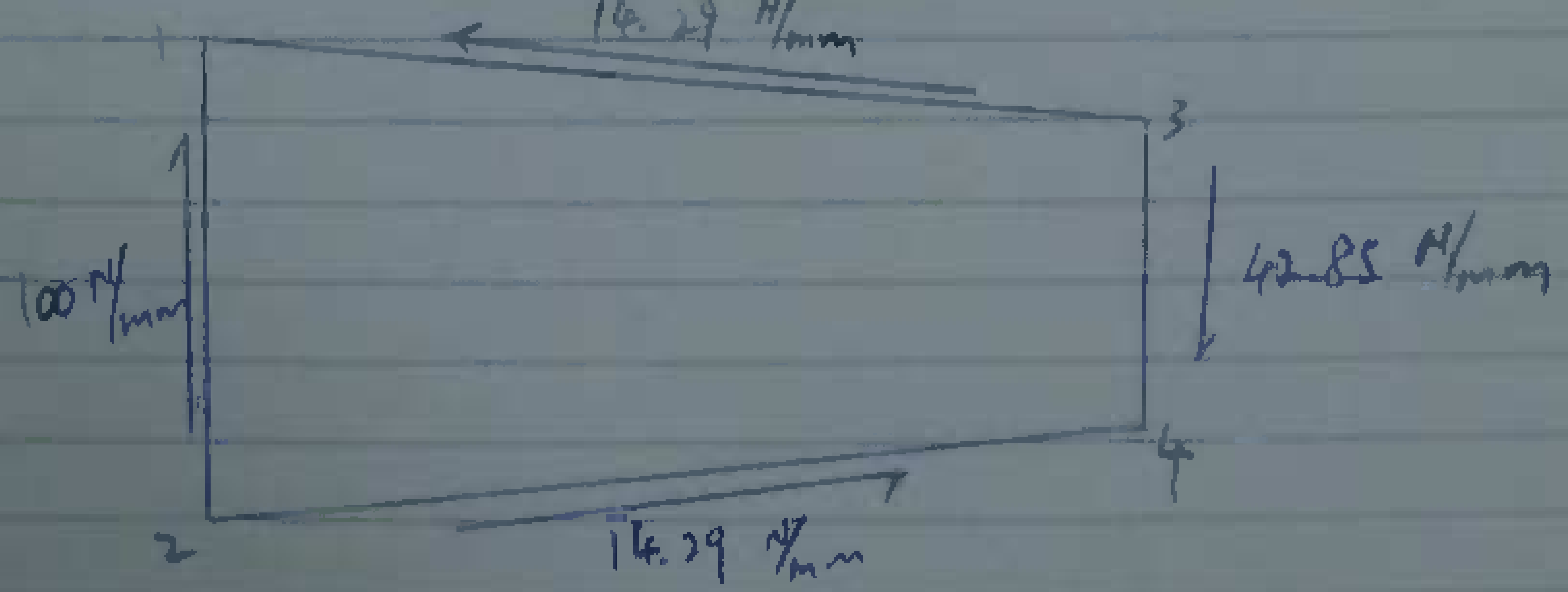


Equate moment

$$2 A_0 q_1 - 57.14 \times (50) \times (200) = 0 \qquad (A_0 = 20000\ mm)$$

$$q_1 = 14.29\ N/mm$$

Final shear flow:



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(b) $q = \tau t$

Section 1-2

$4t = \frac{100}{40}$

$= 2.5$

$t = 0.625 \text{ mm}$

Section 2-4

$t = \frac{14.29}{40}$

$= 0.357 \text{ mm}$

Section 4-3

$3t = 42.85/40$

$= 1.071 \text{ mm}$

$t = 0.357 \text{ mm}$

$$\phi = \frac{1}{2A_0}\int \frac{q}{Gt}\, ds$$

$$\phi = \frac{1}{2\times 20000}\left[100\left(\frac{150}{28000(4t)}\right) - 14.29\left(\frac{206.16}{28000(t)}\right) + 42.85\left(\frac{50}{28000(3t)}\right) - 14.29\left(\frac{206.16}{28000(t)}\right)\right]$$

$$\cancel{\phi = \frac{2.232\times10^{-8}}{t} - \frac{1.276\times10^{-8}}{t} + \frac{1.275\times10^{-8}}{t} - \frac{1.276\times10^{-8}}{t}}$$

$$\phi = \frac{3.35\times10^{-6}}{t} - \frac{2.63\times10^{-6}}{t} + \frac{6.38\times10^{-7}}{t} - \frac{2.63\times10^{-6}}{t}$$

$|t| = 0.036 \text{ mm}$

Choose largest

$t = 0.625 \text{ mm}$ #

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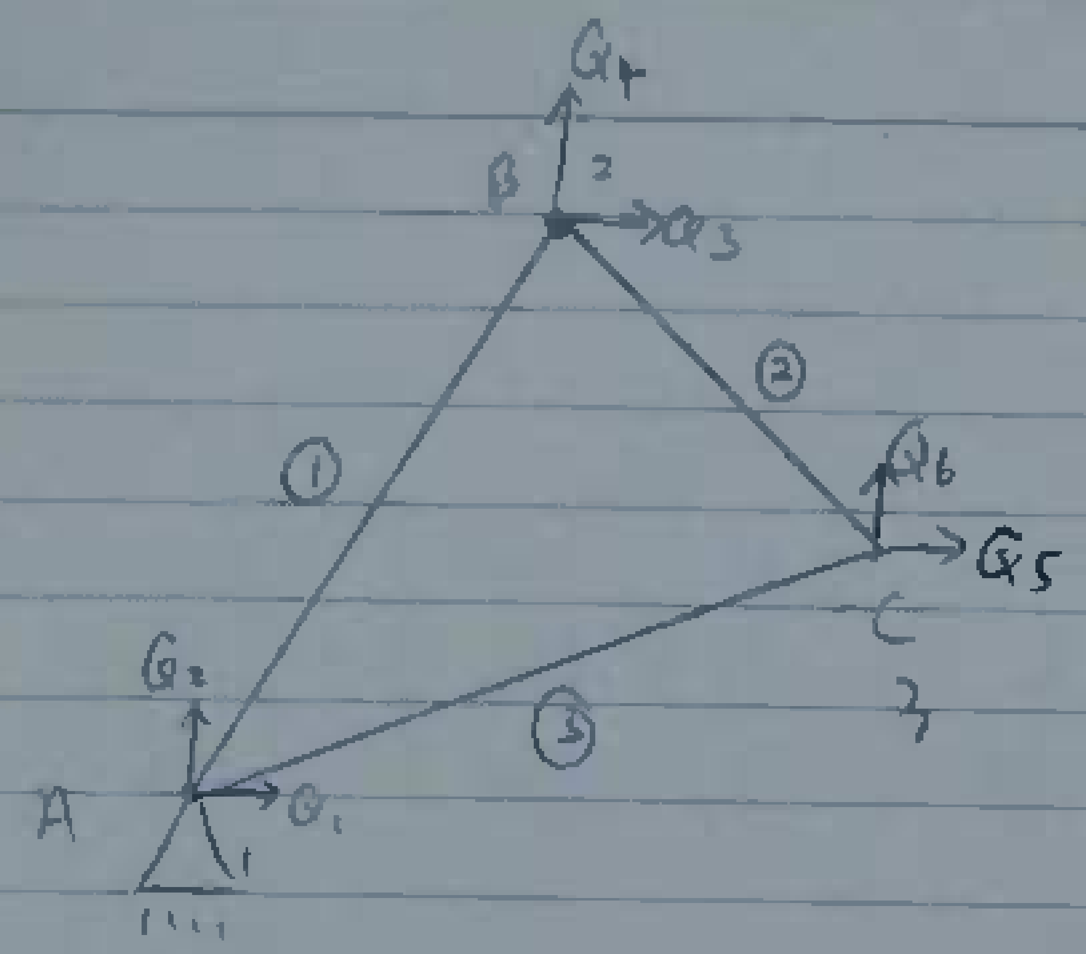
2. a.



Element	1	2	l_e	θ	l	m
1	1	2	1.077m	70.71°	0.33	0.944
2	3	2	0.61m	124.99°	-0.573	0.819
3	1	3	0.901m	33.69°	0.832	0.555

$$K_{(1)} = \frac{5.5\times10^5}{1.077} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 0.1089 & 0.31152 & -0.1089 & -0.31152 \\ 0.31152 & 0.8911 & -0.31152 & -0.8911 \\ -0.1089 & -0.31152 & 0.1089 & 0.31152 \\ -0.31152 & -0.8911 & 0.31152 & 0.8911 \end{bmatrix} \end{array} \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array}$$

$$K_{(3)} = \frac{5.5\times10^5}{0.901} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 5 & 6 \end{array} \\ \begin{bmatrix} 0.692 & 0.462 & -0.692 & -0.462 \\ 0.462 & 0.308 & -0.462 & -0.308 \\ -0.692 & -0.462 & 0.692 & 0.462 \\ -0.462 & -0.308 & 0.462 & 0.308 \end{bmatrix} \end{array}$$

$$K_{(2)} = \frac{5.5\times10^5}{0.61} \begin{array}{c} \begin{array}{cccc} 5 & 6 & 3 & 4 \end{array} \\ \begin{bmatrix} 0.328 & -0.47 & -0.328 & 0.47 \\ -0.47 & 0.67 & 0.47 & -0.67 \\ -0.328 & 0.47 & 0.328 & -0.47 \\ 0.47 & -0.67 & -0.47 & 0.67 \end{bmatrix} \end{array} \begin{array}{c} 5 \\ 6 \\ 3 \\ 4 \end{array}$$

$$K = 5.5\times10^5 \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} 0.869 & 0.802 & -0.1011 & -0.289 & -0.768 & -0.513 \\ & 1.169 & -0.289 & -0.827 & -0.513 & -0.342 \\ & & 0.6388 & -0.481 & -0.538 & 0.77 \\ & \text{Sym} & & 1.926 & 0.77 & -1.098 \\ & & & & 1.306 & -0.258 \\ & & & & & 1.44 \end{bmatrix} \end{array} \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array}$$

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(b) $Q_1, Q_2, Q_5 = 0$

$[K]\{Q\} = \{F\}$

$$5.5 \times 10^5 \begin{bmatrix} 0.6388 & -0.481 & 0.77 \\ -0.481 & 1.926 & -1.098 \\ 0.77 & -1.098 & 1.44 \end{bmatrix} \begin{Bmatrix} Q_3 \\ Q_4 \\ Q_6 \end{Bmatrix} = \begin{Bmatrix} F_3 \\ F_4 \\ F_6 \end{Bmatrix}$$

$F_3 = 0$

$F_4 = -4000N$

$F_6 = 0$

Solve matrix (cramer's rule).

$Q_3 = 0.003270$ m

$Q_4 = -0.006998$ m

$Q_6 = -0.007085$ m

(c) $\sigma = EBq$

$$\sigma_1 = \frac{5.5\times10^5}{A_1}\frac{1}{1.077}\begin{bmatrix} -0.33 & -0.944 & 0.33 & 0.944 \end{bmatrix}\begin{bmatrix} 0 \\ 0 \\ 0.003270 \\ -0.006998 \end{bmatrix}$$

$$\sigma_1 = \frac{-2822.52}{A_1}$$

$$\sigma_2 = \frac{5.5\times10^5}{A_2}\frac{1}{0.61}\begin{bmatrix} 0.573 & -0.819 & -0.575 & 0.819 \end{bmatrix}\begin{bmatrix} 0 \\ -0.0071 \\ 0.003270 \\ -0.006998 \end{bmatrix}$$

$$\sigma_2 = \frac{-48122.68}{A_2}$$

$$\sigma_3 = \frac{5.5\times10^5}{A_3}\frac{1}{0.901}\begin{bmatrix} -0.832 & -0.555 & 0.832 & 0.555 \end{bmatrix}\begin{bmatrix} 0 \\ 0 \\ 0 \\ -0.007085 \end{bmatrix}$$

$$\sigma_3 = \frac{-2400.3288}{A_3}$$

$\sigma_1 = \sigma_2 = \sigma_3$

$A_1 : A_2 : A_3 = 2822.52 : 48122.68 : 2400.329$ #

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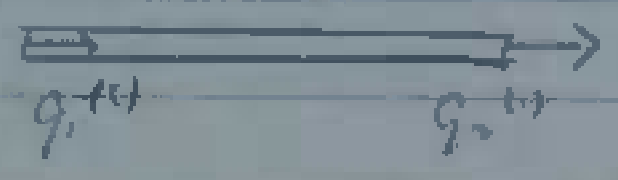
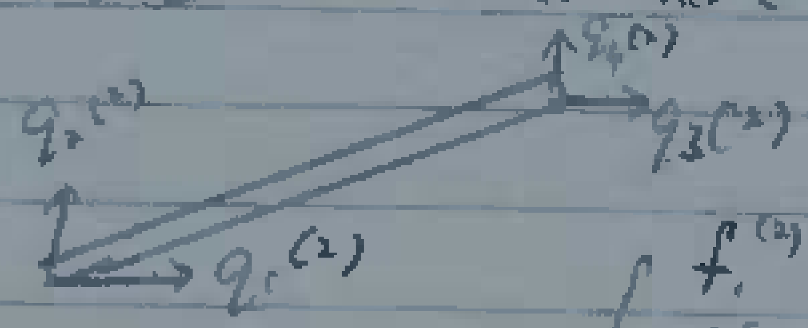
(3) For example : a bar element and a Truss element

(a)

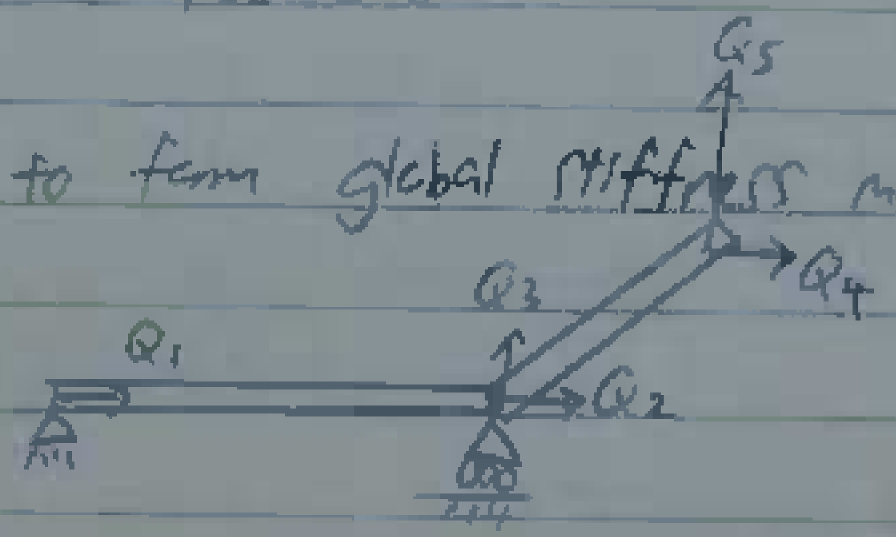




$$\begin{Bmatrix} f_1^{(1)} \\ f_2^{(1)} \end{Bmatrix} = \begin{bmatrix} k_{11}^{(1)} & k_{12}^{(1)} \\ k_{21}^{(1)} & k_{22}^{(1)} \end{bmatrix} \begin{Bmatrix} q_1^{(1)} \\ q_2^{(1)} \end{Bmatrix}$$

$$\begin{Bmatrix} f_1^{(2)} \\ f_2^{(2)} \\ f_3^{(2)} \\ f_4^{(2)} \end{Bmatrix} = \begin{bmatrix} k_{11}^{(2)} & k_{12}^{(2)} & k_{13}^{(2)} & k_{14}^{(2)} \\ k_{21}^{(2)} & k_{22}^{(2)} & k_{23}^{(2)} & k_{24}^{(2)} \\ k_{31}^{(2)} & k_{32}^{(2)} & k_{33}^{(2)} & k_{34}^{(2)} \\ k_{41}^{(2)} & k_{42}^{(2)} & k_{43}^{(2)} & k_{44}^{(2)} \end{bmatrix} \begin{Bmatrix} q_1^{(2)} \\ q_2^{(2)} \\ q_3^{(2)} \\ q_4^{(2)} \end{Bmatrix}$$

After combine to form global stiffness matrix :



equilibrium enforced

Equilibrium are enforced through: $F_2 = f_2^{(1)} + f_1^{(2)}$

compatibility enforced. $= (k_{21}^{(1)} q_1^{(1)} + k_{22}^{(1)} q_2^{(1)}) + (k_{11}^{(2)} q_1^{(2)} + k_{12}^{(2)} q_2^{(2)}$
$+ k_{13}^{(2)} q_3^{(2)} + k_{14}^{(2)} q_4^{(2)})$

$= (k_{12}^{(1)} Q_1 + k_{22}^{(1)} Q_2) + (k_{11}^{(2)} Q_2 + k_{12}^{(2)} Q_3 + k_{13}^{(2)} Q_4 + k_{14}^{(2)} Q_5)$

(b) i)

Interior angle greater than 180° should not be used for four node element. It will result in invalid transformation

(ii). CST Element adjacent to 8 node element will result in inter element incompatibility.

iii) Shape function of quadrilateral element are established in terms of local co-ordinates while triangular element are in terms of global co-ordinate. This may give rise to additional problem and computing time / cost.

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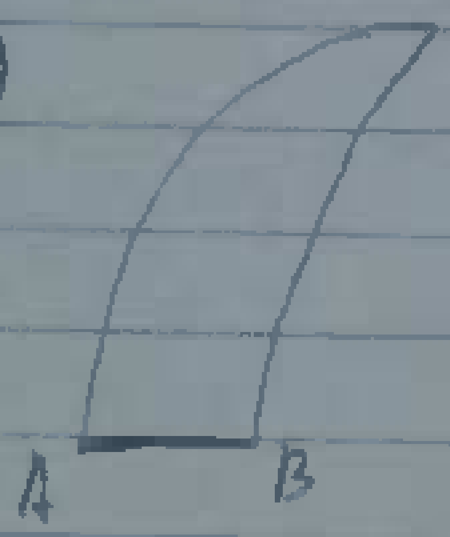
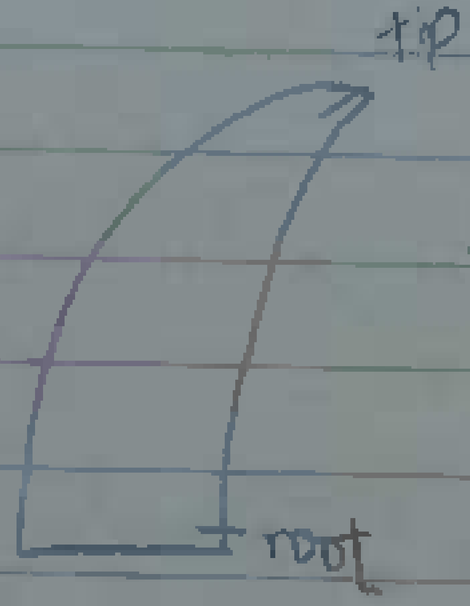
(c) Errors:

i)



Displacement of AB in y direction should set to 0.

ii)



Should set finer mesh at wing root instead of wing tip as there is stress concentration at wing root section.

iii) The loading direction is modeled wrongly. The wing should bend to right instead under the given load w.

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(a) From the crashed comet, you can get a_f which is the length of crack on comet when it fails. With this, we can obtain N_f which is the number of fatigue cycles to failure of the material used on comet.

Through equation 2, we can then determine the initial defect size which caused the crash of comet.

from equation (1)

we can get $\Delta K = Y\sigma\sqrt{\pi a}$

and from $\frac{da}{dN} = A\Delta K^m$

Integrating from initial crack size a_0 to final crack size at failure a_f and the number of fatigue cycles from 0 to that at failure N_f, we reach equation 2.

(b) The defect exist near the starboard rear corner of a a rear window. The crack emanated from a bolt hole and propagated to failure due to pressure cycles of cabin.

The thickness of skin was increased and rounded smaller windows was used in future design to reduce stress concentration.

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4 (c) Feature : Intergranular cracking

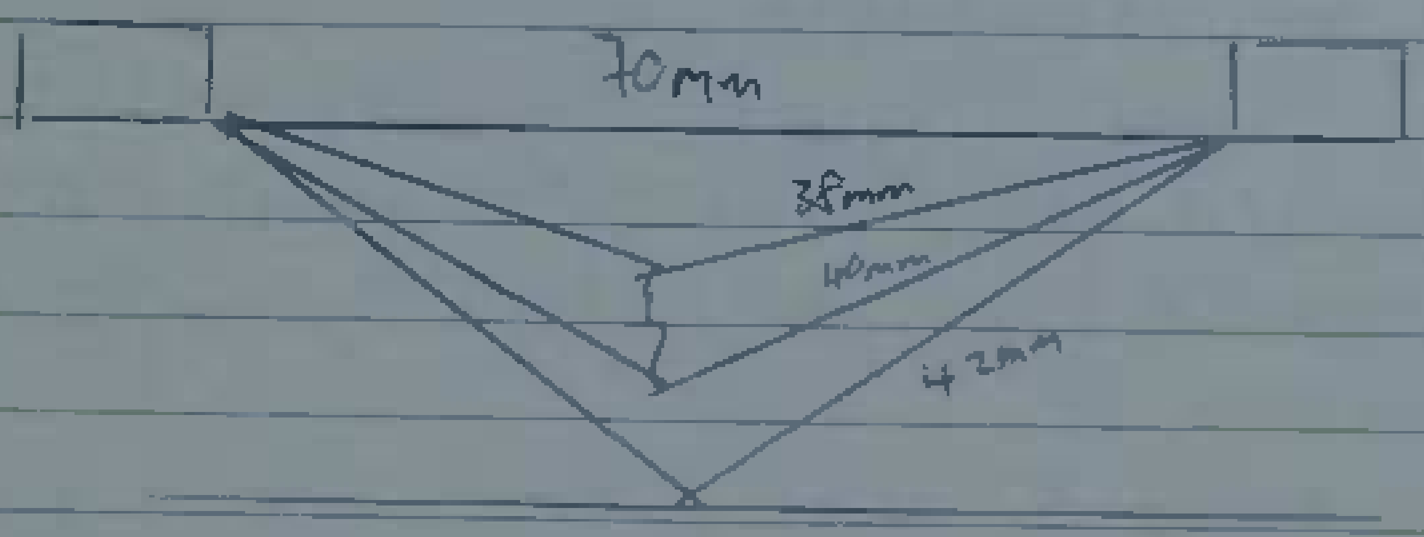
Structural changes: Voids develop in the grain boundaries as the grains move relative to one another

Which part ? => Turbine blade

Conditions : i) Under constant stress and undergo plastic deformation over time

ii) Operate in elevated temperature

(d)



$\sqrt{38^2 - 35^2} = 14.8$ mm

$\sqrt{40^2 - 35^2} = 19.36$ mm

$19.36 - 14.8 = 4.56$ mm (crack size)

(e) i) Digital sensors have a lower spatial resolution limit than film. Film can detect defects of sizes approximately 30 microns. Digital pixel sizes are normally 127 microns or above. Defects smaller than this can not be detected.

Contrast resolution for both radiography are similar. Both can detect in 2%.

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