

Instructions:**Test Cover Page:**

- ⇒ You are allowed one index card (or one 8.5" x 11" sheet of paper) with equations written on it. You are allowed to have writing on both sides. The writing must be hand written by you. (Photocopies are not allowed.) Staple this to the back of your test when you turn it in. You are not to have solutions to problems worked out on your equation card, only equations.* (*You may have your equations written in "graphical" form, such as showing how two vectors can be added together, graphically.)
- ⇒ Write your name at the top of this page only. Write your student number your student number in the space provided at the upper right of every question sheet as well as the cover sheet. Sign the honor pledge on this page when you have completed the examination.
- ⇒ Present your full answer very clearly in all cases. A correct answer without showing all of the supporting work and/or information will not be awarded full credit. Do not forget the importance of free-body diagrams and attention to detail concerning vector notation (where applicable), sign, significant figures, units, and direction. Don't forget to define the coordinate system you've chosen.
- ⇒ Annotate (label) the parts of your solution (e.g. FBD, equilibrium equations, ...etc.).

Extra paper is available if you need it.

- ⇒ If you use an extra piece of paper, write your name, social security number and problem number at the upper right and staple it to the appropriate question sheet when you turn in the examination.

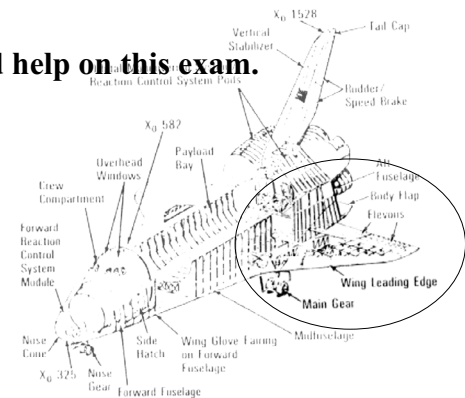
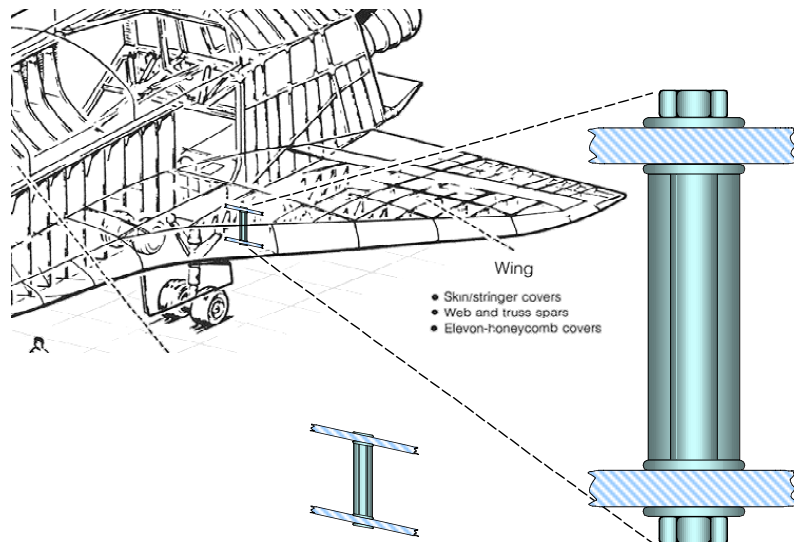
A stapler will be provided.

- ⇒ When you turn in your test, make sure your name is checked off the list as having turned in a test.

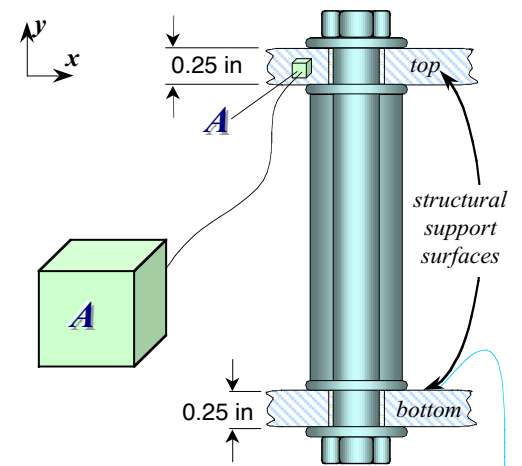
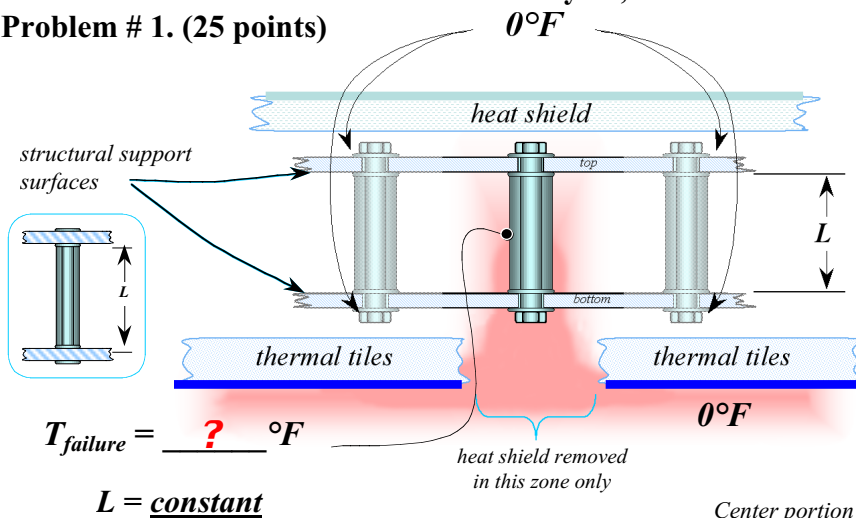
This examination will not be graded unless you have signed the honor pledge below.
Sign the honor pledge on this page when you have completed the examination.

Honor Pledge: I have neither given nor received any unauthorized help on this exam.

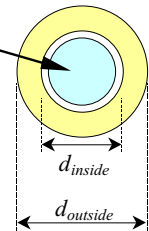
Signature: _____



Problem number:	Score for problem	Total possible:
1		25 <i>c</i>
2		25 <i>f</i>
3		25 <i>b</i>
4		25 <i>s</i>
<i>total</i>		100



Center portion is part of end connection (assume it's a "rivet") and does not support load



$$d_{inside} = 1.0 \text{ in}$$

$$d_{outside} = 1.2 \text{ in}$$

$$A = 0.11 \pi \text{ in}^2$$

Last Saturday, the space shuttle Columbia disintegrated during re-entry through the earth's atmosphere. One possible cause could be the loss of thermal tiles..

- Assume tiles were lost in the localized zone shown above, exposing just one of the many aluminum stiffening tubes, connected to both the top and bottom framework of the wing.
- Assume the remaining structure is completely insulated from the heat and remains at 0°F .
- Assume that the one exposed tube is heated uniformly.
- At 0°F , the aluminum tube is stress free and there are no gaps. Heat shields insulate the structure from temperature variations, as shown above.
- Assume the top and bottom of the framework is made of a solid plate.

$L = \text{constant}$

$$\Delta T_{max} = 3,000^\circ\text{F} \text{ (maximum possible)}$$

Top and Bottom plates:

$$\alpha_{plate} = 0.00 \mu\epsilon/^\circ\text{F}$$

$$E_{plate} = \infty, \quad G = \infty, \quad \nu = 0 \text{ (rigid)}$$

$$\tau_{max} = 10.2 \text{ ksi}$$

$$\sigma_{max} = 104 \text{ ksi (tension)}$$

$$\sigma_{max} = 70 \text{ ksi (compression)}$$

Aluminum (2014-T6):

$$\alpha_{al} = 12.8 \mu\epsilon/^\circ\text{F}$$

$$E_{al} = 10.6 \text{ Msi}, \quad G = 3.9 \text{ Msi}, \quad \nu = 0.34$$

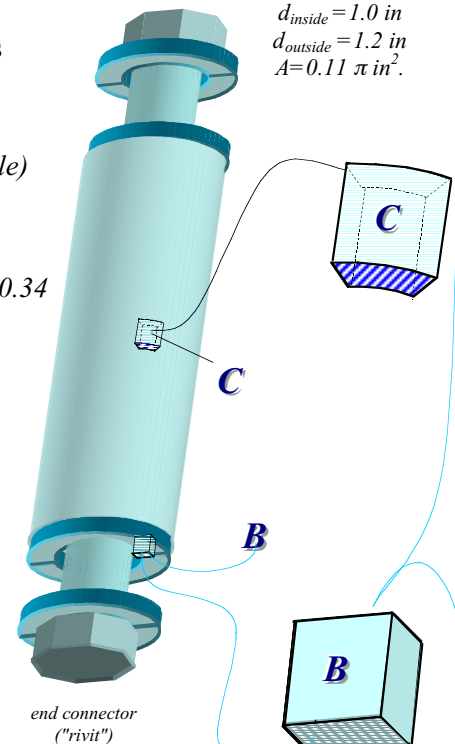
$$\tau_{max} = 19 \text{ ksi}$$

$$\sigma_{max} = 60 \text{ ksi (tension)}$$

$$\sigma_{max} = 60 \text{ ksi (compression)}$$

Given the properties above,

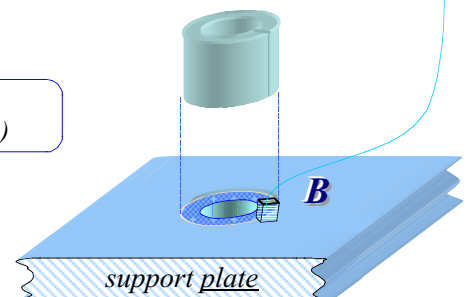
- Determine the maximum temperature of the aluminum tube without causing failure at point A, B, or C. (Note, failure may occur in the plate or the tube.)
- Where is it most likely to fail first (choose location A, B, or C). Why? (i.e. Justify your answer with calculations.)
- Using your answer from part (a), calculate the stress state in locations A, B, and C at the failure temperature.
- Show these stresses (from part (c)) on each of the volume elements (A, B, and C) provided on the right, representing the state of stress at each of the three locations.



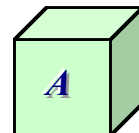
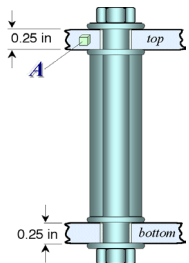
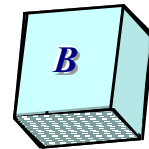
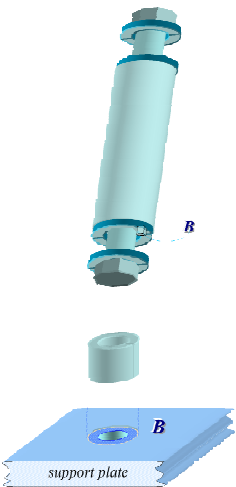
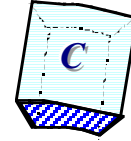
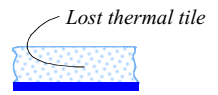
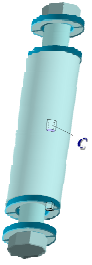
Note: Volume elements C, B, and A are provided on the next page, along with work space. You may present your results for part (d) on either page. (Show part (d) on one page, only.)

Location descriptions:

Point A (zone of material inside top plate),
Point B (surface of plate facing tube end, and surface of tube end facing plate),
Point C (zone of material in outer surface of the aluminum tube)



Workspace:

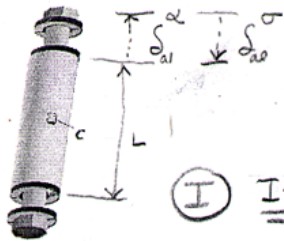


Solution:

EM 304 Test #1

February 06, 2003

Student Number:



L is constant, so $\delta_{al}^{total} = 0 = \delta_{al}^{\alpha} - \delta_{al}^{\sigma}$
 so, $\delta_{al}^{\alpha} = \delta_{al}^{\sigma}$ (1)

$$\alpha(\Delta T)L = \frac{PL}{AE} = \sigma \frac{L}{E} \quad (2)$$

(I) If first failure is aluminum in compression,

$$\Delta T = \frac{\sigma_c}{E\alpha} = \frac{(60 \text{ ksi})}{(10.6 \times 10^3 \text{ ksi})(12.8 \mu\epsilon)} = 442.22^\circ\text{F}$$

$$\Delta T = 442.22^\circ\text{F} \quad (4)$$

(II) If B fails $\sigma > \sigma_f$, we already checked C. Now check at B. support plate fails if B fails if $\sigma_b > \sigma_f = 70 \text{ ksi}$ for plate = 60 ksi for alum

Aluminum Controls

for $\sigma_{max} = 70 \text{ ksi}$

$$\Delta T = \frac{70}{60}(442.22^\circ\text{F}) = 515.9^\circ\text{F} \quad (4)$$

(III) If A is where it fails first, either

$$F > F_{skin}$$

$$\frac{V}{A} \geq 10.2 \text{ ksi}, V_{max} = (A) 10.2 \text{ ksi}$$

$$A = \pi D \left(\frac{1}{4}\right) \text{ in} = \frac{\pi}{4} (1.2 \text{ in})$$

$$A = 0.3\pi \text{ in}^2$$

$$V_{max} = (0.3\pi) \text{ in}^2 \frac{10.2 \text{ kip}}{\text{in}^2} = 3.06\pi \text{ kip} = 9.6133 \text{ kip}$$

The skin is not affected by temp, but aluminum affects skin. What ΔT would cause aluminum to put force V on skin?

$$\text{From equilibrium } F_{plate} = F_{tube} = 3.06\pi \text{ kip} \quad (4)$$

What ΔT makes this force? (use Eqn 1)

$$\delta_{al}^{\alpha} = \delta_{al}^{\sigma} = \frac{PL}{AE} = \alpha \Delta T L$$

$$\Delta T = \frac{P}{AE\alpha} = \frac{(3.06\pi \text{ kip})}{(.11\pi \text{ in}^2)(10.6 \times 10^3 \text{ ksi})(12.8 \times 10^{-6})} = 205.02787^\circ\text{F}$$

$$\Delta T = 205.02787^\circ\text{F}$$

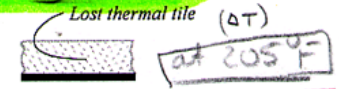
$$\Delta T = 205^\circ\text{F}$$

first failure →

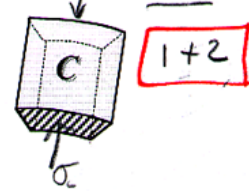
(4)

← This temperature produces

Key

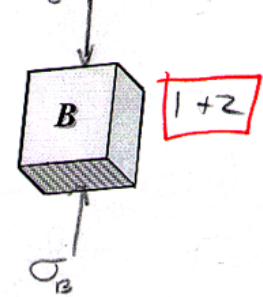


$$\sigma_c = 27.8 \text{ ksi}$$

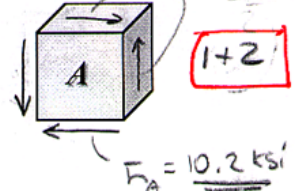


$$\sigma_c = (\Delta T)E\alpha = (205)(10.6 \times 10^3 \text{ ksi})(12.8 \mu\epsilon) = 27.818 \text{ ksi}$$

$$\sigma_b = 27.8 \text{ ksi}$$

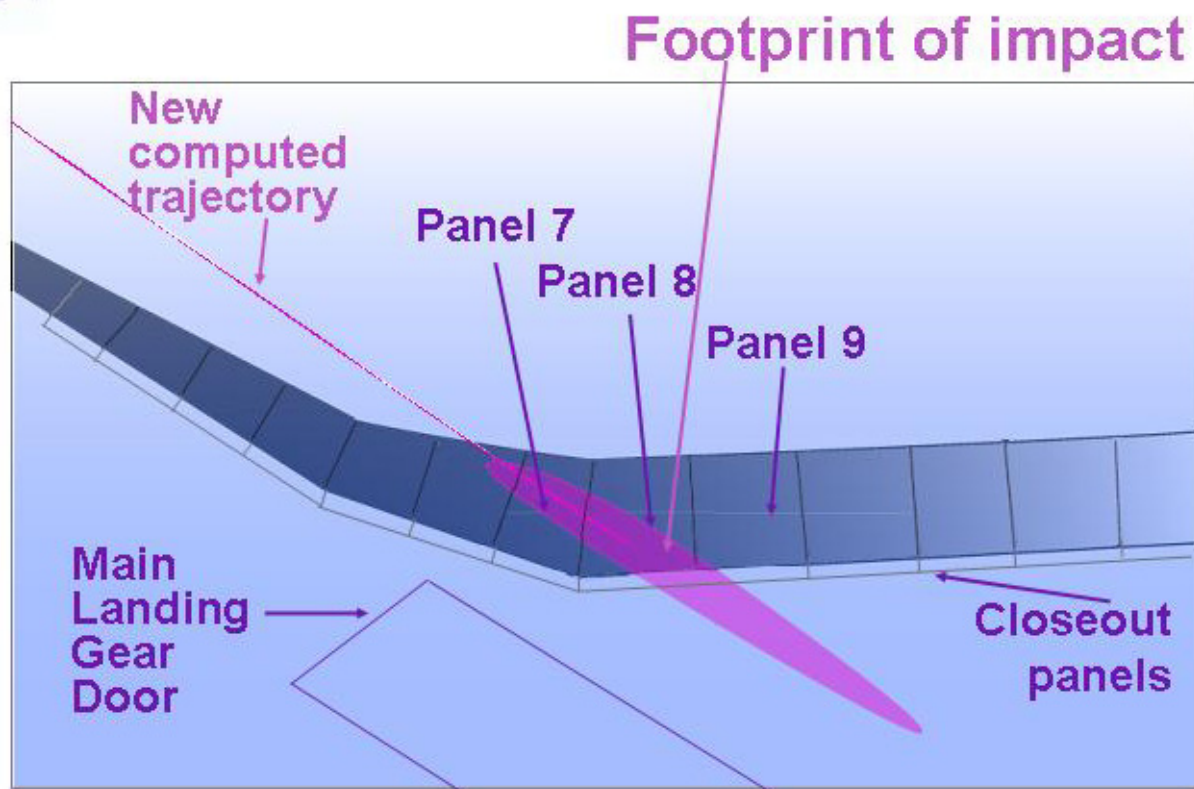


$$T_A = 10.2 \text{ ksi}$$





Debris Impact: New Calculations

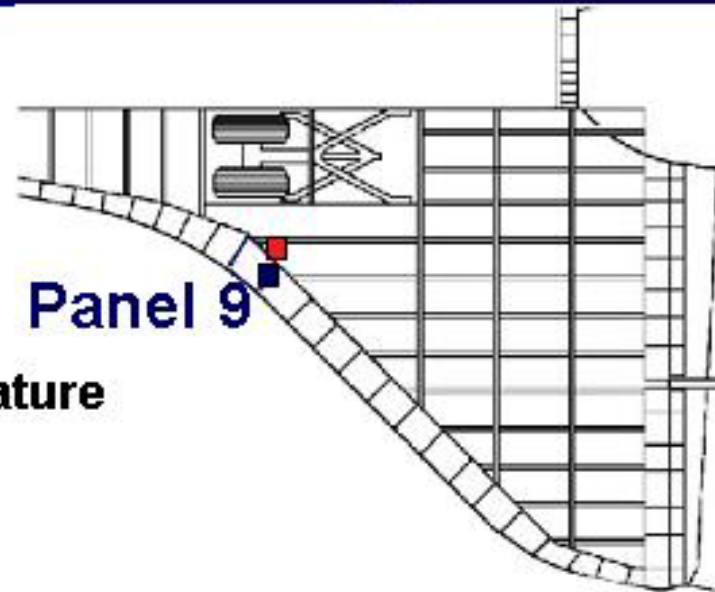


Presentation slide3 by G. Scott Hubbard on 15 April 2003.

http://www.caib.us/news/press_briefings/pb030415-present-hubbard.html

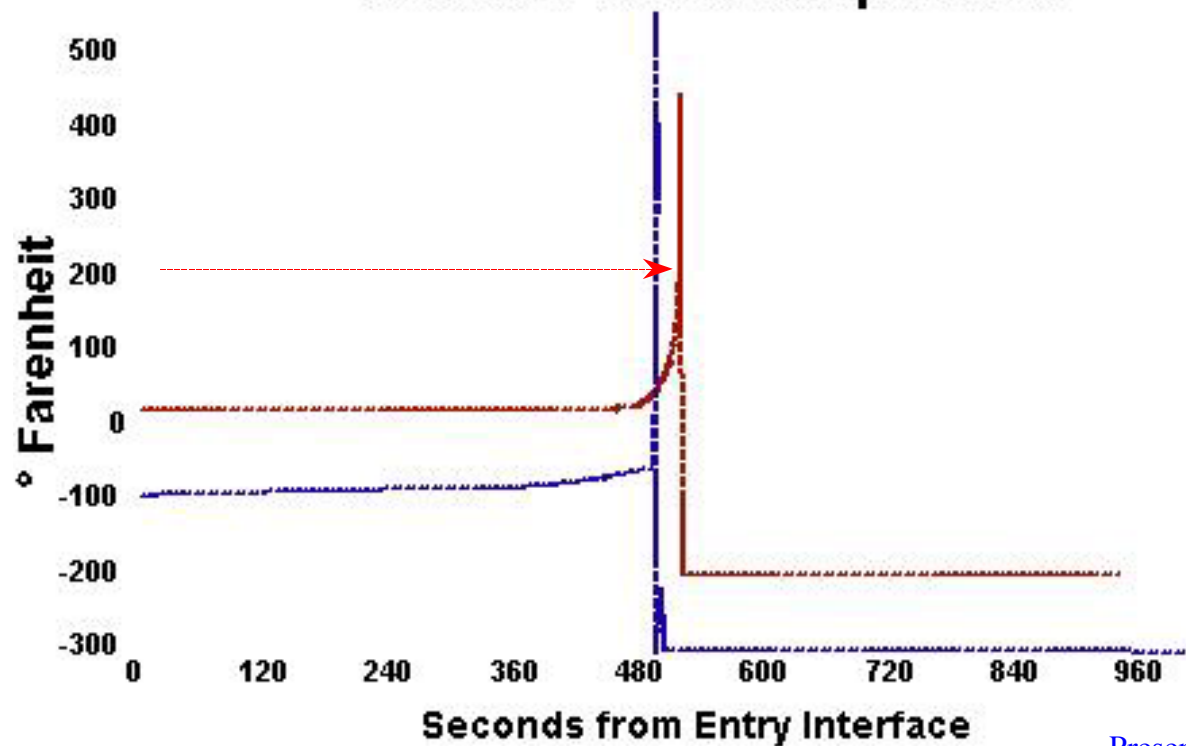


Temperature



Panel 9

STS 107 Panel 9 Temperature



Presentation slide4 by G. Scott Hubbard on 15 April 2003.

http://www.caib.us/news/press_briefings/pb030415-present-hubbard.html