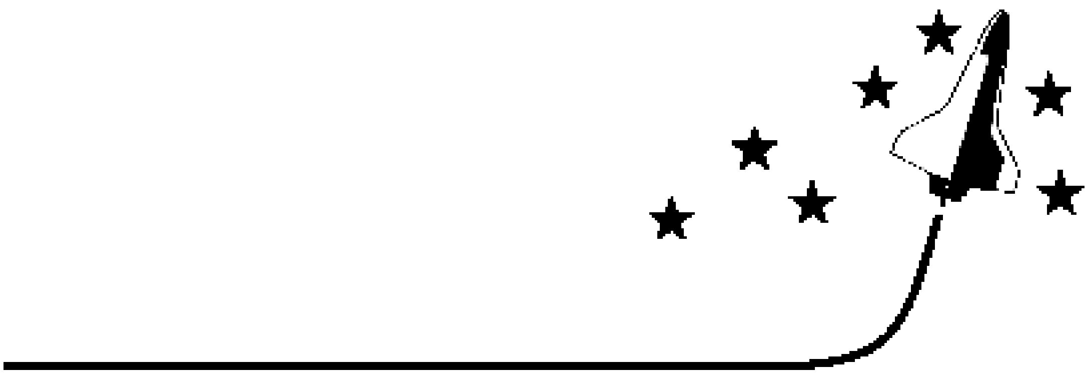
# *FACULTY NOTES*

The LTAs and Spinoffs are designed so that each professor can implement them in a way that is consistent with his/her teaching style and course objectives.  This may range from using the materials as out-of-class projects with minimal in-class guidance to doing most of the work in class.  The LTAs and Spinoffs are amenable to small group cooperative work and typically benefit from the use of some learning technology.  Since the objective of the LTAs and Spinoffs is to support the specific academic goals you have set for your students, the Faculty Notes are not intended to be prescriptive.  The purpose of the Faculty Notes is to provide information that assists you to take full advantage of the LTAs and Spinoffs.  This includes suggestions for instruction as well as answers for the exercises.



## FACULTY NOTES

## SPINOFF 4B

## Calculating Cracks in the Space Shuttle

### Background On Kennedy Space Center

You might want to refer to the first three sections of the Faculty Notes for background information on the Kennedy Space Center, the Space Shuttle as well as Fracture Mechanics.

### Curriculum Information

#### General

It is expected that this will be a culminating activity after students have studied either the Pythagorean Theorem or the distance formula. Depending upon a college's curriculum, students at the **Elementary or Intermediate Algebra** level should be capable of completing this activity.

The activity is designed to increase the student's ability to estimate, to use order of operations, to use a variety of unfamiliar units, and to use technology.

#### Assessment

Although assessment will vary with the instructor, assessment techniques could include the following:

- ♦ Give students a problem similar to the activities, and have them write a formal recommendation to a project director about whether or not corrective action should be taken.
- ♦ Require a written report analyzing the effects that stress and crack length have on each other.
- ♦ Expect students to write or give an oral report on the relationships between the variables in this unit, based on what they have seen numerically and graphically in the problems.
- ♦ Have the students come up with crack lengths that would require a repair action given a specified stress value.

#### Group Work

Group work can be especially useful when the students have to decide **exactly** how long the crack is. Hopefully they will engage in discussion when they find out (especially for crack #6) that their ‘estimate’ of the dimensions makes a difference on the decision whether or not to take action.

#### Technological Information

This activity was written to be calculator-dependent. Students will need a calculator which has a square root key. Depending on the type of calculator, the issue of order of operations may have an effect on the student’s ability to get the correct answer.

**Timeline for Classroom Use**

This activity is intended for approximately one class period with students doing some work outside of class. If they are unable to complete the questions in one class period it should be assigned as homework with perhaps a week to write a report.

**Hints/Comments**

The grids were used so that the Pythagorean Theorem could be used. For those wishing to use the distance formula, simply turn the grids into a portion of a graph by labeling some of the lines. You could make it any quadrant you would like.

Be careful with the last four cracks. Students will probably ignore the 1/16 in scale and use numbers for the lengths of the sides like 3 and 4 instead of 3/16 and 4/16.

Fractions with decimals in the numerator are used in the solutions given below. For those adamantly against this practice please feel free to change the fractions accordingly.

Try to facilitate discussions about the significance of rounding and estimating when you are deciding if something important (like the Shuttle) is still safe to operate.

A variety of rounding was purposely used in the solutions. Students will probably want guidance in this area, so be prepared for questions.

**Solutions**

1) $\text{K} = 150 \text{ psi}\sqrt{p\,(1.1 \text{ in})} = 279 \text{ psi} - \sqrt{\text{in}}$

2) $a = 11 \text{ mm},\ K = 110 \text{ MPa}\sqrt{p\,(11\text{mm})} = 647 \text{ MPa} - \sqrt{\text{mm}}$

3) $a = 1.6 \text{ mm},\ K = 125 \text{ MPa}\sqrt{p\,(1.6\text{mm})} = 280 \text{ MPa} - \sqrt{\text{mm}}$

**Crack Calculations**

For the estimates the answers will vary. When calculating the crack length, answers may also vary, so a typical value has been given.

4)

**Crack 1**

$\text{length} = \sqrt{1^2 + 1^2} = \sqrt{2} \approx 1.414 \text{ mm}$

$a$ » 0.7 mm

$K = 120 \text{ MPa}\sqrt{p\,(0.7\,\text{mm})} \approx 179 \text{ MPa} - \sqrt{\text{mm}}$

$179 \text{ Mpa-}\sqrt{\text{mm}} < 250 \text{ Mpa-}\sqrt{\text{mm}}$ so the crack does not require any action

**Crack 2**

$\text{length} = \sqrt{2^2 + 1.5^2} = 2.5\,\text{mm}$

$a = 1.25$ mm

$K = 120\text{ MPa}\sqrt{p\,(1.25\,\text{mm})} \approx 238\text{ MPa - }\sqrt{\text{mm}}$

238 Mpa-$\sqrt{\text{mm}}$ < 250 Mpa-$\sqrt{\text{mm}}$ so the crack does not require any action

If students estimate 2x2 they should get ≈ 253 Mpa-$\sqrt{\text{mm}}$ , so it would require action.

**Crack 3**

$\text{length} = \sqrt{5^2 + 1^2} \approx 5.099\text{ mm}$

$a$ » 2.55 mm

$K = 50\text{ MPa}\sqrt{p\,(2.55\,\text{mm})} \approx 142\text{ MPa - }\sqrt{\text{mm}}$

142 Mpa-$\sqrt{\text{mm}}$ < 250 Mpa-$\sqrt{\text{mm}}$ so the crack does not require any action

**Crack 4**

$\text{length} = \sqrt{3^2 + 4^2} = 5\text{ mm}$

$a$ = 2.5 mm

$K = 100\,\text{MPa}\sqrt{p\,(2.5\,\text{mm})} \approx 280\,\text{MPa - }\sqrt{\text{mm}}$

280 Mpa-$\sqrt{\text{mm}}$ > 250 Mpa-$\sqrt{\text{mm}}$ so the crack does require action

5)

**Crack 5**

$$\text{length} = \sqrt{\left(\frac{1.5}{16}\right)^2 + \left(\frac{1}{16}\right)^2} \approx \frac{1.8}{16}\text{ in}$$

$$a = \frac{0.9}{16}\text{ in}$$

$$K = 100\,\text{psi}\sqrt{p\left(\frac{0.9}{16}\right)} \approx 42\,\text{psi - }\sqrt{\text{in}}$$

42 psi-$\sqrt{\text{in}}$ < 70 psi-$\sqrt{\text{in}}$ so the crack does not require action

**Crack 6**

$$\text{length} = \sqrt{\left(\frac{3}{16}\right)^2 + \left(\frac{3.75}{16}\right)^2} \approx \frac{4.8}{16}\text{ in}$$

$$a = \frac{2.4}{16}\text{ in}$$

$$K = 100\text{ psi}\sqrt{p\left(\frac{2.4}{16}\right)} \approx 69\text{ psi - }\sqrt{\text{in}}$$

69 psi-$\sqrt{\text{in}}$ < 70 psi-$\sqrt{\text{in}}$ so the crack does not require action

If the students estimate 3x4 they should get 70 psi-$\sqrt{\text{in}}$ ,so it requires action.

**Crack 7**

$$\text{length} = \sqrt{\left(\frac{5}{16}\right)^2 + \left(\frac{2}{16}\right)^2} \approx \frac{5.39}{16} \text{ in}$$

$$a \text{ » } \frac{2.7}{16} \text{ in}$$

$$K = 110 \text{ psi}\sqrt{p\left(\frac{2.7}{16}\right)} \approx 80 \text{ psi - }\sqrt{\text{in}}$$

$80 \text{ psi-}\sqrt{\text{in}} > 70 \text{ psi-}\sqrt{\text{in}}$ so the crack does require action

**Crack 8**

$$\text{length} = \sqrt{\left(\frac{5}{16}\right)^2 + \left(\frac{3}{16}\right)^2} \approx \frac{5.83}{16} \text{ in}$$

$$a \approx \frac{2.9}{16} \text{ in}$$

$$K = 20 \text{ psi}\sqrt{p\left(\frac{2.9}{16}\right)} \approx 15 \text{ psi - }\sqrt{\text{in}}$$

$15 \text{ psi-}\sqrt{\text{in}} < 70 \text{ psi-}\sqrt{\text{in}}$ so the crack does not require action

6) Same $s$, longer crack (2) is unsafe; shorter crack (1) is safe.

7) The values of $a$ are approximately equal, larger $s$ (crack 4) is unsafe; smaller $s$ (crack 3) is safe.

8) According to estimates, some may determine it is unsafe, while others argue it is safe.

9) The answer should be similar to question 7

10) The risk from the crack depends on the stress.