# *SPINOFFS*

Spinoffs are relatively short learning modules inspired by the LTAs.  They can be easily implemented to support student learning in courses ranging from prealgebra through calculus. The Spinoffs typically give students an opportunity to use mathematics in a real world context.

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| LTA - SPINOFF 4A | Measuring Cracks in the Space Shuttle |
| LTA - SPINOFF 4B | Calculating Cracks in the Space Shuttle |

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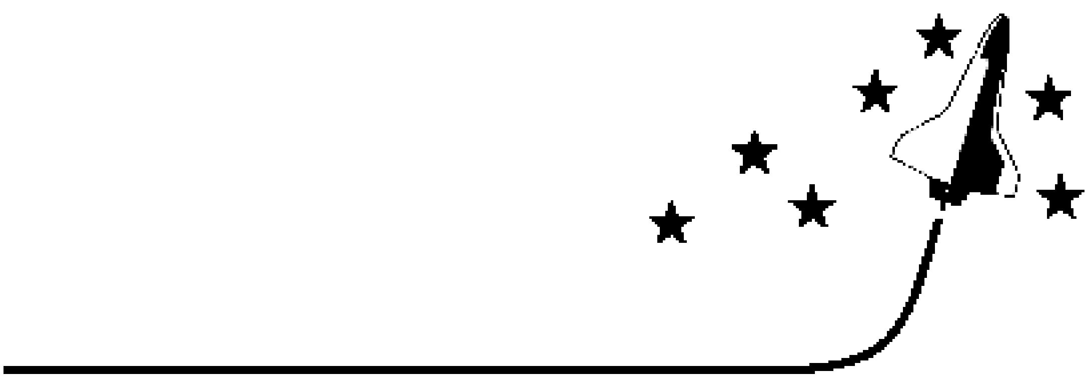

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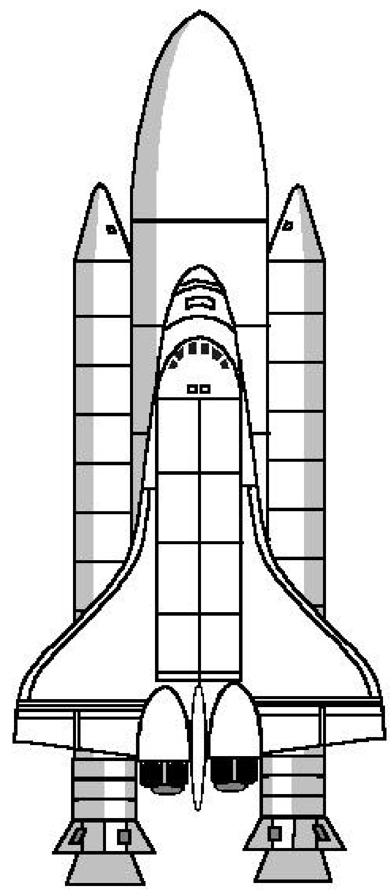
**SPINOFF 4A**

**Measuring Cracks in the Space Shuttle**

## The Background



Eric Thaxton, one of the Mechanical Engineers at NASA's Kennedy Space Center, often is asked to analyze cracks that occur in various structures. These cracks can be found in metallic structures such as tubes, pipes, liquid storage tanks, the Space Shuttle, or components for the space station.

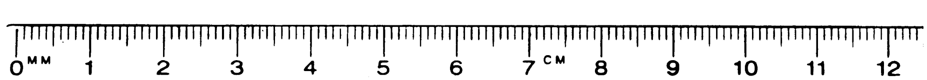
If a crack reaches its critical stage, the crack will then expand at the speed of sound and the structure will most likely burst, causing possibly catastrophic consequences. Years ago, when engineers realized that a critical crack was often the cause for ships to break in half, the need for experts in cracks emerged. The intensive study of cracks, called Fracture Mechanics, is a relatively new field in Mechanical Engineering. As a result of this intensive study, great strides have been made in detecting and analyzing cracks, especially cracks that were previously undetected. The use of ultrasound and/or x-rays enables the engineer to detect microscopic surface cracks as well as cracks embedded in the metal.

Environmental concerns necessitate that we reuse or extend the current use of metal structures that too often would previously have been abandoned. Since pressure vessels (liquid storage tanks with the liquid under pressure) may cost hundreds of thousands of dollars, budgetary concerns demand that they be used as long as possible. Obviously, safety must be an overriding concern of the engineers charged with the decision on continued use.

## The Problem

Your task will be to measure a set of cracks and to determine which ones are critical.

You will need to measure the crack using the metric system of measurement since the stress value that you will be given is in the metric system. So a brief introduction to the metric system might be appropriate. You can see below a metric measurer.

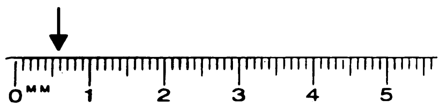


The smallest divisions each represent one millimeter. A convenient reference for one millimeter is the thickness of a dime. Each number marks one centimeter. What common and handy object can you use to estimate one centimeter?

**Exercises**

Determine the metric measure indicated in each of the following:

1)

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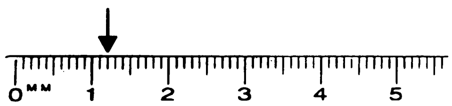


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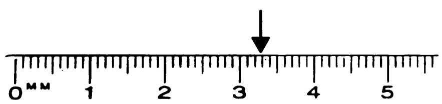
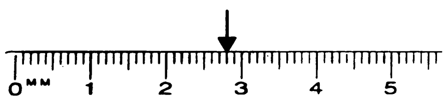



4)




Once you have measured a crack, you need to calculate the Stress Intensity Factor. Using the Stress Intensity Factor formula requires you to find one-half of the length of the crack and to know the stress value. Eric has provided us with appropriate stress values. Stress values are determined by considering the size of the tank, thickness of the tank's walls, and the pressure exerted on the tank by its contents. Here is the formula you will use to calculate the Stress Intensity Factor.

**Stress Intensity Factor**

$$K = s \cdot \sqrt{p \cdot a}$$

where

$a$ = crack half length, crack is $2a$ long (mm)

$s$ = stress (MPa)

$K$ = Stress Intensity Factor (MPa-$\sqrt{\text{mm}}$)

Note: $\sqrt{\text{mm}}$ is pronounced 'root millimeters'

$p \approx 3.14$, but use the calculator value for increased accuracy

To develop a working understanding of the formulas, complete the following exercises. The length of the crack has been measured for you.

**Exercises**

5) Calculate $K$ if $s$ = 110 MPa and the length of the crack is 22 mm.

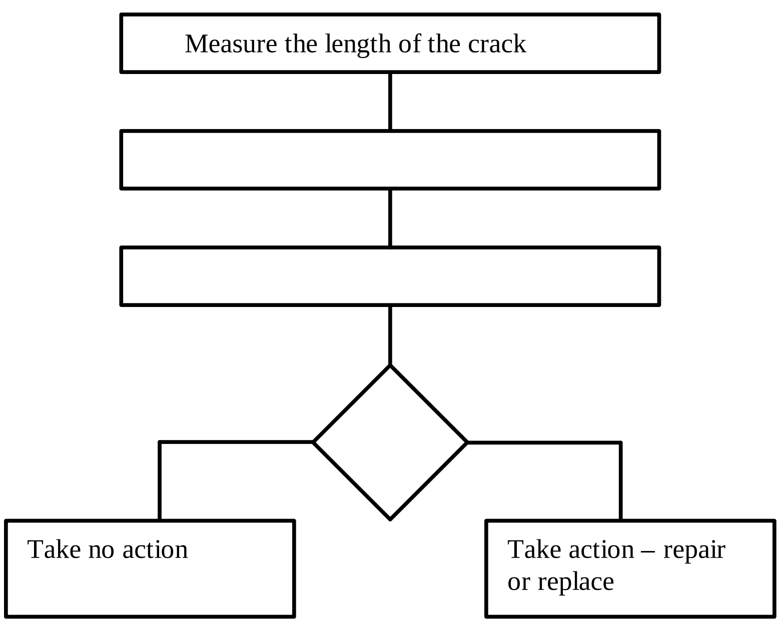
6) Determine the Stress Intensity Factor when $s$ = 125 MPa and the length of the crack is 3.2 cm.

7) Find $K$ when $s$ = 150 MPa and $a$ = 1.1 mm.

Once you calculate the Stress Intensity Factor ($K$), you can compare its value to the allowable Stress Intensity Factor ($K_a$). The allowable Stress Intensity Factor is governed by the type of metal involved as well as a safety factor which varies according to the use of the metal as well as any weight considerations.

If your calculated value of $K$ is greater than the given value of $K_a$, you would take corrective action — usually this would require cutting out a plug around the crack and welding in a new piece of metal.

To help your team remember this process, complete the following flowchart:

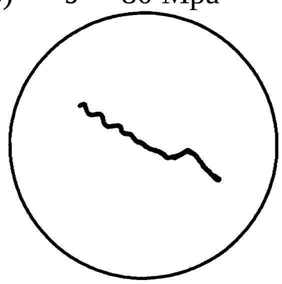


**Exercises**

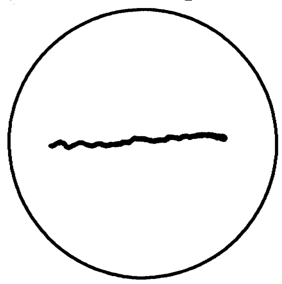
For each of the following cracks, assume that $K_a$ = 500 MPa-$\sqrt{\text{mm}}$ and

A) Measure and record the length of the crack;
B) Find ½ of the length of the crack and record this value as $a$ = ___;
C) Calculate $K$;
D) Report your recommendation for each crack - **No-Action** or **Action** (repair/replace tank).

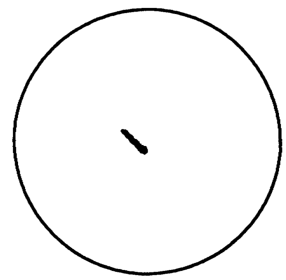
8) $s$ = 80 Mpa



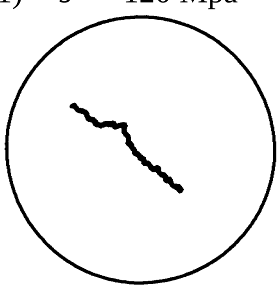
9) $s$ = 100 Mpa



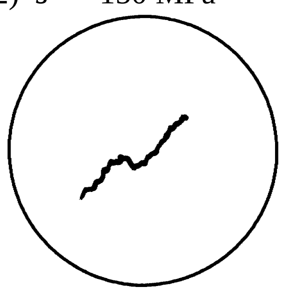
10) $s$ = 120 MPa



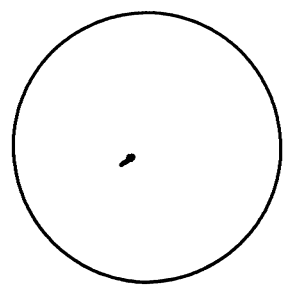
11) $s$ = 120 Mpa



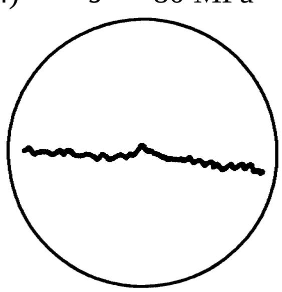
12) $s$ = 150 MPa



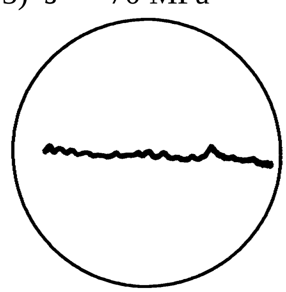
13) $s$ = 285 MPa



14) $s$ = 80 MPa



15) $s$ = 70 MPa



16) Compare and contrast your results from the cracks and pressures of Exercises 10 and 11.

17) Compare and contrast your results from the cracks and pressures of Exercises 13 and 15.

18) Explain why you think a long crack is sometimes safe while a comparatively small crack is sometimes critical.