MSE 23000 Homework Assignment – Week 6 (10 pts)
Fracture Mechanics, Ceramics, and Glasses

Over the next week, think about the following problems and provide your responses as prompted below **using this document as a template**. Responses can be typed and/or inserted as scans or images (*e.g.*, of hand-written calculations or sketches). These questions are reflective of typical exam questions – hence, the students who complete their homework assignments are the best prepared for their upcoming exams. Additionally, *you are encouraged to attempt all homework problems before attending your weekly recitation* so that you are prepared to ask questions and seek guidance & hints from your recitation instructor. This assignment is worth 10 points and will be graded for completion only. **Submit your assignment as a single PDF document** by using the appropriate link on Brightspace. You may choose to complete this assignment independently or work in groups but all submitted responses must be unique/your own work. Correct responses will be discussed in your next recitation lecture.

(1 pt) 1. Callister 8.1: What is the magnitude of the maximum stress that exists at the tip of an internal crack having a radius of curvature of 2.5×10^{-4} mm and a crack length of 2.5×10^{-2} mm when a tensile stress of 170 MPa is applied?

$$Kt = 1 + 2 * (2.5\, x\, 10^{(-5)} / (\pi * 2.5 * 10^{(-7)}))=201$$

MaxStress=201*170=34370Mpa

(1 pt) 2. Callister 8.5: A specimen of a 4340 steel alloy having a fracture toughness of 45 MPa-m$^{1/2}$ is exposed to a stress of 1000 MPa. Will this specimen experience fracture if it is known that the largest surface crack is 0.75 mm long? Why or why not? Assume that the parameter Y has a value of 1.1.

$$K = 1.1 * 1000 * \sqrt{\pi * 0.75 * 10^{-3}}$$
$$K = 67.50Mpa$$

(1 pt) 3. Callister 8.8: A large plate is fabricated from a steel alloy that has a plane strain fracture toughness of 55 MPa-m$^{1/2}$. If, during service use, the plate is exposed to a tensile stress of 200 MPa, determine the minimum length of a surface crack that will lead to fracture. Assume a value of 1.1 for Y.

(3 pts) 4. Your new boss asks you to consider making a small bridge out of two very different materials that contain aluminum atoms. The table below summarizes their properties.

Material	Strength, MPa	Fracture Toughness, MPa-m$^{1/2}$
Alumina (Al_2O_3), a ceramic	Fracture Strength = 550	4
Aluminum Alloy (2024-T3), a metal	Yield Strength = 325	36

(a) Assume that the maximum stress the material will encounter is 100 MPa (when two large trucks simultaneously pass over the small bridge) and a surface crack geometry. Calculate the size of a surface crack that would cause the bridge to fail if it was made from each of the above materials.

$$A = \left(\frac{4}{100\sqrt{\pi}}\right)^2 = 5.092 * 10^{-4}m$$
$$A = \left(\frac{36}{100\sqrt{\pi}}\right)^2 = 0.0412m$$

(b) Considering your calculations in part (a), which material would you rather make the bridge from? Why?

Alumina because it would yield a smaller crack from the same stress

(c) Based on your responses in part (a) and (b), do we only have to consider strength when choosing a material? Explain.

No we should also consider fracture toughness for this because we need to understand that when the strength is exceed how much the damage is

(1 pt) 5. My first bicycle was made mostly from steel – it never wore out but it was HEAVY. For a structural part of a bicycle exposed to repetitive loading/unloading cycles during use, describe one advantage and one disadvantage of having that part made from *aluminum* as compared to *steel*.

One disadvantage is that aluminum is not strong as steel so it will wear out much quicker after use and weathering. One advantage is that Aluminum in a vehicle is light and is useful for when you want something to be fast

(1 pt) 6. Compare and contrast *ceramics* and *glasses*.

Ceramics and glasses are both similar in having the traits of being brittle in how they break, and their chemical composition can be similar or the same, the differences lie in their chemical structure and their mechanical strength

(1 pt) 7. Callister 12.43: A circular specimen of MgO is loaded using a three-point bending test. Compute the minimum possible radius of the specimen without fracture, given that the applied load is 425 N, the flexural strength is 105 MPa, and the separation between load points is 50 mm.

$$r = \sqrt{\frac{(3*425*0.05)}{(2*\pi*105*10^6)}}\text{m}=3.10853321*10^{\wedge-4}\text{m}$$

(1 pt) 8. Callister 12.47: The modulus of elasticity for beryllium oxide (BeO) having 5 vol.% porosity is 310 GPa.

a. Compute the modulus of elasticity for the nonporous material.

$$Em = \frac{310}{(1-0.05)^2} = 343.14$$

b. Compute the modulus of elasticity for 10 vol.% porosity.

$$Em = \frac{310}{(1-0.1)^2} = 382.72$$