Spring 2020: Mechanical Properties Materials Science (MPMS)

Take Home Exam III: (Fracture)
Given out on Friday 04/13/2020, due on Monday 04/20/2020

Each question carries equal points; Please give your answers on the enclosed pages.

Please note:

•When a derivation is requested, please do not simply copy from the notes. Underline the assumptions in the analysis that are of a fundamental nature.

•Keep you answers as short as possible without losing the essence of your answer. You are advised to redo your answer sheet the second time before you submit. You will realize how much better and clearer your response is.

•Two maps needed to answer the questions are on the website but also attached to the end of this HWExam.

Please write your answers on the pages in the print-out of this problem set.

1. Give three iconic examples, in the form of a figure and/or an equation, along with a couple of sentences to explain, of phenomena related to “fracture”.

2. Please see notes where the sinusoidal form of the force-displacement curve for bond stretching leads to the following equation

$$2\gamma_F = \frac{E\Omega^{1/3}}{2\pi^2}$$

In the past we have used a similar approach to derive a relationship between the modulus, E, and the enthalpy of formation ΔH_V. Combine these two analyses to obtain a relationship between $2\gamma_F$ and ΔH_V.

Note: in the sinusoidal curve the initial slope is related to E, and the area within the curve to the work of fracture.

3. Design a double cantilever fracture experiment to measure the fracture toughness of wood. You may assume the length of each cantilever to be 25 cm, the vertical height to be 7.5 cm, and the thickness to be 2.5 cm. (think of a 1x6 plank of wood).

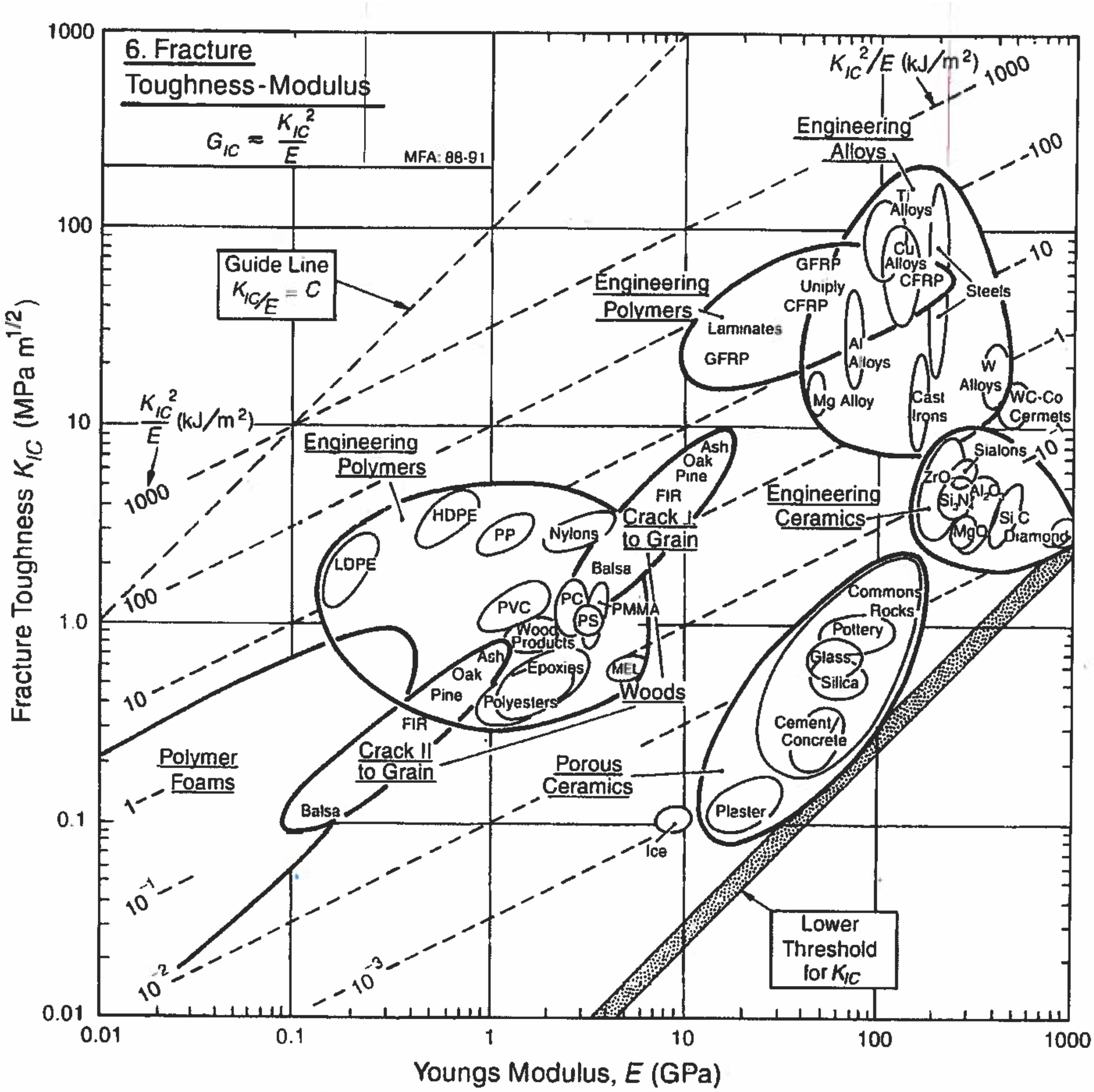
Read the value of the fracture toughness from the notes, and calculate the load that would cause the beam to fracture.

4. The experiment in Problem 3 was a constant load experiment. Now do the same experiment by controlling the displacement by driving a wedge between the two arms of the double cantilever beam specimen. Draw a load vs displacement curve for this scenario and mark the point of fracture on this graph. Draw the distinction between this constant displacement experiment and the constant load experiment in Problem 3 (in a few words).

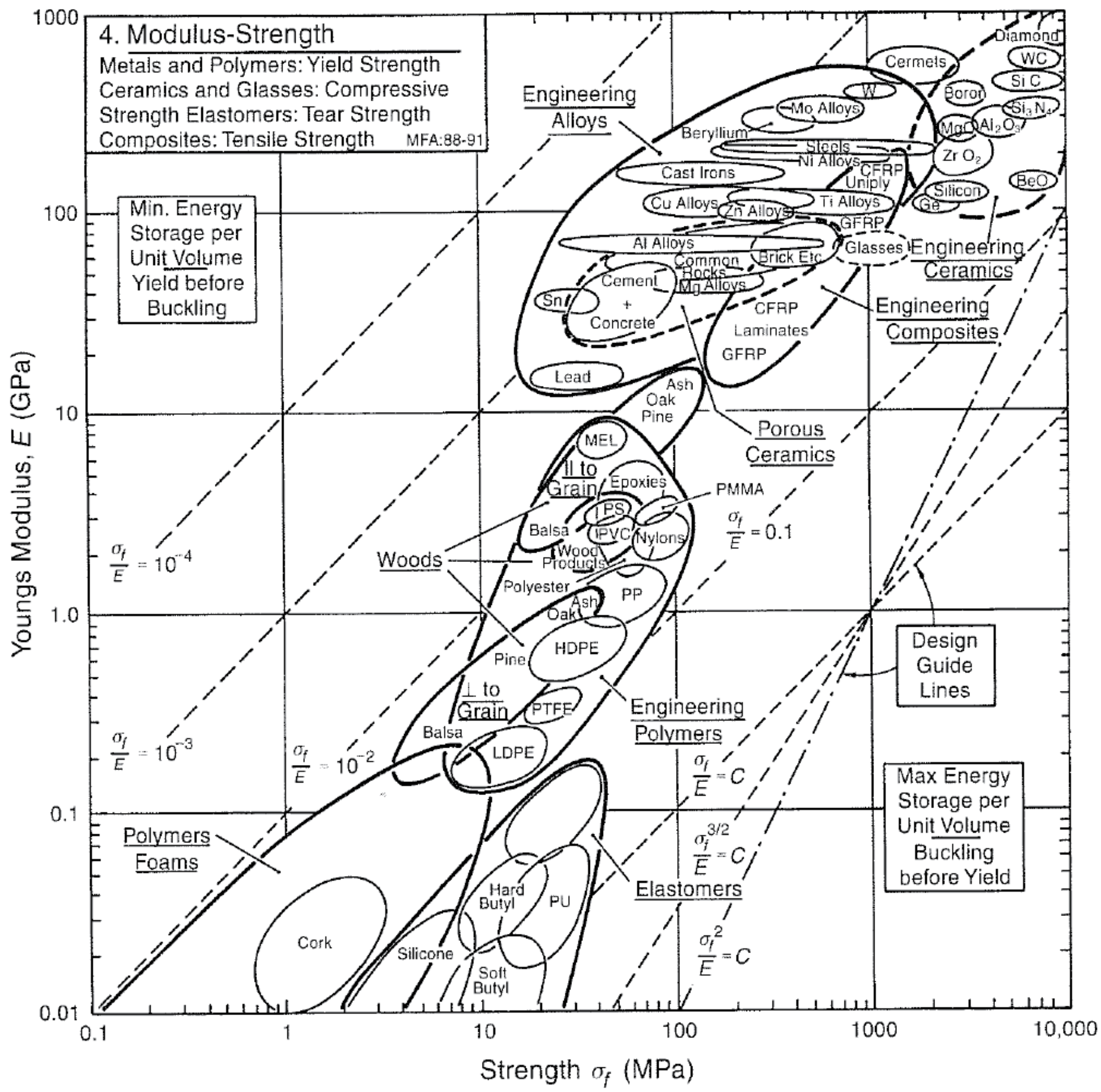
5. Please refer to the map where the Fracture Toughness is plotted against the Young's Modulus. What are the values for GFRP (graphite fiber reinforced polymers) and simple polymers such as epoxy?

Explain the large difference between the fracture toughness of these two materials although even though the matrix phase in GFRP is the epoxy.

6. Apply Eqns (2.7) and (2.8) to calculate the CTOD and the plastic zone size, Z (at the point of fracture) for the following materials,
-silica glass
-polymer, e.g. polypropylene or PMMA
-silicon carbide
-titanium
-GFRP
The data for K_{IC} as a function of E, and the data for the yield strength, Y or σ_f, as a function of E are given on the Fracture Page of the website, and also on the following next two pages.



6. Fracture Toughness-Modulus
$G_{IC} = \frac{K_{IC}^2}{E}$
MFA: 88-91
Guide Line $K_{IC}/E = C$
$\frac{K_{IC}^2}{E}$ (kJ/m²)
K_{IC}^2/E (kJ/m²)
Engineering Alloys
Ti Alloys
Cu Alloys
CFRP
Steels
GFRP Uniply CFRP
Engineering Polymers
Laminates GFRP
Al Alloys
W Alloys
Mg Alloy
Cast Irons
WC-Co Cermets
Sialons
ZrO₂
Si₃N₄
Al₂O₃
SiC
MgO
Diamond
Engineering Ceramics
Engineering Polymers
HDPE
PP
Nylons
LDPE
PVC
PC
PS
PMMA
Wood Products
Epoxies
MEL
Polyesters
Ash Oak Pine
FIR
Crack ⊥ to Grain
Balsa
Woods
Crack ∥ to Grain
Polymer Foams
Porous Ceramics
Commons Rocks
Pottery
Glass
Silica
Cement/Concrete
Plaster
Ice
Lower Threshold for K_{IC}
Fracture Toughness K_{IC} (MPa m^1/2)
Youngs Modulus, E (GPa)


4. Modulus-Strength
Metals and Polymers: Yield Strength
Ceramics and Glasses: Compressive
Strength Elastomers: Tear Strength
Composites: Tensile Strength MFA:88-91
Min. Energy Storage per Unit Volume Yield before Buckling
Max Energy Storage per Unit Volume Buckling before Yield
Design Guide Lines
Engineering Alloys
Engineering Ceramics
Engineering Composites
Porous Ceramics
Engineering Polymers
Woods
Polymers Foams
Elastomers
Youngs Modulus, E (GPa)
Strength σf (MPa)