Problem 1:  

(a) Why is it that exceptionally strong materials, such as ceramics and very high strength steels, are almost inevitably brittle?  

(b) One of the first researchers to investigate the strength of materials was Gallileo, who measured the ultimate tensile strength of piano wire (very high strength, heavily worked, brittle steel). Among other experiments, he measured the maximum weight a sample of wire could support as a function of the original length of the sample, and found that the apparent strength of long wires was below the strength of short ones. Explain this result.  

(c) If you take a length of glass fiber and load it in tension until it breaks, each piece of the broken bar will have higher tensile strength than the original bar did. Why?  

Problem 2:  

The resistance of a material to fracture is usually measured by determining its 'plane strain fracture toughness', $K_{IC}$.  

(a) Suppose you are designing a structure from a material whose fracture toughness is known, and you also know the maximum size and shape of cracks that cannot be detected by the non-destructive analysis that is used to qualify the structure. How can you use this information to set a safe allowable tensile stress for the structure (assume tensile loading perpendicular to the flaw)?  

(b) Structures made of tough, ductile materials are usually designed to the ultimate tensile strength rather than the fracture toughness. Why?  

Problem 3:  

(a) Show a typical plot of the variation of the fracture toughness with temperature for a material that undergoes a ductile-brittle transition. Identify the ductile-brittle transition temperature.  

(b) Give a simple rationalization for the appearance of a ductile-brittle transition in terms of the competition between plastic deformation and fracture.  

(c) How would you use fractographic analysis to determine whether a material had been tested above or below its ductile-brittle transition temperature?
Problem 4:

(a) Sketch the form of the (log-log) plot that relates the rate of fatigue crack growth per cycle (da/dn) to the cyclic stress intensity, (ΔK).

(b) Describe how knowledge of the fatigue crack growth rate can be used with non-destructive testing and periodic inspection to insure that a component does not fail in fatigue.