PHYS1169 tut 13 answers

Fracture of solids.

Q1. See C&L p88. To fracture any material, a new interface is required, and it has a surface energy. (If the cross section of the material is A, an energy 2 γA is required, where γ is the surface energy, also caused specific surfacen energy.) (For solids, this energy is often much less than the work done deforming the material to propagate the stress, or in friction or elsewhere.)

Q2. See C&L pp68-70, 88. The stresses are usually concentrated at the end of the crack. This locally high stress can rupture interatomic/intermolecular bonds locally. The concentration of stress then moves to the new end of the crack.

Q3. See C&L p69. It increases the radius of curvature at the point where stresses are concentrated. This decreases the local stress

Plasticity of solids

Q1. Definitions: For a longitudinal stress and strain,

$$\sigma \equiv F/A. \qquad \varepsilon \equiv \Delta L/L$$

$$dW = FdL = \sigma A.Ld\varepsilon$$

Work done in one cycle is $$W = AL \int_{cycle} \sigma.d\varepsilon$$

$$\therefore \frac{\text{Work done}}{\text{per unit volume}} = \text{area inside } \sigma(\varepsilon) \text{ cycle}$$

Q2. See C&L pp55-64. A pure, single crystal has no cracks, dislocations or grain boundaries, and so a high yield stress.

In polycrystalline materials with large crystals, there are fewer grain boundaries and so there is greater stress concentration on grain boundaries and dislocations.

Alloys are less crystalline and sometimes amorphous. Crystals present are small. Relatively little stress concentration.

A, B, C, D are the expected order of decreasing yield stress.

E1. The etching often increases the radii of curvature at the ends of cracks. This decreases local stress concentration. See C&L p69.

E2. When the tyre is flattened, there is a local strain. Each piece of rubber in turn goes through a stress-strain cycle with a non-zero hysteresis. The work done (as above) is area inside $\sigma(\varepsilon)$ cycle. Much of this work is converted to heat. There are hundreds of such cycles in each km travelled, so the work done is large.

E3.

a) Even at v high speeds, centripital forces give only modest stresses. Need heat moderate resistance. Might use ceramic if we were sure there would be no collisions with foreign objects, but prefer metal.

b) Oh, there's a complex question. The Citroen DS used Al, steel and fibreglass for different panels. For some parts light weight is important, and for others some rigidity is need for the structure and the crumple zone...

c) a material with a higher melting point than glass! Some ceramic.

d) something not dissolved or attacked by the acid. Ceramic sounds good but its brittleness might be dangerous unless there is further containment. Some polymers would be okay for a while. Consider glass lining.

e) not a conductor, not thick. Polymer sounds good.

f) here we want a low modulus to allow vibration on one side but not on the other. Rubber or other polymer.

g) jewels are often used here: eg sapphire or diamond: can withstand high stress on a 'point'—ie a zone of small size. The radius is small so the torque required to turn is small, even if friction is high.

h) biocompatible! some alloys (including titanium), some ceramics, silicone. Combinations of these.

E4. Some of the work you put in to bend it is stored in the interatomic potential energy in the deformed regions. Less energy is required here to reach the activation energy of the oxidtion reaction.