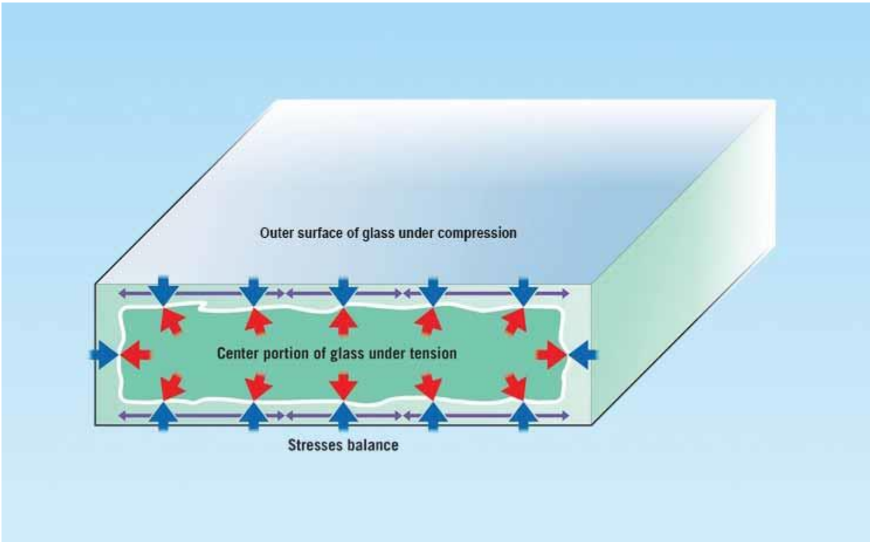
Total Marks: /30

1. Short Answer (7 pts)

a) Explain how tempered glass resists stresses. Use a diagram. (3)



- Tempered glass resists applied loads by having residual compression stresses on the outer areas (+1) and tensile stresses in the centre (+1).

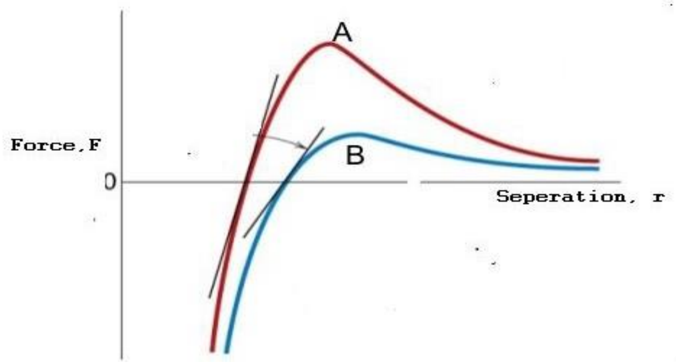
b) Define Poisson's ratio. What does it tell us? (2)

- $\nu = -\frac{\varepsilon_r}{\varepsilon_z} = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z}$ (+1)
- Poisson's ratio tells us the relative change between axial tension and transverse compression (+1)

c) Define Hooke's law and the engineering stress-strain relationship. How is Hooke's law related to stress? How is it different? (2)

- Hook's law describes the linear relationship between the force applied and the displacement of a component (0.5). The slope, Hooke's constant (k), is geometry-dependent (0.5).
- Engineering stress is described by the linear relationship between the strain experienced by a material and the stress (0.5). The slope, Young's modulus (E), is independent of geometry (0.5)

2. The following questions concern two hypothetical materials, A and B, with these curves showing the net interatomic forces as a function of interatomic separation. Which material will have a higher modulus of elasticity (Young's modulus), and why? (3 pts)



- In this diagram, material A will have a higher modulus of elasticity. Because it has a higher slope of the force vs. separation curve at Force = 0, and the smaller separation at Force = 0. E is proportional to slope divided by equilibrium separation distance

3. A bar is at a length of 31.5cm when 200kN of force is applied in tension. The radius of the bar is 15mm. If the strain experienced by the bar is 0.015, what is the Young's modulus for this material? (3 pts)

- $\sigma = \frac{F}{A_o} = E\varepsilon$ (+1)
- $\sigma = \frac{200\ 000N}{\pi(0.015m)^2} = E(0.015)$ (+1)
- $E = 18.87\ GPa$ (+1)

4. For a brass alloy, the stress at which plastic deformation begins is 345 MPa, and the modulus of elasticity is 103 GPa. You are given 0.5m long hollow brass cylinder with an internal external diameter of 2cm and an internal diameter of 1.8cm, which will be required to support a large chandelier. (5 pts)
    a. What is the maximum load that can be supported without plastic deformation? (3 points)

- $\sigma = 345\ 000\ 000\ Pa = \frac{F}{A_o} = \frac{F}{\pi(0.01m^2 - 0.009m^2)}$ (+1)
- $\sigma = 345\ 000\ 000\ Pa = \frac{F}{0.00023864\ m^2}; F = 20.6\ kN$ (+1)
- $F = ma; \frac{82331N}{9.81\frac{m}{s^2}}; m = 2099kg$ (+1)

    b. What is the maximum length to which it can be stretched without causing plastic deformation? (2 points)

- $\sigma = E\varepsilon$ (+1)
- $345\ MPa = 103GPa\ (\varepsilon);\ \varepsilon = \frac{345MPa}{103GPa} = 0.00336 = \frac{\Delta l}{l_o} = \frac{\Delta l}{0.5m};\ \Delta l = 0.00168m$ (+1)

5. A beam (dimensions 3cmx3cmx10cm) is placed under a tensile stress of 5000N along its length. Measuring with calipers while the load is applied, it was found that the dimensions of the beam's cross section were now 2.99cmx2.99cm. (6 pts)

a. If the Poisson's ratio is 0.28, what is the Young's modulus of this unknown material? (4)

- $\sigma = \frac{F}{A_o} = \varepsilon_z E$ (+1)
- $\frac{5000N}{0.03cm^2} = \varepsilon_z E$ (+1)
- $0.28 = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\frac{2.99-3}{3}}{\varepsilon_z}$; $\varepsilon_z = 0.0119$ (+1)
- $\frac{5000N}{0.03cm^2} = 0.0119E$
- E = 467 MPa (+1)

b. What is the shear modulus of this material? (2)

- $E = 2G(1+\nu)$ (+0.5)
- $4.67x10^8 Pa = 2G\ (1+0.28)$ (+0.5)
- $G = 182.3MPa$ (+1)

6. A three-point bending test is performed on a glass specimen having a rectangular cross section of height d = 5 mm and width b = 10 mm. The distance between support points is 45 mm. Compute the flexural strength if the load at fracture is 290 N. (2)

- $\sigma_{flex} = \frac{3FL}{2wd^2}$ (+1)
- $\sigma_{flex} = \frac{3(290N)(0.045m)}{2(0.01m)(0.005m)^2} = 78.3\ MPa$ (+1)

7. A metal component made of unobtanium must be fabricated from a single crystal. This component will have a final volume of 12.3 cubic metres. Unobtanium has a face-centred cubic crystal structure, the atoms have a radius of 1.35 Å, and a molar mass of 75.5 g/mol. Determine the final mass of this component. (3 points)

- 4 atoms per unit cell
- The dimensions of the unit cell is determined by:
  - $a^2 + b^2 = c^2$
  - $a = b; 2a^2 = [4(1.35x10^{-10})]^2$ (+1)
  - $a = 3.82x10^{-10}m$ (+1)
- The unit cell volume
  - $V = (3.82x10^{-10}m)^3 = 5.567x10^{-29}m^3$ (+1)
  - $\rho = \frac{4\ atoms}{5.567x10^{-29}m^3} \cdot \frac{mol}{6.022x10^{23}atoms} \cdot \frac{0.0755kg}{mol} = 9008\frac{kg}{m^3}$ (+1)
  - $mass = 9008\frac{kg}{m^3} * 12.3m^3 = 110799$ kg (+1)