1. A pressure vessel steel specimen made of an A533B steel [ferritic] of diameter 1 mm and grain size of 0.2 mm exhibited an yield point with the lower yield stress equal to 520 MPa. The source hardening term (\(k_y/\sqrt{D}\)) was found to be 150 MPa.
   a. What is the load corresponding to the yield point?
   b. Determine the dislocation density which resulted in the yield stress of 520 MPa.
   c. What will be the yield stress if the grain size of the material changed to 0.3 mm due to the operating thermal environment?
   d. In addition to the increase in the grain size, the dislocation density of the irradiated material increased by \(\Delta \rho\) \(2 \times 10^9\) cm\(^{-2}\). Estimate the yield stress of the irradiated material due to the increased dislocation density.
   e. During irradiation, fine (point size) carbide precipitates formed with a volume concentration of \(9 \times 10^{13}\) cm\(^{-3}\). Estimate the hardening (i.e., increase in the yield stress due to the carbide precipitates).
   f. In addition to the above microstructural modifications, radiation exposure induced copper precipitates of 0.001% volume fraction with a mean diameter of 20 Å. Determine the hardening due to the copper precipitates.
   g. Outline the procedure (write the equations and do not calculate) for estimating the change in DBTT due to radiation exposure (indicating any missing information required)?

2. In a fusion reactor blanket coolant channel, a copper (fcc) coolant tube (exposed to 14 MeV neutron radiation to a fluence of \(5 \times 10^{22}\) n/cm\(^2\)), exhibited radiation hardening and embrittlement with twice the tensile strength accompanied by reduced elongation to fracture (by 1/2 of that before irradiation) with no necking. The following properties were reported on the unirradiated copper: Young’s modulus = \(30 \times 10^6\) psi, nominal tensile strength = 50 ksi, fracture strain = 35%, uniform strain = 25%.
   a. Estimate the change in the toughness of the material following radiation exposure.
   This material is known to follow the Universal Slopes equation relating the fatigue life to the applied strain:
   \[\Delta \varepsilon = \frac{S_f}{E} (N_f)^{-0.12} + (\varepsilon_f)^{0.6} (N_f)^{-0.6},\]
   where \(S_f\) is the fracture strength, \(\varepsilon_f\) is the fracture strain and \(N_f\) is the number of cycles to fatigue failure.
   b. What are the effects of radiation exposure on fatigue life in LCF (\(N_f \leq 50,000\)) and HCF (\(N_f \geq 10^6\))? Does neutron irradiation always decrease fatigue life (explain your answers)?
   c. Calculate the endurance limits before and after radiation exposure?
   d. The radiation exposure resulted in 0.15 dpa. If one vacancy survived per million atomic displacements due to recombination etc., calculate the density of Frenkel defects following radiation exposure? What is the probability (%) that a unit cell contains a vacant lattice site?
   e. How does radiation exposure influence self diffusion? Show the effect on an Arrhenius plot indicating the relevant parameters.

3. An irradiated metal contains a network-dislocation density of \(\rho_d\) and \(N_f\) faulted-loops per unit volume of radius \(R_l\). The yield stress of irradiated specimen is measured at temperature just below and just above the temperature at which the loops unfault. What is the difference in the yield stress between these two measurements? Assume the unfaulted loops become part of the dislocation network of the metal. (This typically occurs in fcc metals such as SSs as per HW#9-5 where Frank faulted loops become unfaulted following heat treatment).

What are the effects of radiation on the following: • dislocation density, • vacancies, diffusion, corrosion, strength (hardness), ductility (RA), toughness, DBTT or NDT, \(C_v\), fracture toughness, strain hardening, creep (low temperatures vs high temperatures), low and high cycle fatigue (fatigue strength & endurance limit), burn-up, reactivity, density, resistivity, conductivity, magnetic susceptibility.
Describe the phenomena: Radiation Swelling of SS vs Radiation Growth of Zircalloys; Friction and Source Hardening - fcc vs bcc: effects of radiation on \(\sigma-\varepsilon\) curves / yield points; Radiation Embrittlement of Ferritic Steels - effects of alloying & weld vs HAZs; Radiation Anneal Hardening; Effects of Radiation on Polymers; PCI and SCC of LWR cladding; He-Embrittlement / Threshold (n,\(\alpha\)) reactions; Effects of radiation and corrosive environments on SCC, fatigue/Corrosion Fatigue \{endurance limit\}, stress-rupture \{\(\sigma\) vs \(\sigma_{\text{uc}}\)\}, creep-rupture, \(K_{\text{sec}}\Delta K_{\text{th}}\)