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Question 1:

Materials Science and Engineering is the study of material behavior & performance and how this is simultaneously related to structure, properties, and processing. Link the following terms to their corresponding fields. e.g. Annealing-Processing.

Terms: Density, Extrusion, Crystalline, Amorphous, Elastic Modulus.

Fields: Structure, Property, Processing

=> Linking the terms with the fields:

- Density - Property
- Extrusion - Processing
- Crystalline - Structure
- Amorphous - Structure
- Elastic Modulus - Property

Question 2:
Choose and fill the blanks from the following options:

(a) Covalent (b) Ionic (c) Van der Waals (d) Hydrogen (e) Metallic

Metallic bonding is similar to ionic bonding, except there are no high-electronegativity atoms present to accept any electrons that the present atoms are willing to donate. Covalent bonds are responsible for binding atoms together within a molecule of propane, whereas Van der Waals bonds bind separate propane molecules together in a condensed state (liquid or crystal). Covalent bonds are the only primary bonds that are directionally dependent. Materials whose constituent particles are bound by Van der Waals bonding are generally expected to have the lowest melting temperatures.

Question 3:

(a) Give the Miller indices for the direction represented by the blue vector and the plane filled by the blue area that have been drawn within a unit cell in Figure 1.

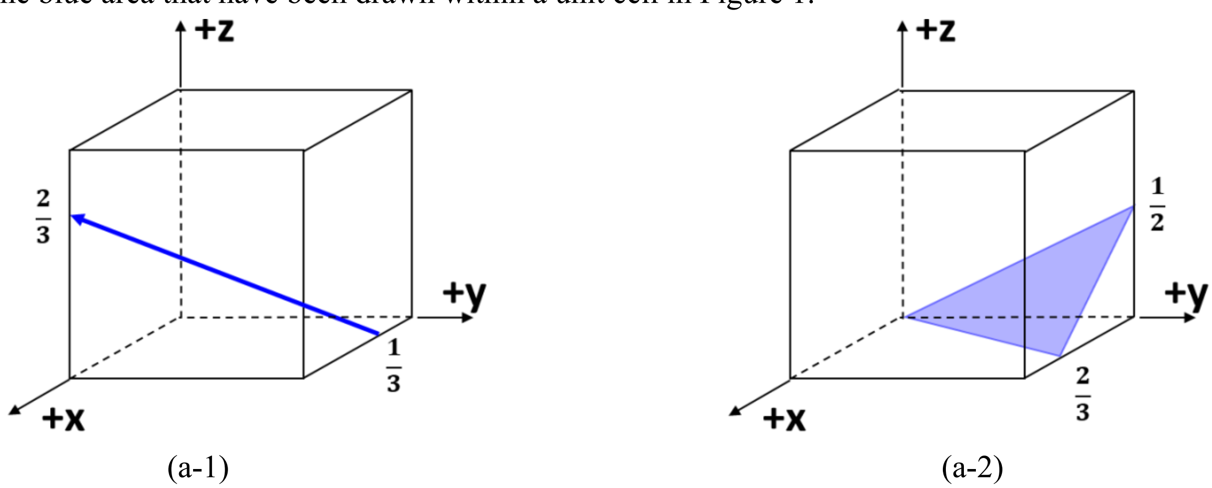


Figure 1

* Figure 1 (a-1)

- Vector tail coordinate: $x_1 = 1/3\,x$, $y_1 = y$, $z_1 = 0$
- Vector head coordinate: $x_2 = x$, $y_{\cancel{1}2} = 0$, $z_2 = 2/3\,z$
- Normalize coordinate difference

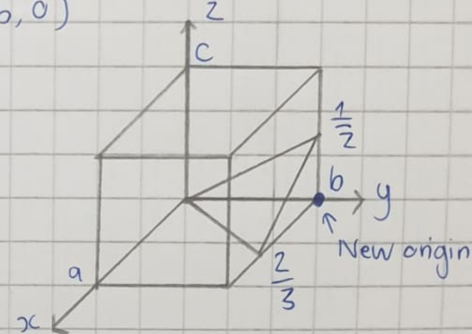
$$\frac{x - 1/3x}{x} \quad \frac{0 - y}{y} \quad \frac{2/3z - 0}{z} \Rightarrow 2/3,\ -1,\ 2/3 \Rightarrow 2, -3, 2$$

$\Rightarrow$ Miller indices of direction (a-1): $[2\bar{3}2]$

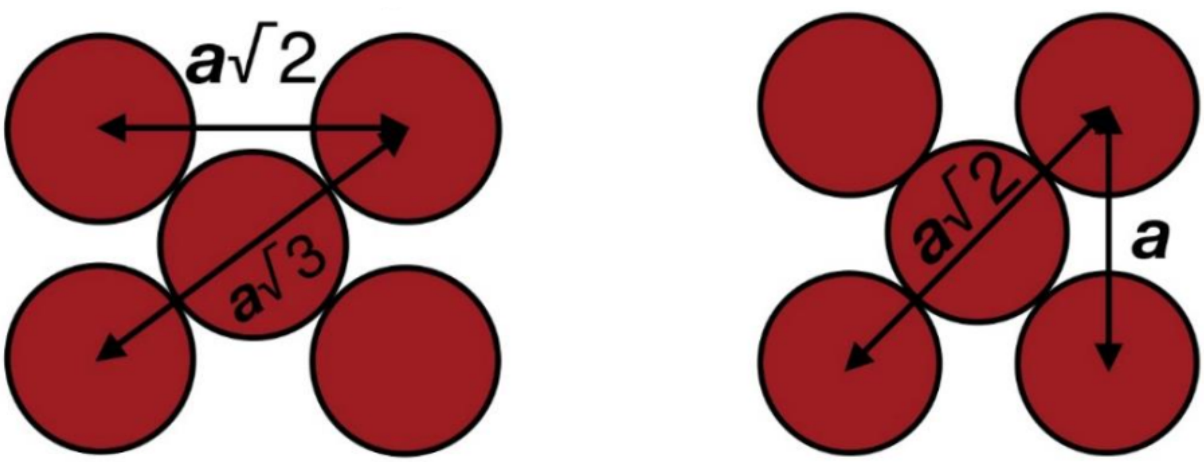
* Figure 1 (a-2)

	x	y	z
Relocate origin - is needed: moved to $(0, b, 0)$			
Intercepts	$(2/3)a$	$-b$	$(1/2)c$
Reciprocals	$3/(2a)$	$-1/b$	$2/c$
Normalize	$3/2$	-1	2
Reduction (x2)	3	-2	4

$\Rightarrow$ Miller indices of plane (a-2): $(3\bar{2}4)$



(b) Figure 2 shows two kinds of atomic packing of a plane in a cubic unit cell; atoms drawn to full size are represented by the circles, i.e. the hardball model is used; a represents the unit cell length. Give the Miller indices for the possible crystal plane family and the corresponding structure (e.g. an example for the answer format: FCC {111} planes).



(b-1) (b-2)

Figure 2

- From the figures in (b-1), we can see that it is BCC crystals. Possible crystal plane families is {110}
- From the figures in (b-2), we can see that it is FCC crystals. Possible crystal plane families is {111}

Question 4:

Consider the schematic nanostructure depicted in Figure 3. Name the structure defects in this region marked with 1, 2, 3, 5, 6, 7.

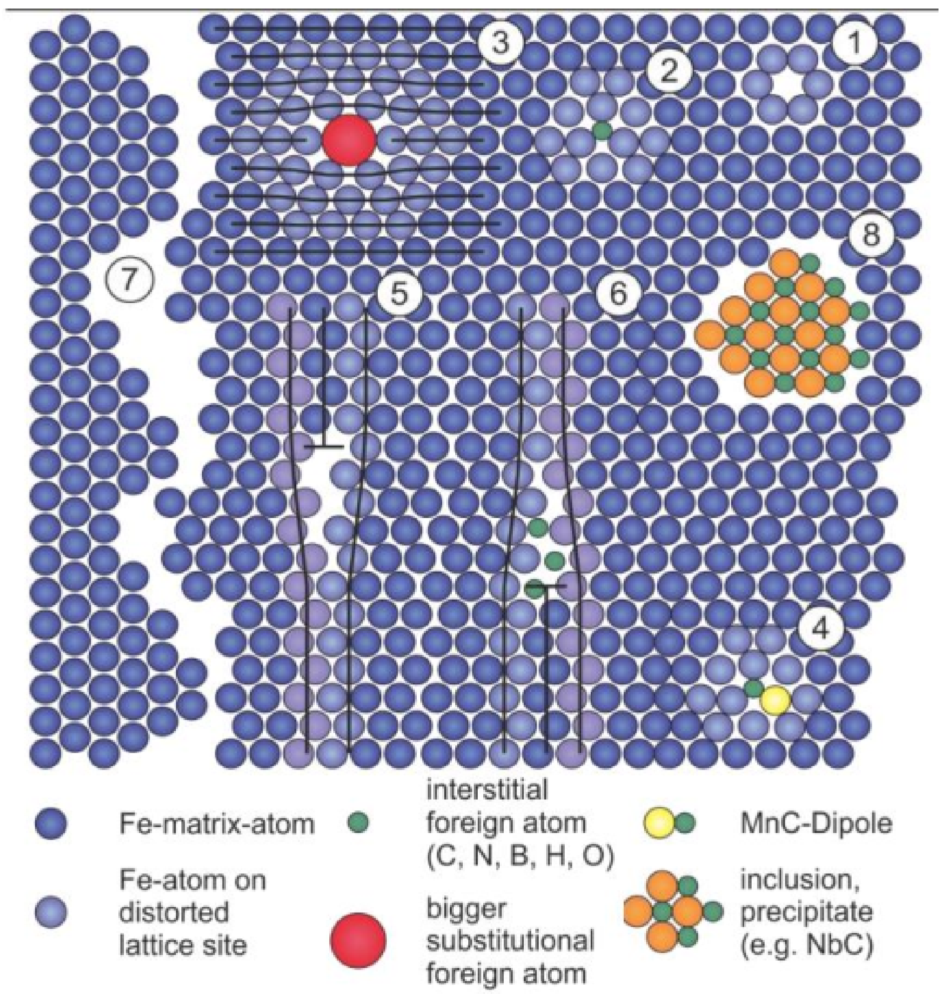
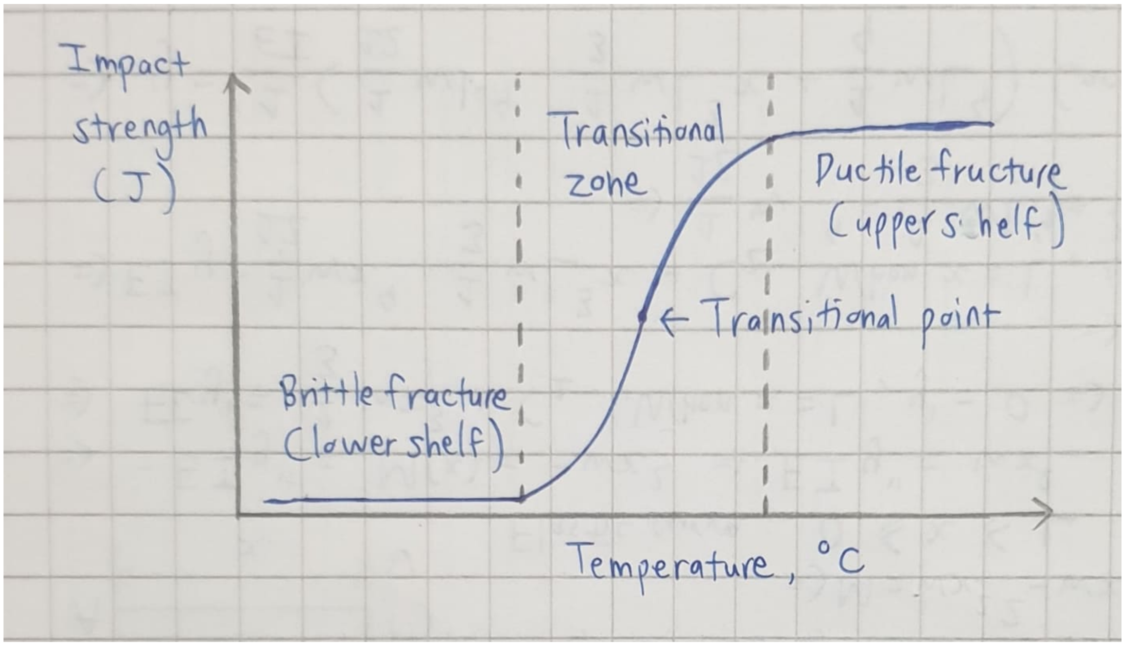


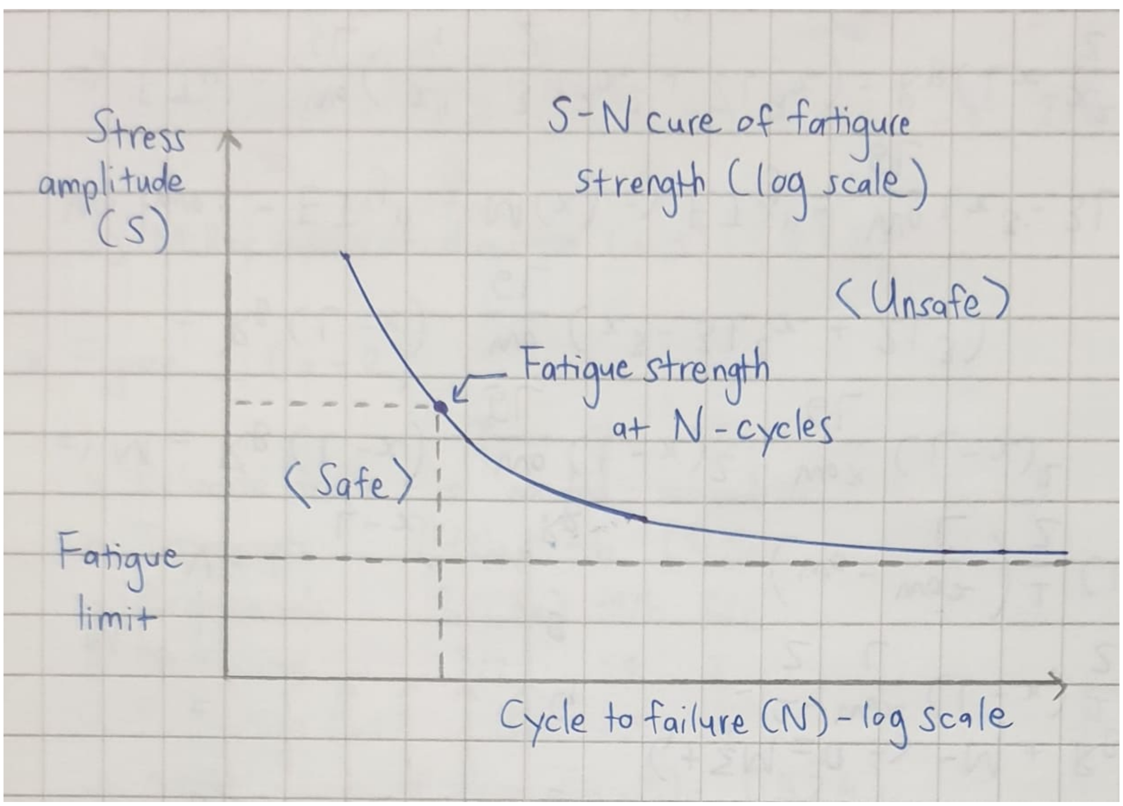
Figure 3

The structure defect in
Region 1: Vacancy defect
Region 2: Interstitial foreign atom impurity defect
Region 3: Substitional foreign atom impurity defect
Region 5: Edge dislocation line defect
Region 6: Edge dislocation line defect with substitutional foreign atom defect
Region 7: Grain boundary defect

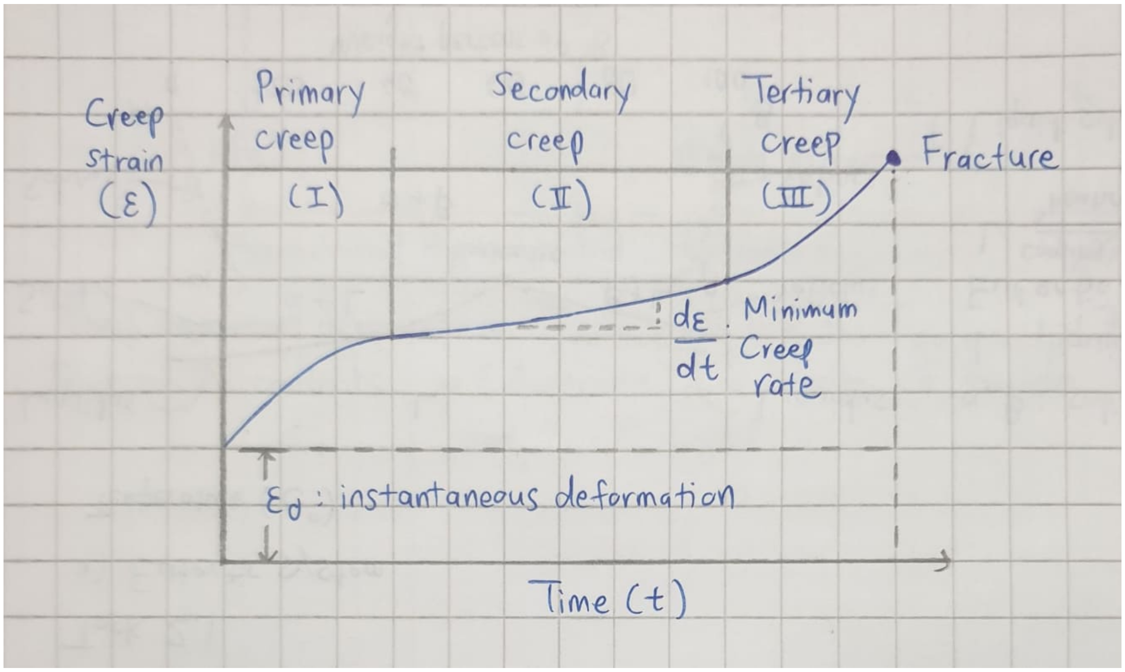
Question 5: Draw the schematic curves for
(a) the BCC transition curve from Charpy testing;



(b) S-N curve from fatigue testing;



(c) strain evolution curve from creep testing. Indicate all the axis titles of each curve



Question 6:

Indicate all the eutectic, eutectoid, and peritectic reaction points in Figure 4 (if any). Give the corresponding reaction equations.

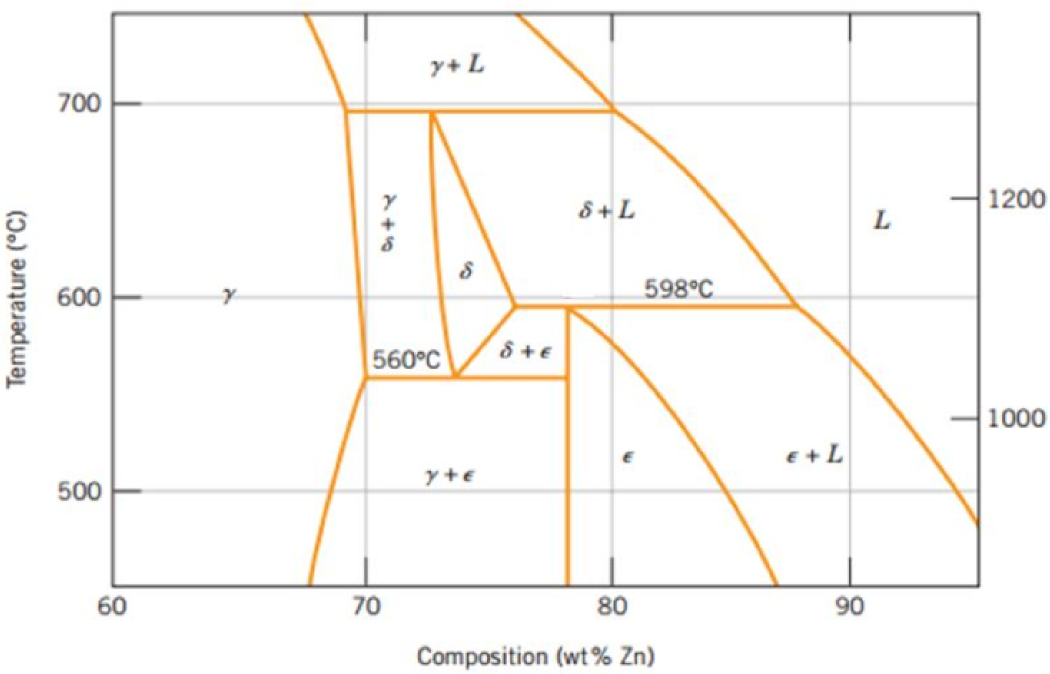
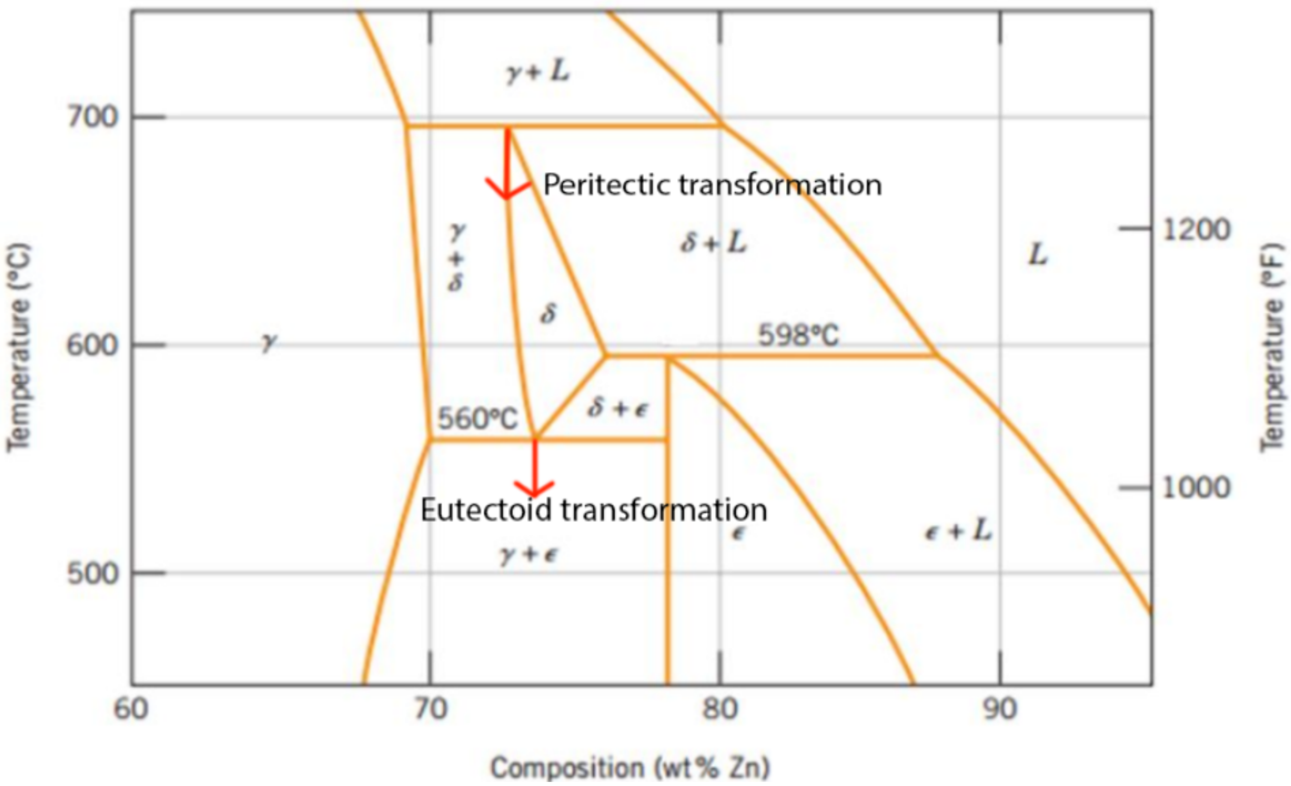


Figure 4



Peritectic transformation : $\gamma + L \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \delta$

Eutectoid transformation : $\delta \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \gamma + \varepsilon$

There is no eutectic transformation in the given phase diagram

Question 7:

The two ends of a cylindrical rod of 1025 steel (75 mm long and 10 mm in diameter) are maintained rigid. If the rod is initially at 25°C, to what temperature must it be cooled to have a 0.008 mm reduction in diameter? The length coefficient of thermal expansion α_l is 12×10^{-6} 1/°C and isotropic, the elastic and shear moduli for this steel are 208 GPa and 80 GPa, respectively. (Step-by-step derivation or calculation processes is necessary!)

$\alpha_\ell = 12 \times 10^{-6}$ 1/°C $\qquad \ell_0 = 75\,mm$

$E = 208$ GPa $\qquad d_0 = 10\,mm$

$G = 80$ GPa $\qquad T_0 = 25°C \Rightarrow T_f = ?$ so that $d_0 \downarrow 0.008\,mm$

The Poisson's ratio: $v = \dfrac{E}{2G} - 1 = \dfrac{208}{2*80} - 1 = 0.3$

- We have: $\sigma = E\alpha_\ell (T_0 - T_f) \Rightarrow \varepsilon_z = \alpha_\ell (T_0 - T_f)$

  $v = -\varepsilon_x / \varepsilon_z \Rightarrow \varepsilon_x = -v\varepsilon_z \Rightarrow \Delta d / d_0 = -v\varepsilon_z$

  $\Rightarrow \Delta d = -d_0 v \alpha_\ell (T_0 - T_f) = d_0 v \alpha_\ell (T_f - T_0)$

  This is expansion due to physical properties of Poisson ratio

- On other hand: $\Delta d = d_0 \alpha_\ell (T_f - T_0) \Rightarrow$ thermal expansion

  $\Rightarrow \Sigma \Delta d = d_0 \alpha_\ell (T_f - T_0) + d_0 v \alpha_\ell (T_f - T_0)$, where $\Delta T = T_f - T_0$

  $\Rightarrow \Delta T = \dfrac{\Sigma \Delta d}{d_0 \alpha_\ell (v + 1)} = \dfrac{(-0.008\,mm)}{(10\,mm) \times 12 \times 10^{-6}\ 1/°C \times (0.3 + 1)}$

  $= -51.282°C$

  $\Rightarrow T_f - T_0 = -51.282 \Rightarrow T_f = 25 - 51.282 = -26.282\,°C$

  $T_f = -26.282°C$ is the temperature to be cooled down to have $0.008\,mm$ reduction in diameter

Question 8:

Describe and compare the physical properties of metals, ceramics, and polymers, in terms of (a) electrical conductivity, (b) specific heat, (c) thermal expansion, and (d) thermal conductivity. (Hint: describe with definitions of these terms, then compare the properties of different materials with explanations.)

Definition:

- Electrical conductivity: Electrical conductivity is the measure of how much a material allows the transport of an electric charge/electric current. Depends on the Interatomic bonds, electronic structure
- Specific heat: The specific heat is the amount of heat per unit mass required to raise the temperature by one unit temperature, such as one degree Celsius. Depends on mass and heat capacity of the material
- Thermal expansion: Thermal expansion is the change of a material in physical properties like shape, volume, and area in response to a change in temperature. The coefficient of thermal expansion is inversely proportional to the bond energy of the material

- Thermal conductivity: Thermal conductivity is the ability of how much a material can conduct or transfer heat. Directly depends on electrical conductivity and density

Physical properties of metals, ceramics and polymers

	Metals	Ceramics	Polymers
bond energy	in between	highest	lowest
chemical bond type	metallic bond, having non localized free electrons	having covalent bond and ionic bonds	Very large molecular structure, held by covalent bonds
density	highest	in between	lowest
chemical elements	Metal elements	Combination of metal elements and non metal elements, like oxides, nitrides and carbides	Mostly C,H,N,O

From the definition of the four physical properties we can compare the magnitude of these physical properties for metals, ceramics, polymers based on the table above:

- Electrical conductivity: Metals > Ceramics > Polymers
- Specific heat: Polymers > Ceramics > Metals
- Thermal expansion: Polymers > Metals > Ceramics
- Thermal conductivity: Metals > Ceramics > Polymers

Question 9:

True or False

(1) The diffusion coefficient is increased with temperature increases => **True**

(2) Compared to the vacancy diffusion, the interstitial diffusion occurs more rapidly in metal alloys => **True**

(3) After an edge dislocation has passed through some region of a crystal, the atomic arrangement of that region is disordered => **True**

(4) The relationship between elastic and shear moduli is approximately G=0.1E for most metals (with Poisson's ratio of 0.30)

=> **False:** Formula: $E = G*2(1+v)$. When $v = 0.3$ => $G = 0.3846E$

(5) The burger vector of an edge dislocation is parallel to its dislocation line

=> **False:** The burger vector of a screw dislocation is parallel to its dislocation line

(6) Oxidation takes place at the anode => **True**

(7) Galvanizing involves applying a layer of zinc to the surface of the steel to protect the steel from corrosion => **True**

(8) Generally, there is a distinct ductile-brittle transition behavior of HCP metals

=> **False:** HCP metals do not have a distinct ductile-brittle transition behavior

(9) Large supercooling will lead to larger grain size than small supercooling

=> **False:** Large supercooling will lead to smaller grain size than small supercooling
(10) Slip system(s) with the largest Schmid factor will be activated firstly when a single crystal is under tension => **True**
(11) Both temperature and cold work will have a significant influence on a material's electrical resistivity => **True**
(12) For a given material, the constant pressure heat capacity, Cp, is always greater than the constant volume value, Cv => **True**
(13) Free electrons play a role in thermal expansion
=> **False**: Free electrons play a role in thermal conduction
(14) The greater the atomic bonding energy, the smaller the value of the thermal expansion coefficient
=> **True**
(15) The electrical conductivity of a single crystal is normally smaller than that of the polycrystalline material
=> **False:** The electrical conductivity of a single crystal is normally larger than that of the polycrystalline material

Question 10:

How long does it take to complete A6
It takes me about 8 hours to finish A6 assignment.