Write down the appropriate equations and intermediate steps neatly so that you may qualify for partial credit even if the final answer is wrong. Use the backside if more room is needed.

- RELEVANT INFORMATION AND DATA GIVEN ON THE LAST PAGE – tear it for convenient usage -

Units should be placed at appropriate places and definitely at the final answer.

1. True / False questions (mark the correct answer) : (1 point each) -------------------------------------[10]

   a. An edge dislocation slips perpendicular to itself (its line).  True or false

   b. A screw dislocation slips along its Burger's vector.  True or false

   c. A sessile dislocation can move easily under an applied stress.  True or false

   d. A dislocation pinned between 2 points remains to be semicircular (radius of curvature is half the pinning distance) under no force.  True or false

   e. Like screw dislocations repel each other.  True or false

   f. A prismatic loop has Burger’s vector perpendicular to the plane of the loop.  True or false

   g. Kinks and jogs on dislocations make the crystals softer.  True or false

   h. Some jogs on screw dislocations have screw character.  True or false

   i. A screw dislocation may change its glide plane by cross slip.  True or false

   j. An edge dislocation may change its glide plane by cross slip.  True or false

2. Evaluate the force on a screw dislocation with Burgers vector along x axis due to an external stress $\sigma_{yy}$.  --------------------------------------------------------------- [3]
3. a. What is the mean distance between dislocations if the dislocation density is $\rho$ ? [2]

b. What will be the strengthening due to dislocations of density $\rho$ (just write down the formula and define the terms) [2]

4. A cylindrical fcc single crystal with diameter of 0.1 mm is pulled in tension with a stress of 1000 MPa. [see fig.]. The loading direction is along $[\overline{1}01]$ while the slip system is $\langle 1\bar{1}1 \rangle [\bar{1}10]$. ($G = 200$ GPa and $a = 2$ Å)

a. What is the resolved shear stress along the slip direction in the slip plane? [4]

b. If $\tau_{\text{CRSS}}$ for the slip system for the material is 550 MPa, would the crystal deform? [1]

An edge dislocation (AB) is situated perpendicular to the slip direction (see Fig.) of the slip system and pinned at two points (A and B) separated by 1000 Å. The Burger’s vector of the dislocation is along the slip direction.

c. Determine the radius of curvature of the dislocation due to the applied stress? [4]
d. What is the critical stress for a Frank-Read source to operate (write down the equation and define the terms)?

\[ \sigma_{cr} = \frac{4G\tau}{h} \]

\( \sigma_{cr} \): Critical stress
\( G \): Shear modulus
\( \tau \): Tensile yield stress
\( h \): Half thickness of the specimen

--- [2]

e. Compute the minimum applied load (normal to the specimen cross-section) in kN required for the pinned dislocation (AB) to operate as a Frank-Read source.

--- [5]

f. If the dislocation line in the figure is a screw dislocation, what will be its Burgers vector?

--- [3]

g. What is the unit line vector (\( \hat{r} \)) of the dislocation (AB)?

--- [2]
5. Consider the following two dislocations in a bcc metal:

\[ b_1 = \frac{a}{2}[\overline{1} \overline{1} 1] \] and \[ b_2 = \frac{a}{2}[111] \] on \{110\} planes (see fig.)

\[ \begin{align*}
A & = C \\
B & = (10\overline{1}) \\
(101) & \quad B \\
(10\overline{1}) & \quad C \\
A & \quad (101)
\end{align*} \]

The two dislocations (#s 1 and 2) glide on the two planes to interact with each other at point C to become one dislocation \( b_3 \): \( b_1 + b_2 \rightarrow b_3 \)

b. Write down the equation and find the Burgers vector of #3 dislocation (at C): ------------------------- [2]

c. Show that the reaction is valid (satisfy the two conditions). ---------------------------------------- [3]

c. What is the plane on which dislocation #3 lies? ------------------------------------------------ [4]

d. Is this a glissile dislocation or sessile dislocation (explain)? -------------------------------------- [2]
Relevant Equations etc

\[ \sigma = E \varepsilon \]
\[ \tau = G \gamma \]
\[ \sigma = K \varepsilon^n \]
\[ U_{el} = \frac{\sigma^2}{2E} \]
\[ J = K \frac{\varepsilon_u}{n+1} \]
\[ \dot{\varepsilon} = A \sigma^n e^{Q/RT} \]
\[ \tau = \sigma \cos \phi \cos \lambda \]
\[ \tau_{P-N} = \frac{2G}{1-\nu} \exp(-\frac{2\pi w}{b}) \]
\[ \dot{\varepsilon} = \alpha \rho b v \]
\[ v_{\perp} = \left( \frac{\tau}{\tau_0} \right)^m \]
\[ \Gamma_{orT} = \alpha Gb^2 \]
\[ E_{el} = \frac{Gb^2}{8\pi^2 r^2} \]
\[ R = \frac{\alpha Gb}{\tau} \]
\[ F = G x t = (\sigma, b) x t \]
\[ h = \frac{Gb}{8\pi(1-\nu)\tau} \]
\[ L = \frac{\pi Gb}{\rho \tau} \]
\[ l = \frac{1}{3\sqrt{c}} \]
\[ f_v = \frac{D^2}{l^2} \]
\[ \sigma = \frac{\alpha Gb\sqrt{\rho}}{\sigma} \]
\[ \sigma = \frac{\alpha Gb\sqrt{f_v}}{D} \]

STRESSES AROUND DISLOCATIONS

Screw Dislocation
\[ b = \hat{b}; \hat{t} = \hat{k} \]
\[ \sigma_{xz} = \sigma_{zx} = -\frac{Gb}{2\pi} \frac{y}{x^2 + y^2} = -\frac{Gb \sin \theta}{2\pi} \]
\[ \sigma_{yz} = \sigma_{zy} = \frac{Gb}{2\pi} \frac{x}{x^2 + y^2} = \frac{Gb \cos \theta}{2\pi} \]

Edge Dislocation
\[ b = \hat{b}; \hat{t} = \hat{k} \]
\[ \sigma_{xx} = -\frac{Gb}{2\pi(1-\nu)} \frac{3x^2 + y^2}{(x^2 + y^2)^2} \]
\[ \sigma_{yy} = \frac{Gb}{2\pi(1-\nu)} \frac{x^2 - y^2}{(x^2 + y^2)^2} \]
\[ \sigma_{xy} = \sigma_{yx} = \frac{Gb}{2\pi(1-\nu)} \frac{x^2 - y^2}{(x^2 + y^2)^2} \]
\[ \sigma_{zz} = \nu (\sigma_{xx} + \sigma_{yy}) \]

Cu : (fcc) \( a = 3 \text{Å}, \ G = 110 \text{GPa}, \nu = 0.33, \ Q_v = 28 \text{kCal/mole}, \ Q_D = 55 \text{kCal/mole}, \sigma_{el} = 3b, E_d = 24 \text{eV} \)
Fe & Steels : (bcc) \( a = 2.8 \text{Å}, \ G = 110 \text{GPa}, Q_v = 35 \text{kCal/mole}, Q_D = 60 \text{kCal/mole}, \sigma_{el} = 3b, E_d = 40 \text{eV} \)

CONSTANTS AND CONVERSIONS

\[ R = 1.987 \text{ Cal/mole-K} \]
\[ k = 13.8 \times 10^{-24} \text{J/K} = 8.31 \text{J/mole-K} \]
\[ N_A = 6.02 \times 10^{23} \]
\[ 1N = 0.224 \text{lbf} = 0.102 \text{kgf} \]
\[ 1J = 0.239 \text{Cal/mole} = 6.24 \times 10^{18} \text{eV} \]
\[ 1Pa = 1 \text{N/m}^2 = 0.145 \times 10^{-3} \text{psi} \]
\[ 1 \text{psi} = 6.895 \times 10^3 \text{Pa} = 6.895 \times 10^4 \text{dy/cm}^2 = 7.03 \times 10^{-2} \text{kgf/cm}^2 \]
\[ 10^6 \text{J/m}^2 = \text{MPa-m} \]
\[ v_D = 10^{13} \text{ per sec} \]
\[ 1 \text{ eV/atom} = 23.05 \text{ kCal/mole} \]
\[ 1 \text{ amu} = 1.66 \times 10^{-24} \text{ g} \]