※ 注意：請於試卷上「非選擇題作答區」標明大題及小題題號，並依序作答。

1. For a tetragonal unit cell:
   (a) Draw [210] direction and (210) plane, respectively. (2%)
   (b) Is [210] direction perpendicular to (210) plane in this tetragonal unit cell? Justify your answer. (3%)
   (c) Draw [201] direction and (201) plane, respectively. (2%)
   (d) Is [201] direction perpendicular to (201) plane in this tetragonal unit cell? Justify your answer. (3%)

2. Nitrogen gas was introduced onto the surface of steel containing 0.002 wt.%N at 650°C. The customer would like to have a nitrogen content of 0.15 wt.% in 0.0126 cm below the surface of this steel after one hour. Find the nitrogen composition that must be introduced close to the surface. (9%)

The frequency factor of nitrogen solute diffusion in ferrite is $D_0 = 0.0047\ \text{cm}^2 \cdot \text{s}^{-1}$, *and the activation energy for diffusion is* $76.6\ \text{KJ} \cdot \text{mol}^{-1}$. *The concentration C at depth x after time t is:*

$$\frac{C(x,t) - C_0}{C_{surface} - C_0} = 1 - erf\left(\frac{x}{2\sqrt{Dt}}\right)$$

where $erf(z)$ *is the Gaussian error function:*

z	*erf(z)*	*z*	*erf(z)*	*z*	*erf(z)*
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

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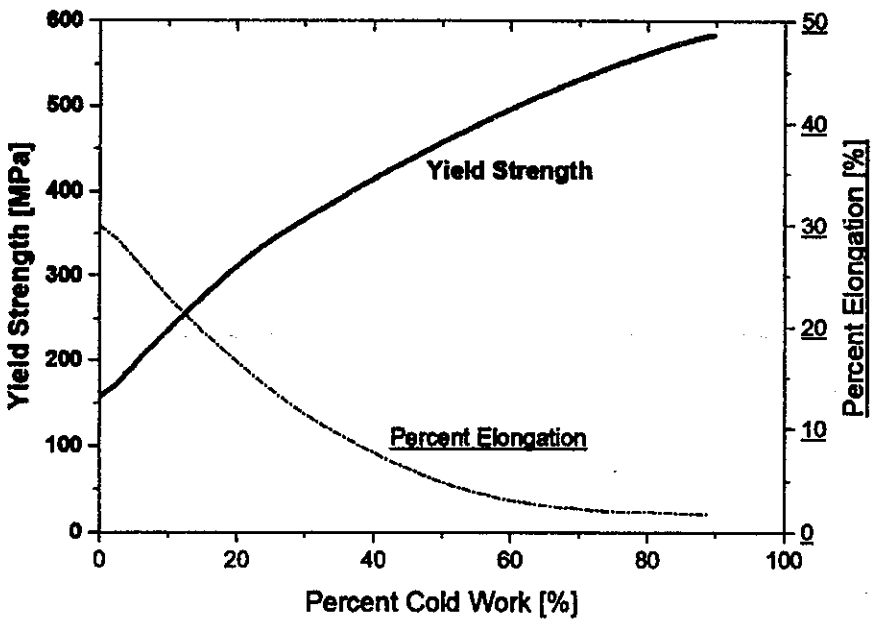
3. We wish to produce a 0.1-cm-thick, 6-cm-wide copper strip with at least 414MPa yield strength and 5%EL. We are able to purchase a 6-cm-wide strip only in a thickness of 5 cm. According to the figure below, design a process to produce the product we need. The maximum percent cold work possible for copper is 88%. (9%)



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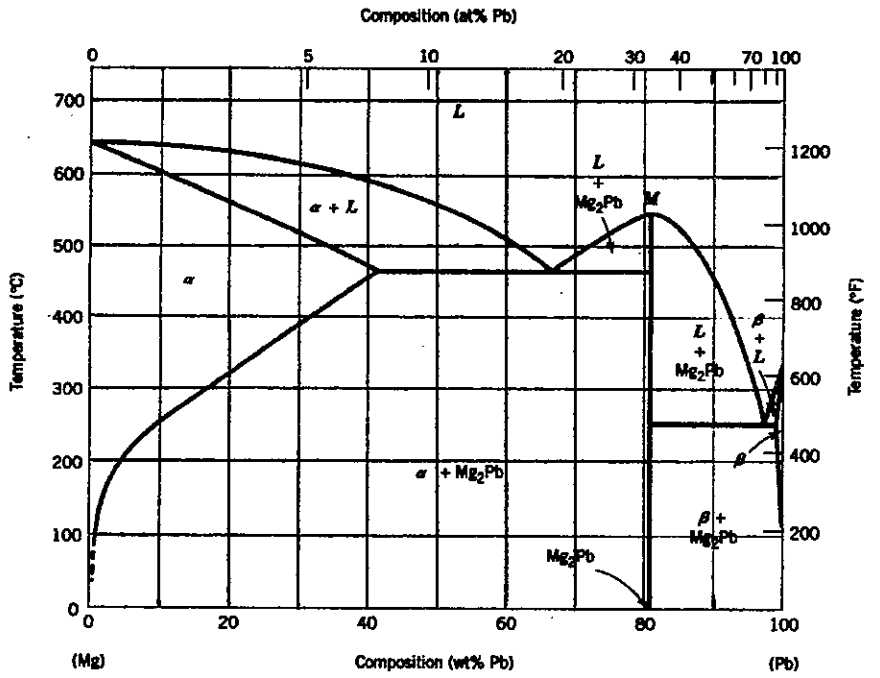
4. **(a)** Define/Explain these terms concisely: (i) Peritectic Reaction, (ii) Gibbs Phase Rule, and (iii) Metastable Phase. (3%)
(b) The Figure below shows the Mg-Pb phase diagram. The 80Mg-20Pb (in wt.%) alloy was cooled from 750°C to 100°C, and directly aged at 100°C for 1h. Please discuss the effects of non-equilibrium cooling on the aged microstructure. Moreover, please draw the expected final microstructure. (8%)



5. Calculate the amount of benzoyl peroxide [$(C_6H_5CO)_2O_2$] initiator required to produce 1 kg of polyethylene with an average molecular weight of 200,000 g/mol. Each benzoyl peroxide molecule produces two free radicals that are each capable of initiating a polyethylene chain. Assume that 20% of the initiator is effective and that all termination occurs by the combination mechanism. (10%)

Atomic weights of H, C, and O are 1.008 $g \cdot mol^{-1}$, 12.011 $g \cdot mol^{-1}$, *and* 15.999 $g \cdot mol^{-1}$, *respectively.*

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6. The density of the clay is 2.4 g·cm^{-3}, and that of nylon is 1.14 g·cm^{-3}. To form a composite material with a density of 2.1 g·cm^{-3}, what should the weight of clay be added to 1 kg of nylon? (8%)

7. FeO has a NaCl-type structure. Suppose one Fe^{+2} is replaced by Fe^{+3} in every 10 unit cells of FeO inside. Please calculate:
   (a) the number of vacancies per cubic centimeter in FeO, and (6%)
   (b) the atomic percentage and weight percentage of oxygen. (6%)

   Atomic weights of O, and Fe are 15.999 g · mol^{-1} *and* 55.845 g · mol^{-1}, *respectively. Ionic radii of* Fe^{+2} *and* O^{2-} *are* 0.74Å *and* 1.32Å, *respectively.*

8. We produce good chemical resistance in a glass when we introduce B_2O_3 into silica. To ensure that we have good glass-forming tendencies, we wish the O:Si atomic ratio to be no more than 2.5, but we also want the glassware to have a low melting temperature to make the glass-forming process easier and more economical by adding B_2O_3 as much as we can. Calculate the maximum weight percentage of B_2O_3 so that O:Si ratio can be lower than 2.5. (9%)

   Atomic weights of B, O, and Si are 10.811 g · mol^{-1}, 15.999 g · mol^{-1}, *and* 28.086 g · mol^{-1}, *respectively.*

9. You've got a GaAs semiconductor sample, and the atomic fractions of Ga and As are 49.99 at.% and 50.01 at.%, respectively.
   (a) Is the semiconductor n-type or p-type? (3%)
   (b) Calculate the conductivity when all the extrinsic charge carriers are involved in conduction. (8%)

   The unit of electrical conductivity should be $(\Omega \cdot \mathrm{cm})^{-1}$. *The GaAs lattice parameter is* 5.68Å *with four Ga atoms and four As atoms in a unit cell. The electrical conductivity formula is* $\sigma = nq\mu_e + pq\mu_h$. *In GaAs,* μ_e *and* μ_h *are* 8500 $\mathrm{cm^2 \cdot V^{-1} \cdot s^{-1}}$ *and* 400 $\mathrm{cm^2 \cdot V^{-1} \cdot s^{-1}}$, *respectively.*

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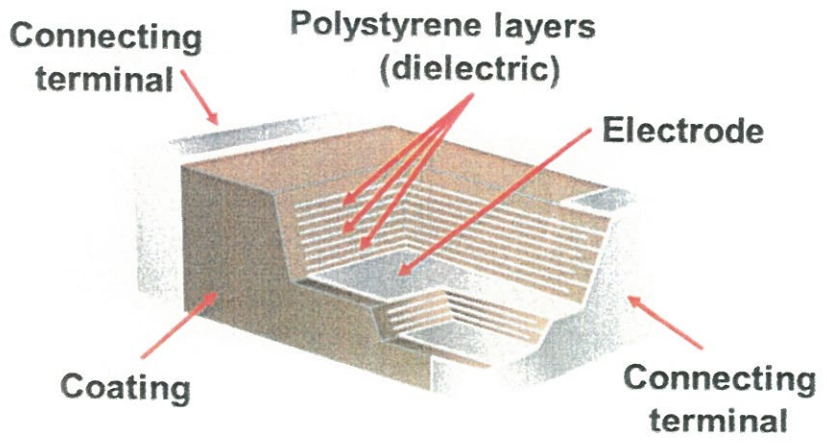
10. A parallel-plate capacitor is made by sandwiching $1\ \text{cm} \times 1\ \text{cm} \times 0.002\ \text{cm}$ sheets of polystyrene (relative permittivity $\varepsilon_r = 2.50$) between conducting electrode sheets, as schematically shown in the figure below:



(a) How many pairs of electrode-polystyrene sheets are needed to get the capacitance to 0.22 μF? (6%)

The relationship between capacitance and the number of layers may be computed from:

$$C = \varepsilon_r \varepsilon_0 \frac{A}{l}(n-1)$$

Vacuum permittivity is $8.85 \times 10^{-12}\ \text{F} \cdot \text{m}^{-1}$.

(b) If a voltage of 20V is applied across the capacitor, find the maximum amount of charge that the capacitor can store. (3%)

(c) Following the previous question, assuming the voltage drop across each layer is mutually the same, find the electric field (in $\text{V} \cdot \text{mm}^{-1}$) across each polystyrene layer. (2%)

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