Student Number: ____________________ Name: ________________________________

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING

Final Examination, April 16, 2001

First Year - Programs 1, 2, 3, 4, 6, 7, 8, 9

MMS 101 – Applied Science: Materials

Exam Type: A

Examiners: T.W. Coyle, U. Erb, G. Bendzsak

Answer all questions on these pages.
Marks for each question are given in the margin.
Only approved calculators are permitted.

Marks
#1:
#2:
#3:
#4:
#5
#6:
Total:

Data & Equations

$e = 1.602 \times 10^{-19}$ C $\quad N_A = 6.023 \times 10^{23}\ \text{mol}^{-1} \quad k = 1.38\text{x}10^{-23}\ {}^{J}/_{K} = 8.62\text{x}10^{-5}\ {}^{eV}/_{K}$

$\varepsilon_o = 8.85 \times 10^{-12}\ {}^{C^2}/_{J\cdot m} \quad c = 3 \times 10^8\ {}^{m}/_{s} \quad h = 6.63 \times 10^{-34}\ J\cdot s = 4.13\text{x}10^{-15}\ eV\cdot s$

$$V = IR \qquad \varepsilon = \frac{V}{L} \qquad \sigma = n\,|e|\,\mu_e + p\,|e|\,\mu_h \qquad \ln\sigma = -\frac{E_g}{2kT} + \ln\sigma_o$$

$$\sigma = \frac{F}{A_o} = E\varepsilon \qquad \varepsilon = \frac{l_i - l_o}{l_o} \qquad \sigma_T = \frac{F}{A_i} = \sigma(1+\varepsilon) \qquad \varepsilon_T = \ln\frac{l_i}{l_o} = \ln(1+\varepsilon)$$

$$\rho = \frac{n \cdot A}{V_C \cdot N_A} \qquad \rho = \frac{n'(\sum A_C + \sum A_A)}{V_C \cdot N_A} \qquad d = \frac{a}{\sqrt{h^2 + k^2 + l^2}} \qquad n\lambda = 2d\sin\theta$$

$$U_r = \int_0^{\varepsilon_y} \sigma d\varepsilon \qquad \tau_R = \sigma \text{ Cos}\phi \text{ Cos}\lambda \qquad v = \mu_e\varepsilon \qquad L = N\,d\,\sin\left({}^{\theta}/_{2}\right)$$

$$\overline{M_n} = \sum x_i M_i \qquad E = h\nu = \frac{hc}{\lambda}$$

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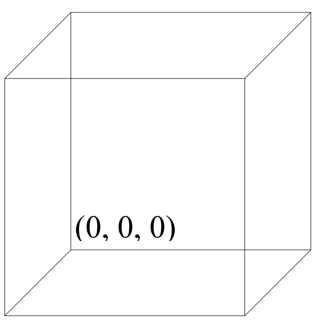
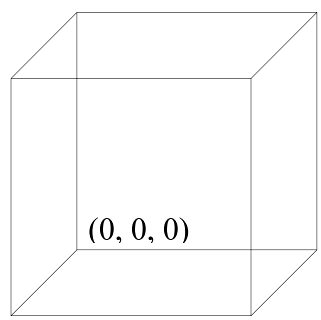
3. (a) Using Bragg's law calculate the diffraction angles (2θ) for the <u>first four peaks</u> in an X-ray diffraction pattern for aluminum, which has the FCC (face centered cubic) structure with a lattice parameter a = 0.404 nm, using monochromatic X-rays having a wavelength of 0.1542nm. Remember, the reflection rules state that for FCC crystals h,k,l must all be either odd or even for diffraction to occur. Enter all relevant data in the following table.

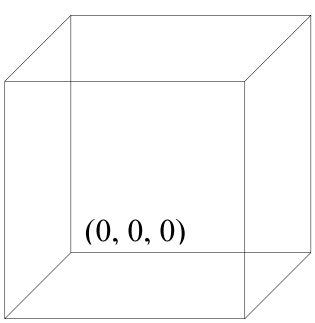
8 mks

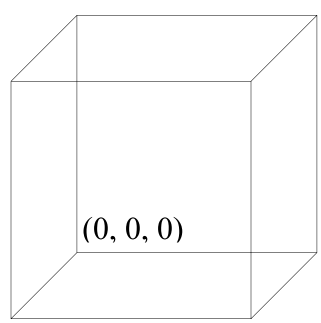
Miller indices for diffracting plane	d-value [nm]	2θ [deg.]

6 mks Draw the four planes identified above in part (a) in the cubic unit cells below. Draw only one plane in each cube. Label each plane.









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4. The combinations of slip planes and slip directions are termed slip systems. For a particular crystal structure the slip planes are the planes having the most dense atomic packing while the slip directions correspond to the directions with the highest linear density in these planes.

12 mks (a) For this problem consider the case of a FCC (face centered cubic) crystal. There are four non-parallel planes of closest packing with three directions of highest linear density in each plane, thus giving a total of 12 possible slip systems. In the following table, list the 12 slip systems using correct crystallographic notations for planes and directions.

Slip plane (hkl)	Slip direction [uvw]

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4. (b) For an applied tensile stress in the [100] direction, which slip system(s) would be most likely to operate? To answer this question you must find the resolved shear stress, τ_R, for each of the 12 systems for an arbitrary value of tensile stress.

6 mks

Slip system (hkl)[uvw]	$\cos\phi$	$\cos\lambda$	τ_R

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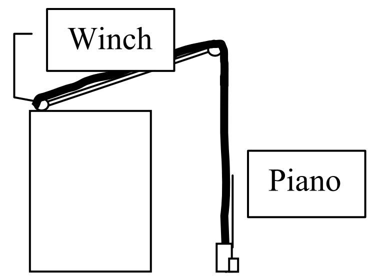
Material	Diameter (mm)	Elastic Modulus (GPa)	Poisson's Ratio	Yield Strength (MPa)	Tensile Strength (MPa)
Nylon	8	3.00	0.39	55	75.9
Steel	3	207	0.30	490	590



5. We need to lift a piano to the 2nd floor deck of a new house because the stairway is too narrow to carry it up the stairs. The piano weighs 250 Kg. We could use a nylon rope or a steel cable. The distance from the piano to the winch is 30 m.

4 mks (a) What is the maximum load that can be supported without permanent deformation by (i) the nylon rope and (ii) the steel cable?

4 mks (b) Calculate the elongation of 30m of steel cable when supporting 250 Kg.

4 mks (c) Calculate the **true stress** in the nylon rope when supporting a load of 250 Kg.

4 mks (d) If both the nylon rope and steel cable were attached to the piano at the same time so that the strain in each was the same, what would the stress be in the rope and in the cable when the piano was lifted?

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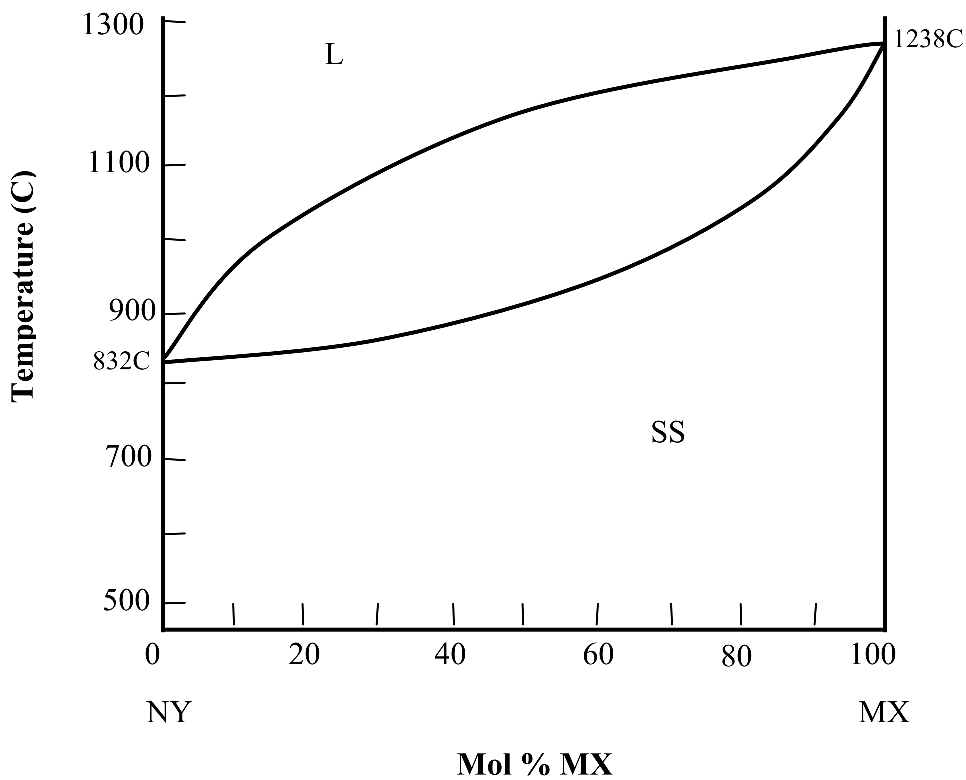
6. (a) **MX - NY phase diagram.**.

2 mks (i) What is the melting point of pure MX?

2 mks (ii) At what temperature would the first liquid appear when heating a solid of composition 75 mol % MX?



(b) **Al-Cu phase diagram.** High strength Al-Cu alloys are widely used in the aerospace industry.

8 mks (i) Fill in the table below by describing the microstructure and phase composition expected at 300ºC for each of the overall compositions given.

Overall composition (weight % Cu)	Sketch of microstructure (label all phases)	Relative amount of each phase	Composition of each phase (weight % Cu)
0.5			
3.0			

6 mks (ii) In the space below, briefly describe three strengthening mechanisms **other than strain hardening** which could contribute to the strength of the an aluminum alloy containing 3.0 weight % Cu.

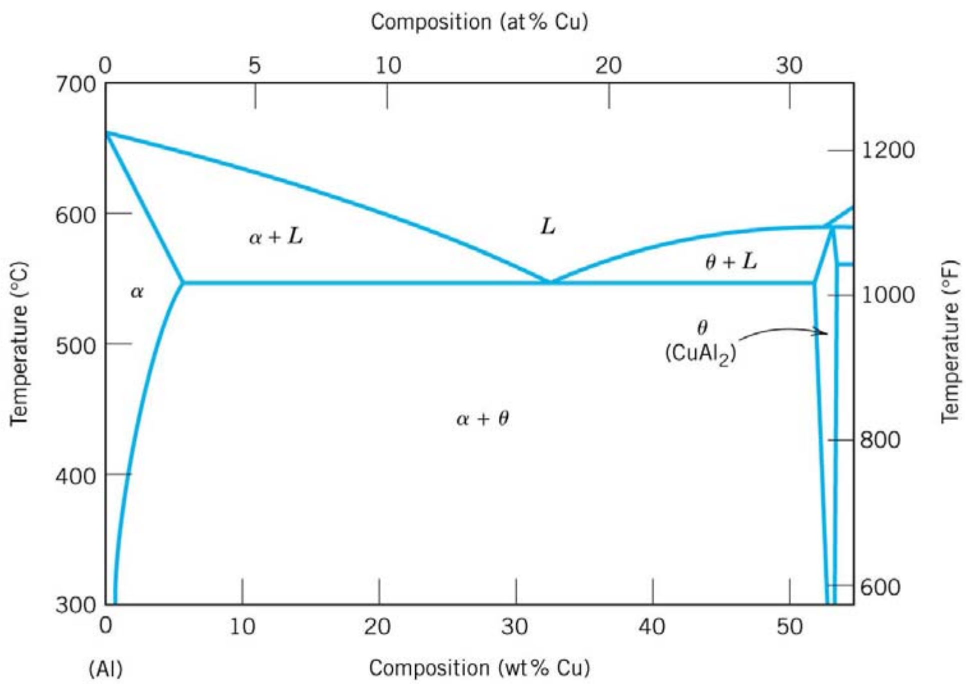


FIGURE 11.22 The aluminum-rich side of the aluminum–copper phase diagram. (Adapted from J. L. Murray, *International Metals Review*, **30**, 5, 1985. Reprinted by permission of ASM International.)