UNIVERSITY OF SASKATCHEWAN
COLLEGE OF ENGINEERING

ELECTRICAL ENGINEERING EE271.3

Final Examination
Part B

Instructor: K.V. Koughia — December 09, 2004
Time allowed: Part B is nominally $1^1/_2$ hour.
Total time allowed: 3 hours for Parts A *and* B.

Instructions: Open book examination. The course textbook *and* one three-ring type binder of any size containing student-selection of notes and course material are allowed. Calculators are also allowed.

Answer any 3 questions from 5 questions. If you answer more than 3 questions, only the first three will be marked. All questions carry equal marks. All answers must be given in conventional units. State clearly all assumptions made in your derivations and calculations. The method of solution must be clearly shown and the assumptions in calculations must be clearly stated. Numerical mistakes, incorrect, unconventional or missing units will be heavily penalized. Mention the source of materials data used.

Important: You must hand in Part A before you can start Part B. Write your answers in the university answer book.

Note: You may spend more or less time on Part B; but the total exam time is 3 hours.

QUESTION 1

[8] A cold worked Al-alloy component takes 200 minutes to recrytallize at 250 °C but takes 14 minutes at 276 °C. How long will the recrystallization take place at 320 °C. Can you cold work or strain harden this component at 320 °C? Why?

Note: recrystallization time shows Arrenius type temperature dependence:

$$t_{rec} = B\exp(-\frac{E_A}{kT}),$$

where B is constant, k is Boltzmann's constant and E_A is activation energy.

[9] A bronze component has the composition 94wt.%Cu-6wt.%Sn. Calculate its resistivity (ρ), and thermal conductivity (κ).

QUESTION 2

Below 24.5K, Ne is a crystalline solid with an FCC structure.

The interatomic interaction energy per Ne atom can be written as

$$E(r) = -2\varepsilon\left[14.45\left(\frac{\sigma}{r}\right)^6 - 12.13\left(\frac{\sigma}{r}\right)^{12}\right] \qquad [E] = \text{eV/atom}$$

where ε and σ are *constants* particular for a given material and crystal system.

For crystalline Ne, $\varepsilon = 3.121\times10^{-3}$ eV and $\sigma = 0.274$ nm.

[5] (a) Using the above relationship, find the equilibrium interatomic separation in the Ne crystal?

[5] (b) Find the bonding energy per atom in solid Ne.

[7] (d) Estimate the elastic modulus of solid Ne.

QUESTION 3

A power transistor with maximum power rating of 25 W has a maximum junction temperature of 140 °C. (Maximum rated power refers to the transistor case at 25 °C.)

[5] (a) What is the thermal resistance between the junction and the case, and the required thermal resistance between the case and the ambient for operation at maximum rated power? Discuss the results of your calculations.

[4] (b) What is the required thermal resistance from case to ambient if the transistor is to be operated at 20 W?

[8] (c) The transistor is mounted on a heat sink using a mica washer (an electrical insulator) and thermal paste (grease). The heat sink has a thermal resistance of 2.3 °C/W. The thermal resistance of the mica and the thermal paste together is 0.4 °C /W. The power amplifier circuit using this transistor is to be placed in a box in which the maximum ambient temperature is expected to reach 60 °C. What is the maximum power that can be dissipated by the transistor? How can you increase the maximum dissipated power?

QUESTION 4

[8] Consider iron (Fe) below 912^0C, where its structure is BCC. Given the density of iron 7.86 g cm^{-3} and its atomic mass as 55.85, calculate the lattice parameter of the unit cell and the radius of the Fe atom.

[9] At 912^0C, iron changes from BCC (α-Fe) to FCC (γ-Fe) structure. The radius of the Fe atom correspondingly changes from 0.1258 nm to 0.1291 nm. Calculate the density of γ-Fe and explain whether there is a volume expansion or contraction during this phase change.

QUESTION 5

[17] A device engineer fabricates a sensor by depositing an a-Si:H film on a glass substrate and then depositing an Al electrode onto the a-Si:H film. The device has the structure glass/a-Si:H/metal. The glass substrate is 5 mm thick. The a-Si: is 4 μm thick and the Al electrode is 0.1 μm thick. The expansion coefficients of glass, a-Si:H and Al are about 7×10^{-6} K^{-1}, 4×10^{-6} K^{-1}, 23×10^{-6} K^{-1} respectively. The elastic moduli of glass, a-Si:H and Al are about 70 GPa, 100 GPa and 70 GPa respectively. Calculate the stress in each layer if the temperature drops from 25 °C to –40 °C. State your assumptions and for each stress identify whether it is tensile or compressive.

PHYSICAL CONSTANTS AND USEFUL INFORMATION

$c = 2.9979 \times 10^{8}$ m s^{-1}
$e = 1.6021 \times 10^{-19}$ C
$m_e = 9.1091 \times 10^{-31}$ kg
$h = 6.62608 \times 10^{-34}$ J s
$\hbar = h/(2\pi) = 1.05459 \times 10^{-31}$ J s
Gas constant, $R = N_A k = 8.3144$ J K^{-1} mol^{-1} = 0.083144 L.bar K^{-1} mol^{-1}
Mass of proton = 1.67495 10^{-27} kg
Mass of hydrogen atom = 1.6736 10^{-27} kg
Acceleration due to gravity (at 45° latitude), g =9.81 m s^{-2}

$N_A = 6.0221 \times 10^{23}$ mol^{-1}
$k = 8.617 \times 10^{-5}$ eV K^{-1}
$\varepsilon_o = 8.8542 \times 10^{-12}$ F m^{-1}
$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}

UNITS

SI UNITS		
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
DERIVED SI UNITS		
Electric charge	coulomb	C = A s
Electrical resistance	ohm	? = V/A = kg m^2 A^{-2} s^{-3}
Electrical conductance	siemen	S =1/?
Electrical capacitance	farad	F = A s V^{-1} = A^2 s^4 kg^{-1} m^{-2}
Electrical inductance	henry	H = V s A^{-1} = kg m^2 s^{-1} A^{-2}
Energy	joule	J = kg m^2 s^{-2} = N m
Force	newton	N = kg m s^{-2}
Magnetic flux	weber	Wb = V s = kg m^2 A^{-1} s^{-2}
Magnetic flux density	tesla	T = Wb m^{-2} = V s m^{-2} = kg A^{-1} s^{-2}
Pressure	pascal	Pa=N m^{-2}
Power	watt	W=J s^{-1}=kg m^2 s^{-3}
Electric potential difference volt	V = N m C^{-1} = kg m^2 s^{-3} A^{-1}	
Frequency	hertz	Hz = s^{-1}

SOME CONVERSION FACTORS

LENGTH
1m = 39.37in = 3.280ft = 6.2137 10^{-4}miles
1 in = 0.0254m

ENERGY
1 kJ mole^{-1} = 0.2389 kcal mol^{-1} = 0.010363 eV atom^{-1}
1 kcal mole^{-1}= 4.1840 kJ mol^{-1} = 0.043360 eV atom^{-1}
1 eV atom^{-1} = 96.490 kJ mol^{-1} = 23.062 kcal mol^{-1}
1 ft lb = 1.356 J
1 erg = 10^{-7} J
1 BTU = 1055 J
1 kWh = 3.600 10^{6} J

FORCE
1 N =0.2248 lb
1 lb = 4.448 N

PRESSURE
1 Pa =1 N.m^{-2} =1.45 10^{-4} psi = 9.869 10^{-6} atm.
1 atm. = 1.013 10^{5} Pa = 1.01325 bar = 760 torr (mm Hg)
1 psi = 6.895 10^{3} Pa