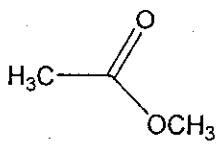
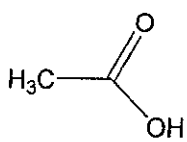
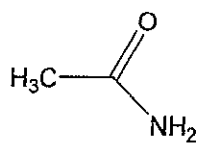
國立中山大學九十二學年度碩士班招生考試試題

科目：有機化學（材料所）（甲組）

1) Physical properties of organic compounds are generally controlled by their chemical structures. Boiling point is one of the important properties for organic compounds. The boiling points of a series of organic compounds are given below:



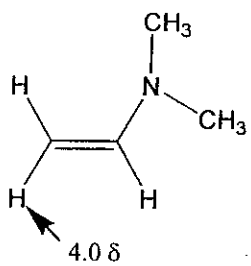


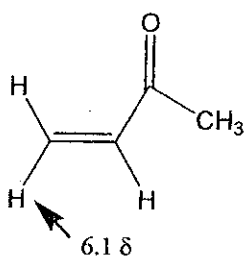


b.p. 52°C 118°C 221°C

Suggest a plausible explanation for the order of boiling point shown above. (20%)

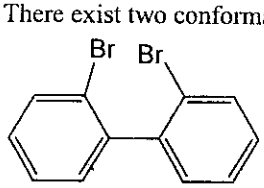
2) Normal ^{1}H NMR resonance position of a vinyl proton falls at around 5.3 δ. However, this value can be shifted dependent on the compound's chemical structure and varied significantly. A typical example can be given for the two compounds below:





Suggest an explanation for such a large resonance difference for the above two compounds. (20%)

3) There exist two conformational isomers for 2,2'-dibromobiphenyl shown below:



a) Draw these two conformations (10%)

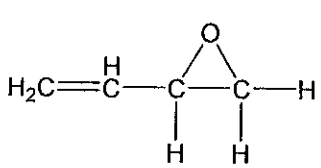
b) What is the main reason for the formation of these two isomers? (10%)

4) Give the chemical structures of I, II, III and IV for the following reactions:

a) $HBr + CH_3CH{=}CH \xrightarrow{ROOR}$ I (5%) (ROOR referrs to alkyl peroxide)

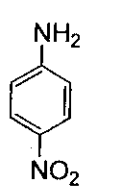
b) $HBr + CH_3CH{=}CH \xrightarrow{\text{no ROOR}}$ II (5%)

c)



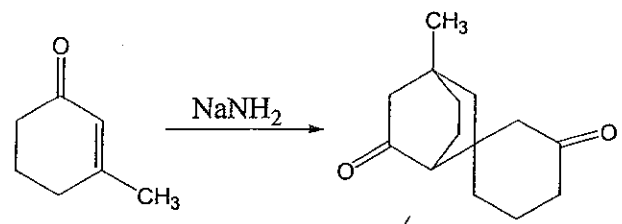
$\xrightarrow{HBr}$ III (5%)

d)

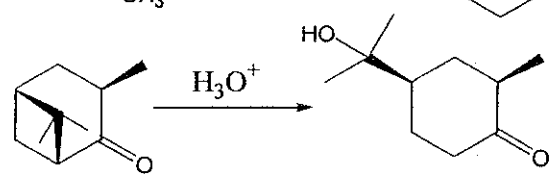


$\xrightarrow{Cl_2}$ IV (5%)

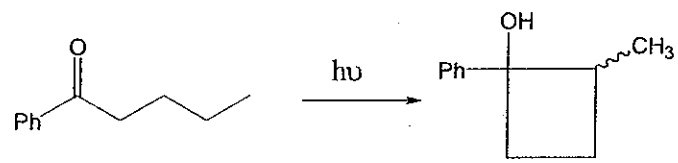
5) Suggest the mechanistic steps involved in the following reactions.

a) 

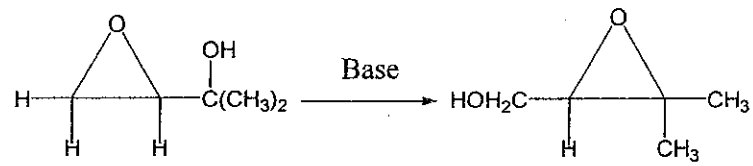
(5 %)

b) 

(5 %)

c) 

(5 %)

d) 

(5 %)

國立中山大學九十二學年度碩士班招生考試試題

科目：物理化學【材料所碩士班】甲組

Multiple-Choice Questions (2% each)

1. A small value for K_c, the equilibrium constant, indicates that (A) the concentration of the un-ionized molecules must be relatively small compared with the ion concentrations (B) the concentration of the ionized molecules must be larger than the ion concentrations (C) the substance ionizes to a large degree (D) the concentration of the un-ionized molecules must be relatively large compared with the ion concentrations.

2. The monomer used to form the polymer $[—CH_2CHCl—]_n$ is (A) CH_3CH_2Cl (B) $CH{\equiv}CCl$ (C) CH_nCHCl_n (D) CHCH + HCl (E) $CH_2{=}CHCl$

3. At 37°C and 1.00 atm of pressure, nitrogen dissolves in the blood at a solubility of 6.0×10^{-4} M. If a diver breathes compressed air where nitrogen gas constitutes 80% of the gas mixture, and the total pressure at this depth is 3.0 atm, what is the concentration of nitrogen in her blood? (A) 1.4×10^{-4} M (B) 1.4×10^{-3} M (C) 1.0×10^{-3} M (D) 6.0×10^{-4} M (E) 6.0×10^{-3} M.

4. A fast reaction should have (A) a high activation energy (B) a catalyst present (C) a large equilibrium constant (D) a low activation energy (E) an exothermic heat of reaction.

5. For the following reaction: heat + $2NO_2(g) \leftrightarrow N_2O_4(g)$
which change will not be effective in increasing the amount of $N_2O_4(g)$? (A) decreasing the volume of the reaction vessel (B) adding N_2 to increase the pressure (C) increasing the temperature (D) adsorbing the $N_2O_4(g)$ with a solid adsorbant (E) adding more $NO_2(g)$ to the reaction vessel.

6. Which element has an electronic configuration that does NOT follow aufbau ordering? (A) Ag (B) Mg (C) Al (D) Fe (E) Ni.

7. Which of the following is LEAST effective on increasing the rate of a reaction? (A) increasing the pressure by adding an inert gas (B) grinding a solid reactant into small particles (C) increasing the temperature (D) eliminating reverse reactions (E) adding a catalyst.

8. Which of the following can change the value of $\Delta G°$ for a chemical reaction? (A) changes in the total pressure (B) changes in the pressure of the reactants (C) changes in the concentrations of the reactants (D) changes in the temperature in C° (E) the presence of a catalyst.

9. The reaction between a compound containing one $–NH_2$ and a compound containing one –COOH functional group is best described as (A) an esterification reaction (B) an acid-base reaction (C) a hydrogenation reaction (D) a hydrolysis reaction (E) a combustion.

10. Which of the following types of electromagnetic radiation has the highest energy? (A) visible (B) ultraviolet (C) microwave (D) infrared (E) X rays.

11. The valance electrons are (A) all electrons in an atom beyond the preceding noble gas (B) all outermost electrons in a sublevel (C) *s* and any *p* electrons in the highest energy level or shell (D) electrons in the last unfilled sublevel (E) any electrons that can ionize.

12. A reaction has a very large equilibrium constant of 3.3×10^{13}. Which statement is NOT true about this reaction? (A) The reaction is very fast. (B) The reaction is essentially complete. (C) The reaction is spontaneous. (D) The equilibrium constant will change if the temperature is changed. (E) The products will react to yield very little reactant.

13. A chemical system in equilibrium will (A) have the same concentrations of all products and reactants (B) form more products if the temperature is increased (C) have a specific ratio of product to reactant concentrations (D) not have any precipitates (E) represent a spontaneous chemical process.

14. Which of the following is most likely to be true? (A) No products are formed in a nonspontaneous reaction. (B) A positive $\Delta G°$ indicates a spontaneous reaction. (C) A positive $\Delta S°$ always means that the reaction is spontaneous. (D) A spontaneous reaction always goes to completion. (E) Combustion of organic compounds has a negative $\Delta H°$.

15. Modern automobiles use a catalytic converter to (A) increase horsepower by burning more gasoline (B) absorb pollutants from the exhaust (C) complete the combustion of unburned gases (D) cool the exhaust gases (E) convert pollutants into water.

16. At the beginning of a reaction, the reaction rate for the reactants is (A) largest, then decreasing (B) largest and remains constant (C) smallest, then increasing (D) smallest and remains constant.

17. Which of the following explains the fact that, when KCl is dissolved, water condenses on the outside of the beaker? (A) $\Delta H°$ is positive, and $\Delta S°$ is negative. (B) $\Delta H°$ is positive, and $\Delta S°$ is positive. (C) $\Delta H°$ is negative, and $\Delta S°$ is negative. (D) $\Delta H°$ is negative, and $\Delta S°$ is positive. (E) $\Delta H°$ is 0.00, and $\Delta S°$ is negative.

18. A protein is (A) a polysaccharide (B) a desoxyribonucleic acid (C) a polymer of amino acid (D) soluble because of the —C=O groups (E) a polyester.

19. Which of the following is TRUE? (A) The number of positive ions in solution equals the number of negative ions. (B) The positive ions are called anions. (C) The positive ions are called cathodes. (D) The total positive charge equals to the total negative charge. (E) None of the above.

20. Given that the first, second, and third dissociation constants for H_3PO_4 are 7.0×10^{-3}, 6.0×10^{-8}, and 5.0×10^{-13}, respectively, calculate K for the overall reaction. (A) 2.10×10^{-32} (B) 2.10×10^{-28} (C) 2.10×10^{-22} (D) 2.10×10^{-11} (E) 2.10×10^{22}.

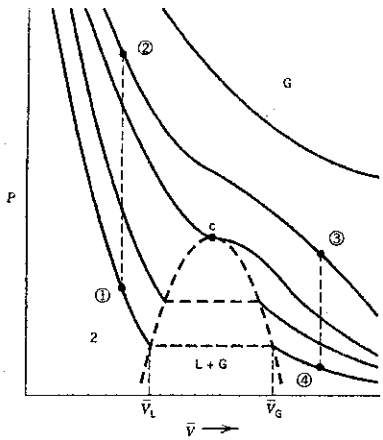


Figure 1

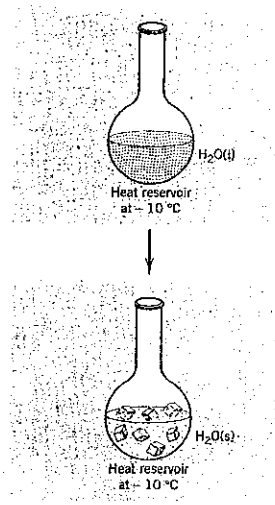


Figure 2

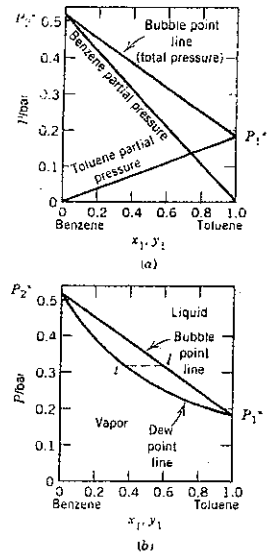


Figure 3

21. Describe how a liquid at point 1 can be converted to a gas at point 4 without the appearance of an interface between two phases from Figure 1. Discuss the labels in this Figure. (6%)

22. Consider the spontaneous (irreversible) freezing of water below its freezing point (see Figure 2). For the crystallization of liquid water at 0°C, $\Delta H = -6004$ J mol^{-1}. The heat capacity of water may be taken to be 75.3 J K^{-1} mol^{-1}, and that of ice may be taken to be 36.8 J K^{-1} mol^{-1} over this range. Calculate the total entropy change. (6%)

23. Mixtures of benzene and toluene obey Raoult's law, as illustrated by Figure 3a. How to plot Figure 3b from 3a? Discuss the meanings of Figure 3b. (6%)

24. One mole of an ideal gas expands from 5 to 1 bar at 298 K. Calculate the work (a) for a reversible expansion and (b) for an expansion against a constant external pressure of 1 bar. (Gas constant 8.3145 J K^{-1} mol^{-1}) (6%)

25. Describe the Joule-Thomson effect and the inversion temperature. (6%)

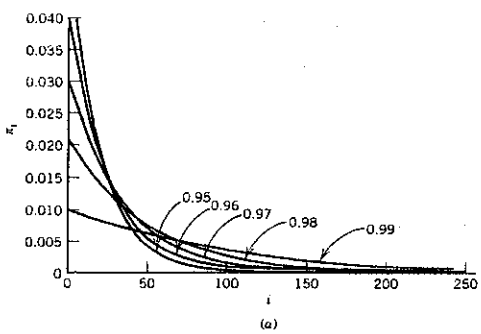
26. Give the schematic representations of vibrational motion for CO_2 and H_2O molecules. (6%)

27. Give linear plots for the zero-, half-, first-, and second-order reactions with $[A]_0 = 1$ mol L^{-1}, each having a half-life of 1 min. (6%)

28. At what angles θ will X rays of wavelength 1.542×10^{-10} m be reflected by planes separated by 3.5×10^{-10} m? What is an alterative interpretation of these reflections? (6%)

29. The number and mass fractions or probabilities of condensation polymer for extents of reaction of 0.95, 0.96, 0.97, 0.98, and 0.99 are plotted in Figure 4. Why the mass fractions go through a maximum while the number fractions do not? (6%)

30. Proton magnetic resonance spectrum of neat ethanol is plotted in Figure 5. Discuss this spectrum. (6%)



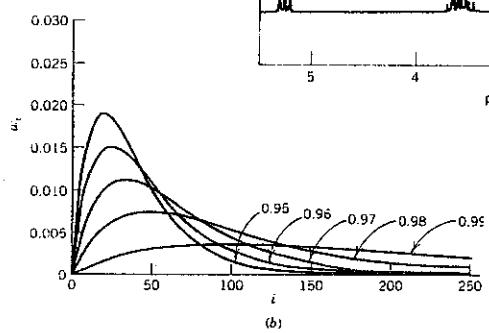


Figure 4

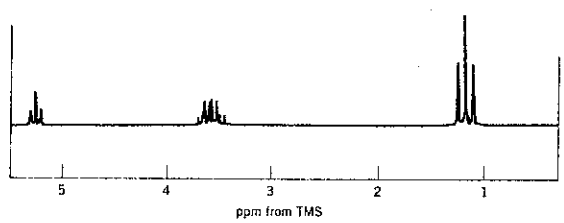


Figure 5

國立中山大學九十二學年度碩士班招生考試試題

科目：工程數學(甲) 材料所乙組

材料所—工程數學(甲)

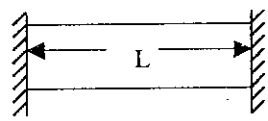
1. Elements in stress matrix Sij exist in a symmetrical condition, where i, j = x, y, z. Please find Sxx + Syy + Szz = constant. (20%, hint: solving eigen values of this matrix)
2. Show the Laplace of f(t) = (sin wt + wt cos wt)/2w (20%)
3. Show the Fourier series of f(x) = sin wx + cos wx (20%)
4. Integrate from $-\infty$ to $+\infty$ for f(x) = sinx/x. (20%)
5. A spring hung on the ceiling with a mass m attached to the free end. Show the equation of the free end. (20%)

國立中山大學九十二學年度碩士班招生考試試題

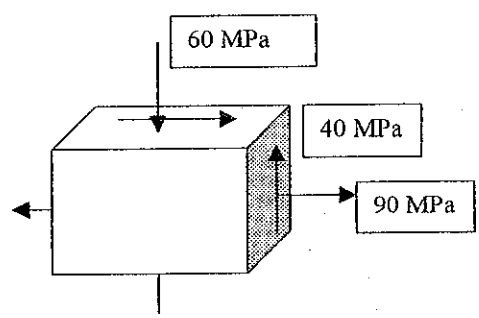
科目：材料力學（材料科學研究所碩士班乙組）

1. (20%) For a plane stress state $\sigma_z = 0$, if the strains ε_x and ε_y have been determined experimentally, determine the expressions for σ_x, σ_y, and σ_z in terms of E, ν, ε_x, and ε_y.

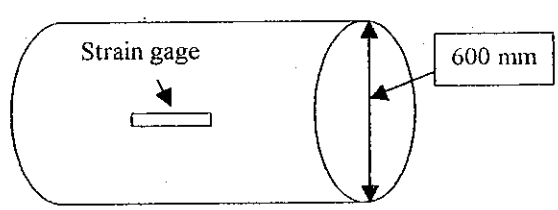
2. (20%) A steel rod of length L and uniform cross section of area A is attached to rigid supports and is unstressed at a temperature of 15°C. The steel is assumed to be elastoplastic with E= 200 GPa and σ_y =250 MPa. Knowing that α =11.7 x 10^{-6}/°C, determine (a) the stress in the rod after the temperature has been raised to 180°C, (b) the residual stress after the temperature has returned to 15°C.



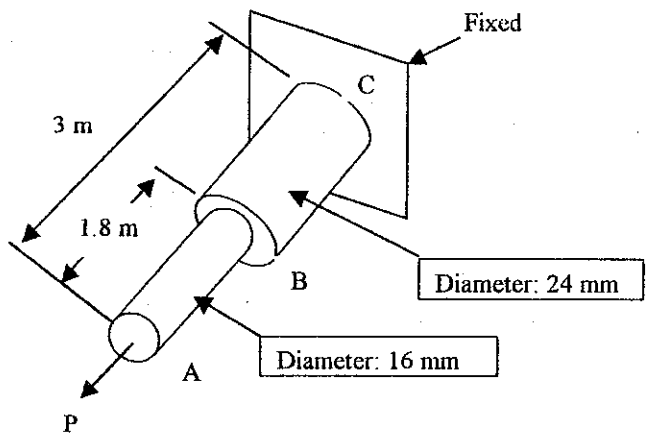
3. (20%) For the state of plane stress shown below, determine (a) the principal planes, (b) the principal stresses, (c) the maximum shearing stress.



4. (20%) A strain gage is attached horizontally to the cylindrical surface of a pressure vessel of 600 mm outside diameter and 7.5 mm wall thickness. Knowing that E=200 GPa and ν =0.25 and that the strain gage reads 120 μ, determine (a) the three principal strains on the cylindrical surface of the vessel, (b) the principal stresses in the wall, (c) the gage pressure inside the vessel.



5. (20%) Using E=75 GPa, (i) if P=60kN, determine (a) the strain energy of the aluminum rod ABC, (b) the corresponding strain-energy density in portions AB and BC of the rod. (ii) If σ_Y= 400 MPa, determine the maximum load P without causing any permanent deformation in ABC.



國立中山大學九十二學年度碩士班招生考試試題

科目：工程數學(乙)（共同科目）

Please note that (1) *a calculator can be used for this test*, and (2) *partial credits will be given* ***only*** *to incomplete answer* ***relevant*** *to the solution of the problem.*

1. (***Algebra***) (15 pts.) Eight alphabets (D, E, M, N, O, R, S, Y) are in the addition formula below representing only eight of the ten numerical digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9). Please find the numerical value for each of the eight alphabets.

$$\begin{array}{rr} & S\ E\ N\ D \\ +) & M\ O\ R\ E \\ \hline & M\ O\ N\ E\ Y \end{array}$$

2. (***Matrix***) (15 pts.) A 3 x 3 matrix $\boldsymbol{B}$ is given below. Please find the inverse matrix $\boldsymbol{B}^{-1}$ which satisfies $\boldsymbol{B}\,\boldsymbol{B}^{-1} = \boldsymbol{B}^{-1}\boldsymbol{B} = \boldsymbol{I}$, here $\boldsymbol{I}$ is the unitary matrix as shown.

$$\boldsymbol{B} = \begin{bmatrix} 0 & 1 & 2 \\ 2 & 1 & 1 \\ 3 & 1 & 1 \end{bmatrix}, \quad \text{and} \quad \boldsymbol{I} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

3. (***Gamma Function***) (20 pts.) Gamma function $\Gamma(n)$ can be defined as

$$\Gamma(n) \equiv \int_0^\infty e^{-t} t^{n-1} dt = 1 \cdot 2 \cdot 3 \cdot 4 \cdots (n-2)(n-1) = (n-1)!$$

Please show that $\int_0^\infty e^{-x^4} dx = (1/4)!$

4. (***Integral Equation***) (25 pts.) A simple *RC* circuit obeys the following integral equation.

$$R\,I + \frac{1}{C}\int I\,dt = E(t)$$

If the electromotive force $E(t) = E_0 \sin \omega t$, please solve the equation for current $I(t)$.

5. (***Fourier Expansion***) (25 pts.) Please show the Fourier series expansion of the output of a simple half-wave rectifier $f(t) = \begin{cases} 0, & -\pi \le \omega t \le 0 \\ \sin \omega t, & 0 \le \omega t \le \pi \end{cases}$.

國立中山大學九十二學年度碩士班招生考試試題

科目：熱力學 （材料所碩士班 丙組）

請於答案卷上依序作答，並清楚標明題號

1. The complete thermodynamic apparatus is capable of evaluating the behavior of the most complex kind of system. These systems are capable of experiencing the full range of influences that have been identified as possibly affecting its state. In order to pinpoint the part of the apparatus that must be used to handle a given case, it is useful to devise a classification of thermodynamic systems as the following categories:
   I. Unary versus multicomponent
   II. Homogeneous versus heterogeneous
   III. Closed versus open
   IV. Non-reacting versus reacting
   V. Otherwise simple versus complex

   Classify the following thermodynamic systems according to the above five categories.
   (a) A glass of ice water
   (b) An yttria stabilized zirconia furnace tube
   (c) A plastic coffee cup
   (d) A eutectic alloy turbine blade rotating at 2000 rpm.
   (Example: A solid bar of copper: pure solid copper is unary, homogeneous, closed, non-reacting otherwise simple system)
   If you find it necessary to qualify your answer by defining the system more precisely, state your assumptions. (20%)

2. Consider an isolated system (no heat, matter or work may be exchanged with the surroundings) considering of three internal compartments A, B and C, of equal volumes. The compartments are separated by partitions; each partition has a valve, which may be opened remotely. Initially the central volume B is filled with a gas at 298 K and the outer two are evacuated. Consider the following two processes:
   (a) The valve to the A side is opened, the gas expands freely into the compartment A, and the system comes to equilibrium. Then the valve to the C side is opened, and the system again comes to equilibrium.
   (b) Both valves are opened simultaneously, the gas expands freely into both compartments, and the system comes to its equilibrium.

   Explain which of these processes produces more entropy? (15%)

3. Calculate the partial pressure of monoatomic hydrogen in hydrogen gas at 2000 K and 1 atm pressure. (20%)

   $1/2\ H_2(g) \Rightarrow H(g)$

   $\Delta H^0_{298} = 217990$ J

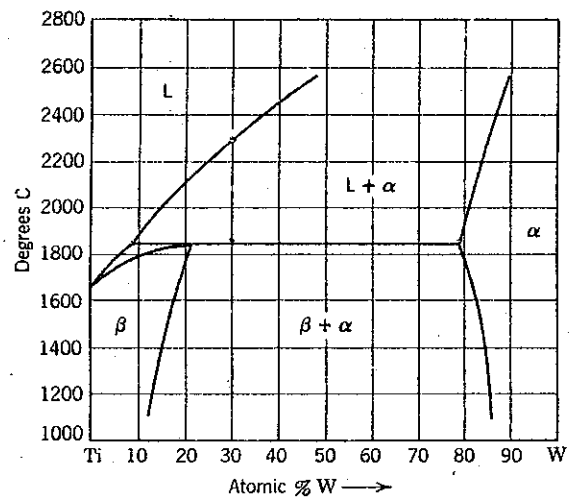
   $\Delta S^0_{298} = 49.35$ J/K

   Assume that the heat capacity of H(g) = 3/2 R and the heat capacity of $H_2(g)$ to be 31 J/(mol.K). [詳列運算式子，依此計分]

4. Atoms of an element E are being adsorbed on the surface of a material M. Material M has N adsorption sites available per square centimeter of surface. (20%)
   (a) Derive an expression for the entropy of N_E atoms of the element E adsorbed on M (per square centimeter of M), assuming that the adsorbing atoms have zero interaction energy with one another. They do have interaction energy with the surface M atoms.
   (b) At what ratio of E atoms to adsorption sites (N_E/N) will this entropy be a maximum?
   (c) Can the number of atoms adsorbed rise above this level? Explain why?

   [詳列推導式子，依此計分。 提示：$\ln N! = N\ln N - N$]

5. There is a high-temperature portion of the titanium-tungsten phase diagram. Answer approximately, using the level rule: (25%)
   (a) What atomic fraction of a 30% W alloy is solid α at 2300 ℃?
   (b) What atomic fraction is α just above the peritectic temperature?
   (c) What atomic fraction is α just below the peritectic temperature ? And what event is responsible for the change?
   (d) What are the compositions of the phases which participate in the peripectic reaction?
   (e) How much α and how much liquid are consumed to form one mole of β by the peritectic reaction?



國立中山大學九十二學年度碩士班招生考試試題

科目：應用數學 (材料所丁組)

Please note that (1) *a calculator can be used for this test*, (2) *partial credits will be given* ***only*** *to incomplete answer relevant to the solution of the problem*, and (3) *the test has five problems.*

1. (***Linear Algebra***) (15 pts.) In Cartesian coordinate system, any point in space can be identified using mutually orthogonal unit vectors $\hat{x}$, $\hat{y}$ and $\hat{z}$. If this coordinate system undergoes a rotational transformation to $\hat{x}'$, $\hat{y}'$ and $\hat{z}'$ with

$$\hat{x}' = \frac{1}{\sqrt{3}}\hat{x} - \frac{1}{\sqrt{3}}\hat{y} - \frac{1}{\sqrt{3}}\hat{z},$$

$$\hat{y}' = \frac{1}{\sqrt{2}}\hat{x} + \frac{1}{\sqrt{2}}\hat{y},$$

please find $\hat{z}'$.

2. (***Integration***) (15 pts.) Please evaluate $\iiint_v e^{-(x^2+y^2+z^2)^3}\,dxdydz$, here v is the volume bounded by the two spheres $x^2+y^2+z^2=1$ and $x^2+y^2+z^2=4$.

3. (***Differential Equation***) (20 pts.) Solve for $y(x)$ from $\frac{d^2y}{dx^2} - 2\frac{dy}{dx} + y = x^2 \sin 2x$.

4. (***Fourier Expansion***) (25 pts.) Please derive the Fourier series expansion for the output of a simple half-wave rectifier $f(t) = \begin{cases} 0, & -\pi \le \omega t \le 0 \\ \sin \omega t, & 0 \le \omega t \le \pi \end{cases}$

5. (***Statistics***) (25 pts.) Stirling's formula of probability theory states that as integer n becomes large, i.e. $n >> 1$, $n! \equiv 1\cdot 2\cdot 3\cdots(n\text{-}1)\cdot n$ can be approximated as

$$\log n! \approx n\log n - n.$$

Please prove this Stirling's formula.

國立中山大學九十二學年度碩士班招生考試試題

科目： 普通物理 (材料科學研究所碩士班丁組)

1. Try to write out the electron configurations for the elements Si (atomic number Z=14) and Zn (Z=30). (10 points)

2. Try to define the bonding and crystal structures for graphite, diamond, and C_{60} carbon Fullerence, including the type of s and p orbital bonding type. (10 points)

3. Try to evaluate the angular momentum of (i) an electron (ele) around the nucleus in a hydrogen atom, and (ii) the earth (ear) around the sun, both assuming a circular orbit (given that the mass $m_{ele}=9.1\times10^{-31}$ kg and $m_{ear}=5.9\times10^{24}$ kg; the mean distance $d_{ele}=5.3\times10^{-11}$ m and $d_{ear}=1.5\times10^{11}$ m; the angular velocity $\omega_{ele}=4.1\times10^{16}$ s^{-1} and $\omega_{ear}=2.0\times10^{-7}$ s^{-1}). What is the significance of the value you calculate for the angular momentum of electron in hydrogen? What is the relationship between the value you calculate with the Planck's constant? (20 points)

4. The position of an electron is determined with an uncertainty of 0.1 Å. Try to find the uncertainty in its momentum. If the electron energy is around 1 keV, estimate the uncertainty in its energy. (10 points)

5. A small ball of 1 kg is tied to the end of a wire 1 m long, spinning in a vertical circle about the other end with a constant angular velocity of 120 rad s^{-1}. (i) Try to calculate the kinetic energy. (ii) If the total energy is fixed, what is the change in kinetic energy and angular velocity when the ball is on the top and bottom of the circle (assume that the value given for the angular velocity is for the top of the circle)? (20 points)

6. What are the first and second laws of thermodynamics? Which of the following quantities below depend on (i) the state of the system, and which on the (ii) transformation: temperature, pressure, heat, work, heat capacity, internal energy, entropy? (20 points)

7. Describe the origin of X-ray emission. What do we mean about a characteristic Cu-K_α X-ray? (10 points)