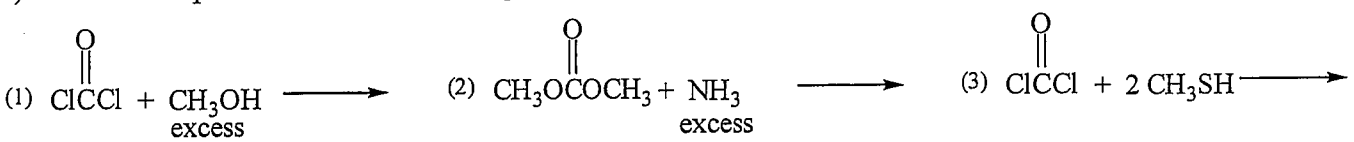
科目：有機化學【材光系碩士班甲組】

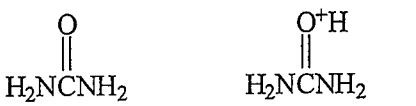
1. (Total: 20 %) Sighting along the C2-C3 bond of 2-methylbutane, there are two different staggered conformations. Draw them both in Newman projections. (6 %) Tell which is more stable? (2%) Why? (4%) There are also two possible eclipsed conformations of 2-methylbutane. Draw them both in Newman projections. (6%) Which is more stable? (2 %)

2. (Total: 20%) Acyl chemistry provides routes to prepare derivatives containing various functional groups such as eater (-C(=O)-)), amide (-C(=O)NH-)), urethane (-OC(=O)NH-)), urea (-NHC(=O)NH-)) etc. Using the acyl chemistry you learned, answer the following questions.

a) Predict the products of the following reactions: (6%)



b) Draw all the resonance structures for urea and protonated urea: (4%)

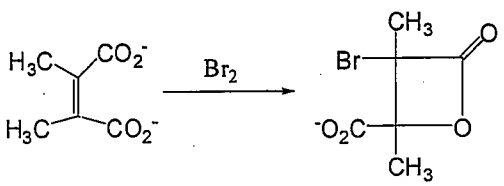


c) Would you expect urea to be a stronger or weaker base than acetamide ($CH_3C(=O)NH_2$)? (2%) Explain it. (4%)

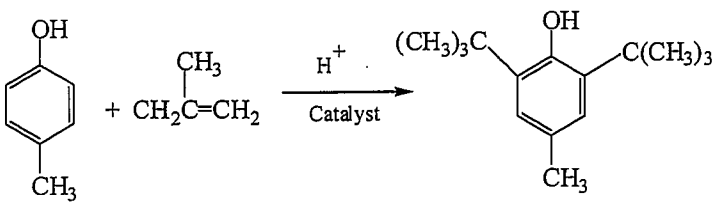
d) The toxicity of phosgene. Cl-C(=O)-Cl, is an extremely poisonous gas which was used in World War I as a chemical weapon. The toxicity of phosgene has been attributed to an increase in the acidity of the lung after inhalation. Write an equation to explain this effect. (4%)

3. (Total: 20%, each 5%) Give a mechanism for each of the following transformations:

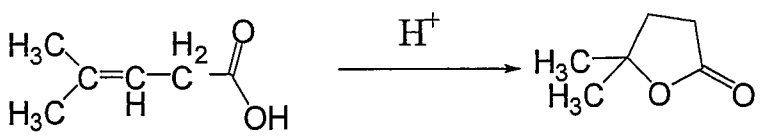
a)



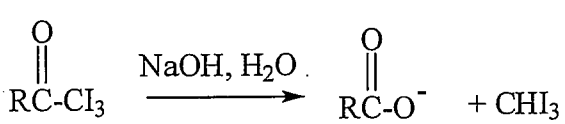
b)



c)



d)

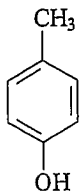


科目：有機化學【材光系碩士班甲組】

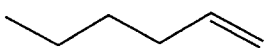
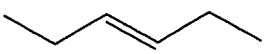
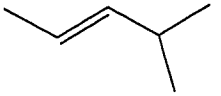
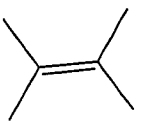
4. (Total: 40%, each 2%) Multiple choice: 請於答案卷「是非、選擇題專用區」作答。

1. (　) The acid-catalyzed reaction of propanal with methanol goes from the hemiacetal to the acetal. This can mechanistically be thought of as: a) an addition reaction followed by a substitution reaction. b) a substitution reaction followed by an addition reaction. c) an elimination reaction followed by a substitution reaction. d) an addition reaction followed by an elimination reaction.

2. (　) How many sets of equivalent hydrogens are there for the following compound? a) 3; b) 4; c) 5; d) 6.



3. (　) Which of the following compounds would best fit a ^{13}C NMR spectrum having peaks at δ 16, 21, 32, 36, 115 and 140?

(a)  (b)  (c)  (d) 

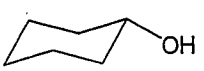
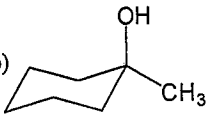
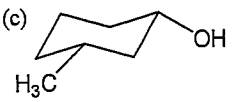
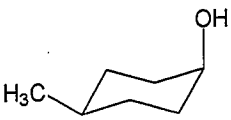
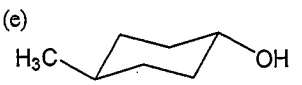
4. (　) The proton NMR of 1,1-dibromoethane would appear as a: a) downfield doublet and upfield quartet, b) downfield quartet and upfield doublet, c) downfield doublet and upfield triplet, d) downfield triplet and upfield doublet.

5. (　) Which of the following is the strongest acid? a) FCH_2CO_2H, b) $ClCH_2CO_2H$, c) $BrCH_2CO_2H$, d) ICH_2CO_2H.

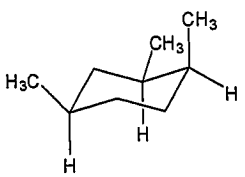
6. (　) In infrared spectroscopy, absorption of electromagnetic radiation results in transitions between _____ energy levels. a) vibrational, b) electronic, c) rotational, d) nuclear.

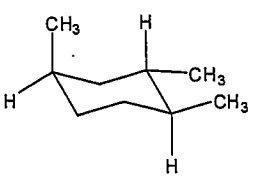
7. (　) which ion is the strongest base? a) $CH_3CH_2O^-$, b) $CH_3C(=O)\text{-}O^-$, c) Cl^-, d) $CH_3CH_2^-$.

8. (　) Which one of the following reacts with HBr at the fastest rate?

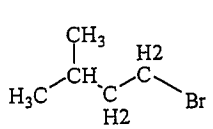
(a)  (b)  (c)  (d)  (e) 

9. (　) The two structure shown here are _____ each other a) identical with , b) conformations of, c) constitutional isomers of, d) stereoisomers of

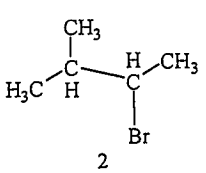




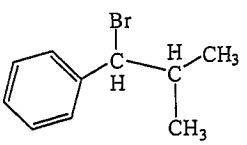
10. (　) Rank the following compounds in order of increasing rate of solvolysis (CN1) in aqueous acetone: a) 1<2<3, a) 2<1<3 a) 3<2<1 a) 1<3<2



1



2

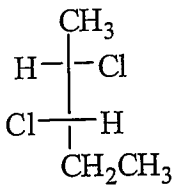


3

11. (　) 2,3-pentadiene, $CH_3CH{=}C{=}CHCH_3$, is: a) a planar substance, b) a conjugated diene, c) an allene, d) a substance capable of cis-trans isomerization.

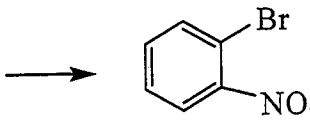
科目：有機化學【材光系碩士班甲組】

12. (　) The 2,3-dichloropentane (structure shown below) is a) 2R, 3R, b) 2R, 3S, c) 2S,3R, d) 2S, 3S.



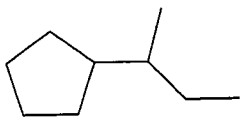
13. (　) Consider the following statements concerning the effect of a trifluoromethyl group, CF_3, on an electrophilic aromatic substitution.　1. The CF_3 group will activate the ring. 2. The CF_3 group will deactivate the ring. 3. The CF_3 group will be a *meta* director. 4. The CF_3 group will be an *ortho*, *para* director. Which of these statements are correct? (a) 1, 3, (b) 1,4, (c) 2,3, (d) 2,4.

14. (　) For the reaction,

? 

, the best reactantsa re: (a) $C_6H_5Br + HNO_3$, H_2SO_4, (b) $C_6H_5NO_2 + Br_2$, $FeBr_3$, (c) $C_6H_5Br + H_2SO_4$, heat, (d) $C_6H_5NO_2 + HBr$.

15. (　) What is the total number of d bond in the molecule shown? (a) 18, b) 26, c) 27, c) 30.



16. (　) Which alkane has the highest boiling point? a) hexane, b) 2, 3-dimethylbutane, c) 2,2,-dimethylbutane, d) 3-methylpentane, e) 2-methylpentane.

17. (　) Which of the following phrases are *not* correctly associated with an SN1 reaction? 1. rearrangement is possible. 2. Rate is affected by solvent polarity. 3. The strength of the nucleophile is important in determining rate. 4. The reactivity series is tertiary > secondary > primaty. 5. proceeds with complete inversion of configuration. a) 3,5, b) 5 only, c) 2,3,5, d) 3 only.

18. (　) Which of the following molecules would you expect to be *nonpolar*? 1. CH_2F_2, 2. CO_2, 3. CF_4, 4. CH_3OCH_3.

a) 1 and 2, b) 1 and 3, c) 1 and 4, d) 2 and 3, e) 2,3, and 4.

19. (　) The formal charge on phosporus in $(CH_3)_4P$ is: a) 0, b) -1, c) +1, d) +2.

20. (　) The relationship between magnetic field strength and the energy difference between nuclear spin states is: a) They are independent of each other. b) They are directly proportional, c) They are inversely proportional. D) The relationship varies from molecule to molecule.

科目：物理化學【材光系碩士班甲組】✓

1. Single choice equations (8%, 2% each) 本大題請於「非選擇題區」作答，並請標明題號。

(1) For a compound to be completely miscible with a solvent at a given temperature
(a) The free energy change ΔG_m must be negative and the second derivative of the free energy must be positive,
(b) ΔG_m must be positive and the second derivative negative,
(c) ΔG_m must be negative and the second derivative must also be negative,
(d) They must both be positive

(2) Given a particle in a box, which of the following quantum statement is not true?
(a) Shifting the box in space will change the wave function of the particle.
(b) If the size of the box is infinite, the energy states of the particle are no more quantized
(c) The energy of the particle depends on the shape of the box
(d) Shifting the box in space will change the energy of the particle.

(3) The half-life of a first-order reaction is 20 min. How much time is required for this reaction to be 25 % complete?
(a) 4.2 min, (b) 8.3 min, (c) 16.8 min, (d) 33.6 min, (e) 40.0 min.

(4) The speed of a projectile of mass $1\times10^{-27}kg$ is known to with 2 um/s. Calculate the minimum uncertainty in its position.
(a) 0.027 m, (b) 0.038 m, (c) 0.053 m, (d) 0.095 m, (e) 0.102 m

2. True or false, and "why" (14%, 2% each) 本大題請於「非選擇題區」作答，並請標明題號。

(a) If a closed system undergoes a reversible process for which $\Delta V = 0$, then P-V work done on the system in this process must be zero.
(b) The criteria for spontaneous change in terms of the entropy $dS > 0$ and $dG < 0$.
(c) For the mixing of ideal gas at fixed T and P, the ΔH，ΔV，ΔG must be zero.
(d) For a one-component system, the most stable phase at a given T and P is the phase with the lowest H_m
(e) The water mixing ethanol could be considered as the ideal solution.
(f) For a real gas $P(v-b) = RT$, where $C_p - C_v = R$.
(g) The value of a in Van-der Waal (VDW) equation for a real gas is the same for different gases.

科目：物理化學【材光系碩士班甲組】

3. (a) Draw a plot of chemical potential versus temperature of solid, liquid, and gas phases for pure substance. (2%)
   (b) What is the meaning of the slope in plot (a) of each phase? (2%)
   (c) What criterion is used in deciding where a phase transition will take place? (2%)
   (d) For an aqueous solution, why the boiling point increases and the melting point decreases? Please use plot (a) to answer the question and give you reason. (2%)
   (e) Pure benzene freezes at 5.4 °C and a solution of 0.223 g of phenylacetic acid ($C_6H_5CH_2COOH$) in 4.4 g of benzene freezes at 4.44 °C. The molar freezing point lowering constant of benzene is 5.12 K/mol, please comment on the result and what kind of intermolecular force exists in this compound? (5%)

4. 1 g of Poly(N-isopropylacrylamide) (PNIPAm, water soluble polymer) is dissolved in 100 g of water at room temperature in a sealed glass vial and observed to be perfectly clear solution. The vial is then taken to the laboratory sink and placed under a stream hot water. The polymer solvent mixture now becomes turbid and looks like milk. Next the vial is placed under a stream of water from the cold water tap and the polymer mixture reverts to a perfectly clear solution. How would you explain this phenomenon? (10%)

5. When 1 mole of water supercooled to -10 °C freezes isothermally, what are the entropy change of the system and surroundings? Give the molar enthalpy of the melting of ice at 0 °C is 6025 J/mol, the molar heat capacities of ice and water are 37.3 and 75.3 J/mol.K, respectively. (10%)

6. (a) The probability of gas speed is: $F(v)=\left(\frac{m}{2\pi kT}\right)^{3/2}\exp(\frac{-mv^2}{2kT})4\pi v^2$ since there is a distribution of molecular speed, there are different measures of the average speed. Derive equations for the mean speed $<v>$, the root-mean-square speed $<v>^{1/2}$, and the most probable speed v_p. (10%)

   (b) For nitrogen (M = 28 g/mol) at 1 atm and 298 K, calculate the most probable speed, mean speed, and root mean square speed ? (5%)

7. (a) Draw the normal modes of vibration for CO_2 molecule. (4%)
   (b) Which kinds of vibrations are infrared (IR) active in question (a)? (3%)
   (c) Compare the magnitudes of frequencies of these normal modes. (3%)

8. In the kinetics of combination of hydrogen and bromine to form hydrogen bromide, the following reactions are postulated:

$Br_2 \rightarrow 2Br$ (k_1)

$Br + H_2 \rightarrow HBr + H$ (k_2)

$H + Br_2 \rightarrow HBr + Br$ (k_3)

$H + HBr \rightarrow H_2 + Br$ (k_4)

$Br + Br \rightarrow Br_2$ (k_5)

According to the steady state approximation for short-lived intermediates, derive the rate equation for HBr. (10%)

9. There is a new DNA-like compound (1-(4-vinylbenzyl)thymine) as shown in Figure 1. The proton magnetic resonance of this compound in *d*-DMSO is plotted in Figure 1. Please discuss this spectrum as best as you can. (10%)

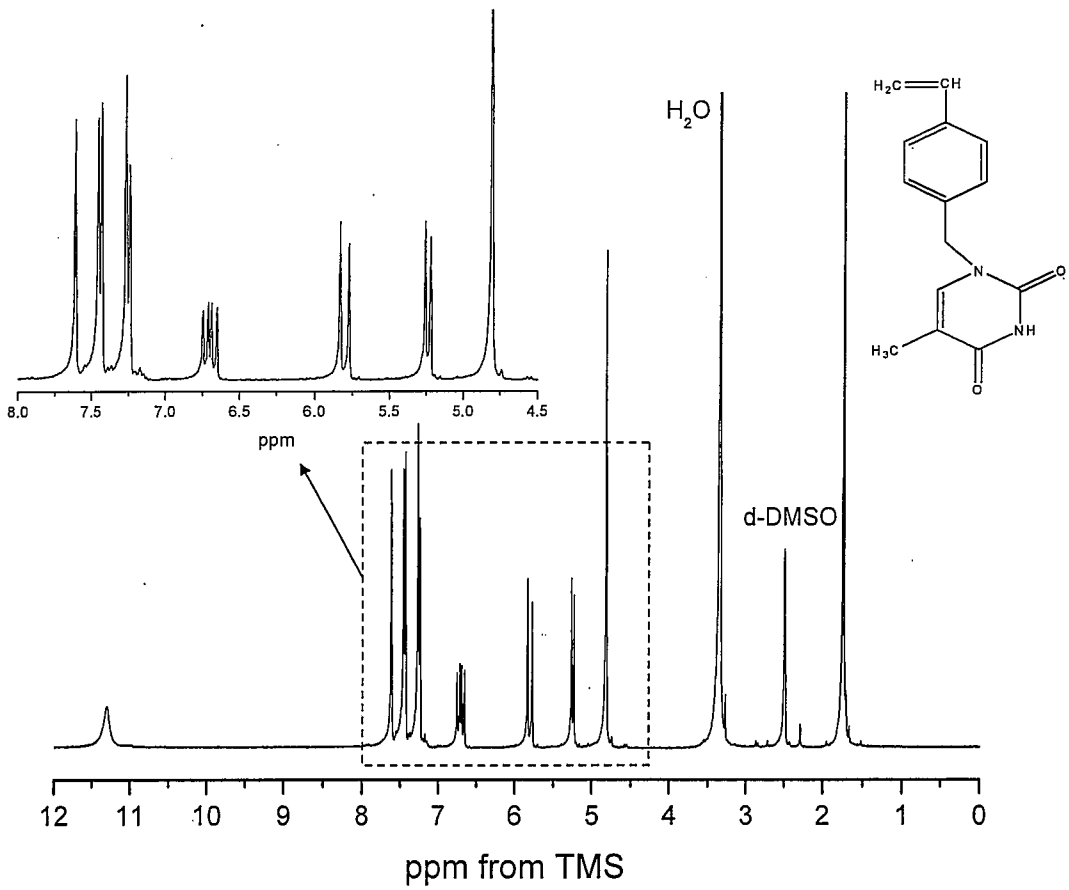


Figure 1

科目：工程數學【材光系碩士班乙組】 √

Prob. #1. (a) Find the volume of the tetrahedron with vertices (0,2,1), (4,3,0), (6,6,5), (4,7,8) (10%)

(b) Find the directional derivative of f at P in the direction of a (10%)

$$f = 4x^2 + y^2 + 9z^2, \quad P: (2,4,0), \quad a = [-2, -4, 3]$$

Prob. #2. Find the Fourier transform of f(x). Show the details

(a) $$f(x) = \begin{cases} x & \text{if } -1 < x < 1 \\ 0 & \text{otherwise} \end{cases} \qquad (10\%)$$

(b) $$f(x) = xe^{-x^2} \qquad (10\%)$$

Prob. #3. Please find their eigenvalues and eigenvector (20%)

$$A = \begin{bmatrix} -2 & 2 & -3 \\ 2 & 1 & -6 \\ -1 & -2 & 0 \end{bmatrix}$$

Prob. #4. Please find the Fourier series of the periodic function f(x). (20%)

$$f(x) = \begin{cases} -k & \text{if } -2 < x < 0 \\ k & \text{if } 0 < x < 2 \end{cases} \qquad p = 2 \cdot L = 4, \quad L = 2$$

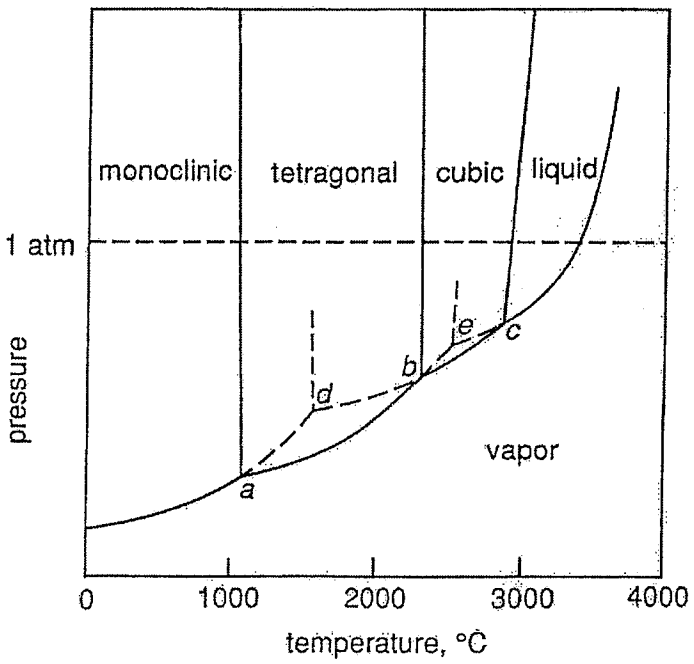
Prob. #5. Find a real general solution, showing the details of your work. (20%)

$$x^2 y'' - xy' + 2y = 0$$

科目：熱力學【材光系碩士班乙組】 √

請於答案卷上依序作答，並清楚標明題號

1. Please describe the meaning of (a) Gibbs-Duhem equation, (b) configurational entropy, (c) thermal entropy and (d) give an example to explain the difference or the relationship of these two types of entropy. (20%)
2. For a binary A-B solution at fixed temperature and pressure, the molar Gibbs free energy is $G = X_A\overline{G}_A + X_B\overline{G}_B$, where $\overline{G}_A$ and $\overline{G}_B$ are, respectively, the partial molar Gibbs free energies of A and B in the solution. Please derive these expressions of $\overline{G}_A$ and $\overline{G}_B$ as the relationships of composition and the molar Gibbs free energy of the solution. Also, describe the meaning of the partial molar Gibbs free energies. (式子推導需步驟分明) 20%
3. According to the schematic phase diagram for zirconia, please describe the equilibrium phase(s) of (a) dash lines a-d, d-b, b-e and e-c; (b) points a, d, b, e, and c. (20%)



科目：熱力學【材光系碩士班乙組】

4. The Thermit reaction is used to weld steel in locations which are not amenable to conventional welding equipment. A mixture of Fe_2O_3 and Al, present in the molar ratio 1:2, is placed in an adiabatic container at 298 K, and the Thermit reaction

$$2\,Al + Fe_2O_3 \longrightarrow 2\,Fe + Al_2O_3$$

is allowed to proceed to completion. Calculate the following conditions,

(a) the thermal balance at 1809 K that Fe become liquid phase, (10%)

(b) the thermal balance at 2325 K that Al_2O_3 become liquid phase, (10%)

(c) the thermal balance at 3343 K that part of liquid iron become iron vapor, (10%) and

(d) the number of moles of Fe which need to be added to limit the Thermit reaction temperature at 1809 K. (10%)

The thermochemical data,

$\Delta H_{298} = -852300$ J

$Cp, Al_2O_{3(s)} = 117.49 + 10.38*10^{-3}T - 37.11*10^{5}T^{-2}$ J/K in the range 298-2325 K

$Cp, Al_2O_{3(L)} = 184.1$ J/K in the range above 2325 K

$Cp, Fe_{(\alpha)} = 37.12 + 6.17*10^{-3}T - 56.92T^{-0.5}$ J/K in the range 298-1187 K

$Cp, Fe_{(\gamma)} = 24.48 + 8.45*10^{-3}T$ J/K in the range 1187 – 1664 K

$Cp, Fe_{(\delta)} = 37.12 + 6.17*10^{-3}T - 56.92T^{-0.5}$ J/K in the range 1664-1809 K

$Cp, Fe_{(L)} = 41.84$ J/K in the range above 1809 K

$Fe_{(\alpha)} \rightarrow Fe_{(\gamma)}, \Delta H_{trans} = 670$ J at 1187 K

$Fe_{(\gamma)} \rightarrow Fe_{(\delta)}, \Delta H_{trans} = 840$ J at 1664 K

$Fe_{(\delta)} \rightarrow Fe_{(L)}, \Delta H_{trans} = 13770$ J at 1809 K

$Fe_{(L)} \rightarrow Fe_{(vapor)}, \Delta H_{trans} = 340159$ J at 3343 K

科目：光電概論【材光系碩士班丙組】√

Electrostatic Fields (50%)

1. In a certain region a charge distribution exists that is spherically symmetric but non-uniform. The electric potential $V(r)$ due to this charge distribution is

$$V(r)=\begin{cases}\dfrac{\rho_0 a^2}{18\varepsilon_0}\left(1-3\dfrac{r^2}{a^2}+2\dfrac{r^3}{a^3}\right), & \text{for } r\le a\\ 0, & \text{otherwise}\end{cases},$$

where ρ_o is a constant having units of C/m^3 and a is a constant having units of meters.

(a) Find the electric field intensity E for the regions $r \le a$ and $r > a$. (15%)

(b) Find the volume charge density $\rho(r)$ for the regions $r \le a$ and $r > a$. (15%)

(c) Calculate the total charge Q. (10%)

(d) Show that the net charge contained in the volume of a sphere of radius greater than a is zero. (10%)

Fourier Optics (50%)

2. A planar object is placed 80cm in front of a converging lens. As shown in Fig. 1, the focal length of the lens is f = 40cm. The size of this lens is much larger than that of the planar object. The amplitude transmittance of the planar object is known as

$$t_A(\xi,\eta)=\frac{1}{2}[1+\cos(2\pi f_0\xi)]rect\left(\frac{\xi}{L}\right)rect\left(\frac{\eta}{L}\right),$$

where $rect(t)=\begin{cases}1 & \text{if } |t|<1/2\\ 1/2 & \text{if } |t|=1/2\\ 0 & \text{otherwise}\end{cases}$, $L = 1cm$, and $f_0 = 10$ cycles/mm.

This object is illuminated by a laser beam with wavelength λ = 0.5μm. It has been shown that the wave field on the focal plane (α, β) can be expressed as

$$U(\alpha,\beta)=B\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}t_A(\xi,\eta)e^{i2\pi\left(\frac{\alpha}{\lambda f}\xi+\frac{\beta}{\lambda f}\eta\right)}d\xi d\eta,$$

where B is a constant. The wave field on the output plane (u, υ) can be expressed as the convolution of the object function with the impulse response, as given by

$$U(u,\upsilon)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}t_A(\xi,\eta)h(u-\xi,\upsilon-\eta)d\xi d\eta.$$

Intensity of the light wave is defined as the squared magnitude of the wave field,

$$I(x,y)=|U(x,y)|^2.$$

It has been known that Fourier transform of $\delta(t-a)$ is $f(w)=e^{-i2\pi aw}$, where

$$\delta(t-a)=\begin{cases}\infty & \text{if } t=a\\ 0 & \text{otherwise}\end{cases}.$$

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Please answer the following questions:

(a) Find an expression for the intensity distribution $I(\alpha, \beta)$ on the focal plane. (15%)

(b) Sketch the intensity distribution across α axis of the focal plane, labeling the numerical values of the distance between diffracted components and the width (between the first zeros) of the individual components. (10%)

(c) The impulse response on the output plane (u, υ) is known as

$$h(u,\upsilon)=\delta(u)\delta(\upsilon).$$

Find an expression for the intensity distribution $I(u, \upsilon)$ on the u-υ plane. (15%)

(d) Continued from (c), what is the magnification of this lens system? (10%)

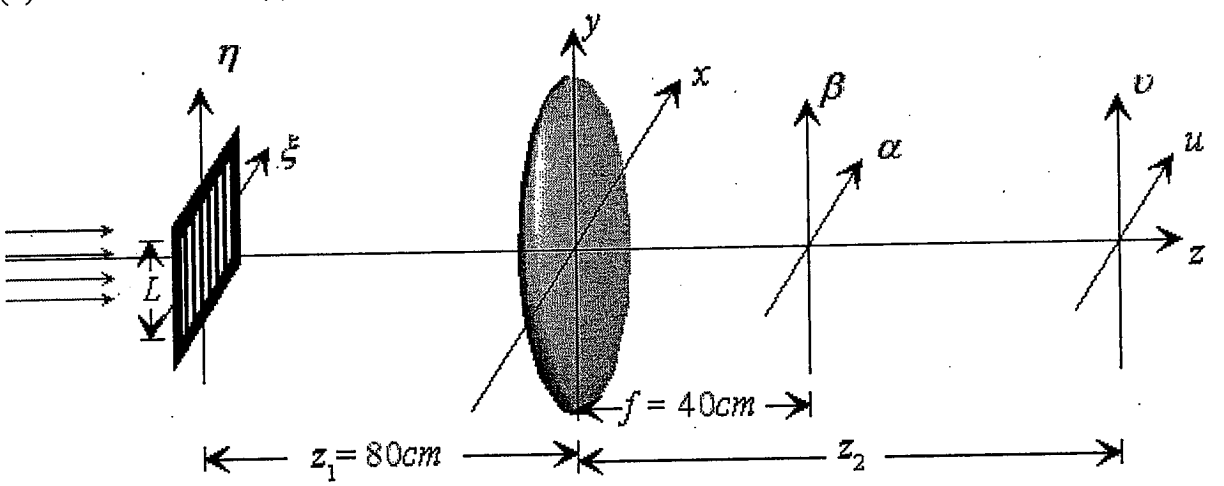

Figure 1

科目：材料科學【材光系碩士班丙組】√

1. Many of the physical and mechanical properties of materials can be predicted on knowledge of the interatomic forces that bind the atoms together. Explain how to decide the melting point, Young's modulus and coefficient of thermal expansion of a material according to the Condon-Morse potential curve shown in Fig. 1. (9%)

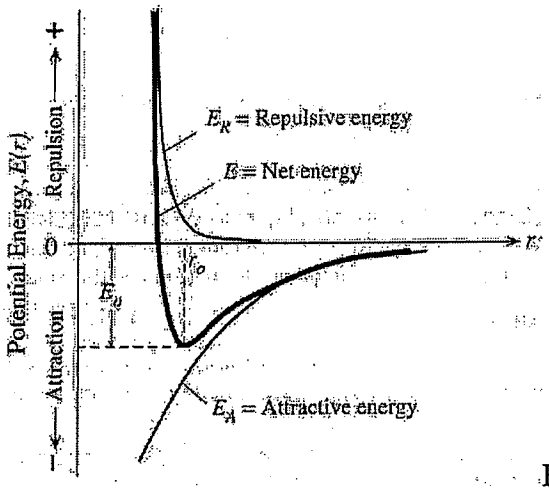

Fig. 1

2. For the cubic crystal structure, show that [hkl] is perpendicular to (hkl). (8%)

3. What is the most significant indication of the result of Kirkendall's experiment in which the diffusion of Cu and Zn was studied. (10%)

4. Fig. 2 shows a schematic stress-strain curve for a high quality GaAs single crystal at a strain rate of $5\text{x}10^{-5}\ s^{-1}$. A yield point is observed in the flow curve. Explain the origin of the yield point based on the Orowan equation: $\dot{\gamma} = \rho b v$. (8%)

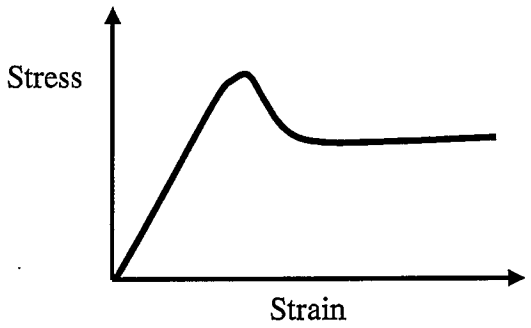

Fig. 2

5. An ultra-low carbon steel has an average grain size of 80μm. Is it possible to reduce its average grain size to 20μm? If so, explain the procedures you would use and name the underline mechanism(s) involved. If it is not possible, explain why. (10%)

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6. Directional plasticity is derived from a processing history that causes a preferred orientation. In other words, a material may exhibit a higher strength in one direction than in another. This phenomenon is called orientation strengthening. Predict that either an FCC metal or an HCP metal is more suitable for employing the orientation strengthening mechanism and explain why. (10%)

7. Predict the tensile strength and electric conductivity as a function of composition for (a) an isomorphous alloy and (b) an eutectic alloy, respectively. (12%)

8. Explain the following terms: (a) pseudoelasticity (b) ferroelectricity, (c) monotectic reaction. (9%)

9. For a ceramic compound, what are the two characteristics of the component ions that determine the crystal structure? (6%)

10. A dielectric material is one that is electrically insulating and exhibits an electric dipole structure. List three major types of polarization observed in the dielectric materials and explain their mechanisms. Please also give one example for each case. (12%)

11. Explain why superheating is rarely observed for metals in melting. (6%)