

# 國立中山大學 113 學年度

## 碩士班暨碩士在職專班招生考試試題

科目名稱：工程數學【材光系碩士班選考、材料前瞻應材碩士班選考、材光聯合碩士班選考】

### — 作答注意事項 —

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# 國立中山大學 113 學年度碩士班暨碩士在職專班招生考試試題

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共 1 頁第 1 頁

Quantitative calculation problems (100 points). You are required to provide a thorough explanation of your calculations and reasoning. Please show all of your work and clearly demonstrate how you arrived at your solutions.

1. Solve the following first-order differential equation  $\cot x dy + y dx = 0$  with the initial condition:  $y(0) = 1$  (10 pt).

2. Show that the general solution to the first-order differential equation:  $\frac{dy}{dx} + P(x)y = Q(x)$  is  $y(x) = [\int I(x)Q(x)dx + c]/I(x)$ , where  $I(x) = \exp[\int P(x)dx]$  and  $c$  is a constant (15 pt).

3. Solve the differential equation:  $x\frac{dy}{dx} + 3y = \frac{\cos x}{x^2}$  with the initial condition:  $y(0) = 0$  (10 pt).

4. Solve the differential equation:  $x^2y^4 + y + 3x\frac{dy}{dx} = 0$  with  $y(0) = 1$  (10 pt).

5. Solve the differential equation:  $2y'' + 6y' - 20y = 120e^{5x}$  with  $y(0) = 7$  and  $y'(0) = -1$  (10 pt).

6. Solve the differential equation:  $y'' - 4y' + 8y = 4e^{2x} \sec 2x$  with  $y(0) = 0$  and  $y'(0) = 0$  (15 pt).

7. Solve the system of first-order differential equations:

$$\begin{cases} \dot{x} = 2x - 4y \\ \dot{y} = x - 3y \end{cases},$$

where the solution satisfies  $x(0) = 9$  and  $y(0) = 3$  (15 pt).

8. Assuming both of the Laplace transforms of  $f(t)$  and  $g(t)$  exist and are denoted as  $\mathcal{L}\{f(t)\} = F(s)$  and  $\mathcal{L}\{g(t)\} = G(s)$ , respectively, prove that:

(A)  $\int_0^t f(x)g(t-x)dx = \int_0^t f(t-x)g(x)dx$  (5 pt);

(B)  $\mathcal{L}\{\int_0^t f(x)g(t-x)dx\} = F(s)G(s)$  (5 pt),

and (C) calculate  $\mathcal{L}\{\int_0^t e^{-ax} \sin[\omega(t-x)]dx\}$ , where  $a$  is a negative constant (5 pt).

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## 碩士班暨碩士在職專班招生考試試題

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※本科目依簡章規定「不可以」使用計算機(混合題)

共 4 頁第 1 頁

第一部分：單選題，每題 5 分，無倒扣

1. Determine the electron configuration  $1s^2 2s^2 2p^6 3d^5 4s^1$  is (A) an inert gas, (B) a halogen, (C) an alkali metal, or (D) a transition metal. (5 points)
2. Which one of the following bonds is **not** a primary interatomic bond? (A) Covalent bond, (B) metallic bond, (C) dipole bond, or (D) ionic bond. (5 points)
3. Based on the hard-sphere model, what is the atomic radius of molybdenum having a body-centered cubic crystal structure with a unit cell length  $a$ ? (A)  $\frac{a}{4}$ , (B)  $\frac{\sqrt{2}a}{4}$ , (C)  $\frac{\sqrt{3}a}{4}$ , or (D)  $\frac{a}{2}$ . (5 points)
4. Which one of the point coordinates is **not** an interstitial site within an FCC unit cell? (A)  $\frac{1}{2} \ 1 \ \frac{1}{2}$ , (B)  $\frac{1}{4} \ \frac{3}{4} \ \frac{1}{4}$ , (C)  $0 \ \frac{1}{2} \ 1$ , (D)  $\frac{1}{2} \ \frac{1}{2} \ \frac{1}{2}$ . (5 points)
5. Cuprous oxide is a direct bandgap semiconductor with a bandgap of 2.1 eV. Over which one of the following wavelength is it opaque? (A) 500 nm, (B) 600 nm, (C) 700 nm (D) 800 nm. (5 points)
6. Which one of the following descriptions is **not** correct for refraction: (A) Light that is transmitted from vacuum into the interior of a transparent material experiences a decrease in velocity. (B) Light beam is not bent at the interface. (C) A consequence of electronic polarization of the atoms. (D) The larger an atom, the greater the index of refraction. (5 points)
7. Which one of the following descriptions is **not** correct for a ferromagnetic single crystal at a temperature below  $T_c$  (Curie temperature)? (5 points)  
(A) The  $B$  (magnetic flux)- $H$  (magnetic field) behavior for the single crystal is isotropic.  
(B) The single crystal is composed of small-volume regions called magnetic domains.  
(C) As an external magnetic field is applied, the magnetic domains change in shape and size.  
(D) As the magnetization reaches a maximum value, the single crystal is a single domain.
8. Which one of the following descriptions is **not** correct for a ferromagnetic single crystal at a temperature below  $T_c$  (Curie temperature)? (5 points)  
(A) Tangled dislocations which can retard the movement of a grain boundary also retard the movement of a domain boundary.  
(B) The thickness of a domain boundary is similar to that of a grain boundary.  
(C) Both hysteresis and permanent magnetization result from the resistance to movement of domain boundaries.  
(D) For an electric steel, the hysteresis loss decreases with increasing the grain size.

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共 4 頁第 2 頁

9. The conductivity of a semiconducting material is **not** affected by (A) pressure, (B) carrier concentration, (C) temperature, (D) dopant content. (5 points)
10. There are three types of electric polarization which do **not** include (A) electronic polarization, (B) ionic polarization, (C) solid solution polarization, (D) orientation polarization. (5 points)

第二部分：問答計算題，無倒扣

11. Fig. 1 is the Al-Ni phase diagram, for which single-phase regions are labeled. Specify temperature-composition points at which all eutectic, eutectoids, peritectics, and congruent phase transformations occur. Also, for each, write the reaction upon cooling. (12 points)

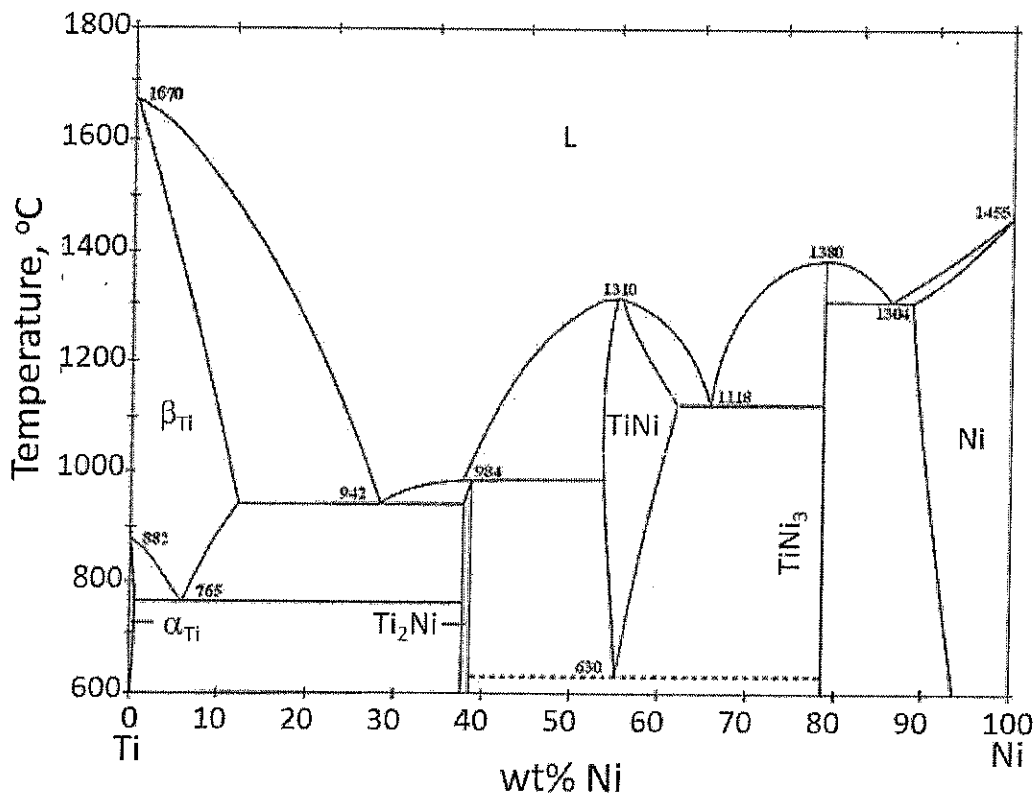


Fig. 1

12. A metal rod will have a length at  $0.95 T_m$  (melting temperature) longer than that at  $0.2 T_m$ . List two reasons contributing to the length increase. (8 points)
13. GaN is a wide bandgap semiconductor having a hexagonal crystal structure. Give the Burgers vector of the edge-type threading dislocations in a GaN (0002) epilayer grown on a sapphire (0002) substrate. An epilayer is a single-crystal thin film, and a threading dislocation is a dislocation extended straightly from the epilayer/substrate interface to the surface of the epilayer. In other words, the dislocation line is perpendicular to the substrate surface. (6 points)

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共 4 頁第 3 頁

14. Fig. 2 shows a concentration profile for a non-steady-state diffusion. The concentration at position  $x$  is  $C_x(t)$  at time  $t$ . Predict the concentration  $C_x(t+\Delta t)$  is higher than, equal to, or lower than  $C_x(t)$  after a time period of  $\Delta t$ . Please justify your answer. (8 points)

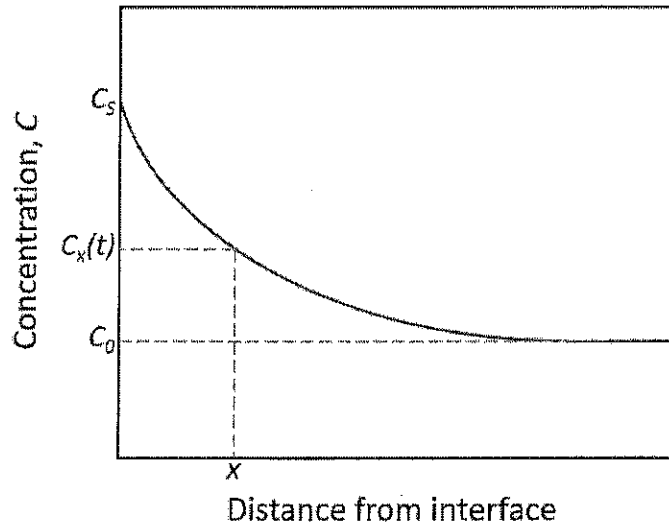


Fig. 2

15. Estimate the yield strength, tensile strength, uniform elongation, and total elongation of a sample whose load-displacement curve is shown in Fig. 3. Explain how the values are derived. (Sample information: gauge width=10 mm, thickness=1 mm, gauge length=40 mm). (8 points)

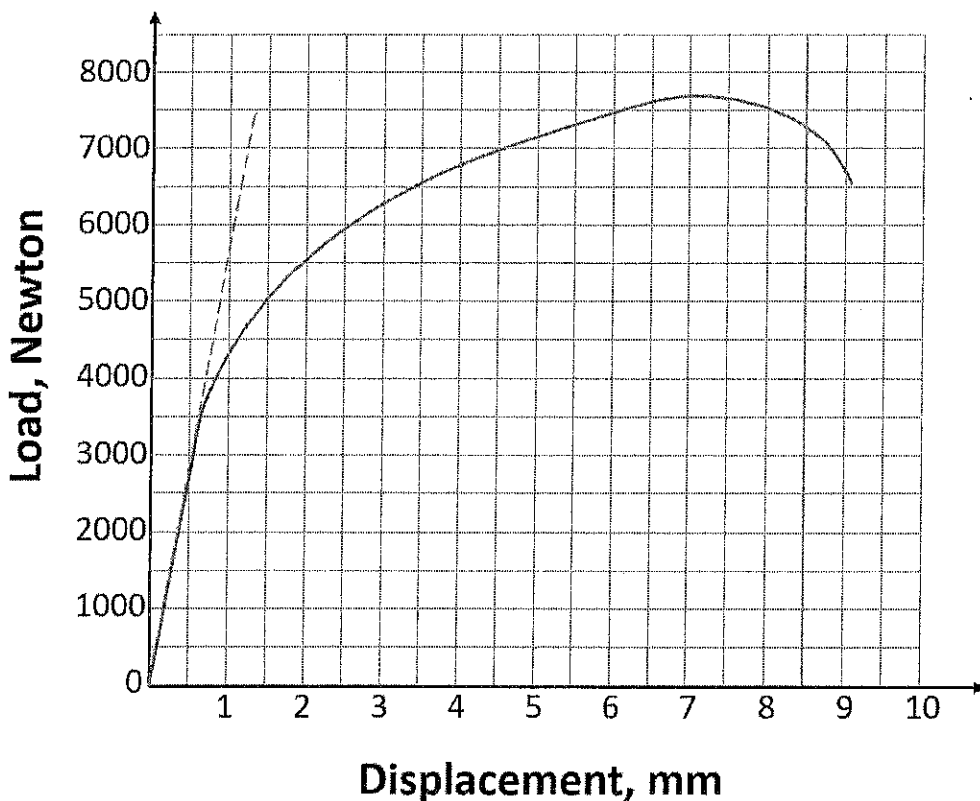


Fig. 3

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共 4 頁第 4 頁

16. Consider a given volume of liquid at a temperature  $\Delta T$  below  $T_m$  (melting temperature) with a free energy  $G_1$  as shown in Fig. 4(a). If some of the atoms of the liquid cluster together to form a small sphere of solid (see Fig. 4(b)), the free energy of the system will change to  $G_2$ . The free energy of the system changes from  $G_1$  to  $G_2$  is given by:

$$\Delta G = G_2 - G_1 = -V_s \Delta G_v + A_{SL} \gamma_{SL}$$

where  $\Delta G_v$  the volumetric free energy difference between the solid and liquid,  $V_s$  the volume of the solid,  $A_{SL}$  the solid/liquid interfacial area, and  $\gamma_{SL}$  the solid/liquid interfacial free energy. Please (a) express  $\Delta G_v$  in terms of  $L_v$ , the latent heat of fusion per unit volume,  $\Delta T$ , and  $T_m$ , and (b) derive the critical nucleus radius in term of  $\Delta T$ . (8 points)

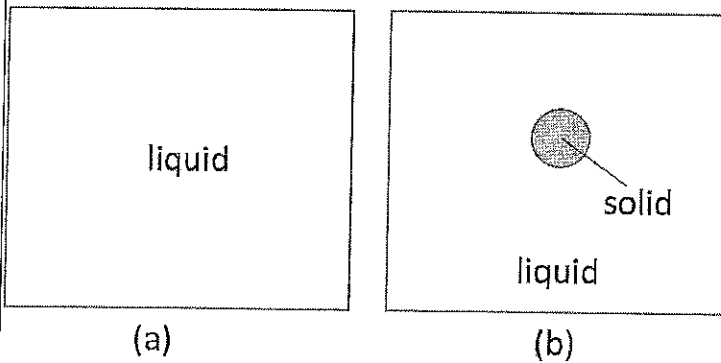


Fig. 4

# 國立中山大學 113 學年度

## 碩士班暨碩士在職專班招生考試試題

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# 國立中山大學 113 學年度碩士班暨碩士在職專班招生考試試題

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題號：488003

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共 3 頁第 1 頁

Single choice questions, one answer per question. (6 questions at 5 points each, totaling 30 points)

- Which one of the major laws of thermodynamics describes the only ways to change the internal energy of a closed system are supply of heat and for work to be done by the system.
  - First
  - Second
  - Third
  - Fourth
- When boiling liquid water, which of the following must be true during this phase transformation?
  - The volume of water must remain constant.
  - The temperature of water must remain constant.
  - The total energy of water must remain constant.
  - The density of water must remain constant.
- In a hypothetical situation, 10 L of ideal gas can be placed in infinite vacuum. Can this gas expand? Why or why not?
  - The gas can infinitely expand because each any gas sample always fills the entire volume of a container.
  - The gas can infinitely expand because each gas molecule has negligible volume.
  - The gas can infinitely expand because there is no attraction between gas molecules and expansion does not require any heat.
  - The gas cannot infinitely expand because the amount of gas in the system remains constant.
- The mixing of liquids can be described using thermodynamic quantities. Which of the following statements is true?
  - Free energy of mixing is always negative for all mixtures of small molecules.
  - Enthalpy of mixing is always positive for all mixtures of small molecules.
  - Entropy of mixing is always negative for all miscible mixtures of small molecules.
  - Increasing the temperature will always cause different components to mix.
- What is a vapor dome in a P-V phase diagram?
  - A vapor dome is a hemispheric shape of condensation that forms naturally.
  - A vapor dome is a feature of a phase diagram at which point the concentration of the sample remains constant.
  - A vapor dome traces out the phase transformation boundary between gases and liquids.
  - A vapor dome is a feature that encompasses the region of a P-V diagram where vapor and liquid coexist.

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題號：488003

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共 3 頁第 2 頁

6. What is a eutectic point?

- A eutectic point is the same as a triple point.
- A eutectic point is the temperature beyond which no amount of compression can condense a sample.
- A eutectic point is the point at which different materials can mix well.
- A eutectic point is the convergence of three or more phases, where a liquid can cool down and transform into two solid phases.

## Long Answers (6 questions totaling 70 points)

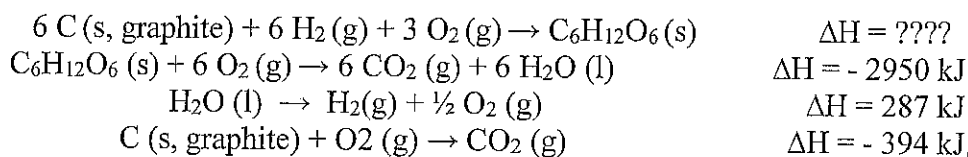
1. If 6.0 L of an ideal gas is heated from  $-60^{\circ}\text{C}$  to  $235^{\circ}\text{C}$ , what is its final volume? (5pt)

2. A generic chemical reactions' rate can be described using the generic formula;

$$\text{Rate} = k [\text{reagent A}]^a [\text{reagent B}]^b$$

- Given that "[reagent A]" and "[reagent B]" refer to the concentrations of the reagents. What are the technical terms for "a" and "b"? (4pt)
- Given that this generic chemical reaction can be affected by temperature, what would be the generic equation for "k"? (4pt)
- If a generic chemical reaction temperature is increased by  $10^{\circ}\text{C}$  from  $150^{\circ}\text{C}$ , how would this change the reaction rate? (6pt)

3. Consider the following combustion reactions and answer the follow up questions.



- What is the change in enthalpy of the synthesis of glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ )? (7pt)
- Is it possible to find out if this reaction is spontaneous? (4pt)

4. A Stirling cycle operates between  $100^{\circ}\text{C}$  and  $500^{\circ}\text{C}$ . Please answer the following questions.

- Stirling cycles typically consist of 4 thermodynamic steps. In sequence of a Stirling cycle's steps, please list the following starting from "isothermal heat addition". The other steps are "isothermal heat removal", "isochoric heat removal", and "isochoric heat addition" (7pt)
- What is the estimated efficiency of this Stirling cycle? (6pt)
- Which thermodynamic law prevents a thermodynamic engine from operating at 100% efficiency? (4pt)

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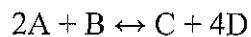
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共 3 頁第 3 頁

5. Phase transformations can be described using the Clausius-Clapeyron equation. Answer the following questions regarding the Clausius-Clapeyron equation.

- a. What is the Clausius-Clapeyron Equation? starting from  $\ln\left(\frac{P_1}{P_2}\right)$  (4pt)
- b. What is the vapor pressure in Pascal for a substance at 35°C if the substance has a boiling point of 120°C at 1 atm? The substance has a  $\Delta H_{\text{vap}}$  of 47.8 kJ/mol (7pt)
- c. Using a form of Clausius-Clapeyron equation, how can you explain the negative slope of the solid water to liquid water transition? (4pt)

6. Consider the following reversible reaction involving 4 gases;



- a. What is the equation for the equilibrium constant of this reaction? (4pt)
- b. Would the equilibrium constant increase or decrease if the pressure of the reaction system increases? (4pt)

# 國立中山大學 113 學年度

## 碩士班暨碩士在職專班招生考試試題

科目名稱：普通物理【材光系碩士班選考、材料前瞻應材碩士班選考、材光聯合碩士班選考】

### —作答注意事項—

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# 國立中山大學113學年度碩士暨碩士專班招生考試試題

科目名稱：普通物理【材光系碩士班選考、材料前瞻應材碩士班選考、材光聯合碩士班選考】

題號：488005

※ 本科目依簡章規定「不可以」使用計算機（問答申論題）

共 2 頁第 1 頁

## Problem 1. [Mechanics: 35 points]

There are two atoms A and B, one with the position  $\mathbf{x}_A$  and mass  $m_A$ , and the other with the position  $\mathbf{x}_B$  and mass  $m_B$ .

(a) [5 points] There is an electrostatic force  $\mathbf{F}_{BA}$  exerted by atom A on atom B, and a force  $\mathbf{F}_{AB}$  exerted by atom B on atom A. According to Newton's third law,  $\mathbf{F}_{BA} = -\mathbf{F}_{AB}$ . If we define the relative displacement  $\mathbf{x} = \mathbf{x}_A - \mathbf{x}_B$ , the relative motion can be described by the equation of motion:

$$\mathbf{F}_{AB} = \mu \frac{d^2 \mathbf{x}}{dt^2},$$

where  $\mu$  is called "reduced mass". Prove

$$\mu = \frac{m_A m_B}{m_A + m_B}$$

(b) [5 points] The potential energy between the two atoms A and B can be approximated as the Lennard-Jones potential

$$U(x) = \epsilon \left[ \left( \frac{\sigma}{x} \right)^{12} - 2 \left( \frac{\sigma}{x} \right)^6 \right]$$

where  $\epsilon$  and  $\sigma$  are constants. Calculate the distance  $x_0$  wherein the potential energy  $U(x_0)$  is the minimum of  $U(x)$ .  $x_0$  is the bond length of the molecule AB.

(c) [10 points] Around the minimum of  $U(x)$ , the potential energy is approximately a parabolic curve. Do Taylor's expansion of  $U(x)$  around  $x = x_0$  to the second order.

(d) [5 points] The force can be derived from the potential energy by  $F_{AB} = -\frac{dU}{dx}$ . Using the Taylor's expansion obtained in the previous problem, calculate the approximate force around the minimum. The force you obtain should look like the Hooke's law  $F = -kx$ . What is the  $k$ ? (expressed you answer with those given physical quantities  $\mathbf{x}_A, m_A, \mathbf{x}_B, m_B, \epsilon, \sigma$ )

(e) [10 points] The two atoms are bound with approximately a Lennard-Jones potential, with a bond length  $x_0$ . The Lennard-Jones force is like a spring with a elastic constant  $k$ . Therefore, the system is 2 balls coupled with a spring. Using the  $k$  you obtain in the previous problem, calculate the vibration (relative motion) angular frequency  $\omega$  of the molecule AB (expressed you answer with those given physical quantities  $\mathbf{x}_A, m_A, \mathbf{x}_B, m_B, \epsilon, \sigma$ ).

## Problem 2. [Electromagnetism: 35 points]

The electric field at a distance  $\mathbf{r}$  from a point charge  $Q$  is:

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \hat{\mathbf{r}},$$

where  $\hat{\mathbf{r}}$  is the unit vector along the vector  $\mathbf{r}$ . The electric potential is:

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$$

# 國立中山大學113學年度碩士暨碩士專班招生考試試題

科目名稱：普通物理【材光系碩士班選考、材料前瞻應材碩士班選考、材光聯合碩士班選考】

題號：488005

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共 2 頁 第 2 頁

Consider the following questions in the vacuum, and use the units in the above formula.

(a) [10 points] Find the electric field inside a solid sphere of radius  $R$  that carries a uniform volume charge density  $\rho$ . Express your answer in terms of the total charge of the sphere,  $q$ .

(b) [5 points] An atom can be approximately thought as a point nucleus ( $+q$ ) surrounded by a uniformly charged solid spherical cloud ( $-q$ ) of radius  $R$ . If there is an external electric field  $\mathbf{E}_{\text{ext}} = E_{\text{ext}} \hat{x}$ , the nucleus would move in the  $+\hat{x}$  direction while the electron sphere would move in the opposite direction. If the distance between the nucleus and the center of the electron sphere is  $d$ , calculate the electric field  $\mathbf{E}_{\text{electron}}$  exerted by the electron sphere to the nucleus.

(c) [10 points] Following the previous problem, there are (1) the external field  $\mathbf{E}_{\text{ext}}$ , and (2) the electric field  $\mathbf{E}_{\text{electron}}$  exerted by the electron sphere, onto the nucleus. If the two electric fields cancel each other,  $\mathbf{E}_{\text{ext}} = -\mathbf{E}_{\text{electron}}$ , then the atom system reaches equilibrium. Calculate the distance  $d$  at equilibrium.

(d) [10 points] An electric dipole is composed of a charge  $+q$  at  $\mathbf{d}/2$ , and a charge  $-q$  at  $-\mathbf{d}/2$ . The dipole moment  $\mathbf{p}$  is defined as  $\mathbf{p} = q\mathbf{d}$ . If there is a uniform external electric field  $\mathbf{E}_{\text{ext}}$ , prove that the torque

$$\mathbf{N} = \mathbf{p} \times \mathbf{E}_{\text{ext}}.$$

### Problem 3. [Thermodynamics: 15 points]

A gas consisting of  $n$  moles of a monoatomic gas goes through the cycle shown in the Figure 1, wherein the pressure is constant for  $A \rightarrow B$ , the volume is constant for  $B \rightarrow C$ , and the temperature is constant for  $C \rightarrow A$ .

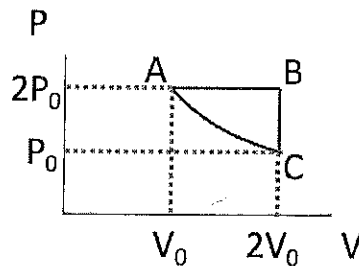


Figure 1

Calculate the heat transfer  $Q$  ( $Q = \Delta U + W$ ) for (a)  $A \rightarrow B$ , (b)  $B \rightarrow C$ , and (c)  $C \rightarrow A$ .

### Problem 4. [Waves/Optics/Modern physics: 15 points]

If a propagating wave along the  $x$  direction has the form  $f(x, t) = Ae^{i(kx - \omega t + \phi)}$ , where  $x$  is the position,  $t$  is the time,  $A$  is a constant amplitude and  $\phi$  is a constant phase.

(a) [5 points] Calculate  $f(x, t_0 + T)$ , what is the difference between  $f(x, t_0 + T)$  and  $f(x, t_0)$ ?

(b) [5 points] The wave is a periodic function of the time, so  $f(x, t_0) = f(x, t_0 + T)$  for arbitrary  $t_0$  (where  $T$  is the period). Use this relation, express the period  $T$  with  $A$ ,  $k$ ,  $\omega$ , and  $\phi$ .

(c) [5 points] (i) Calculate  $[f^*(x) \cdot f(x)]$ . (\* denotes the complex conjugate) (ii) Calculate  $\frac{\partial^2 f}{\partial x^2}$ . (iii) Calculate  $\int_0^\lambda f(x, t) dx$ , where  $\lambda$  is the wave length.

# 國立中山大學 113 學年度

## 碩士班暨碩士在職專班招生考試試題

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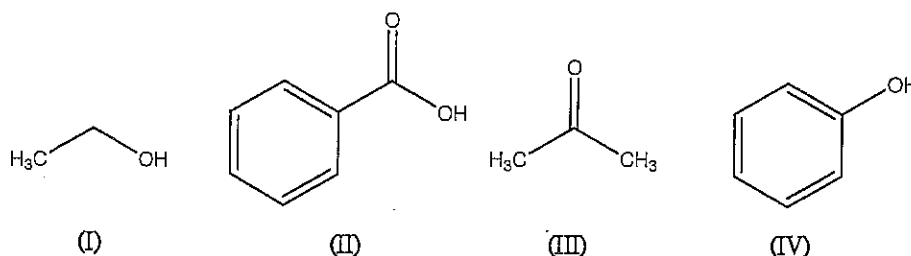
科目名稱：普通化學【材光系碩士班選考、材料前瞻應材碩士班選考、材光聯合碩士班選考】題號：488004

※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）（混合題）

共 4 頁第 1 頁

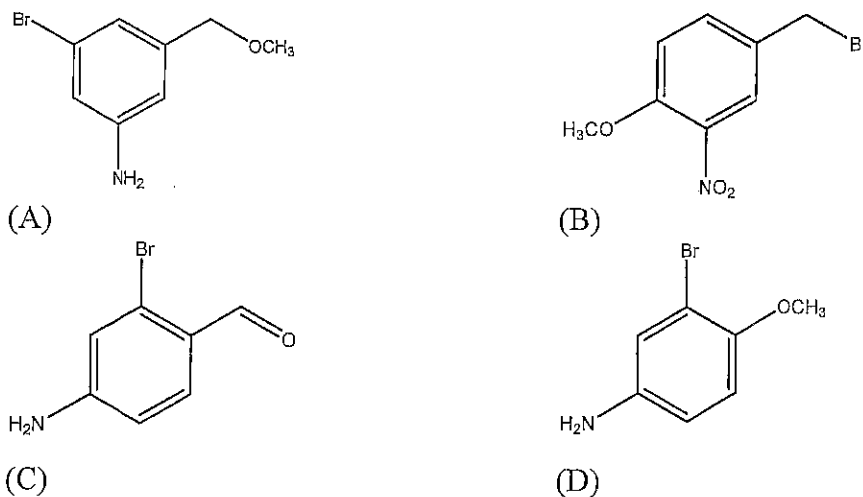
Single choice questions, one answer per question. (10 questions at 5 pt each)

1. Which of the following compounds is appropriately arranged in ascending order according to its  $pK_a$  value?



- (A) II < IV < I < III  
 (B) III < II < I < IV  
 (C) I < III < IV < II  
 (D) IV < II < III < I  
 (E) I < IV < II < III

2. Which of the following compounds is named as 4-amino-2-bromoanisole according to IUPAC nomenclature?



3. Which of the following regions of the electromagnetic spectrum has the highest energy?  
 (A) Infrared light  
 (B) X-rays  
 (C) Ultraviolet light  
 (D) Gamma rays  
 (E) Microwave
4. Consider two liquids,  $X$  and  $Y$ . Liquid  $X$  exhibits stronger intermolecular forces than liquid  $Y$ . Which of the following statements is true?  
 (A) The surface tension of liquid  $X$  is greater than that of liquid  $Y$ ; the viscosity of liquid  $Y$  is greater than that of liquid  $X$ .  
 (B) The surface tension of liquid  $Y$  is greater than that of liquid  $X$ ; the viscosity of liquid  $X$  is greater than that of liquid  $Y$ .  
 (C) The surface tension and viscosity of liquid  $X$  are greater than those of liquid  $Y$ .  
 (D) The surface tension and viscosity of liquid  $Y$  are greater than those of liquid  $X$ .



# 國立中山大學 113 學年度碩士班暨碩士在職專班招生考試試題

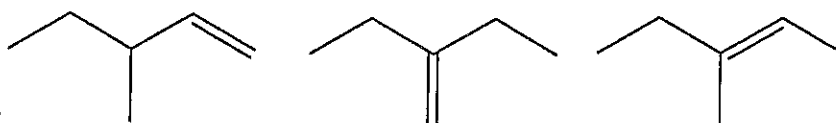
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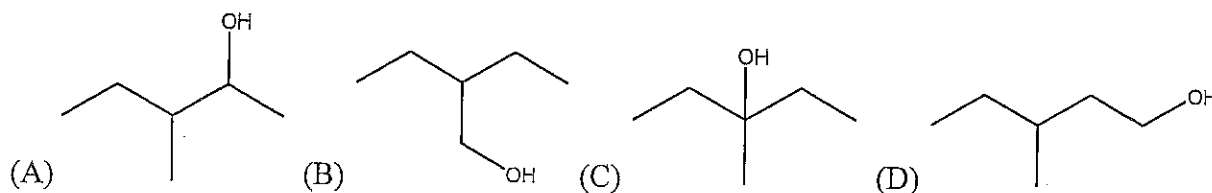
共 4 頁第 2 頁

5. Given that  $\text{Mn} + \text{Zn}^{2+} \rightarrow \text{Zn} + \text{Mn}^{2+}$ ,  $\text{Fe} + \text{Co}^{2+} \rightarrow \text{Fe}^{2+} + \text{Co}$ , and Fe do not react with  $\text{Zn}^{2+}$ , which of the following is correct?
- (A) Oxidizing power:  $\text{Zn}^{2+} > \text{Fe}^{2+} > \text{Co}^{2+}$   
 (B) Oxidizing power:  $\text{Co}^{2+} > \text{Fe}^{2+} > \text{Zn}^{2+}$   
 (C) Reducing power:  $\text{Zn} > \text{Co} > \text{Fe}$   
 (D) Reducing power:  $\text{Fe} > \text{Co} > \text{Zn}$

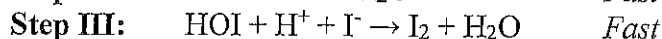
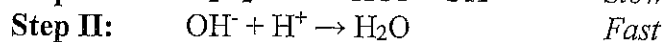
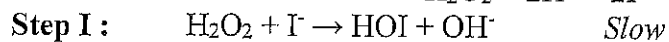
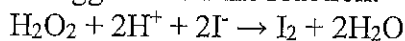
6. By using concentrated sulfuric acid to dehydrate an unknown alcohol, three alkane compounds are obtained. Please speculate on the possible structure of this unknown alcohol.



Three alkane compounds :

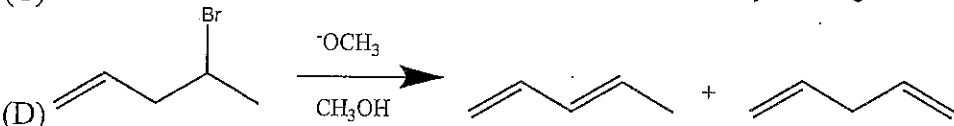
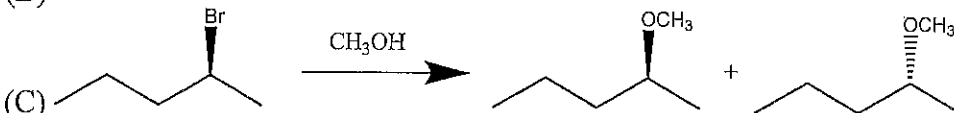
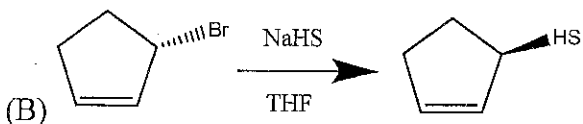
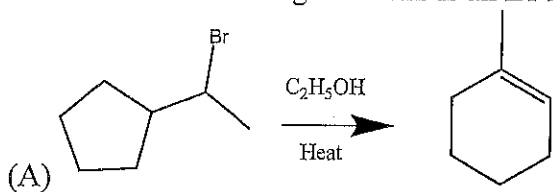


7. The following mechanism has been suggested for the reaction:



- (A) The rate law deduced from the mechanism is :  $\text{Rate} = k[\text{HOI}][\text{I}^-]$ .  
 (B) Step III is the rate determining step.  
 (C)  $\text{OH}^-$  is the intermediate included in this mechanism.  
 (D)  $\text{H}^+$  is the catalyst for the reaction.

8. Which of the following reactions is an E1 reaction?



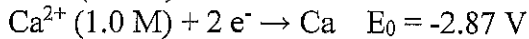
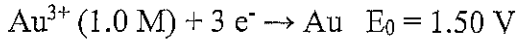
國立中山大學 113 學年度碩士班暨碩士在職專班招生考試試題

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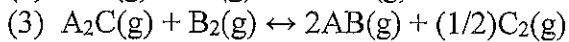
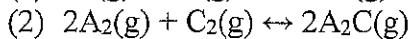
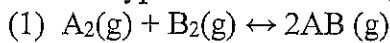
共 4 頁第 3 頁

9. For an electrochemical cell that uses  $\text{Au}^{3+}/\text{Au}$  and  $\text{Ca}^{2+}/\text{Ca}$  half-cell reactions under standard conditions and 298 K:



- (A) Au is the anode.  
 (B)  $E_0 \text{ cell} = 11.61 \text{ V}$ .  
 (C)  $\Delta G_0 = -2530 \text{ kJ}$ .  
 (D)  $E_{\text{cell}} < 0$ , when the reaction reaches equilibrium.

10. For the hypothetical reaction (1) and (2),  $K_1=10^2$  and  $K_2=10^{-4}$ .



What is the value for K for reaction (3)?

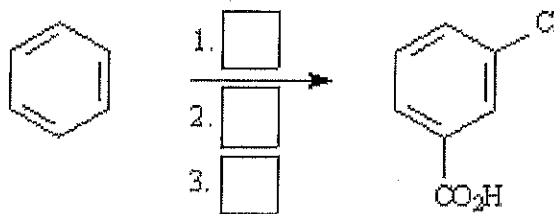
- (A)  $10^{-2}$  (B)  $10^4$  (C)  $10^6$  (D)  $10^2$  (E)  $10^{-4}$

Long Answers (50 pt)

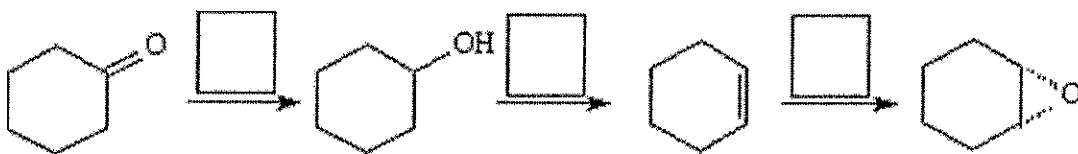
1. Draw the qualitative phase diagrams of  $\text{H}_2\text{O}$  and  $\text{CO}_2$  (two separate plots). Which one has the higher critical temperature? Why? (12 pt)

2. Choose the best reagent(s) from the list provided below for carrying out the following conversions. Place the letter of the reagent in the box beside the reaction number over the arrow. There is only one answer for each reaction. (9 pt at 3 pt each)

- (a)  $\text{KMnO}_4, \text{H}_3\text{O}^+$  (b)  $\text{Br}_2, \text{FeBr}_3$  (c)  $\text{Cl}_2, \text{FeCl}_3$  (d)  $\text{CH}_3\text{Cl}, \text{AlCl}_3$  (e)  $\text{HNO}_3, \text{H}_2\text{SO}_4$



3. Choose the best reagent for carrying out the following reactions from the list below. Place the letter of the reagent(s) in the box over the reaction arrow. Only one letter per box. (9 pt at 3 pt each)



- (A)  $m\text{-ClC}_6\text{H}_4\text{CO}_3\text{H}$  (B)  $\text{H}_2/\text{Pd}$  (C) warm  $\text{H}_2\text{SO}_4/\text{H}_2\text{O}$  (D) PCC,  $\text{CH}_2\text{Cl}_2$   
 (E)  $\text{LiAlH}_4$  in ether, then  $\text{H}_3\text{O}^+$  (F)  $\text{NaOH}$ , heat

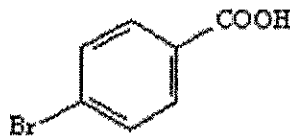
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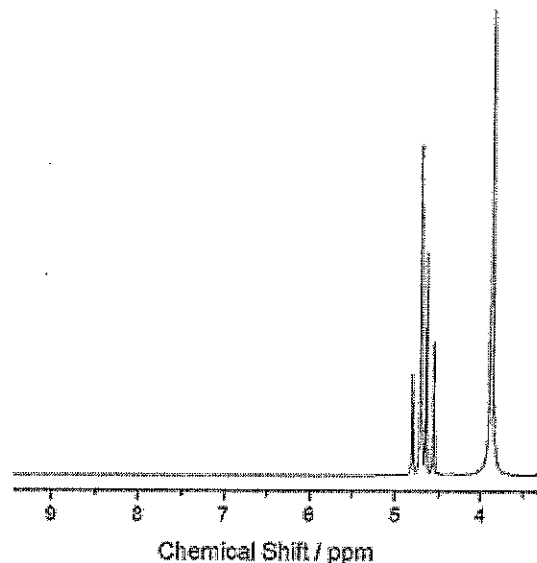
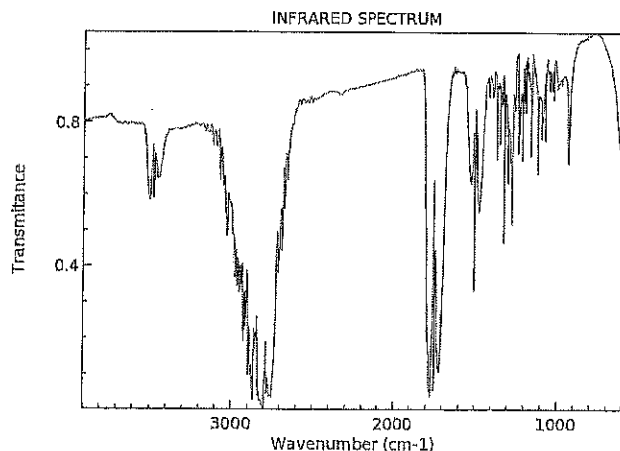
※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）（混合題）

共 4 頁第 4 頁

4. Starting with benzene or toluene, how would you synthesize this compound? Assume *ortho* and *para* isomers can be separated. (10 pt)



5. A forensic investigator is examining the composition of a chemical substance that has caused a fire incident and resulted in discomfort for individuals at the scene after inhalation. However, the investigator currently only has the FTIR (Fourier-transform infrared spectroscopy) and NMR (Nuclear Magnetic Resonance spectroscopy) data of the substance. Please help analyze the composition of this chemical substance and provide your analysis reasons. (Hints: There is only one chemical. The chemical is made from C, H, O atoms.) (10 pt)



Above the left image and right image are the FT-IR and NMR used by the forensic analysis office to identify the unknown chemical, respectively. (<sup>1</sup>H NMR spectrum of the unknown chemical in (Methyl sulfoxide)-d<sub>6</sub>)