國立臺灣師範大學 105 學年度碩士班招生考試試題

科目：**普通物理** 適用系所：**物理學系**

注意：1.本試題共 3 頁，請依序在答案卷上作答，並標明題號，不必抄題。2.答案必須寫在指定作答區內，否則依規定扣分。

1. An electronic device has two bolts attached to different parts of the device where the gap between each other in its interior is very small, as shown in Figure 1. The two bolts are made of different materials and are at different electric potentials. The initial gap between the ends of the bolts is d at 25 ^{o}C. Assume the distance between the walls of the device is not affected by the temperature change. The length at 25 ^{o}C and the linear expansion coefficient are L_1 and α_1 for bolt on the left side; L_2 and α_2 for bolt on the right side, respectively.

   (1) At temperature T, the two bolts touch, and a short circuit develops, damaging the device. Please derive the initial gap d in terms of L_1, α_1, L_2, and α_2, and T. (5 points)

   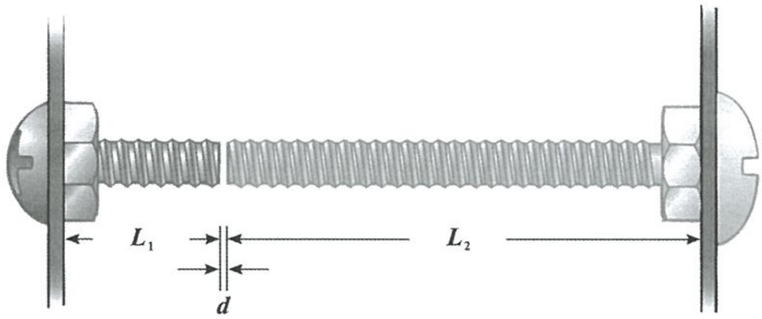

   Figure 1

   (2) The bolt on the right side is made of a mysterious conducting material, and its linear expansion coefficient, α_2, is negative. Please find out the range of α_2, for this device to work properly between 0 ^{o}C and 100 ^{o}C. (10 points)

2. Conservation laws are fundamental and very important concepts in physics, and they are presented in different forms for different field in physics. The followings are two multiple-choice problems concerning conservation laws:

   (1) Which of the following equations, rules, and laws is derived according to conservation of energy? (A) Ampére's law, (B) first law of thermodynamics, (C) Kirchhoff's loop rule of electronic circuits, (D) Bernoulli equation, (E) Kirchhoff's junction rule of electronic circuits. (12 points)

   (2) Which of the following conservation laws can be described by equation of continuity? (A) momentum conservation, (B) mass conservation, (C) entropy conservation, (D) charge conservation, (E) spin conservation. (8 points)

3. Quantum dots are confined solid-state nano-structures made from materials of different energy band gap, and inside the quantum dots, electrons occupy discrete energy levels. These energy levels inside a quantum can be described by hydrogen-like atoms,

$$E_n = (-13.6)\frac{Z^2}{n^2} \ \text{(eV)},$$

where Z is the atomic number of the hydrogen-like atom, and n is the principal quantum number. A researcher carried out experiments on certain quantum dots and found out that energies of three consecutive levels are -489.6, -217.6, and -122.4 eV, respectively. Please determine the corresponding atomic number Z of the quantum dots and the principal quantum number n of the lowest energy level. (10 points)

4. Hall effect is the powerful method to determine the type and density of charge carriers in a conducting material with current flow and an external magnetic field. Figure 2 depicts a semiconducting slab, whose lengths along x-, y-, and z-axis are b, a, and c, respectively. A current I flows towards $+y$-direction, and an external magnetic field B pointing to $-z$-direction is applied.

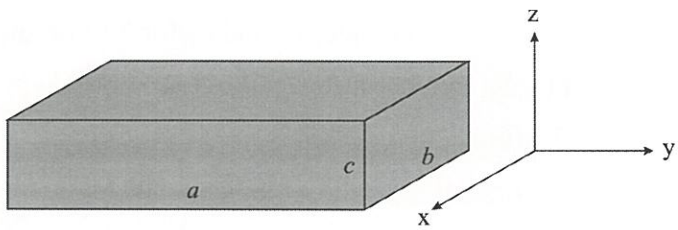

Figure 2

(1) When the semiconductor is p-type, current flow is due to motion of positively charged holes. In which direction will the holes be deflected by the magnetic field? (5 points)
(2) When the semiconductor is n-type, current flow is due to motion of negatively charged electrons. In which direction will the electrons be deflected by the magnetic field? (5 points)
(3) Please derive the relationship between Hall potential V_H and the magnetic field B. The carrier density of the semiconductor is n_q. (10 points)

5. Due to the particle-wave duality of matter in quantum theory, electrons and ions can be applied to acquire diffraction patterns of crystals. The angular position of the diffraction maxima can be found with the formula of single-slit diffraction in optics,

$$d \sin\theta = n\lambda,$$

where d is the lattice spacing and n is the order of diffraction.
(1) Derive the wavelength of a charged particle of mass m and charge q when it is accelerated by a potential difference of V. Note that for diffraction, the potential difference is small that the motion of such charged particle is non-relativistic. (5 points)
(2) When we use the same potential difference to accelerate electrons and protons for diffraction, which will give us better resolution? Explain your reason. (6 points)
(3) For a potential difference of 100 V, a first-order electron diffraction peak of a single crystal

material is observed at a diffraction angle of 30.0°. The mass of an electron is 9.11×10^{-31} kg. Find the lattice spacing of this material. (4 points)

6. One small section of three dominos in a domino game is shown in Figure 3, where the friction between dominos and the ground is negligible. The masses of the three dominos have the ratio that m_1: m_2: m_3 = 1:2:6. The motion of the dominos can separated as the following three parts:

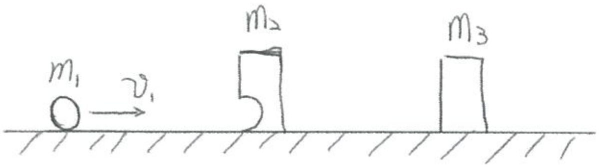

Figure 3

   (1) Domino m_1 moves to the right with a speed of v_1 and hit domino m_2. After m_1 hit m_2, m_1 will stuck in the hole of m_2, and they move as one domino with a speed v_2. Please express v_2 in terms of v_1. (4 points)
   (2) The composite domino of m_1 and m_2 then collides elastically with m_3. After collision, m_3 moves with a velocity v_3, derive v_3 (both magnitude and direction) based on elastic collision. (8 points)
   (3) After the elastic collision with m_3, domino m_2 does not move but m_1 moves with a velocity v_4. Find the velocity v_4 (both magnitude and direction). (8 points)