外国語科目　　20　大修

（物質電子化学専攻・物質科学創造専攻・材料物理科学専攻）

English Examination

Time: 14:00 – 15:00

Instructions:

1. Please confirm that there are **three** answer-sheets to be filled in.
2. Please write your **application number** on **each** of the three answer-sheets.
3. Please answer each Problem (**in English**) on a **separate** answer-sheet on which you have clearly written down the **Problem number** (I, II or III).

Problem I.

Read the following text and answer the questions.

Even the smallest components in a modern desktop computer use tens of thousands of electrons at a time to implement classical logic (the conventional 1s and 0s of binary computation). A computer that operated on single electrons, however, could in principle implement quantum logic functions (quantum bits or "qubits" that could perform computational tasks beyond the ability of classical computers). One proposed architecture for a single-electron computer could be realized in a two-dimensional electron gas (2DEG), a special kind of reservoir in which electrons can travel without dissipation.[1] Fève *et al.* report on an important step toward this vision: a device that can emit single electrons into a 2DEG and absorb them again on nanosecond time scales. With such a controllable electron source, researchers will now be able to set up one or more electrons in well-defined quantum states, which are crucial for any future quantum computer.

A macroscopic electric current, as measured by an ammeter, is the result of the movement of many discrete charges around a circuit. But this discreteness manifests itself as "shot noise"—one of the sources of random fluctuation in the current that engineers need to understand in order to design working components and circuits. Shot noise was first observed by Schottky in 1914, but it was not until the late 1980s that advances in nanofabrication technology first enabled control over the movement of individual electrons, giving birth to the field of single electronics.

The key requirement of a single-electron device is that a small (typically <100 nm) conducting island should be isolated from the rest of the electrical circuit by tunnel barriers, thin regions of insulator through which electrons can "tunnel" according to the laws of quantum mechanics. If the island is small enough, the number of electrons it holds can be changed precisely by adjusting external voltages. Suitable islands and tunnel barriers have been made with metals and metal oxides, and also with the versatile gallium arsenide 2DEG system, which has the additional advantage that the height of the tunnel barriers can be changed easily with a control voltage, making it more or less likely for electrons to pass through. Islands formed in a 2DEG are usually referred to as "quantum dots" or "artificial atoms," because the electrons trapped inside them occupy quantum energy levels similar to those in a real atom.

By combining tunnel barriers with one or more islands, researchers can make charge detectors with subelectron resolution, called single-electron transistors, as well as devices, known as turnstiles[2] or pumps, that can transfer electrons one at a time from a source to a drain electrode. Pumps and turnstiles continue to be of great interest to the electrical metrology[3] community because they offer a new way of generating an accurately known dc current — a primary standard —

based on only the electronic charge *e* and frequency *f*. Pumps based on metal-oxide technology and on gallium arsenide 2DEGs are being extensively studied.

An extract from "One Electron Makes Current Flow" written and reported by Stephen Giblin
Science **316**, 1130 - 1131 (25 May 2007)

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(1) *dissipation*: the process of making something gradually weaker or less until it disappears
(2) *turnstile*: a small gate that spins around and only lets one person at a time go through an entrance
(3) *metrology*: the science of measurement

Questions

I-1. Answer the following questions in English.

(i) Name the thing that is proposed as architecture for a single-electron computer and briefly explain what it is.

(ii) Why is controlling the size of conducting islands so important for the single-electron devices?

(iii) How do the modern desktop computer and the single-electron computer differ in operation?

I-2. Indicate whether the following claims are true (T) or false (F).

(i) The technology based on "shot noise" had been established in nanofabrication before the late 1980s.

(ii) The movement of discrete charges around a circuit can be the sources of random fluctuation in the current.

(iii) Devices known as pumps that can transfer electrons one at a time from a source to a drain electrode can be constructed by the combination of tunnel barriers and islands.

(iv) According to the laws of quantum mechanics, electrons can "tunnel" through thin regions of insulator.

Problem II.

Questions

II-1. Make the following sentences logical and grammatically correct by choosing the most appropriate word or phrase in the parentheses.

The electric resistance in our sample displayed a positive linear dependence (**1:** of / on / to / with) the magnetic field.

The depth of sleep (**2:** can measure/ can be measured / measured / measures) by the amount of sound needed to awaken the sleeper.

In addition to (**3:** be produced / produce / provide / providing) a possible explanation for the behavior, our model suggests potential routes for the construction of magnetic field sensors (**4:** above / at / on / with) a large response.

Newton found out that there is a force that causes everything (**5:** fallen / falling / to fall / which falls) toward the ground.

The catalogue is (**6:** far from / less of / not hardly / nothing at all) complete.

The materials are (**7:** promise / being promised / promising / to promise) candidates (**8:** for / in / of / about) magnetic field sensors.

If we continue to use fossil fuels at the present rate, we (**9:** may run short from/ should run onto / will run out of / would run out from) them in the near future.

II-2. Make the following sentences logical and grammatically correct by putting the words in the parentheses into the correct order.

1. Electric fuses contain an alloy (a / low / melting / point / with).
2. Two (by / makes / multiplied / six / twelve).
3. She is (best / in / second / student / the) her class.
4. Mars is a relatively small planet, (about / diameter / half / the / with) of Earth.

Problem III.

The greenhouse effect is an increase in the temperature of a planet because certain gases such as CO_2 gas in the atmosphere trap energy from the sun. The figure below shows some simplified processes of the greenhouse effect. Describe each process from ① to ④ with one or two complete sentences in English. Scientific accuracy is less essential than the general fluency and the grammatical correctness of your description.

Example: ⑤ Some infrared radiation passes through the atmosphere, and some is absorbed and reemitted in all directions by greenhouse gases.