Sub-course : Natural Science: Basic Questions and Applications

	Course title	[Code]	(Credits)
Undergraduate students:	Summer Program in English Ⅲ	［24N3051］	(2)
Graduate students:	Special Lectures in Humanities and Sciences Ⅲ	［24S0153］	(2)

1. Description

Research in natural sciences is advancing day by day. This sub-course provides lectures comprising four subjects to learn about recent advances in several areas of natural sciences: mathematics, physics, chemistry, biology, and computer science. Students can learn about each subject from basics to the latest topics through this sub-course.

2. Teaching Day and Time

Day	Time	Lecturer	Topic/Contents	Place
July 19 Fri	17:00-	Prof. Takanori KONO	Course Orientation	Room A 2F, Plaza
July 23 Tue	9:30 – 12:40	Prof. Minoru SODA	Magnetism, dielectricity, and multiferroics	Room A 2F, Plaza
July 24 Wed	9:30 – 12:40	Prof. Takanori KONO	Subatomic physics and particle detection	Room A 2F, Plaza
July 25 Thu	9:30 – 12:40	Prof. Sin Yi Tsang	An Introduction to Group Theory and its Applications	Room A 2F, Plaza
July 26 Fri	9:30 – 12:40	Prof. Takayuki ITOH	Computer Graphics and Information Visualization	Room A 2F, Plaza
July 29 Mon	13:30 – 16:00	Prof. Takanori KONO	Field trip (National Museum of Nature and Science)	Ueno, Tokyo
July 31 Wed	9:30 – 12:40	Prof. Mitsuhiko MIYAZAKI	Molecules, light, and colors. The quantum chemical foundations	Room A 2F, Plaza
Aug 1 Thu	9:30 – 12:40	Prof. Hiromu MONAI	• A brief history of brain science research and development of the tool of neuroscience • How to make your brain smarter	Room A 2F, Plaza

3. Class Contents:

Topic: Magnetism, dielectricity, and multiferroics

Prof. Minoru SODA

Magnetic and dielectric materials have been used in various applications. Magnetic and dielectric properties of materials are responded by the magnetic and electric fields, and these properties are discussed by the magnetic and electric dipole moments. Recently, strong coupling between magnetism and dielectricity has attracted great attention. In some materials, an electric polarization P is controlled by a magnetic field H, and a magnetization M is also changed by an electric field E. This is known as the magnetoelectric (ME) effect. In the linear ME effect, in which P and M are in proportion to H and E, respectively, the coupling constant is small. In contrast, the ME effect in multiferroics where an electric polarization and a magnetic order coexist is nonlinear and strongly enhanced. In this lecture, I will talk about the fundamental magnetism and dielectricity, and the recent topics of the unique relationship between the magnetism and dielectricity.

Topic: Subatomic physics and particle detection

Prof. Takanori KONO

Understanding the fundamental building blocks of nature is a very basic question in science. The discovery of the atomic structure of matter has been a great milestone in modern science. In the first part of the lecture, I will review our current understanding of the microscopic structure beyond atoms. In the second part, I will explain experimental techniques to detect individual particles and how we can derive physical picture from observed data.

Topic: An Introduction to Group Theory and its Applications

Prof. Sin Yi TSANG

A group is a set equipped with a binary operation satisfying certain axioms. For example, the integers modulo n form a group under addition and the non-zero real numbers form a group under multiplication. We shall see some other examples of groups in the lecture. After a brief introduction to group theory, we shall discuss some of its applications, in check digit algorithm, cryptography, and Rubik cube, for example.

Topic: Computer Graphics and Information Visualization

Prof. Takayuki ITOH

Recent computer graphics techniques archived realistic and fine representations. It has the power to convert data into visual messages. The former part of this class introduces fundamental computer graphics techniques that are used in various industries including engineering design and entertainment. The latter part introduces information visualization techniques that make visual

representations of daily information.

Topic: Molecules, light, and colors. The quantum chemical foundations.

Prof. Mitsuhiko MIYAZAKI

The appearance of a substance that we see originates from interaction between light and molecules composing the substance, and is finally recognized by our brain through neural action. To understand this phenomenon, it is required to know both molecules and light based on quantum chemistry. In this lecture, I would like to explain fundamentals of what is the color of matter and what happens to the energy of light, based on quantum chemistry of molecules and light.

Topic: A brief history of brain science research and development of the tool of neuroscience

Prof. Hiromu MONAI

In this lecture, we will review the fundamental discoveries of the brain and how our understanding of the brain and mind has evolved. We will also explore the technological advancements developed to monitor brain activity, as the functioning of the living brain is not visible to the naked eye. Researchers have faced significant challenges in observing this "invisible brain function," but their curiosity and passion have led to recent breakthroughs in neuroscience.

Topic: How to make your brain smarter

Prof. Hiromu MONAI

Astrocytes are a kind of brain cell. We thought they were supporting cells for neurons for a long time, such as maintenance of the extracellular environment and energy supply to neurons.
But now we know they are doing more than that. Our lab has developed a system to observe neuronal and astrocytic activities using calcium fluorescence imaging in living mice. When we electrically stimulate the brain with a weak direct current, calcium levels in astrocytes go up, making the transmission between neurons more efficient and enhancing the mice's sensory functions. But detectable neuronal activities didn't show any apparent changes during stimulations. Also, animals with more developed intelligence and cognitive functions, like cats or humans, have more astrocytes per neuron. That is why we think astrocytes are essential for brain functions.

4. Evaluation

The final grade for the course will be determined by the evaluation of Reaction papers. Each participant must submit one paper per lecture, i.e., four papers in total.