# Department of Systems Innovation

2021 Online Written Examination:
Problems Designed to Test Ability of Logical Thinking
Field 3: Earth and planetary science/engineering and frontier resources

## Question 3-1

Several space agencies, including NASA and JAXA, have announced that they are planning to jointly build a space station in the lunar orbit over the next 5-10 years. The primary objectives are to activate lunar developments and to establish technologies for the developments of extraterrestrial resources. Commercial space companies have plans for future missions to the Moon and asteroids for resource exploration, as well as manned Mars missions. The earth-based technology of resource development will be used out in space.

(1) The Apollo program attempted lunar drillings in the 1970s when it reached only about 3 m. In 2019, a new Mars lander, Insight, began excavation on Mars. The original plan was to excavate as deep as 5 m, while it reached only about 40 cm for over a year. Thus, the drilling or excavation on the Moon or Mars is more difficult than that on the earth. Considering the environmental difference between these bodies and the earth, describe the possible technical reasons why drilling or excavation on the Moon or Mars is more difficult.

(2) Hydrogen and carbon are the abundant elements in the solar system, and thus, hydrocarbons commonly exist. For example, Titan, a Saturnian satellite, is covered by large quantities of solid and liquid hydrocarbons. Similarly, hydrocarbons are abundant on earth. Identify hydrocarbons that we use or may use in the future as resources and naturally exist as (a) liquid and (b) solid in the crust of the earth. Then, describe their geological origins, occurrences, and techniques for their efficient exploitation.

(3) Some extraterrestrial materials might be useful in space explorations to significantly reduce the costs of space missions over the next few decades. Suggest a valuable material and describe where and how to use it. If other materials are necessary for the utilization, describe how to get them as well.

# Question 3-2

Due to the COVID-19 pandemic, global daily $CO_2$ emissions in April 2020 were estimated to be 17% lower than the average in the previous year[1]. The figure shows the global daily fossil $CO_2$ emissions ($10^6$ t-C/day; carbon equivalent) from 1960[1,2]. In the figure, the value of each year from 1960 to 2019 corresponds to the annual average. On the other hand, the data for 2020 is that of April 7th, which is the estimated minimum value between January and April. The green area shows an uncertainty range.

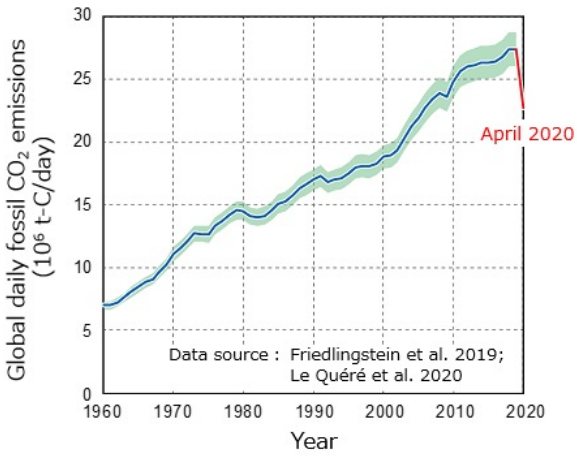


Figure Global daily fossil $CO_2$ emissions

(1) The estimated daily fossil $CO_2$ emissions in 2020 decreased at a rate unseen in the past 60 years. However, the emissions seem to return only to the level of 2006. Based on this fact, describe issues regarding the trend of global fossil $CO_2$ emissions.

(2) Based on the issues described in (1), describe what you think are appropriate measures to be taken against the global fossil $CO_2$ emissions in the future.

1. Le Quéré, C. et al. Nature Climate Change 10, 647-653 (2020).
2. Friedlingstein, P. et al. Earth System Science Data 11, 1783-1838 (2019).