Department of Systems Innovation

Online Written Examination: Problems Designed to Test Ability of Logical Thinking #1

Question A1 (Choose one question from A1-A3)

There is a wide range of material selection when designing industrial products such as automobiles, ships, and aircraft. Therefore, the material selection is an important factor for determining the overall safety and overall performance of the industrial products. It is necessary to select appropriate materials after considering the product requirements under various constraints and characteristic features of each material.

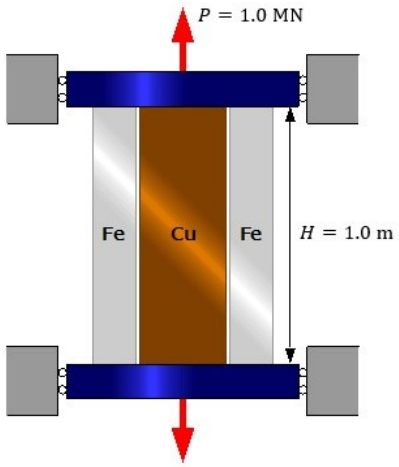

Figure Schematic of composite material consisting of copper alloy (Cu) and mild steel (Fe)

Table Mechanical properties of copper alloy (Cu) and mild steel (Fe)

Properties	Cu alloy	Mild steel
Young's modulus [GPa]	130	205
Yield strength* [MPa]	200	240

*In the case of copper alloy, the 0.1% proof strength is described instead of the yield strength.

(1) In recent years, composite materials, such as carbon fiber reinforced plastics, in which two or more different materials are integrally combined, are increasingly used. The figure schematically shows an example of a composite material consisting of copper alloy (Cu) and mild steel (Fe). The composite is connected to rigid bodies at both ends of the composite that are restricted to move in the loading direction, so that both materials always have the same displacements. The original height (H) is $1.0\,\mathrm{m}$ and the respective total horizontal cross-sectional areas of Cu (A_{Cu}) and Fe (A_{Fe}) are $0.05\,\mathrm{m}^2$ and $0.05\,\mathrm{m}^2$. Calculate the elongation of the composite when a tensile force of $P = 1.0\,\mathrm{MN}$ is applied by using the mechanical properties given in the table. Note that the force of gravity and other body forces are not considered here.

(2) Choose one industrial product either an automobile, ship, or aircraft, and list two or more material properties required for the structural materials that it is made of, excluding Young's modulus and yield strength. Then describe the experimental methods required for evaluating each property and the points to be considered in each evaluation.

Question A2 (Choose one question from A1-A3)

You have N mails in your mailbox. Each mail has its priority for replying, which is denoted by $x \in (0,1)$. At each time step, you either choose the mail which has the highest priority with probability p or randomly choose a mail with probability $1-p$. You reply to the mail you have chosen and delete it from your mailbox. After replying, you receive a new mail whose priority x is drawn from a uniform distribution on the interval $(0,1)$.

(1) First, let $N=2$ and $p=1$. Second, let A and B denote two mails you initially have and let x_{A} and x_{B} be the priorities of these mails, respectively, in the ascending order (i.e. $x_A < x_B$). Find the probability if the duration (the number of time steps) until you reply to the mail A is t .

(2) Next, let $N \gg 1$ and $p=1/2$. Consider the case that the above process (i.e. receiving and replying to mails) is repeated many times. Let $f(x)$ be the distribution function of the priorities x of the mails in your mail box and let $g(t)$ be the distribution function of the duration t (i.e. the number of time steps needed to reply to each mail). Then, describe the characteristic features of these two distribution functions $f(x)$ and $g(t)$, and sketch their curves.

Question A3 (Choose one question from A1-A3)

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.