Question 1 (Compulsory)

Describe each of the following 20 keywords related to environmental design.

（1）Basilica

A type of public building used for multiple purposes in ancient Roman cities. It has usually a rectangular plan with colonnade or arcades. It became one of the prototypes for later Christian church architecture.

（2）Sick building syndrome

Sick building syndrome is a term used to describe symptoms such as fatigue, dizziness, headaches, eczema, sore throats and respiratory illnesses caused by volatile organic compounds (VOCs) in building materials. As a countermeasure, use building materials that emit low levels of VOCs, such as formaldehyde, and ventilate the room at all times to reduce the concentration of VOCs in the room.

（3）Cooperative house

Cooperative housing is a housing supply method where multiple prospective residents jointly acquire land and work with a construction company to build housing. Its distinguishing feature is the ability to create homes that reflect everyone's preferences.

（4）Carbon negative concrete

Since a large amount of CO2 is emitted during cement production, this concrete reduces CO2 emissions by replacing some of the cement with blast furnace slag or other materials, or by fixing CO2 in the concrete.

（5）Nature-based Solutions

Nature-based Solutions refers to sustainable approaches that utilize the power of nature and ecosystem functions to effectively and adaptively address social challenges such as climate change, disasters, water scarcity, and biodiversity loss. It refers to solutions in harmony with nature, such as forest restoration, wetland conservation, and urban greening.

（6）Tatsuno Kingo

Japanese architect. After studying architecture at Imperial College of Engineering he trained future architects at the Imperial University of Tokyo while also operating architectural firms. His representative works include the head office of the Bank of Japan and Tokyo Station.

（7）Chemical weapon

A chemical weapon is made of toxic chemical substances such as poisonous gases used as weapons. Well-known examples include sarin, mustard, and VX gases, and some of them are used as gases directly and also by adsorbing them on solids and liquids. Chemical Weapons Convention prohibits their use in warfare. However, some of the countries have not joined this convention, and they are actually used worldwide. The chemical weapons are also used in terrorist attacks as reported in the news.

（8）The Limits to Growth

A report published by the Club of Rome in 1972. Computer simulations showed that if population growth and economic growth continued at the current rate, the supply of food and resources would not keep pace and would come to a standstill, sounding a warning to the world.

（9）COVID-19

A new type of coronavirus infection appeared in 2019 is referred to as COVID-19, and the symptoms include high fever and sore throat. Symptoms range from asymptomatic to severe cases, leading to fatal death in the worst case. This infection spread in 2020 and became a pandemic in 2022, but the WHO declared the end of emergency in 2023. However, many cases of infection are still being reported to date.

（10）Mies van der Rohe

Architect from Germany. After teaching at the Bauhaus, he moved to the U.S., where he used steel and glass to create universal spaces without limitation of use. His representative works include the National Gallery in Berlin.

（11）Ecosystem service

Ecosystem services are the benefits humans derive from the natural environment, classified into four categories: provisioning services such as food and water; regulating services such as climate regulation and water purification; cultural services such as recreation and spiritual fulfillment; and supporting services such as nutrient cycling and photosynthesis. These represent important natural capital that supports human well-being and economic activities.

（12）Vibration control of buildings

Vibration control of buildings is a structural system designed to reduce the building's response to earthquakes and strong winds by preventing resonance, adding damping forces, or absorbing input energy from external forces. In this system, dampers and other devices are incorporated into the structural frame, which supports the vertical load.

（13）Cross laminated timber（CLT）

A material with a structure of three or more layers, consisting mainly of laminates made of wood boards glued together so that the fibre directions are parallel to each other, and the fibre directions are almost perpendicular to each other. The use of this material is growing rapidly in many countries around the world, for example, as large panels for floors and walls in buildings.

（14）Specialization of environmental design

Using a building as an example, in primitive societies, house building itself was done by the dwellers themselves, and any dissatisfaction was to be given up as a limitation of their own abilities. In medieval society, although carpenters and other professionals were established from among those who excelled at house building, there was no significant friction between professional craftsmen and dwellers because of the implicit cultural norms shared about building. Today, as people's values and lifestyles diversify and as the uses of buildings become more specialized, specialists such as architects have emerged, and the gap between specialists and users has become increasingly problematic. Communication between designers and users is therefore becoming increasingly important.

（15）Shinden-zukuri style

It is a type of Japanese residence based on the aristocratic residences of the Heian period. The building layout is centered on the main building (*shinden*) with an open space to the south, surrounded by eastern or western building (*tai*) and *chumonro* corridor. Inside of the building are not partitioned like rooms, but spaces are arranged by movable furniture and partitions.

（16）Park system

Park system refers to a planning method in urban design that connects multiple parks and green spaces into a network using roads, waterways, and greenways. It was developed in 19th century America by landscape architects such as Olmsted and Cleveland. The approach creates a multifunctional green network that improves urban environments, provides recreational opportunities, and preserves ecosystems.

（17）Metabolism (architectural movement)

Architectural movement of the 1960s by young Japanese architects such as Kisho Kurokawa and Kiyonori Kikutake. They advocated that architecture should change like the metabolism of a cell. Part of this movement was realized in the pavilion at the Osaka Expo and the Nakagin Capsule Tower Building.

（18）Curtain wall

A wall that does not have a load-bearing function but is provided to demarcate space. By distinguishing outer walls from the framework as a structure, high-rise buildings with all-glass walls are possible.

（19）Area classification system

Area Division System is a framework based on Japan's City Planning Act that divides urban planning areas into Urbanization Promotion Areas and Urbanization Control Areas to prevent disorderly urban sprawl. In Urbanization Promotion Areas, development is actively encouraged, while in Urbanization Control Areas, urbanization is restricted. This provides a fundamental mechanism for land use control that promotes planned urban development while preserving natural environments and agricultural land.

（20）World Heritage Convention

Convention adopted by UNESCO in 1972 to protect and preserve cultural and natural heritage of outstanding universal value. Based on the Convention, the sites are registered as World Heritage sites and international assistance is provided.

Question 2 Answer the following questions on Structural Engineering.
For the cantilever beam shown in the figure below, answer (1) through (4). The second area moment of inertia is I and the section modulus is Z. The Young's modulus of the material is E.

(1) Calculate the support reactions. (10 points)

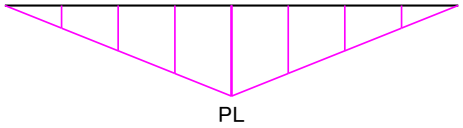
(2) Calculate the shear force and bending moment and draw the shear force and bending moment diagrams. (20 points)

(3) Calculate the maximum value of the concentrated load P that satisfies $\sigma \leq f$. Note that σ is the bending stress and f is the bending strength. (10 points)

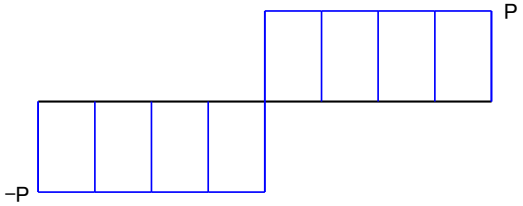
(4) Calculate the vertical displacement at point B. In the calculation, only bending deformation is considered. (10 points)

(1) Ry,c=P（Vertical upward force）

(2)



Bending moment diagram



Shear force diagram

(3) Pmax=fZ/L

(4)Vc=PL^3/EI（Vertical upward displacement）

Question 3 Answer the following questions on Building Materials.

(1) Explain what the alkali-silica reaction in concrete is, and list three possible measures to control it.

(2) Briefly explain what is needed to prevent wood decay and insect damage.

(3) Ceramic tiles are broadly classified into three groups based on their water absorption rate. Explain the desirable usage environment for each group.

(4) Schematically illustrate the stress-strain relationship of general steel (When the yield point is clearly visible), and illustrate the following six points “a” to “f” and “E”.

a. proportional limit b. elastic limit c. upper yield point d. lower yield point

e. tensile strength f. break point E. modulus of elasticity

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(1) Explain what the alkali-silica reaction in concrete is, and list three possible measures to control it.

Alkali-aggregate reaction (alkali-silica reaction) is a phenomenon in which alkali in cement reacts with some aggregate, causing the concrete to expand due to moisture, resulting in cracks that are cracked or reticulated.
The following measures can be taken to control this phenomenon.
(1) Do not use reactive aggregates (minerals).
(2) Reduce the amount of alkali in the concrete.
(3) Preventing water infiltration from the outside
(4) When Portland cement is used, reduce the total amount of alkali in 1 ㎥ of concrete to 3.0 kg or less.

The following concrete types may be used for (2).
(3) Use low alkali Portland cement.
Use blended cement (blast furnace cement or fly ash cement) Class B or C.

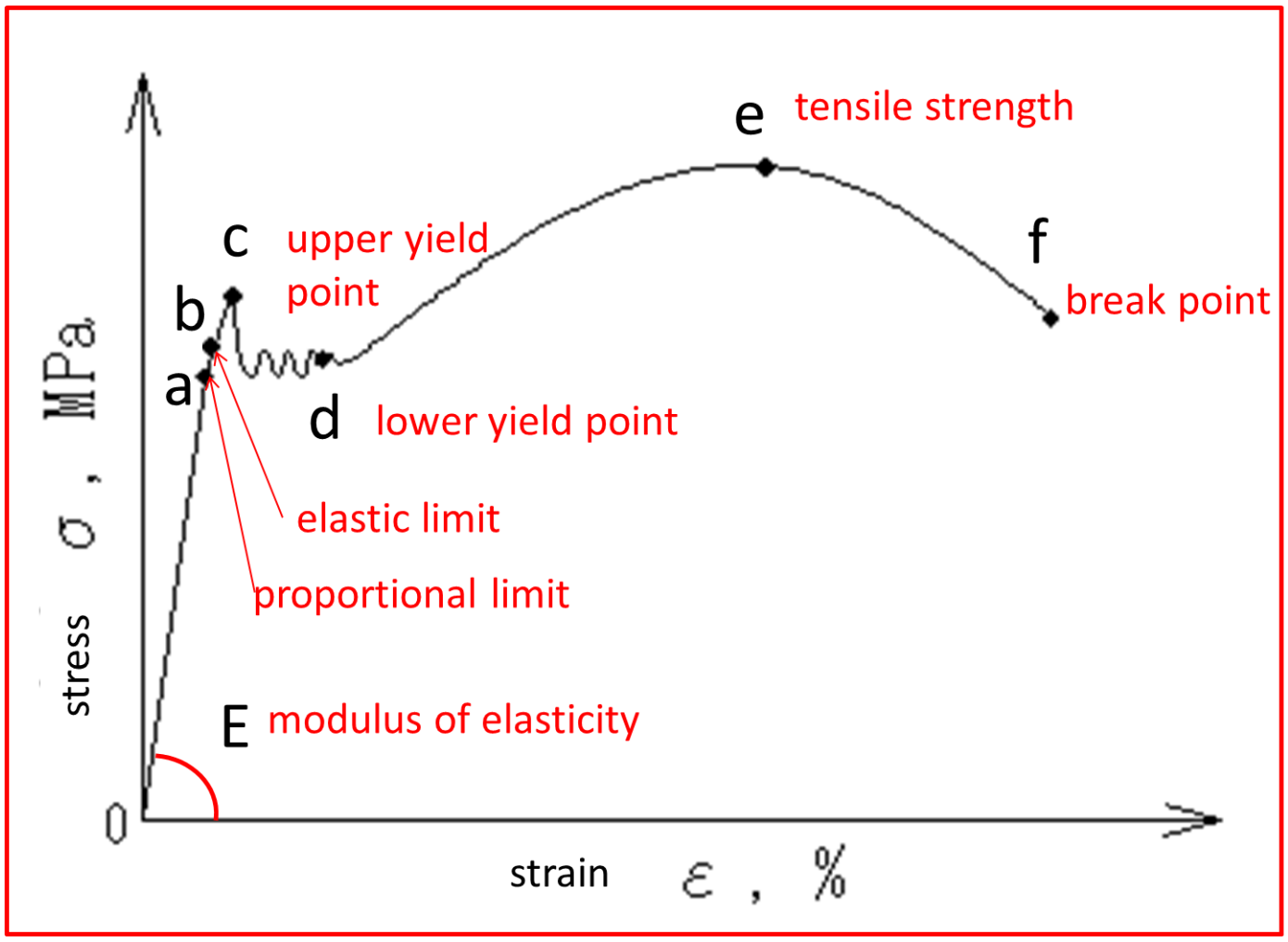
(2) Briefly explain what is needed to prevent wood decay and insect damage.

Wood decay and insect damage can be prevented by the lack of any one of the following breeding conditions for rotting fungi and insects: oxygen, temperature, moisture, and nutrient sources.

(3) Ceramic tiles are broadly classified into three groups based on their water absorption rate. Explain the desirable usage environment for each group.

Ceramic tiles are classified into Class I (porcelain), Class II (stone), and Class III (ceramic) according to water absorption. Type I tiles with low water absorption can be used both indoors and outdoors, while Type II and III tiles need to be considered in terms of resistance to frost damage. For Class II, which may be subject to frost damage, water absorption should be 3% or less for unalloyed tiles and 2% or less for treated tiles. Class III can be used for interiors. In cold climates, where water may come into contact with the tiles (e.g., bathroom walls), Class I and Class II tiles with proven frost resistance should be used because of the high risk of frost damage.

(4) Schematically illustrate the stress-strain relationship of general steel (When the yield point is clearly visible), and illustrate the following six points “a” to “f” and “E”.
a. proportional limit　b. elastic limit　c. upper yield point　d. lower yield point e. tensile strength　f. break point
E. modulus of elasticity



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Question 4 Answer the following questions on Environmental Engineering.

(1) A classroom with a volume of 200.0 m^3 had a carbon dioxide concentration of 1000 ppm at the end of class. At the end of the class, the classroom was unoccupied and carbon dioxide emissions were zero. Thirty minutes after the end of class, the carbon dioxide concentration in the classroom was 800 ppm. During this period, the ventilation rate remained constant. Calculate the amount of ventilation in this classroom when the concentration of carbon dioxide in the outside air is 400 ppm. Note that ln 2 = 0.69 and ln 3 = 1.10. Give the units in your answer. (15 points)

(2) Derive the one-dimensional unsteady heat conduction equation using Fourier's law. (15 points)

(3) Explain how to measure static pressure in a duct using a U-tube manometer. (10 points)

(4) Explain the principle of operation of a heat pump. (10 points)

(1)

When there is no carbon dioxide generation, the time variation in the indoor carbon dioxide concentration p is expressed by the following formula, using the outdoor carbon dioxide concentration p_0, the carbon dioxide concentration at the start of measurement p_1, the ventilation rate Q, the room volume V, and the elapsed time t.

$$p - p_0 = (p_1 - p_0)e^{-\frac{Q}{V}t}$$

If the unit of concentration is m^3/m^3 and the unit of time is hours,

$$p - p_0 = (800 - 400) \times 10^{-6} = (p_1 - p_0)e^{-\frac{Q}{V}t} = (1000 - 400) \times 10^{-6} \times e^{-\frac{0.5Q}{200.0}}$$

$$e^{-\frac{Q}{400.0}} = \frac{2}{3}$$

$$\ln\frac{2}{3} = \ln 3 - \ln 2 = 0.69 - 1.10 = -0.41 = -\frac{Q}{400.0}$$

$$Q = 164.0\ [\mathrm{m^3 \cdot h^{-1}}]$$

If the unit of time is seconds,

$$Q = 0.045\dot{5}\ [\mathrm{m^3 \cdot s^{-1}}]$$

(2)

In a steady state, the heat conduction through a unit area of a one-dimensional wall per second can be calculated using the following Fourier's formula.

$$q = -\lambda\frac{\theta_1 - \theta_2}{\delta} = -\lambda\frac{d\theta}{dx}\ [\mathrm{W \cdot m^{-2}}] \qquad (1)$$

λ [$\mathrm{W \cdot m^{-1} \cdot K^{-1}}$]: Thermal conductivity

θ_1, θ_2 [K or ° C]: Wall surface temperature

δ [m]: Wall thickness

Considering the time variation of temperature in a small part of a wall. The amount of heat flowing into a rectangular solid from the left is

$$\bar{q} = -\lambda S\frac{\partial\theta}{\partial x}\ [\mathrm{W}] \qquad (2)$$

On the other hand, the amount of heat flowing out from the right is

$$\bar{q'} = -\lambda S\frac{\partial}{\partial x}\left(\theta + \frac{\partial\theta}{\partial x}dx\right)\ [\mathrm{W}] \qquad (3)$$

The difference between these is the amount of heat stored in the volume of the wall during the unit time, and is expressed by the following formula.

$$\overline{q''} = c\rho dxS\frac{\partial\theta}{\partial t}\ [\mathrm{W}] \qquad (4)$$

Since $\overline{q''} = \bar{q} - \bar{q'}$, therefore,

$$\frac{\partial\theta}{\partial t} = \frac{\lambda}{c\rho}\left(\frac{\partial^2\theta}{\partial x^2}\right) = a\left(\frac{\partial^2\theta}{\partial x^2}\right)\ [\mathrm{W}] \qquad (5)$$

c: Specific heat [$\mathrm{J \cdot kg^{-1} \cdot K^{-1}}$]

ρ: Density of wall [kg・m^{-3}]

$c\rho$: Volumetric heat capacity [J・m^{-3}・K^{-1}]

a: Thermal diffusivity [m^{2}・s^{-1}]

$Vc\rho$: Heat capacity [J・K^{-1}]

(3)

A U-tube manometer is a device used to measure the pressure inside ducts and other such structures. There are two types of pressure: static pressure and dynamic pressure. Static pressure acts equally in all directions, while dynamic pressure acts only in the direction of flow. The sum of static and dynamic pressure is the total pressure. By making a hole in the side of the duct and taking a sample perpendicular to the flow, and then using a U-tube manometer to measure the difference from atmospheric pressure, it is possible to measure static pressure only, without being affected by the flow.

(4)

A heat pump uses the refrigeration cycle of a compressor-type refrigerator to provide both cooling and heating. A compressor-type refrigerator consists of a compressor, condenser, expansion valve and evaporator.

1. Compression process: Low-pressure steam refrigerant is compressed adiabatically by a compressor to produce high-temperature, high-pressure steam refrigerant. Mechanical energy from the compressor is used. Since adiabatic compression occurs, pressure increases, and specific enthalpy also increases as internal energy rises.
2. Condensation process: As the steam refrigerant is cooled under a constant pressure, when it drops below the saturation temperature, it releases its latent heat of condensation and becomes a liquid refrigerant. As heat is taken away from the outside, the internal energy decreases, and the specific enthalpy decreases. The pressure does not change.
3. Expansion process: When liquid refrigerant that is in a saturated state at high pressure is passed through an expansion valve (small hole) to the low-pressure side, some of the refrigerant evaporates on the low-pressure side and the temperature drops. The pressure decreases, but the specific enthalpy does not change because the work is due to expansion.
4. Evaporation process: The low-temperature vapor refrigerant and liquid refrigerant that have left the expansion valve enter the evaporator, where they absorb heat at a constant pressure and all the liquid refrigerant evaporates. The internal energy increases because heat is received from the outside, and the specific enthalpy also increases, but the pressure does not change.

In summer, the heat of vaporization of the refrigerant liquid is used for cooling (cooling), and in winter, the refrigerant circuit is switched and the heat dissipation in the condenser is used for heating (heating).

Question 5: Answer the following questions on Environmental Chemistry.

(1) The size of supplements market continues to expand year by year. A serious health hazard occurred in 2024, since some chemicals were accidentally produced in the process of rice fermentation using monascus (red yeast). Explain what is necessary to investigate the reason of occurring this health hazard from a scientific point of view. (20 points)

(2) A proposal was shared among numerous countries for aiming to eliminate the additional environmental pollution caused by marine plastic wastes by 2050 in the 2019 G20 Osaka Summit. Describe the possible approach to recycle the waste plastics. (15 points)

(3) The use of biofuels is desirable for achieving carbon neutrality. Explain what kind of biofuels are used in industry, what are biofuels used for, and what are the important characteristics of biofuels. (15 points)

[Sample Answer]

Question 5

(1) It is important to examine the lot of the red yeast product consumed by the patients who are confirmed to have health damage and to check whether it contains any toxic or harmful substances or not. It has been reported to date that it contained puberulic acid in the sample. Although identification of unknown substances is not easy, the analyte is currently separated by liquid chromatography and is measured by mass spectrometry for this purpose, in which the molecule is electro-spray ionized and is subsequently analyzed using a quadruple or time-of-flight mass spectrometer.

(2) There are a few types for recycling, i.e., thermal recycling that uses plastics as a fuel, chemical recycling that reduces the molecular weight and uses it as a raw material, and material recycling that are reproduced as new plastics. In Japan, thermal recycling is the most frequently used technique. However, chemical recycling and material recycling are referred as “recycling” in Europe and the United States. The Basic Act for Promoting the Creation of a Recycling-Based Society stipulates the priority order of processing as follows: reduce, reuse, material recycling, thermal recycling, and proper disposal.

(3) Fuels made from biomass include bio-aviation fuel that is an alternative to a jet fuel, bio-diesel fuel that is an alternative to a diesel fuel, and bio-ethanol fuel that is an alternative to a gasoline. From the perspective view of carbon neutrality, it has been attracting attention as a resource that can replace fossil fuels such as petroleum and coal. However, because it can be oxidized during a storage for a long period of time, care must be taken when using it as a vehicle fuel.