北海道大学大学院環境科学院環境起学専攻

Division of Environmental Science Development
Graduate School of Environmental Science, Hokkaido University

令和 9 年度大学院修士課程入学試験問題（秋季入試）

令和 8 年度 10 月入学大学院修士課程入学試験問題

Entrance Examination

専門科目　解答例

Specialized Subjects Example Answers

Environmental Science

Question 1

(1)

① 800; ② 2200

(2)

sub-Saharan Africa

(3)

40%

(4)

The main cause is the recent global increase in violent conflicts, particularly in food insecure regions, because they disrupt farming and **food supply chains** often causing large-scale food shortage that can derive in famine forcing mass migration of people from affected areas. These situations are aggravated by accelerating climate change, which devastate **agricultural yields**, compromising livelihoods of smallholder farmers and driving-up **food costs**. These factors, together with higher energy costs, repeated macroeconomic shocks, and the effects of the global policy response to the COVID-19 pandemic, have contributed to the recent persistent global food inflation disproportionately impacting **low-income countries** where households have lower purchasing capacity and allocate a much larger share of their income to food.

(5)

The six essential nutrients are comprised of three macronutrient (carbohydrates, protein, and lipids/fats), two micronutrients (minerals, vitamins), and water.

- Carbohydrates are the body's primary and most accessible source of energy. They are also sources of dietary fiber that supports the processes of digestion, regular bowel movements, and balanced blood sugar and food source for the gut microbiome.
- Fats are the building blocks for cells and for critical hormones, and they are required for the absorption of fat-soluble vitamins. They also protect vital organs and provide insulation to help regulate body temperature.
- Proteins are the vital building blocks of the human body, acting as the structural foundation for tissues, cells, and organs. They form enzymes that catalyse metabolic reactions and critical hormones (like insulin) that regulate body processes. They support the immune (antibody formation) and transport (haemoglobin for transport of essential molecules like oxygen) systems.

(6)

GM crops can cause **genetic swamping** through cross-pollination by transferring their engineered genes to sexually compatible wild relatives, possibly causing reduced genetic diversity. When this happens with herbicide tolerance traits, it can result in weeds that are more difficult to manage. Many GM crops are also engineered with internal pesticides to be **pest resistant**. These toxins negatively affect non-target organisms, such as pollinators, as well as increase the evolutionary pressure on the crop's pests and accelerate the development of resistant pest varieties. Finally, **herbicide tolerant** crops can encourage the indiscriminate application of herbicides, which can decrease native plant diversity and impact associated fauna, as well as impact soil and water ecosystems through runoff and groundwater seepage.

Question 2

(1)

During reproduction, as parental DNA is passed on to offspring, random **mutations** may occur in individual **genes** within reproductive cells (gametes), which are then passed over subsequent **generations**. **Mutations** may be associated with variations in morphological or physiological **traits**. Natural **selection** is then the process by which environmental conditions in a particular area favour certain characteristics or **traits** over others resulting in individuals with those **traits** having a competitive advantage in those habitats. As a result, **evolutionary adaptation** in a species happens as individuals inheriting advantageous **traits** persist over **generations** and the **genes** associated with those traits eventually become **dominant** in the population.

(2)

The primary difference is how these two pollutant sources enter a waterbody. Point sources originate from a single, identifiable, and confined location (like the effluent coming out from a pipe in a factory or sewage plant), while nonpoint sources come from diffuse, scattered, and unconfined areas (like farmland or construction sites) driven by rainfall and runoff or groundwater seepage.

(3)

Of the solar energy that reaches the earth's surface, most is absorbed by land and water. This energy is then gradually re-emitted as long-wave **infrared radiation**. Certain gases in the atmosphere, especially carbon dioxide and water vapor, are **called greenhouse gases** because they absorb much of this **infrared radiation** and re-release it in the **lower atmosphere**. If these gases were not in the atmosphere, the earth's average surface temperature would be much colder than it is (about −18°C instead of 15°C).

(4)

Examples of POPs include PCBs, pesticides (DDT, aldrin, chlorpyrifos), dioxins and furans. They can persist for a long time in the environment without degrading or losing toxicity, have also a propensity for long-range transport, and because they are lipophilic (fat-soluble) they bioaccumulate up the food chain to reach toxic concentrations in long-living top predators including humans.

(5)

Total global renewable energy generation has been steadily increasing since 1965 with a particularly sharp rise since 2000. This sudden acceleration from around 2000 has been mainly driven by a rapid increase in the share of wind energy to the total energy, and of solar and other sources to a lesser extent. Meanwhile the rate of growth of hydropower energy remained approximately unchanged as the previous decades although its relative share has decreased significantly. While energy demand tends to remain at relatively stable levels, power generation from renewable energy sources is characterized by its temporal instability because it is influenced by various natural conditions. Therefore, effective electricity storage is necessary to stabilize the supply of renewable energy resources.

(6)

The Montreal Protocol is an international treaty to protect the ozone layer by legally requiring countries to phase out the production, trade and consumption of human-made chemicals that deplete the ozone. The CITES is a global treaty that regulates international trade in endangered wild animals and plants to ensure it is legal, sustainable, and traceable, thereby contributing to their conservation.

(7)

Superbugs are microbes that have evolved to resist antibiotics. The indiscriminate and constant use of antibiotics leads to the natural selection of resistant strains dominating their populations, causing major health problems and huge treatment costs. Examples include CRE (carbapenem-resistant enterobacteriaceae), *Clostridioides difficile* or *Staphylococcus aureus* (MRSA).

(8)

The principle of **competitive exclusion** means that two species with the same ecological niche cannot coexist indefinitely under conditions of limited resources because the superior competitor will ultimately exclude the other species. **Resource partitioning** involves the division of available resources (like food, space or time) among species sharing similar ecological niches to minimize competition and facilitate coexistence through **niche specialization**. In the example, several species of warblers foraging on insects in the same trees avoid competitive exclusion by specializing in different levels of the forest canopy, or in inner and outer branches.

Physics

Question 3

(1)

Relative humidity is the ratio of the actual amount of water vapor present in the air to the maximum water vapor density (saturation vapor density) the air can hold at a given temperature. It is expressed as a percentage.

Atmosphere-ocean coupled model is a type of climate model that combines a numerical weather prediction model with a model that predicts large-scale ocean circulation. It is used to predict climate change and understand long-term climatic phenomena.

Spiral band refers to band shaped cloud structures aligned with the inflowing wind field that wraps into the tropical cyclone center, which exhibit a spiral pattern and become nearly circular pattern near the center.

A wind profiler enables continuous observations of upper air winds by transmitting radio waves into the atmosphere and analyzing the scattered signals. The motion of the air is inferred from the frequency shift between the transmitted and received waves.

(2)

(a) Atmosphere: aerosols, clouds

Ocean: sea ice

(b) The cross-sectional area over which the Earth intercepts solar energy is πr_e^2 . Since the fraction A (albedo) is scattered or reflected, the energy actually absorbed by the Earth becomes $(1-A)I_0\pi r_e^2$. The energy radiated by the Earth into space is $I_e \cdot 4\pi r_e^2$, which is obtained by multiplying the Earth's surface area $4\pi r_e^2$ by the radiative intensity I_e. Under radiative equilibrium, these balance, yielding:

$$I_e \cdot 4\pi r_e^2 = (1-A)I_0\pi r_e^2$$

(c) 240 W m^{-2}

Concerning the relationship answered in (b), dividing both sides by $4\pi r_e^2$ gives:

$$I_e = \frac{(1-A)I_0}{4}.$$

Substituting the values into the equation from (b),

$$I_e = \frac{(1-0.3)\times 1370}{4} = 239.75$$

Rounding to the nearest integer gives 240 W m^{-2}.

(d) This is the law stating that the energy radiated per unit area per unit time (radiative intensity) from a black body is proportional to the fourth power of its absolute temperature. The proportionality constant is known as the Stefan-Boltzmann constant.

(3)

(a) ① convergence ② Hadley ③ high pressure ④ Ferrel

(b) The northeasterly trade winds have an easterly component because air flowing toward the equator in the Northern Hemisphere is curved to the right by the Coriolis force. In the Southern Hemisphere, the deflection is opposite, producing the southeasterly trade winds.

(c) ⑤ z, ⑥ y

(d) In the midlatitudes, air temperature decreases poleward, giving $dT/dy < 0$. The meridional temperature contrast becomes larger with increasing height, strengthening the vertical wind shear associated with the thermal wind. As a result, the westerly geostrophic wind increases with height, forming a jet maximum near the tropopause.

(e) Choice (i) is appropriate.
Precipitation is large in the ITCZ and the midlatitude, where strong upward motion occurs, and small in the subtropics, where subsidence dominates. Evaporation generally decreases with latitude, but it becomes larger in the subtropics than at the equator because cloud cover is small and solar radiation is strong.

(f) In Fig. 3, the difference between precipitation and evaporation is negative in the subtropics and positive near the equator and in the midlatitudes. Consequently, it produces higher salinity of sea surface water in the subtropics.

Ecology and Geography

Question 4

(1)

(a)

A stepped landform in which a formerly flat floodplain is left stranded at a higher elevation as a result of river incision with a relative lowering of the riverbed due to uplift or sea level fall.

(b)

A low, flat landform that spreads outward at the point where a river flows into a standing body of water, such as the sea or a lake, with sediment deposition due to the decrease in flow velocity.

(c)

A landform created near the mouth of a valley, where a mountain torrent or debris flow emerges onto flat ground and, having lost its transport capacity due to the abrupt decrease in gradient, deposits sand and gravel in a cone shape.

(d)

A volcano with a large circular or elliptical depression larger than its crater, formed when a catastrophic eruption ejects volcanic ash and pyroclastic flows, causing the magma chamber to empty rapidly and the ground surface to collapse.

(2)

(a)

The Toyoni surface is the oldest. Marine terraces form through emergence caused by the relative uplift of the land, and the longer the time elapsed since emergence, the higher the terrace surface is positioned.

(b)

Crustal uplift continuously pushes the land upward, producing the relative differences in elevation among the terrace surfaces. Glacial–interglacial sea-level change provides the timing for terrace formation: a wave-cut platform forms during a high sea-level stand in an interglacial period, and this surface then emerges as sea level falls during the subsequent glacial period.

(c)

The soil surface undergoes repeated seasonal freezing and thawing, causing

solifluction, in which saturated soil material moves downslope under gravity. This gradually moves the material composing steep slopes to ease the gradient.

(d)
Soil derived from the peridotite has a chemical composition that is rich in magnesium and heavy metals and poor in calcium, which suppresses the growth of trees, and the tree line is lowered, allowing alpine plants, freed from competition with trees, to establish even at the comparatively low elevation.

(e)
Direct management by the national government makes it possible to enforce protective regulations based on uniform, nationwide standards and to secure stable funding and specialized personnel.

(f)
Residents of a country already bear the costs of maintaining and developing a park through taxation, and from a benefit-based cost-sharing perspective, it is reasonable to charge non-residents an additional fee. This can also help secure funding for measures against overtourism and conservation projects.

Ecology and Geography

Question 5

(1)

(a) Individuals are single, independent living organisms. Populations are groups of individuals of the same species inhabiting a particular area and capable of interbreeding. Populations consist of many individuals.

(b) Primary producers are organisms that produce organic matter from inorganic substances through photosynthesis or other processes. Primary consumers are organisms that obtain organic matter and energy by feeding on primary producers.

(2)

(a) As the climate warms, populations at the southern edge of a species' range may be unable to adapt to higher temperatures and undergo local extinction. In contrast, northern areas may become suitable for survival and reproduction, resulting in the establishment of populations. As a result, the center of the species' range shifts northward.

(b) Species differ in their physiological and ecological traits (e.g., thermal tolerance and developmental rate), resulting in species-specific effects of climate warming on survival, growth, reproduction, and establishment in newly suitable habitats. Therefore, changes in distribution range, shifts in phenology, and changes in population size vary among species.

(c) Climate warming advances the emergence of moth larvae, causing a mismatch between the breeding season of great tits and the peak abundance of their food resources. As a result, food availability is reduced during the period when great tits are feeding their nestlings, leading to lower breeding success.

(3)

(a) An increase in the rat population directly increased predation pressure on seabirds, resulting in a decline in their population size (direct effect). In addition, the increase in the rat population led to an increase in the cat population and consequently higher predation pressure on seabirds, causing a further decline in the seabird population (indirect effect).

(b)Because cats preyed on both seabirds and rats, eradication of cats removed predation pressure on rats, allowing the rat population to increase. The increased rat population then exerted greater predation pressure on seabirds, ultimately causing a decline in the seabird population.

(c)Eradicating both cats and rats simultaneously is most desirable. If this is not feasible, the rat population should first be reduced before cats are removed.

Chemistry

(1)

(a)

Curve i corresponds to the 2s orbital, curve ii to the 3s orbital, and curve iii to the 1s orbital.

(b)

The 1s orbital is the smallest, and the orbital size increases in the order 1s, 2s, and 3s. This is because, as the principal quantum number increases, the probability of finding an electron extends over regions farther from the nucleus. In addition, the orbital energy increases from 1s to 2s to 3s, and the number of radial nodes also increases in the same order, from 0 to 1 to 2.

(2)

(a)

Ozone can be represented by $O{=}O^{+}{-}O^{-} \leftrightarrow {}^{-}O{-}O^{+}{=}O$. In one structure, the left O–O bond is a double bond and the right O–O bond is a single bond, whereas the opposite arrangement is found in the other structure. The actual ozone molecule is a resonance hybrid of these two structures, in which the π electrons are delocalized over both O–O bonds. As a result, each O–O bond has an average bond order of 1.5. Therefore, the two O–O bond lengths are identical, being shorter than a single bond but longer than a double bond.

(b-1)

The reaction rate can be expressed in terms of the stoichiometric coefficients as

$$v = -\frac{1}{2}\frac{d[O_3]}{dt} = \frac{1}{3}\frac{d[O_2]}{dt}$$

where the rate of disappearance of ozone, v_{O3}, and the rate of formation of oxygen, v_{O2}, are defined as

$$v_{O3} = -\frac{d[O_3]}{dt} \quad v_{O2} = \frac{d[O_2]}{dt}$$

Therefore,

$$\frac{v_{O3}}{2} = \frac{v_{O2}}{3}$$

(b-2)

The relationship between the rate of disappearance of ozone, v_{O3}, and the rate of formation of oxygen, v_{O2}, is

$$v_{O2} = \frac{3}{2}v_{O3}$$

Therefore, the rate of disappearance of ozone is

$2/3 \times 3.0 \times 10^{-5} = 2.0 \times 10^{-5}$ mol L^{-1} s

(b-3)

The amount of ozone is

$n(O_3) = 96.0/48 = 2.00$ mol

According to the balanced chemical equation,

2 mol $O_3 \rightarrow 3$ mol O_2

Therefore, the amount of oxygen produced is

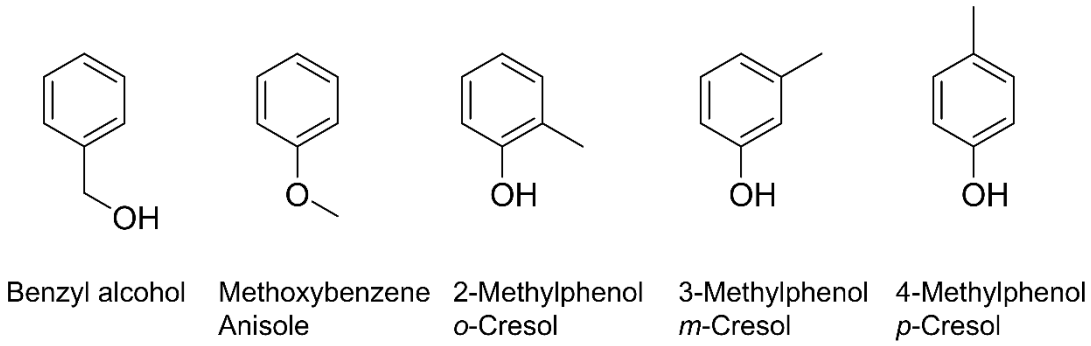
$n(O_2) = 3.00$ mol

At standard temperature and pressure (STP), one mole of an ideal gas occupies 22.4 L. Therefore, the volume of oxygen produced is

$V(O_2) = 3.00 \times 22.4 = 67.2$ L

(3)

(a)



(b)

o-Cresol, *m*-cresol, and *p*-cresol are positional isomers.

(c)

The compounds that exhibit weak acidity are *o*-cresol, *m*-cresol, and *p*-cresol. These compounds contain a phenolic hydroxy group. Upon releasing a proton, they form phenoxide ions, which are stabilized by resonance delocalization over the benzene ring. Therefore, these compounds exhibit weak acidity.