Solutions
Purpose of the Questions

Answer Sheet

Graduate School of Marine Science and Technology

February 3, 2026

Course	Course of Marine Resources and Environment	Applicant's number	
Name of Basic Subject	Mathematics	Name	

※Write answers in English on this page and continue overleaf if necessary.

(1) Since $0=|kI-A|=\begin{vmatrix} k & -1 \\ -2 & k+1 \end{vmatrix}=k(k+1)-2=(k+2)(k-1)$, we have $k=-2,1$.

(2) For $k=k_1=-2$, by solving

$$\begin{pmatrix} -2 & -1 \\ -2 & -1 \end{pmatrix}\begin{pmatrix} p_{11} \\ p_{21} \end{pmatrix}=\begin{pmatrix} 0 \\ 0 \end{pmatrix},$$

we obtain a solution

$$p_1=\begin{pmatrix} p_{11} \\ p_{21} \end{pmatrix}=\begin{pmatrix} 1 \\ -2 \end{pmatrix}.$$

For $k=k_2=1$, by solving

$$\begin{pmatrix} 1 & -1 \\ -2 & 2 \end{pmatrix}\begin{pmatrix} p_{12} \\ p_{22} \end{pmatrix}=\begin{pmatrix} 0 \\ 0 \end{pmatrix},$$

we obtain a solution

$$p_2=\begin{pmatrix} p_{12} \\ p_{22} \end{pmatrix}=\begin{pmatrix} 1 \\ 1 \end{pmatrix}.$$

(3) From (2), we have

$$P=\begin{pmatrix} 1 & 1 \\ -2 & 1 \end{pmatrix},\quad P^{-1}=\begin{pmatrix} 1/3 & -1/3 \\ 2/3 & 1/3 \end{pmatrix},\quad D=P^{-1}AP=\begin{pmatrix} -2 & 0 \\ 0 & 1 \end{pmatrix}.$$

(4) From (3), we have

$$A^n=PD^nP^{-1}=P\begin{pmatrix} (-2)^n & 0 \\ 0 & 1 \end{pmatrix}P^{-1}=\frac{1}{3}\begin{pmatrix} (-2)^n+2 & 1-(-2)^n \\ (-2)^{n+1}+2 & 1-(-2)^{n+1} \end{pmatrix}.$$

Points :
(1) 20 pts. (10 pts. for the definition of the determinant, 10 pts. for the values of k.)
(2) 30 pts. (15 pts. for solving each system of linear equations.)
(3) 20 pts. (10 pts. for the computation of the matrix P^{-1} and D, respectively.)
(4) 30 pts. (10 pts. for the derivation of $A^n=PD^nP^{-1}$, 20 pts. for the computation of A^n.)

The objective of the questions:
A broad understanding of basic topics in linear algebra is tested, including how to compute the determinant of a 2×2 matrix, how to solve basic systems of linear equations, how to find an inverse matrix, and how to compute matrix products and powers.

＊採点	

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1.

(1) $m\ddot{x} = -kx$ (10 points)
(2) $x = A\cos\sqrt{\frac{k}{m}}t + B\sin\sqrt{\frac{k}{m}}t$ (A, B: arbitrary constants) (10 points)
(3) $x = v_0\sqrt{\frac{m}{k}}\sin\sqrt{\frac{k}{m}}t$ (10 points)
(4) (a) and (d) (10 points)

(1)–(3) These questions test the ability to formulate and solve simple equations of motion on the dynamics of particles.
(4) This question tests the ability to qualitatively understand the behavior of motion in a slightly more complex situation.

2.

(1) $m_1a_1^2 + m_2a_2^2$ (10 points)
(2) Torque a_1F (10 points)
Angular acceleration $\frac{a_1F}{m_1a_1^2+m_2a_2^2}$ (10 points)
(3) $\mu_0 n\alpha t$, positive direction of the z-axis (10 points)
(4) $\frac{\mu_0 nb^2\alpha}{2a_1}$, clockwise when viewed from the positive z-axis (10 points)
(5) $\frac{\mu_0 qnb^2\alpha}{2a_1}$, clockwise when viewed from the positive z-axis (10 points)

(1)–(2) These questions test the understanding of moment of inertia and torque, as well as the ability to formulate equations for the rotational motion of a rigid body.
(3)–(5) Taking the magnetic and electric fields generated by a time-varying current as an example, these questions test the understanding of the fundamental laws of electromagnetism.

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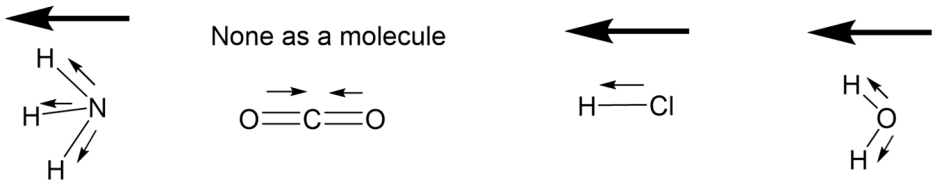
（海洋資源環境学専攻　共通科目　化学）

Question 1

(1)



(2) The dipole moment is a measure of the degree of polarization of a bond or an entire molecule. The dipole moment varies depending on the distribution of electrons in the direction of the bond between atoms and the bond distance. The greater the distance between atoms and the greater the difference in electronegativity, the larger the dipole moment.

Question 2:

(1) Reverse phase chromatography is a type of partition chromatography that utilizes the partitioning of substances between a liquid mobile phase and a solid stationary phase, in which the polarity of the stationary phase is lower than that of the mobile phase. The interaction between the stationary phase and the solute is primarily hydrophobic. There are two types of packing materials for reversed-phase chromatography columns: those that use silica gel as a carrier and have alkyl groups chemically bonded to them, and those that are resin-based. The mobile phase is a mixture of water or a buffer solution and an organic solvent, and the conditions suitable for separation can be found by adjusting the type of organic solvent, the ratio of organic solvents, the pH of the buffer solution, etc. It is used to separate a wide range of substances, from water-soluble to water-insoluble organic compounds.

(2) Size exclusion chromatography is the method used to separate components based on the difference in molecular size in a solution. The packing material in the column used has many pores. As component molecules of various sizes flow through the column, smaller molecules flow slowly, penetrating deep into the packing pores, while larger molecules cannot enter the pores and flow to the column outlet. As a result, the order of elution from the column is faster for larger molecules and slower for smaller molecules, and molecules are sorted according to their size. This is the principle of separation. Its main applications are to measure the molecular weight distribution of synthetic polymers using hydrophobic packing materials and a non-aqueous (organic solvent) mobile phase, and to separate and fractionate water-soluble polysaccharides and proteins or to measure their molecular weight distribution using hydrophilic packing materials and an aqueous mobile phase.

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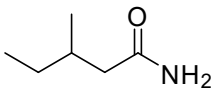
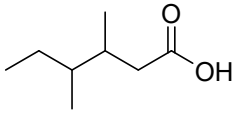
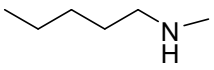
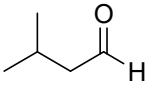
(3) Thin-layer chromatography is a type of liquid chromatography that uses a thin layer of fine powder coated on a support as the stationary phase and an appropriate solvent as the mobile phase. The separation method can be selected from various mechanisms such as adsorption, ion exchange, partitioning, and molecular sieving, depending on the combination of the stationary phase and the mobile phase, but it is generally used to separate fat-soluble substances in a normal phase. It has the advantages of short separation time, can be performed with simple equipment, can analyze (compare) many samples simultaneously, can estimate structure from color reaction and migration pattern, and can be quantified and separated, and is used for simple separation on a small scale.

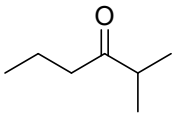
Question 3:

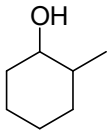
（１） 

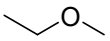
（２） 

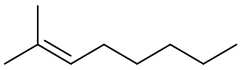
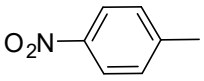
（３） 

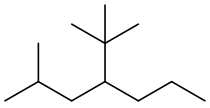
（４） 

（５） 

（６） 

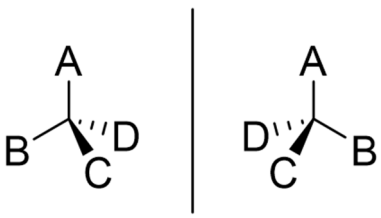
（７） 

（８） 
（９） 

（１０） 

Question 4：

（１）



Enantiomers are isomers that are mirror images of each other, as shown in the diagram on the left, but are not identical. Enantiomers exist in organic compounds that have an asymmetric carbon atom, with four different atoms (groups) attached to a central carbon. Enantiomers have the same physical and chemical properties, such as boiling point.

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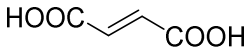
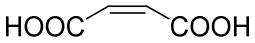
(2) Diastereomers are stereoisomers other than enantiomers and have different physicochemical properties.





The trans and cis forms of 2-butenoic acid are diastereomers and have different boiling points.

Purpose of the Questions

1. These questions are designed to assess whether students have acquired fundamental knowledge of biological indicators and whether they are able to apply this knowledge to logical and scientific reasoning based on given information.
2. The aim is to evaluate understanding of the basic terms of food webs and food chains, as well as basic knowledge of biological taxonomic groups and the ability to perform fundamental calculations of energy flow in food webs.

Answers

1.

Q1.

COD:

Chemical oxygen demand (COD) represents the amount of oxygen required to oxidize organic matter in water using a chemical oxidizing agent. Higher COD values indicate a higher level of water pollution.

BOD:

Biochemical oxygen demand (BOD) represents the amount of oxygen consumed by microorganisms during the biological decomposition of organic matter in water. As with COD, higher BOD values indicate greater organic pollution.

Characteristics of the water body:

Because COD reflects not only biodegradable organic matter but also organic compounds that are resistant to microbial decomposition, COD values higher than BOD values suggest that the water body contains a relatively large proportion of poorly biodegradable (refractory) organic matter.

Q2

Many EPT taxa are highly sensitive to water pollution. As water quality deteriorates, the number of EPT species generally decreases. Therefore, based on the given EPT index values, Site C can be considered the most polluted, followed by Site A, while Site B is the least polluted among the three sites.

Q3

Advantages:

Biological indicators allow for the assessment of the combined effects of multiple environmental factors.

They reflect the long-term cumulative effects of environmental conditions.

They provide direct information on the impacts of environmental factors on living organisms.

They can be assessed relatively easily without the need for specialized analytical equipment.
(Any two of the above)

Disadvantages:
Biological indicators do not directly measure specific physicochemical parameters, which may reduce analytical precision.
They may be influenced by unintended factors such as seasonal variation and interspecific interactions, which are not directly related to pollution.
The identification of indicator species may require specialized taxonomic expertise, potentially reducing the reliability and reproducibility of the assessment.
Biological responses may occur with a time lag, making it difficult to detect recent or short-term pollution events.
(Any two of the above)

2.

Q1.
(1. Carnivore) (2. Herbivore) (3. Omnivore)

Q2.
(Trophic cascade)

Q3.
(1. B) (2. A) (3. B) (4. A)

Q4.
(1. A) (2. D) (3. F)

Q5.
(1)
100 / 0.2 / 0.1 = 5000 g

(2)
Based on the feeding ratio and the conversion efficiencies, 40 g and 60 g of the 100 g increase in body mass are derived from anchovies and copepods, respectively.
The amount of copepods required directly is 60 / 0.09 = 667 g, and the amount of copepods required indirectly via anchovies is 40 / 0.18 / 0.1 = 2,222 g.
Therefore, the total amount of copepods required is 667 + 2,222 = 2,889 g.

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Answer

Q 1 .

(1) (5 point each, total 30)

A	Mesozoic	D	Ordovician
B	Neogene	E	Holocene
C	Carboniferous	F	Oligocene

(2) (10 point)

Pleistocene

(3) (10 point)

Radioactive isotopes decay with their own unique half-lives, which remain constant regardless of physical or chemical conditions. This fact can be used to determine the formation age of igneous rocks and minerals. (32 words)

Q2.

(1) (5 point each, total 10)

A	granite	B	basalt

(2) (name: 8 point, reason: 5 point, total 13)

Name: Moho discontinuity

Reason

because the crust and the mantle consist of different materials

(3) (5 point)

a

(4) (5 point)

C	mechanical (physical) weathering

(5) (17 point)

$CaAl_2Si_2O_8 + CO_2 + 2H_2O \rightarrow Al_2Si_2O_5(OH)_4 + Ca^{2+} + CO_3^-$

Question Purpose

Thess questions are designed to test basic knowledge of the geological time scale, the Earth's internal structure, materials that make it up, and weathering processes of rock and minerals on Earth's surface, which are fundamental to Earth science.