

2017 Examination for Japanese University Admission
for International Students

Science (80 min.)

【Physics, Chemistry, Biology】

- ※ Choose and answer two subjects.
- ※ Answer the questions using the front side of the answer sheet for one subject, and the reverse side for the other subject.

I Rules of Examination

1. Do not leave the room without the proctor's permission.
2. Do not take this question booklet out of the room.

II Rules and Information Concerning the Question Booklet

1. Do not open this question booklet until instructed.
2. After instruction, write your name and examination registration number in the space provided below, as printed on your examination voucher.
3. The pages of each subject are as in the following table.

Subject	Pages
Physics	1 – 21
Chemistry	23 – 37
Biology	39 – 53

4. If your question booklet is missing any pages, raise your hand.
5. You may write notes and calculations in the question booklet.

III Rules and Information Concerning the Answer Sheet

1. You must mark your answers on the answer sheet with an HB pencil.
2. Each question is identified by one of the row numbers **1**, **2**, **3**, ...
Follow the instruction in the question and completely black out your answer in the corresponding row of the answer sheet (mark-sheet).
3. Make sure also to read the instructions on the answer sheet.

- ※ Once you are instructed to start the examination, fill in your examination registration number and name.

Examination registration number			*				*						
Name													

Physics

Marking your Choice of Subject on the Answer Sheet

Choose and answer two subjects from Physics, Chemistry, and Biology. Use the front side of the answer sheet for one subject, and the reverse side for the other subject.

As shown in the example on the right, if you answer the Physics questions, circle “Physics” and completely fill in the oval under the subject name.

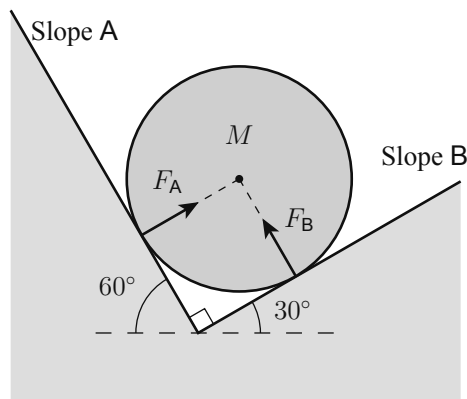
If you do not correctly fill in the appropriate oval, your answers will not be graded.

<Example>

解答科目 Subject		
(物理) Physics	化学 Chemistry	生物 Biology
<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

I Answer questions **A** (Q1), **B** (Q2), **C** (Q3), **D** (Q4), **E** (Q5), and **F** (Q6) below, where g denotes the magnitude of acceleration due to gravity, and air resistance is negligible.

A As shown in the figure below, slope **A**, whose angle with the horizontal is 60° , and slope **B**, whose angle with the horizontal is 30° , are joined so that they form an angle of 90° with each other. A uniform ball of mass M is placed on **A** and **B**, and is at rest. Let us denote the forces exerted on the ball by **A** and **B** as F_A and F_B , respectively. Friction between the ball and the slopes is negligible.

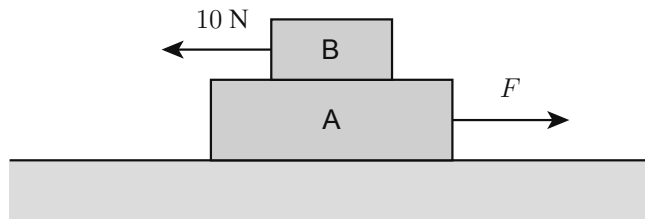


Q1 What are F_A and F_B ? From ①-⑥ below choose the correct combination.

1

	①	②	③	④	⑤	⑥
F_A	$\frac{\sqrt{3}}{3}Mg$	Mg	$\frac{\sqrt{3}}{2}Mg$	$\frac{1}{2}Mg$	$\sqrt{3}Mg$	$\frac{\sqrt{3}}{3}Mg$
F_B	Mg	$\frac{\sqrt{3}}{3}Mg$	$\frac{1}{2}Mg$	$\frac{\sqrt{3}}{2}Mg$	$\frac{\sqrt{3}}{3}Mg$	$\sqrt{3}Mg$

B As shown in the figure below, cuboid A (mass: 6 kg) is placed on a horizontal floor, and cuboid B (mass: 4 kg) is placed on the top of A. B is pulled horizontally to the left with a force of 10 N, while A is simultaneously pulled horizontally to the right with a force of magnitude F . F is gradually increased from 0 N, and at the instant that it exceeds a certain value F_0 , both A and B begin to move together as a single unit. The coefficient of static friction between the floor and A, and between A and B is 0.5. Assume that the magnitude of acceleration due to gravity is 10 m/s^2 .



Q2 What is F_0 (in N)? From ①-⑥ below choose the best answer.

2 N

① 20

② 30

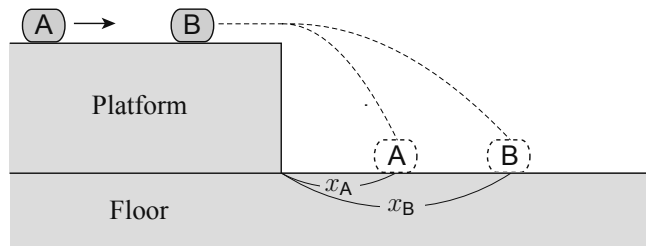
③ 40

④ 50

⑤ 60

⑥ 70

C As shown in the figure below, objects **A** and **B**, both of the same mass, are placed on a horizontal platform fixed in place on a horizontal floor. **A** is made to move with an initial speed so that it collides with **B**, which is initially at rest. Both objects then fly off the edge of the platform and fall onto the floor. **A** and **B** land at points horizontal distances x_A and x_B , respectively, from the edge of the platform. The coefficient of restitution between **A** and **B** is 0.60. Friction between the objects and the platform is negligible.

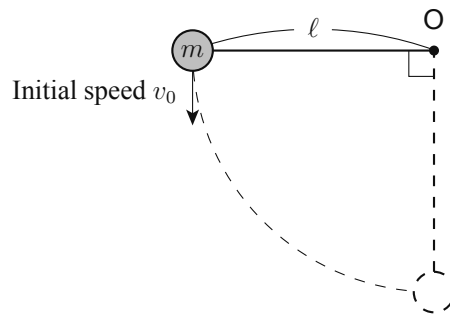


Q3 What is $\frac{x_B}{x_A}$? From ①-⑤ below choose the best answer.

3

- ① 1.7 ② 2.3 ③ 2.7 ④ 3.0 ⑤ 4.0

- D** One end of a lightweight, inelastic string with length ℓ is fixed in place at point O, and a small ball of mass m is attached to the other end. As shown in the figure below, the ball is lifted to the same height as O while the string is kept taut, and is then given an initial speed of v_0 vertically downward. At the moment that the ball is directly below O, the tension in the string is T .



Q4 What is T ? From ①-⑥ below choose the correct answer.

4

- | | | |
|------------------------------|-------------------------------|-------------------------------|
| ① $\frac{mv_0^2}{\ell} + mg$ | ② $\frac{mv_0^2}{\ell} + 2mg$ | ③ $\frac{mv_0^2}{\ell} + 3mg$ |
| ④ $\frac{mv_0^2}{\ell} - mg$ | ⑤ $\frac{mv_0^2}{\ell} - 2mg$ | ⑥ $\frac{mv_0^2}{\ell} - 3mg$ |

E A lightweight spring (spring coefficient: k) is placed on a smooth horizontal floor along with small objects A (mass: m) and B (mass: $2m$), which are placed so that they are in contact with opposite ends of the spring. As shown in Figure 1 below, A and B are pushed closer together until the spring is compressed distance x from its natural length and held at rest with both hands. Then both objects are gently released at the same time. A and B begin moving to the left and right, respectively. As shown in Figure 2, A and B separate from the spring. The speed of A after it separates from the spring is v .

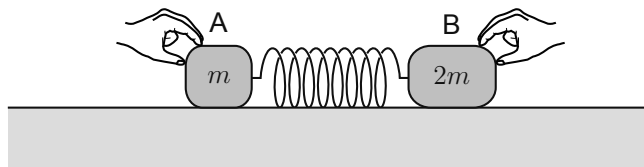


Figure 1

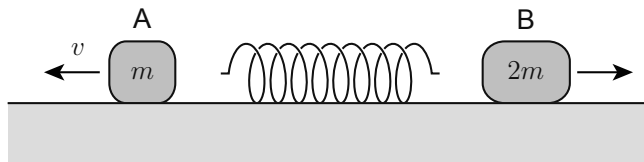


Figure 2

Q5 What is v ? From ①-⑥ below choose the correct answer.

5

① $\sqrt{\frac{k}{6m}} x$

② $\sqrt{\frac{k}{3m}} x$

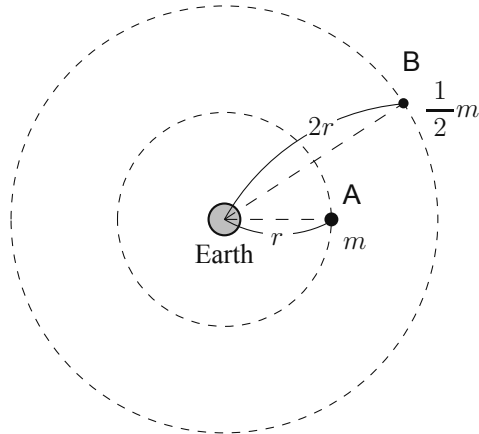
③ $\sqrt{\frac{k}{2m}} x$

④ $\sqrt{\frac{2k}{3m}} x$

⑤ $2\sqrt{\frac{k}{3m}} x$

⑥ $\sqrt{\frac{3k}{2m}} x$

- F** As shown in the figure below, satellites A and B are orbiting the earth with uniform circular motion. A has a mass of m , and an orbital radius of r . B has a mass of $\frac{1}{2}m$, and an orbital radius of $2r$. Let us denote the kinetic energy of A and B as K_A and K_B , respectively.



- Q6 What is $\frac{K_B}{K_A}$? From ①-⑦ below choose the correct answer.

6

- ① $\frac{1}{4}$ ② $\frac{1}{2}$ ③ $\frac{\sqrt{2}}{2}$ ④ 1
- ⑤ $\sqrt{2}$ ⑥ 2 ⑦ 4

II Answer questions **A** (Q1), **B** (Q2), and **C** (Q3) below.

A Ice of 100 g at $-10\text{ }^{\circ}\text{C}$ is placed in water of 200 g at $20\text{ }^{\circ}\text{C}$. After sufficient time elapses, some ice remains in the water, and the temperature of the ice and water is now $0\text{ }^{\circ}\text{C}$. The specific heat of water is $4.2\text{ J}/(\text{g}\cdot\text{K})$, the specific heat of ice is $2.1\text{ J}/(\text{g}\cdot\text{K})$, and the heat of fusion of ice is $3.3 \times 10^2\text{ J/g}$. Assume that there is no exchange of heat with the environment.

Q1 How much ice (in g) remains? From ①-⑦ below choose the best answer. **7** g

① 35

② 40

③ 45

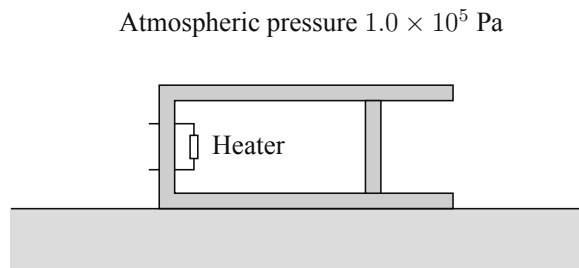
④ 50

⑤ 55

⑥ 60

⑦ 65

- B** As shown in the figure below, a fixed quantity of an ideal gas is enclosed inside a horizontal cylinder using a smoothly moving piston (cross-sectional area: $1.0 \times 10^{-1} \text{ m}^2$). The pressure of the gas is equivalent to atmospheric pressure $1.0 \times 10^5 \text{ Pa}$. A heater inside the cylinder is used to apply a quantity of heat of $2.5 \times 10^3 \text{ J}$ to the gas, causing the piston to move $1.0 \times 10^{-1} \text{ m}$ to the right.



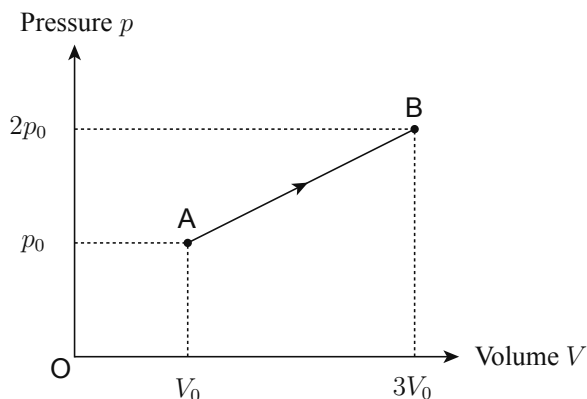
- Q2** How much (in J) does the internal energy of the gas increase as a result of being heated?

From ①-⑥ below choose the best answer.

8 J

- | | | |
|---------------------|---------------------|---------------------|
| ① 1.0×10^3 | ② 1.5×10^3 | ③ 2.0×10^3 |
| ④ 2.5×10^3 | ⑤ 3.0×10^3 | ⑥ 3.5×10^3 |

C A fixed quantity of a monatomic ideal gas is enclosed inside a cylinder. The state of the gas is changed from state A to state B, as shown in the p - V diagram below. Let us denote the work done on the environment by the gas as W , the quantity of heat absorbed by the gas as Q , and change in internal energy resulting from this process as ΔU .



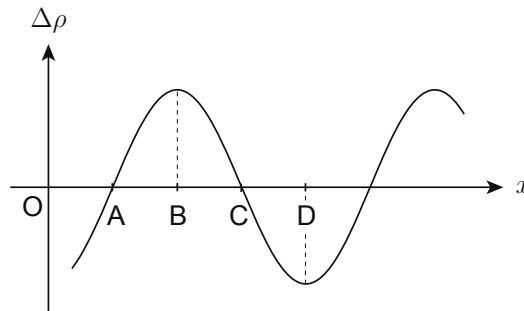
Q3 What are W , ΔU , and Q ? From ①-⑧ below choose the correct combination.

9

	①	②	③	④	⑤	⑥	⑦	⑧
W	p_0V_0	p_0V_0	p_0V_0	p_0V_0	$3p_0V_0$	$3p_0V_0$	$3p_0V_0$	$3p_0V_0$
ΔU	$\frac{15}{2}p_0V_0$	$\frac{15}{2}p_0V_0$	$9p_0V_0$	$9p_0V_0$	$\frac{15}{2}p_0V_0$	$\frac{15}{2}p_0V_0$	$9p_0V_0$	$9p_0V_0$
Q	$\frac{13}{2}p_0V_0$	$\frac{17}{2}p_0V_0$	$8p_0V_0$	$10p_0V_0$	$\frac{9}{2}p_0V_0$	$\frac{21}{2}p_0V_0$	$6p_0V_0$	$12p_0V_0$

III Answer questions **A** (Q1), **B** (Q2), and **C** (Q3) below.

A In longitudinal waves, any given point in the medium oscillates in a direction parallel to the direction of wave propagation, and the waves travel as alternating compressions (high-density regions) and rarefactions (low-density regions) of the medium. The figure below is a graph expressing, for a longitudinal wave propagating in the positive direction of the x -axis, the relationship between change in medium density $\Delta\rho$ (difference from density in the absence of waves) at a certain instant and position x . Position **B** in the figure represents a compression, and position **D** represents a rarefaction.



Q1 Among positions **A**, **B**, **C**, and **D** in the figure, which one has the greatest displacement of the medium in the positive direction of the x -axis? From ①-④ below choose the correct answer. **10**

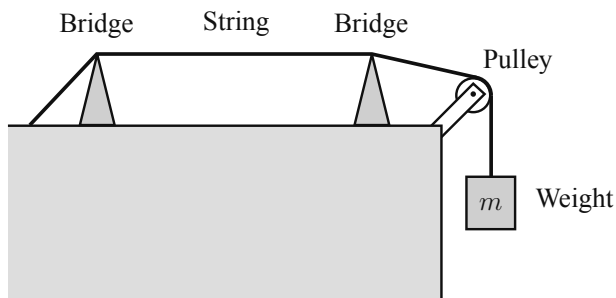
① A

② B

③ C

④ D

B As shown in the figure below, one end of a string is fixed in place, a weight (mass: m) is attached to the other end and is suspended by placing the string over a pulley, and the string is stretched horizontally between two bridges fixed in place. When a vibration of a certain frequency is given to the string, a standing wave with two antinodes forms between the bridges. Next, the mass of the weight is changed to m' and a vibration of the same frequency is given to the string, resulting in the formation of a standing wave with one antinode between the bridges. Here, the speed of a wave traveling along the string is proportional to the square root of the tension in the string.

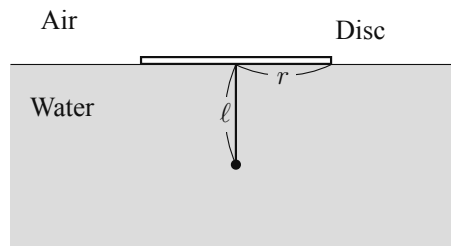


Q2 What is $\frac{m'}{m}$? From ①-⑥ below choose the correct answer.

11

- ① $\frac{1}{4}$ ② $\frac{1}{2}$ ③ $\frac{\sqrt{2}}{2}$ ④ $\sqrt{2}$ ⑤ 2 ⑥ 4

C As shown in the figure below, a thin disc with radius r is floated on the surface of water, and a small weight is suspended from the center of the disc using a string. The string's length from disc center to the weight is ℓ . When ℓ is small, the weight cannot be seen from any point in the air. As ℓ is gradually increased, the weight becomes visible from the air at the moment when ℓ exceeds a certain length ℓ_0 . Let us denote the relative refractive index of water with respect to air as n .



Q3 What is $\frac{\ell_0}{r}$? From ①-⑥ below choose the correct answer.

12

① $\frac{n}{\sqrt{n^2 - 1}}$

② n

③ $\sqrt{n^2 - 1}$

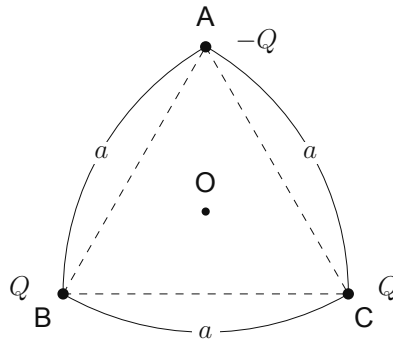
④ $\frac{\sqrt{n^2 - 1}}{n}$

⑤ $\frac{1}{n}$

⑥ $\frac{1}{\sqrt{n^2 - 1}}$

IV Answer questions **A** (Q1), **B** (Q2), **C** (Q3), **D** (Q4), **E** (Q5), and **F** (Q6) below.

A As shown in the figure below, a point charge is fixed in place at each vertex of equilateral triangle ABC , whose sides have length a . The charge at A has quantity of electricity $-Q$ ($Q > 0$), and those at B and C have quantity of electricity Q . Let us denote as E_0 the magnitude of the electric field produced at A by the charge at B .



Q1 What is the magnitude of the electric field at O , the geometric center (centroid) of the triangle? From ①-⑥ below choose the correct answer. **13**

- ① E_0 ② $2E_0$ ③ $3E_0$ ④ $4E_0$ ⑤ $5E_0$ ⑥ $6E_0$

B Figure 1 below shows a parallel plate capacitor whose plates have area S and are separated by distance d . Let us denote the capacitance of this capacitor as C . As shown in Figure 2, a conducting plate with area $\frac{S}{3}$ and thickness $\frac{d}{2}$ is placed between the capacitor's plates, parallel to them. Let us denote the capacitance of the capacitor in this case as C' .

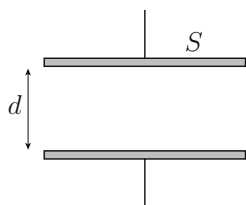


Figure 1

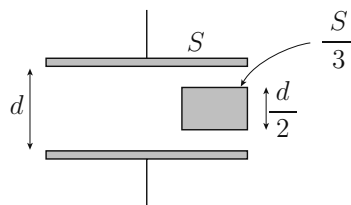


Figure 2

Q2 What is $\frac{C'}{C}$? From ①-⑧ below choose the best answer.

14

① $\frac{3}{10}$

② $\frac{1}{3}$

③ $\frac{2}{5}$

④ $\frac{3}{7}$

⑤ $\frac{5}{4}$

⑥ $\frac{4}{3}$

⑦ $\frac{5}{3}$

⑧ $\frac{7}{4}$

C When a battery with an electromotive force of 6.0 V and an internal resistance of $1.0\ \Omega$ is connected with a certain external resistor, the external resistor consumes 5.0 W of electrical power. Here, the external resistor's resistance is greater than the battery's internal resistance.

Q3 What is the resistance (in Ω) of the external resistor? From ①-④ below choose the best answer. **15** Ω

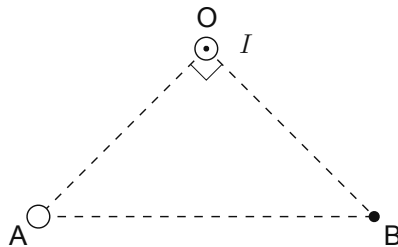
① 5.0

② 6.0

③ 6.2

④ 7.2

D As shown in the figure below, two sufficiently long, straight conducting wires run perpendicular to this page. One runs through vertex O (vertex angle: 90°) of isosceles right triangle OAB on this page, and the other runs through vertex A . An electrical current with magnitude I is flowing through the wire that runs through O , in the direction from the back of this page to the front. When a current with a certain magnitude is passed through the wire that runs through A in a certain direction, the direction of the magnetic field at B is from O to B .



Q4 What are the direction and magnitude of the current passed through the wire running through A ? From ①-⑥ below choose the correct combination. **16**

	Direction	Magnitude
①	from front of page to back	$\sqrt{2} I$
②	from front of page to back	$2I$
③	from front of page to back	$4I$
④	from back of page to front	$\sqrt{2} I$
⑤	from back of page to front	$2I$
⑥	from back of page to front	$4I$

E As shown in Figure 1 below, an electrical current of 5.0 A is flowing through rectangular coil **abcd** in the direction indicated by the arrows. The length of side **ab** is 0.30 m and the length of side **bc** is 0.20 m. As shown in Figure 2, the coil is placed in a uniform magnetic field (magnetic flux density: 4.0 T), such that sides **ab** and **cd** are kept perpendicular to the direction of the magnetic field, and sides **da** and **bc** are kept at angle of 60° to the direction of the magnetic field. Here, a couple of forces is exerted on the current flowing through the coil by the magnetic field.

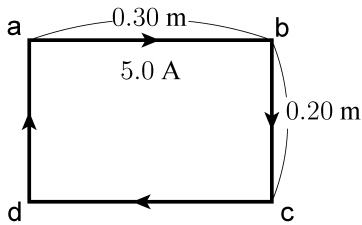


Figure 1

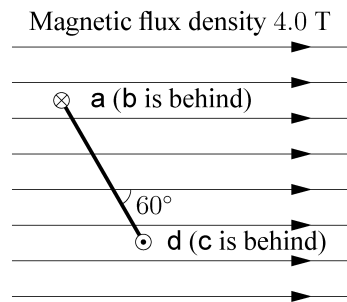


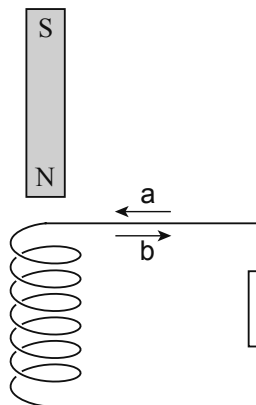
Figure 2

Q5 What is the magnitude of the moment (in N·m) of the couple of forces exerted on the current flowing through the coil by the magnetic field? From ①-⑤ below choose the best answer.

17 N·m

- ① 0.40 ② 0.60 ③ 0.90 ④ 1.0 ⑤ 1.5

F As shown in the figure below, a resistor is connected to a solenoid, and the solenoid is fixed in place so that its central axis is vertical. A bar magnet, oriented with its north (N) pole downward, is dropped above the solenoid so that it falls through the solenoid along the central axis.



Q6 Which of arrows **a** and **b** in the figure indicates the direction of current flowing through the resistor just before the magnet's north (N) pole passes through the top of the solenoid? Also, which of arrows **a** and **b** indicates the direction of current flowing through the resistor just after the magnet's south (S) pole passes through the bottom of the solenoid? From ①-④ below choose the correct combination. **18**

	①	②	③	④
Direction just before N pole passes top of solenoid	a	a	b	b
Direction just after S pole passes bottom of solenoid	a	b	a	b

V Answer question A (Q1) below.

A Nihonium (Nh) is a new synthetic element with an atomic number of 113, whose synthesis was first confirmed in Japan. Experiments have shown that one Nh nucleus changes into one mendelevium (Md, atomic number: 101) nucleus after undergoing several α decays. During the change, only α decays occur.

Q1 How many α particles are emitted in the process whereby one Nh nucleus changes into one Md nucleus? From ①-⑦ below choose the correct answer. **19**

① 2

② 3

③ 4

④ 5

⑤ 6

⑥ 7

⑦ 8

End of Physics questions. Leave the answer spaces **20** – **75** blank. Please check once more that you have properly marked the name of your subject as “Physics” on your answer sheet.

Do not take this question booklet out of the room.

Chemistry

Marking Your Choice of Subject on the Answer Sheet

Choose and answer two subjects from Physics, Chemistry, and Biology. Use the front side of the answer sheet for one subject, and the reverse side for the other subject.

As shown in the example on the right, if you answer the Chemistry questions, circle “Chemistry” and completely fill in the oval under the subject name.

If you do not correctly fill in the appropriate oval, your answers will not be graded.

< Example >

解答科目 Subject		
物理 Physics	化学 Chemistry	生物 Biology
<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>

Use the following values for calculation. The unit of volume “liter” is represented by “L”.

Standard state: 0 °C, 1.01×10^5 Pa (= 1.00 atm)

The molar volume of an ideal gas at the standard state: 22.4 L/mol

Gas constant: $R = 8.31 \times 10^3$ Pa·L/(K·mol)

Avogadro constant: $N_A = 6.02 \times 10^{23}$ /mol

Faraday constant: $F = 9.65 \times 10^4$ C/mol

Atomic weight: H : 1.0 C : 12 N : 14 O : 16

Na : 23 S : 32 Ca : 40 Br : 80

The relation between the group and the period used in this examination is indicated in the following periodic table. Atomic symbols other than **H** are omitted.

	group																	
period \	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	
2																		
3																		
4																		
5																		

Q1 From the following molecules ①-⑤ choose the one in which the number of shared electron pairs and that of unshared electron pairs are equal. 1

- ① N₂ ② Cl₂ ③ CH₄ ④ NH₃ ⑤ H₂O

Q2 Among the following statements (a)-(e) on the elements and their ions belonging to the first three periods of the periodic table, two are correct. From ①-⑥ below choose the combination of them. 2

- (a) Carbon (C) and silicon (Si) have the same number of electrons in the L shell.
- (b) Fluoride ions (F⁻) and aluminum ions (Al³⁺) have the same number of electrons.
- (c) The ionization energy (the first ionization energy) of lithium (Li) is higher than that of helium (He).
- (d) The electron affinity of fluorine (F) is larger than that of oxygen (O).
- (e) The ionic radius of the magnesium ion (Mg²⁺) is larger than that of the oxide ion (O²⁻).

- ① a, b ② a, c ③ a, e ④ b, d ⑤ c, d ⑥ d, e

Q3 An element X and oxygen (O) form a compound XO_2 . Among the following elements (a)-(e), two can be X. From ①-⑥ below choose the correct combination.

3

(a) Al (b) Fe (c) Mg (d) Mn (e) Si

① a, b ② a, d ③ b, c ④ b, d ⑤ c, e ⑥ d, e

Q4 The following gases ①-⑤ are kept in separate containers of the same volume and at the same temperature. From ①-⑤ below choose the gas whose pressure is the highest.

Assume all the gases are ideal gases.

4

① 2.8 g of C_2H_4

② 3.4 g of H_2S

③ 4.5 g of NO

④ 1.4 g of CO

⑤ 3.4 g of NH_3

Q5 Suppose methanol is completely combusted. From the following ①-⑥ choose the correct one for the ratio of the amount (mol) of reacted oxygen (O_2) to that of carbon dioxide (CO_2) formed ($O_2 : CO_2$). **5**

- ① 4 : 1 ② 3 : 1 ③ 2 : 1 ④ 3 : 2 ⑤ 4 : 3 ⑥ 1 : 1

Q6 The solubility of potassium nitrate (KNO_3) in 100 g of water at $20\text{ }^\circ\text{C}$ is 32 g. Calculate the mass percent concentration of the saturated solution of potassium nitrate at $20\text{ }^\circ\text{C}$. From the following ①-⑤ choose the closest value. **6** %

- ① 3.1 ② 4.1 ③ 24 ④ 32 ⑤ 47

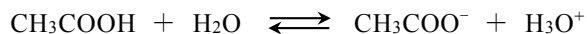
- Q7** 4.2 g of sodium hydrogen carbonate (NaHCO_3) was placed in a 1.0 L container filled with nitrogen (N_2) (27°C , 1.0×10^5 Pa). The container was tightly closed and was heated to 327°C . Then the following pyrolysis occurred.



Calculate the pressure (Pa) in the container at 327°C when the reaction was completed. From the following ①-⑥ choose the closest value. Assume that the volume of solid NaHCO_3 is negligible and that CO_2 and H_2O are both ideal gases. **7** Pa

- ① 1.2×10^5 ② 2.5×10^5 ③ 3.2×10^5
 ④ 4.5×10^5 ⑤ 5.0×10^5 ⑥ 7.0×10^5

- Q8** In an aqueous solution of acetic acid (CH_3COOH), the following electrolytic dissociation equilibrium is established.



When the following procedures (a)-(d) are applied to the aqueous solution, two of them shift the equilibrium to the right. From ①-⑥ below choose the correct combination. **8**

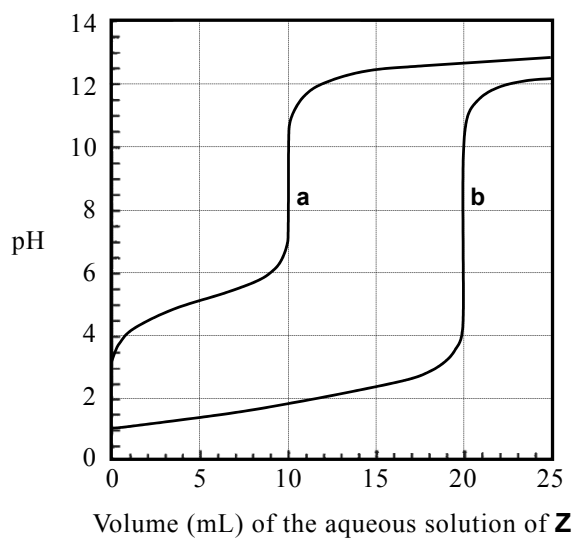
- (a) Water is added.
 (b) Sodium acetate (CH_3COONa) is added.
 (c) Sodium hydroxide (NaOH) is added.
 (d) Hydrogen chloride (HCl) is passed through.

- ① a, b ② a, c ③ a, d ④ b, c ⑤ b, d ⑥ c, d

Q9 Two titration curves **a** and **b** were obtained by the following procedures **A** and **B**, respectively.

Procedure **A**: To 10 mL of 0.1 mol/L aqueous solution of **X**, 0.1 mol/L aqueous solution of **Z** is added.

Procedure **B**: To 10 mL of 0.1 mol/L aqueous solution of **Y**, 0.1 mol/L aqueous solution of **Z** is added.

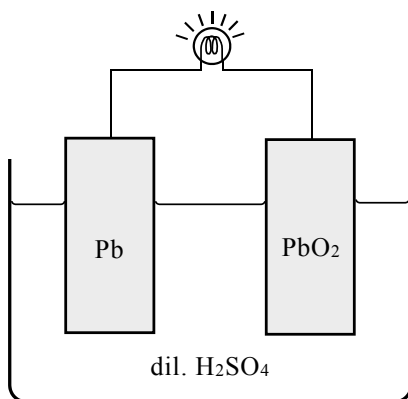


From ①-⑥ in the following table choose the correct combination of **X**, **Y**, and **Z**.

9

	X	Y	Z
①	HCl	H ₂ SO ₄	NH ₃
②	HCl	H ₂ SO ₄	NaOH
③	CH ₃ COOH	HCl	NH ₃
④	CH ₃ COOH	HCl	NaOH
⑤	CH ₃ COOH	H ₂ SO ₄	NH ₃
⑥	CH ₃ COOH	H ₂ SO ₄	NaOH

Q10 From the statements ①-④ below concerning the lead storage battery shown in the following figure choose the correct one. **10**



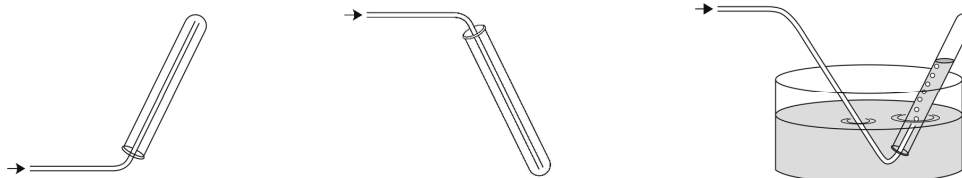
- ① When the battery is discharged, the electric current flows from the Pb electrode to the PbO₂ electrode.
- ② In order to charge the battery, the cathode of the exterior power supply should be connected to the Pb electrode.
- ③ The mass of the Pb electrode increases by the discharge.
- ④ The density of dilute sulfuric acid (dil.H₂SO₄) decreases by the charge.

Q11 Which substance from the following (a)-(c) generates sulfur dioxide (SO₂) on reaction with sulfuric acid (H₂SO₄)? Which method from (i)-(iii) below should be used to collect the generated SO₂? From ①-⑥ in the table below choose the correct combination of them.

11

(a) Zn (b) FeS (c) Na₂SO₃

(i) upward delivery (ii) downward delivery (iii) displacement of water



	A	B
①	a	i
②	a	ii
③	b	i
④	b	iii
⑤	c	ii
⑥	c	iii

Q12 When calcium carbonate (CaCO_3) was strongly heated, 14 g of a white solid was formed together with a gas. Calculate the volume of the gas in L at the standard state. From the following ①-⑥ choose the closest value. **12** L

- ① 1.4 ② 2.7 ③ 3.8 ④ 4.5 ⑤ 5.6 ⑥ 8.4

Q13 Among the following statements (a)-(f) on halogens X ($X = \text{F}, \text{Cl}, \text{Br}, \text{and I}$), there are two whose underlined parts are **not** correct. From ①-⑥ below choose the combination of them. **13**

- (a) All X belong to group 17 of the periodic table.
 (b) All X_2 are colored substances.
 (c) The greater the molecular weight of X_2 , the higher the boiling point.
 (d) The smaller the molecular weight of X_2 , the stronger the oxidizing power.
 (e) All X_2 are gases at normal temperature and pressure.
 (f) All X_2 readily react with water.

- ① a, b ② a, c ③ b, d ④ c, e ⑤ d, f ⑥ e, f

Q14 Among the following statements (a)-(e) on metals and their ions, two are correct. From

①-⑥ below choose the combination of them.

14

- (a) Zinc sulfide (ZnS) precipitates when hydrogen sulfide (H_2S) is passed through an acidic aqueous solution containing zinc ion (Zn^{2+}).
- (b) Alloys of mercury (Hg) are called amalgams.
- (c) Aluminum (Al) is obtained by the electrolysis of aqueous aluminum oxide (Al_2O_3 aq).
- (d) Brass is an alloy of copper (Cu) and tin (Sn).
- (e) Lead(II) sulfate (PbSO_4) precipitates when sodium sulfate (Na_2SO_4) is added to an aqueous solution containing the lead(II) ion (Pb^{2+}).

- ① a, b ② a, e ③ b, c ④ b, e ⑤ c, d ⑥ d, e

Q15 The following procedures **A** and **B** were performed on an aqueous solution containing three kinds of ions Ag^+ , Cu^{2+} , and Fe^{3+} . Which metal ions are contained in the precipitates **X** and **Y** formed by the procedures **A** and **B**, respectively? From ①-⑥ in the table below choose the correct combination. **15**

Procedure **A**: Precipitates **X** were obtained by adding dilute hydrochloric acid (dil. HCl).

Procedure **B**: Precipitates **X** obtained by adding dilute hydrochloric acid were filtered off, and hydrogen sulfide (H_2S) was passed through the filtrate to obtain precipitates **Y**.

	Metal ion contained in X	Metal ion contained in Y
①	Ag^+	Cu^{2+}
②	Ag^+	Fe^{3+}
③	Cu^{2+}	Ag^+
④	Cu^{2+}	Fe^{3+}
⑤	Fe^{3+}	Ag^+
⑥	Fe^{3+}	Cu^{2+}

Q16 How many structural isomers are there in the compound in which two hydrogen atoms (H) of butane ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$) are substituted by two chlorine atoms (Cl)? From ①-⑥ below choose the correct one. Enantiomers are not counted as structural isomers. **16**

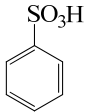
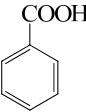
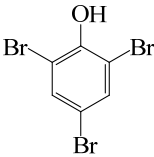
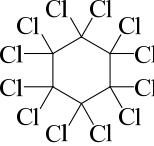
- ① 3 ② 4 ③ 5 ④ 6 ⑤ 7 ⑥ 8

Q17 The following statements (a)-(d) concern benzene. From ①-⑤ below choose the combination in which the “true” or “false” judgments are correct. **17**

- (a) All atoms in a benzene molecule lie in the same plane.
- (b) The molecular formula of benzene is C_6H_6 .
- (c) When benzene is reacted with water containing chlorine (Cl_2) at normal temperature, chlorine is added to benzene by an addition reaction.
- (d) When benzene is burned in air, a large amount of soot is generated.

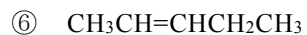
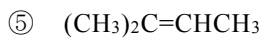
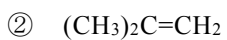
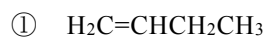
	a	b	c	d
①	true	true	true	true
②	true	true	false	true
③	true	false	false	true
④	false	true	true	true
⑤	false	true	true	false

Q18 In the following table, column **A** describes the procedures of some reactions, and column **B** indicates the main products obtained by the reactions described in column **A**. Among the rows (**a**)-(**d**), two of the products shown in column **B** are not correct. From ①-⑥ below choose the combination. **18**

	A	B
a	Benzene is reacted with a mixture of concentrated nitric acid (conc. HNO_3) and concentrated sulfuric acid (conc. H_2SO_4).	
b	Toluene is air-oxidized in the presence of a catalyst.	
c	Bromine water is added to aqueous phenol.	
d	Benzene is reacted with chlorine (Cl_2) in the presence of iron powder as the catalyst.	

- ① **a, b** ② **a, c** ③ **a, d** ④ **b, c** ⑤ **b, d** ⑥ **c, d**

Q19 A sufficient amount of bromine (Br_2) was added to 1.4 g of an alkene to give 5.4 g of a product which contains two asymmetric carbon atoms. From the following ①-⑥ choose the correct alkene. **19**



Q20 From ①-⑤ in the table below choose the correct combination of polymer and functional group contained in them. **20**

	Polymer	Functional group
①	nylon 6,6	amide bond
②	phenol resin	carbonyl group
③	polyacrylonitrile	ester bond
④	poly(ethylene terephthalate)	hydroxy group
⑤	polypropylene	ether bond

End of Chemistry questions. Leave the answer spaces **21** ~ **75** blank.

Please check once more that you have properly marked the name of your subject as “Chemistry” on your answer sheet.

Do not take this question booklet out of the room.

Biology

Marking Your Choice of Subject on the Answer Sheet

Choose and answer two subjects from Physics, Chemistry, and Biology. Use the front side of the answer sheet for one subject, and the reverse side for the other subject.

As shown in the example on the right, if you answer the Biology questions, circle “Biology” and completely fill in the oval under the subject name.

If you do not correctly fill in the appropriate oval, your answers will not be graded.

< Example >

解答科目 Subject		
物 理 Physics	化 学 Chemistry	生 物 Biology
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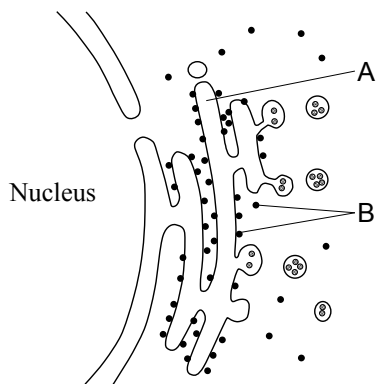
- Q1 From ①–⑥ below choose the combination of terms that correctly fills blanks – in the following paragraph. 1

Biomembranes, such as cell membranes, contain a bilayer structure composed of molecules, and proteins are distributed in a mosaic pattern throughout this structure. Within this bilayer structure, the molecules are arranged so that their ends point inward and their ends point outward.

	a	b	c
①	cellulose	hydrophilic	hydrophobic
②	cellulose	hydrophobic	hydrophilic
③	tubulin	hydrophilic	hydrophobic
④	tubulin	hydrophobic	hydrophilic
⑤	phospholipid	hydrophilic	hydrophobic
⑥	phospholipid	hydrophobic	hydrophilic

Q2 The following figure schematically represents a portion of a eukaryotic cell observed with an electron microscope. From ①–⑥ below choose the combination that correctly indicates the names of parts A and B.

2



	A	B
①	endoplasmic reticulum	ribosomes
②	endoplasmic reticulum	lysosomes
③	nuclear membrane	ribosomes
④	nuclear membrane	lysosomes
⑤	Golgi body	ribosomes
⑥	Golgi body	lysosomes

Q3 Reactions a – d below are reactions that take place in respiration. Each occurs in one of the following processes: glycolysis, the citric acid cycle, or the electron transport system. In which process does each of the reactions a – d occur? From ①–⑥ below choose the correct combination. **3**

- a Pyruvic acid is synthesized.
- b Water (H₂O) is utilized and carbon dioxide (CO₂) is produced.
- c The greatest amount of ATP is synthesized when one molecule of glucose is broken down through these three processes.
- d Oxygen (O₂) is utilized and water is produced.

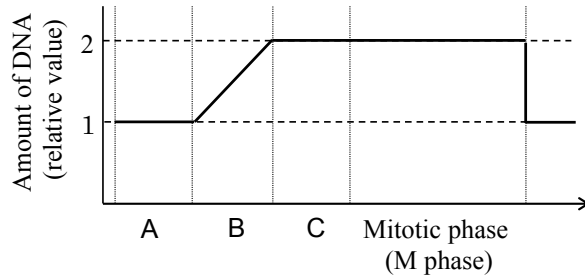
	Process		
	Glycolysis	Citric acid cycle	Electron transport system
①	a	b, d	c
②	b	c	a, d
③	c	a, b	d
④	a	b	c, d
⑤	c, d	a	b
⑥	a, c	b, d	d

Q4 The following paragraph describes prokaryotes that are capable of carbon dioxide assimilation. From ① – ⑥ below choose the combination of terms that correctly fills blanks **a** – **c** in the paragraph. **4**

Among prokaryotes, which do not have chloroplasts, are some that assimilate carbon dioxide. For example, purple sulfur bacteria contain bacteriochlorophyll and carry out photosynthesis using **a** instead of water. Also, **b** carry out the same type of photosynthesis as green plants. Some, such as **c**, synthesize organic substances using energy obtained from the oxidation of inorganic substances, rather than using light energy.

	a	b	c
①	ammonium ions (NH_4^+)	nitrate forming bacteria	yeasts
②	ammonium ions	yeasts	nitrate forming bacteria
③	nitrate ions (NO_3^-)	cyanobacteria	yeasts
④	nitrate ions	yeasts	cyanobacteria
⑤	hydrogen sulfide (H_2S)	cyanobacteria	nitrate forming bacteria
⑥	hydrogen sulfide	nitrate forming bacteria	cyanobacteria

Q5 The following figure shows changes in the amount of DNA per cell during the cell cycle for somatic cell division. A – C on the horizontal axis represent certain phases during the cell cycle. From ① – ⑥ below choose the combination that correctly indicates the names of A – C. **5**



	A	B	C
①	prophase	metaphase	anaphase
②	prophase	S phase	G ₁ phase
③	G ₁ phase	S phase	prophase
④	prophase	G ₁ phase	S phase
⑤	S phase	G ₁ phase	G ₂ phase
⑥	G ₁ phase	S phase	G ₂ phase

Q6 Polymerase chain reaction (PCR) is widely known as a technique for amplifying a certain segment of DNA, which is based on the mechanism of DNA replication. Items I – V below describe steps in the PCR process.

- I Prepare a mixture that contains a DNA template, primers, thermostable DNA polymerase, and four types of nucleotides, among other ingredients.
- II Heat the mixture to approx. 95°C.
- III Cool the mixture to approx. 55°C.
- IV Heat the mixture to approx. 72°C.
- V Repeat steps II – IV.

Referring to the following descriptions a – c, from ①–⑥ below choose the combination correctly indicating what occurs during steps II – IV.

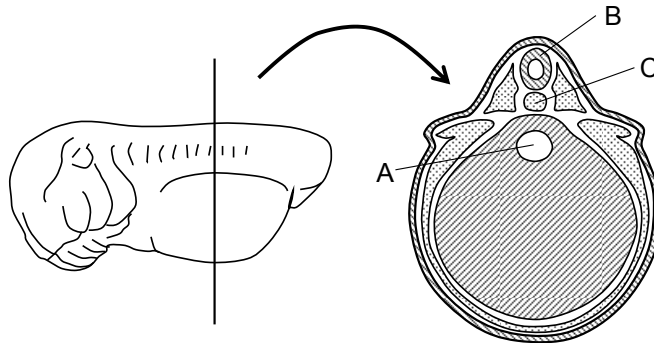
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- a The primers bind to the template DNA.
- b A new DNA chain is synthesized through the activity of thermostable DNA polymerase.
- c The double-stranded DNA is separated into single strands.

	II	III	IV
①	a	b	c
②	b	c	a
③	c	a	b
④	a	c	b
⑤	b	a	c
⑥	c	b	a

Q7 The following figure represents a frog embryo in the tail-bud stage, and a cross section taken when it is bisected along the line shown in the figure. From ①–⑥ below choose the combination correctly indicating which of A–C in the figure represents the neural tube (spinal cord), and the intestinal tract.

7



	Neural tube (spinal cord)	Intestinal tract
①	A	B
②	A	C
③	B	A
④	B	C
⑤	C	A
⑥	C	B

Q8 The skin of chickens is composed mainly of the dermis and the epidermis. The skin of the back forms feathers, and the skin of the legs forms scales.

The following figure shows an experiment using chicken dermis and epidermis. Skin samples were removed from the back and a leg of a 10-day-old embryo, and the dermis and the epidermis were separated in each sample. Next, the dermis and epidermis samples were rearranged to rejoin in four different combinations, which were then cultured. Each cultured combination formed either feathers or scales.

From ①–⑤ below choose the statement that can best be inferred from this experiment.

8

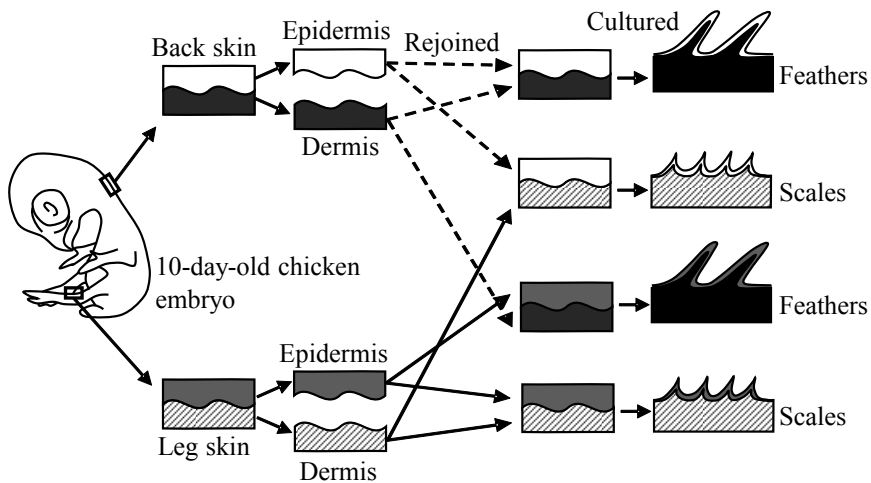
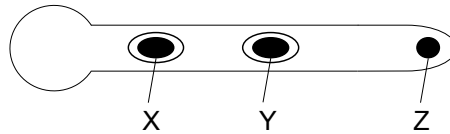


Figure source: *Seibutsu*, Keirinkan

- ① Skin differentiation into feathers or scales is induced by the epidermis.
- ② Skin differentiation into feathers or scales is induced by the dermis.
- ③ Skin differentiation into feathers or scales is induced by tissue other than the skin.
- ④ The back epidermis always differentiates into feathers.
- ⑤ The leg epidermis always differentiates into scales.

- Q9** The following figure schematically represents angiosperm pollen extending a pollen tube. From ①–⑤ below choose the combination indicating the two statements in **a – e** below that correctly describe this figure.

9



- a** The nuclear phases of X, Y, and Z are all n .
- b** The nuclear phase is n for X and Y, and $2n$ for Z.
- c** X, Y, and Z all have the same genetic composition.
- d** X and Y have the same genetic composition, while that of Z may differ.
- e** X, Y, and Z all may have different genetic compositions.
- ① a, c ② a, d ③ a, e ④ b, d ⑤ b, e

- Q10** From ①–⑤ below choose the statement that best describes a characteristic of human hormones.

10

- ① They are produced by the endocrine glands and are secreted via ducts.
- ② They function effectively even in very small amounts, acting on specific organs and inducing specific reactions.
- ③ Generally, their effects are more immediate than those of the autonomic nervous system, and they send signals to the organs via the central nervous system.
- ④ The organs that hormones act upon are called target organs, and the cells of a target organ contain receptors for every type of hormones.
- ⑤ The autonomic nervous system and hormones always act independently of each other, with neither affecting the other.

Q11 The following paragraph describes the reaction of human body when the sodium concentration in blood is elevated. From ①–⑧ below choose the combination of terms that correctly fills blanks **a** – **c** in the paragraph. **11**

When the **a** detects a rise in the sodium concentration in the blood, the secretion volume of **b** from the posterior pituitary increases. The increased secretion of **b** leads to **c** of the reabsorption of water in the kidneys.

	a	b	c
①	hypothalamus	mineralocorticoid	increase
②	hypothalamus	vasopressin	suppression
③	hypothalamus	mineralocorticoid	suppression
④	hypothalamus	vasopressin	increase
⑤	anterior pituitary	mineralocorticoid	increase
⑥	anterior pituitary	vasopressin	suppression
⑦	anterior pituitary	mineralocorticoid	suppression
⑧	anterior pituitary	vasopressin	increase

- Q12** The mechanism by which the human body eliminates foreign substances include physical/chemical defenses, phagocytosis, and humoral immunity. From ①–⑥ below choose the combination correctly indicating the tissue or cells that are involved in these defenses respectively. **12**

	Physical/chemical defenses	Phagocytosis	Humoral immunity
①	skin	macrophages	platelets
②	skin	neutrophils	B cells
③	skin	B cells	T cells
④	macrophages	T cells	platelets
⑤	macrophages	neutrophils	B cells
⑥	macrophages	B cells	T cells

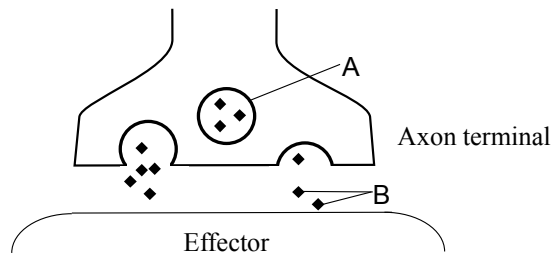
- Q13** The retina of the human eyes contain cone cells and rod cells. From ①–④ below choose the combination that correctly describes their characteristics. **13**

	Cone cells	Rod cells
①	They are involved in the perception of color	They are concentrated in the macula lutea
②	There are three cell types	They are excited even by dim light
③	They are concentrated in the macula lutea	There are three cell types
④	They are excited even by dim light	They are involved in the perception of color

Q14 From ①–④ below choose the statement that correctly describes the conduction and transmission of excitation in neurons. **14**

- ① The conduction velocity of excitation in the myelinated nerve fibers is slower than that in the unmyelinated nerve fibers.
- ② In a single neuron, excitation occurs when the stimulus intensity exceeds the threshold value, but not when it is below the threshold value; the magnitude of excitation increases proportionally to the stimulus intensity.
- ③ The transmission of excitation between neurons occurs only in the direction from the axon terminal to the neighboring cell body or its dendrite, never in the reverse direction.
- ④ In myelinated nerve fiber, saltatory conduction occurs, as excitation does not occur at the nodes of Ranvier.

Q15 The following figure schematically represents an axon terminal of a sympathetic nerve and an effector. A represents a structure that exists in a large quantity in axon terminals, and B represents a substance released from A. From ①–④ below choose the combination that correctly indicates the names of A and B. **15**



	A	B
①	synaptic vesicle	noradrenaline
②	synaptic vesicle	sodium ion
③	mitochondrion	noradrenaline
④	mitochondrion	sodium ion

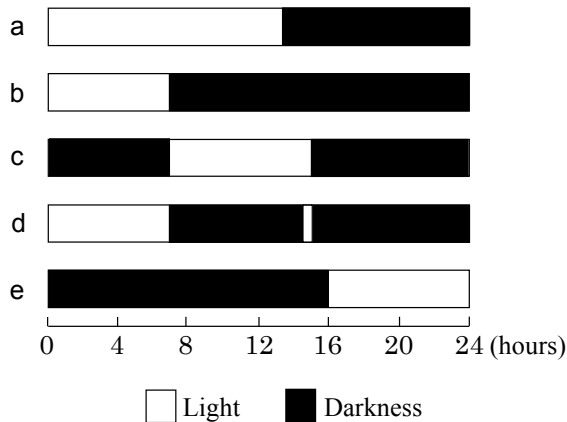
Q16 From ①–④ below choose the statement that correctly describes human reflexes.

16

- ① The term “flexor reflex” refers to the involuntary movement of a leg that jerks upward when the area immediately below the knee joint is lightly struck.
- ② The reflex centers are located mainly in the spinal cord and the cerebellum; none exist in the cerebrum, the midbrain, or the medulla oblongata.
- ③ The term “reflex arc” refers to the following conduction pathway of excitation : receptor → sensory nerve → reflex center → motor nerve → effector.
- ④ The spinal cord is the reflex center for the spinal reflex and has a columnar structure enclosed in the vertebrae; it contains white matter in the interior that is surrounded by gray matter.

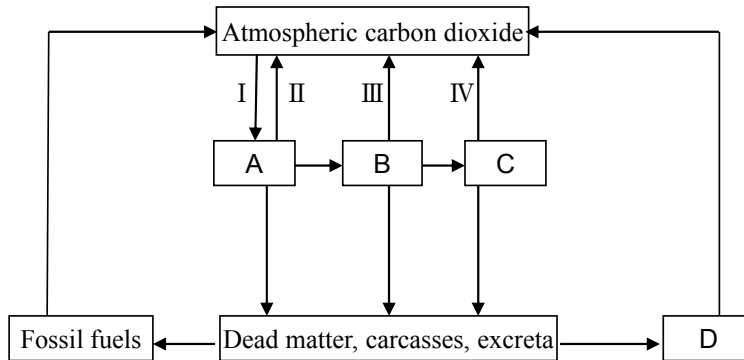
Q17 A short-day plant with a critical dark period of 15 hours was cultivated in the repeated 24-hour light/dark cycles represented in the following figure as a – e. From ①–⑤ below choose the combination correctly indicating all light/dark conditions under which flower buds would form on this short-day plant.

17



- ① a, b, e
- ② a, c, d
- ③ b, c, d
- ④ b, c, e
- ⑤ b, d, e

Q18 The figure below schematically represents a portion of the carbon cycle of the ecosystem. Arrows in the figure represent the flow of carbon, and letters A – D represent any of the following; bacteria/fungi, plants, herbivorous animals, and carnivorous animals. Which of the arrows I – IV in the figure represents photosynthesis? Which of the letters A – D represent herbivorous animals and bacteria/fungi, respectively? From ①–⑧ below choose the correct combination. **18**



	Photosynthesis	Herbivorous animals	Bacteria/fungi
①	I	C	B
②	I	B	D
③	II	B	C
④	II	A	B
⑤	III	C	D
⑥	III	D	A
⑦	IV	D	A
⑧	IV	A	C

End of Biology questions. Leave the answer spaces **19** ~ **75** blank.

Please check once more that you have properly marked the name of your subject as “Biology” on your answer sheet.

Do not take this question booklet out of the room.

