

2016 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 – 36
Biology	37 – 50

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.

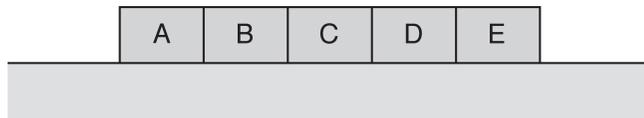
**If you do not correctly fill in the appropriate oval, your answers will not be graded.**

<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.

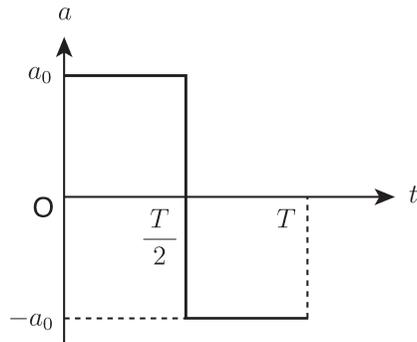
**A** As shown in the figure below, five objects of equal mass (**A**, **B**, **C**, **D**, **E**) are arranged along a straight line on a smooth horizontal plane, in the order indicated and with each in contact with the adjoining object(s). When a force of constant magnitude  $F$  is continuously applied to **A** in a direction from the left and parallel with the line, all five objects undergo motion with constant acceleration as a single unit.



**Q1** What is the magnitude of the force exerted on **C** by **B**? Also, what is the magnitude of the force exerted on **C** by **D**? From ①-④ below choose the correct combination. **1**

	①	②	③	④
Magnitude of force exerted on <b>C</b> by <b>B</b>	$\frac{2F}{5}$	$\frac{2F}{5}$	$\frac{3F}{5}$	$\frac{3F}{5}$
Magnitude of force exerted on <b>C</b> by <b>D</b>	$\frac{2F}{5}$	$\frac{3F}{5}$	$\frac{2F}{5}$	$\frac{3F}{5}$

**B** Acceleration  $a$  of a small object moving in a straight line changes with time  $t$  as shown in the figure below. The object is at rest at  $t = 0$ . Let us denote the distance traveled by the object from  $t = 0$  to  $t = T$  as  $L$ . Here,  $a_0 > 0$ .

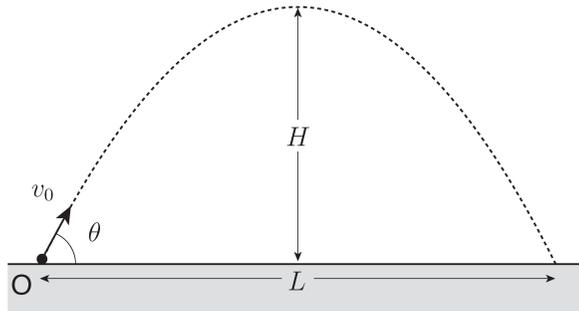


Q2 What is  $L$ ? From ①-⑤ below choose the correct answer.

**2**

- ① 0      ②  $\frac{a_0 T^2}{8}$       ③  $\frac{a_0 T^2}{4}$       ④  $\frac{a_0 T^2}{2}$       ⑤  $a_0 T^2$

- C** As shown in the figure below, a small ball is thrown upward from point  $O$  on a horizontal ground, with initial speed  $v_0$  and at angle  $\theta$  with the horizontal. Let us denote the maximum height attained by the ball above the ground as  $H$ , and the distance between  $O$  and the point where the ball lands as  $L$ .



- Q3** What is  $\frac{H}{L}$ ? From ①-⑥ below choose the correct answer.

<b>3</b>
----------

①  $\frac{\tan \theta}{4}$

②  $\frac{\tan \theta}{2}$

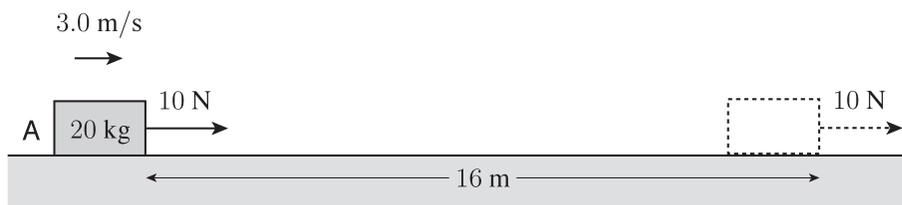
③  $\tan \theta$

④  $\frac{1}{4 \tan \theta}$

⑤  $\frac{1}{2 \tan \theta}$

⑥  $\frac{1}{\tan \theta}$

- D** As shown in the figure below, a small object **A** (mass: 20 kg) is undergoing linear motion on a smooth horizontal surface with a speed of 3.0 m/s. A force of 10 N is continuously applied to **A** in the direction of its motion for a certain period of time. During this time, **A** travels 16 m.



- Q4** After **A** travels 16 m, what are kinetic energy and magnitude of momentum of **A**? From ①-④ below choose the best combination. 4

	①	②	③	④
Kinetic energy (J)	160	160	250	250
Magnitude of momentum (kg·m/s)	80	100	80	100

**E** As shown in Figure 1 below, a small ball A (mass:  $m$ ) with speed  $v_0$  collides with a small ball B (mass:  $2m$ ), which is initially at rest, on a smooth horizontal plane. As shown in Figure 2, following the collision, A moves in a direction forming angle  $\theta$  clockwise with A's pre-collision direction of motion, and B moves in a direction forming angle  $\theta$  counterclockwise with A's pre-collision direction of motion. Let us denote the speed of A and B after the collision as, respectively,  $v_A$  and  $v_B$ .

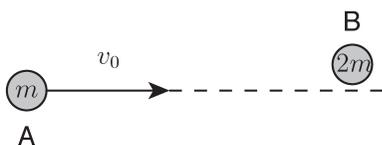


Figure 1

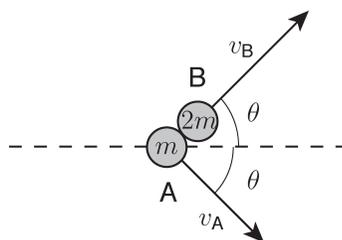


Figure 2

Q5 What is  $\frac{v_B}{v_A}$ ? Also, what is  $\frac{v_A}{v_0}$ ? From ①-⑧ below choose the correct combination.

**5**

	①	②	③	④	⑤	⑥	⑦	⑧
$\frac{v_B}{v_A}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	2	2	2	2
$\frac{v_A}{v_0}$	$\frac{1}{2 \sin \theta}$	$\frac{1}{2 \cos \theta}$	$\frac{1}{5 \sin \theta}$	$\frac{1}{5 \cos \theta}$	$\frac{1}{2 \sin \theta}$	$\frac{1}{2 \cos \theta}$	$\frac{1}{5 \sin \theta}$	$\frac{1}{5 \cos \theta}$

**F** One end of a lightweight, inelastic string of length  $\ell$  is fixed in place at point  $O$  and a small ball of mass  $m$  is attached to the other end. As shown in Figure 1 below, the ball is raised to a position at the same height as  $O$ , while the string is kept taut, and is gently released. When, as shown in Figure 2, the string forms angle  $\theta$  with the vertical, the tension in the string is  $T$ .

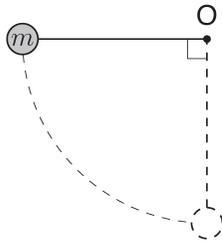


Figure 1

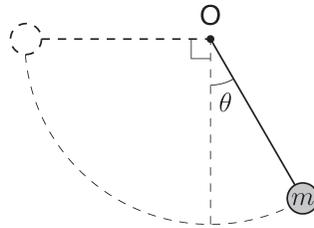


Figure 2

**Q6** What is  $T$ ? From ①-⑥ below choose the correct answer.

6
---

①  $2mg \sin \theta$

②  $2mg \cos \theta$

③  $2mg \tan \theta$

④  $3mg \sin \theta$

⑤  $3mg \cos \theta$

⑥  $3mg \tan \theta$

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

**A** Ice of 20 g at  $-20^{\circ}\text{C}$  is placed in a container, and then water of 100 g at  $20^{\circ}\text{C}$  is added. After sufficient time elapses, all the ice melts and the water in the container is at a constant temperature. The specific heat of ice is  $2.1 \text{ J}/(\text{g}\cdot\text{K})$ , the heat of fusion of ice is  $3.3 \times 10^2 \text{ J/g}$ , and the specific heat of water is  $4.2 \text{ J}/(\text{g}\cdot\text{K})$ . Assume that the heat capacity of the container is negligible and that there is no exchange of heat with the environment.

**Q1** What is the temperature of the water (in  $^{\circ}\text{C}$ ) after sufficient time elapses? From ①-⑤ below choose the best answer. **7**  $^{\circ}\text{C}$

- ① 0.0                      ② 1.9                      ③ 2.9                      ④ 5.4                      ⑤ 14

**B** An ideal gas is enclosed inside a cylinder by a smoothly moving piston. When the pressure of the gas is  $1.0 \times 10^5$  Pa and its absolute temperature is 300 K, its volume is  $6.0 \times 10^{-3}$  m<sup>3</sup>. While keeping the pressure constant, the absolute temperature is raised to 400 K.

**Q2** What is the quantity of work (in J) done on the external environment by the ideal gas ?

From ①-④ below choose the best answer.

**8** J

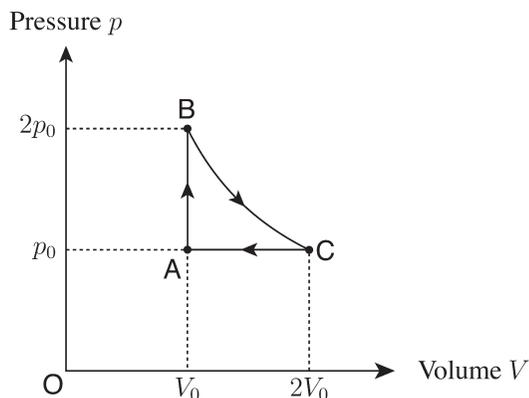
① 2.0

②  $2.0 \times 10^1$

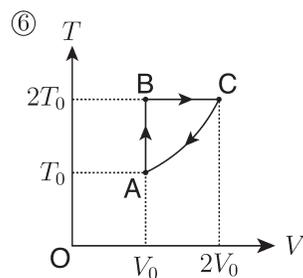
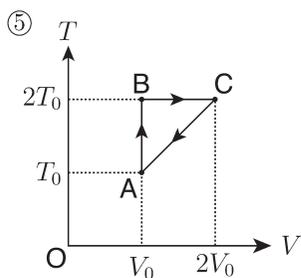
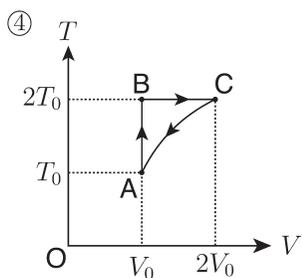
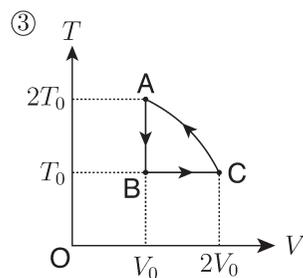
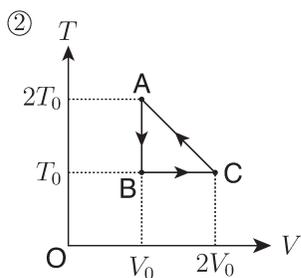
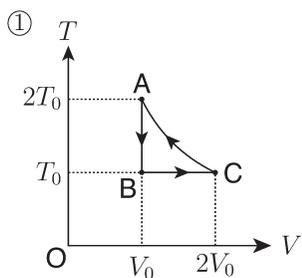
③  $2.0 \times 10^2$

④  $2.0 \times 10^3$

**C** Pressure  $p$  and volume  $V$  of a certain quantity of an ideal gas is changed in the path  $A \rightarrow B \rightarrow C \rightarrow A$  as shown in the  $p$ - $V$  diagram below.  $A \rightarrow B$  is an isochoric change,  $B \rightarrow C$  is an isothermal change, and  $C \rightarrow A$  is an isobaric change.

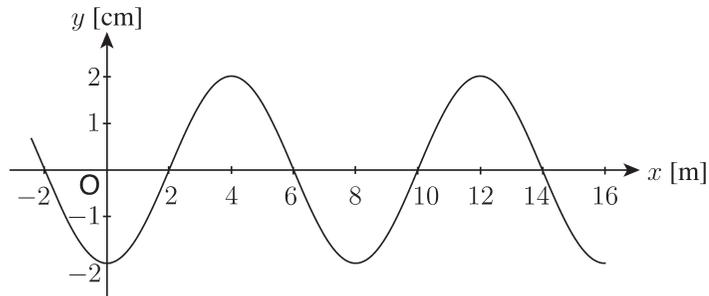


**Q3** From ①-⑥ below choose the graph that best represents the change in absolute temperature  $T$  and volume  $V$  of the gas in this case. 9



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

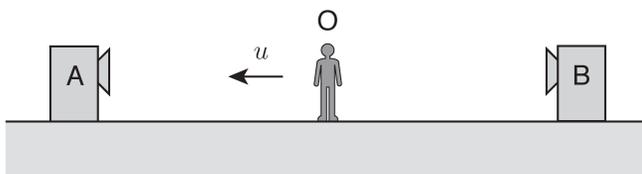
A Consider a sinusoidal wave propagating along an  $x$ -axis in the positive direction. The wave's period is 0.8 s. The figure below is a graph representing, for this wave, the relationship between displacement of the medium,  $y$ , and the  $x$ -coordinate when time  $t = 0$  s.



Q1 What is the value of time  $t$  when the next wave trough (displacement  $y = -2$  cm) appears at position  $x = 6$  m? From ①-⑤ below choose the best answer.  $t = \boxed{10}$  s

- ① 0.2      ② 0.4      ③ 0.6      ④ 0.8      ⑤ 1

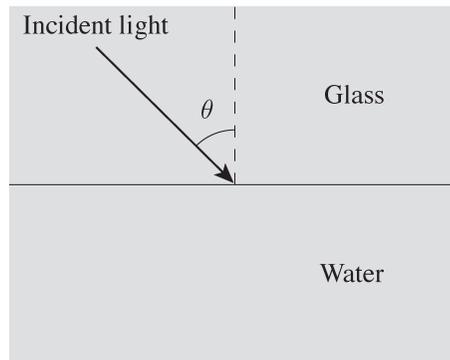
**B** Sound sources **A** and **B** and observer **O** are arranged in a straight line as shown in the figure below. A sound of a constant frequency is emitted from **A**. At the same time, a sound of another constant frequency is emitted from **B**. The observer, who is standing still, hears beats at a rate of  $n$  times per second. Next, the observer starts moving toward **A** at a constant speed of  $u$ , and stops hearing any beats. Let us denote the frequency of **A**'s sound as  $f$  (in Hz), and the speed of sound as  $V$ , where  $u < V$ .



**Q2** What is the frequency of **B**'s sound? Also, what is  $\frac{u}{V}$ ? From ①-④ below choose the correct combination. **11**

	①	②	③	④
Frequency of <b>B</b> 's sound	$f + n$	$f + n$	$f - n$	$f - n$
$\frac{u}{V}$	$\frac{n}{2f + n}$	$\frac{n}{2f - n}$	$\frac{n}{2f + n}$	$\frac{n}{2f - n}$

- C** As shown in the figure below, a block of glass interfaces with water along a planar surface. A beam of monochromatic light is projected from the glass to the water at angle of incidence  $\theta$ , which is gradually increased from zero. When  $\sin \theta$  exceeds 0.8, the light becomes totally reflected. Assume that the refractive index of water is 1.3.



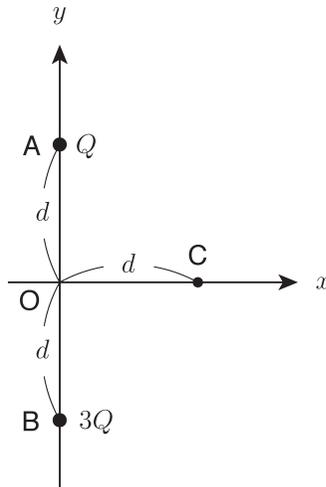
- Q3** What is the refractive index of the glass? From ①-⑤ below choose the best answer.

**12**

- ① 1.0      ② 1.2      ③ 1.4      ④ 1.6      ⑤ 1.8

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

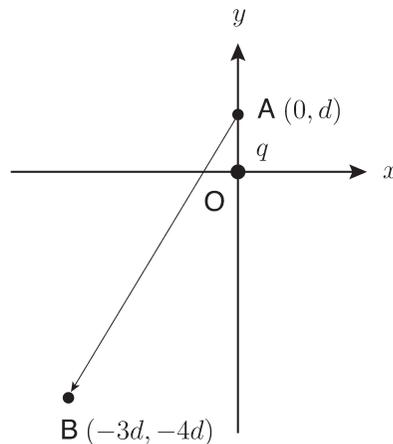
**A** As shown in the figure below, a point charge with quantity of electricity  $Q$  is fixed in place in an  $x$ - $y$  plane at point **A**  $(0, d)$ , and a point charge with quantity of electricity  $3Q$  is fixed in place at point **B**  $(0, -d)$ . Here,  $d > 0$ , and  $Q > 0$ . Let us denote the proportionality constant of Coulomb's law as  $k$ .



**Q1** What is the magnitude of the electric field at point **C**  $(d, 0)$  in the figure? From ①-⑦ below choose the correct answer. **13**

- ①  $\frac{kQ}{d^2}$       ②  $\frac{\sqrt{2}kQ}{d^2}$       ③  $\frac{2kQ}{d^2}$       ④  $\frac{\sqrt{10}kQ}{2d^2}$
- ⑤  $\frac{2\sqrt{2}kQ}{d^2}$       ⑥  $\frac{4kQ}{d^2}$       ⑦  $\frac{\sqrt{10}kQ}{d^2}$

**B** As shown in the figure below, a point charge with quantity of electricity  $q$  is fixed in place in an  $x$ - $y$  plane at the origin  $O$ . A point charge with quantity of electricity  $-2q$  is made to travel from point  $A(0, d)$  to point  $B(-3d, -4d)$  in a straight line connecting  $A$  and  $B$ , in the direction indicated by the arrow in the figure. Here,  $q > 0$ , and  $d > 0$ . Let us denote the proportionality constant of Coulomb's law as  $k$ .

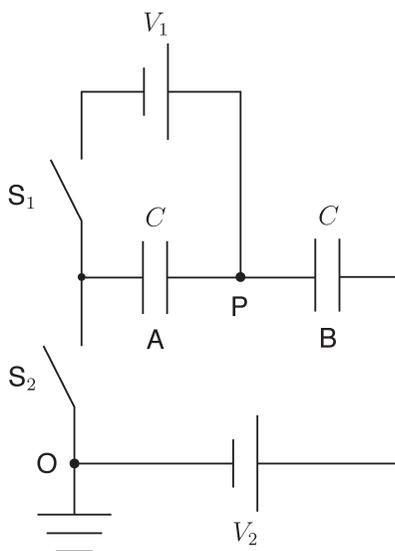


**Q2** What is the work done by the force exerted by the point charge with quantity of electricity  $q$  on the point charge with quantity of electricity  $-2q$  when it travels from  $A$  to  $B$ ? From ①-⑧ below choose the correct answer.

14
----

- |                       |                       |                       |                       |
|-----------------------|-----------------------|-----------------------|-----------------------|
| ① $\frac{2kq^2}{5d}$  | ② $\frac{4kq^2}{5d}$  | ③ $\frac{6kq^2}{5d}$  | ④ $\frac{8kq^2}{5d}$  |
| ⑤ $-\frac{2kq^2}{5d}$ | ⑥ $-\frac{4kq^2}{5d}$ | ⑦ $-\frac{6kq^2}{5d}$ | ⑧ $-\frac{8kq^2}{5d}$ |

**C** Two batteries (electromotive force:  $V_1, V_2$ ), two capacitors (A and B, each with capacitance  $C$ ), and two switches ( $S_1, S_2$ ) are connected as shown in the figure below. Initially,  $S_1$  and  $S_2$  are open, and the two capacitors are uncharged. Next,  $S_1$  is closed, and after sufficient time elapses, is opened. Afterwards,  $S_2$  is closed while  $S_1$  remains open. Let us denote as  $V$  the electric potential at point P in the circuit with respect to point O, after  $S_2$  was closed and sufficient time elapsed.

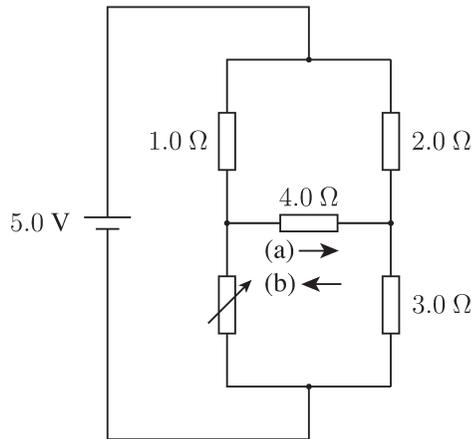


**Q3** What is  $V$ ? From ①-④ below choose the correct answer.

**15**

- ①  $\frac{V_1 + V_2}{2}$       ②  $\frac{V_1 - V_2}{2}$       ③  $\frac{V_2 - V_1}{2}$       ④  $-\frac{V_1 + V_2}{2}$

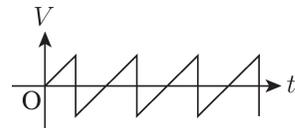
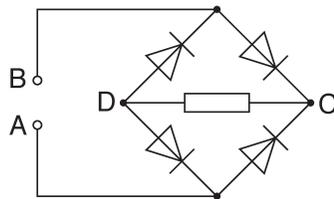
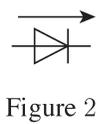
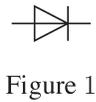
**D** A battery (electromotive force: 5.0 V), four resistors (resistance: 1.0  $\Omega$ , 2.0  $\Omega$ , 3.0  $\Omega$ , 4.0  $\Omega$ ), and a variable resistor (resistance range: 0  $\Omega$  - 5.0  $\Omega$ ), are connected as shown in the figure below.



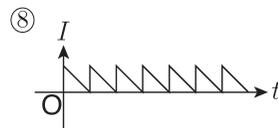
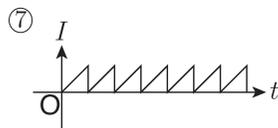
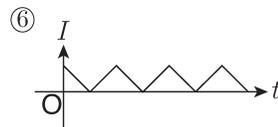
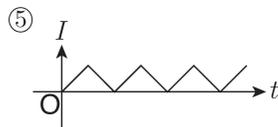
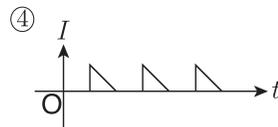
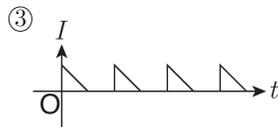
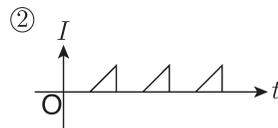
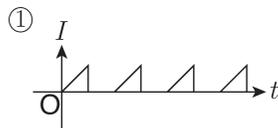
**Q4** When the resistance of the variable resistor is set as 0  $\Omega$ , does the electrical current flowing through the 4.0- $\Omega$  resistor flow in the direction of arrow (a) in the figure, or in the direction of arrow (b)? Also, at what resistance setting of the variable resistor will the current stop flowing through the 4.0- $\Omega$  resistor? From ①-④ below choose the best combination. **16**

	①	②	③	④
Direction of current	(a)	(a)	(b)	(b)
Resistance setting ( $\Omega$ )	0.67	1.5	0.67	1.5

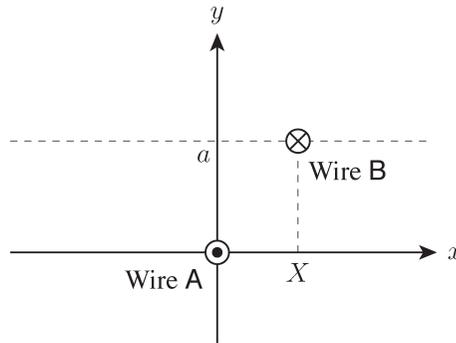
**E** Diodes are represented with the symbol shown in Figure 1 below, and are characterized by their conducting of electrical current in only the direction depicted by the arrow in Figure 2. As shown in Figure 3, four diodes and a resistor are connected. Electromotive force  $V$  is applied to input terminals **A** and **B**, and varies over time  $t$  as indicated in the graph in Figure 4, which expresses the electric potential at terminal **B** with respect to terminal **A**.



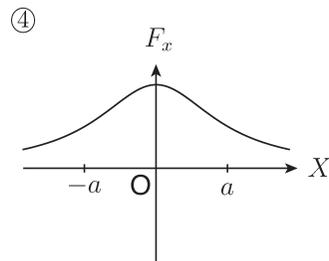
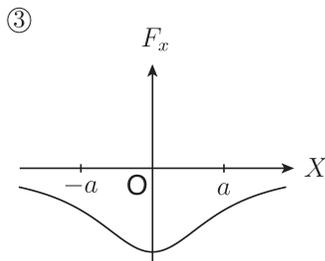
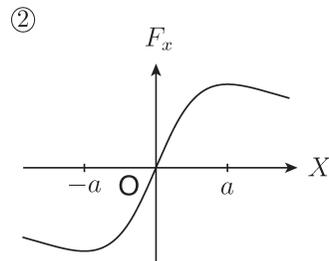
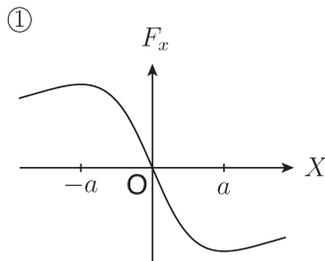
**Q5** If current flowing in the direction from **C** to **D** in the figure is defined as positive, how does current  $I$  flowing through the resistor change over time  $t$ ? From ①-⑧ below choose the graph that best represents this change. 17



**F** As shown in the figure below, long, straight conducting wire **A** is fixed in place so that it passes through the origin of the  $x$ - $y$  plane (the plane of this page) and is perpendicular to the plane of this page, and an electrical current of magnitude  $I$  is passed through this wire in the direction from the back of this page to the front. Also, long, straight conducting wire **B** is placed so that it passes through point  $(X, a)$  of the  $x$ - $y$  plane and is perpendicular to the plane of this page, and a current of magnitude  $I$  is passed through this wire in the direction from the front of this page to the back. Let us denote as  $F_x$  the  $x$ -component of the force that the current flowing through wire **B** exerts on a segment of wire **A** with length  $\ell$ . Here,  $a > 0$ .



**Q6** If  $X$  is varied, how does  $F_x$  change with  $X$ ? From ①-④ below choose the graph that best represents this change. **18**



**V** Answer question **A** ( Q1 ) below.

**A** Uranium 235 ( $^{235}\text{U}$ ) undergoes radioactive decay with a half-life of  $7.0 \times 10^8$  years.

**Q1** How many years would it take for the number of atomic nuclei in a given quantity of  $^{235}\text{U}$  to decrease to  $\frac{1}{1024}$  of its original number? From ①-④ below choose the best answer.

**19** years

- ①  $5.6 \times 10^9$       ②  $6.3 \times 10^9$       ③  $7.0 \times 10^9$       ④  $7.7 \times 10^9$

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:**  $0\text{ }^{\circ}\text{C}$ ,  $1.01 \times 10^5\text{ Pa}$  (= 1.00 atm)

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

**Gas constant:**  $R = 8.31 \times 10^3\text{ Pa}\cdot\text{L}/(\text{K}\cdot\text{mol})$

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

**Faraday constant:**  $F = 9.65 \times 10^4\text{ C/mol}$

**Atomic weight:** H : 1.0    C : 12    N : 14    O : 16    Na : 23

S : 32    Cl : 35.5

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** A manganese(II) ion ( $\text{Mn}^{2+}$ ), the mass number of which is 55, contains 23 electrons. How many neutrons does the manganese(II) ion have? From ①-⑤ below choose the correct number. **1**

- ① 23      ② 25      ③ 30      ④ 32      ⑤ 55

**Q2** From the following combinations of atoms and ions ①-⑤ choose the one in which the two have the same electron configuration. **2**

- ①  $\text{Cl}^-$  and  $\text{Na}^+$       ②  $\text{H}^+$  and He      ③  $\text{Na}^+$  and  $\text{Ca}^{2+}$   
 ④ Ne and  $\text{Mg}^{2+}$       ⑤  $\text{Cl}^-$  and  $\text{Br}^-$

**Q3** Among the following statements (a)-(e) on the periodic table, two are correct. From ①-⑥ below choose the correct combination. **3**

- (a) Elements belonging to the same group are in the same state (either solid, liquid or gas) at normal temperature and pressure.  
 (b) Except for the group 18 elements, among the main group elements belonging to the same period, the larger the number of the group, the higher the electronegativity in general.  
 (c) Transition elements exist in the third to seventh periods.  
 (d) Elements belonging to group 18 are called the noble gases.  
 (e) Among the known elements, nearly half of them are nonmetallic elements.

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

**Q4** Two out of the following (a)-(e) are appropriate as the methods to separate a mixture of sodium chloride (NaCl) and iodine (I<sub>2</sub>). From ①-⑥ below choose the correct combination. **4**

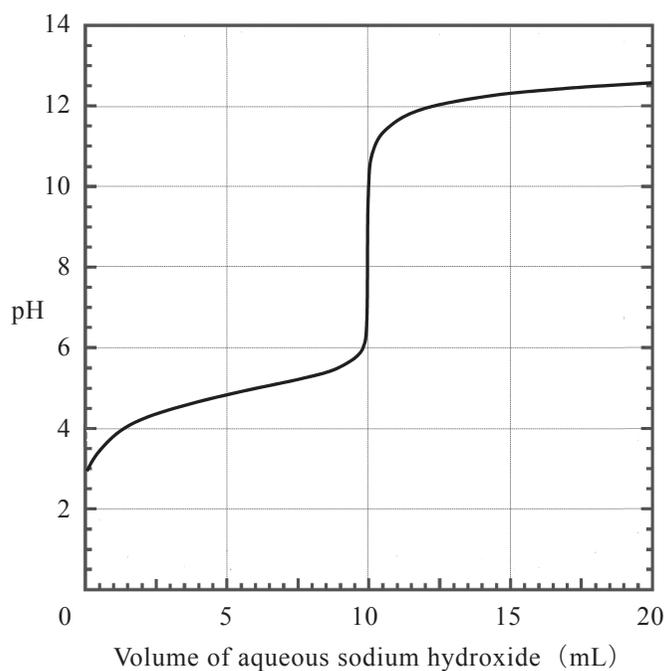
- (a) distillation
- (b) sublimation
- (c) recrystallization
- (d) extraction
- (e) fractional distillation

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

**Q5** From the following gases ①-⑤ choose the one which contains the largest number of molecules in 1 g. **5**

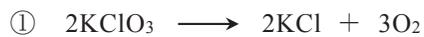
- ① oxygen
- ② nitrogen
- ③ chlorine
- ④ nitrogen monoxide
- ⑤ carbon dioxide

**Q6** The following titration curve was obtained by measuring the pH value of the solution while 10 mL of 0.1 mol/L of an acid **A** was titrated with 0.1 mol/L aqueous sodium hydroxide (NaOH) in the presence of an appropriate indicator **B**. From ①-⑥ in the table below choose the correct combination of **A** and **B**. 6

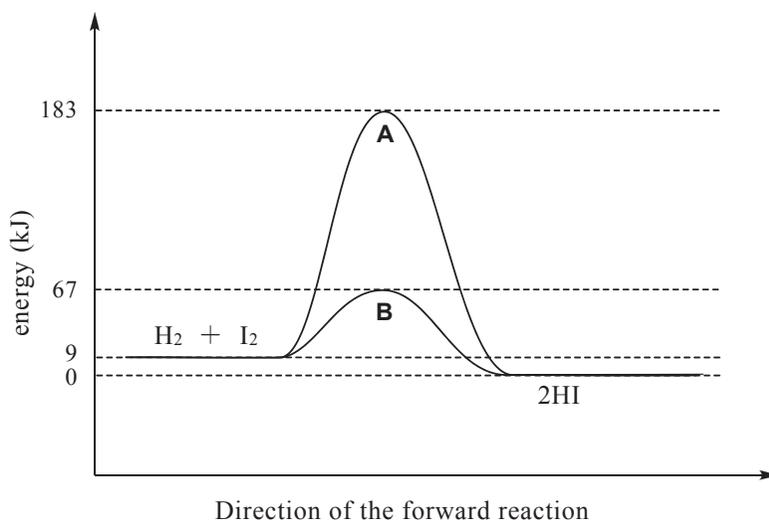


	<b>A</b>	<b>B</b>
①	CH <sub>3</sub> COOH	phenolphthalein
②	CH <sub>3</sub> COOH	Methyl Orange
③	HCl	phenolphthalein
④	HCl	Methyl Orange
⑤	H <sub>2</sub> SO <sub>4</sub>	phenolphthalein
⑥	H <sub>2</sub> SO <sub>4</sub>	Methyl Orange

**Q7** From the following chemical reactions ①-④ choose the one in which the oxidation number of oxygen (O) decreases. **7**

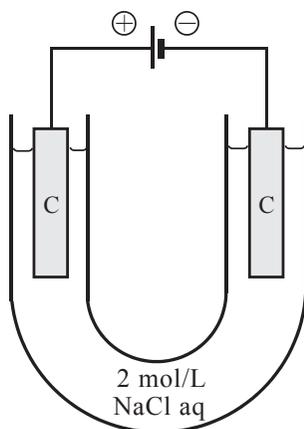


- Q8** The following diagram indicates the change of energy of the reversible reaction (i) as the reaction proceeds. Reaction path **A** corresponds to the case when no catalyst is employed while reaction path **B** is the case when a certain catalyst is employed. From the statements ①-⑥ below choose the correct one. 8



- ① The activation energy of the forward reaction (i) via path **A** is 183 kJ/mol.
- ② The activation energy of the reverse reaction (i) via path **B** is 58 kJ/mol.
- ③ The heat of forward reaction (i) via path **A** is larger than that via path **B**.
- ④ The equilibrium constant of the reaction (i) via path **A** is larger than that via path **B** at the same temperature.
- ⑤ When the reaction (i) is at equilibrium in a reaction vessel, the proportion of HI increases by reducing the volume of the vessel at constant temperature.
- ⑥ When the reaction (i) is at equilibrium in a reaction vessel, the proportion of HI increases by reducing the temperature of the vessel.

- Q9** In a U-tube, 2 mol/L aqueous sodium chloride (NaCl) was electrolyzed with graphite electrodes C by applying a voltage of 3 V.



Among the following observable phenomena **(a)-(d)**, two are correct. From ①-⑥ below choose the correct combination. 9

- (a)** Gas was generated only at the anode.
- (b)** When potassium iodide-starch paper moistened with pure water was brought to the mouths of the U-tube, it turned blue at the anode side.
- (c)** White precipitates formed at the bottom of the U-tube.
- (d)** The aqueous solution near the cathode turned pink when a few drops of aqueous phenolphthalein was added after the electrolysis.

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

**Q10** At 20 °C and  $1.0 \times 10^5$  Pa,  $1.4 \times 10^{-3}$  mol of oxygen dissolves in 1.0 L of water. Convert the amount of oxygen that dissolves in 2.0 L of water at 20 °C and  $5.0 \times 10^5$  Pa into the volume at the standard state in L. From the following ①-⑤ choose the closest value.

**10** L

- ① 0.031      ② 0.063      ③ 0.16      ④ 0.31      ⑤ 0.63

**Q11** In the following table, experimental procedures to generate gases and the properties of the gases generated are listed. From ①-⑥ in the following table choose the one in which the property of the generated gas is **not** correct.

**11**

	Experimental procedures	Properties of gases
①	Dilute sulfuric acid (dil. $\text{H}_2\text{SO}_4$ ) is added to iron(II) sulfide ( $\text{FeS}$ ).	It has a reducing property.
②	Manganese(IV) oxide ( $\text{MnO}_2$ ) is added to concentrated hydrochloric acid (conc. $\text{HCl}$ ), and the mixture is heated.	It has an oxidizing property.
③	Calcium ( $\text{Ca}$ ) is added to water.	It is the lightest gas.
④	Dilute nitric acid (dil. $\text{HNO}_3$ ) is added to copper ( $\text{Cu}$ ).	Its color is brown.
⑤	Concentrated sulfuric acid (conc. $\text{H}_2\text{SO}_4$ ) is added to copper ( $\text{Cu}$ ) and the mixture is heated.	It has a bleaching property.
⑥	Dilute hydrochloric acid (dil. $\text{HCl}$ ) is added to limestone ( $\text{CaCO}_3$ ).	It dissolves in water, and the solution is weakly acidic.

**Q12** From the following statements ①-⑥ on halogens X (X = F, Cl, Br, I) choose the one that is **not** correct. **12**

- ① Concerning the boiling points of  $X_2$ , that of  $F_2$  is the lowest.
- ② Concerning the oxidizing power of  $X_2$ , the smaller the molecular weight, the higher the oxidizing power.
- ③ Concerning the boiling points of  $HX$ , the one that has the lowest boiling point is  $HCl$ .
- ④ To store aqueous hydrogen fluoride ( $HF$ ), plastic bottles should be used.
- ⑤ Hypochlorous acid ( $HClO$ ) exhibits an oxidizing property.
- ⑥ Silver fluoride ( $AgF$ ) is hardly soluble in water.

**Q13** From the following statements ①-⑦ on group 14 elements choose the one that is **not** correct. **13**

- ① Carbon (C) forms covalent crystals.
- ② All allotropes of carbon are good electric conductors.
- ③ Silicon (Si) can be obtained by reducing quartz sand with carbon.
- ④ Silicon is a semiconductor.
- ⑤ Tin (Sn) reacts with both aqueous acids and aqueous bases to generate hydrogen ( $H_2$ ).
- ⑥ Lead (Pb) does not easily dissolve in dilute sulfuric acid (dil.  $H_2SO_4$ ) at normal temperature.
- ⑦ Lead is used as a shielding material against radiation.

**Q14** Among the following statements (a)-(e) two are in common with both iron (Fe) and aluminum (Al). From ①-⑥ below choose the correct combination. **14**

- (a) Both are transition elements.
- (b) Both form trivalent cations.
- (c) Both react with hydrochloric acid (HCl aq) and generate hydrogen (H<sub>2</sub>).
- (d) Both react with aqueous sodium hydroxide (NaOH) and generate hydrogen.
- (e) Both react with aqueous zinc chloride (ZnCl<sub>2</sub>) to deposit zinc (Zn).

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

**Q15** From the statements ①-⑤ on the reactions involving oxides choose the one in which the underlined product is **not** correct. **15**

- ① Aluminum oxide (Al<sub>2</sub>O<sub>3</sub>) reacts with aqueous sodium hydroxide (NaOH) to yield sodium tetrahydroxydoaluminate (Na[Al(OH)<sub>4</sub>]).
- ② Calcium oxide (CaO) reacts with hydrochloric acid (HCl aq) to yield calcium hydroxide (Ca(OH)<sub>2</sub>).
- ③ Manganese(IV) oxide (MnO<sub>2</sub>) catalyzes the reaction of hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) to yield oxygen (O<sub>2</sub>).
- ④ Sodium oxide (Na<sub>2</sub>O) reacts with water to yield sodium hydroxide (NaOH).
- ⑤ Phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) is generated when tetraphosphorus decoxide (P<sub>4</sub>O<sub>10</sub>) is dissolved in water and the solution is heated.

**Q16** The following statements (a)-(d) concern alkanes and alkenes. From ①-⑧ in the table below choose the combination in which the “true” or “false” judgments are correct.

**16**

- (a) Alkanes are readily oxidized with aqueous potassium permanganate ( $\text{KMnO}_4$ ) acidified with sulfuric acid.
- (b) For straight chain alkanes, the larger the number of carbon atoms (C), the higher the boiling points.
- (c) A *trans* alkene and a *cis* alkene with the same number of carbon atoms have the same melting point.
- (d) Alkenes are readily susceptible to addition reactions.

	<b>a</b>	<b>b</b>	<b>c</b>	<b>d</b>
①	true	true	true	true
②	true	true	true	false
③	true	false	false	true
④	true	false	false	false
⑤	false	false	true	false
⑥	false	false	true	true
⑦	false	true	false	false
⑧	false	true	false	true

**Q17** From the following statements ①-⑤ on carboxylic acids and their salts choose the one that is **not** correct. **17**

- ① Phthalic acid possesses one or more asymmetric carbon atoms.
- ② Oxalic acid is a dicarboxylic acid.
- ③ Linoleic acid is classified as a higher fatty acid.
- ④ Oxidation of toluene with potassium permanganate ( $\text{KMnO}_4$ ) acidified with sulfuric acid, yields benzoic acid.
- ⑤ If sodium phenoxide and carbon dioxide ( $\text{CO}_2$ ) are reacted at high temperature and pressure, sodium salicylate is formed.

**Q18** When 8.2 g of sodium acetate ( $\text{CH}_3\text{COONa}$ ) and excess sodium hydroxide ( $\text{NaOH}$ ) were placed in a test tube and the mixture was heated, the reaction proceeded completely and methane ( $\text{CH}_4$ ) was generated. Calculate the amount of generated methane in L at the standard state. From the following ①-⑤ choose the closest value. **18** L

- ① 1.0      ② 1.6      ③ 2.2      ④ 3.4      ⑤ 4.4

**Q19** From ①-⑥ in the following table choose the correct combination of polymer and its precursor, monomer.

**19**

	Polymer	Monomer
①	glycogen	maltose
②	protein	amino acid
③	DNA (deoxyribonucleic acid)	ribose
④	natural rubber	propene (propylene)
⑤	polyamide	aniline
⑥	polyester	ethene (ethylene)

**Q20** From the following statements ①-⑤ on amino acids choose the correct one.

**20**

- ① The number of carboxy groups and that of amino groups constituting an  $\alpha$ -amino acid is one, respectively.
- ② All  $\alpha$ -amino acids contain asymmetric carbon atom(s).
- ③  $\alpha$ -Amino acids contain only carbon (C), hydrogen (H), oxygen (O) and nitrogen (N).
- ④ All essential amino acids are synthesized in the human body.
- ⑤ Compounds formed by dehydration condensation between a carboxy group of one amino acid and an amino group of another amino acid are called peptides.

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
<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>

- Q1** The cytoskeleton includes components such as microtubules, intermediate filaments, and actin filaments. Of these, which component is directly involved in muscle contraction, and which is directly involved in formation of the spindle body? From ①–⑤ below choose the correct combination. 1

	Muscle contraction	Formation of the spindle body
①	microtubule	intermediate filament
②	microtubule	actin filament
③	intermediate filament	actin filament
④	actin filament	microtubule
⑤	actin filament	intermediate filament

**Q2** Statements a – d below describe various organelles. From ①–⑥ below choose the combination correctly indicating the statement that describes mitochondria, and the statement that describes chloroplasts. **2**

- a It is a double-membrane organelle that contains stacks of flat, sac-like structures inside the inner membrane.
- b It is a single-membrane organelle filled with cell fluid.
- c It is a double-membrane organelle in which the inner membrane is highly folded.
- d It is a single-membrane organelle to which ribosomes are attached on the surface.

	Mitochondria	Chloroplasts
①	a	c
②	b	a
③	b	d
④	c	a
⑤	c	d
⑥	d	b

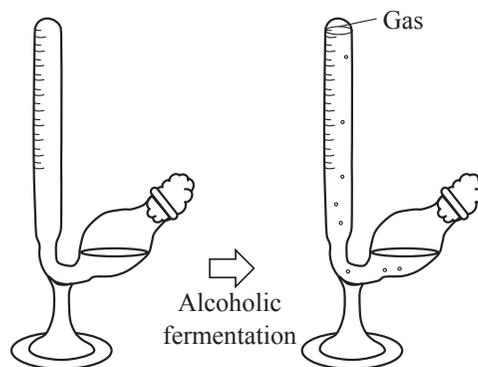
**Q3** Consider the differences between *Escherichia coli* and the leaf cells of plants. From ①–⑤ below choose the statement that applies to a plant leaf cell, but not to *E. coli*. **3**

- ① Translation is initiated after transcription is completed.
- ② ATP is synthesized in the cytoplasmic matrix.
- ③ The cell membrane is surrounded by a cell wall.
- ④ Though it contains DNA within the cell, it does not have a nucleus.
- ⑤ It does not have any centrosomes.

**Q4** From ①–⑧ below choose the combination that best indicates the substrate, product, and optimum pH of amylase, which is present in human saliva. 4

	Substrate	Product	Optimum pH
①	starch	maltose	pH2
②	starch	maltose	pH7
③	starch	glucose	pH2
④	starch	glucose	pH7
⑤	maltose	starch	pH2
⑥	maltose	starch	pH7
⑦	maltose	glucose	pH2
⑧	maltose	glucose	pH7

**Q5** The figure below shows alcoholic fermentation occurring in a Kühne’s fermentation tube. The fermentation solution was prepared by heating a glucose solution, allowing it to cool to room temperature, and then mixing yeast into it in an appropriate ratio. The fermentation solution was poured into the tube and the temperature was maintained at 35°C. A gas evolved as a result of alcoholic fermentation. From ①–④ below choose the answer that correctly identifies the gas that evolved. 5



- ① oxygen (O<sub>2</sub>)      ② hydrogen (H<sub>2</sub>)      ③ carbon dioxide (CO<sub>2</sub>)      ④ nitrogen (N<sub>2</sub>)

**Q6** The reactions of photosynthesis can be summarized with the following reaction equation:



In which photosynthetic process is the  $\text{H}_2\text{O}$  on the left side of the equation broken down? Also, in which photosynthetic process is the  $\text{C}_6\text{H}_{12}\text{O}_6$  on the right side of the equation synthesized? From ①–⑥ below choose the correct combination. 6

	Process in which $\text{H}_2\text{O}$ (on the left side) is broken down	Process in which $\text{C}_6\text{H}_{12}\text{O}_6$ (on the right side) is synthesized
①	Calvin-Benson cycle	photosystem I
②	Calvin-Benson cycle	photosystem II
③	photosystem I	Calvin-Benson cycle
④	photosystem I	photosystem II
⑤	photosystem II	Calvin-Benson cycle
⑥	photosystem II	photosystem I

- Q7** When a synthetic mRNA that contains repeats of a particular base sequence is added to a protein synthesis system, a polypeptide is synthesized. The following table shows the amino acid sequences that are obtained when polypeptides are produced from the synthetic mRNA shown on the left. From ①–⑥ below choose the combination that correctly indicates the amino acids that are coded by codons ACA and CAC.

7

mRNA base sequence	Polypeptides that can be produced
ACACAC...(repeating)	Polypeptides that consist of repeats of alternating threonine and histidine
CAACAACAACAA...(repeating)	Three different polypeptides; chain of glutamine chain of asparagine chain of threonine

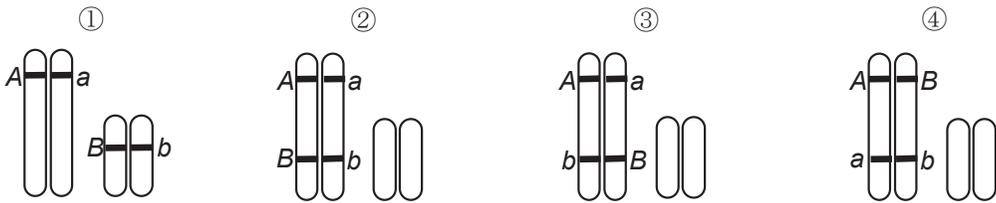
	ACA	CAC
①	threonine	histidine
②	histidine	threonine
③	glutamine	threonine
④	histidine	asparagine
⑤	glutamine	histidine
⑥	threonine	glutamine

**Q8** A certain organism has two pairs of alleles: A(a) and B(b). An individual with genotype *AAbb* was crossed with an individual with genotype *aaBB* to produce the F<sub>1</sub> generation. Next, an F<sub>1</sub> individual is crossed with an individual with genotype *aabb*, resulting in the offspring with the following phenotypes and segregation ratio. Note that A and B are dominant over a and b respectively.

$$[AB] : [Ab] : [aB] : [ab] = 1 : 5 : 5 : 1$$

From ①–④ below choose the figure that best represents the relative position of the alleles on the chromosomes in the above offspring of the phenotype [AB].

8



**Q9** The figure below represents the sex chromosomes in a human somatic cell during mitotic metaphase. Referring to this figure, from ① – ⑤ below choose the statement that best describes human chromosomes. Note that the chromosome number of humans is  $2n = 46$ .

9



- ① X chromosomes are observed only in males.
- ② Human somatic cells have 23 pairs of autosomes.
- ③ Both sex chromosomes in human somatic cells differ in shape between males and females.
- ④ A human somatic cell has 23 chromosomes during mitotic metaphase.
- ⑤ The chromosome marked X in the figure is inherited from the mother.

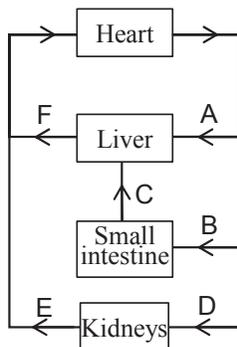
**Q10** From ①–⑥ below choose the combination of terms that correctly fills blanks **a** – **c** in the following statement describing transplantation pertaining to eye formation in the newt. **10**

An optic vesicle was removed from a tailbud-stage newt embryo and transplanted to the head of another tailbud-stage embryo at the position just below the epidermis. A portion of eye structure was formed at the transplant site, where an eye would not normally develop. It is likely that this occurred because the optic vesicle itself, which formed from **a**, became the **b** and at the same time acted on the cells surrounding the transplant site and determined their fates to become an eye tissue. Such action is referred to as **c**.

	a	b	c
①	mesoderm	optic cup	differentiation
②	mesoderm	crystalline lens	differentiation
③	mesoderm	optic cup	induction
④	ectoderm	crystalline lens	differentiation
⑤	ectoderm	optic cup	induction
⑥	ectoderm	crystalline lens	induction

**Q11** The figure below is a simplified representation of part of the human circulatory system. From ①–⑥ below choose the combination that best indicates: the blood vessel in the figure that carries blood with the highest glucose concentration after eating (X), and the blood vessel in the figure that carries blood with the lowest urea concentration (Y), in a healthy individual.

**11**



	Blood vessel X	Blood vessel Y
①	A	C
②	A	E
③	C	E
④	C	F
⑤	D	B
⑥	D	C

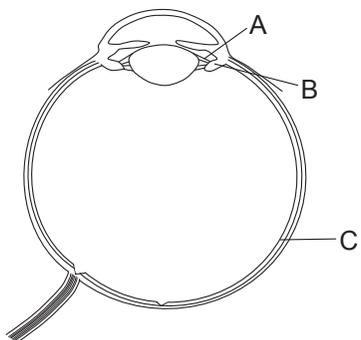
**Q12** Statements a–d below describe arteries, veins, capillaries, or lymph ducts. From ①–⑥ below choose the combination correctly indicating the statement that describes veins, and the statement that describes lymph ducts.

<b>12</b>
-----------

- a They are enveloped by a muscle layer and an elastic layer. They have valves that prevent backflow of blood.
- b They are enveloped by a muscle layer and an elastic layer. The muscle layer is relatively thick. They do not have valves for preventing backflow of blood.
- c Some tissue fluid enters them, and leukocytes are the only blood cells that are observed in them. They have valves that prevent backflow.
- d They are bound by a single layer of cells. A portion of blood plasma flows out from them to form tissue fluid.

	Veins	Lymph ducts
①	a	b
②	a	c
③	a	d
④	b	a
⑤	b	c
⑥	b	d

**Q13** The following figure schematically represents a horizontal cross section of the human eye, as seen from above. Answer questions (1) and (2) below concerning this.



(1) From ①–④ below choose the combination that correctly indicates the names of structures A, B, and C in the figure.

**13**

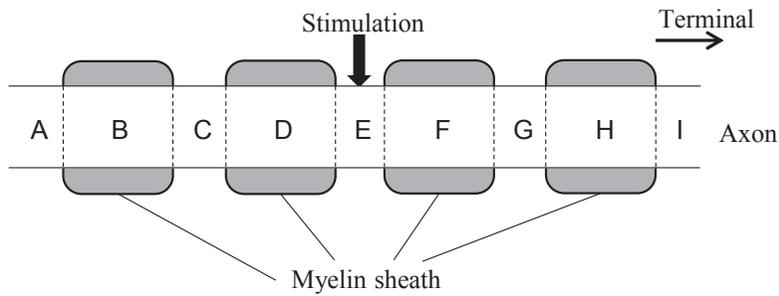
	A	B	C
①	zonule of Zinn	ciliary body	retina
②	zonule of Zinn	ciliary body	cornea
③	ciliary body	zonule of Zinn	retina
④	ciliary body	zonule of Zinn	cornea

- (2) Structures A and B in the figure are involved in accommodation of the human eye. From ①–⑧ below choose the statement that best indicates the changes to A, B, and the crystalline lens when the eye focuses on a nearby object.

**14**

- ① The muscle contained in B contracts and A slackens, causing the crystalline lens to become thinner.
- ② The muscle contained in B contracts and A slackens, causing the crystalline lens to become thicker.
- ③ The muscle contained in B contracts and A tightens, causing the crystalline lens to become thinner.
- ④ The muscle contained in B contracts and A tightens, causing the crystalline lens to become thicker.
- ⑤ The muscle contained in B relaxes and A slackens, causing the crystalline lens to become thinner.
- ⑥ The muscle contained in B relaxes and A slackens, causing the crystalline lens to become thicker.
- ⑦ The muscle contained in B relaxes and A tightens, causing the crystalline lens to become thinner.
- ⑧ The muscle contained in B relaxes and A tightens, causing the crystalline lens to become thicker.

**Q14** The following figure schematically represents a part of a medullated nerve. From ①–⑤ below choose the answer that correctly indicates the order of the regions along which excitation is observed in the axon when region E is given a stimulation exceeding the threshold value. 15



- ① E → F → G → H → I
- ② E → F → H
- ③ E  $\begin{cases} \nearrow D \rightarrow C \rightarrow B \rightarrow A \\ \searrow F \rightarrow G \rightarrow H \rightarrow I \end{cases}$
- ④ E  $\begin{cases} \nearrow D \rightarrow B \\ \searrow F \rightarrow H \end{cases}$
- ⑤ E  $\begin{cases} \nearrow C \rightarrow A \\ \searrow G \rightarrow I \end{cases}$

**Q15** The following ①–⑤ describe various plant hormones and their functions. Choose the best statement as the description of ethylene. 16

- ① It stimulates separation layer formation in the base of each leaf when the leaf shedding season arrives.
- ② It maintains seed dormancy by suppressing germination.
- ③ It is produced in the embryo and stimulates germination.
- ④ It is synthesized at the apex of shoots and stimulates cell elongation.
- ⑤ It stimulates lateral bud growth.

**Q16** The following table shows the gross primary productivity or secondary production at each trophic level in a certain ecosystem. From ①–⑥ below choose the answer that best indicates the order of trophic efficiency (%) among the trophic levels, from most efficient to least efficient. 17

Trophic level	Gross primary productivity or secondary production (J/cm <sup>2</sup> /year)
Solar energy	*499,262.4
Producers	467.9
Primary consumers	62.2
Secondary consumers	13.0

\*Incident light energy

- ① Producers > Primary consumers > Secondary consumers
- ② Producers > Secondary consumers > Primary consumers
- ③ Primary consumers > Producers > Secondary consumers
- ④ Primary consumers > Secondary consumers > Producers
- ⑤ Secondary consumers > Primary consumers > Producers
- ⑥ Secondary consumers > Producers > Primary consumers

**Q17** From ①–⑥ below choose the combination of terms that best fills blanks **a** – **c** in the following paragraphs. **18**

Angiosperms have the reproductive organs that are more structurally complex than those of gymnosperms, and have developed a method of fertilization whereby **a** are transported by animals. Also, some angiosperm species have developed methods of seed dispersal by wind or animals through formation of **b**. Some of today’s birds and insects have specialized beaks/mouthparts that enable them to sip nectar from certain types of flowers.

As illustrated by these examples, it is believed that angiosperms and animals evolved in ways in which they mutually influenced each other. This evolutionary phenomenon is called **c**.

	a	b	c
①	fruits	pollens	neutral evolution
②	fruits	pollens	coevolution
③	fruits	pollens	industrial melanism
④	pollens	fruits	neutral evolution
⑤	pollens	fruits	coevolution
⑥	pollens	fruits	industrial melanism

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.**