

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 – 35
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 Figure 1 below, a weight attached to one end of a string is suspended by holding the other end of the string, and is moved vertically up and down, in such a way that the string remains taut. Figure 2 is a graph showing how the height of the weight above the floor, h , changes with time t .

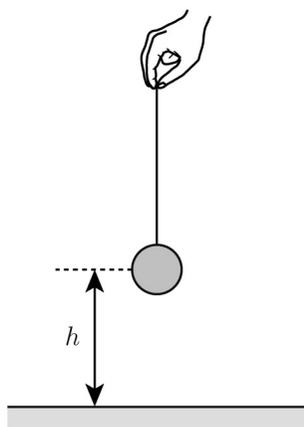


Figure 1

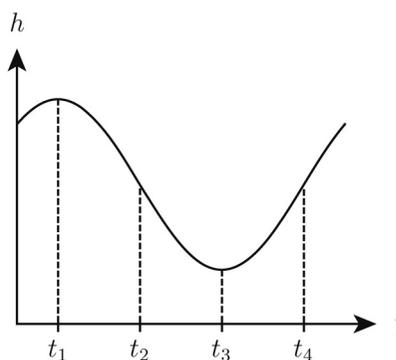


Figure 2

Q1 Among times t_1 - t_4 in Figure 2, at which time is the tension of the string at the largest?

From ①-④ below choose the best answer.

1

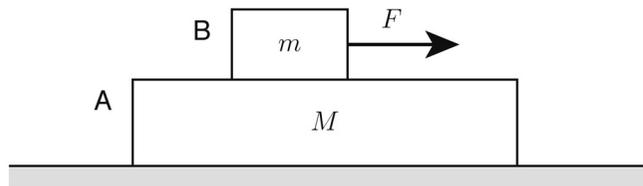
① t_1

② t_2

③ t_3

④ t_4

B As shown in the figure below, rectangular parallelepiped object **A** (mass: M) is at rest on a horizontal floor, and object **B** (mass: m) is at rest on the upper surface of **A**. Friction between the floor and **A** is negligible. Friction exists between **A** and **B**, where the coefficient of static friction is μ . A force is applied to **B** horizontally to the right, with its magnitude, F , gradually increased from zero. When F is small, **A** and **B** travel together as a unit, but when F exceeds a certain value, F_0 , **B** starts to slide along the upper surface of **A**.



Q2 What is F_0 ? From ①-④ below choose the correct answer.

2

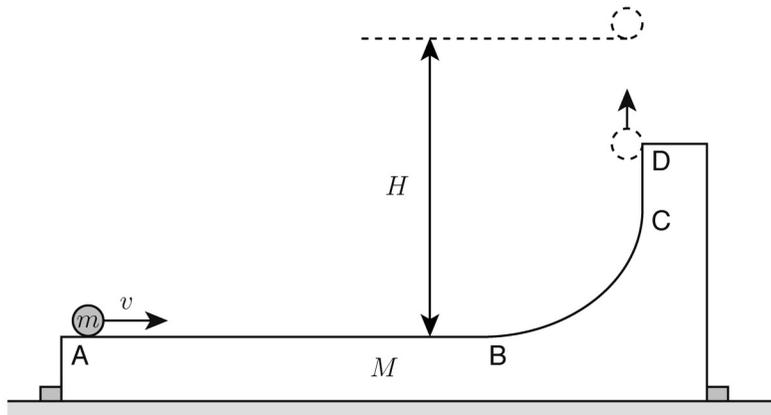
① μmg

② $\mu(M + m)g$

③ $\frac{\mu(M + m)mg}{M}$

④ $\frac{\mu(M + m)Mg}{m}$

C Consider a platform (mass: M) in which horizontal surface **AB** is smoothly joined to vertical surface **CD** as shown in the figure below. Initially, the platform is fixed in place on a horizontal floor. A small object (mass: m) is placed on **AB** and given an initial speed of v in the horizontal direction so that it travels along **CD**, flies vertically off the platform, and reaches a maximum height of H from **AB**. Friction between the platform and the object is negligible. Next, the platform is kept at rest on the horizontal floor, but is no longer fixed in place. Again, the same object is placed on **AB** and given the same initial speed of v . The object travels along **CD**, flies off the platform, and reaches a maximum height of h from **AB**. Friction between the platform and the floor is negligible.

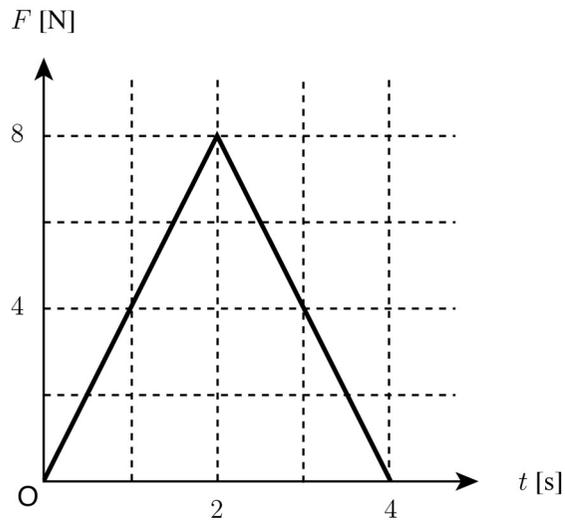


Q3 What is $\frac{h}{H}$? From ①-④ below choose the correct answer.

3

- ① $\frac{M}{M+m}$ ② $\frac{m}{M+m}$ ③ $\sqrt{\frac{M}{M+m}}$ ④ $\sqrt{\frac{m}{M+m}}$

- D** An object with a mass of 4.0 kg is traveling with uniform linear motion at a speed of 3.0 m/s on a smooth horizontal surface. Starting at a certain time, a force is applied to the object for 4.0 s, in the same direction as the velocity of the object. The figure below is a graph showing how the magnitude of the force, F [N], changes with time t [s].



- Q4** What is the momentum of the object after the force was applied to it? From ①-⑥ below choose the closest value. 4 kg·m/s

- ① 0 ② 12 ③ 16 ④ 28 ⑤ 32 ⑥ 44

E As shown in Figure 1 below, a weight is attached to a spring suspended from a ceiling. When the weight is pulled downward from its position of equilibrium and gently released, it starts oscillating vertically. Let us denote as T_1 the period of this simple harmonic motion. Next, two springs of the same type used in Figure 1 are joined by a rod of negligible mass, as shown in Figure 2. The same weight used in Figure 1 is attached to the rod. Let us denote as T_2 the period of simple harmonic motion in this case when the weight is pulled downward and gently released.

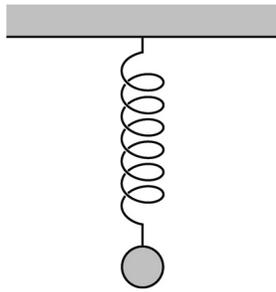


Figure 1

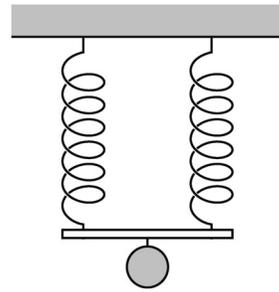


Figure 2

Q5 What is $\frac{T_2}{T_1}$? From ①-⑤ below choose the correct answer.

5

① $\frac{1}{2}$

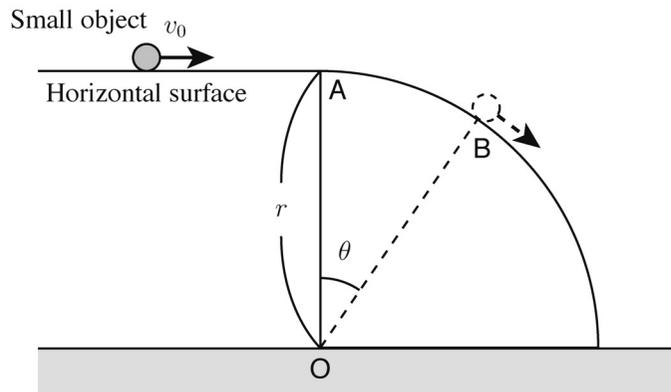
② $\frac{\sqrt{2}}{2}$

③ 1

④ $\sqrt{2}$

⑤ 2

F As shown in the figure below, a quarter cylinder, with radius r from center O , is fixed in place on a horizontal floor and is joined to a horizontal surface at point A on its upper edge. A small object is made to move with speed v_0 on the horizontal surface. When the object reaches point B , it leaves the cylindrical surface. Let us define $\angle AOB$ as θ . Friction between the object and the horizontal/cylindrical surfaces is negligible.



Q6 What is v_0 ? From ①-④ below choose the correct answer.

6

① $\sqrt{(3 \sin \theta - 2)gr}$

② $\sqrt{(3 \cos \theta - 2)gr}$

③ $\sqrt{(2 \sin \theta + \cos \theta - 2)gr}$

④ $\sqrt{(\sin \theta + 2 \cos \theta - 2)gr}$

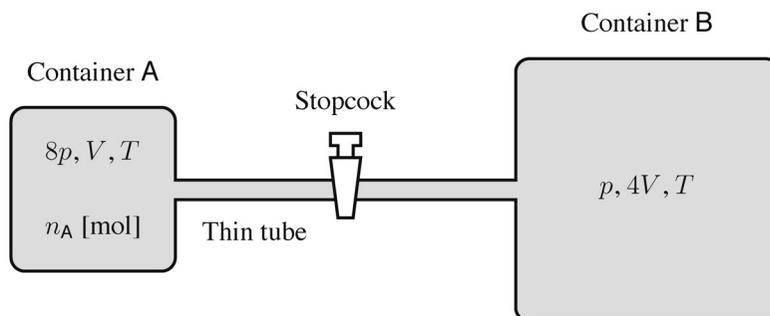
II Answer questions **A** (Q1), **B** (Q2), and **C** (Q3) below.

A Ice with a mass of 1.0 kg and a temperature of -20°C is placed in a container with a temperature of -20°C , and the change in temperature inside the container is measured while a constant quantity of heat per unit time is applied. The temperature increases at a rate of $1.0 \times 10^1 \text{ K}$ per minute. When the temperature reaches 0°C , it stops changing for a certain amount of time, and then begins increasing again. The heat capacity of the container is $1.0 \times 10^3 \text{ J/K}$, the specific heat of ice is $2.0 \times 10^3 \text{ J/kg}\cdot\text{K}$, and the heat of fusion of ice is $3.3 \times 10^5 \text{ J/kg}$. Assume that the temperature of the container always remains the same as the temperature of its interior.

Q1 For how many minutes did the temperature stay at 0°C ? From ①-⑥ below choose the best answer. **7** min

- ① 1.1 ② 2.2 ③ 3.3 ④ 11 ⑤ 22 ⑥ 33

B As shown in the figure below, container **A** (volume: V) and container **B** (volume: $4V$) both contain the same ideal gas and are connected by a thin tube of negligible volume. The tube has a stopcock, which is initially closed. The pressure of the gas in **A** is $8p$, and the absolute temperature is T . The pressure of the gas in **B** is p , and the absolute temperature is T . Let us denote as n_A [mol] the amount of the ideal gas in **A**. The stopcock is opened, allowing the gases in both containers to mix. Let us denote as n'_A [mol] the amount of the ideal gas in **A** after mixing. The containers, thin tube, and stopcock are made of thermally insulating material.

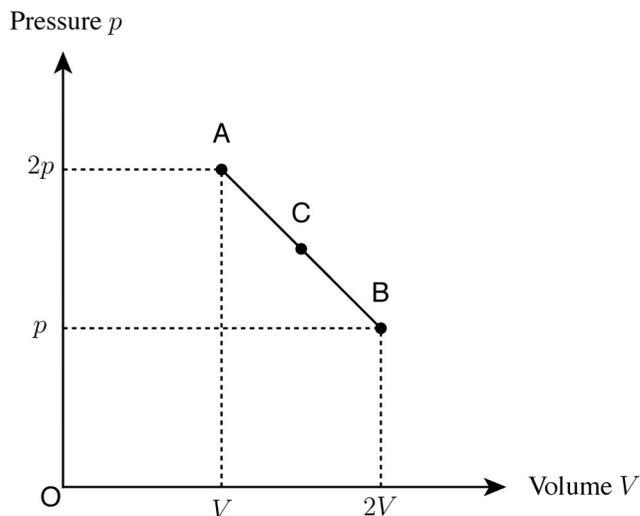


Q2 What is $\frac{n'_A}{n_A}$? From ①-⑤ below choose the correct answer.

8

- ① $\frac{3}{10}$ ② $\frac{1}{2}$ ③ $\frac{3}{5}$ ④ $\frac{3}{4}$ ⑤ $\frac{12}{5}$

C As shown in the figure below, the state of a fixed quantity of an ideal gas is changed in the pathway $A \rightarrow B$. Let us define as **C** the state indicated by the midpoint between **A** and **B** in the figure. Also, let us denote the absolute temperature of the gas at **A**, **B**, and **C** as T_A , T_B , and T_C , respectively.

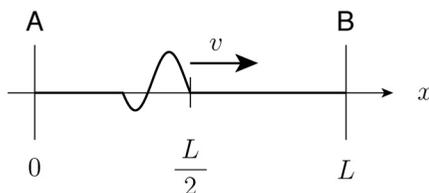


Q3 What is the relationship among T_A , T_B , and T_C ? From ①-⑤ below choose the correct answer. 9

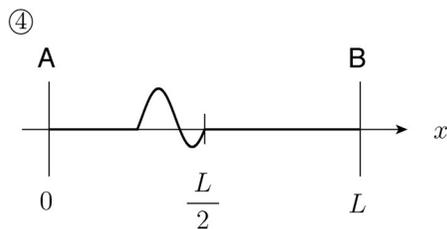
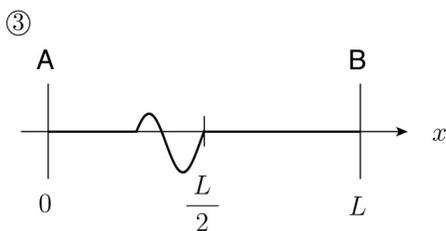
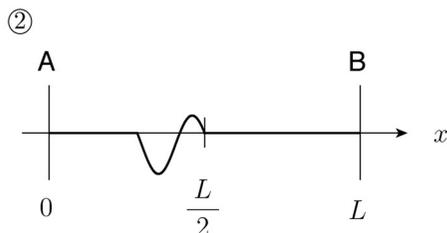
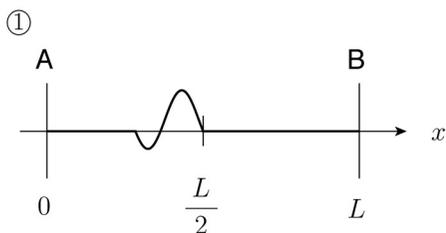
- ① $T_A = T_B = T_C$ ② $T_A = T_B < T_C$ ③ $T_C < T_A = T_B$
- ④ $T_A < T_C < T_B$ ⑤ $T_B < T_C < T_A$

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

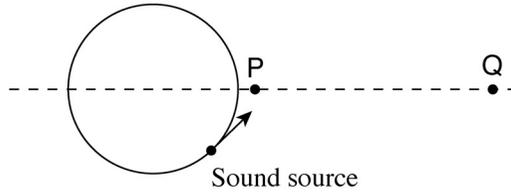
A The figure below represents the waveform at time $t = 0$ for a wave traveling at speed v along an x -axis. The wave reflects off a fixed end at position **A** ($x = 0$), and off a free end at position **B** ($x = L$).



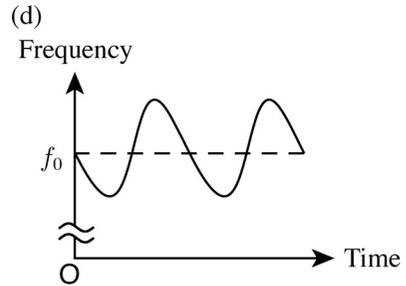
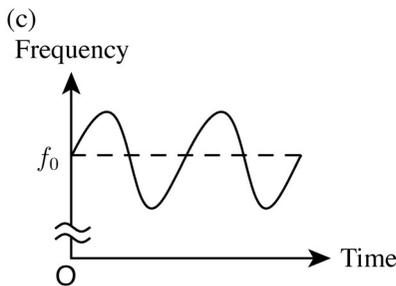
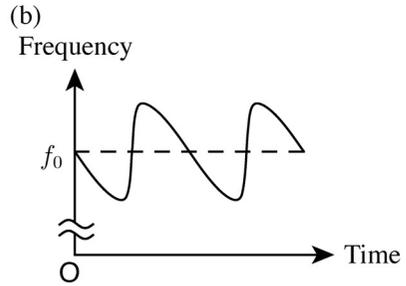
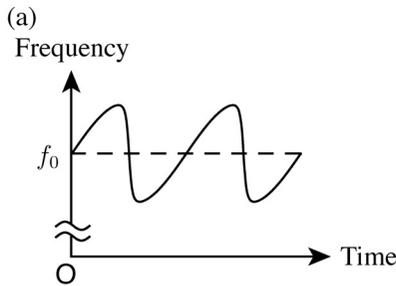
Q1 From ①-④ below choose the figure that best represents the waveform of this wave at time $t = \frac{2L}{v}$. **10**



B As shown in the figure below, a sound source emitting sound with a constant frequency of f_0 is traveling with uniform circular motion in a counterclockwise direction. The frequency of the sound is measured at points P and Q in the figure.

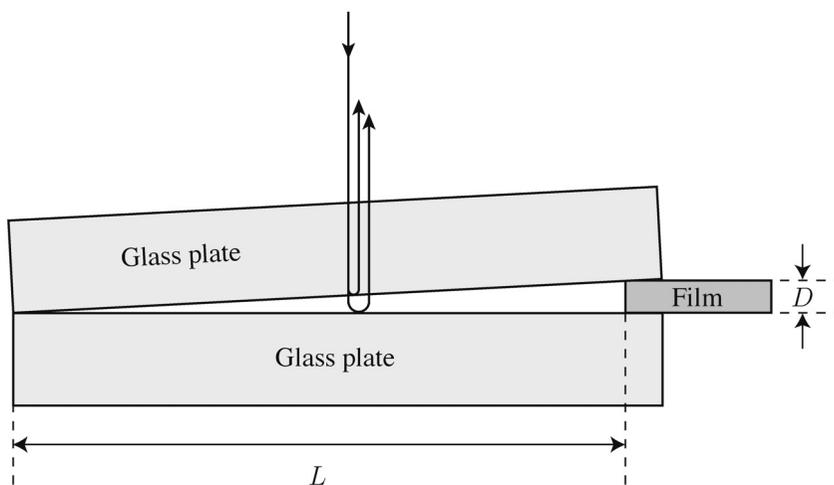


Q2 From ①-④ below choose the best combination indicating the figures in (a)-(d) below that represent the change over time of the sound's frequency as observed at P and Q. 11



	P	Q
①	(a)	(c)
②	(b)	(d)
③	(c)	(a)
④	(d)	(b)

- C** As shown in the figure below, two flat glass plates are adjoined at one end, and a film of thickness D is inserted between them at distance L from the joint, forming a wedge-shaped layer of air. Monochromatic light with a wavelength of λ is projected toward them from directly above. When the plates are viewed from directly above, interference fringes can be seen, with the dark fringes appearing at intervals of Δx . This is the result of interference between the light reflected by the bottom surface of the upper plate and the light reflected by the top surface of the lower plate. Here, $L = 10$ cm, $\lambda = 5.0 \times 10^{-7}$ m, and $\Delta x = 0.50$ mm.



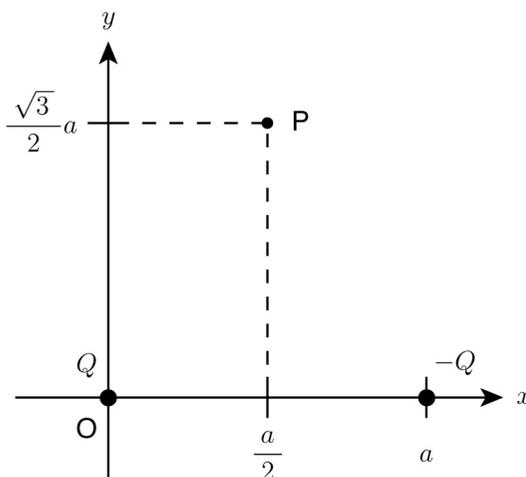
Q3 What is D (in mm)? From ①-④ below choose the best answer.

12 mm

- ① 0.010 ② 0.050 ③ 0.10 ④ 0.50

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 at the origin O of an x - y plane and a point charge with quantity of electricity $-Q$ is fixed in place at point $(a, 0)$ on the x - y plane. Let us denote the proportionality constant of Coulomb's law as k .



Q1 What is the magnitude of the electric field at point $P \left(\frac{a}{2}, \frac{\sqrt{3}a}{2} \right)$ produced by these point charges? From ①-⑤ below choose the correct answer. **13**

- ① $\frac{kQ}{2a^2}$ ② $\frac{\sqrt{3}kQ}{2a^2}$ ③ $\frac{kQ}{a^2}$ ④ $\frac{\sqrt{3}kQ}{a^2}$ ⑤ $\frac{2kQ}{a^2}$

B As shown in Figure 1 below, a metal cylinder is placed in a uniform electric field, at the position indicated by the broken lines. Figure 2 shows the equipotential lines before the cylinder was put in place.

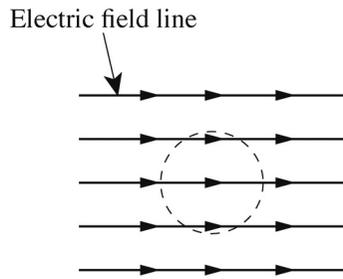


Figure 1

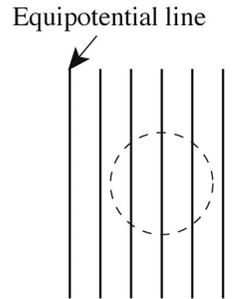
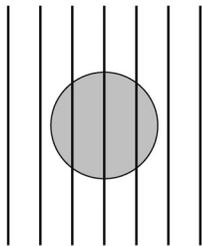


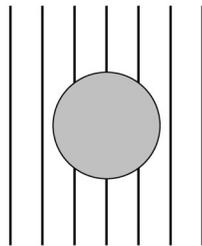
Figure 2

Q2 From ①-⑥ below choose the figure that best represents the equipotential lines around and within the cylinder after it was put in place. 14

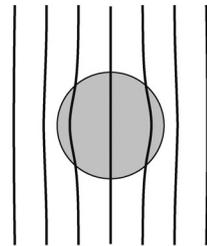
①



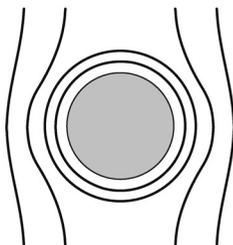
②



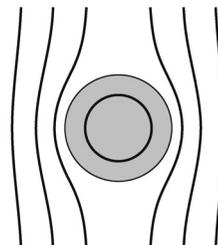
③



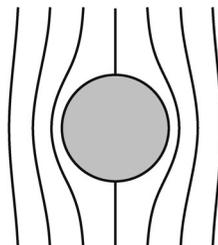
④



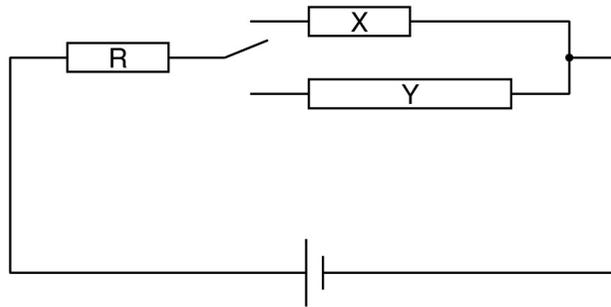
⑤



⑥



C Three resistors (X, Y, R), a battery, and a switch are connected as shown in the figure below. The resistors X and Y are made of the same material and have the same cross-sectional area, while Y is twice as long as X. Initially, the switch is closed at the terminal for X. The power consumption of X is P_X , which is equal to the power consumption of R. Next, the switch is closed at the terminal for Y. The power consumption of Y is P_Y .



Q3 What is $\frac{P_Y}{P_X}$? From ①-⑧ below choose the correct answer.

15

① $\frac{2}{9}$

② $\frac{1}{2}$

③ $\frac{2}{3}$

④ $\frac{8}{9}$

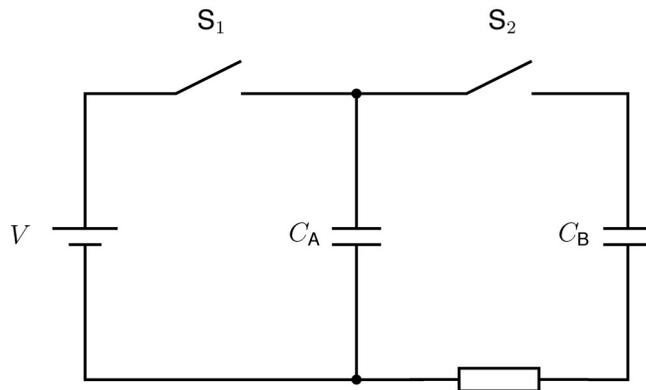
⑤ $\frac{9}{8}$

⑥ $\frac{3}{2}$

⑦ 2

⑧ $\frac{9}{2}$

D A battery (electromotive force: V), two capacitors (capacitance: C_A, C_B), two switches (S_1, S_2), and a resistor are connected as shown in the figure below. Initially, both switches are open and no charge is stored in either capacitor. Next, S_1 is closed and, after sufficient time elapses, is opened again. Afterwards, S_2 is closed while S_1 remains opened. As a result, a current begins to flow through the resistor. After sufficient time elapses, the current stops flowing through the resistor.



Q4 What is the Joule heat generated in the resistor during the time from when S_2 is closed until the current stops flowing through the resistor? From ①-⑦ below choose the correct answer. **16**

- ① $\frac{1}{2}C_B V^2$ ② $\frac{1}{2}(C_A + C_B)V^2$ ③ $\frac{1}{2}\frac{C_A^2}{C_B}V^2$
- ④ $\frac{1}{2}\frac{C_A(C_A + C_B)}{C_B}V^2$ ⑤ $\frac{1}{2}\frac{C_A^2}{C_A + C_B}V^2$ ⑥ $\frac{1}{2}\frac{C_A C_B}{C_A + C_B}V^2$
- ⑦ $\frac{1}{2}\frac{C_B^2}{C_A + C_B}V^2$

E As shown in Figure 1 below, a sufficiently long, straight conducting wire passes through point O on a horizontal plane (this page) and is perpendicular to the plane. A magnetic compass is placed at point P in the same plane, which is located 30° east of north as observed from O . The compass points north when no current flows through the wire. Next, a current is passed through the wire, and the compass points in the direction \overrightarrow{OP} , as shown in Figure 2. Let us denote the distance between O and P as r . Also, let us assume that the direction of the earth's magnetic field is to the north, and denote its magnitude as H_0 .

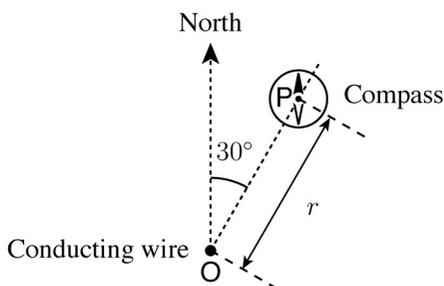


Figure 1

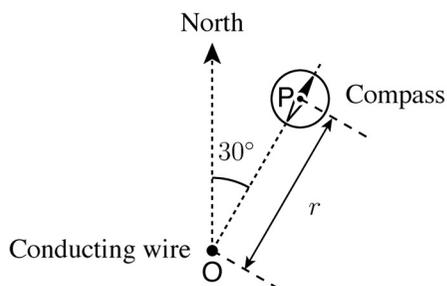


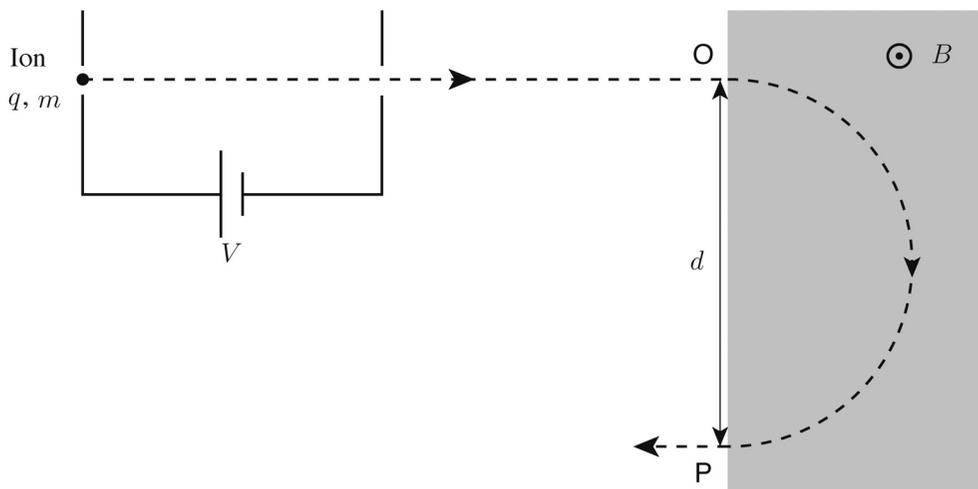
Figure 2

Q5 What are the direction and magnitude of the current flowing through the wire? From ①-⑧ below choose the correct combination.

17

	Direction	Magnitude
①	from back of page to front	rH_0
②	from back of page to front	$\sqrt{3}rH_0$
③	from back of page to front	πrH_0
④	from back of page to front	$\sqrt{3}\pi rH_0$
⑤	from front of page to back	rH_0
⑥	from front of page to back	$\sqrt{3}rH_0$
⑦	from front of page to back	πrH_0
⑧	from front of page to back	$\sqrt{3}\pi rH_0$

F As shown in the figure below, a uniform magnetic field, whose magnetic flux density has a magnitude of B , exists in a certain region. An ion (electrical charge: q ; mass: m) is accelerated from rest using potential difference V and is projected into the region at point O in the direction perpendicular to the magnetic field. The ion follows a semicircular path within the region and exits at point P . The distance between O and P is d . Next, the experiment is repeated using a different ion (electrical charge: q ; mass: m'). This time, the ion exits from a different point, P' , which is distance $4d$ from O .



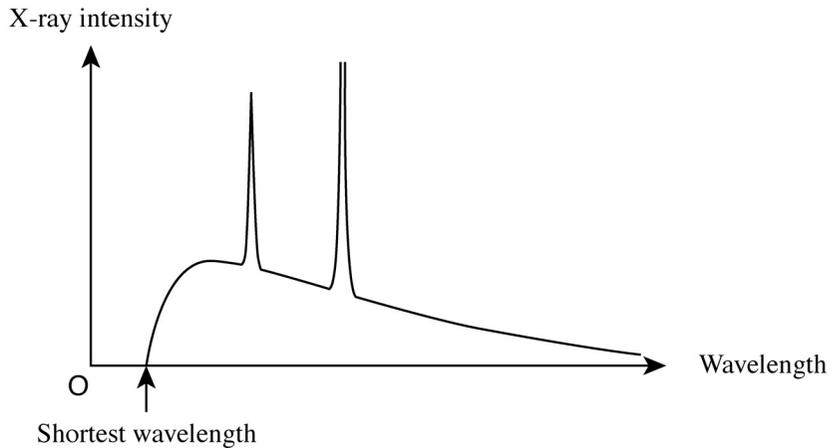
Q6 What is $\frac{m'}{m}$? From ①-⑥ below choose the correct answer.

18

- ① $\frac{1}{16}$ ② $\frac{1}{4}$ ③ $\frac{1}{2}$ ④ 2 ⑤ 4 ⑥ 16

V Answer question A (Q1) below.

A Electrons accelerated using a high voltage are made to collide with a metal in a vacuum. The figure below is a graph showing the relationship between the wavelength and intensity of X-rays emitted in the collisions. Note that there are two sharp peaks in the curve. The arrow at the bottom of the graph indicates the shortest wavelength of the X-rays emitted.



Q1 If we increase the kinetic energy of the electrons by increasing the accelerating voltage, what would happen to the wavelength at the sharp peaks, and the shortest wavelength? From ①-⑦ below choose the correct combination. 19

	Wavelength at sharp peaks	Shortest wavelength
①	decrease	decrease
②	decrease	no change
③	increase	increase
④	increase	no change
⑤	no change	no change
⑥	no change	decrease
⑦	no change	increase

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 O : 16 S : 32

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 whose total number of electrons is **different from the others**. 1

- ① ammonia (NH₃) ② hydrogen chloride (HCl) ③ methane (CH₄)
 ④ neon (Ne) ⑤ water (H₂O)

Q2 From the following combinations of the shape and the polarity of molecules ①-⑤ in the following table choose the correct one. 2

	Molecule	Shape of molecule	Polarity
①	hydrogen chloride (HCl)	linear	nonpolar
②	hydrogen sulfide (H ₂ S)	linear	polar
③	carbon dioxide (CO ₂)	bent	polar
④	ammonia (NH ₃)	trigonal pyramidal	nonpolar
⑤	carbon tetrachloride (CCl ₄)	tetrahedral	nonpolar

Q3 From 1.0 g of the oxide MO of a metal M, a maximum of 2.0 g of the sulfate MSO_4 can be obtained. From the following ①-⑤ choose the closest value for the atomic weight of the metal M. **3**

- ① 48 ② 64 ③ 80 ④ 96 ⑤ 112

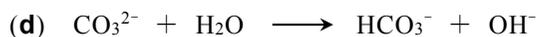
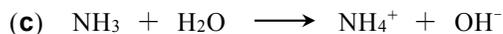
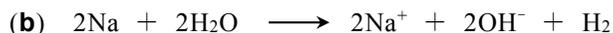
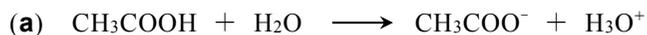
Q4 A given metal has atomic weight M , and the density of the metal crystal is d . From the following expressions ①-⑤ choose the one which correctly expresses the number of atoms in a cube of this crystal with sides of 2 cm. N_A is the Avogadro constant. **4**

- ① $\frac{8dN_A}{M}$ ② $\frac{dN_A}{8M}$ ③ $8dMN_A$ ④ $\frac{d}{8MN_A}$ ⑤ $\frac{8dM}{N_A}$

Q5 From the following ①-⑤ choose the closest value for the molar concentration (mol/L) of dilute sulfuric acid (dil. H_2SO_4), the mass percent concentration of which is 38 %. Assume that the density of this dilute sulfuric acid is 1.29 g/cm^3 . **5** mol/L

- ① 0.49 ② 2.9 ③ 3.8 ④ 5.0 ⑤ 6.8

Q6 Among the following chemical reactions (a)-(d) there are two in which water acts as an acid by the definition of the Brønsted-Lowry theory. From ①-⑥ below choose the correct combination of them. **6**



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

Q7 The volume of a gas at 27 °C and 1.0×10^5 Pa is 2.0 L. Calculate the volume of the gas in L after the temperature and pressure are raised to 127 °C and 2.0×10^5 Pa, respectively. From the following ①-⑥ choose the closest value. **7** L

① 0.21 ② 0.38 ③ 0.75 ④ 1.3 ⑤ 2.7 ⑥ 4.7

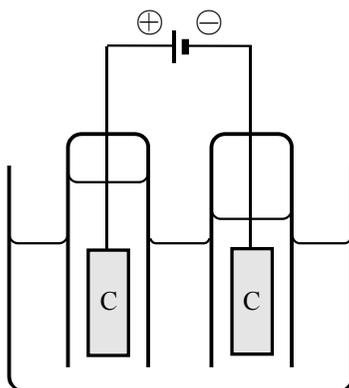
Q8 Calculate the freezing point ($^{\circ}\text{C}$) of the aqueous solution prepared by dissolving 14.4 g of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) in 100 g of water. From ①-⑤ below choose the closest value. Assume that the molar depression of the freezing point of water is $1.85 \text{ K}\cdot\text{kg}/\text{mol}$. 8 $^{\circ}\text{C}$

- ① -1.48 ② -1.29 ③ -0.148 ④ -0.0169 ⑤ -0.0148

Q9 How much heat in kJ is generated when hydrogen chloride gas (HCl) is formed by the reaction between 1.00 mol of hydrogen gas (H_2) and 1.00 mol of chlorine gas (Cl_2)? From ①-⑥ below choose the closest value. Assume that the bond energies of H_2 , Cl_2 and HCl are $436 \text{ kJ}/\text{mol}$, $243 \text{ kJ}/\text{mol}$ and $432 \text{ kJ}/\text{mol}$, respectively. 9 kJ

- ① 56 ② 94 ③ 136 ④ 185 ⑤ 226 ⑥ 380

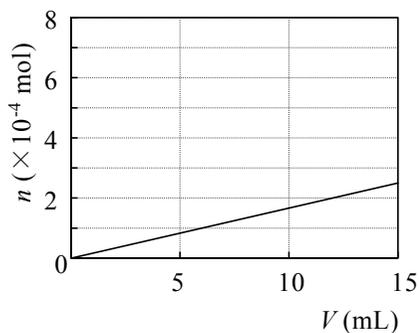
Q10 An aqueous solution was electrolyzed using the graphite electrodes C as shown in the following figure. Oxygen (O_2) was generated from the anode, and hydrogen (H_2) from the cathode. From ①-④ below choose the most appropriate aqueous solution. **10**



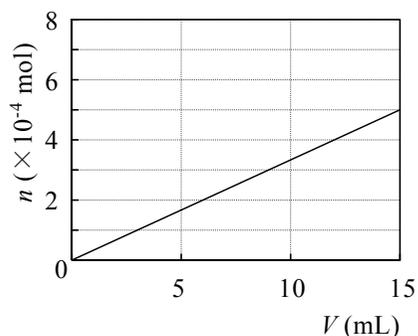
- ① dilute hydrochloric acid (dil. HCl)
- ② dilute sulfuric acid (dil. H_2SO_4)
- ③ aqueous potassium iodide (KI)
- ④ aqueous sodium chloride (NaCl)

Q11 White precipitates were formed when 0.050 mol/L dilute sulfuric acid (dil. H_2SO_4) was added to 5.0 mL of 0.10 mol/L aqueous lead(II) acetate ($\text{Pb}(\text{CH}_3\text{COO})_2$). From the following graphs ①-⑥ choose the one which represents the relation between the volume of the dilute sulfuric acid added (V ; mL) and the amount of white precipitates formed (n ; mol). 11

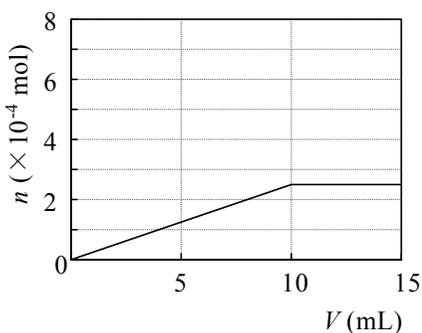
①



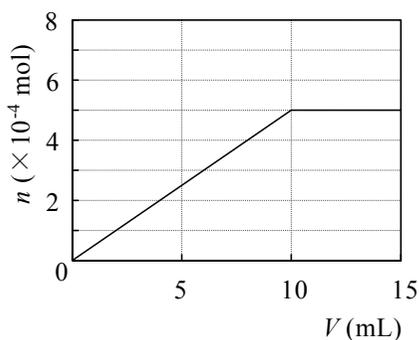
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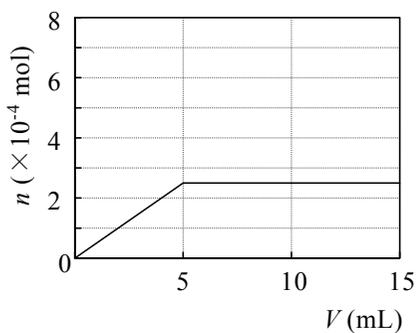
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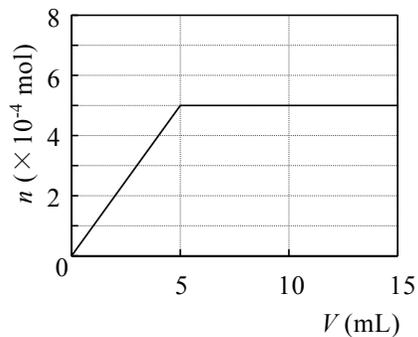
④



⑤



⑥



Q12 The following experiments (a)-(c) were carried out to identify the elements contained in substances **A**, **B** and **C**. From ①-⑥ in the table below choose the most appropriate combination of elements contained in **A**, **B** and **C**. **12**

- (a) When a platinum wire was dipped in the aqueous solution of substance **A**, and the wire was placed in a flame, the flame turned reddish purple.
- (b) White precipitates were formed when aqueous silver nitrate (AgNO_3) was added to the aqueous solution of substance **B**.
- (c) Aqueous calcium hydroxide ($\text{Ca}(\text{OH})_2$) became cloudy white when the gas generated by the complete combustion of substance **C** was introduced into the solution.

	Substance A	Substance B	Substance C
①	K	Cl	C
②	K	I	C
③	K	Cl	H
④	Na	I	H
⑤	Na	Cl	H
⑥	Na	I	C

Q13 Two out of the following compounds (a)-(f) are acidic oxides. From ①-⑥ below choose the correct combination of them. **13**

(a) Al_2O_3 (b) CaO (c) CO_2 (d) K_2O (e) MgO (f) P_4O_{10}

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

Q14 From ①-⑥ in the table below choose the correct combination of a term and chemical formulas which fit into the blanks **a** - **d** in the following statement on calcium (Ca). **14**

Calcium is an **a** and reacts with water at room temperature to generate **b**. Calcium is found as **c**, which is a component of limestone in the earth's crust. When **c** comes into contact with water containing carbon dioxide (CO_2), it changes into **d** and dissolves in water.

	a	b	c	d
①	alkali metal	H_2	CaCO_3	Ca(OH)_2
②	alkali metal	O_2	CaO	Ca(OH)_2
③	alkali metal	O_2	CaCO_3	$\text{Ca(HCO}_3)_2$
④	alkaline earth metal	O_2	CaO	$\text{Ca(HCO}_3)_2$
⑤	alkaline earth metal	H_2	CaCO_3	$\text{Ca(HCO}_3)_2$
⑥	alkaline earth metal	H_2	CaO	Ca(OH)_2

Q15 Hydrogen sulfide (H_2S) is passed through an acidic aqueous solution containing two kinds of metal ions. From the following ①-⑤ choose the most appropriate combination of metal ions only one of which forms a sulfide precipitate. **15**

- ① Ag^+ , Pb^{2+} ② Al^{3+} , Ba^{2+} ③ Ca^{2+} , Cu^{2+}
 ④ Fe^{2+} , Na^+ ⑤ K^+ , Zn^{2+}

Q16 Two out of the following compounds (a)-(e) have both one or more double bonds and one or more oxygen atoms. From ①-⑥ below choose the correct combination of them. **16**

- (a) acetic acid
 (b) acetone
 (c) dimethyl ether
 (d) ethene (ethylene)
 (e) vinyl chloride

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

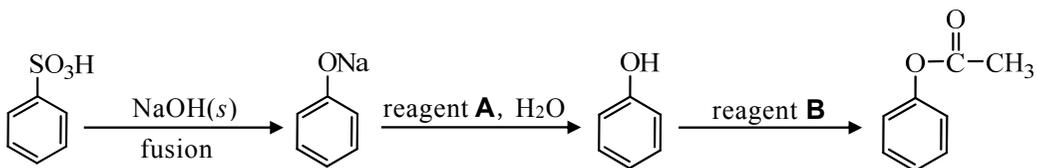
Q17 From the following ①-⑥ choose the correct one as the number of structural isomers of the compound whose molecular formula is C_6H_{14} . **17**

- ① 1 ② 2 ③ 3 ④ 4 ⑤ 5 ⑥ 6

Q18 Stearic acid ($C_{17}H_{35}COOH$) was synthesized by hydrogenation of 1.0 g of linoleic acid ($C_{17}H_{31}COOH$; molecular weight 280). Calculate the volume (mL) of hydrogen (H_2) at the standard state necessary for this reaction. From the following ①-⑤ choose the closest value. **18** mL

- ① 50 ② 80 ③ 100 ④ 160 ⑤ 200

- Q19** Phenyl acetate was synthesized from benzenesulfonic acid as shown in the following scheme. From ①-⑤ in the table below choose the most appropriate combination of reagents **A** and **B** used in this scheme. **19**



	Reagent A	Reagent B
①	CO ₂	(CH ₃) ₂ CO
②	CO ₂	(CH ₃ CO) ₂ O
③	HCl	(CH ₃) ₂ CO
④	HCl	CH ₃ OH
⑤	NaOH	(CH ₃ CO) ₂ O

Q20 From the following statements ①-⑥ choose the one in which the underlined part is correct. **20**

- ① Polyethylene is a polymer obtained by condensation polymerization of ethene (ethylene).
- ② Poly(ethylene terephthalate) contains amide bonds.
- ③ Nylon 6,6 contains ether bonds.
- ④ Starch is a polymer obtained by dehydration condensation of fructose.
- ⑤ A protein is a polymer obtained by addition polymerization of amino acids.
- ⑥ When a small amount of sulfur is added to raw rubber (natural rubber) and the mixture is heated, a cross-linked structure is formed.

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** The following figure shows the order of involvement of cellular organelles/structures in the process whereby a protein is synthesized following the expression of a gene encoding a certain digestive enzyme, and is then secreted outside the cell. From ① – ⑥ below choose the combination that best identifies the organelles/structures represented by A – C in the figure.

1

Nucleus \rightleftarrows A \longrightarrow B \longrightarrow C \longrightarrow Outside cell

	A	B	C
①	endoplasmic reticulum	Golgi body	ribosome
②	endoplasmic reticulum	ribosome	Golgi body
③	Golgi body	ribosome	endoplasmic reticulum
④	Golgi body	endoplasmic reticulum	ribosome
⑤	ribosome	endoplasmic reticulum	Golgi body
⑥	ribosome	Golgi body	endoplasmic reticulum

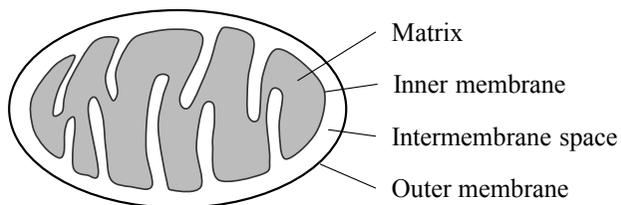
- Q2** The following paragraph describes a certain protein, X. From ① – ⑤ below choose the answer that correctly identifies the name of the protein X. **2**

X is a globular protein that forms a type of cytoskeleton where many of them are joined together in the structure shown in the figure below. Cytoplasmic streaming occurs when motor proteins travel along the surface of this structure. Also, X plays a very important role in muscle contraction.



- ① myosin ② actin ③ dynein ④ kinesin ⑤ collagen

Q3 The following figure schematically represents a mitochondrion. From ① – ⑥ below choose the combination that correctly indicates which statements in a – c below apply to the matrix, inner membrane, and intermembrane space depicted in the figure. **3**



- a Pyruvic acid is broken down into carbon dioxide, and ATP, NADH and FADH₂ are formed.
- b The hydrogen in the synthesized NADH, FADH₂, etc. splits into H⁺ and electrons, and these electrons transfer from one protein to another.
- c H⁺ from NADH and FADH₂ are transported here, resulting in a high H⁺ concentration.

	Matrix	Inner membrane	Intermembrane space
①	a	b	c
②	a	c	b
③	b	a	c
④	b	c	a
⑤	c	a	b
⑥	c	b	a

Q4 In photosynthesis in green plants, starch and other organic compounds are synthesized through the Calvin-Benson cycle, following the processes involving photosystems II and I. In which process do photosynthetic reactions a and b below take place? From ① – ⑥ below choose the correct combination. **4**

- a Fixation of carbon dioxide
- b Breakdown of water

	a	b
①	photosystem II	Calvin-Benson cycle
②	Calvin-Benson cycle	photosystem II
③	photosystem I	Calvin-Benson cycle
④	Calvin-Benson cycle	photosystem I
⑤	photosystem I	photosystem II
⑥	photosystem II	photosystem I

Q5 Let us consider a certain protein, X, which is a chain of 400 amino acids. When one base in the gene encoding X is substituted, a new stop codon is created, and as a result, the only proteins formed are composed of 300 amino acids. In this case, at which base in the mRNA would the substitution be observed, counting from the first base translated in the mRNA for X? From ① – ⑥ below choose the correct answer. **5**

- ① One of the 331st to 333rd bases
- ② One of the 351st to 353rd bases
- ③ One of the 601st to 603rd bases
- ④ One of the 651st to 653rd bases
- ⑤ One of the 901st to 903rd bases
- ⑥ One of the 951st to 953rd bases

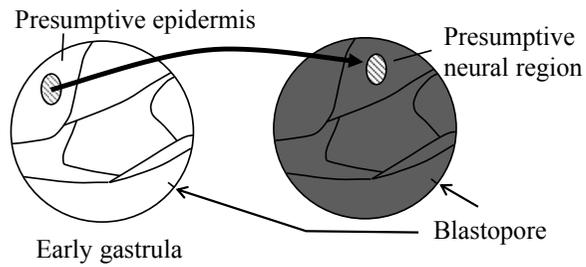
Q6 The following paragraph describes a technique used in biotechnology. From ①–⑧ below choose the combination of terms that best fills blanks **a** – **c** in the paragraph. 6

One technique for artificially amplifying DNA on a large scale is **a**, which uses a DNA polymerase. This method requires **b** corresponding to the target DNA to initiate amplification. The DNA polymerase used is an enzyme that does not become inactivated at **c** temperatures.

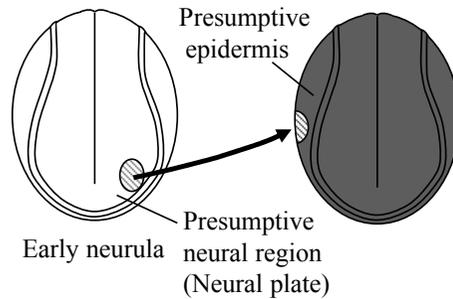
	a	b	c
①	PCR (polymerase chain reaction)	vectors	low
②	PCR	primers	low
③	PCR	vectors	high
④	PCR	primers	high
⑤	electrophoresis	vectors	low
⑥	electrophoresis	primers	low
⑦	electrophoresis	vectors	high
⑧	electrophoresis	primers	high

Q7 The following experiments were performed using early gastrulas and early neurulas of newts.

A As shown in the figure below, a portion of the presumptive epidermis is removed from an early gastrula and transplanted to the presumptive neural region of another early gastrula.



B As shown in the figure below, a portion of the presumptive neural region (neural plate) is removed from an early neurula and transplanted to the presumptive epidermis of another early neurula.



From ① – ④ below choose the statement that correctly describes how the transplanted tissue differentiated after transplantation in each experiment. 7

- ① The transplant differentiated into nerves in A, and into epidermis in B.
- ② The transplant differentiated into epidermis in A, and into nerves in B.
- ③ The transplant differentiated into nerves in both A and B.
- ④ The transplant differentiated into epidermis in both A and B.

- Q8** In a certain angiosperm, pollens from an individual with the genotype AA pollinated the stigma of a pistil of an individual with the genotype aa , resulting in double fertilization. In this case, what would be the genotypes of the fertilized egg and the cell containing the endosperm nucleus, respectively? From ①–⑧ below choose the correct combination. 8

	Fertilized egg	Cell containing endosperm nucleus
①	AAA	AA
②	AAa	AA
③	Aaa	Aa
④	AAA	Aa
⑤	AA	AAA
⑥	AA	AAa
⑦	Aa	Aaa
⑧	Aa	AAA

Q9 The following paragraph describes blood coagulation in humans. From ①–⑥ below choose the combination of terms that best fills blanks **a** – **c** in the paragraph. 9

When bleeding occurs, the blood coagulation process begins with aggregation of **a** at the wound. Blood coagulation factors are released by the **a** at the wound, resulting in the formation of filament-like **b**. The **b** entrap(s) **c**, creating a blood clot that stops bleeding from the wound.

	a	b	c
①	blood cells	fibrin	platelets
②	blood cells	platelets	fibrin
③	fibrin	platelets	blood cells
④	fibrin	blood cells	platelets
⑤	platelets	blood cells	fibrin
⑥	platelets	fibrin	blood cells

Q10 The following statements below describe immunoreactions or applications of them. From ① – ⑤ below choose the statement that best describes vaccines. **10**

- ① They trigger immunoreactions when they perceive the body's own tissues or constituents as antigens.
- ② Venomous snake bites are sometimes treated in emergencies with injections of antibodies prepared in advance from animals such as rabbits and horses.
- ③ They are killed or attenuated pathogens, or pathogen products, and can be injected into the body to artificially trigger an immunoresponse.
- ④ Certain viruses weaken the immune system by infecting helper T cells; as a result, the body becomes susceptible to diseases that normally do not affect healthy people.
- ⑤ A hypersensitive immunoreaction occurs when the immune system perceives substances such as peanuts and bee venom as antigens and initiates a severe inflammatory response across the body.

Q11 Insulin is a hormone that regulates the blood glucose level. From ① – ⑥ below choose the combination correctly indicating the two functions in a – d below that are directly performed by insulin. **11**

- a It acts on the sympathetic nervous system to promote sweating.
- b It acts on liver cells to promote the synthesis of glycogen.
- c It acts on the adrenal medulla to promote the secretion of adrenaline.
- d It acts on many types of cells to promote the uptake of glucose.

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

Q12 Various substances secreted by neuron terminals or by endocrine glands play very important roles in homeostasis. From ①–⑥ below choose the combination correctly indicating the two items in a–e below that are substances secreted by neuron terminals. **12**

- a noradrenaline b thyroxine
- c acetylcholine d glucagon
- e glucocorticoid

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

Q13 The following table lists several human receptors and their adequate stimuli. From ①–⑥ below choose the combination of terms that correctly fills blanks a – c in the table. **13**

Receptor		Adequate stimulus	Sense
Eye	a	Light (visible light)	Vision
Nose	Olfactory epithelium	Chemical substances in b	Smell
Tongue	Taste buds	Chemical substances in c	Taste

	a	b	c
①	cornea	gases	liquids
②	cornea	liquids	gases
③	retina	gases	liquids
④	retina	liquids	gases
⑤	crystalline lens	gases	liquids
⑥	crystalline lens	liquids	gases

Q14 From ① – ⑥ below choose the combination of terms that correctly fills blanks **a** – **c** in the following paragraph. **14**

The direct source of energy for muscle contraction is **a**. The consumed **a** is replenished through respiration and glycolysis, but repeated muscle contraction often leads to a shortage of it. Muscles also store energy in the form of **b**. When **a** is needed, **b** is broken down, and the energy released is used to synthesize **a** from **c**.

	a	b	c
①	ADP	ATP	phosphocreatine
②	ADP	phosphocreatine	ATP
③	ATP	ADP	phosphocreatine
④	ATP	phosphocreatine	ADP
⑤	phosphocreatine	ATP	ADP
⑥	phosphocreatine	ADP	ATP

Q15 Following statements **a** – **d** describe the steps involved in seed germination of plants such as barley and rice. Answer questions (1) and (2) below concerning this process.

- a The amount of substance **X** in the embryo increases.
- b Starch in the endosperm is broken down into sugar.
- c Sugar is supplied to the embryo.
- d Protein **Y** is synthesized in the aleurone layer.

(1) From ①–⑥ below choose the combination that best identifies the names of **X** and **Y**.

15

	X	Y
①	catalase	auxin
②	gibberellin	catalase
③	auxin	gibberellin
④	amylase	abscisic acid
⑤	gibberellin	amylase
⑥	abscisic acid	gibberellin

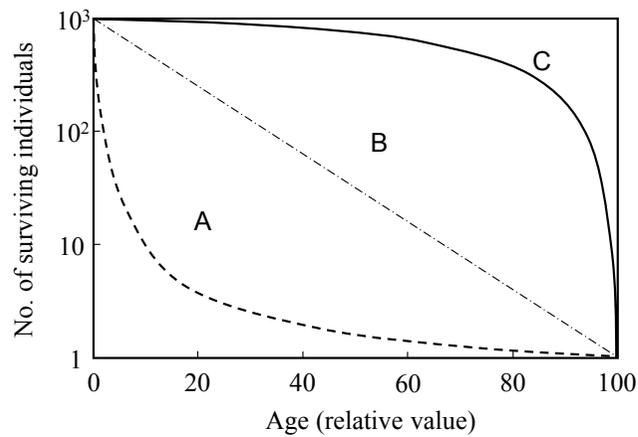
(2) From ①–⑥ below choose the answer that correctly arranges steps **a** – **d** in the order of occurrence.

16

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

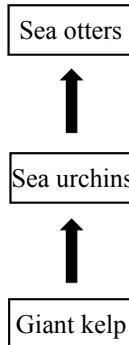
- Q16** A survival curve is a graph that shows how the number of surviving eggs or offsprings produced decreases as they progress in life. The following figure shows three types of survival curves, A – C. From ① – ⑤ below choose the answer that best indicates the relationship among the types A – C in terms of the average number of eggs/offsprings produced per individual of representative species of each type.

17



- ① $A > B > C$
 ② $A > B = C$
 ③ $A < B < C$
 ④ $A = B < C$
 ⑤ $A = B = C$

Q17 The following figure shows the food chain for sea otters, sea urchins, and giant kelp. If the sea otter population were to significantly decline due to overexploitation, what effect would this have on sea urchins and giant kelp? Assuming that there are no other organisms that are involved in this food chain, from ①–⑨ below choose the combination indicating the two statements in a–f below that correctly answer this question. Note that giant kelp is a type of seaweed related to sea tangle. **18**



- a The sea urchin population would significantly increase.
- b No change would be seen in the sea urchin population.
- c The sea urchin population would significantly decrease.
- d The giant kelp population would significantly increase.
- e No change would be seen in the giant kelp population.
- f The giant kelp population would significantly decrease.

- ① a, d ② a, e ③ a, f ④ b, d ⑤ b, e ⑥ b, f
 ⑦ c, d ⑧ c, e ⑨ c, f

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.