2020 Examination for Japanese University Admission
for International Students

Science (80 min.)

【Physics, Chemistry, Biology】

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

Ⅰ Rules of Examination

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

Ⅱ Rules and Information Concerning the Question Booklet

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

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

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

Ⅲ Rules and Information Concerning the Answer Sheet

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

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

Examination registration number			*					*						
Name														

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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
●	○	○

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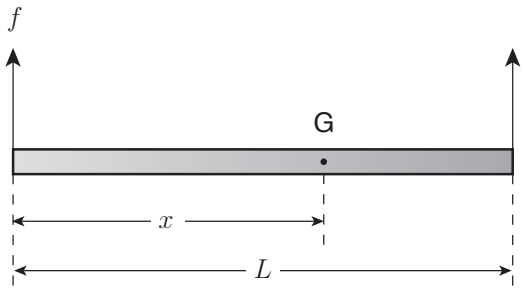
I Answer questions **A** (Q1), **B** (Q2), **C** (Q3), **D** (Q4), **E** (Q5), and **F** (Q6) below, where g denotes the magnitude of acceleration due to gravity, and air resistance is negligible.

A As shown in the figure below, a thin rod (length: L; mass: M) with nonuniform density is maintained in a horizontal position by applying forces to both ends in the vertically upward direction. The magnitude of the force applied to the left end of the rod is f. Let us denote as x the distance from the left end to the rod's center of mass, G.



Q1 What is $\frac{x}{L}$? From ①-⑥ below choose the correct answer. **1**

① $\frac{Mg}{f}$　② $\frac{f}{Mg}$　③ $\frac{Mg}{f} - 1$

④ $1 - \frac{f}{Mg}$　⑤ $\frac{f}{Mg - f}$　⑥ $\frac{f}{Mg + f}$

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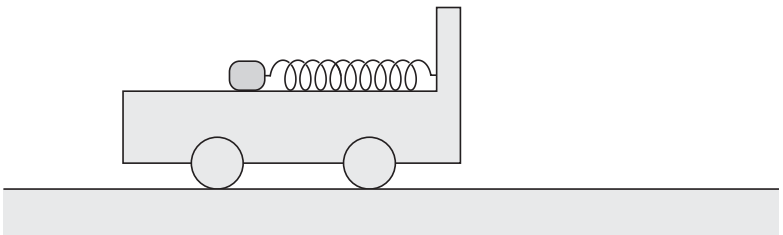
B As shown in the figure below, a spring with a spring constant of 30 N/m is placed on the smooth, horizontal upper surface of a wagon, parallel to the wagon's direction of motion. One end of the spring is attached to a wall on the right side of the wagon, and a small object (mass: 0.5 kg) is attached to the other end of the spring. The wagon is moving linearly on a horizontal surface with velocity in the direction to the right of the figure, and is slowing down with uniform acceleration (magnitude of acceleration: 3 m/s^2) while the object is at rest relative to the wagon.



Q2 How much does the length of the spring change from its natural length? From ①-⑥ below choose the best answer. **2**

① compressed 0.03 m ② compressed 0.05 m ③ compressed 0.1 m

④ extended 0.03 m ⑤ extended 0.05 m ⑥ extended 0.1 m

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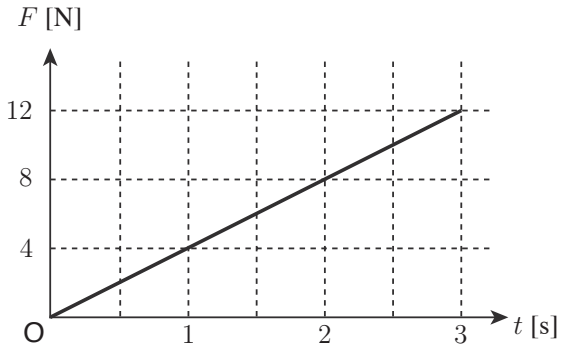
C A force is applied to an object moving with a certain velocity, from time $t = 0$ s to time $t = 3.0$ s, in the same direction as the object's velocity. The magnitude of this force, F, changes as shown in the figure below.



Q3 What is the change in the magnitude of the object's momentum from time $t = 0$ s to time $t = 3.0$ s? From ①-⑥ below choose the best answer. **3** kg·m/s

① 2.0 ② 4.0 ③ 8.0 ④ 9.0 ⑤ 18 ⑥ 36

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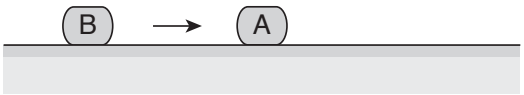
D On a rough horizontal floor, small object A is at rest and small object B collides with A while moving at a certain speed, as shown in the figure below. Both objects have the same mass. Following the collision, A and B come to rest after sliding distances L_{A} and L_{B}, respectively, on the floor. Let us denote as e the coefficient of restitution between A and B. The coefficient of kinetic friction between A and the floor is equal to that between B and the floor.



Q4 What is $\dfrac{L_{\mathrm{A}}}{L_{\mathrm{B}}}$? From ①-④ below choose the correct answer. **4**

① $\dfrac{1-e}{1+e}$ ② $\dfrac{1+e}{1-e}$ ③ $\left(\dfrac{1-e}{1+e}\right)^2$ ④ $\left(\dfrac{1+e}{1-e}\right)^2$

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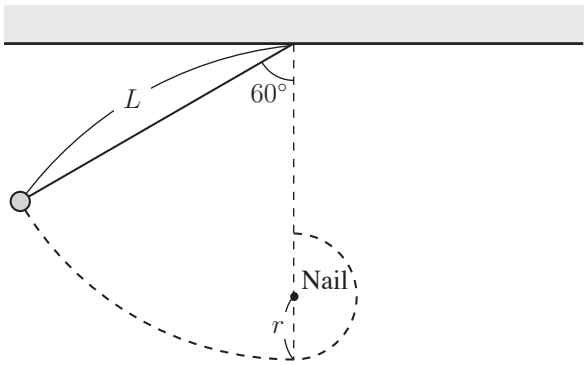
E One end of an inelastic lightweight string (length: L) is attached to a ceiling, and a small object is attached to the other end. As shown in the figure below, the object is gently released from a position where the string forms an angle of $60°$ with the vertical. After the object reaches its lowest point, it begins to travel with circular motion of radius r, centered on a thin nail located distance r directly above the lowest point. When r exceeds a certain length R, the object is unable to reach the point directly above the nail as it undergoes circular motion.



Q5 What is $\frac{R}{L}$? From ①-⑥ below choose the correct answer. **5**

① $\frac{1}{8}$ ② $\frac{1}{6}$ ③ $\frac{1}{5}$ ④ $\frac{1}{4}$ ⑤ $\frac{1}{3}$ ⑥ $\frac{2}{5}$

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F An artificial satellite is travelling in an elliptical orbit where one of the foci coincides with the earth's center of mass. When the satellite is nearest to the earth, the distance between the satellite and the earth's center of mass is five times as long as the earth's radius. Also, when nearest to the earth, the satellite's speed is two times as large as when farthest from the earth.

Q6 What is the ratio of the magnitude of the earth's gravity acting on the satellite when it is farthest from the earth, to the magnitude of the earth's gravity acting on the satellite when it is resting on the earth's surface? From ①-⑧ below choose the best answer. **6**

① 0 ② $\frac{1}{500}$ ③ $\frac{1}{250}$ ④ $\frac{1}{100}$

⑤ $\frac{1}{50}$ ⑥ $\frac{1}{25}$ ⑦ $\frac{1}{10}$ ⑧ $\frac{1}{5}$

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

A Water of 100 g at 10 °C is placed in a container that has a heat capacity of 150 J/K and is at temperature t. After sufficient time elapses, the container's temperature changes to 0.0 °C. Also, a portion of the water in the container turns into ice, with the container now holding ice of 5.0 g at 0.0 °C and water of 95 g at 0.0 °C. The specific heat of water is 4.2 J/(g · K), and the heat of fusion of ice is 330 J/g. Assume that there is no exchange of heat with the environment.

Q1 What is t (in °C)? From ①-⑥ below choose the best answer. **7** °C

① -54　② -43　③ -39

④ -21　⑤ -17　⑥ -4.0

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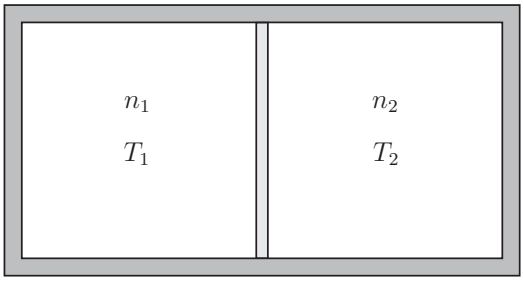
B As shown in the figure below, the interior of a container made of thermally insulated walls is partitioned into two regions by an immobile wall that conducts heat. A monatomic ideal gas with amount of substance n_1[mol] and absolute temperature T_1 is enclosed in one region, and a monatomic ideal gas with amount of substance n_2[mol] and absolute temperature T_2 is enclosed in the other region. After sufficient time elapses, the gases in both regions reach the same absolute temperature, T_3. Here, $n_1 > n_2$, and $T_1 > T_2$.



Q2 What is T_3? From ①-⑦ below choose the correct answer. **8**

① $\dfrac{T_1 + T_2}{2}$ ② $\dfrac{T_1}{2} + \dfrac{n_2 T_2}{2n_1}$ ③ $\dfrac{T_1}{2} + \dfrac{n_1 T_2}{2n_2}$

④ $\dfrac{n_1 T_1}{2n_2} + \dfrac{T_2}{2}$ ⑤ $\dfrac{n_2 T_1}{2n_1} + \dfrac{T_2}{2}$ ⑥ $\dfrac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$

⑦ $\dfrac{n_2 T_1 + n_1 T_2}{n_1 + n_2}$

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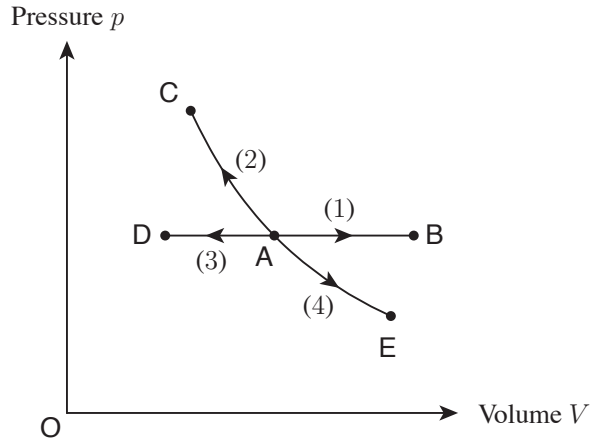
C A certain quantity of a monatomic ideal gas is enclosed in a cylinder. Consider how the state of this gas changes when it undergoes the processes shown in the p–V diagram below: process (1), which changes the state of the gas from state A to state B; process (2), which changes the state of the gas from state A to state C; process (3), which changes the state of the gas from state A to state D; and process (4), which changes the state of the gas from state A to state E. Processes (1) and (3) are isobaric changes, and processes (2) and (4) are adiabatic changes.



Q3 In which of processes (1)-(4) does the internal energy of the gas decrease? From ①-④ below choose the correct answer. **9**

① Processes (1) and (2)

② Processes (2) and (3)

③ Processes (3) and (4)

④ Processes (1) and (4)

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

A A sinusoidal wave is propagating along an x–axis. Figure 1 below is a graph showing the relationship between the wave's displacement of the medium, y, and its position coordinate, x, at time $t = 0$ s. Figure 2 is a graph showing the relationship between y and t at position $x = 0$ m.

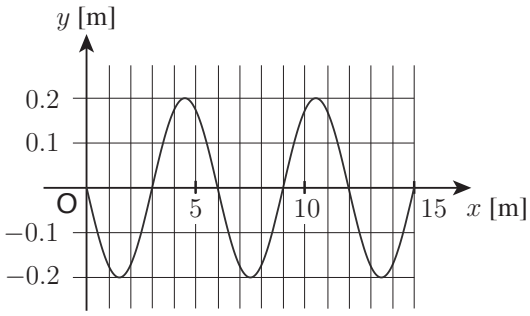

Figure 1

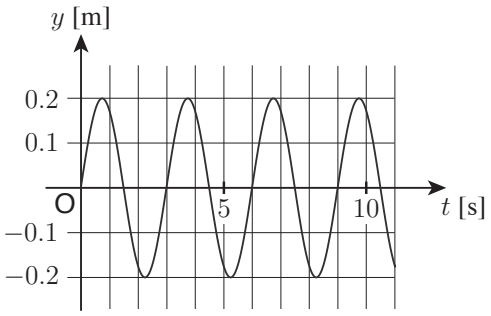

Figure 2

Q1 What is the mathematical formula for this sinusoidal wave? From ①-⑧ below choose the best answer, where the unit of y and x is m, and the unit of t is s. **10**

① $y = 0.2\sin\left(\frac{\pi}{3}t - \frac{2\pi}{3}x\right)$ ② $y = 0.2\sin\left(\frac{\pi}{3}t + \frac{2\pi}{3}x\right)$

③ $y = 0.2\sin\left(\frac{2\pi}{3}t - \frac{\pi}{3}x\right)$ ④ $y = 0.2\sin\left(\frac{2\pi}{3}t + \frac{\pi}{3}x\right)$

⑤ $y = 0.4\sin\left(\frac{\pi}{3}t - \frac{2\pi}{3}x\right)$ ⑥ $y = 0.4\sin\left(\frac{\pi}{3}t + \frac{2\pi}{3}x\right)$

⑦ $y = 0.4\sin\left(\frac{2\pi}{3}t - \frac{\pi}{3}x\right)$ ⑧ $y = 0.4\sin\left(\frac{2\pi}{3}t + \frac{\pi}{3}x\right)$

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B As shown in Figure 1 below, one end of a string is fixed in place, a weight of mass m_1 is attached to the other end and is suspended by placing the string over a pulley, and the string is stretched horizontally between two bridges fixed in place and separated by distance L_1. The string between the bridges is made to vibrate in its fundamental mode, and the frequency of this vibration is determined to be f. Next, as shown in Figure 2, the mass of the weight is changed to m_2 ($> m_1$) and the distance between the bridges is changed to L_2. The string between the bridges is again made to vibrate in its fundamental mode, and the frequency of this vibration is determined to be the same as before, f. Here, the speed of the wave traveling through the string is directly proportional to the square root (the $\frac{1}{2}$ power) of the magnitude of the force pulling the string.

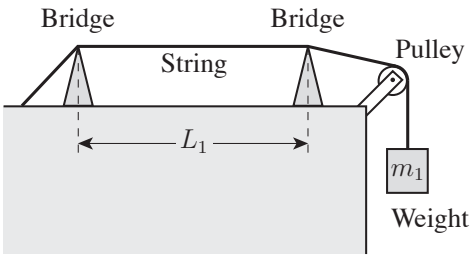

Figure 1

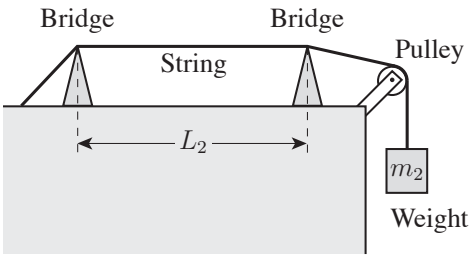

Figure 2

Q2 What is $\frac{L_2}{L_1}$? From ①-⑦ below choose the correct answer. **11**

① $\left(\frac{m_1}{m_2}\right)^2$ ② $\frac{m_1}{m_2}$ ③ $\sqrt{\frac{m_1}{m_2}}$ ④ 1

⑤ $\sqrt{\frac{m_2}{m_1}}$ ⑥ $\frac{m_2}{m_1}$ ⑦ $\left(\frac{m_2}{m_1}\right)^2$

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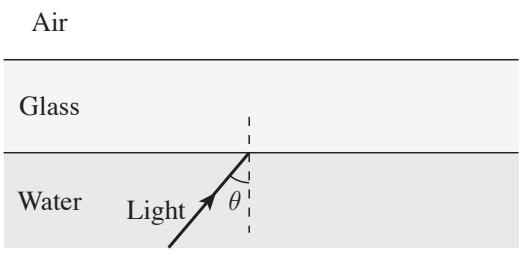
C As shown in the figure below, water, glass, and air adjoin along parallel boundary planes. A beam of light is directed from the water toward the glass, with the angle of incidence, θ, gradually increased from zero. When θ is small, the light refracted at the boundary plane of the glass and air travels into the air. However, when θ exceeds θ_0, the light is completely reflected at the boundary plane of the glass and air. Here, the absolute refractive indexes of water, glass, and air are $\frac{4}{3}$, $\frac{3}{2}$, and 1, respectively.



Q3 What is $\sin\theta_0$? From ①-⑦ below choose the best answer. **12**

① $\frac{1}{4}$ ② $\frac{1}{3}$ ③ $\frac{1}{2}$ ④ $\frac{2}{3}$

⑤ $\frac{3}{4}$ ⑥ $\frac{4}{5}$ ⑦ $\frac{8}{9}$

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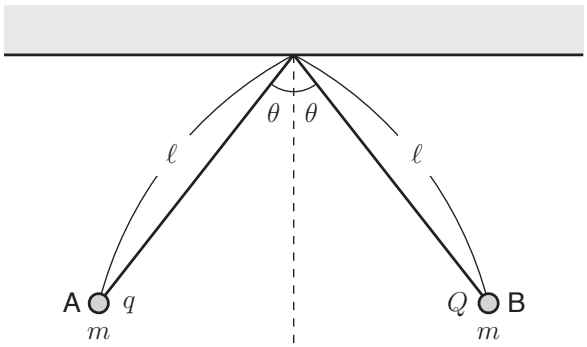
IV Answer questions **A** (Q1), **B** (Q2), **C** (Q3), **D** (Q4), **E** (Q5), and **F** (Q6) below.

A Small balls A and B, each having a mass of m, are each attached to the end of one of two lightweight, electrically insulated strings of the same length, ℓ. An electric charge with quantity of electricity q (> 0) is imparted to A, and an electric charge with quantity of electricity Q ($> q$) is imparted to B. As shown in the figure below, when the two objects are suspended from the same point, they come to rest within a vertical plane such that each string forms angle θ with the vertical. Let us denote as k the proportionality constant of Coulomb's law, and as g the magnitude of acceleration due to gravity.



Q1 What is Q? From ①-⑦ below choose the correct answer. **13**

① $\dfrac{4mg\ell^2 \sin\theta}{kq}$ ② $\dfrac{4mg\ell^2 \cos\theta}{kq}$ ③ $\dfrac{4mg\ell^2 \sin\theta\cos\theta}{kq}$

④ $\dfrac{4mg\ell^2 \sin^2\theta}{kq\cos\theta}$ ⑤ $\dfrac{4mg\ell^2 \cos^2\theta}{kq\sin\theta}$ ⑥ $\dfrac{4mg\ell^2 \sin^3\theta}{kq\cos\theta}$

⑦ $\dfrac{4mg\ell^2 \cos^3\theta}{kq\sin\theta}$

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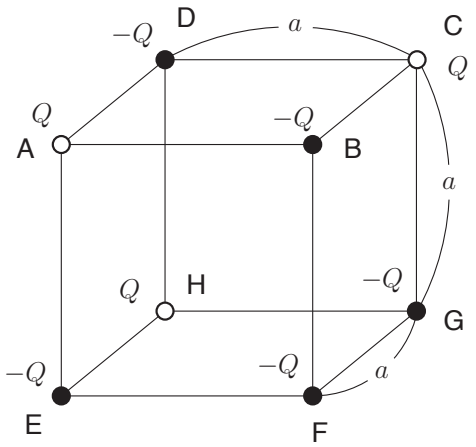
B As shown in the figure below, point charges with quantity of electricity Q (> 0) are fixed in place at vertices A, C, and H of a cube whose edges have length a, and point charges with quantity of electricity $-Q$ are fixed in place at vertices B, D, E, F, and G of the cube. Here, the reference position for electric potential is at infinity. Let us denote as k the proportionality constant of Coulomb's law.



Q2 What is the electric potential at the center of the cube (the midpoint of segment AG)? From ①-⑧ below choose the correct answer. **14**

① $-\dfrac{2\sqrt{3}\,kQ}{3a}$ ② $-\dfrac{4\sqrt{3}\,kQ}{3a}$ ③ $-\dfrac{\sqrt{2}\,kQ}{a}$ ④ $-\dfrac{2\sqrt{2}\,kQ}{a}$

⑤ $\dfrac{2\sqrt{3}\,kQ}{3a}$ ⑥ $\dfrac{4\sqrt{3}\,kQ}{3a}$ ⑦ $\dfrac{\sqrt{2}\,kQ}{a}$ ⑧ $\dfrac{2\sqrt{2}\,kQ}{a}$

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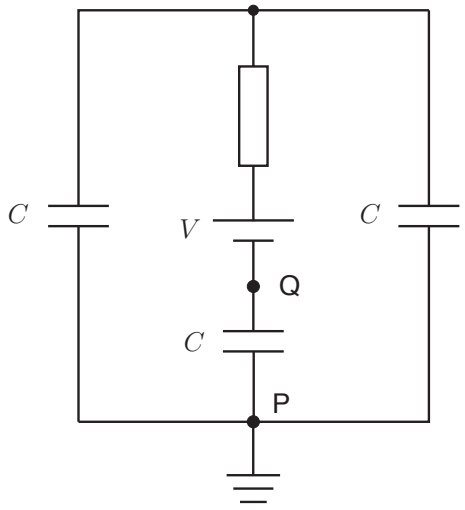
C Three capacitors, each with capacitance C, a battery with electromotive force V, and a resistor are connected as shown in the figure below. The capacitors, initially uncharged, are charged for a sufficient amount of time. Point P in the circuit is the reference position for electric potential.



Q3 What is the electric potential of point Q in the circuit? From ①-⑧ below choose the correct answer. **15**

① $-V$　② $-\frac{2}{3}V$　③ $-\frac{1}{2}V$　④ $-\frac{1}{3}V$

⑤ V　⑥ $\frac{2}{3}V$　⑦ $\frac{1}{2}V$　⑧ $\frac{1}{3}V$

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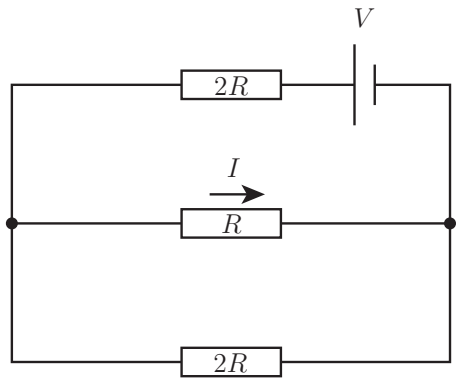
D A resistor with resistance R, two resistors, each with resistance $2R$, and a battery with electromotive force V are connected as shown in the figure below. Assume that the internal resistance of the battery is negligible.



Q4 What is magnitude I of the electric current flowing through the resistor with resistance R? From ①-⑥ below choose the correct answer. **16**

① $\dfrac{V}{8R}$ ② $\dfrac{V}{6R}$ ③ $\dfrac{V}{5R}$

④ $\dfrac{V}{4R}$ ⑤ $\dfrac{V}{3R}$ ⑥ $\dfrac{2V}{5R}$

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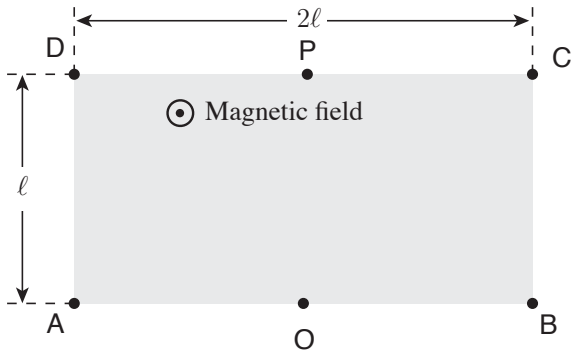
E As shown in the figure below, a uniform magnetic field exists within the region of rectangle ABCD, in the direction perpendicular to this page, from the back of the page to the front. Sides BC and DA have length ℓ and sides AB and CD have length 2ℓ. Point O is the midpoint of side AB, and point P is the midpoint of side CD. A charged particle with mass m and quantity of electricity q (> 0) is launched into this region from O with speed v, in the direction parallel to this page and perpendicular to side AB. The particle begins undergoing uniform circular motion and then exits this region from a certain point on side BC that is neither vertex B nor vertex C. Next, a charged particle with mass $2m$ and quantity of electricity $-q$ is launched into this region from O with speed v, in the same direction.



Q5 Where is the point at which the charged particle with mass $2m$ and quantity of electricity $-q$ exits the region of the magnetic field? From ①-⑥ below choose the correct answer.

17

① on segment OB ② on side BC ③ on segment CP

④ on segment PD ⑤ on side DA ⑥ on segment AO

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F Let us define a coordinate system where the x–y plane exists within this page and the positive direction of the z–axis is from the back of the page to the front. As shown in Figure 1 below, a rectangular circuit, ABCD, is formed with a resistor and a conducting wire, and is fixed in place in the x–y plane such that side AB is parallel to the y–axis. A spatially uniform magnetic field that changes with time t is applied to the region containing the circuit, parallel to the z–axis. Figure 2 is a graph showing the relationship between the z–component of the magnetic field's magnetic flux density (B_z) and time t. Let us denote as F_x the x–component of the force exerted by the magnetic field on side AB of the conducting wire. Assume that the magnetic field produced by the electric current flowing through the circuit is negligible.

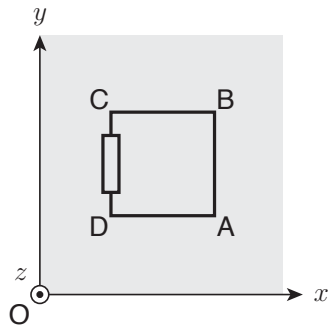


Figure 1

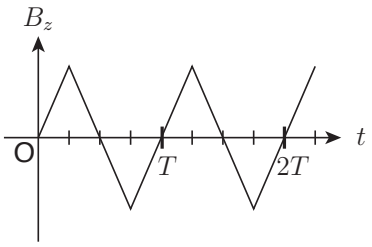
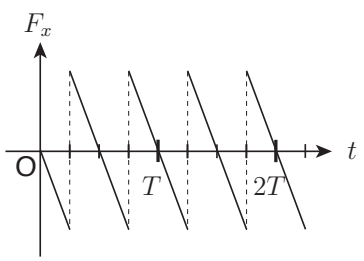
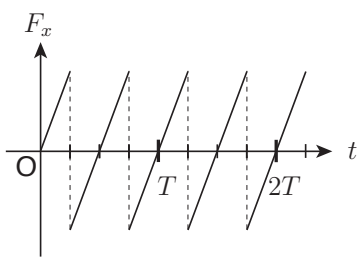


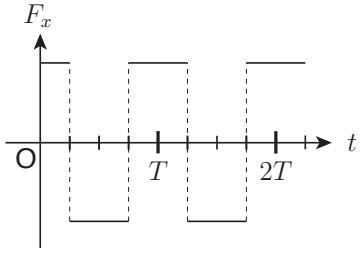
Figure 2

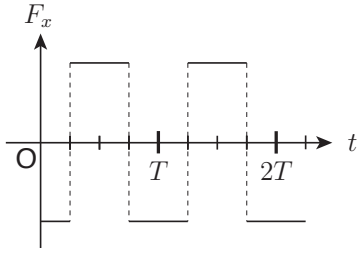
Q6 From ①-④ below choose the graph that best represents the relationship between F_x and t.

18

① 

② 

③ 

④ 

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

A Let us denote as λ the de Broglie wavelength of an electron wave (matter wave) where the electron's kinetic energy in a vacuum is K. Let us denote as m the electron's mass, and as h Planck's constant.

Q1 What is K, expressed with λ? From ①-④ below choose the best answer. **19**

① $\dfrac{h^2}{2m\lambda^2}$ ② $\dfrac{\lambda^2}{2mh^2}$ ③ $\dfrac{mh^2}{2\lambda^2}$ ④ $\dfrac{m\lambda^2}{2h^2}$

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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.

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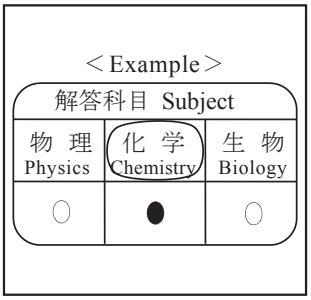
Chemistry

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.



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

Standard state: 0 ℃, 1.01×10^5 Pa (1 atm)

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

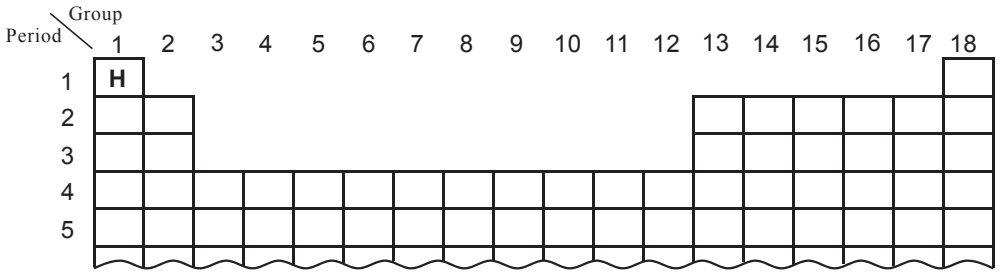
Gas constant: $R = 8.31 \times 10^3$ Pa·L/(K·mol)

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 Na : 23 Al : 27 Cl : 35.5

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



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Q1 Among the following statements (**a**)-(**d**) on atomic structure and electron configuration, two are correct. From ①-⑥ below choose the combination of these. **1**

(**a**) The Na atom and the K atom have a different number of protons.

(**b**) The ^{12}C atom and the ^{13}C atom have a different number of neutrons.

(**c**) The Ne atom and Mg^{2+} have a different number of electrons.

(**d**) The O atom and the S atom have a different number of valence electrons.

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

Q2 From the following compounds ①-⑥, choose the one that has the largest number of unshared electron pairs. **2**

① water (H_2O) ② hydrogen chloride (HCl) ③ methane (CH_4)

④ ammonia (NH_3) ⑤ nitrogen (N_2) ⑥ carbon dioxide (CO_2)

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Q3 When 37 g of the carbonate of metal M (MCO_3) was heated, it decomposed as indicated in the following equation, and 11 g of carbon dioxide (CO_2) was generated.

$$MCO_3 \longrightarrow MO + CO_2$$

From ①-⑥ below, choose the closest value for the atomic weight of the metal M.

3

① 24 ② 36 ③ 40 ④ 55 ⑤ 88 ⑥ 140

Q4 The reaction in which aluminum (Al) is combusted to form aluminum oxide (Al_2O_3) is expressed by the following equation:

$$x\,Al + y\,O_2 \longrightarrow z\,Al_2O_3$$

where x, y, and z are coefficients.

From ①-⑥ below choose the closest value for the mass (g) of aluminum necessary to obtain 5.1 g of aluminum oxide. **4** g

① 1.8 ② 2.3 ③ 2.7 ④ 3.2 ⑤ 4.8 ⑥ 5.4

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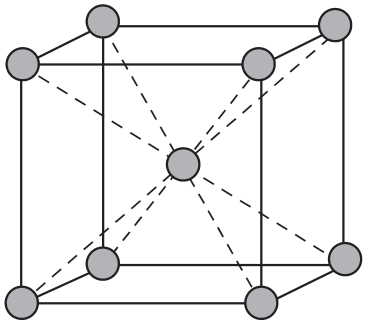
Q5 The following drawing indicates a unit cell of a crystal of potassium (K). From ①-⑥ below choose the correct one which indicates the density (g/cm^3) of potassium. Assume that the atomic weight of potassium is M, the length of an edge of the unit cell is a (cm), and the Avogadro constant is N_A (/mol). **5** g/cm^3



① $\dfrac{M}{a^3 N_A}$　② $\dfrac{2M}{a^3 N_A}$　③ $\dfrac{4M}{a^3 N_A}$

④ $\dfrac{N_A M}{a^3}$　⑤ $\dfrac{2N_A M}{a^3}$　⑥ $\dfrac{4N_A M}{a^3}$

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Q6 The temperature of water (H_2O) rose by 10 ℃ when 15 kg of water was heated with the heat generated by combustion of 4.2 g of hydrogen (H_2). Calculate the heat of formation of water in kJ/mol. From ①-⑥ below choose the closest value. The specific heat capacity (specific heat) of water is 4.2 J/(g･K). Assume that all the heat generated is used to raise the temperature of the water. **6** kJ/mol

① －600　② －300　③ －150　④ 150　⑤ 300　⑥ 600

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Q7 The following reaction is in an equilibrium state. Among the following statements (**a**)-(**d**) on this reaction, two are correct. From ①-⑥ below choose the correct combination.

7

$$H_2 + I_2 \rightleftharpoons 2HI + 9.0\ kJ$$

(**a**) If the temperature of this reaction is raised, the equilibrium constant will become smaller.

(**b**) If a catalyst is added, the equilibrium constant will become larger since the rate of reaction increases.

(**c**) Though the path of the reaction will not change by adding a catalyst, the activation energy of the reaction will become smaller.

(**d**) It is impossible to derive an equation explaining the relation between the rate of reaction and the concentration of reactants directly from the chemical equation.

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

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Q8 In the following statements (**a**) and (**b**), the relationship between the magnitudes of the molar concentrations, c_1 and c_2, of two substances and between the amounts, n_1 and n_2, of two other substances, are given. From ①-⑨ in the table below choose the correct combination. **8**

(**a**) c_1 : molar concentration of chloride ion (Cl^-) in hydrochloric acid (HCl) with a pH of 3

c_2 : molar concentration of acetate ion (CH_3COO^-) in aqueous acetic acid (CH_3COOH) with a pH of 3

(**b**) n_1 : the amount of sodium hydroxide (NaOH) required to neutralize 10 mL of hydrochloric acid with a pH of 3

n_2 : the amount of sodium hydroxide required to neutralize 10 mL of aqueous acetic acid with a pH of 3

	c_1 and c_2	n_1 and n_2
①	$c_1 > c_2$	$n_1 > n_2$
②	$c_1 > c_2$	$n_1 = n_2$
③	$c_1 > c_2$	$n_1 < n_2$
④	$c_1 = c_2$	$n_1 > n_2$
⑤	$c_1 = c_2$	$n_1 = n_2$
⑥	$c_1 = c_2$	$n_1 < n_2$
⑦	$c_1 < c_2$	$n_1 > n_2$
⑧	$c_1 < c_2$	$n_1 = n_2$
⑨	$c_1 < c_2$	$n_1 < n_2$

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Q9 From the following reaction formulas ①-⑤ choose the one in which the underlined substance acts as an oxidizing agent. **9**

① $\underline{SO_2} + Br_2 + 2H_2O \longrightarrow H_2SO_4 + 2HBr$

② $\underline{CaO} + 2HCl \longrightarrow CaCl_2 + H_2O$

③ $\underline{Zn} + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

④ $\underline{HCl} + NaOH \longrightarrow NaCl + H_2O$

⑤ $\underline{H_2O_2} + SO_2 \longrightarrow H_2SO_4$

Q10 A sufficient amount of sodium chloride (NaCl) was placed in a crucible, melted, and electrolyzed using carbon electrodes with a 10.0 A electric current for 1930 seconds. From ①-⑧ in the table below choose the correct combination of the substance generated at the cathode and its mass. Assume that the reaction proceeded completely, and that all the electric current was used to generate the products. **10**

	Substance generated	Mass (g)
①	chlorine (Cl_2)	0.36
②	chlorine (Cl_2)	0.71
③	chlorine (Cl_2)	3.6
④	chlorine (Cl_2)	7.1
⑤	sodium (Na)	0.23
⑥	sodium (Na)	0.46
⑦	sodium (Na)	2.3
⑧	sodium (Na)	4.6

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Q11 From the following statements ①-⑤ on properties of Group 2 elements, choose the correct one. **11**

① Mg exhibits a yellow color, Ca orange-red, and Ba yellow-green in the flame test.

② Each of Mg, Ca, and Ba metals reacts with water (H_2O) at normal temperature and generates hydrogen (H_2).

③ Each of $Mg(OH)_2$, $Ca(OH)_2$, and $Ba(OH)_2$ readily dissolves in water and the resultant aqueous solutions are strongly basic.

④ Each of $MgCl_2$, $CaCl_2$, and $BaCl_2$ easily dissolves in water.

⑤ Each of $MgSO_4$, $CaSO_4$, and $BaSO_4$ is hardly soluble in water.

Q12 Among the following statements (**a**)-(**f**) on halogens, F, Cl, Br, and I, two are **not** correct. From ①-⑥ below choose the combination of these. **12**

(**a**) F_2 reacts with H_2O to generate O_2.

(**b**) I_2 will be released when bromine water is added to aqueous KI.

(**c**) HF, HCl, HBr, and HI are all strong acids.

(**d**) HF will be generated when concentrated sulfuric acid (H_2SO_4) is added to CaF_2 and the mixture is heated.

(**e**) HClO possesses strong oxidizing property.

(**f**) The boiling point of HF is lower than that of HCl.

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

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Q13 Among the gases generated by means of the following procedures (**a**)-(**d**), two exhibit reducing ability. From ①-⑥ below choose the correct combination. **13**

(**a**) Aqueous sodium hydroxide (NaOH) is added to aluminum (Al).

(**b**) Concentrated sulfuric acid (H_2SO_4) is added to sodium chloride (NaCl) and the mixture is heated.

(**c**) Concentrated hydrochloric acid (HCl) is added to manganese(IV) oxide and the mixture is heated.

(**d**) Dilute sulfuric acid (H_2SO_4) is added to iron(II) sulfide (FeS).

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

Q14 From the following statements ①-⑤ on the compounds of copper (Cu), choose the correct one. **14**

① When copper is heated in air, black copper(II) oxide (CuO) is formed.

② When copper(II) sulfate is recrystallized from hot water, colorless crystals are obtained, the color of which changes into blue by heating.

③ When a small amount of sulfuric acid (H_2SO_4 aq) is added to a blue-colored aqueous solution of copper(II) sulfate, blue-white precipitates are formed.

④ When an aqueous solution of sodium hydroxide (NaOH) is added to an aqueous solution of copper(II) chloride ($CuCl_2$) at room temperature, red-brown precipitates of copper(I) oxide (Cu_2O) are formed.

⑤ When hydrogen sulfide (H_2S) is passed through an aqueous solution containing copper(II) ion (Cu^{2+}), yellow precipitates of copper(II) sulfide (CuS) are formed.

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Q15 From the following statements ①-⑤ choose the one which describes a chemical change that takes place in an aqueous solution containing silver ions (Ag^+), but does not take place in an aqueous solution containing lead(II) ions (Pb^{2+}). **15**

① A metal deposits when zinc (Zn) is added.

② Precipitates are formed when hydrochloric acid (HCl) is added.

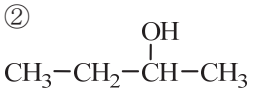
③ Precipitates are formed when aqueous potassium chromate (K_2CrO_4) is added.

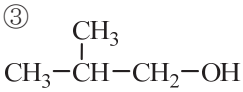
④ Precipitates are formed when aqueous ammonia (NH_3) is added, and the precipitates will dissolve if it is added in excess.

⑤ Precipitates are formed when aqueous sodium hydroxide (NaOH) is added, and the precipitates dissolve if it is added in excess.

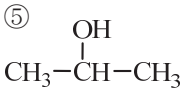
Q16 A carboxylic acid and an alcohol were obtained by hydrolysis of an ester with the molecular formula $C_5H_{10}O_2$. The carboxylic acid was positive to the silver mirror test, and the alcohol was positive to the iodoform reaction. From ①-⑤ below choose the correct structural formula of the alcohol. **16**

①


②


③


④


⑤


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Q17 From ①-⑥ in the table below, choose the correct combination of organic compounds obtained by the following procedures (**a**)-(**c**). **17**

(**a**) Sodium acetate (CH_3COONa) is heated together with sodium hydroxide (NaOH).

(**b**) Dry distillation of calcium acetate ($(CH_3COO)_2Ca$) is carried out.

(**c**) Water (H_2O) is added to calcium carbide (CaC_2).

	a	**b**	**c**
①	methane	acetylene (ethyne)	acetone
②	methane	acetone	acetylene (ethyne)
③	acetylene (ethyne)	methane	acetone
④	acetylene (ethyne)	acetone	methane
⑤	acetone	methane	acetylene (ethyne)
⑥	acetone	acetylene (ethyne)	methane

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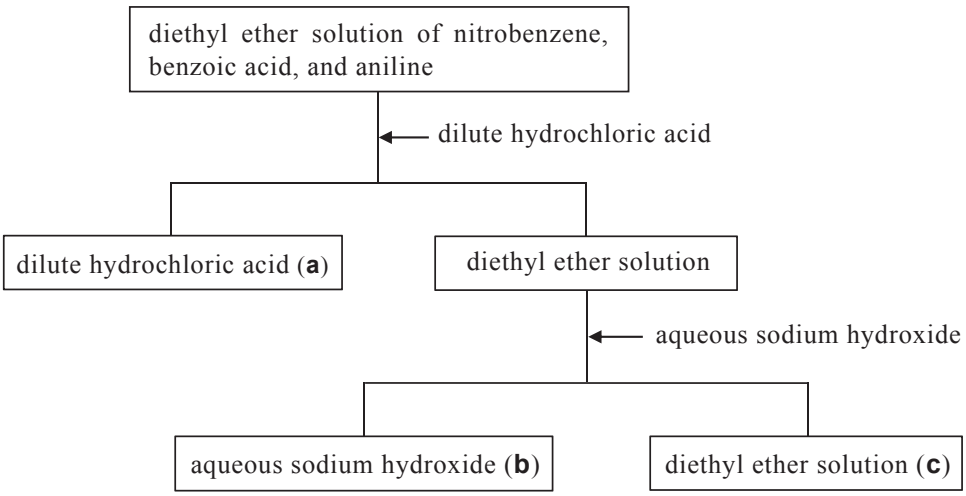
Q18 A diethyl ether solution containing nitrobenzene, benzoic acid, and aniline was placed in a separatory funnel, and a separation procedure was carried out with dilute hydrochloric acid (HCl) and aqueous sodium hydroxide (NaOH) as is shown in the following figure. Indicate the substances contained in dilute hydrochloric acid (**a**), aqueous sodium hydroxide (**b**), and diethyl ether solution (**c**), respectively. From ①-⑥ in the table below choose the correct combination. **18**



	a	b	c
①	nitrobenzene	sodium benzoate	aniline
②	nitrobenzene	aniline	benzoic acid
③	benzoic acid	nitrobenzene	aniline
④	benzoic acid	aniline	nitrobenzene
⑤	aniline hydrochloride	nitrobenzene	benzoic acid
⑥	aniline hydrochloride	sodium benzoate	nitrobenzene

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Q19 From ①-⑤ in the table below choose the correct combination of the type of polymerization to produce the polymer and constituent elements of the polymer compounds. **19**

	Polymer compound	Type of polymerization	Constituent elements
①	nylon 6,6	condensation polymerization	C, H, O
②	poly(ethylene terephathalate)	addition polymerization	C, H, O
③	butadiene rubber	addition condensation	C, H
④	polyacrylonitrile	addition polymerization	C, H, N
⑤	phenol resin	addition condensation	C, H, N

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Q20 From the following statements ①-⑤ on proteins, choose the one in which the underlined part is **not** correct. **20**

① Proteins are made by the condensation of α-amino acids and are called polypeptides.

② Proteins have secondary structures such as α-helices and β-sheets made by intramolecular hydrogen bonds between C=O and N-H groups.

③ Proteins denature when heated.

④ When concentrated sulfuric acid (H_2SO_4) is added to an aqueous solution of proteins and the solution is heated, the color of the solution changes to yellow.

⑤ The protein composing hair which contains cysteine has a structure that is stabilized by formation of disulfide bonds (-S-S-).

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.

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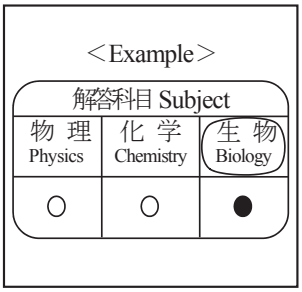
Biology

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.



Q1 From ① – ④ below choose the statement that correctly describes ribosomes. **1**

① Ribosomes are the site of protein synthesis.

② Prokaryotic ribosomes reside in the cytoplasm; eukaryotic ribosomes reside in the nucleus.

③ Ribosomes have a double-membrane structure.

④ Ribosomes contain an enzyme that breaks down excess proteins.

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Q2 Statements a – d below describe protein structure. From ① – ⑥ below choose the combination indicating the two statements that are correct. **2**

a There are 20 types of amino acids that are used to form proteins.

b A sequence of amino acids that are linked together is described as the primary structure; the bonds joining these amino acids together are called S-S bonds (disulfide bonds).

c Some proteins are made up of multiple polypeptide chains aggregated together.

d The α-helix and β-sheet structures are described as tertiary structure.

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

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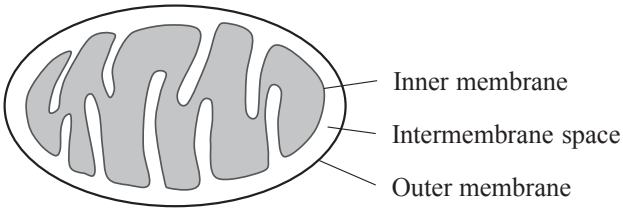
Q3 The following figure schematically represents a mitochondrion. Referring to this figure, from ① – ⑧ below choose the combination of terms that correctly fills blanks [a] – [c] in the paragraph below describing the electron transport system of respiration. **3**



Electrons from the NADH and $FADH_2$ produced by glycolysis and the citric acid cycle are transferred to the electron transport system, which is embedded in the inner membrane of the mitochondrion. The electrons transferred to the electron transport system pass through a series of [a] complexes. Energy released by this process drives the transport of H^+ from the [b] of the mitochondrion to the intermembrane space. Consequently, the H^+ concentration of the intermembrane space becomes higher than that of the [b]. Due to this concentration gradient, H^+ travels from the intermembrane space to the [b] via the ATP synthase in the [c] membrane, resulting in the synthesis of ATP.

	a	b	c
①	carbohydrate	stroma	inner
②	carbohydrate	stroma	outer
③	carbohydrate	matrix	inner
④	carbohydrate	matrix	outer
⑤	protein	stroma	inner
⑥	protein	stroma	outer
⑦	protein	matrix	inner
⑧	protein	matrix	outer

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Q4 From ① – ④ below choose the statement that correctly describes photosynthesis in green sulfur bacteria. **4**

① Photosynthesis in green sulfur bacteria takes place in the chloroplasts.

② Oxygen is released in the process of photosynthesis in green sulfur bacteria.

③ A photosynthetic pigment called bacteriochlorophyll is used in photosynthesis in green sulfur bacteria.

④ Electrons from H_2O are used to synthesize organic compounds in the process of photosynthesis in green sulfur bacteria.

Q5 The following paragraph describes DNA replication. From ① – ④ below choose the combination of terms that best fills blanks [a] – [c] in the paragraph. **5**

During DNA replication, an enzyme called [a] breaks the hydrogen bonds between the bases to separate the strands of the double-helix structure. [b] uses each separated nucleotide chain as a template to synthesize a nucleotide chain with a base sequence complementary to that of the template. The newly synthesized nucleotide chains elongate in the [c] direction.

	a	b	c
①	DNA polymerase	DNA helicase	3′→5′
②	DNA polymerase	DNA helicase	5′→3′
③	DNA helicase	DNA polymerase	3′→5′
④	DNA helicase	DNA polymerase	5′→3′

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Q6 The following paragraph describes transcription and splicing in eukaryotic cells. From ① – ⑥ below choose the combination of terms that best fills blanks [a] – [c] in the paragraph. [6]

During transcription in eukaryotic cells, the DNA base sequence is used as a template to synthesize precursor [a] with a complementary base sequence. Next, the regions corresponding to [b] are removed from the precursor [a] and the remaining [c] are joined together to form [a]. This process is called splicing.

	a	b	c
①	mRNA	exons	introns
②	mRNA	introns	exons
③	rRNA	exons	introns
④	rRNA	introns	exons
⑤	tRNA	exons	introns
⑥	tRNA	introns	exons

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Q7 In humans with sickle cell anemia, the base sequence of the hemoglobin gene is different from that of a normal hemoglobin gene by one base. Due to this difference, the mRNA codon that codes for glutamic acid is changed to one that codes for valine (GUG). From ①－⑧ below choose the answer that correctly indicates the normal codon. If necessary, refer to the following mRNA genetic code table. **7**

1st base	2nd base				3rd base
	U	C	A	G	
U	phenylalanine	serine	tyrosine	cysteine	U
	phenylalanine	serine	tyrosine	cysteine	C
	leucine	serine	(stop codon)	(stop codon)	A
	leucine	serine	(stop codon)	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	threonine	asparagine	serine	U
	isoleucine	threonine	asparagine	serine	C
	isoleucine	threonine	lysine	arginine	A
	methionine (start codon)	threonine	lysine	arginine	G
G	valine	alanine	aspartic acid	glycine	U
	valine	alanine	aspartic acid	glycine	C
	valine	alanine	glutamic acid	glycine	A
	valine	alanine	glutamic acid	glycine	G

① CUG ② GAA ③ GAG ④ GCG ⑤ GUA ⑥ GUC
⑦ GUU ⑧ UUG

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Q8 The following paragraph describes the relative positions of genes on a chromosome. From ①–④ below choose the combination of terms that best fills blanks [a] – [c] in the paragraph. **8**

Genetic [a] occurs between two genes on the same chromosome when chromosomal [b] takes place. By investigating the frequency of [a], we can determine the relative positions of genes. For example, if the [a] values calculated for the three genes X, Y, and Z are 11% between X and Y, 7% between X and Z, and 4% between Y and Z, we know that the relative positions of the three genes are as indicated in [c].

Figure 1

Figure 2

	a	b	c
①	recombination	crossover	Figure 1
②	recombination	crossover	Figure 2
③	crossover	recombination	Figure 1
④	crossover	recombination	Figure 2

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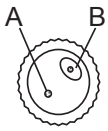
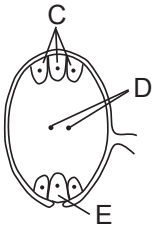
Q9 The following figure schematically represents a mature pollen grain and an embryo sac of an angiosperm. After pollination, either A (pollen tube nucleus) or B (generative cell) in the pollen grain, divides once and fertilizes one of C (antipodal cell), D or E in the embryo sac, to form an embryo. From ①–⑥ below choose the combination correctly indicating the two structures that together develop into an embryo. **9**



Mature pollen grain



Embryo sac

① A, C　② A, D　③ A, E　④ B, C　⑤ B, D　⑥ B, E

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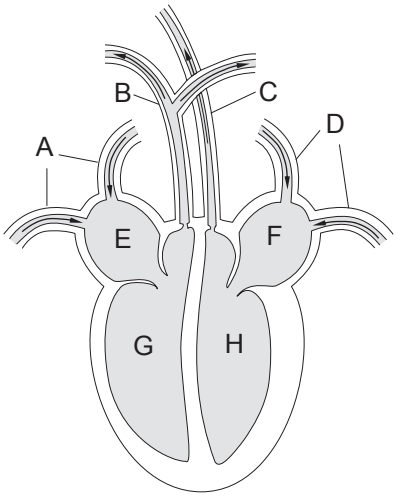
Q10 The following figure schematically represents the human heart. From ①–⑧ below choose the combination that best fills blanks [x] – [z] in the paragraph below describing this figure.

10



Among blood vessels A – D connected to the heart, the blood vessels through which venous blood flows are [x]. Among the four heart chambers E – H, [y] is the one where the sinoatrial node (pacemaker) is located. H is called the [z].

	x	y	z
①	A, B	E	left ventricle
②	A, B	F	left atrium
③	A, B	G	right ventricle
④	A, B	H	right atrium
⑤	C, D	E	left ventricle
⑥	C, D	F	left atrium
⑦	C, D	G	right ventricle
⑧	C, D	H	right atrium

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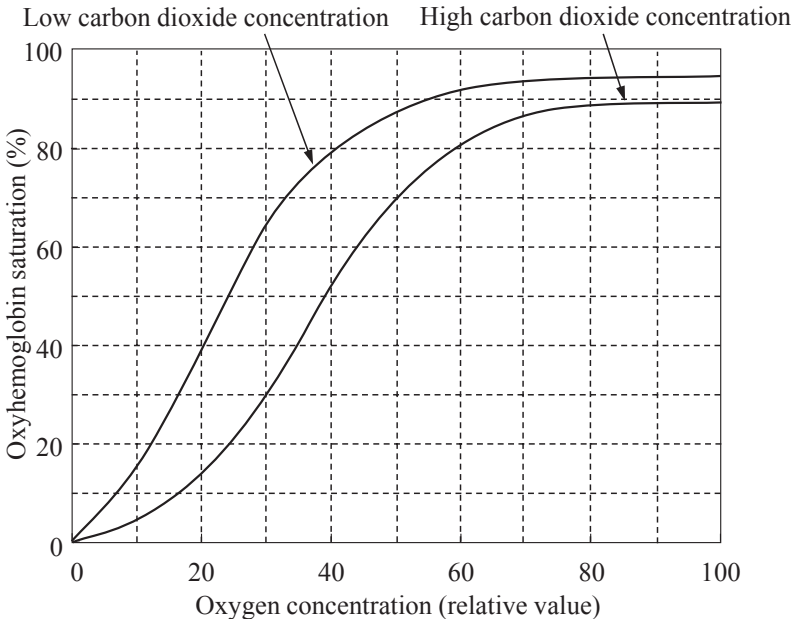
Q11 Hemoglobin in the blood is involved in oxygen (O_2) transport. The following graph shows oxygen dissociation curves. One curve is for when the carbon dioxide (CO_2) concentration is low, and the other is for when the carbon dioxide concentration is high. When the oxygen concentration at the alveoli and tissue is 100 and 30, respectively, what is the percentage (%) of oxyhemoglobin saturation at each location? From ① – ⑥ below choose the best combination. **11**



	Alveoli	Tissue
①	100	60
②	95	60
③	90	60
④	100	30
⑤	95	30
⑥	90	30

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Q12 What happens in the human body when the body temperature decreases? From ① – ⑤ below choose the statement that is **not** correct. **12**

① Heartbeat is accelerated by the action of the sympathetic nervous system.

② Adrenaline secretion is stimulated.

③ Arrector pili muscles contract.

④ Blood vessels in the skin constrict.

⑤ Metabolism in the liver and skeletal muscles is inhibited.

Q13 From ① – ④ below choose the statement that best describes immunity. **13**

① Serotherapy is a therapy in which the body is injected with serum containing killer T cells that react to antigens.

② After the body is vaccinated with a vaccine against a particular disease, immunoreaction is less likely to occur at a subsequent invasion by the pathogens of the same disease.

③ Secondary response refers to the immunoreaction that occurs when the tissue or constituents of the own body are perceived as antigens.

④ AIDS occurs as a result of infection of helper T cells by the human immunodeficiency virus (HIV).

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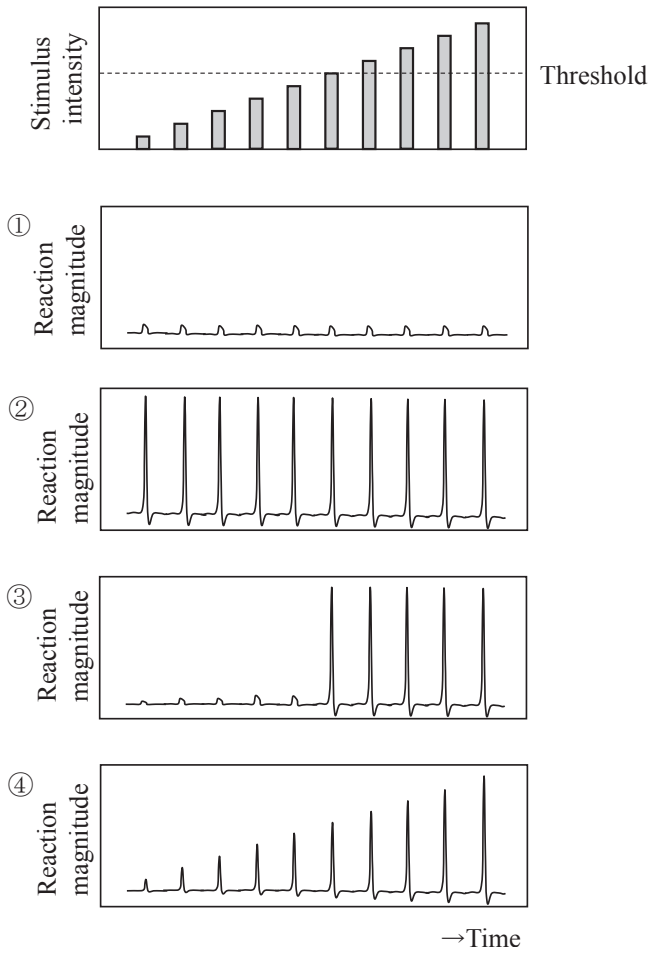
Q14 In an experiment, the intensity of a stimulus applied to a neuron was gradually increased, as shown in the following figure. Changes in the magnitude of the action potential were recorded. From ① – ④ below choose the figure that correctly represents how the magnitude of the action potential changed.

14



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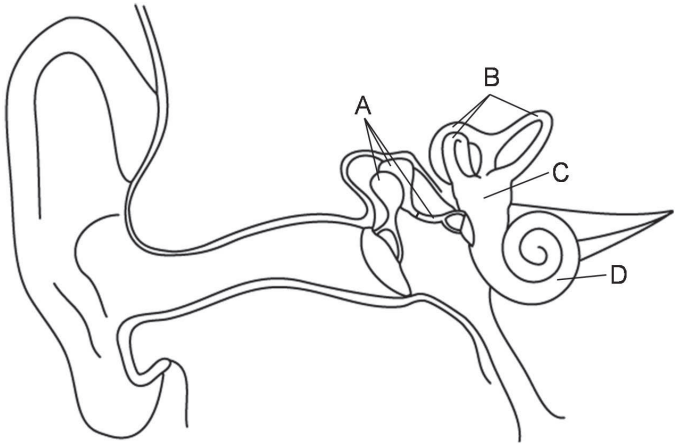
Q15 The following figure schematically represents the structure of the human ear. Among regions A – D in the figure, which one detects body rotation, and which one detects body inclination? From ① – ⑥ below choose the correct combination. **15**



	Region that detects body rotation	Region that detects body inclination
①	A	B
②	A	C
③	A	D
④	B	C
⑤	B	D
⑥	C	D

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Q16 From ① – ④ below choose the statement that correctly describes a human reflex. **16**

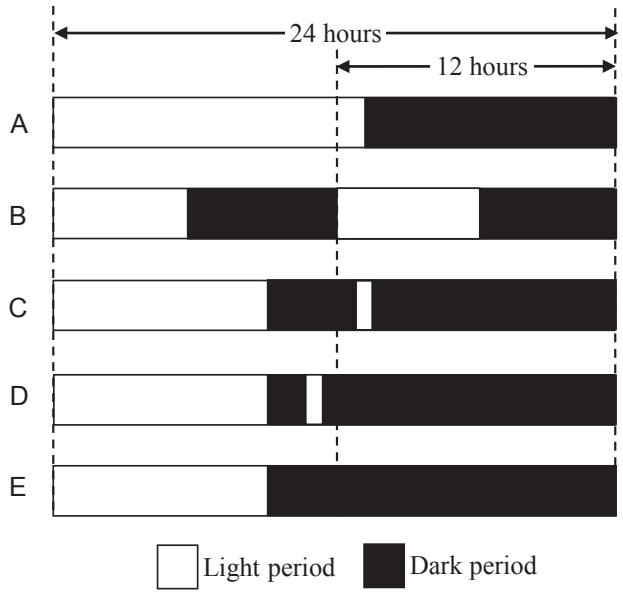
① The center of the patellar tendon reflex is the medulla oblongata.

② The center of the flexor reflex is the midbrain.

③ The pathway by which excitation is transmitted during a reflex is called the reflex arc.

④ During a reflex, the excitation is transmitted to the reflex center via the cerebrum.

Q17 A certain long-day plant with a 12-hour critical dark period was grown under the repeated 24-hour light/dark cycles shown in the figure below (A – E). Under which cycles would this plant form flower buds? From ① – ⑧ below choose the combination that correctly indicates all applicable cycles. **17**



① A ② A, B ③ A, B, C ④ B, C ⑤ C, D ⑥ C, E
⑦ D, E ⑧ E

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Q18 The substances listed in a – c below are believed to have been in existence or formed during the process of chemical evolution that preceded the emergence of life. From ① – ⑥ below choose the answer that correctly arranges a – c in the order in which they appeared. **18**

a Proteins, nucleic acids, etc.

b Amino acids, sugars, phospholipids, etc.

c Hydrogen sulfide, hydrogen, ammonia, methane, etc.

① a → b → c ② a → c → b ③ b → a → c ④ b → c → a

⑤ c → a → b ⑥ c → b → a

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.

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