2018 Examination for Japanese University Admission for International Students

Science (80 min.)

【Physics, Chemistry, Biology】

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

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 – 39
Biology	41 – 57

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 $\boxed{1}$, $\boxed{2}$, $\boxed{3}$, ···.
   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

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 string is attached to a small object (mass: m) placed on a rough horizontal floor, and is pulled so that the angle between the string and the horizontal remains θ. Initially, the object is at rest. As the magnitude of the tension in the string gradually increases, the object begins sliding horizontally along the floor when the magnitude of the tension exceeds T_0. Let us denote as μ the coefficient of static friction between the floor and the object.
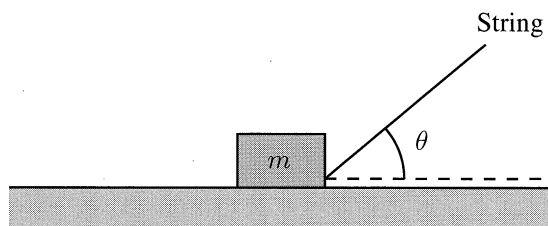
Q1 What is $\dfrac{T_0}{mg}$? From ①-⑥ below choose the correct answer.   1

① $\dfrac{\mu}{\sin\theta}$

② $\dfrac{\mu}{\cos\theta}$

③ $\dfrac{\mu}{\sin\theta + \mu\cos\theta}$

④ $\dfrac{\mu}{\sin\theta - \mu\cos\theta}$

⑤ $\dfrac{\mu}{\cos\theta + \mu\sin\theta}$

⑥ $\dfrac{\mu}{\cos\theta - \mu\sin\theta}$

B As shown in the figure below, weight 1 and weight 2 are joined with an inelastic lightweight string, and weight 1 is placed on a smooth horizontal platform and held still by hand while weight 2 is suspended by the string passing over a smoothly rotating pulley of negligible mass. Weight 1 is gently released and both weights begin uniformly accelerated motion.

Weight 1

m_1

Pulley
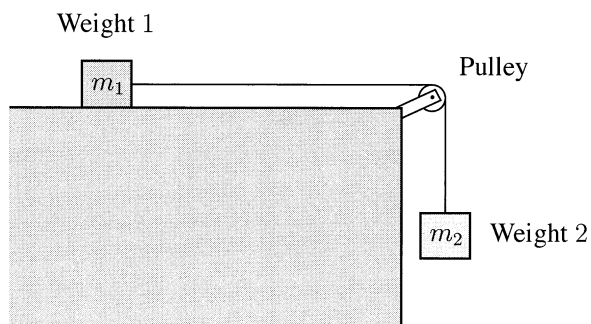
m_2 Weight 2

The experiment was repeated with the three variations (A, B, C) listed in the following table, where m_1 and m_2 are the masses of weight 1 and weight 2, respectively.

	A	B	C
m_1	5kg	4kg	3kg
m_2	3kg	4kg	5kg

Q2 In which of the three cases is the magnitude of acceleration of weight 1, a, the greatest? Also, in which case is the magnitude of the tension in the string, T, the greatest? From ①-⑥ below choose the correct combination. **2**

	①	②	③	④	⑤	⑥
greatest a	A	A	B	B	C	C
greatest T	B	C	A	C	A	B

C As shown in the figure below, small objects A (mass: m), B (mass: $\frac{m}{2}$), and C (mass: $\frac{m}{4}$) are placed in a straight line on a smooth horizontal floor. A moves along this line with speed v_A and collides elastically with B, which was at rest. Then, B begins moving along the line and collides elastically with C, which was at rest. Then, C begins moving along the line with speed v_C.
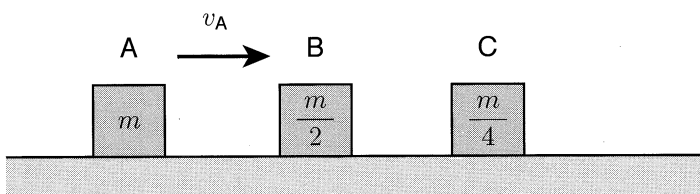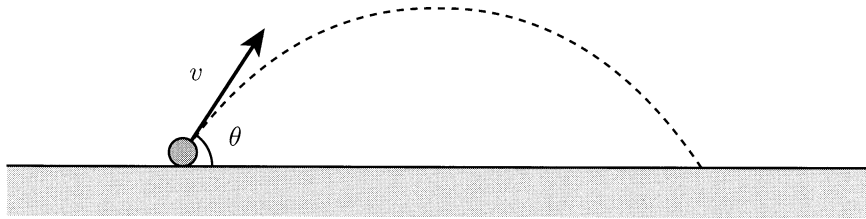

Q3 What is $\dfrac{v_C}{v_A}$? From ①-⑧ below choose the correct answer. [3]

① $\dfrac{1}{4}$ ② $\dfrac{1}{2}$ ③ $\dfrac{9}{16}$ ④ $\dfrac{3}{4}$

⑤ $\dfrac{4}{3}$ ⑥ $\dfrac{16}{9}$ ⑦ 2 ⑧ 4

D As shown in the figure below, a small object of mass m is launched from a horizontal floor with speed v in a direction forming angle θ with the horizontal.

Q4 What is the magnitude of the impulse imparted to the object by gravity from launch to the instant just before the object lands on the floor? From ①-⑧ below choose the correct answer. **4**

① $mv\sin\theta$ ② $mv\cos\theta$ ③ $2mv\sin\theta$ ④ $2mv\cos\theta$

⑤ $mv\sin2\theta$ ⑥ $mv\cos2\theta$ ⑦ $2mv\sin2\theta$ ⑧ $2mv\cos2\theta$

E As shown in the figure below, one end of an inelastic lightweight string of length ℓ is fixed in place at point O, and the other end is attached to small object P (mass: m). Small object Q (mass: M) is placed on a smooth horizontal surface, directly below O at a distance of ℓ. While the string is kept taut, P is raised to the same height as O and is gently released. Then, P collides with Q and both join into a single unit, which rises to a maximum height of h from the horizontal surface.
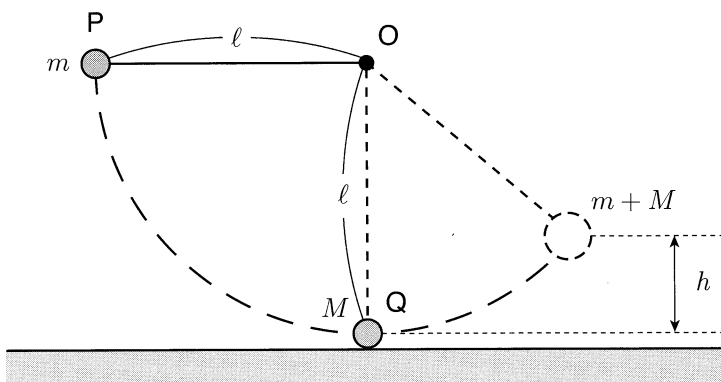
Q5 What is $\dfrac{h}{\ell}$? From ①-⑥ below choose the correct answer. | **5** |

① $\dfrac{m}{m+M}$

② $\dfrac{M}{m+M}$

③ $\left(\dfrac{m}{m+M}\right)^2$

④ $\left(\dfrac{M}{m+M}\right)^2$

⑤ $1-\left(\dfrac{m}{m+M}\right)^2$

⑥ $1-\left(\dfrac{M}{m+M}\right)^2$

F As shown in the figure below, a weight of mass m_1 is suspended with a lightweight spring and the weight is held at a point where the spring is at its natural length. The weight is gently released and begins undergoing simple harmonic motion with amplitude A_1 and period T_1. The experiment is repeated with the same spring and a different weight, of mass m_2. In this case the weight undergoes simple harmonic motion with amplitude A_2 and period T_2.

Natural length
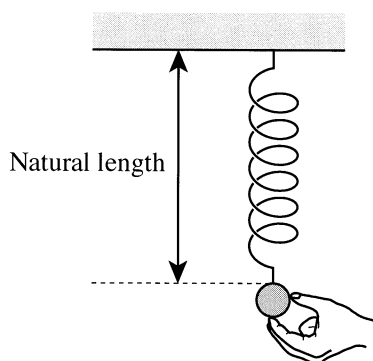
Q6 What is $\dfrac{A_2}{A_1}$? Also, what is $\dfrac{T_2}{T_1}$? From ①-⑥ below choose the correct combination.

<div style="text-align:right">**6**</div>

	①	②	③	④	⑤	⑥
$\dfrac{A_2}{A_1}$	$\dfrac{m_2}{m_1}$	$\dfrac{m_2}{m_1}$	$\sqrt{\dfrac{m_2}{m_1}}$	$\sqrt{\dfrac{m_2}{m_1}}$	1	1
$\dfrac{T_2}{T_1}$	$\sqrt{\dfrac{m_2}{m_1}}$	$\sqrt{\dfrac{m_1}{m_2}}$	$\sqrt{\dfrac{m_2}{m_1}}$	$\sqrt{\dfrac{m_1}{m_2}}$	$\sqrt{\dfrac{m_2}{m_1}}$	$\sqrt{\dfrac{m_1}{m_2}}$

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

A A metal of 500 g whose specific heat is c is heated to 55 °C and then immersed in water of 500 g at 20 °C in a container at 20 °C. After sufficient time elapses, the temperature of the metal, container, and water becomes 25 °C. Assume that heat moves only among the metal, container, and water. The heat capacity of the container is 300 J/K, and the specific heat of water is $4.2 \, \text{J}/(\text{g} \cdot \text{K})$.

Q1 What is c (in $\text{J}/(\text{g} \cdot \text{K})$)? From ①-⑤ below choose the best answer. **7** $\text{J}/(\text{g} \cdot \text{K})$

    ①   0.50   ②   0.60   ③   0.70   ④   0.80   ⑤   0.90

B Two identical cylinders, A and B, enclose ideal gases of the same volume with two smoothly moving pistons of the same cross-sectional area. As shown in the figure below, A and B are fixed in place on a horizontal floor, facing each other, and their pistons are joined with a rod. Initially, the gases in A and B both have pressure p_0, volume V_0, and absolute temperature T_0. Next, the absolute temperature of the gas in B is changed to T_1 while the absolute temperature of the gas in A is kept at T_0. As a result, the pressure of the gas in B changes to p_1.

Cylinder A   Cylinder B
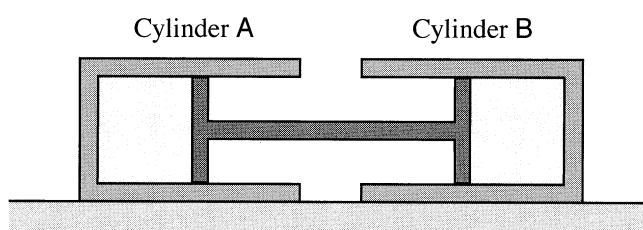
Q2   What is $\dfrac{T_1}{T_0}$? From ①-⑥ below choose the correct answer.   **8**

① $\dfrac{p_1}{p_0}$ ② $\dfrac{p_0}{p_1}$ ③ $\dfrac{2p_1}{p_0} - 1$ ④ $\dfrac{2p_0}{p_1} - 1$

⑤ $2 - \dfrac{p_1}{p_0}$ ⑥ $2 - \dfrac{p_0}{p_1}$

C Consider a gas of hydrogen molecule (H_2) and a gas of oxygen molecule (O_2) at the same temperature. Let us denote the root-mean-square speed of hydrogen molecule as $\sqrt{\overline{v_{H_2}^2}}$, and that of oxygen molecule as $\sqrt{\overline{v_{O_2}^2}}$. Here, root-mean-square speed is the square root of the mean square speed of molecules. Assume that the gases can be regarded as ideal gases, and that the molecular weight of hydrogen molecule is 2.0, and that of oxygen molecule is 32.

Q3   What is $\dfrac{\sqrt{\overline{v_{H_2}^2}}}{\sqrt{\overline{v_{O_2}^2}}}$? From ①-⑤ below choose the best answer. | 9 |

①   0.063   ②   0.25   ③   1.0   ④   4.0   ⑤   16

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 representing the relationship between the displacement of the medium, y, and the position coordinate, x, at time $t = 0$ s. Figure 2 is a graph representing the relationship between y and t at $x = 0$ m.
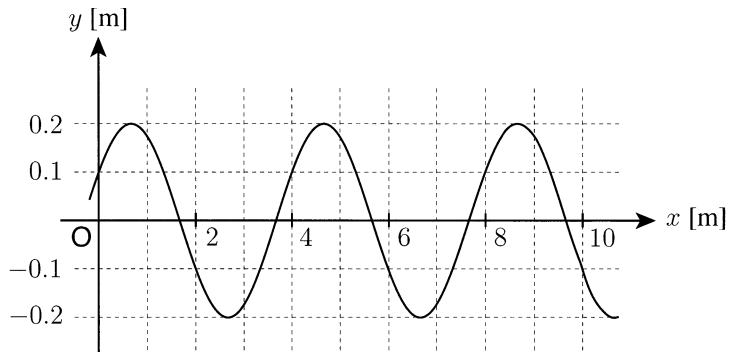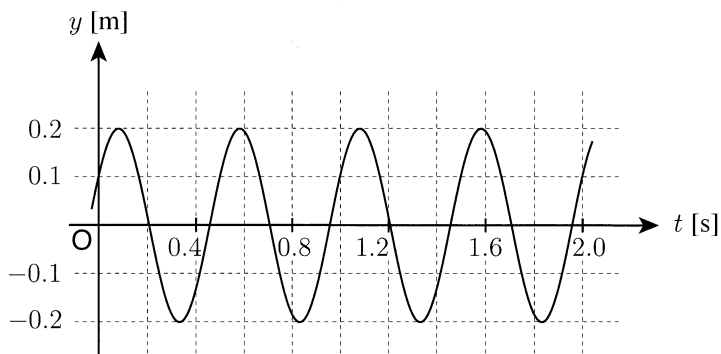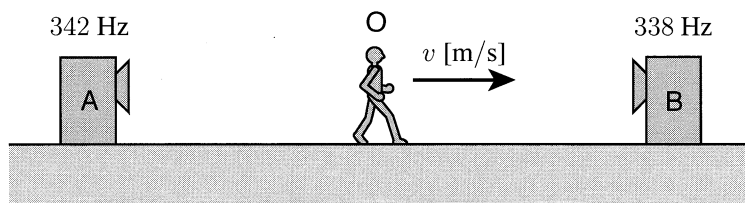
Figure 1

Figure 2

Q1 What is the propagation speed of the wave (in m/s)? Also, is the propagation direction of the wave in the positive direction, or the negative direction of the x-axis? From ①-⑥ below choose the best combination. **10**

	①	②	③	④	⑤	⑥
Speed [m/s]	2	2	4	4	8	8
Direction	positive	negative	positive	negative	positive	negative

B An observer O and two fixed sound sources, A and B, are arranged in a straight line as shown in the figure below. The sound source A is emitting sound with a frequency of 342 Hz, and the sound source B is emitting sound with a frequency of 338 Hz. When at rest, the observer O observes beats. When moving along the line in the direction from A to B with speed v [m/s], the observer O does not observe beats. Assume that the speed of sound is 340 m/s.

Q2 What is v (in m/s)? From ①-④ below choose the best answer. $\boxed{11}$ m/s
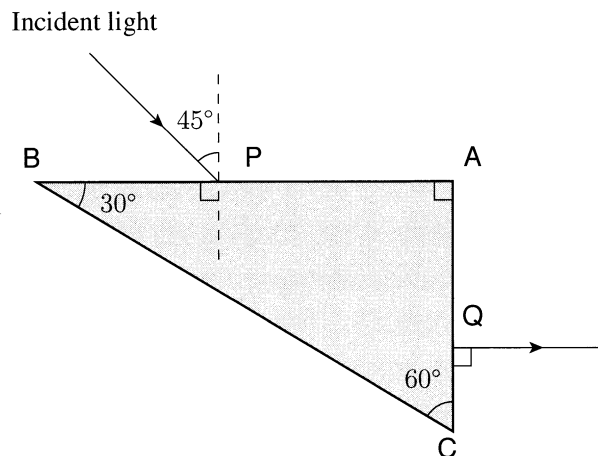
  ① 1   ② 2   ③ 3   ④ 4

C Consider a right triangular prism, ABC, whose acute angles measure $30°$ and $60°$. As shown in the figure below, monochromatic light is directed at point P on face AB with an angle of incidence of $45°$. The light is totally reflected by face BC, and perpendicularly exits face AC from point Q. Assume that the refractive index of air is 1.

Incident light

B $45°$ P   A

$30°$

$60°$

Q

C

Q3 What is the refractive index of this prism? From ①-④ below choose the correct answer.

| 12 |

① $\dfrac{\sqrt{6}}{2}$　　　② $\sqrt{2}$　　　③ $\sqrt{3}$　　　④ $\sqrt{6}$

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 (> 0) is fixed in place at vertex **A** of equilateral triangle **ABC**, and two point charges, each with quantity of electricity $-Q$, are fixed in place at vertices **B** and **C**. When a point charge with quantity of electricity q is fixed in place at point **D**, the midpoint of segment **BC**, the magnitude of the electrostatic force acting on the point charge at vertex **A** becomes zero.
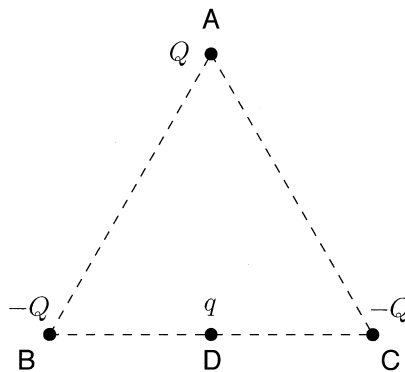
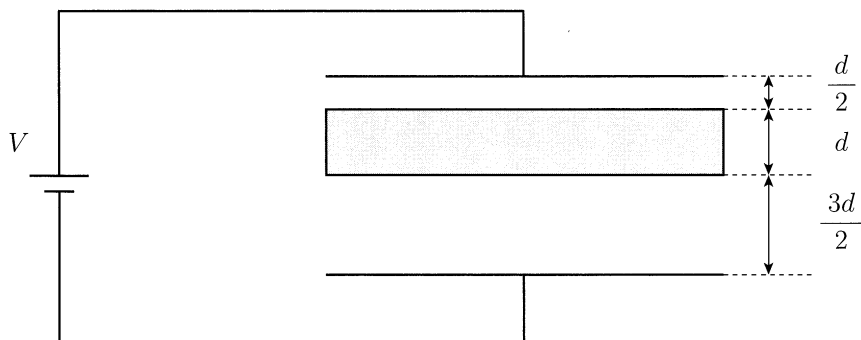**Q1** What is $\dfrac{q}{Q}$? From ①-⑦ below choose the correct answer. **13**

 ① $3\sqrt{3}$ ② $2\sqrt{3}$ ③ $\dfrac{4\sqrt{3}}{3}$ ④ $\sqrt{3}$

 ⑤ $\dfrac{3\sqrt{3}}{4}$ ⑥ $\dfrac{\sqrt{3}}{2}$ ⑦ $\dfrac{\sqrt{3}}{3}$

B As shown in the figure below, the plates of a parallel plate capacitor are separated by distance $3d$, and a conducting plate of thickness d and the same area as the capacitor plates is inserted parallel between them. The conducting plate is not charged. The distance between the lower capacitor plate and the bottom of the conducting plate is $\dfrac{3d}{2}$. The positive and negative electrodes of a battery of electromotive force $V\ (>0)$ are connected to the upper and lower capacitor plates, respectively. Let us denote as $V_1\ (>0)$ the electric potential difference between the conducting plate and the upper capacitor plate, and as $V_2\ (>0)$ the electric potential difference between the conducting plate and the lower capacitor plate.
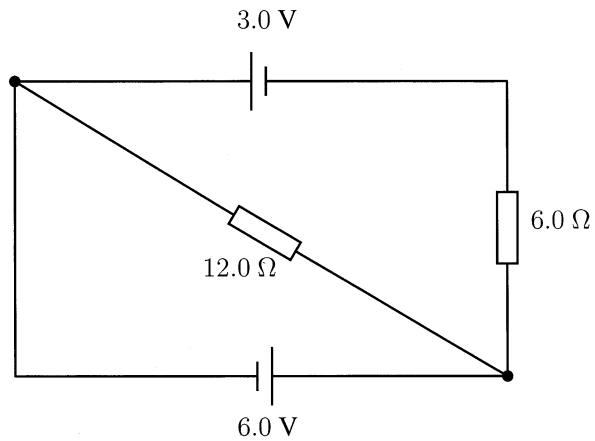

Q2 What is $V_1 - V_2$? From ①-⑥ below choose the correct answer. **14**

① $-\dfrac{V}{2}$ ② $-\dfrac{V}{3}$ ③ $-\dfrac{V}{4}$ ④ $\dfrac{V}{4}$ ⑤ $\dfrac{V}{3}$ ⑥ $\dfrac{V}{2}$

C Two batteries (electromotive force: 3.0 V, 6.0 V) and two resistors (resistance: 6.0 Ω, 12.0 Ω) are connected as shown in the figure below. The internal resistance of the batteries is negligible.

Q3 What is the electrical power (in W) supplied by the 6.0 V battery? From ①-⑦ below choose the best answer. $\boxed{15}$ W

① 3.0   ② 4.5   ③ 6.0   ④ 9.0

⑤ 12   ⑥ 15   ⑦ 17

D As shown in the figure below, two sufficiently long, straight conducting wires pass through points **A** and **B** on this page, perpendicular to the page. Electric currents of the same magnitude flow through the wires in the direction from the back of the page to the front.

⊙ A

⊙ B

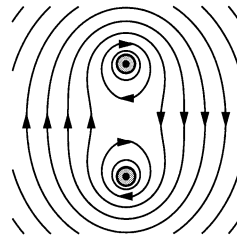Q4 From ①-④ below choose the figure that best represents the magnetic lines of force of the magnetic field produced by the currents. 16
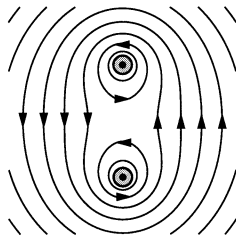
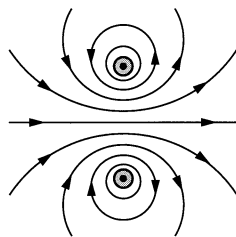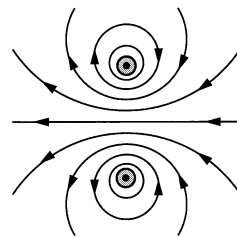① ②

③ ④

E As shown in the figure below, three sufficiently long, straight conducting wires pass through points **A** $(-\ell, 0)$, **B** $(\ell, 0)$, and **C** $(0, a)$ in an x-y plane within this page, perpendicular to the page $(a, \ell > 0)$. Electric currents of the same magnitude flow through the three wires. The current in the wire passing through **C** flows in the direction from the front of the page to the back. Then, the direction of the force acting on the wire passing through **C** is the positive direction of the x-axis.
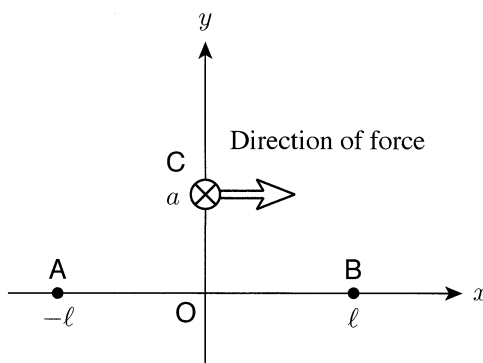
Q5 What is the direction of the current in the wire passing through **A**? Also, what is the direction of the current in the wire passing through **B**? From ①-④ below choose the correct combination. ⟨17⟩

	Direction of current in wire passing through **A**	Direction of current in wire passing through **B**
①	from front of page to back	from front of page to back
②	from front of page to back	from back of page to front
③	from back of page to front	from front of page to back
④	from back of page to front	from back of page to front

F As shown in Figure 1 below, a 400-turn coil with a cross-sectional area of 3.0×10^{-4} m^2 is placed in a uniform magnetic field, perpendicular to its cross section. The direction of the magnetic field is the direction indicated by the arrow in Figure 1. Terminals P and Q are connected with a resistor, and the electric potential difference between P and Q is measured while changing the magnitude of the magnetic flux density of the magnetic field, B [T], over time t [s], as shown in Figure 2.

Magnetic field

Coil   P   Q
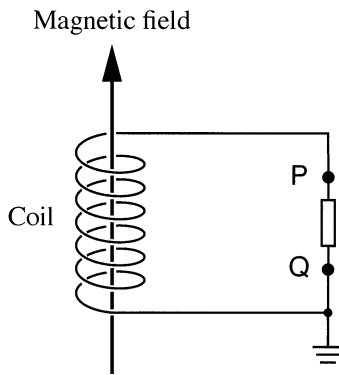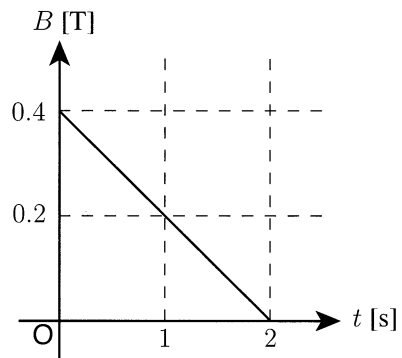
Figure 1   Figure 2

Q6   What is the difference in electric potential between P and Q? From ①-⑥ below choose the best answer.   **18**

①   P is 1.2×10^{-2} V higher than Q   ②   Q is 1.2×10^{-2} V higher than P

③   P is 2.4×10^{-2} V higher than Q   ④   Q is 2.4×10^{-2} V higher than P

⑤   P is 4.8×10^{-2} V higher than Q   ⑥   Q is 4.8×10^{-2} V higher than P

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

A Light is a wave, but it also behaves as particles referred to as photons. Photons have a and b . Using the speed of light, c, and the Planck constant, h, we can express the a of a photon of wavelength λ as c , and its b as d . When an electron and its antiparticle, a positron, undergo annihilation at rest, photons are produced. Here, at least two photons are produced, as the creation of only one photon would not obey the law of conservation of a .

Q1 What terms fill blanks a and b in the paragraph above? Also, what expressions fill blanks c and d ? From ①-④ below choose the correct combination. **19**

	①	②	③	④
a	momentum	momentum	energy	energy
b	energy	energy	momentum	momentum
c	$\dfrac{hc}{\lambda}$	$\dfrac{h}{\lambda}$	$\dfrac{hc}{\lambda}$	$\dfrac{h}{\lambda}$
d	$\dfrac{h}{\lambda}$	$\dfrac{hc}{\lambda}$	$\dfrac{h}{\lambda}$	$\dfrac{hc}{\lambda}$

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

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

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.

Q1 From ①-⑧ in the table below choose the correct combination of numbers of neutrons, electrons, and the outermost shell electrons contained in the atom ^{40}Ar.

	Number of neutrons	Number of electrons	Number of outermost shell electrons
①	20	18	0
②	20	18	8
③	20	20	0
④	20	20	8
⑤	22	18	0
⑥	22	18	8
⑦	22	20	0
⑧	22	20	8

Q2   From the following molecules and ions ①-⑥ choose the one in which the total number of electrons contained is **different from the others**. $\boxed{2}$

① CH_4 ② F^- ③ Na^+ ④ $NH_4{}^+$ ⑤ NO   ⑥ OH^-

Q3   From the following statements ①-⑥ on atoms and ions choose the correct one.

$\boxed{3}$

①   An atom whose atomic number is 6 possesses 6 valence electrons in the L shell.

②   An ^1H atom and an ^2H atom have the same electron configuration.

③   Among the atoms belonging to the same period, the alkali metal atoms have the largest first ionization energy.

④   Among Li^+, Na^+, and K^+, the one that has the largest ionic radius is Li^+.

⑤   Halogen atoms readily release electrons and form monovalent anions.

⑥   Among He, Ne, and Ar, the one that is lighter than air is Ar.

Q4   Among the following statements (**a**)-(**e**) on crystals, two are **not** correct. From ①-⑥ below choose the combination of them. | **4** |

(**a**)   Crystals of magnesium chloride ($MgCl_2$) are formed by ionic bonds.

(**b**)   Crystals of silver (Ag) are formed by metallic bonds.

(**c**)   Crystals of silicon (Si) are formed by metallic bonds.

(**d**)   Diamond possesses free electrons.

(**e**)   Dry ice readily sublimates.

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

Q5   When 10.0 L of oxygen (O_2) was passed through an ozone generator, 9.5 L of a gas mixture of oxygen and ozone (O_3) was obtained at the same temperature and pressure. Calculate the volume of ozone in L at the same temperature and pressure, when it was separated from the gas mixture. From ①-⑤ below choose the closest value.

| **5** | L

① 0.5   ② 1.0   ③ 1.5   ④ 2.0   ⑤ 2.5

Q6   The density of a gas is 1.2 g/L at 27 ℃ and 1.0×10^5 Pa. From ①-⑤ below choose the closest value for the molecular weight of this gas. Assume that the gas is an ideal gas.   **6**

　① 16　　② 27　　③ 30　　④ 32　　⑤ 44

Q7   4.0 g of solid sodium hydroxide (NaOH) is added to react with 100 mL of 0.50 mol/L hydrochloric acid (HCl). Calculate the amount of heat generated in kJ. From ①-⑤ below choose the closest value. Assume that the heat of neutralization is 56 kJ/mol and that the heat of dissolution of sodium hydroxide to water is 44 kJ/mol.   **7** kJ

　① 2.8　　② 7.2　　③ 10　　④ 32　　⑤ 60

Q8 Two electrolytic cells shown in the following figure were connected in series, and electrolysis was carried out. Aqueous copper(II) sulfate ($CuSO_4$) was placed in the electrolytic cell I, and copper (Cu) was used for electrodes **A** and **B**. Aqueous sodium chloride (NaCl) was placed in the electrolytic cell II, and carbon (C) was used for electrodes **C** and **D**.

electrolytic cell I   electrolytic cell II
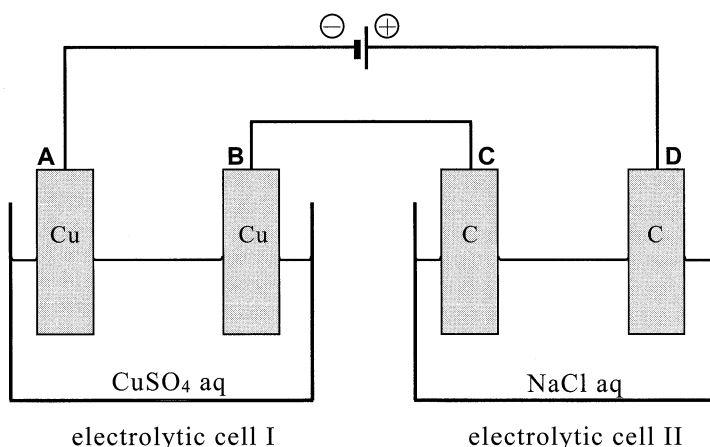
From the following statements ①-⑤ on this electrolysis choose the one that is **not** correct.   **8**

① The mass of the copper electrode **A** increases.

② The mass of the copper electrode **B** decreases.

③ The solution around the carbon electrode **C** becomes acidic.

④ A gas is generated from the carbon electrode **D**.

⑤ The amount of electricity flowing through electrolytic cell I and that of cell II are equal.

Q9   When a catalyst is added to aqueous hydrogen peroxide (H_2O_2), the following reaction takes place, and oxygen (O_2) is generated.

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

From the following statements ①-④ on this reaction, choose the one that is **not** correct. | **9** |

①   The rate of decomposition of hydrogen peroxide is one half of the rate of generation of oxygen.

②   The smaller the concentration of hydrogen peroxide, the lower the rate of generation of oxygen.

③   The lower the temperature of aqueous hydrogen peroxide, the lower the rate of generation of oxygen.

④   The smaller the amount of catalyst, the lower the rate of generation of oxygen.

Q10 In the aqueous solution of a weak acid HA, the following electrolytic dissociation equilibrium is established.
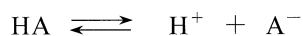
$$HA \rightleftharpoons H^+ + A^-$$

The electrolytic dissociation constant K_a is expressed by the molar concentration (mol/L) of each component.

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

Suppose the concentration of the acid is c (mol/L) and the degree of electrolytic dissociation is α in that case. How can K_a be expressed by c and α? From ①-⑥ below choose the correct one. **10**

① $\dfrac{\alpha}{c(1-\alpha)}$

② $\dfrac{\alpha^2}{c(1-\alpha)}$

③ $\dfrac{c\alpha}{1-\alpha}$

④ $\dfrac{c\alpha^2}{1-\alpha}$

⑤ $\dfrac{c\alpha}{1+\alpha}$

⑥ $\dfrac{c\alpha^2}{1+\alpha}$

Q11   From the following statements ①-④ on alkali metals from the second period to the fourth period choose the correct one. $\boxed{11}$

①   The densities of all alkali metals are larger than 1.0 g/cm^3.

②   Among alkali metals there is one that exhibits green color in the flame test.

③   Alkali metals should be kept in petroleum.

④   The electron affinities of alkali metals are large.

Q12   From the following procedures ①-⑤ choose the one which generates the smallest amount (mol) of gas at normal temperature and pressure when 1 mol of the underlined compound is completely reacted. $\boxed{12}$

①   Manganese(IV) oxide (MnO_2) is added to aqueous hydrogen peroxide (H_2O_2).

②   Dilute sulfuric acid (dil. H_2SO_4) is added to iron sulfide (FeS).

③   Dilute hydrochloric acid (dil. HCl) is added to calcium carbonate ($CaCO_3$).

④   Dilute hydrochloric acid is added to sodium hydrogencarbonate ($NaHCO_3$).

⑤   A mixture of ammonium chloride (NH_4Cl) and calcium hydroxide ($Ca(OH)_2$) is heated.

Q13 From ①-⑨ in the table below, choose the correct combination of the oxidation numbers of nitrogen atoms (N) in the following compounds **A**-**C**. $\boxed{13}$

    A : The nitrogen compound obtained by the Haber-Bosch process

    B : The colorless nitrogen compound generated by the reaction between nitrogen (N_2) and oxygen (O_2) at high temperature

    C : The nitrogen compound produced by the Ostwald process

	A	**B**	**C**
①	-3	+2	+3
②	-3	+2	+5
③	-3	+4	+5
④	-1	+2	+3
⑤	-1	+4	+3
⑥	-1	+4	+5
⑦	+3	+2	+3
⑧	+3	+2	+5
⑨	+3	+4	+5

Q14   From the following statements ①-⑤ choose the one that describes a change that takes place for both aqueous Fe^{2+} and aqueous Fe^{3+}.   **14**

① Precipitates are formed when aqueous sodium hydroxide (NaOH) is added.

② The color of the aqueous solution turns into blood red when aqueous potassium thiocyanate (KSCN) is added.

③ The color of the aqueous solution turns into reddish purple when aqueous salicylic acid is added.

④ Dark blue precipitates are formed when $[Fe(CN)_6]^{3-}$ is added.

⑤ Dark blue precipitates are formed when $[Fe(CN)_6]^{4-}$ is added.

Q15 An aqueous solution containing two kinds of metal ions is given in column **A** of the following table. Among the procedures in column **B**, two of them can separate one of the ions in column **A** as a precipitate. From ①-⑥ below choose the correct combination. 　**15**

	A	B
a	Al^{3+}, Fe^{3+}	Aqueous ammonia (NH_3) is added.
b	Ag^+, Cu^{2+}	Dilute hydrochloric acid (dil. HCl) is added.
c	Ba^{2+}, Pb^{2+}	Aqueous sodium sulfate (Na_2SO_4) is added.
d	Ca^{2+}, K^+	Aqueous sodium hydroxide (NaOH) is added.
e	Cu^{2+}, Zn^{2+}	The aqueous solution is acidified and then hydrogen sulfide (H_2S) is passed through.

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

Q16 From the following combinations of organic compounds having a hydroxy group ①-⑥ choose the most appropriate one in which all are compatible with statements (**a**)-(**c**), respectively. $\boxed{16}$

(**a**) It turns purple when aqueous iron(III) chloride ($FeCl_3$) is added.

(**b**) It undergoes the iodoform reaction.

(**c**) It yields a carboxylic acid by oxidation.

	a	b	c
①	C_6H_5OH	$(CH_3)_3COH$	$(CH_3)_2CHOH$
②	$C_6H_5CH_2OH$	$(CH_3)_3COH$	$(CH_3)_2CHCH_2OH$
③	C_6H_5OH	$(CH_3)_2CHOH$	$(CH_3)_2CHCH_2OH$
④	$C_6H_5CH_2OH$	$(CH_3)_2CHOH$	$(CH_3)_2CHCH_2OH$
⑤	C_6H_5OH	$(CH_3)_2CHOH$	$(CH_3)_2CHOH$
⑥	$C_6H_5CH_2OH$	$(CH_3)_3COH$	$(CH_3)_2CHOH$

Q17   From the following statements ①-⑤ on toluene ($C_6H_5CH_3$) choose the one that is **not** correct.   **17**

① It is a liquid at normal temperature and pressure.

② It is hardly soluble in water.

③ All carbon atoms lie in the same plane.

④ Three structural isomers are obtained when one hydrogen atom is replaced with a chlorine atom.

⑤ When oxidized with aqueous potassium permanganate ($KMnO_4$) and then acidified, benzoic acid is obtained.

Q18 Among the following (**a**)-(**f**), two combinations include stereoisomers of each other. From ①-⑥ below choose the correct combination. | 18 |

(**a**)

(**b**)

(**c**)

(**d**)

(**e**)

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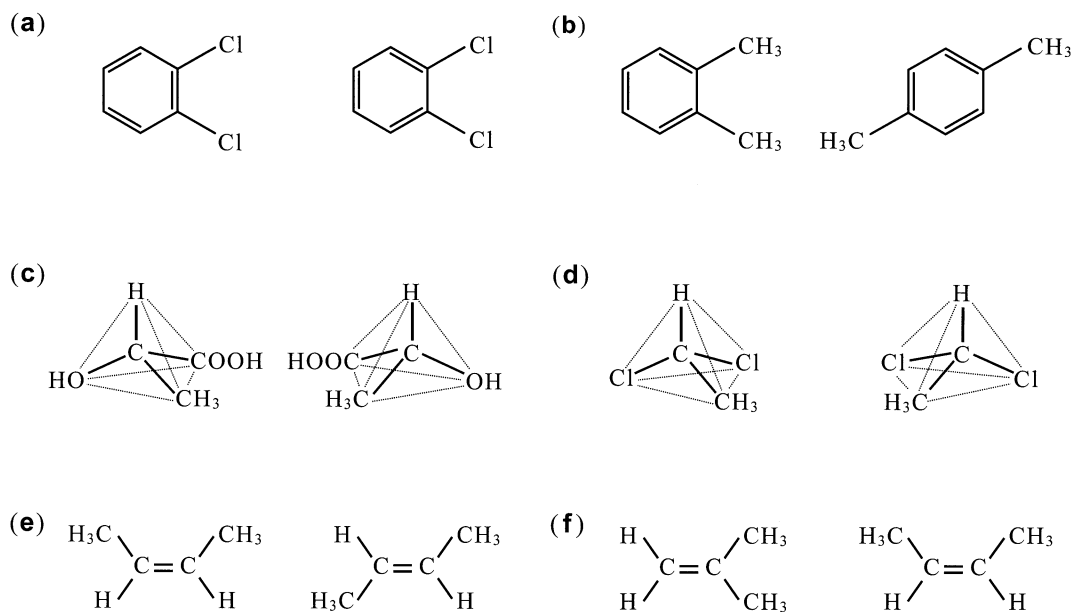
① **a, c**　② **a, d**　③ **b, e**　④ **c, e**　⑤ **d, e**　⑥ **d, f**

Q19 4.50 mg of a monocarboxylic acid composed of carbon (C), hydrogen (H), and oxygen (O) was completely combusted to yield 6.60 mg of carbon dioxide (CO_2) and 2.70 mg of water (H_2O). From ①-⑤ below choose the correct molecular formula for this compound. $\boxed{19}$

   ① CH_2O ② CH_2O_2 ③ $C_2H_4O_2$ ④ $C_3H_6O_2$ ⑤ $C_4H_8O_2$

Q20 From the following statements ①-④ on saccharides choose the one that is **not** correct. $\boxed{20}$

   ①   The molecular formulas of glucose, fructose, and galactose are all $C_6H_{12}O_6$.

   ②   Glucose, fructose, and galactose all have reducing ability.

   ③   The molecular formulas of maltose, sucrose, and lactose are all $C_{12}H_{22}O_{11}$.

   ④   Maltose, sucrose, and lactose all have reducing ability.

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

Q1 From ①－④ below choose the statement that correctly describes photosynthesis in plant chloroplasts.

1

① The photochemical reactions take place in the stroma of chloroplast, and the Calvin-Benson cycle reactions take place on the thylakoids.

② The photochemical reactions require light energy but do not need carbon dioxide.

③ There are two photosystems, Photosystem I and Photosystem II; electrons are passed down from Photosystem I to Photosystem II.

④ In Photosystem I, water molecules are broken down using light energy, resulting in the release of oxygen.

Q2 The following statement describes mitochondria. From ①–⑥ below choose the combination of terms that best fills blanks [a] – [c] in the statement.

[**2**]

Mitochondria are involved in respiration and are enclosed in two membranes, the inner membrane and the outer membrane. The inner membrane has inward protrusions called [a]. The inner membrane also contains proteins involved in the electron transport system. The region enclosed by the inner membrane is called the [b].

Like [c], mitochondria possess their own DNA.

	a	b	c
①	matrix	cristae	Golgi bodies
②	matrix	cristae	chloroplasts
③	matrix	cristae	vacuoles
④	cristae	matrix	Golgi bodies
⑤	cristae	matrix	chloroplasts
⑥	cristae	matrix	vacuoles

Q3 From ①–④ below choose the combination of terms that best fills blanks ☐a☐ and ☐b☐ in the following paragraphs. **3**

The rate of an enzyme reaction is significantly affected by the ☐a☐ concentration when the enzyme concentration remains constant. Generally, the reaction rate increases almost proportionally with the ☐a☐ concentration, but eventually it becomes constant.

However, if the reaction solution contains a substance that is structurally very similar to the substrate, the substance will bind to the active site of the enzyme in the same way as the substrate. As a result, the rate of enzyme reaction will slow down. This phenomenon is called ☐b☐.

	a	b
①	substrate	feedback inhibition
②	substrate	competitive inhibition
③	product	feedback inhibition
④	product	competitive inhibition

Q4 In eukaryotic cells, where do transcription, splicing, and translation take place in the process of synthesizing protein from nuclear DNA? From ①–⑥ below choose the correct combination. **4**

	Transcription	Splicing	Translation
①	nucleus	nucleus	nucleus
②	nucleus	nucleus	cytoplasm
③	nucleus	cytoplasm	cytoplasm
④	nucleus	cytoplasm	nucleus
⑤	cytoplasm	nucleus	cytoplasm
⑥	cytoplasm	cytoplasm	cytoplasm

Q5 Polymerase chain reaction (PCR) is a technique for amplifying a target DNA segment exponentially by repeating a cycle of reactions. The following figure shows an example of the temperature settings for one cycle of PCR. What takes place in reactions A – C in the figure, respectively? From ① – ⑥ below choose the correct combination.
$\boxed{5}$
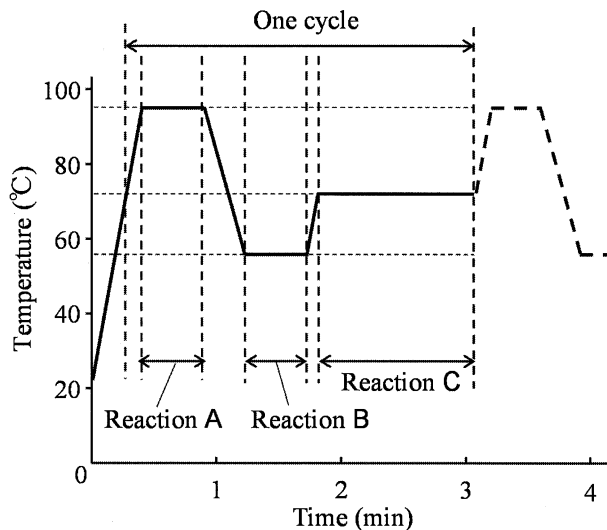
	Reaction A	Reaction B	Reaction C
①	Replication occurs	Primers bind to the DNA	The DNA separates into single strands
②	Replication occurs	The DNA separates into single strands	Primers bind to the DNA
③	The DNA separates into single strands	Primers bind to the DNA	Replication occurs
④	The DNA separates into single strands	Replication occurs	Primers bind to the DNA
⑤	Primers bind to the DNA	The DNA separates into single strands	Replication occurs
⑥	Primers bind to the DNA	Replication occurs	The DNA separates into single strands

Q6 The following figure shows the process of eye formation in the newt, with a focus on differentiation and induction. The thin arrows indicate differentiation and the thick arrows indicate induction. A – C in the figure function as organizers. From ①－④ below choose the combination of terms that correctly identifies A – C. **6**
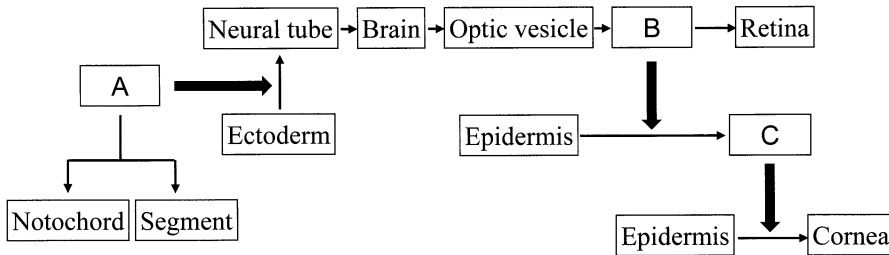
	A	B	C
①	dorsal lip	optic cup	crystalline lens
②	dorsal lip	crystalline lens	optic cup
③	endoderm	optic cup	crystalline lens
④	endoderm	crystalline lens	optic cup

Q7 The following figure shows, for a certain angiosperm, the amount of DNA per nucleus (as a relative value) as an embryo sac mother cell undergoes meiosis to form an embryo sac. Of A – E in the figure, which represents the first meiotic division (meiosis Ⅰ)? From ①－⑤ below choose the correct answer. **7**
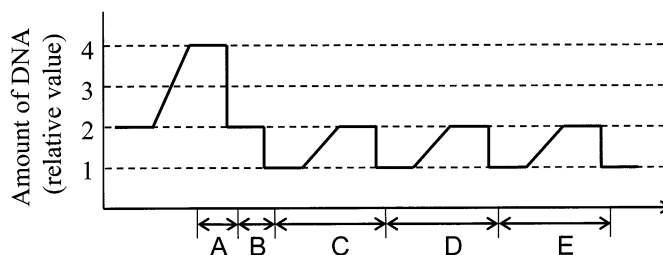
① A   ② B   ③ C   ④ D   ⑤ E

Q8 Answer questions (1) and (2) below concerning the mechanism of humoral immunity.

(1) From ①－⑧ below choose the combination of terms that correctly fills blanks $\boxed{\text{a}}$ － $\boxed{\text{c}}$ in the paragraph.

$\boxed{\textbf{8}}$

Antigens that have invaded the body are engulfed and broken down by $\boxed{\text{a}}$ through the process of phagocytosis. The $\boxed{\text{a}}$ then present the antigens' information on their surface. Upon receiving that antigen information, $\boxed{\text{b}}$ become activated and proliferate. The antigen information is received from the activated $\boxed{\text{b}}$ by $\boxed{\text{c}}$, which become activated and proliferate. The activated $\boxed{\text{c}}$ differentiate into memory cells and antibody-forming cells (plasma cells) that release antibodies capable of binding to the antigen.

	a	b	c
①	dendritic cells	helper T cells	macrophages
②	dendritic cells	helper T cells	B cells
③	dendritic cells	killer T cells	macrophages
④	dendritic cells	killer T cells	B cells
⑤	neutrophils	helper T cells	macrophages
⑥	neutrophils	helper T cells	B cells
⑦	neutrophils	killer T cells	macrophages
⑧	neutrophils	killer T cells	B cells

(2) From ① – ④ below choose the statement that does **not** correctly describe the antigen-antibody reaction. 　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　 **9**

① The effect produced by an antibody binding to an antigen includes neutralizing the antigen and decreasing the infectivity of the antigen.

② Antigens bound with an antibody are phagocytosed and broken down by macrophages.

③ Antigens are directly broken down by antibodies.

④ When antigens of the same type invade the body in two separate occasions, the antibodies are produced more in quantity and more quickly at the second time than at the first time.

Q9 Figures A – C below schematically represent a portion of the structure of a healthy human kidney. Protein and glucose each pass along mainly one of the routes (→) shown in Figures A – C. From ①– ⑨ below choose the correct combination of the answers. **10**
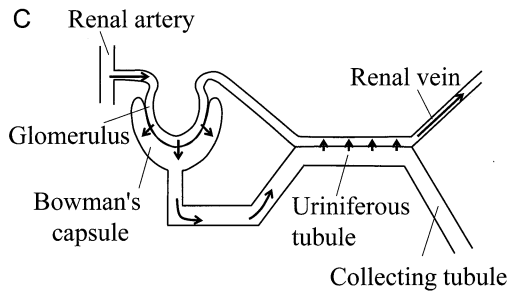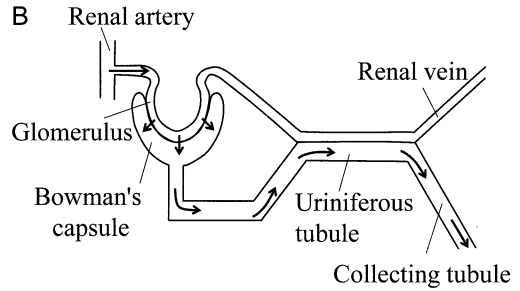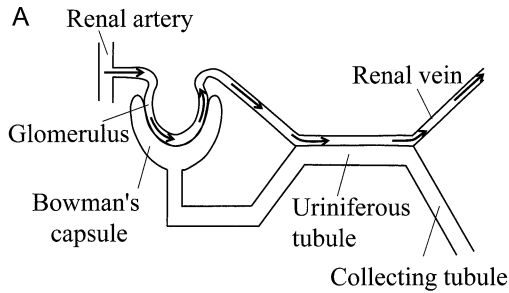

	Protein	Glucose
①	A	A
②	A	B
③	A	C
④	B	A
⑤	B	B
⑥	B	C
⑦	C	A
⑧	C	B
⑨	C	C

Q10 The following graph is an oxygen dissociation curve, which shows the relationship between oxyhemoglobin percentage and oxygen concentration in erythrocytes. A represents the oxygen dissociation curve taken at the CO_2 concentration found in the lungs, and B represents the oxygen dissociation curve taken at the CO_2 concentration found in tissue. From ①－⑥ below choose the answer that correctly indicates the percentage of oxyhemoglobin that dissociates from oxygen in tissue, assuming that the O_2 concentration is 100 in the lungs and 30 in tissue. 　**11**
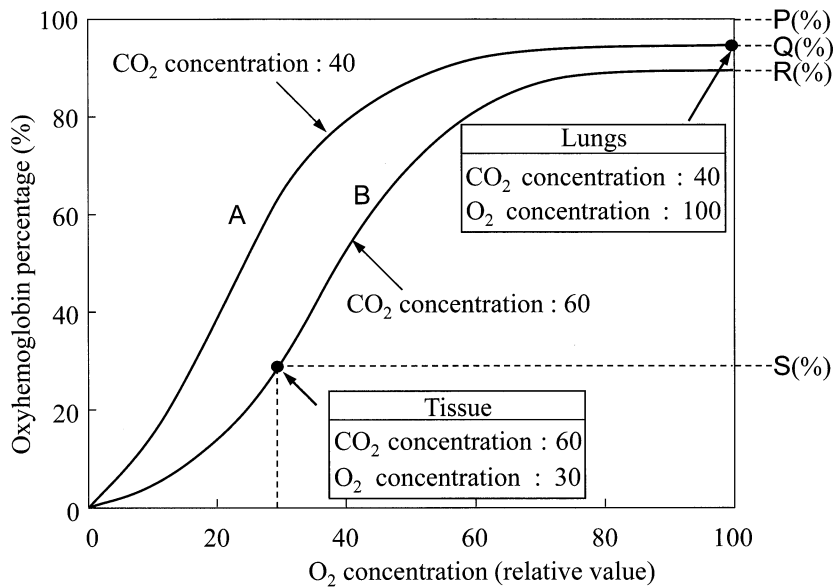
① P－Q (%)　　　② P－R (%)　　　③ P－S (%)　　　④ Q－R (%)

⑤ Q－S (%)　　　⑥ R－S (%)

'－' indicates the process of subtraction here.

Q11 The following paragraph describes the process of auditory sensation in humans. From ①－⑧ below choose the combination of terms that best fills blanks ⟨ a ⟩ － ⟨ c ⟩ in the paragraph. **12**

Sound waves conducted through the air pass through the external auditory canal to the tympanic membrane, causing the membrane to vibrate. The vibrations are transmitted through the ⟨ a ⟩, then to the ⟨ b ⟩ in the cochlear duct, and eventually cause the basilar membrane to vibrate. The auditory cells on the basilar membrane receive the stimulus caused by the vibration of the membrane and become excited. This excitation is conveyed by the auditory nerve to the ⟨ c ⟩, resulting in the sensation of sound.

	a	b	c
①	auditory ossicle	air	midbrain
②	auditory ossicle	air	cerebrum
③	auditory ossicle	lymph	midbrain
④	auditory ossicle	lymph	cerebrum
⑤	Eustachian tube	air	midbrain
⑥	Eustachian tube	air	cerebrum
⑦	Eustachian tube	lymph	midbrain
⑧	Eustachian tube	lymph	cerebrum

Q12 The following table lists, for a population of a certain organism, the percentages of the genotypes for the alleles A and a. From ①－⑥ below choose the answer indicating the allele frequency of a. $\boxed{13}$

| Genotype	Percentage (%)
AA	60
Aa	20
aa	20

① 0.2　　② 0.25　　③ 0.275　　④ 0.3　　⑤ 0.6　　⑥ 0.7

Q13 Answer questions (1) and (2) below concerning phototropism of oat coleoptiles.

(1) From ①－⑥ below choose the combination that correctly indicates the mechanism of phototropic response, and the plant hormone largely involved in phototropism. **14**

	Phototropic mechanism	Plant hormone
①	curvature due to difference in growth rates of illuminated side and shaded side	gibberellin
②	curvature due to difference in growth rates of illuminated side and shaded side	ethylene
③	curvature due to difference in growth rates of illuminated side and shaded side	auxin
④	curvature due to difference in growth rate not related to illumination/shading	gibberellin
⑤	curvature due to difference in growth rate not related to illumination/shading	ethylene
⑥	curvature due to difference in growth rate not related to illumination/shading	auxin

(2) An experiment using oat coleoptiles was performed as shown in Figures A − D below. From ① − ⑥ below choose the combination indicating all cases where coleoptile curvature toward light was clearly observed. 15
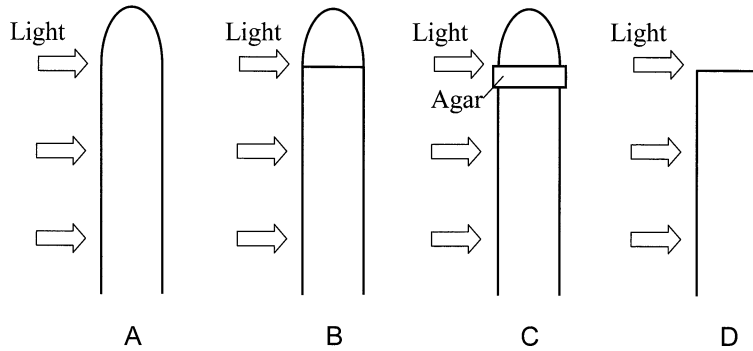
A   The coleoptile was used unprocessed.

B   The tip was severed and replaced in its original position.

C   The tip was severed and a piece of agar was inserted.

D   The tip was removed.

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

⑥ A , B , D

Q14 From ①–④ below choose the combination correctly indicating the two effects exhibited by the plant hormone abscisic acid among the following statements a – d. `16`

    a   It maintains seed dormancy.

    b   It breaks seed dormancy.

    c   It stimulates the closing of stomata.

    d   It stimulates the opening of stomata.

    ① a, c   ② a, d   ③ b, c   ④ b, d

Q15 Items a – d below are events pertaining to the rise of oxygen on the early earth. From ①–⑧ below choose the answer that best arranges these events in chronological order. ☐17

    a   Decrease in ultraviolet radiation

    b   Emergence of cyanobacteria

    c   Formation of the ozone layer

    d   Colonization of land by living organisms

① a → b → c → d

② a → b → d → c

③ b → a → c → d

④ b → c → a → d

⑤ c → b → a → d

⑥ c → b → d → a

⑦ d → c → a → b

⑧ d → a → c → b

Q16 Soybeans were planted in various population densities. Figure 1 below shows the average weight of individual plants, and Figure 2 shows the population weight per square meter. The numbers inside the graphs are the number of days elapsed after sowing.
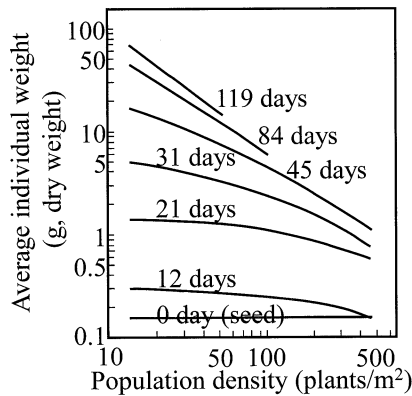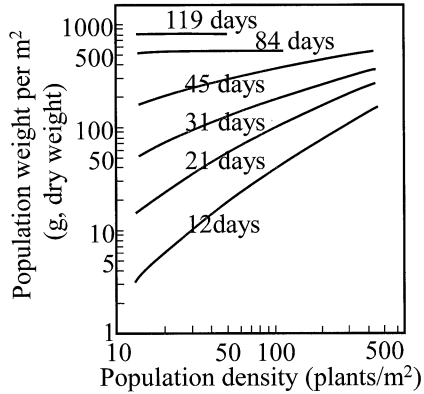

Figure 1

Figure 2

From ①－⑧ on the next page choose the combination of terms that correctly fills blanks a －
c in the following paragraph describing the results of this experiment.

18

In the early stage of growth, differences in the average individual weight due to varying population density were a , and the higher the density was, the b the population weight per square meter was. However, as time passed, the higher the population density was, the lower the average individual weight was, and differences in population weight per square meter due to varying population density became c .

	a	b	c
①	large	more	large
②	large	more	small
③	large	less	large
④	large	less	small
⑤	almost non-existent	more	large
⑥	almost non-existent	more	small
⑦	almost non-existent	less	large
⑧	almost non-existent	less	small

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.