2019 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 – 37
Biology	39 – 56

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

$\boxed{\text{I}}$ 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, two thin uniform rods of negligible mass are joined together at a right angle. Their lengths are ℓ_1 and ℓ_2. A small ball of mass m_1 is attached to the end of the rod of length ℓ_1, and another of mass m_2 is attached to the end of the rod of length ℓ_2. The rods are suspended using a string attached to their joint and come to rest. The angle formed between the rod of length ℓ_1 and the vertical in the downward direction is θ.
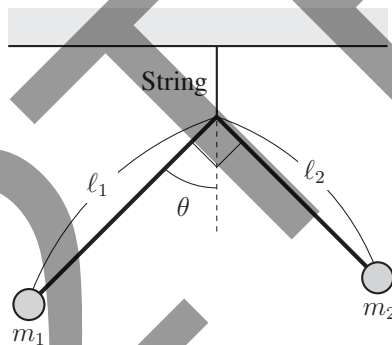
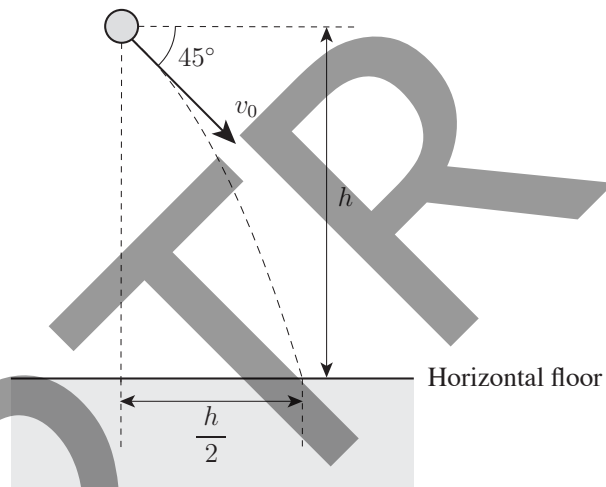Q1 What is $\tan\theta$? From ①-④ below choose the correct answer. $\boxed{1}$

① $\dfrac{m_1\ell_1}{m_2\ell_2}$ ② $\dfrac{m_2\ell_2}{m_1\ell_1}$ ③ $\dfrac{m_2\ell_1}{m_1\ell_2}$ ④ $\dfrac{m_1\ell_2}{m_2\ell_1}$

B As shown in the figure below, a small ball is thrown with initial speed v_0 from height h above a horizontal floor, in a downward direction forming an angle of $45°$ with the horizontal. The ball lands on the floor at a position that is horizontal distance $\dfrac{h}{2}$ from the position the ball was thrown.

Horizontal floor

Q2 What is v_0? From ①-⑤ below choose the correct answer. $\boxed{2}$

① $\dfrac{\sqrt{gh}}{2}$ ② $\dfrac{\sqrt{2gh}}{2}$ ③ $\sqrt{gh}$ ④ $\sqrt{2gh}$ ⑤ $2\sqrt{gh}$

C As shown in Figure 1 below, a small object is gently placed on a slope that has friction and forms angle θ with the horizontal, and it begins sliding down with uniform acceleration. Let us denote as a the magnitude of the object's acceleration in this case. Next, as shown in Figure 2, an initial speed is applied to the same object in the upward direction, causing it to move up the same slope with uniform acceleration. Let us denote as a' the magnitude of the object's acceleration in this case.

Direction of motion

Direction of motion

Figure 1   Figure 2
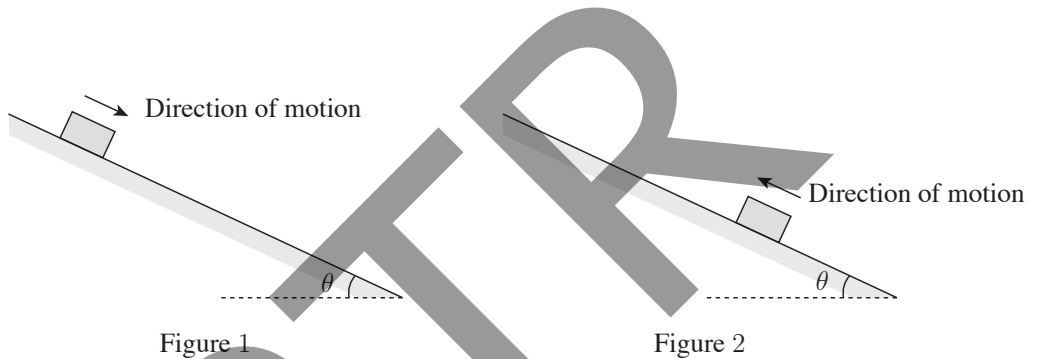
Q3   What is a'? From ①-⑥ below choose the correct answer.   **3**

① $2g\sin\theta + a$ ② $2g\cos\theta + a$ ③ $2g\tan\theta + a$

④ $2g\sin\theta - a$ ⑤ $2g\cos\theta - a$ ⑥ $2g\tan\theta - a$

D As shown in the figure below, one end of a lightweight inelastic string (length: ℓ) is fixed in place at point O, and small object P (mass: M) is attached to the other end. While keeping the string taut, P is raised to position A, which is at the same height as O, and is gently released. P inelastically collides with small object Q (mass: m), which is at rest at position B directly below O, on a horizontal floor with friction. After the collision, P rises to position C, whose height above the floor is $\dfrac{\ell}{4}$, and Q comes to rest at position D after sliding distance d on the floor. Let us denote as μ' the coefficient of kinetic friction between Q and the floor.
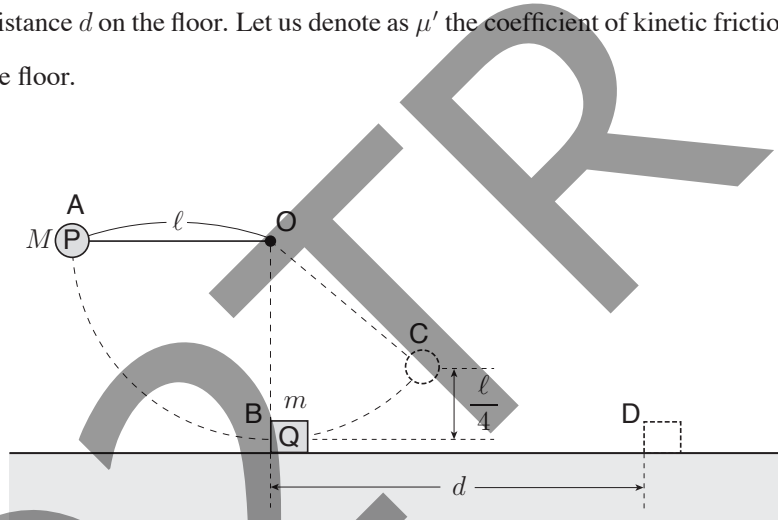
Q4 What is d? From ①-④ below choose the correct answer. **4**

① $\dfrac{M^2\ell}{4\mu' m^2}$ ② $\dfrac{M^2\ell}{2\mu' m^2}$ ③ $\dfrac{3M^2\ell}{2\mu' m^2}$ ④ $\dfrac{9M^2\ell}{4\mu' m^2}$

E A vertical spring pendulum is formed by suspending a small ball of a certain mass from a lightweight helical spring. When the ball is at rest at the position of equilibrium, the spring is stretched distance d from its natural length. The period of simple harmonic oscillation of the vertical spring pendulum is T. Next, the same ball is attached to one end of a lightweight inelastic string (length: ℓ), and the other end is fixed in place. When this is made to undergo oscillation with small amplitude in a vertical plane as a simple pendulum, it has the same period, T.

Q5 What is $\dfrac{\ell}{d}$? From ①-⑦ below choose the best answer.　　　　　 **5**

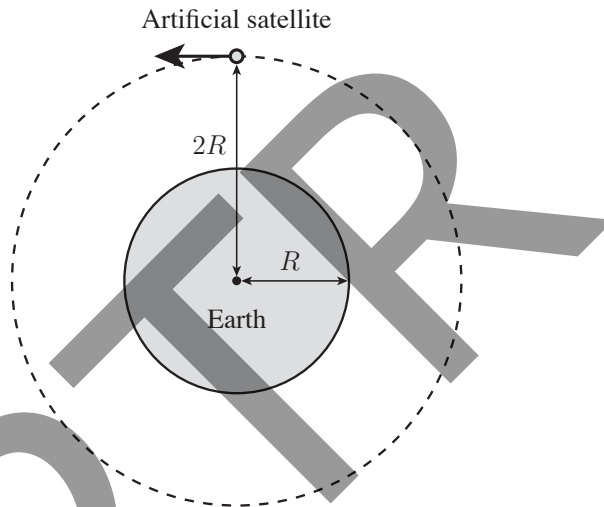① $\dfrac{1}{4}$ 　　　　② $\dfrac{1}{2}$ 　　　　③ $\dfrac{\sqrt{2}}{2}$ 　　　　④ 1

⑤ $\sqrt{2}$ 　　　　⑥ 2 　　　　⑦ 4

F Let us denote as R the earth's radius, and as g the magnitude of acceleration due to gravity at the earth's surface. As shown in the figure below, an artificial satellite is moving in uniform circular motion concentric with the earth, with a radius of $2R$.

Artificial satellite

$2R$

R

Earth

Q6 What is the period of the satellite's uniform circular motion? From ①-⑥ below choose the correct answer.

6

① $\pi\sqrt{\dfrac{R}{g}}$　　　　② $\pi\sqrt{\dfrac{2R}{g}}$　　　　③ $2\pi\sqrt{\dfrac{R}{g}}$

④ $2\pi\sqrt{\dfrac{2R}{g}}$　　　　⑤ $4\pi\sqrt{\dfrac{R}{g}}$　　　　⑥ $4\pi\sqrt{\dfrac{2R}{g}}$

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

A A thermally insulated container holds a liquid at temperature t_1. A metal ball at temperature t_2 $(< t_1)$ is placed in the liquid. After sufficient time elapses, the liquid and the ball reach the same temperature. Let us denote as C_1 the liquid's heat capacity, and as C_2 the ball's heat capacity. Assume that the transfer of heat occurs only between the liquid and the ball.

Q1 What is the quantity of heat transferred from the liquid to the ball? From ①-⑥ below choose the correct answer. **7**

① $(C_1 + C_2)(t_1 - t_2)$ ② $\dfrac{(C_1^2 + C_2^2)(t_1 - t_2)}{C_1 + C_2}$ ③ $\dfrac{C_1 C_2 (t_1 - t_2)}{C_1 + C_2}$

④ $(C_1 - C_2)(t_1 - t_2)$ ⑤ $\dfrac{(C_1^2 + C_2^2)(t_1 - t_2)}{C_1 - C_2}$ ⑥ $\dfrac{C_1 C_2 (t_1 - t_2)}{C_1 - C_2}$

B As shown in the figure below, ideal gases of equal amount of substance are enclosed inside cylinders A and B (cross-sectional areas: S_A and S_B, respectively) using smoothly moving pistons. A and B are placed facing each other, and are fixed in place so that their central axis is horizontal. The two pistons are connected with a rod. The piston in A comes to rest at distance L_A from A's base, and the piston in B comes to rest at distance L_B from B's base. The absolute temperature and pressure of the ideal gas inside A are T_A and p_A, respectively. The absolute temperature and pressure of the ideal gas inside B are T_B and p_B, respectively. Ignore the effect of atmospheric pressure.

Cylinder B

Cylinder A

L_A

L_B
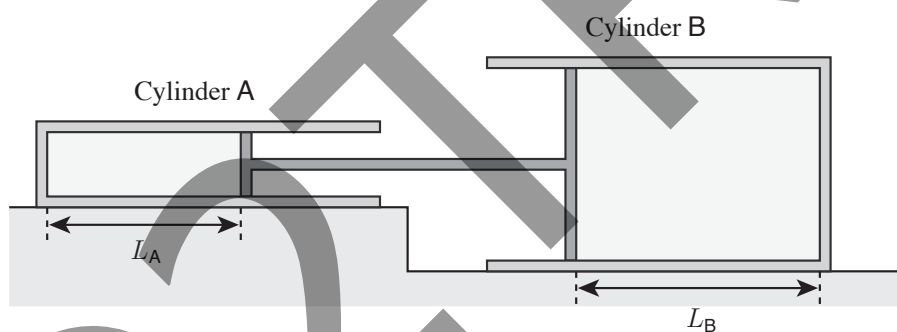
Q2 What is $\dfrac{T_B}{T_A}$? From ①-⑥ below choose the correct answer. 8

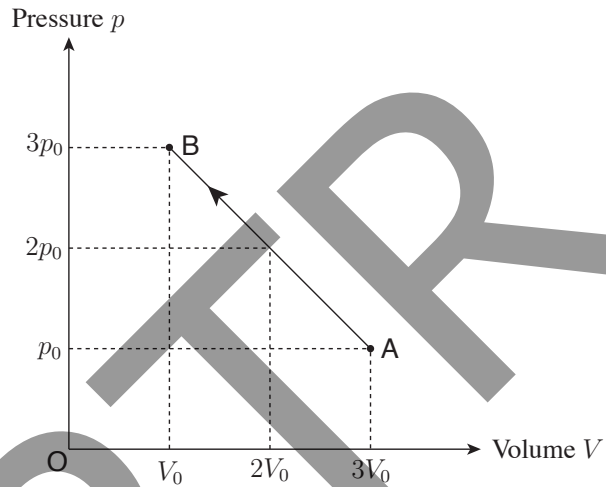① $\dfrac{L_B}{L_A}$

② $\dfrac{S_B L_B}{S_A L_A}$

③ $\dfrac{p_B L_B}{p_A L_A}$

④ $\dfrac{L_A}{L_B}$

⑤ $\dfrac{S_A L_A}{S_B L_B}$

⑥ $\dfrac{p_A L_A}{p_B L_B}$

C A fixed quantity of a monatomic ideal gas is enclosed inside a cylinder. As shown in the p-V diagram below, the state of the gas is changed in the path state A → state B.

Pressure p

$3p_0$ B

$2p_0$

p_0 A

O V_0 $2V_0$ $3V_0$ Volume V

Q3 What is the net quantity of heat absorbed by the gas in the entire process of state A → state B? From ①-⑥ below choose the correct answer. **9**
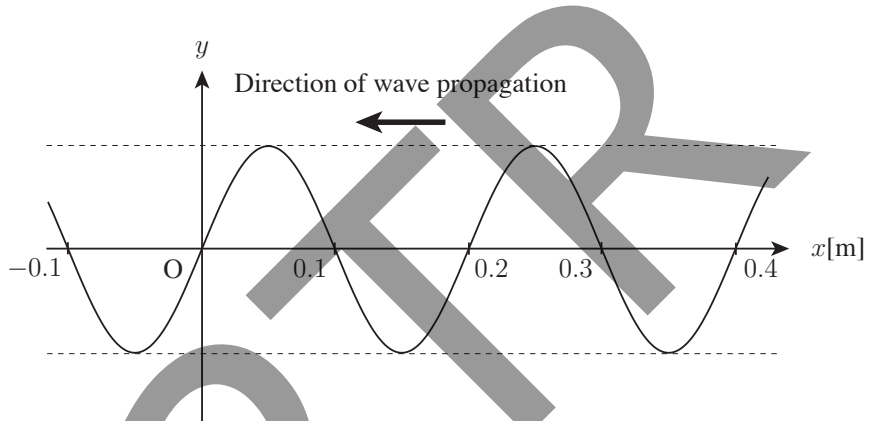
① $2p_0V_0$ ② $4p_0V_0$ ③ $6p_0V_0$

④ $-2p_0V_0$ ⑤ $-4p_0V_0$ ⑥ $-6p_0V_0$

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

A Consider a sinusoidal wave with a frequency of 0.50 Hz that is propagating in the negative direction of an x-axis. The figure below is a graph representing the relationship between the displacement of the medium, y, and position x at time $t = 0$ s.

Q1 From ①-④ below, choose the graph that best represents the relationship between y and x at time $t = 3.5$ s. **10**
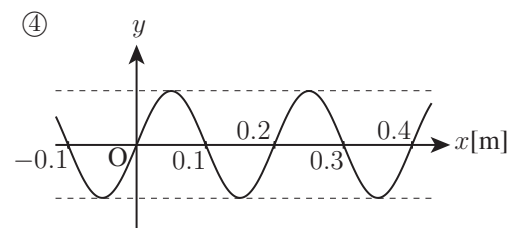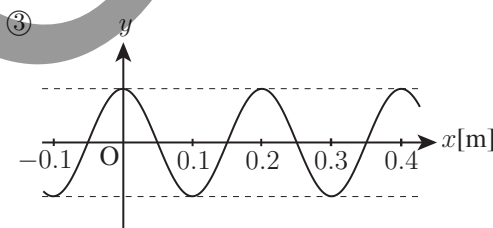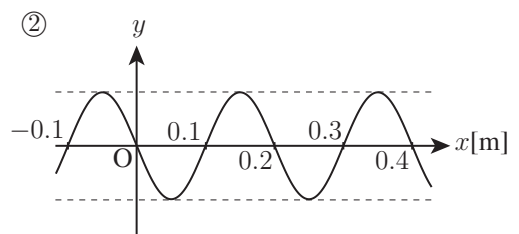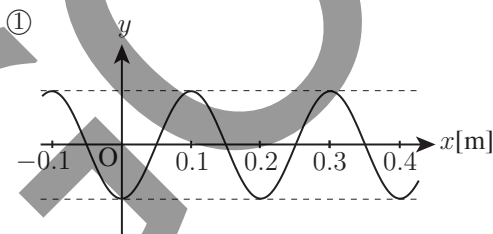
B As shown in the figure below, a speaker emitting sound of frequency f is placed near one end of an open tube of length ℓ. A standing wave with n antinodes (including both mouths of the tube) forms in the air column and resonance occurs. Here, let us denote as V the speed of sound. Assume that open end correction is negligible.
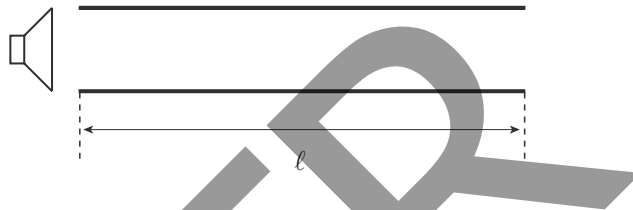
Q2 What is f? From ①-⑥ below choose the correct answer. $\boxed{11}$

① $\dfrac{(n-1)V}{4\ell}$ ② $\dfrac{nV}{4\ell}$ ③ $\dfrac{(n+1)V}{4\ell}$

④ $\dfrac{(n-1)V}{2\ell}$ ⑤ $\dfrac{nV}{2\ell}$ ⑥ $\dfrac{(n+1)V}{2\ell}$

C As shown in the figure below, glass plate 2 is tightly adhered to the upper surface of glass plate 1. The glass plates have different absolute refractive indices. Light is directed at the interior of glass plate 1 from point A on the left side of glass plate 1, and the light's angle of incidence, θ, is gradually decreased. When θ reaches $30°$, the light that has entered glass plate 1 is at the critical angle of incidence with respect to point B on the boundary surface. When θ falls below $30°$, the light is completely reflected at the boundary surface. The left side of glass plate 1 is perpendicular to the upper surface. Denoting the upper left vertex as O, OA is 5.0 cm, OB is 12 cm, and AB is 13 cm. Assume that the absolute refractive index of air is 1.0.
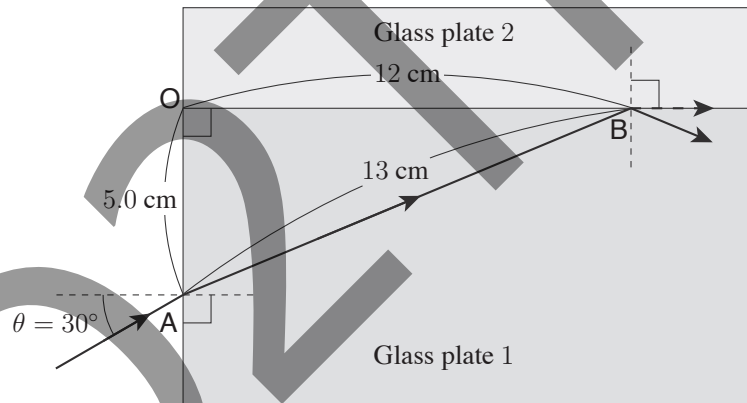
Q3 What is the absolute refractive index of glass plate 2? From ①-⑥ below choose the best answer. **12**
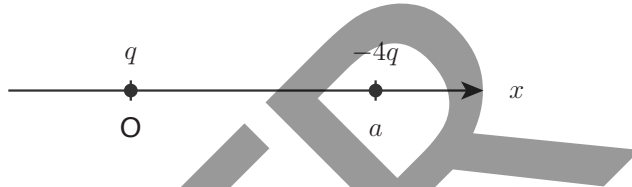
①　1.1 　　　　　　　② 　1.2 　　　　　　　③ 　1.3

④　1.4 　　　　　　　⑤ 　1.5 　　　　　　　⑥ 　1.6

$\boxed{\text{IV}}$ 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 $(q > 0)$ is fixed in place at the origin of an x-axis, and another with quantity of electricity $-4q$ is fixed in place on the x-axis at $x = a$ $(a > 0)$.

$$q \qquad\qquad -4q$$
$$\bullet \qquad\qquad \bullet \longrightarrow x$$
$$\text{O} \qquad\qquad a$$

Q1 Excluding infinite distance, are there any points on the x-axis where the magnitude of the electric field is zero? If there are, how many exist in what ranges? From ①-⑧ below choose the correct answer. $\boxed{\textbf{13}}$

① One each for $x < 0$, $0 < x < a$, and $a < x$

② One each for $0 < x < a$ and $a < x$ ③ One each for $x < 0$ and $0 < x < a$

④ One each for $x < 0$ and $a < x$ ⑤ One for $a < x$

⑥ One for $0 < x < a$ ⑦ One for $x < 0$

⑧ There are no such points

B As shown in the figure below, a spherical conductor with a positive electric charge of q is concentrically placed inside the cavity of an uncharged hollow spherical conductor (spherical conducting shell). Due to electrostatic induction, a charge of $-q$ develops on the inner surface of the spherical conducting shell, and a charge of q develops on the shell's outer surface. The figure below shows a cross-section that includes the center.
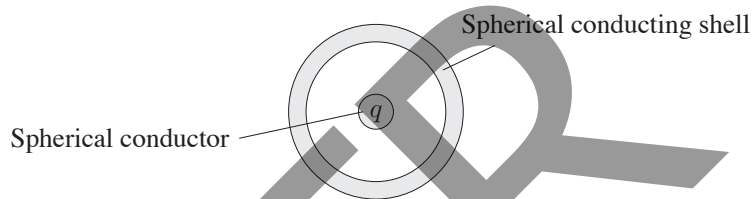
Q2 From ①-⑥ below choose the figure that best represents the electric lines of force within the cross-section including the center. **14**
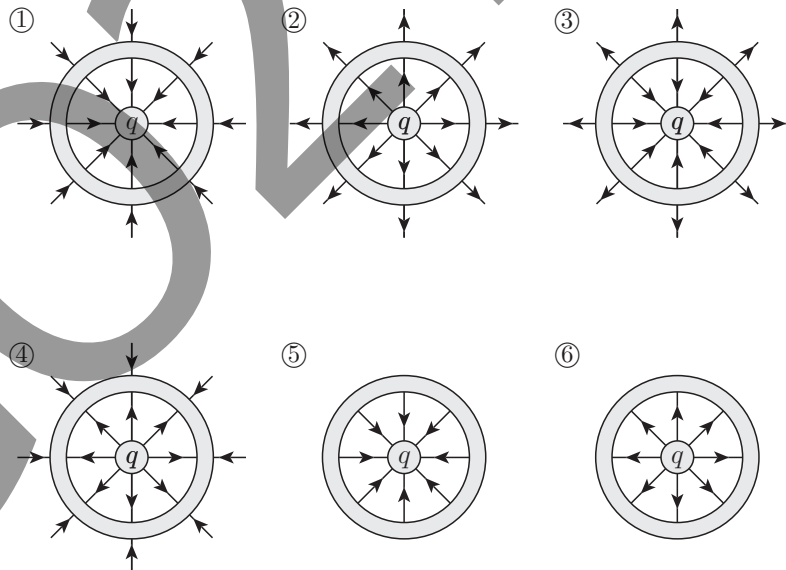
C　A battery (electromotive force: 9.0 V), two resistors (resistance: 0.50 kΩ and 3.0 kΩ), and a resistor of unknown resistance, R, are connected as shown in the figure below. The magnitude of the electric current flowing through point P is 6.0 mA. The internal resistance of the battery is negligible.
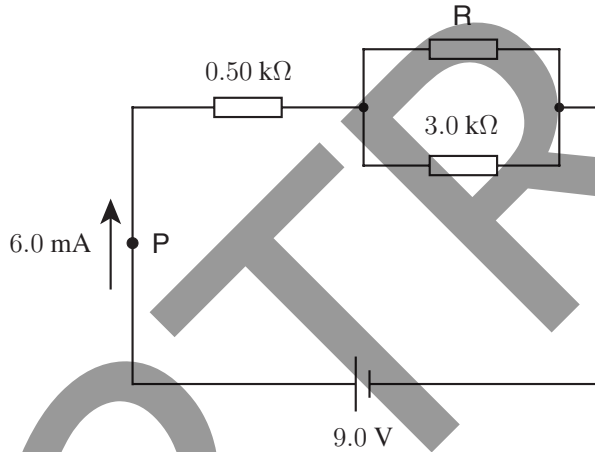
Q3　What is the quantity of electric power (in mW) consumed by R? From ①-⑥ below choose the best answer. 　　　　　　　　　　　　　　　　　　　　 **15** mW

① 6.0 　　　　　　　　② 12 　　　　　　　　③ 18

④ 24 　　　　　　　　⑤ 30 　　　　　　　　⑥ 36

D A battery (electromotive force: 1.0 V), switch S, resistor R (resistance: 1.0 kΩ), and capacitors C_1 and C_2 (each with capacitance of 1.0 μF) are connected as shown in the figure below. Initially, S is open and C_1 and C_2 are not charged. Next, S is closed and C_1 and C_2 become charged. The internal resistance of the battery is negligible.
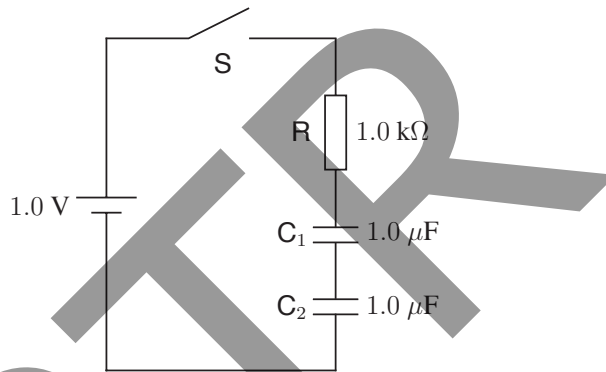
Q4 What is the quantity of Joule heat (in μJ) evolved at R from when S is closed until C_1 and C_2 become fully charged? From ①-④ below choose the best answer. $\boxed{16}$ μJ

① 0.25   ② 0.50   ③ 1.0   ④ 2.0

E As shown in the figure below, three sufficiently long straight conducting wires are parallel to one another and are perpendicular to this page. They pass through vertices A, B, and D of square ABCD (side length: a) within the plane of this page. An electric current of magnitude I flows through each wire. The current in the wire passing through A flows from the front of this page to the back, and the currents in the wires passing through B and D flow from the back of this page to the front.
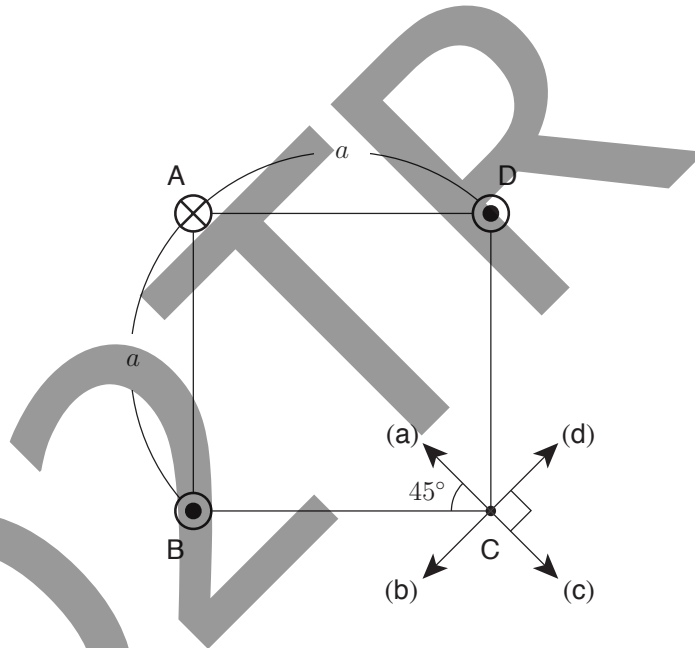
Q5 What is the magnitude (denoted as H) of the magnetic field produced at C by the currents flowing through the three wires? Also, which arrow among (a)-(d) in the figure indicates the direction of that magnetic field? From ①-⑧ below choose the correct combination.

17

	①	②	③	④	⑤	⑥	⑦	⑧
H	$\dfrac{3\sqrt{2}\,I}{4\pi a}$	$\dfrac{3\sqrt{2}\,I}{4\pi a}$	$\dfrac{3\sqrt{2}\,I}{4\pi a}$	$\dfrac{3\sqrt{2}\,I}{4\pi a}$	$\dfrac{\sqrt{2}\,I}{4\pi a}$	$\dfrac{\sqrt{2}\,I}{4\pi a}$	$\dfrac{\sqrt{2}\,I}{4\pi a}$	$\dfrac{\sqrt{2}\,I}{4\pi a}$
Direction	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)

F A charged particle (quantity of electricity: q; mass: m) is projected with speed v perpendicularly into a uniform magnetic field (magnitude of magnetic flux density: B), and begins undergoing uniform circular motion with radius r within the magnetic field. The same experiment is repeated with varying B while maintaining q, m, and v.

Q6 From ①-⑥ below choose the graph that best represents the relationship between r and B.

18

①

②

③

④

⑤

⑥
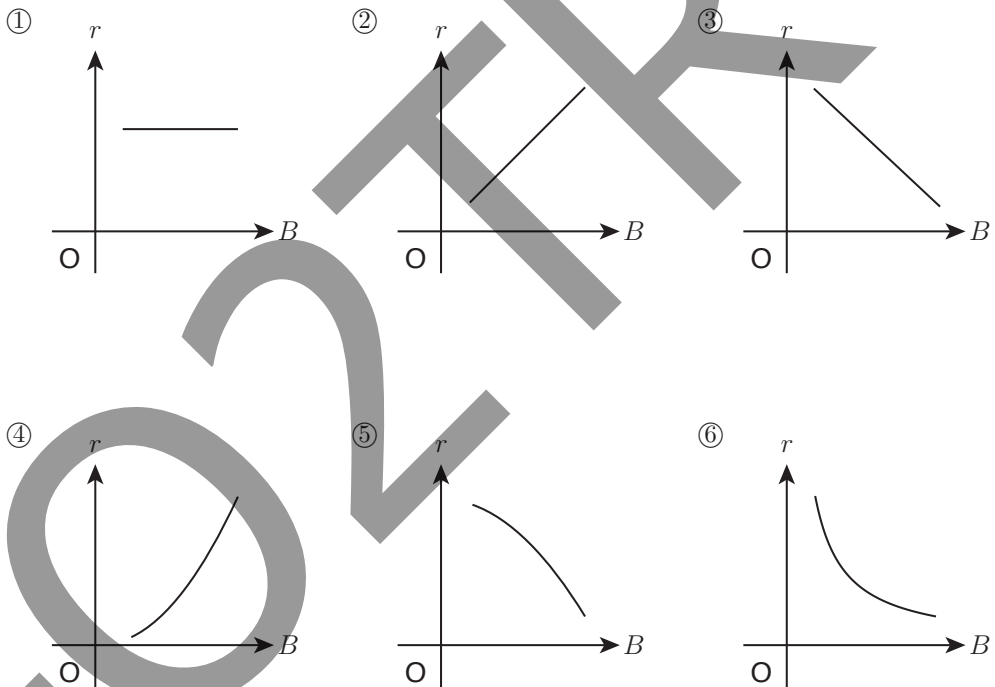
V Answer question **A** (Q1) below.

A The quark model states that constituent particles of matter, such as protons and neutrons, are themselves made up of elementary particles called quarks. For examples, a proton is composed of two up quarks (u) and one down quark (d), while a neutron is composed of one up quark (u) and two down quarks (d). Each type of quark carries a specific quantity of electric charge, and the charge of a proton or neutron is the sum of the charges carried by their constituent quarks. Let us denote as e the elementary charge.

Q1 What is the charge of a down quark (d)? From ①-⑥ below choose the correct answer.

$\boxed{19}$

① $-e$ ② $-\dfrac{2}{3}e$ ③ $-\dfrac{1}{3}e$

④ $\dfrac{1}{3}e$ ⑤ $\dfrac{2}{3}e$ ⑥ e

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

Do not take this question booklet out of the room.

Chemistry

Marking Your Choice of Subject on the Answer Sheet

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

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

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

＜Example＞

解答科目 Subject		
物　理 Physics	化　学 Chemistry	生　物 Biology
○	●	○

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　　N : 14　　O : 16　　Ca : 40

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   The following atoms or ions **a**-**d** have the electron configurations as indicated in the illustration below. Here the central circles represent the atomic nuclei, and the figures in them the number of protons. The outer concentric circles represent electron shells and the black circles electrons.

a	**b**	**c**	**d**
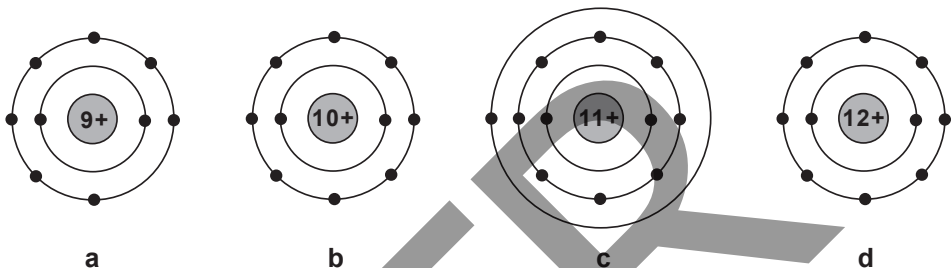
From the following statements ①-⑤ on **a**-**d**, choose the one that is <u>**not**</u> correct.

$\boxed{1}$

①   Figure **a** represents the atom whose atomic number is 9.

②   Atom **a** readily forms a monovalent anion.

③   The first ionization energy of atom **b** is smaller than that of atom **a**.

④   Atom **c** readily forms a monovalent cation.

⑤   Figure **d** represents a divalent cation.

Q2   From the following statements ①‐⑤, choose the correct one. $\boxed{2}$

①   The energy required to remove one outermost shell electron is called the first ionization energy. Among the atoms belonging to the same period, the ionization energy of noble gases is the smallest.

②   The larger the ionization energy of an atom, the easier it is to form a cation.

③   The energy required for an atom to form a monovalent anion by obtaining an electron is called the electron affinity.

④   The electron affinity of the halogens is small, and they easily form anions.

⑤   The energy required for removing one electron from a monovalent anion to form an atom is equal to its electron affinity.

Q3   From the following molecules ①‐⑤, choose the one that has both one or more double bonds and unshared electron pairs. $\boxed{3}$

① C_2H_4 ② CO_2 ③ N_2 ④ NH_3 ⑤   HCN

Q4   110 g of the nitrate of metal M, $M(NO_3)_2$, was obtained when nitric acid (HNO_3 aq) was added to 45 g of the oxide MO and completely reacted. From ①-⑥ below choose the closest value for the atomic weight of metal M.　　　　　　　　　 **4**

①　27　　　　②　40　　　　③　59　　　　④　68　　　　⑤　89　　　　⑥　110

Q5   Carbon dioxide (CO_2) is generated by the reaction between calcium carbonate ($CaCO_3$) and hydrochloric acid (HCl aq). This reaction is represented by the following equation. Here, a-e are coefficients.

$$a\ CaCO_3\ +\ b\ HCl\ \longrightarrow\ c\ CaCl_2\ +\ d\ H_2O\ +\ e\ CO_2$$

   Assume that the mass of carbon dioxide generated is X (g) when 2.0 g of calcium carbonate is added to 25 mL of 2.0 mol/L hydrochloric acid, and that the mass of carbon dioxide is Y (g) when 3.0 g of calcium carbonate is added to the same amount of hydrochloric acid. From ①-⑧ in the table below, choose the most appropriate combination of X and Y.　　　　　 **5**

	X	Y
①	0.44	0.44
②	0.44	0.66
③	0.88	0.88
④	0.88	1.1
⑤	0.88	1.3
⑥	1.1	1.1
⑦	1.1	1.3
⑧	1.1	1.7

Q6 1000 g of water at 15 ℃ is heated by complete combustion of 32 g of methane (CH_4). What is the temperature (℃) of the water after combustion if 10 % of the heat generated is used to raise the temperature of the water. From ①-⑤ below choose the closest value. Assume that the heat of combustion of methane is 890 kJ/mol, and the specific heat capacity (specific heat) of water is 4.2 J/(g·K). **6** ℃

① 21 ② 27 ③ 36 ④ 42 ⑤ 57

Q7 When 1.0 mol of N_2O_4 was enclosed in a container with a fixed volume and kept at a constant temperature, 60 % of it dissociated into NO_2. The pressure at this point was 1.0×10^5 Pa, and the following equilibrium state was established.

$$N_2O_4 \rightleftharpoons 2NO_2$$

Calculate the pressure equilibrium constant in Pa at this temperature. From ①-⑤ below choose the closest value. Assume that all substances in the container are ideal gases. **7** Pa

① 1.3×10^5 ② 2.3×10^5 ③ 3.0×10^5 ④ 3.6×10^5 ⑤ 4.8×10^5

Q8 20 g of water is evaporated from 200 g of a saturated aqueous solution of potassium nitrate (KNO_3) at 60 ℃ by heating, and the solution was cooled to 20 ℃. How many grams of potassium nitrate were deposited? From ①-⑤ below choose the closest value. Assume that the solubility of potassium nitrate in 100 g of water is 32 at 20 ℃, and 109 at 60 ℃. **8** g

① 24 ② 34 ③ 70 ④ 76 ⑤ 80

Q9 The following statements (**a**)-(**c**) concern acids and bases. From ①-⑧ in the table below, choose the combination in which the "true" or "false" judgments are correct. **9**

(**a**) The pH value of 0.20 mol/L hydrochloric acid (HCl) is smaller than that of 0.10 mol/L sulfuric acid (H_2SO_4).

(**b**) The pH value of 10^{-8} mol/L hydrochloric acid is larger than 7.0.

(**c**) The higher the concentration of aqueous acetic acid (CH_3COOH), the larger its pH value.

	a	b	c
①	true	true	true
②	true	true	false
③	true	false	true
④	false	true	true
⑤	true	false	false
⑥	false	true	false
⑦	false	false	true
⑧	false	false	false

Q10　The following is a schematic diagram of a fuel cell using hydrogen (H_2). The fuel cell works as follows.

・Substance **A** is oxidized at the anode.
・Substance **B** is reduced at the cathode to yield substance **C**.
・Ions migrate in the electrolytic solution.
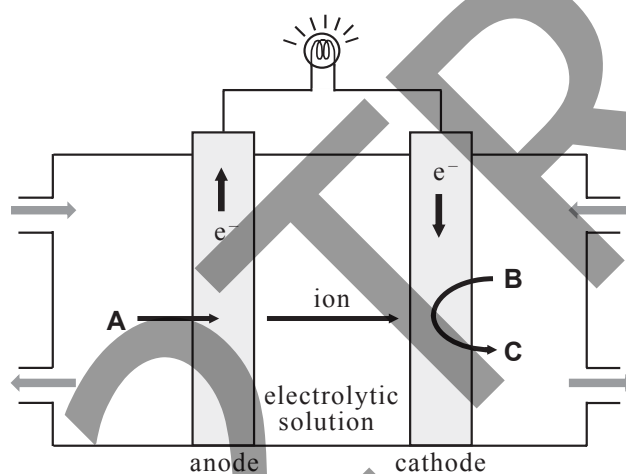
From ①-⑥ in the table below, choose the correct combination of substances **A**-**C**.

10

	A	**B**	**C**
①	H_2	O_2	H_2O
②	H_2	H_2O	O_2
③	O_2	H_2	H_2O
④	O_2	H_2O	H_2
⑤	H_2O	H_2	O_2
⑥	H_2O	O_2	H_2

Q11　From the following statements ①-⑥, choose the one that applies to all of the following group 2 elements. 　|11|

　　　　　Mg　　Ca　　Sr　　Ba

①　All are positive to flame tests.

②　All react with water at normal temperature.

③　All of their sulfates are readily soluble in water.

④　All form 1:1 oxides with oxygen (O), and their aqueous solutions are acidic.

⑤　The electron configurations of their divalent cations are the same with those of group 18 elements belonging to the same period, respectively.

⑥　The ionic radii of their divalent cations are smaller than those of monovalent cations of group 1 elements belonging to the same period, respectively.

Q12　Among the following statements (**a**)-(**d**) on phosphorous (P) and its compounds two are correct. From ①-⑥ below choose the correct combination. 　|12|

(**a**)　White phosphorous (P_4) is stored in water because it spontaneously ignites in air.

(**b**)　Tetraphosphorous decaoxide (P_4O_{10}) shows efflorescence.

(**c**)　When tetraphosphorous decaoxide is dissolved in water and heated, phosphoric acid (H_3PO_4) is formed.

(**d**)　Potassium phosphate (K_3PO_4) is the main component of bones and teeth.

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

Q13 Excess amounts of hydrochloric acid (HCl aq), aqueous ammonia (NH$_3$), and aqueous sodium hydroxide (NaOH) are added, respectively, to the following aqueous solutions (**a**)-(**c**). From ①-⑧ in the table below, choose the correct combination of solutions that **do not** form any precipitates. $\boxed{13}$

(**a**) aqueous solution containing Ag$^+$ and Cu^{2+}

(**b**) aqueous solution containing Fe^{3+} and Pb^{2+}

(**c**) aqueous solution containing Zn^{2+} and Al^{3+}

	HCl aq	NH$_3$ aq	NaOH aq
①	**a**	**b**	**c**
②	**a**	**c**	**b**
③	**b**	**a**	**b**
④	**b**	**a**	**c**
⑤	**b**	**c**	**a**
⑥	**c**	**a**	**b**
⑦	**c**	**a**	**c**
⑧	**c**	**b**	**a**

Q14 The following results were obtained from Experiment 1 and Experiment 2 on a certain powdery reagent. From ①-⑤ below choose the most appropriate one for this reagent. $\boxed{14}$

Experiment 1　This reagent was readily soluble in water, and the resulting aqueous solution was acidic.

Experiment 2　When aqueous sodium hydroxide (NaOH) was added to the aqueous solution obtained from Experiment 1, an irritating smell was detected.

① ammonium chloride (NH_4Cl)

② calcium chloride ($CaCl_2$)

③ glucose ($C_6H_{12}O_6$)

④ sodium hydrogen carbonate ($NaHCO_3$)

⑤ sodium hydrogen sulfate ($NaHSO_4$)

Q15 The following statements (**a**)-(**e**) concern the metals Ag, Cu, Fe, and Zn. Which metals are compatible with **A**-**D** in the statements (**a**)-(**e**) below? From ①-⑧ in the table below, choose the correct combination. | 15 |

(**a**) **A** and **B** dissolve in dilute sulfuric acid (dil. H_2SO_4) and generate hydrogen (H_2) while **C** and **D** do not dissolve.

(**b**) When **D** is dipped in an aqueous solution of a salt of **C**, **C** deposits on the surface of **D**.

(**c**) **A** dissolves in nitric acid (HNO_3 aq) to generate hydrogen.

(**d**) **B** dissolves in dilute nitric acid (dil. HNO_3) to generate hydrogen while it turns into a passive state and does not dissolve in concentrated nitric acid (conc. HNO_3).

(**e**) **C** and **D** dissolve in nitric acid to generate nitrogen oxides.

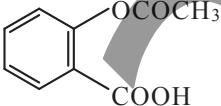|	A	B	C	D
①	Ag	Cu	Fe	Zn
②	Ag	Fe	Zn	Cu
③	Cu	Ag	Zn	Fe
④	Cu	Zn	Fe	Ag
⑤	Fe	Zn	Cu	Ag
⑥	Zn	Cu	Ag	Fe
⑦	Zn	Fe	Ag	Cu
⑧	Zn	Fe	Cu	Ag

Q16 From the following statements ①-⑤ on ethanol (C_2H_5OH) and acetic acid (CH_3COOH), choose the one that is **not** correct. | 16 |

① Both the melting and boiling points of acetic acid are higher than those of ethanol.

② When iodine (I_2) and aqueous sodium hydroxide (NaOH) are added to ethanol, yellow precipitates are formed. Acetic acid does not, however, form precipitates.

③ Dehydration condensation of acetic acid is caused by tetraphosphorus decaoxide (P_4O_{10}) and that of ethanol by concentrated sulfuric acid (conc. H_2SO_4).

④ Both react with sodium metal (Na) and generate hydrogen (H_2).

⑤ Both generate carbon dioxide (CO_2) when aqueous sodium hydrogen carbonate ($NaHCO_3$) is added.

Q17 From the following statements ①-⑤ on ethanol (C_2H_5OH) choose the correct one. | 17 |

① Two carbon atoms and one oxygen atom align on the same straight line.

② Ethanol is prepared by the addition reaction of water (H_2O) to acetylene ($HC \equiv CH$).

③ The boiling point of ethanol is higher than that of dimethyl ether (CH_3OCH_3), its isomer.

④ Ethanol reacts with sodium metal (Na) to generate carbon dioxide (CO_2).

⑤ When ethanol is oxidized by aqueous potassium dichromate ($K_2Cr_2O_7$) acidified with sulfuric acid, CH_3CH_2CHO is formed.

Q18   Compounds listed in column **A** of the following table are to be prepared in a laboratory by the procedures described in column **B**. Among **a-d** in the table below, there are two for which the statement in column **B** is correct. From ①-⑥ below choose the correct combination.   **18**

	A	**B**
a	CH_4	A mixture of sodium acetate (CH_3COONa) and sodium hydroxide (NaOH) is heated.
b	CH_3COCH_3	Propanol ($CH_3(CH_2)_2OH$) is oxidized by aqueous potassium dichromate ($K_2Cr_2O_7$) acidified with sulfuric acid.
c	$CH_3COOC_2H_5$	A small amount of concentrated sulfuric acid (conc. H_2SO_4) is added to a mixture of acetic acid (CH_3COOH) and ethanol (C_2H_5OH) and then the mixture is heated.
d	$OCOCH_3$ $COOH$	A small amount of concentrated sulfuric acid is added to a mixture of salicylic acid (o-$C_6H_4(OH)COOH$) and methanol (CH_3OH).

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

Q19 From the following statements ①-⑤ on the compounds indicated by the structural formulas **A**-**F**, choose the correct one.

$\boxed{19}$

A OH

B SO_3H

C CH_3

D NO_2

E NH_2

F COOH
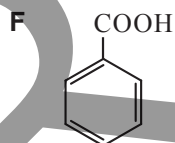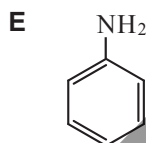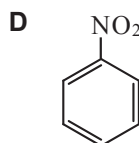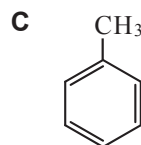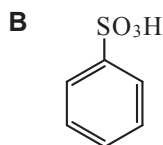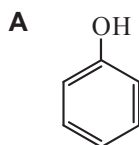
① The aqueous solution of **A** is neutral.

② The aqueous solution of **B** is weakly acidic.

③ **C** is readily soluble both in water and in organic solvents.

④ When **D** is reduced, it becomes **E**.

⑤ The color of **F** changes into red-purple by an aqueous solution of bleaching powder (the main component is CaCl(ClO)).

Q20 From the following polymers ①-⑤, choose the one which **does not** contain nitrogen (N).   [20]

①   albumin

②   deoxyribonucleic acid (DNA)

③   nylon 6,6

④   poly(ethylene terephthalate)

⑤   polyacrylonitrile

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 – ⑤ below choose the statement that correctly describes carbon dioxide assimilation by cyanobacteria, such as *Nostoc*.

$\boxed{1}$

① They use a photosynthetic pigment called bacteriochlorophyll.

② They have chloroplasts and perform the same type of photosynthesis as land plants.

③ They use energy released from the oxidization of inorganic substances such as ammonium ions.

④ They take up hydrogen sulfide to perform photosynthesis.

⑤ They produce oxygen by splitting water.

Q2 The following table summarizes the presence or absence of various structures in prokaryotic cells and eukaryotic (animal/plant) cells. ＋ indicates presence; － indicates absence.

From ①－⑥ below choose the combination that correctly identifies structures A－C in the table.

2

Structure	Prokaryotic cells	Eukaryotic cells	
		Animal cells	Plant cells
nucleus	－	＋	＋
cell membrane	＋	＋	＋
A	－	＋	＋
B	－	－	＋
C	＋	－	＋

	A	B	C
①	mitochondria	cell wall	chloroplasts
②	mitochondria	chloroplasts	cell wall
③	chloroplasts	cell wall	mitochondria
④	chloroplasts	mitochondria	cell wall
⑤	cell wall	mitochondria	chloroplasts
⑥	cell wall	chloroplasts	mitochondria

Q3 The following figure schematically represents the process of respiration in cells. From ①－④ below choose the combination of substances that correctly fills blanks ☐A☐ － ☐D☐ in the figure.

3
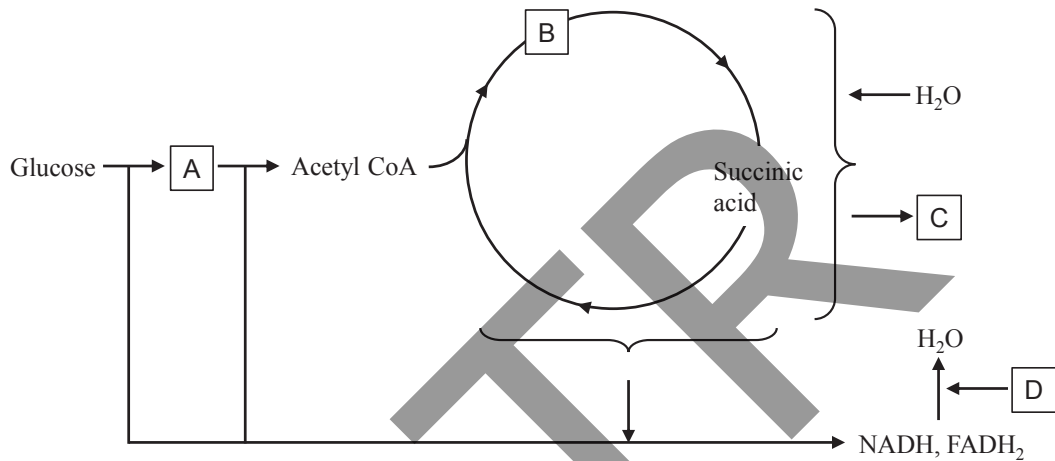
	A	B	C	D
①	citric acid	pyruvic acid	O_2	CO_2
②	citric acid	pyruvic acid	CO_2	O_2
③	pyruvic acid	citric acid	O_2	CO_2
④	pyruvic acid	citric acid	CO_2	O_2

Q4 The following paragraphs describe nitrogen metabolism in plants. From ①－⑧ below choose the combination of terms that correctly fills blanks [a] － [d] in the following paragraphs. **4**

The process whereby plants synthesize organic matter by using inorganic nitrogen compounds absorbed at their roots is called [a]. The organic matter produced by this process includes substances such as proteins and [b].

[c], which form a symbiotic relationship with legumes, are able to convert atmospheric nitrogen gas (N_2) into ammonium ions. This process is called [d].

	a	b	c	d
①	nitrogen assimilation	starch	leguminous bacteria	nitrogen fixation
②	nitrogen assimilation	starch	nitrifying bacteria	nitrogen fixation
③	nitrogen assimilation	nucleic acids	leguminous bacteria	nitrogen fixation
④	nitrogen assimilation	nucleic acids	nitrifying bacteria	nitrogen fixation
⑤	nitrogen fixation	starch	leguminous bacteria	nitrogen assimilation
⑥	nitrogen fixation	starch	nitrifying bacteria	nitrogen assimilation
⑦	nitrogen fixation	nucleic acids	leguminous bacteria	nitrogen assimilation
⑧	nitrogen fixation	nucleic acids	nitrifying bacteria	nitrogen assimilation

Q5 The following figures schematically represent DNA replication, where a section of double-stranded DNA initially unwinds and splits into two single strands which serve as templates. The arrows indicate the direction of replication in the newly synthesized DNA. From ①－④ below choose the figure that correctly indicates the direction of replication. 　**5**
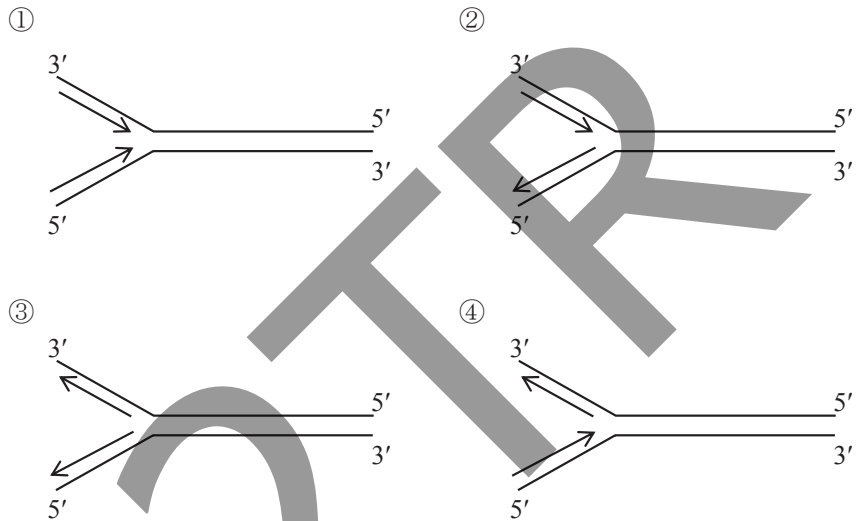
Q6 When artificially synthesized mRNA that consists of repeats of a specific base sequence is added to a protein synthesis system, it results in the formation of certain polypeptides. The following table lists the amino acid sequences of the polypeptides that are obtained from such synthetic mRNA. Referring to the results listed in the table, from ①－⑥ below choose the answer that indicates the codon of cysteine.

6

mRNA base sequence	Polypeptides formed
UGUGUG... (repeated)	Only a chain of alternating cysteine and valine
UUGUUG... (repeated)	Three kinds of polypeptides: a chain of leucine only, a chain of cysteine only, or a chain of valine only
GGUGGU... (repeated)	Three kinds of polypeptides: a chain of glycine only, a chain of valine only, or a chain of tryptophan only

① UGU   ② GUG   ③ UUG   ④ GUU   ⑤ GGU   ⑥ UGG

Q7 Much of the insulin used to treat diabetic patients is currently produced with genetic recombination and gene transfer technologies. The following figure schematically represents the method of production. What do A－C in the figure represent? From ①－④ below choose the correct combination. **7**
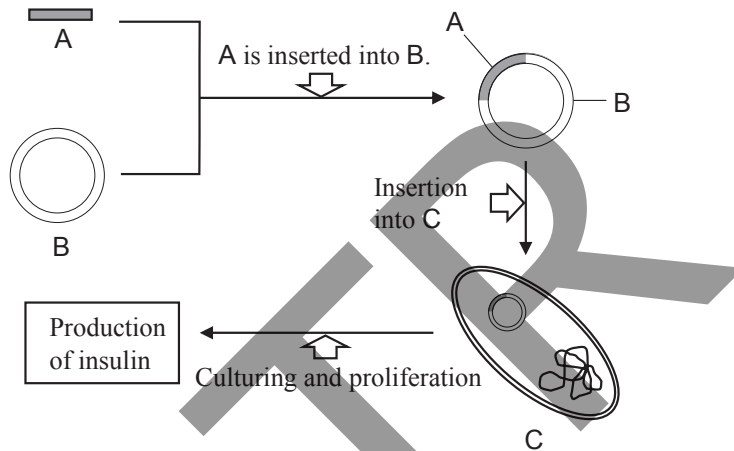
	A	B	C
①	plasmid	human insulin gene	agrobacterium
②	plasmid	human insulin gene	*Escherichia coli*
③	human insulin gene	plasmid	agrobacterium
④	human insulin gene	plasmid	*Escherichia coli*

Q8 A certain organism has the following pairs of alleles: A(a) and B(b). An individual with genotype *AAbb* was crossed with an individual with genotype *aaBB* to produce F_1. When an F_1 individual was crossed with an individual with genotype *aabb*, the resulting offspring exhibited the phenotypic segregation ratio shown below. A and B are dominant over a and b, respectively. The phenotype of individuals with genotypes *AABB*, *AaBb*, etc. is represented as 〔AB〕, and that of individuals with genotypes *AAbb* or *Aabb* is represented as 〔Ab〕.

$$〔AB〕 : 〔Ab〕 : 〔aB〕 : 〔ab〕 = 1 : 8 : 8 : 1$$

In what percentage (%) of gametes produced in the F_1 did recombination occur? From ① – ⑤ below choose the best answer. | 8 |

①　0.1　　　②　1.1　　　③　11.1　　　④　12.5　　　⑤　25.0

Q9 The following figure shows the process of sperm formation of a certain animal. From ①−⑥ below choose the combination that correctly indicates all cells among A−F in the figure that are in the haploid nuclear phase (*n*). | **9** |
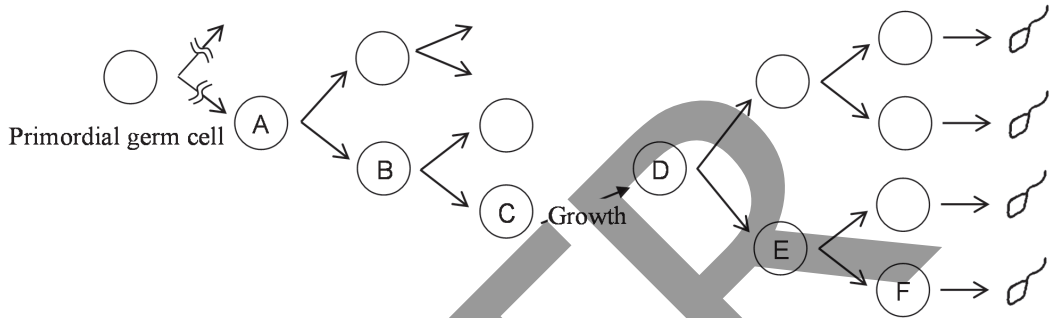
① A, B, C, D, E, F   ② B, C, D, E, F   ③ C, D, E, F

④ D, E, F   ⑤ E, F   ⑥ F

Q10 The following figure schematically represents an ovule and a pollen tube of a plant known as *Torenia fournieri*.

The embryo sac of *T. fournieri* is partially exposed from the ovule.

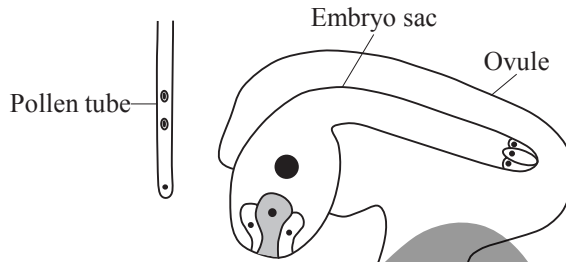An experiment was performed to investigate which cells in the *T. fournieri* embryo sac induce the pollen tube to grow toward the embryo sac, using a laser to destroy certain cells in each test. The table below shows the results of the experiment; ＋ indicates that the cell was untreated with the laser and kept alive, and － indicates that the cell was destroyed by the laser. Judging from these results, which cell(s) can be inferred to induce the pollen tube to grow toward the embryo sac? From ①－⑤ below choose the best answer. 　10

Embryo sac condition	Embryo sac				Induction rate (%)
	Egg cell	Central cell	Synergids		
No cells destroyed	＋	＋	＋	＋	98%
One cell destroyed	－	＋	＋	＋	94%
	＋	－	＋	＋	100%
	＋	＋	－	＋	71%
Two cells destroyed	－	－	＋	＋	93%
	－	＋	－	＋	61%
	＋	－	－	＋	71%
	＋	＋	－	－	0%

① egg cell ② central cell ③ synergids ④ egg cell and central cell

⑤ central cell and synergid

Q11 The following table shows the concentration (%) of three constituents of healthy human blood plasma, a－c, in primitive urine and urine.

	a	b	c
Primitive urine	0%	0.1%	0.30%
Urine	0%	0%	0.35%

From ①－⑥ below choose the combination that best identifies substances a－c. | 11 |

	a	b	c
①	Na^+	glucose	protein
②	Na^+	protein	glucose
③	glucose	Na^+	protein
④	glucose	protein	Na^+
⑤	protein	Na^+	glucose
⑥	protein	glucose	Na^+

Q12 The following figure schematically represents the structure of the human brain. Among regions A－E in the figure, which is the center for coordinating movement and maintaining balance of the body? Also, what is the name of that region? From ①－⑥ below choose the correct combination. **12**
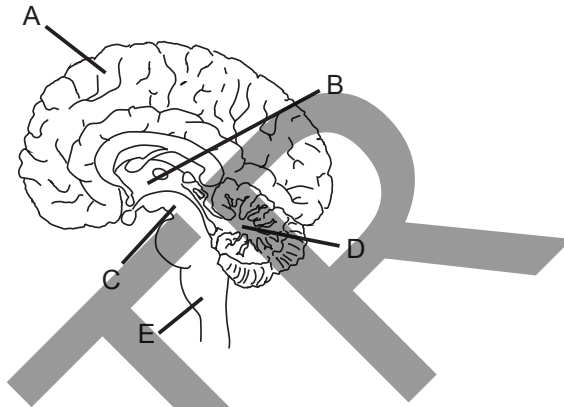
	Region	Name
①	A	cerebrum
②	B	midbrain
③	C	diencephalon
④	D	cerebellum
⑤	E	cerebellum
⑥	E	medulla oblongata

Q13 Following an infection by a pathogen, the blood contains antibodies that target the pathogen. The graphs below show the amount of the antibodies measured after infection. The amount of antibodies was recorded with the number of days elapsed after the first and second infections with the same pathogen. From ① – ④ below choose the graph that best indicates the amount of antibodies after the first and second infections. ⑬
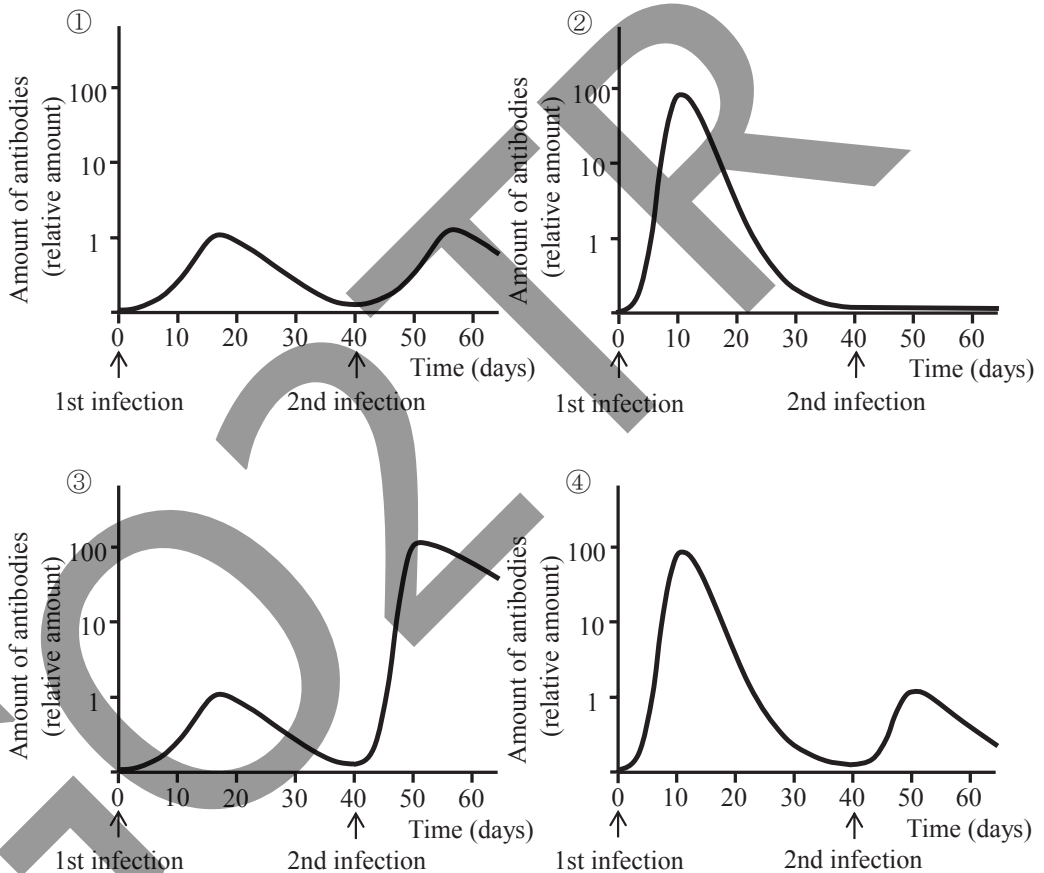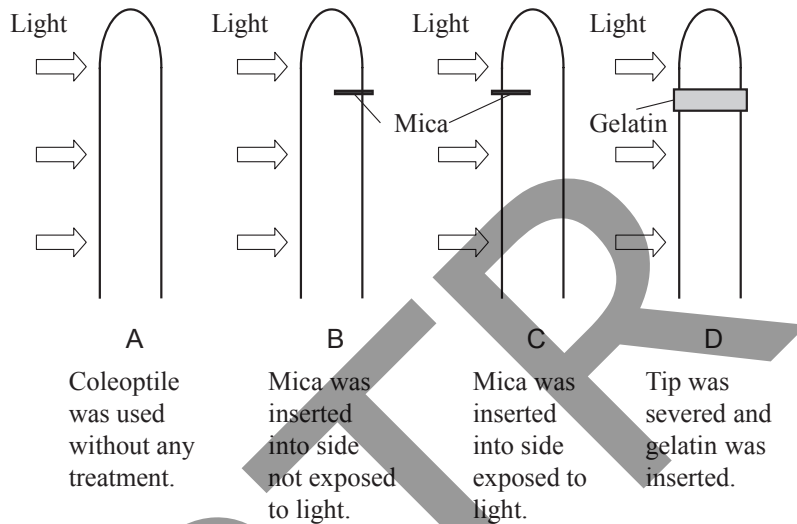
Q14 Innate behaviors and learned behaviors are two categories of animal behavior. From ① – ⑤ below choose the answer that best represents an example of learned behaviors.   14

①　Humans reflexively draw back their hand when the fingers touch something hot.

②　During breeding season, male three-spined sticklebacks (a freshwater fish) attack other red-bellied males that enter their territory, but do not attack females whose abdomen is swollen with eggs.

③　Male silkmoths are attracted by a pheromone to locate females.

④　As exemplified by how earthworms move away from light, some animals move in a certain direction in response to a specific stimulus, such as light or a chemical substance.

⑤　The sea hare retracts its gill when a tactile stimulus is applied to its siphon. However, when the stimulus is applied repeatedly, the sea hare stops retracting its gill.

Q15 The experiments, A – D, were performed as described in the following figures on oat coleoptiles to observe curvature of coleoptiles when exposed to light from a certain direction.

	A	B	C	D
	Coleoptile was used without any treatment.	Mica was inserted into side not exposed to light.	Mica was inserted into side exposed to light.	Tip was severed and gelatin was inserted.

In experiments A, C, and D, curvature of the coleoptile toward the side exposed to light was clearly observed, but curvature was not observed in B. Which two statements in Ⅰ–Ⅴ below describe insights about the substance produced in the coleoptile tip that can be inferred from the experiments? From ①–⑥ below choose the correct combination.

15

Ⅰ The substance produced in the coleoptile tip descends toward the base without being affected by the light stimulus.

Ⅱ Due to the effect of the light stimulus, the substance produced in the coleoptile tip moves in greater amount to the side not exposed to light and descends toward the base.

Ⅲ Due to the effect of the light stimulus, the substance produced in the coleoptile tip moves in greater amount to the side exposed to light and descends toward the base.

Ⅳ The substance produced in the coleoptile tip is able to pass through gelatin.

Ⅴ The substance produced in the coleoptile tip is able to pass through mica.

   ① Ⅰ,Ⅳ   ② Ⅰ,Ⅴ   ③ Ⅱ,Ⅳ   ④ Ⅱ,Ⅴ   ⑤ Ⅲ,Ⅳ   ⑥ Ⅲ,Ⅴ

Q16 The following figures show the results of culturing *Paramecium caudatum*, *Paramecium aurelia*, and *Paramecium bursaria* separately or in combination with one of the others. From ①－④ below choose the combination of terms that correctly fills blanks ⬚ a ⬚ and ⬚ b ⬚ in the paragraph below that describes the results.

16
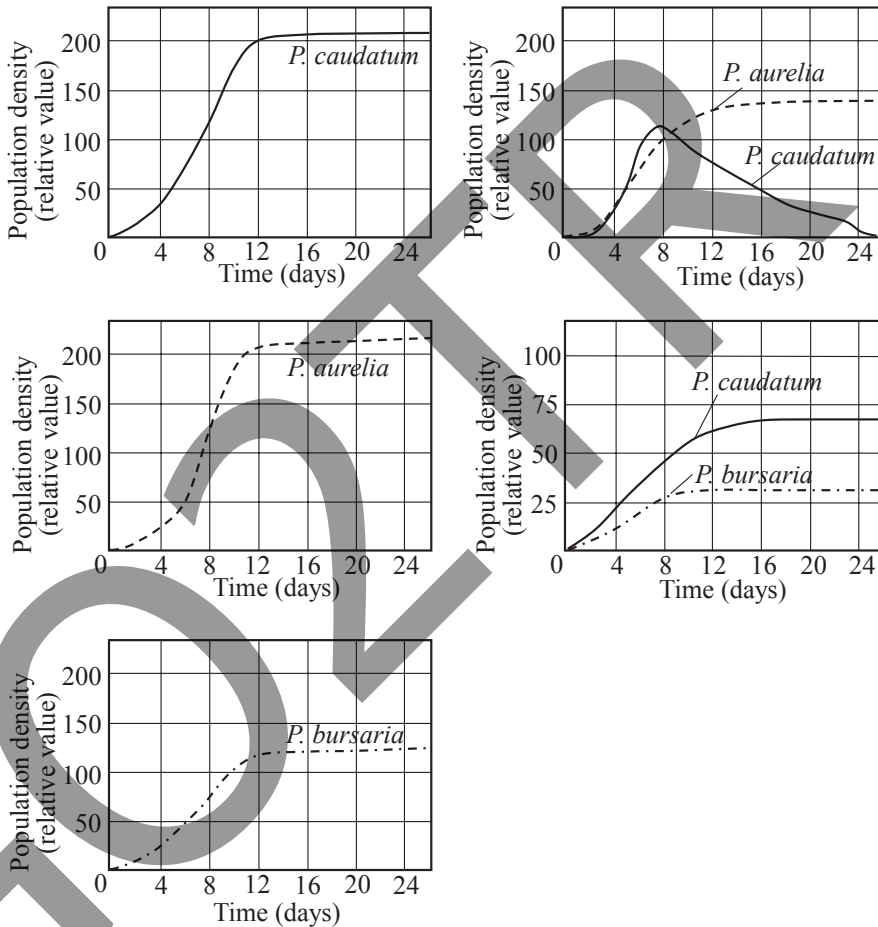
Of *P. aurelia* and *P. bursaria*, ⬚ a ⬚ has an ecological niche that is more similar to that of *P. caudatum*. When cultured together with *P. caudatum*, ⬚ b ⬚ is able to coexist for a longer time.

	a	b
①	*P. aurelia*	*P. aurelia*
②	*P. aurelia*	*P. bursaria*
③	*P. bursaria*	*P. aurelia*
④	*P. bursaria*	*P. bursaria*

Q17 The following paragraph describes the flow of energy in an ecosystem. From ① – ⑧ below choose the combination of terms that correctly fills blanks a – c in the paragraph.

17

The producers in an ecosystem convert a energy from the sun into b energy that is stored in organic matter. Consumers feed on the organic matter synthesized by producers, resulting in the transfer of part of that energy with the organic matter, which is then transferred up the food chain to higher consumers. The energy used by these organisms ultimately becomes c energy that is released into the atmosphere and eventually escapes the ecosystem.

	a	b	c
①	thermal	chemical	thermal
②	thermal	chemical	light
③	thermal	light	thermal
④	thermal	light	chemical
⑤	light	chemical	chemical
⑥	light	chemical	thermal
⑦	light	thermal	thermal
⑧	light	thermal	chemical

Q18 The following paragraph describes the mechanism of evolution of organisms. From ①－⑥ below choose the combination of terms that correctly fills blanks a － c in the following paragraph.

| 18 |

In a given population of an organism, allele frequencies sometimes randomly change as genetic information is passed to the next generation. This type of change is called a . There is also a phenomenon called b , in which the individuals that have survival and breeding advantages due to intraspecies variation survive. It is believed that c first occurs and then spreads among the population through phenomena such as a and b , resulting in the process of evolution.

	a	b	c
①	natural selection	mutation	genetic drift
②	natural selection	genetic drift	mutation
③	genetic drift	natural selection	mutation
④	genetic drift	mutation	natural selection
⑤	mutation	natural selection	genetic drift
⑥	mutation	genetic drift	natural selection

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.