2018 Examination for Japanese University Admission for International Students

Science (80 min.)

【Physics, Chemistry, Biology】

※ Choose and answer two subjects.

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

Ⅰ Rules of Examination

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

Ⅱ Rules and Information Concerning the Question Booklet

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

Subject	Pages
Physics	1 − 21
Chemistry	23 − 40
Biology	41 − 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

Marking your Choice of Subject on the Answer Sheet

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

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

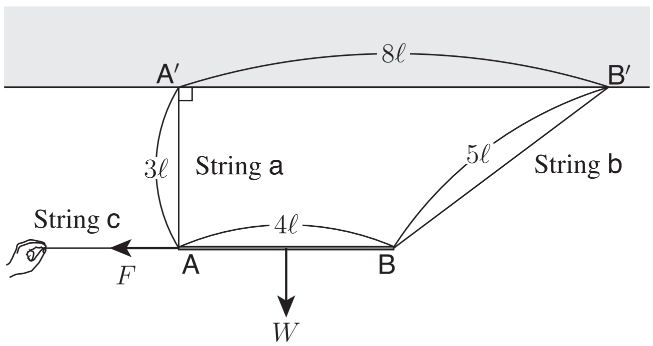
If you do not correctly fill in the appropriate oval, your answers will not be graded.

<Example>

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

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.

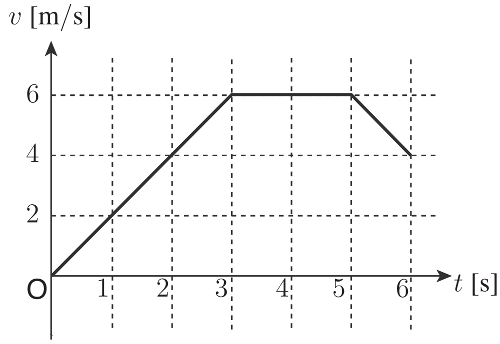
A As shown in the figure below, string a (length: 3ℓ) and string b (length: 5ℓ) are attached to ends A and B, respectively, of a thin uniform rod (length: 4ℓ) and the rod is suspended from two points on a horizontal ceiling, A′ and B′. The distance between A′ and B′ is 8ℓ. Another string, c, is attached to A and pulled in the horizontal direction so that the rod rests in a position where the rod is horizontal and string a is vertical. Let us denote as F the magnitude of the pulling force exerted on A by string c, and as W the magnitude of gravity acting on the rod. All three strings are lightweight and inelastic.



Q1 What is F? From ①-⑥ below choose the correct answer. **1**

① $\frac{3}{10}W$　② $\frac{3}{8}W$　③ $\frac{2}{5}W$　④ $\frac{5}{8}W$　⑤ $\frac{2}{3}W$　⑥ $\frac{5}{6}W$

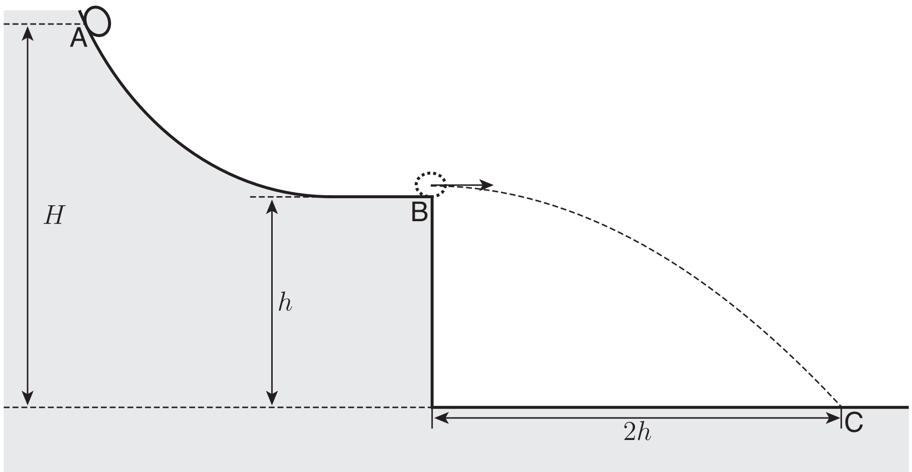
B A train at rest begins moving at time $t = 0$ s, and travels on a straight railroad. The figure below is a graph showing the relationship between the velocity of the train, v [m/s], and time t [s].



Q2 What distance (in m) does the train travel in the time from $t = 0$ s to $t = 6$ s? From ①-⑥ below choose the best answer. **2** m

① 20 ② 22 ③ 24 ④ 26 ⑤ 28 ⑥ 30

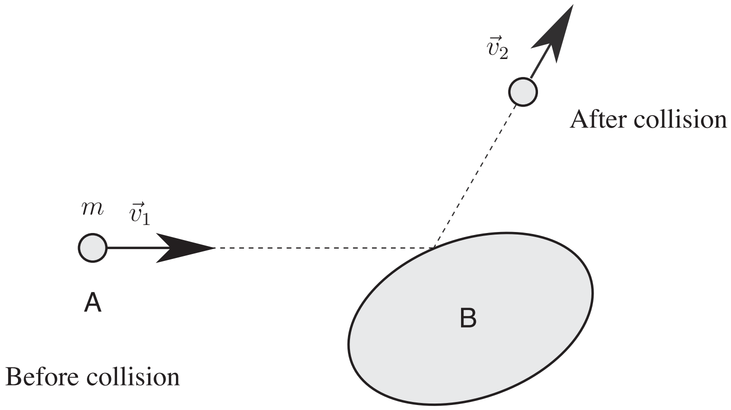
C Consider a smooth curved surface, AB, as shown in the figure below. The upper and lower edges of the surface, A and B, are heights H and h, respectively, above a horizontal ground. A small object of mass m is placed at A and gently released. The object begins sliding down the surface, horizontally jumps off B, and lands at point C on the ground. The horizontal distance between B and C is $2h$.



Q3 What is $\dfrac{H}{h}$? From ①-⑥ below choose the correct answer. $\boxed{3}$

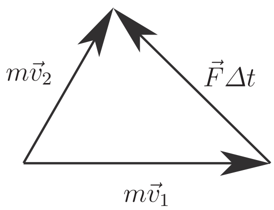
① $\dfrac{5}{4}$ ② $\dfrac{3}{2}$ ③ $\dfrac{7}{4}$ ④ 2 ⑤ $\dfrac{9}{4}$ ⑥ $\dfrac{5}{2}$

D As shown in the figure below, small object A (mass: m) is traveling at velocity $\vec{v}_1$, and it collides with object B. The velocity of A then changes to $\vec{v}_2$. Let us denote as $\vec{F}\Delta t$ the impulse imparted to B by the collision.

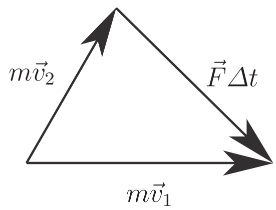


Q4 From ①-④ below choose the figure that correctly represents the relationship of $\vec{F}\Delta t$ with $m\vec{v}_1$ and $m\vec{v}_2$. $\boxed{4}$

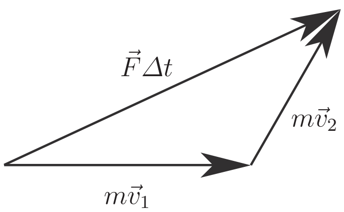
①



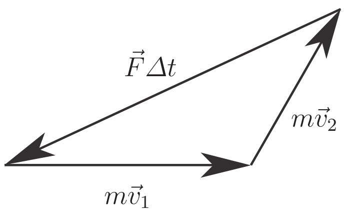
②



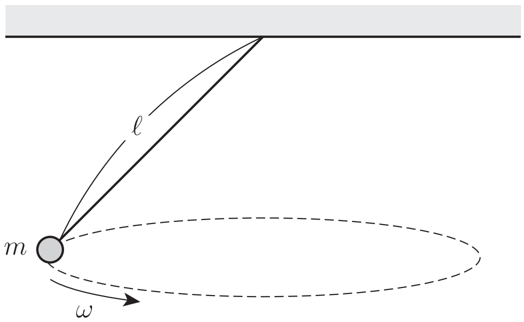
③



④



E As shown in the figure below, one end of a lightweight inelastic string (length: ℓ) is fixed in place and a small ball of mass m is attached to the other end and suspended. The ball is made to undergo uniform circular motion within a horizontal plane, where the pulling force exerted on the ball by the string is $2mg$. Let us denote as ω the angular velocity of the ball's circular motion.



Q5 What is ω? From ①-⑥ below choose the correct answer. $\boxed{5}$

① $\sqrt{\dfrac{g}{\ell}}$　② $\sqrt{\dfrac{2g}{\ell}}$　③ $\sqrt{\dfrac{3g}{\ell}}$

④ $2\sqrt{\dfrac{g}{\ell}}$　⑤ $\sqrt{\dfrac{5g}{\ell}}$　⑥ $\sqrt{\dfrac{6g}{\ell}}$

F A small object is undergoing simple harmonic motion on an x-axis, with the motion centered on the origin ($x = 0$). The amplitude and angular frequency of the simple harmonic motion are 0.50 m and 1.0 rad/s, respectively.

Q6 What is the object's acceleration (in $\mathrm{m/s^2}$) at the instant when it passes through position $x = 0.10$ m? From ①-⑥ below choose the correct answer, where the positive direction of acceleration is the positive direction of the x-axis. $\boxed{\mathbf{6}}$ $\mathrm{m/s^2}$

① -0.50 ② -0.25 ③ -0.10 ④ 0.10 ⑤ 0.25 ⑥ 0.50

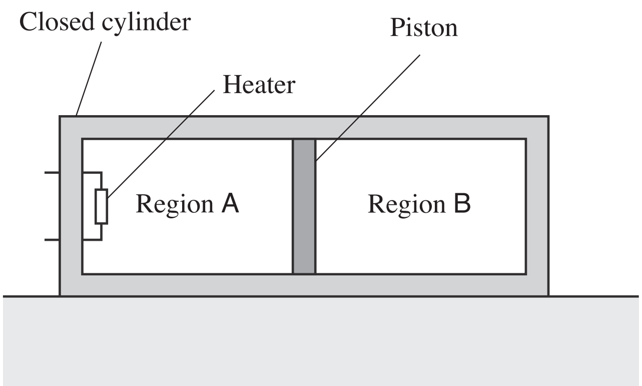
$\boxed{\text{II}}$ Answer questions **A** (Q1), **B** (Q2), and **C** (Q3) below.

A Water of 5.0×10^2 g at 60 °C is placed in a metal container at 20 °C. After sufficient time elapses, the temperature of both the water and the container becomes 50 °C. Next, water of 1.0×10^2 g at 60 °C is placed in the same metal container at 20 °C. After sufficient time elapses, the temperature of both the water and the container becomes t [°C]. Assume that heat is transferred only between the container and the water.

Q1 What is t (in °C)? From ①-⑤ below choose the best answer. $\boxed{7}$ °C

① 25 ② 30 ③ 35 ④ 40 ⑤ 45

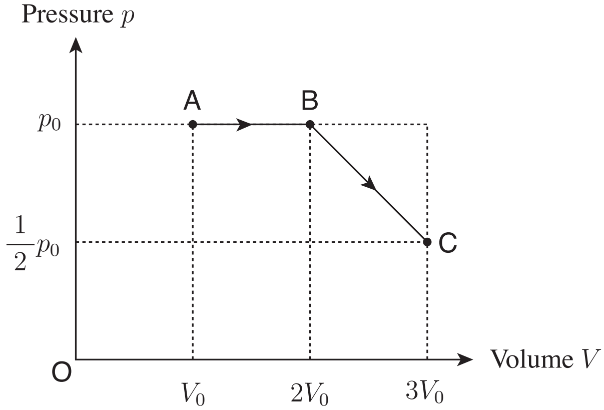
B As shown in the figure below, a closed cylinder is divided into two regions, A and B, by a smoothly moving piston. The cylinder and piston are made of thermally insulating material. There is a heater in A. Ideal gases are enclosed in A and B in equal quantities. Initially, the gases in A and B have the same temperature, pressure, and volume. The heater is used to slowly heat the gas in A for a certain period of time. As a result, the piston moves and comes to rest at a position where the volume of the gas in A has increased by a factor of $\frac{6}{5}$. Here, let us denote as T_{A} and T_{B} the absolute temperature of the gases in A and B, respectively.



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

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

C A fixed quantity of a monatomic ideal gas is enclosed in a cylinder and its state is changed in the path State A→State B→State C as shown in the p-V diagram below.

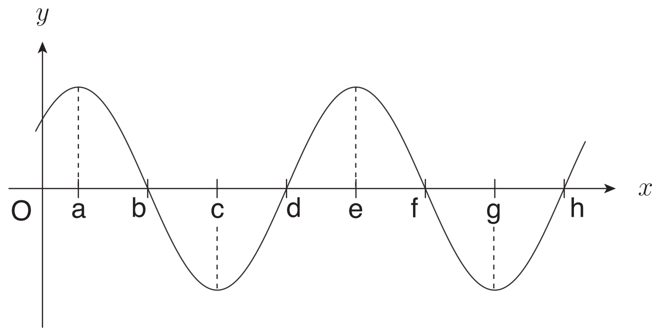


Q3 What is the quantity of heat absorbed by the gas in the process of State A→State B→State C? From ①-⑤ below choose the correct answer. $\boxed{9}$

① $\frac{1}{2}p_0V_0$ ② p_0V_0 ③ $\frac{3}{2}p_0V_0$ ④ $2p_0V_0$ ⑤ $\frac{5}{2}p_0V_0$

$\boxed{\text{III}}$ Answer questions **A** (Q1), **B** (Q2), and **C** (Q3) below.

A The figure below is a graph representing, at a certain instant, the relationship between displacement y of a medium and position x for a longitudinal wave propagating in the positive direction of an x-axis. Here, y is positive when displacement is in the positive direction of the x-axis.



Q1 At which of points a-h in the figure is the velocity of the medium at its maximum magnitude with its direction being in the positive direction of the x-axis? From ①-④ below choose the correct combination. $\boxed{10}$

① a and e ② b and f ③ c and g ④ d and h

B As shown in the figures below, a sound source is traveling with speed v_{S} along a straight line while emitting sound at frequency f_0 from the front and back. An observer is traveling in the same direction along the same line with speed v_{O}. When the observer is traveling in front of the sound source as shown in Figure 1, the frequency of the sound as observed by the observer is f_1. When the observer is traveling behind the sound source as shown in Figure 2, the frequency of the sound as observed by the observer is f_2. Let us denote as V the speed of sound.

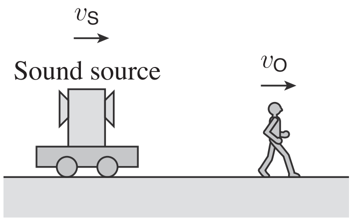


Figure 1

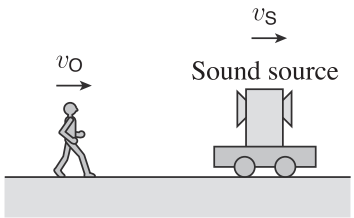


Figure 2

Q2 What is $\dfrac{f_2}{f_1}$? From ①-④ below choose the correct answer. **11**

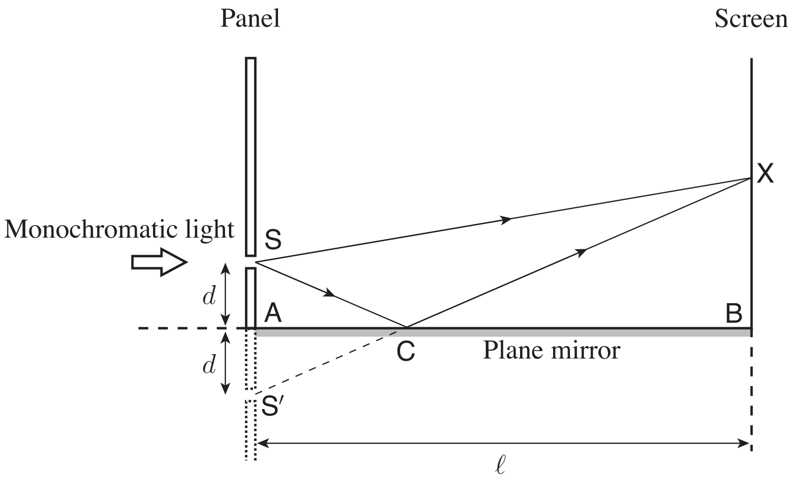
① $\dfrac{(V-v_{\mathrm{S}})(V+v_{\mathrm{O}})}{(V+v_{\mathrm{S}})(V-v_{\mathrm{O}})}$

② $\dfrac{(V+v_{\mathrm{S}})(V-v_{\mathrm{O}})}{(V-v_{\mathrm{S}})(V+v_{\mathrm{O}})}$

③ $\dfrac{(V-v_{\mathrm{S}})(V-v_{\mathrm{O}})}{(V+v_{\mathrm{S}})(V+v_{\mathrm{O}})}$

④ $\dfrac{(V+v_{\mathrm{S}})(V+v_{\mathrm{O}})}{(V-v_{\mathrm{S}})(V-v_{\mathrm{O}})}$

C As shown in the figure below, a plane mirror is placed horizontally, and a panel with slit S and a screen are placed vertically at the edges of the mirror, A and B, respectively. The distance between A and B is ℓ and the distance between S and A is d. Monochromatic light of wavelength λ is directed from the left of S. Bright and dark bands form on the screen as a result of interference between light that passes through S and directly reaches position X on the screen and light that passes through S, reflects at position C on the mirror, and reaches X. Due to reflection by the mirror, the phase of the light changes by π (i.e., it is inverted). The light reaching X after reflection at C can be thought of as light, whose phase differs by π from that of the light passed through S, that directly reaches X after passing through a hypothetical slit S′ distance d vertically below A. Let us denote as x the distance between B and the bright band on the screen that is nearest to B. Assume that the slit is sufficiently narrow, and d and x are extremely small compared with ℓ.

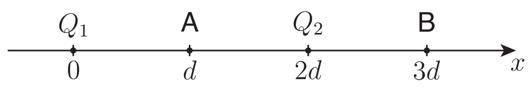


Q3 What is x? From ①-⑤ below choose the best answer. $\boxed{12}$

① $\dfrac{\lambda\ell}{4d}$ ② $\dfrac{\lambda\ell}{2d}$ ③ $\dfrac{\lambda\ell}{d}$ ④ $\dfrac{2\lambda\ell}{d}$ ⑤ $\dfrac{4\lambda\ell}{d}$

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

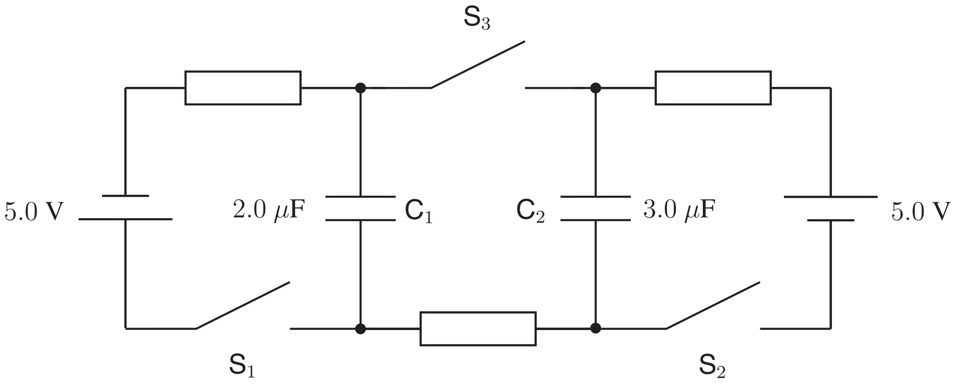
A As shown in the figure below, a point charge with quantity of electricity Q_1 is fixed in place at the origin of an x-axis, and another with quantity of electricity Q_2 is fixed in place at a point on the x-axis where $x = 2d\,(> 0)$. The direction of the electric field at point A on the x-axis ($x = d$) is the positive direction of the x-axis. Also, the electric potential at A is 0 V. Here, the reference position for electric potential is at infinity.



Q1 What is the direction of the electric field at point B on the x-axis ($x = 3d$)? Also, is the electric potential at B positive, or negative? From ①-④ below choose the correct combination. $\boxed{13}$

	Direction of electric field	Electric potential
①	positive direction of x-axis	positive
②	positive direction of x-axis	negative
③	negative direction of x-axis	positive
④	negative direction of x-axis	negative

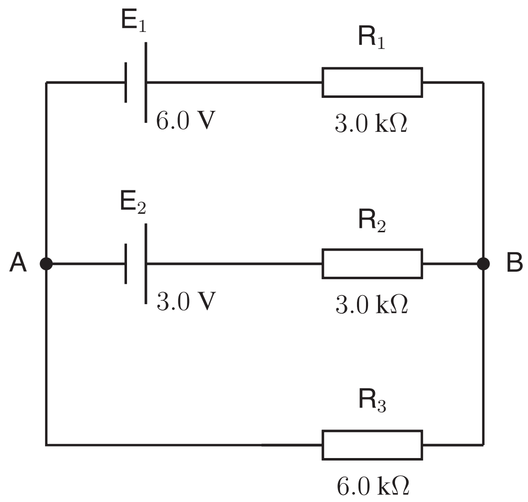
B Capacitors C_1 and C_2 (capacitance: $2.0\ \mu$F and $3.0\ \mu$F, respectively), two batteries (electromotive force: 5.0 V each), three resistors, and three switches (S_1, S_2, S_3) are connected in a circuit as shown in the figure below. Initially, S_3 is open and S_1 and S_2 are closed, resulting in the charging of C_1 and C_2. Next, S_1 and S_2 are opened and S_3 is closed. Let us denote as Q the quantity of electricity of the charge stored in the plate of C_1, connected to S_3, (the upper plate shown) after sufficient time elapses.



Q2 What is Q (in μC)? From ①-⑥ below choose the best answer. $\boxed{14}$ μC

① -5.0 ② -2.0 ③ -1.0 ④ 1.0 ⑤ 2.0 ⑥ 5.0

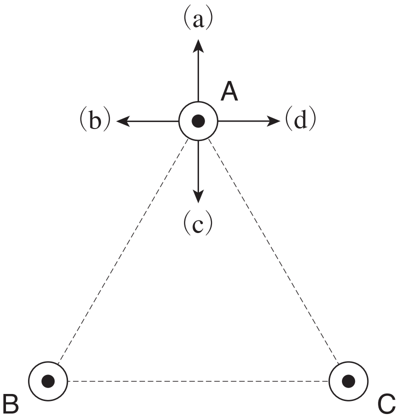
C Resistors R_1, R_2, and R_3 (resistance: $3.0\ \mathrm{k\Omega}$, $3.0\ \mathrm{k\Omega}$, and $6.0\ \mathrm{k\Omega}$, respectively) and batteries E_1 and E_2 (electromotive force: 6.0 V and 3.0 V, respectively) are connected in a circuit as shown in the figure below. A and B in the figure are connecting points in the circuit.



Q3 What is the magnitude of the electric current flowing through resistor R_2 (in mA)? Also, is the direction of the current from A to B, or from B to A? From ①-⑥ below choose the best combination. **15**

	Magnitude of current	Direction of current
①	0.20 mA	from A to B
②	0.20 mA	from B to A
③	0.40 mA	from A to B
④	0.40 mA	from B to A
⑤	0.60 mA	from A to B
⑥	0.60 mA	from B to A

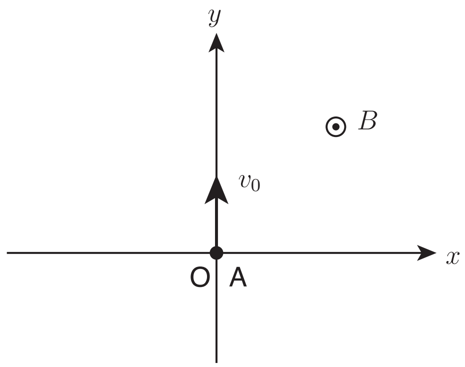
D As shown in the figure below, three straight, sufficiently long conducting wires are parallel to one another and perpendicular to this page, passing through the vertices of equilateral triangle ABC within this page. Electric currents of the same magnitude, I, flow through the three wires, all in the direction from the back of this page to the front. Let us denote as $\vec{F}_{\mathrm{B}}$ and $\vec{F}_{\mathrm{C}}$ the forces exerted on a segment of length ℓ of the wire passing through A by the current flowing through B and by the current flowing through C, respectively. Let us denote as $\vec{F}$ the resultant force of $\vec{F}_{\mathrm{B}}$ and $\vec{F}_{\mathrm{C}}$.



Q4 What is the direction of $\vec{F}$, in terms of the directions indicated by arrows (a)-(d) in the figure? Also, what is $\dfrac{F}{F_{\mathrm{B}}}$, where F denotes the magnitude of $\vec{F}$, and F_{B} denotes the magnitude of $\vec{F}_{\mathrm{B}}$? From ①-⑧ below choose the correct combination. $\boxed{16}$

	①	②	③	④	⑤	⑥	⑦	⑧
Direction of $\vec{F}$	(a)	(a)	(b)	(b)	(c)	(c)	(d)	(d)
$\dfrac{F}{F_{\mathrm{B}}}$	1	$\sqrt{3}$	1	$\sqrt{3}$	1	$\sqrt{3}$	1	$\sqrt{3}$

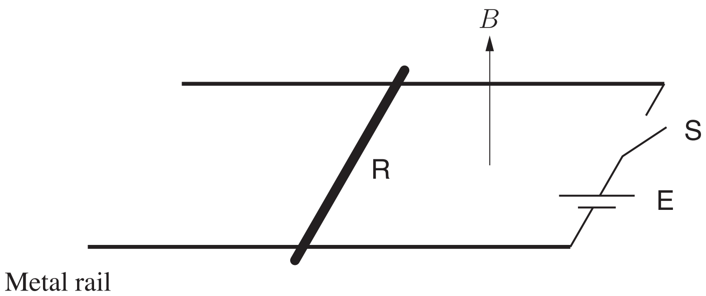
E As shown in the figure below, a uniform magnetic field (magnitude of magnetic flux density: B) is applied to a sufficiently wide region of an x-y plane (this page), perpendicular to this page and in the direction from the back of the page to the front. A represents a charged particle (mass: m) that has a negative quantity of electricity, $-q$ ($q > 0$). At time $t = 0$, A is launched from origin O in the positive direction of the y-axis with an initial speed of v_0. Let us denote as x_1 the x-coordinate of the point where A returns to the x-axis for the first time, and as t_1 the time of that occurrence.



Q5 What are x_1 and t_1? From ①-⑧ below choose the correct combination. $\boxed{17}$

	①	②	③	④	⑤	⑥	⑦	⑧
x_1	$-\dfrac{2v_0m}{qB}$	$-\dfrac{2v_0m}{qB}$	$-\dfrac{v_0m}{qB}$	$-\dfrac{v_0m}{qB}$	$\dfrac{v_0m}{qB}$	$\dfrac{v_0m}{qB}$	$\dfrac{2v_0m}{qB}$	$\dfrac{2v_0m}{qB}$
t_1	$\dfrac{\pi m}{qB}$	$\dfrac{2\pi m}{qB}$	$\dfrac{\pi m}{qB}$	$\dfrac{2\pi m}{qB}$	$\dfrac{\pi m}{qB}$	$\dfrac{2\pi m}{qB}$	$\dfrac{\pi m}{qB}$	$\dfrac{2\pi m}{qB}$

F As shown in the figure below, metal rod R is placed on and perpendicular to two long, parallel metal rails fixed in place in a horizontal plane. R can slide on the rails without friction while constantly remaining perpendicular to the rails. A uniform magnetic field (magnitude of magnetic flux density: B) is applied to the region encompassing the rails, in the vertically upward direction. Battery E and switch S are connected to the rails at one end. The rod is electrically resistant, but the electrical resistance of the rails is negligible. When S is open, the rod is at rest. When S is closed, the rod begins moving in the direction $\boxed{\text{I}}$. Thereafter, the speed of the rod increases, and the magnitude of the rod's acceleration $\boxed{\text{II}}$.



Q6 What terms fill blanks $\boxed{\text{I}}$ and $\boxed{\text{II}}$ in the paragraph above? From ①-⑥ below choose the correct combination. Assume that the effects of the magnetic field produced by the current flowing through the rod and the rails are negligible. **18**

	I	II
①	toward the battery	decreases
②	toward the battery	remains constant
③	toward the battery	increases
④	away from the battery	decreases
⑤	away from the battery	remains constant
⑥	away from the battery	increases

$\boxed{\text{V}}$ Answer question **A** (Q1) below.

A Light and electrons behave like both particles and waves. Their particle-like properties and wave-like properties are interrelated.

By denoting the wavelength of light as λ, photon energy is proportional to $\boxed{\text{I}}$. By denoting the wavelength of electron waves as λ, the kinetic energy of electrons is proportional to $\boxed{\text{II}}$.

Q1 What expressions fill blanks $\boxed{\text{I}}$ and $\boxed{\text{II}}$ in the paragraphs above? From ①-⑧ below choose the correct combination.

19

	I	II
①	λ^2	λ^2
②	λ^2	λ
③	λ	λ^2
④	λ	λ
⑤	$\frac{1}{\lambda}$	$\frac{1}{\lambda}$
⑥	$\frac{1}{\lambda}$	$\frac{1}{\lambda^2}$
⑦	$\frac{1}{\lambda^2}$	$\frac{1}{\lambda}$
⑧	$\frac{1}{\lambda^2}$	$\frac{1}{\lambda^2}$

End of Physics questions. Leave the answer spaces $\boxed{20}$ – $\boxed{75}$ 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.

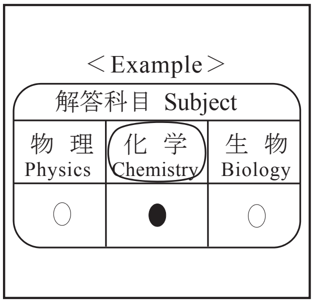
Chemistry

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.



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

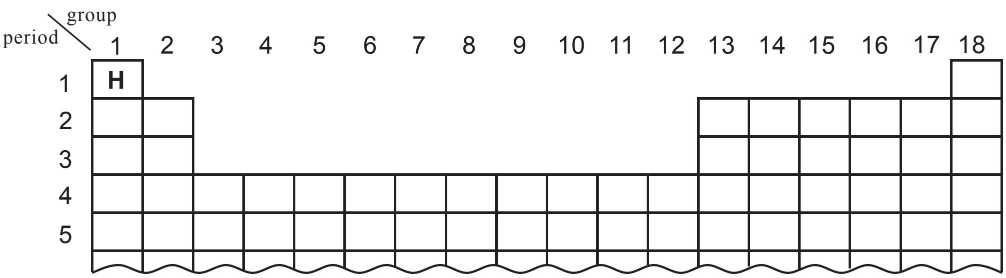
Gas constant: $R = 8.31 \times 10^3$ Pa・L/(K・mol)

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 Na : 23 Cl : 35.5 Ca : 40 Cu : 64

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 electron configurations for atoms **a**-**d** are given in the following table. From ①-⑥ below choose the correct combination of elements belonging to the same group in the periodic table. $\boxed{1}$

	Electron configuration		
	K shell	L shell	M shell
a	2	0	0
b	2	2	0
c	2	8	6
d	2	8	8

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

Q2 Among the elements Li, Be, B, C, N, O, F, and Ne belonging to the second period of the periodic table, choose the one which is compatible with the following statements (**a**)-(**c**), respectively. From ①-⑥ below choose the correct combination. **2**

(**a**) the one that has the largest first ionization energy

(**b**) the one whose divalent anion has the electron configuration of a noble gas

(**c**) the one that forms a diatomic molecule with a triple bond from two of the same kind of atoms

	a	**b**	**c**
①	Li	Be	C
②	Li	Be	N
③	Li	O	C
④	Ne	Be	N
⑤	Ne	O	C
⑥	Ne	O	N

Q3 1.82 g of a metal oxide contains 1.02 g of the metal M, the atomic weight of which is 51. From the following ①-⑥ choose the correct compositional formula for this oxide. **3**

① MO ② MO_2 ③ M_2O ④ M_2O_3 ⑤ M_2O_5 ⑥ M_3O_2

Q4 From the following ①-⑥ choose the closest value for the total number of atoms contained in 5.6 L of carbon dioxide (CO_2) at 0 ℃ and 1.0×10^5 Pa. Suppose carbon dioxide is an ideal gas. **4**

① 1.5×10^{23} ② 3.0×10^{23} ③ 4.5×10^{23}
④ 2.4×10^{24} ⑤ 4.8×10^{24} ⑥ 7.2×10^{24}

Q5 From the following combinations of molecules ①-⑥ choose the one in which the oxidation number of the sulfur atom (S) is the lowest while that of the nitrogen atom (N) is the highest. **5**

① SO_4^{2-}, NH_3 ② SO_2, HNO_3 ③ S_8, N_2
④ H_2S, NO_3^- ⑤ $S_2O_3^{2-}$, NO_2^- ⑥ Na_2S, NO_2

Q6 Among the following reaction formulas (**a**)-(**e**), there are two in which the underlined substance acts as a base as defined by Brønsted-Lowry theory. From ①-⑥ below choose the correct combination. $\boxed{6}$

(**a**) $\underline{Mg} + 2HCl \longrightarrow MgCl_2 + H_2$

(**b**) $HCl + \underline{H_2O} \longrightarrow H_3O^+ + Cl^-$

(**c**) $\underline{NH_4^+} + H_2O \longrightarrow NH_3 + H_3O^+$

(**d**) $\underline{HCO_3^-} + OH^- \longrightarrow H_2O + CO_3^{2-}$

(**e**) $\underline{CH_3COO^-} + H_2O \longrightarrow CH_3COOH + OH^-$

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

Q7 The following three kinds of aqueous solutions **A**, **B**, and **C** were placed in the same cooling tank which was gradually cooled. From ①-⑥ below choose the one giving the correct order in which the solutions freeze. Assume all the electrolytes are completely dissociated in water and supercooling does not take place. $\boxed{\mathbf{7}}$

Aqueous solution **A** : 10 g of urea ($CO(NH_2)_2$) is dissolved in 100 g of water.

Aqueous solution **B** : 10 g of sodium chloride ($NaCl$) is dissolved in 100 g of water.

Aqueous solution **C** : 10 g of calcium chloride ($CaCl_2$) is dissolved in 100 g of water.

① **A** → **B** → **C**

② **A** → **C** → **B**

③ **B** → **A** → **C**

④ **B** → **C** → **A**

⑤ **C** → **A** → **B**

⑥ **C** → **B** → **A**

Q8 The reaction between a gaseous substance **A** and a gaseous substance **B** to give a gaseous substance **C** was reversible at a certain temperature. This reaction can be represented by the following thermochemical equation,

$$a\,\mathbf{A} + b\,\mathbf{B} = c\,\mathbf{C} + Q\,(\mathrm{kJ})$$

where a, b, and c are coefficients and Q is the heat of reaction.

When the mixture of the three gases **A**, **B**, and **C** reached equilibrium in a closed container whose volume is variable, the following experimental results (i)-(iii) were obtained.

(i) When argon was added at constant temperature and volume, the equilibrium did not shift.

(ii) When argon was added at constant temperature and total pressure, the equilibrium shifted to the left.

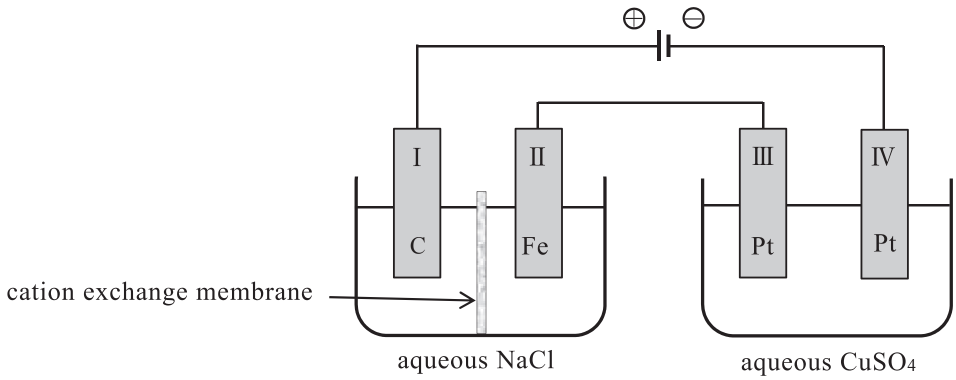
(iii) When the pressure was kept constant while the temperature was raised, the equilibrium shifted to the left.

From the following ①-⑥ choose the one that is correct for the relationship among a, b, and c, and the equation for Q. **8**

① $a + b = c,\ Q > 0$ ② $a + b > c,\ Q > 0$ ③ $a + b < c,\ Q > 0$

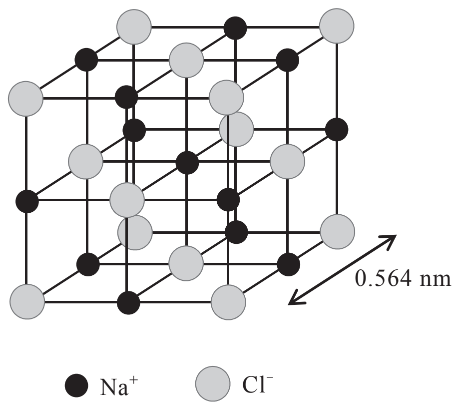
④ $a + b = c,\ Q < 0$ ⑤ $a + b > c,\ Q < 0$ ⑥ $a + b < c,\ Q < 0$

Q9 Electrolysis was carried out using the device shown in the following figure with a direct current of 2.00 A for 32 min 10 sec. From ①-⑥ in the table below choose the combination of the closest values for the volume (L) of the gas generated at electrode I at the standard state and the mass (g) of the metal deposited at electrode IV. **9**



	Volume (L) of gas generated at electrode I	Mass (g) of metal deposited at electrode IV
①	0.224	0.640
②	0.224	1.28
③	0.448	0.640
④	0.448	1.28
⑤	0.896	0.640
⑥	0.896	1.28

Q10 The unit cell of crystals of sodium chloride (NaCl) is, as shown in the following figure, a cube with a side of 0.564 nm formed by arranging sodium ions (Na^+) and chloride ions (Cl^-).



From the following ①-⑤ choose the closest value for the density of sodium chloride. Regard $0.564^3 = 0.179$. $\boxed{10}$ g/cm^3

① 1.1 ② 1.6 ③ 1.9 ④ 2.2 ⑤ 3.1

Q11 In the following oxidation-reduction reaction, H_2O_2 acts as either an oxidizing agent or a reducing agent.

$$2KMnO_4 + 5H_2O_2 + 3H_2SO_4 \longrightarrow 2MnSO_4 + 5O_2 + 8H_2O + K_2SO_4$$

Among the following reaction formulas (**a**)-(**e**), there are two in which the underlined substance acts in a similar manner to H_2O_2 in the above oxidation-reduction reaction. From ①-⑦ below choose the correct combination. $\boxed{11}$

(**a**) $\underline{MnO_2} + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2$

(**b**) $\underline{H_2O_2} + 2KI + 2HCl \longrightarrow 2KCl + 2H_2O + I_2$

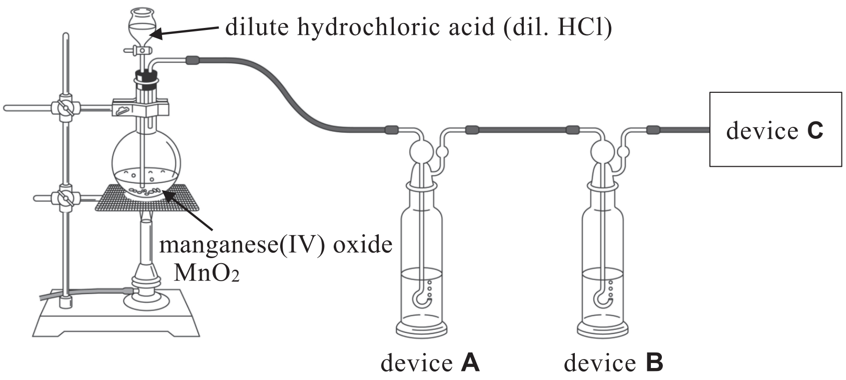
(**c**) $\underline{Zn} + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

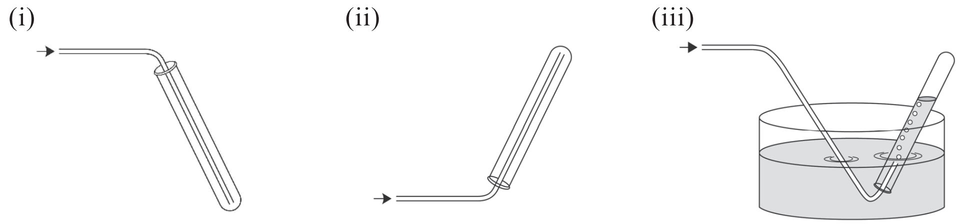
(**d**) $\underline{SO_2} + I_2 + 2H_2O \longrightarrow 2HI + H_2SO_4$

(**e**) $\underline{SO_2} + 2H_2S \longrightarrow 3S + 2H_2O$

① **a**, **b**	② **a**, **d**	③ **b**, **c**	④ **b**, **d**
⑤ **b**, **e**	⑥ **c**, **d**	⑦ **c**, **e**	

Q12 Chlorine (Cl_2) is generated with the aid of the apparatus shown in the following figure. The generated chlorine is passed through liquids in devices **A** and **B**, and is collected by device **C**. Device **C** is either (i), (ii), or (iii) shown below. From ①-⑥ in the table below, choose the correct combination of the liquid in device **A**, the liquid in device **B**, and device **C**. **12**





	Liquid in device **A**	Liquid in device **B**	Device **C**
①	water	conc. H_2SO_4	i
②	water	conc. H_2SO_4	ii
③	water	conc. H_2SO_4	iii
④	conc. H_2SO_4	water	i
⑤	conc. H_2SO_4	water	ii
⑥	conc. H_2SO_4	water	iii

conc. H_2SO_4 (concentrated sulfuric acid)

Q13 From ①-⑥ in the table below choose the combination of substances both of which are compatible with the following statements (**a**) and (**b**), respectively. **13**

(**a**) The material is a black-purple crystal composed of covalent bonds between the same atoms. The solid sublimates and does not conduct electricity.

(**b**) The material is composed of double bonds between two different atoms. It is a gas at normal temperature and pressure, and sublimates in the solid state.

	a	**b**
①	iodine	ammonia
②	iodine	carbon dioxide
③	diamond	water
④	diamond	ammonia
⑤	graphite	carbon dioxide
⑥	graphite	water

Q14 From the following chemical formulas ①-⑤ choose the one that does **not** take place judging from the ionization tendencies of the metals. **14**

① $Fe + Hg^{2+} \longrightarrow Fe^{2+} + Hg$

② $Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu$

③ $2Ag + Zn^{2+} \longrightarrow 2Ag^{+} + Zn$

④ $Zn + Pb^{2+} \longrightarrow Zn^{2+} + Pb$

⑤ $Mg + Cu^{2+} \longrightarrow Mg^{2+} + Cu$

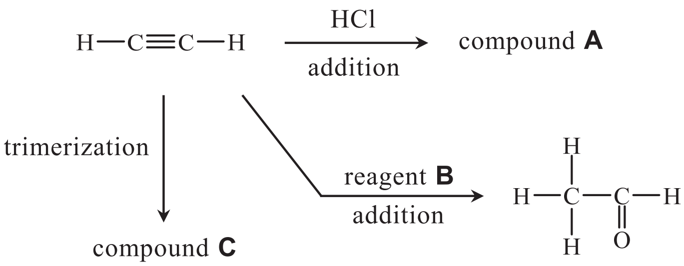
Q15 The following procedures **A** and **B** were applied to an aqueous solution containing three kinds of metal ions Al^{3+}, Fe^{3+}, and Zn^{2+}. What metal ion is contained in filtrates **X** and **Y** obtained by procedures **A** and **B**, respectively? From ①-⑥ in the table below choose the correct combination. **15**

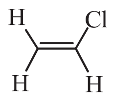
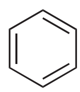
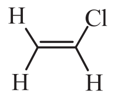
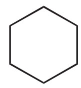
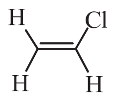
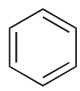
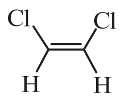
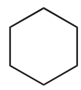
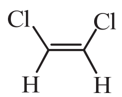
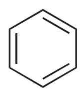
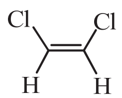
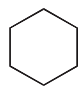
Procedure **A** : Aqueous ammonia (NH_3 aq) was added in excess, and the precipitates formed were filtered off to obtain filtrate **X**.

Procedure **B** : To the precipitates obtained by procedure **A**, aqueous sodium hydroxide (NaOH aq) was added in excess, and the precipitates remained intact were filtered off to obtain filtrate **Y**.

	Metal ion included in filtrate **X**	Metal ion included in filtrate **Y**
①	Al^{3+}	Fe^{3+}
②	Al^{3+}	Zn^{2+}
③	Fe^{3+}	Al^{3+}
④	Fe^{3+}	Zn^{2+}
⑤	Zn^{2+}	Al^{3+}
⑥	Zn^{2+}	Fe^{3+}

Q16 The following chart describes the reaction path of compounds obtained from acetylene (ethyne). From ①-⑥ in the table below choose the correct combination of substances corresponding to **A**, **B**, and **C**. $\boxed{16}$



	A	B	C
①		H_2O	
②		H_2O	
③		O_2	
④		O_2	
⑤		CH_3OH	
⑥		CH_3OH	

Q17 From the following reactions ①-④ choose the one which occurs for only one out of the following four kinds of compounds: ethanol (CH_3CH_2OH), acetaldehyde (CH_3CHO), acetone (CH_3COCH_3), and formic acid ($HCOOH$). **17**

① A gas is generated when sodium hydrogencarbonate ($NaHCO_3$) is added.

② A gas is generated when metallic sodium (Na) is added.

③ Silver (Ag) deposits when ammoniacal silver nitrate solution is added and heated.

④ Yellow precipitates are formed when iodine (I_2) and aqueous sodium hydroxide (NaOH) are added and heated.

Q18 Concerning compounds which contain a benzene ring and are represented by the molecular formula C_7H_8O, from ①-⑥ in the table below choose the correct combination of numbers which agree with the following (**a**)-(**c**) on the isomers of this compound. **18**

(**a**) the number of all isomers

(**b**) the number of isomers possessing a hydroxy group

(**c**) the number of isomers which react with aqueous iron(III) chloride ($FeCl_3$) and exhibits coloration

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

Q19 From the following ①-⑤ choose the correct structure that is contained in both ethyl acetate and poly(ethylene terephthalate). $\boxed{19}$

① $-CH_2-O-CH_2-$

② $-O-CH_2-O-$

③ $-CH_2-\underset{\underset{\displaystyle O}{\|}}{C}-CH_2-$

④ $-\underset{\underset{\displaystyle O}{\|}}{C}-O-$

⑤ $-\underset{\underset{\displaystyle H}{|}}{N}-\underset{\underset{\displaystyle O}{\|}}{C}-$

Q20 From ①-⑥ below choose the combination of statements (**a**)-(**d**) which are compatible for both starch and cellulose. $\boxed{20}$

(**a**) Their molecular formulas are $(C_6H_{10}O_5)_n$.

(**b**) They have helical structures.

(**c**) They are hydrolyzed to glucose when an acid is added and heated.

(**d**) They have reducing ability and are positive to the silver mirror test.

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

End of Chemistry questions. Leave the answer spaces $\boxed{21}$ ～ $\boxed{75}$ blank.
Please check once more that you have properly marked the name of your subject as “Chemistry” on your answer sheet.

Do not take this question booklet out of the room.

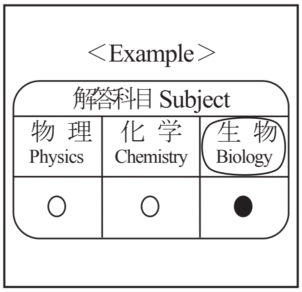
Biology

Marking Your Choice of Subject on the Answer Sheet

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

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

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



Q1 The following statements describe the structure of cells. Which statement applies to all prokaryotic and eukaryotic cells? From ①–⑤ below choose the correct answer. $\boxed{1}$

① The cells have cell walls.

② Cell membranes are present in the cells and their main component is phospholipid.

③ The nucleus is enclosed by the nuclear membrane and contains DNA.

④ Chloroplasts are present in the cells.

⑤ Mitochondria are present in the cells.

Q2 From ①–⑤ below choose the statement that does **not** correctly describe proteins. $\boxed{2}$

① Proteins referred to as enzymes catalyze various chemical reactions that occur in living organisms.

② When heated to above 60°C, most proteins undergo a change in their primary structure due to the heat, and thus lose their function.

③ Proteins are the second most abundant substance among the substances that form the body of animals.

④ Many proteins can also be denatured by strong acids or alkalis.

⑤ Proteins are synthesized on the ribosomes in cells.

Q3 From ①–⑤ below choose the statement that does **not** correctly describe chloroplasts. $\boxed{3}$

① Chloroplasts are enclosed in a double membrane.

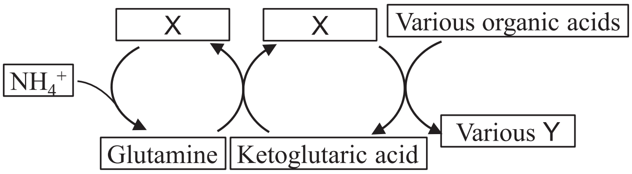
② Reactions involving Photosystems Ⅰ and Ⅱ take place in thylakoid membranes.

③ Carotene and chlorophyll a are present in the stroma.

④ The Calvin-Benson cycle takes place in the stroma.

⑤ Chloroplasts proliferate through division in the cell.

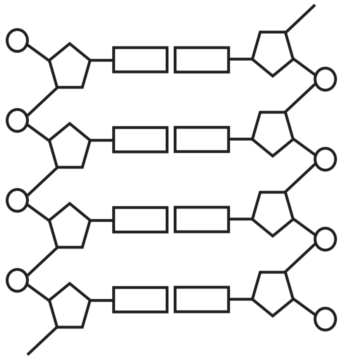
Q4 The following figure shows part of the process of nitrogen assimilation in plants. From ①–⑥ below choose the combination that correctly indicates the names of substances X and Y in the figure. **4**



	X	Y
①	glutamic acid	nucleic acids
②	glutamic acid	amino acids
③	glutamic acid	proteins
④	phenylalanine	nucleic acids
⑤	phenylalanine	amino acids
⑥	phenylalanine	proteins

Q5 From ①–④ below choose the figure that is a correct schematic representation of the structure of DNA. In the figures, ○ represents a phosphate, ⬠ represents a sugar, and ▭ represents a base. $\boxed{5}$

①



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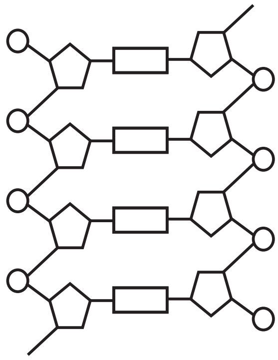

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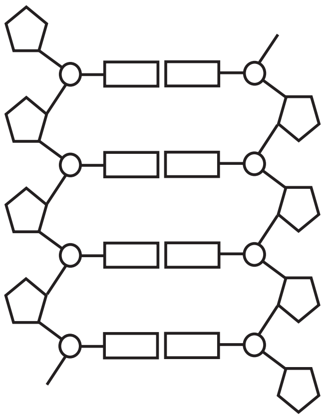
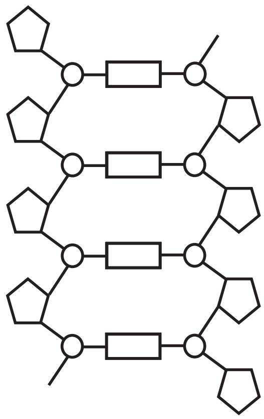


④



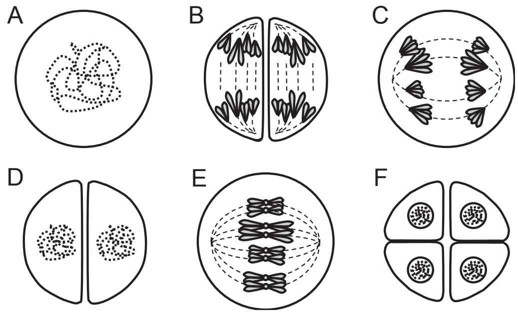
Q6 The following paragraph describes part of the process of transcription in eukaryotes. From ①–④ below choose the combination of terms that correctly fills blanks $\boxed{a}$ and $\boxed{b}$ in the paragraph.

$\boxed{6}$

The genetic information of organisms is stored as DNA base sequences. A DNA base sequence is copied to an RNA base sequence through transcription. This process begins when $\boxed{a}$ recognizes and binds to a specific base sequence of the DNA called the $\boxed{b}$.

	a	b
①	DNA polymerase	promoter
②	DNA polymerase	operator
③	RNA polymerase	promoter
④	RNA polymerase	operator

Q7 Figures A – F below schematically represent observations of the various phases of meiosis in a certain angiosperm. Answer questions (1) and (2) below concerning this.



(1) From ① – ⑥ below choose the answer that correctly arranges figures A – F in the order of progression of meiosis. **7**

① A → C → E → B → D → F

② A → C → E → D → B → F

③ A → E → C → B → D → F

④ A → E → C → D → B → F

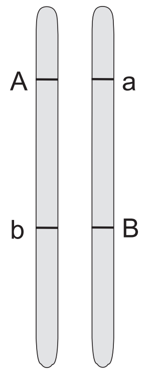
⑤ E → C → A → B → D → F

⑥ E → C → A → D → B → F

(2) From ①– ⑥ below choose the combination that correctly indicates the number of chromosomes per somatic cell and the number of chromosomes per cell in phase F for this plant. **8**

	No. of chromosomes per somatic cell	No. of chromosomes per cell in phase F
①	16	8
②	16	4
③	8	4
④	8	2
⑤	4	2
⑥	4	1

Q8 For a certain plant with the genotype *AaBb*, the two pairs of alleles A(a) and B(b) are located on the chromosomes as shown in the following figure. From ①–⑤ below choose the answer that correctly indicates the phenotypic segregation ratio in the offspring produced by self-fertilization of this plant. A and B are dominant over a and b, respectively. Assume that recombination does not occur between genes A and b, nor between a and B. **9**



① [AB] : [Ab] : [aB] : [ab] = 0 : 1 : 1 : 0

② [AB] : [Ab] : [aB] : [ab] = 9 : 3 : 3 : 1

③ [AB] : [Ab] : [aB] : [ab] = 2 : 1 : 1 : 0

④ [AB] : [Ab] : [aB] : [ab] = 3 : 0 : 0 : 1

⑤ [AB] : [Ab] : [aB] : [ab] = 0 : 3 : 1 : 0

Q9 Angiosperms undergo double fertilization, as two sperm cells are formed in the pollen tube. From ①–⑤ below choose the statement that correctly describes this. **10**

① Both two sperm cells fuse with the egg cell to form a fertilized egg.

② Both two sperm cells fuse with the central cell to form endosperm.

③ Both two sperm cells fuse with an antipodal cell and eventually degenerate.

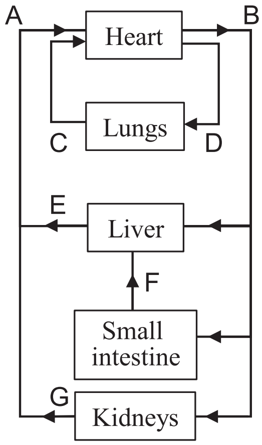
④ One sperm cell fuses with the egg cell to form a fertilized egg, and the other fuses with the central cell to form endosperm.

⑤ One sperm cell fuses with the central cell to form endosperm, and the other fuses with an antipodal cell and eventually degenerates.

Q10 The following figure schematically represents the human circulatory system. The arrows indicate the direction of blood flow.

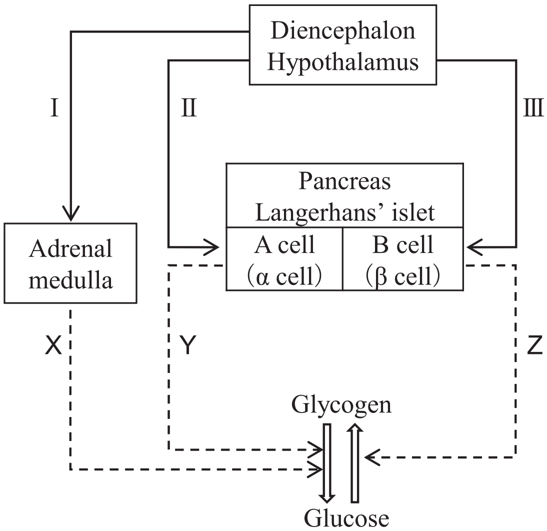
For a healthy human, which of A – G in the figure corresponds with the blood vessel X in which the blood of the highest oxygen concentration flows, and with the blood vessel Y in which the blood of the highest blood glucose level flows after eating? From ①– ⑧ below choose the best combination.

11



	Blood vessel X	Blood vessel Y
①	A	E
②	A	G
③	B	C
④	B	G
⑤	C	B
⑥	C	F
⑦	D	B
⑧	D	F

Q11 The following figure schematically represents part of the process by which the human body maintains the blood glucose level constant. Answer questions (1) and (2) below concerning this.



(1) Arrows I – III in the figure represent autonomic nerves involved in the regulation of blood glucose level. From ①–⑥ below choose the combination that correctly identifies the names of I , II and III. **12**

	I	II	III
①	sympathetic nerve	sympathetic nerve	parasympathetic nerve
②	sympathetic nerve	parasympathetic nerve	sympathetic nerve
③	sympathetic nerve	parasympathetic nerve	parasympathetic nerve
④	parasympathetic nerve	sympathetic nerve	sympathetic nerve
⑤	parasympathetic nerve	sympathetic nerve	parasympathetic nerve
⑥	parasympathetic nerve	parasympathetic nerve	sympathetic nerve

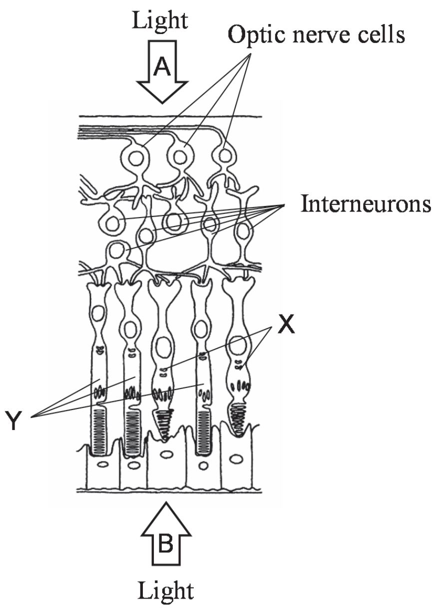
(2) Arrows X – Z in the figure represent hormones involved in the regulation of blood glucose level. From ①– ⑥ below choose the combination that correctly identifies the names of X, Y and Z.

13

	X	Y	Z
①	adrenaline	insulin	glucagon
②	adrenaline	glucagon	insulin
③	insulin	adrenaline	glucagon
④	insulin	glucagon	adrenaline
⑤	glucagon	adrenaline	insulin
⑥	glucagon	insulin	adrenaline

Q12 The following figure schematically represents a cross section of the human retina. From ①–④ below choose the combination of terms that correctly fills blanks $\boxed{X}$ – $\boxed{Z}$ in the following paragraph describing the figure. **14**

There are two types of visual cells that receive light: $\boxed{X}$, which are involved in color vision, and $\boxed{Y}$, which can function even in dim light. Of the two arrows A and B in the figure, arrow $\boxed{Z}$ shows the direction from which light enters the retina.



	X	Y	Z
①	rod cells	cone cells	A
②	rod cells	cone cells	B
③	cone cells	rod cells	A
④	cone cells	rod cells	B

Q13 From ①–④ below choose the statement that correctly describes muscle contraction. **15**

① In muscle contraction, myosin functions to break down ATP.

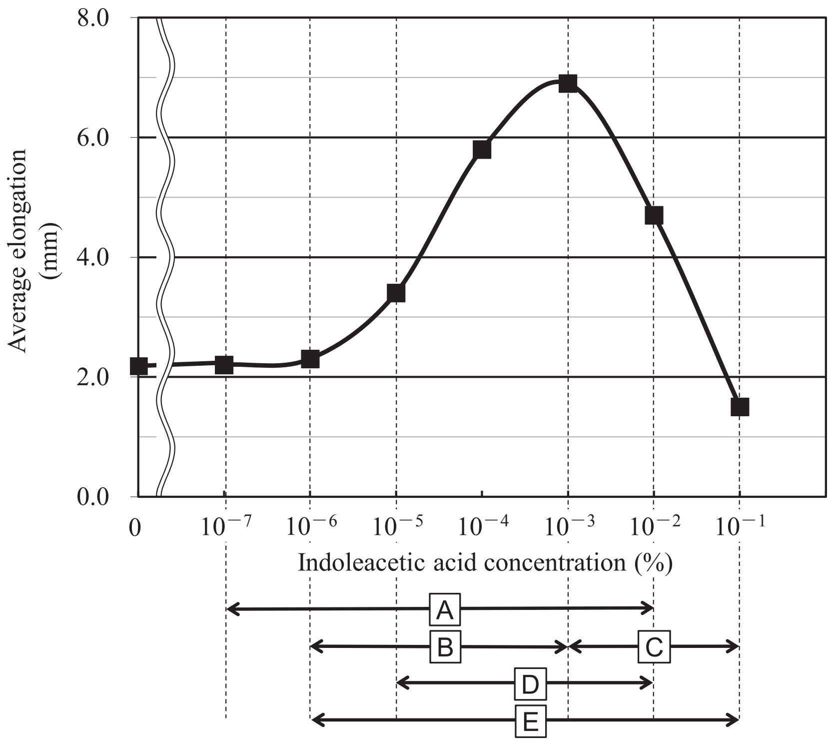
② In muscle contraction, tropomyosin functions as a motor protein for actin.

③ The regions occupied by myosin filaments in sarcomeres are called light bands.

④ When a muscle contracts, the dark bands shorten.

Q14 Oat coleoptile sections were prepared by removing 5 mm from the tip and cutting at 10 mm from the top-end to cut out a 10-mm section. Five sections each were immersed in distilled water or indoleacetic acid solutions ranging in concentration from 10^{-7} % to 10^{-1} %, and were cultured in dark for 24 hours. The length of the sections was then measured for each concentration. The table below shows the average length of elongation in each case, and the graph was drawn based on the result. Among the ranges labelled A – E below the graph, which represents the range of indoleacetic acid concentration in which the degree of elongation increases as the concentration increases? From ① – ⑤ below choose the correct answer. **16**

	Distilled water	Indoleacetic acid concentration (%)						
		10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}
Average elongation (mm)	2.1	2.2	2.3	3.4	5.8	6.9	4.7	1.5



① A　　② B　　③ C　　④ D　　⑤ E

Q15 The following paragraph describes material production and consumption in ecosystems. From ①–⑥ below choose the combination of terms that best fills blanks $\boxed{a}$ – $\boxed{c}$ in the paragraph.

17

The total quantity of organic matter created by producers in an ecosystem is called the $\boxed{a}$. When $\boxed{b}$ is subtracted from $\boxed{a}$, the remainder is called the $\boxed{c}$.

	a	b	c
①	gross primary production	growth	net primary production
②	gross primary production	growth	standing stock
③	gross primary production	respiration	net primary production
④	gross primary production	respiration	standing stock
⑤	net primary production	growth	standing stock
⑥	net primary production	respiration	standing stock

Q16 Items a – d below are events that occurred in the history of life. From ①– ⑥ below choose the answer that correctly arranges these events in chronological order. **18**

a　Colonization of land by vertebrates

b　Colonization of land by plants

c　Extinction of dinosaurs

d　Flourishing of mammals

① a → b → c → d

② a → c → b → d

③ a → d → b → c

④ b → a → c → d

⑤ b → a → d → c

⑥ b → c → a → d

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.