2010 年度日本政府（文部科学省）奨学金留学生選考試験

QUALIFYING EXAMINATION FOR APPLICANTS FOR JAPANESE

GOVERNMENT (MONBUKAGAKUSHO) SCHOLARSHIPS 2010

学科試験　　問題

EXAMINATION QUESTIONS

（学部留学生）

UNDERGRADUATE STUDENTS

物　　理

PHYSICS

注意　☆試験時間は 60 分。

PLEASE NOTE : THE TEST PERIOD IS 60 MINUTES.

Physics

$\boxed{\text{I}}$ Answer questions **A** (Q1), **B** (Q2), **C** (Q3), **D** (Q4), **E** (Q5), **F** (Q6) and **G** (Q7) on pages 2-8, where g denotes the magnitude of acceleration due to gravity and air resistance is negligible.

A As shown in Figure 1, two tanks of different cross-sectional areas are connected by a pipe. The tanks are filled with water, and openings A and B are tightly sealed with pistons that can move without friction. Initially, both pistons are in equilibrium at the same height. The cross-sectional area of B is n times larger than that of A.
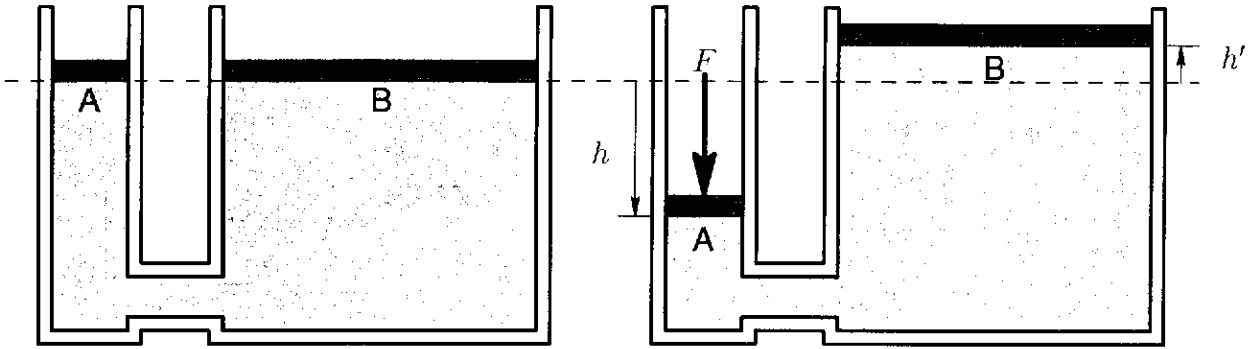
Figure 1   Figure 2

Q1 As shown in Figure 2, a force of magnitude F is applied vertically downward to the piston at A, causing it to move downward by distance h. As a result, the piston at B moves upward by distance h'. Next, a force of magnitude F' is applied vertically downward to the piston at B. As a result, both pistons return to their original positions shown in Figure 1. From ①-⑨ below choose the combination that correctly expresses h' and F'. ⬚**1**

	①	②	③	④	⑤	⑥	⑦	⑧	⑨
h'	$\dfrac{h}{\sqrt{n}}$	$\dfrac{h}{\sqrt{n}}$	$\dfrac{h}{\sqrt{n}}$	$\dfrac{h}{n}$	$\dfrac{h}{n}$	$\dfrac{h}{n}$	$\dfrac{h}{n^2}$	$\dfrac{h}{n^2}$	$\dfrac{h}{n^2}$
F'	$\sqrt{n}F$	nF	n^2F	$\sqrt{n}F$	nF	n^2F	$\sqrt{n}F$	nF	n^2F

B As shown in Figure 1, two people of the same height are holding up a box attached to a pole. The center of gravity of the pole and the box is located at point G. The pole is supported at points A and B. The pole and the box do not change form.
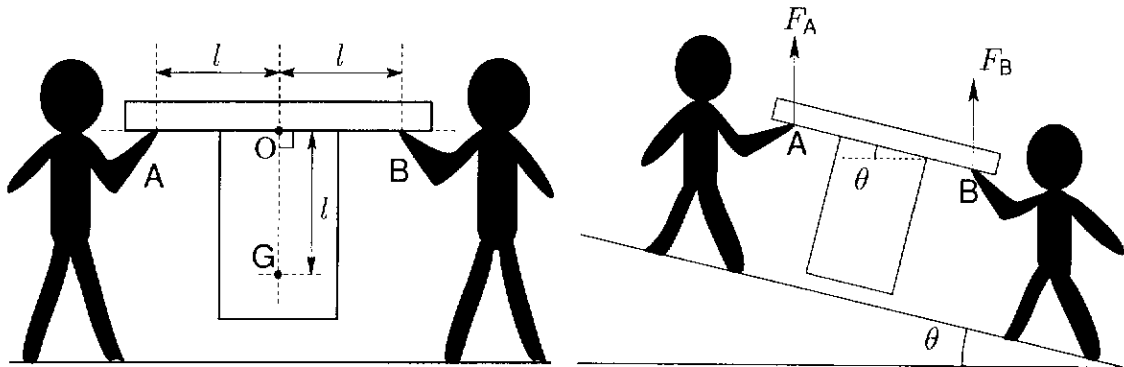

Figure 1   Figure 2

Q2 As shown in Figure 2, the two people are now standing on a slope inclined by angle θ $(< \frac{\pi}{4})$ from the horizontal. The person supporting the upper end at A exerts a force of magnitude of F_A vertically upward. The person supporting the lower end at B exerts a force of magnitude of F_B vertically upward. What is the value of the ratio $\frac{F_A}{F_B}$?   From ①-⑥ below choose the correct answer.

$\boxed{2}$

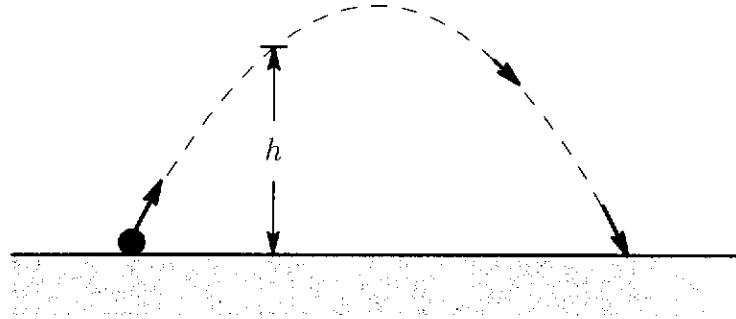① $\dfrac{1 + \cos\theta}{1 - \cos\theta}$ ② $\dfrac{1 - \cos\theta}{1 + \cos\theta}$ ③ $\dfrac{1 + \sin\theta}{1 - \sin\theta}$

④ $\dfrac{1 - \sin\theta}{1 + \sin\theta}$ ⑤ $\dfrac{1 + \tan\theta}{1 - \tan\theta}$ ⑥ $\dfrac{1 - \tan\theta}{1 + \tan\theta}$

C As shown in the figure below, a ball is launched diagonally upward from a horizontal ground. The time at launch is 0. After passing through a point at height h at time t, the ball lands at time T.

Q3 What is the height h? From ①-⑤ below choose the correct answer. $\boxed{\textbf{3}}$

① $\dfrac{1}{2}gt^2$ ② $\dfrac{1}{2}gtT$ ③ $\dfrac{1}{2}gT(T-t)$

④ $\dfrac{1}{2}gt(T-t)$ ⑤ $\dfrac{1}{2}g(T-t)^2$

D Consider two springs of negligible mass that have the same natural length (50 cm) and the same spring constant. As shown in Figure 1, the two springs are joined together, and then are suspended vertically, with the lower end also fixed in place. Next, as shown in Figure 2, when small object A (mass: 500 g) is attached at the point where the springs are joined, object A descends 20 cm and comes to rest.
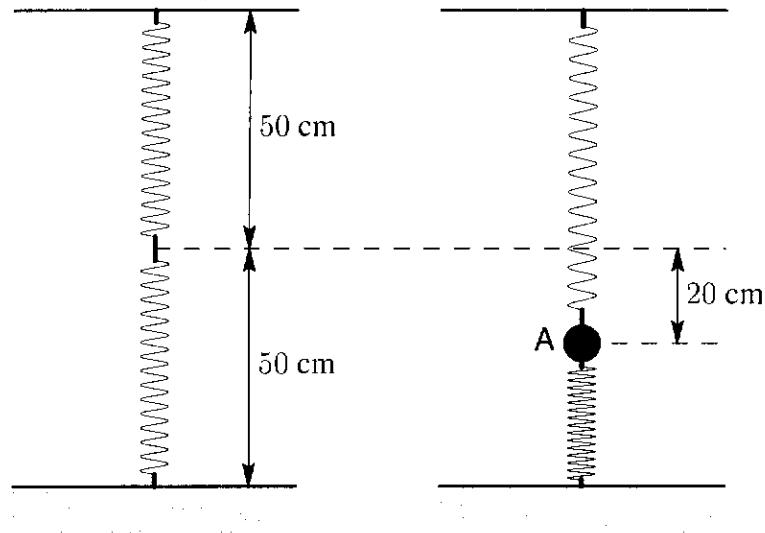
50 cm

50 cm

20 cm

A

Figure 1   Figure 2

Q4 A is pulled downward and released gently. How much time elapses from release until A reaches its maximum height? From ①-⑥ below choose the best answer, where $g = 9.8\text{m/s}^2$. ⟦4⟧ seconds
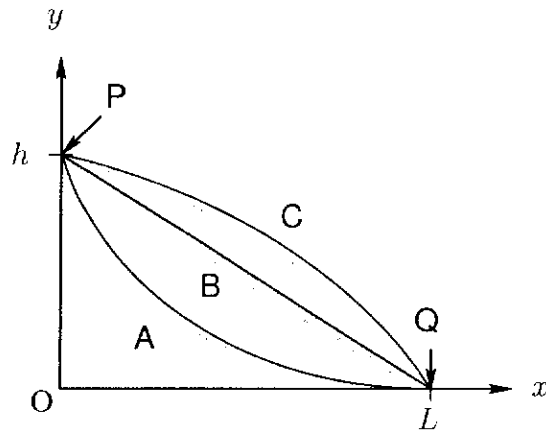
① 0.15   ② 0.30   ③ 0.45

④ 0.60   ⑤ 0.90   ⑥ 1.2

E The figure below shows three different types of slides, A, B, and C. Their friction is negligible. The coordinate system is taken with the x-axis horizontal and the y-axis vertically upward. An object, initially at rest, is made to slide down each slide, from starting point P $(0, h)$ to lowest point Q $(L, 0)$.

Q5 The object's x-coordinate is x, and its kinetic energy is K. How does K change with x when x changes from 0 to L? From ①-④ below choose the graph that best indicates this change for A, B, and C.

$\boxed{5}$
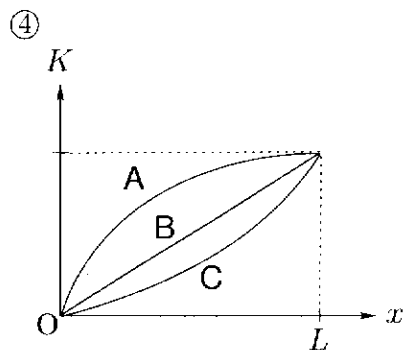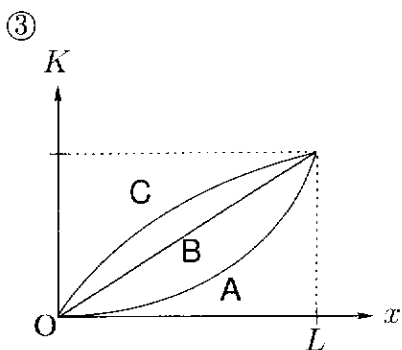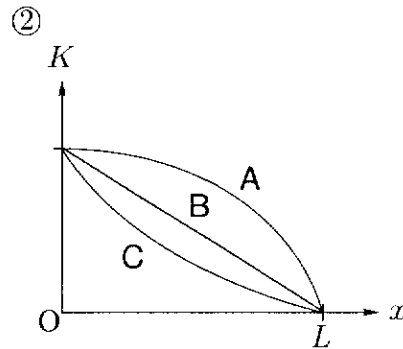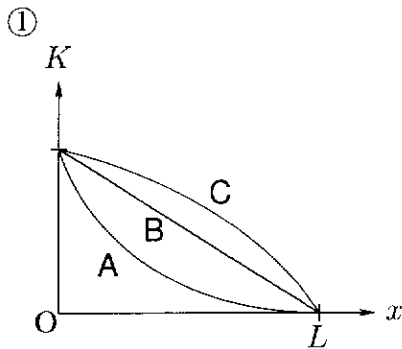
F As shown in Figure 1, a thin, lightweight rubber string is suspended from a ceiling. When a weight (mass: 500 g) is attached to the lower end, it descends 10 cm and comes to rest, as shown in Figure 2. Next, as shown in Figure 3, the weight is pulled down 20 cm, where it touches the floor. The string's restoring force is proportional to the string's extension from its natural length. The restoring force is not exerted when the string is at less than its natural length.

10 cm

500 g

20 cm

Figure 1   Figure 2   Figure 3
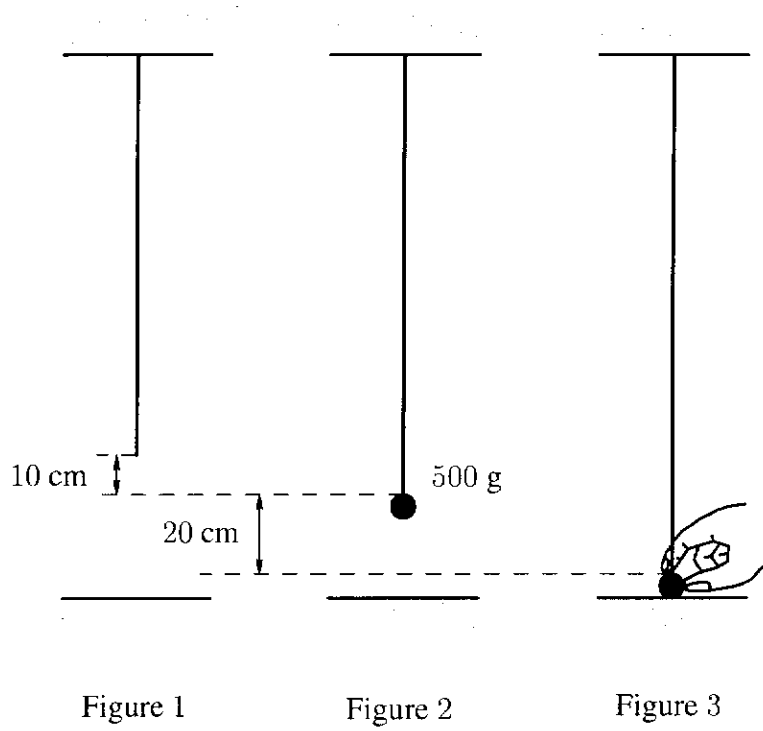
Q6 When the weight is gently released from its position shown in Figure 3, what maximum height (from the floor) does it attain? From ①-⑥ below choose the best answer, where $g = 9.8\text{m/s}^2$.

| 6 | cm

① 20   ② 30   ③ 40

④ 45   ⑤ 50   ⑥ 60

G As shown in the figure below, an artificial satellite is traveling in a circular orbit around the earth. The radius of the orbit from the earth's center is r. Assume that the earth is a uniform sphere with a radius of R. The magnitude of acceleration due to gravity at the earth's surface is g.

Artificial satellite
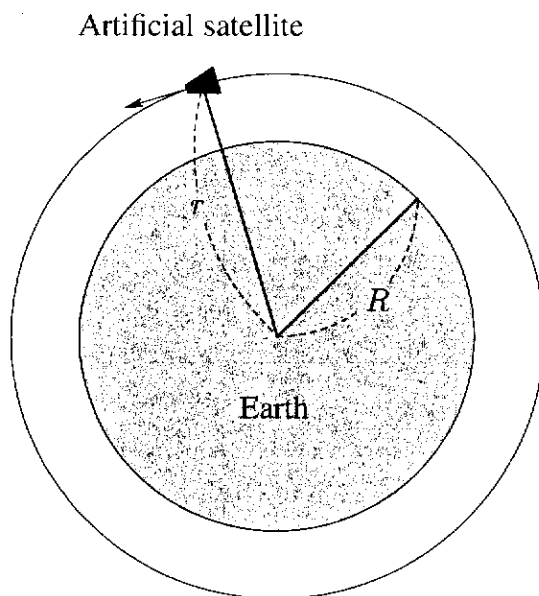
Q7 What is the period of the satellite's orbital motion? From ①-④ below choose the correct answer. $\boxed{7}$

① $2\pi \dfrac{r}{\sqrt{gR}}$

② $2\pi \dfrac{R}{\sqrt{gr}}$

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

④ $2\pi \dfrac{R}{r}\sqrt{\dfrac{R}{g}}$

Answer the following questions **A** (Q1), **B** (Q2) and **C** (Q3).

A A copper container (mass: 100 g) holds 200 g of water. The temperature of the container and water is 20 ℃.

Q1 A 150-g piece of copper heated to 80 ℃ is placed in the water. The water is stirred thoroughly. After sufficient time elapses, to what temperature does the water change? From ①-⑤ below choose the best answer. Assume that no heat is transferred to or from the environment. The specific heat of water is 4.2 J/g·K, and the specific heat of copper is 0.40 J/g·K.

$\boxed{8}$ ℃

① 23   ② 24   ③ 25

④ 26   ⑤ 27

B As shown in the figure below, an enclosed cylindrical container (cross-sectional area: S) is divided into two sections (**A**, **B**) by a piston (**P**). The length of each section is 10 cm. Each section contains a monatomic ideal gas at temperature 0 ℃ and pressure 1.0×10^5 Pa (both contain the same type of gas). The gas in **B** is in contact with a thermostatic bath at temperature 0 ℃, and does not change in temperature. The piston and container do not conduct heat. The area of contact between the piston and the container is tightly sealed and frictionless.
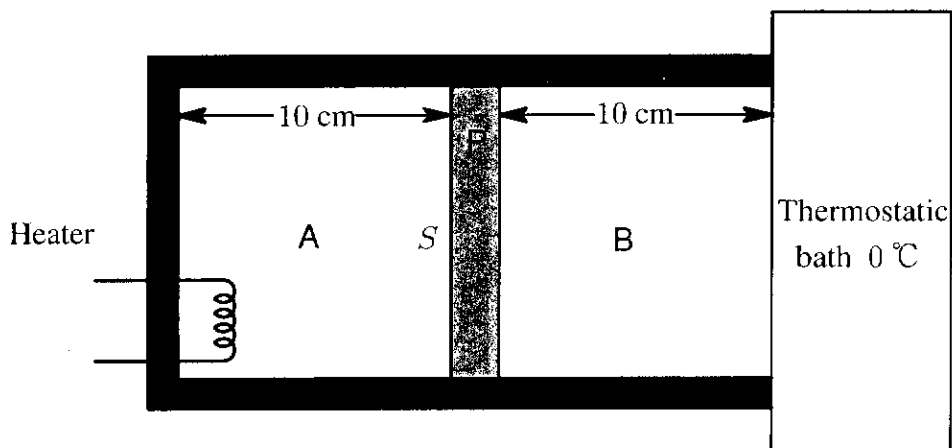
Q2 When the gas in A is heated to 57 ℃ using a heater, what distance is traveled by **P**? From ①-⑤ below choose the best answer.

$\boxed{9}$ cm

① 0.1

② 0.5

③ 1

④ 5

⑤ 10

C This question deals with the types of energy involved when a gasoline-powered automobile travels in a straight line on a level surface, and with how the energy is converted. Assume that brake friction is the only force involved in stopping the automobile.

From the time that an automobile begins moving until it reaches a constant speed, the [a] from gasoline is converted to [b] of the automobile. Then, when the brakes are applied to stop the automobile, the automobile's [b] is completely converted to [c] . When this happens, energy is lost to the environment and cannot be reused. From the perspective of saving energy, it is necessary to convert some of the energy of braking into a form that can be reused when accelerating the automobile.

Q3 From ①-⑧ below choose the combination of terms that best fills blanks [a] , [b] , and [c] in the paragraph above.   **10**

	a	b	c
①	heat	electrical energy	heat
②	heat	electrical energy	work
③	heat	kinetic energy	heat
④	heat	kinetic energy	work
⑤	chemical energy	electrical energy	heat
⑥	chemical energy	electrical energy	work
⑦	chemical energy	kinetic energy	heat
⑧	chemical energy	kinetic energy	work

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

A It is observed that the wave front of ocean waves takes on the same shape as the shoreline as the waves move toward the beach. In order to examine the reason for this, the following experiment is conducted.

As shown in Figure 1, a thick sheet of glass was submerged in a shallow tank filled with water. When plane waves were propagated from the deep side toward the shallow side, the wave-front pattern shown in Figure 2 was observed.
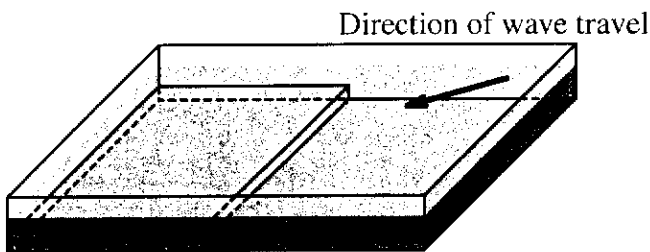
Figure 1
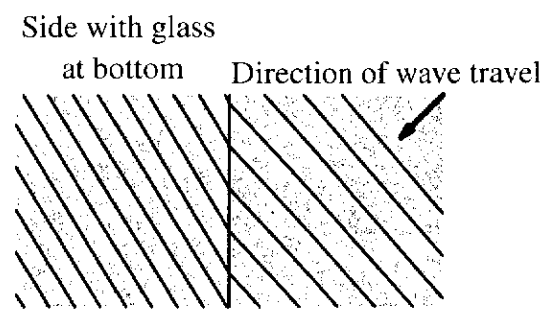
Figure 2　Wave-front pattern seen from above

Q1　Based on the result of the experiment above, what reason can be inferred for why the wave front takes on the same shape as the shoreline? From ①-⑤ below choose the best answer.

11

① Wave speed increases as water depth decreases.

② Wave speed decreases as water depth decreases.

③ Wave frequency increases as water depth decreases.

④ Wave frequency decreases as water depth decreases.

⑤ Wave speed and frequency remain constant even if water depth decreases.

B On cloudless winter nights, the sound from a distant sound source is sometimes heard more clearly than during the daytime.

Q2 Given the condition above, from ①-④ below choose the answer that correctly indicates the relationship between air temperature in the upper sky (t_h) and air temperature near the ground (t_g), and between the speed of sound in the upper sky (v_h) and the speed of sound near the ground (v_g). 　12

① $t_h < t_g$, 　 $v_h < v_g$

② $t_h < t_g$, 　 $v_h > v_g$

③ $t_h > t_g$, 　 $v_h < v_g$

④ $t_h > t_g$, 　 $v_h > v_g$

C As shown in Figures 1 and 2 below, light from a white light source passes through a slit and then passes through a prism (Fig. 1) or a diffraction grating (Fig. 2). As a result, a band of continuously varying colors appears between points a and b on the screen in Fig. 1 and between points c and d on the screen in Fig. 2.
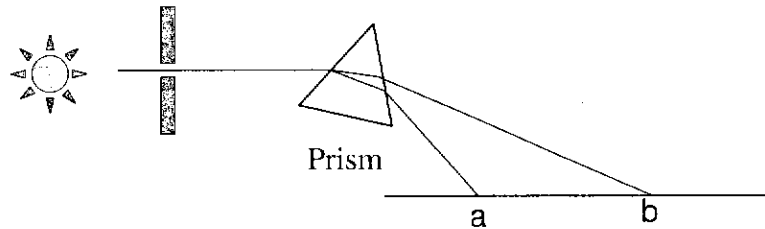
Prism
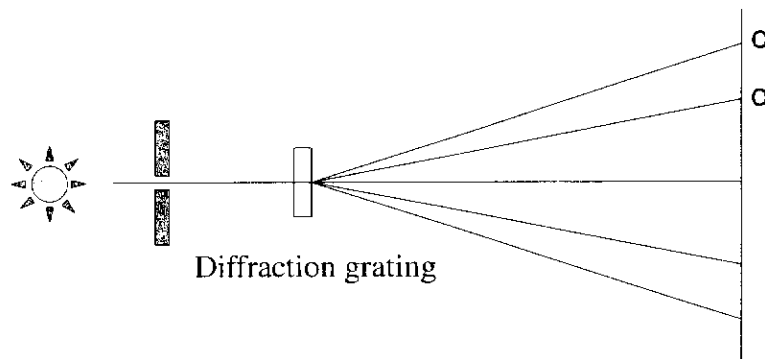
a   b

Figure 1   Dispersion of light by a prism

c
d

Diffraction grating

Figure 2   Dispersion of light by a diffraction grating

Q3 In the two experiments above, what color of light is observed at the edges of the colored bands on the screens (points a, b, and c, d)? From ①-④ below choose the correct combination. 13

	a	b	c	d
①	red	violet	red	violet
②	violet	red	violet	red
③	red	violet	violet	red
④	violet	red	red	violet

$\boxed{\text{IV}}$ Answer questions **A** (Q1), **B** (Q2), **C** (Q3), **D** (Q4), **E** (Q5) and **F** (Q6) below.

A As shown in the figure below, four electrical point charges ($+Q$, $-Q$, $+Q$, and $-Q$, where $Q > 0$) are fixed to the corners of a square insulator plate (side length: $4a$).
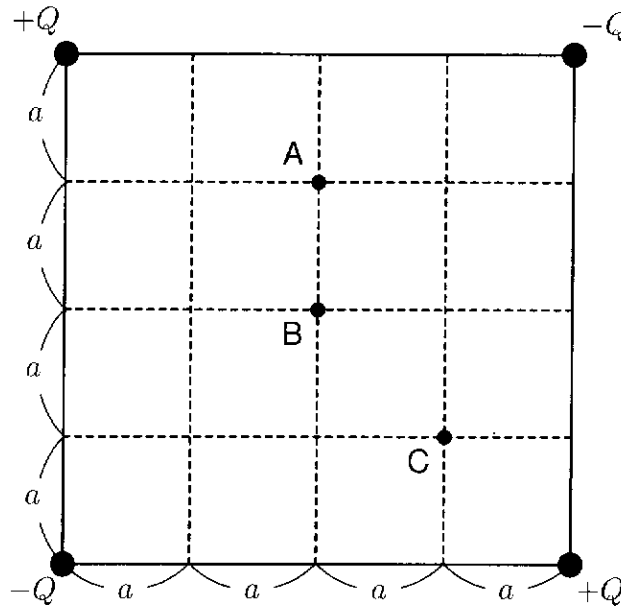
Q1 What is the relationship between the level of electrical potential V_A, V_B, and V_C at points **A**, **B**, and **C** in the figure? From ①-⑦ below choose the correct answer. $\boxed{14}$

① $V_A = V_B < V_C$

② $V_A = V_B > V_C$

③ $V_A < V_B = V_C$

④ $V_A > V_B = V_C$

⑤ $V_A = V_C < V_B$

⑥ $V_A = V_C > V_B$

⑦ $V_A < V_B < V_C$

B The parallel-plate capacitor shown in Figure 1 consists of two plates (each with area S) separated by a distance of $2d$. A charge of Q is stored in the capacitor. Next, as shown in Figure 2, an uncharged conductor of thickness d and area S is inserted between the capacitor's plates, parallel to them.
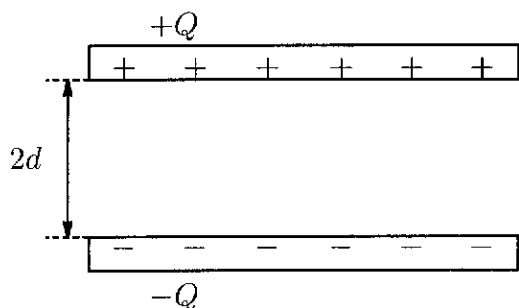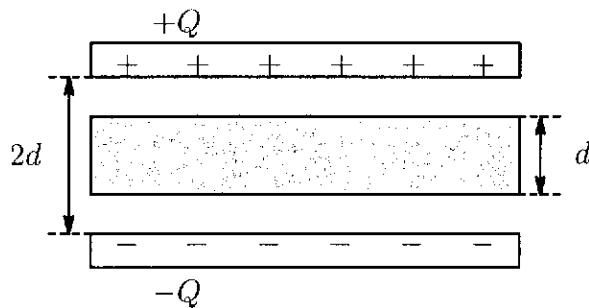

Figure 1   Figure 2

Q2 What is the ratio of the electrostatic energy in Figure 2 to the electrostatic energy in Figure 1? From ①-⑤ below choose the correct value.

| 15 |

① $\dfrac{1}{4}$ ② $\dfrac{1}{2}$ ③ 1

④ 2   ⑤ 4

C Figure 1 shows the relationship between voltage and current when voltage is applied to a certain light bulb. Next, as shown in Figure 2, the bulb is connected in series with a 12-V battery and a 5-Ω resistor.
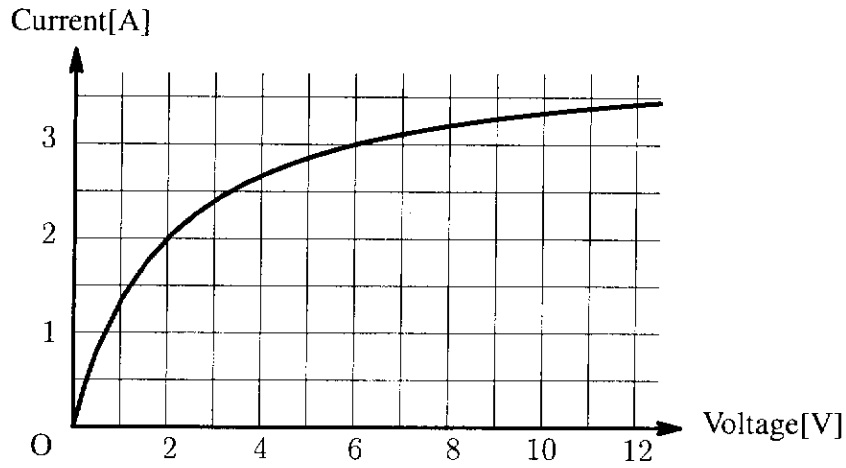
Current[A]

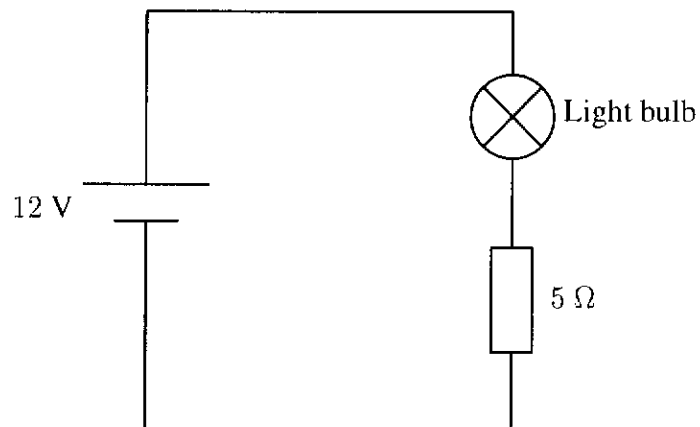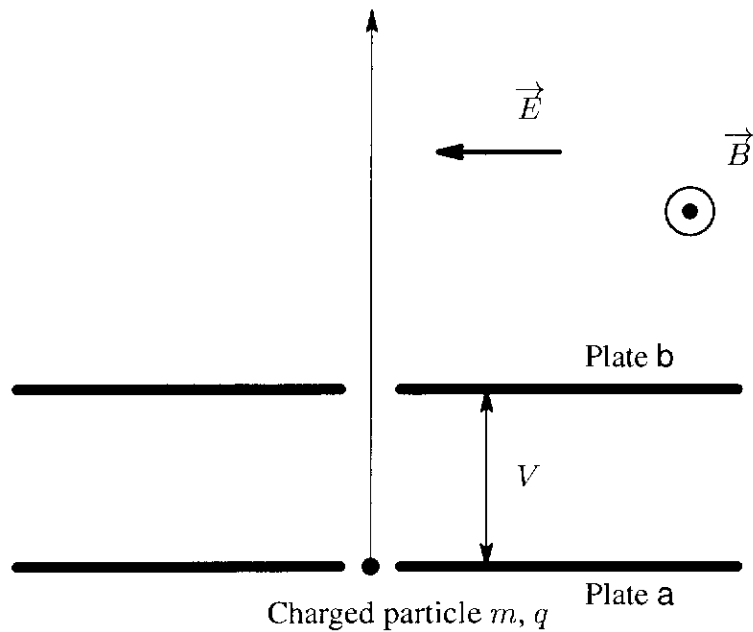Figure 1

Figure 2

Q3 What is the amount of power consumed by the light bulb? From ①-⑥ below choose the best answer. $\boxed{16}$ W

① 1   ② 4   ③ 10

④ 18   ⑤ 34   ⑥ 42

D As shown in the figure below, potential difference V exists between two parallel plates (a, b) that have a small hole. Uniform electric field $\vec{E}$ and magnetic flux density $\vec{B}$ exist in the region above the plates, and are perpendicular to each other. The direction of $\vec{E}$ is parallel to this page and plate b. The direction of $\vec{B}$ is perpendicular to this page, from back to front. A positively charged particle of charge q and mass m, initially at rest in the hole of plate a, is accelerated by potential difference V so that it enters the region above the plate perpendicularly to $\vec{E}$ and $\vec{B}$ and travels straight through the region.

Charged particle m, q Plate a

Q4 What is the ratio of the magnitude E of the electric field to the magnitude B of the magnetic flux density $\dfrac{E}{B}$? From ①-⑥ below choose the correct answer.   17

① $\sqrt{\dfrac{m}{2qV}}$ ② $\sqrt{\dfrac{2qV}{m}}$ ③ $\sqrt{\dfrac{m}{qV}}$

④ $\sqrt{\dfrac{qV}{m}}$ ⑤ $\sqrt{\dfrac{2m}{qV}}$ ⑥ $\sqrt{\dfrac{qV}{2m}}$

E As shown in the figure below, a current I passes through a straight conducting wire located within this page. Rectangular circuit ABCD on the page is moving away from the straight conducting wire with speed v, while side AB remains parallel with current I. The length of side AB is $2a$, and the length of side AD is $2b$. The resistance of the circuit is R.
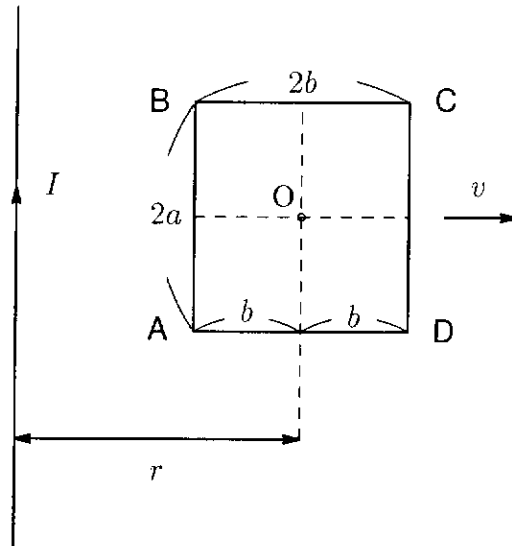
Q5 How much current flows through circuit ABCD when the center of the circuit (O) is distance r from the straight wire? From ①-⑥ below choose the correct answer. The magnetic permeability of a vacuum is μ_0, and the magnetic flux density created by the circuit's current is negligible. $\boxed{18}$

① $\dfrac{\mu_0 abvI}{\pi R(r^2 - b^2)}$

② $\dfrac{2\mu_0 abvI}{\pi R(r^2 - b^2)}$

③ $\dfrac{\mu_0 avI}{\pi R(r - b)}$

④ $\dfrac{2\mu_0 avI}{\pi R(r - b)}$
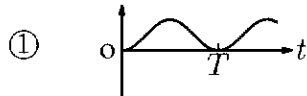
⑤ $\dfrac{\mu_0 avI}{\pi R(r + b)}$

⑥ $\dfrac{2\mu_0 avI}{\pi R(r + b)}$

F As shown in the figure below, a uniform magnetic field exists perpendicular to this page, in the direction from back to front. A coil is placed in the field, parallel to the page. At time $t = 0$, the coil (initially in the state shown) begins to rotate about its central axis at a constant angular velocity with period T. The direction of rotation is so that at $t = 0$ side BC moves from back to front of this page, and side DE moves from front to back.

Central axis

Direction of rotation
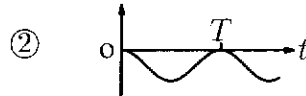
D ——————— C

Magnetic field
⊙

E ———— B

F A
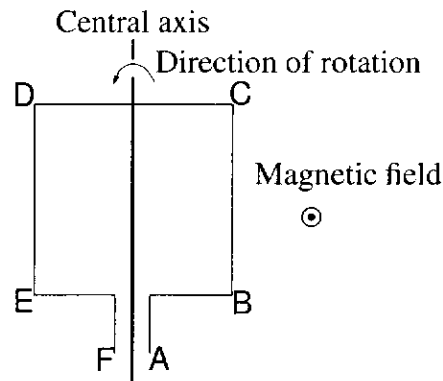
Q6 From ①-⑥ below choose the graph that best represents the change over time of the electromotive force generated in the coil. The positive direction of the electromotive force is the direction A → B → C → D → E → F. |19|

Electromotive force

① o ⌒⌒ t / T

Electromotive force

② o T ⌄⌄ t

Electromotive force

③ o ⌄⌒ T t

Electromotive force

④ o ⌄⌒ T t

Electromotive force

⑤ o ⌒⌒⌒ T t

Electromotive force

⑥ o ⌄⌄⌄ T t