

2024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 THE JAPANESE
GOVERNMENT (MEXT) SCHOLARSHIPS 2024

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.

(2024)

Physics

Nationality		No.		Marks	
Name	(Please print full name, underlining family name)				

Before you start, fill in the necessary details (nationality, examination number, name etc.) in the box at the top of this examination sheet and on the answer sheet.

For each question, select the correct answer and write the corresponding letter in the space provided on the answer sheet.

1. Answer the following questions.

- (1) As shown in Fig. 1-1, a block with mass m_A on a smooth horizontal surface is connected by a thin cord that passes over a pulley to another block with mass m_B , which hangs vertically. Ignore friction and the masses of the pulley and cord. The acceleration of gravity is denoted by g . Find the formula for the acceleration of the system.

- (a) $\frac{m_A + m_B}{m_A}g$ (b) $\frac{m_A + m_B}{m_B}g$ (c) $\frac{m_A}{m_A + m_B}g$
 (d) $\frac{2m_A}{m_A + m_B}g$ (e) $\frac{m_B}{m_A + m_B}g$ (f) $\frac{2m_B}{m_A + m_B}g$

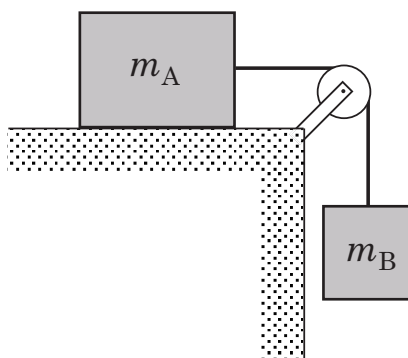


Fig. 1-1

- (2) A 1000-kg car moving in a straight line on a horizontal surface collides with a long coiled spring placed horizontally at a speed of 72 km/h and is brought to rest in a distance of 4.0 m. Find the spring stiffness constant of the spring.

- (a) 5.0×10^4 N/m (b) 5.0×10^5 N/m (c) 2.5×10^4 N/m
(d) 2.5×10^5 N/m (e) 2.0×10^4 N/m (f) 2.0×10^5 N/m

- (3) Find the equivalent capacitance between points A and B for the combination of capacitors shown in Fig. 1-2.

- (a) $\frac{11}{5}C$ (b) $\frac{12}{5}C$ (c) $\frac{12}{7}C$
(d) $\frac{12}{17}C$ (e) $7C$ (f) $\frac{17}{12}C$

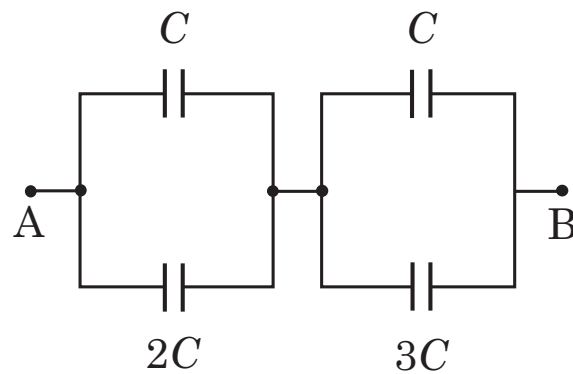


Fig. 1-2

2. A boat heads directly across a river with the width L as shown in Fig. 2-1. The river flows at speed u relative to the shore from left to right. The boat's speed in still water is v , which is larger than u . The boat starts from point P and reaches point R instead of Q because it is pulled downstream by the flow of the river. Answer the following questions.

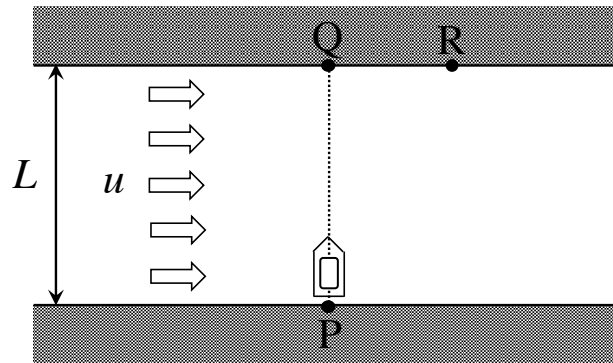


Fig. 2-1

- (1) Find the boat's velocity with respect to the shore.

- (a) v (b) u (c) $v + u$
 (d) $v - u$ (e) $\sqrt{v^2 + u^2}$ (f) $\sqrt{v^2 - u^2}$

- (2) Find the expression for the distance between Q and R.

- (a) $\frac{uL}{\sqrt{u^2 + v^2}}$ (b) $\frac{\sqrt{u^2 + v^2}L}{v}$ (c) $\frac{vL}{u}$
 (d) $\frac{\sqrt{v^2 - u^2}L}{v}$ (e) L (f) $\frac{uL}{v}$

The same boat heads upstream from point P at angle θ as shown in Fig. 2-2 and reaches point Q.

- (3) Find the expression for $\tan \theta$.

- (a) $\frac{u}{\sqrt{v^2 - u^2}}$ (b) $\frac{u}{\sqrt{v^2 + u^2}}$ (c) $\frac{v}{\sqrt{v^2 - u^2}}$
 (d) $\frac{v}{\sqrt{v^2 + u^2}}$ (e) $\frac{u}{v}$ (f) $\frac{v}{u}$

(4) How long does the boat take to cross the river?

- (a) $\frac{L}{v}$ (b) $\frac{L}{u}$ (c) $\frac{L}{v - u}$
- (d) $\frac{L}{v + u}$ (e) $\frac{L}{\sqrt{v^2 + u^2}}$ (f) $\frac{L}{\sqrt{v^2 - u^2}}$

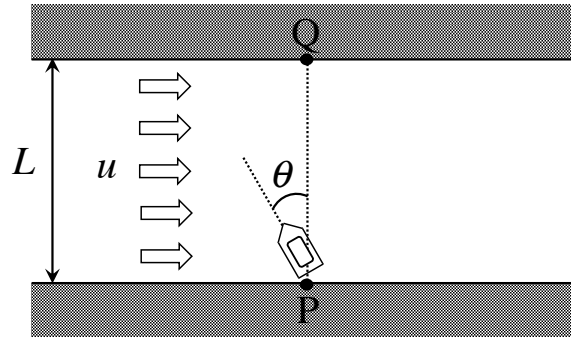


Fig. 2-2

3. A circuit is placed horizontally in a uniform magnetic field with magnetic flux density B , which is directed vertically upward, as shown in Figure 3. Here, XX' and YY' are sufficiently long and parallel with a distance l , connected to a variable resistor R and a battery of voltage V . The conducting rod PQ can move smoothly parallel to XY along XX' and YY' . An object of mass M is connected to PQ by a light string through a pulley. When the resistance of the variable resistor is set to R_0 , the object is at rest. When the resistance is set to $\frac{3}{4}R_0$, the object rises at a constant velocity after a long time. The acceleration of gravity is denoted by g . Answer the following questions.

- (1) Find the value of the current flowing in the circuit when the object is at rest.

- | | | |
|-----------------------|-----------------------|-----------------------|
| (a) $\frac{Bl}{Mg}$ | (b) $\frac{Mg}{Bl}$ | (c) $MgBl$ |
| (d) $\frac{3}{4}MgBl$ | (e) $\frac{3Bl}{4Mg}$ | (f) $\frac{3Mg}{4Bl}$ |

- (2) Find the expression for R_0 .

- | | | |
|------------------------|------------------------|----------------------|
| (a) $\frac{3VB}{4Mg}$ | (b) $\frac{3VMg}{4Bl}$ | (c) $VMgBl$ |
| (d) $\frac{3}{4}VMgBl$ | (e) $\frac{VB}{Mg}$ | (f) $\frac{VMg}{Bl}$ |

- (3) Find the value of the current flowing in the circuit when the object rises at a constant velocity.

- | | | |
|-----------------------|-----------------------|-----------------------|
| (a) $\frac{Bl}{Mg}$ | (b) $\frac{Mg}{Bl}$ | (c) $MgBl$ |
| (d) $\frac{3}{4}MgBl$ | (e) $\frac{3Bl}{4Mg}$ | (f) $\frac{3Mg}{4Bl}$ |

- (4) Find the magnitude of the induced electromotive force in the circuit when the object rises at a constant velocity.

- | | | |
|--------------------|--------------------|--------------------|
| (a) V | (b) $\frac{3}{4}V$ | (c) $\frac{2}{3}V$ |
| (d) $\frac{1}{2}V$ | (e) $\frac{1}{3}V$ | (f) $\frac{1}{4}V$ |

(5) What percentage of the energy supplied by the battery is used to pull the object up?

(a) 100%

(b) 75%

(c) 50%

(d) 25%

(e) 20%

(f) 60%

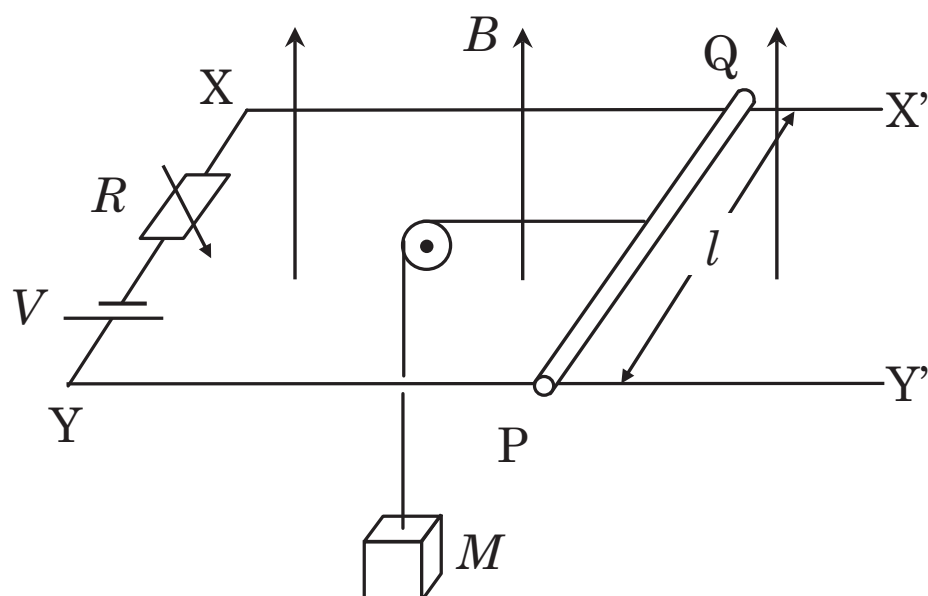


Fig. 3

4. One mole of a monatomic ideal gas is taken through the cycle shown in Fig. 4. In process AB the gas volume increases from V_A to V_B at constant pressure P_A . In process CD the gas pressure decreases from P_C to P_D at constant volume V_C . Processes BC and DA are adiabatic. The molar specific heat at constant volume is C_V and the molar specific heat at constant pressure is C_P . The temperatures of A, B, C, and D are T_A , T_B , T_C , and T_D , respectively. Answer the following questions.

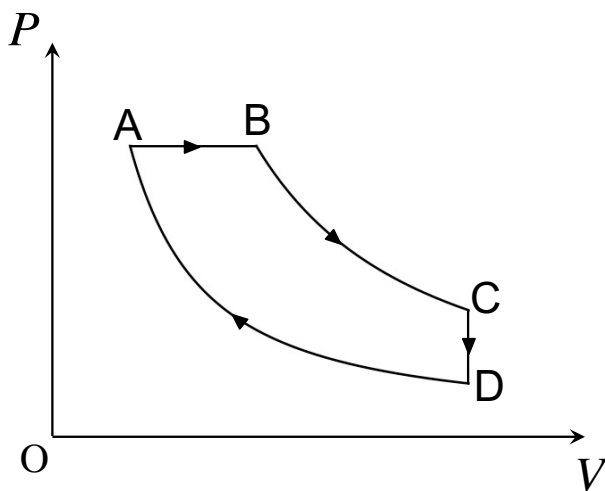


Fig. 4

- (1) Find the change in the system's internal energy in process AB.
- | | | |
|---------------|-----------------------|---------------|
| (a) $C_P T_A$ | (b) $C_P (T_B - T_A)$ | (c) $C_P T_B$ |
| (d) $C_V T_A$ | (e) $C_V (T_B - T_A)$ | (f) $C_V T_B$ |
- (2) Find the heat added to the system in process AB.
- | | | |
|---------------|---------------|-----------------------|
| (a) $C_P T_A$ | (b) $C_P T_B$ | (c) $C_P (T_B - T_A)$ |
| (d) $C_V T_A$ | (e) $C_V T_B$ | (f) $C_V (T_B - T_A)$ |
- (3) Find the heat that flows out of the gas in process CD.
- | | | |
|-----------------------|---------------|---------------|
| (a) $C_V (T_C - T_D)$ | (b) $C_V T_C$ | (c) $C_V T_D$ |
| (d) $C_P (T_C - T_D)$ | (e) $C_P T_C$ | (f) $C_P T_D$ |
- (4) Find the work done by the gas in process BC.

$$(a) \quad C_P T_C \qquad (b) \quad C_P T_B \qquad (c) \quad C_P (T_C - T_B)$$

$$(d) \quad C_V T_B \qquad (e) \quad C_V T_C \qquad (f) \quad C_V (T_C - T_B)$$

(5) Find the efficiency of the cycle.

$$(a) \quad 1 - \frac{C_V(T_C - T_D)}{C_P(T_B - T_A)} \quad (b) \quad \frac{C_V(T_C - T_D)}{C_P(T_B - T_A)} \quad (c) \quad \frac{C_V T_C}{C_P T_B}$$

$$(d) \quad 1 - \frac{T_C - T_D}{T_B - T_A} \quad (e) \quad 1 - \frac{C_P(T_B - T_A)}{C_V(T_C - T_D)} \quad (f) \quad \frac{C_P(T_B - T_A)}{C_V(T_C - T_D)}$$

5. As shown in Fig. 5-1, a speaker at the origin produces a sound wave with a constant frequency f that travels in the positive x -direction. The speed of the sound wave is v . At a certain time, the air pressure p is measured along the x -axis. The result is shown in Fig. 5-2. p_0 is the atmospheric pressure in the absence of the sound wave. Answer the following questions.

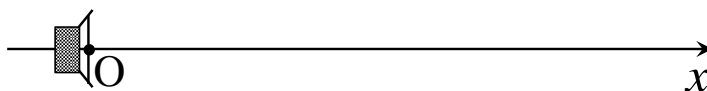


Fig. 5-1

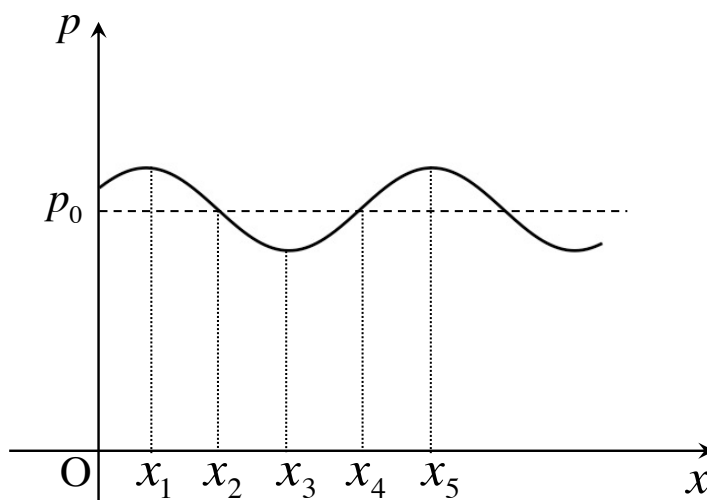


Fig. 5-2

- (1) Find the points where the air density reaches the maximum value.
 - (a) x_2 and x_4
 - (b) x_1 and x_5
 - (c) x_1 , x_3 , and x_5
- (2) Find the point where the displacement of the air molecules in the positive x -direction reaches the maximum value.
 - (a) x_1
 - (b) x_2
 - (c) x_3
 - (d) x_4
 - (e) x_5
- (3) Find the point where the speed of the air molecules in the negative x -direction reaches the maximum value.

- (a) x_1 (b) x_2 (c) x_3
- (d) x_4 (e) x_5

We then place a plate that is perpendicular to the x -axis as shown in Fig. 5-3. The plate completely reflects the sound wave. After that, there were several points where the pressures are constant at p_0 and time independent. These points are equally spaced with the same interval d .

(4) Find the expression for d .

- (a) $\frac{v}{f}$ (b) $\frac{v}{4f}$ (c) $\frac{2v}{f}$
- (d) $\frac{v}{2f}$ (e) $\frac{4v}{f}$ (f) $\frac{8v}{f}$

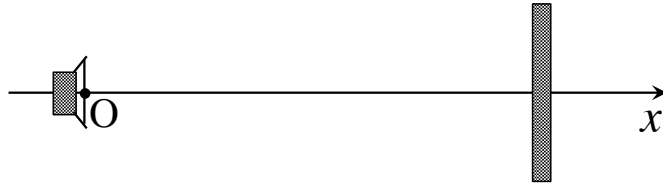


Fig. 5-3