

(2016)

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 script and on the answer sheet.

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

**1.** Answer the following questions.

- (1) A car accelerates uniformly from rest to a speed  $v$  for time  $t$ . Find the distance the car travels during the time  $t$ .

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

- (2) A monatomic ideal gas expands from  $100\text{cm}^3$  to  $200\text{cm}^3$  at a constant pressure of  $1.0 \times 10^5$  Pa. Find the change in the internal energy of the gas.

- |         |          |          |
|---------|----------|----------|
| (a) 5J  | (b) 10J  | (c) 15J  |
| (d) 50J | (e) 100J | (f) 150J |

- (3) A parallel-plate capacitor with a plate separation  $d$  has a capacitance  $C$ . The capacitor is charged to  $Q$  and then disconnected from the battery as shown in Fig. 1-1. Find the electric field between the plates.

- |                   |                    |                    |
|-------------------|--------------------|--------------------|
| (a) $\frac{Q}{C}$ | (b) $\frac{C}{Qd}$ | (c) $Cd$           |
| (d) $\frac{C}{d}$ | (e) $\frac{Q}{d}$  | (f) $\frac{Q}{Cd}$ |

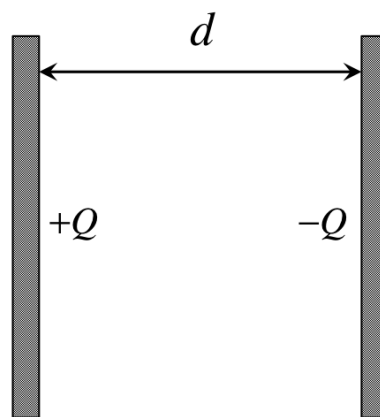


Fig. 1-1

- (4) In Fig. 1-2, a box of mass  $m$  is on an inclined plane. The angle of incline is  $\theta$ . The coefficient of static friction between the box and the incline is  $\mu$ . Find the condition where the box will slide.

- |                         |                         |                         |
|-------------------------|-------------------------|-------------------------|
| (a) $\mu < \tan \theta$ | (b) $\mu = \tan \theta$ | (c) $\mu > \tan \theta$ |
| (d) $\mu < \cot \theta$ | (e) $\mu = \cot \theta$ | (f) $\mu > \cot \theta$ |

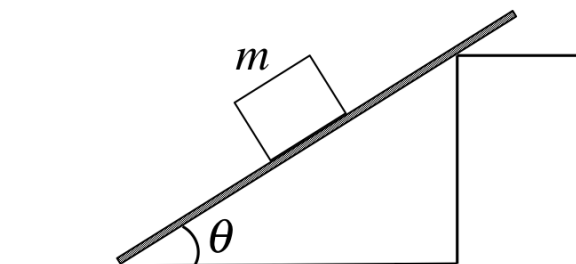


Fig. 1-2

- (5) An object attached to a spring vibrates with a simple harmonic motion as described in Fig. 1-3. Here  $t$  is time and  $x$  is the position of the object. Find the maximum speed for this motion.

(a)  $\frac{A}{2t_0}$

(b)  $\frac{\pi A}{2t_0}$

(c)  $\frac{2\pi A}{t_0}$

(d)  $\frac{\pi A}{t_0}$

(e)  $\frac{A}{\pi t_0}$

(f)  $\frac{A}{t_0}$

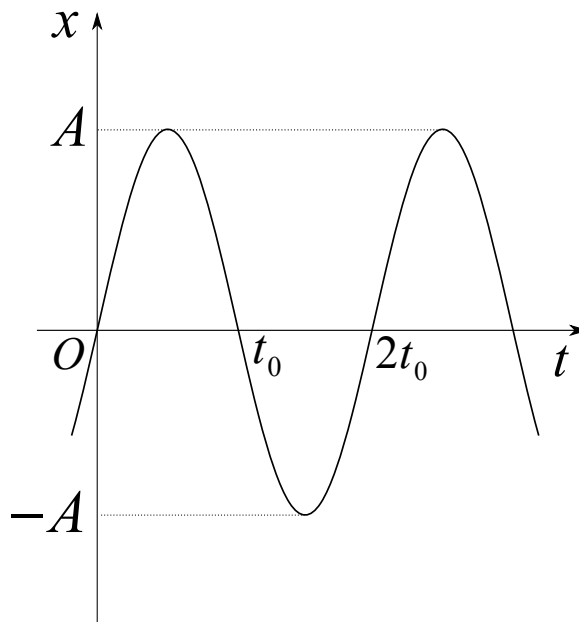


Fig. 1-3

- 2.** The right half of the  $x$ - $y$  plane is filled with a uniform magnetic field of magnitude  $B$  pointing out of the page as shown in Fig. 2-1. A charged particle of mass  $m$  enters the magnetic field region along the negative  $x$  axis in the positive  $x$  direction with speed  $v$ . The magnitude of the charge is denoted by  $q$ . The trajectory of the particle describes a semi-circle as shown in Fig. 2-1. Answer the following questions.

- (1) Is the charge of the particle positive or negative?

(a) Positive                      (b) Negative

- (2) Find the magnitude of the force on the particle.

(a)  $B$                       (b)  $vB$                       (c)  $qB$   
 (d)  $\frac{vB}{q}$                       (e)  $qvB$                       (f)  $\frac{qB}{v}$

- (3) Find the radius of the circular orbit.

(a)  $\frac{mv}{B}$                       (b)  $\frac{v}{qB}$                       (c)  $\frac{m}{qB}$   
 (d)  $\frac{mv}{qB}$                       (e)  $\frac{2mv}{qB}$                       (f)  $\frac{mv}{2qB}$

- (4) Find the time it takes the particle to travel from  $O$  to  $P$ .

(a)  $\frac{2\pi m}{qB}$                       (b)  $\frac{\pi m}{qB}$                       (c)  $\frac{m}{\pi qB}$   
 (d)  $\frac{m}{qB}$                       (e)  $\frac{m}{2qB}$                       (f)  $\frac{4\pi m}{qB}$

- (5) Now we change the magnitude of the magnetic field from  $B$  to  $2B$  and change the value of the particle speed from  $v$  to  $3v$ . What multiple of the radius of the original circular orbit is the new radius now after these changes. Choose the correct answer from the following.

(a)  $\frac{3}{2}$                       (b)  $\frac{2}{3}$                       (c)  $\frac{1}{2}$   
 (d)  $3$                       (e)  $\frac{3}{4}$                       (f)  $\frac{9}{2}$

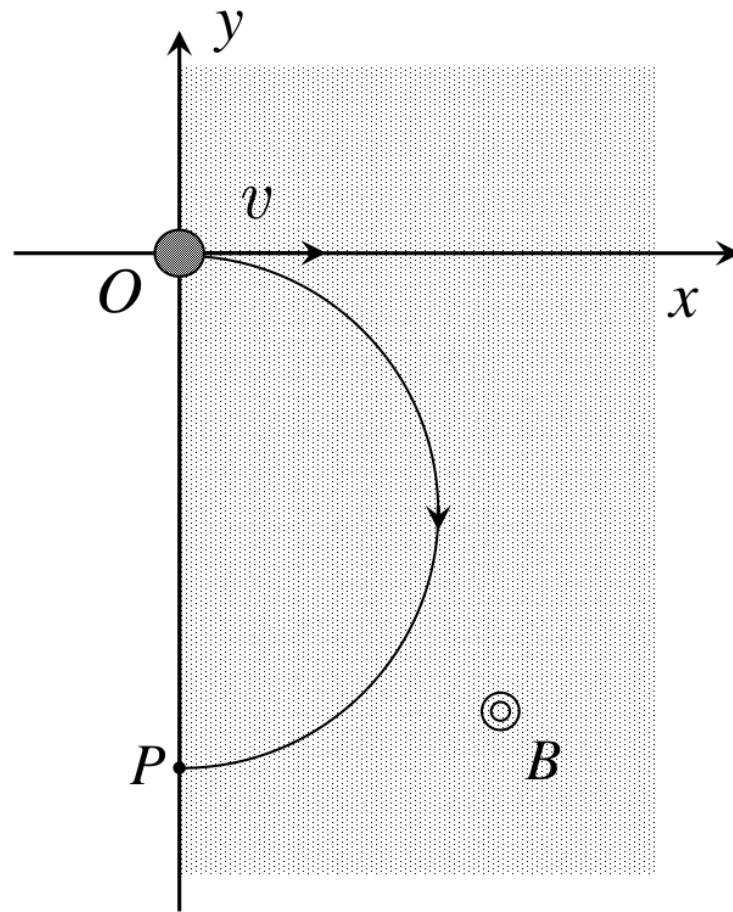


Fig. 2-1

- 3.** A block P of mass  $M$  is on a smooth horizontal plane, and an object Q of mass  $m$  is always on top of the block P. Initially both P and Q are at rest. At a time  $t = 0$ , an initial speed  $v_0$  is given to P in the rightward direction. Then Q also starts to move. When a time  $T$  is passed after P is given an initial speed, the velocity of P coincides with the velocity of Q. A coefficient of kinetic friction between P and Q is denoted as  $\mu$ . Treat the rightward direction as positive, and the acceleration of gravity is denoted as  $g$ . Answer the following questions.

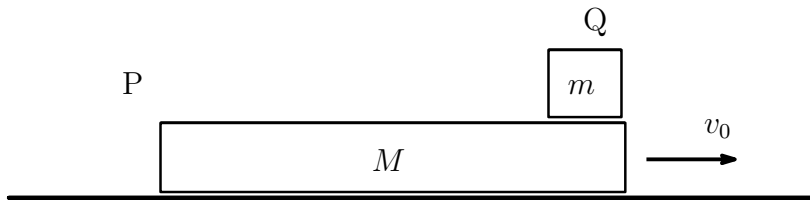


Fig. 3

- (1)** Find the force acting on Q at time  $t$  ( $0 < t < T$ ).

- |               |                   |                    |
|---------------|-------------------|--------------------|
| (a) $\mu mg$  | (b) $-\mu mg$     | (c) $\mu Mg$       |
| (d) $-\mu Mg$ | (e) $\mu(M + m)g$ | (f) $-\mu(M + m)g$ |

- (2)** Find the force acting on P at time  $t$  ( $0 < t < T$ ).

- |               |                   |                    |
|---------------|-------------------|--------------------|
| (a) $\mu mg$  | (b) $-\mu mg$     | (c) $\mu Mg$       |
| (d) $-\mu Mg$ | (e) $\mu(M + m)g$ | (f) $-\mu(M + m)g$ |

- (3)** Find the velocity of P at time  $t$  ( $0 < t < T$ ).

- |                                |                              |                                    |
|--------------------------------|------------------------------|------------------------------------|
| (a) $\mu gt$                   | (b) $v_0 - \mu gt$           | (c) $\frac{m}{M} \mu gt$           |
| (d) $v_0 - \frac{m}{M} \mu gt$ | (e) $\frac{m}{M + m} \mu gt$ | (f) $v_0 - \frac{m}{m + M} \mu gt$ |

(4) Find the expression of  $T$  using some other suitable quantities.

(a)  $\frac{v_0}{\mu g}$

(b)  $\frac{\mu g}{v_0}$

(c)  $\frac{m}{M} \frac{v_0}{\mu g}$

(d)  $\frac{M}{m} \frac{v_0}{\mu g}$

(e)  $\frac{m}{M} \frac{\mu g}{v_0}$

(f)  $\frac{M}{m} \frac{\mu g}{v_0}$

(g)  $\frac{M}{M+m} \frac{v_0}{\mu g}$

(h)  $\frac{M+m}{M} \frac{v_0}{\mu g}$

(i)  $\frac{M}{M+m} \frac{\mu g}{v_0}$

(j)  $\frac{M+m}{M} \frac{\mu g}{v_0}$

(5) Find the distance which Q moved against P in the duration from  $t = 0$  to  $t = T$ .

(a)  $\frac{\mu g v_0^2}{2}$

(b)  $\frac{v_0^2}{2\mu g}$

(c)  $\frac{m\mu g v_0^2}{2M}$

(d)  $\frac{M v_0^2}{2m\mu g}$

(e)  $\frac{(M+m)\mu g v_0^2}{2M}$

(f)  $\frac{M v_0^2}{2(M+m)\mu g}$

4. Two containers A and B of volume  $V$  are connected by a thin tube. A cock is equipped in the thin tube, and is closed initially. A gas of a pressure  $P$  and a temperature  $T$  is contained in the container A, and a gas of a pressure  $2P$  and a temperature  $3T$  is contained in the container B. Exchange of thermal energies between the gas and the containers may be ignored. The volume of the thin tube may be ignored. The gas may be considered as an ideal gas composed of monatomic molecules. The universal gas constant is denoted as  $R$ . Answer the following questions.

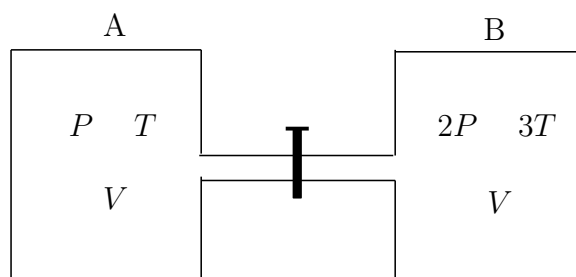


Fig. 4

- (1) Find the number of moles of the gas contained in container A.

(a)  $\frac{VRT}{P}$

(b)  $\frac{PVT}{R}$

(c)  $\frac{RT}{PV}$

(d)  $\frac{VR}{PT}$

(e)  $\frac{PV}{RT}$

(f)  $\frac{R}{PVT}$

- (2) What multiple of the number of moles of the gas contained in container A is there in container B?

(a) 6

(b) 3

(c) 2

(d)  $\frac{3}{2}$

(e) 1

(f)  $\frac{2}{3}$

(g)  $\frac{1}{2}$

(h)  $\frac{1}{3}$

(i)  $\frac{1}{6}$



(3) What multiple of the internal energy of the gas in container A is there in container B?

- |                   |                   |                   |
|-------------------|-------------------|-------------------|
| (a) 6             | (b) 3             | (c) 2             |
| (d) $\frac{3}{2}$ | (e) 1             | (f) $\frac{2}{3}$ |
| (g) $\frac{1}{2}$ | (h) $\frac{1}{3}$ | (i) $\frac{1}{6}$ |

(4) After opening the cock, the gas in containers A and B eventually reaches equilibrium. Find the temperature of the gas in equilibrium.

- |                    |                    |                     |
|--------------------|--------------------|---------------------|
| (a) $6T$           | (b) $\frac{9}{2}T$ | (c) $\frac{10}{3}T$ |
| (d) $3T$           | (e) $2T$           | (f) $\frac{9}{5}T$  |
| (g) $\frac{3}{2}T$ | (h) $T$            | (i) $\frac{3}{5}T$  |

(5) As in (4), when the gas reaches equilibrium after opening the cock, find the pressure of the gas.

- |                    |                    |                     |
|--------------------|--------------------|---------------------|
| (a) $6P$           | (b) $\frac{9}{2}P$ | (c) $\frac{10}{3}P$ |
| (d) $3P$           | (e) $2P$           | (f) $\frac{9}{5}P$  |
| (g) $\frac{3}{2}P$ | (h) $P$            | (i) $\frac{3}{5}P$  |

5. As shown in the figure, rectangular glass blocks with an index of refraction of  $n_2$  are attached to the upper and lower planes of a rectangular glass block with an index of refraction of  $n_1$ . A light ray enters the glass block at point A from the vacuum in the incident angle  $\theta$ . The light ray reaches point B after repeating total internal reflections in the block. The speed of light in the vacuum is denoted as  $c$ . Answer the following questions.

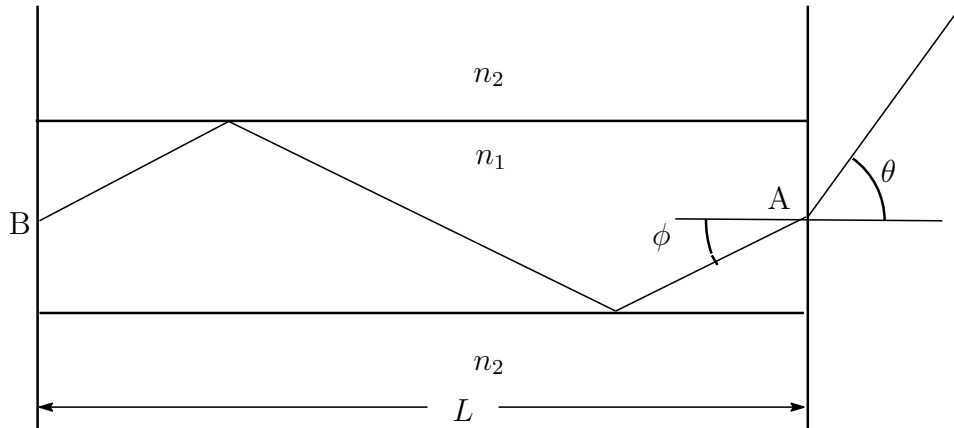


Fig. 5

- (1) An angle of refraction of the light ray entered at point A is denoted as  $\phi$ . Find the correct expression for  $\sin \phi$ .

- |                                 |                                 |                               |
|---------------------------------|---------------------------------|-------------------------------|
| (a) $n_1 \sin \theta$           | (b) $n_1 \cos \theta$           | (c) $\frac{\sin \theta}{n_1}$ |
| (d) $\frac{\cos \theta}{n_1}$   | (e) $\frac{n_1}{\sin \theta}$   | (f) $\frac{n_1}{\cos \theta}$ |
| (g) $\frac{1}{n_1 \cos \theta}$ | (h) $\frac{1}{n_1 \sin \theta}$ |                               |

- (2) Find the condition that  $n_1$  and  $n_2$  should satisfy in order that total internal reflections take place in the upper and lower planes of the glass block.

- |                           |                   |                           |
|---------------------------|-------------------|---------------------------|
| (a) $n_1 n_2 > 1$         | (b) $n_1 n_2 < 1$ | (c) $\frac{n_1}{n_2} > 1$ |
| (d) $\frac{n_1}{n_2} < 1$ |                   |                           |

(3) Find the condition that  $\phi$  should satisfy in order that total internal reflections take place in the upper and lower panels of the glass block.

(a)  $\sin \phi > \frac{n_2}{n_1}$

(b)  $\sin \phi > n_1 n_2$

(c)  $\sin \phi > \frac{n_1}{n_2}$

(d)  $\sin \phi > \frac{1}{n_1 n_2}$

(e)  $\cos \phi > \frac{n_2}{n_1}$

(f)  $\cos \phi > n_2 n_1$

(g)  $\cos \phi > \frac{n_1}{n_2}$

(h)  $\cos \phi > \frac{1}{n_1 n_2}$

(4) Find the time at which the light entering at point A reaches point B penetrating through the glass block. The distance between the two planes including points A and B is denoted as  $L$ .

(a)  $\frac{Ln_1}{c \cos \phi}$

(b)  $\frac{L}{cn_1 \cos \phi}$

(c)  $\frac{Ln_1 \cos \phi}{c}$

(d)  $\frac{L \cos \phi}{n_1 c}$

(e)  $\frac{Ln_1}{c \sin \phi}$

(f)  $\frac{L}{cn_1 \sin \phi}$

(g)  $\frac{Ln_1 \sin \phi}{c}$

(h)  $\frac{L \sin \phi}{n_1 c}$