(2020)

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.

Write the answers in the separate answer sheet.

1. Answer the following questions.

(1) In Fig. 1-1, three blocks with masses of m, $2m$, and $3m$ are connected and pulled to the right on a horizontal frictionless table by a force with a magnitude of F. Find the magnitudes of the tensions T_1 and T_2 in the interconnecting cords.

(a) $T_1 = F, \quad T_2 = F$

(b) $T_1 = \frac{1}{2}F, \quad T_2 = \frac{1}{2}F$

(c) $T_1 = \frac{1}{2}F, \quad T_2 = \frac{1}{6}F$

(d) $T_1 = \frac{1}{6}F, \quad T_2 = \frac{1}{2}F$

(e) $T_1 = \frac{1}{2}F, \quad T_2 = \frac{1}{3}F$

(f) $T_1 = \frac{1}{3}F, \quad T_2 = \frac{1}{2}F$

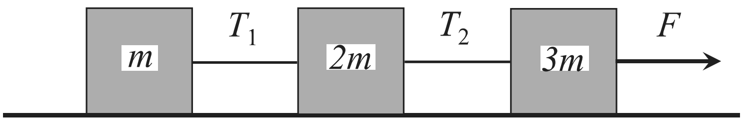

Fig. 1-1

(2) In Fig. 1-2, block A of mass m is released from rest at a height of h, slides along a frictionless slope, and then collides with stationary block B of mass $3m$. After the collision, block A stops while block B moves to the right. Find the coefficient of restitution between block A and block B.

(a) $\frac{1}{6}$ (b) $\frac{1}{3}$ (c) $\frac{1}{4}$

(d) $\frac{1}{2}$ (e) $\frac{2}{3}$ (f) 1

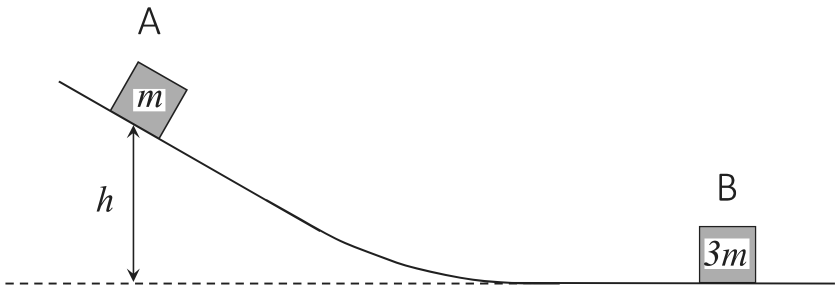

Fig. 1-2

(3) A parallel-plate capacitor has plates of area S and separation d and is charged to a potential difference V. The charging battery is then disconnected, and the plates are pulled apart until their distance becomes $d + \Delta d$. The vacuum permittivity is denoted as ε_0. Find the work required to separate the plates.

(a) $\frac{V^2 d}{\varepsilon_0 S}\Delta d$ (b) $\frac{V^2 d}{2\varepsilon_0 S}\Delta d$ (c) $\frac{\varepsilon_0 SV}{d^2}\Delta d$

(d) $\frac{\varepsilon_0 SV}{2d^2}\Delta d$ (e) $\frac{\varepsilon_0 SV^2}{d^2}\Delta d$ (f) $\frac{\varepsilon_0 SV^2}{2d^2}\Delta d$

(4) A sinusoidal wave travels in the positive x-direction with a constant speed of 0.30 m/s. Figure 1-3 shows a snapshot of the wave at $t = 0$ s as a function of x. The wave is reflected at a fixed end at $x = 0.90$ m. Find an appropriate graph for the wave at $t = 2.0$ s from Fig. 1-4.

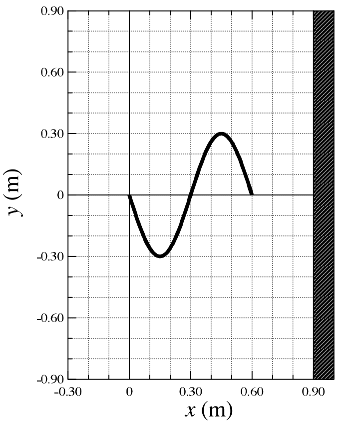

Fig. 1-3

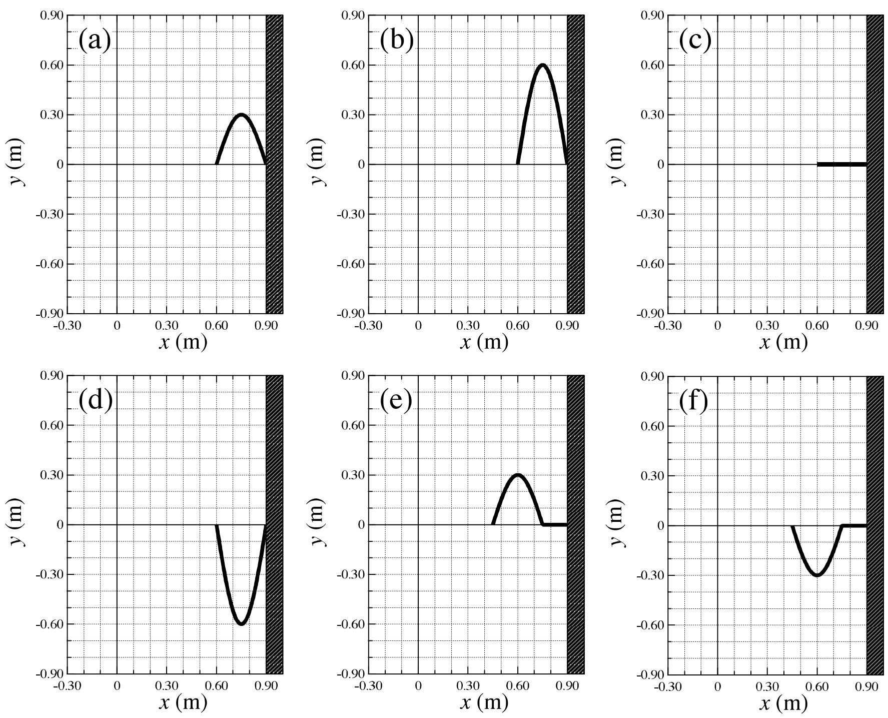

Fig. 1-4

(5) An ideal gas undergoes the cycle shown in the P-V diagram of Fig. 1-5. Find the net thermal energy added to the system during one complete cycle.

(a)	0	(b)	$\frac{1}{2}P_0V_0$	(c)	P_0V_0
(d)	$\frac{3}{2}P_0V_0$	(e)	$2P_0V_0$	(f)	$\frac{5}{2}P_0V_0$

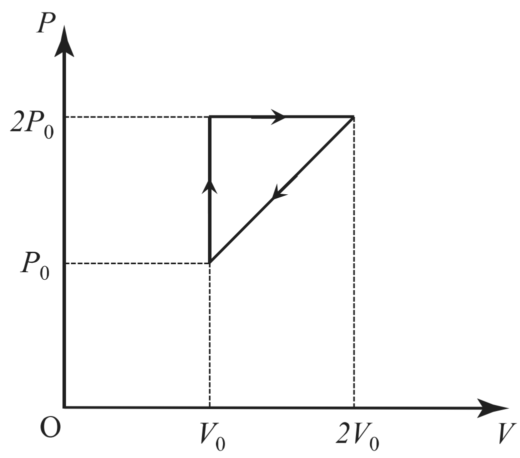

Fig. 1-5

2. As shown in Fig. 2, two particles, each of charge q ($q > 0$), are fixed at A $(-a,0)$ and B$(a,\ 0)$ ($a > 0$) in the x-y plane. A proportionality constant of the Coulomb's law is denoted as k.

(1) Find the magnitude of the electric field at C$(0,a)$.

(a) $\dfrac{kq}{\sqrt{2}a^2}$ (b) $\dfrac{kq}{\sqrt{2}a}$ (c) $\dfrac{\sqrt{2}kq}{a}$

(d) $\dfrac{\sqrt{2}kq}{a^2}$ (e) $\dfrac{kq}{a^2}$ (f) $\dfrac{kq}{a}$

(2) Find the electric potential at C. Note that the potential is zero at infinity.

(a) $\dfrac{kq}{\sqrt{2}a^2}$ (b) $\dfrac{kq}{\sqrt{2}a}$ (c) $\dfrac{\sqrt{2}kq}{a}$

(d) $\dfrac{\sqrt{2}kq}{a^2}$ (e) $\dfrac{kq}{a^2}$ (f) $\dfrac{kq}{a}$

Then, a particle with a charge $-q$ and a mass m is placed at C.

(3) Find the magnitude of the force acting on the particle at C.

(a) $\dfrac{kq^2}{a}$ (b) $\dfrac{\sqrt{2}kq^2}{a}$ (c) $\dfrac{kq^2}{\sqrt{2}a}$

(d) $\dfrac{kq^2}{a^2}$ (e) $\dfrac{\sqrt{2}kq^2}{a^2}$ (f) $\dfrac{kq^2}{\sqrt{2}a^2}$

(4) The particle at C starts to move from rest and passes through the origin O. Find the speed of the particle at O.

(a) $\sqrt{\dfrac{\sqrt{2}kq^2}{ma}}$ (b) $\sqrt{\dfrac{2\sqrt{2}kq^2}{ma}}$ (c) $\sqrt{\dfrac{(2-\sqrt{2})kq^2}{ma}}$

(d) $\sqrt{\dfrac{2(2-\sqrt{2})kq^2}{ma}}$ (e) $\sqrt{\dfrac{(\sqrt{2}-1)kq^2}{2ma}}$ (f) $\sqrt{\dfrac{2(\sqrt{2}-1)kq^2}{ma}}$

(5) When the particle at C has an initial speed v_0 in the negative y-direction, it escapes from the influence of the Coulomb forces from the particles at A and B and moves to infinity. Find the minimum value of v_0.

(a) $\sqrt{\frac{\sqrt{2}kq^2}{ma}}$ (b) $\sqrt{\frac{2\sqrt{2}kq^2}{ma}}$ (c) $\sqrt{\frac{(2-\sqrt{2})kq^2}{ma}}$

(d) $\sqrt{\frac{2(2-\sqrt{2})kq^2}{ma}}$ (e) $\sqrt{\frac{(\sqrt{2}-1)kq^2}{2ma}}$ (f) $\sqrt{\frac{2(\sqrt{2}-1)kq^2}{ma}}$

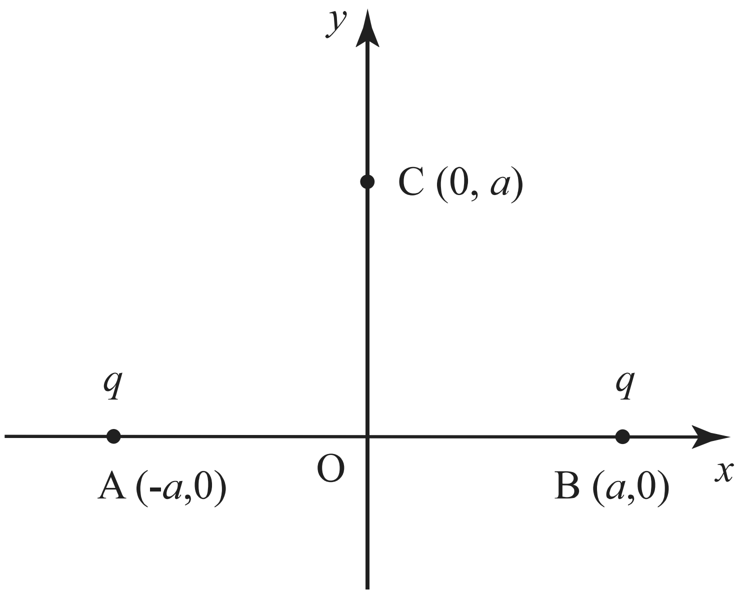

Fig. 2

3. As shown in Fig. 3, object A of mass m is moving with speed v on a frictionless surface. Object B of mass $3m$ is at rest and attached to the end of a spring with spring constant k. The other end of the spring is fixed to a wall. Objects A, B, and the spring are aligned on a straight line.

Fig. 3

At time $t = 0$, object A hits object B elastically.

(1) Find the velocity of object A after the collision.

(a) $\frac{v}{2}$ (b) $-\frac{v}{2}$ (c) $\frac{v}{3}$

(d) $-\frac{v}{3}$ (e) v (f) $-v$

(2) Find the velocity of object B after the collision.

(a) $\frac{v}{2}$ (b) $-\frac{v}{2}$ (c) $\frac{v}{3}$

(d) $-\frac{v}{3}$ (e) v (f) $-v$

After the collision, the spring is compressed. At time $t = T$, the spring takes the maximum compression, ℓ.

(3) Find the formula for ℓ.

(a) $\sqrt{\frac{mv^2}{9k}}$ (b) $\sqrt{\frac{3mv^2}{9k}}$ (c) $\sqrt{\frac{mv^2}{k}}$

(d) $\sqrt{\frac{3mv^2}{10k}}$ (e) $\sqrt{\frac{mv^2}{5k}}$ (f) $\sqrt{\frac{3mv^2}{4k}}$

(4) Find the formula for T.

(a) $2\pi\sqrt{\dfrac{3m}{k}}$ (b) $\pi\sqrt{\dfrac{3m}{k}}$ (c) $\dfrac{\pi}{2}\sqrt{\dfrac{3m}{k}}$

(d) $2\pi\sqrt{\dfrac{m}{k}}$ (e) $\pi\sqrt{\dfrac{m}{k}}$ (f) $\dfrac{\pi}{2}\sqrt{\dfrac{m}{k}}$

(5) Find the compression of the spring at time $t = T/2$.

(a) $\dfrac{\ell}{\sqrt{3}}$ (b) ℓ (c) 2ℓ

(d) $\dfrac{\ell}{2}$ (e) $\dfrac{\sqrt{3}\ell}{2}$ (f) $\dfrac{\ell}{\sqrt{2}}$

4. A hot air balloon of mass M is shown in Fig. 4. The volume of the air bag is V. Mass M does not include the mass of the air inside the bag. The bottom of the bag is open, and the air pressure inside the bag is equal to the surrounding air pressure, P. The burner sitting on the basket is used to heat the air inside the bag. The molar mass of air is denoted by m and the acceleration of gravity is denoted by g. The air is an ideal gas and the universal gas constant is denoted by R. The temperature of the surrounding air is T_0.

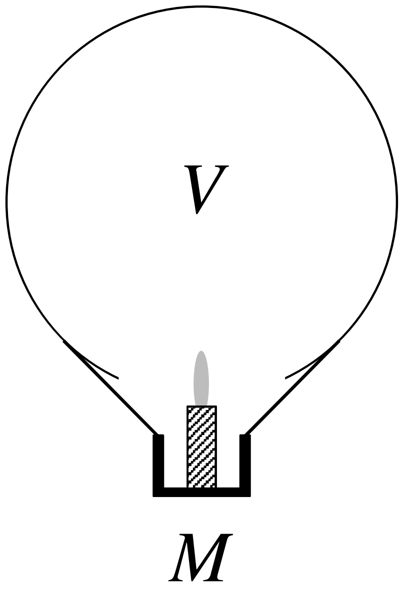

Fig. 4

After the air inside the bag is heated by the burner, the temperature of the air becomes T.

(1) Find the density of the air inside the bag.

(a) $\dfrac{mP}{2RT}$ (b) $\dfrac{mP}{RT}$ (c) $\dfrac{2mP}{RT}$

(d) $\dfrac{PV}{RT}$ (e) $\dfrac{M}{V}$ (f) $\dfrac{Mg}{V}$

(2) Find the buoyancy force, namely the upward force created by the air surrounding the balloon, acting on the balloon.

(a) Mg (b) $\dfrac{PVmg}{RT_0}$ (c) $\dfrac{2PVmg}{RT_0}$

(d) $\dfrac{PVmg}{2RT_0}$ (e) $\dfrac{5PVmg}{RT_0}$ (f) $\dfrac{mg}{RT_0}$

The balloon starts rising from the ground when the temperature of the air inside the bag is T_1.

(3) Find the formula for T_1.

(a) $\dfrac{mPVT_0}{mPV - MRT_0}$ (b) $\dfrac{mPVT_0}{mPV - 2MRT_0}$ (c) $\dfrac{mPV}{MR}$

(d) $\dfrac{mPV - MRT_0}{mPVT_0}$ (e) T_0 (f) $2T_0$

(4) Using the values $m = 2.9 \times 10^{-2}\,\mathrm{kg \cdot mol^{-1}}$, $M = 5.0 \times 10^2\,\mathrm{kg}$, $P = 1.0 \times 10^5\,\mathrm{Pa}$, $V = 3.0 \times 10^3\,\mathrm{m^3}$, $T_0 = 3.0 \times 10^2\,\mathrm{K}$, and $R = 8.3\,\mathrm{J \cdot K^{-1} \cdot mol^{-1}}$, find the approximate value of T_1.

(a) 3.0×10^2 K (b) 7.0×10^2 K (c) 2.5×10^3 K

(d) 3.5×10^2 K (e) 4.5×10^2 K (f) 4.0×10^3 K

5. Two loudspeakers S_1 and S_2 are placed on a plane as shown in Fig. 5. The x and y axes are defined as shown in the figure, and an observer is located at the origin O of the $x-y$ plane. The speed of the sound is constant and denoted by v. The distances $\overline{OS_1}$ and $\overline{OS_2}$ are denoted by d_1 and d_2, respectively.

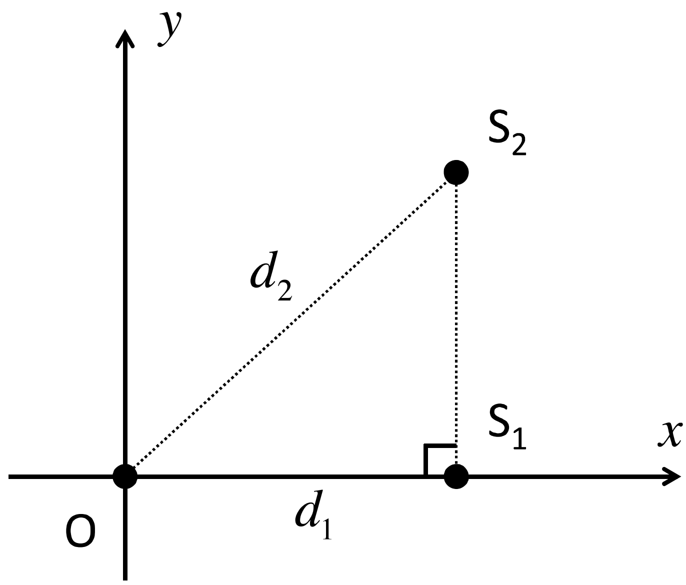

Fig. 5

Initially, both speakers are at rest and the x coordinates of S_1 and S_2 are the same. They emit sound waves with the same frequency f and the same amplitude. There is no phase difference between their sound waves.

(1) Starting from a frequency, which is lower than $v/(d_1+d_2)$, the frequency is increased gradually. At a certain frequency, the observer first heard the sound with maximum intensity. Find the formula for this frequency.

(a) $\dfrac{v}{d_1+d_2}$ (b) $\dfrac{v}{d_1}$ (c) $\dfrac{v}{d_2}$

(d) $\dfrac{v}{\sqrt{d_2^2-d_1^2}}$ (e) $\dfrac{v}{|d_1-d_2|}$ (f) $\dfrac{v}{\sqrt{d_1^2+d_2^2}}$

Next, speaker S_1 starts to move at a constant speed u, which is much smaller than v, in the direction of the positive x axis.

(2) Find the frequency of speaker S_1 heard by the observer.

(a) $\dfrac{v}{v+u}f$ (b) $\dfrac{u}{v+u}f$ (c) $\dfrac{v+u}{v}f$

(d) $\dfrac{u}{v}f$ (e) f (f) $\dfrac{v-u}{v}f$

(3) A beat is heard by the observer due to the interference between the sound waves emitted by speakers S_1 and S_2. Find the period of the beat .

(a) $\dfrac{v+u}{vf}$ (b) $\dfrac{v}{uf}$ (c) $\dfrac{v+u}{uf}$

(d) $\dfrac{1}{f}$ (e) $\dfrac{v+u}{(v-u)f}$ (f) $\dfrac{v-u}{(v+u)f}$

Speaker S_2 starts to move as well at a constant speed u in the direction parallel to the positive x axis. A beat is heard by the observer at a different frequency.

(4) Find the frequency of the beat.

(a) $\dfrac{(d_2-d_1)\,vf}{d_2v+d_1u}$ (b) $\dfrac{(d_2-d_1)\,uf}{d_2v+d_1u}$ (c) f

(d) $\dfrac{(d_2-d_1)\,uvf}{(v+u)\,(d_2v+d_1u)}$ (e) $\dfrac{(v+u)\,f}{(d_2-d_1)\,uv}$ (f) $\dfrac{(d_2-d_1)\,vf}{(v+u)\,d_1}$