# 2009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 2009

学科試験　　問題

EXAMINATION QUESTIONS

(学部留学生)

UNDERGRADUATE STUDENTS

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# PHYSICS

**注意**　☆試験時間は60分。

PLEASE NOTE : THE TEST PERIOD IS 60 MINUTES.

(2009)

PHYSICS

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

Choose the correct answer, and circle the letter preceding it.

**1** Answer the following questions.

(1) A half sphere of radius $r$ is fixed to a horizontal floor. The inner surface of the sphere is smooth. A small ball of mass $m$ is at the bottom point P of the sphere and is given an initial velocity $v$ as in Fig. 1. The initial velocity $v$ is sufficiently large so that the small ball reaches a point Q at height $r$. Find the magnitude of the normal force exerted by the sphere on the small ball when the ball passes through the point Q. The acceleration due to gravity is denoted as $g$.

(a) $\dfrac{mv^2}{r}$ (b) $\dfrac{mv^2}{r} - mg$ (c) $\dfrac{mv^2}{r} - 2mg$

(d) $mrv$ (e) $mrv - mg$ (f) $mrv - 2mg$

(g) $\dfrac{1}{2}mv^2$ (h) $\dfrac{1}{2}mv^2 - mgr$ (h) $\dfrac{1}{2}mv^2 - 2mgr$

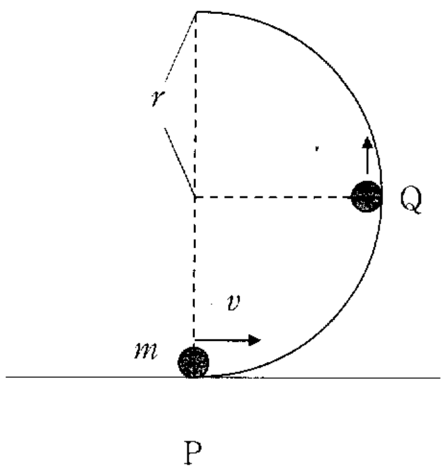


Fig. 1

(2) What multiple of the distance between the center of the earth and that of the moon is the distance between the center of the earth and a geostationary satellite, which always stays above a fixed location on the equator? Take the cycle of revolution of the moon around the earth to be 27 days.

(a) $\frac{1}{3}$ (b) $\frac{1}{9}$ (c) $\frac{1}{27}$ (d) 3

(e) 9 (f) 27

(3) A charge $Q$ is placed at the center of a spherical-shell conductor as in Fig. 2. Both the radius of the inner shell and the thickness of the conductor are $R$. Which of the following is correct?

(a) A charge of amount $-Q$ is distributed uniformly on the inner surface of the conductor.

(b) A charge of amount $-Q$ is distributed uniformly on the outer surface of the conductor.

(c) A charge of amount $Q$ is distributed uniformly on the inner surface of the conductor.

(d) A charge of amount $Q$ is distributed uniformly on the outer surface of the conductor.

(e) Charges of amount $-Q/2$ are distributed uniformly both on the inner and outer surfaces of the conductor.

(f) Charges of amount $Q/2$ are distributed uniformly both on the inner and outer surfaces of the conductor.

(g) Charges of amount $-Q$ and $Q$ are distributed uniformly on the inner and outer surfaces of the conductor, respectively.

(h) Charges of amount $Q$ and $-Q$ are distributed uniformly on the inner and outer surfaces of the conductor, respectively.

(i) No charge appears in the conductor.

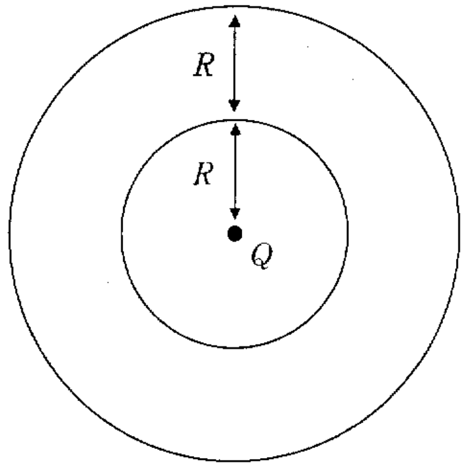


Fig. 2

(4) A cylinder with a frictionless piston of mass $M$ and cross section $S$ is placed vertically in an atmosphere of pressure $p$ as shown in Fig. 3. The cylinder is then rotated 180 degrees so that the opening of the cylinder faces down. During the operation, the temperature of the gas inside the cylinder is kept fixed, and the volume of the gas is doubled. Which of the following is correct? The acceleration due to gravity is denoted as $g$.

(a) $p = \frac{3Mg}{S}$ (b) $p = \frac{2Mg}{S}$ (c) $p = \frac{Mg}{S}$

(d) $p = \frac{Mg}{2S}$ (e) $p = \frac{Mg}{3S}$

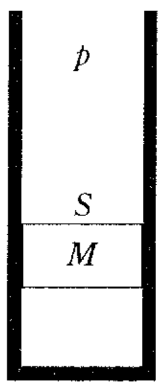


Fig. 3

(5) A plane mirror is placed horizontally at the bottom of a transparent liquid of 10 cm depth. When one looks at the image of a small object floating at the surface of the liquid right above the object, the image is seen at 14 cm below the surface of the liquid. Find the approximate value of the index of refraction of the liquid.

(a) 0.63 (b) 0.80 (c) 1.43 (d) 1.60

2 An overview of a mass spectrometer is shown in Fig. 4. The whole spectrometer is placed in a vacuum. A positive ion (ion with positive charge) of mass $M$, charge $q$, and speed $v$ emitted from the ion source passes through the slits $S_1$, $S_2$, $S_3$, keeping a constant velocity. Between the slits $S_2$ and $S_3$, a uniform electric field of magnitude $E$ from a parallel plate capacitor PQ and a uniform magnetic field of magnitude $B_1$ apply to the ion. After passing through the slit $S_3$, the ion moves circularly under a uniform magnetic field of magnitude $B_2$ and collides with the photographic plate.

(1) Which of the following is a correct explanation for the force acting on a charged particle under a uniform magnetic field?

(a) The direction of the force lies in the plane composed by the magnetic field and the velocity, and the magnitude of the force is independent of the speed.

(b) The direction of the force lies in the plane composed by the magnetic field and the velocity, and the magnitude of the force is proportional to the speed.

(c) The direction of the force is perpendicular to the plane composed by the magnetic field and the velocity, and the magnitude of the force is independent of the speed.

(d) The direction of the force is perpendicular to the plane composed by the magnetic field and the velocity, and the magnitude of the force is proportional to the speed.

(2) Which is the direction of the uniform magnetic field acting in the region of parallel plate capacitor PQ where the positive ion moves straight with a constant speed?

(a) In the same direction as the electric field.

(b) In the opposite direction to the electric field.

(c) Perpendicular to and into the plane of the paper.

(d) Perpendicular to and out of the plane of the paper.

(e) From up to down in the plane of the paper.

(f) From down to up in the plane of the paper.

(3) Which of the following is the correct relationship among the speed $v$ of the positive ion passing through the slit $S_3$, the magnitude of the electric field $E$, and the magnitude of the magnetic field $B_1$ ?

(a) $v = EB_1$ (b) $v = \frac{EB_1}{M}$ (c) $v = \frac{E}{B_1}$

(d) $v = \frac{E}{MB_1}$ (e) $v = \frac{B_1}{E}$ (f) $v = \frac{B_1}{ME}$

(g) $v = \frac{1}{EB_1}$ (h) $v = \frac{1}{MEB_1}$

(4) What is the radius of the circular motion of the positive ion after passing through the slit $S_3$ ?

(a) $r = \frac{qB_2}{mv}$ (b) $r = \frac{mv}{qB_2}$ (c) $r = \frac{qvB_2}{m}$

(d) $r = \frac{m}{qvB_2}$ (e) $r = \frac{qB_2}{mv^2}$ (f) $r = \frac{mv^2}{qB_2}$

(g) $r = \frac{qv^2B_2}{m}$ (h) $r = \frac{m}{qv^2B_2}$

(5) Consider the case where a proton and an alpha particle are emitted from the ion source. What multiple of the radius of the circular motion of the proton is that of the alpha particle?

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

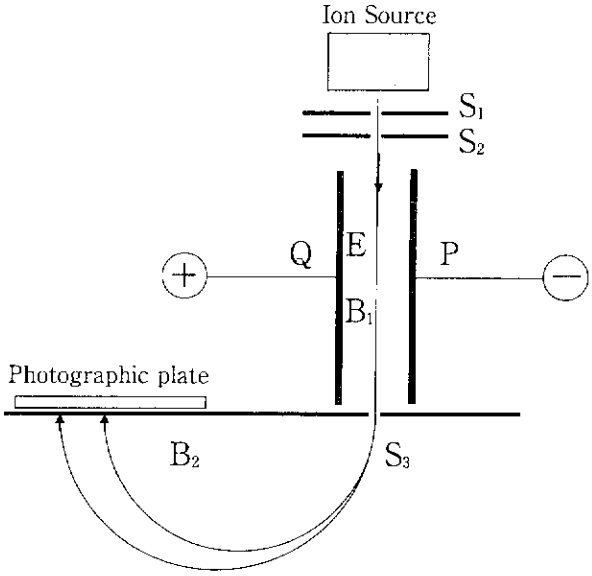


Fig. 4

3 A point object of mass $m$ is connected to an inertialess string of length $L$, the other end of which is fixed to a point O. At time $t=0$, the object is assumed to begin to move horizontally in a vertical plane from the bottom point A ($\overline{OA}=L$) in the clockwise direction with an initial speed $v_0$ as shown in Fig. 5.

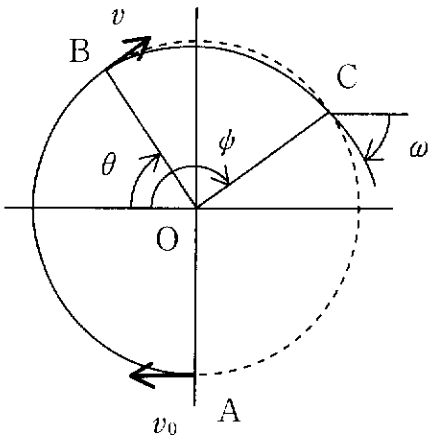


Fig. 5

If $\sqrt{2gL} < v_0 < \sqrt{5gL}$ ($g$ : acceleration due to gravity), then at a point B (the angle between $\overrightarrow{OB}$ and the horizontal direction is designated $\theta$ as in Fig. 5 ) the magnitude of the force acting on the object from the string becomes zero, where $\overline{OB}=L$ and the velocity of the object is perpendicular to $\overrightarrow{OB}$, $v$ being the magnitude of the velocity vector. We restrict ourselves to the case $0<\theta<\pi/2$.

Circle the correct answers to questions (1)-(5). The speed, $v$, is given by

(1) (a) $\sqrt{gL}$, (b) $\sqrt{2gL}$, (c) $\sqrt{gL\sin\theta}$, (d) $\sqrt{2gL\sin\theta}$

The initial speed, $v_0$, is

(2) (a) $\sqrt{(2+2\sin\theta)gL}$, (b) $\sqrt{(2+3\sin\theta)gL}$, (c) $\sqrt{(1+4\sin\theta)gL}$

From the point B, for a while, the object takes a parabolic orbit till a point C, where $\overline{OC}=L$. The maximum elevation (with respect to the location B) is expressed as

(3) (a) $\frac{v_0^2}{2g}\sin^2\theta$, (b) $\frac{v_0^2}{2g}\cos^2\theta$, (c) $\frac{v^2}{2g}\sin^2\theta$,

(d) $\frac{v^2}{2g}\sin\theta\cos\theta$ (e) $\frac{v^2}{2g}\cos^2\theta$

In the case $\theta = \pi/3$, the angle $\phi$, measured as in Fig. 5 for specifying the point C, becomes

(4) (a) $\pi/2$, (b) $(2/3)\pi$, (c) $(5/6)\pi$, (d) $\pi$

and finally the angle $\omega$, the angle between the object velocity at the point C and the horizontal dirction, is

(5) (a) $\pi/2$, (b) $\pi/3$, (c) $\pi/4$, (d) $\pi/6$

4 Let the universal gas constant be $R$ ($J \cdot K^{-1} \cdot mol^{-1}$). Let $c_p$ ($J \cdot K^{-1} \cdot mol^{-1}$) and $c_v$ ($J \cdot K^{-1} \cdot mol^{-1}$) be the specific heat of a gas at constant pressure and one at constant volume respectively. Circle the correct answers to questions (1)–(4).

For argon gas, Ar, the value $(c_p - c_v)/R$ is

(1) (a) 0, (b) 1/2, (c) 1, (d) 3/2, (e) 2

The value of $c_v/R$ for Ar is

(2) (a) 1/2, (b) 1, (c) 3/2, (d) 2, (e) 5/2

The value of $c_v/R$ for the diatomic gas $N_2$ is

(3) (a) equal to, (b) less than, (c) greater than

that for Ar.

The value of $(c_p - c_v)/R$ for $N_2$ is

(4) (a) equal to, (b) less than, (c) greater than

that for Ar.

5 An ambulance is running along a straight main road at a speed of $U$ (m/s) with a siren of frequency $\nu$ (Hz). It is assumed that a wind is blowing at speed $W$ (m/s) in the same direction as that of the ambulance. Let $\nu_+$ (Hz) and $\nu_-$ (Hz) be the frequency of the siren sound detected at the road side in the case of approach of the ambulance and its leaving respectively. Let $c$ (m/s) be the sound velocity in air. In the following three categories, choose the appropriate one in each.

(1) (a) always $c > U + W$, (b) always $c < U + W$, (c) neither (a) nor (b)

(2) (a) $\nu_+ - \nu = 0$, (b) $\nu_+ - \nu = \nu \dfrac{U}{c - U}$, (c) $\nu_+ - \nu = \nu \dfrac{U}{c + W - U}$, (d) $\nu_- - \nu = \nu \dfrac{U}{c - W - U}$, (e) $\nu_+ - \nu = \nu \dfrac{U}{c + U}$

(3) (a) $\nu_- - \nu = 0$, (b) $\nu_- - \nu = -\nu \dfrac{U}{c + U}$, (c) $\nu_- - \nu = -\nu \dfrac{U}{c - W + U}$, (d) $\nu_- - \nu = -\nu \dfrac{U}{c + W + U}$, (e) $\nu_- - \nu = -\nu \dfrac{U}{c - U}$