浙江大学 2023－2024 年春夏学期

《普通物理学Ⅰ（H）》课程期中测试卷

课程号：061R0060，开课学院：物理学院

考试试卷：√A 卷、B 卷（请在选定项上打√）

考试形式：√闭、开卷（请在选定项上打√），允许带 纸质词典、计算器 入场

考试日期：2024 年 5 月 19 日，考试时间：120 分钟

诚信考试，沉着应考，杜绝违纪。

考生姓名：____________ **学号：**____________ **所属专业：**____________

题序	I	II	III. 13	III. 14	III.15	III. 16	III. 17	III. 18	总 分
得分									
评卷人									

Physical constants you may use:

Gravitational acceleration on the earth's surface	$g = 9.80\ \mathrm{m/s^2}$
Speed of light in a vacuum	$c = 3.00 \times 10^8\ \mathrm{m/s}$
Gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$

Enjoy your exam and good luck!

I. MULTIPLE CHOICE

[18 points] Choose only ONE correct answer.

(1) **[3 points]** From the top of a very tall building in Melbourne (墨尔本), Australia (38°S, 145°E), a ball is freely thrown from rest. Due to the Earth's rotation, the ball doesn't fall vertically downward but deviates (偏移) slightly. In which direction will it deviate?

(A) Eastward;

(B) Southward;

(C) Westward;

(D) Northward;

(E) It will fly towards the moon.

(2) **[3 points]** A particle is moving in a circle at the constant speed v. Which of the following descriptions about the magnitude of the time derivative (时间导数) of its momentum is correct?

(A) It is zero;

(B) It is a non-zero constant independent of v;

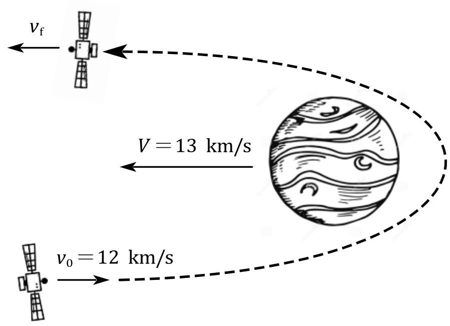
(C) It is proportional to (正比于) v;

(D) It is proportional to v^2;

(E) It is proportional to v^3.

(3) **[3 points]** The Voyager 2 probe (旅行者 2 号探测器) is flying towards Jupiter directly. Under Jupiter's gravitation, it goes halfway around Jupiter and leaves in the opposite direction. This "slingshot" ("弹弓") encounter is like a completely elastic collision. Assuming the probe's initial speed relative to the Sun is $v_0 = 12$ km/s, Jupiter's orbital speed relative to the Sun is $V = 13$ km/s, and Jupiter's mass is much greater than the probe's mass, what is the probe's final orbital speed relative to the Sun v_f?

(Choose the closest one.)



(A) 1 km/s;

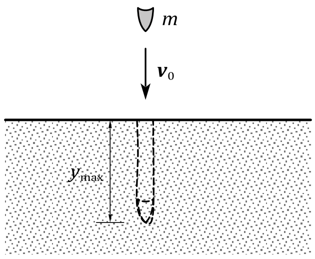
(B) 14 km/s;

(C) 25 km/s;

(D) 38 km/s;

(E) 51 km/s.

(4) **[3 points]** A bullet with mass $m = 7.91$ g and initial speed $v_0 = 713$ m/s is vertically downward shot into sand. The resistance force exerted by the sand on the bullet is proportional to its velocity, that is $\boldsymbol{f} = -b\boldsymbol{v}$, where $b = 56.2$ kg/s is a constant. Gravity acting on the bullet is neglected. What is the maximum depth $y_{\max}$ the bullet can penetrate into (穿入) the sand? (Choose the closest one.)



(A) 5.00 cm;

(B) 10.0 cm;

(C) 15.0 cm;

(D) 20.0 cm;

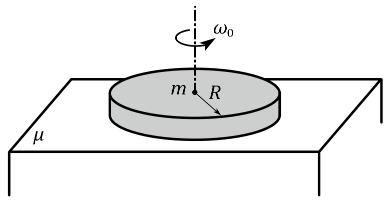
(E) 25.0 cm.

(5) **[3 points]** A uniform disk with radius R and mass m is placed flat on a rough horizontal table, with its center fixed to an axis of rotation. The friction coefficient between the disk and the table is μ. Assuming the disk starts rotating about the axis with an initial angular speed ω_0, how long time does it take for the disk to come to a stop?

(A) $\dfrac{\omega_0 R}{\mu g}$; (B) $\dfrac{\omega_0 R}{2\mu g}$;

(C) $\dfrac{2\omega_0 R}{3\mu g}$; (D) $\dfrac{3\omega_0 R}{4\mu g}$;

(E) $\dfrac{2\omega_0 R}{\mu g}$.



(6) **[3 points]** Water with density ρ flows from an open large tank into a funnel-shaped conduit (喇叭形导管). The cross-sectional area at the inlet (入口) of the conduit is S_1, and at the outlet (出口) is S_2. The conduit has a length of H. The outlet of the conduit is open to the atmosphere, and the flow is steady. If the atmospheric pressure is denoted as p_0, at what h will the pressure at the inlet of the conduit be zero?

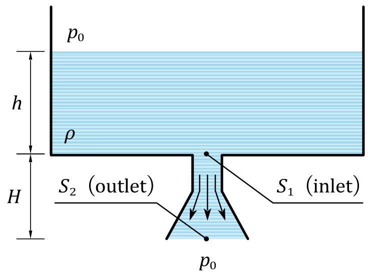
(A) $h = \dfrac{S_2^2}{S_2^2 - S_1^2}\left(\dfrac{p_0}{\rho g}\right)$;

(B) $h = \dfrac{S_2^2}{S_2^2 - S_1^2}\left(\dfrac{p_0}{\rho g} - \dfrac{S_2^2}{S_1^2}H\right)$;

(C) $h = \dfrac{S_1^2}{S_2^2 - S_1^2}\left(\dfrac{p_0}{\rho g} - \dfrac{S_2^2}{S_1^2}H\right)$;

(D) $h = \dfrac{S_1^2}{S_2^2 - S_1^2}\left(\dfrac{p_0}{\rho g} - \dfrac{S_1^2}{S_2^2}H\right)$;

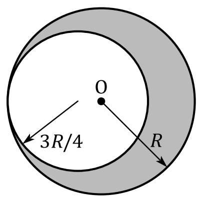
(E) $h = \dfrac{S_2^2}{S_2^2 - S_1^2}\left(\dfrac{p_0}{\rho g} - \dfrac{S_1^2}{S_2^2}H\right)$.



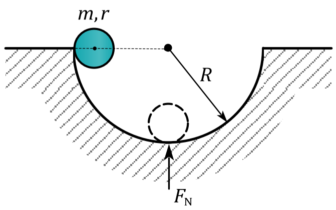
II. BLANK FILLING

[22 points] Fill in your answers in the blanks.

(7) **[4 points]** A uniform circular disk originally with a mass of M and a radius of R. Now it has a circular cutout (剪除) of radius $3R/4$ that is inscribed to (内切于) the big circle, remaining a "crescent" (“月牙”). Then the distance from the center of mass of the "crescent" to point O is $r_C =$ ____________, and the rotational inertia of the "crescent" about point O is $I_O =$ ____________.



(8) **[2 points]** As shown in the right figure, placing a solid sphere (mass m, radius r) at the highest point of a vertical plane's semicircular (半圆形的) track (radius R) and releasing it from rest. If it rolls purely, when it reaches the lowest point of the track, the track's normal force on it is $F_N =$ ____________.



(9) **[4 points]** A particle moves in a three-dimensional conservative force field (三维保守力场), and its potential energy function is: $U(x, y, z) = -5x^2 + 2xy + 3z$ (J).

(a) Find the force acting on the particle: $\boldsymbol{F}(x, y, z) =$ ________________________ (N).

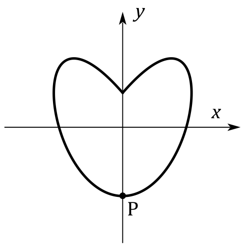
(Use $\boldsymbol{e}_x$, $\boldsymbol{e}_y$, $\boldsymbol{e}_z$ to represent the unit vectors in the x, y, z directions respectively.)

(b) The particle moves along a straight line from the origin $(0\text{ m}, 0\text{ m}, 0\text{ m})$ to $(3\text{ m}, 3\text{ m}, 3\text{ m})$. The work done by this force on the particle is $W =$ __________ J.

(10) **[2 points]** If a celestial body (天体) has such strong gravitation that its escape speed (i.e., the second cosmic speed) exceeds the light speed c, then any material, even light, cannot escape. This type of celestial body is known as a "black hole." The mass of the Sun is $M_S = 1.99 \times 10^{30}$ kg. If it were to collapse into a black hole (of course, it's impossible) while maintaining its original mass, then its radius would need to shrink (收缩) to at least $R_{\max} =$ ____________.

(11) **[6 points]** A particle moves along:

$$\begin{cases} x(t) = A\cos(3\omega t + \pi/2) \\ y(t) = A\cos(4\omega t - \pi/3) \end{cases}$$



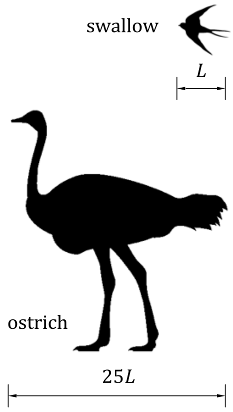
(a) Given that at $t = \pi/3\omega$, the particle reaches point P, then at this moment, the magnitude of the particle's velocity and acceleration are $v_P =$ ____________ and $a_P =$ ____________.

(b) At point P, the curvature radius (曲率半径) of the trajectory (轨迹) is $\varrho_P =$ ____________.

(12) **[4 points]** Why can't ostriches (鸵鸟) fly? Let's attempt some simple physics analysis:

(a) Assuming that the lift force F on the bird during flight depends only on the following factors: the wing (翅膀) area S, flight speed v, and air density ρ, please use dimensional analysis (量纲分析) to express: $F =$ ____________. (Use C to represent the dimensionless coefficient (无量纲系数).)

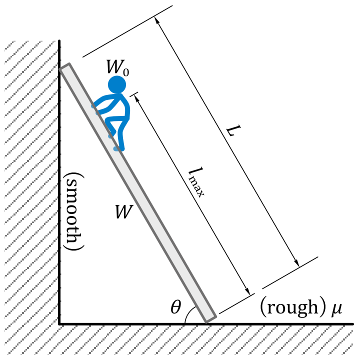
(b) If the lift force is greater than the bird's own weight, it can take off (起飞). Suppose an ostrich's body size (in each direction) is 25 times that of a swallow (燕子), and their wings occupy the same proportion (比例) of their body surface area. If the minimum takeoff speed for a swallow is $v_1 = 20$ km/h, then the estimated minimum speed for an ostrich to take off would need to be $v_2 =$ ____________.



III. CALCULATION AND ANALYSIS

[60 points] Present the necessary equations and descriptions in your solution.

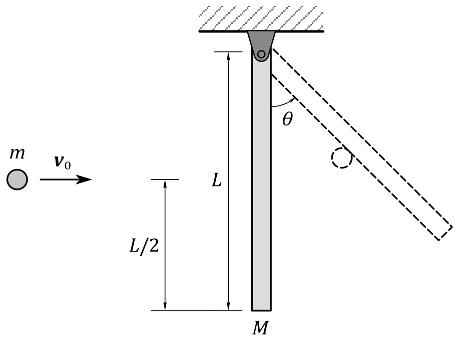
(13) **[10 points]** A uniform ladder with weight W and length L is positioned with its upper end against a smooth wall and its lower end on rough ground with a friction coefficient μ. The ladder makes an angle θ with the ground. The worker's weight is W_0. What is the highest position $l_{\max}$ the worker can climb to ensure safety (no sliding of the ladder)? The worker can be treated as a point mass (质点) .



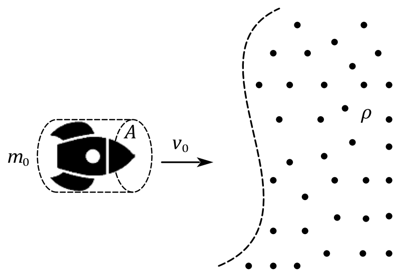
(14) **[10 points]** A uniform rod of mass $M = 1.50$ kg and total length $L = 1.00$ m is suspended (悬挂) from a smooth nail at its top, remaining stationary in a vertical position. A very small ball coated with glue (涂满胶水) with mass $m = 500$ g and speed $v_0 = 10.0$ m/s horizontally hits the rod at exactly half its length. After hitting, the ball remains stuck to (固定于) the rod and moves together with it.

(a) What is the angular speed ω of the rod immediately after the hit?

(b) What is the maximum angle θ to which the rod can swing?



(15) **[10 points]** A spacecraft with initial mass m_0 and cross-sectional area A travels through space at an initial speed v_0. It enters a stationary dust cloud with uniform density ρ. As the spacecraft travels through the dust cloud, all the dust particles swept over (扫过) by the spacecraft's front section adhere (黏附) to it. The spacecraft has no additional propulsion (推动力), and its cross-sectional area will not change. Determine the speed $v(t)$ and displacement $s(t)$ of the spacecraft after entering the dust cloud. Take the moment when the spacecraft first enters the dust cloud as $t = 0$.

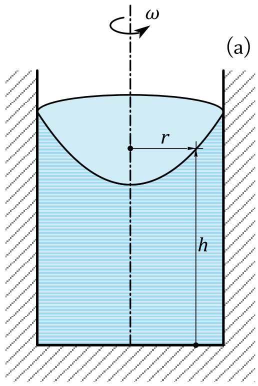


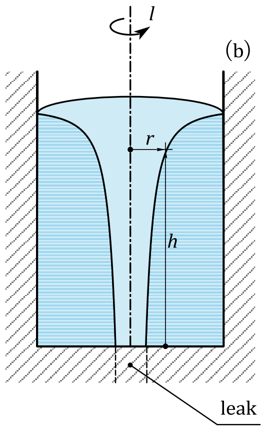
(16) **[10 points]** In a cylindrical container (圆柱形的容器) filled with water, the water rotates around the central axis of the cylinder. The density of water is ρ.

(a) If the water has a uniform angular speed ω everywhere, find the shape of the water surface $h(r)$.

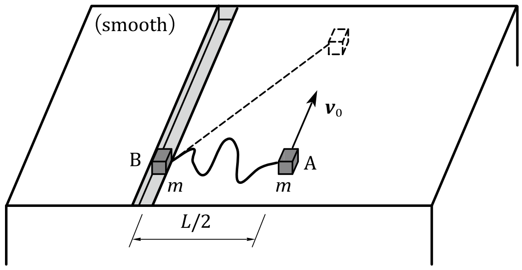
(b) If the water has a uniform specific angular momentum (比角动量，即单位质量的角动量) l everywhere, find the shape of the water surface $h(r)$. This situation occurs when there is a leak (漏水口) below.

(Here, h is the height of the water level, and r is the distance to the central axis, and you can define a constant h_0. No need to consider any limit situations.)





(17) **[10 points]** A small slider (滑块) A is placed on a smooth horizontal table, while a small slider B is placed in a smooth groove (凹槽) on the same table. Slider B can only slide along the groove. Both sliders have a mass of m, and they are connected by an unextendible (不可伸长的) light rope of length L. Initially, sliders A and B are both at rest, with a distance of $L/2$ between them, and the line between A and B is perpendicular to (垂直于) the groove. Now give a sudden push to slider A, then slider A obtains a velocity $\boldsymbol{v}_0$ which is parallel to (平行于) the groove. Assuming the table is large enough, what is the velocity of slider B when it begins to move?



(18) **[10 points]** On May 3rd, 2024, the Chang'e 6 (嫦娥六号) probe was successfully launched from the Wenchang Space Launch Site in Hainan, China. It will head towards the far side of the Moon (月球背面) and collect samples from there for the first time in human history. Answer the following questions:

(a) After entering a circular orbit around the Earth at an altitude of $h = 200$ km, the probe needs to accelerate at point A to enter an elliptical (椭圆的) Earth-Moon transfer orbit. This process is called a Hohmann transfer (霍曼转移). The farthest end of the elliptical orbit approaches the Moon, with an Earth-Moon distance of $d = 3.84 \times 10^5$ km. What is the speed increment (增量) Δv of the probe due to acceleration at point A?

(b) Using Kepler's laws, calculate how many days it will take for the Chang'e 6 probe to travel from point A to point B?

(The radius of the Earth is $R_\mathrm{E} = 6370$ km, and the mass of the Earth is $M_\mathrm{E} = 5.98 \times 10^{24}$ kg. Ignore the gravitation from the Moon during the transfer, and do not consider the movement of the Earth and the Moon. **Just a reminder:** When the masses of the Earth and the probe are fixed, the total energy and period on an elliptical orbit are determined only by the semi-major axis (半长轴).)

(c) On April 17th, Bill Nelson, the Administrator of NASA (美国国家航空航天局局长), stated during a hearing (听证会):

> *"They are going to have a lander on the far side of the moon, which is the side which is always in dark. Uh, we're not planning to go there... I have no idea (why China chose to go there)..."*

Is there any scientific inaccuracy (科学性错误) in his statement? Try to refute (批驳) this statement using your understanding of the "far side of the Moon." **(Bonus)**