Midterm Exam for University Physics I

Beijing Institute of Technology

8:00-9:35 Apr. 25, 2023

Class（Major）_____Student ID_____Name_____

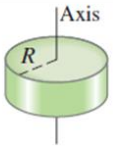
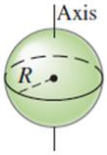
Multiple Choice	Completion	Problems	Total Score

Place a **circle or box** around each answer. Specify **units** for each answer.
Report all numbers to three significant figures.

Instructions: Do not forget to write your full name, student number on each of your answer sheets. Copy problem numbers and solve problems step by step on your answer sheets so that your reasonings are clearly presented. Do not panic or be discouraged if you cannot do every problem; there are both easy and hard parts in this exam. If a part of a problem depends on a previous answer you have not obtained, assume it and proceed. Keep moving and finish as much as you can.

Useful Information:

1 ft = 12 in (exact)
1 mile = 5280 ft (exact)
1 day = 24 hr (exact)
g_{moon} = 1.67 m/s^2 = 5.48 ft/s^2
1 kg = 0.0685 slug
1 m = 3.28 ft
1 hour = 3600 sec = 60 min (exact)
g_{earth} = 9.80 m/s^2 = 32.2 ft/s^2
1 year = 365.25 days
1 N = 0.225 pound

Object	Location of axis		Moment of inertia
Solid cylinder, radius R	Through center		$\frac{1}{2}MR^2$
Uniform sphere, radius R	Through center		$\frac{2}{5}MR^2$

1. Multiple Choice (4 points for each, 20 points in total)

(Circle all that apply!!!)

1-1. Which of the following statements cannot be true?

(A) An object has a northward velocity and a southward acceleration.

(B) An object has a varying velocity while its speed is constant.

(C) An object is increasing speed as its acceleration decreases.

(D) An object has a varying speed while its velocity is constant.

1-2. Which of the following is always true in a collision between two objects?

(A) Total linear momentum is conserved.

(B) Total kinetic energy is conserved.

(c) If the second object is at rest initially, the object that collides with it will be at rest after the collision.

(d) None of the above.

1-3. A particle moving along the x axis has a position given by $x = 54t - 2.0t^3$ m. At time t = 3.0 s, the speed of the particle is zero. Which of the following statements is correct?

(a) The particle remains at rest after t = 3.0 s.

(b) The particle no longer accelerates after t = 3.0 s.

(c) The particle can be found at position $x < 0$ m only when $t < 0$ s.

(d) None of the above is correct.

1-4. Which of the following statements is true?

(A) If a force on an object is zero, the torque is also zero.

(B) If a torque on an object is zero, the force is zero.

(C) If the net force on a system is zero, the net torque is also zero.

(D) If the net torque on a system is zero, the net force is zero.

1-5. Two uniform solid spheres simultaneously start rolling from rest down an incline. One sphere has twice the radius and twice the mass of the other ($m_1 = 2m_2$, $R_1 = 2R_2$).

(A) Sphere 1 reaches the bottom of the incline first.

(B) Sphere 2 reaches the bottom of the incline first.

(C) Sphere 2 has a greater speed at the bottom of the incline.

(D) Sphere 1 has a greater total kinetic energy at the bottom.

2. Completion (4 points for each, 20 points in total)

(Report all numbers to <u>three significant figures</u>!!!)

2-1. A helicopter rotor has four blades, each 27.0 ft long from the central shaft to the blade tip. The rotor rotates at 450 rev/min in a test. What is the radial acceleration of the blade tip in m/s^2?

_____

2-2. A 1050-kg sports car is moving westbound at 15.0 m/s on a level road when it collides with a 6320-kg truck driving east on the same road at 10.0 m/s. The two vehicles remain locked together after the collision. What is the velocity (magnitude and direction) of the two vehicles just after the collision?_____

2-3. A baseball has mass 0.145 kg. The velocity of a pitched ball has a magnitude of 45.0 m/s and the batted ball's velocity is 55.0 m/s in the opposite direction. If the ball remains in contact with the bat for 2.00 ms, what is the magnitude of the average force applied by the bat?_____

2-4. A boat moves at 10.0 m/s relative to the water. If the boat is in a river where the current is 2.00 m/s, how long does it take the boat to complete a round trip of 1.00 mile upstream followed by a 1.00 km trip downstream? _____

2-5. Two teams of movers are lowering a piano from the window of a 10-floor apartment building. The rope breaks when the piano is at rest 30.0 m above the ground. The movers on the ground, alerted by the shouts of the movers above, first notice the piano when it is 14.0 m above the ground. How long do they have to get out of the way before the piano hits the ground? _____

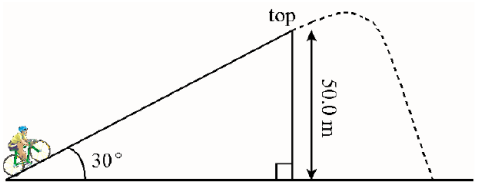
3. Problems (60 points in total) (Keep three significant figures!!!)

3-1. Consider two vectors $\vec{A}$ and $\vec{B}$. $\vec{A} = 3.0\hat{i} - 5.2\hat{j}$, $\vec{B}$ has a length 12.0 and makes an angle of 110° with respect to the positive x-axis.

(a) *[5 pts.]* Calculate the length of vector $\vec{C}$, where $\vec{C} = \vec{A} + \vec{B}$.

(b) *[5 pts.]* Calculate the angle that vector $\vec{C}$ makes with the positive x-axis.

3-2. When Jim and Bob ride bicycles, Jim can accelerate at only three quarters the acceleration of Bob. Both start from rest at the bottom of a long straight road of constant upward slope and each travel at his own maximum constant acceleration. The road makes an angle 30.0° with respect to the horizontal and the top is at a height of 50.0 m above the starting point.



(a) [*7 pts*.] If Bob takes 1.20 minutes to reach the top, how much earlier should Jim start to reach the top at the same time as Bob?

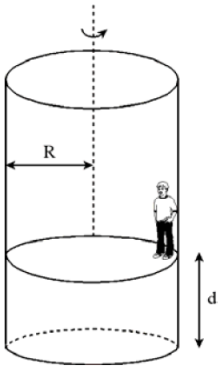
(b) [*8 pts*.] Unfortunately, Jim did not realize that the road ended at the top and he kept going. Calculate the time that elapsed from the moment his bicycle left the road to the point where it hits the ground 50.0 m below the top.

3-3. A baseball batter is observed to hit a ball of mass m = 0.15 kg that was pitched horizontally to him at a speed of 20 m/s. The ball is observed to leave his bat with a speed of 30 m/s at an upwards angle of 30° with respect to the horizontal.

(a) [*7 pts*.] Determine the angle that the impulse force exerted by the bat on the ball makes with the horizontal.

(b) [*8 pts*.] If the mean impulsive force has a magnitude of 4500 N, calculate the approximate time that the bat was in contact with the ball.

3-4. A person of mass **m** is standing on the floor of an amusement park ride with his back against the wall. The amusement park ride consists of a cylinder of radius **R** that spins about a vertical axis. When the cylinder achieves a sufficiently large rotation speed, the floor is removed but the person remains "stuck" to the wall. Assume that the coefficient of kinetic friction is $\boldsymbol{\mu_k}$ and the coefficient of static friction is $\boldsymbol{\mu_s}$.



(a) [*10 pts*.] Calculate in terms of given quantities the maximum period of revolution of the cylinder necessary to keep the person from falling.

(b) [*10 pts*.] Suppose that suddenly a malfunction occurs and the cylinder's period doubles from the value in part (a). Calculate in terms of given quantities the time that the person takes to fall a distance d into the pit below. Assume that the person is in contact with the wall at all times.

Solution for the Midterm Exam for University Physics I

1. Multiple Choice

1-1. D;
1-2. A;
1-3. D;
1-4. A;
1-5. D;

2. Completion

2-1. $v = 2\pi Rf;\ a_r = v^2/R$

$a_r = 4\pi^2 Rf^2 = 4\pi^2 * \frac{27.0}{3.28} m * \left(\frac{450}{60}\right)^2 = 1.83 \times 10^4 m/s$

2-2. (m+M)v_f=mv_m+Mv_M $\rightarrow$ $v_f = (1050 * 15.0 - 6320 * 10.0)/(1050 + 6320) = -10.7 m/s$

Magnitude: 10.7 m/s Direction: heading east

2-3. $\vec{I} = \Delta\vec{p} = \overrightarrow{p_f} - \overrightarrow{p_i} = \vec{F}\Delta t$

$\vec{F} = (55.0 m/s + 45.0 m/s) * 0.145 kg/2.00 ms = 7.25 \times 10^3 N$

2-4. $(v_{bw} + v_{wg})t = \Delta x;$

Upstream: $t_1 = 1.00 * \frac{5280}{3.28}/(10.0 - 2.00) = 201.2 s$

Downstream: $t_2 = 1000/(10.0 + 2.00) = 83.33 s$

$t = t_1 + t_2 = 285 s$

2-5. $\Delta x = v_0 t + \frac{1}{2}at^2;\ t = \sqrt{2\Delta x/a}$

$t_{30m} = \sqrt{2 * 30 m/9.80 m/s^2} = 2.474 s$

$t_{14m} = \sqrt{2 * 16 m/9.80 m/s^2} = 1.807 s$

$\Delta t = t_{30m} - t_{14m} = 0.667 s$

3. Problems

3-1.

(a) $B_x = 12 * \cos 110^0;\ B_y = 12 * \sin 110^0$

$|\vec{C}| = \sqrt{(A_x + B_x)^2 + (A_y + B_y)^2}$

$= \sqrt{(3.0 + 12 * \cos 110^0)^2 + (-5.2 + 12 * \sin 110^0)^2}$

$= 6.18;$

(b) $\vec{C} = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j}$

$\tan\theta = \frac{A_y + B_y}{A_x + B_x} = \frac{-5.2 + 12 * \sin 110^0}{3.0 + 12 * \cos 110^0} = \frac{6.08}{-1.104}$

$\theta = -79.7^0$ (From calculator)

Vector $\vec{C}$ in the second quadrant, so the actual angle with the x-axis is $180^0 - 79.7^0 = 100^0$

3-2.

(a) According to $\Delta x = v_0 t + \frac{1}{2}at^2;\ \Delta x = \frac{50}{sin30^0} = 100m$

$v_0 = 0 \rightarrow a = \frac{2\Delta x}{t^2}$ and $t = \sqrt{2\Delta x/a}$

Since $a_J = \frac{3}{4}a_B;\ t_B = 1.20 * 60s = 72.0s;\ t_J = \sqrt{\frac{4}{3}}t_B = 83.14s;$

$t = t_J - t_B =$ 11.1s *or* 0.186 min (Three significant number)

(b) Velocity at top for Jim $v_J = v_0 + a_J t_J = 0 + \frac{3}{4}a_B t_J = \frac{\frac{3}{4}(2*100)}{72.0^2} * 83.14 = 2.406\ m/s$

Jim becomes a projectile with this initial speed at 30^0 to horizontal, since x and y are independent, only need to work with the y motion.

$a_y = -9.80\ m/s^2;\ y_0 = 50m,\ y_f = 0m;\ v_{y0} = v_J * sin30^0 = 1.203\ m/s$

$\Delta x = v_0 t + \frac{1}{2}at^2;\ 0 - 50 = 1.203 * t + \frac{1}{2} * (-9.80) * t^2 \rightarrow t =$ 3.32*s*

3-3.

(a) $\vec{I} = \Delta\vec{p} = \overrightarrow{p_f} - \overrightarrow{p_i} = \vec{F}\Delta t;$

$\overrightarrow{p_f} = m\overrightarrow{v_f} = 0.15 * (30m/s * \cos30^0\hat{i} + 30m/s * \sin30^0\hat{j})$

$\overrightarrow{p_i} = m\overrightarrow{v_i} = 0.15 * -20m/s\hat{i}$

$\theta = tan^{-1}(\Delta p_y/\Delta p_x) = tan^{-1}(30 * \sin30^0/(30 * \cos30^0 + 20)) =$ 18.1^0

(b) $|\vec{I}| = |\vec{F}|\Delta t;\ \sqrt{(0.15kg * 15m/s)^2 + (0.15kg * 45.981m/s)^2} = 4500N * \Delta t$

$\Delta t = 1.61 \times 10^{-3}s =$ 1.61*ms*

3-4.

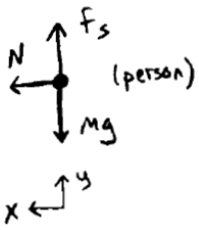
(a) Maximum period for person not to fall → friction is static and maximum and $a_y = 0$

$F_x = N = ma_c = mv^2/R$

$F_y = f_{s,\max} - mg = \mu_s N - mg = 0$

$v = 2\pi R/T_{\max}$

Combine those equations: $T_{\max} = 2\pi\sqrt{\mu_s R/g}$



(b) With T=2T_{max}, $v' = v/2;\ N' = N/4$ person is falling;

$f_s \rightarrow f_k$ and $a_y \neq 0$

NII law: $ma_y = mg - \mu_k N';$

$\Delta y = v_{y0}t + \frac{1}{2}a_y t^2;\ \rightarrow\ t = \sqrt{2\Delta y/a_y}$

$t = \sqrt{\frac{2d}{(1-\frac{\mu_k}{4\mu_s})g}}$