Physics 201 Midterm Exam 3

Information and Instructions

Student ID Number: ______________________

Section Number: ______________________

TA Name: ______________________

Please fill in all the information above.

Please write and bubble your Name and Student ID number on your scantron. Also, fill in your section number under special codes. Finally question 1 asks you to fill in your test ID code which is necessary to correctly grade your exam.

The exam has 20 questions (questions 2-21) and you have 1 hour and 15 minutes to complete the exam.

Please use 9.80 m/s^2 for the acceleration of gravity on the Earth.

1. Please fill in your test ID code
   a. A
   b. B
   c. C
   d. D
Multiple Choice

Identify the choice that best completes the statement or answers the question.

2. A disk (radius = 8.0 cm) that rotates about a fixed axis starts from rest and accelerates at a constant rate to an angular velocity of 4.0 rad/s in 2.0 s. What is the magnitude of the total linear acceleration of a point on the rim of the disk at the instant when the angular velocity of the disk is 1.5 rad/s?
   a. 24 cm/s²
   b. 16 cm/s²
   c. 18 cm/s²
   d. 34 cm/s²
   e. 2.0 cm/s²

→ a: 24 cm/s²

\[ a_r = R\alpha = R \frac{\Delta \omega}{\Delta t} = 8.0 \times \frac{4.0}{2.0} = 16 \text{ cm/s}^2 \]
\[ a_c = \frac{v^2}{R} = \frac{(R\omega)^2}{R} = \frac{(8.0 \times 1.5)^2}{8.0} = 18 \text{ cm/s}^2 \]

adding vectors: \( a = \sqrt{16^2 + 18^2} = 24 \text{ cm/s}^2 \)

3. A horizontal disk with a radius of 10 cm rotates about a vertical axis through its center. The disk starts from rest at \( t = 0 \) and has a constant angular acceleration of 2.1 rad/s². At what value of \( t \) will the radial and tangential components of the linear acceleration of a point on the rim of the disk be equal in magnitude?
   a. 0.55 s
   b. 0.63 s
   c. 0.69 s
   d. 0.59 s
   e. 0.47 s

→ c: 0.69 s

\[ \frac{(R\omega)^2}{R} = \frac{(R\alpha t)^2}{R} = R\alpha \]
\[ t^2 = \frac{1}{\alpha}, \quad t = \frac{1}{\sqrt{\alpha}} = \frac{1}{\sqrt{2.1}} = 0.69 \text{ s} \]
4. The rigid body shown rotates about an axis through its center of mass and perpendicular to the paper. If \( M = 2.0 \) kg and \( L = 80.0 \) cm, what is the kinetic energy of this object when its angular speed about this axis is equal to 5.0 rad/s? Neglect the mass of the connecting rod and treat the masses as particles.

\[
\begin{align*}
x_{CM} &= \sum \frac{m x}{M} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2} = \frac{0 \times M + L \times 3M}{4M} = \frac{3L}{4} \\
l &= \sum m r^2 = M \left( \frac{3}{4} L \right)^2 + 3M \left( \frac{1}{4} L \right)^2 = \frac{12}{16} ML^2 = \frac{3}{4} ML^2 \\
K &= \frac{1}{2} l \omega^2 = \frac{13}{2} 2.0 \times 0.8^2 \times 5.0^2 = 12 J
\end{align*}
\]

5. A campus bird spots a member of an opposing football team in an amusement park. The football player is on a ride where he goes around at angular velocity \( \omega \) at distance \( R \) from the center. The bird flies in a horizontal circle above him. Will a dropping the bird releases while flying directly above the person's head hit him?

a. Yes, because it falls straight down.

b. Yes, because it maintains the acceleration of the bird as it falls.

c. No, because it falls straight down and will land behind the person.

d. Yes, because it maintains the angular velocity of the bird as it falls.

e. No, because it maintains the tangential velocity the bird had at the instant it started falling.

\( \Rightarrow \) c. No, because it maintains the tangential velocity the bird had at the instant it started falling.

The dropping maintains the same momentum because there is no force or torque on the dropping.
6. When the center of a bicycle wheel has linear velocity $\vec{v}_{cm}$ relative to the ground, the velocity relative to the ground of point $P'$ at the top of the wheel is

$$\vec{v}_{CM}$$

a. 0.
b. $\vec{v}_{cm}$.
c. $2\vec{v}_{cm}$.
d. $-\vec{v}_{cm}$.
e. $-2\vec{v}_{cm}$.

$\rightarrow$ c: $2\vec{v}_{cm}$

The wheel moves with $\vec{v}_{cm}$ forward. The wheel is also rolling so my have tangential velocity $\vec{v}_{cm}$ which is forward at point $P'$.

7. A particle whose mass is 2 kg moves in the $xy$ plane with a constant speed of 3 m/s in the $x$ direction along the line $y = 5$. What is its angular momentum (in kg·m$^2$/s) relative to the origin?

a. $-30\hat{k}$
b. $30\hat{k}$
c. $-15\hat{k}$
d. $15\hat{k}$
e. $45\hat{k}$

$\rightarrow$ a: $-30\hat{k}$

Considering the pint when the object is at $x=0$ and $r$ is perpendicular to $p$.

$L = rmv = 5 \cdot 2.0 \cdot 3 = 30$ clockwise which is negative
8. A puck on a frictionless air hockey table has a mass of 5.0 g and is attached to a cord passing through a hole in the surface as in the figure. The puck is revolving at a distance 2.0 m from the hole with an angular velocity of 3.0 rad/s. The cord is then pulled from below, shortening the radius to 1.0 m. The new angular velocity (in rad/s) is

a. 4.0  
b. 6.0  
c. 12  
d. 2.0  
e. 8.0

→ c: 12.0 rad/s
No Torque is applied to the system so angular momentum should be conserved.
\[ I_i \omega_i = I_f \omega_f \]
\[ m r_i^2 \omega_i = m r_f^2 \omega_f \]
\[ 5.0 \times 2.0^2 \times 3.0 = 5.0 \times 1.0^2 \times \omega_f \]
\[ \omega_f = 12 \text{ rad/s} \]

9. A merry-go-round of radius \( R = 2.0 \text{ m} \) has a moment of inertia \( I = 250 \text{ kg}\cdot\text{m}^2 \), and is rotating at 10.0 rpm. A child whose mass is 25 kg jumps onto the edge of the merry-go-round, heading directly toward the center at 6.0 m/s. The new angular speed (in rpm) of the merry-go-round is approximately

a. 10  
b. 9.2  
c. 8.5  
d. 7.1  
e. 6.4

→ d: 7.1 rpm
No Torque is applied to the system so angular momentum should be conserved. Revolutions per minute are a measure of angular velocity so we will stick with those units.
\[ I_i \omega_i = \sum I_f \omega_f \]
\[ I \omega_i = I \omega_f + m_c r^2 \omega_f \]
\[ 250 \times 10 = 250 \times \omega_f + 25 \times 2.0^2 \omega_f \]
\[ \omega_f = 7.1 \text{ rpm} \]
10. A solid sphere, spherical shell, solid cylinder and a cylindrical shell all have the same mass \( m \) and radius \( R \). If they are all released from rest at the same elevation and roll without slipping, which reaches the bottom of an inclined plane first?
   a. solid sphere
   b. spherical shell
   c. solid cylinder
   d. cylindrical shell
   e. all take the same time

→ a: solid sphere.

The solid sphere which has the smallest moment of inertia because more of it’s mass is located near the center of mass around which it is rotating. With a lower moment of inertia less energy has to go into rotational energy.

11. A hockey puck traveling at speed \( v \) on essentially frictionless ice collides elastically with one end of a straight stick lying flat on the ice. In this collision
   a. momentum is conserved.
   b. angular momentum is conserved.
   c. energy is conserved.
   d. all of the above are conserved.
   e. only momentum and angular momentum are conserved.

→ d: all of the above are conserved.

In an elastic collision momentum, all types, and kinetic energy are conserved. Note that momentum of all types is always conserved in collisions.
12. The figure shows a uniform, horizontal beam (length = 10.0 m, mass = 25 kg) that is pivoted at the wall, with its far end supported by a cable that makes an angle of 51° with the horizontal. If a person (mass = 60.0 kg) stands 3.0 m from the pivot, what is the tension in the cable?

\[ F_x: F_{pivotx} - T\cos(51) = 0 \]
\[ F_y: F_{pivoty} + T\sin(51) - F_{gb} - F_{gp} = 0 \]

Center of rotation at the pivot point
Torque: \( 10.0 \times T\cos(51) - 5.0 \times F_{gb} - 3.0 \times F_{gp} = 0 \)

Just need the last equation to solve the problem
Torque: \( 10.0 \times T\sin(51) - 5.0 \times 9.8 \times 25 - 3.0 \times 9.8 \times 60.0 = 0 \), \( T = 380 \text{ N} \)

\( \rightarrow \) c: 0.38 kN

13. A 20.0-m long steel wire (cross-section 1.0 cm², Young's modulus \( 2.0 \times 10^{11} \text{ N/m}^2 \)), is subjected to a load of 25,000 N. How much will the wire stretch under the load?

\( \Delta L = \frac{FL}{AY} = \frac{25000 \times 20}{1 \times 4 \times 2.0 \times 10^{11}} = 0.025 \text{ m} = 2.5 \text{ cm} \)

\( \rightarrow \) b 2.5 cm
14. Sebastian has drawn a free-body diagram for a ladder of mass $m$ leaning against a frictionless wall. His diagram is shown below. What is his error?

- $f_s$ is in the wrong direction.
- $P$ should be directed upwards, not down.
- $P$ should be perpendicular to the wall, not parallel to it.
- $n$ should be down into the floor for $f_s$ to have the given direction.
- $P$ is correct, but there should also be a force perpendicular to the wall.

→ c: $P$ should be perpendicular to the wall, not parallel to it

15. The period of a satellite circling planet Nutron is observed to be 84 s when it is in a circular orbit with a radius of $8.0 \times 10^6$ m. What is the mass of planet Nutron?

- $6.2 \times 10^{28}$ kg
- $5.0 \times 10^{28}$ kg
- $5.5 \times 10^{28}$ kg
- $4.3 \times 10^{28}$ kg
- $3.7 \times 10^{28}$ kg

→ d: $4.3 \times 10^{28}$ kg

Using:

$$T^2 = \left(\frac{4\pi^2}{GM_N}\right)r^3$$

$$M_N = \left(\frac{4\pi^2}{G}\right)\frac{r^3}{T^2} = \left(\frac{4\pi^2}{6.673e-11}\right)\frac{(8.0e6)^3}{84^2} = 4.3e28$$
16. Planet Zero has a mass of \(4.0 \times 10^{23}\) kg and a radius of \(2.0 \times 10^6\) m. A 10.0-kg space probe is launched vertically from the surface of Zero with an initial kinetic energy of \(8.0 \times 10^7\) J. What maximum distance from the center of Zero is achieved by the probe?

- a. \(3.2 \times 10^6\) m
- b. \(4.0 \times 10^6\) m
- c. \(6.0 \times 10^6\) m
- d. \(5.0 \times 10^6\) m
- e. \(2.5 \times 10^6\) m

\(\Rightarrow\) d: \(5.0 \times 10^6\) m

Using conservation of energy

\[
E_i = E_f
\]
\[
K + U_i = U_f
\]
\[
K - G \frac{Mm}{r_i} = -G \frac{Mm}{r_f}
\]
\[
8.0e7 - 6.673e-11 \frac{4.0e23 \times 10}{2e6} = -6.673e-11 \frac{4.0e23 \times 10}{r_f}
\]

\[
r_f = 5.0e6 \text{ m}
\]

17. The figure below shows a planet traveling in a counterclockwise direction on an elliptical path around a star located at one focus of the ellipse. When the planet is at point A,

- a. its speed is constant.
- b. its speed is increasing.
- c. its speed is decreasing.
- d. its speed is a maximum.
- e. its speed is a minimum.

\(\Rightarrow\) e: its speed is decreasing.
Physics 201 Midterm Exam 3
Answer Section

MULTIPLE RESPONSE

1. ANS: A, B, C, D

MULTIPLE CHOICE

2. ANS: A
3. ANS: C
4. ANS: C
5. ANS: E
6. ANS: C
7. ANS: A
8. ANS: C
9. ANS: D
10. ANS: A
11. ANS: D
12. ANS: C
13. ANS: B
14. ANS: C
15. ANS: D
16. ANS: D
17. ANS: C