1. Please print your name and enter your seat number to identify you and your examination.
Student’s Printed Name: _______________________________ Recitation Section Number: ___
Seat Number: ______________

2. The University has a nationally recognized Honor Code, administered by the Student Honor Council. The Student Honor Council proposed and the University Senate approved an Honor Pledge. The University of Maryland Honor Pledge reads: 
"I pledge on my honor that I have not given or received any unauthorized assistance on this assignment/examination."  
Student’s Signature (in ink please): ______________________

This test consists of 4 parts, each worth 25 points. The exam is printed on 8 pages and is to be completed in 50 minutes. Please check that you have a complete exam. In most cases partial credit will be given, so show your work. If you need additional space use the reverse side of the sheets, or ask for additional paper. Some of the following information may be useful in the exam.

\[ g = 9.8 \text{ m/s}^2 \]

SCORING TABLE (Each student should check the addition of his own score.)

<table>
<thead>
<tr>
<th>Problem</th>
<th>Points</th>
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<tbody>
<tr>
<td>1.</td>
<td>/25</td>
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<td>2.</td>
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<td>3.</td>
<td>/25</td>
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<tr>
<td>4.</td>
<td>/25</td>
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<tr>
<td>Total</td>
<td>/100</td>
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</table>
1. A 1.00-kg object (mass $m$) slides to the right on a surface having a coefficient of kinetic friction $\mu_k = 0.250$ (See Fig).

The object has a speed of $v_i = 3.00$ m/s when it makes contact with a light spring that has a force constant $k = 50.0$ N/m.

The object comes to rest after the spring has been compressed a distance $d$.

The object is then forced toward the left by the spring and continues to move in that direction beyond the spring’s unstretched position.

Finally the object comes to rest a distance $D$ to the left of the unstretched spring.

\[ a) \quad (10 \text{ points}) \quad \text{Find a (quadratic) equation for } d \text{ in terms of } m, \mu_k, g, k \text{ and } v_i. \]

\[ b) \quad (8 \text{ points}) \quad \text{Assume } d = 0.378 \text{ m and, find the speed } v \text{ at the un-stretched position when the object is moving to the left.} \]

\[ c) \quad (7 \text{ points}) \quad \text{Assume } d = 0.378 \text{ m and find the distance } D \text{ where the object comes to rest.} \]
2. A sports car traveling North at 30 m/s collides head on with a truck heading South at 15 m/s. The mass of the car including the driver is 1,500 kg and the mass of the truck including the driver is 20,000 kg. After the collision the two vehicles stick together.
   a) (8 points) Find the speed of the wreckage. Is it moving North or South?

   b) (5 points) What is the impulse applied to the truck due to the collision?

   c) (6 points) Assume that the mass of the truck driver is 100 kg and that he is “belted in”. What is the impulse experienced by the driver due to the collision? If the collision lasts 0.2 s, what is the average force experienced by the driver?

   d) (6 points) Assume that the mass of the sports car driver is 100 kg and that he is “belted in”. What is the impulse applied to the driver due to the collision? If the collision lasts 0.2 s, what is the average force experienced by this driver?
Two blocks are connected by a string of negligible mass passing over a pulley of radius 0.250 m and moment of inertia $I$.

The block on the frictionless incline is moving up with a constant acceleration of 2.00 m/s$^2$.

a)  (4 points) What is the angular acceleration of the pulley?

b)  (6 points) What is the angular velocity of the pulley after it has completed 3 complete revolutions starting from rest?

c)  (6 points) Determine $T_1$ and $T_2$, the tensions in the two parts of the string.

d)  (5 points) What is the torque applied to the pulley?

e)  (4 points) Find the moment of inertia of the pulley.
4. **Mixed bag**  
   a) *(10 points)* A bowling ball with mass $M$, radius $R$, and a moment of inertia of $\frac{2}{5} MR^2$ is released from the top of an inclined plane of height $H$. A cylindrical ring with the same mass $M$, radius $R$, and with a moment of inertia $MR^2$ is also released at the same time. Both roll without slipping. Use energy methods to find the center of mass velocity, $V_{CM}$, of each object when it reaches the bottom of the incline. Express your result in terms of $R$, $H$ and the acceleration due to gravity, $g$. Which object reaches the bottom first?  

b) A billiard ball moving at 5.00 m/s strikes a stationary ball of the same mass (each mass is 1 kg). After the collision, the first ball moves at 4.33 m/s, at an angle of 30.0° with respect to the original line of motion.  
   i. *(10 points)* Find the struck ball's velocity after the collision.  
   ii. *(5 points)* What is the velocity of the center of mass before the collision?
Possibly useful information

Chapter 1

Dimensions [M], [L], [T]  \( \rho = M / V \)  sig. figs.

Chapter 2

\( \Delta x = x_f - x_i \)  \( \Delta t = t_f - t_i \)  \( \Delta v_x = v_{xf} - v_{xi} \)
\( \bar{v}_x = \Delta x / \Delta t \)  \( \bar{a}_x = \Delta v_x / \Delta t \)  av. speed = total dist./time
\( v_x = dx/dt \)  \( a_x = dv_x / dt \)  \( v_{xf} = v_{xi} + a_x t \)
\( x_f = x_i + \frac{1}{2} (v_{xi} + v_{xf}) t \)  \( x_f = x_i + v_{xi} t + \frac{1}{2} a_x t^2 \)  \( v_{xf}^2 = v_{xi}^2 + 2a_x (x_f - x_i) \)

Chapter 3

\( x = r \cos(\theta) \)  \( y = r \sin(\theta) \)  \( r = \sqrt{x^2 + y^2} \)
In 2 dimensions: \( \vec{A} = \vec{A}_x + \vec{A}_y \)  \( \vec{B} = \vec{B}_x + \vec{B}_y \)
\( \vec{C} = \vec{A} + \vec{B} \)  \( C_x = A_x + B_x \)  \( C_y = A_y + B_y \)
\( C = \sqrt{C_x^2 + C_y^2} \)  \( \tan \theta = C_y / C_x \)  and in 3d. using unit vectors:
\( \vec{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k} \)  \( \vec{B} = B_x \hat{i} + B_y \hat{j} + B_z \hat{k} \)  \( \vec{A} = \sqrt{A_x^2 + A_y^2 + A_z^2} \) etc.

Chapter 4

\( v_{xf} = v_{yi} + a_y t \)  \( y_f = y_i + v_{yi} t + \frac{1}{2} a_y t^2 \)  \( v_{xf}^2 = v_{yi}^2 + 2a_y (y_f - y_i) \) etc.
\( a_x = 0 \)  \( a_y = -g \)  \( R = v_i^2 \sin(2\theta) / g \)  \( h = v_i^2 \sin^2(\theta) / 2g \)
\( a_x = v^2 / r \)  \( a_i = \overline{v} / dt \)  \( \ddot{a} = -a_x \hat{i} + a_y \hat{j} \)
\( a = \sqrt{a_e^2 + a_i^2} \)
Chapter 5
\[ \sum \vec{F} = m \ddot{a} \quad \ddot{w} = mg \quad f_s \leq \mu_s R \]
\[ f_k = \mu_k R \]

Chapter 6
\[ a_c = \frac{v_t^2}{r} \]

Chapter 7
\[ W = F \Delta r \cos(\theta) = \vec{F} \cdot \Delta \vec{r} \quad W = \int \vec{F} \cdot d\vec{r} \quad F_s = -kx \]
\[ K = \frac{1}{2} mv^2 \quad W_{net} = K_f - K_i \]
\[ \bar{P} = \frac{W}{\Delta t} \quad \bar{P} = \vec{F} \cdot \vec{v} \]

Chapter 8
\[ U_g = mgy \quad U_s = \frac{1}{2} kx^2 \quad E = K + U \]
\[ K_i + U_i = K_f + U_f \quad W_g = -(U_f - U_i) \quad W_{nc} = (K_f + U_f) - (K_i + U_i) \]
\[ W_{friction} = -f_k d \quad \frac{1}{2} mv_f^2 + mgy_f = \frac{1}{2} mv_i^2 + mgy_i + f_k d \quad F_x = -\frac{dU}{dx} \]

Chapter 9
\[ \ddot{p} = m \ddot{v} \quad impulse \equiv \bar{I} \equiv \bar{F}_{AV} \Delta t \]
\[ \bar{I} = \Delta \bar{p} = m \bar{v}_f - m \bar{v}_i \quad m_1 \bar{v}_{1i} + m_2 \bar{v}_{2i} = m_1 \bar{v}_{1f} + m_2 \bar{v}_{2f} \]
\[ \bar{r}_{cm} = \frac{1}{M} \sum_i m_i \bar{r}_i \quad \bar{r}_{cm} = \frac{1}{M} \int \bar{r} dm \quad \bar{v}_{cm} = \frac{m_1 \bar{v}_1 + m_2 \bar{v}_2}{m_1 + m_2} \]
\[ \sum \vec{F}_{external} = M \ddot{a}_{cm} \quad M \ddot{v}_{cm} = \sum_i \ddot{p}_i = \ddot{p}_{total} \]
### Chapter 10

<table>
<thead>
<tr>
<th>Equation</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>( \theta = s/r )</td>
<td>( \omega ) = ( d\theta/dt )</td>
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<tr>
<td>( \omega_f = \omega_i + \alpha t )</td>
<td>( \theta_f = \theta_i + \omega_i t + \frac{1}{2} \alpha t^2 )</td>
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<tr>
<td>( v_i = r\omega )</td>
<td>( a_i = r\alpha )</td>
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<tr>
<td>( \theta_f = \theta_i + \frac{1}{2}(\omega_i + \omega_f) t )</td>
<td></td>
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<tr>
<td>( K = \frac{1}{2} I \omega^2 )</td>
<td>( I \equiv \sum_i m_i r_i^2 )</td>
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<tr>
<td>( P = \tau \omega )</td>
<td>( \tau = Fd )</td>
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\( s \) is the position, \( r \) is the radius, \( \omega \) is the angular velocity, \( \alpha \) is the angular acceleration, \( I \) is the moment of inertia, \( F \) is the force, \( M \) is the mass, \( v \) is the linear velocity, and \( m \) is the mass of each particle.