You are subject to the Bryn Mawr College honor code while taking this exam. This is a **closed book** exam. You may use a simple calculator and a pencil during this exam, as well as both sides of a single page of notes. Do all questions on the exam. Do all work directly on the examination, in the space provided. If you run out of room, you may use the back of the page. Be sure to answer all parts of each question. Some problems will take longer than others, but all will be weighted equally when graded. When providing a sketch, please be as neat, accurate, and quantitative as possible. A sloppy sketch indicates misunderstanding and will receive a reduced grade. The final pages of this exam provide several potentially useful equations. You may remove these page for easy reference.

This exam will be available between Friday, 24 April 2015 and Wednesday, 29 April 2015, at the reserve desk in the Collier Science Library during normal library operating hours. I will collect all of the exams Thursday morning when the library opens. Take the exam during a single **90 minute** sitting in the library.

Before you begin, **write your name in the space below and at the top of EVERY page of this exam**, note the date in the space provided on this page, and note the time. When you finish, note the time and return the exam to the circulation desk. The difference between your start and finish times should be no more that 90 minutes.

Name:

Date:

Start time:

Finish time:
1. A ladder leans against a frictionless wall. When is it more likely to slip: when a person stands near the top or near the bottom? Explain.
2. A thin hoop, a solid cylinder, and a sphere roll without slipping down an incline. In what order do they reach the bottom of the incline if they all start from rest at the same time (explain your answer)? What is the ratio of the speed of the hoop at the bottom of the ramp to the speed of the cylinder at the bottom of the ramp, \( \frac{v_{\text{hoop}}}{v_{\text{cylinder}}} \)?
3. A rod of mass $M$ and length $L$ hangs vertically and is free to pivot about its top end. A bullet with mass $m$ passes in a very short time through the bottom end of the rod. The bullet, both before and after passing through the rod, is traveling horizontally, perpendicular to the rod and to the axis about which the rod can pivot. Before the collision the speed of the bullet is $v$ and after the collision it is $v/2$. Determine the angular velocity of the rod just after the bullet has passed through the rod. Determine what speed the bullet should have to make the rod swing through an angle of exactly $90^\circ$ from its initial equilibrium position.
4. A thin stick of mass $M$ and length $L$ is positioned vertically, with its tip on a frictionless table. It is released and allowed to fall. Describe the path of the center of mass of the stick. Determine the speed of the center of mass of the stick just before it hits the table.
Potentially useful equations

\[ v_x = v_{0x} + a_x t \]
\[ x = x_0 + v_{0x} t + \frac{1}{2} a_x t^2 \]
\[ v_x^2 = v_{0x}^2 + 2a_x (x - x_0) \]

\[ \mathbf{r} = r \hat{\mathbf{r}} \]
\[ \mathbf{v} = r \hat{\mathbf{r}} + r \hat{\theta} \hat{\theta} \]
\[ \mathbf{a} = (\dot{r} - r \dot{\theta}^2) \hat{\mathbf{r}} + (r \ddot{\theta} + 2 \dot{r} \dot{\theta}) \hat{\theta} \]

\[ a_c = \frac{v^2}{r} = \omega^2 r \]
\[ v = r \omega \]
\[ \omega = 2\pi f = \frac{2\pi}{T} \]

\[ \mathbf{F} = m \mathbf{a} \]
\[ F_{friction} = \mu N \]
\[ W = mg \]
\[ F_s = -kx \]
\[ F_{grav} = \frac{GM_a M_b}{r^2} \]

for \( \ddot{q} + \omega^2 q = 0 \), \( q(t) = A \sin(\omega t + \phi) \)

\[ \mathbf{A} \cdot \mathbf{B} = \| \mathbf{A} \| \| \mathbf{B} \| \cos \theta \]
\[ \mathbf{A} \cdot \mathbf{B} = A_x B_x + A_y B_y + A_z B_z \]
\[ | \mathbf{A} \times \mathbf{B} | = \| \mathbf{A} \| \| \mathbf{B} \| \sin \theta \]
\[ \mathbf{A} \times \mathbf{B} = i(A_y B_z - A_z B_y) - j(A_x B_z - A_z B_x) + k(A_x B_y - A_y B_x) \]

\[ g = 10 \text{ m/s}^2 \]
\[ G = 6.673 \times 10^{-11} \text{ m}^3 \text{kg}^{-1} \text{s}^{-2} \]

for \( ax^2 + bx + c = 0 \), \( x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \)
More potentially useful equations

\[ \mathbf{p} = m \mathbf{v} \]
\[ \mathbf{F} = \frac{d\mathbf{p}}{dt} \]
\[ \Delta \mathbf{p} = \int \mathbf{F} \, dt \]
\[ \mathbf{R} = \frac{1}{M} \sum_i m_i \mathbf{r}_i \]

\[ W_{ba} = \int_a^b \mathbf{F} \cdot d\mathbf{r} \]

\[ K = \frac{1}{2} m v^2 \]
\[ W_{ba} = K_b - K_a \]

\[ U_b - U_a = - \int_a^b \mathbf{F} \cdot d\mathbf{r} \]
\[ U_{spring} = \frac{1}{2} k x^2 \]
\[ U_{grav} = mgh \]
\[ U_G = -\frac{GMm}{r} \]

\[ \mathbf{p}_1 + \mathbf{p}_2 = \mathbf{p}_1' + \mathbf{p}_2' \]
\[ K_1 + K_2 = K_1' + K_2' \]
\[ v_1 - v_2 = v_2' - v_1' \]

\[ K + U = K' + U' \]
\[ W_{nc} = \Delta K + \Delta U \]
More potentially useful equations

\[ \mathbf{L} = \mathbf{r} \times \mathbf{p} \]
\[ L = I\omega \]

\[ \tau = \mathbf{r} \times \mathbf{F} \]
\[ \tau = \frac{d\mathbf{L}}{dt} \]
\[ \tau = I\alpha \]

\[ I = \sum_j m_j \rho_j^2 \]

\[ \theta = s/r \]
\[ \omega = v/r \]
\[ \alpha = a/r \]

\[ K = \frac{1}{2} I\omega^2 \]
Table 11.1. Moments of inertia for selected bodies

<table>
<thead>
<tr>
<th>Body of total mass $M$</th>
<th>Moment of Inertia</th>
</tr>
</thead>
<tbody>
<tr>
<td>thin rod</td>
<td>$\frac{1}{3}Ma^2$</td>
</tr>
<tr>
<td>thin rod</td>
<td>$\frac{1}{12}Ma^2$</td>
</tr>
<tr>
<td>circular disk</td>
<td>$\frac{3}{2}MR^2$</td>
</tr>
<tr>
<td>circular disk</td>
<td>$\frac{1}{2}MR^2$</td>
</tr>
<tr>
<td>circular disk</td>
<td>$\frac{1}{4}MR^2$</td>
</tr>
<tr>
<td>thin spherical shell</td>
<td>$\frac{2}{3}MR^2$</td>
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<tr>
<td>homogenous sphere</td>
<td>$\frac{2}{5}MR^2$</td>
</tr>
<tr>
<td>rectangular plate</td>
<td>$\frac{1}{12}M(a^2 + b^2)$</td>
</tr>
</tbody>
</table>