Name: SOLUTION  
Section: ____________

Instructions:
- Put name and section on exam and on equation sheet.
- Do not open the test until you are told to do so.
- Write your final answer in the box provided.
- If you finish with less than 5 minutes remaining, please stay seated until the exam is over.
- Stop work immediately when time is over; pass exams to the aisle; stay seated until all exams are collected. Working after time is over is an automatic 10 point deduction.
- Turn in your equation sheet with your examination.

Guidelines:
- Assume 3 significant figures for all given numbers unless otherwise stated.
- Show all of your work – no work, no credit.
- Include units for all answers; include directions for all vectors.

Mass Moments of Inertia:

\[ I_{center} = \frac{mL^2}{12} \]

Thin-walled hollow cylinder

\[ I = mr^2 \]

Center of Mass:

\[ \quad \]

<table>
<thead>
<tr>
<th>111 Front</th>
<th>111 Back</th>
<th>Est 209</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:10 S1a Tyler</td>
<td>S1b Tayler</td>
<td>S1c Rachel</td>
</tr>
<tr>
<td>12:40 S2a Tyler</td>
<td>S2b Tayler</td>
<td>S2c Rachel</td>
</tr>
<tr>
<td>2:10 S3a Tyler</td>
<td>S3b Tayler</td>
<td>S3c Rachel</td>
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1. (2 pt) An ice skater spins on ice with her arms tucked at her sides. When she pushes her arms straight out so that her body forms a T shape, what happens?
   a. Mass moment of inertia increases; rotational speed increases
   b. Mass moment of inertia decreases; rotational speed decreases
   c. Mass moment of inertia increases; rotational speed decreases
   d. Mass moment of inertia decreases; rotation speed increases

   \[ I\omega = I'\omega' \]
   \[ I \uparrow \omega \downarrow \]

2. (2 pt) Rachel is sitting on a spinning stool, holding a spinning bicycle wheel. What is conserved when the plane of the spinning wheel is rotated 180 deg?
   a. Linear energy
   b. Rotational Energy
   c. Spring Energy
   d. Linear Momentum
   e. Angular Momentum
   f. Spring Momentum
   g. Nothing is conserved

3. (2 pt) The value of \((\vec{j} \times \hat{\vec{i}}) \cdot \hat{\vec{k}}\) is:
   a. 0
   b. 1
   c. -1
   d. \(\hat{\vec{k}}\)
   e. \(-\hat{\vec{k}}\)

   \[ \vec{j} \times \vec{e} = -\vec{k} \]
   \[ -\vec{k} \cdot \vec{k} = -1 \]

4. (2 pt) A 10 lb solid cylinder and a 2 lb solid cylinder start at rest roll down an incline. Which one reaches the bottom first.
   a. 10 lb solid cylinder
   b. 2 lb solid cylinder
   c. The cylinder with the larger radius
   d. The cylinder with the smaller radius
   e. They both reach the bottom at the same time
   f. Cannot determine the winner

   \[ \text{same shape} \]
   \[ m \neq r \text{ have no effect} \]
5. (2 pt) A car is going around a banked turn as shown. What is the direction for the centripetal acceleration?
   a. Right  b. Left
c. Up  d. Down
e. Up the incline  f. Down the incline
g. Out of the paper  h. Into the paper

6. (2 pt) A bike wheel is given a positive rotation and hung from a rope as shown. If the rope is moved closer to the center of the bike wheel, what will happen to the precession speed?
   a. Precession speed will increase
   b. Precession speed will decrease
c. Precession speed will be unchanged

   \[ \Omega = \frac{mg r}{Iw} \]
   smaller r \rightarrow smaller \Omega

7. (2 pt) A rotating object has a angular speed of \( \omega \). What is its speed if you double its kinetic energy?
   a. \( 4\omega \)
   b. \( 2\omega \)
c. \( 1.4\omega \)
d. \( \omega \)
e. \( 0.7\omega \)
f. \( 0.6\omega \)
g. \( 0.25\omega \)

   \[ KE = \frac{1}{2}I \omega^2 \]
   \[ 2KE = \frac{1}{2}I \omega'^2 = 2 \left( \frac{1}{2}I \omega^2 \right) \]
   \[ \omega'^2 = 2 \omega^2 \]
   \[ \omega' = \sqrt{2} \omega = 1.4 \omega \]

8. (2 pt) Which situation causes the greatest torque about the door hinge?
   a. Situation A
   b. Situation B
c. Both cause an equal amount of torque

   A: \( \tau = 1.5(20) \)  
   B: \( \tau = 3(10) \cos 30 \)  

   \( \tau_A > \tau_B \)
9. (14 pt) Find the total moment about point O. Assume that CCW is positive.

\[ -1.96 \text{ ft} \cdot \text{lb} \]

\[ \mathcal{L}_x = +41 \text{ lb} \]

\[ +5 \text{ lb} \cos 180 \cdot (3.5) \]

\[ -5 \text{ lb} \sin 180 \cdot (1 \text{ ft}) \]

\[ -6 \text{ lb} \cos 72 \cdot (0.5 \text{ ft}) \]

\[ -3 \cdot (3.5) \]

\[ +5 \sin 72 \cdot (0.35) = -1.96 \text{ ft} \cdot \text{lb} \]

10. (14 pt) The object pictured has a uniform mass and density. The square is a perfect square. If the center of mass in the x direction of the total object is 5.69 in, what is the length of a side of the square hole?

\[ 2.44 \text{ in} \]

\[ 5.69 = \frac{\frac{1}{2}(15 \text{ in})(17 \text{ in})(\frac{17}{3} \text{ in})}{\frac{1}{2}(15 \text{ in})(17 \text{ in})} - \pi (1.2 \text{ in})^2 - x^2 \cdot 0.8 \text{ in} \]

\[ x = 2.44 \text{ in} \]

\[ \mathcal{A}_{\text{tri}} = 127.5 \quad \bar{x}_{\text{tri}} = 5.67 \]

\[ \mathcal{A}_{\text{cir}} = 4.524 \quad \bar{x}_{\text{cir}} = 2 \]

\[ \bar{x}_{\text{sq}} = 8 \]
11. (14 pt) Two gears are oriented as shown and start at rest. The smaller gear has 13 teeth. Assuming constant acceleration, when the small gear has an \( \omega_s = 9.2 \text{ rad/s} \), the large gear has an \( \alpha = 0.197 \text{ rad/s}^2 \) and has gone 5 revolutions. How many teeth are on the bigger gear?

\[
\Delta \phi = \frac{\omega_f^2 - \omega_s^2}{2 \alpha} = \frac{31.116 \text{ rad}}{2(0.197 \text{ rad/s}^2)} = 34 \text{ teeth}
\]

12. (14 pt) A barrel (\( m = 30 \text{ kg}, r = 0.3 \text{ m} \)) starts from rest at the bottom of a hill. The hill is 17 m high. Its linear speed at the top of the hill is 5 m/s. Determine the average power required to roll the barrel up the hill in 30 seconds. Assume the barrel is a thin-walled hollow cylinder.

\[
I = mr^2 = (30 \text{ kg})(0.3 \text{ m})^2 = 2.7 \text{ kg m}^2
\]

\[
W_{in} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + mgh = \frac{1}{2}(30 \text{ kg})(5 \text{ m/s})^2 + \frac{1}{2}(2.7 \text{ kg m}^2)(0.3 \text{ m})^2 + 30 \text{ kg}(9.81 \text{ m/s}^2)(17 \text{ m})
\]

\[
W_{in} = 5753.1 \text{ J}
\]

\[
P = \frac{W}{t} = \frac{5753.1 \text{ J}}{30 \text{ s}} = 192 \text{ W}
\]

-4 Use \( T = I\omega \) and \( T_{net} 

+3 recognizing CoE

-4 use \( T = I\omega \) and \( T_{net} \)
13. (14 pt) Our mascot, Smokey, rides on a ferris wheel that is moving at a constant speed. If the vertical force on Smokey is 135 lb at the shown location, what is the rotation speed (in rpm) of the ferris wheel? (*FBD = *KD required*)

\[ \text{W} = 175 \text{ lb} \]
\[ \text{r} = 58 \text{ ft} \]
\[ \theta = 27^\circ \]

\[ 135 \text{ lb} - 175 \text{ lb} = -\left(\frac{175 \text{ lb}}{32.2 \text{ ft/s}^2}\right)\left(\omega^2 \cdot 58 \text{ ft}\right)\sin 27^\circ \]

\[ \alpha_n = \frac{16.2 \text{ ft}}{3^2} \]
\[ \omega = 0.5287 \frac{\text{rad}}{s} \cdot \frac{60}{2\pi} \]

\[ = 5.05 \text{ rev/min} \]

\[ \text{Conversion} \]

\[ 41 - 2 \text{ Conversion} \]

\[ = 4 + \]

\[ -1 \text{ ME} \]

\[ -1 \text{ Wrong trig function} \]

14. (14 pt) A golf club can be modeled as a thin rod with a small point mass connected at the end, where the point mass represents the head of the golf club. What torque should be applied at A so that the club swings with an angular acceleration of 7.6 rad/s^2?

\[ T = I \alpha \]

\[ I = \frac{1}{12} m L^2 + m d^2 + mr^2 \]

\[ = \frac{1}{12} (0.13 \text{ kg})(0.67 \text{ m})^2 + (0.13 \text{ kg})(0.67 \text{ m})^2 + (0.24 \text{ kg})(0.67 \text{ m})^2 \]

\[ I = 0.1272 \text{ kg m}^2 \]

\[ \alpha = \frac{1}{3} \text{ s}^2 \]

\[ \tau = 0.1272 \text{ kg m}^2 \times 7.6 \text{ rad/s}^2 \]

\[ \tau = 0.967 \text{ Nm} \]

Point A

Shaft: \( m = 0.13 \text{ kg} \)
\( L = 0.67 \text{ m} \)

Head: \( m = 0.24 \text{ kg} \)