As always, show all your work and circle your final answer (both numerical and multiple choice). All numeric values have 3 significant figures. Ignore air resistance. You should have three (3) pages in this exam, not including the cover sheet.

Multiple choice: Each question is worth 5 points (30 points total).

1. Which of the following forces cannot produce a torque?
   - A. A “contact force”
   - B. Friction
   - C. Weight
   - D. Tension
   - E. None of the above can potentially produce a torque.

2. An object is said to be in equilibrium, so that there is no acceleration of any kind. In this case, the net force on the object should be zero. Additionally,
   - A. There can be no individual torques on the object.
   - B. All torques in one direction must equal the torques in the opposite direction.
   - C. There can be no friction acting on the system.
   - D. There can be no contact forces acting on the system.
   - E. Both C & D.

3. Considering kinetic energy and work, by what factor would your necessary stopping distance change if you increased your car’s velocity by a factor of 2.00?
   - A. No change in stopping distance
   - B. 1.44 times the stopping distance
   - C. 2.00 times the stopping distance
   - D. 4.00 times the stopping distance
   - E. 8.00 times the stopping distance

4. A collision between two carts occurs. Even though you don’t know any other details about the collision, you know for certain that in the collision
   - A. kinetic energy is conserved.
   - B. rotational energy is conserved.
   - C. momentum is conserved.
   - D. Both A & B.
   - E. Both A & C.

5. A Ferris wheel rider is going around and around in a vertical circle. While moving at the bottom of this ride, the magnitude of the “contact force” pushing upwards on this rider is
   - A. equal to the magnitude of the weight of the rider.
   - B. greater than the magnitude of the weight of the rider.
   - C. less than the magnitude of the weight of the rider.
   - D. More information is needed to compare these forces.

6. A kilowatt-hour is a unit that accesses how much electricity your household has used during a month. It’s simply the product (multiplication) of “kilowatts” and “hours”. What is it a measure of?
   - A. Energy
   - B. Power
   - C. Force
   - D. Time
Situation 41: The spinning cockroach [35 points]
The subject of this page is a 2.00-kg solid disk whose radius is 0.250 m. It spins at a rate of 1.50 rad/s.

A. [15 points] A small cockroach is standing on top of the disk at the very edge. What is the minimum coefficient of static friction between this cockroach and the disk if it isn’t sliding off the disk as it spins around?

\[ f = \mu_s N = \mu_s mg \]
\[ f = \mu_s \times 2 \rightarrow \frac{m}{2} \times \frac{v^2}{r} = \mu_s \times 2 \]
\[ \mu_s = \frac{v^2}{2g} \]
\[ \mu_s = 0.0574 \]

B. [15 points] You have another disk that has twice the radius of the first disk, but half the mass. Initially this new disk is at rest, but you drop it on the disk that is rotating at 1.50 rad/s. (Yes, you squish the cockroach, but don’t consider that in the problem.) After the two disks collide, what is their final angular velocity?

\[ I_1 = \frac{1}{2} MR^2 \]
\[ I_2 = \frac{1}{2} \left( \frac{1}{2} M \right)(2R)^2 = \frac{1}{2} M 4R^2 = 2MR^2 \]
\[ I_1 + I_2 = \frac{3}{2} MR^2 \]

\[ \omega_f = \omega_i \frac{I_1}{I_1 + I_2} \]
\[ \omega_f = \frac{1.5 \text{ rad/s}}{\frac{3}{2} \times 2} = \frac{3}{2} = 1.5 \text{ rad/s} \]

C. [5 points] After the collision, the rotational kinetic energy of the rotating disks

<table>
<thead>
<tr>
<th>A. was the same as before the collision.</th>
<th>B. became less than before the collision.</th>
<th>C. became more than before the collision.</th>
<th>D. More information is needed to answer this question.</th>
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Situation #2: Another stupid roller coaster just like Adam always uses as an example [35 points]

A. [15 points] A roller coaster (m=300 kg) starts at the top of a track that is 25.0 m above the ground. It moves down to the bottom (ground level) of the frictionless track and then gains another 10.0 m of height and runs into a spring. If this spring brings the roller coaster to a stop over a horizontal distance of 5.00 m, what is the spring constant, $k$?

\[
E = E_f
\]

\[
w x dG = mg z_1 + \frac{1}{2} k z^2
\]

\[
\frac{1}{2} k z^2 = mg (z_2 - z_1)
\]

\[
L = \frac{1}{2} k z^2 = \frac{2 \times 300 \text{ kg} \times (9.8 \text{ m/s}^2 \times (25 \text{ m} - 10 \text{ m})}{(5 \text{ m})^2}
\]

\[
= 3530 \text{ N/m}
\]

B. [20 points] What if the roller coaster (m=300 kg) starts at the top of a track that is 25.0 m above the ground and then runs into an identical roller coaster cart (m=300 kg)? What is the final velocity of these two if they stick together at ground level? [Hint: This is a two-part problem.]

1. Conserve energy:

\[
E = E_f
\]

\[
w x dG = \frac{1}{2} k z^2
\]

\[
V = \sqrt{-\frac{w x dG}{k}}
\]

\[
(= 22.1 \text{ m/s})
\]

2. Conserve momentum in collision

\[
m V = (2m) V_f
\]

\[
V_f = \frac{V}{2m} \sqrt{2} = \frac{1}{2} \sqrt{2} \times 22.1 \text{ m/s}
\]

\[
V_f = 11.1 \text{ m/s}
\]