Examination 2

Name: ____________________________
Section: __________________________

Physics 201
Fall 2010
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Time: 1 hour 15 minutes

Show all of your work.

Part I: Multiple Choice Questions

1. What are the units of the following quantities?
   (5 pts)
   Torque = \( \text{N} \cdot \text{m} \)
   Moment of inertia = \( \text{kg} \cdot \text{m}^2 \)
   Stress = \( \text{N} / \text{m}^2 \)
   Strain = \( \text{u} \text{one} \)
   Angular momentum = \( \text{kg} \cdot \text{m}^2 / \text{s} \)

2. Two balls having different masses reach the same height when shot into the air from the ground. If there is no air drag, which of the following statements must be true? (More than one statement may be true.)
   (5 pts)
   (a.) Both balls left the ground with the same speed.
   (b.) Both balls left the ground with the same kinetic energy.
   (c.) Both balls will have the same gravitational potential energy at the highest point.
   (d.) The heavier ball must have left the ground with a greater speed than the lighter ball.
   (e.) Both balls have no acceleration at their highest point.
3. Suppose you increase the amplitude of oscillation of a mass vibrating on a spring. Which of the following statements about this mass are correct? (More than one statement may be true.)

(a.) Its maximum speed increases.

(b.) Its period of oscillation increases.

(c.) Its maximum acceleration increases.

(d.) Its maximum kinetic energy increases.

4. A mass oscillates with simple harmonic motion of amplitude $A$. The kinetic energy of the mass will equal the potential energy of the spring when the position is:

(a.) $x = 0$

(b.) $x = \frac{A}{2}$

(c.) $x = \frac{A}{\sqrt{2}}$

(d.) $x = \frac{A}{4}$

\[ \frac{1}{2} m v^2 + \frac{1}{2} k x^2 = \frac{1}{2} k A^2 \]

\[ \frac{1}{2} k A^2 = \frac{k A^2}{2} \]

\[ x = \frac{A}{\sqrt{2}} = \frac{A}{\sqrt{12}} \]

5. Why does the rotating physics professor on the turntable rotate faster when he pulls the dumbbells close to his body?

(a.) Because he increases his moment of inertia.

(b.) Because, without friction, angular momentum is conserved.

(c.) Because the rotational velocity increases when he puts energy into the motion by pulling the dumbbells in.

(d.) Because the gravitational torque increases.
6. In the race of various round objects shown, which is:

(a.) first? the sphere
(b.) second? the cylinder
(c.) third? the ring (hoop)

Assume that all the round objects have the same mass \( M \) and radius \( R \), and friction can be neglected.

(d.) Compare the winner of this first race to a square box of sides \( l = R \) and the same mass \( M \) and neglect friction. The box was entered late. Who wins this run-off race?

![Diagram of objects on a slope]

\[
\frac{1}{2} k x^2 + \frac{1}{2} I \omega^2 = \frac{1}{2} m v^2 + \frac{1}{2} \beta M R^2 \left( \frac{v}{R} \right)^2
\]

Small \( \beta \) - bodies win.

\[
I_{cm} = \beta M R^2
\]

- a. for a thin walled ring (hoop) \( \beta = 1 \)
- b. for a solid cylinder \( \beta = \frac{1}{2} \)
- c. for a solid sphere \( \beta = \frac{2}{5} \)
- d. for the box \( \beta = 0 \)

\[
v = \sqrt{\frac{2 g x}{1 + \beta}}
\]
Part II: Problems

7. An empty freight car with a mass of 10,000 kg rolls at 5.00 m·s⁻¹ along a level track and collides with a loaded car with a mass of 20,000 kg, standing at rest with brakes released. Friction can be neglected. If the cars couple together,

(a.) Find their speed after the collision.

(b.) Find the decrease in kinetic energy as a result of the collision.

(c.) With what speed should the loaded car be rolling toward the empty car for both to be brought to rest by the collision?

(d.) What kind of collision is this? Give a reasoning for your answer.

\[
P = P'
\]

\[
m u_{f} = m' u'_{f}
\]

\[
10,000 \times 5 = 30,000 \cdot u'_{f}.
\]

\[
\frac{50,000}{30,000} = u'_{f} = 1.67 \text{ m/s}
\]

\[
\Delta K_{E} = \frac{1}{2} m u'_{f}^{2} - \frac{1}{2} m u_{f}^{2}
\]

\[
K_{E_{i}} = \frac{1}{2} (10,000) (5)^{2} = 125,000 \text{ J}
\]

\[
K_{E_{f}} = \frac{1}{2} (30,000) (1.67)^{2} = 41,833.5 \text{ J}
\]

\[
\Delta K_{E} = 41,833 - 125,000 = -83,166 \text{ J (lost)}
\]

\[
< : 10,000 (5) + 20,000 (0) = 0 \quad v = 2.5 \text{ m/s}
\]

(d.) Inelastic, KE is lost into the system.
8. A uniform plank is supported horizontally by a brick at one end and an egg at the other. The plank is 8.00 m long and weighs 60 N, and you weigh 450 N. If a force of 150 N will break the egg, how far from the end of the plank where the brick is can you stand and not break the egg?

\[ \sum F = 0 \]
\[ 4 \times 60 \text{N} + x \times 450 \text{N} = 150 \text{N} \cdot \delta \]

\[ x = 2.13 \text{ m} \]
\[ 8 - 2.13 = 5.87 \text{ m} \]
Calculate the torque (magnitude and direction) about point $O$ due to the force $\vec{F}$ in each of the situations sketched below. In each case, the force $\vec{F}$ and the rod both lie in the plane of the page, the rod has a length of 4.00 m and the force has a magnitude of 10.0 N.

\[ \vec{\tau} = \vec{F} \cdot \ell \]

\[ a \quad \tau = 10 \cdot 4 = 40 \text{ Nm} \]

\[ b \quad \tau = 10 \cos 30 \cdot 4 = 34.64 \text{ Nm} \]

\[ c \quad \tau = 10 \cos 60 \cdot 4 = 20 \text{ Nm} \]

\[ d \quad \tau = 10 \cos 60 \cdot 2 = 17.32 \text{ Nm} \]

\[ e \quad \tau = 0 \]

\[ f \quad \tau = 0 \]
10. Four small spheres, each with a mass of 0.300 kg, are arranged in a square 0.400 m on a side and are connected by light rods, as shown below. Find the moment of inertia of the system about an axis

(a.) through the center of the square, perpendicular to its plane (an axis through point O in the figure)

(b.) bisecting two opposite sides of the square (an axis along line AB in the figure).

\[ R = 0.283 \]

\[ I = 4 \cdot m \cdot R^2 = 4 \cdot 0.3 \cdot (0.283)^2 \]

\[ = 0.096 \text{ Nm}^2 \]

\[ b \cdot I = 4 \cdot m \cdot R^2 \]

\[ \int_{R=0.2} \text{ Nm}^2 \]

\[ = 0.048 \text{ Nm}^2 \]