Physics 213H Test 2

Dr. Gladden, Oct. 27, 2009

NAME: KEY UM ID#:____________________

Conceptual Questions (*5 points each*) Answer each of the following questions drawing on and referencing the physical concepts we have covered. Sketches may aid your discussion and no more than 2 - 4 sentences should be required.

1. Consider the completely inelastic collision of two train cars colliding and hooking together. What is conserved and what is not? Make some comments about any quantity that is not conserved (i.e. why it is not conserved).

In an inelastic collision, KE is not conserved, but momentum is. The KE lost goes into deformation, heat, sound, ... through non-conservative work.

2. Explain why it is that a gymnast will tuck into a tight ball when executing a flip in mid air.

The gymnast is reducing her moment of inertia by bringing more of her body mass closer to her axis of rotation. By conservation of angular momentum, if I ↓ then ω ↑ so she spins faster.

$\vec{L} = I\vec{\omega}$, $I_1 \omega_1 = I_2 \omega_2$

3. Write down the conservation of energy equation and briefly explain what each term represents.

$KE_i + PE_i = KE_f + PE_f + W_{nc}$

KE : Kinetic energy - translational or rotational

PE : potential energy - could be gravitational, elastic, electrostatic, ...

W_{nc} : Work done by non conservative forces such as friction.

Conceptual Multiple Choice (*4 points each*): Clearly write the letter corresponding to the BEST possible answer in the space provided. You may also circle the answer to be sure.

1. C An object moves in a circular path at a constant speed. Compare the direction of the object's velocity and acceleration vectors.
A) Both vectors point in the same direction.
B) The vectors point in opposite directions.
C) The vectors are perpendicular.
D) The question is meaningless, since the acceleration is zero.

2. A A roller coaster car is on a track that forms a circular loop in the vertical plane. If the car is to just maintain contact with track at the top of the loop, what is the minimum value for its centripetal acceleration at this point?
A) g downward
B) 0.5g downward
C) g upward
D) 2g upward

3. D A car goes around a curve of radius r at a constant speed v. Then it goes around the same curve at half of the original speed. What is the centripetal force on the car as it goes around the curve for the second time, compared to the first time?
A) twice as big
B) four times as big
C) half as big
D) one-fourth as big

4. D If you push twice as hard against a stationary brick wall, the amount of work you do

A) doubles.
B) is cut in half.
C) remains constant but non-zero.
D) remains constant at zero.

5. B Car J moves twice as fast as car K, and car J has half the mass of car K. The kinetic energy of car J, compared to car K is

A) the same.
B) 2 to 1.
C) 4 to 1.
D) 1 to 2.

6. A You slam on the brakes of your car in a panic, and skid a certain distance on a straight, level road. If you had been traveling twice as fast, what distance would the car have skidded, under the same conditions?

A) It would have skidded 4 times farther.
B) It would have skidded twice as far.
C) It would have skidded 1.4 times farther.
D) It is impossible to tell from the information given.

7. A When is kinetic energy conserved?

A) in elastic collisions
B) in inelastic collisions
C) in any collision in which the objects do not stick together
D) in all collisions

8. C Which of the following is an accurate statement?

A) The momentum of a projectile is constant.
B) The momentum of a moving object is constant.
C) If an object is acted on by a non-zero net external force, its momentum will not remain constant.
D) If the kinetic energy of an object is doubled, its momentum will also double.

9. A A boy and a girl are riding a merry-go-round which is turning at a constant rate. The boy is near the outer edge, while the girl is closer to the center. Who has the greater centripetal acceleration?

A) the boy
B) the girl
C) Both have the same non-zero centripetal acceleration.
D) Both have zero centripetal acceleration.

10. C A uniform solid sphere has mass M and radius R. If these are increased to 2M and 3R, what happens to the sphere's moment of inertia about a central axis?
A) increases by a factor of 6
B) increases by a factor of 12
C) increases by a factor of 18
D) increases by a factor of 54

Problems: Work each of the following problems. Make sure to **show your work** and put a box around your final answer. (*15 points each*)

1. The figure shows a 10.0 kg box at rest which has compressed a spring by 0.25 m. The spring constant of the spring is 100 N/m. The coefficient of kinetic friction against the box and table is $\mu_k = 0.2$.

(a) (5 points) What is the total potential energy stored in the spring?

$$PE_{elas} = \frac{1}{2} k \Delta x^2$$
$$= \frac{1}{2} (100 \tfrac{N}{m})(0.25m)^2 = 3.13 \text{ J}$$

(b)(10 points) How far will the box slide before coming to rest?

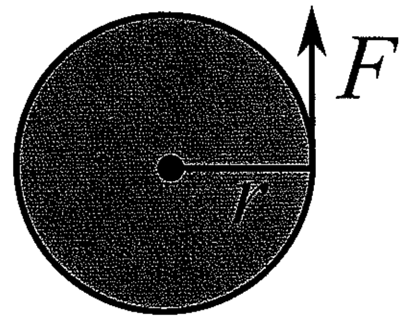
Use Conservation of Energy

$$PE_{elas} = W_{NC}$$

$$\frac{1}{2} k \Delta x^2 = F_f d$$, where $F_f = \mu_k mg$ and d is the distance we are after

So $$d = \frac{k \Delta x^2}{2 \mu_k Mg} = 0.16m$$
$$= \boxed{16 \text{ cm}}$$

2. A boy is pushing a merry-go-round with radius 1.5 m and mass of 150.0 kg as shown in the figure. The boy pushes with a force of 200.0 N tangentially at the outer edge of the merry-go-round.



(a)(5 points) Assuming the merry-go-round is a cylinder, what is the moment of inertia?

$$I_{cyl} = \frac{1}{2} MR^2 = \frac{1}{2}(150\,kg)(1.5\,m)^2$$
$$= 169\ kg \cdot m^2$$

(b)(5 points) What is the angular acceleration?

$$\tau = I\alpha$$

so $$\alpha = \frac{\tau}{I} = \frac{Fr\sin\theta}{I_{cyl}} = \frac{200N\,(1.5m)}{169\ kg \cdot m^2} =$$
$$= \boxed{1.78\ \frac{rad}{sec^2}}$$

(c)(5 points) After 1 full revolution, what will the angular velocity be?

$$\omega_f^2 = \omega_o^2 + 2\alpha\Delta\theta, \quad \omega_o = 0, \quad \Delta\theta = 2\pi$$

$$\omega_f = \sqrt{2(1.78)(2\pi)}$$
$$= \boxed{4.73\ \frac{rad}{sec}}$$

Two bumper cars (both with a mass of 100.0 kg) are heading straight for each other. Car A has a velocity of 2.5 m/s and car B has a velocity of -1.5 m/s. Assume the collision is perfectly elastic and there is no friction.

(a) (10 points) What will the final velocity of EACH car be?

$m_A = m_B = m$

$P_A + P_B = P_A' + P_B'$ by Conservation of momentum

$m v_A + m v_B = m v_A' + m v_B'$

So $v_A + v_B = v_A' + v_B'$ ... (1)

also KE is Conserved

so

$v_A - v_B = -(v_A' - v_B')$

so

$v_A' = v_B - v_A + v_B'$

plug into (1)

Then $v_A + v_B = v_B - v_A + 2v_B'$

$v_B' = v_A = +2.5$ m/s

(b) (5 points) For the rider in car B, what is the impulse she experiences during the collision?

Impulse is $F\Delta t = \Delta P$

and $\Delta P_B = m_B v_B' - m_B v_B$

$= m_B(v_B' - v_B)$

$= 100\text{ kg}(2.5\text{ m/s} - (-1.5\text{ m/s}))$

$= \boxed{400\text{ N}\cdot\text{s}}$

Then

$v_A' = v_B - v_A + v_B'$

$= -1.5 - 2.5 + 2.5$

$= -1.5$ m/s

so

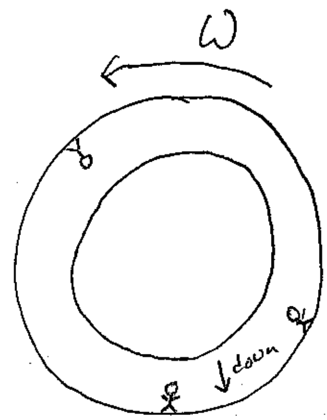
$v_A' = -1.5$ m/s

$v_B' = +2.5$ m/s

They "exchange" velocities!

Extra Credit(+5 points)

A space station far from earth is designed to simulate gravity by spinning. How would this work? (Draw a diagram and label what direction would appear to be "down".) If the station is 300 m in radius, how fast would it have to spin in order to simulate earth gravity of 9.8 m/s^2?



"down" is radially outward

need $a_c = 9.8\ m/s^2$

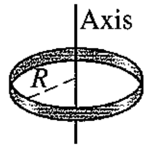
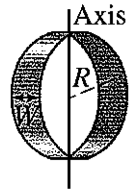
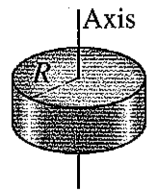
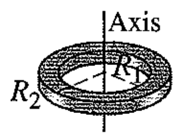
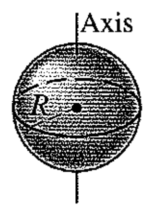
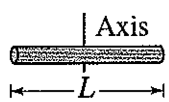
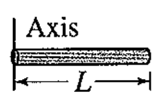
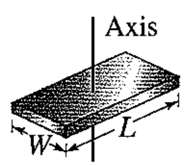
$$a_c = \frac{v^2}{r} = \frac{(\omega r)^2}{r} = \omega^2 r$$

$$\text{So } \omega = \sqrt{\frac{a_c}{r}}$$

$$= \sqrt{\frac{9.8\ m/s^2}{300\ m}}$$

$$\boxed{\omega = 0.18\ \frac{rad}{sec}}$$

Moments of Inertia

	Object	Location of axis		Moment of inertia
(a)	**Thin hoop,** radius R	Through center		MR^2
(b)	**Thin hoop,** radius R width W	Through central diameter		$\frac{1}{2}MR^2 + \frac{1}{12}MW^2$
(c)	**Solid cylinder,** radius R	Through center		$\frac{1}{2}MR^2$
(d)	**Hollow cylinder,** inner radius R_1 outer radius R_2	Through center		$\frac{1}{2}M(R_1^2 + R_2^2)$
(e)	**Uniform sphere,** radius R	Through center		$\frac{2}{5}MR^2$
(f)	**Long uniform rod,** length L	Through center		$\frac{1}{12}ML^2$
(g)	**Long uniform rod,** length L	Through end		$\frac{1}{3}ML^2$
(h)	**Rectangular thin plate,** length L, width W	Through center		$\frac{1}{12}M(L^2 + W^2)$