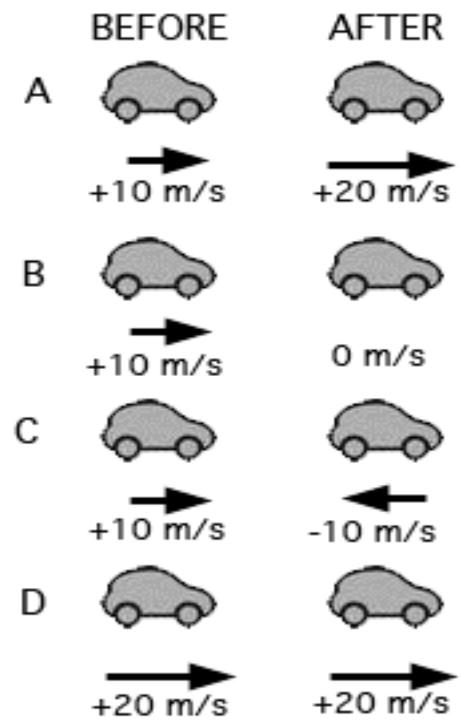
Physics 204A THIRD EXAM Chapters 1 - 11 Spring 2007

Name:____

Solve the following problems in the space provided. Use the back of the page if needed. Each problem is worth 20 points. You must show your work in a logical fashion starting with the correctly applied physical principles. The equations you need are on the equation sheet. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. The four situations to the right show before and after "snapshots" of a car's velocity. Rank these situations, in terms of the impulse on the car required to create these changes in velocity, from most positive to most negative, All cars have the same mass. Explain your reasoning for full credit.



The main principle is the Impulse-Momentum Theorem,

$$\vec{J} = \Delta\vec{p}.$$

Using the definition of linear momentum,

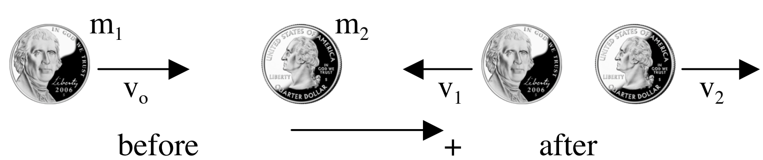
$$\vec{p} \equiv m\vec{v} \Rightarrow \vec{J} = m\vec{v} - m\vec{v}_o.$$

Calculating the change in momentum gives the impulse,
A: $J = m(20) - m(10) = 10m$
B: $J = m(0) - m(10) = -10m$
C: $J = m(-10) - m(10) = -20m$
D: $J = m(20) - m(20) = 0$

The ranking is, $\boxed{\text{A>D>B>C}}$.

2. A nickel (m = 5.00g) slides along a smooth counter at 3.00m/s and collides head-on with a quarter (m = 5.67g) originally at rest. The speed of the quarter just after the collision is 2.75m/s. (a)Find the speed of the nickel just after the collision and (b)determine if the collision is elastic.

(a)The initial momentum is, $p_o = m_1 v_o$.
The final momentum is, $p = m_2 v_2 - m_1 v_1$.



Using the Law of Conservation of Linear Momentum,

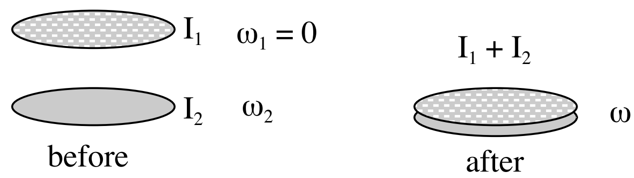
$$p_o = p \Rightarrow m_1 v_o = m_2 v_2 - m_1 v_1.$$

Solving for the speed of the nickel,

$$v_1 = \frac{m_2 v_2 - m_1 v_o}{m_1} = \frac{m_2}{m_1} v_2 - v_o = \frac{5.67}{5.00}(2.75) - 3.00 \Rightarrow v_1 = 0.119 m/s.$$

(b)The initial kinetic energy is, $K_o = \frac{1}{2} m_1 v_o^2 = \frac{1}{2}(5.00)(3.00)^2 = 22.5 mJ$.
The final kinetic energy is, $K_o = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2}(5.00)(0.119)^2 + \frac{1}{2}(5.67)(2.75)^2 = 21.5 mJ$.
Since the kinetic energy is not conserved, the collision is inelastic.

3. A CD player consists of a rotating palate with a rotational inertia of 1800g·cm^2 that spins at 100rpm. A CD, which can be treated as a 50.0g disk of radius 5.00cm, is dropped on to the center of this palate. Find the rotation rate of the palate and CD just after it lands.



The initial angular momentum is due to the palate alone,

$$L_o = I_2\omega_2.$$

The final angular momentum is from both the CD and the palate,

$$L = (I_1 + I_2)\omega.$$

Applying the Law of Conservation of Angular Momentum,

$$L_o = L \Rightarrow I_2\omega_2 = (I_1 + I_2)\omega.$$

Solving for the final angular speed, $\omega = (\frac{I_2}{I_1 + I_2})\omega_2$.

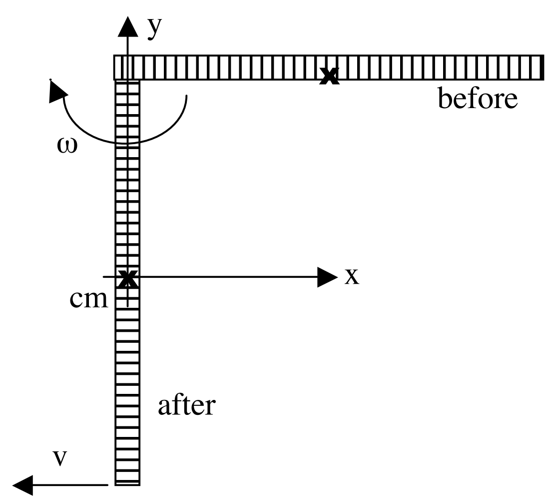
The rotational inertia of the CD can be found from the formula for a disk, $I_1 = \frac{1}{2}mr^2$.

Finally, $\omega = (\frac{I_2}{\frac{1}{2}mr^2 + I_2})\omega_2$.

Plugging in the numbers,

$$\omega = (\frac{1800}{\frac{1}{2}(50.0)(5.00)^2 + 1800})(100) \Rightarrow \boxed{\omega = 74.2rpm}.$$

4. A 150g meterstick is pivoted at one end. It is initially held horizontally and released from rest. Find the speed of the tip of the meterstick when it reaches the vertical.



Initially, there is only the gravitational potential energy of the center of mass,

$$K_o = 0 \text{ and } U_o = mg\tfrac{\ell}{2}.$$

At the bottom, there is only rotational kinetic energy,

$$K = \tfrac{1}{2}I\omega^2 \text{ and } U = 0.$$

Applying the Law of Conservation of Energy

$$\Delta K + \Delta U = 0 \Rightarrow (\tfrac{1}{2}I\omega^2 - 0) + (0 - mg\tfrac{\ell}{2}) = 0 \Rightarrow \tfrac{1}{2}I\omega^2 = mg\tfrac{\ell}{2}$$

The rotational inertia of a stick about its end is, $I = \frac{1}{3}m\ell^2$.

The speed of the tip is related to the angular speed by the angular/linear rule,

$$v_t = r\omega \Rightarrow v = \ell\omega.$$

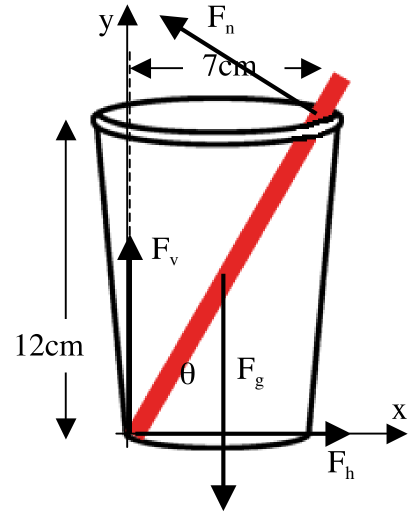
Finally,

$$\tfrac{1}{2}I\omega^2 = mg\tfrac{\ell}{2} \Rightarrow \tfrac{1}{2}\tfrac{1}{3}m\ell^2\omega^2 = mg\tfrac{\ell}{2} \Rightarrow \tfrac{1}{6}mv^2 = mg\tfrac{\ell}{2} \Rightarrow v = \sqrt{3g\ell}.$$

Plugging in the numbers,

$$v = \sqrt{3(9.80)(1.00)} \Rightarrow \boxed{v = 5.42m/s}.$$

5. A 5.00g straw is just long enough to rest across the glass as shown. Assume the top of the glass is smooth. (a)Show the forces that act on the straw. Find (b)the weight of the straw and (c)the force exerted on the straw by the top of the cup.



(a)see diagram

(b)The weight of the straw is given by the mass/weight rule,

$$F_g = mg = (5.00)(9.80) \Rightarrow \boxed{F_g = 49.0mN}.$$

(c)Apply the Second Law for Rotation using the origin as the pivot point. Notice that the force exerted by the top of the cup is a normal force, which is perpendicular to the straw.

$$\Sigma\tau_o = I\alpha \Rightarrow \ell F_n - \tfrac{\ell}{2} F_g \cos\theta = 0.$$

Note that the angle can be found from the definition of the tangent,

$$\tan\theta = \tfrac{12.0}{7.00} \Rightarrow \theta = \arctan\tfrac{12.0}{7.00} = 59.7^\circ.$$

Solving the torque equation for the normal force,

$$F_n = \tfrac{1}{2} F_g \cos 59.7^\circ \Rightarrow \boxed{F_n = 12.4mN}.$$