PHY115: Final Exam

Spring 2021

Deadline: Wednesday the 21th

Theory Questions (30 p)

1. Newton's Laws
   - When are Newton's Laws valid?
   - Can you use the second Law of Newton to explain the first one? How?
   - Is the normal force the reaction pair of the weight? Why not? or why yes?
2. Linear Momentum
   - Define Linear Momentum.
   - Write the 2nd Law of Newton in terms of the linear momentum.
   - When is the linear momentum conserved?
   - When is a component conserved?
   - Give an example in which the linear momentum is not conserved, but one of its coordinates is.
   - EXTRA CREDIT (5 p): Find a scene on a Movie or in your animation short to illustrate the previous point, attach the link to the scene.
3. Angular Momentum
   - Define Torque and Angular Momentum.
   - Write the equation that relates the angular momentum and torque.
   - Write the equation for Angular Momentum that is equivalent to the definition of Linear Momentum.
   - Write the equation for Torque that is equivalent to the 2nd Law of Newton.
   - When is the Angular Momentum conserved?
   - Give an example in which the Angular Momentum is conserved.
   - EXTRA CREDIT (5 p): Find a scene on a Movie or in your animation short to illustrate the previous point, attach the link to the scene.

Test your undertanding (20 p)

1. A helicopter has a large main rotor that rotates in a horizontal plane and provides lift. There is also a small rotor on the tail that rotates in a vertical plane. What is the purpose of the tail rotor? (Hint: If there were no tail rotor, what would happen when the pilot changed the angular speed of the main rotor?).
2. A bullet spins on its axis as it emerges from a rifle. Explain how this prevents the bullet from tumbling and keeps the streamlined end pointed forward.
3. A client brings a treasured ball to your engineering firm, wanting to know whether the ball is solid or hollow. Design a simple, inexpensive experiment that you could perform quickly, without injuring the precious ball, to find out whether it is solid or hollow.

Exercises (50 p)

1: Billiard Physics

A cue ball (a uniform solid sphere of mass m and radius R) is at rest on a level pool table. Using a pool cue, you give the ball a sharp, horizontal hit of magnitude F at different heights (see figure 1 panels a-d) In panel (a) h is defined so that the ball will roll without slipping. In panel (b), the hit height is higher than h. In panel (c) the hit is right in the center of the ball, and in panel (d) the hit height is lower than h.

- In panels 1-4 of the figure 1, we can observe how the ball will move after the hit. Match each one of the panels a-d with the corresponding motion after the hit shown in panels 1-4.
- What is the acceleration of the center of mass after the hit in terms of the friction force and m?
- What is the torque after the hit in terms of the friction force and R?

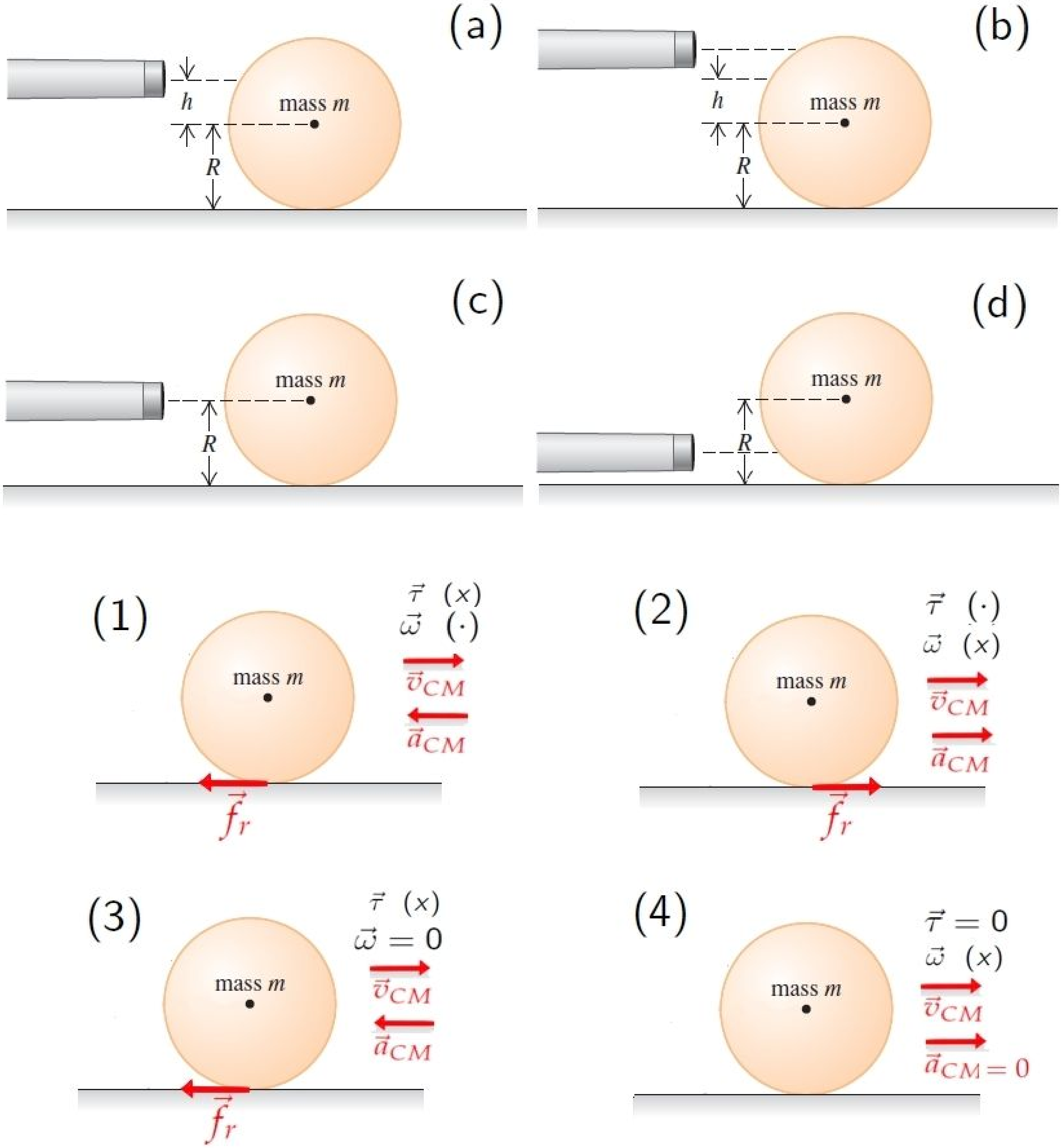

Figure 1: Panels (a) to (d): h is defined so that the ball will roll without slipping. In panel (b), the hit height is higer than h. In panel (c) the hit is right in the center of the ball, and in panel (d) the hit height is bellow. Panels (1) to (4): motion after the hit .

2: Elastic Collision

Consider a ball that bounces with a wall on a horizontal surface without friction. If the collision is elastic, the kinetic energy of the ball is conserved, and the magnitude of the linear momentum after the collision is equal to the initial:

$$|\vec{p}_f| = |\vec{p}_i| \tag{1}$$

Proof that the initial angle (θ_i) is equal to the final angle (θ_f).

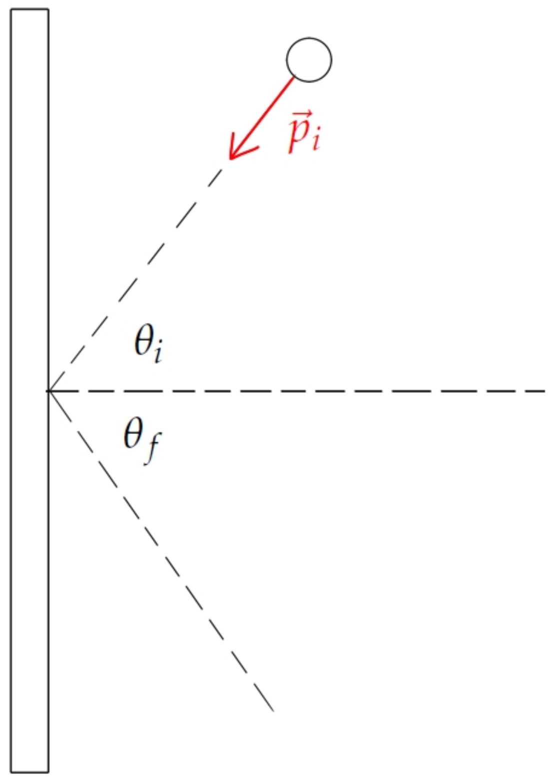

Figure 2: Ball bouncing with a wall in an horizontal surface without friction.

Hint= Which component of $\vec{p}$ is conserved?

3: Light and materials

Find and explain the difference in the parameters for the materials shown in the figure 2.

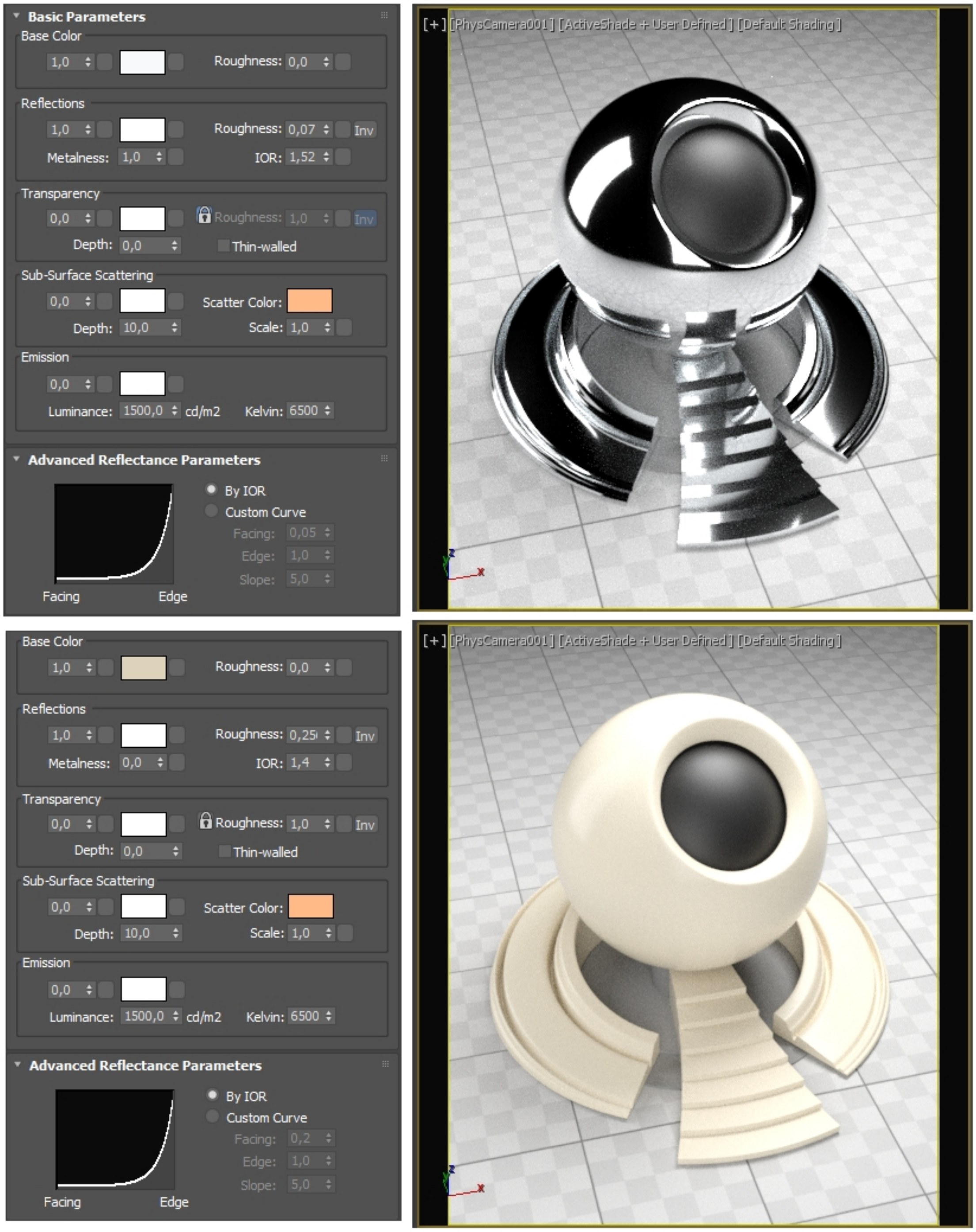

Figure 3: Interaction of light with a metal (top panel) and a non-metallic material (lower panel).