Physics 200 (Stapleton) Name: ________________________________
2020-21 Test Version: Momentum and Impulse

Short Answer**:**

1. Gigi the stunt cat is dropped from a height to the ground. Gigi can rotate herself, but she still has to deal with the force of impact. What can be done to lessen that force – without changing the height from which she is dropped?

   a. (1 point) Suggest a strategy that can be employed to lessen Gigi's force of impact. This could be something Gigi does, or something someone can do for Gigi.

   - **Gigi needs to <u>lengthen the time of impact.</u>**
   - **Some ways to do this…**
     - **She can do this by landing on something soft.**
     - **She can also stretch out her legs before landing and then let them collapse during impact, so that she stops slowly.**
     - **If she could make her paws pointy so that she sinks into the ground, that would also lengthen impact time.**

   b. (3 points) How does your strategy work?
   - Describe what happens to Gigi's momentum as she lands.
   - Describe the relationship between impulse and momentum.
   - Use the impulse formula to explain why your suggested strategy lessens the impact force.

   - **In order to stop, Gigi needs to lose all of her momentum.**
   - **Impulse (Ft) = change in momentum (Δp).**
   - **In order to experience the change in momentum that is necessary for stopping, Gigi must experience an impulse (a force exerted over a period of time) equal to that change in momentum. For the same change in momentum (and therefore the same impulse), she can experience a smaller force if she lengthens impact time ($_F\mathbf{t}$ = Δp).**

2. a. Define a "system" of one or more objects (in other words, provide an example). Then describe a specific situation in which momentum would <u>not</u> be conserved in that system.
   - **My system = two frictionless carts on a level surface**
   - **Momentum would <u>not</u> be conserved if one of the carts bumped into a bystander**

   b. Explain why momentum is not conserved in that situation.
   - **Momentum is only conserved in a system that does not experience an outside force. In the case of the carts, if one cart bumps a bystander (not part of the system), then the bystander applies an equal and opposite force to the cart. This force applied by the cart is an outside force on the system.** ***[Note that gravity can be an outside force, preventing momentum from being conserved, but for energy conservation purposes, work done by gravity does not count as non-conservative work. Energy is conserved when an object free-falls, but momentum is not.]***

   c. Explain how you can tell whether or not kinetic energy is conserved during a collision.

- **If the coefficient of restitution is one (separation speed and closing speed are equal), kinetic energy is conserved.**
- **If you calculate ½mv^2 for all of the objects, before and after the collision, and the total remains constant.**
- **If there is no non-conservative work done on the colliding objects. *[Note that, for energy conservation purposes, work done by gravity does not count as non-conservative work, but in the case of conserving momentum, the force of gravity can be an outside force.]***

3. Two spheres of the same mass and radius are dropped from different heights onto a force plate that measures impact force and impact time. Sphere A is dropped from a height of 4m, and sphere B is dropped from a height of 3m.

a. **True** or false (circle one): It is possible that the two spheres will experience the same impact force.
b. Provide evidence to support your answer to part A.

One Possibility: **Quick answer – Sphere A could be softer.**

> **Sphere A will hit the ground with a greater speed than sphere B. So if both objects are brought to a stop, sphere A will have a greater change in momentum and, therefore, a greater impulse. But since impulse = Ft, we an object can experience a greater impulse without experiencing a greater force. Suppose sphere A is soft, and sphere B is hard. In this case, sphere A will have a longer impact time. That would allow it to have a greater impulse, even if the two forces are identical (F*t* vs Ft). So the ball falling from a greater height can hit the surface with the same force (with a cushioned landing) as the ball falling from a lower height (with a harder landing).**

Another possibility: **Quick answer -- Sphere B could be bouncier (higher coefficient of restitution) while having the same impact time.**

> **Suppose sphere A hits the ground and does not bounce. That gives it a Δp equal to its closing speed times its mass. If sphere B bounces, its Δp will be equal to its closing speed plus its separation speed (x mass). So even though one is falling from higher, they can both have the same change in momentum. Since Δp = Ft, they can have the same impact force, as long as the impact time is the same.**

c. **True** or false (circle one): It is possible that the two spheres will experience the same impulse.
d. Provide evidence to support your answer to part c.

I already answered this in part b, with "another possibility." If B is bouncier (higher coefficient of restitution), its momentum can change as much as A's momentum.

Let's assume that they both have masses of 1kg. Using kinematics, it can be shown that a ball falling 4m will have a closing speed of 8.85m/s. A 3m drop gives a closing speed of 7.66 m/s. If the ball falling 4m simply stops, its change in momentum will be 8.85kgm/s. If the ball falling 3m bounces back up to a height of 0.071m, its separation speed will be 1.18m/s, so its change of momentum will also be 1kg(7.66m/s +1.18m/s) = 8.85kgm/s. If change in momentum is the same, so is impulse.