Your Name: ______________________________

Teammates: ____

Physics 8, Fall 2023, Worksheet #5.

http://positron.hep.upenn.edu/p8/files/ws05.pdf

Upload PDF (smartphone scan or tablet edit) to Canvas after class on Mon, Sep 18, 2023.

Problems marked with (*) must include your own drawing or graph representing the problem and at least one complete sentence describing your reasoning.

Discuss each problem with your teammates (usually groups of 3), then write up your own solution. Be sure to compare final results with your teammates, as a way to catch mistakes. It can also be very interesting when you and a teammate use different methods to arrive at a result. Do not hesitate to ask for help from other students or from the instructors — but don't just copy down other people's results!

1*. **Hands-on activity (visit as available):** colliding pairs of carts on a track! Each setup contains one yellow cart, one blue cart, a track, and some added masses. Each cart has mass $m = 0.30\,\mathrm{kg}$. If the magnetic sides of two carts meet, you get elastic collisions ($e = 1$). (Magnets should all have "N" sides facing outward.) If the velcro sides of two carts meet, you get totally inelastic collisions ($e = 0$).

Joining one velcro and one magnet side, you can release the spring-loaded plunger to get an explosive separation ($e = \infty$). If you collide one velcro and one magnet side, you get inelastic collisions ($e < 1$), with e not too much smaller than 1. If you like, you can try a small ball of play doh to get inelastic collisions with a smaller restitution coefficient e.

Try at least a few of these, but you don't need to do all of them. Doing a few cases with clear descriptions of the results earns full credit. Doing more will earn extra credit, but be mindful of giving other groups access to the shared equipment. Focus on the cases that most interest you. For each case that you try, indicate whether $m_1 = m_2$, $m_1 = 2m_2$, $m_1 = 3m_2$, etc. Draw arrows indicating (approximately) the two carts' initial velocities and the two carts' final velocities, roughly along the lines of my diagrams in the ch05 video. For each case that you try, somehow argue (eg by drawing arrows, or some other method you prefer) that total momentum in the initial state equals total momentum in the final state. Also, for each case, argue that the results are compatible with the desired type of collision (elastic, inelastic, totally inelastic, explosive separation): for instance, you might roughly compare the *relative* speeds of the two carts after vs before.

(a) Elastic collision of two equal-mass carts, with cart 2 initially stationary. Should look like a billiards "stop shot," where $v_{2xf} = v_{1xi}$ and $v_{1xf} = 0$.

(b) Elastic collision of two equal-mass carts moving toward one another at roughly equal speeds.

(c) Totally inelastic collision of two equal-mass carts moving toward one another at roughly equal speeds.

(d) Inelastic (but not totally) collision of two equal-mass carts moving toward one another at roughly equal speeds.

(e) Totally inelastic collision of carts of 2:1 or 3:1 mass ratio moving toward one another at roughly equal speeds.

(f) Totally inelastic collisions with 1:1, 2:1, and 3:1 mass ratios, with one cart initially stationary. In all cases, see whether the (approximate) final velocity makes sense.

(g) Explosive separation with 1:1, 2:1, and 3:1 mass ratios. See if you can position the carts so that they audibly hit opposite ends of the track simultaneously. To do this, work out the ratio of distances the far ends of both carts must travel. (If you try to calculate the position where the two carts' near ends start out before separating, it is easy to forget to account for the lengths of the carts.)

(h) Low-mass cart recoiling elastically from a stationary much-higher-mass cart. For large mass ratio, low-mass cart should approximately reverse its velocity.

(i) Stationary low-mass cart struck elastically by much-higher-mass cart. For large mass ratio, low-mass cart's final velocity should be approximately $2\times$ the high-mass cart's initial velocity.

2*. Draw diagrams that show the initial and final velocity vectors and initial and final momentum vectors when a rapidly moving golf ball hits (a) a golf ball at rest or (b) a basketball at rest. In each case, assume that the golf ball moves along the line connecting the centers of the two balls, and assume that the collisions are elastic. (The mass of a basketball is about $14\times$ the mass of a golf ball.) There's no need for perfection, but try to get the scales roughly right.

3*. A green shopping cart of inertia 15.3 kg rolls into a stationary blue cart of inertia 24.5 kg. The green cart's initial velocity is 0.475 m/s eastward. After the collision, the blue cart has a velocity of 0.245 m/s eastward. (a) What is the final velocity (magnitude and direction) of the green cart? (b) What is the coefficient of restitution of this collision?

Chapter 5 problems. Note that Equation 5.4 hugely simplifies calculations involving elastic collisions ($e = 1$): $(v_{1xf} - v_{2xf}) = -e\,(v_{1xi} - v_{2xi})$.

4*. A wagon is coasting along a level sidewalk at 15.0 m/s. Its wheels have very good bearings. You are standing on a very low wall and drop vertically (a very short distance) into the wagon as it passes by. The wagon has an inertia of 75.0 kg, and your inertia is 55.0 kg. (a) Use conservation of momentum to determine the (horizontal) speed of the wagon after you are in it. (b) Use conservation of energy to determine that speed. (c) After comparing your answers, explain which method is correct and which is incorrect (and why). [Hint: notice that you and the wagon are stuck together after you land in it. Also assume for part (b) that your vertical motion before landing in the wagon is negligibly slow, since you dropped only a very short distance.]

5. You have an inertia of 57.0 kg and are standing at rest on an iced-over pond in your skates. Suddenly, your 73.0 kg brother skates in from the left at $v_x = +4.0\,\mathrm{m/s}$ and collides elastically with you. (You can suspend your disbelief and accept that an elastic collision is possible here because you and your brother are both wearing inflatable "Sumo suits!") (a) What is the two siblings' relative speed before the collision? (b) Given the details stated of the collision, what do you expect the two siblings' relative speed to be after the collision? (c) If your brother's final velocity is $v_x = +0.492\,\mathrm{m/s}$, what is your final velocity (computed using momentum conservation)? (d) Is your answer to part c consistent with your answer to part b? (e) What is the change in kinetic energy of the you+brother system? (You can either calculate this change explicitly or else argue from the problem details what the physics says this change must be.)

6. A 2500 kg truck is sitting at rest (in neutral) when it is rear-ended by a 1500 kg car going 20.0 m/s. After the collision, the two vehicles stick together. (a) What is the final speed of the car-truck combination? (b) What is the kinetic energy of the two-vehicle system before the collision? (c) What is the kinetic energy of the system after the collision? (d) Based on the results of (b) and (c), what can you conclude about which type of collision this is? [You can learn from (b) and (c) whether or not the collision is elastic, but you can't easily tell from (b) and (c) whether the collision is inelastic vs. totally inelastic.] (e) Calculate the coefficient of restitution for this collision. Is this the result you would expect for the coefficient in this type of collision?

***** Please check in with one of the instructors before you leave, so that we can give you some quick feedback on your work and get your impressions of the appropriateness of today's assignment. *****