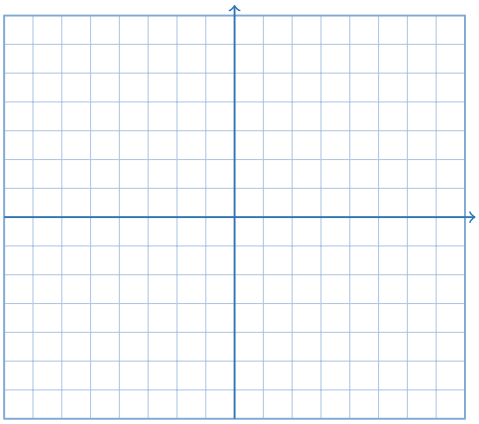
Problem Set 5: Linear Momentum

Name: _____ **Date:** _____

Topics 4.1 through 4.4. Out of 100 points.

Equations: $\vec{p} = m\vec{v}$ $\quad \vec{J} = \vec{F}_{\text{avg}}\,\Delta t = \Delta\vec{p}$ $\quad \sum \vec{p}_{\text{before}} = \sum \vec{p}_{\text{after}}$ $\quad K = \frac{1}{2}mv^2$

1. A car of mass 1200 kg travels east at 15.0 m/s. A baseball of mass 0.145 kg is thrown east at 40.0 m/s. **[17 pts]** (4.1)



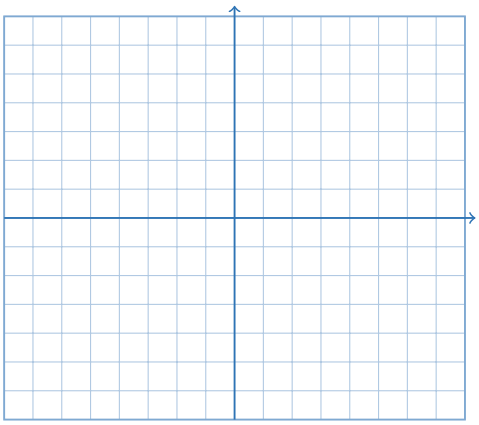
(a) Find the momentum of each object, with its direction. **[4 pts]**

(b) Find the kinetic energy of each object, and say which quantity, the momentum or the kinetic energy, separates the two by the larger factor. **[4 pts]**

(c) On the grid, to a stated scale, sketch the momentum of the car against its speed for speeds from 0 to 30 m/s, and mark the speed above. **[4 pts]**

(d) A student says the baseball is harder to stop because it is moving much faster. Write a short argument saying what is wrong with the claim, using both your graph and the equation, and say what quantity the student should have compared instead. **[5 pts]**

2. A ball of mass 0.150 kg travels horizontally at 12.0 m/s and strikes a wall. It rebounds along the same line at 9.00 m/s. The ball is in contact with the wall for 0.0250 s. (4.2) **[17 pts]**



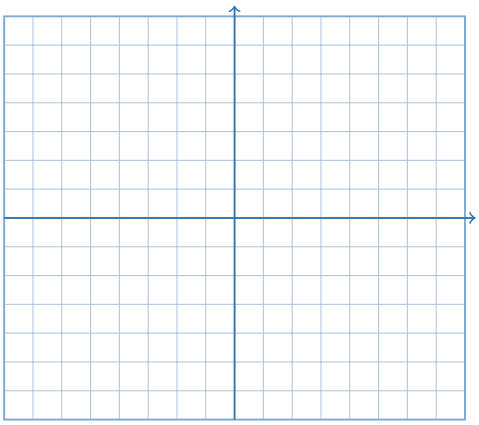
(a) Find the change in the momentum of the ball, with its direction. **[4 pts]**

(b) Find the average force the wall exerts on the ball. **[4 pts]**

(c) On the grid, to a stated scale, sketch a possible force against time graph for the contact, and say what the area of your sketch represents. **[4 pts]**

(d) The same ball, thrown at the same 12.0 m/s, is instead caught in a soft net that brings it to rest in 0.400 s. Find the average force the net exerts, then say which two changes between the wall and the net each reduced the force, and which quantity was fixed by the question before either of them acted. **[5 pts]**

3. A cart of mass 3.00 kg rests on a level track. A net force acts along the track. The force rises steadily from 0 to 12.0 N over the first 2.00 s, then holds at 12.0 N for a further 1.00 s. (4.2) **[16 pts]**



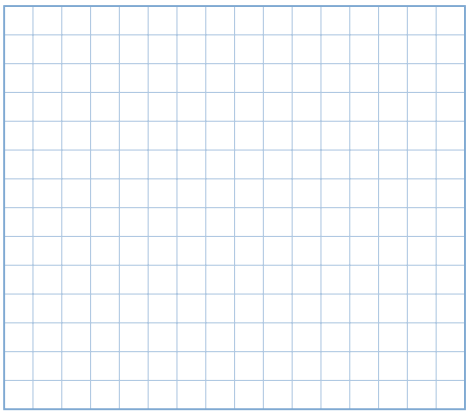
(a) Find the impulse delivered during the first 2.00 s. **[4 pts]**

(b) Find the impulse delivered during the next 1.00 s, and the total impulse over the 3.00 s. **[4 pts]**

(c) Find the speed of the cart at $t = 3.00$ s. **[4 pts]**

(d) On the grid, to a stated scale, sketch the momentum of the cart against time for the whole 3.00 s, and say where on your sketch the slope is largest and why. **[4 pts]**

4. Two skaters stand at rest on ice, facing each other. One has mass 45.0 kg and the other has mass 60.0 kg. They push off each other and slide apart. Friction with the ice is small enough to ignore. (4.3) **[17 pts]**



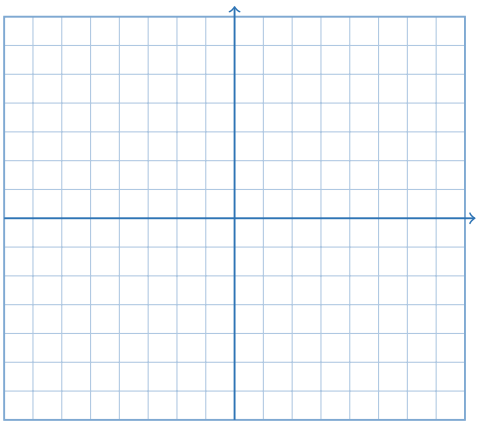
(a) State the total momentum of the two skaters before the push, and say what the system is. **[3 pts]**

(b) The 45.0 kg skater moves off at 3.00 m/s. Find the velocity of the 60.0 kg skater. **[5 pts]**

(c) On the grid, draw a bar chart of the momentum of each skater and of the system, before the push and after it. **[4 pts]**

(d) A student says the lighter skater must have been pushed harder, because that skater ends up moving faster. Write a short argument saying what is wrong with that, naming the law you use, and say what would have to be true of the ice for the total momentum to change. **[5 pts]**

5. A puck of mass 0.500 kg slides east at 4.00 m/s across frictionless ice and strikes a second puck of mass 0.500 kg that is at rest. After the collision the first puck moves off at $30.0°$ north of east. (4.3) **[16 pts]**



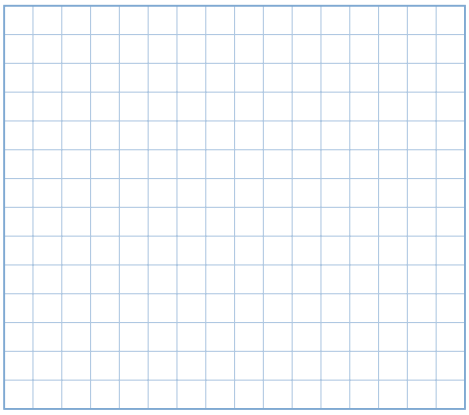
(a) Write the two conservation equations for this collision, taking east as the positive x direction and north as the positive y direction. **[4 pts]**

(b) State the total momentum in the y direction before the collision and after it, and say what that forces about the direction of the second puck. **[4 pts]**

(c) On the grid, to a stated scale, draw the momentum vector before the collision and a possible pair of momentum vectors after it. **[4 pts]**

(d) Say what one further piece of information would be enough to find both final speeds, and name two different pieces of information that would each do. **[4 pts]**

6. A cart of mass 2.00 kg moves at 3.00 m/s along a level track and strikes a cart of mass 4.00 kg that is at rest. (4.4) **[17 pts]**



(a) The carts stick together. Find their velocity immediately after the collision. **[4 pts]**

(b) Find the total kinetic energy before the collision and after it, and state how much left the kinetic account. **[4 pts]**

(c) The same collision instead leaves the carts moving at -1.00 m/s and $+2.00$ m/s. Show that this outcome satisfies both conservation statements, and name the kind of collision it is. **[4 pts]**

(d) A student says a collision that loses kinetic energy must lose momentum as well, because the carts are moving more slowly afterward. Write a short argument saying what is wrong with that, and state the one condition that decides whether the total momentum holds. **[5 pts]**