AP/Honors Quiz: Momentum

Full Name, Period, AP/Honors:

1 Choose Wisely

1. (3 pt, **All**) A truck, with mass m is initially sliding across (frictionless) ice with velocity $\vec{v}$. An block with mass $\frac{m}{10}$ that is initially at rest falls into the truck and slides across the truck bed for a while. Eventually it stops moving relative to the truck. Which of the following will be true? Take the system to consist of the object and the truck. **Select all that apply**.

   $\boxed{\text{A.}}$ Momentum of the system will be conserved

   B. Kinetic energy of the system will be conserved

   $\boxed{\text{C.}}$ The block's speed will be less than v

   $\boxed{\text{D.}}$ The block's temperature increased.

   Explanation: No external forces act, so momentum is conserved. As the object stops relative to the truck, the kinetic energy becomes heat. When the truck and block are moving together at the end, they must be moving with a higher speed than the block, but lower speed than the truck had initially, so the block's speed less than v

2. Why isn't your name at the top of your paper?

   A. It is!

   B. The education system has failed me.

   C. Because I don't want credit.

3. (3 pt, **All**) A constant force is applied in the positive $\hat{x}$ direction to an object that is initially at rest. No other forces act on the object. Which of these statements are true about the increase of momentum and energy with time?

   A. Momentum and Kinetic Energy increase linearly.

   $\boxed{\text{B.}}$ Momentum increases linearly, but kinetic energy increases faster than linearly.

   C. Momentum increases linearly, but kinetic energy increases more slowly than linearly.

   D. Kinetic energy increases linearly, but momentum increases faster than linearly.

   E. Kinetic energy increases linearly, but momentum increases more slowly than linearly.

   We know that $\vec{F}t = \Delta\vec{v}$. This means that $\vec{v}$ increases faster than linear (we also need to check that we are moving in the positive direction, but that is given in the problem.)

   To find the rate energy increases, we recall that $E = \frac{p^2}{2m}$ so if p is increased linearly, E is increased quadratically.

4. (3 pt,**Honors**) A 100 kg unicorn is at rest eating rainbow hay. A 5 kg (spineless) flying cactus runs into the unicorn with a velocity of 60 $\frac{\text{m}}{\text{s}}\hat{y}$. The final velocity of the unicorn is 4 $\frac{\text{m}}{\text{s}}\hat{y}$. What is the final velocity of the cactus?

   A. 20 $\frac{\text{m}}{\text{s}}\hat{y}$

   B. 0 $\frac{\text{m}}{\text{s}}\hat{y}$

   $\boxed{\text{C.}}$ -20 $\frac{\text{m}}{\text{s}}\hat{y}$

   D. -200 $\frac{\text{m}}{\text{s}}\hat{y}$

   Use momentum conservation

   $$m_u v_{ui} + m_c v_{ci} = m_u v_{uf} + m_c v_{cf}$$

   now plug in values and solve

2 Anything Could Happen, Unless it Can't

For each of the scenarios below, determine if the event is allowed to occur. If it isn't allowed, determine whether it is disallowed by momentum conservation or energy conservation. In the case that something was violated, explain your answer in 1-2 sentences. If you prefer explain why the scenario violates Newton's laws instead, that is also fine.

1. *(3 pt, **Honors**) Two rigid objects with equal masses moving in opposite directions collide. No noise is produced, and the objects are not damaged or heated by the collision. After the collision, the objects are both at rest.*

   This violates energy conservation. The energy needs somewhere to go for the objects to stop.

2. *(2 pt, **All**) A Jupiter sized planet is orbiting an otherwise isolated star with the same mass as the sun. The star is observed to move in a small circle while the planet orbits.*

   Nothing is violated. This is exactly what happens, and is directly required by momentum conservation.

3. *(3 pt, **AP**) You create a system consisting of a single rope and a single pulley. You hang the pulley from the ceiling and put the rope through it. You then tie one end to a mass and pull on the other end. You observe that the pulley reduces the force necessary to lift the mass.*

   Violates energy conservation. If you pull the object a distance D, it gains energy mgD, so the force that you apply cannot be less than mg, or more energy would be gained by the object than you put into the system as work.

4. *(3pt, **AP**) A child is skating across a rink behind an adult. The adult has attached an (initially uncompressed) spring to his back, as one does while skating. The child is initially moving faster. After some time the child runs into the spring and compresses it. After the collision the child's speed has increased and the adult's speed has decreased.*

   Violates momentum conservation. The adult was in front of the child, so when the child impacts the adult, the adult must feel a force forward. Such a force could not slow the adult down.

3 That is Forbidden... Probably

Two objects with masses m_1 and $m_2 = 2m_1$ collide. Before the collision the first object was traveling at $\vec{v}_1 = -5\frac{\text{m}}{\text{s}}\hat{\text{y}}$ and the second was traveling at $\vec{v}_2 = 5\ \frac{\text{m}}{\text{s}}\hat{\text{x}}$. After the collision, the two objects have velocities of $\vec{v}_1 = \vec{v}_2 = 5\ \frac{\text{m}}{\text{s}}\hat{\text{x}} - 5\ \frac{\text{m}}{\text{s}}\hat{\text{y}}$. For both parts, a 1-2 sentence explanation or a calculation is required for credit.

1. *(3 pt, **All**)Would this collision be allowed by momentum conservation in the absence of outside forces?*

   No, this collision could not occur. We started out with $-5m$ units of $\hat{\text{y}}$ momentum, but ended with $-15m$ units of $\hat{\text{y}}$ momentum. T

2. *(3 pt, **All**) What was the initial kinetic energy of the system?*

   Direction doesn't matter for energy, so just square the values. so $E = 25m\ \frac{\text{J}}{\text{kg}} + 50\text{m}\ \frac{\text{J}}{\text{kg}} = \boxed{75m\ \frac{\text{J}}{\text{kg}}}$. Note that the units are weird, this is part of why it is usually ill advised to mix numbers and variables.