DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS

AP PHYSICS

LSN 7-4: CONSERVATION OF ENERGY AND MOMENTUM IN COLLISIONS
LSN 7-5: ELASTIC COLLISIONS IN ONE DIMENSION
LSN 7-6: INELASTIC COLLISIONS

Questions From Reading Activity?

Big Idea(s):

- The interactions of an object with other objects can be described by forces.
- Interactions between systems can result in changes in those systems.
- Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding(s):

- A force exerted on an object can change the momentum of the object.
- Interactions with other objects or systems can change the total linear momentum of a system.
- The linear momentum of a system is conserved.

Enduring Understanding(s):

- Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.

Essential Knowledge(s):

- The change in momentum of an object occurs over a time interval.
  - The force that one object exerts on a second object changes the momentum of the second object (in the absence of other forces on the second object).
  - The change in momentum of that object depends on the impulse, which is the product of the average force and the time interval during which the interaction occurred.
- The change in linear momentum for a constant-mass system is the product of the mass of the system and the change in velocity of the center of mass.

Essential Knowledge(s):

- For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.
- An interaction can be either a force exerted by objects outside the system or the transfer of some quantity with objects outside the system.

Essential Knowledge(s):

- The boundary between a system and its environment is a decision made by the person considering the situation in order to simplify or otherwise assist in analysis.

Essential Knowledge(s):

- In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.
  - In a closed system, the linear momentum is constant throughout the collision.
  - In a closed system, the kinetic energy after an elastic collision is the same as the kinetic energy before the collision.

Essential Knowledge(s):

- In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
  - In a closed system, the linear momentum is constant throughout the collision.
  - In a closed system, the kinetic energy after an inelastic collision is different from the kinetic energy before the collision.

Learning Objective(s):

- The student is able to justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction.
- The student is able to predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.
- The student is able to analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.

Learning Objective(s):

- The student is able to design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time.
- The student is able to calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.).
- The student is able to analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass.

Learning Objective(s):

- The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.
- The student is able to make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions.

Learning Objective(s):

- The student is able to apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations.

Learning Objective(s):

- The student is able to apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy.
- The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.

Learning Objective(s):

- The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.
- The student is able to make predictions of the dynamical properties of a system undergoing a collision by application of the principle of linear momentum conservation and the principle of the conservation of energy in situations in which an elastic collision may also be assumed.

Learning Objective(s):

- The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.
- The student is able to qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic.

Learning Objective(s):

- The student is able to plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically.
- The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.

Learning Objective(s):

- The student is able to analyze data that verify conservation of momentum in collisions with and without an external friction force.
- The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.

Learning Objective(s):

- The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.

Conservation of Momentum

- In all collisions, momentum is conserved.

$$m_1 v_1 + m_2 v_2 = m_1 v_1^{'} + m_2 v_2^{'}$$

Conservation of Energy

- If energy is not lost, energy is conserved.
- If energy is lost, energy is not conserved.
- Duh

Conservation of Energy

- An ***elastic*** collision is defined as one in which energy is conserved.
  - No energy is lost to heat, sound, etc.
- An ***inelastic*** collision is defined as one in which energy is ***not*** conserved.
  - Energy is lost to heat, sound, etc.
- For our purposes, we aren't going to work with potential energy – we will only be concerned with ***kinetic energy***

Conservation of Energy

- An ***elastic*** collision is defined as one in which ***kinetic energy*** is conserved.

$$\frac{1}{2}m_1v_1^{\ 2}+\frac{1}{2}m_2v_2^{\ 2}=\frac{1}{2}m_1v_1^{'2}+\frac{1}{2}m_2v_2^{'\ 2}$$

- And, momentum is still conserved

$$m_1v_1+m_2v_2=m_1v_1^{'}+m_2v_2^{'}$$

Cool Math Stuff

$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

$$m_1v_1 - m_1v_1' = m_2v_2' - m_2v_2$$

$$m_1\left(v_1 - v_1'\right) = m_2\left(v_2' - v_2\right)$$

Now hold that thought

More Cool Math Stuff

$$\frac{1}{2}m_1 v_1^{\,2} + \frac{1}{2}m_2 v_2^{\,2} = \frac{1}{2}m_1 v_1^{'2} + \frac{1}{2}m_2 v_2^{'2}$$

$$\frac{1}{2}m_1 v_1^{\,2} - \frac{1}{2}m_1 v_1^{'2} = \frac{1}{2}m_2 v_2^{'2} - \frac{1}{2}m_1 v_1^{'2}$$

$$m_1 v_1^{\,2} - m_1 v_1^{'2} = m_2 v_2^{'2} - m_2 v_2^{\,2}$$

$$m_1\left(v_1^{\,2} - v_1^{'2}\right) = m_2\left(v_2^{'2} - v_2^{\,2}\right)$$

Last line look familiar?

Even More Cool Math Stuff

$$m_1\left(v_1^{\,2} - v_1^{'\,2}\right) = m_2\left(v_2^{'\,2} - v_2^{\,2}\right)$$

$$a^2 - b^2 = (a-b)(a+b)$$

$$m_1\left(v_1 - v_1^{'}\right)\left(v_1 + v_1^{'}\right) = m_2\left(v_2^{'} - v_2\right)\left(v_2^{'} + v_2\right)$$

Still remember that first equation?

Way Way Cool Math Stuff

From conservation of momentum

$$m_1\left(v_1 - v_1^{'}\right) = m_2\left(v_2^{'} - v_2\right)$$

$$\frac{m_1\left(v_1 - v_1^{'}\right)\left(v_1 + v_1^{'}\right) = m_2\left(v_2^{'} - v_2\right)\left(v_2^{'} + v_2\right)}{m_1\left(v_1 - v_1^{'}\right) = m_2\left(v_2^{'} - v_2\right)}$$

$$\left(v_1 + v_1^{'}\right) = \left(v_2^{'} + v_2\right)$$

$$v_1 - v_2 = v_2^{'} - v_1^{'}$$

Way Way Cool Math Stuff

$$v_1 - v_2 = v_2' - v_1'$$

Only for elastic, head-on collisions where kinetic energy is conserved!!!

Way Way Cool Math Stuff

$$v_1 - v_2 = v_2^{'} - v_1^{'}$$

To understand just how way way cool this is, let's revisit the bowling problem.

Tooootaly Inelastic

- ***Elastic collisions*** – object bounce off each other with no loss of energy
- ***Inelastic collisions*** – still bounce off each other, but mechanical energy is NOT conserved
- ***Tooootaly Inelastic collisions*** – objects don't bounce off each other at all, remain stuck together

Toooootaly Inelastic

- ***Toooootaly Inelastic collisions*** – objects don’t bounce off each other at all, remain stuck together
  - Momentum is still conserved
  - Kinetic energy is NOT conserved
  - Masses of the two objects are combined

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v_3$$

WATCH YOUR SIGNS

- If the objects are going in the same direction, they can both be positive
- If the objects are going in opposite directions, one of the velocities must be negative
- The conservation of momentum equation does not include direction of the velocity
- Conservation of kinetic energy equation – sign doesn’t matter because you square it.

Summary Video:

Energy and Momentum (21 min)

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QUESTIONS?

Homework

#22-28 and 31-38