The Physics of Tennis

Lesson 6: Forces and force interactions acting on a ball

Unit Overview: In this unit students continue to develop understanding of what can be at first glance a complicated system, the game of tennis. In this activity we have taken two components of the game of tennis, the ball and court, to see if we can model the interactions between them.

Objectives:
Students will be able to-

- Demonstrate that vectors can show the nature of force and how we utilize simple vector diagrams to show force pairs (action-reaction.) Also, show that a vector is an arrow whose length represents the magnitude of a quantity and whose direction represents the direction of the quantity such as a force.
- Explain that force is an influence that tends to accelerate an object; a push or pull and is measured in Newton’s.
- Explain that if the state of motion of an object is at rest, or moving in a constant velocity in a straight line, then all forces are balanced.
- Identify the forces involved as causal factors in describing the motion of the ball, racquet, and interactions with the surface of the court.
- Use Newton’s three laws of motion, which also will be illustrated throughout the unit and remaining activities, to describe the motion and interactions of the components as a game is played.
- Collect data for representative mass and diameters of tennis balls. They can calculate their respective volumes and can also calculate utilizing $F_w = mg$ the equivalent weights in the metric system if HS. Note: “g” is the acceleration due to gravity and does vary with location so it is a small variable introduced into the game of tennis around the world. See Wikipedia information in activity #5 that also can be discussed with students.
- Calculate impulse-change in momentum before and after collisions with the court surface.
Lesson Time Required: 1 class period

Next Generation Science/Common Core Standards:

NGSS.MS PS2 - Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. (This activity sets up students for prior knowledge when the third law is introduced.)

NGSS.MS PS2-A1 - Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

PS2.A: Forces and Motion: Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.

PS2.B: Types of Interactions: Objects in contact exert forces on each other.

Possible Sources:

• instructional video of various types of ground strokes

Materials Needed:

• tennis balls
• tennis racquets
• different types of strings

Lesson & Activity

Focus/Essential Question: How do forces and interaction force pairs act on an object?
1) Look at the above pictures A & B. One is an apple sitting on a table and the other is a tennis player holding a tennis ball.

a. Describe how the forces acting on the apple and ball in each case (A & B) are similar or different.
b. Draw the forces using vector representations that are acting on the apple and on the ball.
c. For the bird in flight (C) describe the forces acting on the bird.
d. If the tennis ball shown (D) is moving through the air describe the forces acting on the ball.
e. What do you think the effect would be of increasing the mass (weight) of the ball in “D above?

f. As shown a moving tennis racket hits a ball forward. Describe the forces on the ball and then describe the forces on the racket.

2) In Investigation #4 you were asked to qualitatively describe what forces act on a ball when it is held, thrown upward, thrown horizontally and when it interacts with the court.

a. Draw scale vector diagrams to represent each situation.
b. Represent the vector components of the force exerted by the ball on the court (horizontal and vertical) when the ball interacts with the court surface at an angle.

3) Describe in terms of force(s), impulse, and changes in momentum the various interactions of ball, court, and racquet.

a. Represent the vector components of the force exerted by the ball on the court (horizontal and vertical) when the ball interacts with the court surface at an angle.
b. Describe in terms of force(s), impulse, and changes in momentum the various interactions of ball, court, and racquet.