INTERNATIONAL
TENNIS HALL OF FAME

# The Physics of Tennis

## Lesson 5: Energy Changes when a ball interacts with a racquet

**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-

- Observe and compare the energy changes of the tennis ball as it is dropped from a fixed distance onto a tennis racquet in different locations.

**Lesson Time Required:** 1 class period

**Next Generation Science/Common Core Standards:**

CCSS.MATH.CONTENT.HSG.GPE.A.2 Derive the equation of a parabola given a focus and directrix (This activity supports in part this Common Core Math Standard)

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

- **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)
- **PS2B: Types of Interactions: Objects in contact exert forces on each other**

[Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.]
[Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.

## Possible Sources:

- video of a serve

## Materials Needed:

- tennis balls
- tennis racquets
- different types of strings

## Lesson & Activity

This activity affords the student the opportunity to observe that the location of impact of a ball by a racquet can have various effects. Students can design, or teachers can utilize the suggested procedure as a guided inquiry, an experiment that allows the ball to contact the racquet in various locations. A racquet can be fixed to a table or lab bench by using a "c" clamp. Students can drop the ball from a fixed height above the racquet and hit the racquet in various locations. This also could be set up as a ramp for the ball to roll down from a fixed height and strike a racquet being held by a student (or clamped) and observe the interactions. As an extension students at the high school level could compare various racquets for differences relative to the above.

Middle school students can focus on a tennis ball rolling down an incline as an introduction to this activity. The ball can interact with various tight string type materials such as string, fishing line, at the end of the incline. Two clamps and an incline with some string like materials is all they need to use to observe the effects of tightened strings and the effects of the collision. Students need to address the following:

## Focus Question: What effect does string stiffness have when a ball hits a racquet?

The stiffness of the strings relative to the ball determines how much energy is lost when the ball and racquet collide. Stiffness is a resistance force opposing the change in shape of the ball when it collides with the racquet. During the interaction, the ball is compressed as it bounces off the racquet (or court surface). The string is also stretched. Although this is a bit over simplified, it does create a framework for a

model for this interaction.  That interaction when the ball is compressed and the string is stretched end up providing the energy to the ball after the collision, just like a stretched elastic can propel an object when it is in contact. Also, when the two objects collide, they create a force between them that depends on the speed, mass, and relative stiffness of the objects.  That force created by the collision of the two objects pushes equally on each object.  It also is important to note that balls lose more energy in the collision than the strings of the racquet.