# A Fun General Education Physics Course: Physics of Sports

*John Eric Goff,* Lynchburg College, Lynchburg, VA

During a two-year visiting appointment at Oberlin College in Oberlin, OH, I offered a course called Physics of Sports for the fall 2000 semester and the fall 2001 semester. While preparing the course, I faced a challenge that confronts many physics teachers: How can I make a general education physics course fun for nonscience students? With only an algebra prerequisite for the course, the typical student did not have a particularly strong mathematical background. My goal was to not only teach those students a little physics, but also show them how physicists try to understand and describe the world of sports. I also wanted to make the course sufficiently enjoyable that the students had a positive experience in what may have been the last science course some of them ever took. After discussions with the students, I feel the course succeeded in fulfilling my goals.

## Course Description

On the physics side, my course covered most of the standard mechanics topics seen in the first semester of an algebra-based introductory physics course. We also discussed, among other topics, energy in the body and the difference between light speed and sound speed when one is, for example, at a baseball game and hears the crack of the bat after seeing the ball hit. There were two required textbooks: *The Dynamics of Sports*[1] by David Griffing and *The Physics of Baseball*[2] by Robert Adair. The former book provided a more traditional set of mechanics topics, as well as some problems to use for homework assignments. The latter book provided more qualitative reading, dealing with one particular sport whose ideas could be applied to other sports. I was able to create many of my own problems from Adair's book.

On the sports side, we were able to discuss many different sports, enough that there was something for everyone's sports interest by the end of the course. We looked at baseball, football, basketball, hockey, gymnastics, swimming, diving, tennis, running, many track and field events, sumo wrestling, ballet, golf, billiards, skiing, figure skating, and cricket.

Assessment consisted of two large midterm exams, weekly homework assignments, class participation, discussion of a sports video, and a course project. The use of sports videos and the course project were vital parts of my class, and I would like to devote the majority of my remaining space to those areas.

## Sports Videos

Students earned 5% of their course grade by bringing in one sports video during the semester. All I asked of them was that they read ahead for a given day's physics topic and bring in a video clip that illustrated that physics principle. The tapes were all in VHS format and were played on the lecture hall's VCR. The student would say a few words to the class about the physics involved in the clip and the class would have some time for further discussion. This very easy 5% that a student earned gave each student a chance to participate, and more importantly, allowed the students to dictate the topics discussed in many of the classes. I love this facet of the course because no


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two Physics of Sports courses that I offer are ever the same; each course reflects the interests of the students.

Here are just a few examples of the many video clips (all taken from sports videos from a movie store or simply taped from a televised sporting event) my classes analyzed:

- The famous end to the 1982 Stanford-Cal football game was shown in the first class to demonstrate the idea of **average velocity.** After the kickoff was caught, there were several laterals, and the actual path of the football from the instant it was caught to when it crossed the goal line was quite complicated. The students noted the displacement of the ball (about 55 yards) and the total time it took the ball to cross the goal line (about 19.2 s). They then found the magnitude of the average velocity to be about 5.9 mph, which is just the velocity someone would need to jog along the sideline starting when the ball was first caught and cross the goal line at the instant the ball did.
- **Projectile motion** was studied using video clips of Bob Beaman's famous 1968 long jump and Doug Flutie's famous "Hail Mary" pass in a 1984 college football game. In both cases, the students noted projectile distance and time of flight to calculate launch speed and launch angle. The results were obtained using constant-acceleration kinematics in a vacuum. After getting the results, we were able to then discuss how the numbers would qualitatively change if we could include air resistance, a topic that was quantitatively beyond the scope of the course.
- A video of Michael Jordan dunking a basketball was used to study **hang time**. We then worked out that about 71% of the time of flight is spent in the top half of the motion, thus giving the illusion of hang time.
- A video showing Jeff Hartwig performing in the pole vault was instructive in illustrating how **energy is transferred in a system.** Hartwig's initial kinetic energy as he ran to the jump spot was estimated, as was his gravitational potential energy at the top of his jump. The students then made estimates as to how much energy was stored in the bent pole.
- Al Oeter throwing the discus demonstrated **centripetal motion.** The students learned that the velocity of an object moving in a circle is tangent to the path when they saw Oeter release the discus.
- Watching Dick Fosbury perform the high jump provided a great segue into a discussion of **center of mass and gravitational potential energy.** The students could appreciate the "Fosbury Flop" once they learned that work has to be done to raise a person's gravitational potential energy. The "Fosbury Flop" allows the athlete to get over the high bar with his or her center of mass possibly passing *under* the bar at the apex of the motion.
- Videos of Greg Louganis diving and Kristi Yamaguchi skating were very helpful in getting the students to understand **conservation of angular momentum.** Watching Louganis go from a "layout" position to a "tuck" position and Yamaguchi pull her arms in for the final spin, students had a qualitative understanding that reducing one's moment of inertia will cause one to spin faster (and increasing one's moment of inertia will make one spin more slowly).

## Course Projects

In lieu of a course final, the students were required to complete a course project that accounted for 25% of their course grade. The project consisted of making measurements and/or reading material dealing with an area of sports of interest to the students. A formal paper was required, and an oral presentation was given to the entire class at the end of the semester. Many of my students pleasantly surprised me with their creativity and the time they were willing to invest in the project. For many students, the project represented the only time in their lives that they had made a serious scientific inquiry into a problem of interest. While the projects were certainly not at the level of publishable research, many of them were quite interesting and I learned a great deal from reading the papers.

Here is a brief list of some of the projects that I enjoyed the most:

- A very popular project topic dealt with **coefficient of restitution.** Part of the reason this was a popular choice is because the experiment is quite easy. One can easily show that if one object, such as a ball, is dropped on an immovable object, the coefficient of restitution is just $(h_f / h_i)^{1/2}$ where $h_i$ is the initial height from which the first object is dropped and $h_f$ is the first rebound height. One student made use of a freezer, a refrigerator, an oven, and a thermometer to make a nice plot of coefficient of restitution for a baseball hitting an ash board as a function of temperature. A tire pump with a good pressure gauge allowed another student to plot coefficients of restitution for basketballs dropped onto the surface of a court as a function of the pressure.

» One student who had an interest in running analyzed three different strategies (constant speed, slower at the beginning and faster at the end, and faster at the start while slowing down at the end). At various points on an indoor track the student's partner would record times. When the student plotted the positions versus time, she noticed a zigzag in her data. What she discovered was that local minima in the plot corresponded to the times when she rounded the turn in the track. That revelation motivated her to investigate why her speed dropped, and then she looked at the physics associated with rounding a turn on a flat track. While not her original project intention, this student had a nice discussion of friction and centripetal motion in her paper.

» A hockey coach told one of my students that a good practice technique for stickhandling a hockey puck on ice is to stickhandle a golf ball on concrete. The latter technique is used in practice, because one does not always have access to an ice rink. The student created a pendulum out of his hockey stick so that he could ensure that when it hit the puck or the golf ball, it would do so with the same velocity. He analyzed the motion of each object after being hit by the hockey stick and determined that the puck on ice and golf ball on concrete each move with very similar velocities over the range of distances useful for stickhandling. This nice project serves as an example of a student who, playing a particular sport received advice from a coach, and then decided to scientifically investigate that advice.

» Another project involved bowling. A couple of students made measurements of a bowling ball's motion and deduced kinetic energy and linear momentum at the time of impact with the pins. They then looked at linear momentum conservation after impact and made estimates on kinetic energy losses. This is a very hard project to do completely, but the students made a very nice first start. They calculated the ball's energy and momentum just before impact and assumed the ball hit just one pin. They then assumed the ball hit a second pin with a lowered energy and momentum. This was as far as they could go, but they did make some nice qualitative statements regarding the more complicated problem of having the ball interact with more pins.

» Two students on the football team created a great project in which they studied the work and power required to push a 300-lb sled over a distance of five yards. They examined pushing the sled on both wet and dry grass. The sled was something they used in practice to help with blocking and they were curious to know how much power they could generate while pushing it. Once they were able to get the sled pushed at a maximum speed, a third partner timed their motion over a distance of five yards. Applying some simple physics, they determined that they could deliver almost two horsepower (combined) while pushing the sled. This large power output could obviously only be achieved for a short distance.

## Course Success

According to discussions with students and course evaluations, using videos quite extensively in the course was very successful. While possessing a certain entertainment value, the videos gave the students an opportunity to see physics in action. They could relate the material on which I lectured to real-world examples that interested them. The course project was also well received. In addition to providing a welcome reprieve from a course final, the project gave the students a chance to investigate something relating to their own interests.

I think word-of-mouth helped enrollment as my class size quadrupled from the first offering (six students) to the second (24 students). My course also became the subject of two newspaper articles.[3,4] I just started teaching at Lynchburg College, and I hope to offer Physics of Sports again in the near future. I hope that this work adds to the many fine papers[5,6] written on sports physics in this journal in recent years. As a new member of AAPT, I welcome any comments and suggestions from readers.

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## References

1. David F. Griffing, *The Dynamics of Sports,* 4th ed. (The Dalog Company, Oxford, OH, 1999).
2. Robert K. Adair, *The Physics of Baseball*, 2nd ed. (HarperPerennial, New York, 1994).
3. Kimberly Bonvissuto, "Not just Bio 101," *Crain's Cleveland Business* (Oct. 15, 2001). (My course was the first of three discussed in a story of "unconventional offerings.")
4. Mark Sullivan, "Famous Flutie pass now in its own class," *Boston College Chronicle* (Nov. 1, 2001.)
5. D.A. Wardle, "The time delay in human vision," *Phys. Teach.* **36,** 442–444 (Oct. 1998).
6. Ole Anton Haugland, "Physics measurements for sports," *Phys. Teach.* **39**, 350–353 (Sept. 2001).

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**John Eric Goff** *chose a physics career over one in baseball while in high school. He earned a B.S. in physics and mathematics from Vanderbilt University, and an M.S. and Ph.D. from Indiana University in condensed matter theory. Before beginning work at Lynchburg College in the fall of 2002, he held visiting appointments at Kenyon College and Oberlin College.*

**School of Sciences, Lynchburg College, Lynchburg, VA 24501; goff@lynchburg.edu**