THE OHIO STATE UNIVERSITY

PHYS 1111 - Physics of Sports

Class Meeting Days, Time, Location:
Class will be held on M for 110 minutes (lab), Tu and Th 80 min each (lecture).

Attendance Policy:
Due to in-class lab work/video analysis and quizzes, attendance is required, except when excused by prior arrangement or due to documented illness.

Course Description:
This course examines the physics of motion set in the context of sports. We will introduce foundational physics concepts (force, momentum, acceleration, etc) and learn how to apply these concepts to sports through the analysis of videos of actual sporting events. Using this data, students will construct physics models to represent, calculate, analyze, interpret, and explain the motion and interactions between people and equipment. Students will also learn how to make useful and appropriate approximations in these complex environments. This is a GE Foundations Natural Sciences course.

Required eBook:
The Physics of Sports by Michael Lisa, McGraw-Hill (2016), ISBN: 9781259315251. It may be available at the OSU Bookstore, but it should be easiest and/or cheapest to access it directly through Carmen, where you should find it at the McGraw-Hill Connect option on the sidebar. Alternatively, you can obtain it directly from the publisher at https://connect.mheducation.com/class/c-hill-sp2024-tu-th-1245. You will need the Connect Access card to access the eBook as well as to do online reading and homework assignments. You must purchase this ASAP.

Grading:
The grading components are:

- SmartBook reading assignments from the textbook- 10%. These are e-reading assignments that are assigned prior to material being covered in class. The contain integrated questions that test your comprehension as you read. Grades are based on correctly completing these questions, with unlimited attempts
- Homework (after dropping lowest score) - 20%.
- Quizzes (after dropping lowest score) - 25%.
- Lab - 25 %. Labs are graded on completion of the pre-lab assignment (5%), which typically will be finding a suitable video for analysis, performance of the video analysis in the lab (15%) and accuracy of the quatitative results obtained via the video analysis

(5%). The grading rubric for the labs is presented at the end of the syllabus. The entire group in the labs will receive the same grade each lab.
- Choice of either summative final exam, or culminating project – 20%. The final project is described at the end of the syllabus.

Course grades will be assigned A-E according to the following grading scheme:
93–100: A
90–92.9: A-
87–89.9: B+
83–86.9: B
80–82.9: B-
77–79.9: C+
73–76.9: C
70–72.9: C-
67–69.9: D+
60–66.9: D
Below 60: E

Missed Quiz, Late HW Policies:

There are no make-up quizzes. Should you miss one quiz for any reason, this quiz will count as your lowest score and will be dropped. Should you miss more than one quiz, you will receive a zero for that quiz (unless excused by prior arrangement or due to documented illness.) Late reading assignments or homework is not accepted.

Schedule, Due-dates, etc.

A detailed, up-to-date, schedule of class activities and due dates for all assignments is maintained on Carmen.

Course Goals:

1. Students learn to identify and quantify relevant quantities such as force, power, and speed, in realistic physical situations, including the use of both Imperial and metric (SI) units.
2. Students can explain and apply basic physical concepts that drive the action in athletics and other complex physical systems, kinematics, forces, energy, and momentum.
3. Students develop and grow confident in the basic mathematical skills to model physical phenomena in terms of mathematical equations and graphical and diagrammatic representations gain a deeper understanding of the phenomena and to solve problems.
4. Students become confident in approximation and estimation to apply their knowledge to real-world situations in which the interactions are complex and not completely understood, and where the physical conditions are only approximately known.

5. Students appreciate the process of science as applied to complex real-world systems, such as athletics, facilitating participation in an increasingly complex and technological society, where science has wide-reaching implications on their lives.
6. Students will develop skills relevant to empirical scientific investigation, including measurements of physical quantities, data collection, analysis and representation.
7. Students will apply physical models to interpret and explain data and use data to assess model quality.

Physics 1111 meets these objectives through a pedagogical discussion of fundamental physics principles as they relate to the real world in the context of athletics. Note is taken of the historical context in the development of these principles, and the connection between fundamental principles and technological implementation is discussed. In addition to regular coursework, the student is provided the opportunity to strengthen understanding of these principles through an independent group project and presentation on the application of physics in sports.

General Education (GEN) Goals and Expected Learning outcomes

Aligned with the goals described above, as part of the Natural Sciences Foundations of the General Education curriculum, this course is also designed to meet the GEN goals and learning outcomes listed below. We include some details of the how the learning outcomes are applied to this course.

Goal 1: Successful students will engage in theoretical and empirical research study within the natural sciences while gaining an appreciation of the modern principles, theories, methods, and models of inquiry used generally across the natural sciences.

- Learning outcome 1.1 Explain basic facts, principles, theories and methods of modern natural sciences, and describe and analyze the process of scientific inquiry.
- Learning outcome 1.2 Identify how key events in the development of science contribute to the ongoing and changing nature of scientific knowledge and methods.
- Learning outcome 1.3 Employ the processes of science through exploration, discovery and collaboration to interact directly with the natural world when feasible, using appropriate tools, models and analysis of data.

Goal 2: Successful students will discern the relationship between the theoretical and applied sciences while appreciating the implications of scientific discoveries and the potential impacts of science and technology.

- Learning outcome 2.1 Analyze the inter-dependence and potential impacts of scientific and technological developments.

- Learning outcome 2.2 Evaluate social and ethical implications of natural scientific discoveries.
- Learning outcome 2.3 Critically evaluate and responsibly use information from the natural sciences

Statements on OSU policies and services:

For up-to-date information on the OSU policies and services relevant to this course on the topics of :

1. Academic Misconduct,
2. Artificial Intelligence and Academic Integrity,
3. Student Life - Disability Services,
4. Religious Accommodations,
5. Intellectual Diversity,
6. Grievances and Solving Problems,
7. Creating an Environment Free from Harassment, Discrimination, and Sexual Misconduct,

please visit:
https://ugeducation.osu.edu/academics/syllabus-policies-statements/standard-syllabus-statements

Student Technology Loan Program:

If you do not have access to a device with digital inking capability, an iPad or MS Surface Go are good options. If you do not currently have such a device, you may borrow one from OSU free of charge. Visit the Student Technology Loan Program website to self-request a device to borrow for the semester.

Sample Schedule of Topics/Labs/Assessments:

Week	Chapter	Reading	Instruction Mode
1	Ch 1 - Warm up, center of mass Ch 2.1 - Michael Phelps in math and graphs Lab 1 - Intro to Video Analysis	Tutorials/Ch 1 Sec 2.1	Lecture Lecture Lab
2	Ch 2.2 - Usain Bolt and acceleration Ch 2.2 (cont.) Lab 2 – Video Analysis: Acceleration in Sports	Sec 2.2	Lecture Lecture Lab
3	Ch 2.3 - Vertical motion - diving and climbing Ch 3.1-3.2 - Forces in sports; Dwight Howard jump Quiz 1	Sec 2.3 Sec 3.1	Lecture Lecture Quiz

Week	Chapter	Reading	Instruction Mode
4	Ch 3.2-3.3 - Howard's landing; friction Ch 3.3-3.4 - Sideways traction; vectors Lab 3 –Video Analysis: Friction in Sports	Sec 3.2 Sec 3.3	Lecture Lecture Lab 3
5	Ch 3.4 - Vector forces Ch 3.4-3.5 - Ankle forces in football; imaginary force Lab 4 - Video Analysis: Forces in Sports	Sec 3.4 Sec 3.5	Lecture Lecture Lab
6	Ch 3.5 - Imaginary forces and centripetal force Ch 4.1-4.2 - The math behind a football punt Quiz 2	Sec 4.1,4.2 Sec 4.4	Lecture Lecture Quiz
7	Ch 4.2, 4.4 - Humans in flight Ch 5.1-5.2 - Aerodynamics in sports; buoyancy Lab 5 - Video Analysis: Buoyancy in Sports	Sec 5.1	Lecture Lecture Lab
8	Ch 5.3 - Aerodynamic drag Ch 5.3 - Effects of drag in sports Lab 6 - Video Analysis: Drag in Sports	Sec 5.2 Sec 5.3	Lecture Lecture Lab
9	Ch 5.4-5.5 - The physics of a curveball Ch 5.5-5.6 - Curveballs and knuckleballs Lab 7 - Video Analysis: Spin in Sports	Sec 5.4-5.5 Sec 5.6	Lecture Lecture Lab
10	Ch 6 - Collisions in sports: football Ch 6 - Collisions in sports: football (cont.) Quiz 3	Sec 6.1, 6.2 Sec 6.3	Lecture Lecture Quiz
11	Ch 6 - Collisions in sports: dribbling, golf Ch 6 - Collisions in sports: dribbling, golf (cont.) Lab 8 - Video Analysis: Collisions in Sports	Sec 6.4 Sec 6.5	Lecture Lecture Lab
12	Ch 7 - Energy in Sports: Bursts of Power Ch 7 - Energy in Sports: Bursts of Power (cont.) Lab 9 - Video Analysis: Energy/Power in Sports	Sec 7.1, 7.2 Sec 7.3, 7.5	Lecture Lecture Lab
13	Ch 8 - Energy and Timing win Elastic Equipment Lab 10 - Video Analysis: Timing in Sports Quiz 4	Sec 8.1 Sec 8.2, 8.3	Lecture Lab Quiz
14	Ch 11 - Lines of Action on the Line of Scrimmage Ch 12 - A Barry Bonds Home Run Lab 11 - Video Analysis: Line of Scrimmage	Sec 11 Sec 12.1	Lecture Lecture Lab
15	Ch 12 - A Barry Bonds Home Run (cont.) Lab 12 - Video Analysis: Home Run Quiz 5	Sec 12.2-12.3	Lecture Lab Quiz

Using software for video analysis

An important component of this course will be using readily available software that is free or available for free to OSU students. Students will need to bring a laptop or ipad to class and labs. Students will need to use a spreadsheet (like Excel or Google sheets) and will learn skills of making simple calculations and graphs with spreadsheets. Students must have access to powerpoint/keynote or equivalent, to draw simple vectors on screenshot images, and to estimate length scales using scaling of arrows. If a student opts to do a project, such software will also be used to put together their presentation. Students will also need access to (free) video software such as Quicktime or equivalent, to count frames in videos, and they will also need access to a (free) video downloader.

Description of major course assignments

Reading assignments

Reading assignments, are completed using the adaptive learning "SmartBook" feature that McGraw Hill Connect offers. Each assignment typically takes students in the range of 10-35 minutes to complete.

Homework assignments

The HW is typically 4-5 questions drawn from the text book (assigned and completed online, through McGraw Hill Connect). Each assignment typically takes students about one hour to complete.

Quizzes

There are 5 in-class quizzes spaced throughout the semeseter. Quizzes last the whole class period (80 minutes) and consist of 2-3 multiple choice and 1-2 calculations with reasoning and showing your math work.

Labs

There are 12 lab sessions in which students will work in groups to use video analysis to obtain data from specific sports actions. As mentioned in the grading section, there is a pre-lab assignment which typically will be finding a suitable video for analysis. Then the groups perform the video analysis in the lab which includes extracting data and making estimations, calculations, evaluations and conclusions. The grading rubric for the labs is presented at the end of the syllabus. The entire group in the labs will receive the same grade each lab. Groups will be changed at least once in the semester. Below are brief descriptions of each lab.

Lab 1 - Intro to Video Analysis
Students will be introduced to technical aspects of extracting recent sports clips from various publicly available sources (e.g. from YouTube), finding the #frames/second in such clips, and using frame-by-frame analysis to estimate the duration of the sporting

activities being analyzed. Estimation techniques for other variables on interest will be practiced.

Lab 2 – Video Analysis: Acceleration in Sports
Students will work in groups to analyze sports clips of their choosing that contains measurable acceleration (e.g. 100 m dash in track, touchdown run in football). Comparison of extracted kinematic quantities will be made to typical values, and limitations of the accuracy/precision of the analysis will be investigated.

Lab 3 –Video Analysis: Friction in Sports
Students will work in groups to analyze sports clips of their choosing that contains observable effects of friction (e.g. friction between basketball shoes and the court). Calculation of frictional forces, and their effects on the dynamics of the sport under study via Newton's second and third laws will be investigated up to the limitations of the accuracy/precision of the analysis.

Lab 4 - Video Analysis: Forces in Sports
Students will work in groups to analyze sports clips of their choosing that contains one or more isolatable forces that have been studied so far (gravity, friction, normal). Calculation of all relevant forces and their vector summation, if necessary, will be done and the net effects on the dynamics of the sport under study (e.g. acceleration of the athlete) will be investigated up to the limitations of the accuracy/precision of the analysis.

Lab 5 - Video Analysis: Buoyancy in Sports
Students will work in groups to analyze sports clips of their choosing that contains quantifiable effects of buoyancy (e.g. time-of-flight of a ping pong ball). Comparison of measured quantities that affect the sporting outcome will be compared to those obtained without taking buoyancy into account, with discussion of the limitations of the accuracy/precision of the video analysis.

Lab 6 - Video Analysis: Drag in Sports
Students will work in groups to analyze sports clips of their choosing that contains quantifiable effects of drag (e.g. flight distance of a baseball, carry distance of a driven golf ball, etc.). Comparison of measured quantities that affect the sporting outcome will be compared to those obtained without taking drag into account, with discussion of the limitations of the accuracy/precision of the video analysis.

Lab 7 - Video Analysis: Spin in Sports
Students will work in groups to analyze sports clips of their choosing that contains quantifiable spin and measurable effects of that spin (e.g. spin rate of thrown curveball in baseball, backspin on a basketball free throw). Comparison of measured quantities that affect the sporting outcome will be compared to those obtained without taking spin into account, with discussion of the limitations of the accuracy/precision of the video analysis.

Lab 8 - Video Analysis: Collisions in Sports
Students will work in groups to analyze sports clips of their choosing that contains collisions between two or more objects involved in the sport (ball vs. bat in baseball, player vs. ground in football). Dynamical quantities at work in the sport (e.g. forces, acceleration, impulse) will be calculated employing physical concepts such as conservation of momentum. Limitations of the accuracy/precision of the analysis will be studied.

Lab 9 - Video Analysis: Energy/Power in Sports
Students will work in groups to analyze sports clips of their choosing that can illustrate the effects of energy/power on the outcome of the athletic activity). Energetic quantities (work, kinetic energy, potential energy, power) will be measured and/or calculated for the sporting event employing physical concepts such as conservation of energy. Comparison to familiar forms of energy (calories in food) will be made up to the limitations of the accuracy/precision of the analysis.

Lab 10 - Video Analysis: Timing/Elasticity in Sports
Students will work in groups to analyze sports clips of their choosing that contain examples of elastic forces acting in a short amount of time as is commonplace in sports (e.g. slapshot in hockey). Comparison of extracted dynamical quantities will be made to those arising in non-sporting activities with which the student might be more familiar up to the limitations of the accuracy/precision of the analysis.

Lab 11 - Video Analysis: Line of Scrimmage
Students will work in groups to analyze football clips of their choosing that contain one or more plays from scrimmage. This will be a culminating activity, where the many relevant physical phenomena involved in the battle for the line of scrimmage (e.g. vectors, friction, momentum, impulse, power, etc.) that have been learned over the course of this class will be utilized in the analysis of the video clip with appropriate precision and understood accuracy.

Lab 12 - Video Analysis: Home Run
Students will work in groups to analyze baseball clips of their choosing that contain one or more home runs. This will be a culminating activity, where the many relevant phenomena involved in the physics of hitting of a home run (e.g. gravity, spring force of the bat/ball, aerodynamic forces, etc.) that have been learned over the course of this class will be utilized in the analysis of the video clip with appropriate precision and understood accuracy.

Choice between final exam or final project

Students may choose whether they want to complete a final exam or complete a final project. Students must notify the instructor **by the end of week 10** which option they choose.

Final exam: The final exam is comprehensive with questions drawn (and modified) from the quizzes. The final is 110 minutes and will consist of 3-5 multiple choice and 2-4 show work questions requiring explanations and showing math work.

Final Project: Students must submit there project proposal by week 12. The instructor will provide feedback and resubmission with iteration if necessary. The proposal must have final approval by the end of Week 13.

Your assignment is to find and analyze another video clip of a sports activity that interests you. The clip should show one or more elite athletes (i.e., professional, NCAA D1, Olympic) engaging in their sport where the maneuver they are performing demonstrates one or more of the physics principles we have discussed in class and/or you have read about in the textbook. Alternatively, you may produce the video (of an elite athlete) yourself.
Once you have found such or generated such a clip, you will need to do the following to get full credit:

- *Trim it so that it just shows the sports maneuver that you will analyze*
- *Quantify the situation using the estimation and/or timing techniques we have learned to use in class*
- *Perform at least three different calculations based on the physics of the video that allows you to predict the evolution/outcome of the play/event.*
- *If you need a second or third clip to perform the the three required calculations you may do that, just remember that they must be **different** physics calculations.*
- *Quantitatively compare your predictions to the actual evolution/outcome of the play/event that the remainder of the clip(s) shows*
- *Submit your clip(s) together with a powerpoint presentation of your analysis via Carmen by the assigned due date.*

The powerpoint presentation should be around 10 slides long containing roughly the following structure

1. *Title with your name*
2. *1 slide Introduction*
3. *1 slide showing 1st (part of) video clip and/or extracted photos*
4. *1 slide explaining your quantification of the sports maneuver in this video clip*
5. *1 slide with your calculation, prediction and comparison to observed outcome*
6. *1 slide showing 2nd (part of) video clip and/or extracted photos*
7. *1 slide explaining your quantification of the sports maneuver in this video clip*
8. *1 slide with your calculation, prediction and comparison to observed outcome*
9. *1 slide showing 2nd (part of) video clip and/or extracted photos*
10. *1 slide explaining your quantification of the sports maneuver in this video clip*
11. *1 slide with your calculation, prediction and comparison to observed outcome*
12. *Summary & Conclusion*

The project will be graded according to the following rubric:

Final Project Rubric

Criteria	Ratings	Pts
Video clip(s) are appropriate. The submitted video(s) shows an elite athlete demonstrating a 3 physics principles and is trimmed to an appropriate length.	**3 ptsFull Marks** **0 ptsNo Marks**	3 pts
Quantification is accurate. Times have been accurately measured and lengths/distances/angles have been estimated to a reasonable precision for all clip(s).	**2 ptsFull Marks** **0 ptsNo Marks**	2 pts
Calculation 1 is correct. The analysis of the physical principle is correct (e.g. appropriate formulae are used) and the quantities estimated from the video are correctly used in these formulae to make a prediction.	**3 ptsFull Marks** **0 ptsNo Marks**	3 pts
Calculation 2 is correct. The analysis of the physical principle is correct (e.g. appropriate formulae are used) and the quantities estimated from the video are correctly used in these formulae to make a prediction.	**3 ptsFull Marks** **0 ptsNo Marks**	3 pts
Calculation 3 is correct. The analysis of the physical principle is correct (e.g. appropriate formulae are used) and the quantities estimated from the video are correctly used in these formulae to make a prediction.	**3 ptsFull Marks** **0 ptsNo Marks**	3 pts
Comparison with outcome. Quantitative comparison is made between your prediction and the actual evolution/outcome of the play/event for each of the calculations. Uncertainties in the prediction are included (quantitatively) in these comparisons.	**3 ptsFull Marks** **0 ptsNo Marks**	3 pts

Final Project Rubric

Criteria	Ratings	Pts
Presentation. Uploaded file follows the structure given in assignment, looks professional, and is a clear presentation of the physics.	3 ptsFull Marks 0 ptsNo Marks	3 pts

Total Points: 20

Video Lab Rubric

Criteria	Ratings		Pts
Video is appropriate The chosen video shows an elite athlete demonstrating a physics principle and is trimmed to an appropriate length.	5 pts Full Marks	0 pts No Marks	5 pts
Quantification is accurate Relevant parameters have been accurately measured or have been estimated to a reasonable precision.	5 pts Full Marks	0 pts No Marks	5 pts
Calculation is correct The analysis of the physical principle is correct (e.g. appropriate formulae are used) and the quantities estimated from the video are correctly used in these formulae to make a prediction.	5 pts Full Marks	0 pts No Marks	5 pts
Comparison with Outcome Quantitative comparison is made between your prediction and the actual evolution/outcome of the play/event. Uncertainties in the prediction are included (quantitatively) in this comparison.	5 pts Full Marks	0 pts No Marks	5 pts
Presentation is clear and effective Presentation to peers clearly demonstrates the physical principles being applied, clearly shows the mathematical/graphical analysis, clearly presents any sources of uncertainty in the labwork and effectively discusses the accuracy of the work compared to the actual athletic outcome.	5 pts Full Marks	0 pts No Marks	5 pts

Total Points: 25