

# **INTRODUCTION TO BIOMECHANICS**

## **LABORATORY INTRODUCTION**

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## 408L Policies

### Introduction/Expectations

The purpose of the laboratory experience is to provide hands on experience quantifying and analyzing human motion from a biomechanics perspective. You are expected to attend your lab session, participate in every lab, complete all pre- and post-lab assignments, and complete a final project. The lab TAs are here to help you. However, in order to have a proper learning experience, you must, as part of asking questions in class or office hours, be able to show your TA your attempts to work the problems. Although you must attend the lab section in which you are registered, you may seek help from *either* TA during office hours.

You are expected to be an active participant in all aspects of the laboratory experience. Prior to your lab session, you must read the material and complete the pre-lab questions for that lab and complete the post-lab homework from the previous session.

When you come to lab, you must bring:

1. Pre/Post lab assignments
2. Slide
3. Lab manual
4. A **usb drive** or other **external storage device** to store large data and video files

### Attendance

- Attendance is mandatory.
- If you need to miss a lab, you must notify your TA *BEFORE* your lab section in order to get approval. You may be required to provide written documentation for your absence. You will be expected to attend another lab section that week.
- You can make up no more than 2 labs by attending another section.
- If you do not make up a missed lab, you will be penalized 10% on your lab report for that week's lab.
- Any unexcused absences will result in a ZERO for the quiz and the lab report for the lab you missed.

### Quizzes & Exams

- Quizzes will be given at the beginning of lab; no extra time will be given to students arriving late. If you are more than 10 minutes late, you will receive a ZERO for that day's quiz.
- Quizzes will contain material from the previous week's lab as well as material to be covered during the current lab session.
- A comprehensive lab practical exam will be given midway through the semester. This will be a written exam, similar to the quizzes, which includes all of the quantitative concepts covered in lab, as well as pre- and post-lab assignments.
- Bring your own calculators to lab. **Calculators can not be shared/borrowed during quizzes or the practical.**

### Pre/Post Lab Activities

- Pre/Post Lab Activities are **due at the beginning of class.**
- Even if you are missing lab, your report is due on time or earlier.
- **We WILL NOT accept late labs. No exceptions!**
- Do not come in and print your lab report during lab time.
- Pre-labs will consist of questions related to the present lab. It must be completed before coming to the lab, or you must have attempted to complete it and have specific questions for the TA.
- **If your data/results are wrong, your lab will not be graded. It will be returned to you and you will have one week to turn in a corrected copy, with a 10% penalty.**
- If you disagree with the grading of a lab report, you have one week from the day it is returned to you to discuss it with your lab instructor for a grade change consideration.

### **Academic Integrity Violations**

- Consequences:
  - Practical, Midterm, Final, Project: F
  - Quiz, Lab Reports, etc.: 0
- Academic dishonesty/misconduct (plagiarism, cheating, unauthorized collaboration, etc.) will not be tolerated. All academic integrity violations will result in a grade sanction and will be reported to the Office for Student Judicial Affairs.
- It is your responsibility to “reasonably” protect your own work from the plagiarism of others.
- If plagiarism is detected on a group project, all members of the group will be held responsible.
- You are expected to be familiar with the Academic Integrity guidelines found in the current SCampus (student guidebook). An electronic version is available at <http://usc.edu/scampus>.

Refer to “EXSC Departmental Laboratory Policies” for the general Kinesiology Department policies.

## 408L Lab Reports

### Lab Reports:

- Must be neat, you are partly graded on grammar, neatness, and organization.
- ***If your data/results are wrong, your lab will not be graded. It will be returned to you and you will have one week to turn in a corrected copy, with a 10% penalty.***
- Must contain the following sections, outlined and stapled in the following order:
  - I. Typed cover page on top containing the following information:  
(\*Do not put your name on any page other than the cover page.\*)
    - Title of lab (be creative)
    - Your name
    - Lab day & time
    - Lab Instructor's name
  - II. Purpose
    - One or two sentences
    - What did we do/measure & how did we do it/measure it?
  - III. Results/Postlab questions
    - Answers to questions numbered, in order, and easy to identify.
    - Keep answers short! Most questions can be answered thoroughly in 2-3 sentences.
    - Drawings are encouraged for explaining answers.
    - For calculations, show all of your work, starting with the general equation(s) you are using.
    - Drawings and calculations can be hand-written, scanned in (or submitted as a hardcopy, though this is not preferred).
    - If a question asks you to compare two or more values, include a table of the values along with your discussion.
    - Graphs:
      - Make sure all text (axes labels, legend) is large enough to be legible.
      - If printing in black and white, make sure that data points from different trials are distinguishable by using different symbols or line styles.
      - Every graph should have a title, axes labels (with units), and a legend.
      - Always include units in graphs, charts, and written responses.
  - IV. Data
    - Print out your Excel data file. Because there are large quantities of data, we will not be asking for the entire file. For most labs the first page will suffice. For some, we will want the first and last page. This will be specified during lab.
    - If you used formulas in your Excel file, print out the data such that the formulas are printed.
  - V. Closing Paragraph
    - Short paragraph.
    - This is NOT a conclusion based on the data.
    - Take-home message. What did you get out of this lab? Feedback to Lab Instructor.

### Answering assigned questions:

- ***Lab reports should be done completely on your own and written in your own words. Unauthorized collaboration is plagiarism and will result in a grade sanction and a report sent to the Office for Student Conduct. (See the lab policies for more information.)***
- Information for answering questions can be drawn from lab data, lab and lecture notes, textbooks, or other scientific reference material. Do not copy material from any reference unless you cite it properly.
- Be thorough, always explain "why", and show that you understand. Write as if you are explaining it to someone who has no prior knowledge of the subject matter (i.e. your parents). Do not assume that anything is obvious.
- Each question is graded individually, so answer each question completely. Don't assume that if you already gave an explanation when answering another question that you don't need to explain it again if it is relevant to the question.
- Use scientific language and your knowledge of physiology.

## 408L Project

The ability to analyze and describe human motion is a fundamental skill in the field of kinesiology. The lab project provides you with an opportunity to practice the skills you have learned in lab by analyzing movements of your choice.

You will work in teams of two to compare the biomechanics of two movements of your choice. You will capture video and force data for these movements. Once in digital format, you will conduct biomechanical analyses to determine the essential elements of your particular human motor performance.

The project requires your team to do the following:

1. Select two movements to compare and contrast.
2. Perform a literature search for background information related to your movements of interest.
3. Formulate a testable hypothesis and outline a biomechanical analysis that will help prove or disprove your hypothesis.
4. Identify events, phases, and system(s) of interest.
5. Perform a data collection (force and kinematics).
6. Use the applet to digitize your movements and calculate x and y coordinates of body landmarks.
7. Analyze the kinematics of each movement, including temporal, linear, and angular measures.
8. Analyze the whole body kinetics of each movement, including impulse and momentum.
9. Calculate relevant joint kinetics.
10. Assimilate and interpret your results to prove or disprove your hypothesis.
11. Create a (~10-slide) PowerPoint or Prezi presentation with embedded motion images and graphs pertinent to your stated hypothesis.
12. Present your PowerPoint/Prezi presentation to your class in a professional manner.

## Problem Solving Skills

### General Approach

Solving problems is usually the most important aspect of math or science courses. You must, therefore, spend much of your study time either working or studying problems. When working a problem, follow these steps:

1. Read through the problem at a moderate speed to get an overview of the problem.
2. Read through the problem again for the purpose of finding out what the problem is asking you to find (your unknown). Be able to state this in your own words.
3. Define your reference system and draw a diagram.
4. Reread the problem. This time, write down (symbolically or otherwise) all information that is given.  
 LIST ALL KNOWN AND UNKNOWN VARIABLES. These may include:

Reference System	Angle	( $\theta$ )
Initial position ( $x_o$ )	Angular velocity	( $\omega$ )
Final position ( $x_f$ )	Angular acceleration	( $\alpha$ )
Initial velocity ( $v_o$ )	Torque	( $\Gamma$ )
Final velocity ( $v_f$ )	Distance from Center of Mass	( $d$ )
Acceleration ( $a$ )	Distance from axis	( $r$ )
Time ( $t$ )	Moment of Inertia	( $I_{cm}$ )
Force ( $F$ )	Momentum	
Mass ( $m$ )	Impulse	

5. What are your assumptions? Use these assumptions to find unknown variables that may be relevant to solving the problem
  - ex. If starting at rest, the initial velocity is zero.
  - If there is no net force acting on the subject, acceleration is zero.
  - If the velocity is constant, acceleration is zero.
6. Devise a tentative plan to solve the problem by using one or more of the following tactics:
  - a. Form relationships among all facts given. (Write an equation that includes your unknown.)
  - b. Think of every equation, formula or definition that might be relevant to the problem. Which of the following equations or combinations of equations can be used to solve for the unknowns?

avg. $v = (y_f - y_o) / t$	F = m * a
avg. $a = (v_f - v_o) / t$	Momentum = m * v
$y_f = 1/2 * a * t^2 + v_o * t + y_o$	Net Impulse = $\Sigma F * \Delta t = m * \Delta v$
$v_f = v_o + a * t$	Torque = F * r = $I_{cm} * \text{avg. } a$

- c. If you cannot find an appropriate equation, read the problem again, and look for key phrases that may allow you to determine an extra known quantity. Examples would be “at its peak” and “at the beginning of its motion.”
- d. Work backwards; ask yourself, “What do I need to know in order to get the answer?”
- e. Relate the problem to a similar example from your notes.
- f. Solve a simpler case of the problem using extremely large or small numbers; then follow your example as if it is an example from your notes.
- g. Break the problem into simpler problems.
- h. Guess an answer and then try to check it to see if it’s correct. The method you use to check your answer may suggest a possible plan.
- i. If you are making no progress, take a break and return to the problem later.
- j. If you still cannot solve the problem, read the problem again (perhaps out loud this time) and make certain that you understand each statement. If you are still stuck, see your teaching assistant or instructor.

Once you have a plan, carry it out. If it doesn’t work, try another plan.

7. Substitute, solve, and eliminate unknowns.
8. Check your solution.
  - a. Check to see if the answer is in the proper form. Always include units in your final answer.
  - b. Check that your units cancelled properly.
  - c. Insert your answer back into the problem.
  - d. Make sure your answer is "reasonable." Ask yourself, "Does this make sense?"

### Example

A 50.0 kg gymnast has a total body center of mass (TBCM) vertical velocity of 2.0 m/s at the time of horse contact. What net vertical impulse would she need in order to depart the horse at a vertical velocity of 3.0 m/s? If the total time of horse contact was 0.20 seconds, what was the average net vertical force she applied during horse contact?

1. Scan the problem.
2. We need to determine the gymnast's net vertical impulse and the force she applied to the horse.
3. Draw a free body diagram (FBD).
4. Variables:

Knowns:	$m = 50.0 \text{ kg}$	Unknowns:	net vertical impulse
	$v_o = 2.0 \text{ m/s}$		net vertical force
	$v_f = 3.0 \text{ m/s}$		
	$t = 0.20 \text{ s}$		

5. Relevant equations:  
$$\text{Net Impulse} = \Sigma F * \Delta t = m * \Delta v$$
6. Plan: Solve for net impulse first, then find the total force applied.
7. Substitute and solve.  
$$\begin{aligned} \text{Net Vertical Impulse} &= m * (v_2 - v_1) \\ &= 50.0 \text{ kg} * (3.0 \text{ m/s} - 2.0 \text{ m/s}) \\ &= 50.0 \text{ Ns} \end{aligned}$$
$$\begin{aligned} \text{Net Vertical Impulse} &= \Sigma F * \Delta t \\ F &= \text{Net Vertical Impulse} / \Delta t \\ &= 50.0 \text{ Ns} / 0.20 \text{ s} \\ &= 250 \text{ N} \end{aligned}$$
8. Does this make sense? Substitute the answers back into the equations to solve for all known values.
9. Check the units

### Problem Analysis

After you have worked a problem, analyze it. This can help sharpen your understanding of the problem as well as aid you when working future problems.

1. Focus on the processes you used (not the answer) and ask yourself these questions:
  - a. What concept, formulas, and rules did I apply?
  - b. What methods did I use?
  - c. How did I begin?
  - d. How does the solution compare with worked examples from the textbook or my notes?
  - e. Can I do this problem another way? Can I simplify what I did?
2. Explain each step using your own words. Write these explanations on your paper.

## Basic Terminology and Concepts in Biomechanics

Use this list of terms as a guide to important biomechanics concepts. Be able to define each of these terms and provide original examples where appropriate.

### Math Basics

Vector	Pythagorean Theorem
Scalar	Sine
Resultant vector	Cosine
Parallel construction	Tangent
Graphic division of resultant into components	Arc tangent
Trigonometric division of resultant into component	Arc cosine
	Arc sine

### Projectile Motion

- Constant horizontal velocity ( $a = 0$ )
- Constant vertical acceleration ( $a = -9.81 \text{ m/s}^2$ )

Projectile motion equations for uniformly accelerated motion

### Angular Kinematics (Effect)

Angle	Degree
Angular distance	Revolution
Angular displacement	Resultant angular velocity vector
Angular speed	Right hand rule
Angular velocity	Acceleration of a body on a curved path
Average angular velocity	Tangential acceleration
Angular acceleration	Radial acceleration
Radian	

### Linear Kinetics (Cause)

Mass	Mass Acceleration Diagram
Inertia	Normal force
Force	Friction
Internal force	Coefficient of friction
External force	Impulse
Equilibrium	Linear impulse
Newton's Law of Gravitation	Net impulse
Newton's Second Law of Motion	Momentum
Newton's Third Law of Motion	Impulse momentum relationship
Free Body Diagram	Conservation of Momentum

### Angular Kinetics

Eccentric Force	Segment center of mass
Moment	Weight
Torque	Segmental methods of TBCM
Moment arm	Moment of inertia
Perpendicular distance	Moment of inertia about segment CM
Pivot/axis/fulcrum	Angular momentum
Center of gravity	Angular impulse
Total body center of gravity	Conservation of angular momentum
Segment mass	Levers



## **Journals of Interest in Sports Biomechanics**

Acta Orthopaedica Scandinavium  
Acta Scandinavium Physiologica  
Applied Ergonomics  
British Journal of Sports Medicine  
Canadian Journal of Applied Sport Medicine  
Canadian Journal of Sport Sciences  
Engineering and Medicine  
Ergonomics  
Human Factors  
Human Movement Science  
International Journal of Sport Medicine  
International Journal of Sports Biomechanics  
Journal of Biomechanical Engineering

Journal of Biomechanics  
Journal of Biomedical Engineering  
Journal of Bone and Joint Surgery  
Journal of Experimental Psychology  
Journal of Human Movement Studies  
Journal of Medicine Science Sports &  
Exercise  
Journal of Orthopedic Research  
Journal of Sports Science  
Orthopedics  
Physical Therapy  
Research Quarterly  
Scandinavian Journal of Sports Science