# Physics 105

## Handbook of Instructions
## Spring 2010

M.J. Madsen
*Wabash College, Crawfordsville, Indiana*

During the Middle Ages there were all kinds of crazy ideas, such as that a piece of rhinoceros horn would increase potency… Then a method was discovered for separating the ideas—which was to try one to see if it worked, and if it didn't work, to eliminate it. This method became organized, of course, into science.

-- Richard Feynman, *The Pleasure of Finding Things Out*.

# Welcome to PHY 105!

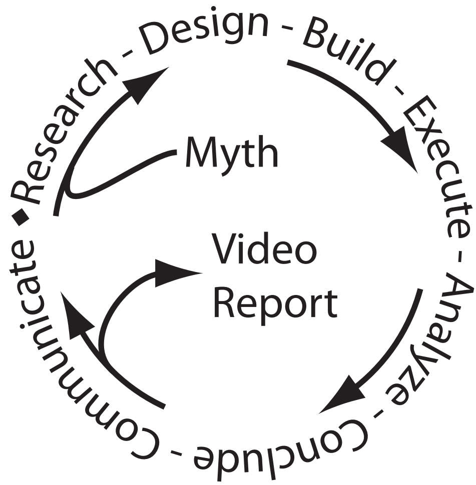
I welcome you to this lab science distribution course, one which is centered on the lab experience. In this course you should learn the core principles of science as described by Feynman in the quote above: 1) try ideas out to see if they work and 2) organize and communicate those ideas. This course is loosely based on methods popularized by the TV show "Mythbusters". Their model encourages critical thinking about the physical world and can be summarized by the following steps:

1. You will be presented a variety of "myths" or stories about some physical situation.
2. You will do background research into the physics models that apply to the situation.
3. You will work in teams to design, build, run, and analyze experiments that will test the physical ideas central to the myths and compare them to known models.
4. Your team will then present your findings to the class (and to the world!) and make conclusions as to whether the situation described by the myth is physically plausible or even possible.

The course will teach you the skills needed to carry out these experiments. At the end of the semester, you will be asked to implement this experimental methodology in a unique team project.

After completing this course, you should be able to:

- Research physics models and design experiments based on those models that test ideas about the physical world,
- Build and safely execute a variety of experiments that carefully and controllably test the physics models relevant to the ideas,
- Analyze the results of your experiments both qualitatively and quantitatively, and,
- Clearly communicate the results of your experiments in video format to a general audience.




## Research

- Begins with an initial brainstorming session talking through what you think is happening with the myth.
- Next, connect these ideas with models from physics: A model is a physics approximation that provides a simple picture about how one piece of the universe works.
- What math relationships describe those models?
- From those models, determine the kinds of things you will need to measure.
- Finally, determine how you are going to approach measuring them.

## Design

- Design preliminary experiments that test the key ideas associated with the physics models.
- Incorporate experimental controls and clearly test the important variables.
- Design experiments that will test your methods and analysis.

## Build

- Every experiment will require some building. This may be as simple as setting up a measuring scale, or as complex as building a custom machine to make a measurement.
- Follow your design plans in building your experiment.
- Safely use power tools as necessary when building your experiments.

## Execute

- Safely executing an experiment includes thinking through how the experiment is going to work and move, as well as how to keep all the experimenters safe.
- Use appropriate safety equipment such as pads, helmets, and goggles as needed.
- Run your experiments multiple times to either
  1. Gather statistics by running the same experiment multiple times OR
  2. Change one variable by some increment and measure the change in the outcome

## Analyze

- All experiment results require analysis. Measurement is the language of science and you will use that language to understand your results.
- Extract quantitative results from your experiments through a variety of analytical tools including:
  - rulers
  - scales
  - video analysis (Logger Pro)
  - other measurement tools
- Compare your results against the relevant physics models:
  - Did you find results that agree with your models?
  - What can your experiments tell you about making modifications to the model?
- Record any quantitative results and observations in the digital experiment log.

## Conclude

- Following your analysis, reach a conclusion about both the relevance of the physics models and the validity of the myth.

## Communicate

- You will present your experiment in video form to a general audience, teaching the audience about your physics models, your experiment design, what you built, how you executed the experiments, your quantitative results, and finally, your conclusions.

## Cycles

Most myths are evaluated through a number of cycles of the experimental method, described above. Typically, these cycles can be broken down into two phases:

## Phase 1: Preliminary Experiments (PEs)

The purposes of doing preliminary experiments are to:

1. Test whether a physics model is relevant to the myth,
2. Test simple components of the myth, one piece at a time,
3. Run small versions of the experiment, testing the experiment design and method,
4. Evaluate the data analysis procedure to see if it provides the needed quantitative information, and to
5. Practice running the experiment in a small, controlled format.

Based on what you learn from the PEs, you might need to do additional research, modify your experiment design, and build new experiments. There may be a number of PEs that are run before you are ready to test on a larger scale.

## Phase 2: Full-Scale Experiments (FSEs)

The second stage of experiments is to come as close as possible to the conditions described in the myth in a controlled experiment. FSEs may also be run multiple times, varying experiment parameters in order to evaluate whether the physics models still apply.

## Experiment Roles

These roles are filled as you are building and executing experiments. The Recorder notes down who is filling each role.

**Experimenter (E1)**

- Responsible for setting up and running the experiments from left to right on Camera 1A
- Directs different experiments
- Ensures lighting is set up and suitable for the experiment
- Ensures all data is collected and all experiments are run

**Recorder (R1)**

- Responsible for recording log of each experiment on the computer
- Responsible for recording who is filling each role
- Ensures all data is recorded along with a brief description of each run
- Ensures all video is recorded and appropriately tagged with experiment runs
- Helps Experimenter run experiments as necessary

**Camera 1** (**C1**/R2)

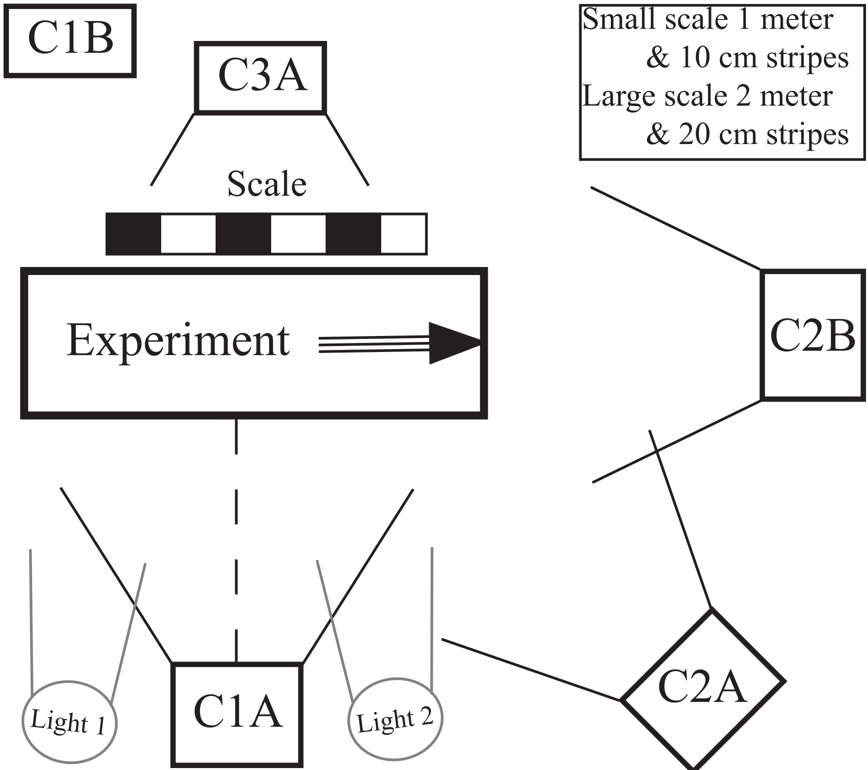
- Responsible for primary video data collection
- Runs Cameras C1A and C1B
- Identify the video by providing an audible record of the run: Tell the camera what you are doing.
- Helps Recorder document log of each experiment on the computer as necessary

**Camera 2** (**C2**/E2)

- Responsible for secondary video data collection
- Runs Cameras C2A and C2B
- Identify the video by providing an audible record of the run: Tell the camera what you are doing.
- Helps Experimenter run experiments as necessary

**Auxiliary** (**Aux**/E2/R2)

- Responsible for highlight video data collection
- Runs Camera C3A
- Helps Experimenter run experiments as necessary
- Helps Recorder document log of each experiment on the computer as necessary




**Experiment Camera Setup**

The following describes how to set up cameras and lights for recording experiments, design work, and builds.

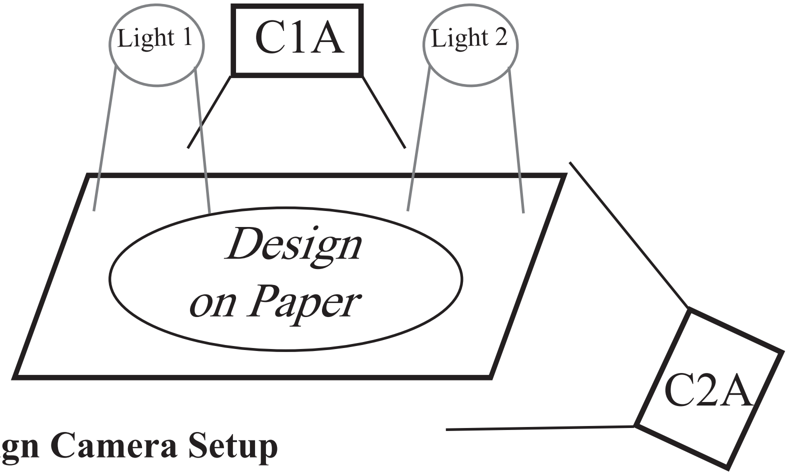
**C1A**: "Data Collection." Straight in front of the experiment with the scale positioned close in the background. Records the experiment moving from left-to-right with a field of view slightly larger than the scale.

**C2A**: "Big Picture." Off to the right of the experiment. Records a much larger view including all the experimenters and action.

**C1B**: "Effects." Records special effects such as on-board the experiment, head camera, etc.

**C2B**: "Front-on." Records more of the larger view of the action, this time from front-on, or 90 degrees to C1A. Provides an alternative angle for data analysis.

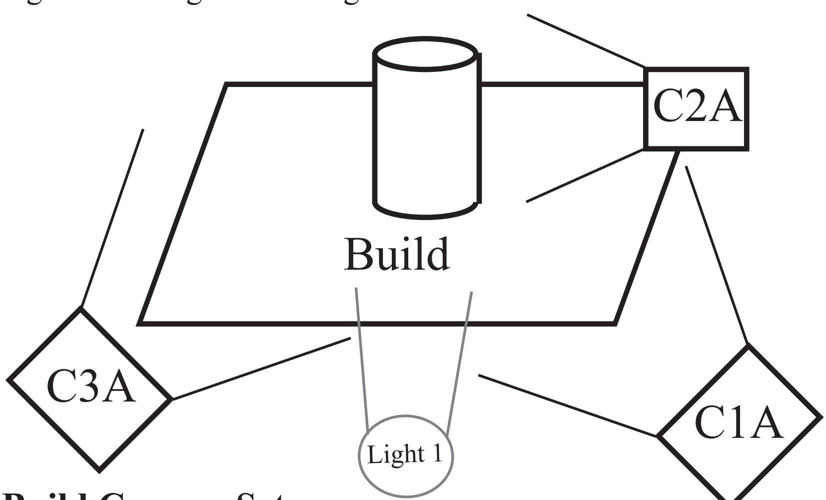
**C3A**: "Top Down." This camera, if available, records a secondary view of the experiment with a close-up view including slightly less than the scale.




**Design Camera Setup**

**C1A**: "Top-Down." A top-down view of the paper, showing the details of the design.

**C2A**: "Big Picture." A large field of view showing the person doing the drawing of the design.




**Build Camera Setup**

**C1A**: "Right View." Large field of view capturing a big picture of the build activities.

**C2A**: "Details." Small field of view capturing the important details of the experiment setup.

**C3A**: "Left View." This camera, if available, records a second large view, providing additional coverage of the build.

## Communication Roles

These roles are filled as you creating your video lab reports. Each role should be filled and the Script Writer records who is filling each role. Your individual grade on the video lab report is based on your performance in your role.

**Script Writer**

- Reviews computer log and works with R1 to review experiments.
- Responsible for drafting the script.
- Ensures all group members proofread, improve, and sign script.
- Records who is filling each communication role.
- Ensures the narration is created and follows final script.

**Animation Editor**

- Responsible for creating animations to explain physics.
- Works with Script Writer to determine what animations will be needed.

**Video Organizer**

- Reviews and organizes all video footage from experiment.
- Reviews computer log and labels video.
- Works with Film Editor to determine what footage is needed.

**Film Editor**

- Responsible for combining narration with video and animation
- Coordinates script, animation, and video.
- Ensures all group members view, proof, and approve final video report.
- Ensures final video is turned in on time.

**Assistant Film Editor**

- Works with Film Editor to combine narration and video.
- Provides support and help to all other team members.

## Digital File Organization

We will be handling a large quantity of digital files during the course of this semester. Keeping these files organized with aid greatly in reducing the overall workload of this class. There are two main storage locations for digital files:

### Courses on Caleb

Each group has a folder assigned to them on Caleb. This file storage will hold:

- Recorder Logs
- Data files (from Logger Pro, etc)
- Script Drafts

Additionally, there are two common spaces that will hold files that are accessible to the entire class:

- *CompletedVideo* folder where your final video lab reports are turned in.
- *Resources* folder that has instructional videos, high-speed videos, and other materials created or recorded by the instructor.

### Firewire Hard Drive

Each group will also have an external firewire hard drive assigned to them for storage and editing video. Each firewire hard drive is labeled physically and digitally with group colors. You must return this hard drive at the end of the semester. Damage to, or loss of, the hard drive will result in a replacement charge to the responsible group.

The firewire hard drive contains a group of sub-folders, one for each myth, that will hold the

- Video files from each camera
- Audio files from the narration
- Any still image or resources files

for each myth. The firewire hard drive also maintains the Final Cut Pro caches and renders for editing video.

## Video File Naming Scheme

The Video Organizer renames video files in preparation for the Film Editor placing them with the report narration. Use the following naming scheme to organize all the video files:

**PE/FSE#-R/D/B/E/A#-C#A/B.mov**

## PE/FSE#

If the video covers Preliminary Experiments, begin the file name with PE. For full-scale experiments, begin the file name with FSE. Because there will often be multiple preliminary and full-scale experiments, number each file based on the experiment run number. For example, the third preliminary experiment file would begin:

**PE3-**

## R/D/B/E/A#

Label the second marker position with the portion of the method cycle that the video records: Research (R), Design (D), Building (B), Executing (E), or analysis (A). Whenever there are multiple runs, or takes of the same experiment, use the number at the end to distinguish the videos. By default, use a 1 at the end. For example, a video recording the design written on a page for a full-scale experiment would have the notation:

**FSE1-D1**

## C#A/B

Finally, record which camera recorded the video. This will help the Film Editor choose a variety of angles to show different perspectives of the experiment. A video of the first preliminary experiment, second take on the experiment run, recorded by camera 2A would be named:

**PE1-E2-C2A.mov**

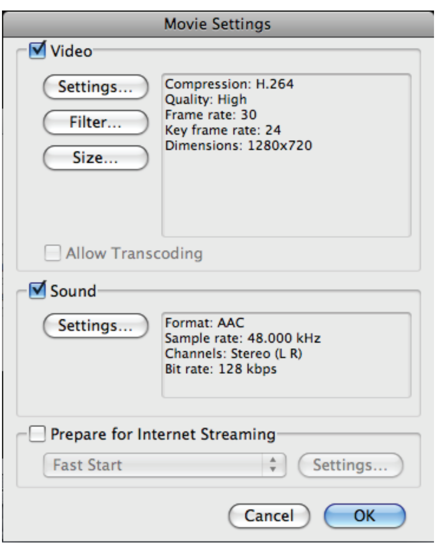
A second example follows: A video of the build for the full scale experiment, the third clip on record recorded by camera 1A would be named:

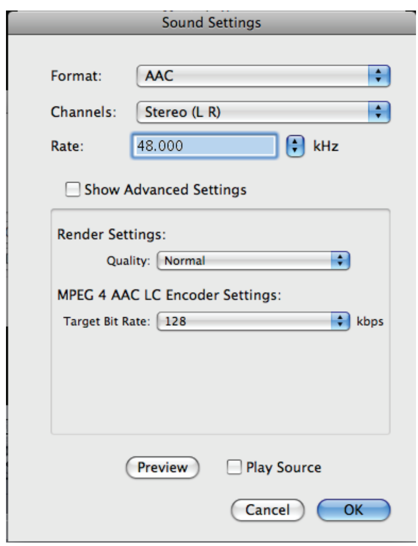
**FSE1-B3-C1A.mov**

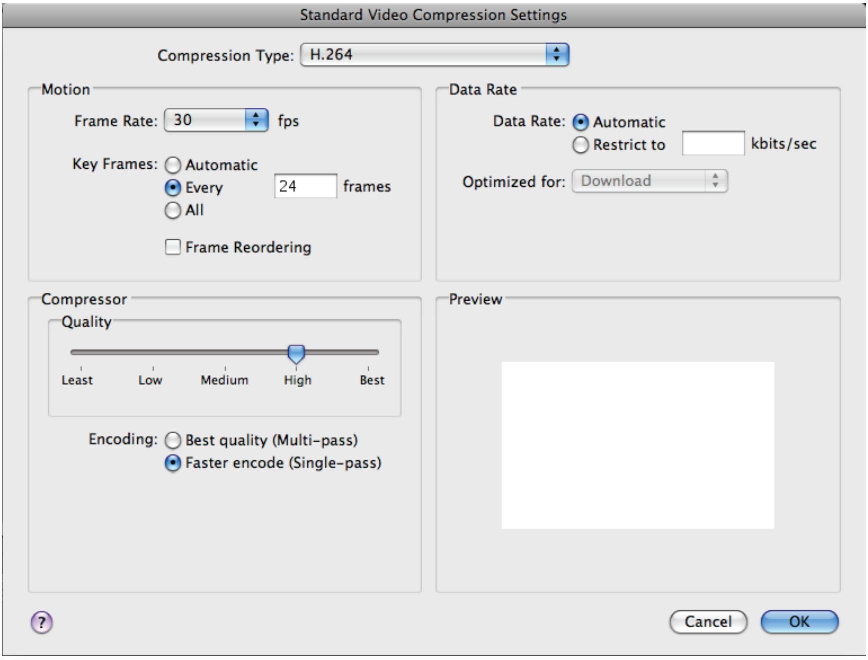
## Final Cut Pro Essentials

The following steps should be followed when working with Final Cut Pro (FCP).

1. When starting ANY session working with FCP, begin by changing the scratch files and cache files to the appropriate myth folder on the firewire hard drive.
2. Ensure that ALL files relevant to a project are stored in the appropriate myth folder on the firewire hard drive. Do NOT drag files from any other location into the project.
3. Begin a new myth project by inserting the audio narration files into tracks 5 and 6 (leave 1-4 blank).
4. Add video to the first two video tracks. Disconnect the audio (Command-L) and delete the audio.
5. Render all audio and video as you go: select the clip that needs rendering (has a red line over it) and render it. (Command-R).
6. When finished, select Sequence 1 from the browser window and choose File-Export-"Using Quicktime Conversion..." Select a file name on your Firewire Hard Drive. Make sure the "Options" are as shown below.








## Sixty Second Summary

Each week you will assemble a short "Sixty Second Summary" of your work in lab. Follow the steps below to create your summary:

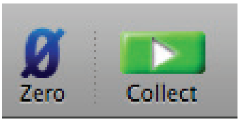
1. Begin by loading all your video on to the Firewire Hard Drive, in the appropriate myth folder. Create sub-folders for each camera (C1A, C2A, etc) to help maintain file organization.
2. Review the key experiments from the Recorder's Log. Select the videos that cover your key experiments (Design, Build, and Execute) from lab.
3. Use Quicktime Pro to cut the appropriate segments from the video. Use the "i" key to select the beginning of the segment. The "o" key selects the end. Copy the video selection.
4. Paste your video selections into a single video for showing in class on Friday. Use File-"New Player" to create a new video. Move the play head to where you want to insert the clip and paste it in.
5. Save your final Sixty Second Summary on your Firewire Hard Drive. Be sure to bring the drive to class so that you can present your summary to the class.

## Logger Pro
Logger Pro is a software application used in Physics labs to facilitate computer data acquisition and to analyze the motion of objects in video.  We will be using Logger Pro extensively.  While the Recorder will typically run Logger Pro while taking data, all team members should contribute to the quantitative analysis of motion in their video data.

## Force Probes
These instruments measure the force applied to them, either pushing or pulling.  The probes are attached to the computer through the green “Lab Pro” interface boxes, then connected via USB.  The software recognizes when the probes are attached and automatically configures them based on the probe settings.  Typically you will be provided with a file that has pre-configured the settings for an experiment.

These are the basic steps for collecting data with the force probes:

1. Once the probe is connected AND the experiment is set up and ready to go, click the “Zero” button to reset the probe.  The force reading should then be approximately zero (close, but not exactly)
2. When you are ready to collect data, press the “Collect” button. Wait for the data screen to read “Waiting for data...”, then data should begin to appear on the graph.  At this point, begin your experiment.




## Video Analysis of Motion
We will often record the motion of an object against a background black-and-white scale.  We can then analyze the motion of these objects using Logger Pro’s video analysis tools.  The basic idea is to first set the scale of the video using the black-and-white board as a reference.  Then select the position of the object, frame by frame to determine its motion.  See the tutorial video in the *Resources* folder for details on how to use the video analysis.

## Audio Recording Essentials

You may use any audio recording software to record your narration for your video report. The following essentials apply in general when recording.

- Make sure you have the appropriate microphone selected.
- Reduce all background noise, especially “white” noise from heating/cooling systems.
- Hold the microphone about six inches from your mouth when speaking.
- Check that the audio levels are appropriate- typically in the mid-yellow.

## Narration

- Speak clearly and slowly- don’t be in a hurry to get through it.
- Leave quiet spaces- it helps make it easier to cut and edit.
    - Leave short pauses at periods
    - Leave slightly longer pauses between paragraphs
- Break up your narration into logical pieces. Do not try and do the entire narration in one single file. Typically you should have 4-6 separate files, numbered and labeled. Each chunk should be 1-2 minutes long.

## File Compression

- Export or save your audio file using mp3 compression. Test to make sure the output of your audio software works in FCP.
- Save your audio in the appropriate folder on the Firewire Hard Drive.

It is possible to make various adjustments to the audio tracks in FCP. Two of the most useful things are to:

1. Check your audio levels to make sure the audio is clear and easy to hear.
2. Use the Blade tool (press B) to cut out the unneeded silent sections. If you turn on the audio waveforms (Command-0 (Zero)), you can easily see where the silent sections are and cut them out.

## Flash Animation Basics

Each video lab report will have some animations with it. This is an excellent way to communicate

- the myth
- the physics models, and
- how the models relate to your data.

There are two main types of animations that we will use: pure animations that describe the myth and physics models associated with your experiments, and animations placed on top of video, used to clarify how the models apply to your experimental data.

## New Animations

The basic idea behind a flash animation is that you draw objects then animate them automatically. Animation is controlled as changes between key moments, denoted as "keyframes" on the timeline. Simple animations are created by selecting a segment between two key frames and inserting a "tween" in that segment. You determine the initial and final positions of your object and the software animates "beTWEEN" those two points.

1. Begin by creating a New flash file, Actionscript 3.0.
2. Use the Modify-Document menu item to re-size your animation to match your video: 1280 by 720. Select your background color and framerate (typically 10fps works well).
3. Create your animation from drawings, text, and other objects. Use keyframes on the timeline to adjust how your animation plays.

## Animation on Video

Creating animations on top of your video data is a two-step process. First you need to convert the video clip into a FLV file that can be ready by Adobe Flash. Then you insert that clip into a new animation and add lines, motion tweens, etc. on top of the video. A basic tutorial on how to do both of these steps on a Mac computer is available in the *Resources* folder on Caleb.Courses.

Export all animations using the File-Export-"Export Movie..." menu item. Export using Quicktime to a MOV file.

## Video Lab Report Tentative Grade Rubric

This is a TENTATIVE grading rubric for the video lab reports. You will be notified of any changes prior to the due date.

### Introduction:

1. Did they capture the audience's attention?
2. Did they introduce the team members?
3. (R) Did they introduce the myth?
4. (R) Did they use animations to describe the physics models behind the myth?

### Preliminary Experiments (PEs):

1. (R) Did they communicate how the physics models relate to their PEs?
2. (D) Did they communicate the design of their experiments?
3. (D) Did they describe what they wanted to find out with their PEs?
4. (B) Did they describe what they built?
5. (E) Did they introduce each test/run, describing their controls and variables?
6. (A) Did they describe their results?
7. (A) Did they discuss quantitative results?
8. (C) Did they discuss conclusions from their PEs?
9. (C) Did they use animations to describe the significance of their results?

### Transition:

1. Did they transition from the PEs to the FSEs?

### Full-scale Experiments (FSEs):

The same basic rubric as for the PEs.

### Conclusion:

1. Did they phrase an inductive statement at the end?
2. Do I agree with their conclusion?

The final video report grade will be based on the group presentation and individual contributions. For example, a group that fails to include animations to explain the physics concepts will lose points for failing to complete that part of the video, plus the Animation Editor will lose *additional* points off his video grade since he was responsible for the animations.