In Class Activity Plan
Week Five: Deploying 2-d Motion Models & Investigating Energy

ANNOUNCE: First exam is in 2 weeks!

120 min **Two-dimensional Motion Model Validation Lab (Word, Pdf)**

PURPOSE: Develop and accurately deploy a 2D model

Video Examples: (Students alone, Students with professor)

Logistic Notes:

- There is no whiteboarding with this lab because they are going to do a lab write-up. Also, this is the point where the instructor enforces what makes a good model. Most likely the students will turn something in that is not up to par, you will tear it apart and ask them to do it again. See the sample lab report for what a stellar report looks like.
- Make sure they make their measurements and try to get the ball in the cup all on the same day because small differences in measurement will make a big difference in the end result.
- There are two possible set-ups for this, see "Set-up for the Ball in Cup Lab (Word, Pdf)" for more information
- There are at least two models for them to consider here (because of two different accelerations), that for when the ball is on the ramp, and that for the time when the ball is in the air. If they let the ball roll on the table (Option 1) then there is also a constant velocity model.

General Outline:

- Students are given a stopwatch, meter stick, a ball, and a ramp
- They are told that they need to construct a complete model that will be able to predict where the ball will hit the floor
- They will be given one shot to get their ball into a cup which will be placed on the floor
- The assignment is to write up this lab with the goal of having a complete model
- Emphasize that if they use trial and error to predict where the ball will land they will get a "0" because they will not be able to construct a robust model

Logistic Notes for the Week:

- *The previous lab validates a model, and the next one introduces a new concept or tool. So they do different things, but it's best to do them on separate days because it feels like tons of lab to students, who won't see the differences.*
- *Modeling Note: We have now developed both descriptive and predictive models, the next step is to develop a causal model.*

120 min **Ball Bounce Lab (Word, Pdf)**

PURPOSES: Introduce

Video Example: (Discussion1, Discussion2, Discussion3)

- To see that the constant acceleration model breaks (at the bounce), and that we need to develop a new kind of model (causal).
- Introduce interactions within in a system and energy as a causal mechanism.
- Introduce system schema and energy pie charts as new tools.

Logistic Notes:

There's a great deal of instructor management that happens in this lab. For example, it's important that they see that the constant acceleration model doesn't work when the ball is in contact with the floor. This is most easily seen in the velocity graph. There's a spike in the acceleration graph, but often the students just ignore that spike, so the instructor is critical here.

- *Don't let them throw the ball, make them drop the ball.*
- *Most of the class should be focused on understanding what happens during the bounce*
  - *Get the graphs and motion maps clearly made*
  - *Have them indicate on the representations where the bounce occurs*
  - *What models are appropriate and when?*
    - *Constant acceleration for a particle when the ball is in the air*
    - *The ball must not be modeled as a particle when it hits the ground, which is why the constant acceleration model doesn't work here*
- *When seeding the pie charts and system schema focus on making sure one group can explain each concept very well*

Note: Need to reassign the idea of "Potential Energy" instead; it is an "Interaction Energy" or gravitational interaction energy (E_{Ig})

Seeding questions:

- Why doesn't the ball bounce as high? (generally this leads to energy dissipation and the seeds below)
- Energy needs to be a part of the model as a way of explaining the bounce
- When can you use a constant acceleration model?
  - Is it ok to model only one part of the motion of the ball?
  - Why would you want to model only one part?

SEED:

- Pie charts – How do your models account for energy?
- System schema – Where did the energy go? Is energy conserved?

10 min **Whiteboard – Results from Ball Bounce Lab**

PURPOSE: Report results of investigation (different groups will have different results) See example graphs (Word, Pdf)

- What did you learn?
- What rules can you make?
- What questions do you still have?

1 hr **Board Meeting**

PURPOSE: Compile results from labs; introduce energy pie charts as representational tool; introduce system schema as representational tool; identify that constant a models don't always work.

Video Examples: (Group1, Group2, Group3)

- Constant acceleration model only applies before and after the bounce
- Need energy to explain the bounce and the model break
- How to keep track of the energy? – Pie Chart Group
  - E_{int} encompasses all the energy that can't be used again (so has to stay in the E_{int} accounting space)
- Where does the energy go? – System Schema Group (E_{int})
  - *Note:* Sometimes students get confused with the pie representing the ball or the system. The idea of E_{int} being inside the pie should convince them it represents the energy in the system.

15 min **Practice with Pie Charts & System Schema (Word, Pdf)**

PURPOSE: Provide practice using system schema and energy pie charts for various situations.

Handouts: Analysis Tool Energy Pie Charts (Word, Pdf) & Analysis Tool System Schema (Word, Pdf)

Goal for system schema:

- Make pie charts and system schema that are internally consistent
- Interactions must be labeled – 1 arrow for each interaction
- All arrows in system schema should have two heads
- Dashed lines tell us what part of the system is closed

Goals for pie charts:

- Must always have at least 2 pies because the charts are about transfer and what changes between points in time
- When the system is closed all the pies should be the same size

15 min **Whiteboard - Practice with Pie Charts & System Schema**

PURPOSE: Share use of pie charts and system schema

Video Example: (Creating controversy)

20 min **Board Meeting**
PURPOSE: Build consensus regarding use of system schema and energy pie charts.
Video Example: (Group1, Group2)

- It is useful to have groups that have different pie charts for the same situation to present their whiteboards and to try see why they are different and how they explain the same phenomena.
- Generally it is good practice at this stage to keep everything in the system so pies don't change size.

15 min **Energy Ranking Task (Word, Pdf)**
PURPOSE: Emphasize that pie charts are sufficient to answer some questions; utility of energy pie charts.

10 min **Whiteboard Energy Ranking Task**
PURPOSE: Share interpretation of representations of energy

20 min **Board Meeting**
PURPOSE: Utility of energy pie charts; characteristics of energy.

- Can solve real problems with just pie charts alone (powerful)
- Energy is a scalar quantity
  - Pie charts don't have direction
  - On this task initial pie charts are all the same size (as well as the final ones) so the direction of the velocity vector doesn't matter.