In Class Activity Plan
10/10/11 – 10/14/11
Week 8: Investigating Forces

10 min **Whiteboard - Motivating a Shift to Forces**
PURPOSE: Sets up a situation where energy isn't useful in modeling coffee cup, necessitating a shift to forces.

Create a complete model for a coffee cup sitting on a table

Note this is a constant position model, so there isn't much interesting and should take almost no time.

10 min **Board Meeting or Instructor led discussion**
PURPOSE: Build consensus about when energy isn't useful in modeling situations, necessitating a shift to forces.
Video Example: (Discussion)
Note: This could be a white board meeting or a lecture/discussion led by the professor, but it should be a quick refresher of all the elements included in a model up until this point and a motivation to include forces.
- Constant position model
- How many pie charts?
  - 2 – but they don't show any change in energy
- Energy is about showing change, but we don't have any change, so we need a new tool to model what's going on
- Enter forces

150 min total **Investigating Forces Lab- Broken down into three parts (Word, Pdf)**
PURPOSE: Sets up a situation where energy isn't useful in modeling coffee cup, necessitating a shift to forces.
Note: While the Investigating Forces Lab comes as one large document, it actually works best when broken into three distinct parts. The first part moves from a model that only includes energy, to considering the role of that force plays. The second part is "messing around" with the equipment to get a feel for forces. The third part is actually doing the experiment. In the guide all of these parts have been broken up, but refer to the same 9 page document.

15 min **Whiteboard - Investigating Forces pg 1: Introducing force**
15 of 150 PURPOSE: Sets up a model using what they already know as a way to see how to incorporate forces into this model.
Video Example: (Boarding)
Technical Notes:
- There is no equipment for the first part, only a thought experiment.
- Have students put their model from page 1 on a whiteboard.

15 min
30 of 150

Board Meeting

PURPOSE: Build consensus on specific model using what they already know as a way to see how to incorporate forces into this model.
Video Example: (Discussion)
Note: You can skip this board meeting if short on time.

- Note that there is an acceleration from rest to moving, but you don't have to make everyone say that it will always accelerate
- Correct system schema's with the person in the system
- Is energy conserved?
  - Depends on whether they put the person in or out of the system
- What would happen if the cart were bigger? (Pies would be larger)
- What model are we using?
- The question on how the concept of force applies has no right answer, but it is important to elicit ideas about what they think will happen

35 min
65 of 150

Investigating Forces pg 2 – 5: Messing around

PURPOSE: Encourages them to seek patterns among data and to use data to support claims about the relationship between forces and models using kinematics.

Technical Notes:

- For pulling using the force sensor, you get much cleaner data if you use a string rather than simply pulling on the hook with your hands
  - They should also "zero" the force sensors before taking data each time because the zero drifts during use
- Page 2 should be quick, they are learning how to use the force sensors
- On page 4, don't let them get away with simply writing F=ma for a rule, make them think about the evidence they have.

10 min
75 of 150

Whiteboard - Investigating Forces p 5

PURPOSE: Propose patterns among data; establish relationships to be investigated in part three of the lab.

Make sure you get to force being proportional to both mass and acceleration, and that it has a direction in the following discussion

25 min
100 of 150

Board Meeting

PURPOSE: Builds consensus about patterns among data; establishes relationships to be investigated in part three of the lab.
Video Examples: (Discussion1, Discussion2, Discussion3)

- Push/pull is causing the motion
- Force probe measures the amount of push/pull on the sensor (it doesn't measure the amount at an angle, only straight in and out)
- Forces & causes acting on the cart

- Gravity - Earth
- Pushing/pulling - Person
- Contact – Track

- System Schema
  - Car/Person/Track with labeled interactions
  - Notice this is useful for telling us where the forces are and what *types* of forces are there (emphasize arrowheads going both directions)
- What did we learn from the first two experiments?
  Note: This part is not necessarily on their whiteboards, but they should be able to talk about it because they have answered the questions on page 4.
  - Force is proportional to acceleration
    - Force graph and acceleration graph look similar
    - But not the same!
  - Does mass make a difference?
  - Anything surprising?

50 min
150 of 150

Investigating Forces pg 6 – 9: Design your own experiment

PURPOSE: Design experiments to test the relationships proposed in part two of the lab.

Technical Notes:

- When they do their own experiments have them use the pulleys instead of just pushing and pulling, they get cleaner data this way
  - Also note that if they want accurate numbers, they need to calibrate the force sensors. The easiest way to do this is to first have nothing on the hook, and calibrate to "0 N" and then put a 1kg mass on the hook and calibrate to "9.8 N." The sensors need be calibrated each time they are plugged/unplugged from the system, but only need to be "zeroed" between runs.
- This is a good lab to have them write up either their proposal for the experiment, or the complete model (evidence gives us rules) for homework
- The instructor should enforce the need for students to get approval of their proposed experiments before they begin collecting data
- Ideas for experiments include (but are not limited to):
  - Constant mass of car, change force (mass on pulley)
  - Constant force, change mass of car
  - Different directions of force, measure acceleration (for vector relationship)
  - Hardest to do, but important is to get an a = 0 experiment with multiple forces acting on a single object (see a=0 picture in additional resources)
- During this lab, it is often useful to have students make use of some of the more advanced features of the software, including average and zooming in on data that is "clean"

20 min **Whiteboard - Investigating Forces pg 6 – 9**

PURPOSE: Compare experimental designs and results of experiments testing the relationships proposed in part two of the lab.

NOTE: Emphasize the need for evidence to go with their claims in this part!

1) What have you learned?
2) What rules can you make?
    a. Note that this is often done better if they focus on the rules from each experiment rather than trying to come up with one set of rules that arches over all the experiments.
3) What questions do you still have?

45 min **Board Meeting**

Note: This meeting is long, so it may need to be broken up into two. Also note that the discussion goals this time are in a chronological order. You want to address them in this order because we want to build up to the full Newton's 2nd law

Video Example: (Discussion)

Discussion Goals:

- $\vec{F} = m\vec{a}$ (*even though this isn't the "net" force, allow it at the beginning the net force will come later in the discussion)*
    - As force increases acceleration increases
    - a = 0 when there is no force applied, even with a change in mass
        i. Indicates a multiplicative relationship
    - Have a constant F if we change the mass and the acceleration in a proportional way
    - Force is a vector (depends on the direction)
- So for every force, there is an acceleration, right?
- To get the sum of forces, return to the coffee cup example – what forces are on it?
    - Why is there not an acceleration if there is a force?
    - So our equation is not complete: $\sum \vec{F} = m\vec{a}$ or $\vec{F}_{net} = m\vec{a}$
    - So it would be useful to have a new tool for keeping track of forces (here you can hand out the handout for the next activity)

20 min **Whiteboard - Handout: Analysis Tool – Force Diagrams (Word, Pdf)**

PURPOSE: Introduce Force Diagrams as a new tool for modeling phenomena.

Have the students whiteboard the situation from the handout in order to make sure they think about what the force diagram represents

Seed:

- Make sure you have groups doing both the forces are equal, and the forces not equal as the situation in the handout does not tell us whether the girl is moving at a constant speed or at a changing speed.

20 min **Board Meeting**

PURPOSE: Build consensus on use and interpretation of force diagrams as modeling tool in conjunction with system schema.

- What does a force diagram show?
  - Direction
  - Size and amount of forces
  - Interaction causes the force – this is the label in the top right-hand corner of the force (i.e. "c" in $F^{c}_{rope->girl}$)
  - Direction of the acceleration
- Is every interaction a force?
  - Every interaction *can be* described by a force
  - Modeling! 1,000 interactions means 1,000 forces, but we don't need to deal with each and every interaction. The choice of what we are modeling helps guide us to include/exclude interactions.
- System schemas
  - 1 arrow for each interaction
  - labels are important
  - Consistency with the force diagrams