Unit IV - Scope & Sequence

1. Dry ice demo to get at concept that force is not required for motion; instead an object will maintain constant velocity condition unless there is some interaction between an agent and the object. We call this interaction a force. We can define forces in terms of contact interactions and long-range interactions (see descriptive page of forces).

Examine the "at rest" condition of an object on a table. If the earth is exerting a pull on the object, why is its velocity constant (v = 0)? Similarly, for the object undergoing uniform linear translation on a table, why is its velocity constant (v ≠ 0)? Conduct the normal force bridging exercise to convince students that the table does not simply impede the motion of the object, it must exert a force to counter gravity.

Hand out the reading on drawing force diagrams.

2. Thoroughly discuss how to draw force diagrams. In them, we isolate the system from the surroundings; agents belong to the surroundings. Objects are reduced to points; forces are vectors with tails originating at the points. This seems to be a reasonable time to introduce rules of vector addition, first in the 1-D case where vectors are parallel or anti parallel, then in 2-D cases. This can be done semi-quantitatively with rulers and protractors on graph paper, if you like, to determine resultants.

Start work on worksheet 1.

3. Carefully whiteboard worksheet 1. Recognize that some of the situations are deliberately ambiguous, allowing for multiple, valid interpretations. What's important here is for the students to be able to articulate the model they employ. At this stage, there are only two: either the sum of the forces acting on the object is zero, and the velocity is constant, or a net force acts on the object and the object is accelerating.

4. Introduce the spring scale (force probe later) as a device for measuring force, which is calibrated in newtons (or pounds). Suspend an object (standard laboratory mass or whatever) from a spring scale; draw a force diagram. Convince the students that for the vast majority of objects they'll work with (so long as they are in an inertial frame), the reading on the spring scale is equivalent to the magnitude of the force of gravity. Lead the students to the conclusion that mass (as measured by a balance) is the property of the object upon which the force of gravity depends. Do the experiment in which they develop a law relating the force of gravity to the mass of the object. You could use standard lab masses, or suspend a cup with varying amounts of sand from the scale if you wish to reinforce the distinction between mass (balance) and weight (scale).

Students should arrive at the law: \( F_g = 9.8 \frac{N}{kg} \cdot m. \)

5. This is an appropriate time to introduce the decomposition of vectors into components, first graphically, then with trigonometry. One could perform a demonstration, or if time and equipment allow, have students perform an experiment with force tables. One could use spring scales to directly measure the forces, or after a brief discussion of the role of the pulley, use high quality pulleys and mass hangers. It is advisable that you assign two forces (magnitude and angle), and have the students first graphically determine the force required to keep the object in equilibrium, then test their prediction with the force table. Depending on the level of your class, you could help your students build a spreadsheet to perform the calculations of the resultant force.
6. Have students produce solutions to assigned problems on worksheet 2, then whiteboard. Require students to begin their solution with explicit reference to the appropriate model. (How can they say that $\sum F_x = 0$ and $\sum F_y = 0$?) Encourage students to sum force vectors, then, according to the reference system they have chosen, substitute (-) magnitudes where appropriate.

7. Introduce Newton’s 3rd Law (see lab/demo notes). My favorite statement is: All forces come in pairs; paired forces are equal in magnitude and opposite in direction. There are numerous questions that probe naive conceptions about this law. Most notable perhaps is the dominance misconception and the confusion of paired forces between agent and object and force diagrams for a given object.