

How Mosquitoes Fly in the Rain

Teacher's Guide

Below we provide a brief teacher's guide. We include the learning objectives of this module, prerequisites and suggested activities during each of the breaks between your segments.

Learning objectives of module

This lesson uses high-speed videos of raindrops striking mosquitoes to help the students practice the following skills:

- thinking visually and physically (how is a mosquito shaped and what kind of impacts are possible?)
- gathering data from videos and graphs (and practice being a scientist)
- ****making approximations (back-of-the-envelope calculations)****
- making quantitative hypotheses
- considering different limits in order to test hypotheses (e.g., mosquito and dragonfly)

Printing the graphs in the attached activity document may make these tasks easier for the student.

A word on making approximations, or "order-of-magnitude physics"

The hardest part and also most important activity for the students will be in making approximations, also called "scaling" or order-of-magnitude physics. The skill is especially useful for studying biomechanics, as organisms have such a large range of length scales (sperm to whale is over 6 orders of magnitude).

I teach this topic in the first week of my fluid mechanics class for college sophomores. Most of the students dislike it. This is because it non-intuitive and sloppy to the students. Moreover, it asks them neglect previous teachings in math classes regarding precision. In fact, being imprecise, but within an order of magnitude is an invaluable skill. With practice, it will become faster, easier, more intuitive and eventually second nature.

I will consider this lesson a success if students can look at everyday phenomena and make scientific claims and calculations using "back of an envelope" calculations.

In these activities, students will learn to use only a 1-2 significant digit. In everyday life, one usually has one unit of precision anyway. However, the advent of calculators and the internet has made students think we can measure everything to infinite precision. Not true. Keeping in mind the number of significant digits is an important part of being a scientist. Moreover, often 1 significant digit is enough to test a hypothesis.

The students will have difficulty keeping track of units (force, mass, length, and time) when doing these calculations. This will take time. I recommend using cm-gram-second or cgs units for all calculations here. The teacher should make sure certain constants such as density and surface tension of water are available. The teacher might also teach them the significance of the units. For example surface tension units is in force per unit length and so signifies the force required to extend a soap film.

They should use scientific notation when necessary. This will simplify work and help avoid mistakes.

Prerequisites

Students will apply the following concepts they learned in high-school physics

- terminal velocity and drag (activity 1—size of a raindrop)
- surface tension laws (activity 1)
- conservation of mass (activity 2 – frequency of impacts)
- torque balances (activity 3 – force of impact due to glancing blow)
- conservation of momentum (activity 4 –speed of mosquito after impact)

Although surface-tension is usually not covered in high school or even college, a lesson based on wikipedia's definition of surface tension should suffice. Also, for activity 1, the students may need to know the equation for drag at high Reynolds number.

Suggested activities during each of the breaks between your segments.

I suggest having the students attempt experiments and analysis themselves. That way they can appreciate how much work it takes to make a good movie and take good data. Invaluable software for this is the free online software "tracker"
<http://www.cabrillo.edu/~dbrown/tracker/>

A commercial-grade high speed camera can be purchased for a few hundred dollars. Using it will take practice but will yield an entirely new world of physics to the students. Otherwise, experiments we conducted can be repeated with an air-track or other frictionless device to demonstrate conservation of momentum.