# Combining computational physics with video analysis in Tracker


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## Introduction

Videos can provide a convenient and effective focus for introducing computational physics models to lower division students. Because videos are perceived as reality, direct visual comparisons between model overlays and video images enables students to explore different model equations, parameters and algorithms in a real-world context.

This paper describes a Spring 2007 experiment at Cabrillo College in which students used 2D particle models in Tracker--a free Open Source Physics video/image analysis program--to study the effect of air resistance on falling cupcake cups [1-3]. The models:

- use ODE numerical solvers to compute their behavior
- draw graphical overlays directly on the video image
- generate data for graphing and analysis

## Particle Models

There are two types of particle model: analytic and dynamic. An analytic model defines position functions of time, while a dynamic model defines force functions and initial conditions for numerical ODE solvers.

Function expressions are interpreted and evaluated using a parser which recognizes parameter and variable names, standard operators ( + - * / ^ ), parentheses, and common one- and two-parameter math functions.

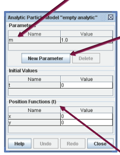



**Figure 1.** Analytic particle model. Students define parameters, set initial time, and enter position functions of time. Parameters are easy to define and edit, and full undo/redo encourages experimenting with changes.

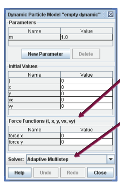



**Figure 2.** Dynamic particle model. Students define parameters, set initial values, and enter force functions f (t, x, y, vx, vy).

## The Experiment

Students explored the motion of a cupcake cup dropped from rest. The mass of a cup was varied by hanging different numbers of paper clips from it. After observing and predicting the qualitative features of the motion, students opened a prerecorded video of eight cupcake cups with identical area but different masses falling side by side. The cups in the video were then analyzed by:

- tracking their motion with a mouse
- comparing their motion with a viscous force model
- comparing their motion with a drag force model
- comparing their terminal velocities with model predictions

Students completed the experiment in small groups in Cabrillo's Physics/Engineering Learning Community, a required drop-in lab with peer tutors that supplements the scheduled lectures and labs.

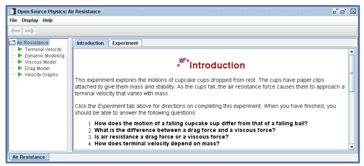
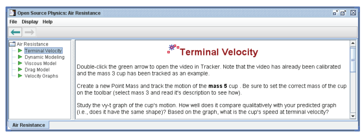



**Figure 3 (above and below).** Launcher presentation of the experiment. Launcher displays html pages and launches Tracker video exercises.




1. Describe and compare the motions of a dropped cup and ball. How does the velocity change qualitatively with time?
2. Sketch predicted velocity-time graphs. What is the slope of the velocity-time graph when the cup has reached terminal velocity?
3. Sketch force diagrams. Do the cup and ball experience the same weight force? The same initial acceleration? The same air resistance force at the same speed?
4. Track a cup and compare the velocity-time graph with your sketch. Based on the graph, what is the cup's speed at terminal velocity?
5. Model the behavior of a falling cup experiencing a viscous or drag force. Can you tell which of the two force types is a better model for air resistance?
6. Compare the viscous force model with the motions of lighter and heavier cups. Does the viscous force model match the motions of all three cups well?
7. Compare the drag force model with the motions of lighter and heavier cups. Can you now tell which of the two force types is a better model for air resistance?
8. Derive an equation for terminal velocity as a function of mass. How is the ratio of the predicted terminal velocities related to the ratio of the masses?
9. Study the video of sonic ranger velocity-time graphs for the falling cups. How well do the measured velocities compare with your predicted values?

**Figure 4.** Summary of experimental procedures and questions.

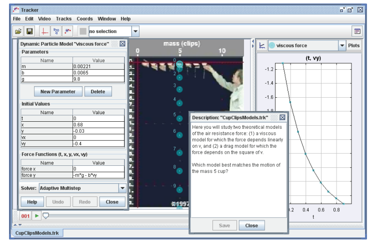


**Figure 5.** Tracker video modeling exercise. Here a viscous model particle (automatically synchronized with the video and drawn as a trail of blue circles) is provided as a guide for students creating their own drag models.

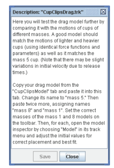


**Figure 6.** The description pane opens automatically and can give valuable information to students.

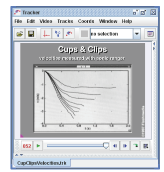



**Figure 7.** Model data and graphs are compared with sonic ranger measurements, also in a video.

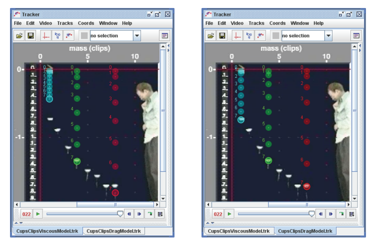


**Figure 8.** Viscous force (left) and drag force (right) models. Both have been adjusted to closely match the mass 4 cup motion (green), but only the drag model also matches the behavior of lighter and heavier cups.

## Discussion

While my students had no serious problems completing this experiment, it was their only exposure to dynamic modeling, and thus too brief an introduction for significant understanding and retention. A better approach would be to build up modeling knowledge and skills through a series of exercises of increasing sophistication [4,5]. Nevertheless, Tracker's ability to combine dynamic modeling with real-world videos extends traditional video analysis experiments [6] and provides new opportunities to introduce computational physics to beginning students. We are currently developing a mechanism for combining Tracker video analysis with far more powerful and flexible model simulations created with Easy Java Simulations.

This experiment is available for download from the Tracker website or OSP-BQ database (see further information below).

## References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6. P. Laws and H. Pfister, "Using Digital Video Analysis in Introductory Mechanics Projects," *Phys. Teach.* **36**, 282-287 (May 1998).


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## For further information

Please contact *dobrown@cabrillo.edu*. More information on the following topics can be obtained at:

- Tracker: http://www.cabrillo.edu/~dbrown/tracker/
- Open Source Physics: http://www.opensourcephysics.org/
- Easy Java Simulations: http://www.um.es/fem/Ejs/
- BQ Database: http://www.bqlearning.org/ospdb/