Physics 200 Name: _____
Water Rocket Project, Handout #2

What to do, and in what order:

1. Do this first! -- **Complete the part 1 handout** (Video Data Analysis and Spreadsheet Population)
    a. Make sure that you're using a spreadsheet with updated formulas in columns C and D (drag and Area). The new formulas model parachute deployment more realistically. **An updated copy of this spreadsheet is provided in the Google Classroom assignment. You may copy and use it.**
    b. Name your spreadsheet **"[your names] Water Rocket Flight Model"**
    c. Using the water rocket flight model spreadsheet data, **print out a full-page graph of acceleration vs time** (see details below).
2. The rest of this can be completed in any order.
    - Copy, rename, and then complete the "Water Rocket Analysis: Thrust Calculations and Snapshots" spreadsheet.
        - Complete the "thrust phase calculations" and enter your answers (or formulas, if you wish) into the first sheet of the workbook.
        - Complete the "snapshots" sheet of the same spreadsheet.
    - Annotate the acceleration graph that you printed (see 1c, above).
    - Discuss the drag coefficient that you entered into the Water Rocket Flight Model spreadsheet. If it seems unreasonable, discuss possible sources of error.

How to turn everything in:

- Only one of each item should be turned in by each group. Make sure that you put everyone's name on the items that you turn in.

1. **Physical Items To Hand-In:** Staple these four items together and physically turn them in during class.
    a. a completed part 1 handout
    b. this handout (#2), with section 4 completed
    c. annotated acceleration graph
    d. a discussion of possible error
2. **Digital Items.** In Google Classroom, attach these items in the "Turn-in Location – Water Rocket Spreadsheets" assignment:
    a. Your group's copy of the "Water Rocket Analysis: Thrust Calculations and Snapshots."
    b. Your group's "…Water rocket Flight Model." I don't plan to grade this, but it may help me communicate problems relating to your submissions.

Specific Instructions:

Part 1: (Video Data Analysis and Spreadsheet Population) **See the other handout**

Part 2: "Water Rocket Analysis: Thrust Calculations and Snapshots." Go to Google Classroom and make a copy of the spreadsheet with this name. Then complete the two sheets of the workbook *[FYI, "workbook" is the name of a spreadsheet file. The workbook may contain multiple "sheets," which can be reached by tabs.]*.

1. **Sheet 1: "Thrust calculations"**
    a. The numbers on the sheet will prompt you to enter data from part 1.
    b. Use the data from part 1 to perform the requested calculations. The calculations should be straightforward until you get to the last two (items 36 and 37). Those are harder. You can check with me occasionally to see if your answers to 36 and 37 are correct.

2. **Sheet 2** (2nd tab at bottom of workbook screen)**: "Snapshots of Moments During Flight"**
    a. For each numbered moment, enter the required data. Get data from your your Flight Model spreadsheet and the "thrust calculations" on sheet 1 of this workbook.
    b. For the moment of impact with the ground, you will need to estimate some new information. You will not lose points for "wrong estimates" as long as they are reasonable.
    c. Create a **simple** drawing illustrating each of the moments. I suggest creating drawings by hand, scanning them, emailing them to yourself, taking screenshots of your scans, and pasting the screenshots into the spreadsheet -- but you can do it however you want as long as you…
        i. Use arrows to represent individual forces and the net force acting on the rocket.
            1. Label each arrow with the name of the force it represents.
            2. Make sure that the arrow lengths are reasonably proportional.
            3. The arrows must point in the correct direction.
            4. Except for Net Force, do not draw arrows for forces that are zero. When net force is zero, write that it equals zero.

Part 3: Acceleration Graph: Print, Modify, and Annotate an Acceleration Graph – print out an acceleration graph from you Flight Model spreadsheet and add hand-written labels corresponding to snapshots #1-6 from the spreadsheet above.

a. Make sure that your graph has time increments on the X axis and acceleration increments on the Y axis.
b. Sketch-in two more sections that are not included in your model:
    i. Thrust phase acceleration – if you were to draw this correctly, your graph would go off the top of the page. Just draw what you can and add a note saying it goes off the page.
    ii. Acceleration during impact – this may also go off the page. If it does, add a note.
c. Add *annotations* to the graph for snapshots 1-6 from the sheet above. For each snapshot…
    i. Add a dot to the graph.
    ii. Label the dot with…
        1. The snapshot number (1-6)
        2. A brief description of the moment during the flight that is being represented. You can use my description from the "Water Rocket Analysis…" spreadsheet.

Part 4: Rocket Characteristics and possible error. Use your completed flight model spreadsheet to answer these questions. If you think any of the answers are unrealistic, discuss likely sources of error.

a. What was your rocket's drag coefficient during its ascent? $Cd_{initial}$ = _____

b. What height did your rocket reach at apogee? $Height_{apogee}$ = _____ m

c. Did your rocket reach its terminal velocity before it touched the ground? _____ (yes or no)

d. What was your rocket's terminal velocity? $V_{terminal}$ = _____

e. Do any of these measurements (or any other parts of your model) seem unrealistic? If so, which parts seem unrealistic, and what do you think went wrong? Where do you think the error might have come from? [Add extra paper if necessary.]