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Project SMART Vehicle Model Drag Coefficient Testing

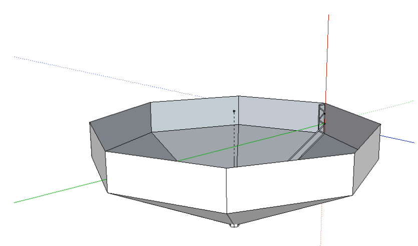
Overview:

The space science section of the Project SMART program at the University of New Hampshire has been developing a high-altitude ballooning project over the past several years. Several high schools have become involved with the development as well. As part of the program, a re-entry vehicle was developed to take measurements and images from a stable platform during ascent and descent. The shape of the vehicle was determined though experimentation by students to be very stable, but the coefficient of drag for the shape was unknown. The drag coefficient is a dimensionless number that can be thought to rate how easily a shape slips through a fluid. An arrow would have a very low drag coefficient (C_D) while a motorcyclist sitting upright would have a very high coefficient of drag.

To determine the full-scale size of the descent vehicle, the drag coefficient for this shape must be determined. By dropping a model of the vehicle and measuring its area and terminal velocity, the drag coefficient can be determined.[i]

Instructions:

1. Print the model of the flight vehicle on card stock (printer paper will work too, card stock works better).
2. Cut out the perimeter of the model.
3. Cut out the darker shaded area, but leave the tape tab.
4. Carefully crease all seven of the radial lines by folding along the radii. Bend the paper about 90°. These are shaded gray.
5. Carefully crease the line connecting the collar tabs (eight) to the triangular wedges. These lines are also shaded gray.
6. Use clear tape to form the triangular wedges into a cone-like shape. Use the tape tab to help secure the edges.
7. Tape the eight collar tabs together using small pieces of clear tape.
8. Add mass (such as paper clips) until the model weighs 3.8g. This simulates a four pound model
9. Drop the model and check that it falls smoothly.



Testing Procedure:

Materials: Tape measure, stopwatch, scale

1. Measure vertical distance the model is going to fall in meters. DO NOT place yourself under a tape measure that is being lowered.
2. Drop the model from a window or balcony such that the model fall for at least one story and time the descent. Repeat 10 times and record in a table.
3. Calculate the speed of the model in meters per second from the average time and measured distance.
4. Compare to other groups.
5. Record data and calculations.

Calculations:
To determine the drag coefficient we will need several parameters.

1. Frontal area:
    a. Turn the model over such that it rests octagon side down on a sheet of paper and mark the outer points of the octagon.
    b. Connect the points to form an octagon. Connect the points to the center of the octagon to form radii. You should now have eight triangles.
    c. Measure the sides of the triangles and record on the diagram.
    d. Determine the area of the octagon by determining the area of one triangle and multiplying
2. Air density
    a. Go online (there are many resources) and determine the density of air at your current temperature and altitude. Record your source and the reported units.
    b. The air density, ρ (pronounced rho), needs to be converted to kg/m^3. Show any work needed using the factor label method.
3. Drag force
    a. Convert the mass of your vehicle (actual) to its weight in units of newtons. Show work using the factor label method.
    b. At terminal velocity, the drag force balanced the weight of the vehicle. The drag (measured in newtons) is equal to the weight of the vehicle.
4. Drag Coefficient:
    a. The formula for drag is
    $F_d = \frac{1}{2}\rho C_d A v^2$
    where
        i. F_d = is drag (N)
        ii. ρ is the air density (kg/m^3)
        iii. C_d is the drag coefficient (dimensionless)
        iv. A is the frontal area (m^2)
        v. v is the terminal velocity (m/s)
    b. Algebraically solve this formula for C_d, the drag coefficient.
    c. Substitute your values and compute the drag coefficient.

Conclusion:

1. Go online and find the drag coefficient for other shapes. There are many available.
2. Does your calculated value make sense in terms of similar shapes? It would be unlikely for your answer to be more than ten times different than known value for a similar shape. Unusual answers are typically the result of poor conversions.
3. What shape is closest to your measured value?
4. Discuss the uncertainty of your measurements. To how many decimal places would you be willing to guarantee your answer? Why?

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[i] please forward any results you are willing to share to <Scott Goelzer> sgoelzer@coebrown.org

Scale Flight Vehicle Model

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