Problem Set 1

18.355, Fall 2012
Due Sept.17

Apply some combination of dimensional analysis and scaling arguments to address the following.

1. What is the frequency of oscillation of an inviscid drop in zero gravity?

2. What is the size of the largest pendant water drop, and the largest animal that can stand at rest on the water surface? (The surface tension at an air-water surface is approximately 70 dynes/cm).

3. Deduce the scaling for the settling speed of a marble falling in a) air, and b) honey.

4. Identify and interpret the dimensionless groups that describe a drop of one fluid translating uniformly through another. Assume an interfacial tension σ and an unbounded geometry.

5. Rationalize the size of raindrops.

6. If an insect is water-repellent as a result of a rough surface coat, it may survive beneath the surface by virtue of an air layer trapped on its surface, which it uses as an external lung. If its roughness scale is 1μm, deduce the depth to which it can safely submerge.

7. A water drop falls onto a horizontal soap film. Make an estimate for the critical height above which it will break through the film.

8. A cornerstone of biomechanics (supported by the Olympic world records in power lifting) is that the force that can be generated or sustained by a creature scales as its cross-sectional area. Use this fact to deduce the dependence on body size of the height that may be achieved by a leaping animal.

9. Certain creatures are able to run on water, supporting their weight by thrusting water downwards as they run. The largest such animal, the basilisk lizard, is typically 2 feet long.

a) Deduce a criterion involving the creature's foot size, number of feet and foot speed that must be satisfied in order for it to walk on water.

b) Deduce the minimum foot size required for a human being to walk on water.

c) Comment on the relevance of water-repellent shoes for humans walking on water.

10. a) Deduce the dependence on body size of the 'acceleration length', L_a, the distance required for a body falling at high Reynolds number to achieve its terminal velocity.

b) '*The bigger they come, the harder they fall.*'

Quantify the above statement, deducing the dependence of speed and force of impact on body size L and distance fallen H for the cases of: (i) tripping ($H \sim L$), (ii) falling ($H < L_a$), and (iii) free-falling ($H > L_a$).

c) Comment on the invincibility of mice and smaller animals in falling from arbitrary heights.