Order-of-Magnitude Physics – Problem Set 3

Guidelines:

- If a question is ill-defined, it is your responsibility to quantify it.
- Please cite any resources used. If you get information off the web, cite the website.
- You are encouraged to rely as much as possible on your own wits. For example, looking up a "fundamental" parameter such as the mass of hydrogen is fine (and you don't need to cite such a routine task), but looking up advertising revenues is not as interesting or as instructive as trying to estimate it yourself. Credit will be awarded for independence and ingenuity.

Problem 1. Microwave Mistakes

Putting cookware plated with metal (e.g., plates decorated with gold foil) inside microwave ovens is not recommended because the metal becomes so hot that it burns off.

This is a problem only for thin metal coatings. How thin is thin?

Problem 2. Sea Level

(a) The Earth's atmosphere is thought to warm by about $\sim$3.5° C over the next century due to increasing concentrations of carbon dioxide.

If the ocean also warms by this amount, by how much will the sea level rise worldwide? Neglect melting of ice sheets.

(b) How much denser is the water at the bottom of the ocean compared to the top? Neglect variations in salinity. If this density contrast were to (magically) disappear, how much higher would the Earth's oceans be?

Problem 3. How Round is Round

How large must an asteroid be before self-gravity makes it round?

Problem 4. Water Striders

Based on research on bio-locomotion by Hu, Chan, and Bush (2003):

Water striders are insects that can walk on water. The picture on the website is that of the common water strider (*Gerris remigis*).

Consider instead the largest of water striders, *Gigantometra gigas*, having a reputed mass of 3 gm (not pictured). The shape of *Gigantometra gigas* is similar to that of the pictured strider insofar as it also balances principally on the longest 4 of its 6 legs. (The other two, shorter legs are for grabbing prey).

It is known that water striders are *not* isometric; that is, the relative proportions of their lengths (e.g., body length to leg length) do not remain constant as the absolute size of the insect increases. Therefore do not make the mistake of assuming that you can derive answers to questions below merely by scaling from the picture on the web. In any case, a scale bar for the picture on the web has not been provided.

Observe in the picture that all legs press *dimples* into the surface of the water.

(a) Each of the 4 long legs of *Gigantometra gigas* must be in a certain minimum contact with the water, as measured parallel to the leg. Estimate this minimum contact length.

(b) Estimate the characteristic length of a dimple, measured perpendicular to a long leg.

You may use a generalized version of Archimedes' principle: the mass of water displaced by an object floating in water, even if that object does not pierce the surface of the water, equals the mass of the object.[1]

(c) Are buoyancy (pressure) forces exerted by the water on the wetted bottoms of the legs important for support against gravity? Provide a quantitative assessment. Assume the cross-sectional radius of a leg is $w \approx 100\,\mu$m.

Problem 5. Ask Your Own Question

Ask an OOM question of your own. You don't have to answer it.

[1]Mansfield et al. (1997, Philosophical Transactions of the Royal Society of London, Series A, 355, 869); Keller (1998, Physics of Fluids, 10, 3009).