INSTITUT DES HAUTES ÉTUDES

POUR LE DÉVELOPPEMENT DE LA CULTURE, DE LA SCIENCE ET DE LA TECHNOLOGIE EN BULGARIE

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Concours Général de Physiques

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The main problem and the three exercises are completely independent and can be solved in any order.

All the answers must be given in English or French. The clarity and precision will be taken into account for the final note.

The exam is 4 hours long! The calculators are authorized.

Problem: Flat water!

The main goal of this problem is to obtain numerical values. An analytical expression of the result as a function of the given parameters should be given, but it's just a bypass to the final solution.

The surface tension, or interface energy, or surface energy is defined as energy per unit area:

$$dE = \gamma . dS$$

This effect allows for example insects to walk on water and explains the capillary. The surface tension also explains the formation of soap bubbles.

Here we do not take into account the interaction between the liquid and the surface on which it is fixed. It is assumed that the liquid does not wet the surface and the bottom-side of the drop is a liquid-air interface. This situation is observed in the case of a drop of water on a hot plate or on a hydrophobic surface (duck feathers, lotus leaf, etc.).

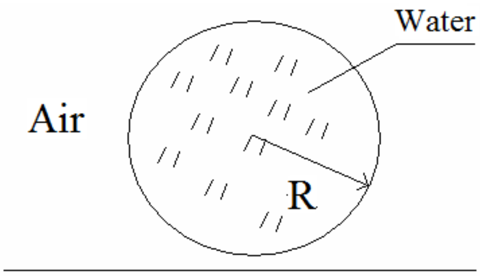
1. Capillary length.

a) What is the dimension of γ (called surface tension)?

b) Using γ, ρ (mass per unit volume) and g (acceleration of gravity) construct a quantity l_c having a dimension of a length. We will call this length l_c «capillary length».

c) What is the capillary length of the water? $\gamma_{water} = 7\times10^{-2}\,SI$

2. The small droplets.

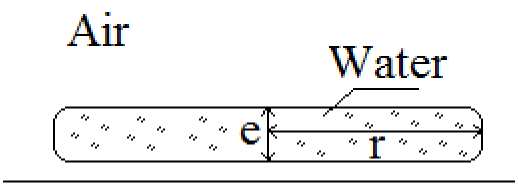


a) Considering one small droplet give the expression of the surface energy and the energy of gravitation as a function of the radius of the droplet (R), the acceleration of gravity (g) and the mass per unit volume of the water (ρ_{water}).

b) What is the condition, on the radius of the droplet, to have its size essentially dictated by the capillary forces?

3. The big drops.

Here the drop is sufficiently large to be considered as « puddle » flattened by gravity (thickness **e** and radius ***r***, with $r >> e$).



a) ***Estimate*** the total surface of the drop, the surface energy and the gravitational energy, as a function of **r**, **e**, ρ, **g** and γ.

b) Minimizing the total energy, determine the thickness of the puddle.

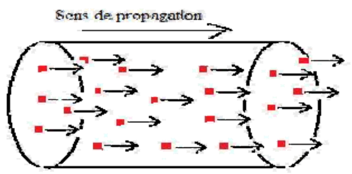
4. Give the relationship between the volume ***V*** of the drop and its apparent diameter **d**, viewed from above, in the case of small drops and big drops. Sketch the function $\log(d) = f(\log(V))$.

5. Using figure 1, estimate the «capillary length» and the surface tension of the mercury.

FIG. 1: Drops of different volumes of mercury fixed on a glass (photo from «Hydrodynamique physique» Guyon, Hulin and Petit.). The smallest droplet has a diameter of 2 mm. approximately.

Exercise 1

Let's consider a beam of electrons, which is propagating in a vacuum with a speed $\vec{V}$, electronic density ρ and radius R.

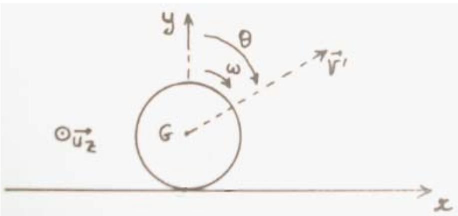


1.) Considering only the electromagnetic interactions, calculate the expression of the magnetic and electrostatic fields created by the electrons as a function of ε_0, μ_0, ρ, R, $\vec{V}$ and r (the distance to the center of the beam). We can ignore the side effects and suppose that the beam has the form of an infinite cylinder.

2.) Making a balance of all forces try to find out the sense of evolution of the radius of the electronic beam in the time.

Hint: The speed of light in the vacuum is $c = \dfrac{1}{\sqrt{\varepsilon_0 \times \mu_0}}$, with $\varepsilon_0 = 8{,}85.10^{-12}\, SI$, $\mu_0 = 4\pi \times 10^{-7}\, SI$

Exercise 2



You have a homogenous sphere of mass m, radius R, and an initial angular speed ω around a horizontal axe passing by its center. We drop this sphere from a vertical height h, without an initial speed. By introducing a coefficient of restitution e (the norm of the final speed divided by the norm of the initial speed):

1.) Formulate the forces acting on the sphere and write the fundamental principle of dynamic applied to the sphere.

2.) By analyzing the following two cases:

a) Rotation with slipping during all the time of the shock.

b) Rotation without slipping during the last part of the shock.

Calculate the bounce angle ϑ, i.e. the angle between the vertical axis and the speed of the center of the masses of the sphere G, just after the impact. Comment.

Exercise 3

Consider two identical homogeneous balls, A and B, with the same initial temperatures. One of them is at rest on a horizontal plane, while the second one hangs on a thread. The same quantities of heat Q have been supplied to both balls. Are the final temperatures of the balls the same or not? Justify your answer. (All kinds of heat losses are negligible.)

****FIN****