INSTITUT DES HAUTES ÉTUDES
POUR LE DÉVELOPPEMENT DE LA CULTURE, DE LA SCIENCE ET DE LA TECHNOLOGIE EN BULGARIE
http ://www.ccr.jussieu.fr/iheb/

# Concours Général de Physiques "Minko Balkanski"

*May 15th 2004*

*The two problems are unrelated to each other.*

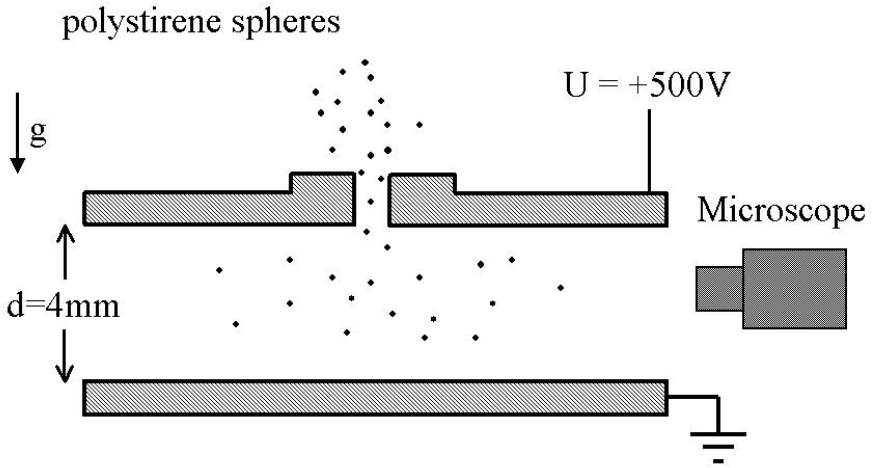
*All the answers must be given in* **English** *or in* **French**. *The clarity and precision will be taken into account for the final note.*

The exam is 4 hours long.

### The Millikan experiment

The electrical charge $e$ of the electron is a fundamental physical constant. It was the American physicist Robert Andrews Millikan who measured it for the first time in 1909 and showed that all charge appears only in multiples of $e$. For his experiments Millikan was awarded the Nobel Price in 1923.

In this problem we study a simplified version of the original Millikan experiment, shown in the figure below :




Very small polystyrene spheres (of radii up to several microns) are injected between the plates of a planar capacitor. The spheres are observed with a microscope. The distance between the capacitor plates is $4mm$ and the applied voltage is noted by $U$. The spheres could became charged owing to the friction in the air.

**1.** The applied tension is zero. Consider a sphere of radius $r$. We recall *the Stokes's law* :

$$F = 6\pi\eta r v,$$

describing the friction force applied to a spherical body moving in a medium of viscosity $\eta$.

**1.a** Compute the final velocity $v_0$ of the sphere as a fonction of $\rho$ - the density of the polystyrene, $\eta$, $r$ and $g$ - the intensity of the gravitational field.

What is the direction of the motion of the sphere ?

**1.b** Cast the relation between the radius $r$ and the velocity $v_0$ under the form :

$$r = A\sqrt{v_0},$$

with $A$ a constant that you will compute numerically. Data : $\rho = 1,2 \times 10^3 kg/m^3$, $\eta = 1,8 \times 10^{-5}$ SI units, $g = 9,8 ms^{-2}$.

**2.** A voltage $U = +500V$ is now applied. The sphere of the previous question is now moving *upwards*, with a new final velocity $v_1$.

**2.a** What is the sign of the electrical charge of the sphere ? Why ?.

**2.b** Analyse the new movement of the sphere with the Newton's law. Compute the velocity $v_1$ as fonction of the data and $q$ - the charge of the sphere. We recall that the distance between the capacitor plates is $d = 4mm$.

**2.c** By eliminating the force of gravity in the expressions obtained in **2.b** show the following relation :

$$|q| = Br(v_0 + v_1).$$

The constant $B$ should be expressed as a function of $V$, $d$ and $\eta$.

**2.d** What is the numerical value of $B$ in SI units ?

**3** The mesures of $v_0$ and $v_1$ are repeated with different spheres. The radii of the spheres are unknown. The following chart is obtained :

| Experiment n° | $v_0$ $mm/min$ | $v_1$ $mm/min$ | radius $r$ (microns) | charge $\lvert q\rvert \times 10^{-19}$ C |
|---|---|---|---|---|
| 1 | 4,3 | 10,9 | | |
| 2 | 2,6 | 10,2 | | |
| 3 | 7,9 | 10,7 | | |
| 4 | 7,5 | 11,5 | | |
| 5 | 5,6 | 3,3 | | |
| 6 | 5,6 | 7,7 | | |
| 7 | 8,7 | 5,4 | | |
| 8 | 12,5 | 5,1 | | |
| 9 | 3,9 | 11,9 | | |
| 10 | 2,2 | 12,0 | | |
| 11 | 7,9 | 7,0 | | |
| 12 | 11,5 | 3,8 | | |

**3.a.** Complete the columns "$r$" et "$q$" with the help of previous results. (Beware the units !)

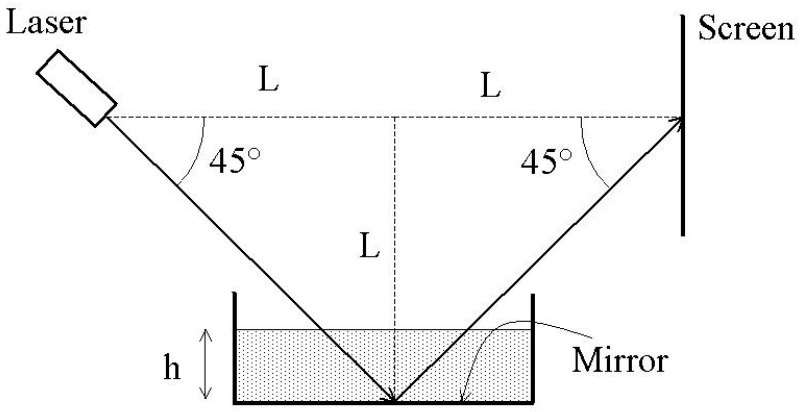
**3.b.** Represent each measure as a point in a co-ordinate system with the "$x$" axis being the radius, and "$y$" axis being the charge.

**3.c.** What do you observe ? What is the value of the "elementary charge" ? What is the minimal charge in these measures ?

**3.d.** Instead of going upwards, some of the spheres continue their downward motion. What could be said about the charge of those spheres ? Is it possible that spheres charged like in **2.a** move downwards ?

**3.e.** The air density is $\approx 1kg.m^{-3}$. Estimate the force of buoyancy. Why is this force not taken into account ?

**Exercice : Measure of the refraction index of a liquid**




A laser beam is reflected on a mirror placed on the bottom a recipient like on the figure above. When the recipient is empty, the laser beam spot is observed on a screen right in front of the laser. The distance $L$ is $10cm$, and the angle of incidence of the beam is $45^\circ$ according to the mirror.

While the recipient is being filled with a liquid of dept $h = 1.0cm$, the laser beam spot undergoes a distance of $\Delta x = 0.7cm$ on the screen.

What is the refraction index $n$ of the liquid ?

THE END