# Trapping a charged micro droplet with linear quadrupole

It has been demonstrated in the literature that linear quadruple with AC voltage applied on it can trap charged micro droplets. The linear quadruple setup simply composes of four metal rods placed parallel with each other as shown in Figure 1:


Fig 1: Linear quadrupole setup.

Two rods opposite each other have the same voltage, which is Vcos(wt), the other two opposing rods have the same magnitude of voltage but differ in polarity (-Vcos(wt)).

The electric field is approximated by: $E_x = -\frac{2x}{r_0^2} V\cos(wt)$, $E_y = \frac{2y}{r_0^2} V\cos(wt)$ where $r_0$ is the distance from center to rod surface (shown in Fig 2).

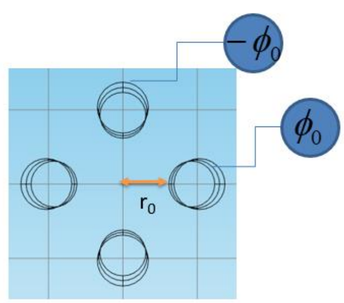


Fig2: Side view of linear quadrupole and voltage on it

Assume the droplet charge is q, it diameter is d, mass is m.  Air drag force is proportional to velocity, which is $-3\pi\eta d v$ . In x direction, the motion equation is:

$E_x q - 3\pi\eta d\frac{dx}{dt} = m\frac{d^2x}{dt^2}$. Where $\eta$ is air dynamic viscosity.

(1) Assume the motion is only on x direction (y=0), write a MATLAB code to simulation the motion of a charged water droplet.

Assume the water droplet diameter is 50 um, its charge is 30% Rayleigh limit. You can choose your own parameter though. Rayleigh limit is the maximum charge a droplet can hold, which is defined as

Rayleigh_limit = 8*pi*sqrt(EPS0 * surface_tension *radius * radius * radius)

Where EPS0 is vacuum permittivity, EPS0 = 8.85e-12; surface_tension is water surface tension, radius is water droplet radius.

You can choose your own parameters regarding droplet size and charge. Use initial position and velocity as x=1mm and $v_x$=1mm/s. Use $r_0$=1.2cm.

Use your code to pick out several (V, f) ( peak AC voltage and frequency) values under which the droplet can be trapped.

(2) Do the same thing for the combination of both x and y direction motions. Choose some (V, f) combinations for which the droplet can be trapped. Plot x and y as a function of time.

(3) Analyze your simulation results and find effect of some variables (such as droplet size, liquid type, volatility of the droplet, charge) on the criteria to successfully trap the water droplet. You can refer to my thesis to get some background related to this experiment as well as analytical solution of the equation.

The above questions are clues that help me organize your thoughts and interpret the solution of the mathematical equations from the engineering perspective. You are expected to **write a report** that follows **ASME format**. Please submit your **code and report (in PDF format)** through Blackboard by **the end of 4/24/2022.**

**The grading rubric are as follows:**

1. Correctness. The equations involved in the project are solved correctly. **40%**
2. Clearness. The results are analyzed in the right track, what and how to suspend the droplet successfully. **25%**
3. Insightfulness. Taking into the variations in experiment into account and use your code to look into it. **25%**
4. Going beyond. Correlate the project with your potential project of your interest and explore the possibility of the experiment in application in other fields. **10%**