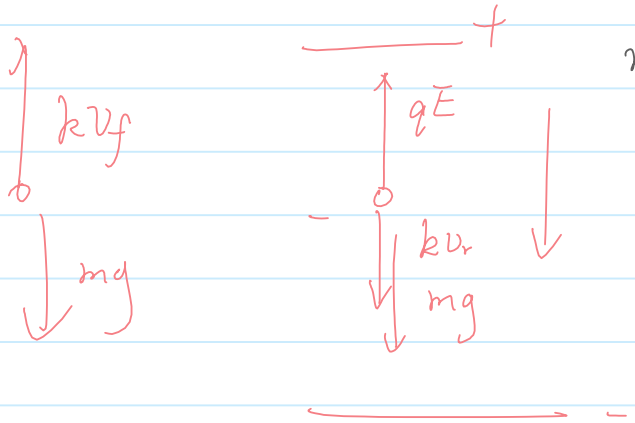
Millikan Prelab

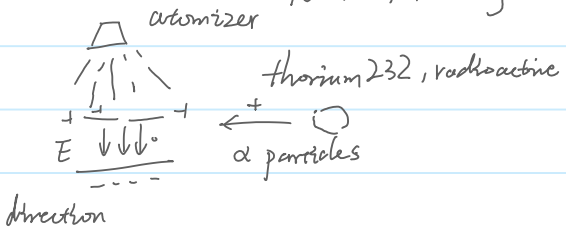
Monday, April 29, 2019 2:00 PM



measure of electron charge e

1.6×10^{-19} C

10^{-12} mm, 10^{-15} kg



$$q = \frac{mg(V_f + V_r)}{EV_f} \qquad m = \frac{4}{3}\pi a^3$$

viscosity

$$a = \sqrt{\frac{9\eta V_f}{2\rho g}}\ * \qquad \eta_{eff} = \eta\left(\frac{1}{1 + \frac{b}{pa}}\right)\ **$$

$$\Rightarrow q = \frac{4\pi}{3}\rho g\sqrt{\left(\frac{9\eta V_f}{2\rho g}\right)\left(\frac{1}{1+\frac{b}{pa}}\right)^3}\ \frac{V_f + V_r}{EV_f}$$

corrected formula.

$$q = \frac{4\pi}{3}\sqrt{\left(\frac{9\eta V_f}{2\rho g}\right)^2 + \frac{9\eta V_f}{2\rho g}} - \frac{b}{2p}\Bigg]^3 \frac{\rho g d (V_f + V_r)}{V V_f}$$

measured quantities

V_f, V_r, V, d, T (η).

```
D[Log[q], v_f] // FullSimplify
```

$$\frac{b^2 g \rho + 18 p^2 \eta v_f + 3 b g p \rho \sqrt{\frac{b^2}{p^2} + \frac{18 \eta v_f}{g \rho}}}{2 v_f \left(b^2 g \rho + 18 p^2 \eta v_f\right)} + \frac{1}{v_f + v_r}$$

```
D[Log[q], v_r] // FullSimplify
```

$$\frac{1}{v_f + v_r}$$

error propagation.

$$\delta q = q\sqrt{\left(\frac{\partial \ln q}{\partial V_r}\delta V_r\right)^2 + \left(\frac{\partial \ln q}{\partial V_f}\delta V_f\right)^2 + \left(\frac{\delta V}{V}\right)^2 + \left(\frac{\delta d}{d}\right)^2}$$

↓ do it using mathematica.

Day 1 Lab Note

Monday, April 29, 2019 2:00 PM

Partner: Casteneda Angle, Moshirfatemi Nastazia

① Leveling the apparatus with bubble level

② disassemble the chamber and measure the thickness

	1	2	3	4	5	6
d(mm)	7.55	7.59	7.60	7.60	7.60	7.61

③ reassemble the spacer and capacitor.

④ install the focusing wire.

⑤ connect power cable, set to 500V DC

⑥ measure the voltage of the capacitor and the resistance of the thermistor

V: 501V, 501V, 501V thermistor: 2.16. ~22°C

⑦ fix the phone on the viewing hole and adjust the camera

⑧ introduce droplets, turn on ionization, manipulate the movement of droplets by change the direction of the electric field. Make the droplets rising and falling for 10-20 times.

⑨ recording the video, save for later processing (on Nastazia's phone)

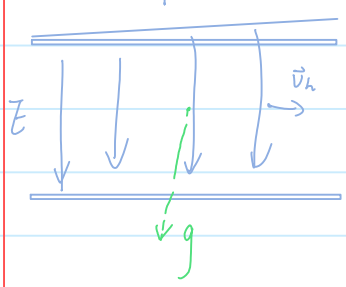
THERMISTOR RESISTANCE TABLE

°C	X 10^6 Ω	°C	X 10^6 Ω	°C	X 10^6 Ω
10	3.239	20	2.300	30	1.774
11	3.118	21	2.233	31	1.736
12	3.004	22	2.169	32	1.700
13	2.897	23	2.110	33	1.666
14	2.795	24	2.053	34	1.634
15	2.700	25	2.000	35	1.603
16	2.610	26	1.950	36	1.574
17	2.526	27	1.902	37	1.547
18	2.446	28	1.857	38	1.521
19	2.371	29	1.815	39	1.496

Droplet	Distance(mm)	Time(s)	direction
0A	0.5	8.86	U
	0.5	7.61	D
	0.5	8.47	U
	0.5	7.17	D
	0.5	7.96	U
	0.5	7.73	D
	0.5	8.04	U
	0.5	7.45	D
	0.5	7.92	U

Major Reticle: 0.5mm

Some problem encountered



During observation, some droplets going bigger and transperant. finally lose focus and disappear.

possible reason:

1. Platform not strictly leveled, gravitation produce horizontal velocity
2. the two plates of capacitor are not parallel.
3. electric repulsion or attraction between charged droplets.

Day 2 Lab Note

Wednesday, May 1, 2019 2:00 PM

Partner: Casteneda Angle, Moshirfatemi Nastazia

① assumble the apparatus and focus the microscope.

② connect DC power & measure the voltage

DC voltage: 5.04 V thermosistence: 2.22 ~ 21.5°C

③ fix the phone on the viewing hole and adjust camera

④ start manipulating the droplets and record video (on Yuning's Phone)

⑤ stop and level the plat-form again because some droplets quitely lose focus and disappear.

⑥ take videos recording the movement of the droplets

21.5°C thermistor : 2.20. DC voltage: 5.04V.

⑦ recording videos. (Yuning).

⑧ upload all the videos to google drive for later analysis.

⑨ name all the videos properly

{ video 01 - 05, Wed. May 1
video 06 - 13, Mon. April 29

Procedures of video preprocessing

A. try to convert all videos directly from sample.mp4 to sample.tiff. (unavalable)

we use 1080P 60fps when recording video, really a mistake. video files too large.

B. Compressed these videos to a proper resolution without losing too much accuracy on data extracting

So the video can be tackled with processing software more efficiently

using ffmpeg (video processing tool) to compress video.

```
ffmpeg -i "obj.mp4" -pix_fmt gray -r 5 -s 720x1280  "obj.avi"
```

- resolution: 1080P → 720P
- colorspace: RGB → Gray scale.
- audio: audio → null
- frame-rate: 60fps → 5fps

more space-efficient without losing much resolution.

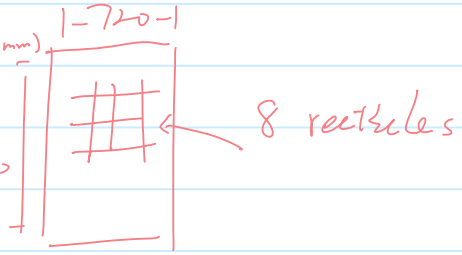
max 8 major rectiles (0.5mm) on vertical direction

8 × 0.5 mm / 1280

resolution = 3.125×10^{-6} m.

(max length for each pixel (enough)

time interval: 1/5fps = 0.2s



Day 3 Lab Note

Monday, May 6, 2019 2:30 AM

Partner: Casteneda Angle, Moshirfatemi Nastazia

work division : image processing, tracking particles and extract data from videos recorded.

process video using tracker ® (opensource physics software)

a) import video

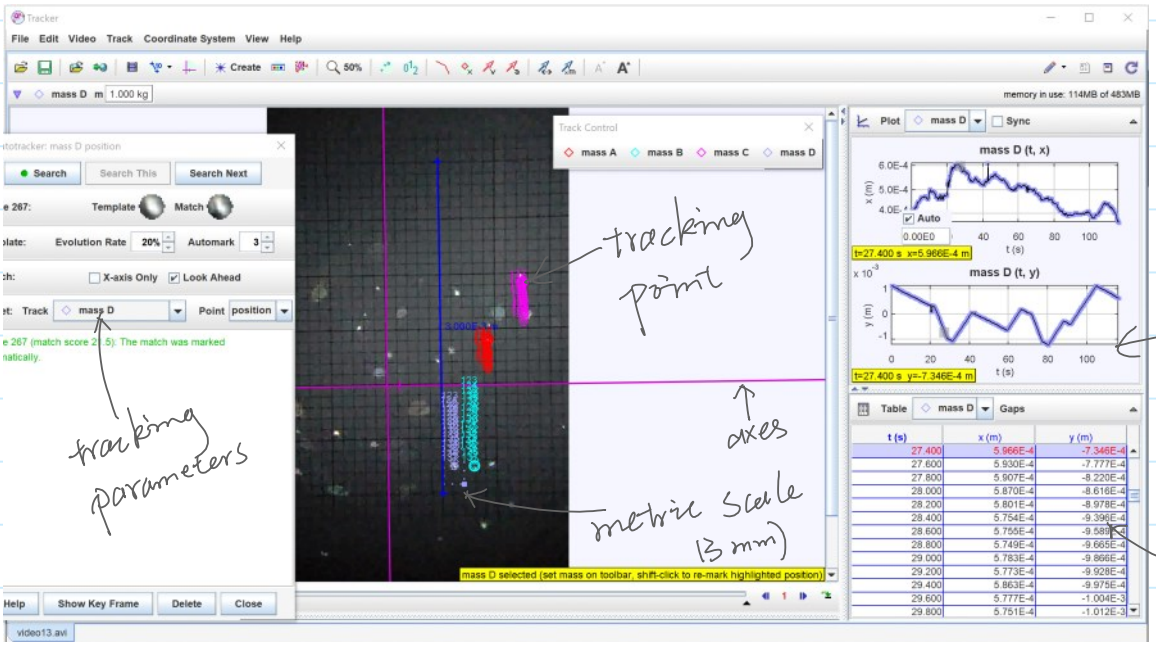
b) set x-y axes and metric scale

c) create point mass and use auto-tracking function to track trajectory of a specific droplet

d) adjust the recognizing features to reach the best tracking effect

e) derive velocity of x.y directions, (carefully watch the falling velocities, only need free-falling v_f without electric field!)

f) export data to .csv files, name it properly



name of data file: 13A.csv → video number + droplet number

↑ use to determine measuring temperature & voltage

Sample of raw data shown as right →

length of data array depend on number of frames captured in the table, $\Delta t = 0.2s$, velocity is calculated using

$$v_y^{(i)} = \frac{y^{(i)} - y^{(i-1)}}{\Delta t}$$

02A.csv - Notepad

File Edit Format View Help

```
,t,x,y,v_{x},v_{y}
1,3.8,0.000241,-0.000282,-2.29E-06,-3.77E-05
2,4,0.00024,-0.000297,6.76E-07,-5.47E-05
3,4.2,0.000241,-0.000304,-1.83E-07,-4.60E-05
4,4.4,0.00024,-0.000315,7.07E-06,-4.12E-05
5,4.6,0.000244,-0.00032,1.06E-05,-1.65E-05
6,4.8,0.000244,-0.000322,-7.66E-06,-3.06E-05
7,5,0.000241,-0.000332,-9.84E-06,-4.39E-05
8,5.2,0.00024,-0.000339,7.73E-06,-2.91E-05
9,5.4,0.000244,-0.000344,9.20E-06,-3.67E-05
10,5.6,0.000244,-0.000354,-7.87E-06,-3.01E-05
```

Sample of raw data shown as right →

length of data array depend on number of frames captured in the table, $\Delta t = 0.2\,s$, velocity is calculated using

$$v_y^{(i)} = \frac{y^{(i)} - y^{(i-1)}}{\Delta t}$$

02A.csv - Notepad

File Edit Format View Help

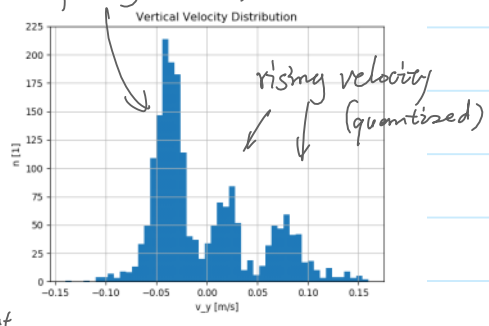
```
,t,x,y,v_{x},v_{y}
1,3.8,0.000241,-0.000282,-2.29E-06,-3.77E-05
2,4,0.00024,-0.000297,6.76E-07,-5.47E-05
3,4.2,0.000241,-0.000304,-1.83E-07,-4.60E-05
4,4.4,0.00024,-0.000315,7.07E-06,-4.12E-05
5,4.6,0.000244,-0.00032,1.06E-05,-1.65E-05
6,4.8,0.000244,-0.000322,-7.66E-06,-3.06E-05
7,5,0.000241,-0.000332,-9.84E-06,-4.39E-05
8,5.2,0.00024,-0.000339,7.73E-06,-2.91E-05
9,5.4,0.000244,-0.000344,9.20E-06,-3.67E-05
10,5.6,0.000244,-0.000354,-7.87E-06,-3.01E-05
```

Day 4 Lab Note

Wednesday, May 1, 2019 1:44 PM

Partner: Casteneda Angle, Moshirfatemi Nastazia

falling velocity ($v<0$)



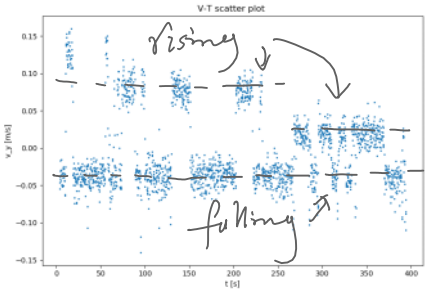
video 13-18, Wed. May 8

video 19-20, Mon. May 6.

- continue on data analysis and video processing

Some problem: the rising velocity (with field on) changed several times in measurement. The possible reason for that is the charge of droplets changed during moving.

↳ seperate these into different data files (unique to charge)



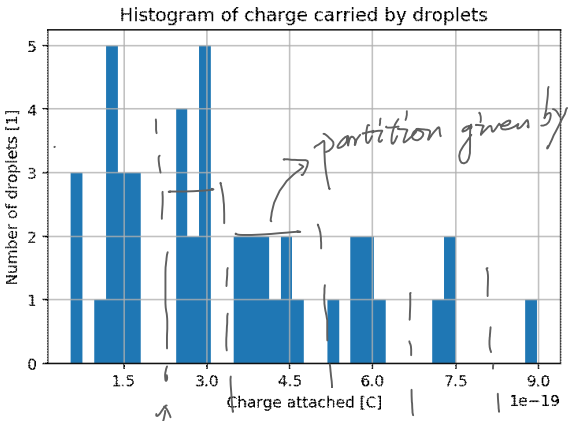
mean data for

assume the error of V to be 1 V (minimum precision of multimeter)

4.29	V=601V	T=22°C
5.1	V=604V	T=21.5°C
5.6	603-505V.	R=2.18~2.20 $10^6\Omega$
6.8	605 V	R=2.19~2.20 $10^6\Omega$

neglecte the error of Temperature

$\delta V = 1V \quad \delta T = 0$



divide into different parts.

another problem: deal with quantized data

We need to converted the data from 45 droplets to one single value of e.

① clustering. $q_i^{(n)}$ n: cluster

② calculate average value of charge $\frac{1}{N^{(n)}}\sum_i q_i^{(n)}$

③ substract by order. find the average difference

$$e \simeq \left| \frac{1}{N^{(j)}}\sum_i q_i^{(j)} - \frac{1}{N^{(j+1)}}\sum_i q_i^{(j+1)} \right|$$

assuming the e is unknown, estimate the error of assuming.

$$\text{error} = \left[e_{assume} - \text{Average}^{(j)}\left(\frac{1}{N^{(j)}}\sum_i q_i^{(j)} - \frac{1}{N^{(j+1)}}\sum_i q_i^{(j+1)} \right) \right]^2$$

↑ minimize this function to acquire a proper e.