

# Analyzing Trajectories of Oxygen Drops in an Azimuthal-Symmetric Magnetic Field

Version 1.2

Update in 1.2: Plot legends and labels have been added.

Update in 1.1: I added a mean filter to make the trajectory smooth.

This program imports text files that contain the trajectories of oxygen drops (each file corresponds to a single trajectory) and analyses them in order to obtain useful information. In each text file, the first column must contain the x coordinates, the second column must contain the y coordinates, and the third column must contain the t (time) values. It is recommended (for useful analysis) that every batch of files you import should have oxygen drops with roughly the same initial velocity.

The program requires you to [specify the directory](#) of the folder that contains the batch of data files you want to analyse, and then imports them for analysis. The loop runs over the files, one at a time, and stores the data in arrays. It then uses the data to calculate the experimental values of the peri-center of the trajectory,  $r_p$ , and the angle of deflection,  $\alpha$ . The next part of the program calculates the experimental values of  $r_p$  and  $\alpha$ . To achieve this, you must [enter values for the fitting parameters](#) (a1, a2, a3) for the magnetic field profile. The program calculates the theoretical values for each drop separately. However, since a complete curve for the theoretical values may be more useful, the last part of the program uses the average value of the initial velocity of the batch of drops being analysed, and gives the theoretically predicted values in the form of a curve (the user may view the experimental values superposed on this curve to compare values).

```
In[229]:= a1 = 66.9;
a2 = 0.008886;
a3 = 0.3122;
ρ = 1141;
```

```
Off[Solve::ratnz];
Off[NIntegrate::ncvb];
```

```
In[235]:= Clear["Global`*"]
files = FileNames["*.txt", "/Users/airfan/Documents/OneDrive - Higher Education
Commission/summer2019@physlab/Experimental Data/session_1/all files/"];
analyseddata = {};
total = Length[files];
```

```
For[i = 1, i < total + 1, i++, data = Import[files[[i]], "Table"];
```

## (\*Calculating experimental values of required var

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x = data[[All, 1]];
y = data[[All, 2]];
t = data[[All, 3]];
n = Length[x];
x = MeanFilter[x, 3];
y = MeanFilter[y, 3];
Delete[x, {{1}, {2}, {3}, {n}, {n-1}, {n-2}}];
Delete[y, {{1}, {2}, {3}, {n}, {n-1}, {n-2}}];
Delete[t, {{1}, {2}, {3}, {n}, {n-1}, {n-2}}];
cartesiantrajectory = Thread[{x, y}];
polartrajectory = CoordinateTransform[{"Cartesian" -> "Polar"}, cartesiantrajectory];
r = polartrajectory[[All, 1]];
θ = polartrajectory[[All, 2]];
dx = Differences[x];
dt = Differences[t];
dr = Differences[r];
vx =  $\frac{dx}{dt}$ ;
V = Mean[vx[[1;;10]]];
vr =  $\frac{dr}{dt}$ ;
b = Abs[Mean[y[[1;;10]]]];
rp = Part[r[[Flatten[Position[Abs[vr], Min[Abs[vr]]]]], 1];
hypotenuse =  $(y[[n]] - y[[n-20]])^2 + (x[[n]] - x[[n-20]])^2$ 1/2;
perpendicular = y[[n]] - y[[n-20]];
base = x[[n]] - x[[n-20]];
α = ArcTan[ $\frac{\text{Abs}[perpendicular]}{\text{Abs}[base]}$ ];
If[(base > 0 && perpendicular > 0), α = α, If[(base < 0 && perpendicular > 0), α = π - α, If[(base < 0 && perpendicular < 0), α =  $\frac{180}{\pi}$ α];
```

## (\*Calculating theoretical values of required variat

```

a1=66.9;
a2=0.008886;
a3=0.3122;
ρ = 1141;
Emag[R_]:= - $\frac{a1}{a3 + \left(\frac{R}{a2}\right)^6}$ ;
Eeff[R_]:=Emag[R] +  $\frac{\rho b^2 V^2}{2 R^2}$ ;
Einitial[R_]=  $\frac{\rho V^2}{2}$ ;
solutions = Values[Solve[Eeff[R]==Einitial[R], {R}, Reals]];
rptheoretical = Abs[solutions[[1, 1]]];
f[R_]:=  $\frac{1}{R^2 \left(1 - \frac{2 E_{eff}[R]}{\rho V^2}\right)^{\frac{1}{2}}}$ ;
(*Plot[f[R], {R, 0, 0.2}]*)
αtheoretical =  $\frac{180}{\pi} \left(2 b \text{NIntegrate}[f[R], \{R, r_{ptheoretical}, \infty\}] - \pi\right)$ ; AppendTo[analyseddata, {rp, rptheoretical, αtheoretical
];
analyseddata;
valuesrp = analyseddata[[All, 1]];
valuesrptheoretical = analyseddata[[All, 2]];
valuesα = analyseddata[[All, 3]];
valuesαtheoretical = analyseddata[[All, 4]];
b=analyseddata[[All, 5]];
V=analyseddata[[All, 6]];
p1 = ListPlot[Thread[{b, valuesrp}], PlotLegends->{"rp"}, PlotStyle->Black, AxesLabel->{"b (m)", "rp"}];
p2 = ListPlot[Thread[{b, valuesrptheoretical}], PlotStyle->Red, AxesLabel->{"b (m)", "rptheoretical (m)"}];
p3 = ListPlot[Thread[{b, valuesα}], PlotLegends->{"α"}, PlotStyle->Black, AxesLabel->{"b (m)", "α"}];
p4 = ListPlot[Thread[{b, valuesαtheoretical}], PlotStyle->Red, AxesLabel->{"b (m)", "αtheoretical (degree)"}];

```

## (\*Calculating theoretical values of required variat

```

V= Mean[V];
αdata = {};
rdata = {};
For[b=0.0005, b<0.03, b=b+0.0001,
Emag[R_]:= - $\frac{a1}{a3 + \left(\frac{R}{a2}\right)^6}$ ;
Eeff[R_]:=Emag[R] +  $\frac{\rho b^2 V^2}{2 R^2}$ ;
Einitial[R_]=  $\frac{\rho V^2}{2}$ ;
solutions = Values[Solve[Eeff[R]==Einitial[R], {R}, Reals]];
rptheoretical = Abs[solutions[[1, 1]]];

```

```

f[R_] :=  $\frac{1}{R^2 \left(1 - \frac{2 \text{Eeff}[R]}{\rho v^2}\right)^{\frac{1}{2}}}$ ;
 $\alpha_{\text{theoretical}} = \frac{180}{\pi} (2 b \text{NIntegrate}[f[R], \{R, r_{p\text{theoretical}}, \infty\}] - \pi)$ ;
AppendTo[adata, {b,  $\alpha_{\text{theoretical}}$ }]];
AppendTo[rdata, {b,  $r_{p\text{theoretical}}$ }]];
]

```

```

In[293]= p5 = ListPlot[adata, PlotStyle -> PointSize[Medium], PlotLegends -> {" $\alpha_{\text{theoretical}}$ "}];
p6 = ListPlot[rdata, PlotStyle -> PointSize[Medium], PlotLegends -> {" $r_{p\text{theoretical}}$ "}];
Show[p1, p6, PlotLabel ->
  Style[Framed["A comparison of the experimental and theoretical values of  $r_p$ "],
    12, Black, Background -> Lighter[LightBlue]]]
Show[p3, p5, PlotLabel -> Style[Framed[
  "A comparison of the experimental and theoretical values of  $\alpha$ "],
    12, Black, Background -> Lighter[LightBlue]]]

```

