

Scientific inquiry - Just do it

Digital measurement and Data analysis by Smartphone

@Online Exchange Programme



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2021.1.27



Self-introduction

- **Physics teacher at Kaohsiung Senior High School**
- **Ph.D. :Atomic Physics, National Taiwan University**
- **Adjunct Assistant Professor at Kaohsiung Normal University**
- **Associate Editor of the Journal of Chinese Physics Education**
- **Chairman of The Inquiry-Based Science Education Society of Taiwan**
- **Assisting IYPT national team training**
- **Cross-strait exchange demonstration teaching**
- **Co-organizing physics debate competition**
- **Continuing to publish articles in various seminars, publications, and sharing teaching experience**



Outline

- **Warm-up activity**
- Digital measurement
- Data analysis
- Some demonstrations
- Scientific modeling

Let's Kahoot!



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Phyphox

The image shows a screenshot of the Phyphox website. At the top left is the logo, which consists of an orange square containing a white stylized hand holding a phone receiver, followed by the text "phyphox" in a bold, lowercase font, and "physical phone experiments" in a smaller font below it. To the right of the logo is a navigation menu with the items "News", "Download", "Experiments", and "More" with a dropdown arrow. Further right is a language selector showing "English" with a dropdown arrow. Below the navigation is a large video player area. The video content is a dark grey gradient with the Phyphox logo centered in the middle. Below the video player is a progress bar showing a time of 1/1:11, a volume icon, and a download icon. At the bottom right of the page are two buttons: "Download for free:" followed by "GET IT ON Google Play" and "Download on the App Store".

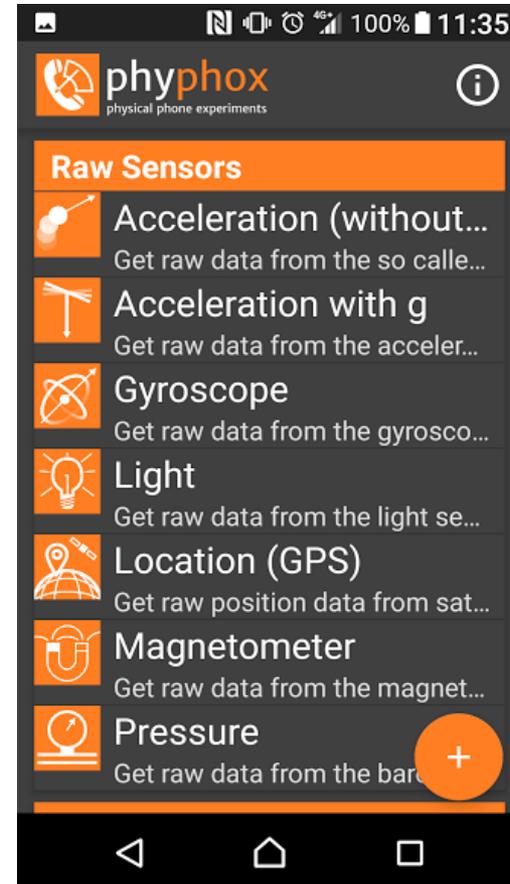
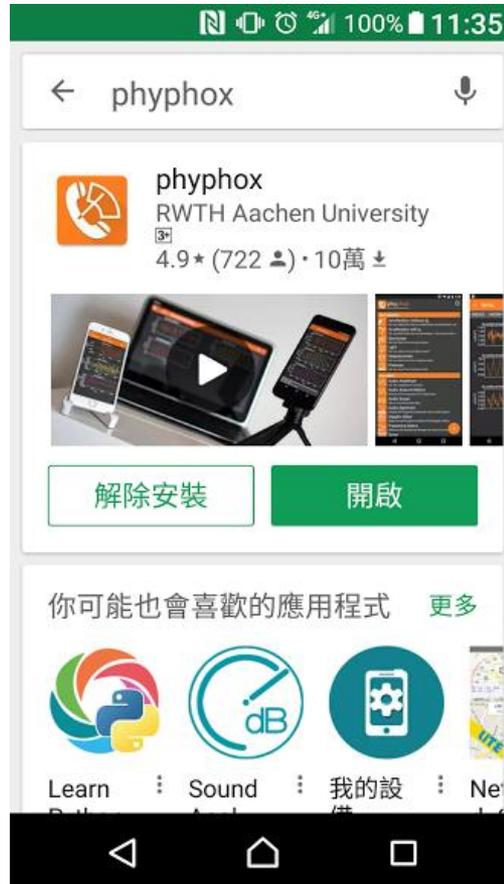
phyphox
physical phone experiments

News Download Experiments More ▾ English ▾

1/1:11

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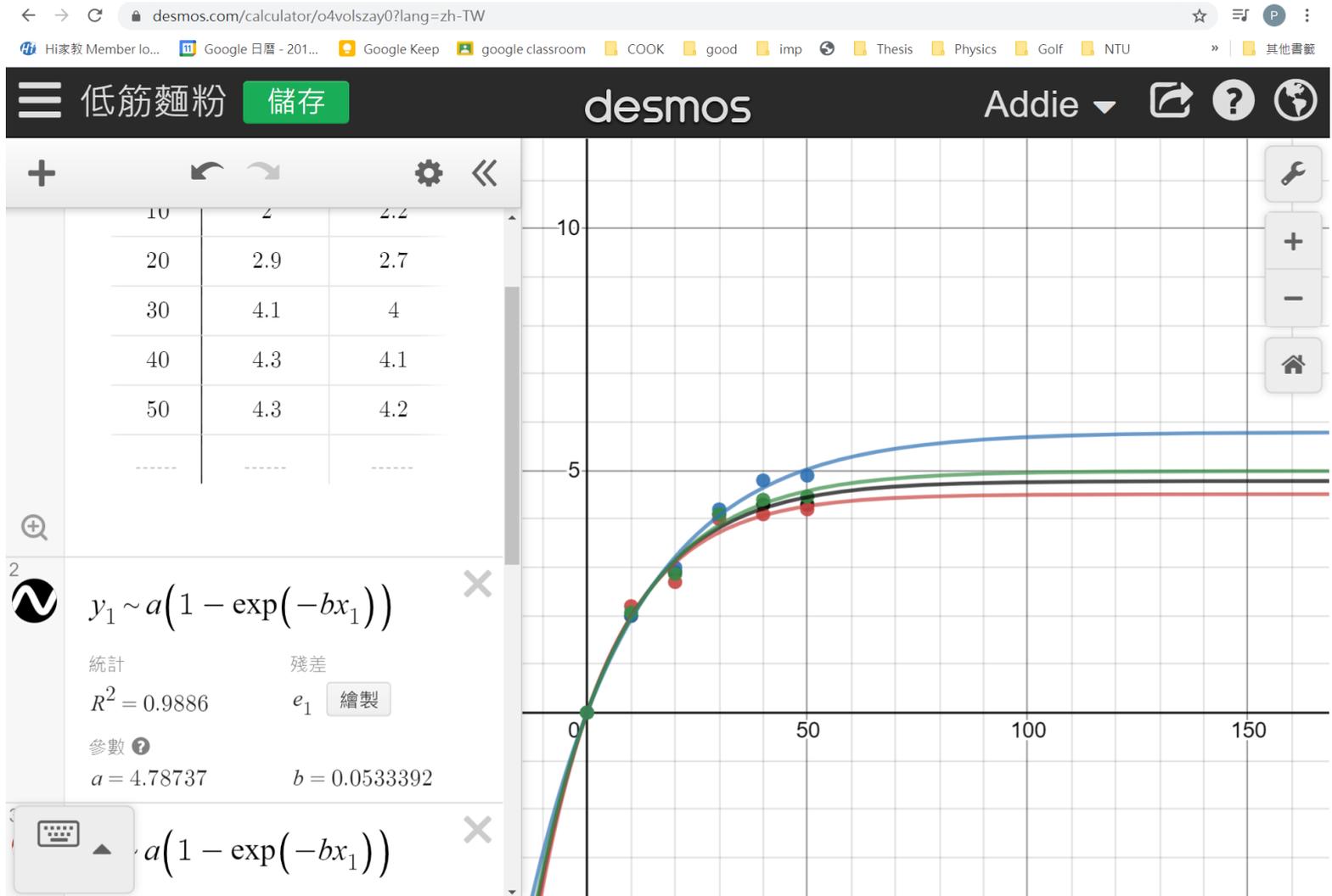
Phyphox Introduction



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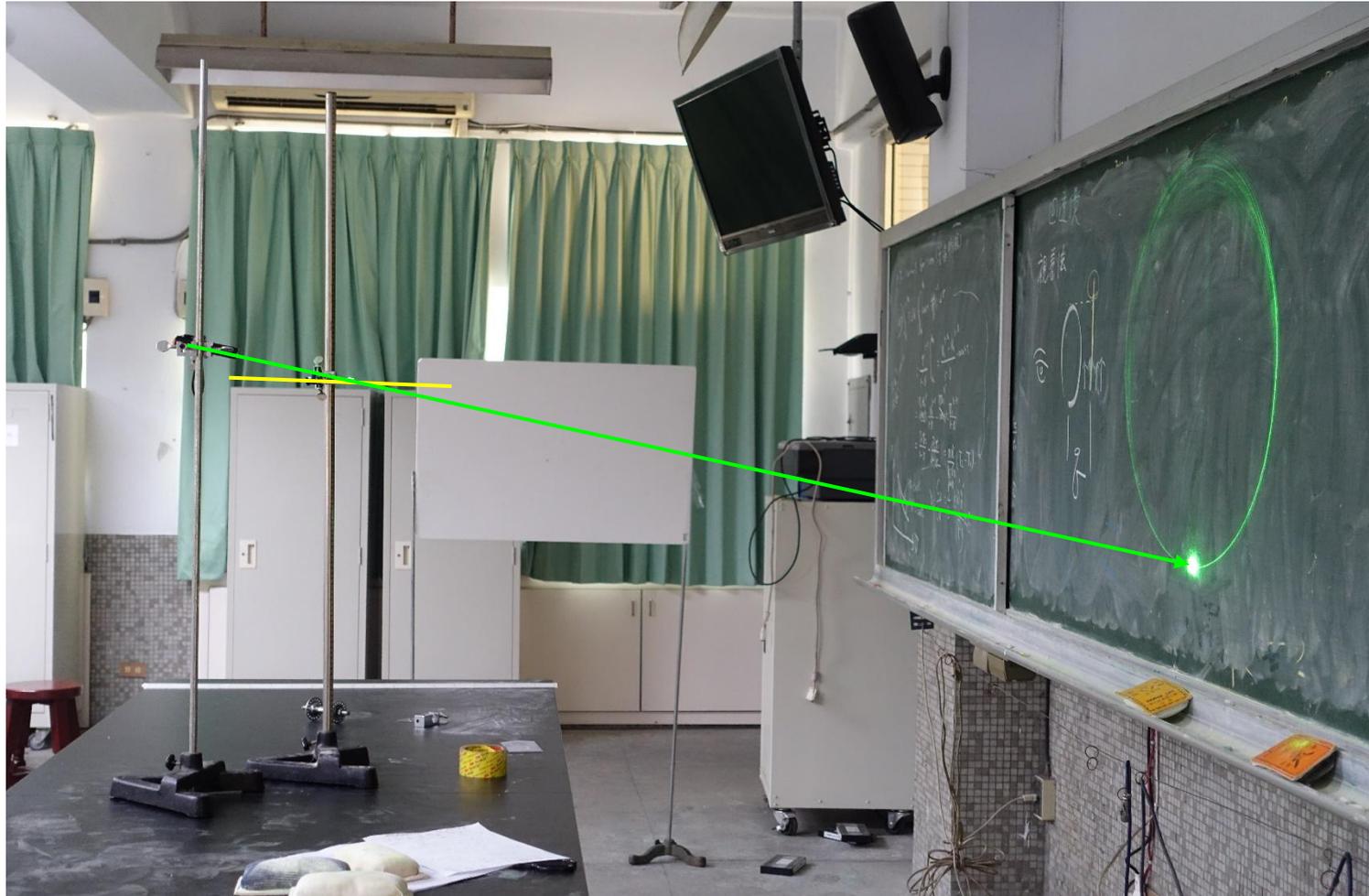
Curve fitting



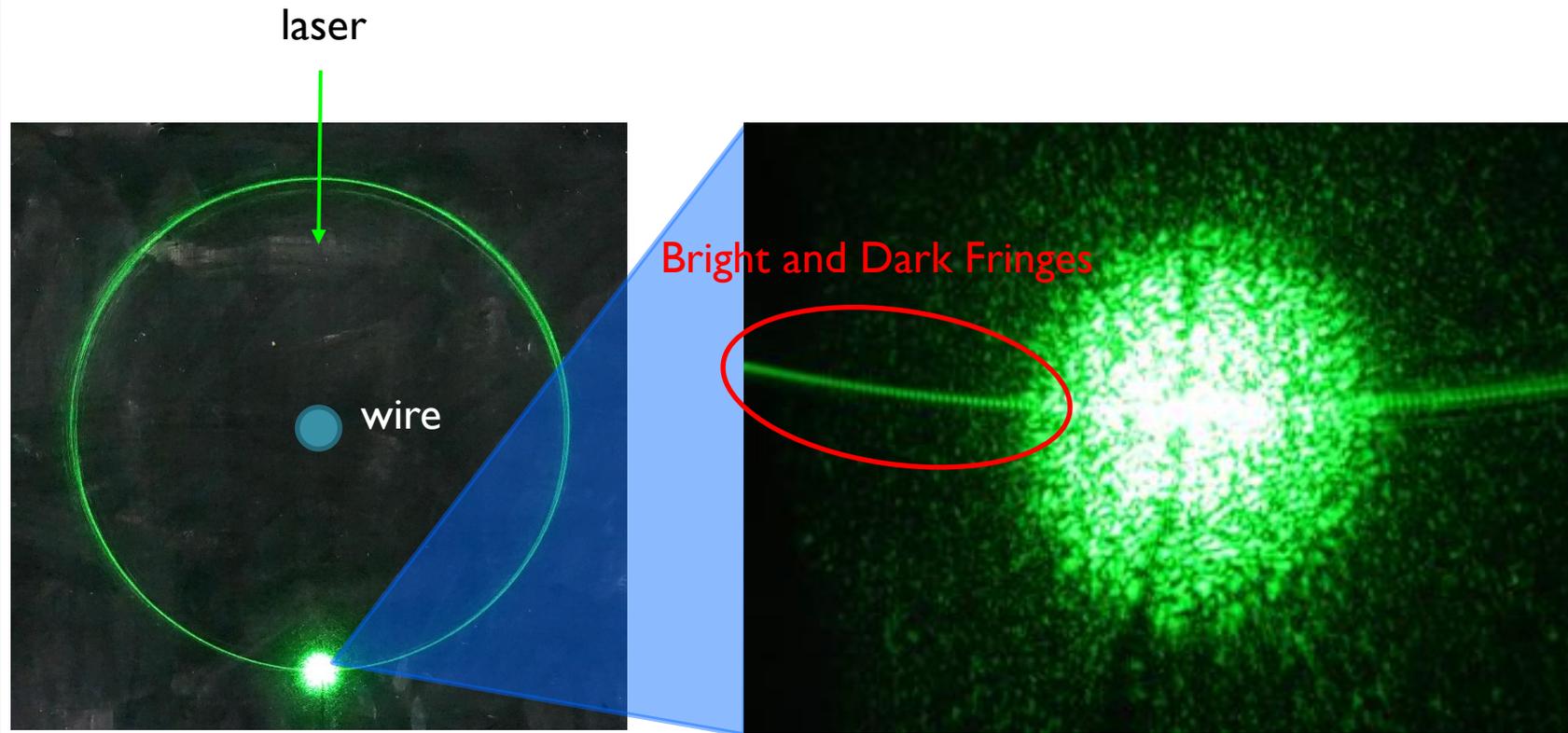
Outline

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Phenomena

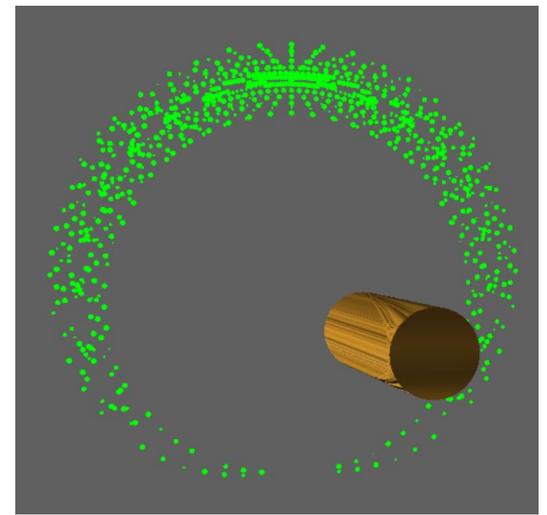
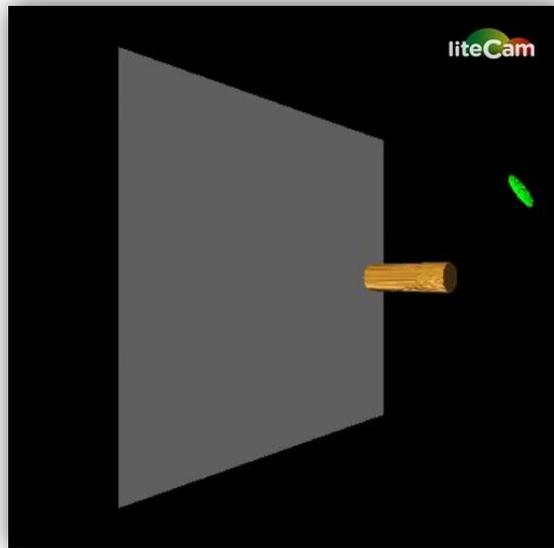
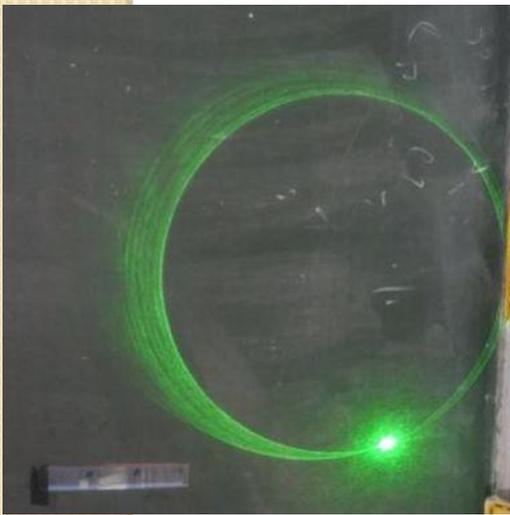


Phenomena

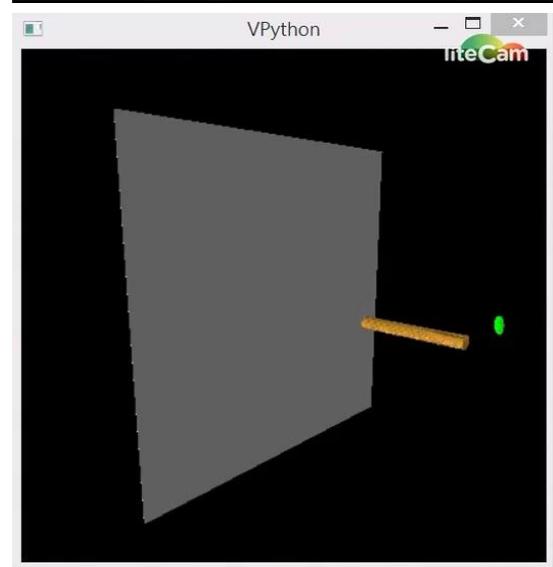
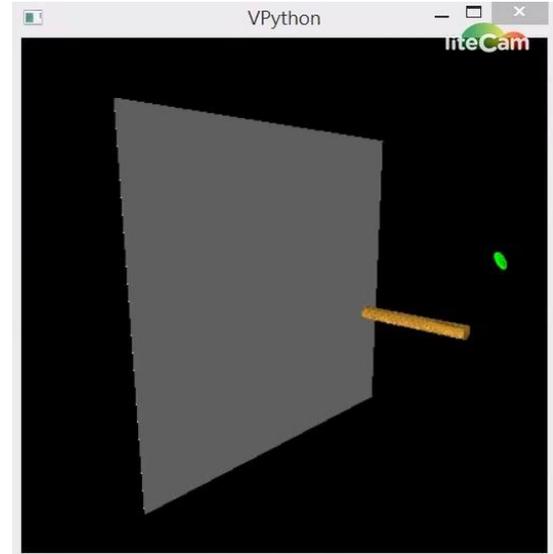
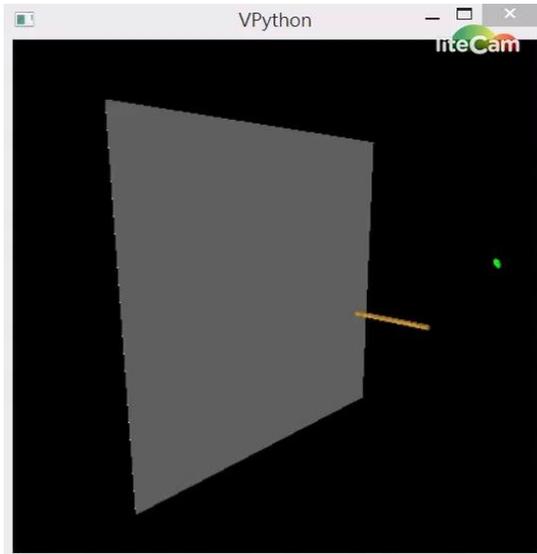


Conclusion

- The simulation we made verified our reflection model

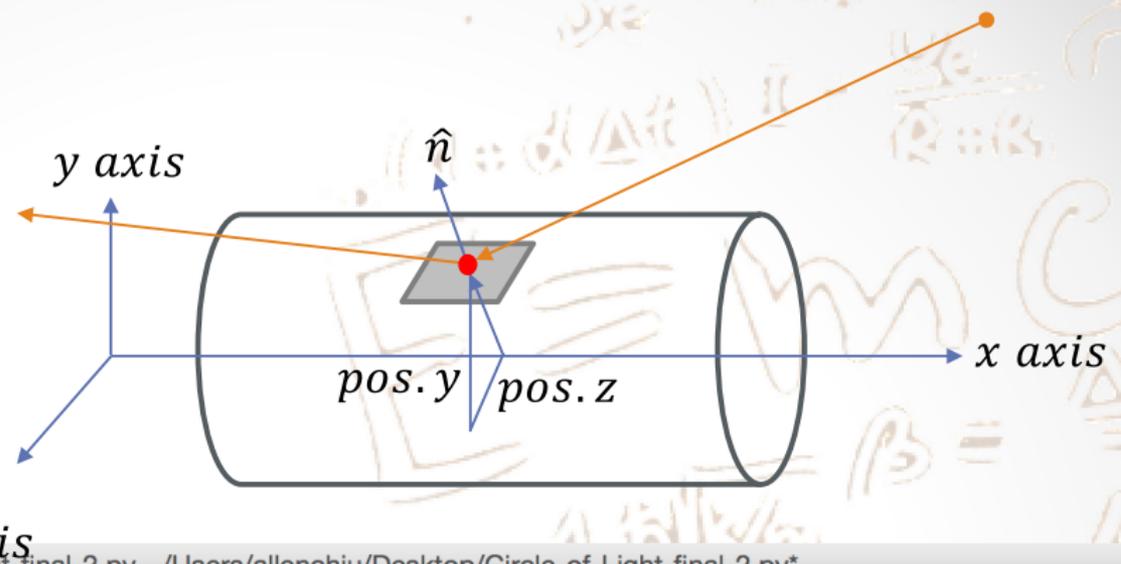


Thickness of Circle





Code



Circle-of-Light-final-2.py - /Users/allenchiu/Desktop/Circle-of-Light-final-2.py

```
def reflection(v,ballpos):
    n=vector(0,ballpos.y,ballpos.z)
    a=-dot(v,n)/(mag(n))*norm(n)
    v_prime=v+2*a
    v=v_prime
    return (v)
```

Reflection Function

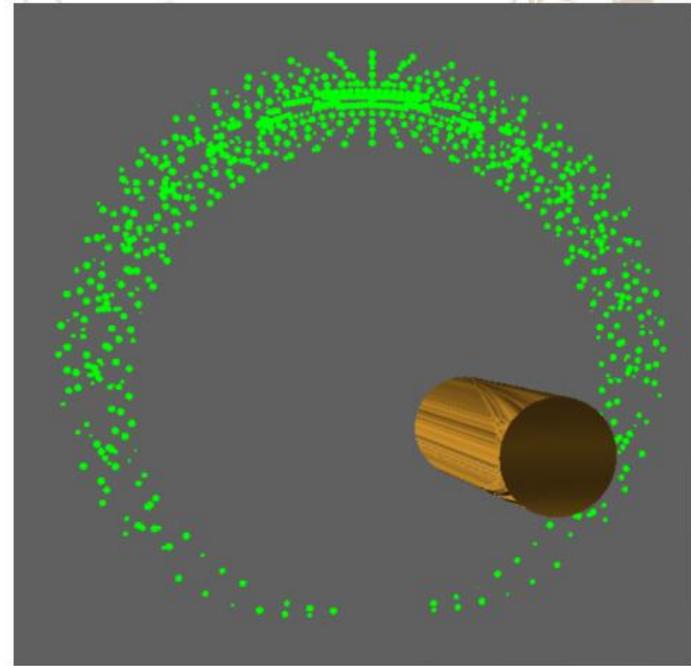
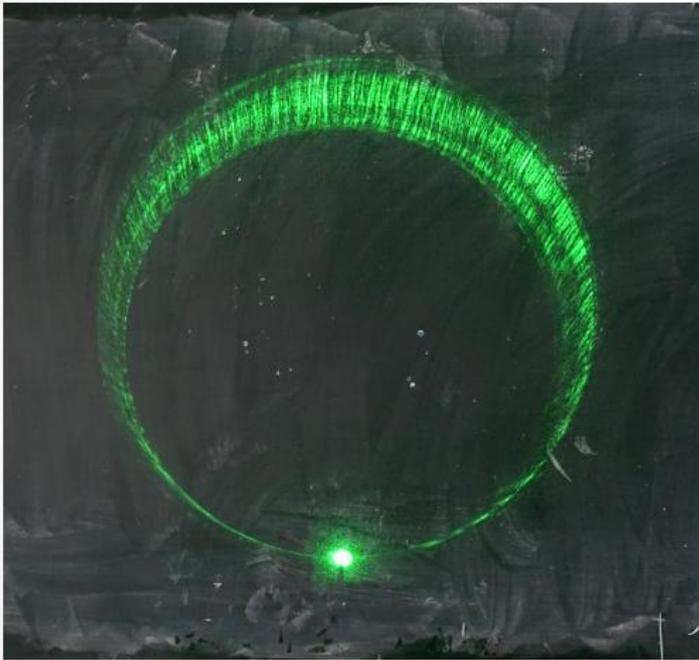
```
while 1:
    rate(1000)
    for i in range(1100):
        ball[i].pos=ball[i].pos+ballv[i]*dt
        if ball[i].pos.y**2+ball[i].pos.z**2<r**2:
            (ballv[i])=reflection(ballv[i],ball[i].pos)
        if ball[i].pos.x<=0:
            ballv[i].x=0
            ballv[i].y=0
            ballv[i].z=0
```

Motion of Laser beam

Ln: 49 Col: 24



Comparison



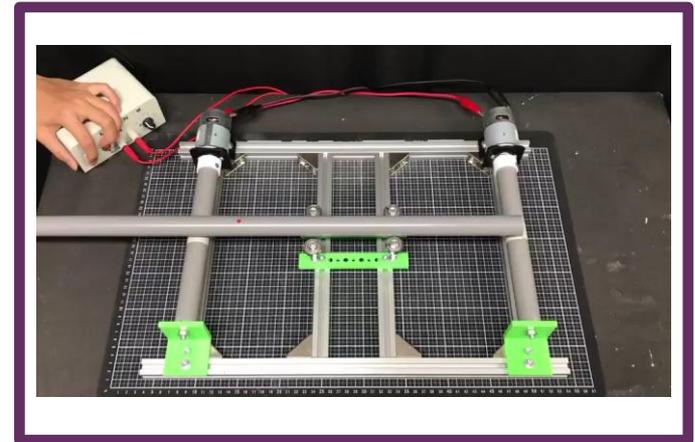
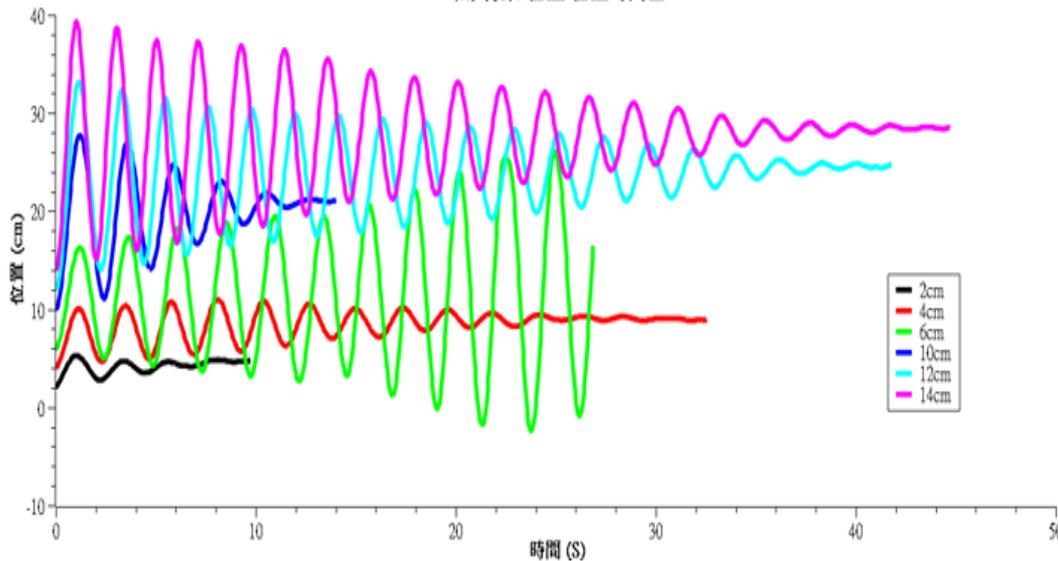
$E = mc^2$
 $F = ma$
 $F = \frac{d}{dt} \Delta \Pi$
 $\Delta \Pi = \frac{d}{dt} \Delta \Pi$
2



2

Initial position ($\mu_k = 0.191129$)

相異初始位置-位置時間圖



$$\mu_k = 0.191129$$

接觸面 A	接觸面 B	接觸面 C	接觸面 D	接觸面 E
0.191129	0.256593	0.262935	0.333484	0.351752

Wine Glass

1 Frequency of an empty wine glass

$$f_0 = \frac{1}{2\pi} \left(\frac{3Y}{5\rho_s} \right)^{1/2} \frac{a}{R^2} \left[1 + \frac{4}{3} \left(\frac{R}{H_0} \right)^4 \right]^{1/2}$$



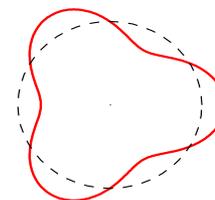
2 Frequency of a partially filled wine glass

$$\left(\frac{f_0}{f_h} \right)^2 = 1 + \frac{\alpha \rho_l R}{5 \rho_g a} \left(\frac{h}{H} \right)^5$$

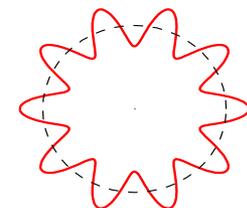
3 Frequency of higher harmonics

$$f(n) = \frac{1}{12\pi} \left(\frac{3Y}{\rho_g} \right)^{1/2} \frac{a}{R^2} \left[\frac{(n^2 - 1)^2 + \left(\frac{R}{H} \right)^4}{1 + 1/n^2} \right]^{1/2}$$

n=3



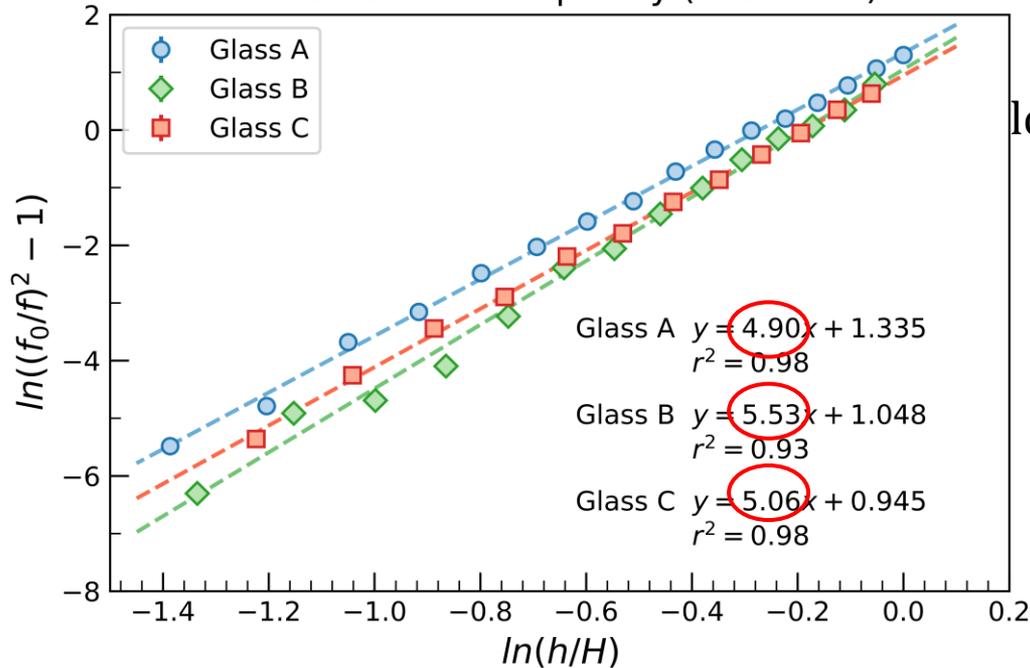
n=10



Parameter: Amount of water

Discussion

water level vs frequency (linearized)



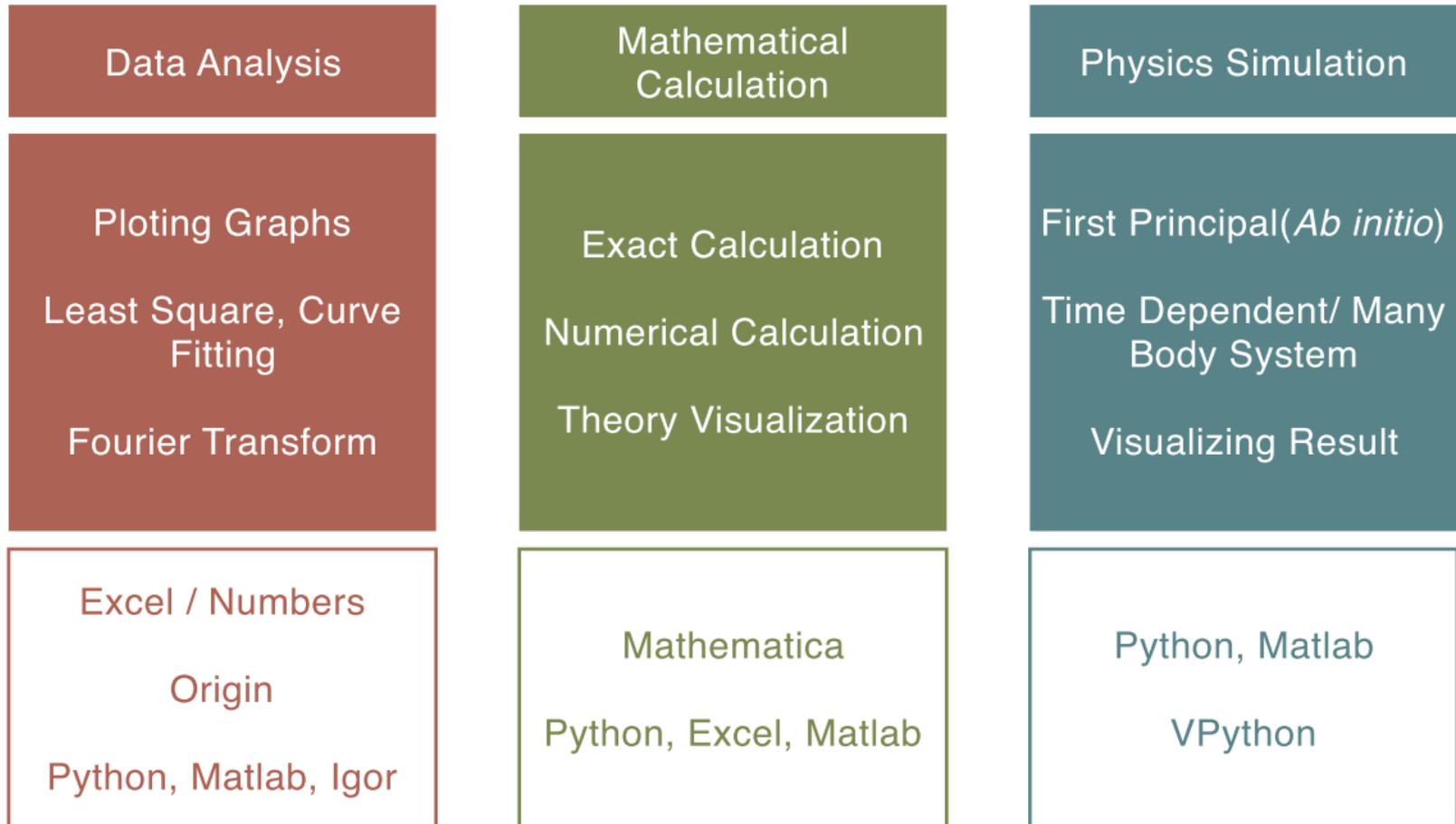
$$\log \left[\left(\frac{f_0}{f_H} \right)^2 - 1 \right] \propto 4.9 \log \left(\frac{h}{H} \right) + const.$$

$$\Rightarrow \left(\frac{f_0}{f_h} \right)^2 = 1 + \frac{\alpha \rho_l R}{5 \rho_g a} \left(\frac{h}{H} \right)^5$$

Our theoretical prediction had a not-bad correspondence with the experiment.

Possible errors might come from:

The role of Programming



The role of Programming

Data Analysis

Plotting Graphs

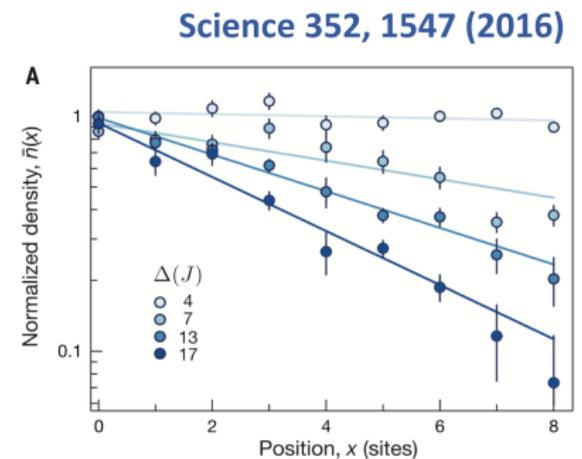
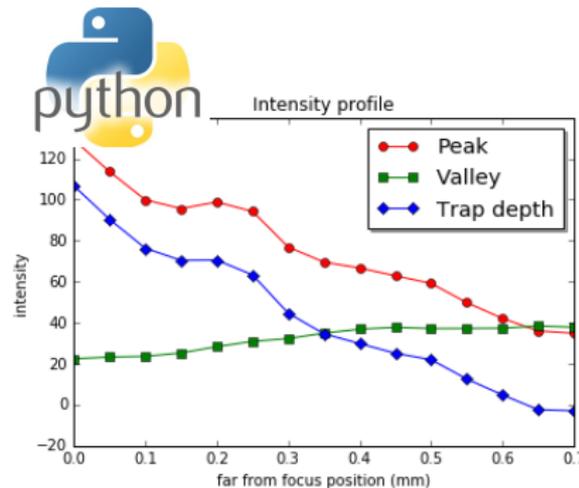
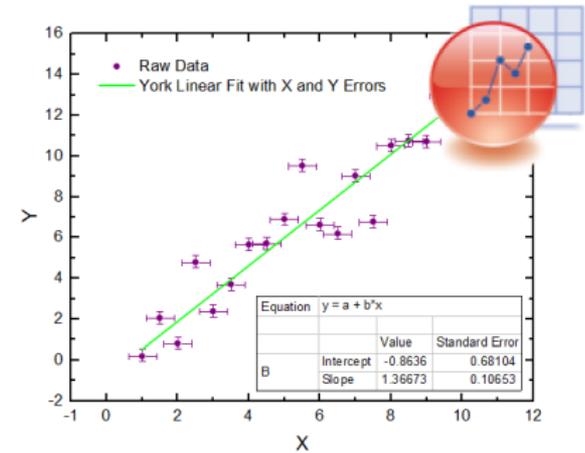
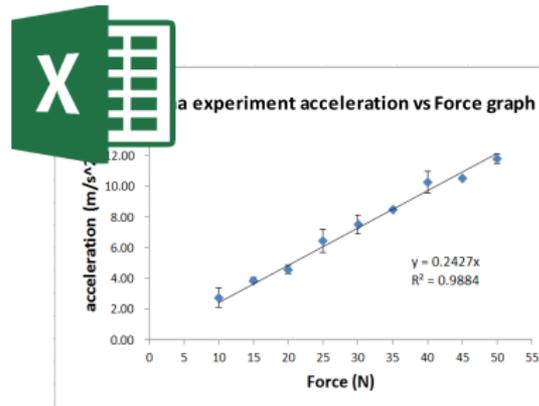
Least Square, Curve Fitting

Fourier Transform

Excel / Numbers

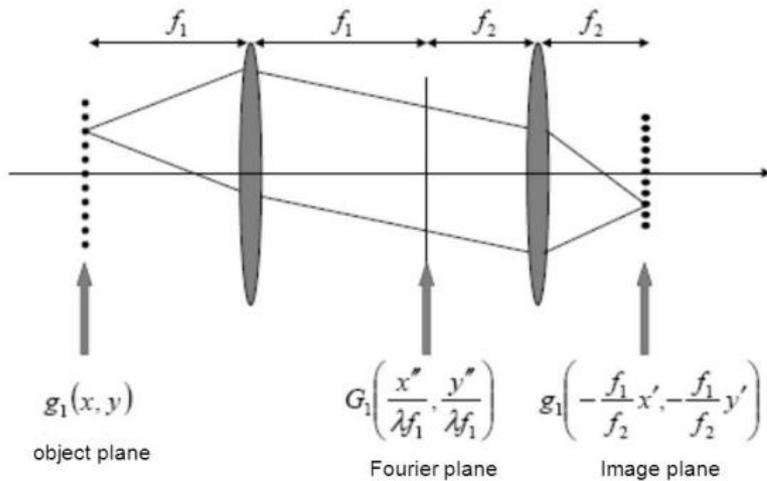
Origin

Python, Matlab, Igor

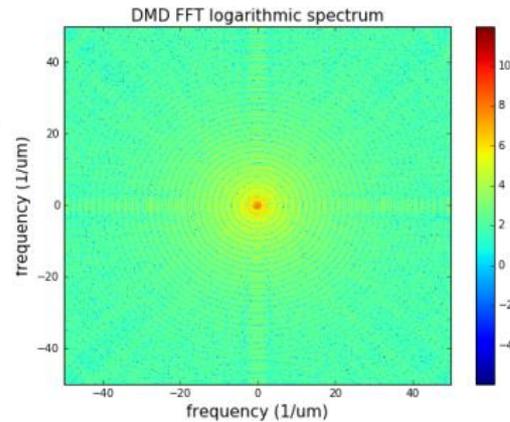


From Neng-Ching Chiu

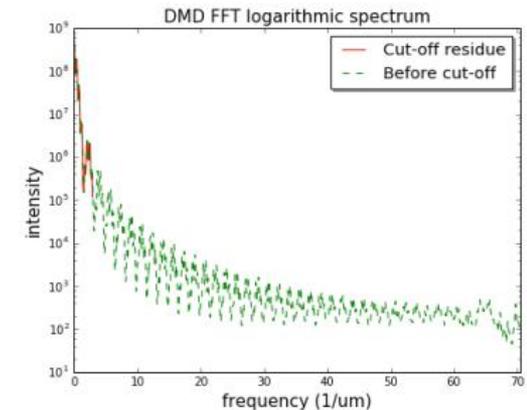
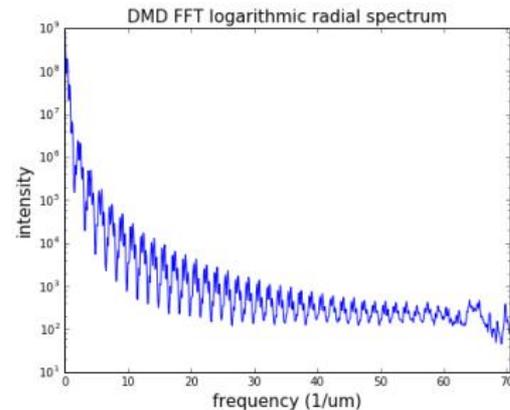
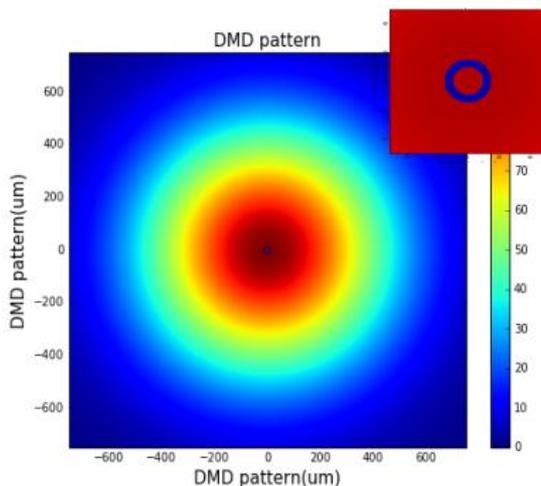
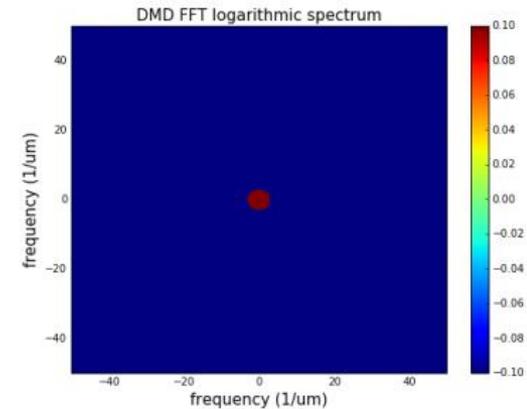
2D Fourier Transform with Python



1. Fourier plane image



2. Iris cut-off



Mathematica



Wolfram
Mathematica

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help 100% 週三 下午3:08

3-level, detuning= $\Delta 0$, quadratic shift $q 0$, absolute value of $q 0 = (1/8) * 575 \text{ Hz} / G^2 * B^2$

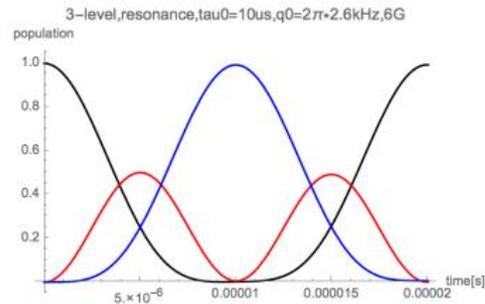
in absolute time scale: Ωabs

```

tau0 := 10 * 10-6 (*flopping period of mf=0 state, unit [s]*)
Omegaabs := 2 * Pi *  $\frac{1}{\text{tau0}}$  *  $\frac{1}{\sqrt{2}}$  (*absolute value of Rabi frequency=104 Hz, frequency unit*)
B0 := 6 (*unit [G]*)
q0 := 2 * Pi * 1 / 8 * 575 * B02
Delta0 := q0

endtime := 2 * tau0
solthree[Delta, q] :=
  NDSolve[(I * c1'[t] == (-Delta + q) * c1[t] + Omegaabs / 2 * c2[t] + 0 * c3[t], I * c2'[t] == Omegaabs / 2 * c1[t] + (0) * c2[t] + Omegaabs / 2 * c3[t],
I * c3'[t] == 0 * c1[t] + Omegaabs / 2 * c2[t] + (Delta + q) * c3[t], c1[0] == 1, c2[0] == 0, c3[0] == 0), {c1[t], c2[t], c3[t]}, {t, 0, endtime}, MaxSteps -> 5000]
R1three[x_, Delta_, q_] := Abs[Evaluate[c1[t] /. solthree[Delta, q] /. t -> x]2
R2three[x_, Delta_, q_] := Abs[Evaluate[c2[t] /. solthree[Delta, q] /. t -> x]2
R3three[x_, Delta_, q_] := Abs[Evaluate[c3[t] /. solthree[Delta, q] /. t -> x]2

Plot[(R1three[y_, Delta0_, q0], R2three[y_, Delta0_, q0], R3three[y_, Delta0_, q0]), {y, 0, endtime}, PlotStyle -> {Black, Red, Blue},
AxesLabel -> {"time[s]", "population"}, PlotLabel -> "3-level, resonance, tau0=10us, q0=2pi*2.6kHz, 6G"
  
```



```

tau0 := 400 * 10-6 (*flopping period of mf=0 state, unit [s]*)
Omegaabs := 2 * Pi *  $\frac{1}{\text{tau0}}$  *  $\frac{1}{\sqrt{2}}$  (*absolute value of Rabi frequency=104 Hz, frequency unit*)
B0 := 5 (*unit [G]*)
q0 := 2 * Pi * 1 / 8 * 575 * B02
Delta0 := q0
  
```

Symbolic Calculation

Theoretical Visualization

Problem Statement

Take two similar paperback books and **interleave a few pages** at a time. Push the books together. Hold the two books by their spines and try to pull them apart.

Investigate the **parameters** that **set the limits of being able to separate the books**.

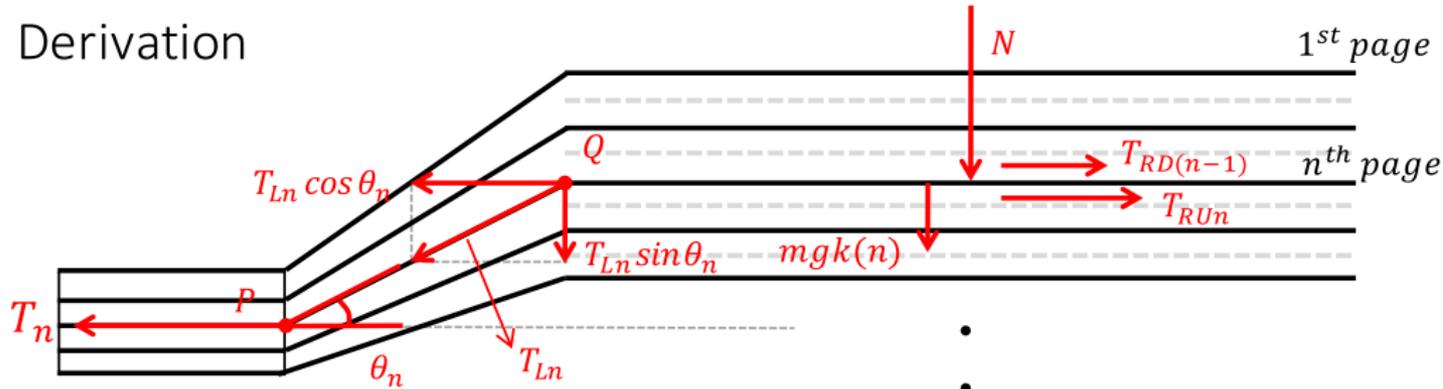


From Neng-Ching Chiu

(Image from Reference Kit)

Horizontal Model

- Derivation



Here, we get a recursive relationship:

$$T_{Ln} = \frac{2T_{RD(n-1)} + \mu mgk}{(1 - \mu \tan \theta_n) \cos \theta_n}, n > 1 \quad T_{L1} = \mu mgk, T_{RD0} = 0$$

$$T_{RD(n-1)} = \frac{(T_{L(n-1)} \cos \theta_n - T_{RD(n-2)})(1 + \mu \tan \theta_{(n-1)}) + \mu mgk}{1 - \mu \tan \theta_{(n-1)}}, n > 1$$

the force required to pull apart: $T_n = T_{RD(n-1)} + T_{RUn}$, $T_{total} = \sum_{n=1}^a T_n$

Parameter #1 The Number of Pages (Horizontal Model)

- Data graph

Static coefficient of friction: $\mu = 0.48 \pm 0.03$

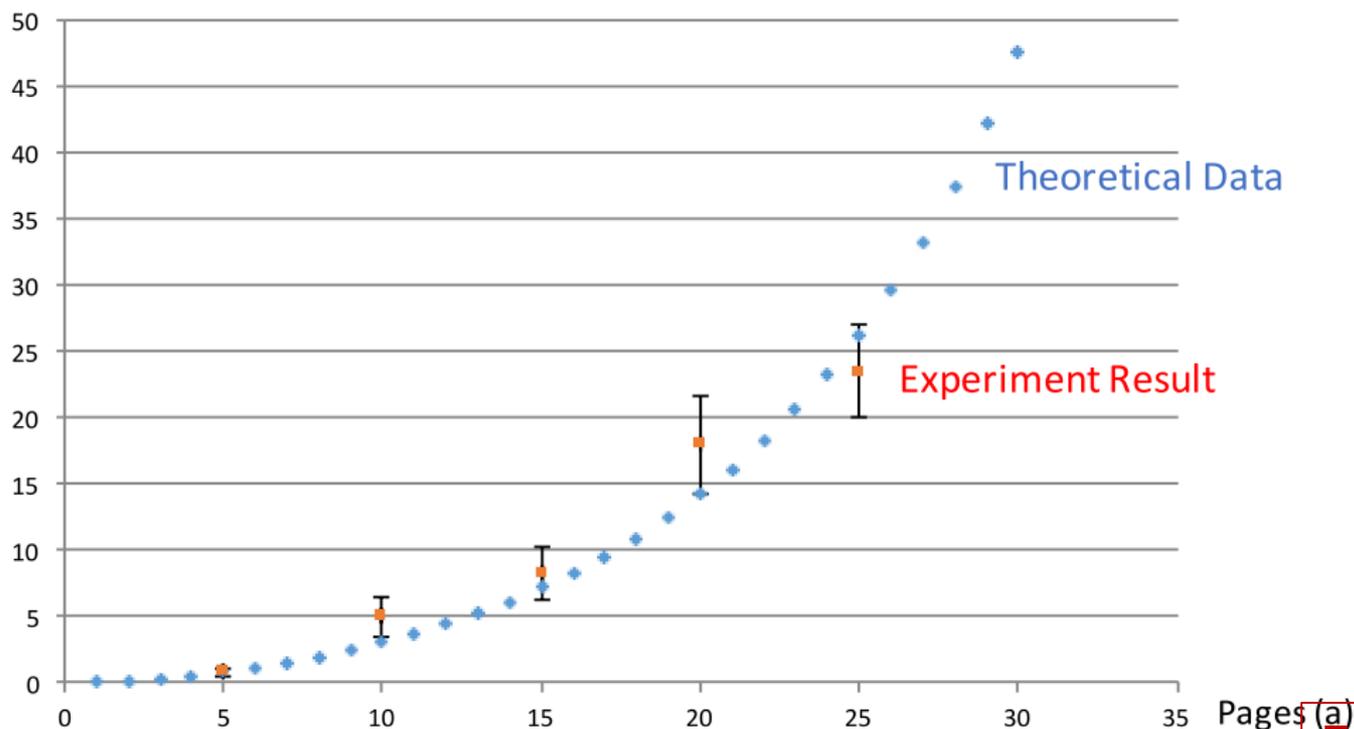
Thickness per page: $\tau = 0.012 \pm 0.001$ (cm)

Length of the book: $L = 18.30 \pm 0.05$ (cm)

Length interleaved inside: $x = 9.05 \pm 0.05$ (cm)

Weight per page: $mg = 3.5 \pm 0.1$ (g)

Force (N)

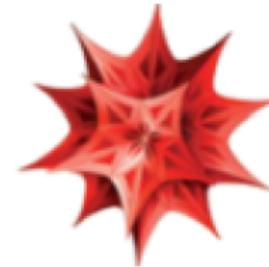


Acoustic field of the FZP

- The intensity is thus the square of the complex amplitude

$$U(O) = \left(\frac{2\pi U(S)\rho_0}{2ik} \right) \left(\frac{e^{i2k\rho_0}}{\rho_0^2} \right) (e^{ika^2/\rho_0} - 1) + \left(\frac{U(S)2\pi\rho_0}{2ik} \right) \left(\frac{-e^{(ik\sqrt{a^2+\rho_0^2})}}{a^2 + \rho_0^2} \right) - \frac{U(S)e^{ikr}}{r}$$

$$\Rightarrow I(O) = U^*(O)U(O)$$



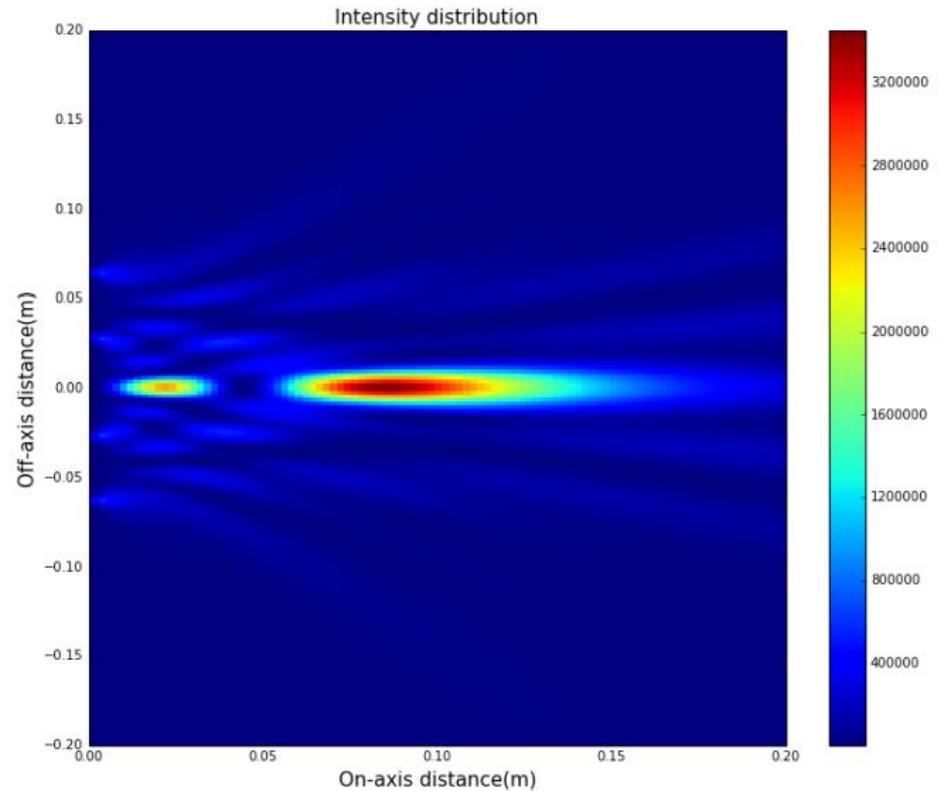
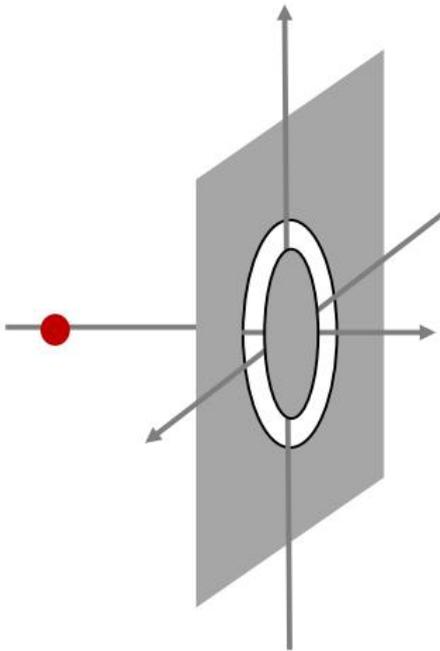
Wolfram
Mathematica

We sort mathematica for further computation

$$\begin{aligned} & \text{Expand} \left[\left(-i e^{2ik\rho} \left(-1 + e^{\frac{2ia^2k}{\rho}} \right) m - \frac{A e^{ik\rho}}{\rho} + \frac{i A e^{ik\sqrt{a^2+\rho^2}} \pi \rho}{k (a^2 + \rho^2)} \right) \left(i e^{-2i[k\rho]} \left(-1 + e^{-\frac{2ia^2k}{\rho}} \right) m - \frac{A e^{-ik\rho}}{\rho} - \frac{i A e^{-i[k\sqrt{a^2+\rho^2}]} \pi \rho}{k (a^2 + \rho^2)} \right) \right] \\ \ln[1]= & \text{KK} = \text{Re} \left[2 e^{2ik\rho-2i[k\rho]} m^2 - e^{-\frac{2ia^2k}{\rho}+2ik\rho-2i[k\rho]} m^2 - e^{\frac{2ia^2k}{\rho}+2ik\rho-2i[k\rho]} m^2 + \frac{A^2}{\rho^2} - \frac{i A e^{ik\rho} m}{\rho} + \frac{i A e^{\frac{2ia^2k}{\rho}+ik\rho} m}{\rho} + \right. \\ & \frac{i A e^{ik\rho-2i[k\rho]} m}{\rho} - \frac{i A e^{-\frac{2ia^2k}{\rho}+ik\rho-2i[k\rho]} m}{\rho} + \frac{A^2 e^{ik\sqrt{a^2+\rho^2}-i[k\sqrt{a^2+\rho^2}]} \pi^2 \rho^2}{k^2 (a^2 + \rho^2)^2} - \frac{i A^2 e^{-ik\rho+ik\sqrt{a^2+\rho^2}} \pi}{k (a^2 + \rho^2)} + \\ & \frac{i A^2 e^{ik\rho-i[k\sqrt{a^2+\rho^2}]} \pi}{k (a^2 + \rho^2)} + \frac{A e^{ik\sqrt{a^2+\rho^2}-2i[k\rho]} m \pi \rho}{k (a^2 + \rho^2)} - \frac{A e^{-\frac{2ia^2k}{\rho}+ik\sqrt{a^2+\rho^2}-2i[k\rho]} m \pi \rho}{k (a^2 + \rho^2)} + \frac{A e^{2ik\rho-i[k\sqrt{a^2+\rho^2}]} m \pi \rho}{k (a^2 + \rho^2)} - \\ & \left. \frac{A e^{\frac{2ia^2k}{\rho}+2ik\rho-i[k\sqrt{a^2+\rho^2}]} m \pi \rho}{k (a^2 + \rho^2)} \right]; \end{aligned}$$

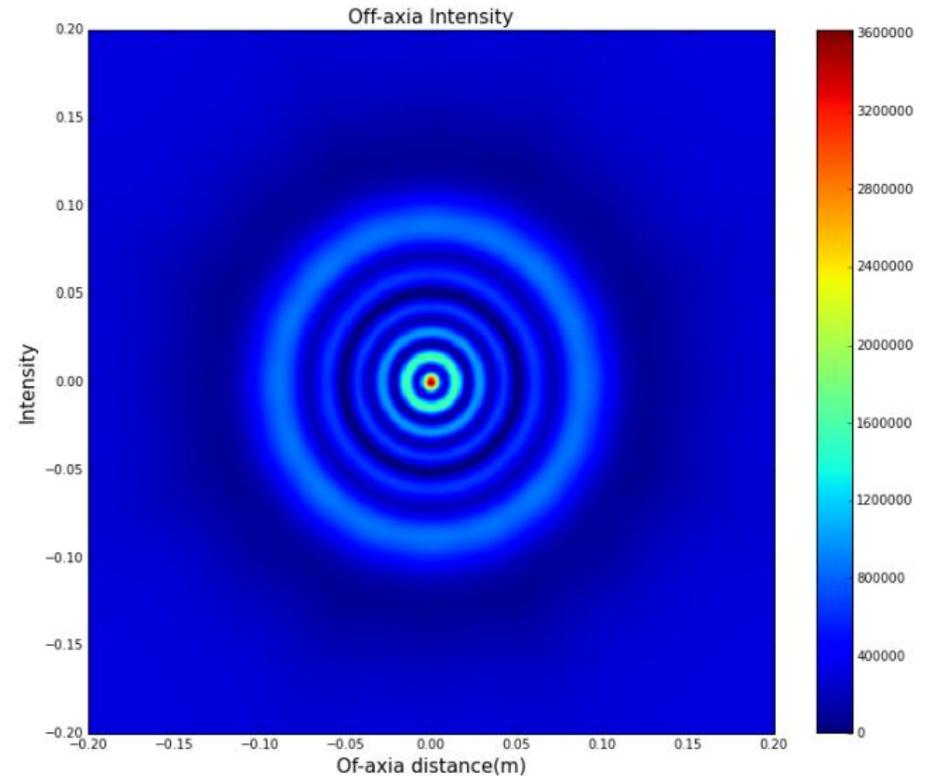
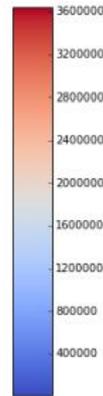
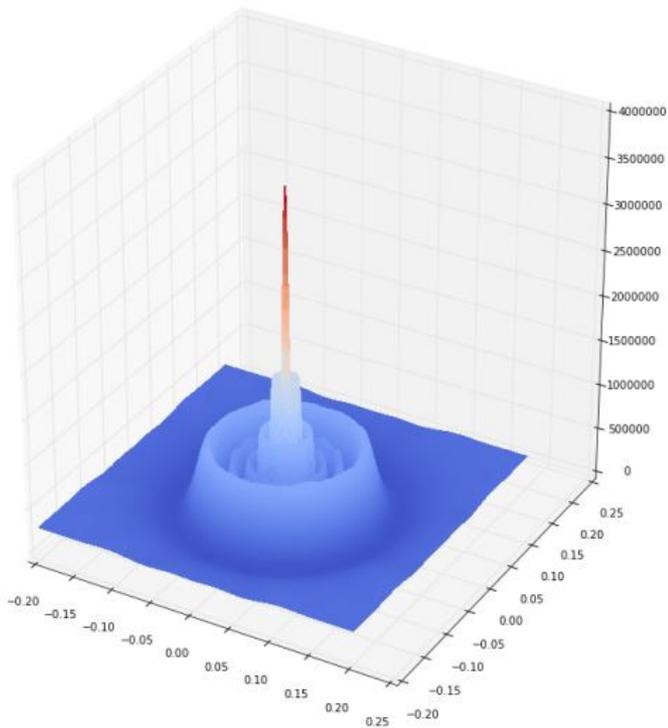
Numerical Calculations

- Intensity distribution

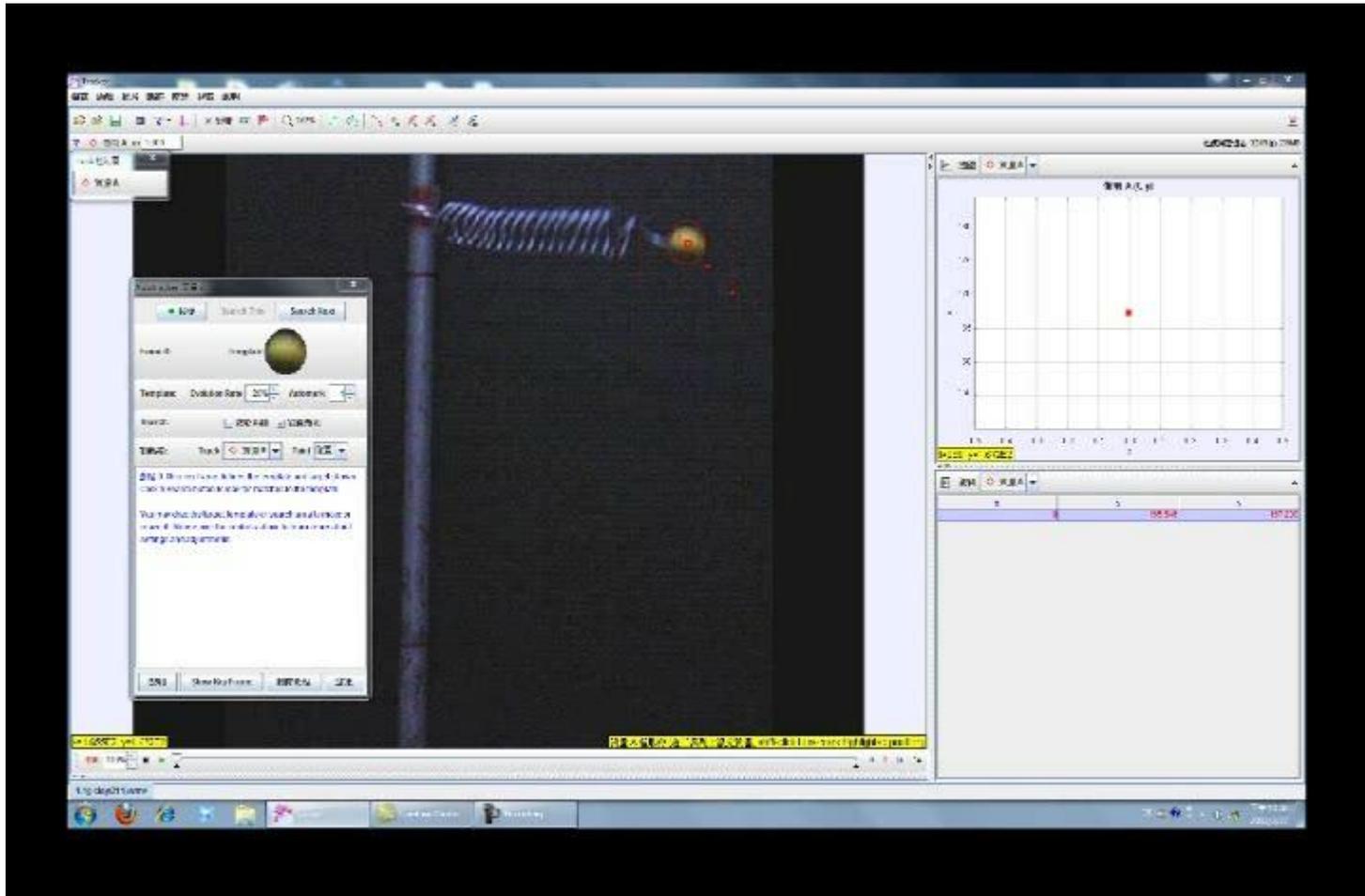


Numerical Calculations

- Off-axis cross section intensity



Tracker



聲音分析

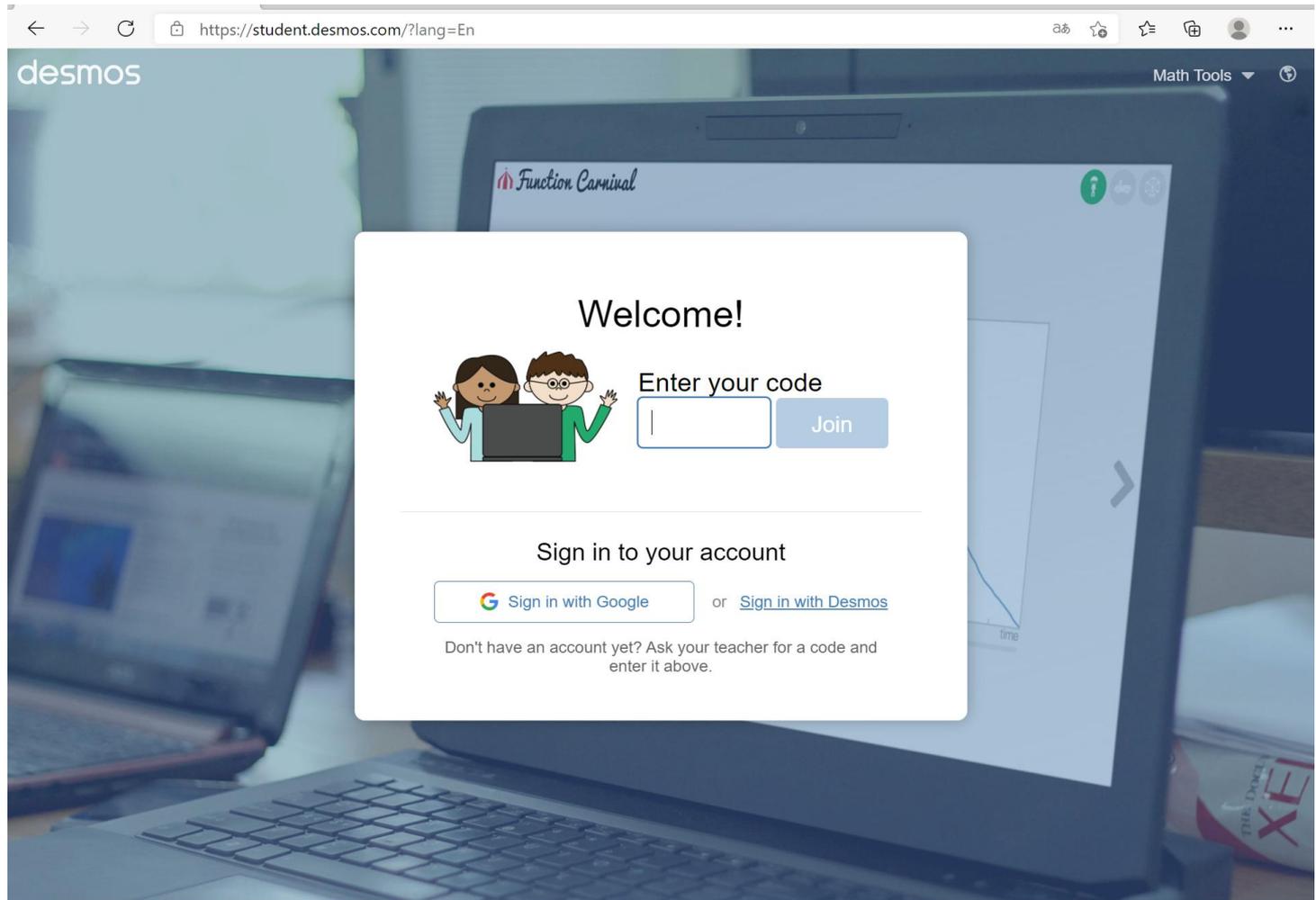


Outline

- Warm-up activity
- Digital measurement
- Data analysis
- Some demonstrations
- **Scientific modeling**

<http://student.desmos.com>

code: QQK853



Try it !

student.desmos.com/activitybuilder/student/601071b51f78cbab0d968962?lang=en#screenIdx=2

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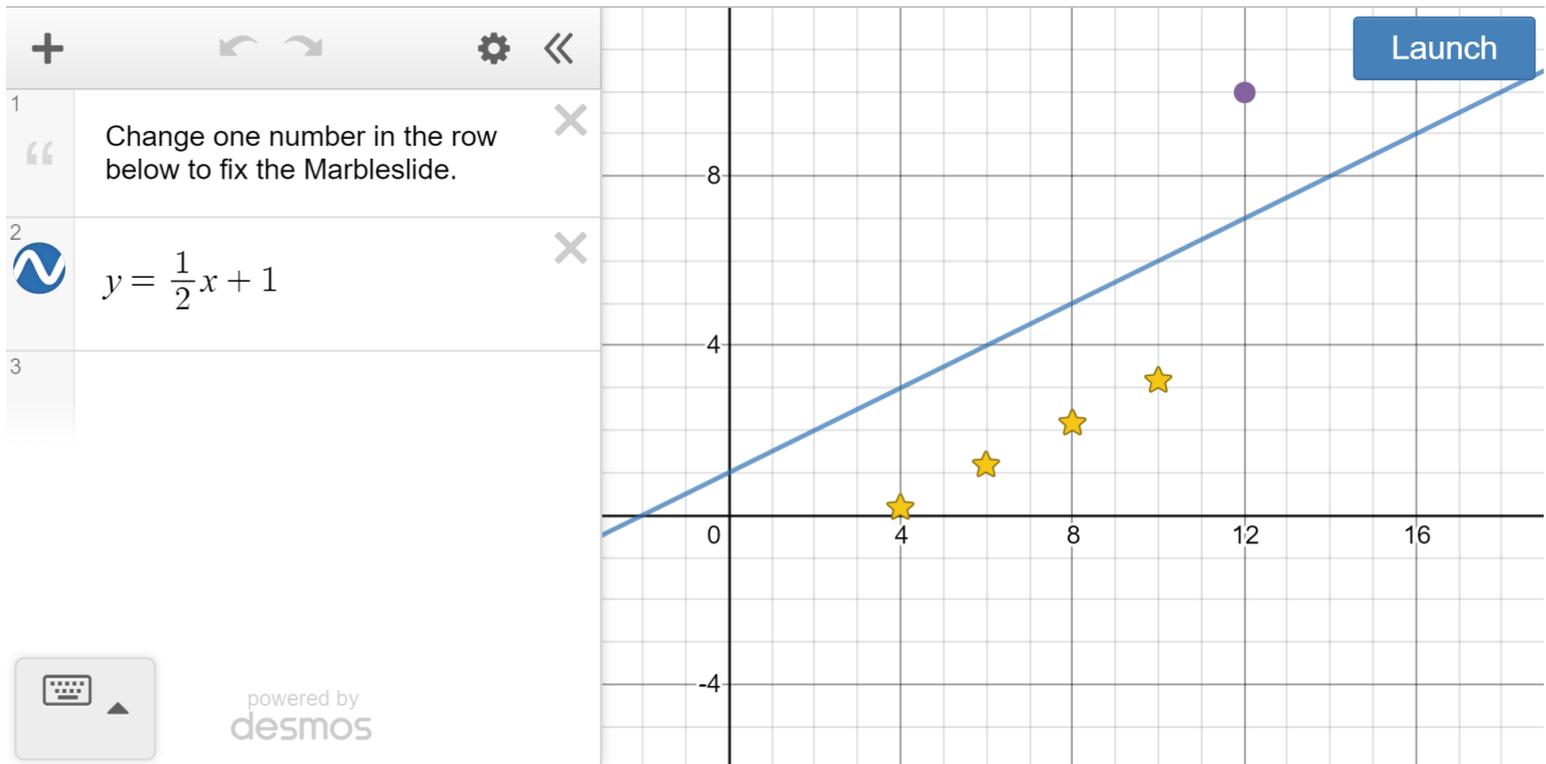
Marbleslides: Lines

Addie Lu

2 of 24

Next

Fix It #1



Thank you for your listening!!

