

Virtual Experiments and Differential Equations Models

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City University of New York

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Baltimore

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Virtual experiments and Differential Equations

Computer simulations,
or
videos or photos of an actual physical
experiment,
from which data can be culled
and
which can be modeled using differential
equations.

Why teach modeling in a Diff Eq class?

1. Most of my students are interested in applications, engineering, and science.
2. Modeling gives math physical meaning.
3. Joy of Discovery. Enthusiasm. Creative Thinking. Fun.

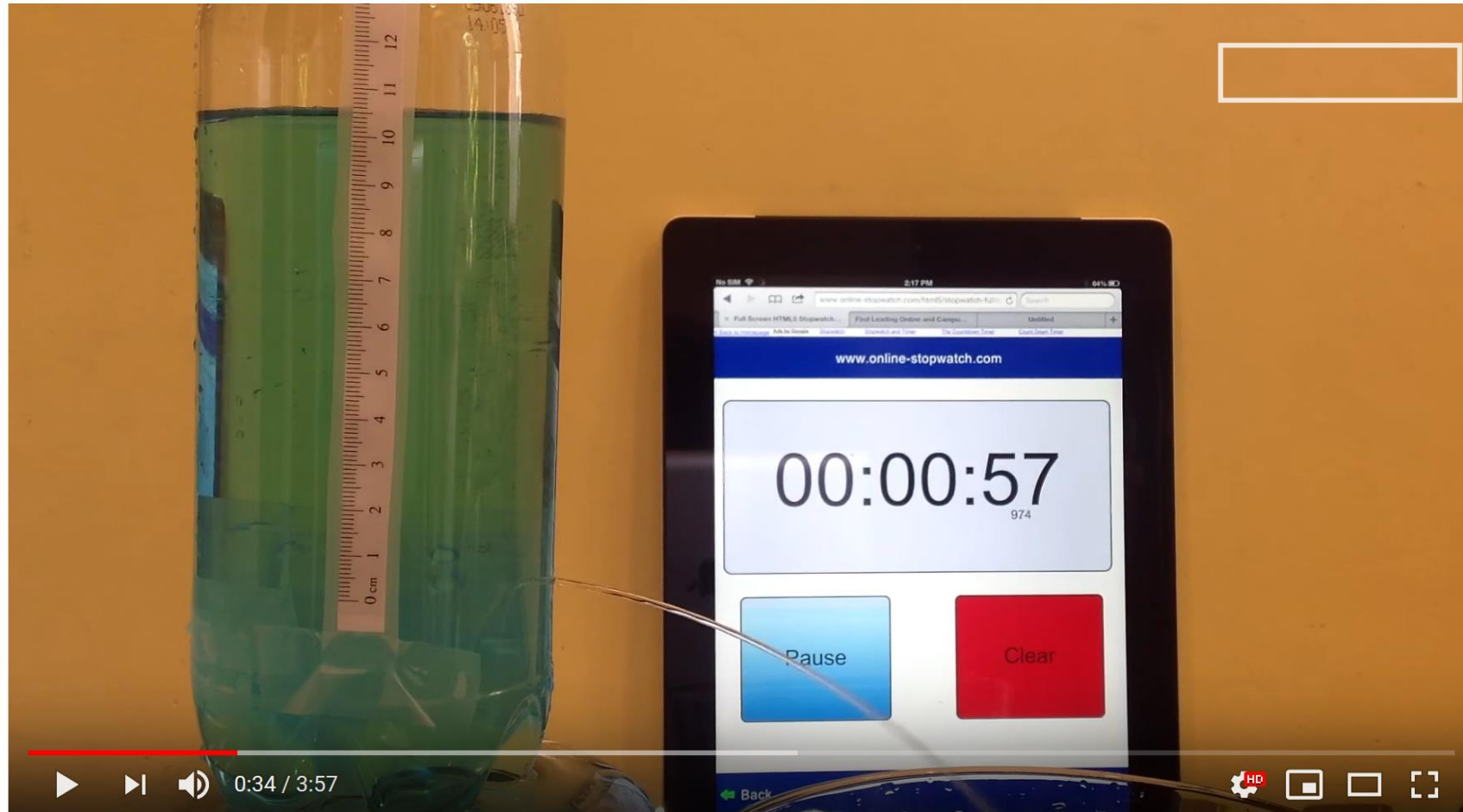
Why Virtual Experiments?

1. Quicker than real experiments.
2. Not messy. No lab needed.
3. Makes the modeling even more real. More thinking.
4. Students learn about data analysis and parameter estimation in the context of diff eq models.

Sources for Virtual Experiments

WWW.SIMIODE.ORG

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INITIATIVE FOR
SIMIODE
MODELING
INVESTIGATIONS &
WITH OPPORTUNITIES
DIFFERENTIAL
EQUATIONS



SIMIODE Torricelli's Law 50over64 Inch Diameter Small Hole Collection Video

Brian Winkel (2017),
1-073-S-Water Exit
Bottle,

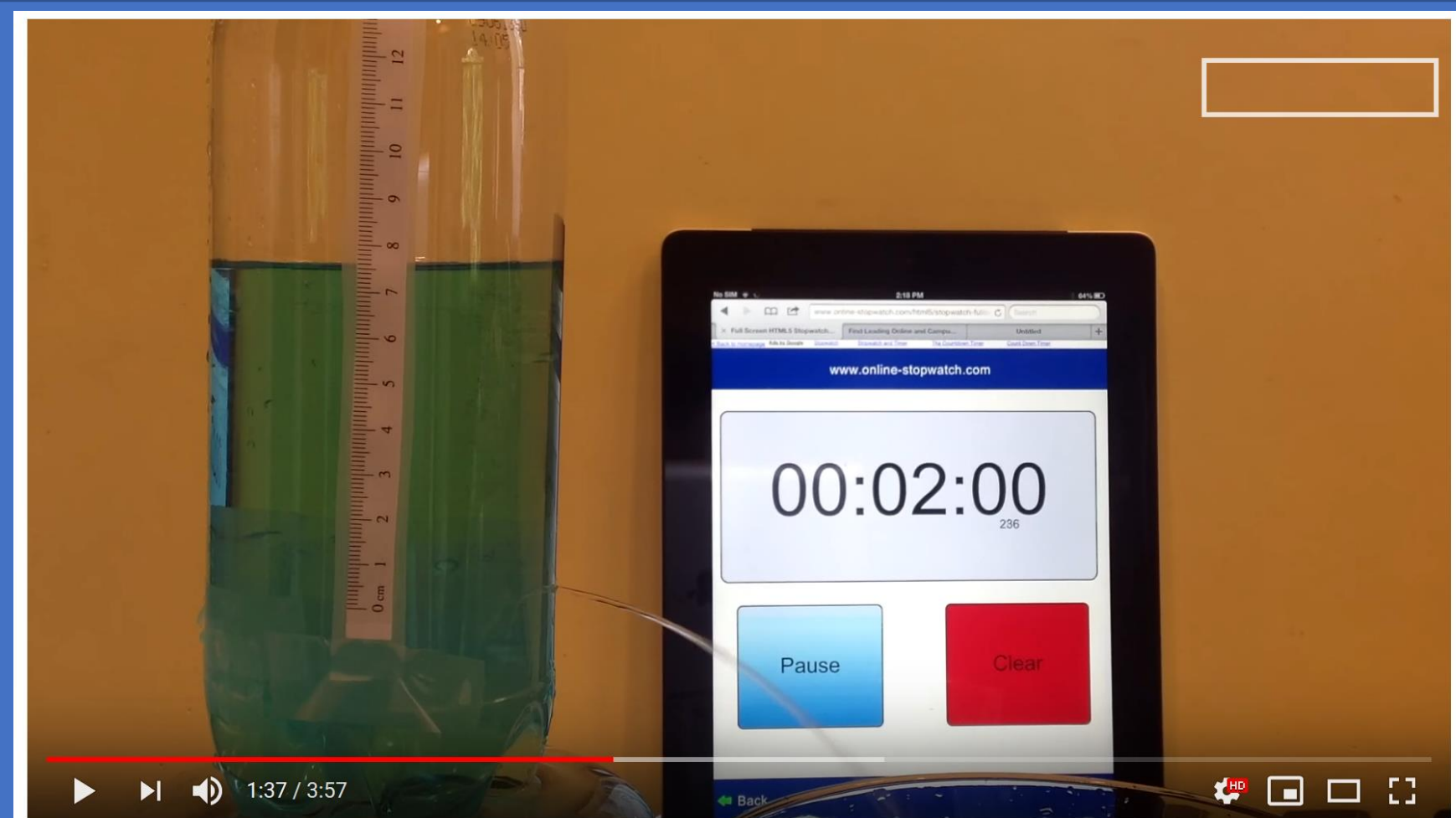
<https://www.simiode.org/resources/3507>

(Torricelli's Law)

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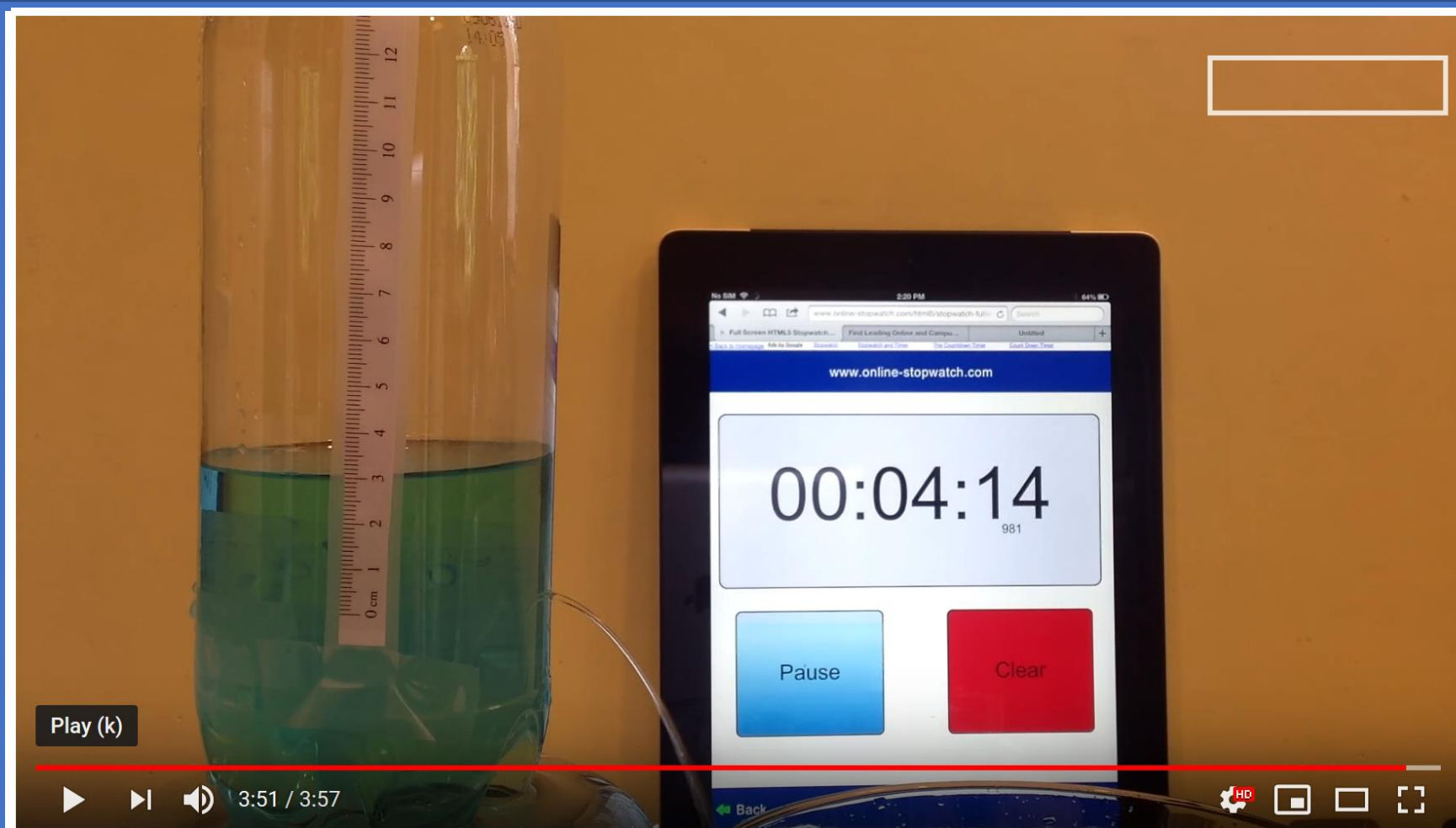
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(Torricelli's Law)

Sources for Virtual Experiments University of Reading (England)

Virtual Experiments
AT THE UNIVERSITY OF READING



https://www.reading.ac.uk/virtualexperiments/index.html

170%



Virtual Experiments
AT THE UNIVERSITY OF READING

Home

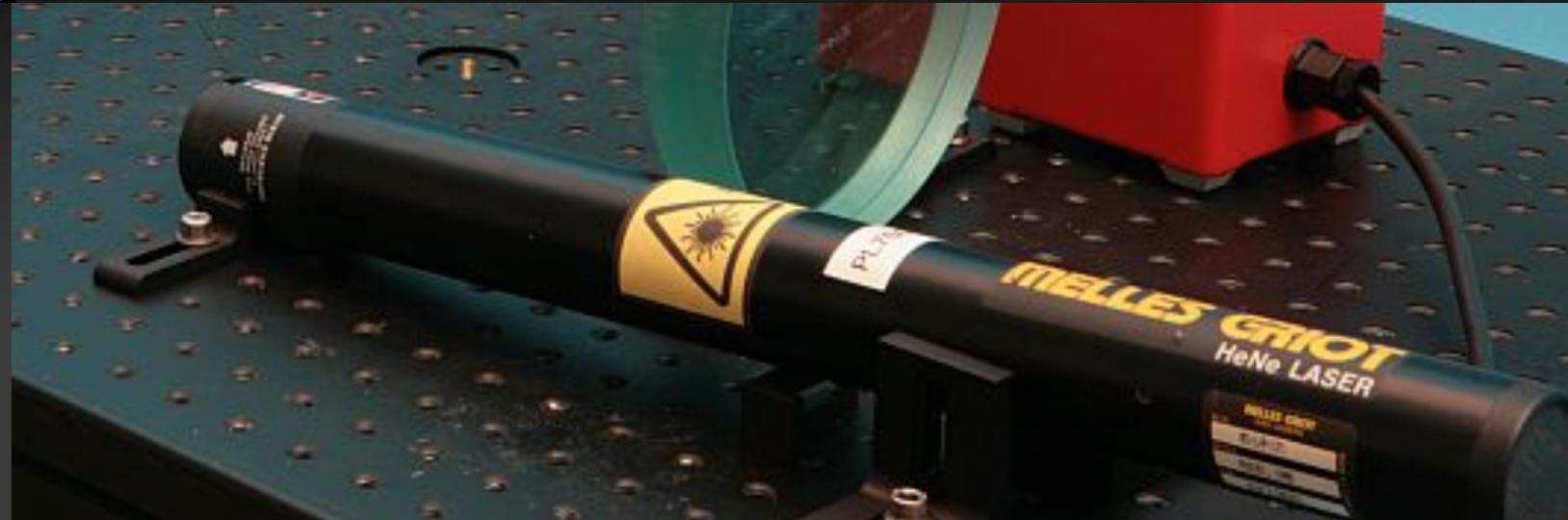
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*“Adding real educational
value to the science lab ”*



News & Updates

Welcome to the world of Virtual Experiments

Sources for Virtual Experiments University of Reading (England)

Virtual Experiments
AT THE UNIVERSITY OF READING

The screenshot shows a virtual experiment interface for observing the growth of *Gibberella zeae*. The main view is a circular petri dish containing a petri agar medium with a small, white, fuzzy fungal colony in the center. A ruler is placed over the dish for scale. To the right of the dish, the text "*Gibberella zeae*" is displayed. Below the name, there are two digital displays: "Temperature: 29.0" and "Time: 10:10". At the bottom of the interface is a timeline slider with markers at 0, 24, 48, 72, and 96 hours. The slider is currently set to 24 hours. Below the slider are navigation buttons for back, forward, and play. At the bottom right, there are two buttons: "Ruler" and "Choose Fungus". The University of Reading logo and name are also present at the bottom right. At the bottom center, it says "In partnership with Syngenta".

Virtual
Experiment:

Fungus growth.

U of Reading, UK.

Sources for Virtual Experiments University of Reading (England)

Virtual Experiments
AT THE UNIVERSITY OF READING

The screenshot shows a virtual experiment interface for observing the growth of *Gibberella zeae* fungus. The main view is a petri dish containing a circular agar plate with a white, fuzzy fungal growth in the center. A ruler is placed over the growth for scale. To the right of the petri dish, the text "Gibberella zeae" is displayed. Below this, a digital temperature display shows "29.5" with a degree Celsius symbol. Underneath the temperature, a digital clock shows "Time:" followed by a circular clock face with hands pointing to approximately 1:50. At the bottom of the interface, a horizontal timeline slider is visible, with markers for "0 hours", "24 hours", "48 hours", "72 hours", and "96 hours". The slider is currently positioned at 72 hours. Below the slider are navigation controls: a play button, a pause button, and a seek bar with left and right arrows. In the bottom right corner, there are two buttons: "Ruler" and "Choose Fungus". At the very bottom, the text "In partnership with Syngenta" is visible on the left, and the "University of Reading" logo and name are on the right.

Virtual
Experiment:

Fungus growth.

U of Reading, UK.

Sources for Virtual Experiments



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K-12

Virtual Experiments

Virtual Experiments

[Creep Experiment](#)

[Tensile Test Experiment](#)

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Experiments

Mechanical Behavior

[Creep](#)

[Tensile](#)

Sources for Virtual Experiments

NetLogo Simulation & Programming Environment

NetLogo is Free

GDDBH6 - NetLogo {C:\Users\chris\Desktop\sync\Fall 2018 WI\Honors JMM Poster CRSP\CRSP 20... - □ ×

File Edit Tools Zoom Tabs Help

Interface Info Code

Edit Delete Add abc Button | normal speed | view updates | Settings...
ticks: 31 on ticks

setup go

numberPredat... 20 numberPrey 100

chemo-attractant decay rate per clock tick:
chemo-attractant diffuse rate per clock tick:
From 0 to 1. 0.20 = 20%

decay_rate 0.3 DiffuseRate 0.2

count prey 51

Totals
totals 110 0
time 0 36.3
prey

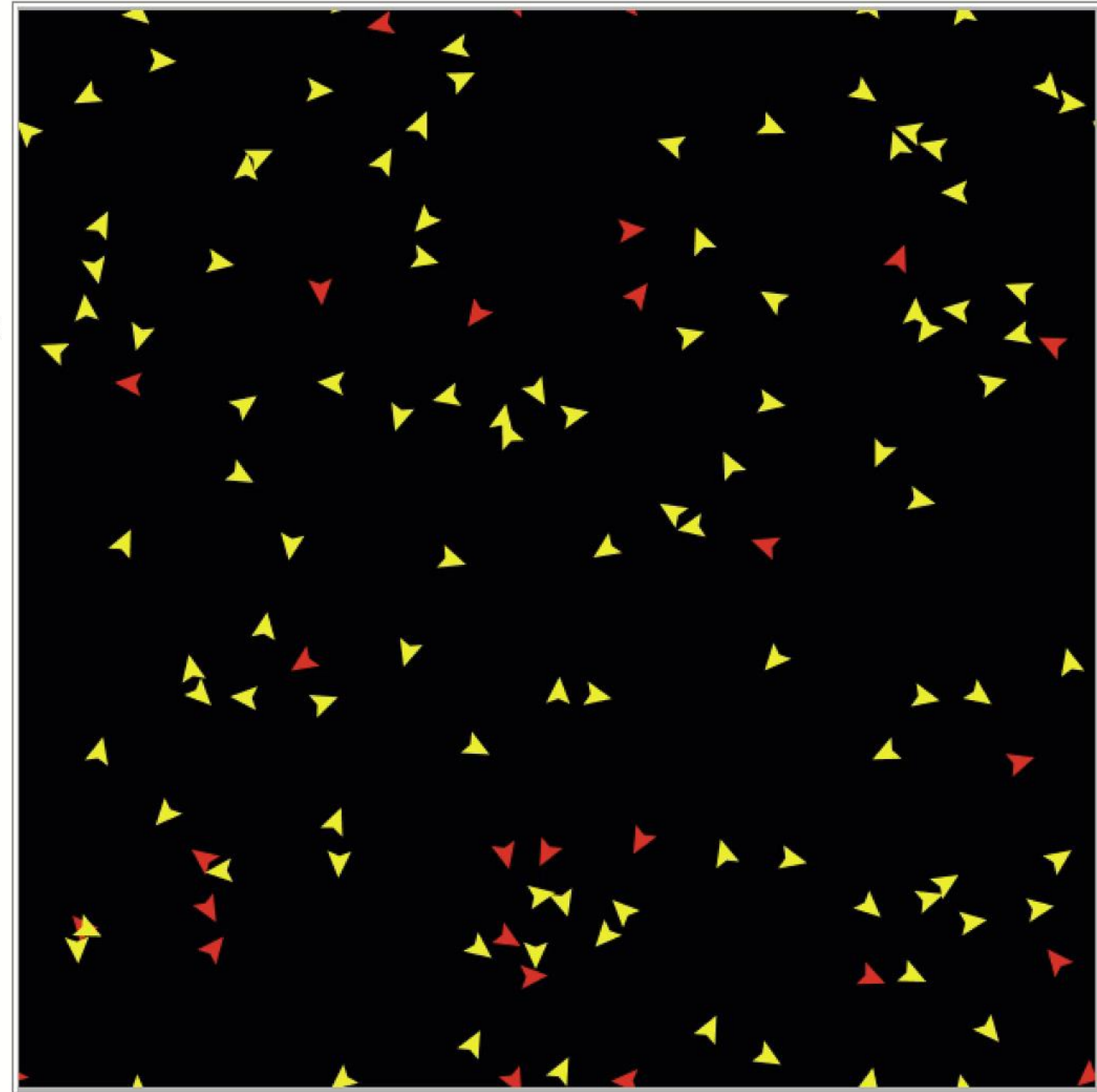
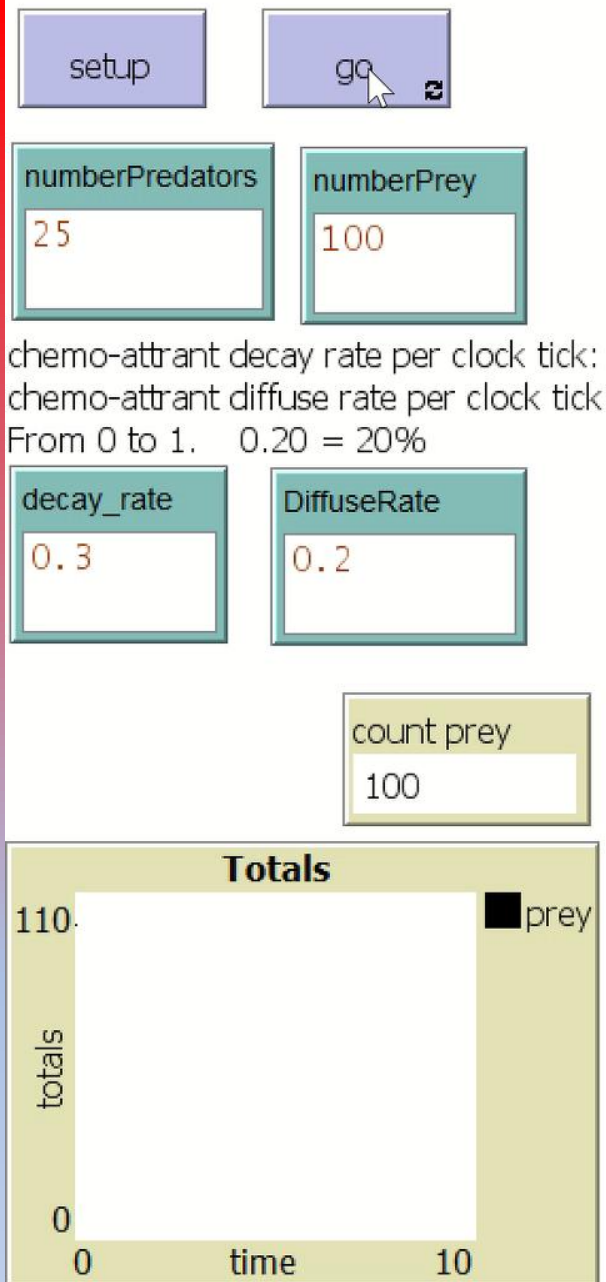
Sources for Virtual Experiments

NetLogo Simulation & Programming Environment

Chemotaxis Sim

McCarthy & Watts (2019)

Predators (**red**)
find their prey
(**yellow**) via
chemoattractants
(**blue**).



Long term goals

1. To have virtual experiments for each topic in "the" diff eq syllabus
2. To put these experiments\ modeling scenarios online as an Open Educational Resource (OER) in a nicely organized fashion

I am very happy 😊 to share, collaborate, and borrow.
And, to involve students in the production.

Now I will discuss one of my virtual experiments.
It is on Newton's Law of Cooling.
It is hosted on the CUNY Academic Commons

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CUNY Academic Commons Annual Report 2017-2018
Our annual report shows how the Commons continues to integrate into the life of the university by offering opportunities to every campus, faculty member, and student.

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CUNY faculty can create Wordpress based pages for free on the "Commons".

Here is its webpage...

ONLINE <https://mccarthy501.commons.gc.cuny.edu/newtonian-cooling/>

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Professor McCarthy Mat 501 BMCC

Differential Equations

Differential Equations Home Page *Newton's Law of Cooling* 🔍

Newton's Law of Cooling

Newton's Law of Cooling¹ is based on the differential equation $\frac{dy}{dt} = k(T - y)$, where



Students copy and modify the R script. They run it on online (RexTester.com) or on their computer.

R is open source!



Browser address: https://rextester.com/r_online_compiler

[Run Code](#) | [Code Wall](#) | [Users](#) | [Misc](#) | [Feedback](#) | [About](#)

compile R online

Language: R Editor: CodeMirror Layout: Vertical

```
1 # RcodeNewtonLawOfCoolingRegPlot.R
2 # Does regression on data from Newton's Law of Cooling Experiment and
3 # plots results. For Mat 501 notes.
4
5 # Experiment notes:   Date: Feb 9, 2018
6 # 500 mL of near to boiling water in a pyrex measuring cup.
7 # about 50 mL evaporated eventually.
8
9 # air and initial water temp (C)
10 T = 28.6 # air temp (78 deg F)
11 y0 = 81.0 # initial water temperature (177.8 deg F)
12
13 # data from experiment taken manually
14 # (t_i, y_i) = (time in min, water temp in C);
15
16 # t_i time data (min) Note a measurement like 60+34+9/60 means 1 hr 34 min 9 sec
17 t_i = c(4/60, 30/60, 1, 1+31/60, 2, 2+30/60, 3+2/60, 3+34/60,
18 6+35/60, 7+17/60, 8+30/60, 9+39/60, 10+30/60, 11+24/60, 13+11/60, 15 + 37/60, 17+6/60,
19 19+23/60, 21+43/60, 26+51/60, 26+55/60, 31+41/60, 40+44/60, 44+6/60, 48+42/60, 50+38/60,
20 60+14+12/50, 60+16+10/60, 60+34+9/60, 60+35+20/60, 60+38+4/60, 60+48+17/60 );
21
22 # y_i water temperature data (C)
23 y_i = c(80.0, 78.3, 77.6, 77.6, 77.2, 76.5, 76.3, 76.6,
24 72.6, 71.3, 69.8, 68.2, 67.2, 66.1, 64.3, 62.2, 60.6,
25 58.9, 57.1, 54.0, 54.0, 51.3, 47.2, 45.8, 43.8, 43.1,
26 37.0, 36.6, 33.6, 33.5, 33.1, 32.1);
27
28 # display data in console.
29 t_i;
30 y_i;
31
32 # approximate k
```

Absolute running time: 2.89 sec, cpu time: 0.88 sec, memory peak: 34 Mb, absolute service time: 2,96 sec

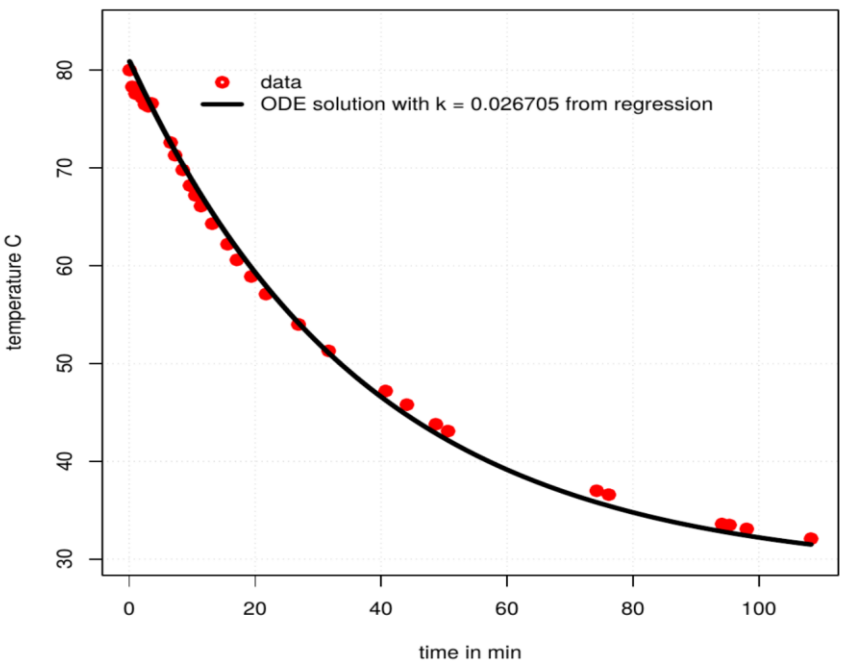
```
[1] 0.06666667 0.50000000 1.00000000 1.51666667 2.00000000
[6] 2.50000000 3.03333333 3.56666667 6.58333333 7.28333333
[11] 8.50000000 9.65000000 10.50000000 11.40000000 13.18333333
```

Residual standard error: 0.9992 on 31 degrees of freedom

Number of iterations to convergence: 3
Achieved convergence tolerance: 9.936e-06

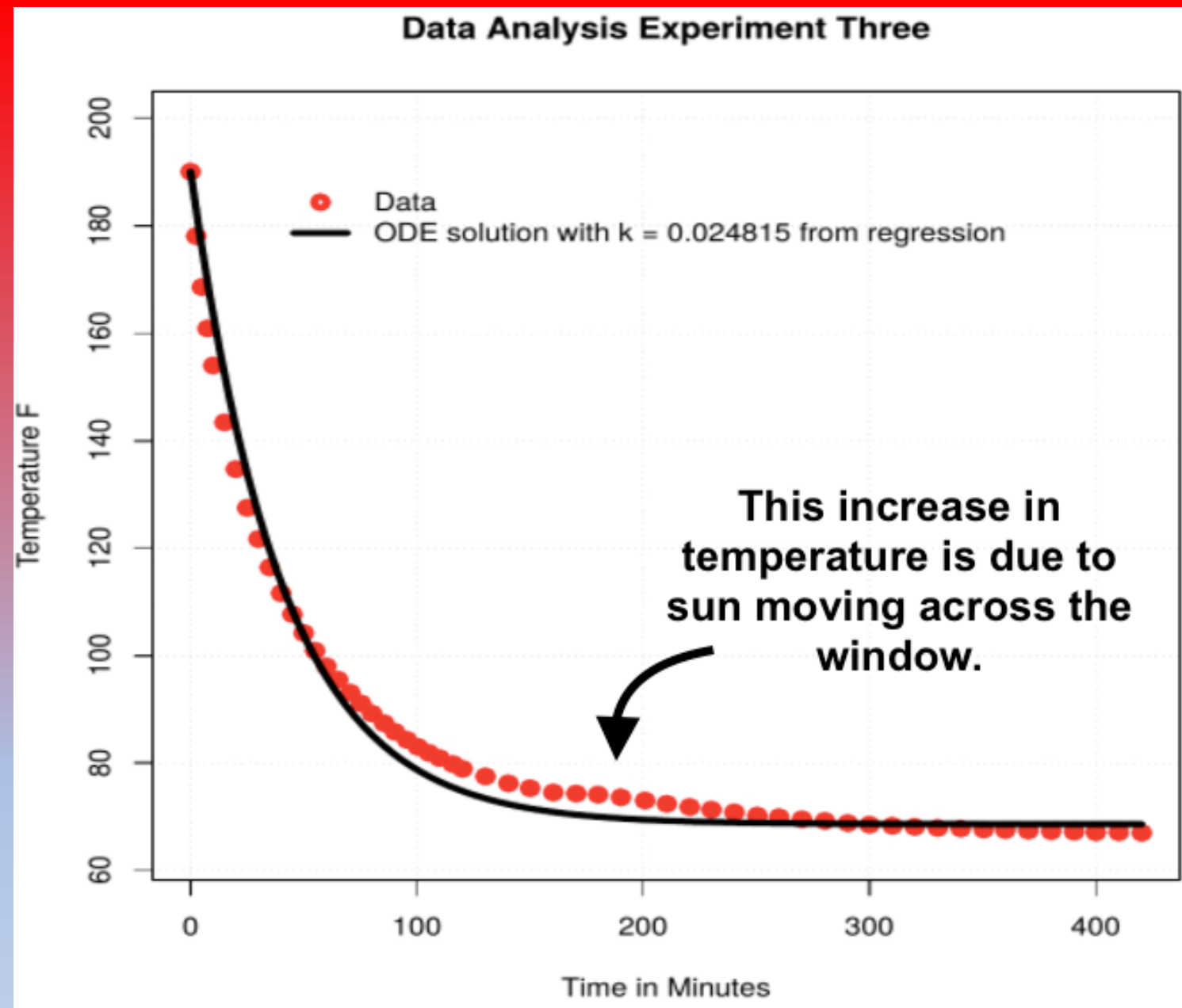
k
0.02670549

Data analysis by Prof. McCarthy



Open ended modeling question for students

Modify Newton's model to account for the varying room temperature.



Thank You! Please contact me for more information.

Funding Acknowledgements:

NYS OER Scale Up Initiative & CUNY

CUNY (City University of New York) was awarded \$4,000,000 from New York State to establish, sustain, and enhance new and ongoing OER initiatives throughout CUNY (FY 2018). The expected result will be large-scale course conversions throughout the university.

BMCC Librarian Professor Jean Amaral

OER Warrior Extraordinaire