

# Fostering a Conceptual Understanding in Undergraduate Materials Education: A Multivariable Animated Spreadsheet Approach



PRINCE GEORGE'S  
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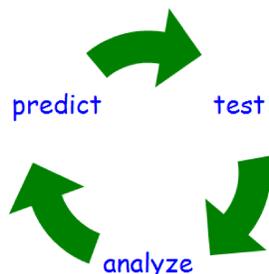
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Develop an engaging pedagogy in the classroom

In the classroom: What if... ?



and explain !

All by adjusting variables with a variety of interactive features

## Behavior of Light at the Interface between Materials

Discover the behavior of the reflection coefficient and transmission of light through a medium

What enhances reflection?

Reflected Light from a Material

index of refraction for medium 1  $n_1 = 1$  (air)    index of refraction for medium 2  $n_2 = 1.5$

incoming light 100%    reflected light 4.00%    transmitted light 96.00% (assuming no absorption)

reflection coefficient,  $R = 0.04$     transmission coefficient,  $T = 0.96$

Fresnel Equation

%reflected: 4.0    %transmitted: 96.0    %absorbed: 0.0

Why does the transmitted beam bend downward? see refracted light tab

What if light is absorbed by medium 2? 0%

$$R = \frac{(n_1 - n_2)^2}{(n_1 + n_2)^2} \quad T = 1 - R$$

Discover the behavior of light as it passes from one medium to another

Light Across an Interface

angle of incidence from normal  $\theta_1 = 28^\circ$

angle of refraction from normal  $\theta_2 = 13.53^\circ$

How the angles are measured? cursor here

Snell's Law

index of refraction for medium 1  $n_1 = 1$  (air)    index of refraction for medium 2  $n_2 = 2$

What about the angle of the reflected beam of light? add reflected beam

angle of incidence = angle of reflection

$$\frac{n_1}{n_2} = \frac{\sin \theta_2}{\sin \theta_1}$$

## Burning of a Virtual Candle

Discover the behavior of a burning candle (zero-order kinetics)

What do the slope and x- and y-intercepts represent?

Adjustable Burn Rate

set time for green tracer line: 5

starting height = candle 1: 10 cm    starting height = candle 2: 6 cm

time as set for green tracer line and the candle burns down: height = 8.5 cm    height = 2.25 cm

Observation at tracer line setting

What does the value of the x-intercept represent? Set the burn rates: 0.3 cm/time (candle 1), 0.75 cm/time (candle 2)

Add random and systematic error to make it real world behavior

Real-world Data

height = 10 cm    burn rate = 0.5 cm/time

Now consider adding some error (one at a time)

random error: none to increase

As random error is added, what happens to the data? As random error is added, how does  $R^2$  respond?

systematic error: - to 0 to +

As systematic error is added, how does the line respond?

time vs height table:

| time | height |
|------|--------|
| 0    | 10.0   |
| 1    | 9.2    |
| 2    | 8.8    |
| 3    | 8.2    |
| 4    | 7.7    |
| 5    | 7.5    |
| 6    | 7.4    |
| 7    | 6.4    |
| 8    | 6.3    |
| 9    | 5.9    |
| 10   | 4.8    |

Linear regression:  $y = -0.4605x + 9.7923$ ,  $R^2 = 0.976$

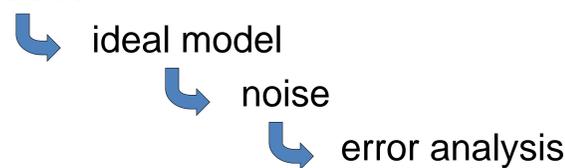
The green line is the line of best fit to the data, a linear regression line.  $R^2$  is a measure of the goodness-of-fit of the regression line to the experimental data. A perfect fit (no error) has  $R^2 = 1$ .

Derive the rate equations from the simulation

differential form                      integrated form

$$-\frac{d(A)}{dt} = k(A)^0 = k \quad (A)_t = (A)_0 - kt$$

The computational process for many of the Excelets: simulation



## Student Feedback

for the Burning Candle Excelet (n = 16 students)

Students like the dynamic visual aspects.

How would you characterize the use of the interactive Excel spreadsheet for this activity?

very easy    easy    so, so    difficult    very difficult

50% (8)    50% (8)

Excelets offer a more visual experience with graphs instead of using just the mathematical equations.

most I think so    just barely    not at all    don't know

88% (14)    12% (2)

Did the mathematics in the model seem easier?

most I think so    just barely    not at all    don't know

56% (9)    38% (6)    6% (1)

Excelets make it easier to grasp or learn a concept.

most I think so    just barely    not at all    don't know

69% (11)    25% (4)    6% (1)

## Conclusions

1. Develop higher-order thinking questions
2. Enhance scientific and algebraic thinking
3. Students develop a deeper understanding of concepts
4. Develop a more multivariable approach
5. Computational and mathematical modeling skills are enriched
6. Easy to modify
7. Operate on PC or Mac platforms and most in OpenOffice Calc

Over 30 animated interactive spreadsheets for use in sophomore materials science and introductory chemistry and physics, at the URL below.



Materials Science Excelets are available for download at [http://academic.pgcc.edu/~ssinex/excelets/matsci\\_excelets.htm](http://academic.pgcc.edu/~ssinex/excelets/matsci_excelets.htm)



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