

Virtual University and Virtual Course on Energy

Wolfgang Bauer

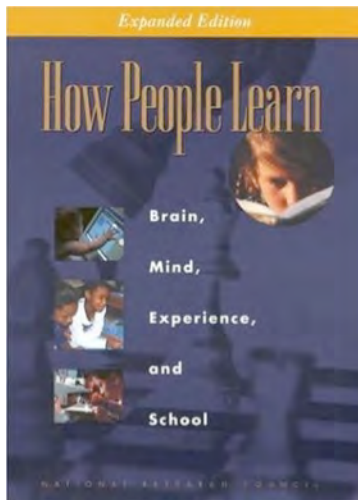
Michigan State University

A satellite image of the Earth showing North America. The landmasses are outlined in yellow. A red arrow originates from a grey rectangular box containing the text 'East Lansing Michigan' and points to a location in the state of Michigan, specifically in the central-eastern part of the Lower Peninsula.

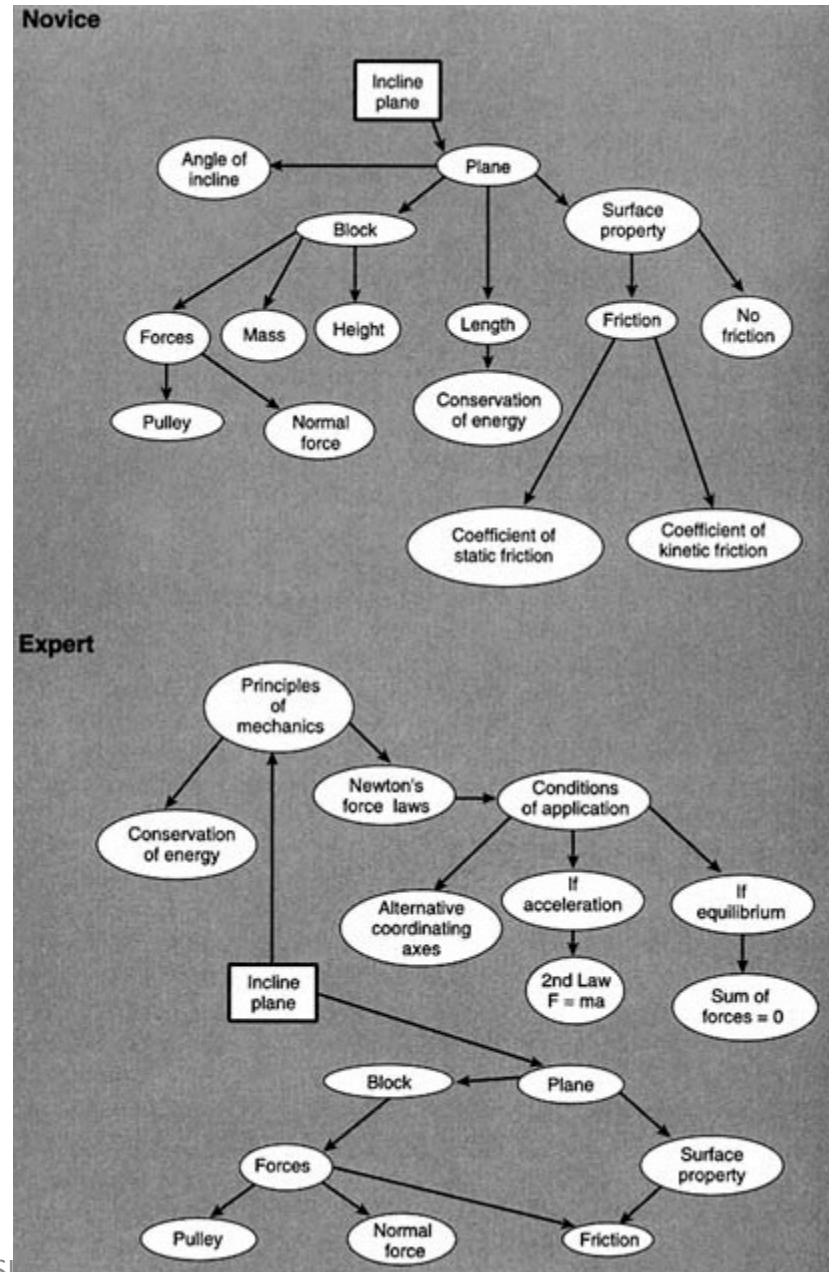
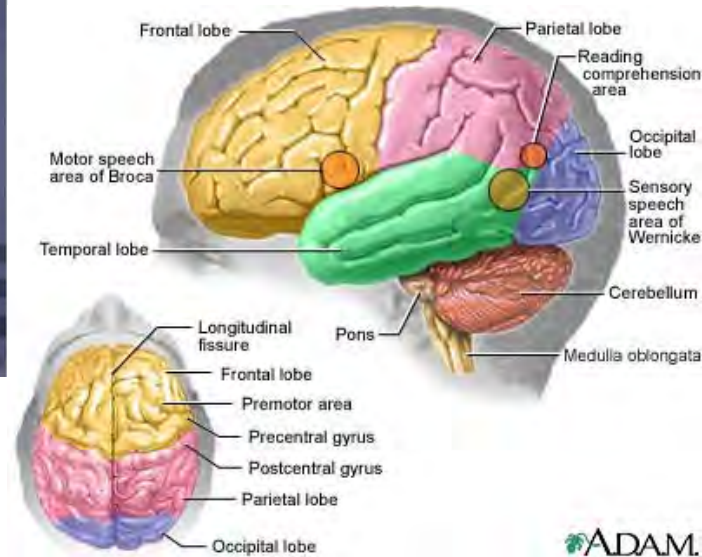
East Lansing
Michigan

Michigan State University

- Premier land-grant university (est. 1855)
 - 5,200-acre campus with 2,100 acres in existing or planned development
 - 577 buildings, including 83 with instructional space
- 36,500 undergraduate and 11,000 graduate student from 130 countries (53% women)
- ~430,000 living alumni
- ~5,000 faculty and academic staff
- 17 colleges, 200 different programs of study



How Does One Learn?



How People Learn:

Brain, Mind, Experience, and School (1999)

Commission on Behavioral and Social Sciences and Education

1. Memory & structure of knowledge
2. Analysis of problem solving and reasoning
3. Early foundations
4. Metacognitive processes and self-regulatory capabilities
5. Cultural experiences and community participation

28-Oct-13

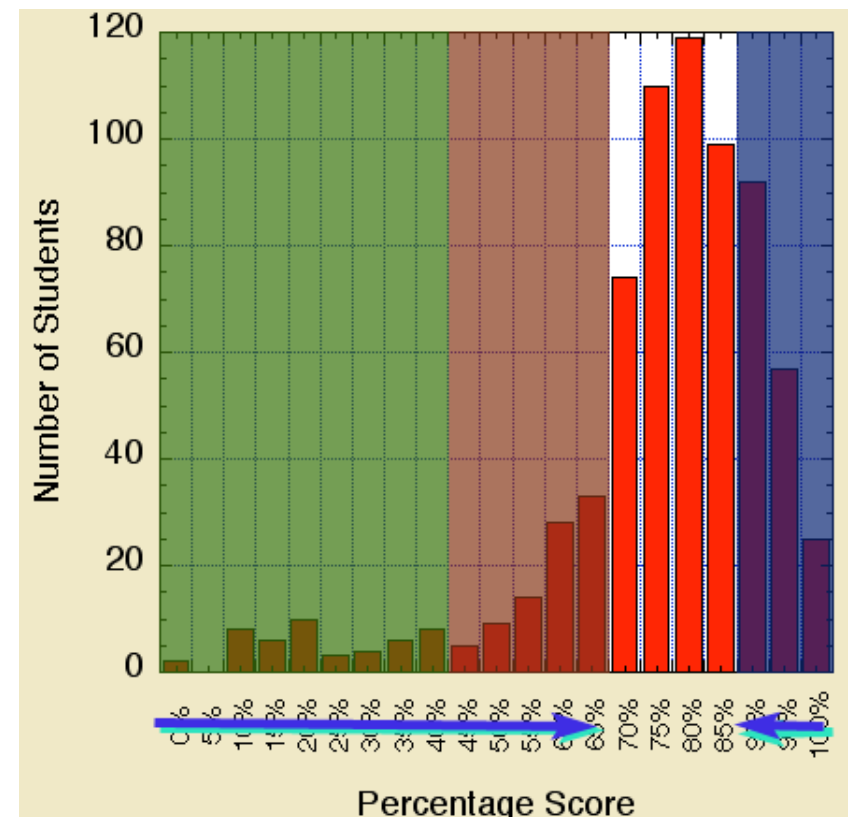
Wolfgang Bauer, MSU

“I think, however, that there isn’ t any solution to this problem of education other than to realize that the best teaching can be done only when there is a direct individual relationship between a student and a good teacher [...] It is impossible to learn very much by simply sitting in a lecture [...] But in our modern times we have so many students to teach that we have to try to find some substitute for this ideal.”

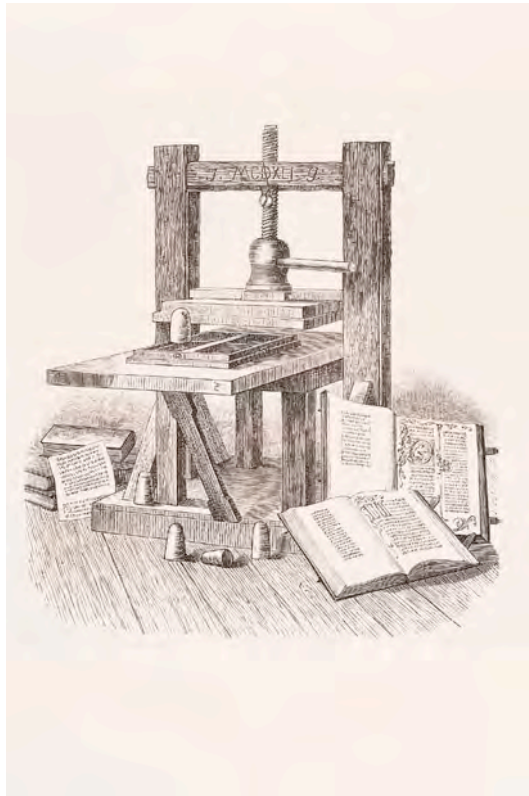
*Richard P. Feynman, June 1963
(Introduction to Feynman Lectures)*

Potential Problems in Large Lecture Classes

- Large spread in preparation of a diverse student population
- Impersonal nature of instruction / little one-on-one contact between instructor and students
- Achieving and maintaining high standards
- Large human resources required for grading
- Timely recognition of students' problems and difficulties
- Cheating on exams/Copying assignments



Technology Teaching Innovations



Gutenberg Press
~1450

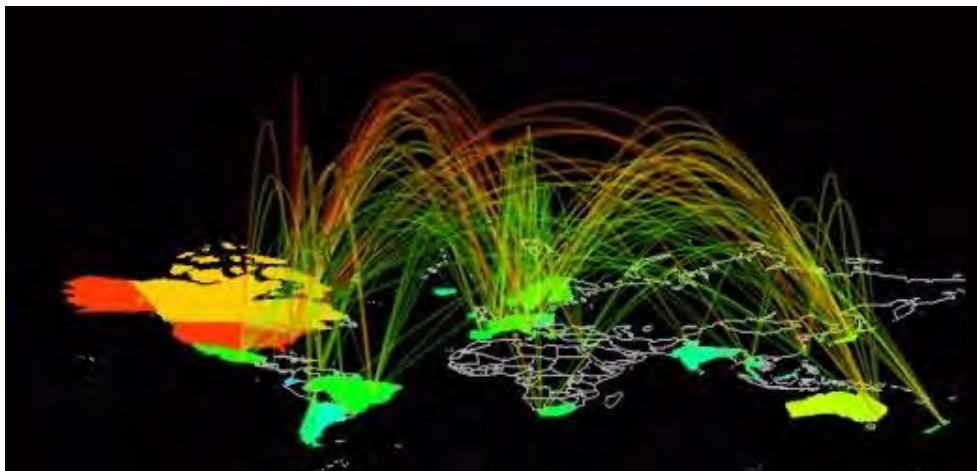
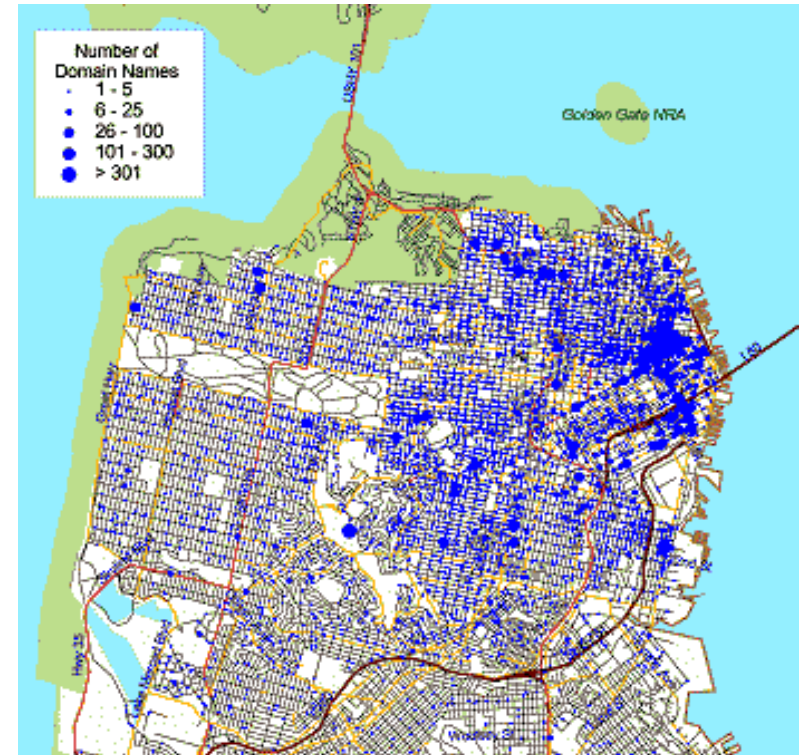


Radio
~1900



Television
~1930

Internet



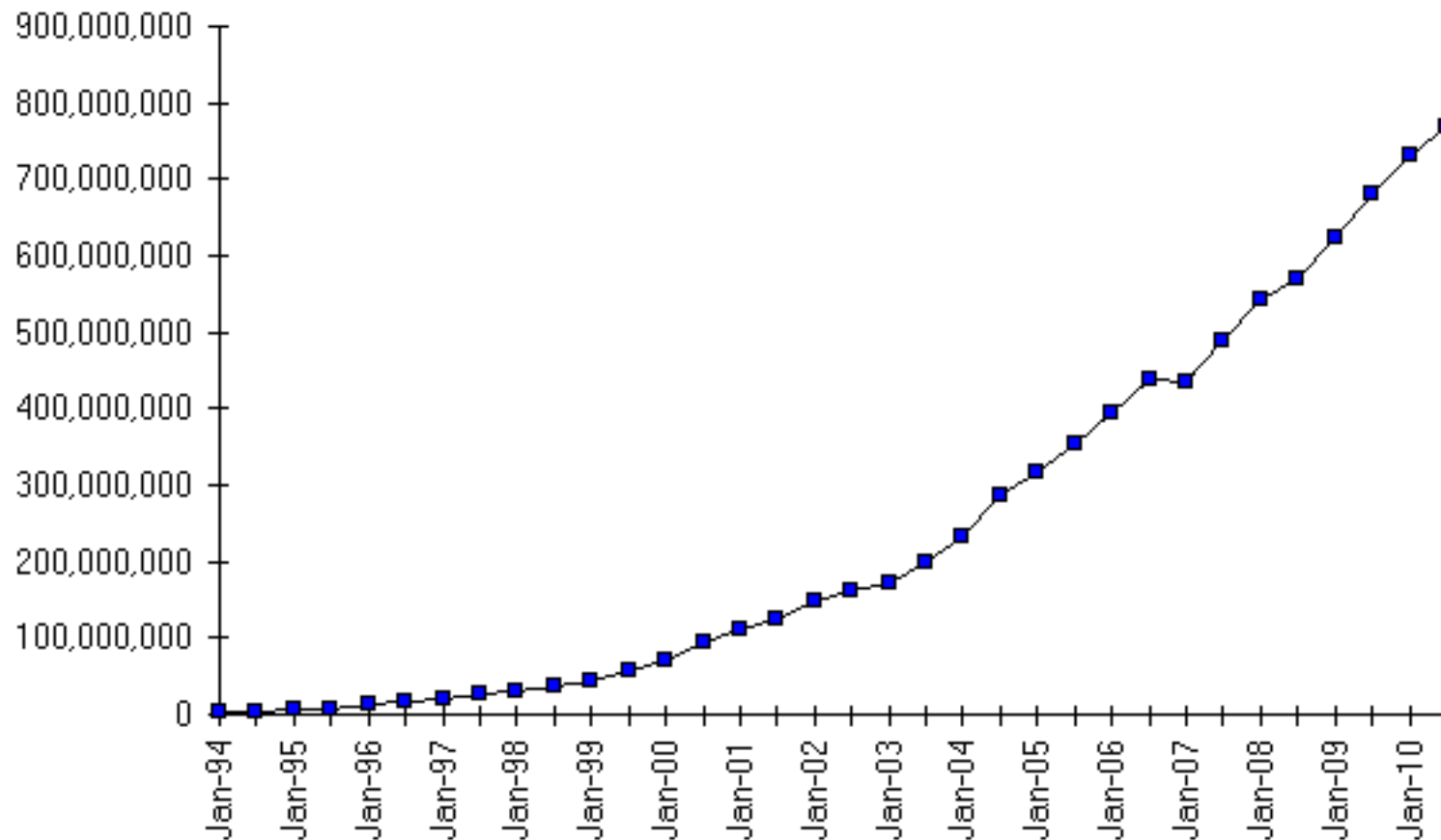
88-Oct-13

Wolfgang Bauer, MSU

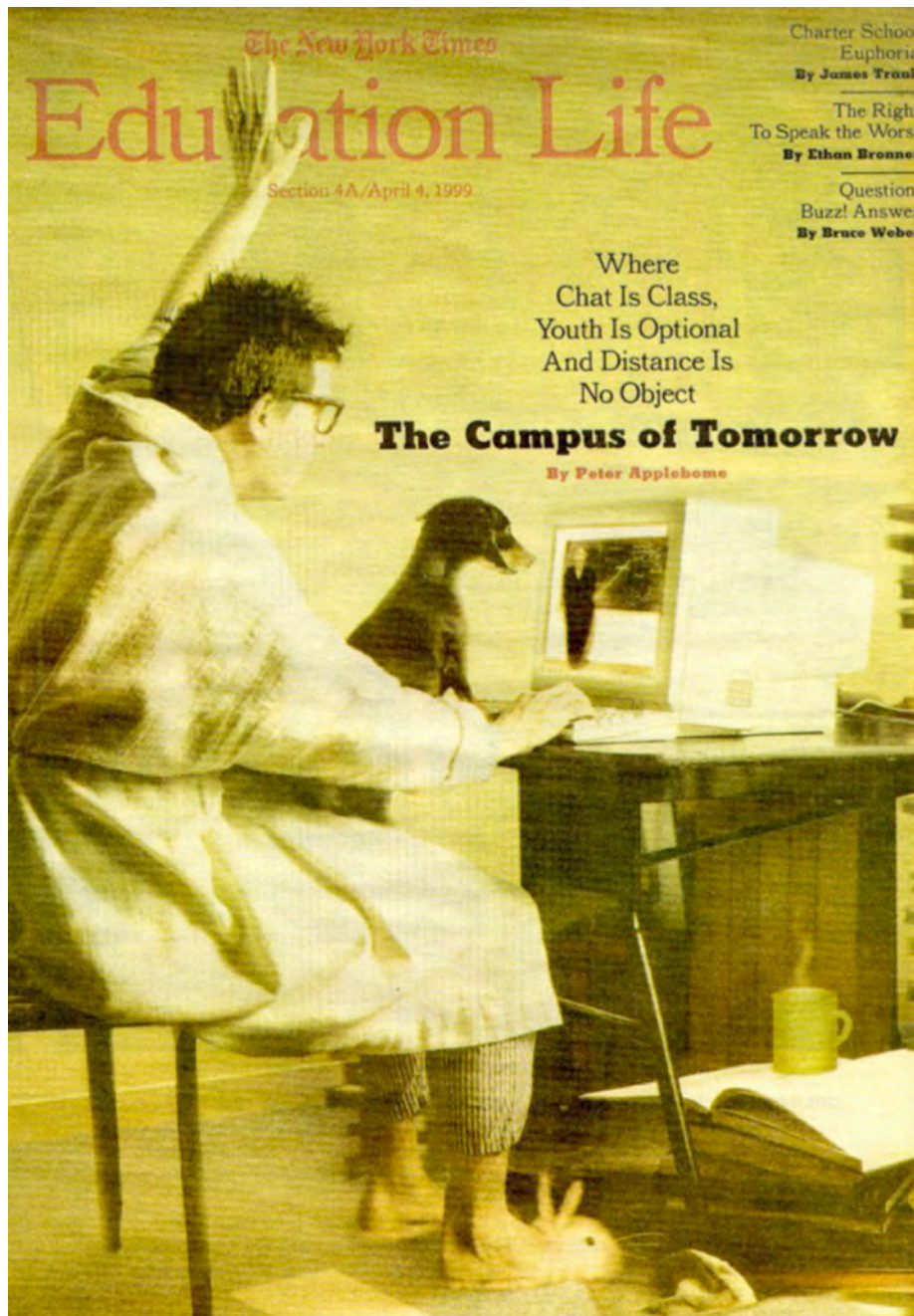


of Sites on Internet

Internet Domain Survey Host Count



Source: Internet Systems Consortium (www.isc.org)

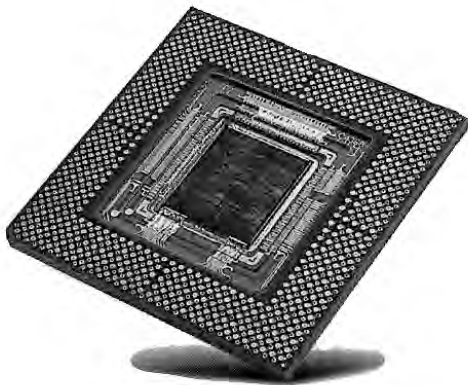


NY Times
April 1999

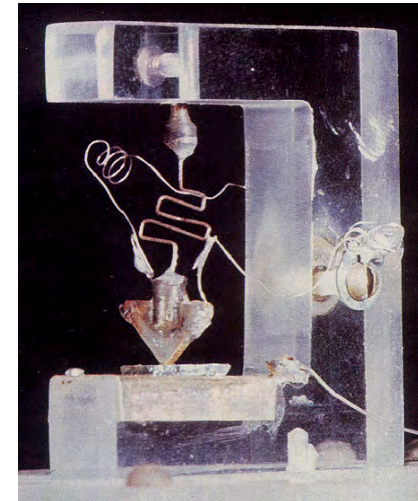
Moore's Law

- 1947: Transistor is invented
- 2006: Each Intel CPU chip has $\sim 10^8$ transistors
- This year, ~ 100 quadrillion transistors will be produced

Microchips double in power and halve in price every 18 months



Gordon Moore



LON-CAPA

- Learning Online Network
- Computer-Assisted Personalized Approach
- Course management system
- Homework engine
 - Individualized
 - Reusable shared resources
- Next generation system **CourseWeaver**
 - <http://www.courseweaver.org>

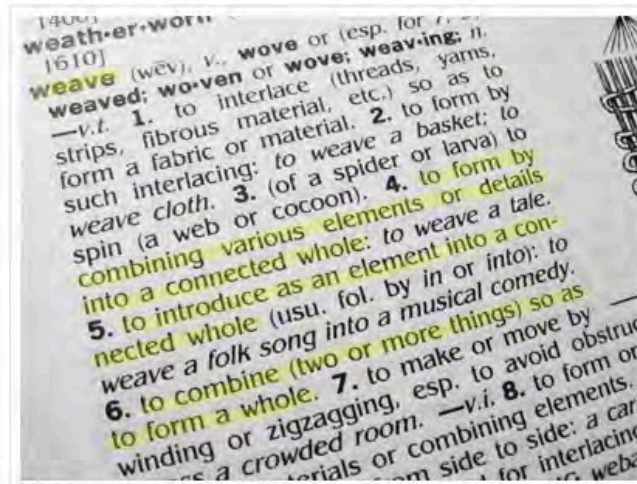


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[Users](#)
[Course Management](#)
[System](#)
[About](#)

Welcome to CourseWeaver!

Next Generation Free Open- Source Learning Content and Course Management

We are building the next generation learning content management: a sustainable economy for online educational content, which will enable institutions to combine the best of open, shared, and publisher content with the best of bricks-and-mortar.



COURSEWEAVER

Next Generation Learning Content
Management

WHAT WE ARE ABOUT

[analytics architecture](#)
[assessment authors](#)
[blended cloud collaboration](#)
[content course](#)
[course](#)
[management crowd-](#)
[sourcing data mining](#)
[deployment discussions](#)
[enterprise experience](#)
[expertise formative free](#)
[granularity higher education](#)
[innovation instructors](#)
[integration learners learning](#)
[machine room management](#)
[massively online modular](#)
[navigation networking open-](#)

Problem Solving

- Homework Problems are an integral part of the learning experience
- Not simply repetition of concepts learned in class!
- Instead: Transfer of Knowledge
 - Independent creation of new connections
 - Deeper anchoring of context

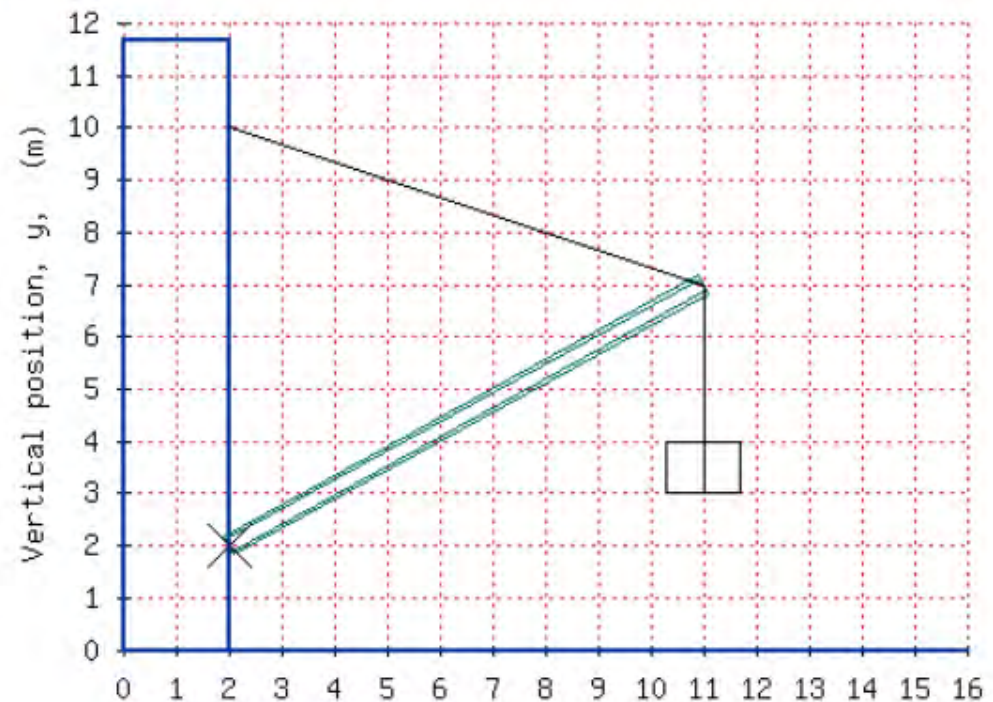
Problem Randomization

- Every student sees the same basic problem
- Every student has different numbers
- Allows groups of students to work together without the ability to just copy solutions

Homework

More sophisticated
highly randomizing
problems

A crate with a mass of 177.5 kg is suspended from the end of a uniform boom with mass of 88.5 kg. The upper end of the boom is supported by a cable attached to the wall and the lower end by a pivot (marked X) on the same wall. Calculate the tension in the cable.



Homework

- ...special emphasis on mathematics
 - including support of
 - LaTeX
 - Maxima
 - R

Give an example of a function

1. which is orthogonal to $6\cos(7x) - 2\sin(2x)$ with respect to the scalar product

$$\langle g | h \rangle = \frac{1}{\pi} \int_{-\pi}^{\pi} dx g(x) \cdot h(x)$$

2. whose norm is 1.

The function you have provided does not have a norm of one.

Incorrect. Tries 1

What is the derivative of

$$\begin{pmatrix} 4t^3 \\ 8t^8 \end{pmatrix}$$

with respect to t ?

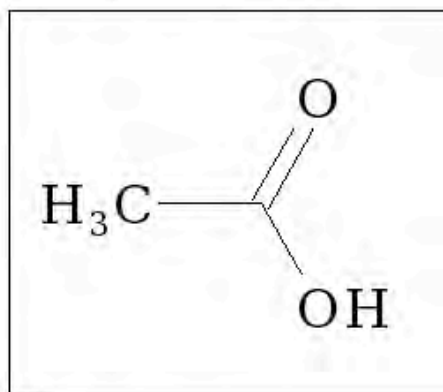
You need to multiply with the original exponent.

Incorrect. Tries 1

Homework

- ... chemistry ...

The image below is C₂H₄O₂



Draw acetic acid.

Draw Molecule

Submit Answer Tries 0/99

[Post Discussion](#)

A screenshot of the JME Editor window, titled "Untitled". The window displays the chemical structure of acetic acid (CH₃COOH) in the center. The top toolbar includes buttons for CLR, DEL, D-R, +/-, UDO, JME, and a "Select substituent" dropdown. Below these are icons for various chemical structures and bonds. On the left side, there is a vertical toolbar with buttons for C, N, O, S, F, Cl, Br, I, P, and X. At the bottom of the window, there is a text box with the text "JME Editor courtesy of Peter Ertl, Novartis" and buttons for "Insert Answer", "Close", and "Help".

Homework

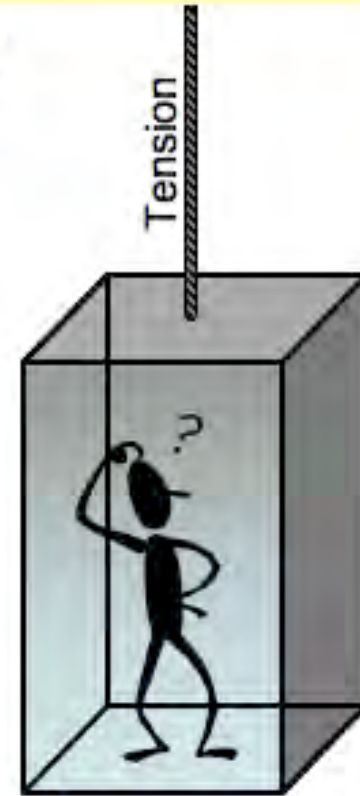
- ... physical units ...

Elevator Problem

Due never

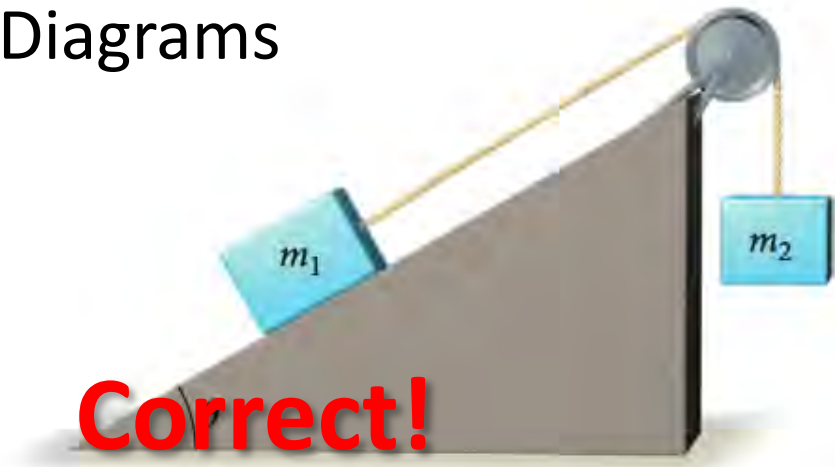
An elevator (cabin mass 500 kg) is designed for a maximum load of 2600 kg, and to reach a velocity of 3 m/s in 5 s. For this scenario, what is the tension the elevator rope has to withstand?

Tries 0/99



Homework

Free-Body Diagrams



Select Force

\vec{F}_g = weight

\vec{N} = normal force

\vec{T} = string tension

\vec{f} = friction with ramp

\vec{f}_o = friction from pulley

\vec{F} = external force from pulley

Angles

Submit Answer Tries 0

Exam Support

A capacitor is completely charged with 650 nC by a voltage source that had 350 V.

1 pt What is its capacitance? (in F)

7.A ☐ 1.49×10^{-9} B ☐ 1.86×10^{-9} C ☐ 2.32×10^{-9}

D
G

Students receive automatically generated individualized multiple choice exams with their names (and photos).

1 pt
gether

8.

LON-CAPA machine-grades the bubble sheets.

B ☐ The energy stored in the capacitor remains the same.

C ☐ The capacitance increases.

D ☐ The voltage drop between the plates increases.

E ☐ The energy stored in the capacitor increases.

1 pt The initial air gap was 8 mm. What is the stored energy if the air gap is now 6 mm? (in J)

9.A ☐ 0.00 B ☐ 8.53×10^{-5} C ☐ 1.14×10^{-4}

D ☐ 1.30×10^{-4} E ☐ 1.52×10^{-4} F ☐ 3.41×10^{-4}

G ☐ 3.44×10^{-4} H ☐ 4.87×10^{-4}

A capacitor is completely charged with 670 nC by a voltage source that had 350 V.

1 pt What is its capacitance? (in F)

7.A ☐ 1.91×10^{-9} B ☐ 2.39×10^{-9} C ☐ 2.99×10^{-9}

B ☐ The energy stored in the capacitor remains the same.

C ☐ The charge on the plates increases.

D ☐ The capacitance increases.

E ☐ None of the above.

1 pt The initial air gap was 6 mm. What is the stored energy if the air gap is now 11 mm? (in J)

9.A ☐ 0.00 B ☐ 6.40×10^{-5} C ☐ 1.17×10^{-4}

D ☐ 2.15×10^{-4} E ☐ 2.91×10^{-4} F ☐ 3.63×10^{-4}

G ☐ 4.39×10^{-4} H ☐ 5.42×10^{-4}

part

Exam Support: Re-Takes

A capacitor is completely charged with 650 nC by a voltage source that had 350 V.

1 pt What is its capacitance? (in F)

7. ☐ A 1.49×10^{-9} ☐ B 1.86×10^{-9} ☐ C 2.32×10^{-9}
☐ D 2.90×10^{-9} ☐ E 3.63×10^{-9} ☐ F 4.53×10^{-9}
☐ G 5.67×10^{-9} ☐ H 7.08×10^{-9}

1 pt Now the plates of the charged capacitor are pulled apart with the voltage source already disconnected.

8. ☐ A The charge on the plates increases.
☐ B The energy stored in the capacitor remains the same.
☐ C The capacitance increases.
☐ D The voltage drop between the plates increases.
☐ E The energy stored in the capacitor increases.

1 pt The initial air gap was 8 mm. What is the stored energy if the air gap is now 6 mm? (in J)

9. ☐ A 0.00 ☐ B 8.53×10^{-5} ☐ C 1.14×10^{-4}
☐ D 1.30×10^{-4} ☐ E 1.52×10^{-4} ☐ F 3.41×10^{-4}
☐ G 3.44×10^{-4} ☐ H 4.87×10^{-4}

A capacitor is completely charged with 670 nC by a voltage source that had 350 V.

Problem 6

Due on Tuesday, Feb 22 at 10:00 am

A capacitor is completely charged with 640 nC by a voltage source that has 375 V.

What is its capacitance?

Tries 0/3

Now the plates of the charged capacitor are pulled apart with the voltage source still connected.

- ☐ The capacitance increases.
☐ The voltage drop between the plates increases.
☐ The energy stored in the capacitor increases.
☐ The energy stored in the capacitor remains the same.
☐ None of the above.

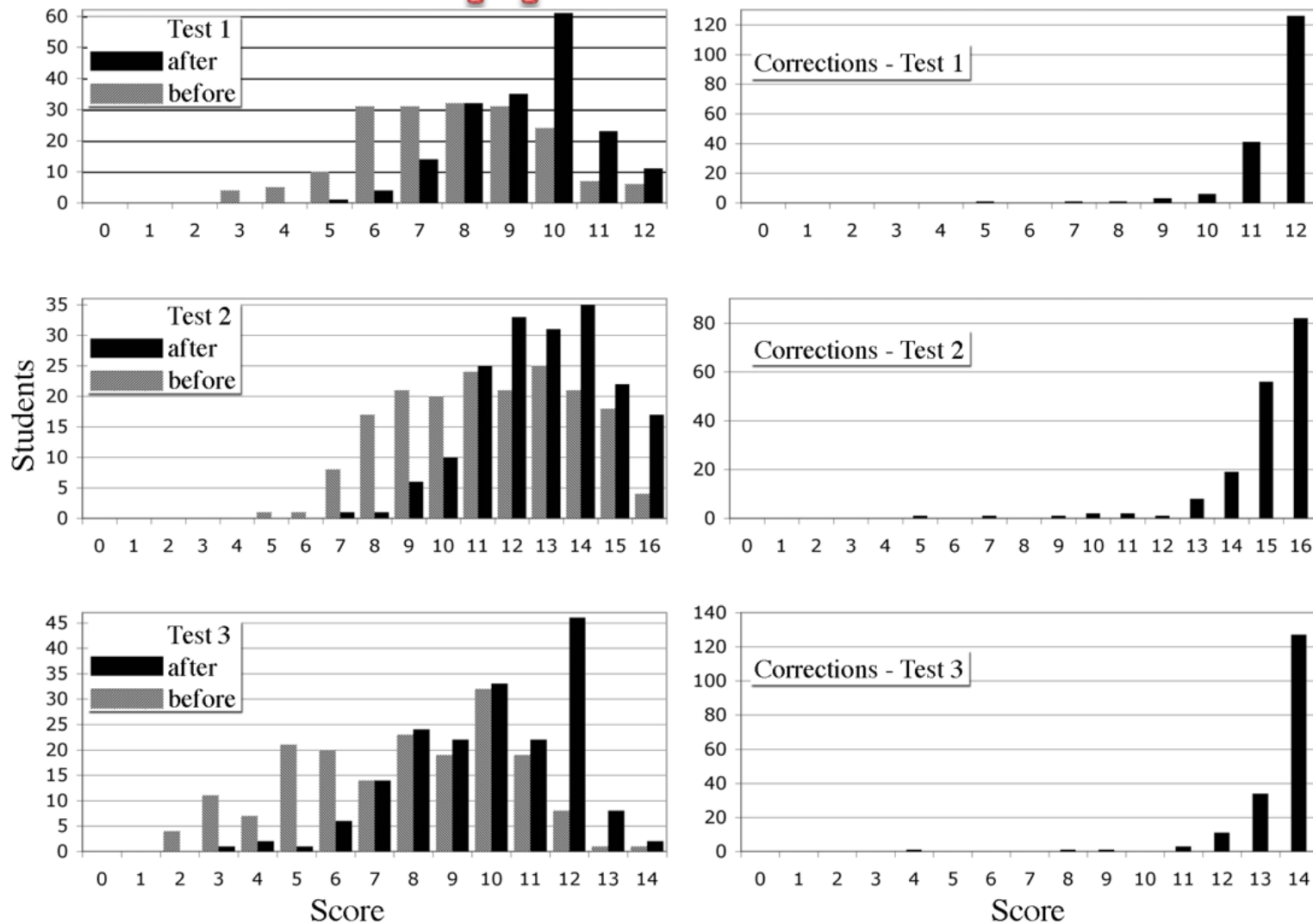
Tries 0/2

The initial air gap was 5 mm. What is the stored energy if the air gap is now 10 mm?

Tries 0/3

9. ☐ A 0.00 ☐ B 6.40×10^{-5} ☐ C 1.17×10^{-4}
☐ D 2.15×10^{-4} ☐ E 2.91×10^{-4} ☐ F 3.63×10^{-4}
☐ G 4.39×10^{-4} ☐ H 5.42×10^{-4}

Exam Support: Re-Takes



Kortemeyer, Bauer, Benenson, Kashy, The Physics Teacher 44, 235 (2006)

How is all of this possible?

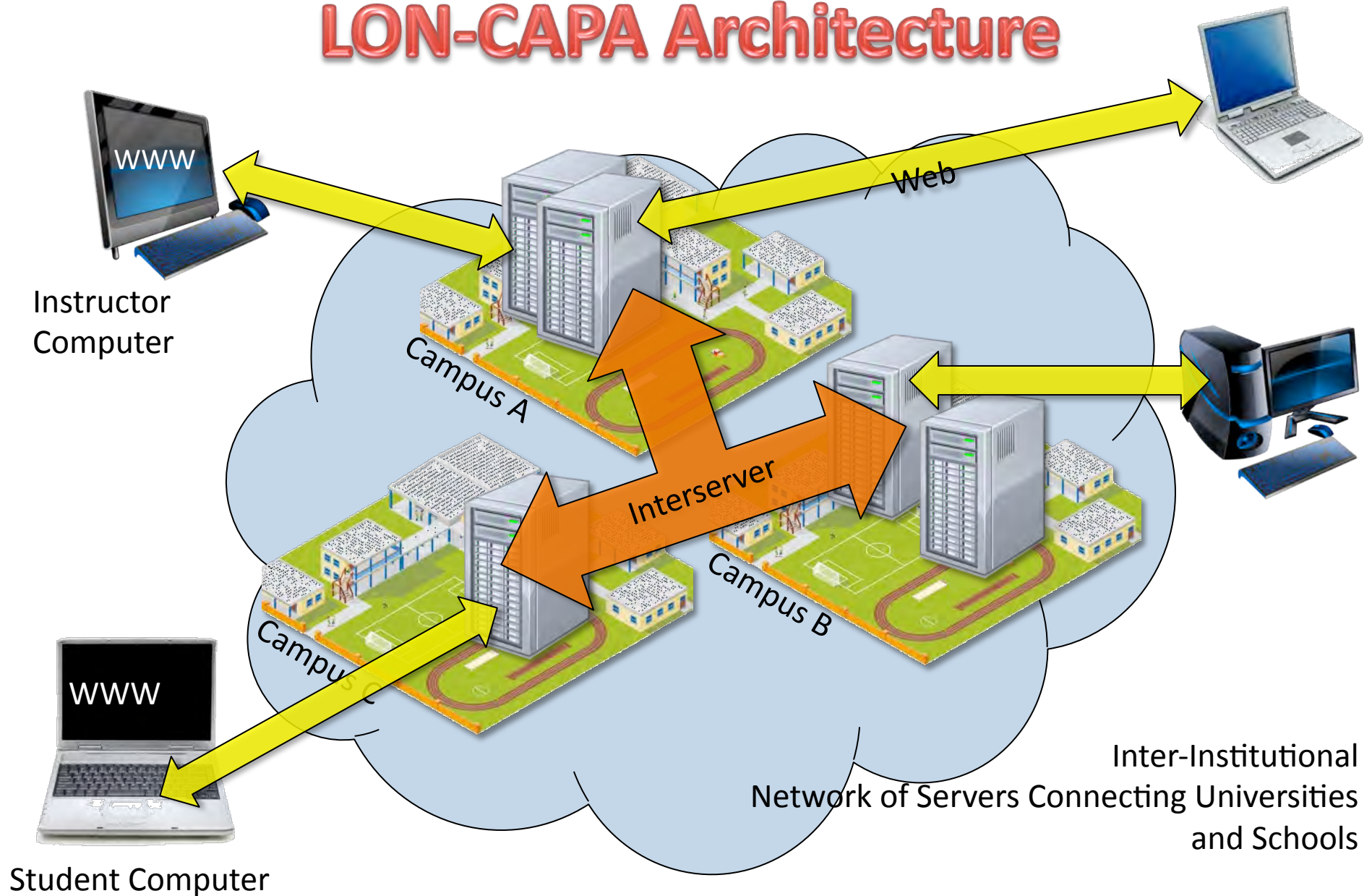
Too much work for any instructor!

Sharing of Resources!

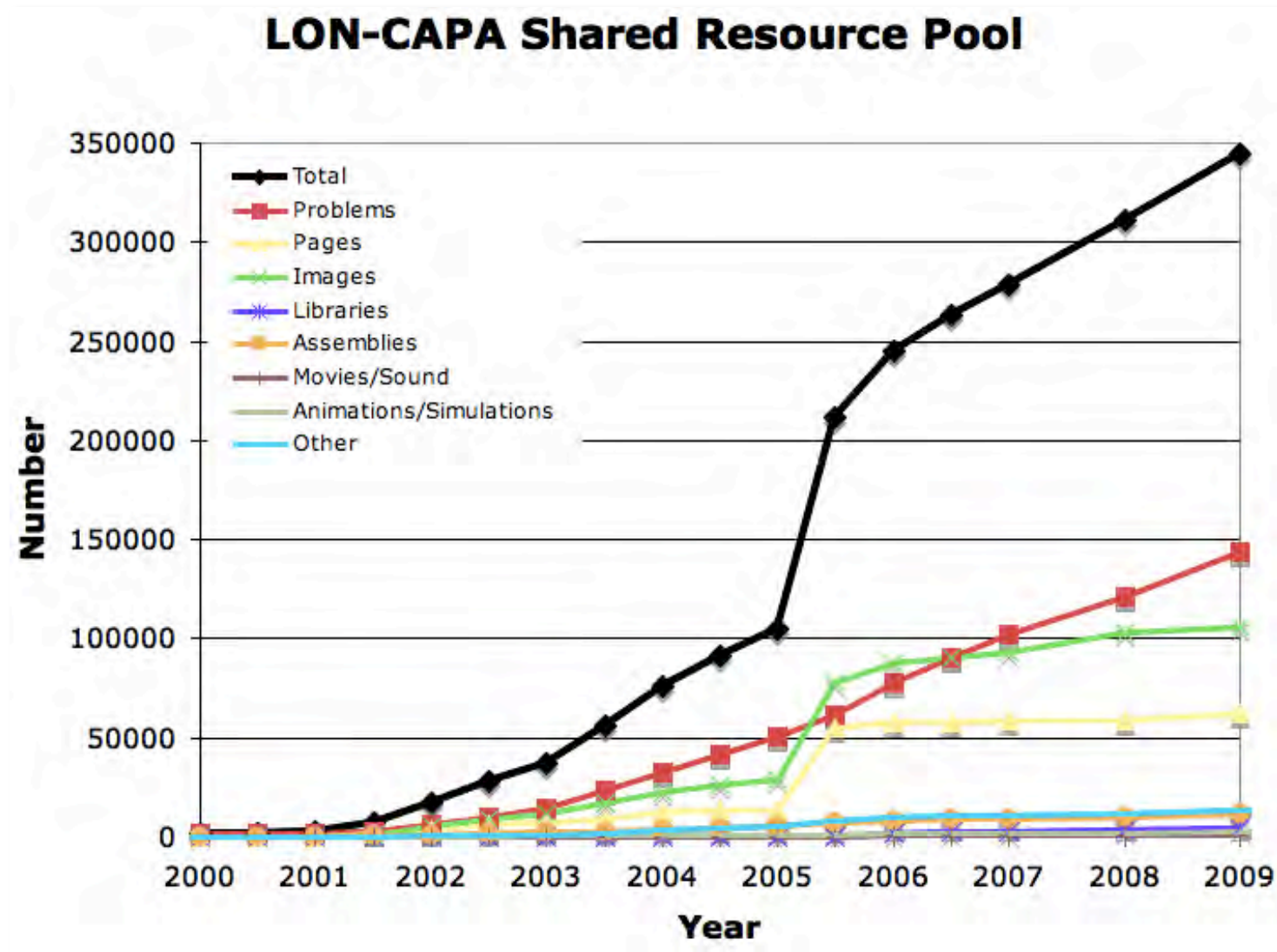
- Creating online resources is a lot of work
- Doing so for use in just one course is a waste of time and effort
- Many resources could be used among a number of courses and across institutions



LON-CAPA Architecture

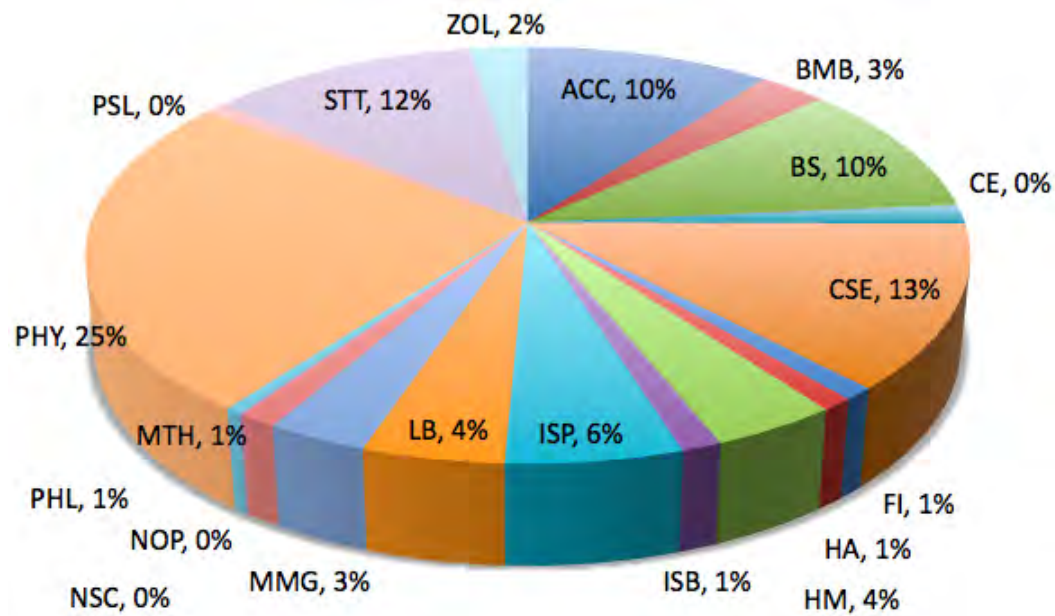


The LON-CAPA Community

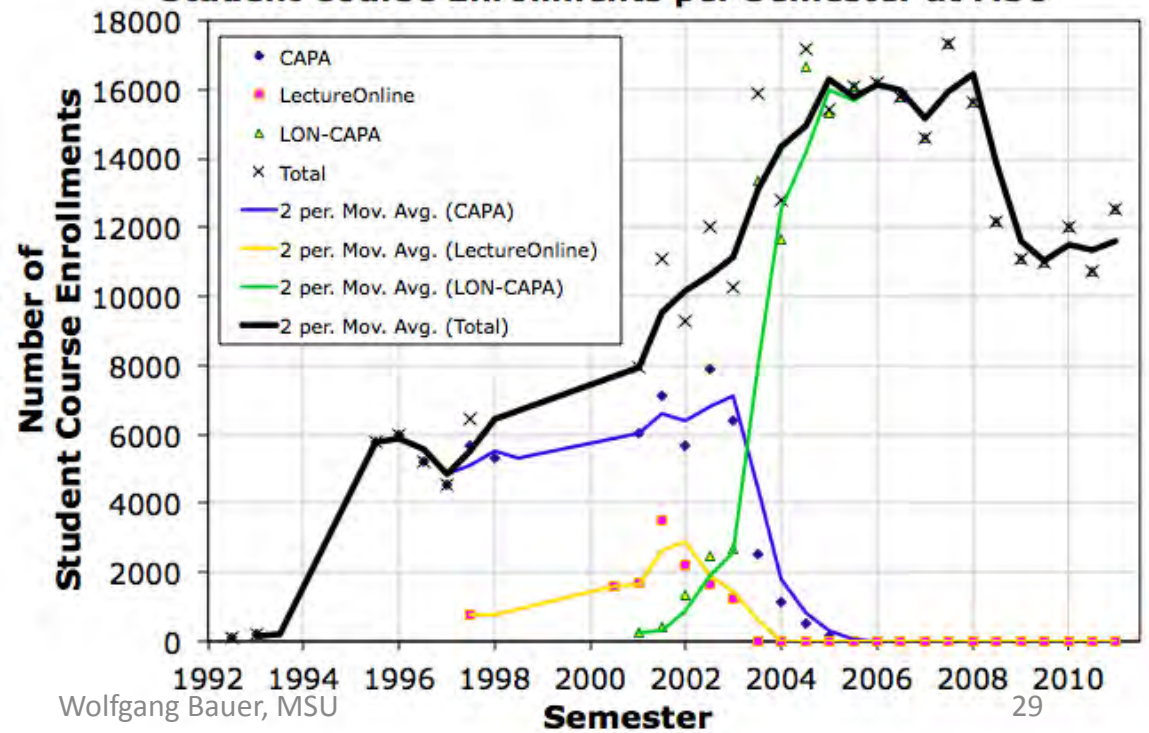




Example:
> 2,000 End-of-Chapter
problems coded in LON-CAPA



**CAPA/LectureOnline/LON-CAPA
Student Course Enrollments per Semester at MSU**



The LON-CAPA Community

The screenshot shows a web browser window titled "LON-CAPA Change Preferences". The address bar displays the URL <http://educog.com/adm/preferences?action=changelanguages>. The browser's toolbar includes navigation buttons and a search bar with the text "Google". Below the toolbar, a navigation bar contains links: [Main Menu](#), [Roles](#), [Help](#), and [Exit](#). The main content area has a yellow header with the title "Change Preferences" and the user's name "Wolfgang Bauer" with the role "No Role, Cumulative Privileges". Below the header, a breadcrumb trail reads "Menu ► Set User Preferences ► Change Language". A "Change Preferences" link with a question mark icon is also visible. The "Preferred language:" section shows a dropdown menu currently set to "English - UTF". A "Change" button is located below the dropdown. The dropdown menu is open, displaying a list of languages: Arabic, German, English, Spanish, Persian, French, Hebrew, Japanese, Portuguese, Russian, Turkish, and Swedish.

LON-CAPA Change Preferences

[Main Menu](#) [Roles](#) [Help](#) [Exit](#)

Change Preferences Wolfgang Bauer
No Role, Cumulative Privileges

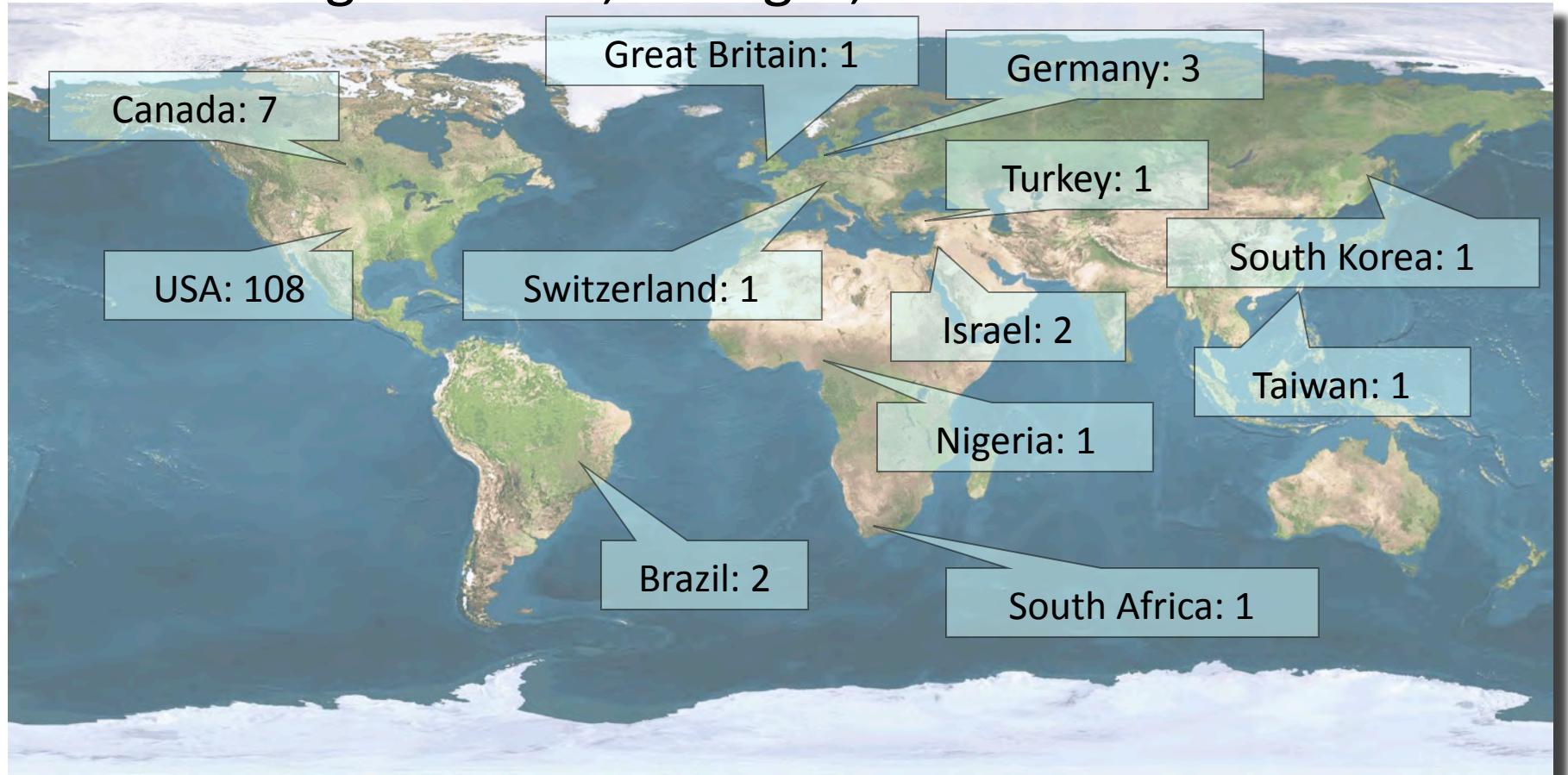
Menu ► Set User Preferences ► Change Language Change Preferences ?

Preferred language: English - UTF Change

- Arabic
- German
- English
- Spanish
- Persian
- French
- Hebrew
- Japanese
- Portuguese
- Russian
- Turkish
- Swedish

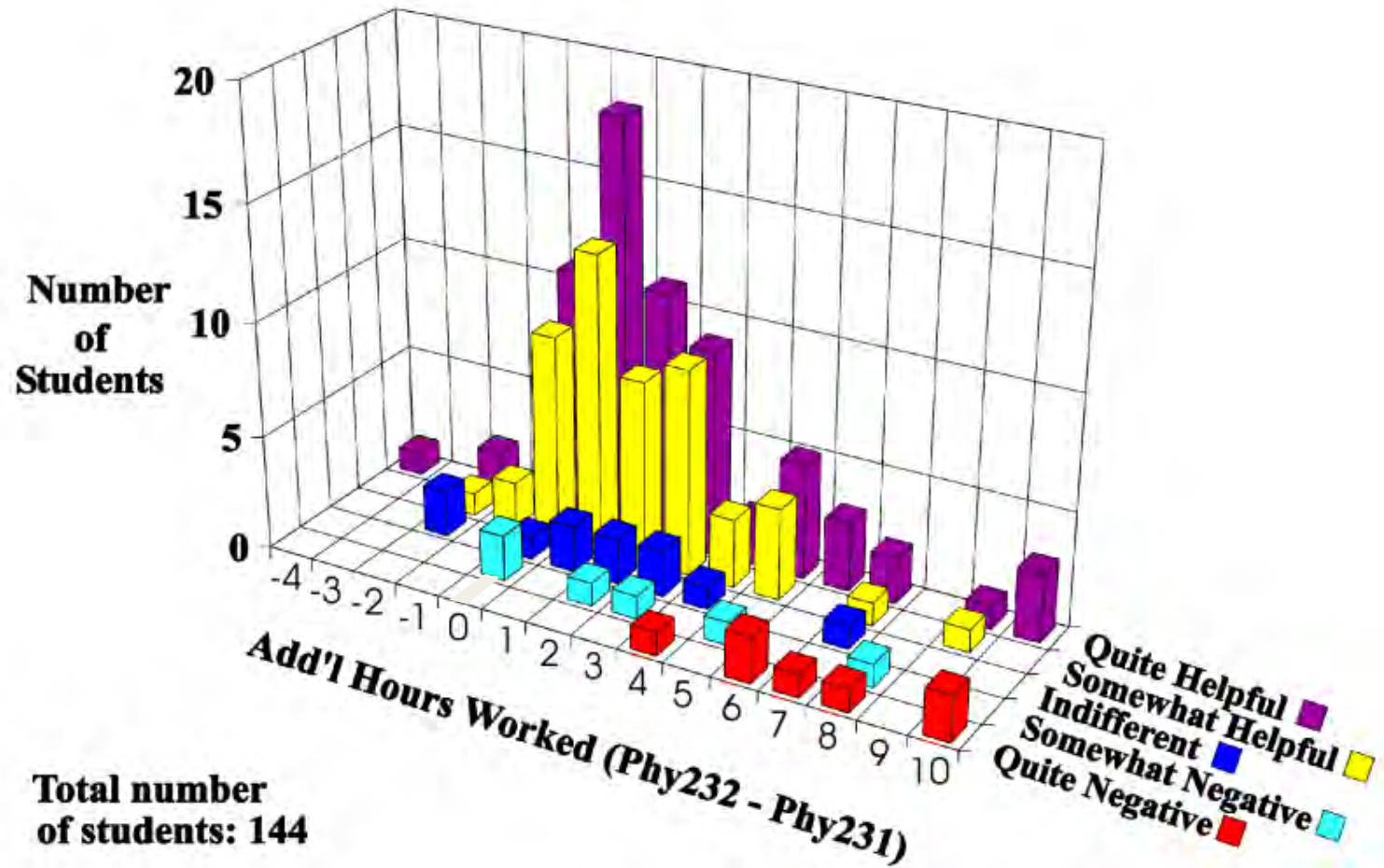
The LON-CAPA Community

High Schools, Colleges, and Universities



... plus grant projects and publishing companies.

**Students spend more time on task
AND rate LON-CAPA as very helpful!**



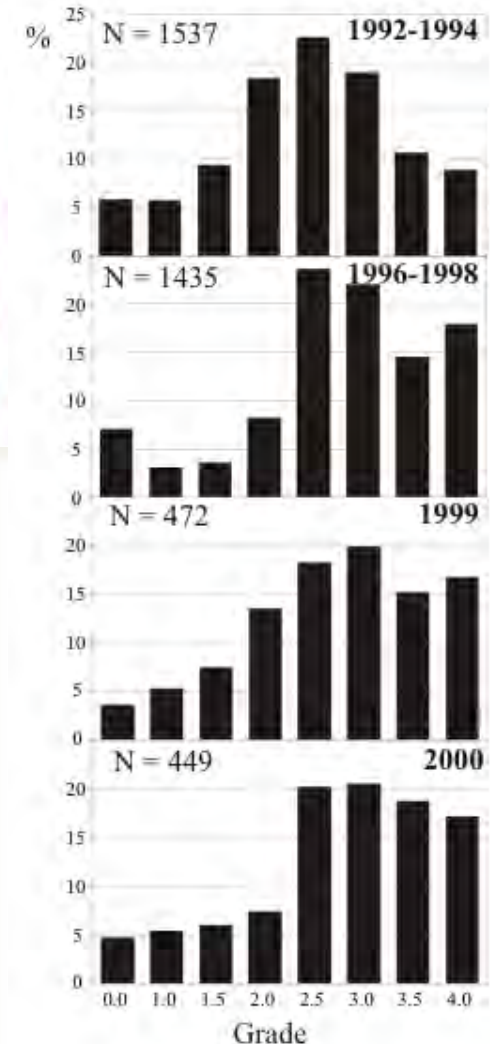
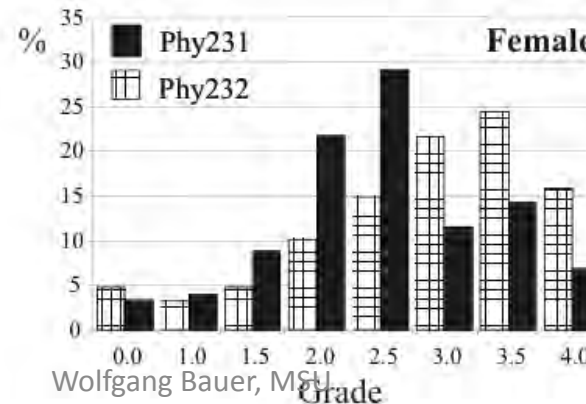
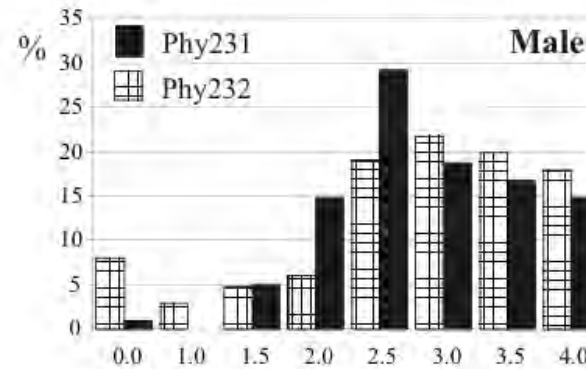
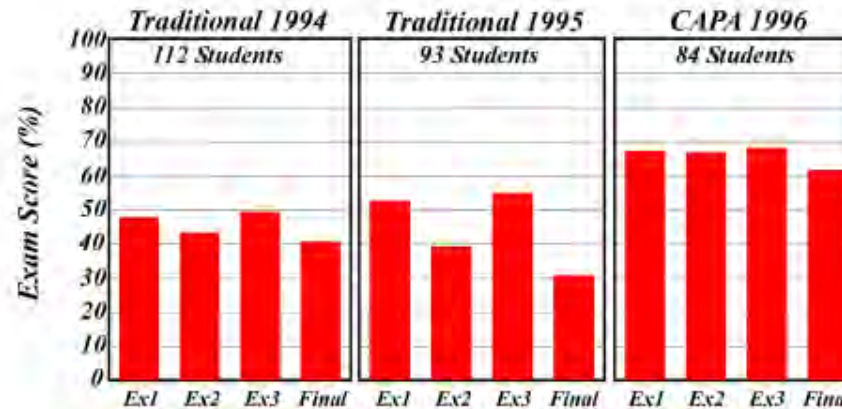
LON-CAPA - Research on Learning

Across a number of studies:

Improved exam performance

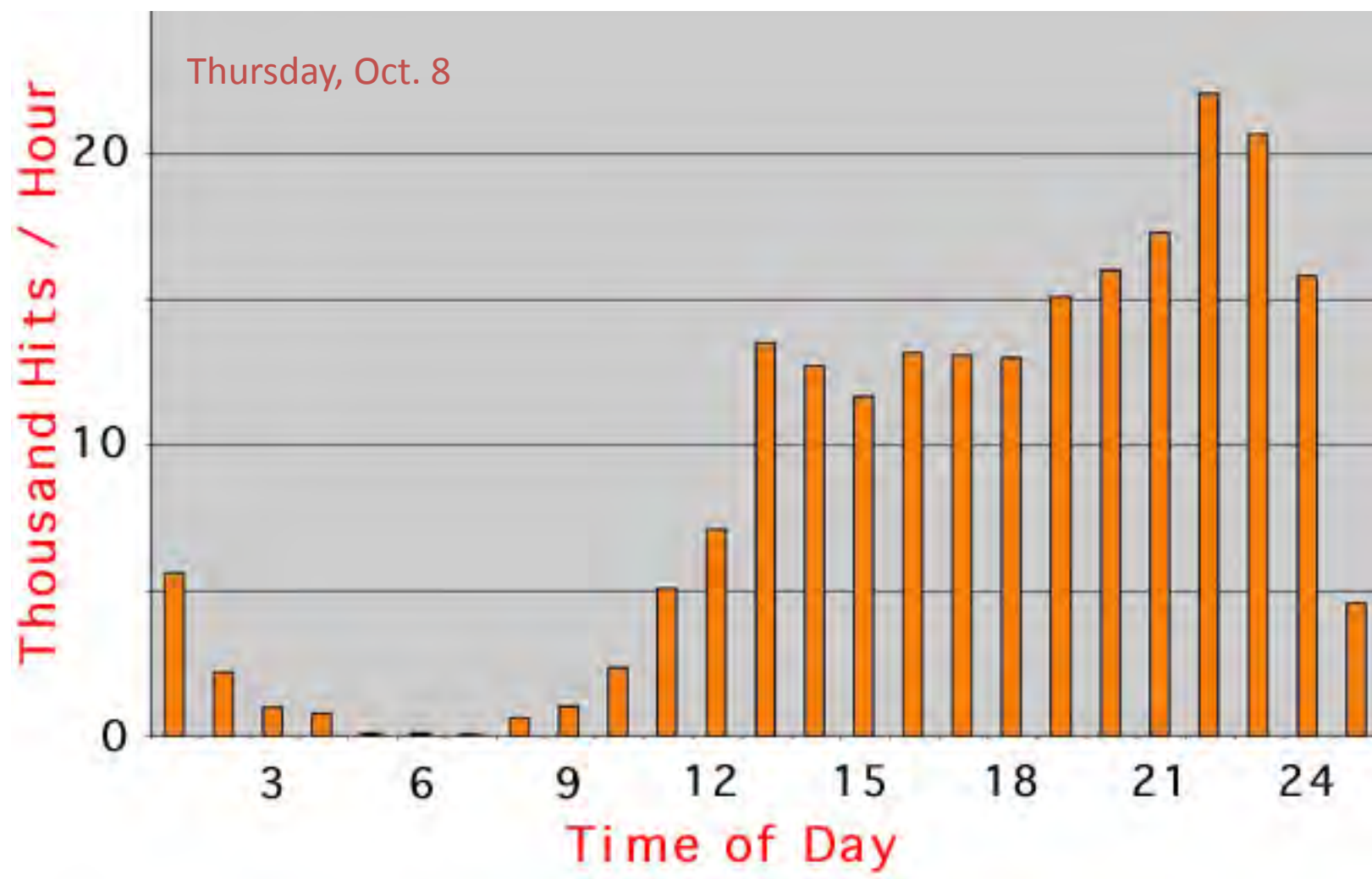
Improved course performance

Improved performance especially of female students



When do Students Work?

- Homework due at midnight
- 770 students in class



**Much more information
at lon-capa website:**

<http://www.lon-capa.org/>

and CourseWeaver website:

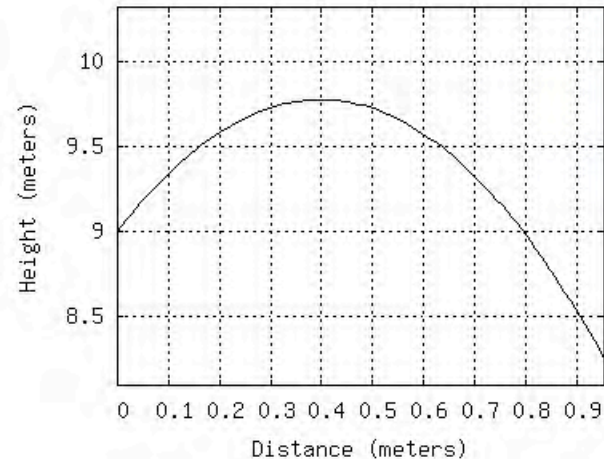
<http://www.courseweaver.org>

Working Together

In their jobs, people need to be able
to function as part of a team

➔ We need to teach these skills

Online Discussions



The plot shows the trajectory (height versus distance) of an object launched at an angle of 75.6 degrees. What was the initial speed of the object? **4.0 m/s**
Computer's answer now shown above. Tries 0/12

[Threaded View](#) [Chronological View](#) [Sorting/Filtering options](#) [Export?](#)

Anonymous 1 (Fri Sep 22 01:26:29 2006 (EDT))

any hints to start?

Re: *Anonymous 2* (Fri Sep 22 01:56:48 2006 (EDT))

You need to find the Y component of velocity... you can do this by finding the height traveled (notice it does not start on the ground) and combining that with acceleration in a kinematics equation. From there use trig to get the original velocity.

Re: Re: *Anonymous 1* (Fri Sep 22 12:10:37 2006 (EDT))

how can we find the height traveled and how can we get the acceleration if we don't have the time?

Anonymous 3 (Fri Sep 22 16:41:27 2006 (EDT))

i'm lost on this one... can anyone help?

Re: *Anonymous 4* (Fri Sep 22 20:02:45 2006 (EDT))

Use the squared kinematics equation - so $V_f^2 = V_i^2 + 2a(X_f - X_i)$.

Discussions

- Encouraged, since all students have different versions.
- Again: Peer-Instruction.

Help Rooms

- Staffed with Learning Assistants in the evenings
- Honors option: better students help weaker ones
- Collaborative learning space, peer instruction





The Answer Sheet

A School Survival Guide for Parents (And Everyone Else)

By Valerie Strauss | March 17, 2010

But one practice to which at least half of students admit--copying homework or working with others when they aren't supposed to--is not viewed by many undergraduates as real cheating. For example, more than 40% of undergraduates and 30% of graduate students (and almost 20% of faculty) do not think that 'cut and paste' plagiarism on homework is moderate or serious cheating.

The Washington Post

Cheating on homework in the Internet age

Solution « Cramster.com

http://www.cramster.com/solution/solution/759981

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View Solution:
Ch 8 15P GO
Rating (0 users)

College Physics (2nd)
By Giambattista, Richardson, Richardson
99% Answered

Find Another Textbook
Enter Title or Author
GO

Step 1

a) Torque due to upward force is $\tau_1 = Fx_1$
(\therefore Force is up ward and torque is CCW)
Torque due to down ward force is $\tau_2 = -Fx_2$
(\therefore Force is downward and torque is CW)
Then the magnitude of net torque is
$$|\tau| = |\tau_1 + \tau_2| = |Fx_1 - Fx_2|$$
$$= F|x_1 - x_2|$$
$$= Fd$$

Comments (0) Mistakes (0) +

Step 2

b) In this case also the perpendicular distance between the rotation of axis and the upward force is still x_1 and to the downward force it is x_2
Therefore the torque to the upward for is $\tau_1 = Fx_1$
And torque due to downward force is $\tau_2 = -Fx_2$
Then net torque is $\tau_2 = |Fx_1 - Fx_2|$
$$= F|x_1 - x_2|$$
$$= Fd$$

Comments (0) Mistakes (0) +

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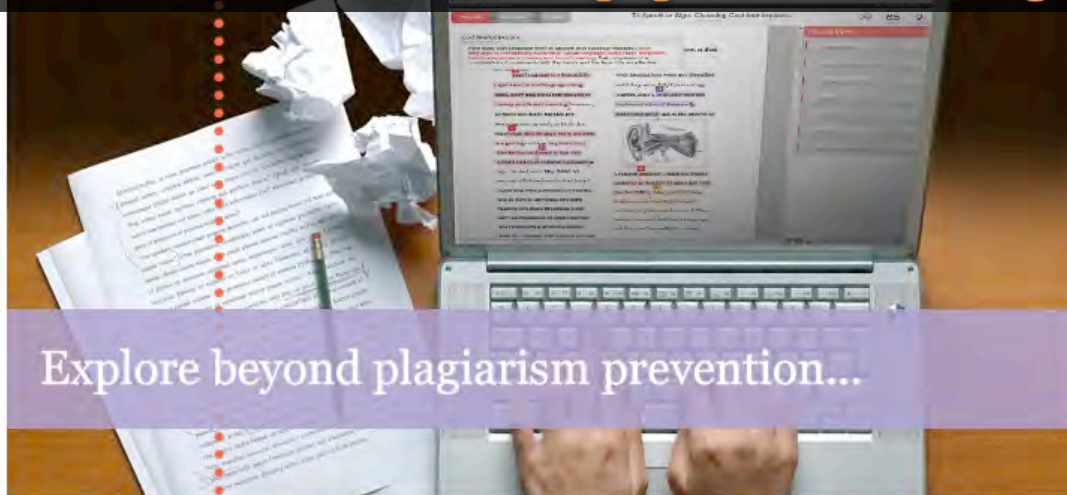
More Help For This Problem

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REMINDER: Plagiarism is a serious academic violation! Read the Cramster Honor Code

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Jenny Edwards
Fielding Graduate University

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- ♦ **19 million** licensed students
- ♦ **126** countries

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All files are

01/11/11 - Turnitin Begins 2011
With Record Growth and
Customer Satisfaction Levels

11/16/10 - 'Turnitin' Adds ETS's e-
rater Essay Scoring Engine to
Provide Powerful Grading Tools
for Instructors

09/21/10 - iParadigms Announces
the Formation of iParadigms
Europe Ltd



Steve Johnson for The New York Times

University of Central Florida testing center

- No chewing gum
- Date-stamped scratch paper
- 228 recessed computers (harder to photograph)
- Overhead video cameras
- 64000 test taken and only 14 incidents of suspected cheating

Homework copying can turn As into Cs, Bs into Ds

MIT physics educators investigate a bad habit's perils — and demonstrate a solution.

News Office

today's news

Canned, good



In this photo taken in the 1920s, Samuel Cate Prescott, left, and William Lyman Underwood discuss their canning research. Image courtesy of the MIT Museum

More than 100 years ago, 2 pioneering scientists figured

March 18, 2010

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Copying a few answers from another student's math or science homework assignment occurs much more frequently than copying during examinations or plagiarism on term papers. It is rarely prosecuted by discipline committees and is regarded by many American college students as either not cheating at all or simply a minor



multimedia



Former postdoctoral fellow Young-Jin Lee, left, and David E. Pritchard, the Cecil and Ida Green Professor of Physics

Patterns, correlates, and reduction of homework copying

David J. Palazzo

*Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA
and Department of Physics, United State Military Academy, West Point, New York 10996, USA*

Young-Jin Lee

*Department of Physics, Massachusetts Institute of Technology, Cambridge,
and Department of Educational Leadership and Policy Studies, The University of Kentucky, Lexington, Kentucky 40506, USA*

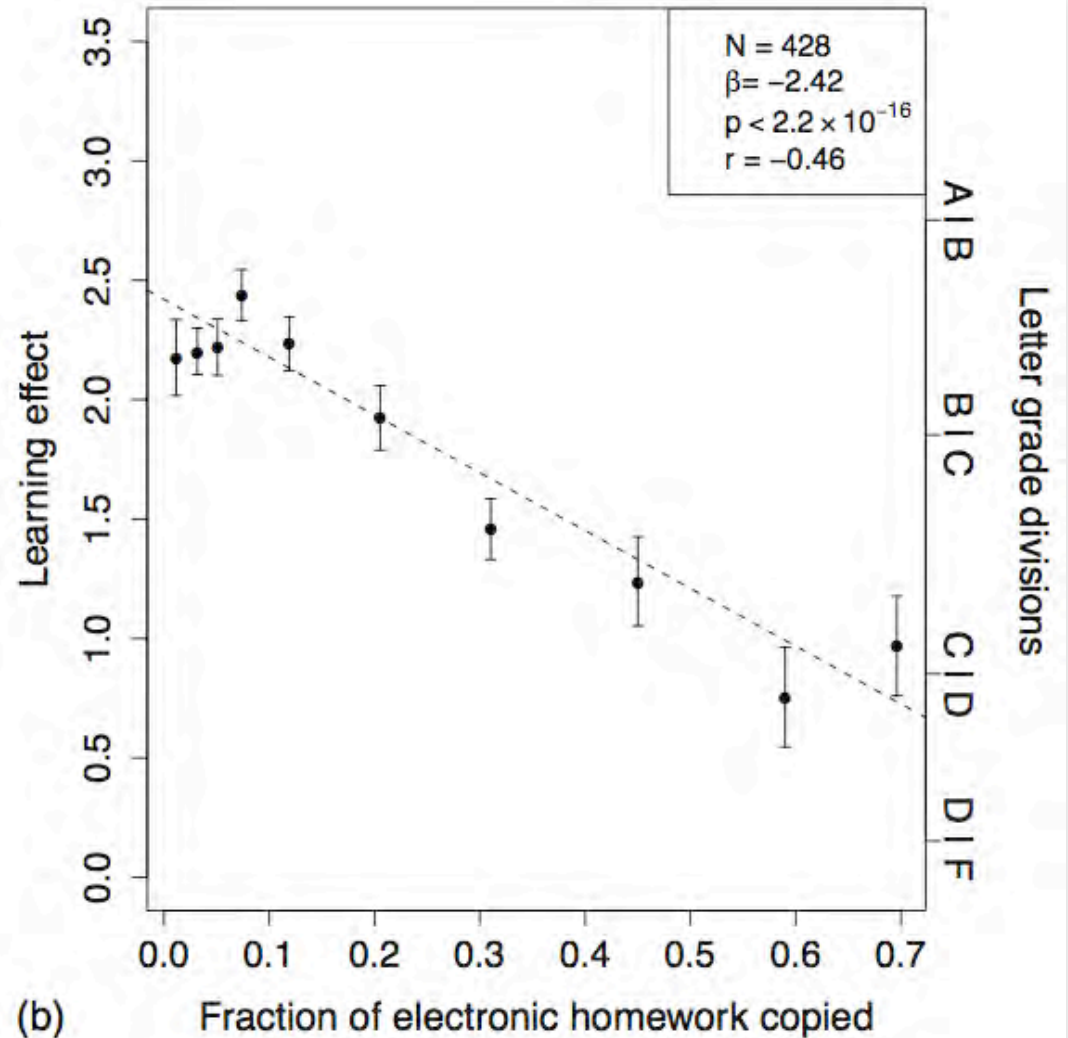
Rasil Warnakulasooriya

*Department of Physics, Massachusetts Institute of Technology, Cambridge,
and Pearson Education, Boston, Massachusetts 02116, USA*

David E. Pritchard

*Department of Physics, Massachusetts Institute of Technology, Cambridge,
(Received 4 October 2008; published 18 March 2010)*

“The message of this paper is that online homework copying can be detected, follows understandable temporal patterns, and is sufficiently prevalent that it is very likely causative of a significant fraction of course failure, especially in large lecture-based classes.”



INFLUENCE OF NON-MODERATED AND MODERATED DISCUSSION SITES ON STUDENT SUCCESS

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| | 3 rd Party Percent | Post-sanctioned | Look-sanctioned |
|-----------------|-------------------------------|-----------------|-----------------|
| Homework | 0.041 (0.655) | 0.118 (0.016) | -0.109 (0.026) |
| Final Exam | -0.348 (0.001) | 0.147 (0.003) | 0.129 (0.008) |
| Midterm Exams | -0.352 (0.001) | 0.166 (0.001) | 0.160 (0.001) |
| Quizzes | -0.302 (0.001) | 0.098 (0.044) | 0.069 (0.157) |
| FCI Improvement | -0.151 (0.162) | 0.121 (0.034) | 0.152 (0.008) |

Table 1: Correlation coefficients (and p-values) among the scores on the exams, homework, and improvement on the Force Concept Inventory test and student use of different web sites. The column named 3rd Party Percent refers to percent use of a web site that simply gave away the solution. The other two columns refer to the use of our own course sanctioned web site with threaded discussion forum, which did not give away the solution, but attempted to guide the students to find their own solution.

“The results suggest that high-tech copying is associated with lower levels of performance across all levels of academic ability. However, even if students are provided with this information (i.e., they are told that use of high-tech copying has been shown to lower overall course performance), it is not clear that the majority will be convinced to do their own work.”

Timeline

- Mid-Dec.: Final exam in PHY183
- Dec. 20: Sent initial questionnaire
- Early Jan.: Start of PHY184
- Jan. 31: Sent result of survey to all students
- End of April: Final exam in PHY184
- May 3: Sent follow-up questionnaire

Dear PHY183 student,

As you may know there is a commercial web site with help for the CAPA homework assignment system that you have been using during the past term:

<http://www.intereaction.com/>

In my role as undergraduate program director I would like to find out how useful this web site has been. Could you therefore reply to this message with a simple number between 0 and 100, telling me the (approximate) percentage of your homework problems that you used the above site for. If you never used the site, please send back the number 0.

You have my word that this information will be treated in a confidential manner, and that your answers will in no way influence the grade of this class or any future class you will take.

Thanks for your help
W. Bauer

Sample answers ...

0%

The site will give you the answers, but you don't learn anything, so it actually hinders a lot of people

I used the site for 80% of my homework problems. I sincerely hope I am not being "suckered" into admitting this. I would have not completed a large majority of the homework problems if it were not for the chutzpah of the site authors.

This web site helped me out a lot. I would give it a 95!

95

=====

bite me!

I think that I used the website for a about 25% of the problems. Only the ones that I really couldn't get on my own.

100% I have to take the class again and I blame it on the use of interaction.com I don't plan on making it a regular habit next semester of using this web page.

Dear PHY184 student,

After finals I had distributed an email to you in which I was asking for what fraction of your homework assignments you had consulted the web site <http://www.intereaction.com/>

As promised, we have treated all responses in a confidential manner. And as promised, I am giving you the results of this survey now.

I received a total of 133 responses. Many of you responded not just with a percentage, but with very thoughtful observations. Thanks to all who responded!

While we still have to work on cause-and-effect questions and on further correlation studies, I feel that it is important that I let you know right away the most important outcome of the survey. When we correlated the percentages with your grades in the quizzes and exams, the following correlation coefficients were obtained:

Correlations between Percent used the web site and:

final: $r = -.349, p < .001$

quiz: $r = -.302, p < .001$

midterms: $r = -.352, p < .001$

The first number in each row is the correlation coefficient, and the second the probability that the observed result is not significant. You can see a VERY strong negative correlation between use of the web site and all graded assessments of your class performance: the more you use the web site, the worse you do in your exams.

Quite a large number of you actually reported this correlation from their own experiences. The above statistics show that your feelings were essentially correct.

Honesty dictates that I also report that many of you praised the web site as a time saver and a valuable learning tool. I am sure that this might be true in some individual cases.

As promised: I will not move to close this web site. But I also feel very strongly that you should think about the results of our survey and act accordingly. I believe that the survey shows that there is no substitute for actually doing the work of finding the solution for the homework problems on your own. I admit that this can be very hard, but in my eyes it is still the best recipe for success.

Sincerely
W. Bauer

Dear PHY184 student,

This is a follow-up to the survey I sent to you after last semester, the one that asked about your use of the intereaction.com web site. Early this semester I had emailed you the results of that survey. In order for us to complete our study, could I please ask you to take a couple of minutes to answer the following questions?

- 1) Did you reply to last semester's questionnaire? (Y/N)
- 2) What percentage of the homework assignments did you use intereaction.com for for this semester's homework?
- 3) Did you change your use of intereaction.com after you received our performance analysis early this semester?
 - A) I used the site much less.
 - B) I use the site somewhat less.
 - C) I used the site about the same amount.
 - D) I used the site a little more.
 - E) I used the site a lot more.



Self-test opportunity

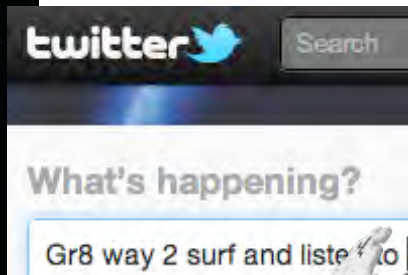
As before, I guarantee you that your answers will have absolutely no influence, positive or negative, on your grades.

Thanks very much, and have a great summer
W. Bauer

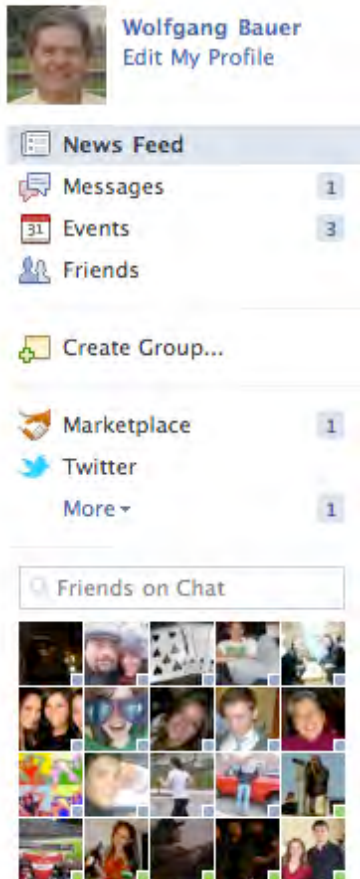
Exam Experiment

- Give a 50-min exam each Monday
- Covers concepts of the previous week
- Large overlap with homework due the previous Friday
- Outcomes:
 - **As expected:** Cuts down on cheating on homework, because concepts have to be mastered for next exam right away!
 - **As expected:** students learn significantly more!
 - **Huge surprise:** students like new frequent exam system!

J. Laverty, G. Kortemeyer, W. Bauer, and G.D. Westfall, "Want to Reduce Guessing and Cheating While Making Students Happier? Give More Exams!", Phys. Teach. 50, 464-467 (2012).



1998: Page, Brin



How our students interact with the world



1994: Andreessen

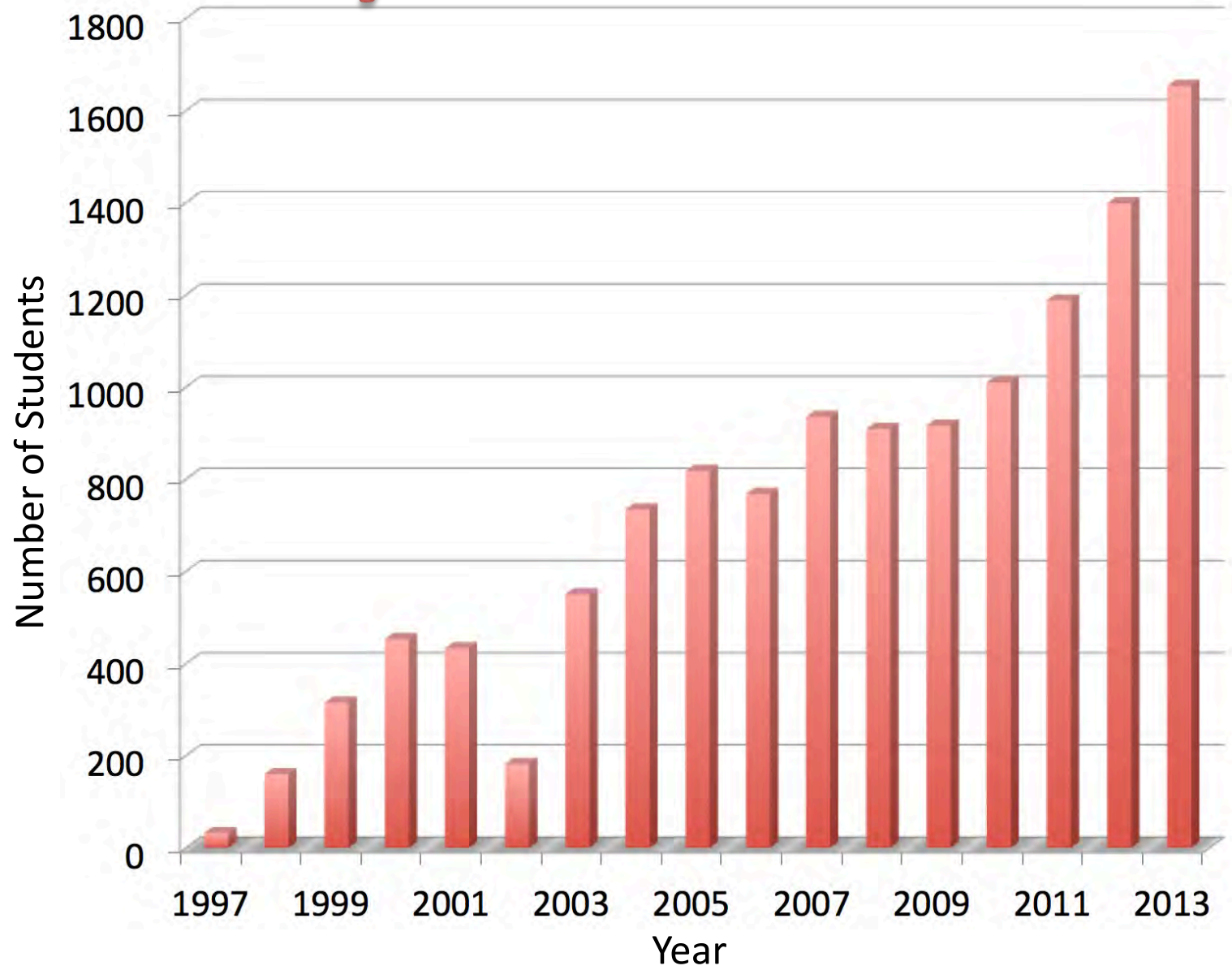


1989: WWW, Berners-Lee

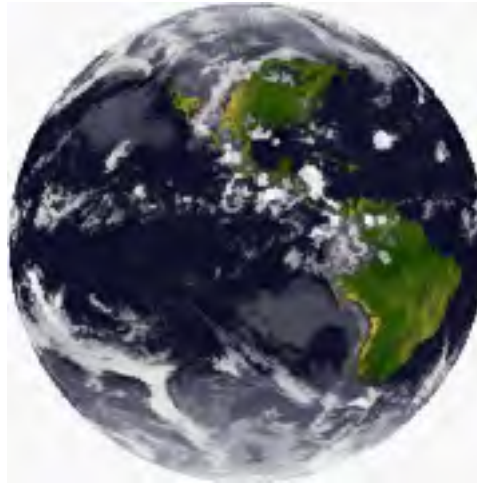


2007: iPhone (Apple)

MSU Physics Online Students

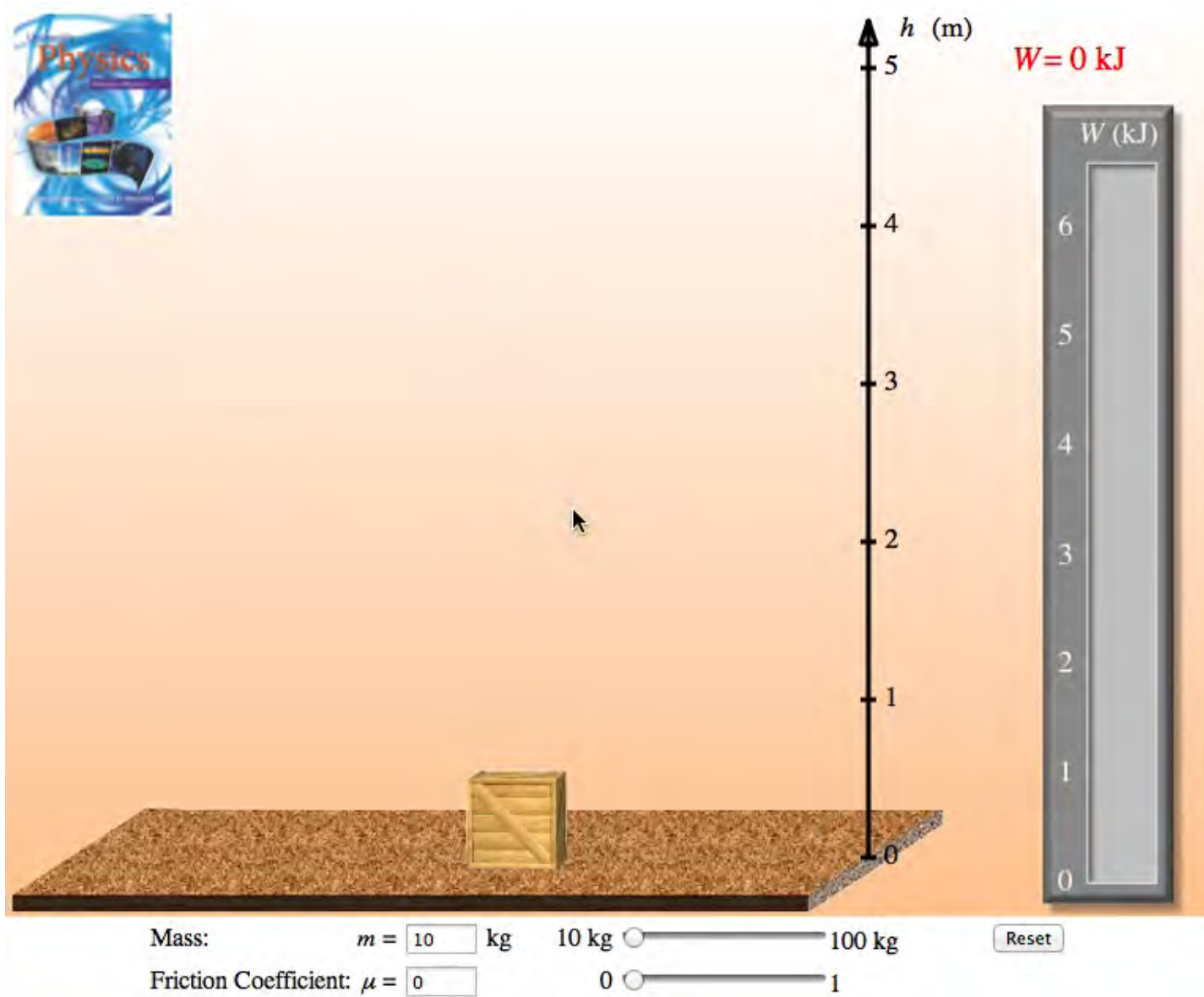


Online Course “Energy”



- Basic physics principles
- Advanced technology
- Solving largest problem of our civilization

Basic Concepts, Using Interactives



Lecture Demonstrations Videos



Time-lapse



Real-time

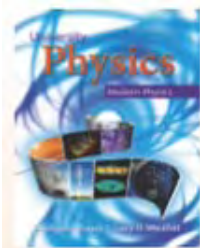


Slow-motion

Narrated Problem Solutions



Advanced Concepts



$P = 0 \text{ W}$



Rotor diameter: $d =$ m 20 m 120 m

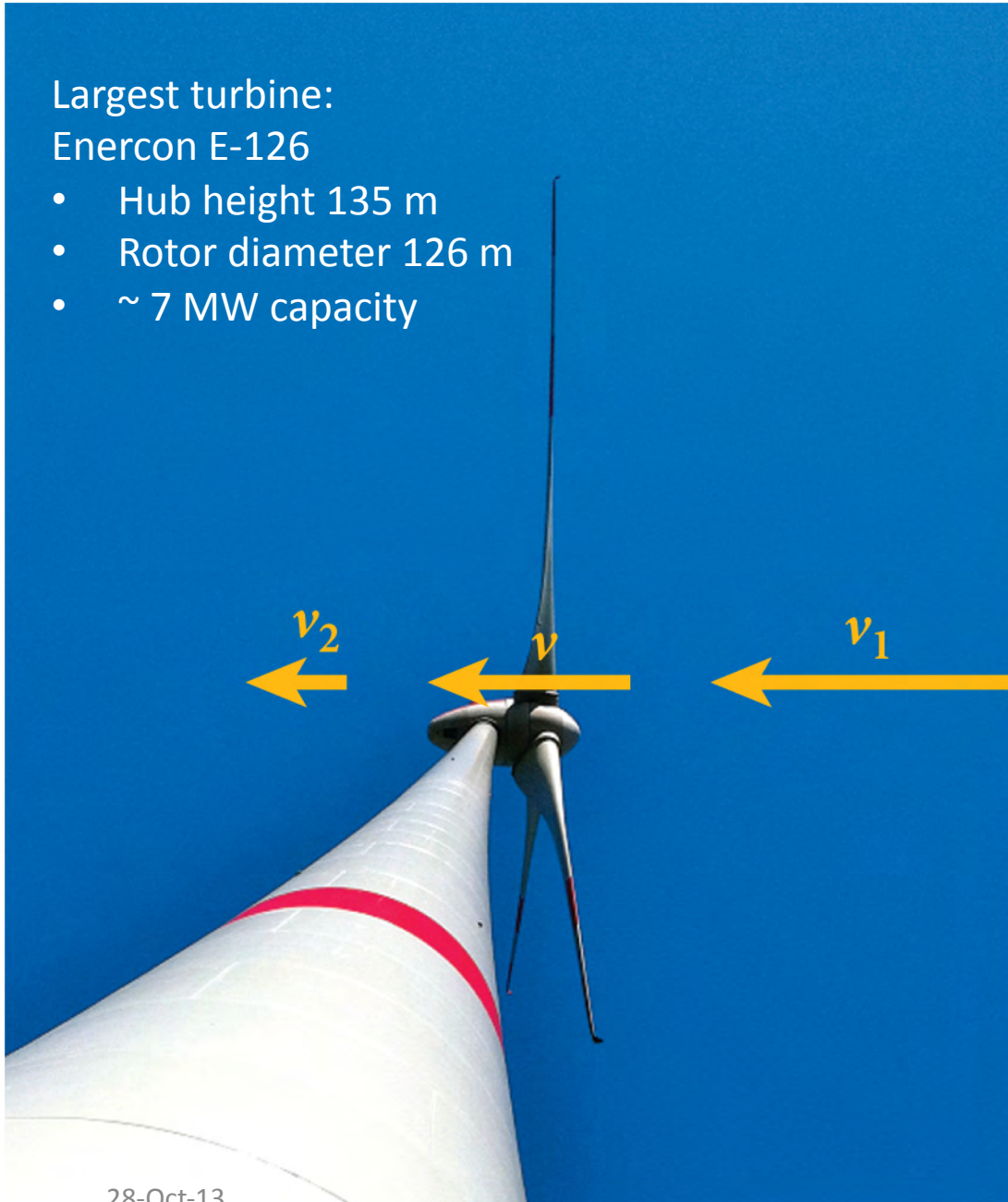
Wind speed: $v =$ m/s 0 m/s 10 m/s

Wind

Largest turbine:

Enercon E-126

- Hub height 135 m
- Rotor diameter 126 m
- ~ 7 MW capacity



$$P = \frac{1}{2} \rho A v_1^3 \frac{1}{2} \left(1 + \frac{v_2}{v_1} - \left(\frac{v_2}{v_1} \right)^2 - \left(\frac{v_2}{v_1} \right)^3 \right)$$

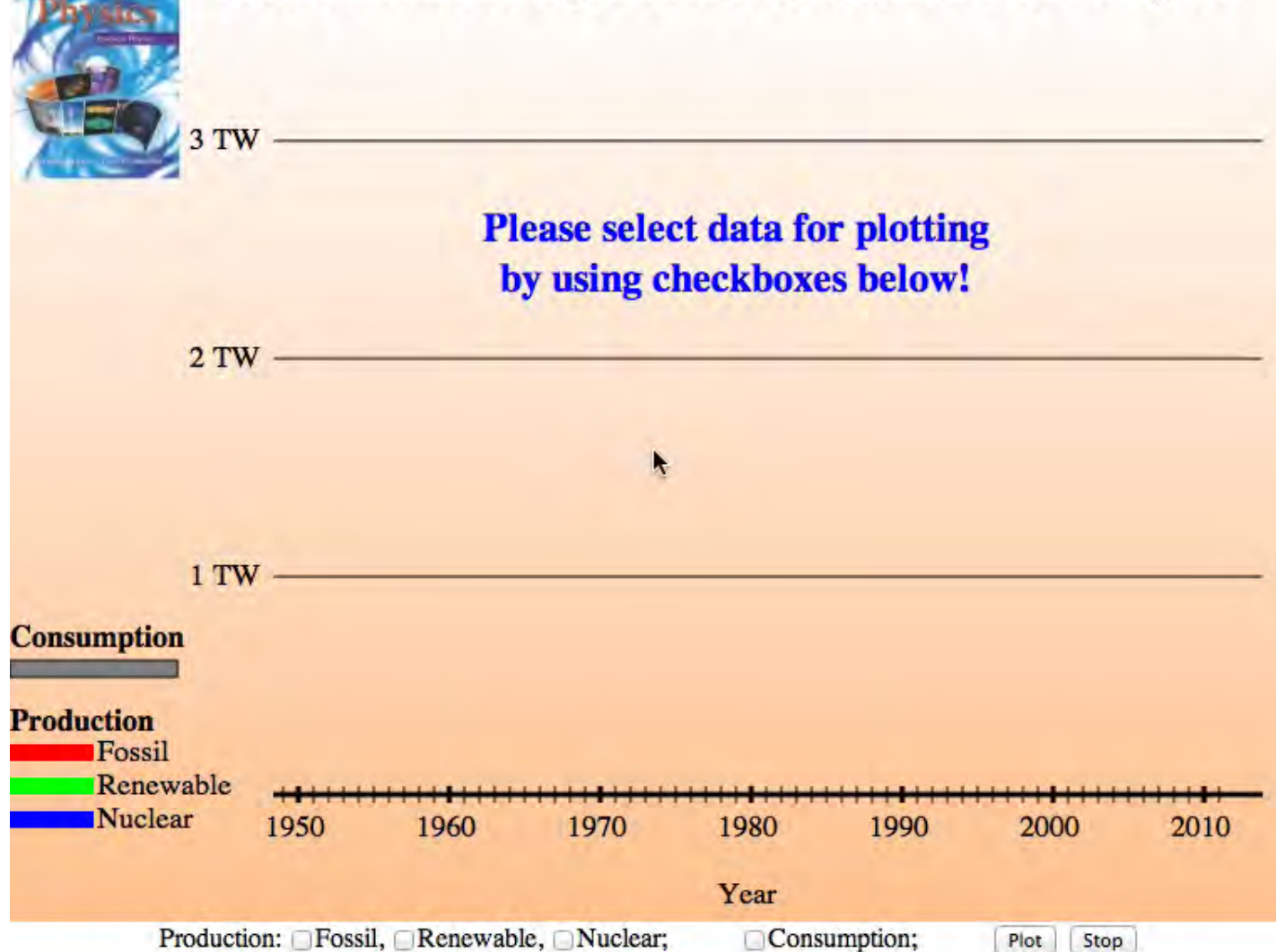
$$f(\chi) = \frac{1}{2} \left(1 + \chi - \chi^2 - \chi^3 \right) \quad \chi \equiv \frac{v_2}{v_1}$$

$$f\left(\chi_{\max} = \frac{1}{3}\right) = \frac{1}{2} \left(1 + \frac{1}{3} - \left(\frac{1}{3} \right)^2 - \left(\frac{1}{3} \right)^3 \right) \\ = \frac{16}{27} = 0.593$$

Use of Actual Data



USA Annual Average Power Production and Consumption



Summary

- The time is right for online education
- LON-CAPA / CourseWeaver provides the appropriate modern computational and network infrastructure
- An online course with the central theme of energy (English and/or Portuguese) can educate students on basic principles and at the same time address concepts with great consequences for our society

... what book to use?



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<http://www.pa.msu.edu/~bauer/>