

# Just In Time Teaching to 600 Students:

*More fun than you thought  
for less work than you'd think!*

(Mats Selen, UIUC Department of Physics)

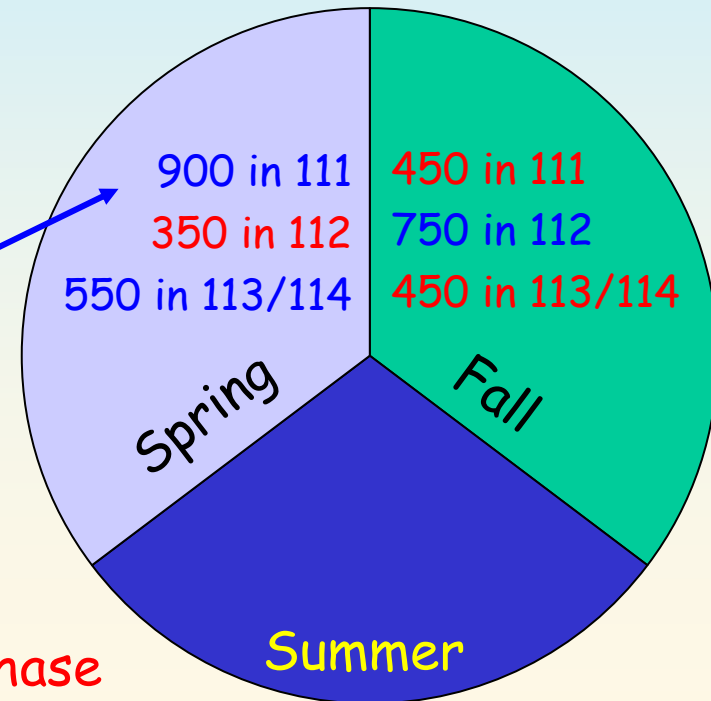
- Why I got into it.
- Why I'll never do it any other way again.
- Why you should try it too !

# Overview of the UICU calculus-based introductory physics sequence

- Physics 111 (4 hrs, mechanics)
  - Physics 112 (4 hrs, E&M)
  - Physics 113 (2 hrs, thermo/stat-mech)
  - Physics 114 (2 hrs, waves/quantum)
- Total enrollment of about 3500
  - Mostly Engineering & Physics students

Most freshmen start here

In Phase  
Out of Phase



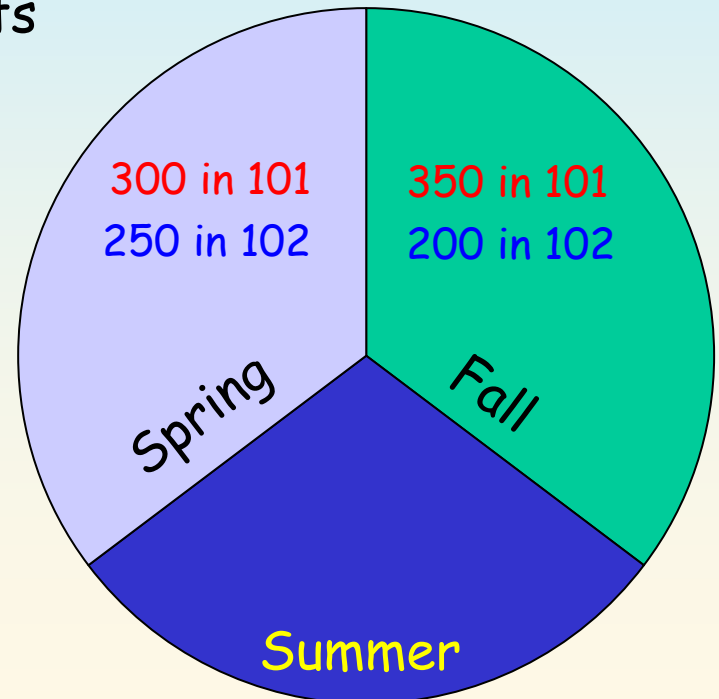
# Overview of the UICU algebra-based

• Will focus mostly on this introductory physics sequence

→ Physics 101 (5 hrs, mechanics, heat, fluids, waves)

→ Physics 102 (5 hrs, E&M, Light, Atoms, Relativity)

- Total enrollment of about 1100
- Mostly pre-med & life-science students



# How it used to work:

- Tradition, Tradition, Tradition

- Lecturer "owns" the course and is free to "reinvent the flat tire" every semester.
- Discussion TAs pretty much on their own.
- Labs intellectually disconnected from rest of course.
- Typically only quantitative problems on exams.

- RESULTS: NOBODY IS HAPPY !!

- Lecturer dislikes it since it's a monster teaching assignment.
- Students dislike it because they see the lecturer dislikes it and because the organization is often "uneven" at best.

# How we do it now:

- Integrate all aspects of a course using active learning methods in a team teaching environment.
  - Typically 3 faculty share the load:
    - » Lecturer (lectures, ACTs, preflights, exams).
    - » Discussion Director (TA training, quizzes, exams).
    - » Lab Director (TA training, web homework, exams).
  - Course administration is shared responsibility:
    - » Faculty meet at least once a week with each-other and with their TA's to plan the campaign.
    - » Overall co-ordination is very tight (web helps this).
    - » Everybody works on creating exams.

- Course material changes adiabatically:
  - » Recycled & tuned from semester to semester.
  - » People don't need to re-invent the whole stew, but can focus on the spices!

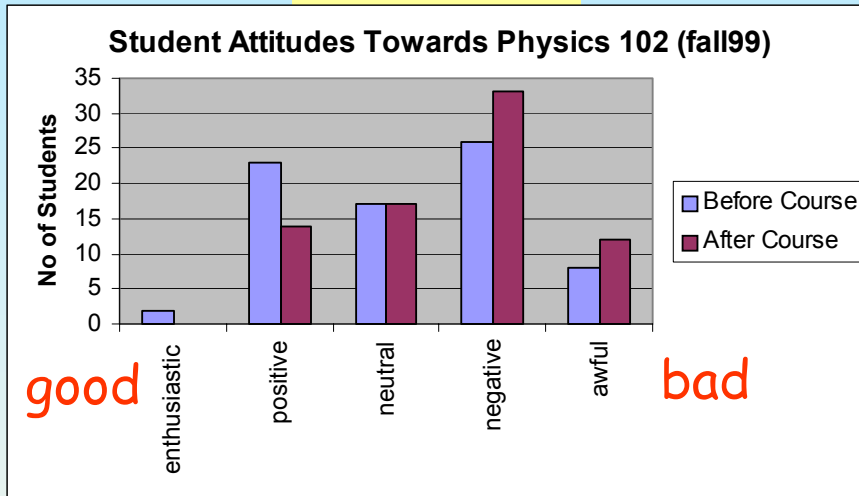
## Advantages of this approach:

- Existing (evolving) infrastructure lowers the bar for participation.
  - » This is now seen as a reasonable teaching load.
  - » Most of our new junior faculty start teaching in these courses (i.e. not a heavy assignment).
- Pain & Gain are shared
  - » No burnout & No heroes.
  - » Makes it possible to keep quality high and material consistent even though instructors are changing.

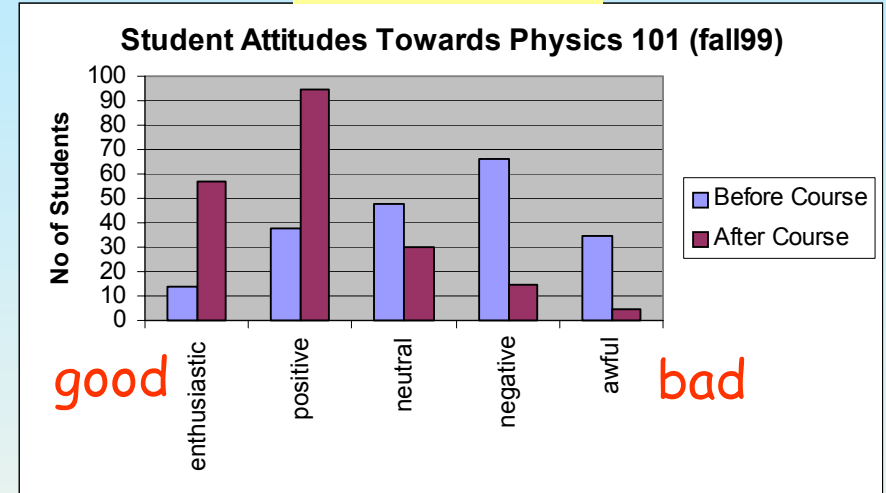
# Feedback

(are things better now ?)

## THE OLD



## THE NEW



## THE OLD

Spring 95

Total Physics TAs = 77  
 # "Excellent" = 15  
**19 ± 5 %**

## THE NEW

Spring 01

Total Physics TAs = 75  
 # "Excellent" = 58  
**77 ± 6 %**

# Details of some key components:

WEB-centric organization

Peer instruction in Discussion & Lab sections

ACTs & Preflights in Lecture

Homework & Interactive Examples

Exams

# Active Learning: Motivation ?

Ruhl, K. L., Hughes, C. A., & Schloss, P. J. (1987, Winter).  
Using the pause procedure to enhance lecture recall.  
*Teacher Education and Special Education*, 10, 14-18.

In this study an instructor **paused for two minutes on three occasions** during each of five lectures: the [lecture segments] ranged from 12 to 18 minutes. During the pauses, while students worked in pairs to discuss and rework their notes, no interaction occurred between instructor and students.

At the end of each lecture, students were given three minutes to write down everything they could remember from the lecture (free recall); 12 days after the last lecture, the students were also given a 65 item multiple-choice test to measure long-term retention.

A control group received the same lectures (using the same anecdotes and visual aids) and was similarly tested. In two separate courses repeated over two semesters, the results were striking and consistent:

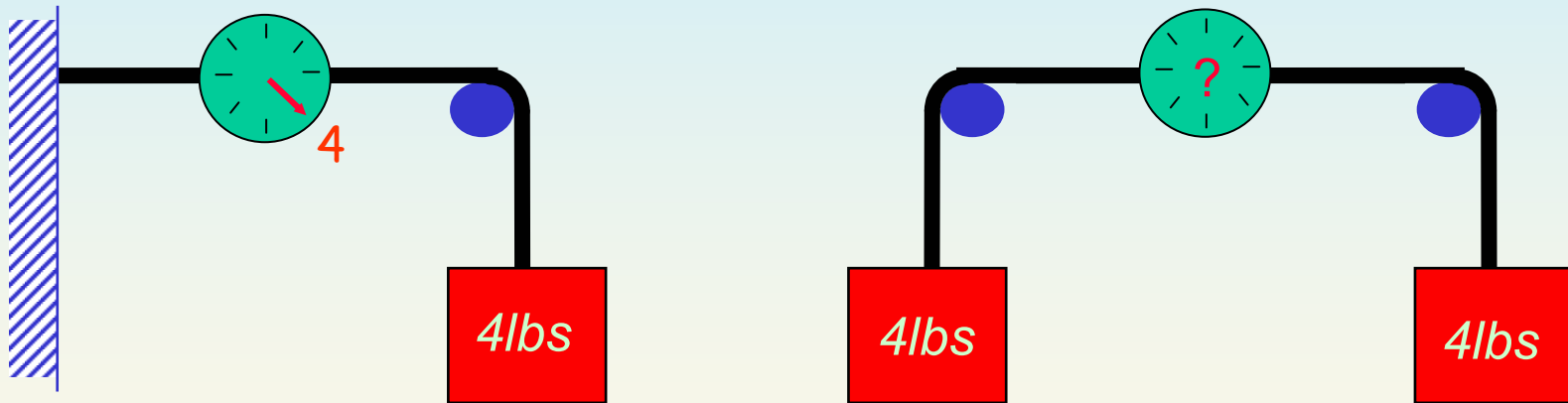
**Students hearing the lectures while the instructor paused did significantly better on the free recall and the comprehensive test. In fact, the magnitude of the difference in mean scores between the two groups was large enough to make a difference of two letter grades depending upon cutoff points!**

# What we did: ACT's

- Break the lecture into 10-15 minute segments (attention span).
- Lecture segments separated by 3-5 minute Active Learning Segments (ACTs).
  - Students work in groups of 3-4 on a conceptual problem posed by the lecturer.
  - Lecturer and (several TA's) wander around the room asking leading questions.
    - » Helps the students figure out problem
    - » Helps the lecturer understand the students misconceptions.
  - Students "Vote" on the correct answer (in groups)
  - Lecturer presents solution and discusses perceived misconceptions.
  - Lecturer does appropriate demo (if possible).

# Example:

- A block weighing 4 lbs is hung from a rope attached to a spring scale. When the other side of the scale is attached to a wall it reads 4 lbs. What will the scale read when the other side is instead attached to another block weighing 4 lbs?



(a) 0 lbs.

(b) 4 lbs.

(c) 8 lbs.

Most students get it wrong ... fuel for discussion

# Drawbacks & Limitations?

ACT's are great during lecture, but do nothing to prepare students for the lecture!

# Pre-Flights !!

- Based on *Just-In-Time Teaching* approach  
Novak, Patterson, Gavrin, Christian (Prentice Hall).
- Students are asked to answer a set of conceptual questions (on the Web) prior to every lecture. This guides lecture preparation.
- The main structure in Physics 101 is:
  - Students read about material in text.
  - Students answer pre-flight questions on material prior to lecture.
    - » Physics 101 PF's due at 6am, lecture starts at 1pm.
    - » Graded on participation, not correctness.
  - Instructor uses pre-flight responses to guide lecture preparation.
    - » Stress difficult material
  - Pre-flights are reviewed during lecture, often presented again as ACTs, and often capped off with a demo.
- With careful preparation, the pre-flights can form the "backbone" of the lecture - took a while for me to figure this out.

## What the students see on the web:

### Lecture 2 Preflight

(6 questions)

If you change any of your answers, be sure to click on Store My Answers at the bottom of this page before you leave. The deadline for storing your answers is 0600 on 01/24/2001.

1) If the average velocity of a car during a trip along a straight road is positive, is it possible for the instantaneous velocity at some time during the trip to be negative?

Yes  No

2) Briefly justify your answer:

3) If the velocity of some object is not zero, can its acceleration ever be zero?

Yes  No

4) Briefly justify your answer:

5) Is it possible for an object to have a positive velocity at the same time as it has a negative acceleration?

Yes  No

6) Briefly justify your answer:

Store My Answers

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## What I typed in a simple text file:

```
title "Lecture 2 Preflight";

question "If the average velocity of a car during a
trip along a straight road is positive, is it
possible for the instantaneous velocity at some
time during the trip to be negative?";

right "Yes";
wrong "No";

radioh;

question "Briefly justify your answer::";

textarea;

question "If the velocity of some object is not
zero, can its acceleration ever be zero?";

right "Yes";
wrong "No";

radioh;

question "Briefly justify your answer:";

textarea;

question "Is it possible for an object to have a
positive velocity at the same time as it has a
negative acceleration?";

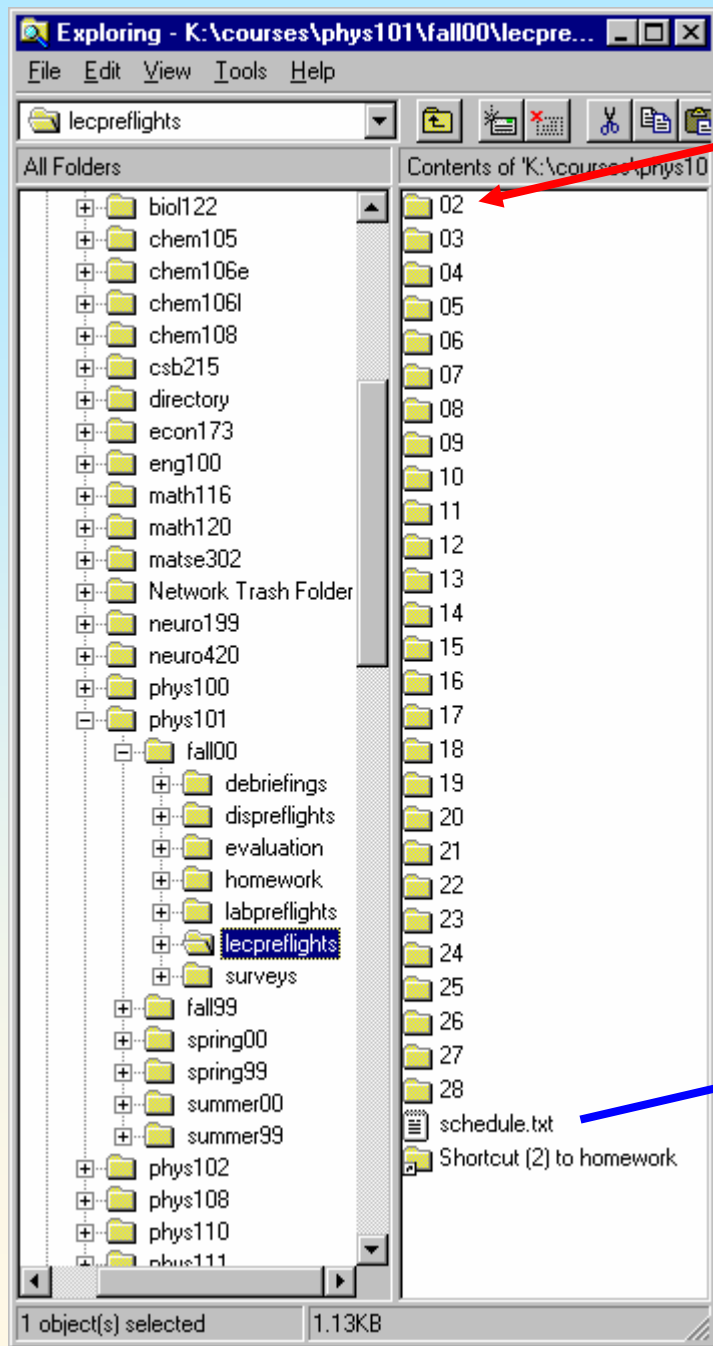
right "Yes";
wrong "No";

radioh;

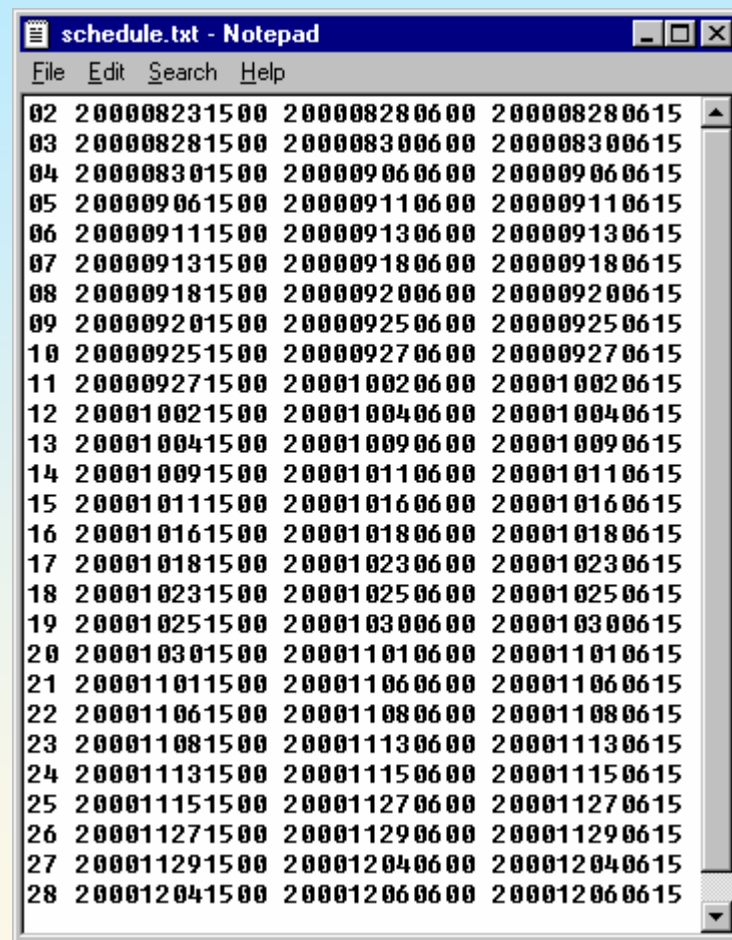
question "Briefly justify your answer:";

textarea;
```

Notice: Lots of folks use our web-based grade-book:



Simple setup on our NT server:  
Text (& pictures) for PF 2 in here



# The instructors interface to the student responses (also on web):

## phys101/spring00 lecture preflight responses

Pick a lecture preflight from this list:

Mark the number(s) of the answer(s) you want displayed: [optional]  
If you don't mark any, the answers to all of the questions will be displayed.

Pick section(s): [required]

Choose the students to include:  those who responded  those who did not respond

Set filter if needed. ([samples](#))

Include only students for whom:

Specify the student identifier(s) to be displayed:  name and netid  section  special id

Then click on this button:

Or click on this one:

## Statistics:

QUESTION 1 (249 responses)

answer number	student count	percentage
1	183	73 %
2	66	27 %

## Free response:

**Afsharzadeh Majid (afsharza) T2 F3X lecture preflight 02**  
2: It could be possible that in a short amount of time the velocity decreased yet for the whole time the average can be positive.

**Ahn Bonnie Se-Jeong (bsahn) J2 L2X lecture preflight 02**  
2: during the course of the trip, the car could have traveled in both positive and negative directions. The positive average velocity just indicates that net displacement of the car was positive.

**Akbar Imran Shaan (iakbar) R2 F3X lecture preflight 02**  
2: the overall velocity can be positive even though the car might have went in the negative direction with velocity

**Alfano Lisa Marie (alfano) G1 L1X lecture preflight 02**  
2: An average velocity is just that, an average of the total instantaneous velocities. Somewhere in the average, an instantaneous velocity can be negative since the average does not account for these variations.

**Ambler Steven Benton (sambler) T2 A1X lecture preflight 02**  
2: Instantaneous is the velocity at a single point in time. Since the car only travels in one direction, it will always be positive

# Lecture 2, Pre-Flights 1&2

If the average velocity of a car during a trip along a straight road is positive, is it possible for the instantaneous velocity at some time during the trip to be negative?

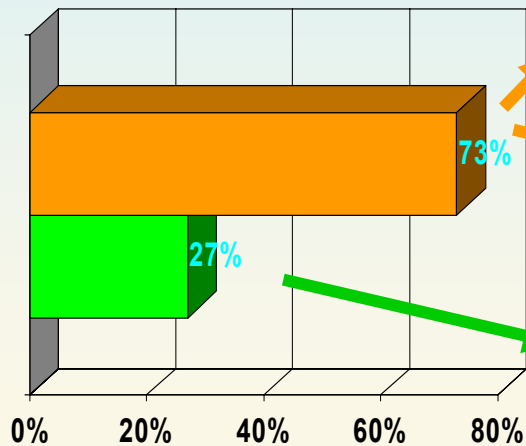
1 - Yes ← correct

2 - No

As long as the net distance traveled over the given time was positive, the average velocity will be positive—regardless of whether the car went in reverse at any point during that time.

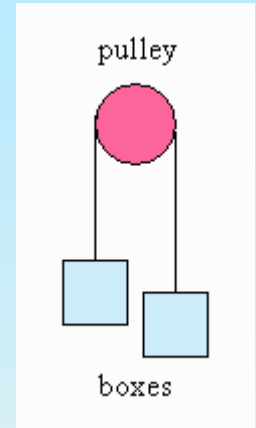
I could have forgotten something at home and had to turn around, but eventually I reached my destination away from my starting pt.

Velocity cannot be negative in reality.

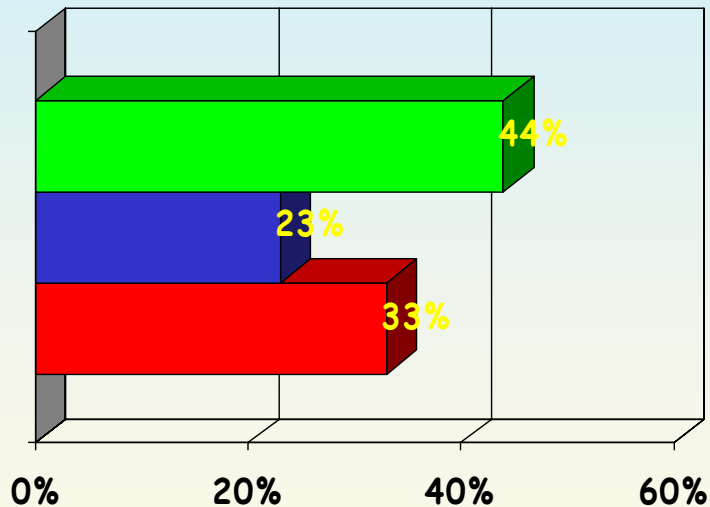


# Lecture 6, Pre-Flight Questions 7&8

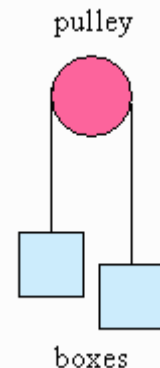
Two identical boxes, each having a weight  $W$ , are tied to the ends of a string hung over a pulley (see picture). What is the tension  $T$  in the string? [see text 4.10]



1.  $T=0$
2.  $T=W$  ← correct
3.  $T=2W$



# Students see their own answers



Two identical boxes, each having a weight  $W$ , are tied to the ends of a string hung over a pulley (see picture). What is the tension  $T$  in the string? [see text 4.10]

1.  $T=0$

2.  $T=W$

3.  $T=2W$

Due to Newton's second and third laws, the rope itself is massless, so any force transmitted across it is done so without the diminishing of any magnitude. As each box has an equal weight, the tension  $T$  must be zero, as each box's force cancels the other's out.

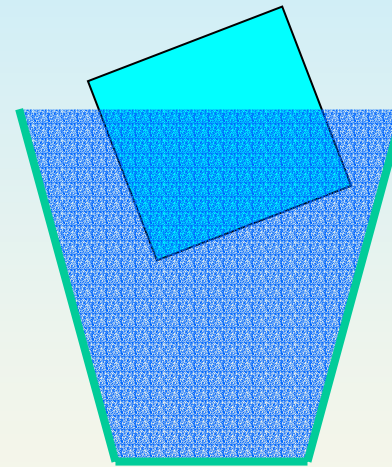
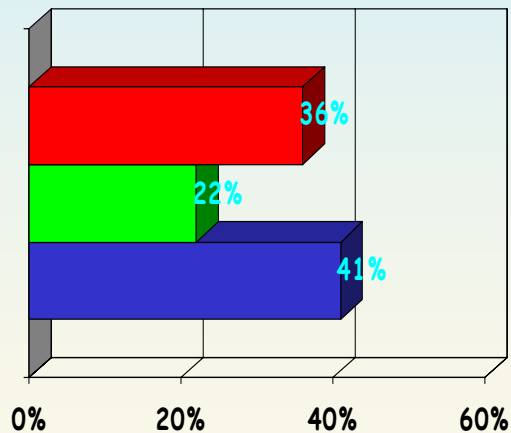
The force applied to the rope is transmitted to the other side. This example would be just like a person hoisting up a box, pulling on the rope with a force of  $W$ . In this case, the tension would just be  $W$ .

The string has the tension of two weights.

# Lecture 20, Preflight 1

Suppose you float a large ice-cube in a glass of water, and that after you place the ice in the glass the level of the water is at the very brim. When the ice melts, the level of the water in the glass will:

1. Go up, causing the water to spill out of the glass.
2. Go down.
3. Stay the same. ← CORRECT



# phys101/spring00 lecture preflight responses

Pick a lecture preflight from this list:

Mark the number(s) of the answer(s) you want displayed: [optional]  
If you don't mark any, the answers to all of the questions will be displayed.

Pick section(s): [required]

Choose the students to include:  those who responded  those who did not respond

Set filter if needed. [\(samples\)](#)

Include only students for whom:

Specify the student identifier(s) to be displayed:  name and netid  section  special id

Then click on this button:

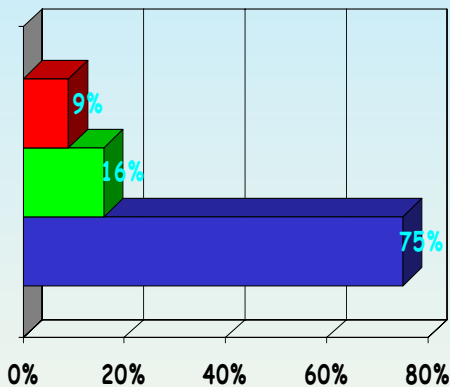
Or click on this one:

**Nice Tools:**  
We can "filter" on responses based on other questions !!

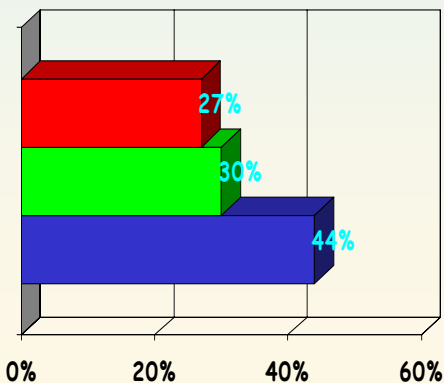
# Lecture 20, Preflight 2

Which weighs more:

1. A large bathtub filled to the brim with water.
2. A large bathtub filled to the brim with water with a battle-ship floating in it.
3. They will weigh the same. ← CORRECT

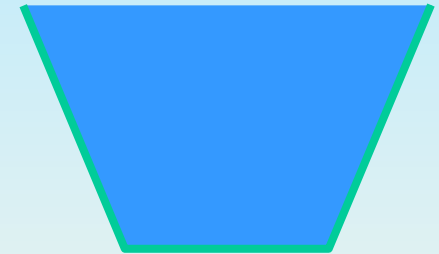


Students who got Preflight #1 **right**.

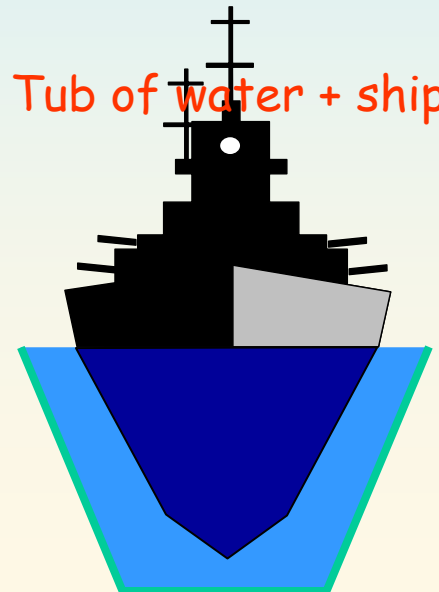


Students who got Preflight #1 **wrong**

Tub of water



Tub of water + ship



# Students have fun with answers...

Shown is a yummy doughnut. Where would you expect the center of mass of this breakfast of champions to be located? (Explain your reasoning Homer).



In the center. Assuming a perfectly symmetrical donut, all the mass is equidistant from the center. Until someone takes a bite. (Doh)

←← CORRECT

you're not getting my answer unless i get sprinkles.....suckers ! unfortunately, i think the center of mass of this perfectly symmetrical donut would be the center of the donut which does not seem to exist; so, i'll just say homer ate it.

I think it would be in a the middle of the dough in a circular pattern. Kind of like the onion in an onion ring. UMMMMM..... Onion rings!!!!

← INCORRECT

# Details of some key components:

WEB-centric organization

Peer instruction in Discussion & Lab sections

ACTs & Preflights in Lecture

Homework & Interactive Examples

Exams

# Web-based Homework:

## Three Blocks

Blocks of mass **3**, **6**, and **9 kg** are lined up from left to right in that order on a frictionless surface so each block is touching the next one. A rightward-pointing force of magnitude **12 N** is applied to the left-most block. What is the magnitude of the force that the middle block exerts on the rightmost one?

$F_{\text{right, middle}} =$   N

What is the magnitude of the force that the leftmost block exerts on the middle one?

$F_{\text{middle, left}} =$   N

Suppose now that the left-right order of the blocks is reversed. Now find the magnitude of the force that the leftmost block exerts on the middle one?

$F'_{\text{middle, left}} =$   N



Tycho

Students are (usually) told whether their answer is correct.  
Students can try as many times as they like before deadline.

## A drawback for some students: Limited help available...

### Three Blocks

Blocks of mass **3**, **6**, and **9 kg** are lined up from left to right in that order on a frictionless surface so each block is touching the next one. A rightward-pointing force of magnitude **12 N** is applied to the left-most block. What is the magnitude of the force that the middle block exerts on the rightmost one?

$$F_{\text{right, middle}} = \text{[input box]} \text{ N} \quad \text{Reset} \quad \text{Enter}$$

**HELP:** Draw a Free-Body Diagram to find the forces on the rightmost block. Then apply  $F = ma$ .

**HELP:** What is acceleration of the rightmost block? Is it the same as the other blocks? How can you determine the acceleration of the system of three blocks?

What is the magnitude of the force that the leftmost block exerts on the middle one?

$$F_{\text{middle, left}} = \text{[input box]} \text{ N} \quad \text{Reset} \quad \text{Enter}$$

**HELP:** Draw a Free-Body Diagram to find the forces on the middle block. Remember Newton's Third Law. Then apply  $F = ma$ . You should already know the acceleration from part (a).

**HELP:** Newton's Third Law says that the force exerted on the middle block by the right block is equal in magnitude and opposite in direction to the force exerted on the right block by the middle block.

Suppose now that the left-right order of the blocks is reversed. Now find the magnitude of the force that the leftmost block exerts on the middle one?

$$F'_{\text{middle, left}} = \text{[input box]} \text{ N} \quad \text{Reset} \quad \text{Enter}$$

# Interactive Examples (Socratic Dialogue)



## INTERACTIVE EXAMPLE

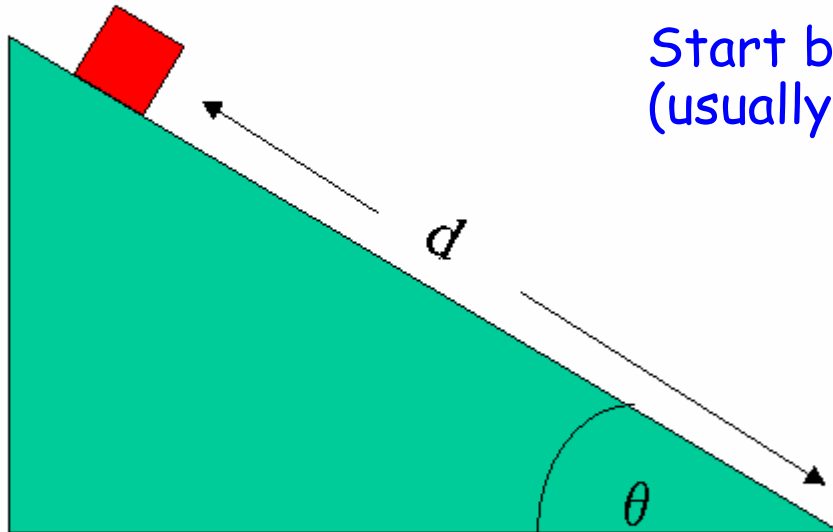
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[Comments](#)

EX

### Block on Incline

A block is positioned on an incline of angle 30 degrees a distance  $d = 10$  meters up the incline as shown in the picture.



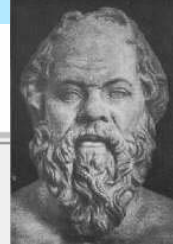
Start by asking a numeric question  
(usually multi-step)

If the block is assumed initially at rest, how long will it take to reach the bottom of the incline?

$t =$    $s$

→ when students click in "Help"...

t =  s



### HELP

This problem is a little more difficult. It combines two different class topics. If we can find an acceleration for the block we can compute the time it takes to slide down using techniques from the last couple of weeks.

Now if we were to apply Newton's second law to our problem we could compute an acceleration. So as with this type of problem we again should turn to Tipler's five steps for solving mechanics problems (on pg. 96 of text):

1. Draw a diagram
2. Isolate the object and draw a free-body diagram with the forces acting on that object
3. Choose a coordinate system and apply Newton's second law  $\Sigma F = ma$  in component form
4. Solve for any unknowns
5. Check to see if answer is reasonable

So again go ahead and try these steps and see how far you can get. If you need additional help click below.

Alright, so we'll assume you have already drawn a picture. We'll also assume that our object of interest here is the block. So our next step is to figure out which forces act on the block and construct our Free-Body-Diagram (FBD).

So first of all how many forces are acting on the block (Remember the incline is said to be frictionless)?

- One
- Two
- Four

...“Help” results in a discussion followed by some multiple-choice questions that lead them toward the answer...



So first of all how many forces are acting on the block (Remember the incline is said to be frictionless)?

One

OK  Two

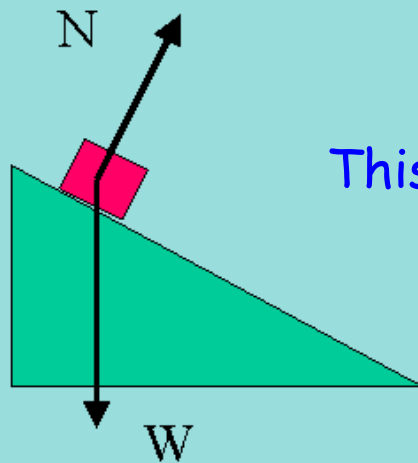
Four

Good, we have two forces

(1) the force of gravity pulling down on the block, we'll call it  $W$

(2) the force of the incline pushing up on the block, we'll call it  $N$  the normal force

Your Free-Body-Diagram should look similar to this:



This dialogue can take several steps...

You will find that problems like these (i.e. Incline problems) tend to be similar. A very important aspect of Incline problems is choosing a correct coordinate system. When doing this you must keep in mind your final goal; in our case you want to get the acceleration of the block parallel to the incline.

Think about what coordinate system you think would be best to use.

CLICK  TO CONTINUE.

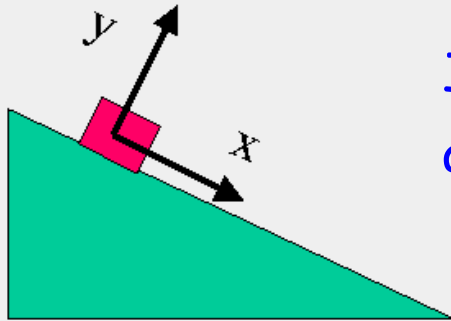


You will find that problems like these (i.e. Incline problems) tend to be similar. A very important aspect of Incline problems is choosing a correct coordinate system. When doing this you must keep in mind your final goal, in our case you want to get the acceleration of the block parallel to the incline.

Think about what coordinate system you think would be best to use.

Which coordinate system do you think is best to use?

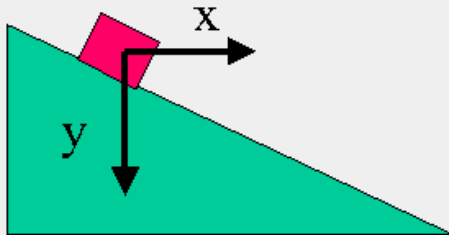
Coordinate system A



...these steps are designed to teach students problem solving approaches as well as physics...

Coordinate System A

Coordinate system B



Coordinate System B

Enter



Correct, With this system you can apply Newtons second equation in the x-direction and solve for the acceleration down the incline; which is what you want. Remember that a good rule is to choose one of your axes to be parallel to the direction that the object is accelerating. With this choice of axes this is the x direction.

Our next step is to apply Newtons second law to our x-direction and solve for the acceleration. After that we use constant acceleration equations from the last few weeks to compute the time it takes the block to slide down the incline.

Now, what is the acceleration down the incline?

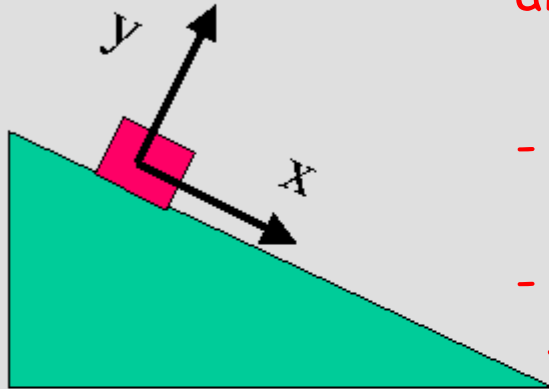
$a_{\text{incline}} =$    $\text{m/s}^2$

Eventually they get another (simpler) numeric question whose answer is needed to solve the primary numeric question.



## HELP HELP

So with our coordinate system



Clicking on "Help" again results in a similar dialogue as the first time, although one level "deeper".

- Problems can be 4-5 levels deep
- Eventually they get enough info to solve the problem.

## Coordinate System A

we have to apply Newton's second law to the x-direction so we can find the acceleration in our x-direction, which is the acceleration down the incline.

So our first step must be to figure out which forces act on the block in our x-direction.

The normal force is completely in the y-direction, so we need not worry about it. However there will be a component of the block's weight  $W$  in the x-direction. We must use trigonometry to compute what it is. Let's do that now.



If the block is assumed initially at rest, how long will it take to reach the bottom of the incline?

t =  s \*

2 OK

Good job! You have solved the problem - let's summarize what you did:

- Determine what concepts apply to this problem.
- Draw a Free-Body Diagram and choose your axes.
- Set up an equation (or system of equations) and solve for acceleration.
- Use the acceleration to find the time it takes the block to fall.

FOLLOW-UP QUESTION 1 (not for credit):

If the angle of the incline were decreased:

- OK  The time taken would increase.
- The time taken would stay the same.
- The time taken would decrease.

Good, if the angle were to decrease the acceleration would decrease. Therefore it would take longer to go down the incline.

FOLLOW-UP QUESTION 2 (not for credit):

If the mass of the block were to increase:

- The time taken would increase.
- OK  The time taken would stay the same.
- The time taken would decrease.

Good, the acceleration is not changed by the mass. In our Newtons second equation  $\Sigma F = ma$  we get

$$mg \sin(\theta) = m a$$

so the mass cancels out. If the Acceleration is the same, the time it takes to slide down must also be the same.

Once they get right the answer

They get a recap

And some follow-up questions

# Bonus: Student Logs

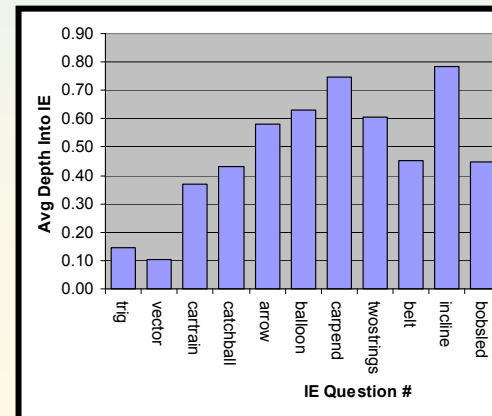
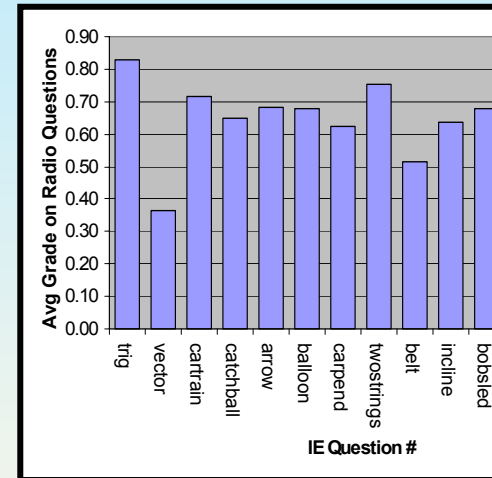
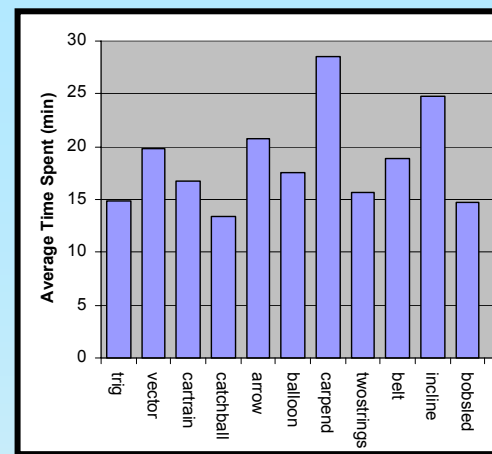
- We record all student submissions on IEs: (the conversation)

phys101/fall00/[REDACTED]/ielogs/04/car

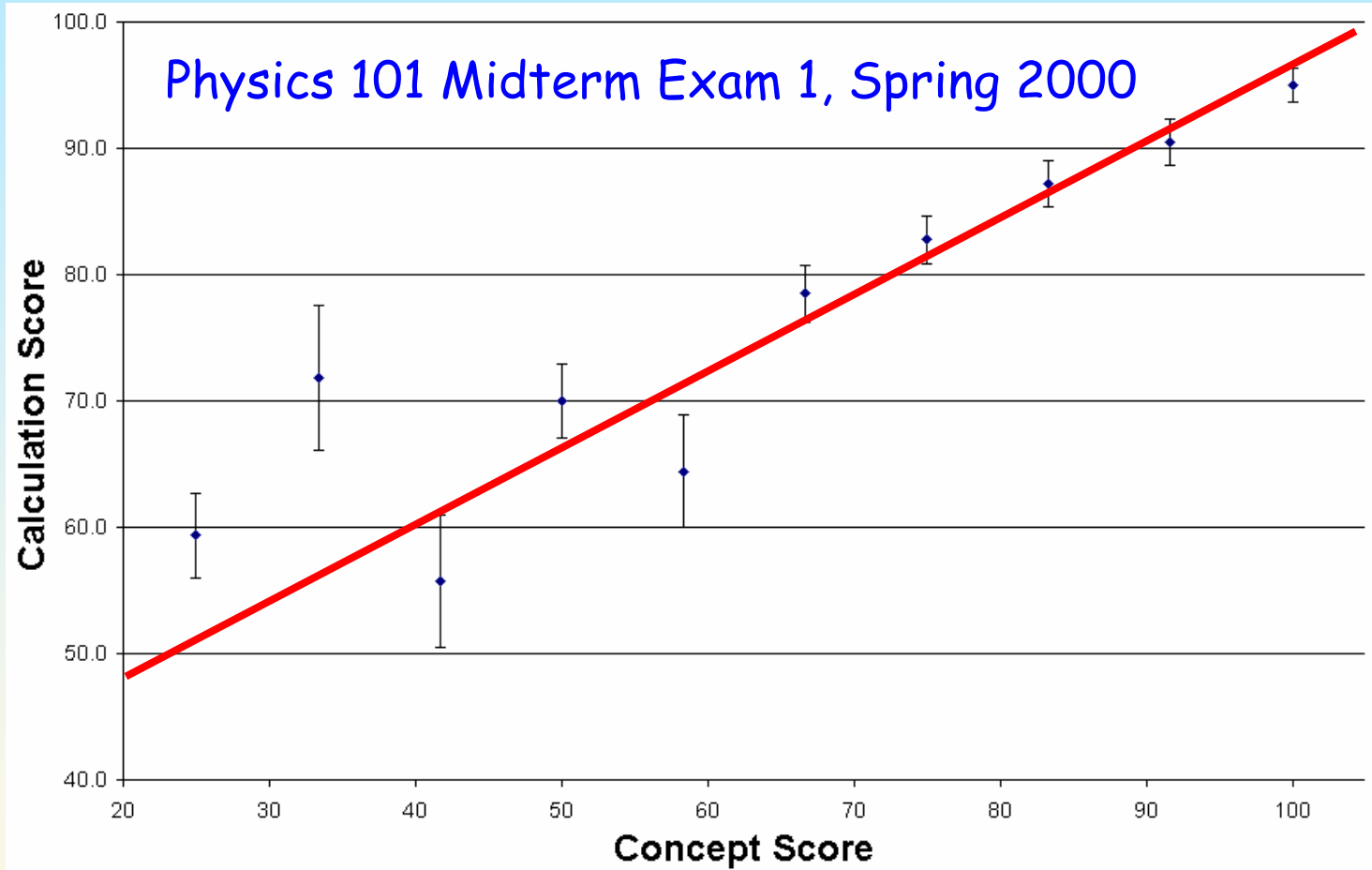
submit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
seconds	0	96	23	20	4	21	10	31	13	18	8	8	9	81	17	15	40	37	7	12	25	25	13	176
clicked	I0	H	E1	E1	E1	E1	E1	E1	E1	E1	E1	E0	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E0
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1 04							5																	
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1 07												gravity												
1 08													PS											
1 09														PS										
1 10															1									
1 11																PS								
1 12																	1							
1 13																		PS						
1 14																			PS					
1 15																					3			
1 16																						1	2	
1 17																								PS

# This is Research data!

- How much time do students spend on the IEs?
- How well do the students do on their first response to questions?
- How deep into the IE do students go?






# How can we convince students that learning concepts is important?



The proof is in the pudding !

# Some students thoughts on doing ~50 pre-flights

Address  https://webug-s.physics.uiuc.edu/cgi/courses/shell/phys101/spring00  Go  Links

**6) How often do you attend the lectures?**

- 69 50 % **Always.**
- 49 36 % **Regularly.**
- 10 7 % **Occasionally.**
- 4 3 % **Rarely.**
- 5 4 % **Never.**



**7) How often do you read the text before attending lecture?**




- 10 7 % **Always.**
- 27 20 % **Regularly.**
- 50 36 % **Occasionally.**
- 26 19 % **Rarely.**
- 24 18 % **Never.**

**8) Overall how important were the preflights in helping you understand the material?**

- 11 8 % **Essential.**
- 50 37 % **Very useful.**
- 55 40 % **Useful.**
- 14 10 % **Not very useful.**
- 6 4 % **Useless.**

**9) Here is a space for any additional comments on the lectures:**

Done   Internet

Address  https://webug-s.physics.uiuc.edu/cgi/cour  Go  Links

I didn't read the chapters and use the preflights very much in the beginning of the semester but lately I've been using them more and it has been helping very much.

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The lectures were great.

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More lectures needed.

---

Pre-flights were a good idea, but often I would forget about them when I had so many other more intense homework to worry about them. I wish there was a way for me to keep them in mind better.

---



it was easy to pay attention to Mats during lecture most of the time, but I was always behind on the reading, so I always guessed on the preflights.

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I think this is a great teaching tehnique (as a future teacher). Even when I didn't have time to read the entire text before coming to lecture. I at least had to flip through the teext a couple times.

---

I should read. =)

Done   Internet

# Concluding Comments

- Preflights, ACT's and Homework go hand in hand:
  - ➔ Get your students attention before, during and after class.
  - ➔ Students know you are interested in their ideas & problems.
  - ➔ Probing their thoughts is very interesting.
  - ➔ Teaching this way is FUN (in particular the JiTT aspect) !!
- Integrated web approach is a win-win situation:
  - ➔ Students like simple web access to homework, preflights, grade-book, exam-prep, lecture notes, lab & discussion problems etc...
  - ➔ Makes course management much easier for us.
    - » Cut & paste between semesters - make incremental changes.
    - » Facilitates communication between instructors & TA's.
- Still working on evaluation.
- Anybody interested in using our software and/or content should talk to me, Gary Gladding or Tim Stelzer.