Establishing a Collaborative Student-Centered Learning Environment Using the SCALE-UP Pedagogy

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currently at UvA for Spring semester 2024

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What is SCALE-UP?

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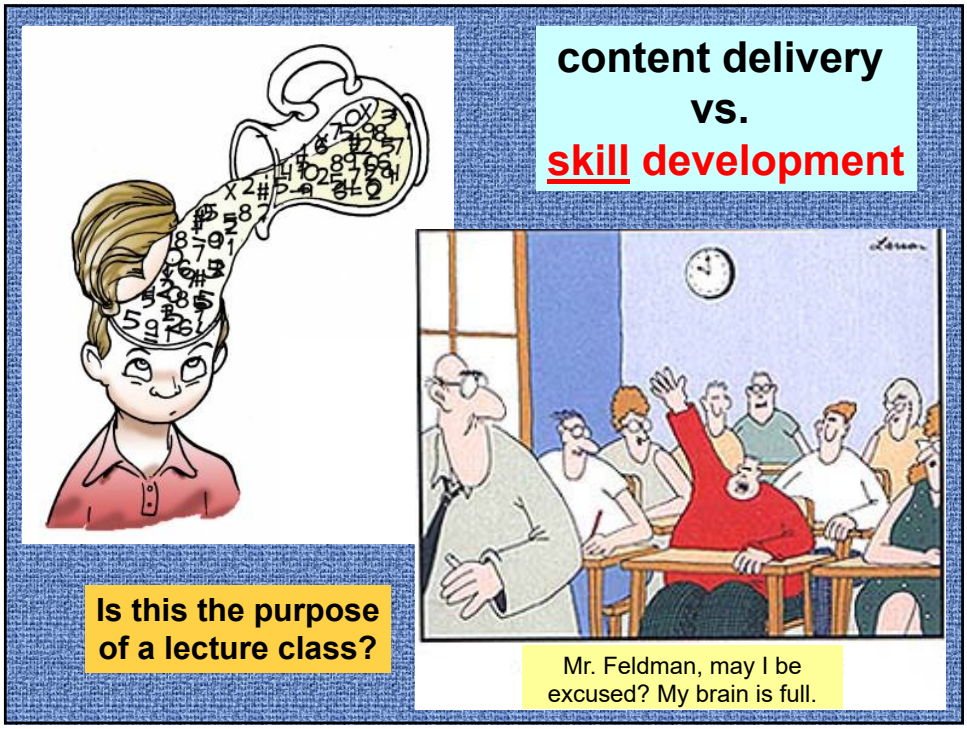
SCALE-UP Background

Student
Centered
Active
Learning
Environment for
Undergraduate
Programs

- Basic characteristics
  - Active learning
  - Collaborative groups
  - Integrated lecture/lab
  - Technology assistance
- Practical aspects
  - Minimal lecturing in the conventional sense
    - ✓ supplement textbook, students are always ***doing***
  - Ponderables
    - ✓ whiteboard problems (numerical, conceptual)
  - Tangibles
    - ✓ short hands-on activities and regular labs (with reports)
  - Computer simulations using Python numerical methods

3



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Implementation at GWU

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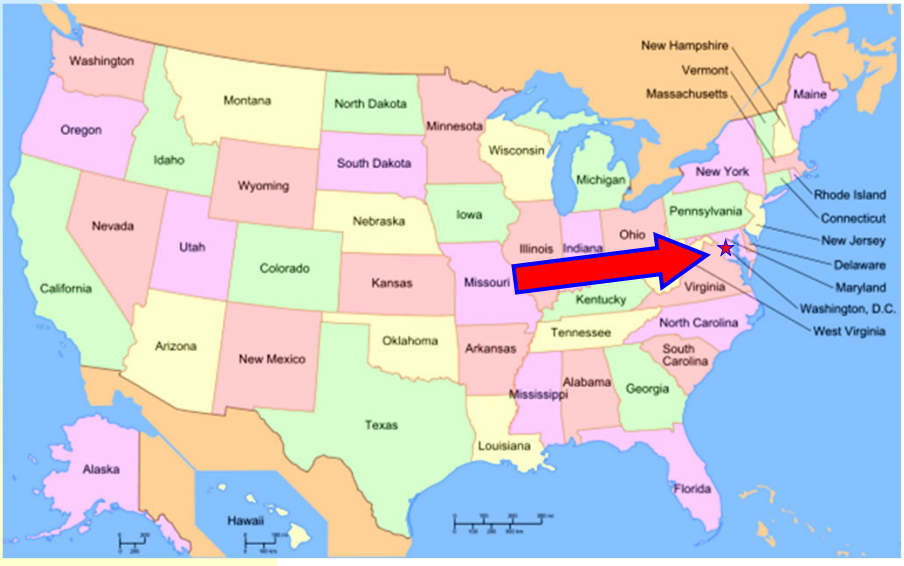
United States



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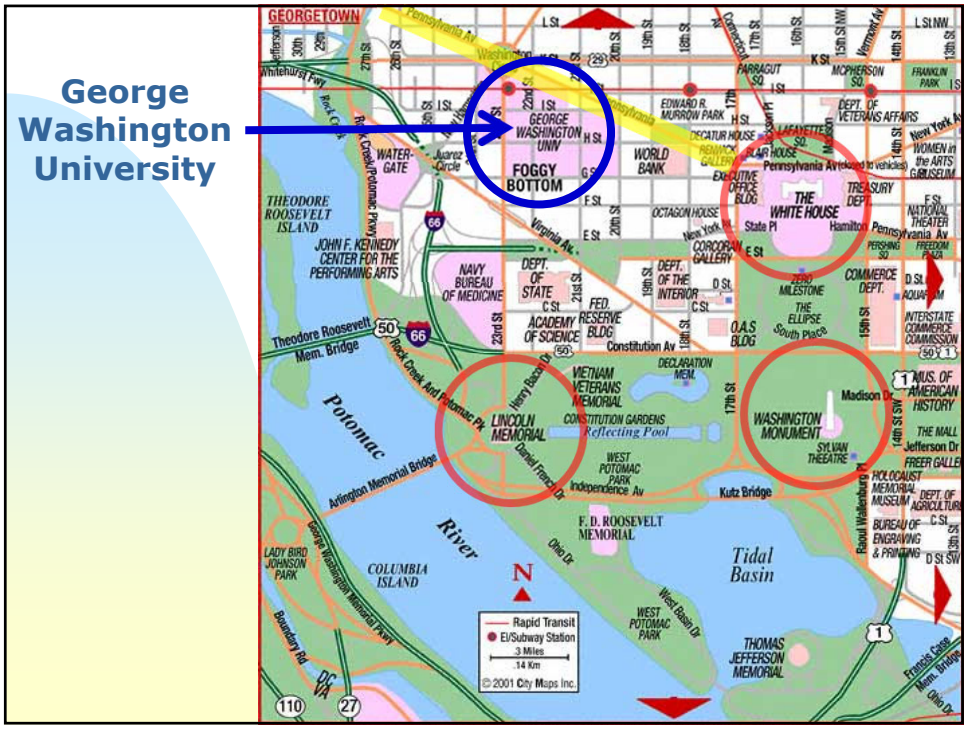
George Washington University
GEORGETOWN
FOGGY BOTTOM
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VIETNAM VETERANS MEMORIAL
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WASHINGTON MONUMENT
WEST POTOMAC PARK
F. D. ROOSEVELT MEMORIAL
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THOMAS JEFFERSON MEMORIAL
COLUMBIA ISLAND
LADY BIRD JOHNSON PARK
Potomac River
Theodore Roosevelt Mem. Bridge
Arlington Memorial Bridge
Kutz Bridge
Rapid Transit
El/Subway Station
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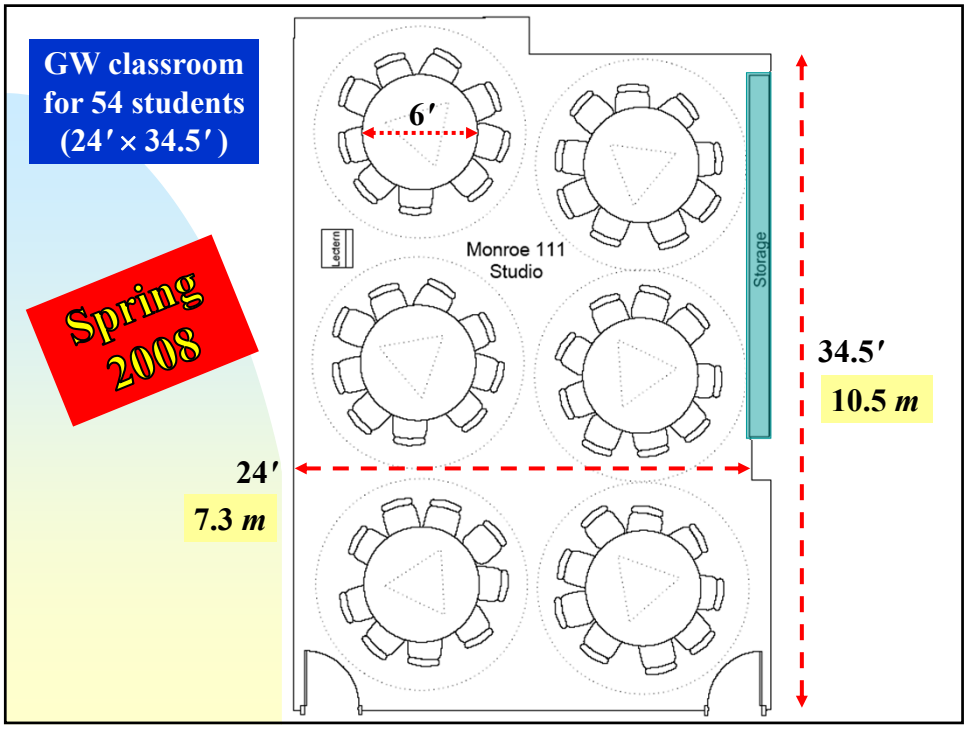
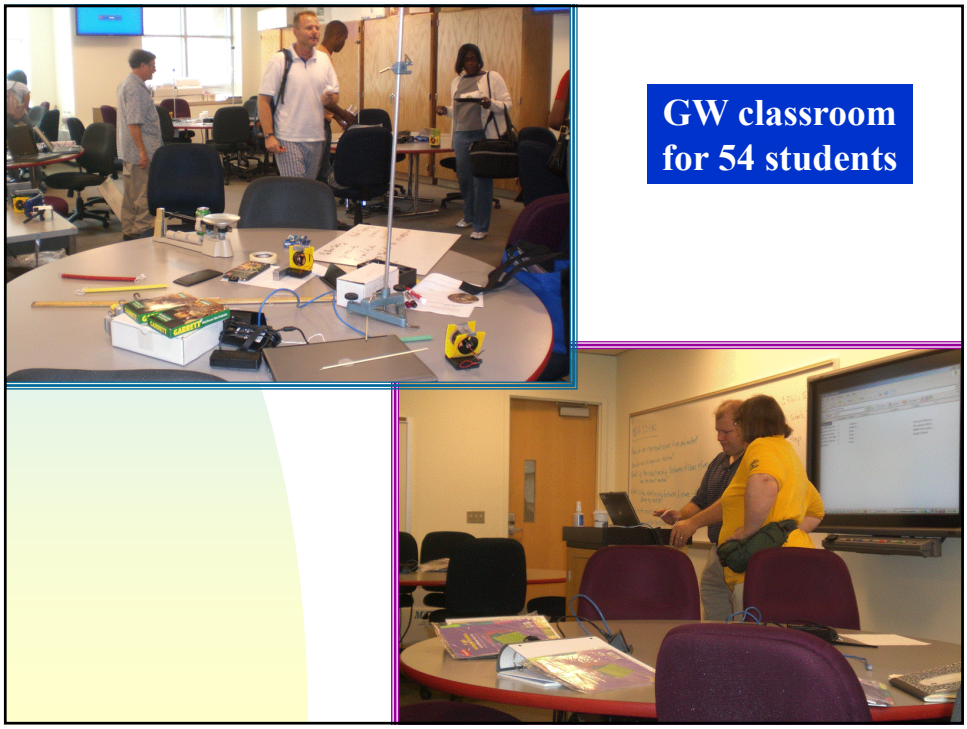
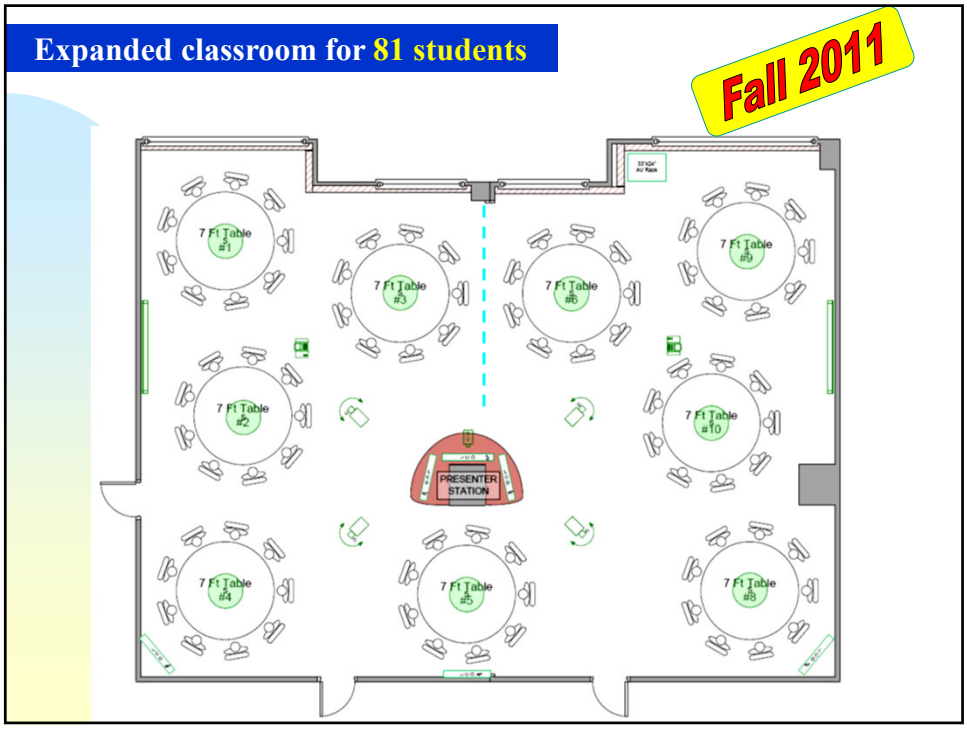

GW classroom for 54 students (24′ × 34.5′)
Spring 2008
6′
Monroe 111 Studio
Lectern
Storage
34.5′
10.5 m
24′
7.3 m

8


GW classroom
for 54 students

9


Expanded classroom for 81 students
Fall 2011
7 Ft Table #1
7 Ft Table #3
7 Ft Table #6
7 Ft Table #9
7 Ft Table #2
7 Ft Table #10
PRESENTER STATION
7 Ft Table #4
7 Ft Table #5
7 Ft Table #8

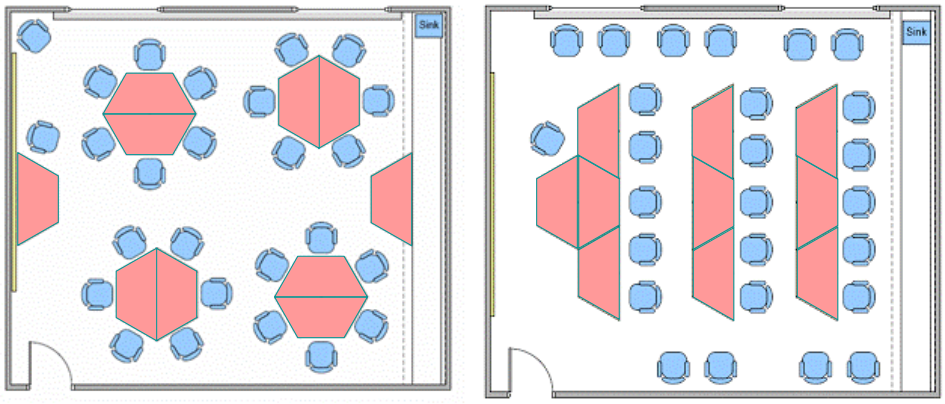
10

11

12

GW lab room for 24 students

conversion to classroom for 24 students



Flexibility: trapezoidal tables enable multiple configurations!

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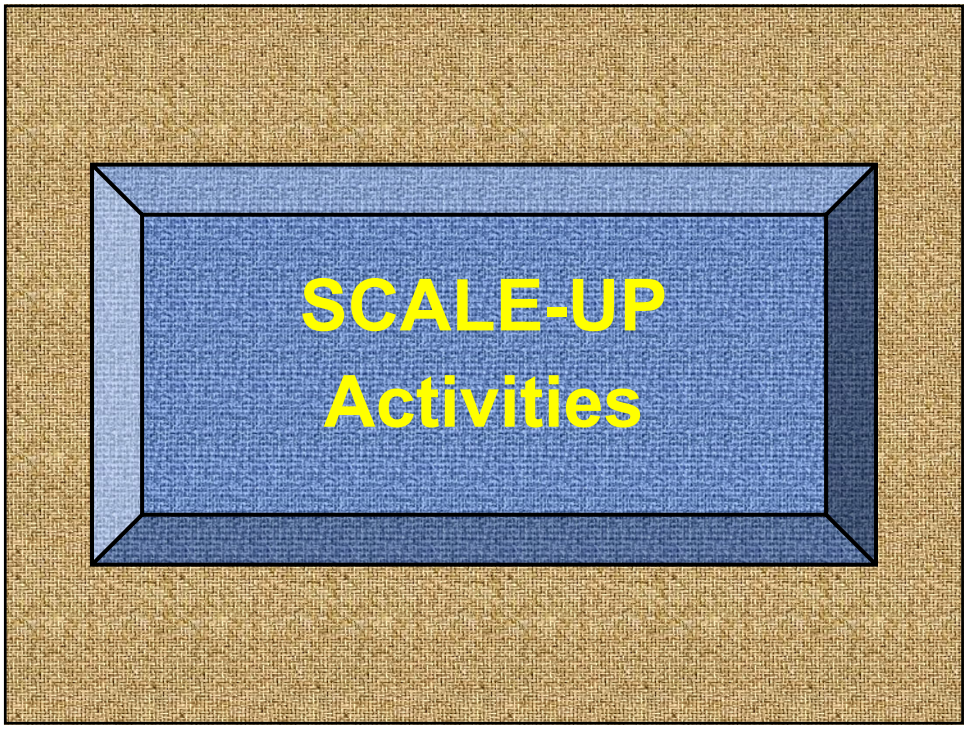
Fall 2012

Smaller classroom for 36 students

14



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SCALE-UP Activities

- **Ponderables**
  - conceptual and numerical problems
    - ✓ work in groups around small whiteboards
    - ✓ Peer Instruction *ConcepTests* via electronic response system
  - competitive activities raise student interest (and adrenalin)

- **If I throw a ball straight up into the air, at the top of its trajectory, its acceleration is:**
  - **A) greater than *g***
  - **B) equal to *g***
  - **C) less than *g* (but not zero)**
  - **D) zero**

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Let's try it...

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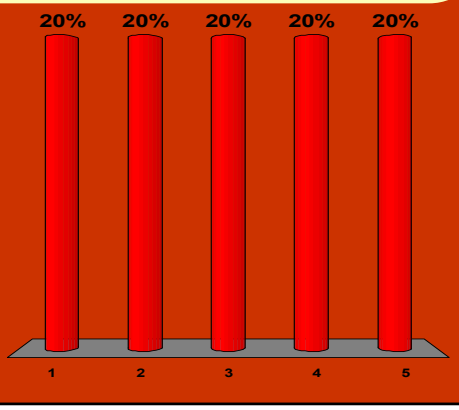
Question 1

Working by himself, John can paint a room in ½ hour. For Mary alone, it takes 1 hour to paint the room. If John and Mary work together, how long would it take?

John and Mary

1. 15 minutes
2. 20 minutes
3. 25 minutes
4. 45 minutes
5. 1½ hours



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When the moving sidewalk at Dulles Airport is broken, it takes you **50 s** to walk from the gate to baggage claim. When it is working and you stand still on the moving sidewalk, it takes **75 s** to go there.

How long will it take you if you walk while riding on the moving sidewalk?

$t = 30$ s

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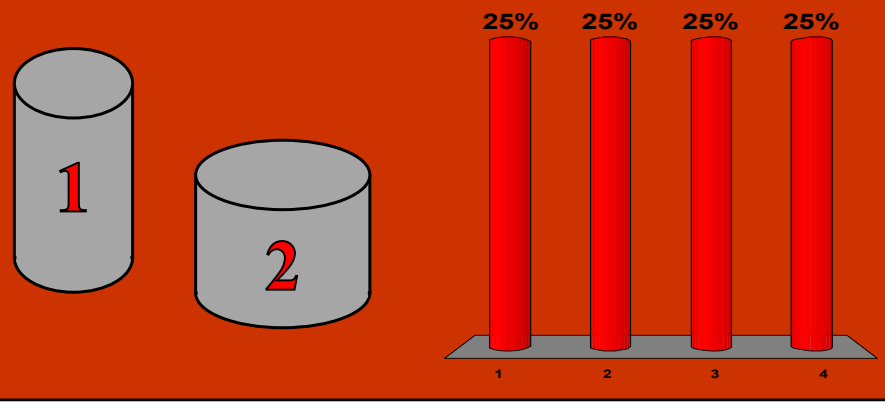
Question 3 — Volume of Cylinder

Roll a piece of paper into a cylinder two different ways: (1) long side vertical as the height, or (2) long side horizontal as the circumference. Which one has the larger volume?

1. cylinder 1
2. cylinder 2
3. both the same
4. need more information



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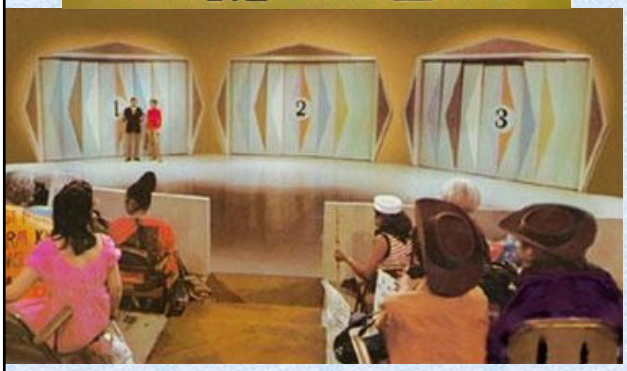
Let's Make A Deal



What should you do?

- There are 3 closed doors, behind which are 2 goats and an expensive sports car. You pick one of the doors, hoping for the car!
- The host, who knows where the prize is located, opens one of the doors with a goat. Now he offers you the opportunity to stick with your original door, or else to switch to the other unopened door.

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Pick a door

MH opens one of the other doors

MH offers you a chance to switch

Switch or stay?

(or does it not matter at all?)

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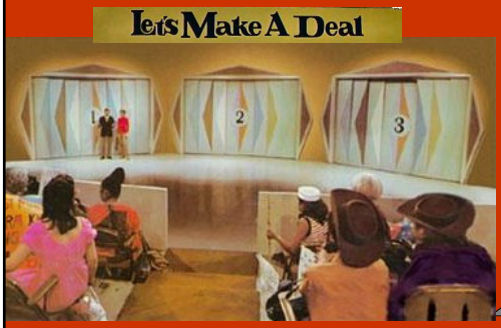
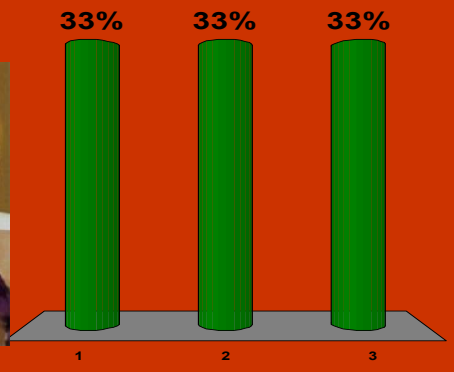
Question 4

What is the best strategy for winning the big prize?

Let's Make a Deal

1. you win more often if you stay with your door
2. you win more often if you switch your door
3. it does not matter if you stay or switch





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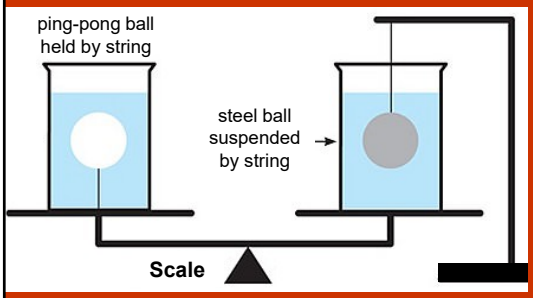
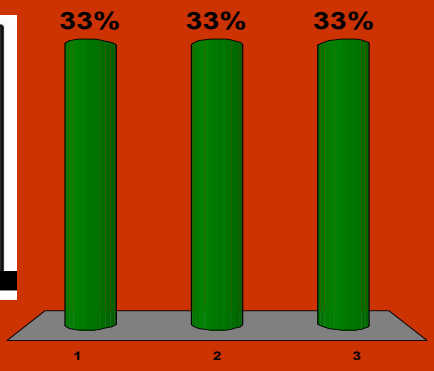
Question 5

Two balls of equal volume are submerged in two beakers of water. Which side weighs more – the one with the steel ball or the one with the ping-pong ball?

Buoyancy

1. right side (steel ball) weighs more
2. both sides weigh the same
3. left side (ping-pong ball) weighs more





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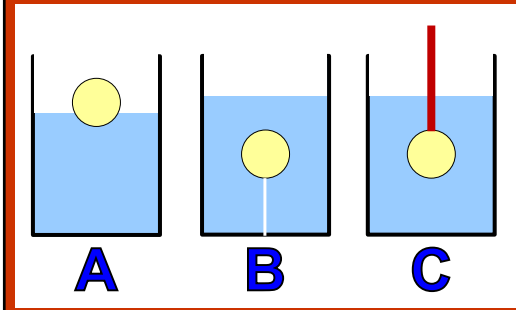
Question 6 Buoyancy

A ping-pong ball in a beaker of water is observed to be in three scenarios:
1) floating on top of the water
2) tied to the bottom by massless string
3) held underwater by massless rod

Rank the weights as seen by a scale.

1. C > A > B
2. A > (B = C)
3. A = B = C
4. C > (A = B)
5. B > C > A



(all beakers initially contain the same volume of water)

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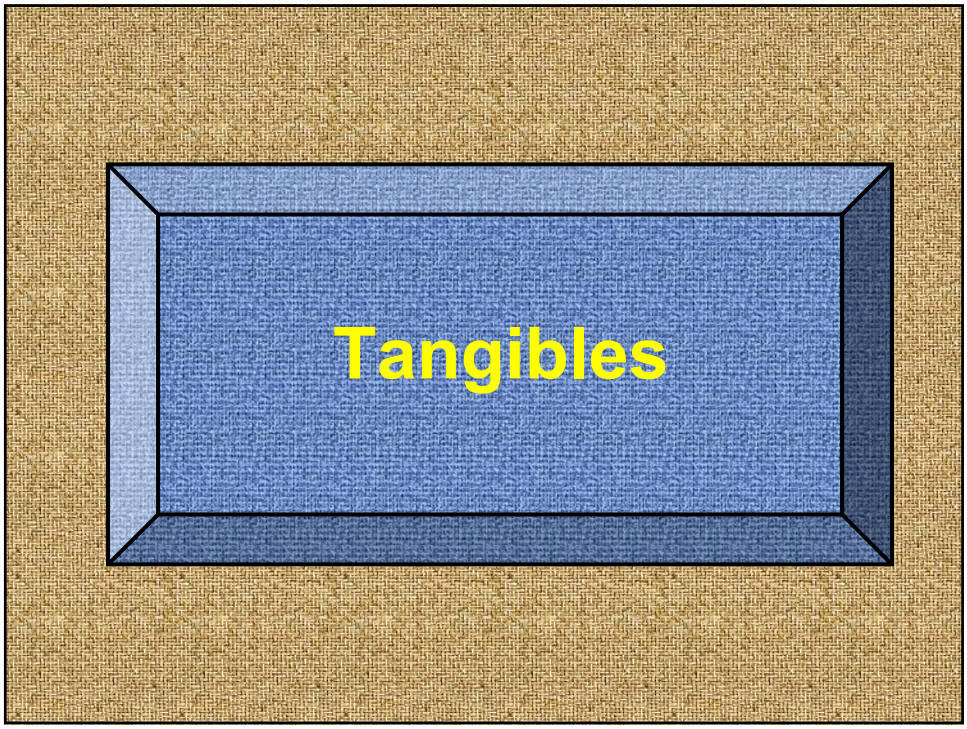

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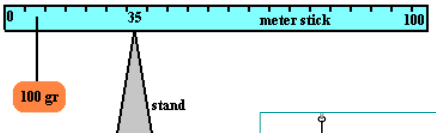
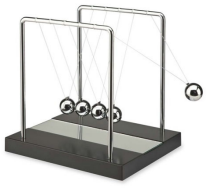
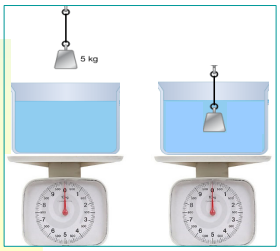
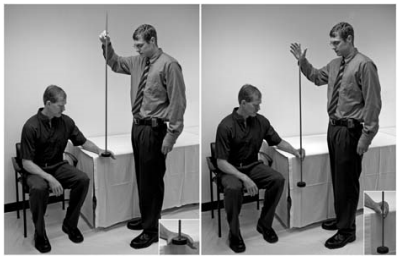
SCALE-UP Activities

- **Tangibles**
  - **short hands-on activities**
    - ✓ dropping meter stick to measure reaction time (kinematics)
    - ✓ colliding balls (elastic collisions) with Newton's Cradle
    - ✓ measuring mass of meter stick by balancing (torque)
    - ✓ determining buoyant force of submerged mass in water









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Let's try it...

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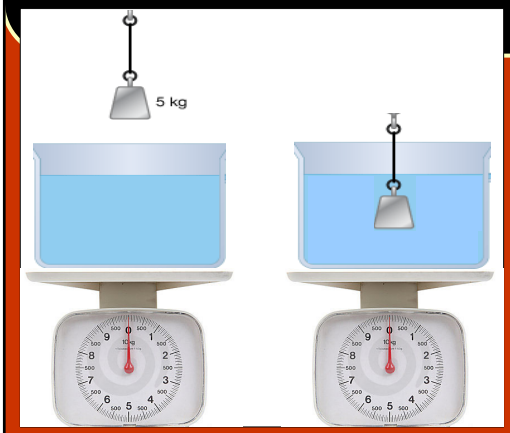
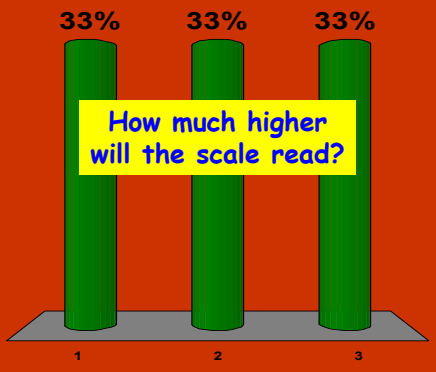
Question 2 Buoyancy

The left scale reads 10 kg for the beaker of water. What will it read if a 5 kg mass is submerged in the water (without touching the bottom or sides)?

1. scale will read a lower value
2. scale will read the same
3. scale will read a higher value





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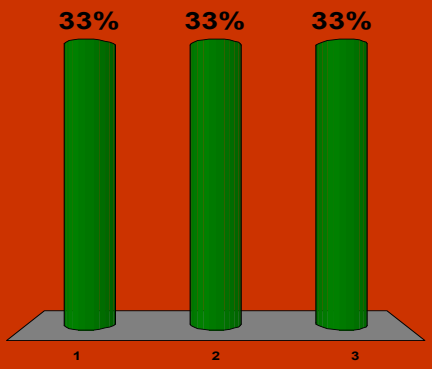
Question 4 Falling Magnet

A scale currently reads the mass of an aluminum tube. If a magnet is dropped in the tube, what will the scale read while the magnet is falling through the tube?

1. scale will read a lower value
2. scale will read the same
3. scale will read a higher value



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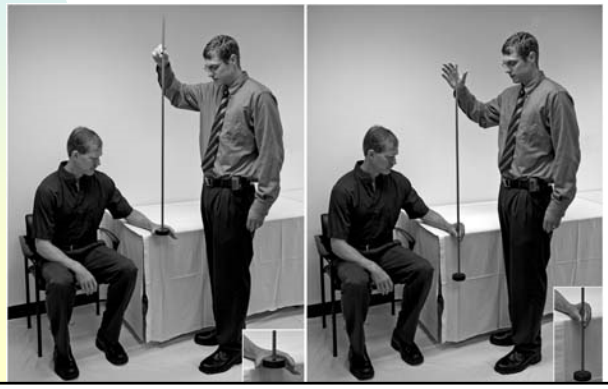
Example of a "Tangible"

- Tangible
  - use free fall to determine reaction time
    - ✓ student catches meter stick to measure distance
    - ✓ use known free-fall acceleration to calculate time
    - ✓ compare to expected human reaction time (real world)



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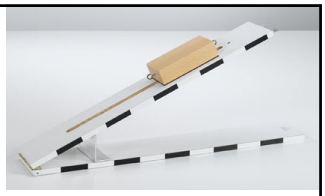
Example of a "Tangible"



- Ponderable
  - A block resting on a flat surface will eventually slip if the surface is tilted at a sufficient angle θ. How is the coefficient of static friction μ_s related to this angle?
    - ✓ students work together on their whiteboards
    - ✓ obtain the usual result: $\mu_s = \tan\theta$
- Tangible
  - use aluminum block and reverse side of whiteboard
    - ✓ each group member tilts the board until block slips
    - ✓ other group members measure the angle
    - ✓ three results are averaged for final answer
  - overall class results come out to be about $\mu_s \sim 0.35$

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Tangible

Ponderable

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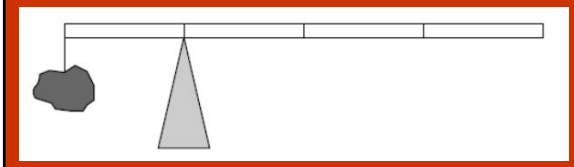
Question 5 Balancing a Meterstick

A rock of mass 400 g is suspended by a massless string from one end of a meterstick. What is the mass of the meterstick if the system is balanced by a fulcrum located at the 25 cm position?

1. 100 g
2. 200 g
3. 400 g
4. 800 g
5. 1600 g



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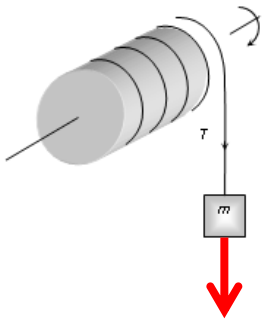
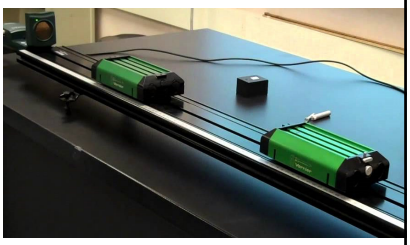
SCALE-UP Activities

did not use VPython computer simulations

- **Tangibles**
  - full lab exercises (Vernier lab probes/software with laptops)
    - ✓ carts rolling down incline; colliding carts (plus video analysis)
    - ✓ moment of inertia of cylinder by unwinding mass
    - ✓ density of air with floating helium balloons
    - ✓ specific heat of unknown sample; coffee and cream problem





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phyphox
physical phone experiments

RWTH AACHEN UNIVERSITY

Measuring the speed of sound using two smart phones triggered by two sequential sound triggers

Your smartphone can become the science lab that helps you to discover the world of physics!

Tangible

@OLEWIS_COACHING

https://phyphox.org

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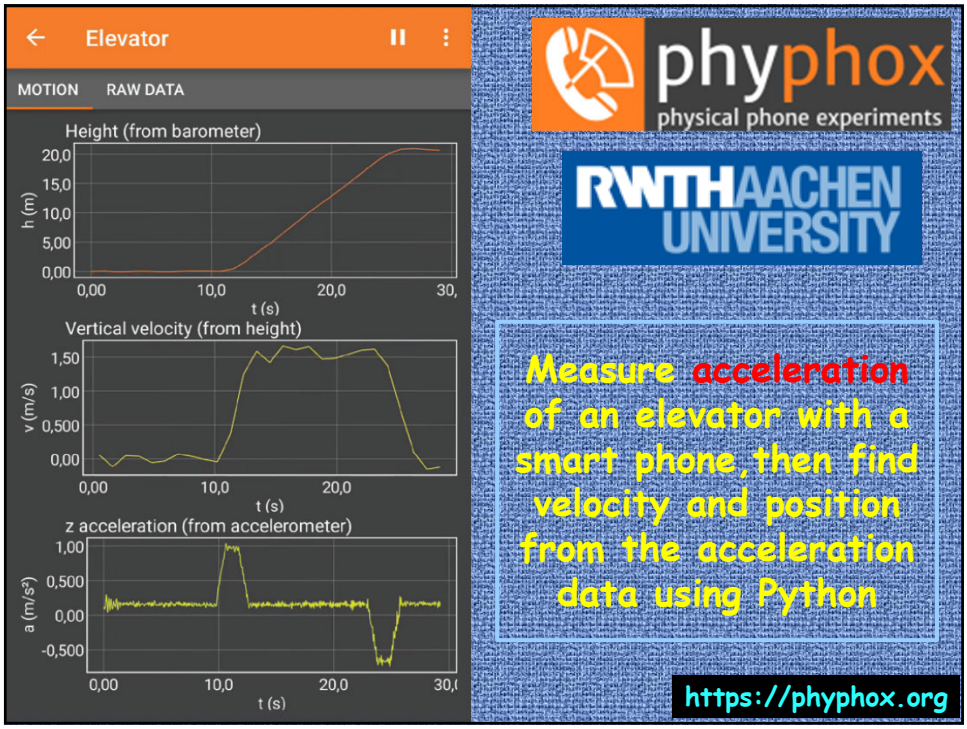

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Other SCALE-UP Details

- **Groups**
  - triplets are composed of high, medium, low students
    - ✓ switch groups once at mid-point of semester
  - each table has 9 students (3 groups of 3)
  - group dynamics must be enforced for smooth operation
- **Schedule of classes**
  - class meets 3 times a week (total of 5 hrs)
    - ✓ ideal setup is Mon-Wed-Fri (2 + 2 + 1 hrs)
- **Friday quiz each week**
  - two problems (one conceptual, one numerical)
    - ✓ duration = 20 minutes
    - ✓ simulation of exam environment (difficulty a bit higher)
    - ✓ excellent predictor of exam performance

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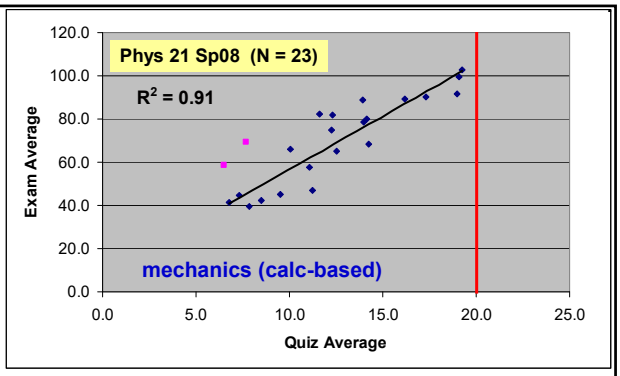
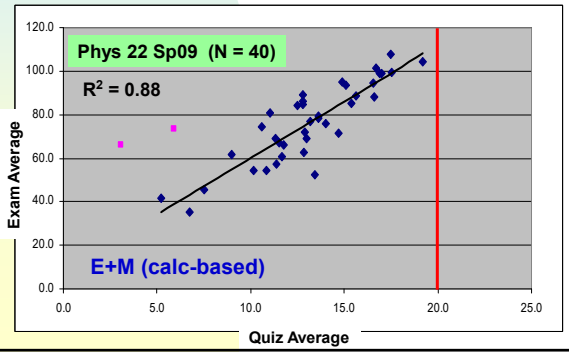
Quiz Grades as Predictors





Phys 21: mechanics (calc-based)

Phys 22: E+M (calc-based)

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Other SCALE-UP Details

- **Warmups**
  - necessity of encouraging student preparation for class
    - ✓ online pre-class "mini-quiz" promotes textbook reading
    - ✓ 10 conceptual multiple-choice questions (~30 mins)
- **Homework**
  - use *MasteringPhysics* online system
  - 7-8 problems assigned twice per week
- **Lab activities**
  - students work entirely as a group
  - one lab report submitted per group
  - enhances teamwork and collaboration

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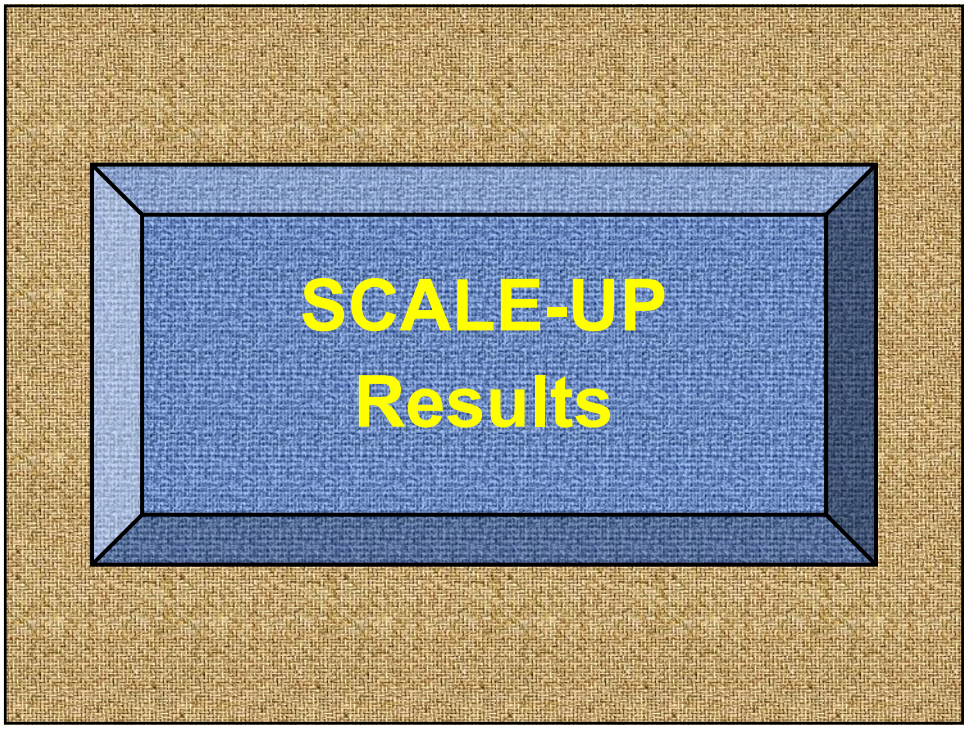

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Comparative Results

- **Phys 21 (Sp08): first semester calculus-based physics**
  - **lecture/lab, bio-focused SCALE-UP, regular SCALE-UP**
  - **common assessments**
    - ✓ **Force Concept Inventory (pre and post)**
    - ✓ **CLASS science attitudes survey (pre and post)**
    - ✓ **identical classroom mid-term and final exams**

	Exam #1	Exam #2	Final Exam
Sec. 10 (N = 50) (standard lecture)	63.0	62.4	55.0
Sec. 11 (N = 14) (bio-focused SCALE-UP)	81.0	70.5	60.3
Sec. 12 (N = 23) (SCALE-UP)	70.0	72.9	64.0

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Comparative Results

- **Phys 21 (Sp11): first semester calculus-based physics**
  - **lecture/lab, bio-focused SCALE-UP, regular SCALE-UP**
  - **common assessments**
    - ✓ **Force Concept Inventory (pre and post)**
    - ✓ **identical/similar classroom mid-term and final exams**

	Exam #1	Exam #2	Final Exam
Sec. 10 (N = 120) (standard lecture)	68.2	61.8	68.1
Sec. 11 (N = 19) (bio-focused SCALE-UP)	77.2	75.8	81.6
Sec. 12 (N = 29) (SCALE-UP)	76.9	71.5	72.4

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Force Concept Inventory (FCI)

Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a building at the same instant. The time it takes the balls to reach the ground will be:

A bowling ball falls out of the cargo bay of an airliner as it flies in a horizontal direction. What path will the ball most closely follow?

A large truck collides head-on with a small compact car. During the collision, the force exerted by the truck…

A woman exerts a constant horizontal force on a large box. The box moves across a flat floor at a constant speed. The constant force applied by the woman:

The woman now doubles her horizontal force. The box then moves:

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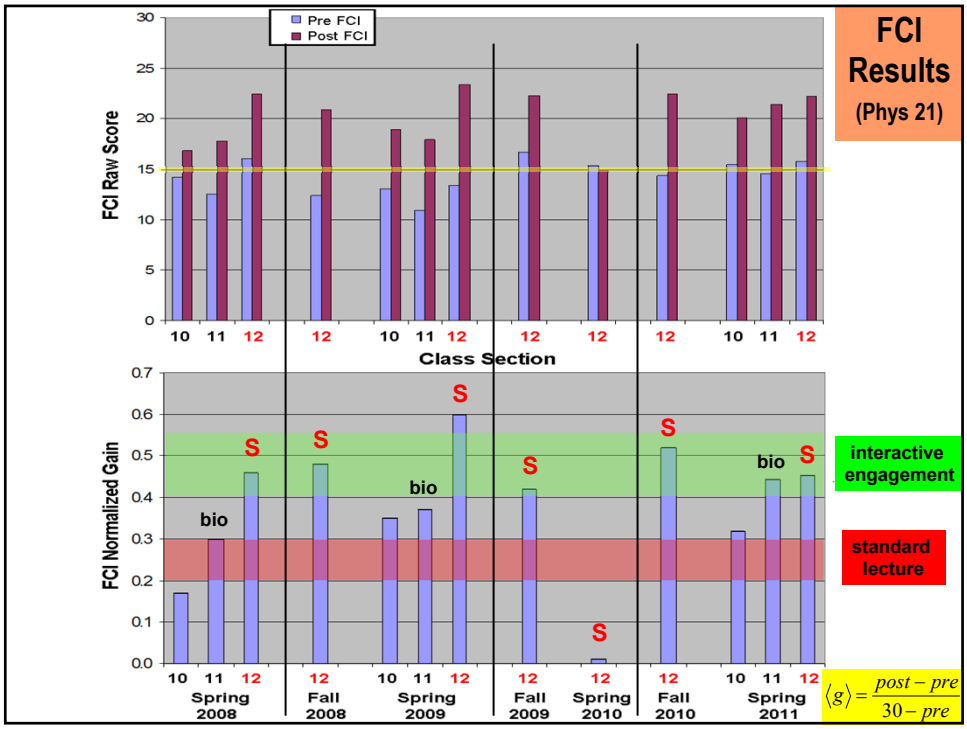
FCI Results
(Phys 21)
Pre FCI
Post FCI
FCI Raw Score
Class Section
FCI Normalized Gain
bio
S
interactive engagement
standard lecture
Spring 2008
Fall 2008
Spring 2009
Fall 2009
Spring 2010
Fall 2010
Spring 2011
$\langle g \rangle = \frac{post - pre}{30 - pre}$

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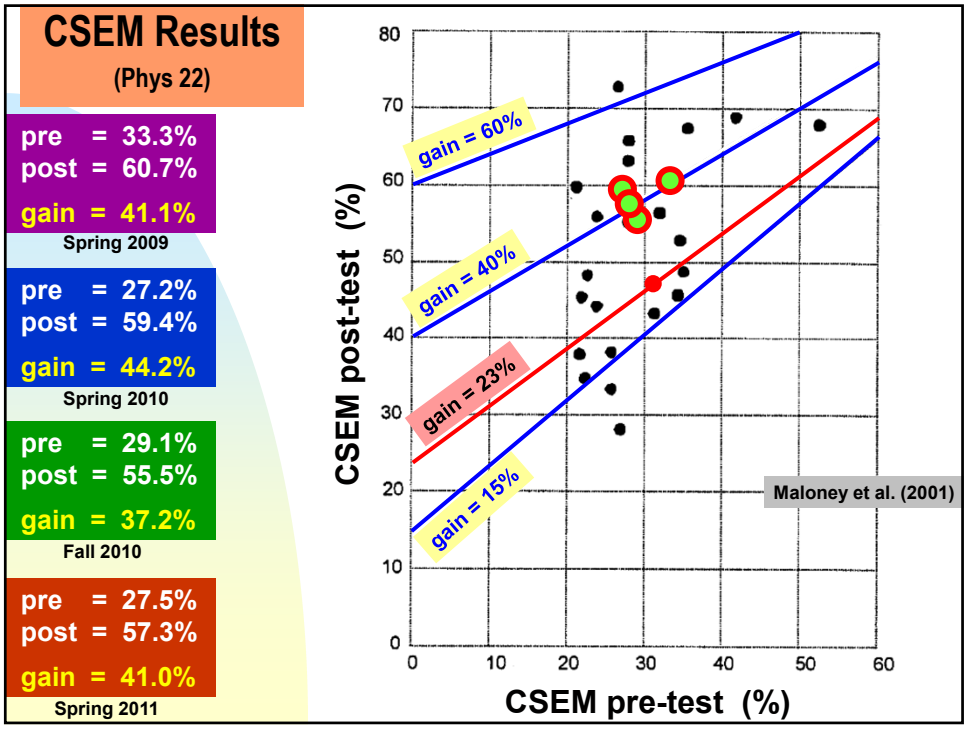
CSEM Results
(Phys 22)
pre = 33.3%
post = 60.7%
gain = 41.1%
Spring 2009
pre = 27.2%
post = 59.4%
gain = 44.2%
Spring 2010
pre = 29.1%
post = 55.5%
gain = 37.2%
Fall 2010
pre = 27.5%
post = 57.3%
gain = 41.0%
Spring 2011
gain = 60%
gain = 40%
gain = 23%
gain = 15%
Maloney et al. (2001)
CSEM post-test (%)
CSEM pre-test (%)

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Group Quizzes

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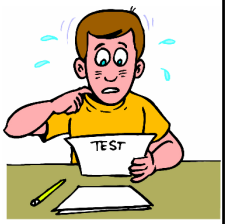
Group Quizzes

- **Why do we give quizzes?**
  - ✓ for students: frequent checking of their understanding
  - ✓ for instructor: feedback to identify difficult concepts
  - ✓ formative assessment (but low stakes)
  - ✓ keep students on track (accountability)



- **Problems with quizzes…**
  - ✓ students hate quizzes
  - ✓ source of anxiety for students
  - ✓ delayed posting of quiz solutions
  - ✓ grades are returned even later than that!
  - ✓ students do not view this as a positive learning experience
    - ❑ it's just another way to lose valuable grade points

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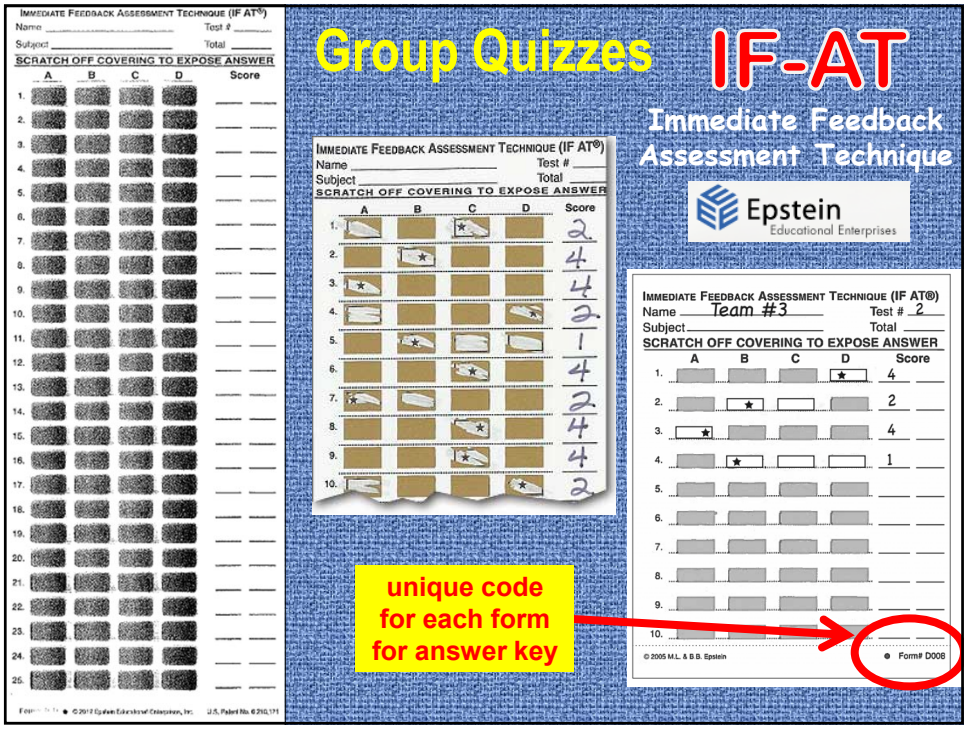

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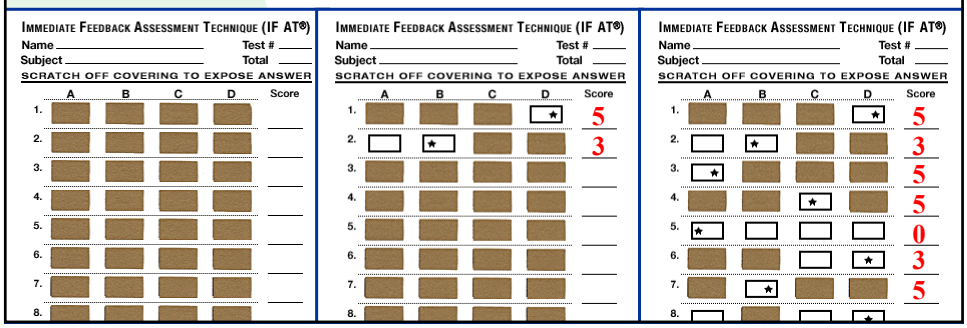
Delivering Group Quizzes

- quiz consists of 10 multiple-choice questions (5 pts each)
- part 1 – students work on quiz individually (50 pts)
- part 2 – rework quiz in groups using scratch-off cards (50 pts)
  - decreasing point values (5,3,1) for multiple attempts
- each part is about 10-15 minutes



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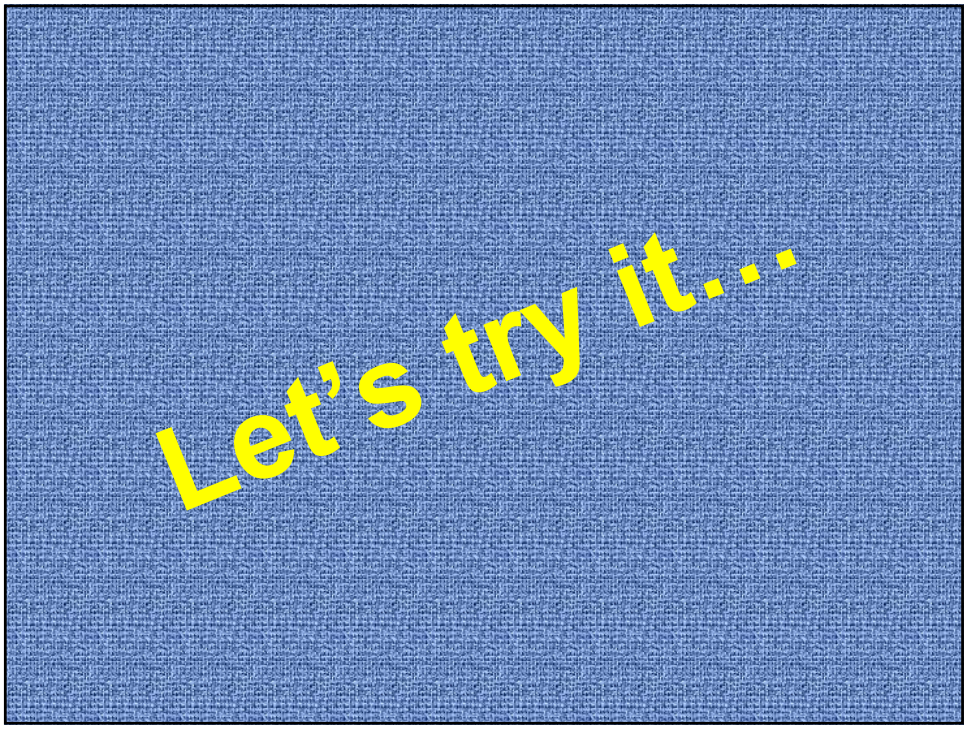

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Name	Individual	Group	Total	Group-Indiv.
Student 1 (group 1)	20	50	70	
Student 2 (group 1)	40	50	90	+0
Student 3 (group 1)	50	50	100	
Student 1 (group 2)	20	37	57	
Student 2 (group 2)	35	37	72	+2
Student 3 (group 2)	35	37	72	
Student 1 (group 3)	25	42	67	
Student 2 (group 3)	25	42	67	+12
Student 3 (group 3)	30	42	72	
Student 1 (group 4)	25	48	73	
Student 2 (group 4)	30	48	78	+13
Student 3 (group 4)	35	48	83	
Student 1 (group 5)	35	44	79	
Student 2 (group 5)	40	44	84	+4
Student 3 (group 5)	35	44	79	

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Whiteboard Activity

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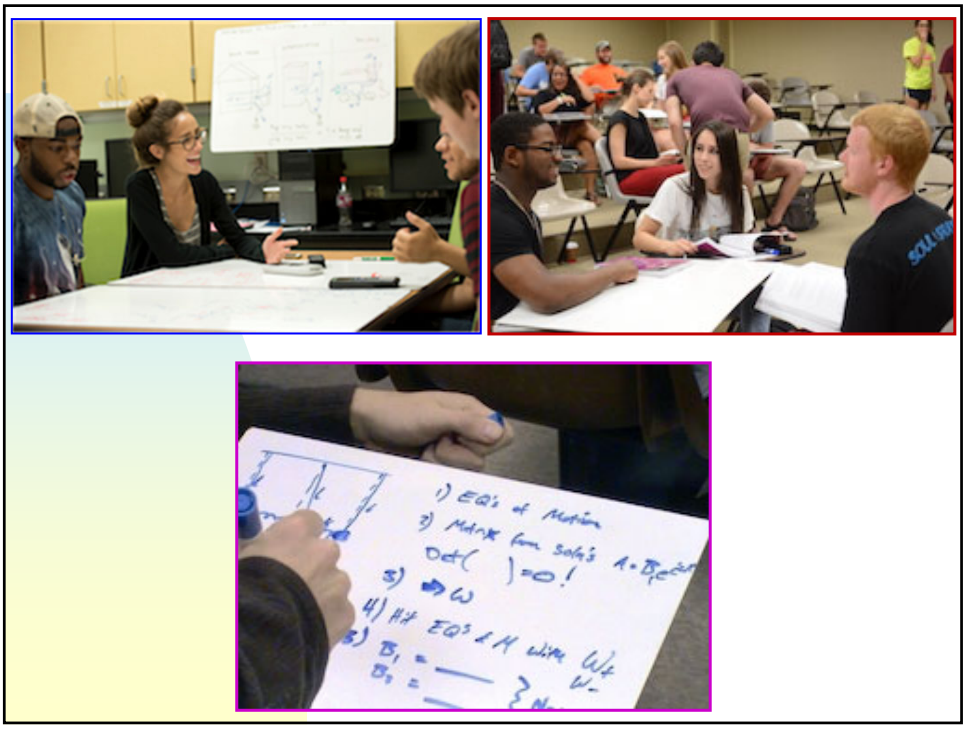

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Whiteboarding

Whiteboarding activities usually have two parts:

Working out the problem: The students are given a challenging conceptual or numerical problem to work out together on a whiteboard in small groups.

The instructor can get a good sense of how the students are doing and what they are thinking by walking around the room and scanning the whiteboards.

Presenting the solution: After each group has worked out the problem, one or more of the groups will share their work with the whole class.

Other classmates or the instructor can ask questions to help clarify and refine their ideas.

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Presenting Solutions
ETH Zürich
Spring 2017

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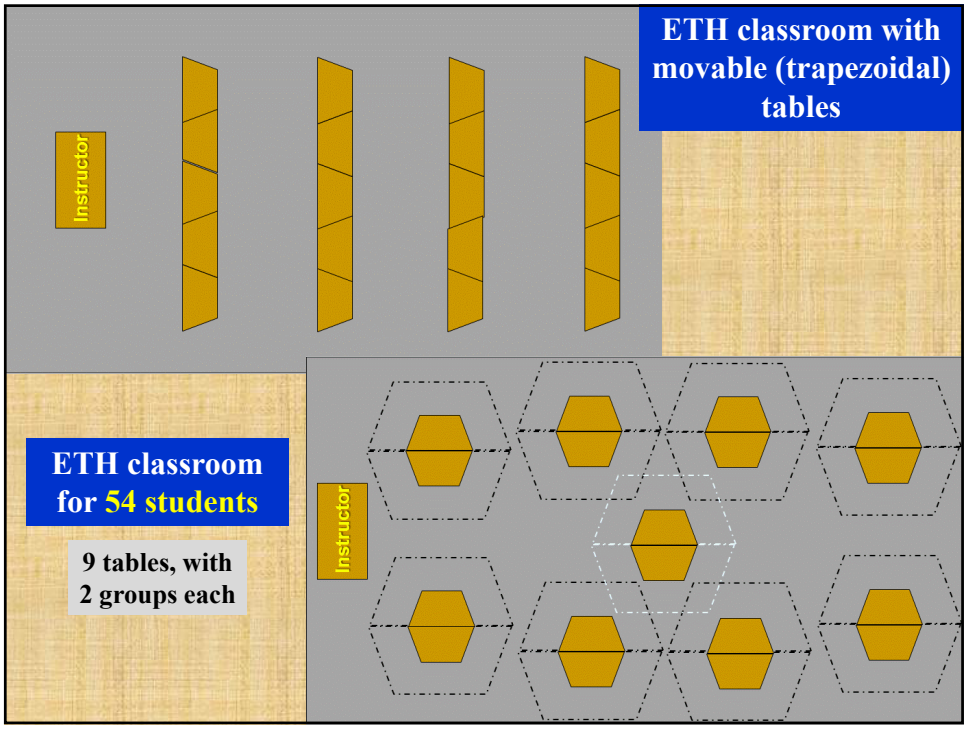
ETH classroom with movable (trapezoidal) tables
Instructor
ETH classroom for 54 students
9 tables, with 2 groups each
Instructor

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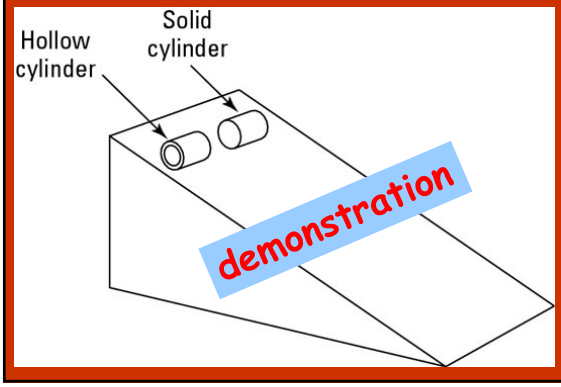
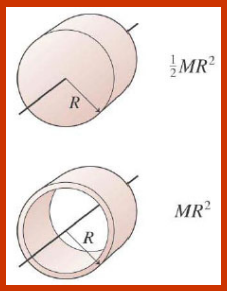
ConcepTest 4 Rotational Dynamics

A solid cylinder and hollow cylinder (both with equal radius and same material) are released at the same time and roll down a ramp without slipping. Which cylinder will reach the bottom first?

1. solid cylinder
2. hollow cylinder
3. both the same
4. need more info





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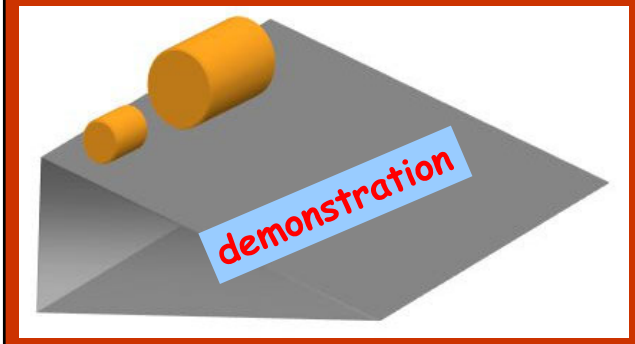
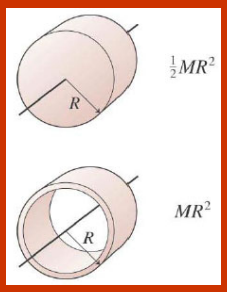
ConcepTest 5 Rotational Dynamics

A small light solid cylinder and a large heavy solid cylinder are released at the same time and roll down a ramp without slipping. Which cylinder will reach the bottom first?

1. small cylinder
2. large cylinder
3. both the same
4. need more info





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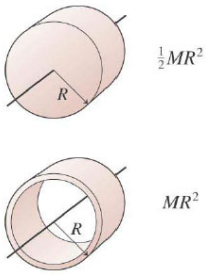
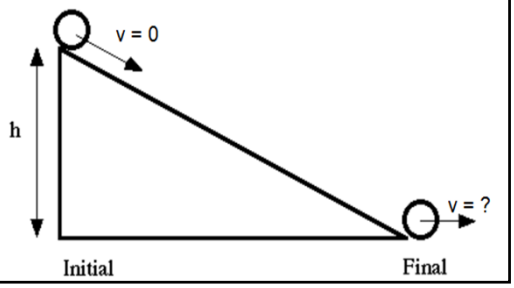
Numerical Problem

Prove symbolically that the acceleration of a rolling object down an incline is *not* dependent on the mass or radius of the object, and that it is *only* dependent on the shape of the object, where the moment of inertia is $I = C \cdot mr^2$.





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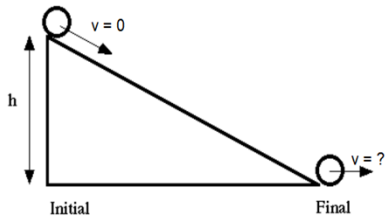
Energy Conservation



$$mgh = \frac{1}{2}mv_{cm}^2 + \frac{1}{2}I\omega^2$$

$$= \frac{1}{2}mv_{cm}^2 + \frac{1}{2}(Cmr^2)\left(\frac{v_{cm}}{r}\right)^2$$

$$= \frac{1}{2}mv_{cm}^2 + \frac{1}{2}Cmv_{cm}^2$$

$$= \frac{1}{2}m(1+C)v_{cm}^2 \quad \Rightarrow \quad v_{cm}^2 = \frac{2gh}{1+C}$$

$$I = Cmr^2$$

$$v_{cm} = \omega r$$

PHYS 21: Chap. 12, Pg 64

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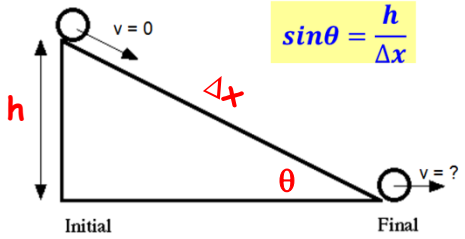
$$v_{cm}^2 = \frac{2gh}{1+C}$$

$$v_{cm}^2 = 2a_{cm}\Delta x$$



$$sin\theta = \frac{h}{\Delta x}$$

$$a_{cm} = \frac{v_{cm}^2}{2\Delta x} = \frac{\left(\frac{2gh}{1+C}\right)}{2\left(\frac{h}{sin\theta}\right)} = \frac{g\ sin\theta}{1+C} = \frac{a_{particle}}{1+C}$$

acceleration of a rolling object is LESS than acceleration of a sliding particle!!

Why?

PHYS 21: Chap. 12, Pg 65

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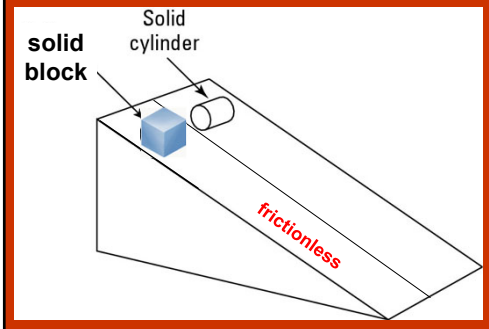
ConcepTest 4 Rotational Dynamics

A solid cylinder and a solid block (both with equal mass) are released at the same time and move down a ramp. Which object will reach the bottom first?

1. cylinder
2. block
3. both the same
4. need more info



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Whiteboard Question

With your group, identify THREE major challenges that you would envision when trying to implement a collaborative group-learning environment like SCALE-UP in a class at your home institution.

Also, think about strategies that you could employ to overcome those challenges. Outline at least TWO options that you could use to make your case.

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Personal Observations

- really squeezes the best out of students
- students work harder, but for greater rewards
- groups actually gel into cohesive units
- classroom atmosphere is much more dynamic
- instructor gets to know the students better
  - and students get to know each other better
- more satisfying to be a *coach* rather than a lecturer !

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