Combining Active Learning with Lectures

iTeach
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Introductory Physics (Physics 197/198)

- 4.0 credit calculus-based general introduction to physics (includes mandatory lab section)

- Approximate student demographics
  - ~750 total students divided into six sections of 120-130 students, taught by 5 different instructors
  - 45% freshmen engineers
  - 45% sophomore and junior pre-meds (evenly split)
  - Remaining 10% are physics majors (~5%) and various others (architecture, chemistry, EPS, etc.)

- Course structure: modified flipped classroom
  - Daily reading and homework due before the material is taught
  - Additional weekly homework assignments
  - Clicker-type questions used since Fall 2004
  - Taught in large auditorium-style lecture hall

General Chemistry (Chem 111A/112A)

- 3.0 credit lecture course with mandatory recitation subsection

- Important Course Aspects:
  - ~850 total students
  - 3 Lecture sections taught by different instructors, but treated as a single class
  - Traditional, large lecture environment with clicker questions incorporated since the Fall 2014
  - Weekly recitations (traditional and POGIL)
  - Weekly quizzes written by instructors
  - Optional weekly help sessions run by instructors
  - Optional PLTL study groups
  - Optional Residential Peer Mentoring (RPM) sessions held weekly

- Weekly assignments
  - Weekly reading assignments posted in advance of lecture covering the material
  - Weekly homework assignments, 2-3 problems per week submitted online for credit and ~10 problems assigned, no credit earned
  - Recitation activity packet
  - PLTL problem set

Why Use Clicker Questions?

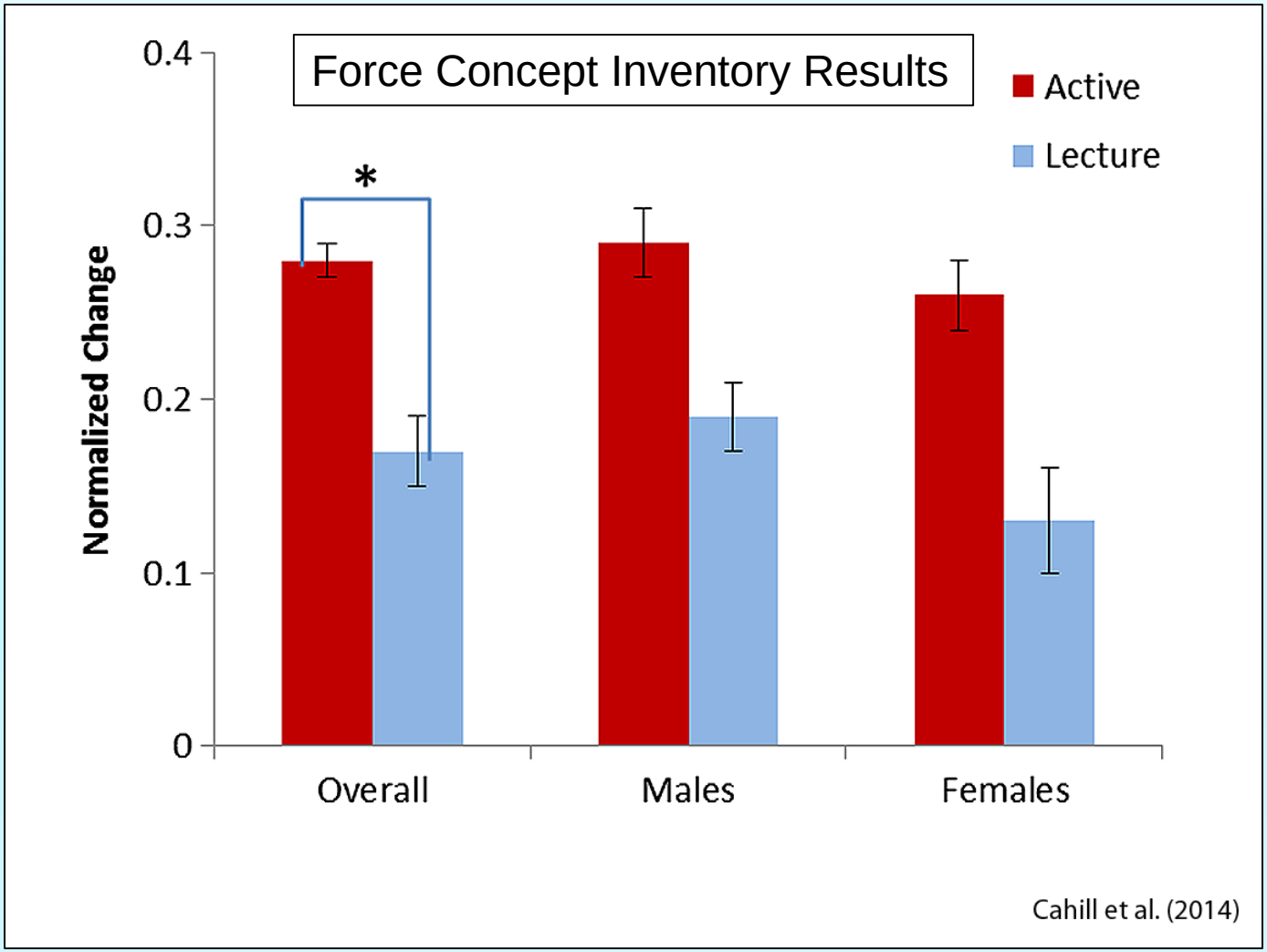
- Data show student attention lapses after 30 seconds, again at 4.5 minutes, and then at increasingly shorter intervals during lecture (Bunce et al., *J. Chem. Ed.,* 2010)
  - Lapses are significantly less frequent during active learning activities AND during lectures directly following those activities

- Clicker questions are one of the easiest ways to incorporate active learning into your current class
  - Questions can be created from material you already use
  - Usually takes ~5 minutes of class time per question
  - Gives you a break from lecturing
  - Easy to use software or low-tech options available
  - Quantitative way to assign participation points in a large class

Benefits to Students

- Students extremely engaged
  - Provides a low-risk way for students to participate
  - Encourages students to work together
  - Gives students practice explaining and defending their answers
  - Nearly all students discuss the questions, but actual clicker voting may be affected by whether participation points are awarded
- Immediate class-wide feedback
  - You can better judge how well students understand the material and proceed accordingly
  - Students can quickly tell how they compare to their classmates
- Provides benefits to students

Benefits to Students



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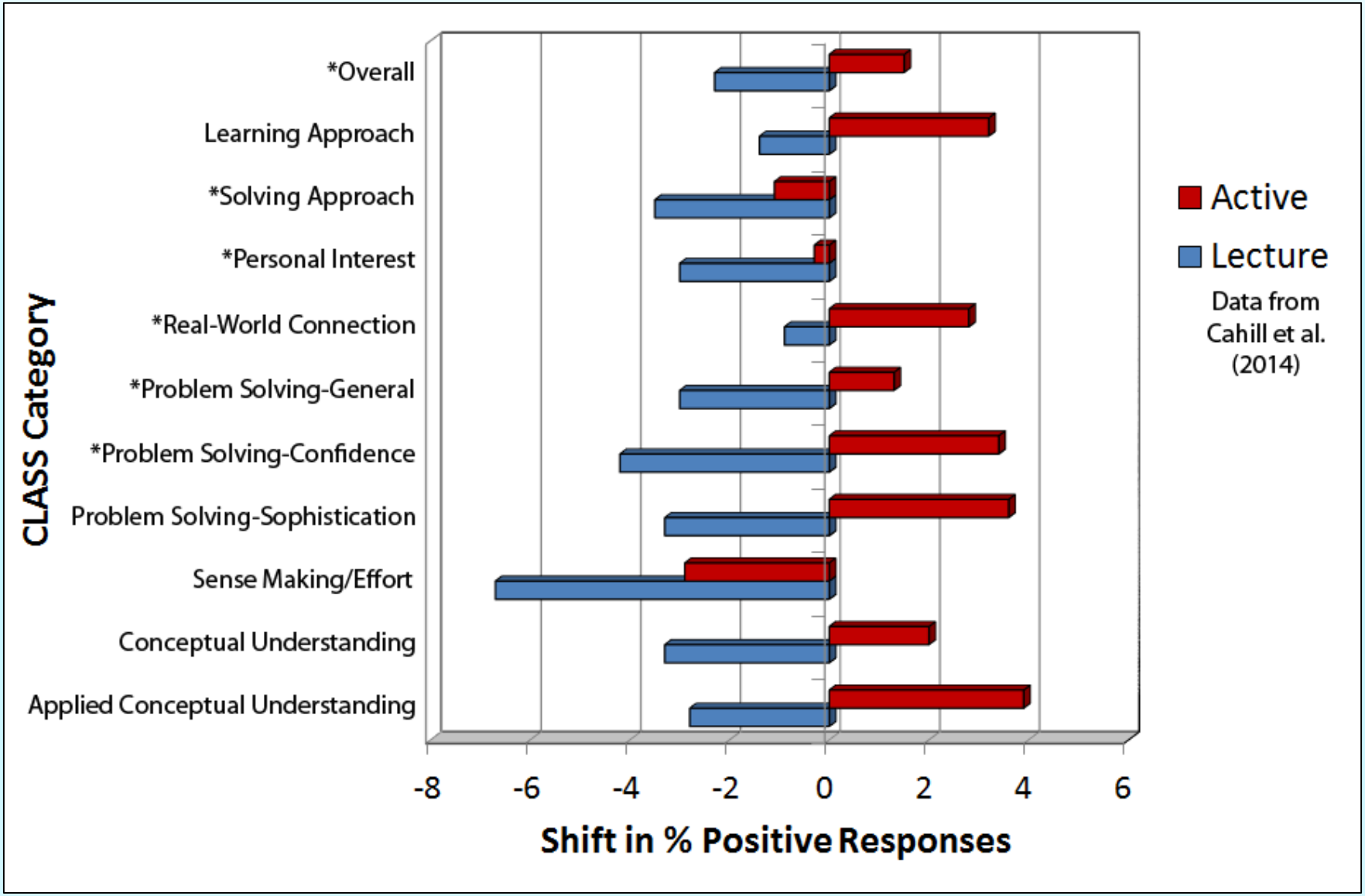

Anecdotal Evidence in Support of i>Clicker Use in Chem 111

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- Students were encouraged (both in the wording of the problem and by the instructors) to work together.
  - And they did!! Throughout the entire semester!
- Students responded overwhelmingly that they liked the clicker questions.
  - Responses evaluated over…
    - Two different semesters (Fall 2014 and Fall 2015)
    - 3 different sections with different instructors
    - Did you find the use of i-Clickers during lecture to be helpful? Please briefly explain.
    - Only 29 students out of 590 students replied something other than "yes" (often with further commentary) to this question.

Anecdotal Evidence in Support of i>Clicker Use in Chem 111

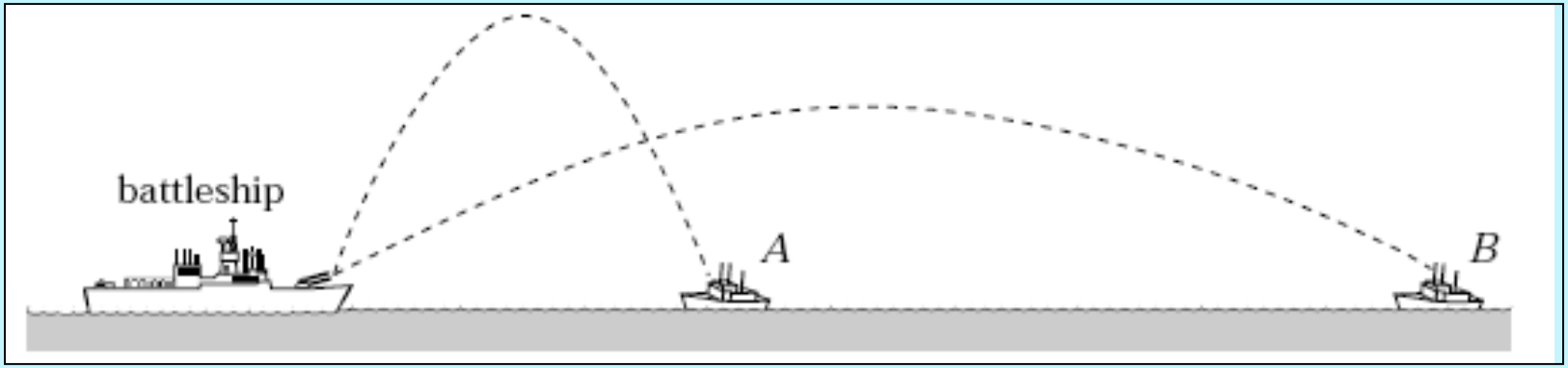
- Sample of common themes in the students' free responses to the question, "Did you find the use of i-Clickers during lecture to be helpful? Please briefly explain."
  - "It was helpful to go through examples and practice problems and then discuss them after we had already given our answers. It helped me stay focused in class and made it more interesting, and also made me more likely to come to class prepared."
  - "They kept me engaged."
  - "I really liked the i-Clickers and would like to see them in Chem 112. They make otherwise passive learning active. Also, when I answered incorrectly, I was more likely to remember the correct answer."
  - "I think they were very helpful and allowed me a chance to truly say the answer I wanted without fear of being embarrassed by saying the wrong answer didn't affect my grade."
  - "Good break from lecture and allows us to apply our knowledge."

Types of Clicker Question - Conceptual

- Checks students' fundamental understanding of key ideas
  - Forces students to think about a problem from a purely conceptual level, without the crutch of calculations
  - Helps students practice assessing the plausibility of their results
- Difficulty level can vary depending on your goals for the question
- Can easily be incorporated at any point during class
  - As an introduction to a mini-lecture on a topic
  - As a precursor to a quantitative example
  - As a mid-lecture check for understanding and a break from lecturing
  - As a reminder of concepts from a previous class

Clicker Question: Introducing an Idea

A battleship simultaneously fires two shells at enemy ships. If the shells have the same initial speed and follow the parabolic trajectories shown, which ship gets hit first?



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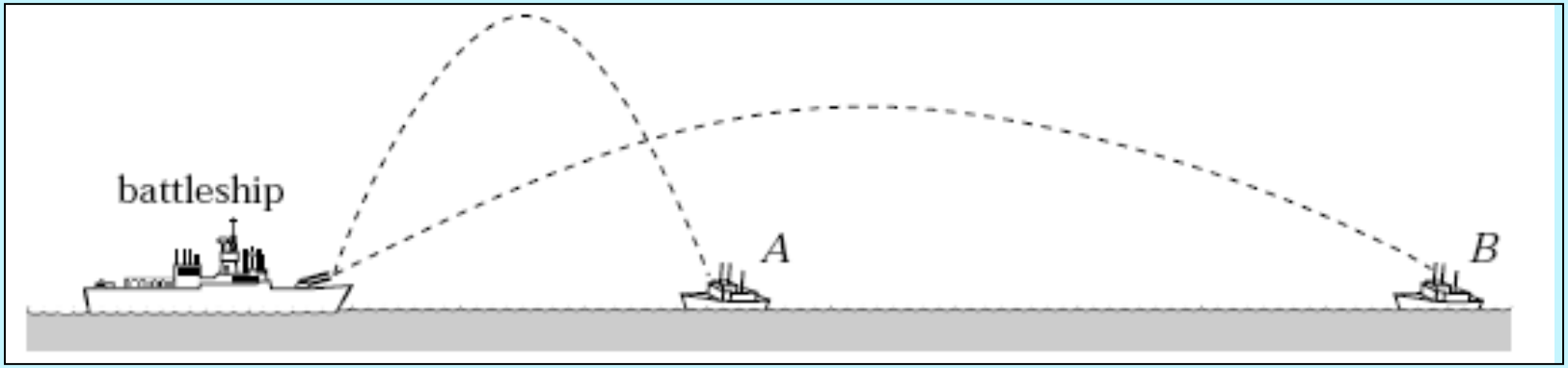

A. Ship A is hit first.
B. Ship B is hit first.
C. Both are hit at the same time.
D. It depends on additional constraints (specify).
E. I'm not sure.

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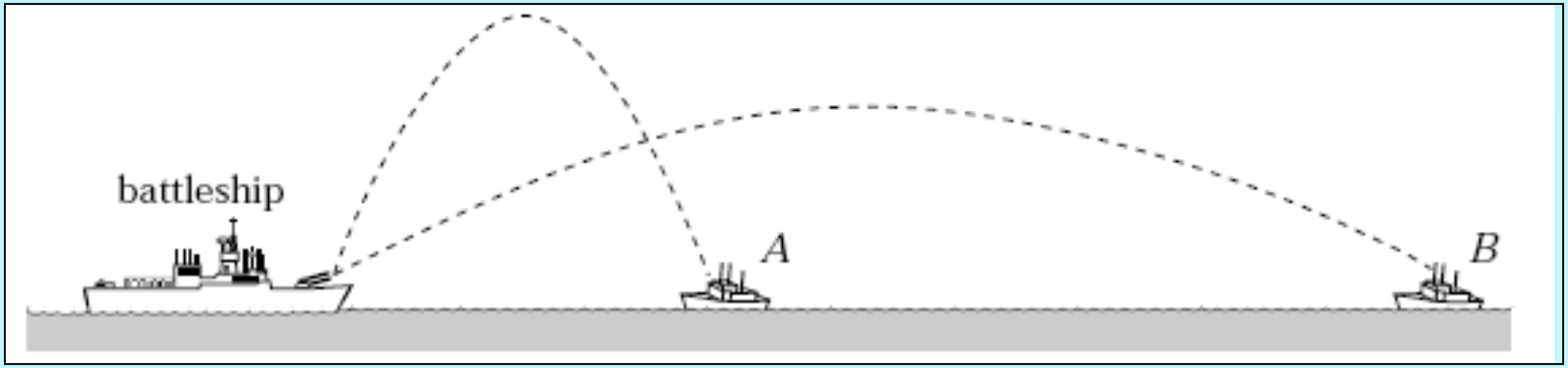

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Clicker Question: Students Work the Example

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Have students work an example that you would normally provide during lecture.

Example from Chem 111.

Radial wavefunctions of the hydrogen atom.

1. Determine how many nodes the function has.

Use the formula: $n - \ell - 1$

Recall: for a 4*p* orbital

n = 4

$\ell = 1$ for a p orbital

Therefore, a 4*p* orbital would have: 4 – 1 – 1 = 2 nodes

Clicker Question: Students Work the Example

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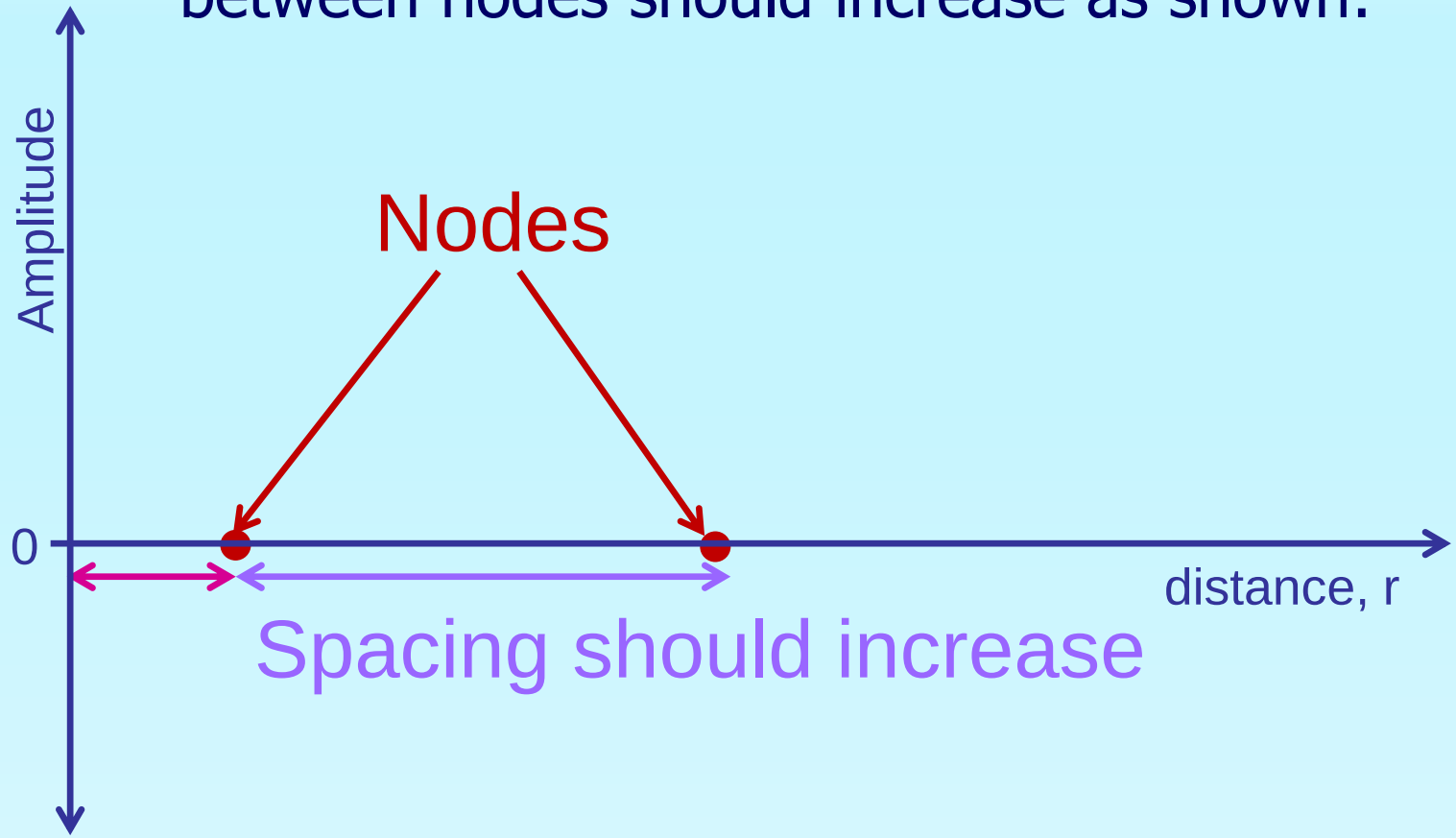
Radial wavefunctions of the hydrogen atom.

2. Mark the number of nodes on the horizontal axis. Spacing between nodes should increase as shown:



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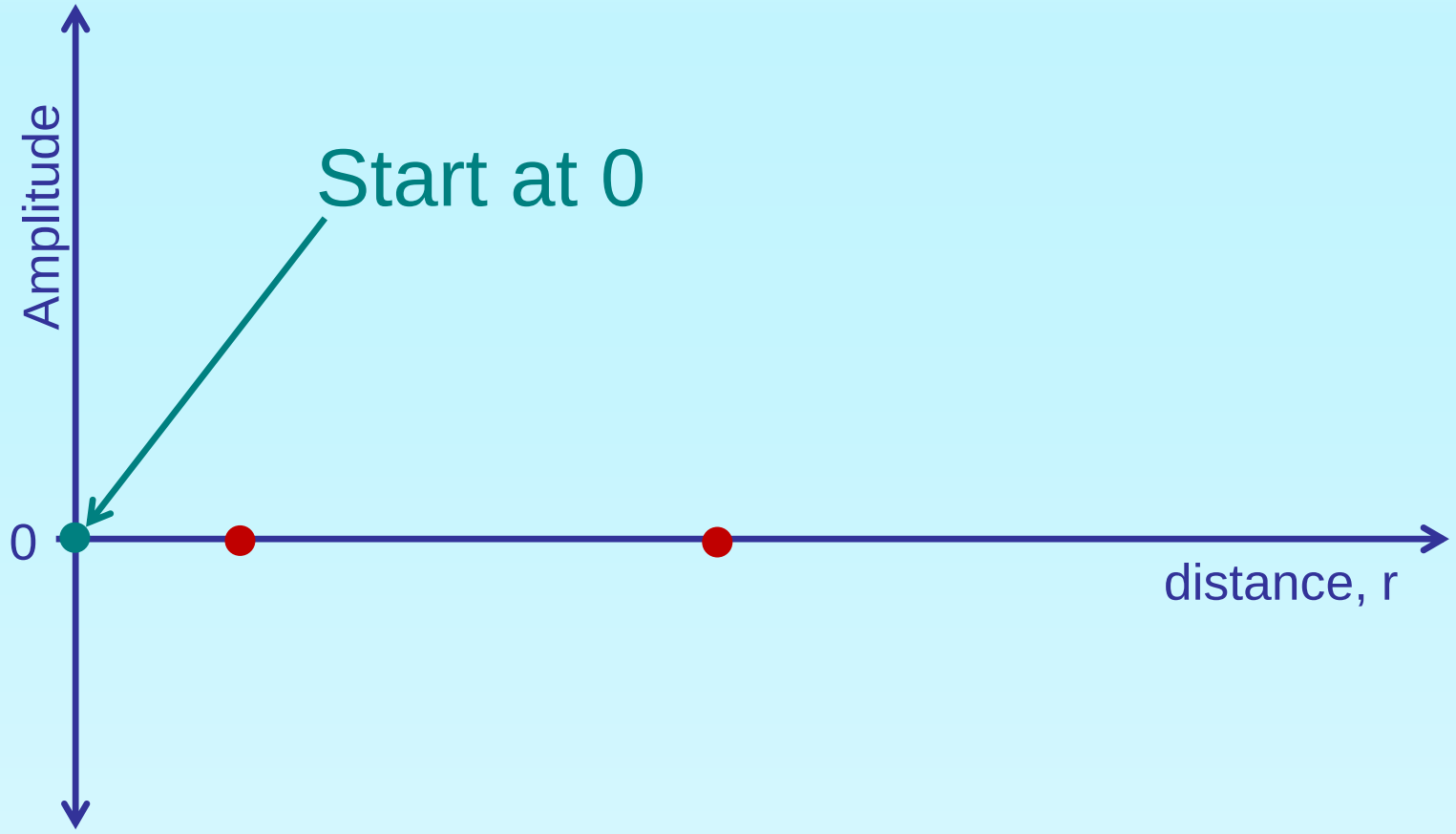
3. Start at 0 and sketch the curve as shown:



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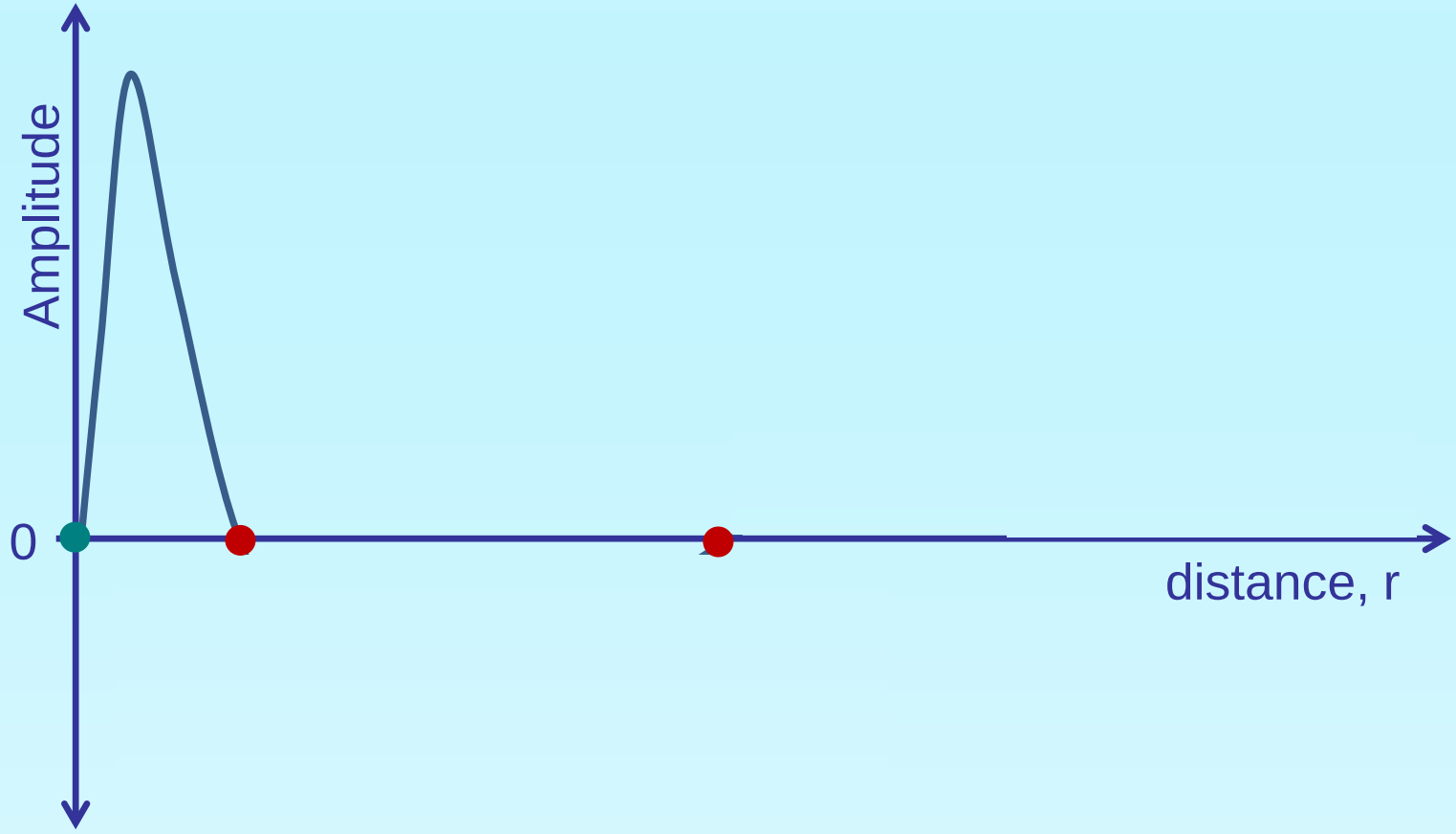

Clicker Question: Students Work the Example

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Sketching the Radial wavefunctions of the hydrogen atom.

1. Determine how many nodes the function has.

   Use the formula: $\mathrm{n} - \ell - 1$

   $\ell = 1$ for a p orbital

2. Mark the number of nodes on the horizontal axis.
3. Sketch the curve.

i>Clicker question:

Sketch the radial wavefunction of a 5p orbital of the hydrogen atom. You may work with your neighbors.

Clicker Question: Students Work the Example

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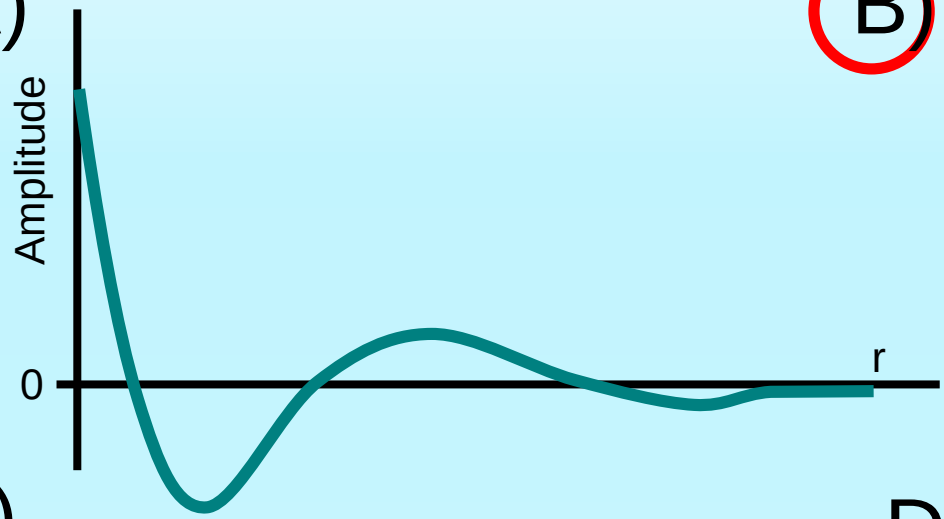
Sketch the radial wavefunction of a 5*p* orbital of the hydrogen atom.

A)



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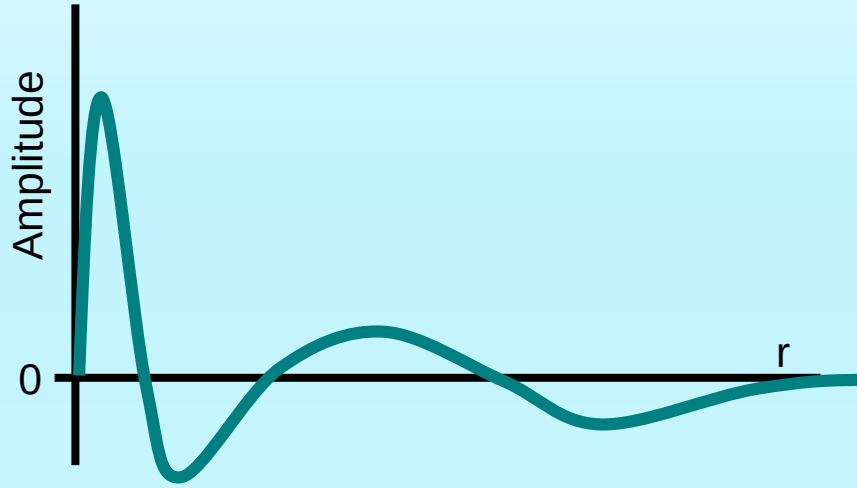
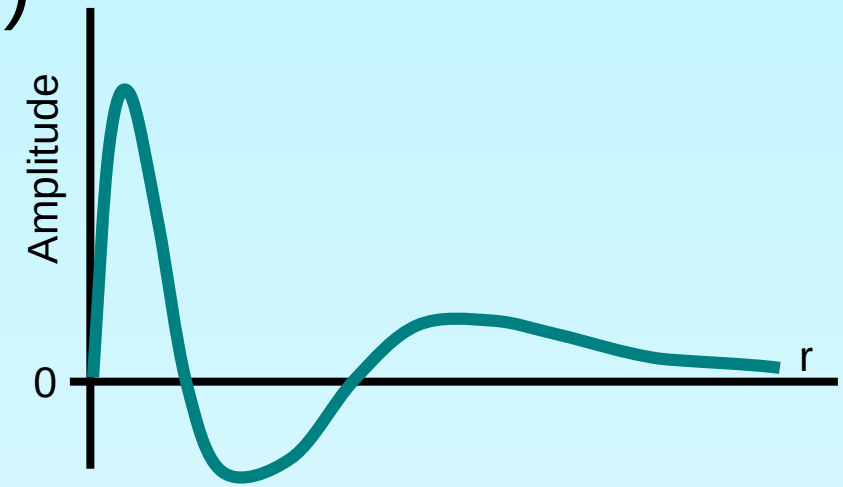


C)



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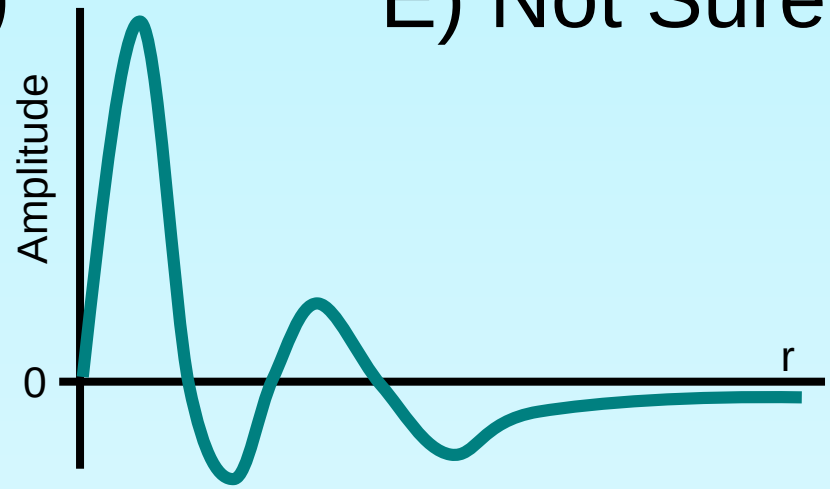

E) Not Sure

Clicker Question: Students Draw the Conclusion

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Have students draw a conclusion or attempt an application after a unit/concept/etc. is complete.

Example from Chem 111.

- An early experiment regarding the discovery and nature of the electron was presented.
- Only the parameters of the experiment and the resultant data were presented.
- Students were expected to draw the conclusions that I would normally list at this point in the lecture.

Clicker Question: Students Draw the Conclusion

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Considering **only** the results of the Cathode-ray experiment, what can be concluded? You may discuss with your neighbors.

1) The cathode ray behaved as a stream of negatively-charged particles.
2) The cathode ray behaved as a stream of positively-charged particles.
3) Atoms of different elements must contain both negatively- and positively-charged particles.

A) 1 only
B) 2 only
C) 3 only
D) 1 and 3
E) 2 and 3

Clicker Question: Review of Previous Material

- Actively review concepts from the reading or from a previous class
- Quickly assess whether or not to spend additional time on a topic
- Identify and target areas of significant confusion
- Feedback is reliable and from the entire class

Clicker Question: Review of Previous Material

In a closed system, is momentum always conserved in an inelastic collision? What about energy?

A. Both are conserved.
B. Neither are conserved.
C. Momentum is conserved but energy is not.
D. Energy is conserved but momentum is not.
E. I'm not sure.

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E. I'm not sure.

Common Misconception: *Kinetic Energy* is not conserved, but total energy is

Lessons Learned

- Getting the appropriate level of difficulty can be challenging.
  - Cannot be as difficult as homework problems.
  - Cannot be so easy that everyone loses interest.

- Difficult/involved quantitative questions do not work. Students simply sit and wait for the correct answer.
  - The fix? Identify the conceptual leap/hardest part of the plug-and-chug process.

i-Clicker Question

The first ionization energy (I_1) for ground-state Na atoms is 496 kJ/mol. The Z^* on the 3*s* electrons in these atoms is 2.507. The ionization energy for Na atoms in which the outermost electron has been placed in a 4*f* orbital instead of the 3*s* may be estimated using the equation below (the "modified Bohr equation). Which of the following values is most appropriate for the Z^* of this 4*f* electron?

$$I = (1313 \text{ kJ/mol})(Z^*)^2/(n^2)$$

A) 11.00
B) 2.51
C) 1.26
D) 1.00
E) 0.50

Lessons Learned

- Timing…(timing, timing, timing!!!!)…is everything
  - End of lecture questions don't work
    - Students are far more likely to just wait for the correct answer.
    - No one sticks around for a detailed justification/explanation.
  - How long to give them to work the question and when to cut them off?
    - Votes seem to pour in when you tell them you are about to close the polls.
    - Were they really finished discussing?
    - Can make it difficult to budget class time.

Take Home Messages

- Implementing clickers is a relatively low-stress way to incorporate active learning.
  - Reshape material you already use.
  - Questions can be used at almost any point in class.
  - Increases student attention during the clicker question **AND** directly following it.

- However, there are challenges…

- Where it falls in lecture is just as important as what question you pose.
  - Be consistent with your implementation.
  - You must be willing to accept it will take more time than lecture and deal with content accordingly.

Take Home Messages

- Leave yourself plenty of time to write!
  - Achieving an appropriate level of difficulty is hard enough, coming up with multiple reasonable but incorrect answers takes a lot of time too!
    - Don't necessarily need 5 possible answers all the time.
    - Always include an "I don't know" option.

- The occasional ambiguous question can be a benefit.
  - Can promote great discussion of important nuances you hadn't considered asking.
  - Helps students focus on what ideas are central and what are less important details, rather than focusing on right vs. wrong.
  - Demonstrates how science is done: complications, assumptions, and debates (without making you look unprepared!)

- Forgive yourself the occasional "easy" question. It will still break up the lecture and get them talking!

For Discussion

How would you incorporate clicker questions into your classroom?