

Student Understanding of Vectors and Superposition in the Context of Electric and Magnetic Fields

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The Physics Education Group (PEG)

What is Physics Education Research (PER)?

....and why is it so
important?

Today: One piece of an
exploratory study

Introductory Physics at UW

Physics 121-Mechanics

Physics 122-Electromagnetism

Physics 123-Waves, Optics, and Modern Physics

Class Structure

Online Pre-lecture(s): SmartPhysics

Lecture(s)

Pre-lab

Lab

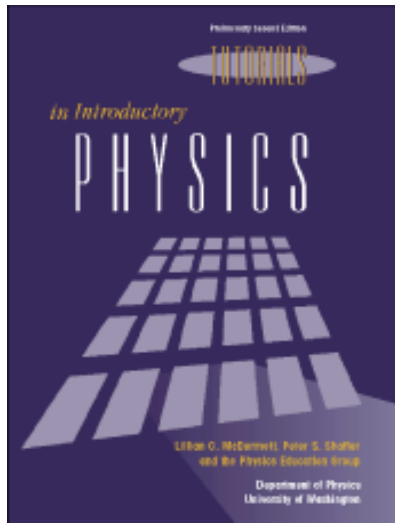
Post Lab

Tutorial Pretest

Tutorial Session

Tutorial HW

Exam



Superposition Tutorial- Pretest

- First pretest and tutorial in 3rd quarter of intro sequence

Suppose you are given two vectors (**A** and **B**) that lie in the xy-plane. Let vector **C** be given by the sum of these two vectors: $\mathbf{C} = \mathbf{A} + \mathbf{B}$.

Suppose you wanted to determine the **magnitude** of vector **C**. (You are not concerned about its direction.) Which of the following pieces of information would be sufficient? (Check all that apply.)

- The magnitude of vector **A**
- The magnitude of vector **B**
- The angle between **A** and **B**
- None of the above are necessary

Explain your reasoning.

Pretest Results

($n_{\text{total}}=292$, Spring 2014)

- Correct Answer → magnitude of vector A, magnitude of vector B,

One-third of the class did
NOT answer correctly.

- Most correct answers were for magnitude of vector A and magnitude of vector B.

- Angle between vectors A and B.

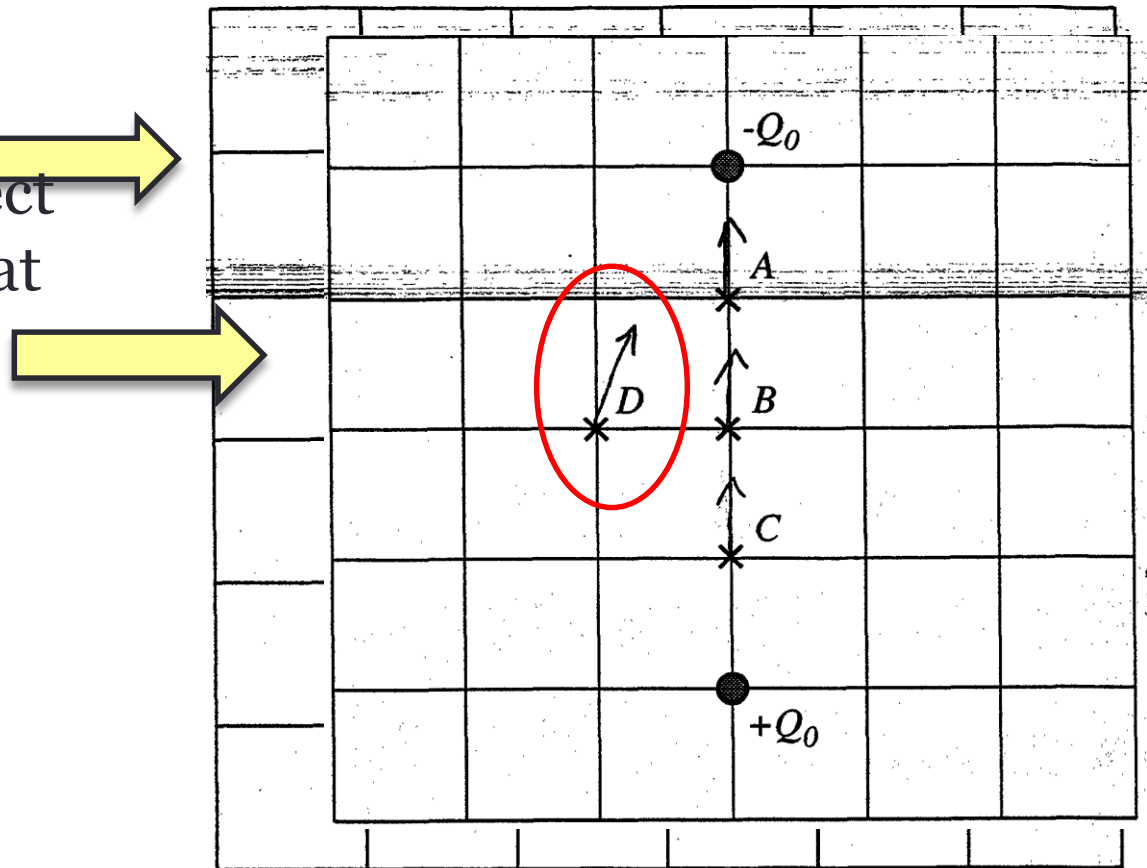
* Percentages are rounded to nearest 5%

Paper-Based Electric Potential Difference Pretest

($n_{\text{total}} = 90$, Winter 1996)

Directions: Sketch arrows on the diagram to indicate the direction of the electric field, if any, at each of the locations A, B, C, and D.

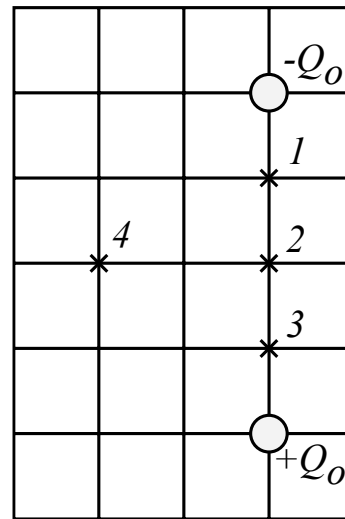
- Correct Answer
- Most Common Incorrect Answer (Non-tangent at Point D)



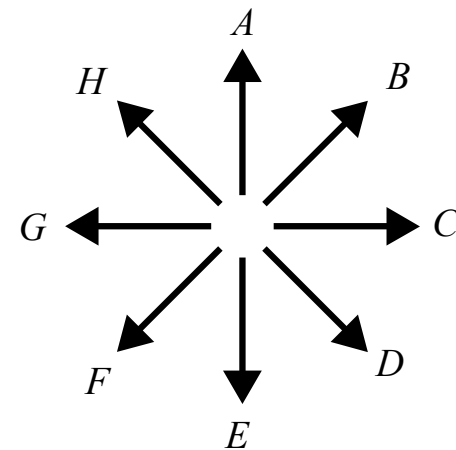
- Zero at Point B

Electric Potential Difference (EPD) Tutorial- Pretest

- Two charges $+Q_0$ and $-Q_0$ are fixed in place at the positions shown. Four locations 1, 2, 3, and 4 are each marked with an 'x.'



Possible choices for arrows indicating the direction of the electric field. (Part A)

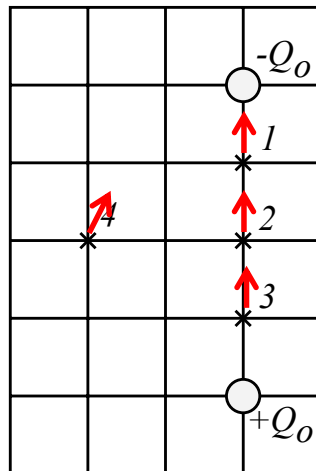


- Select the arrow that most accurately indicates the direction of the electric field for each point. Select zero if the field is zero at any point.

Pretest Results

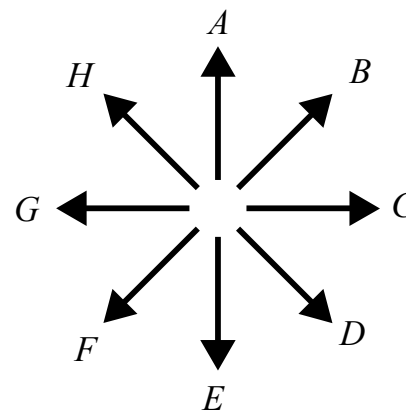
($n_{\text{total}} = 337$, Winter 2014)

- Most Common Incorrect Answer (Non-tangent at Point 4)
- Correct Answer
- Zero at Point 2



Possible choices for arrows

Possible choices for arrows indicating the direction of the electric field. (Part A)



EPD Pretest Results

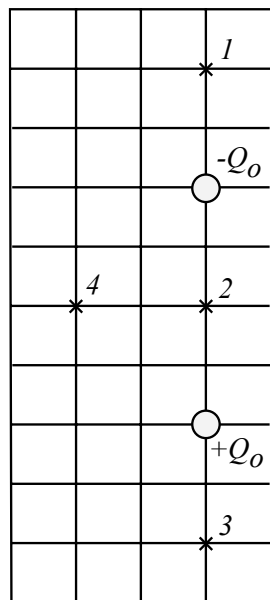
	1996-Paper Based (n=90)	Winter '14-Computer Based (n=337)
% Correct	55%	55%
Zero at the center	10%	10%
Not tangent at point 4	25%	15%

Summer Modification to EPD Pretest

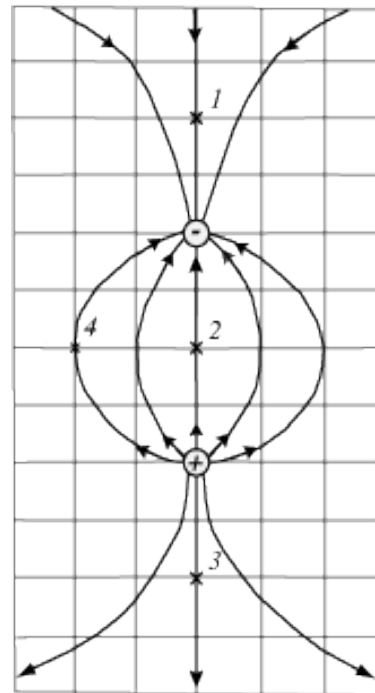
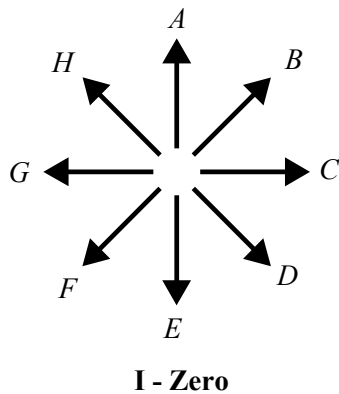
Question 1: No Field Lines

Question 2: Field Lines

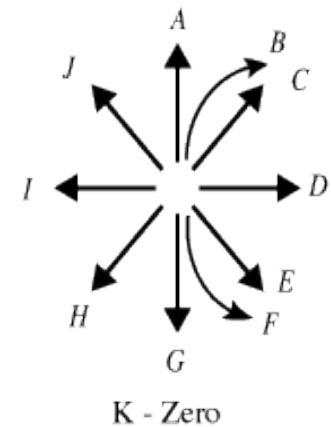
Select the arrow that most accurately indicates the direction of the electric field at the points given (1-4). Explain your reasoning.



Possible choices for arrows indicating the direction of the electric field. (Part A)



Possible choices for arrows indicating the direction of the electric field.

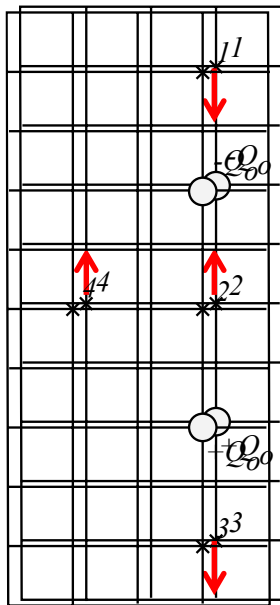


Summer Results

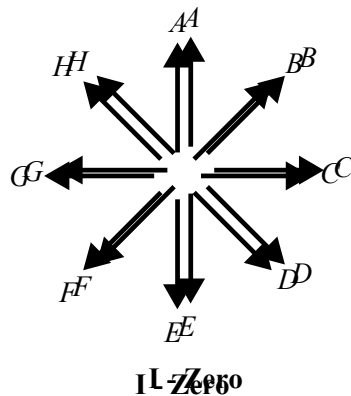
($n_{\text{total}} = 54$)

Question 1-No field lines

■ Correct Answer



Possible choices for arrows indicating the direction of the electric field. (Part A)



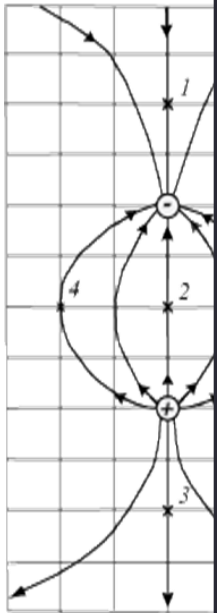
"2: Net force is zero so E field is zero"

"2 is zero because it's in between the positive and negative charges."

Increases.

Question 2-Field Lines

- ~~Correct Answer~~ Incorrect Answer (Curved at Point 4)



Are results consistent across
many quarters?

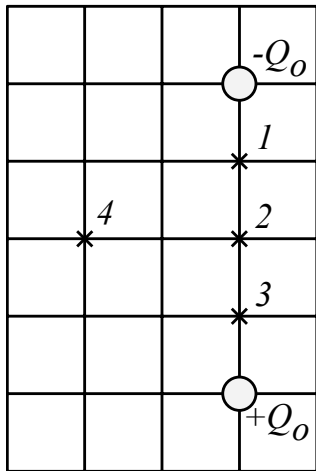
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Further Comparison of EPD Data



Points 'inside'



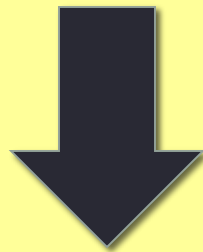
Points 'outside'



	1996-Paper Based (n=90)	Winter '14 Computer Based (n=337)	Summer '14- No Field Lines (n=54)	Summer '14- Field Lines (n=54)
% Correct	55%	55%	60%	55%
Zero at the center	10%	10%	20%	<5%
Not tangent at point 4	25%	15%	<5%	30%

Consistency Across the Two Modified Questions

Only about half of the students answered
BOTH questions correctly.



Difficulty in relating vector field and field
line diagrams.

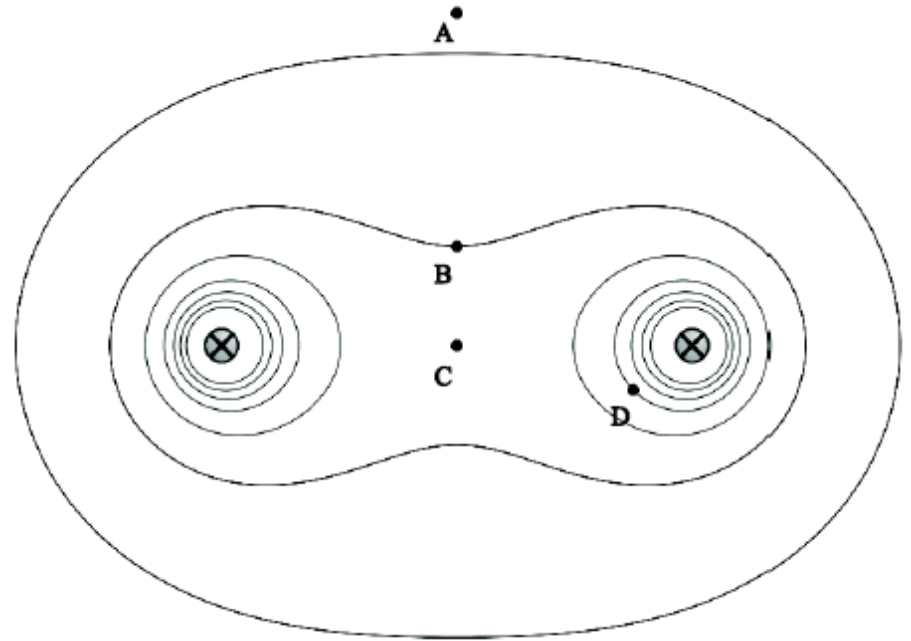
Qu

Exam Three

- Administered week 9 of the quarter

The diagram at right shows magnetic field lines for a pair of long wires. Both currents are directed **into the page**.

- At each labeled point (A-D), draw a vector to show the direction of the magnetic field.

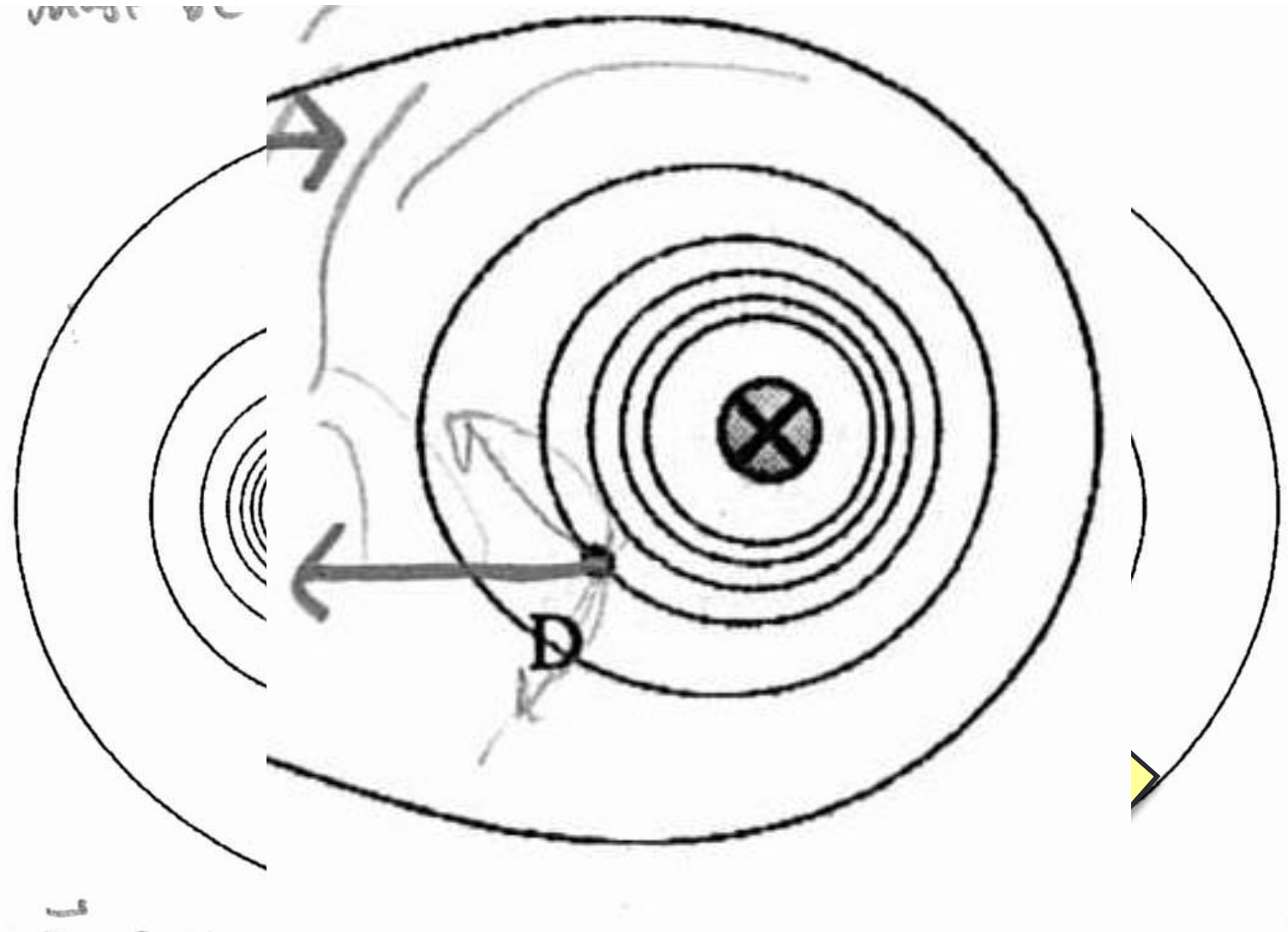


Exam Results

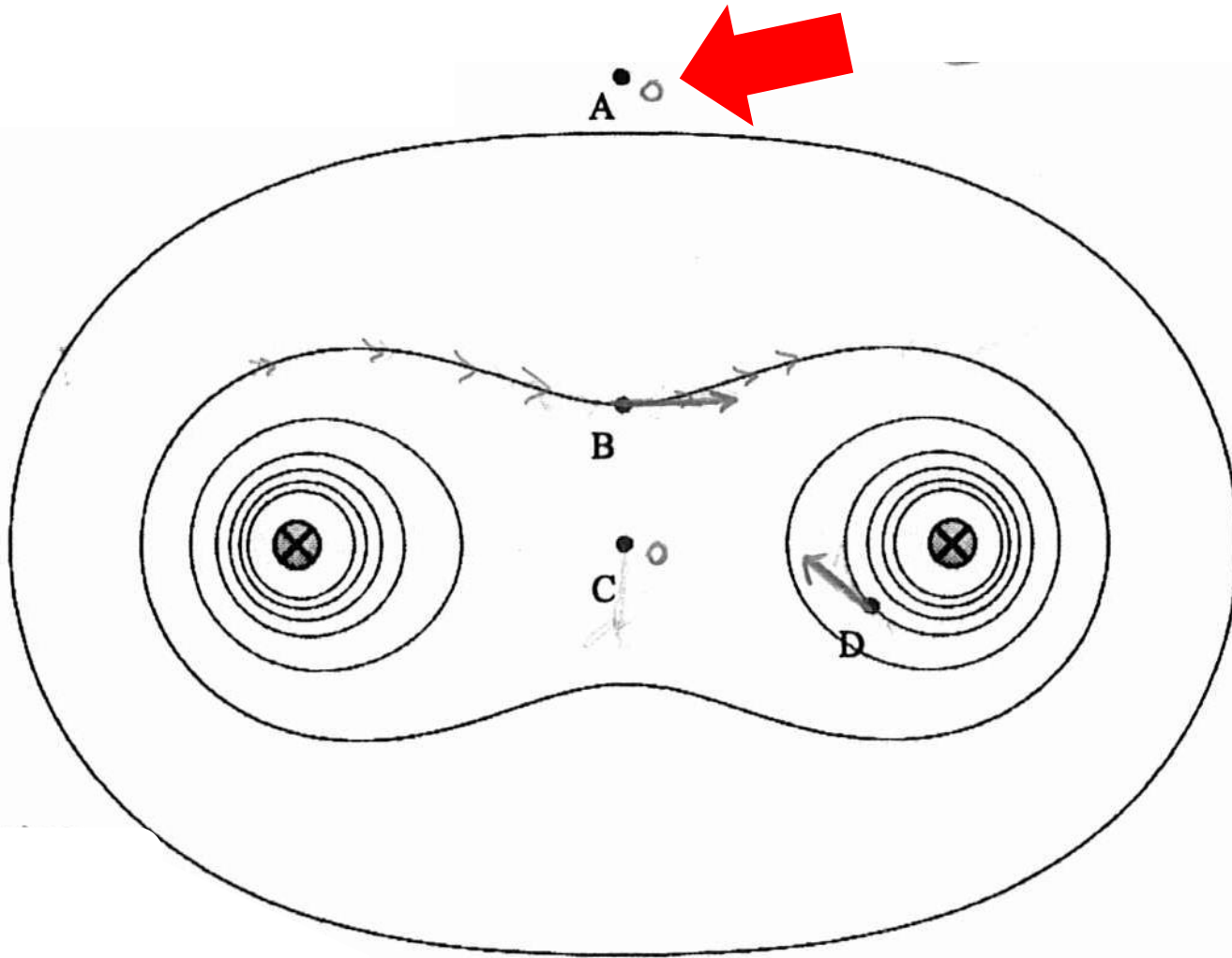
($n_{\text{total}}=210$)

What are students' underlying difficulties?

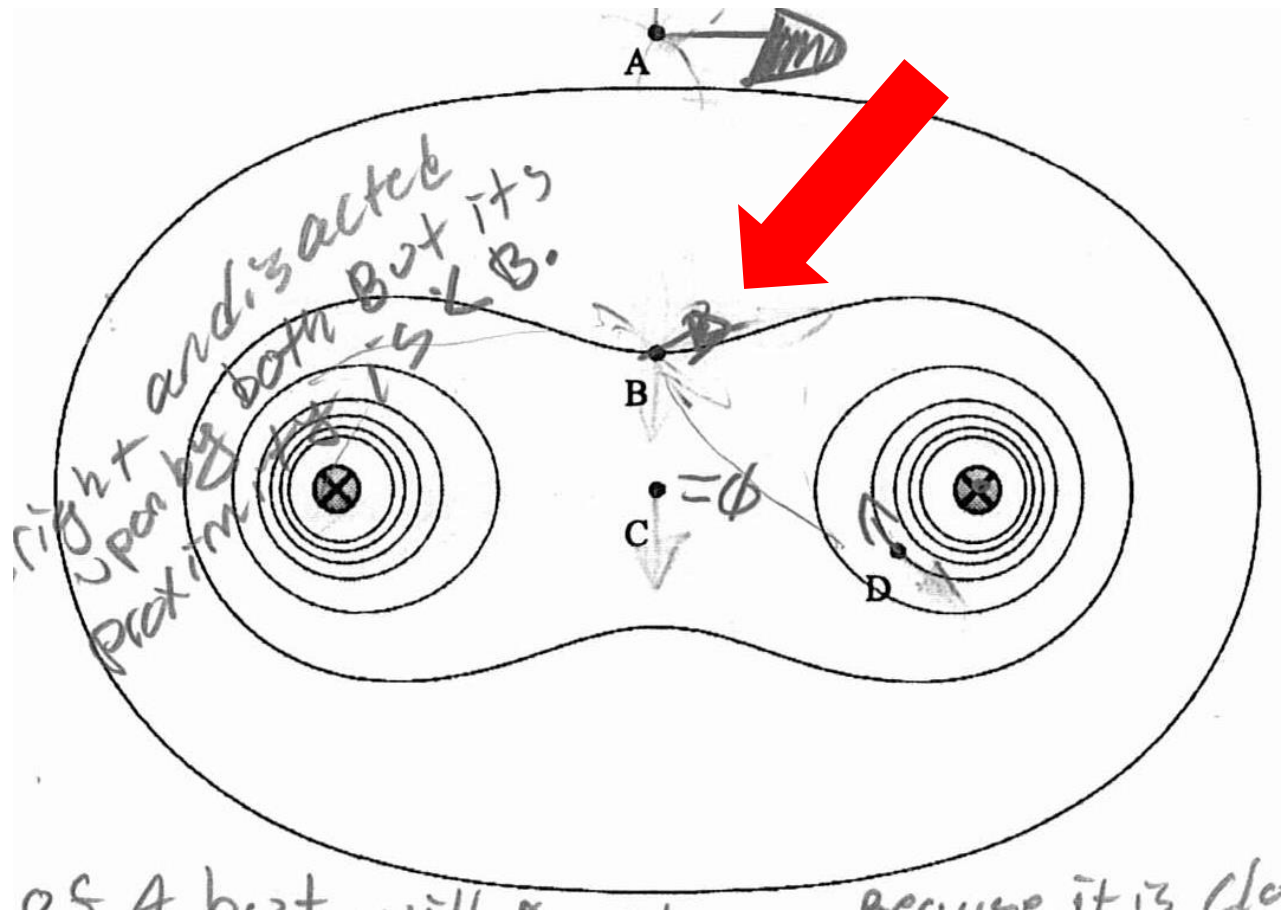
- Failure to relate the direction of the *net* field with the tangent to the field line



- Belief that field is 0 when outside last field line drawn

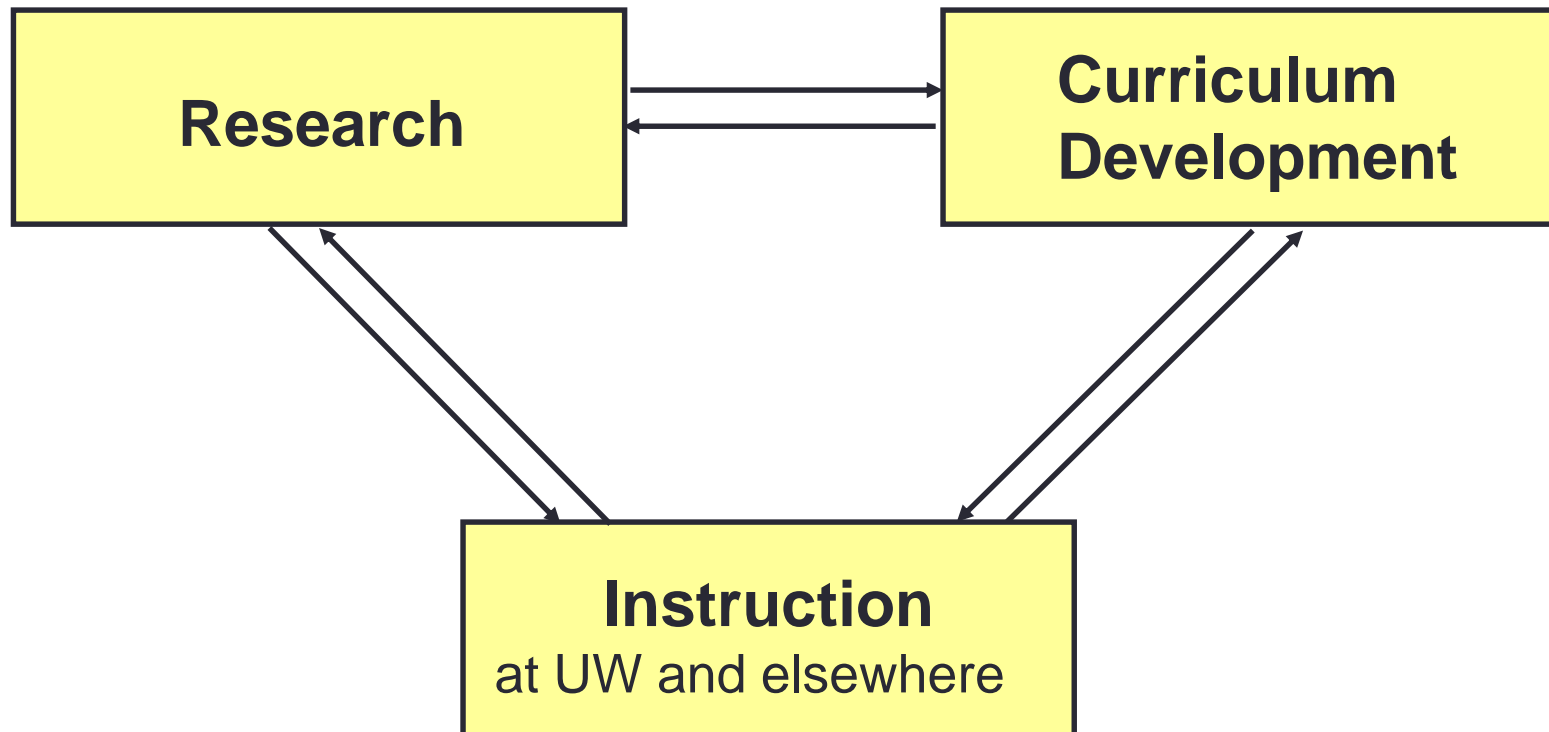


- Associating vector at a point with the direction of the field over a region



Conclusions and Next Steps

- Robust evidence that students struggle with both the mechanics and conceptual understanding of vectors
- Iterative Process

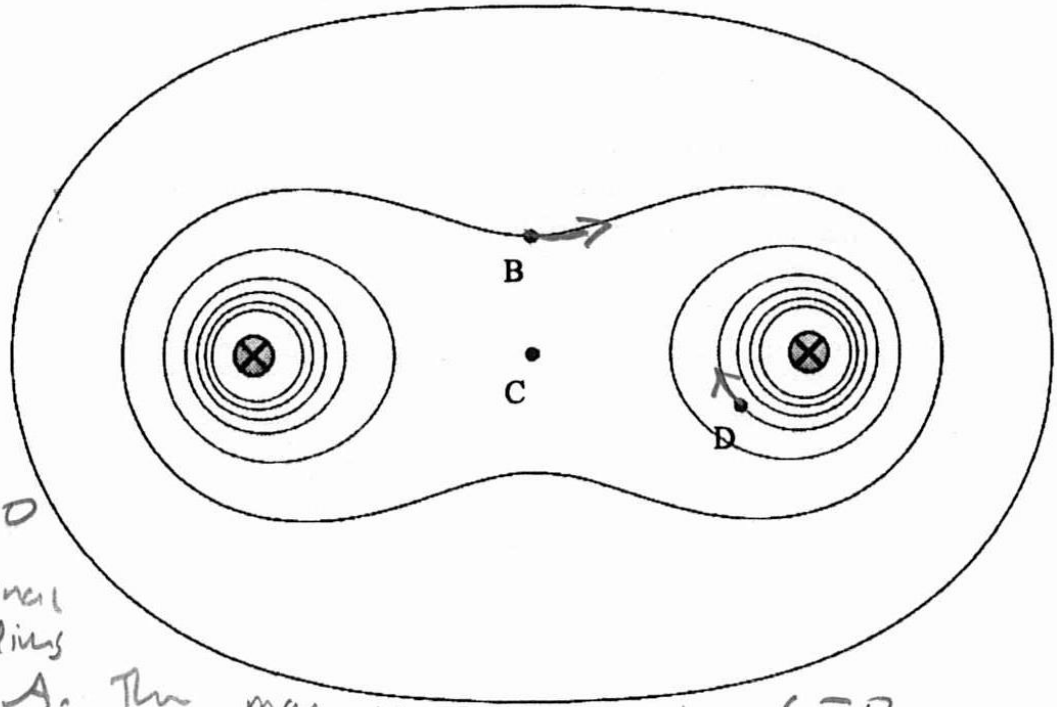


Thanks!

- PEG
- REU Staff: Linda Vilett, Janine Nemerever, Dr. Deep Gupta, Dr. Alejandro Garcia, Dr. Gray Rybka, and Dr. Shih-Chieh Hsu
- NSF

Questions?

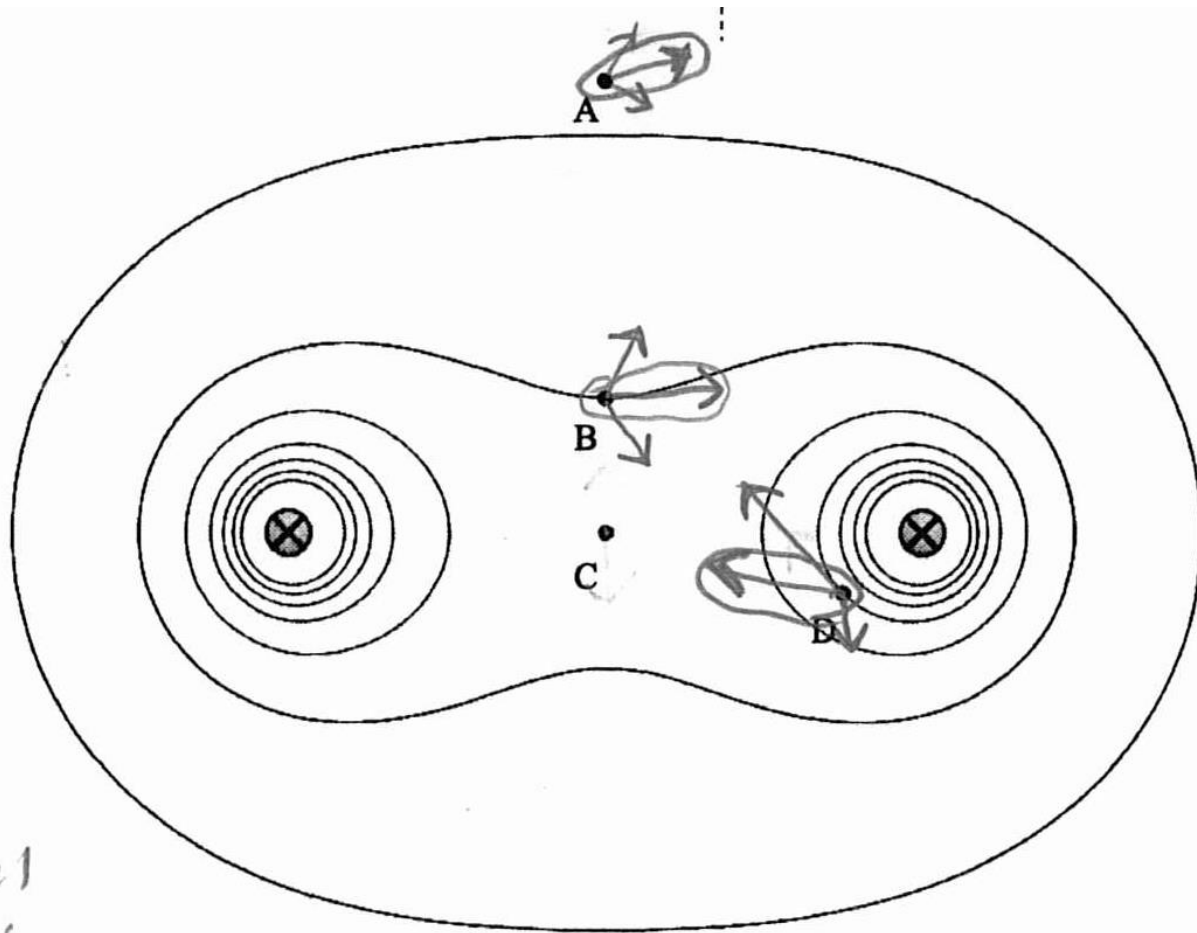
$\vec{v} \times \vec{B} = 0$ 



$\vec{v} \times \vec{B} = 0$

directional field lines in A.

The magnetic field at C = 0



trái

...

Field lines indicate direction of electric field. Can just look at direction of field line at each point. **RT ANSWER**

VS

The electric field is in the same direction as the electric field lines. **Puts B at pt 4**