

Students should practice several times with the equipment before they begin taking data. Several actions need to be coordinated and every member of the group must be prepared to make the appropriate measurements and recognize events which might lead to error. If errors are recognized, students should repeat the scenario. Decisions should be made by the group relating to measurement techniques. For example, a common point on the toy should be agreed upon for determining displacement of the ladybug relative to the grid and relative to the frame of reference. Students could select the front, the wind up knob or the back feet as long as they agree upon a common reference. Strategies such as marking starting points should be decided upon by each group. Each student should be assigned a role within the group. Here is a possible division of tasks for a group of three students:

- One student pulls paper at a constant speed
- One student times the motion
- One student winds the ladybug, releases the ladybug and stops the ladybug. This individual is responsible for clearly communicating start and stop to the other members of the group.
- At the conclusion, one student should use a dry erase marker to indicate each of the following end points 1) the grid relative to the fixed frame 2) the ladybug toy relative to the grid and 3) the lady bug relative to the fixed frame. This task could be assigned to the student with the timer or a fourth group member if possible.

Students will then take measurements and record in the data tables provided for each scenario.

At the outset of the activity, each student group should define the horizontal and vertical axis. Since the activity requires 3-4 participants it should not be assumed that each individual has the same view point, but they must agree on the same definition for the positive axes. The gridded surface moves between the meter sticks on the horizontal axis in either the positive or negative direction. The toy can move in any direction but will be limited in this activity to motions parallel or perpendicular to the surface. The grid is useful in verifying the toys horizontal or vertical motion. If the toy deviates from straight line motion, the trial should be repeated. If a slight deviation is unavoidable due to a malfunction of the toy's mechanism, students should make note on their data and move on. The fixed dry erase board and the movable grid must be clean and flat so as not to interfere with the toys turning mechanism.

Students must first determine the average speed of the toy on the gridded surface. This value will be used as reference throughout the lab. After several trials with the toy, students should find a fixed distance reached while toy still maintains a constant speed and determine the amount of time it takes for the toy to reach that point. (This will vary depending on the type of toy). In this discussion the toy will be referred to as a ladybug, which was the toy used in the activity at our school.

During the first phase of the activity students observe the addition of parallel vectors by moving the toy and paper in the same direction and then compare with motion in opposing

like wheel?

can the bug carry the marker?

what meter sticks? do you mean?

unclear photo?

unclear need photo or sketch

ok say this much earlier please (pages ago?)

identity briefly

direction. In addition to collecting data and observing the resultant motion, students are asked to translate information into a graphical representation of the components and the resultant (Student questions #2 and 3). Students are led to make a conclusion about how the relative direction of motion impacts the size of the resultant (Student question #4).

Questions 5 through 11 apply to scenarios in which the components are perpendicular. Two questions require students to collect data and analyze in a similar method as previously used with parallel vectors. It is important to check student diagrams of head-to-tail or parallelogram addition to be certain that the resultant drawn in the diagram matches the actual path of motion for the toy.

At the initial stages of this investigation, students are asked to make the horizontal and vertical velocities a similar magnitude. Several questions contained in this portion of the activity introduce the idea of inequality between the horizontal and vertical in order to assess the students' ability to visualize the resultant angle based on the relative size of the components. A prediction stage is added during this step to encourage students to move beyond pure drill practice with equations and to assess student ability to apply reasoning behind the equations.

After a significant number of practice questions asking students to find the resultants from the horizontal and vertical components it is advisable to change the pattern. This ensures that students are able to identify the variables and apply the concepts rather than just plug in values and solve. Questions 12-14 require students to apply the same set of equations that have been used throughout the lab but in with different input values.

Outcomes:

The activities were conducted in their entirety in my classroom with 93 Regents Physics students across three sections containing 31 students each. Students were grouped primarily in groups of four with a one group of three in each section. Two other teachers used the materials to provide an interactive demonstration without the full worksheets with a total of 175 students for the purpose of providing students with a visual activity for concurrent velocities. These teachers continued to use the force table lab to reinforce vectors. These activities were not used, in either of these classes as an introduction but rather as a part of a unit review.

Overall the activities kept the students engaged and students were actively questioning the predictions against the results. While students initially needed significant help with understanding the set-up of the materials and the vocabulary adapted quickly after some discussion and examples. From my viewpoint the activities and the rearrangement of teaching sequence achieved the objectives for which it was designed; to confront vector misconceptions at the outset of concept development. This conclusion was corroborated by evidence from a common assessment on motion given to the 268 students who had exposure to the activity. The common assessment covered all aspects of motion from constant velocity through two dimensional projectiles. While no significant difference was noted between percentages of

too informal Outcome Observations Feedback then your analysis Comments

which? both?

Past tense

unclear sentence fragment

close up

consistent

unclear

can this all be written in past tense?

assessor develop or improve?

But you compare claim "hands on" introduction in your title.

From the course assessment?

incorrect answers for twelve of the twenty test items not related to the activities, the eight test items that related to vectors showed a significantly higher success rate for students who completed both Activity One and Activity Two as part of the introduction to non-accelerated motion (See Appendix C). Specific items from this assessment and item analysis are outlined within this discussion. Overall the incorrect response rate was consistent for all 8 items suggesting that as a whole only a handful of students continued to show any significant deficits on vector skills. Upon further investigation many of the same students were represented within the group who incorrectly answered these questions.

vague remove

Eight

write out this single digit here please

Feedback for Activity One: Lady Bug transit

After minimal instruction, students were able to successfully determine the horizontal and vertical components of each vector without much difficulty. With guidance they were able to determine the total horizontal and total vertical displacement for the toys motion. Students easily applied the Pythagorean Theorem to determine the length of the hypotenuse but only a small portion of students understood the significance of that step in determining the overall resultant. Equations involving the determination of the angle were introduced for the first time at this point, so while many were able to manipulate and solve, students were not at a stage at which they could replicate the process. By tying the action of the toy to the resultant or hypotenuse of the triangle, the directionality of the horizontal and vertical components was intuitively understood in a way that is not as clear when presented in a lecture format. When asked if the horizontal component was positive or negative students were able to respond correctly with little need for explanation. Only a handful of students demonstrated any difficulty, which was easily remedied by asking them to describe the overall motion and then break it down into components. Many students were able to explain correctly in the conclusion. From experience this is a more advanced stage than most students reach upon initial introduction to vectors.

unclear restate

I think you should prefer to use x + y components rather than vertical + horizontal. More consistent + safer.

small fraction? 5%??

The idea that the summation of the horizontal and vertical components of the motion was equal to the horizontal and vertical components of the resultant displacement was retained by many but not all students as we proceeded through other stages of concept development. Even though students were instructed during the introduction that the order of vectors does not impact the resultant, the process of switching component values from one group in a random order of vectors was instructional. Some students tried to sneak a look at the partner groups diagram so they could replicate the order and be the ones who get it right. Those students were completely shocked to find that the order of addition is irrelevant to the outcome.

The final phase of the activity was a largely successful activity for introducing the reference equations. Some guidance was still required for identifying variables to substitute into equations. Most students were able to recognize the difference between the addition of parallel vectors and perpendicular vectors by the following day. More than half of the students were able to determine the resultant and angle based on horizontal and vertical components in a introductory problem the following day and during the first portion of "Activity Two: Lady bug

should only those students trying to "cheat" learn this?

unclear restate

lower case

on a conveyor belt." In light of past experience with the force table, lab this activity was highly successful despite the fact that students did not all achieve mastery at this point. A higher number than in previous years demonstrated a functional skill level as evidenced by test outcomes.

Activity 2: Ladybug on a Conveyor Belt

At the outset of Activity Two students showed some frustration with the coordination of the materials; but, this was quickly resolved with some individual instruction for each group. The nature of the data in this lab invites some error but is sufficient to demonstrate the major ideas to students.

help

unclear restate

This activity serves not only to reinforce the idea of a vector but also to further develop the idea of displacement, speed and velocity. Regular checks of understanding are critical. As I walked around the room I heard many conversations in which students were actively working through the difference between the idea of displacement and velocity. In several cases I needed to work with students on the difference between the two values. This was a very instructional moment for me. The difference between the idea of distance and speed seems implicit. Several students needed to engage in a discussion about the difference between the distance traveled and the rate of travel before they were able to proceed with the worksheet and build vector skills.

Past Tense please (insightful)

The activity provided a useful shared experience for students to establishing a model for future discussions. The method I used to help students understand the idea of reference frame was to query students as to what would be observed from various view points. Examples of queries included: "what would lady bug moving parallel on the vertical path to the first ladybug observe?"; "what would a ladybug moving only due to the horizontal motion of the paper observe?"; and "how are these motions different from a lady bug watching from a completely fixed position near the starting point?". Each of these could be directly observed through demonstration. After adequate discussion students were able to explain the role of frame of reference in determining the magnitude and direction of the resultant.

shared experience

excellent

The first part of the activity dealt with the parallel velocities. Students were tasked with determining the resultant displacement and velocity of the ladybug toy if both the lady bug and the paper are moving in the same direction. Students recognize quickly that the displacement of the paper with respect to the frame of reference and the displacement of the lady bug on the grid add to equal the total displacement of the bug relative the fixed frame of reference.

In past years, I hadn't explicitly discussed frame of reference with students; however, after completing this activity with the students I realized that the concept of frame of reference was critical for students who struggle with presentations of vectors added at different angles. (See Appendix C; June 2008, #38 or June 2010, #2). Most students at this stage of learning needed to understand the difference between the ladybug's motion relative to grid and the ladybug's motion relative to the fixed frame. In subsequent lessons, I was careful to provide

were past

scenarios which considered frames of reference for students such as person moving on an escalator or moving sidewalk. I attribute the high success rate of students on this type of problem on the common assessment (Appendix C) to the added focus on frame of reference. Given enough practice problems with a frame of reference, the majority of students were able to visualize the situation.

The ultimate goal of this activity was for students to recognize the concurrent nature of the components and to visualize both parallel and perpendicular vectors. It was particularly rewarding to observe the conceptual connection made when students explored perpendicular velocities. This was the first time students showed a true recognition of the idea that a single object was experiencing two different velocities in such a short period of time. In past years I have been forced to move on from projectile motion without evidence of mastery because of time constraints. The resultant displacement and the resultant velocity were represented by the actual path of the toy. While this is a statement that I make frequently in relation to projectiles, this is the first time that students seemed to be able to verbalize the idea to me rather than nod with vague recognition. This realization is an important idea to establish before beginning a discussion of projectiles.

Once students established the idea for independence of horizontal and vertical motion, they moved quickly through the phase of the activity in which the horizontal velocity vector was changed in order to determine the impact on angle of motion. This provided an important framework for many subsequent vector skills. After this activity I was able to introduce the idea of initial velocity components for objects launched at angle without progressing the projectile phase after launch. By the time we addressed projectile motion several weeks later, students had significant practice with two dimensional vectors and some of the difficulty separating the two tasks was minimized.

The common assessment question that best represented this skill asked students to find the horizontal component of a ball launched at an angle. Only 4% of students in my classes were unable to correctly set up the equation and solve compared to 15% for the larger group. The follow up question which required determining the height of the projectile had a success rate consistent with the other classes. This question is not related to the activity so it is not item analyzed in Appendix C.

In classes where teachers had completed significant instruction prior to the activity, teachers reported that the greatest impact occurred for students who had struggled with visualizing problems up to this point. One teacher commented that one group of students exclaimed "Now I get it!" This was not the response of the same students after the Force Table Lab. The other useful feedback from one colleague was that the activity set the stage for the discussion of the independence of horizontal and vertical components. During the activity, students concluded that the vertical motion of the bug was not affected by the horizontal motion of the gridded surface. Introducing two separate axes in this scenario allowed students to

in activity two? redundant fight up

how did you observe this? So their discourse or verbiage seemed more sophisticated + facile to you? good

develop the idea of two things happening simultaneously to a single object. The other teacher stated that this visual translated easily to the independence of horizontal and vertical motion for a two dimensional projectile.

For each scenario students were tasked to create vector diagram based on data and observations. The connection between the observed motion of the toy and the task of drawing the vector diagram illustrated clearly for students the directionality of the resultant vector. In five years of experience with the Regents Physics course, this is the most effective strategy I have found to teach students how to draw or identify a resultant vector using either the tip-to-tail or parallelogram method of vector addition. In past years, a small portion of students demonstrated great difficulty with this seemingly simple task. Despite the arrows on the components they would draw a line to complete the triangle and arbitrarily assign a direction.

For my students, assessments of this skill from tests and quizzes when compared to prior years showed a significant improvement in mastery early on in the unit. This data comes from recorded skill checklists by curriculum date rather than specific question item analysis. Tests are varied year to year and even within the class. This conclusion was further supported by the comparison of outcomes for a question that on a common assessment given to 268 physics students at the conclusion of the first academic quarter. The question asked students to draw in a resultant given two tail-to-tail vectors. The 93 students who completed the activity with the worksheet had a four percent incorrect response. By contrast the 175 students who were exposed to the activity by demonstration or as just a quick visual reinforcement had a 13 percent incorrect response rate. The 4% of the students who got this question wrong drew an arrow between the tips. The larger group made a similar error but at a much higher rate. The common assessment was given a month after the activity was completed, suggesting a high level of student retention.

When queried about the reason for an incorrect response, students who had some level of understanding would often reflect on the activity as an explanation for a corrected direction of the resultant vector. A similar problem was presented in quiz given only to the 93 students who had completed the activity; however, in this problem the vectors were shown tip to tail. The rate of incorrect responses for this scenario was also minimal but in that case the line was drawn correctly in all but one case. An additional 4 students did not include an arrow on the resultant vector.

Conclusions:

After introducing the lady bug activity on the moving grid, I developed a new appreciation for the difficulty prior students experienced when attempting to connect observations from the force table lab to motion problems. Force tables do not encourage students to confront preconceptions involving frame of reference or help students develop the characteristics of vector quantities. Understanding the frame of reference is critical to visualizing two dimensional velocity problems. Vectors and vector arithmetic are crucial skills

unclear restate

put these together

which leaders? vague

what?

activity two

to question #

unclear restate

unclear

Conclusion?

unclear restate

unclear restate

put this all together

good

yes

perhaps this could be one of w/several sources of data + comments

"I now believe" would read better here

for a successful physics student. The literature supports my personal finding that students find vectors very challenging and that more instructional time and care must be devoted to developing student understanding. The background literature on how students learn vectors and student level of understanding contains many conclusions that instructors at the college and high school level do not realize how much difficulty students have with learning vectors. Shafer and McDermott, 2005; Knight, 1995; Nguyen and Meltzer, 2002; Arons, 1997).

While some teachers may in fact gloss over some concepts mistakenly assuming the ideas to be implicit understandings, many teachers do in fact attempt to address the various preconceptions referenced within this document. In my opinion many teachers are very aware of the degree of difficulty student encounter when learning vectors, but lack of time and effective tools minimize the number of students who will reach mastery of these skills. A commonly held view is that vectors are simply "over the heads" of students. Additionally, planning adequate curricular time for this introduction strategy is difficult but necessary for future skills. One of the difficulties in convincing teachers to expand time spent on vector quantities is the seemingly minimal treatment of complex vector problems on the New York State Regents; however, vector skills underlie a number of questions that might be categorized under a different topic. More investigation would be needed to find out whether student difficulty with some of these concepts arises from a lack of vector knowledge, a lack of understanding of the specific concept or a combination of both. on.

Despite the challenges with equipment manipulation posed by these activities, both were very effective tools for developing both vector understanding and vector computation skills. Students often referred back to the activities when explaining answers in subsequent drill exercises demonstrating that they served the intended role of a highly visual set of touchstone activities. With each new addition of a vector quantity throughout the curriculum, thought must be given to how students visualize the combination of the new vectors quantity, but the characteristics of vectors presented in this unit can be applied. A higher functional skill level with vectors from the outset allows students to focus on new challenges while perfecting existing skills rather than making students feel overwhelmed by the compounding effect of the content.

so the activities develop a referential base of shared experiences & vocabulary

force page break.

References:

top of next page

Nice return to literature

now + here your opinion is acceptable not before the v. end. (you can use opinions of others earlier).

Fit

too fat a sentence simplify + get clear with the final sentences.

either do hanging indent or don't. get consistent

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How do I reference the many REGENTS EXAMS included in the APPENDIX and throughout the document?

↑
cite the main
URL; the table
info will do the
rest.

Appendix A:

Activity One - Student Worksheet: Introduction to Vector Components

Procedure: Map the path of the wind-up toy as it moves around the board.

- Assign directions on the board representing the directions of +x, -x, +y and -y
- Fully wind the "Never Fall" ladybug and place at a location on the dry erase board.
- Trace the motion with a dry erase marker. Use an arrow to indicate the direction of the toy. Each line is a vector. [Optional: Copy the motion of the toy onto a piece of graph paper indicating scale of original grid in centimeters (ie, 1 block equals)]
- Label each vector with a letter.
- Determine the horizontal and vertical component of each vector by counting grid blocks. Note the sign of each motion according to grid set-up in Step A. Record in table provided below.

	Horizontal X	Vertical Y
A		
B		
C		
D		
E		
	Σ	Σ

- Determine the total horizontal and vertical components by finding the sum of each column.
- Create a triangle using the total horizontal and vertical components from the table (Draw in the space below, horizontal first). Using your knowledge of geometry and trigonometry, what is the length of the hypotenuse of the triangle? What is the angle between the hypotenuse and the horizontal component? Based on the X and Y values, in what quadrant is this vector?
- Draw a line from the start point to the end point of the ladybug motion with an arrow pointing toward the end point. This line is called the **resultant**.