Physics Educations Technology in an International Baccalaureate/ Advanced Placement High School Classroom

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Independent study with

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I. Introduction

It has only been a short four years since I graduated from Douglas County High School, but the advanced physics class for International Baccalaureate and Advanced Placement students has changed dramatically. Technology has made its way into high school classrooms. Not only have computers, wireless internet connections and wireless projection connections, but student-friendly, effective software has also made its way into the classroom. Even though technology has been embedded into practically every part our 21st-Century lives, the introduction of this technology into high schools has not been met without controversy.

Specifically Shirley Turkle has asked some very important questions that are shared by many critics of having technology in the classroom. [1]

> Why should fifteen-year-olds pour virtual chemicals into virtual beakers? Why should eighteen-yeah-olds do virtual experiments in virtual physics laboratories? The answer to these questions is often: because the simulations are less expensive; because there are not enough science teachers. But these answers beg a large question: Are we using computer technology not because it teaches best but because we have lost the political will to fund education adequately?

While Turkle asks and gives a valid answer to her own question, I believe that there is a more adequate and encompassing answer to her question. In the past there were insufficient amounts of computers for students and usually the whole class would have to relocate to a computer laboratory. With more of the county educational budget going towards technological equipment, this issue may have been resolved despite national education begets decreasing. Specifically, the advanced physics class has enough laptop computers for every two students that have wireless internet connections and wireless connections to the overhead project.

Traditionally computers have been used for data collection and analysis when used in the laboratory. Now there is Physics Education Technology (PhET) developed by at the University of Colorado for teachers to utilize in the classroom. PhET is a compilation of simulations that cover many of the major topics in physics. [2]

This semester I have had the opportunity to observe an advanced physics high school course that used the PhET simulations as part of their review for IB or AP tests they will be taking at the end of the semester. I examined the following questions through out the semester:

- Is there a significant advantage to using computer simulation in reviewing for a major test?
- Is there a difference in understanding (test scores) between International Baccalaureate (IB) and Advance Placement (AP) students?
- What are the effects of the PhET simulations on the students? How did they respond to using PhET in their review?

II. Study

IIa. Design

To answer the questions above, I gave the students a pre-test prior to their review using PhET simulations and then I gave them the same test as a post-test after they used both the Moving Man Simulation (MMS) and the Circuit Construction Kit (CCK). (Appendix A) The test contains questions that pertain directly to the information that is touched upon in the simulations, questions related to the simulation topics but not directly, and finally questions on topics not covered at all by the simulations. This allows me to see the students' progress on simulation topics compared to their progress on non-related physics topics. In turn I will compare how much the students learned from simulations and how much they learned from review lectures. These questions were pulled from numerous sources to include: IB tests, Physics 2010/2020 tutorials, FMCE and ECCE. [3][4][5][6] I gave the students guided-activities for both simulations to help guide them through the programs. (Appendix B and Appendix C) These "wrappers" help me gauge their understanding of the program and work ethic while performing a simulated experiment. I then asked the students to take a survey on how effective and efficient PhET was for them. (Appendix D) Lastly, I took observational field notes of how the students react to the simulations and their interactions while performing the simulations. (Appendix E)

I am hoping to see that the PhET simulations help the students with their understanding of motion and circuitry that this will be reflected in their pre/post-test scores. I also hypothesize that AP students will have a higher increase their test scores than the IB students. This isn't to say that they are more intelligent, but just the fact that IB students have six tests to take at the end of the semester and the AP students only have one would lead one to think that AP students have less stress and have more time to concentrate on their physics studies.

IIb. PhET Simulations

PhET has developed simulations that cover many the topics within physics. [2] All of PhET simulations are accessible to everyone online, making them useful for students to study with on their own time not only in the classroom. The simulations are designed to be fun and easily usable for students, so that they don't even know that they are learning while using the simulations. Aside from either entertainment value, PhET simulations are physically accurate and represent real life physical situations. The simulations aid students with connecting their understanding of physics to their everyday life experiences. More can be found at the PhET website. [2]

The two PhET simulations used in this study were Moving Man Simulation and Circuit Construction Kit. In the MMS program students develop a basic understanding of position, velocity, acceleration and the relationship between all three. Students can set an initial position, an initial velocity and an initial acceleration for any given scenario. Then time is allowed to elapse while the position, velocity and acceleration are graphed. The position, velocity and acceleration can be changed at anytime through the simulation. This simulation is designed to aid students in understanding the connection between position, velocity and acceleration graphs in 1-dimensional motion.

The second simulation studied was the Circuit Construction Kit. This simulation provides students with a virtual toolbox, containing wire, resistors, switches and light bulbs to create circuits. There is also a grab bag provided that allows students to insert a variety of objects into the circuit to gain a better understand of insulators and conductors. Students can see the electrons move and the light bulb light up to visually understand how the circuit they just built is working.

IIc. Population

24 senior students are in the advanced physics class that meets 0730 to 0900 every other morning at Douglas County High School. They are all either taking the class for International Baccalaureate program and for Advanced Placement. The main difference between the American Advanced Placement program and the European International Baccalaureate is that IB students are required to take six advanced classes where as AP students can select the advanced classes they would like. Both programs cover the same physics topics and have similar tests, so Douglas County High School has combined the classes to have a sufficient amount of students. These

students have all been in the two-year-long class since they were juniors. They finished learning new material in Feb 05 including; mechanics, thermodynamics, waves, electricity and magnetism, nuclear, astrophysics and optics. [7] After all new material was covered, the remainder of the semester was used to review for their respective tests. For their review, their teacher used class time to go over the basic concepts of every section that would appear on the test. This included lecture, group discussion and practice IB tests.

IId. Simulation Data Collection

To aid in their review I created questions to help guide the students through two simulations over topics covered in the IB and AP tests. A pre-test was given prior to the start of the review to determine students' base-line understanding. Three students' tests were not included in the study because they took the test on their own time instead of in the classroom like the remainder of their peers.

MMS was the first simulation performed by the students. (Appendix B) The students were asked to first read scenarios graphing position vs. time, velocity vs. time and acceleration vs. time prior to using the simulation. Then they were asked to graph a scenario and then use the simulation to see how the graphs really would appear for that particular scenario. To make sure that the students were really making a real world connection, they were given a real life scenario and then asked to graph its position vs. time, velocity vs. time and acceleration vs. time. Lastly, students were asked to come up with their own scenario and graph it. The students were given an hour and fifteen minutes to complete the simulation. Most students didn't need the entire time. But there was bad weather that morning and numerous students came to class tardy, and took the remainder of class. Students were paired off and allowed to speak with their peers about the simulations.

Two weeks later, the CCK simulation was used by the students. (Appendix C) They were asked to build virtual circuits that would and would not light a light bulb. They were then asked to explore the grab bag to determine which objects are insulators and which objects are conductors. Then the students were asked to explore parallel circuits and circuits in series. Students were asked leading questions to see their understanding of current and resistance of the circuits in the different configurations. Students were given an hour to finish the simulation, but most students only needed forty-five minutes. Once again, they were paired up and allowed to speak with their peers about the simulations.

Immediately following the CCK simulation, the students were given the same pre-test given earlier the semester as a post-test. (Appendix A) The pre-test had not been given back to the students, so that they would not have the opportunity to memorize and study the questions. The post-test was given to see if there was any improvement in the students' scores, their understanding of physics. Specifically the questions pertaining to the two simulations were analyzed to see if the students' conceptual understanding increased after performing the simulations. There are in Appendix F.

Along with the post-test was a survey for the students to fill out about using PhET. (Appendix D) The students were asked the following questions:

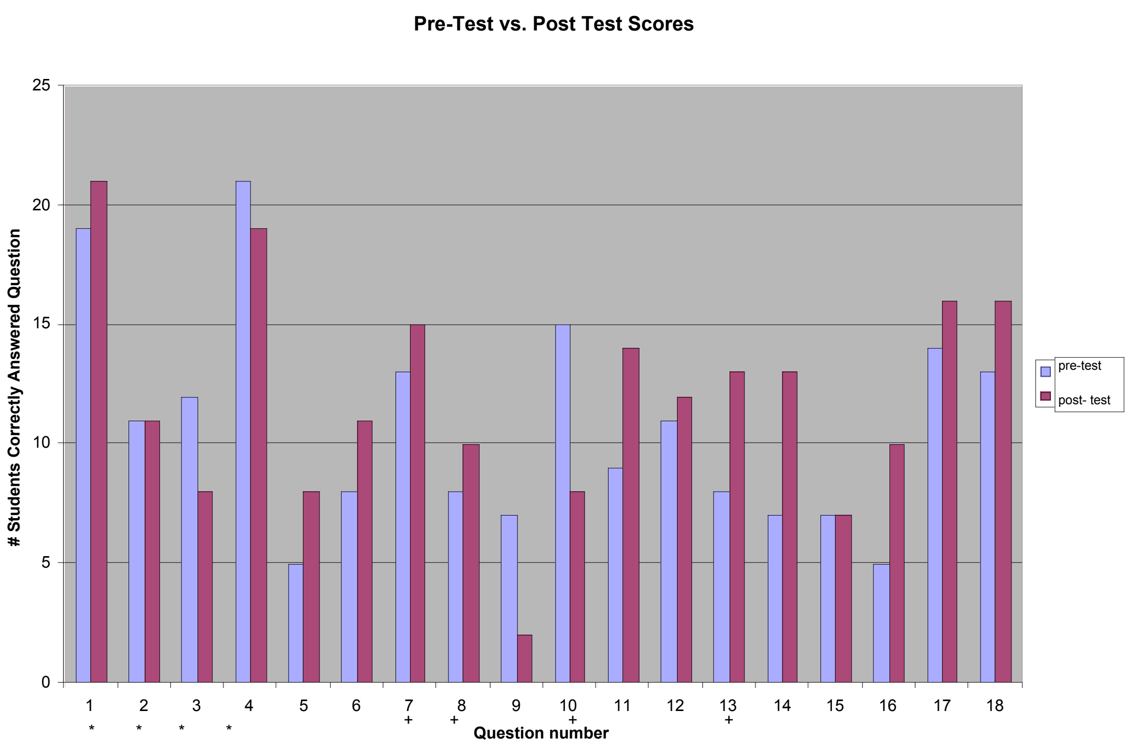
- How did you like the PhET simulations?
- Was the PhET simulation hard to use?
- Would you recommend the PhET simulations to a friend?
- Do you prefer real experiments to simulated PhET experiments?
- Would you use the PhET simulations on your own free time?
- Would you recommend using the PhET simulations in future advanced physics classes?

These surveys along with observational field notes give a deeper understanding of how exactly the students felt towards using the simulations.

III. Results

IIIa. Pre-Test/Post-Test Concepts

Appendix F has the pre-test scores for the students who took the test in the classroom. Only certain questions on the test pertained to the information that would eventually be covered in the simulations. There were four questions that pertained directly to the MMS and four questions that pertained directly to the CCK simulation. Below is a graph showing how many students got the questions correct on the pre-test and on the post-test.



In comparing the pre-test and post-test scores it is easy to see how the scores changed. On the pre-test, 73.8% of students got the MMS questions correct. Unfortunately, on the post-test only 70.2% of the students got the same questions correct. These are the questions marked by * on the above graph. 50.0% of the students answered the questions pertaining directly to the CCK simulation correctly on the pre-test. On the post-test, 54.8% of the students got the same questions correct. These are the questions marked by + on the above graph. The remainder of the questions on the pre-test and post-test did not directly relate to either simulation. On the pre-test, 41.0% of the students got these questions correct. 51.9% of the students got the same questions correct on the post test.

The number of students getting the question correct decreased for three of the eight questions. These amounts decreased only slightly, but two of the questions were in reference to material covered in MMS. MMS was performed and motion was reviewed two weeks prior to taking the post-test and this could have affected the results.

On the rest of the questions that did not pertain directly to the simulations on the pre-test and post-test, the scores increased on all the question accept for one. The question that had scores decrease dealt with momentum in one dimension with gravity.

As a whole, the average test scores increased from a 9.2 to a 10.14. It was interesting to see that some students' scores improved as much as 8 points, but there were also students who decreased by as much as 5 points. Even though the there was a greater increase in test scores, instead of reduction in points, most students either maintained their score or decreased it slightly.

The AP students had an increase in average test score from a 9.45 to 9.81. The IB students had an even larger increase in average test scores from an 8.9 to 10.5. Even though the AP students had a higher pre-test average test score, the IB students had a higher increase in score between the pre-test and the post-test. Even though I hypothesized that the AP students would do better than the IB students, the IB students had a greater increase in test score because they remained on task more often than the AP students. This allows them more quality time to work with the simulation, in turn reviewing more of the material. They could then apply the simulations to the post-test, increasing their scores.

In a normal lecture review session, many students would appear uninterested and bored. The simulations kept the students engaged and interactive through out the entire class period. A normal lecture review covers the basic concepts and equations pertaining to a certain topic. Whereas a simulation will not directly give a student the equation or concept in which they are supposed to use, they gain a more real world application which in turn gives the student a deeper knowledge of the topic. Please refer to Appendix E, field notes, to read actual notes pertaining to student interactions.

Even though students have more of chance to get off topic then sitting listening to a lecture, there is learning being done while they "play around" with the simulation. For example, during the CCK simulation many groups spent the first fifteen minutes of the class period trying to electrocute the dog. While this was not a part of the wrapper, it got many students thinking about why they were unable to drive a current when the dog was placed within the circuit.

IIIb. Survey Results

The students were also given the opportunity to voice their opinions about PhET.

Question	**% of Students**	**Student Comments**
How would you rate the PhET simulations as a whole?	86% rated PhET a 4 or 5 on a scale of 5 being really liked	
How easy was PhET to use?	48% rated PhET a 1 or 2 on a scale of 0 being really easy	
How was the difficulty of the wrappers?	41% rated 3 or lower, 36% rated a 4 or 5, 23% rated 7 or higher when 0 is easy to 10 is difficult	

Would you rather use PhET or real lab equipment?	64% preferred PhET, 27% preferred a combination of PhET & real equipment, 9% preferred real equipment	"PhET = less clean-up - less thinking about set-up"
Would you use PhET in your own time?	82% of students said that they would or already had used the simulations on their own time	"Sure for fun- burn the dog!"
Would you tell a friend about PhET?	95% of students said that would or already had told a friend about PhET	"Already did" "Yes, because it's thoroughly entertaining"
Do you think you learned from using PhET?	68% of students felt they had learned from PhET, 27% said it was a good review, but didn't learn anything new	"Specifically no, but it did help me review what I have learned"
Do you think PhET should be used in advanced physics next year?	95% of students said that PhET should be used next year	"it would be better to use it when the particular unit is being covered."
Any other comments you would like to share?		"Interesting program but should not be substituted for hands-on labs. PhET has less practical real world use"

The most surprising information I received was that the students had actually gone onto PhET on their own time, 87.5% of the class said that they would or already had used the simulations in their free time either for educational purposes or just for fun. [8] The most popular simulation was the Electric Field Hockey, many students would play this simulation before class and whenever they were able to find free time in class. When a student was asked if she would use the simulation in her free time, she commented "I would, because most of the simulations are silly and rather entertaining."

Also, every student said that they enjoyed using PhET in the classroom and suggested using PhET again next year in the advanced physics class. The only criticism the students had, was that the simulations should have been incorporated within the course and used earlier than the review stage. A great suggestion that a few students had was to incorporate the wrappers into the simulation itself. One student suggested "Put the experiments in the program instead of all on paper." They thought that if there were slides with the exercises to walk through it would be more effective than having to write their answers into paper packets. [9]

V. Conclusion

Technology has found its place in high school classrooms. Science classrooms currently have the hardware, and now PhET has brought the software. It is fair to suggest that simulations are an entertaining way for students to learn. Students increased their understanding on the majority of test questions that pertained to the simulations. On the same note, the average test scores also increased. This could be due to the questions pertaining to the simulations or it could be due to the review of unrelated physics topics. This is supported with the fact that only one of the questions that were not directly related to the simulations went down in average, where as three of the questions that were directly related to the simulations went down in average.

This study has supported the idea that computer simulations are beneficial to high school students in supporting a review for large tests. Simulations aid in the giving students a deeper understanding of the concepts that they will need to know for the test. Simulations should not replace lecture reviews, but instead support and be incorporated into lectures for maximum efficiency.

References

[1] S. Turkle. Seeing Through Computers. The American Prospect, 8, 1997

[2] phet.colorado.edu

[3] International Baccalaureate Physics Standard Level Paper1, Paper2, Paper 3. Fall 1998 through Spring 2004

[4] University of Colorado Physics 2010/2020 tutorials

[5] Survey 2010

[6] Background Electricity and Magnetism Survey

[7] International Baccalaureate Physics Syllabus. 1996

[8] PhET Survey. Sarah Spence. April 2005

[9] PhET Survey. Stuart Reed. April 2005

Appendix A

Pre-Test/ Post-Test

Appendix B

Moving Man Simulation Guided Question Survey

Name:

IB or AP

1. Open Moving Man, investigate the program by having the man move using the manual, walk and accelerate modes. Have man move forwards and backwards at a constant rate and with acceleration. Examine the graphs and discuss with your partner the reasons why they look the way they do.

2. Without using the simulation sketch; position vs. time, velocity vs. time, and acceleration vs. time graphs for the following situations:

   a. Start at -2 position and moving forward with constant velocity
   b. Start at +2 position and moving backwards accelerating at a constant rate
   c. Start at 0 position, stand still for awhile, than move forward at constant velocity then come to a quick stop
   d. Start at +3 position, stand still for awhile, move backwards at a constant velocity than slow to a slow stop

3. Use Moving Man to verify graphs from step # 2. Use a different color pen to mark correction on your graphs. Explain any corrections that you need to make.

4. Using Moving Man, sketch a position vs. time, velocity vs. time, and accelerate vs. time graphs for the following scenario. A man starts 5m from a tree and constantly accelerates for about 3 seconds. He stops for about 2 seconds, then moves at a constant velocity forward for another 3 seconds. He then finally decelerates to a stop.

5. With your lab partner, come up with a scenario (use step #4 as an example) for Moving Man. Use the program to graph out the scenario. Sketch a position vs. time, velocity vs. time, and acceleration vs. time graph for the scenario.

2a.
Position vs. Time

Explain the reason for graph’s appearance and any changes you made to the graph.

Velocity vs. Time

Explain the reason for graph’s appearance and any changes you made to the graph.

Acceleration vs. Time

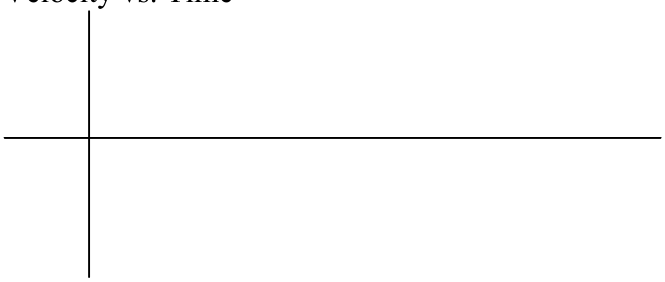
Explain the reason for graph’s appearance and any changes you made to the graph.

2b.

Position vs. Time

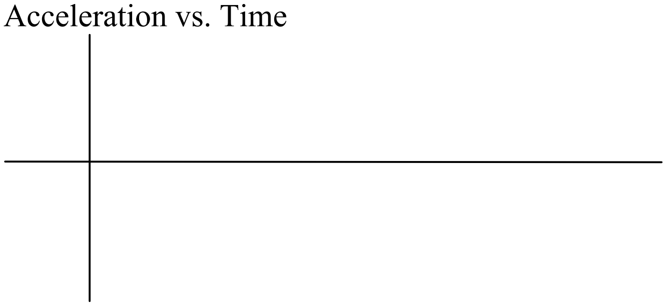
Explain the reason for graph’s appearance and any changes you made to the graph.

Velocity vs. Time



Explain the reason for graph’s appearance and any changes you made to the graph.

Acceleration vs. Time

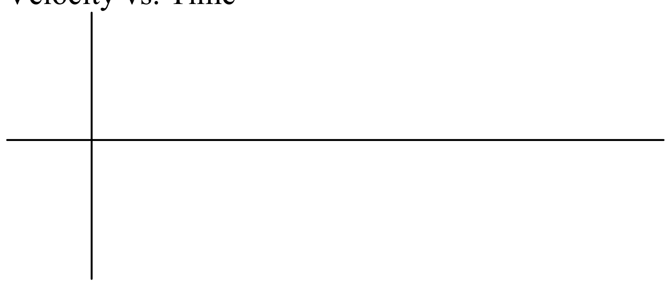


Explain the reason for graph’s appearance and any changes you made to the graph.

2c.
Position vs. Time

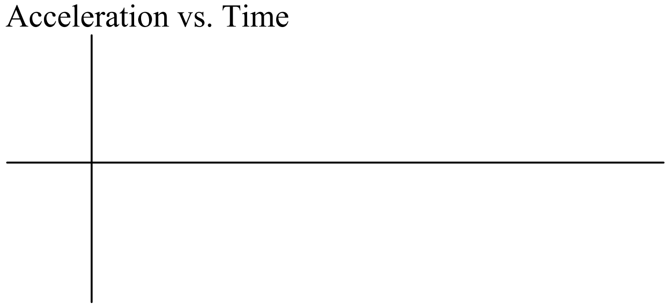
Explain the reason for graph’s appearance and any changes you made to the graph.

Velocity vs. Time



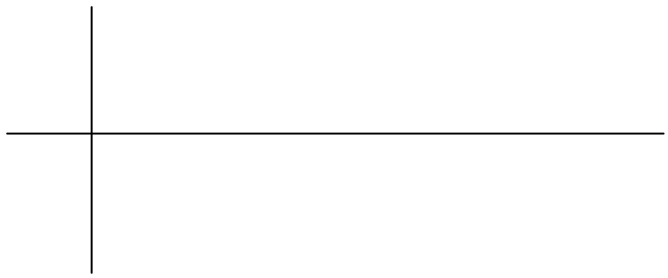
Explain the reason for graph’s appearance and any changes you made to the graph.

Acceleration vs. Time



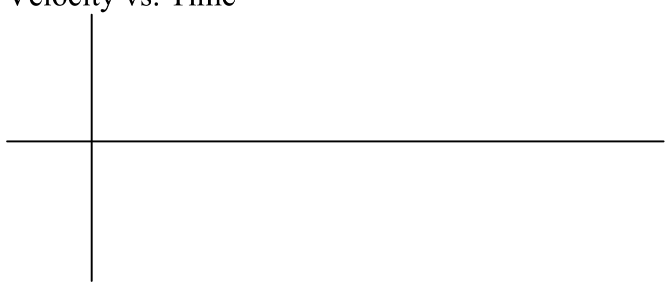
Explain the reason for graph’s appearance and any changes you made to the graph.

2d.
Position vs. Time



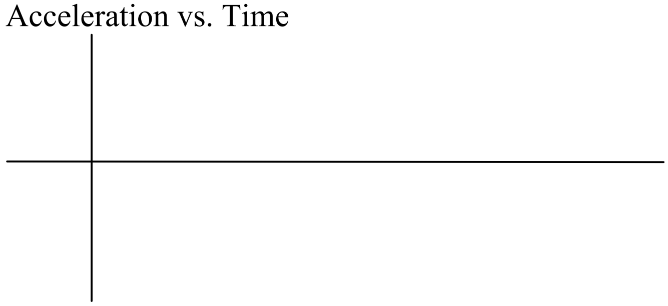
Explain the reason for graph’s appearance and any changes you made to the graph.

Velocity vs. Time



Explain the reason for graph’s appearance and any changes you made to the graph.

Acceleration vs. Time



Explain the reason for graph’s appearance and any changes you made to the graph.

4.
Position vs. Time

Explain the reason for graph’s appearance and any changes you made to the graph.

Velocity vs. Time

Explain the reason for graph’s appearance and any changes you made to the graph.

Acceleration vs. Time

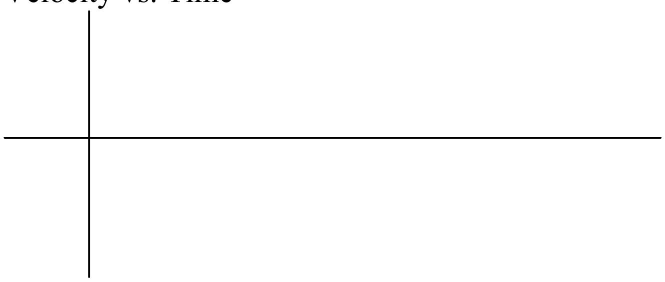
Explain the reason for graph’s appearance and any changes you made to the graph.

5. Scenario:

Position vs. Time

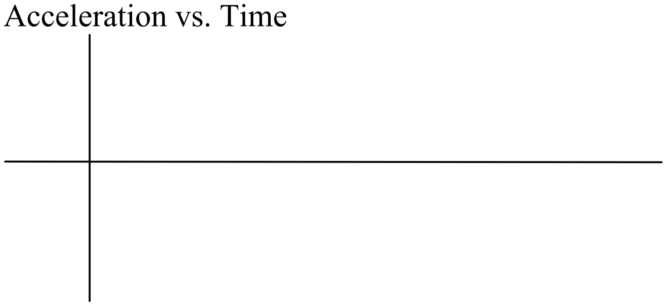
Explain the reason for graph's appearance and any changes you made to the graph.

Velocity vs. Time



Explain the reason for graph's appearance and any changes you made to the graph.

Acceleration vs. Time



Explain the reason for graph's appearance and any changes you made to the graph.

6. You pull out of driveway, but forget that it is trash day and reverse at a constant velocity right into a trash can. You stop the car immediately, get out and move the trash can out of the way. You then return to your car and finish reversing at a constant velocity down the driveway. You then put your car in drive and accelerate as you drive to class. Plot the car's position vs. time and velocity vs. time graphs below. Label the different sections: reversing down the driveway, stopping to move the trashcan, reversing down the rest of the driveway and accelerating away from your house.

Appendix C

Circuit Construction Kit Guided Question Survey

Name:
Circle one: IB AP

I. Complete circuits

A. Drag and drop a battery, a light bulb, and a single piece of wire into the work area of CCK. Connect these in a variety of ways. Sketch each arrangement below.

Arrangements that *do* light the bulb	Arrangements that *do not* light the bulb

You should have found at least three different arrangements that light the bulb. How are these arrangements similar? How do they differ from arrangements in which the bulb does not light?

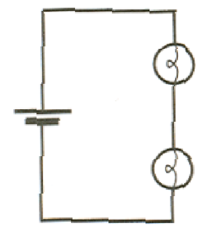
State the requirements that must be met in order for the bulb to light.

B. Light a bulb using a battery and a single wire. Observe and record the behavior (*i.e.*, brightness) of the bulb when objects made out of various materials are inserted into the circuit. (Try materials available in the "grab bag", such as paper, coins, pencil lead, eraser, a finger, *etc.*)

What is similar about most of the objects that let the bulb light?

II. Bulbs in series

Set up a two-bulb circuit with identical bulbs connected one after the other as shown. Bulbs connected in this way are said to be connected in *series*.



A. Compare the brightness of the two bulbs with each other. (Pay attention only to large differences in brightness. You may notice minor differences if two "identical" bulbs are, in fact, not quite identical.)

   Use the assumptions we have made in developing our model for electric current to answer the following questions:

   1. Is current "used up" in the first bulb, or is the current the same through both bulbs?

   2. Do you think that switching the order of the bulbs might make a difference? Check your answer.

B. Compare the brightness of each the bulbs in the two-bulb series circuit with that of a bulb in a single-bulb circuit. *Note: make sure that the bulb resistances and the battery voltages are identical for the two circuits.*

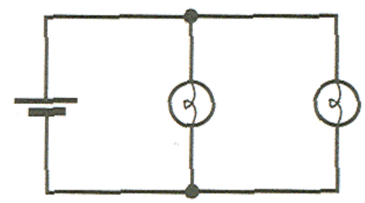
   Use the assumptions we have made in developing our model for electric current to answer the following questions:

   1. How does the current through a bulb in a single-bulb circuit compare with the current through the same bulb when it is connected in series with a second bulb? Explain.

2. What does you answer to question 1 imply about how the current through the *battery* in a single-bulb circuit compares to the current through the *battery* in a two-bulb series circuit? Explain.

Bulbs in parallel

Set up a two-bulb circuit with identical bulbs so that their terminals are connected together as shown. Bulbs connected together in this way are said to be connected in *parallel*.



A. Compare the brightness of the bulbs in this circuit.

1. What can you conclude from your observation about the amount of current through each bulb?

2. Describe the current in the entire circuit. Base your answer on your observations. In particular, how does the current through the battery seem to divide and recombine at the junctions of the two parallel branches?

B. Is the brightness of each bulb in the two-bulb parallel circuit *greater than, less than,* or *equal to* that of a bulb in a single-bulb circuit? *Note: make sure that the bulb resistance and the battery voltage are identical for the two circuits.*

How does the amount of current through a *battery* connected to a single bulb compare to the current through a *battery* connected to a two-bulb parallel circuit? Explain based on your observations.

Deeper Look

A. Predict the brightness of the bulbs in the following circuit. If there are two light bulbs in parallel, Bulb 1 and Bulb 2. Following the parallel bulbs, there is another light bulb (in series with the parallel bulbs), Bulb 3. Rank the light bulbs in terms of brightness. (ie. Bulb1>Bulb2>Bulb3)

Appendix D

PhET Survey

Name:
(Circle One) IB AP

1. How would you rate the PhET computer simulations as a whole?

(disliked) 0 1 2 3 4 5 (liked)

2. How easy was the PhET simulations to use?

(too easy) 0 1 2 3 4 5 (too hard)

3. How was the difficulty of the worksheets compared to the simulations? 0 (very easy) to 10 (very difficult)

0 1 2 3 4 5 6 7 8 9 10

4. Would you rather have used PhET or real equipment to perform an experiment?

5. Would you use (or have you ever used) the PhET simulations on your own time to study or just for fun?

6. Would you tell a friend about PhET?

7. Do you think you learned more about physics by using PhET?

8. Do you think that PhET simulations should be used next year in the advanced physics class?

9. Any comments or suggestions for the PhET program?

Appendix E

Field notes