

Technology-based TIPERs in Conceptual Physics II  
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## **Abstract**

27 activities have been developed to incorporate technology into Tasks Inspired by Physics Education Research (TIPERs). The technology was incorporated into the TIPERs through student interaction via clickers and posing and resolution of the TIPERs with simulations. This report will give a brief description of the activities developed, give mid-instruction student results of the activities for the majority of the activities, give conclusions and suggestions for future improvements, and detail dissemination efforts. Approximately 60 documents are included as an appendix to this report.

## **Planning and Development**

27 Technology-based Tipers were developed for the second semester Conceptual Physics Course, PHYS 1407 – Conceptual Physics II. Conceptual Physics II is a course which has significant potential impact for Technology Education as both students majoring in technology and future teachers form the primary audience for the course. Conceptual Physics II covers a broad range of topics in Electricity and Magnetism, light, and modern physics.

The activities were developed to target common student alternate conceptions in Physics. Two principle sources were drawn on as a reference for common student alternate conceptions including *Five Easy Lessons* by Randy Knight and *Teaching Introductory Physics* by Arnold Aarons. An initial planning period was conducted in which target conceptual difficulties were identified.

Two other tasks were accomplished during the planning period. The format of various TIPER's were reviewed, and those that seemed likely to be adaptable to the multiple choice format used for clickers were identified. Additionally, various simulation packages were extensively explored and suitable simulations identified for use. The original plan was to have the bulk of the activities based on Physlets, however the Physics Educational Technology (PhET) website turned out to be very useful and approximately half of the activities employed simulations from the PhET website.

Several activities used the simulations from the Visual Quantum Mechanics (VQM) website, as well.

A planning document was made that covered approximately half of the Conceptual Physics II course. The document was particularly sparse for some of the modern physics topics. Only one of the items that was originally planned, an activity on magnetism, was not completed because of difficulties encountered in adapting the Physlet to the task. A different activity on the magnetic field was used instead.

### Overview of Activities

In addition to the simulation used, the principle curriculum piece for each activity is a PowerPoint file for the presentation of the activity and to manage the clickers. A pen and paper version of each activity was developed as well. Additional pen and paper activities used as homework, test review and test items were also developed. The activities typically take about 5 to 10 minutes of class time to deliver.

The activities were originally developed using the TurningPoint Clicker System. In Summer, 2007 I switched to the iClicker system, and a few PowerPoint files for iClicker are included as well. The activities which use Physlets have a web page hosted on my instructional website to run the simulation. The activities which use either PhET or VQM simulations were run from the PhET or VQM website, respectively. Information about files is included in an appendix.

A deliberate effort was made to use several different types of TIPERs to explore the applicability of this approach to different format of Tipers. Table 1 lists the TIPER types used with a brief general description of that type of activity.

Table 1 Description of Tipers Used in this Project

Acronym	Task Type	Brief Description
WWT	What if Anything is Wrong Task	A situation is posed. Students must determine if the situation is correct or if there is an error
PET	Predict and Explain Task	Students must make a prediction about a physical situation and explain the reasoning for their prediction
RT	Ranking Task	Students must rank a resultant physical property- typically from greatest to least - based on the variation of one or more dependent properties
OT	Ordering Task	Variation on the Ranking Task where the physical property is ordered spatially from left to right.
CST	Contending Students Task	Debate among Fictional “students” is presented. Students must determine with which if any of the students they agree and explain their reasoning.
WBT	Working Backwards Tasks (Jeopardy Questions)	The answer to a physical situation is given, and students work backwards to

		determine what the question was.
LMC	Linked Multiple Choice Tasks	A series of related multiple choice tasks for a common physical situation are given. The questions all use the same set of distractors.
CT	Comparison Task	Students must compare relative size of one quantity compared to another for two different related physical situations

Table 2 gives a brief description of the underlying task for each of the activities developed. The table also gives the target conceptual difficulty and the simulation employed for each activity.

Table 2 List of Activities. Several of the tasks listed include multiple activities.

Topic	Target Conceptual Difficulty	Task Description	Applet/ Simulation
Static Electricity	We know there are two types of charge since we observe attractive and repulsive behavior	<i>What if anything is wrong task</i> 4 charged particles with force vectors. One of the four charges changes signs when another is brought near it	Problem 22.2 from <i>Physlet Physics</i>
Static Electricity	Distinguishing between attractive behavior of oppositely charged objects and attractive behavior between charged object and induced dipole	<i>Predict and Explain Task</i> A balloon is rubbed on a sweater. Predict and explain what will happen when the balloon is held near the sweater and released. Then the balloon is held near a wall. Predict and explain what happens when the balloon is held near the wall.	PhET – Balloons and static electricity
Electricity	Battery is a source of constant potential difference	<i>Ranking Task</i> Ideal battery is connected across successively 1,2,3 light bulbs in series and with an open circuit. Potential difference between the terminals is ranked	PhET circuit construction kit
Electricity	Current is consumed in a circuit by resistors	<i>What if anything is wrong task</i> Series circuit will be shown with ammeters with incorrect currents. Students	PhET circuit construction kit

		will answer if anything is wrong.	
Electricity	Inability to reason correctly about the behavior of series and parallel circuits	<i>Predict and explain task</i> Circuit will be altered by adding a light bulb in parallel. Students will predict and explain changes in brightness of light bulbs and current supplied by the battery.	PhET circuit construction kit
Electricity	Inability to reason correctly about the behavior of series and parallel circuits	<i>Predict and explain task</i> Circuit will be altered by adding a light bulb in series. Students will predict and explain changes in brightness of light bulbs and current supplied by the battery.	PhET circuit construction kit
Magnetism	The magnetic field of a long straight wire is perpendicular to the radial vector	<i>Working Backwards Task</i> Students will be shown a compass and various wires. Students have to determine the direction of the current in the wire by the behavior of the compass	Bfield Physlet
Electro-magnetic Induction	Determination of direction of induced current due to a changing magnetic flux	<i>Working backwards task</i> The direction of an induced current in a loop will be shown. The students will determine the direction of a moving magnet of known orientation or the polarity of a magnet moving in a known direction	Faraday Physlet
Color	Color filters add color to light as opposed to removing the complementary color	<i>Predict and Explain Task</i> Students will predict and explain the color of light transmitted through two overlapping filters	PhET Color Vision
Color	Color filters add color to light as opposed to removing the complementary color	<i>What if Anything is Wrong Task</i> Students are shown a statement that light passing through red then green filter will be yellow. Students answer what if anything is	PhET Color Vision

		wrong.	
Geometric Optics	A Concave Mirror can Form Both a Real and a Virtual Image	<i>Working Backwards Tasks</i> Two tasks where mirrors are hidden behind a pink box. A point source is dragged in front of the mirrors and the reflected rays are observed. Students must determine what type of mirror is behind the box. One activity has a concave and the other a convex mirror.	Optics Physlet
Geometric Optics	Inability to distinguish between the focal point and the location of the image	<i>Ordering Task</i> A point source is shown in front of a mirror. The focal point will be identified. Students will be asked to predict the location of the image for various positions of the source.	Optics Physlet
Geometric Optics	A Convex lens can Form Both a Real and a Virtual Image	<i>Working Backwards Tasks</i> Two tasks where lenses are hidden behind a pink box. A point source is dragged in front of the lenses and the transmitted rays are observed. Students must determine what type of lens is behind the box. One activity has a concave and the other a convex mirror.	Optics Physlet
Geometric Optics	Inability to distinguish between the focal point and the location of the image	<i>Ordering Task</i> A point source is shown in front of a lens. The focal point will be identified. Students will be asked to predict the location of the image for various positions of the source.	Optics Physlet
Physical Optics	Inability to describe the change in interference pattern as the slit spacing and the wavelength change	<i>Ranking Task</i> Students will rank the width of the interference pattern on a screen for different spacings of two parallel coherent sources.	PhET Wave Interference
Physical	Inability to describe the	<i>What if Anything is Wrong</i>	PhET Wave

Optics	change in interference pattern as the slit spacing and the wavelength change	<i>Task</i> Students are given statement that if wavelength is changed, for a two slit experiment, there will be no change on the spacing of the interference pattern. Students must determine what if anything is wrong.	Interference
Physical Optics	Inability to describe the change in diffraction pattern as the slit spacing and the wavelength change	<i>Contending Students Task</i> A single slit pattern is shown. The wavelength of light is changed and contending predictions about the effect on the pattern are made. Students decide with whom they agree and why.	PhET Wave Interference
Electro-dynamics of Charged Particles	Inability to understand the discovery of the electron	<i>Working Backwards Task</i> The path of a charged particle is shown in a region of uniform magnetic field. The students have to determine the sign of the charged particle.	<i>Physlet Physics Problem 27.9</i>
Electro-dynamics of Charged Particles	Inability to understand the discovery of the electron	<i>Predict and Explain Task</i> For the same charged particle in the previous activity, the students must predict and explain the deflection of the particle in an electric field. Note that the simulation is set up so that the deflection of the particle in the electric field is opposite the deflection of due to the magnetic field.	<i>Physlet Physics Problem 27.9</i>
Electro-dynamics of Charged Particles	Inability to understand the discovery of the electron	<i>Predict and Explain Task</i> For the same charged particle in the previous two activities, the students must predict and explain the path of the particle in both the magnetic and electric fields of the previous two activities.	<i>Physlet Physics Problem 27.9</i>
Atomic	Inability to distinguish	<i>What if Anything is Wrong</i>	Visual Quantum

Spectra	between absorption and emission spectra	<i>Task</i> Following statement is presented to students. “In the absorption spectrum for hydrogen, the hydrogen emits a continuous spectrum except at the wavelengths corresponding to the lines in the hydrogen emission spectrum.” Students must determine what if anything is wrong with the statement.	Mechanics
Atomic Spectra	Inability to distinguish between absorption and emission spectra	<i>Predict and Explain Task</i> Students are Presented a Helium emission spectrum. They have to predict the appearance of the absorption spectrum for helium and explain their prediction.	Visual Quantum Mechanics
Light Quanta	Distinguishing between the classical and the quantum predictions of the photoelectric effect	<i>Linked Multiple Choice Task</i> Students will consider the prediction of both the classical and quantum models applied to photoelectric effect and will answer a series of linked MC tests for prediction of both	PhET Photo-electric Effect
Special Relativity	Difficulty in applying the constancy of the speed of light to different physical situations	<i>Comparison Task</i> Students predict the relative number of pulses for two light clocks, with the pulses transverse to the direction of relative motion. One clocks moves at $v/c = .5$ with respect to the other.	Physlet Special_Relativity
Special Relativity	Difficulty in applying the constancy of the speed of light to different physical situations	<i>Comparison Task</i> Students predict the relative number of pulses for two light clocks, with the pulses parallel to the direction of relative motion. One clocks moves at $v/c = .5$ with respect to the other.	Physlet Special_Relativity

## Student Results

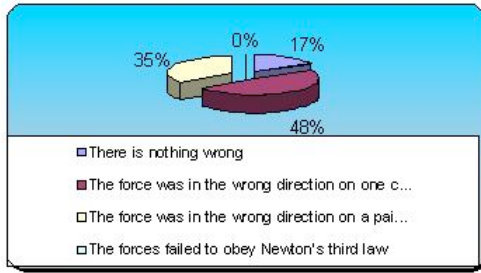
The bulk of this section is in essence a long table. Clickers allow you to collect data in real time from students, and these clicker results for students are given below. The clicker results are all mid instruction, so they don't show the effectiveness of the activity as much as the student thinking at the time. Clicker results combined with the class discussion can be used to validate the activities. For instance confusing distractors, poor wording, or distractors that are interpreted differently by the students and instructor can frequently be identified during class discussion of the activity.

Several activities were either presented in class without using clickers or there was a clicker malfunction, so not all activities have student response data.

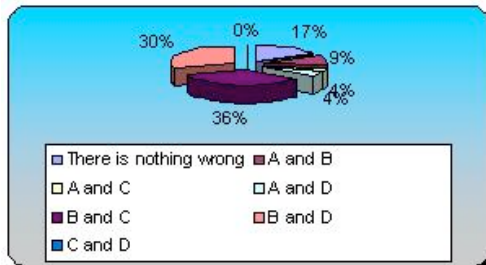
Table 3 PHYS 1407 Student Results by Activity

### Activity 1: WWT - Force between Charges

Even though the forces obeyed Newton's third law, most students (48%) identified an error with only one charge.



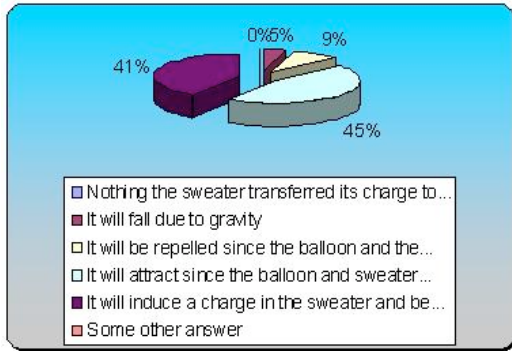
Only 30% of students correctly identified the flawed interaction as being between charged B and D. The most common response (36%) was that the problem was with the charge pair B and C.



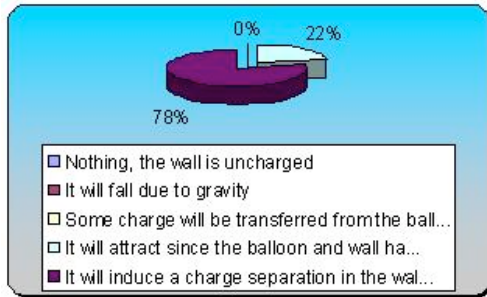
### Activity 2: PET - Induced Polarization

Student Prediction for interaction between sweater and balloon. Predictions were about evenly split between charge transfer and charge induction.



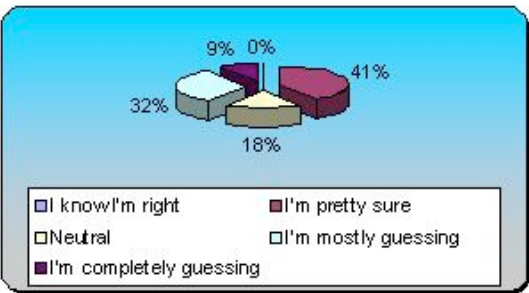
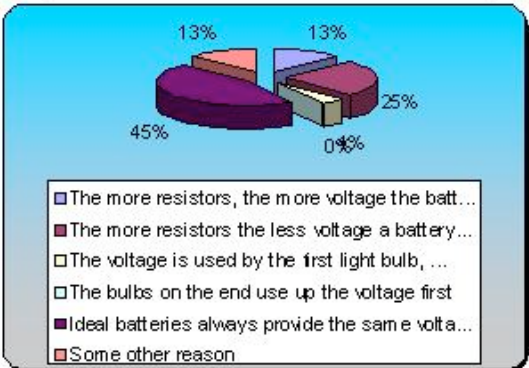
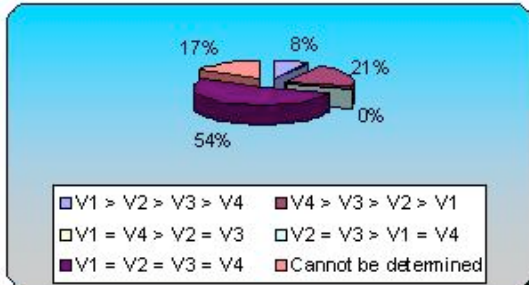


Student prediction for interaction between sweater and wall. 78% of students correctly identified that an attractive force would result due to an induced dipole.



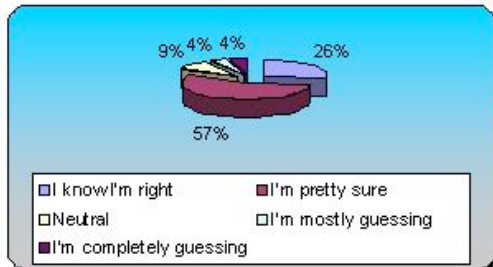
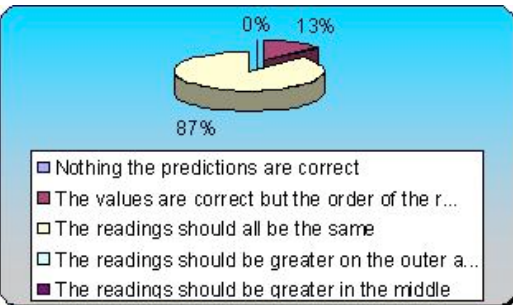
### Activity 3: RT - Potential Difference supplied by ideal battery

Student Predictions for ranking of terminal voltage of the batteries. 54% of the students correctly ranked the terminal voltages as all equal, although only 45% of the students gave the correct reasoning.



#### Activity 4: WWT - Current is a Series Circuit

Student response to the what if anything is wrong task. 87% of the students correctly determined that the current should be constant through the circuit.



#### Activity 5: PET - Add a Resistor in Parallel

No data was collected for this activity.

#### Activity 6: PET - Add a resistor in Series

No data was collected for this activity.

#### Activity 7: WWT - The Magnetic Field of a Long Straight Wire

The WWT question was administered in a peer instruction format. Prior to group discussion the students answered as follows.

1.) What if anything is wrong with the student's diagram?

Responses (percent) (count)

Nothing, the diagram is fine 54.17% 13

The field lines point the wrong way 16.67% 4

The field should look like a bar magnet 25% 6

Some other answer 4.17% 1

Totals 100% 24

Following small group discussion the students answer gave the following distribution.

2.) What if anything is wrong with the student's diagram?

Responses (percent) (count)

Nothing, the diagram is fine 79.17% 19

The field lines point the wrong way 8.33% 2

The field should look like a bar magnet 12.50% 3

Some other answer 0% 0

Totals 100% 24

In this situation Peer Instruction seemed to work well as the number of students correctly identifying that the diagram was correct changed from 54% to 79% following the small group interaction.

#### Activity 8: WBT - Faraday's Law

This task proved to be a very difficult one for the students and in future use I plan to use several easier tasks prior to giving the students this one. Prior to small group discussion only 38% of the students correctly that the N pole of the magnet was inserted through the loop first.

1.) Which pole of the magnet was put through the loop first?

Responses (percent) (count)

N 37.50% 9

S 41.67% 10

It cannot be determined 20.83% 5

Totals 100% 24

Following small group discussion students were swayed away from the correct answer with 50% identifying that the S pole was inserted through the loop first.

2.) Which pole of the magnet was put through the loop first?

Responses (percent) (count)

N 16.67% 4

S 50% 12

It cannot be determined 33.33% 8

Totals 100% 24

#### Activity 9: WWT - Absorption of Light by a Filter

This question was posed in a Peer Instruction format. The students answered the question on their own with only 32% giving the correct answer that no light is passed by the combination of filters. The most common answer was that the light would be red with 58% of the students giving that response.

1.) What if anything is wrong with the student's statement?

Responses (percent) (count)

Nothing the statement is fine 10.53% 2

If you mix red and green paint you get brown not yellow 0% 0

The light will be red since the green was absorbed by the red filter 57.89% 11

The light will be green since it passes through the green filter last 0% 0

No light will pass through that combination of filters. 31.58% 6

Totals 100% 19

Following group discussion many students changed their answers and the most common answer became that no light passed through both filters with 68% of the students answering that. The second most common answer following group discussion was the light would be red, definitely suggesting that the students held an idea that a filter changes the color of light to the same as the filter.

2.) What if anything is wrong with the student's statement?

Responses(percent) (count)

Nothing the statement is fine 0% 0

If you mix red and green paint you get brown not yellow 0% 0

The light will be red since the green was absorbed by the red filter 31.58% 6

The light will be green since it passes through the green filter last 0% 0

No light will pass through that combination of filters. 68.42% 13

Totals 100% 19

#### Activity 10: PET - Transmission of Light by a Filter

This activity taught me a very valuable lesson concerning asking questions about color. Where I had intended the adjective bright to indicate a relative intensity the students largely interpreted it as a shade of color. My intent was that the correct answer was yellow orange but most students interpreted the transmitted color as "bright yellow". Initially 68% gave this answer and following small group discussion, 95% of the students gave that as the correct answer. I learned this when presenting the simulation and causing significant consternation on the part of the students when I announced that the correct answer was yellow-orange. Notice that 68% of the students gave the correct reasoning for the answer while 32% still held the idea that the filters added color to the light.

1.) Predict what color light will be transmitted by both filters?

Responses(percent) (count)

None 0% 0

Bright yellow 68.42% 13  
 Yellow orange 21.05% 4  
 Orange 0% 0  
 White 10.53% 2  
 Totals 100% 19

2.) Predict what color light will be transmitted by both filters?

Responses(percent) (count)  
 None 0% 0  
 Bright yellow 94.74% 18  
 Yellow orange 5.26% 1  
 Orange 0% 0  
 White 0% 0  
 Totals 100% 19

3.) Explain your reasoning.

Responses(percent) (count)  
 The filters absorb different colors of light so all of the light is absorbed 0% 0  
 Light from the part of the curves that overlap will be transmitted 68.42% 13  
 The light from the filters will add together 31.58% 6  
 Some other reason 0% 0  
 Totals 100% 19

#### Activity 11: OT - Location of Image formed by Concave Mirror

This was not a very successful activity. If you look at the most common student responses, they correctly answered the activity if all of the images had been real. The main difficulty of this activity stemmed from the inclusion of both real and virtual images in the ordering task. In the future, this activity should be broken into smaller steps.

1.) Arrange the location of the images formed when the object is placed at the three point from left to right

	Responses (percent)	(count)
The image is always formed at the focal point	20%	4
A then B then C	10%	2
B then A then C	0%	0
C then B then A	65%	13
C then A then B	5%	1
Some other order	0%	0
Totals	100%	20

2.) Arrange the location of the images formed when the object is placed at the three point from left to right

	Responses (percent)	(count)
The image is always formed at the focal point		10% 2
A then B then C	10%	2
B then A then C	0%	0
C then B then A	75%	15
C then A then B	5%	1
Some other order	0%	0
Totals	100%	20

#### Activity 12 and 13: WBT - Hidden Mirrors

The students generally did very well on this activity and the peer instruction format seemed to be particularly effective here. For the concave mirror initially 55% identified it correctly when answering on their own.

1.) What type of mirror is behind the screen?

Responses (percent) (count)

Plane 5% 1

Concave 55% 11

Convex 30% 6

Cannot be determined 10% 2

Totals 100% 20

Following small group discussion, the percentage of students correctly identifying the mirror as concave grew to almost 80%.

2.) What type of mirror is behind the screen?

Responses (percent) (count)

Plane 0% 0

Concave 78.95% 15

Convex 10.53% 2

Cannot be determined 10.53% 2

Totals 100% 19

For the convex mirror initially 65% answered correctly that the mirror was convex.

3.) What type of mirror is behind the screen?

Responses (percent) (count)

Plane 30% 6

Concave 5% 1

Convex 65% 13

Cannot be determined 0% 0

Totals 100% 20

After small group discussion the percentage grew to 70%. A good class discussion arose at this point as to why the mirror was convex and not plane.

4.) What type of mirror is behind the screen?

Responses (percent) (count)  
 Plane 20% 4  
 Concave 5% 1  
 Convex 70% 14  
 Cannot be determined 5% 1  
 Totals 100% 20

Activity 14: OT - Location of Image formed by Convex Lens

This was not a very successful activity. From the students' previous experience with activity 11, they knew that the answer for all real images was incorrect, but they could not construct a correct answer. The main difficulty of this activity stemmed from the inclusion of both real and virtual images in the ordering task. In the future, this activity should be broken into smaller steps.

1.) Arrange the location of the images formed when the object is placed at the three points from left to right

	Responses (percent)	(count)
The image is always formed at the focal point	0%	0
A then B then C	13.64%	3
B then A then C	36.36%	8
C then B then A	18.18%	4
C then A then B	27.27%	6
Some other order	4.55%	1
Totals	100%	22

2.) Arrange the location of the images formed when the object is placed at the three point from left to right

	Responses (percent)	(count)
The image is always formed at the focal point	0%	0
A then B then C	4.55%	1
B then A then C	31.82%	7
C then B then A	50%	11
C then A then B	9.09%	2
Some other order	4.55%	1
Totals	100%	22

Activity 15 and 16: WBT - Hidden Lenses

Following their experience with the hidden mirror tasks, the students did very well on this task. For the first lens 72% initially identified the lens correctly as a concave lens. Following small group discussion 100% of the students correctly identified the lens as

concave. For the convex lens 100% of the students correctly identified it as convex initially and no follow up small group discussion was held.

1.) What type of lens is behind the screen?

Responses (percent) (count)

Concave 72.73% 16

Convex 27.27% 6

Cannot be determined 0% 0

Totals 100% 22

2.) What type of lens is behind the screen?

Responses (percent) (count)

Concave 100% 22

Convex 0% 0

Cannot be determined 0% 0

Totals 100% 22

3.) What type of lens is behind the screen?

Responses (percent) (count)

Concave 0% 0

Convex 100% 22

Cannot be determined 0% 0

Totals 100% 22

Activity 17: RT - Double Slit Pattern

No student results are available for this activity.

Activity 18: WWT - Dependence of 2 slit pattern on Wavelength

No student results are available for this activity.

Activity 19: CST - Single slit pattern

Students seemed to be about evenly split before 1) and after 2) small group discussion about the effect of increasing the slit width on a diffraction pattern. This activity reinforced in the students minds the activities on the double slit pattern, for which data was not collected for technical reasons.

1.) With which student do you agree?

Responses (percent) (count)

A 8.70% 2

B 56.52% 13

C 34.78% 8

I don't agree with any of them 0% 0

Totals 100% 23

2.) With which student do you agree?

Responses (percent) (count)

A 0% 0



B	56.52%	13		
C	43.48%	10		
I don't agree with any of them			0%	0
Totals	100%	23		

#### Activity 20: WWT - Emission Spectra

This task proved to be quite challenging for the students. The incorrect "student" statement was quite attractive and following small group discussion, over half of the students went with the choice that the "student" statement was correct.

1.) What if anything is wrong with the student's statement?

Responses

	(percent)	(count)
The statement is correct	40.91%	9
The light is emitted by a source different than the hydrogen. The missing lines have nothing to do with hydrogen	4.55%	1
The hydrogen emits at all frequencies just a smaller amount for the dark lines	9.09%	2
Hydrogen absorbs light from another source, and reemits in all directions reducing the brightness	45.45%	10
Totals	100%	22

2.) What if anything is wrong with the student's statement?

Responses

	(percent)	(count)
The statement is correct	54.55%	12
The light is emitted by a source different than the hydrogen. The missing lines have nothing to do with hydrogen	4.55%	1
The hydrogen emits at all frequencies just a smaller amount for the dark lines	0%	0
Hydrogen absorbs light from another source, and reemits in all directions reducing the brightness	40.91%	9
Totals	100%	22

#### Activity 21: PET - Absorption Spectra

The difficulties the students had with Activity 20 nicely set up this activity. Almost 80% of the students predicted the correct answer, and so no answers were clicked following small group discussion.

1.) Helium has the following emission spectrum. Predict which of the following is an absorption spectrum for He?

Responses

	(percent)	(count)
Picture Choice 1	77.27%	17
Picture Choice 2	9.09%	2
Picture Choice 3	4.55%	1
Picture Choice 4	9.09%	2
Totals	100%	22

#### Activity 22: LMC - Comparison of Predictions for the Photoelectric Effect

The distractors for the linked multiple choice questions on the photoelectric effect are listed below.

1. photocurrent increases immediately
2. photocurrent increases gradually
3. photocurrent decreases immediately
4. photocurrent decreases gradually
5. No change in the photo current
6. Cannot be determined

Students showed definite difficulties in distinguishing between effects that were small but immediate and effects that were gradual.

1.) Infrared light shined on the photocathode initially emits no electrons. The intensity of the light is increased. The classical prediction is

Responses	(percent)	(count)
1	22.22%	4
2	72.22%	13
3	0%	0
4	0%	0
5	5.56%	1
6	0%	0
Totals	100%	18

2.) Infrared light shined on the photocathode initially emits no electrons. The intensity of the light is increased. The quantum prediction is

Responses	(percent)	(count)
1	50%	9
2	0%	0
3	0%	0
4	0%	0
5	50%	9
6	0%	0
Totals	100%	18

3.) Ultraviolet light shined on the photocathode initially emits electrons. The intensity of the light is increased. The classical prediction is

Responses	(percent)	(count)
1	11.11%	2

2	88.89%	16
3	0%	0
4	0%	0
5	0%	0
6	0%	0
Totals	100%	18

4.) Ultraviolet light shined on the photocathode initially emits electrons. The intensity of the light is increased. The quantum prediction is

Responses	(percent)	(count)
1	88.24%	15
2	0%	0
3	0%	0
4	0%	0
5	11.76%	2
6	0%	0
Totals	100%	17

5.) It is observed that light of 430 nm just begins to emit photoelectrons. The wavelength of the incident light is changed to 440 nm. The classical prediction is

Responses	(percent)	(count)
1	0%	0
2	27.78%	5
3	0%	0
4	5.56%	1
5	66.67%	12
6	0%	0
Totals	100%	18

6.) It is observed that light of 430 nm just begins to emit photoelectrons. The wavelength of the incident light is changed to 440 nm. The quantum prediction is

Responses	(percent)	(count)
1	44.44%	8
2	16.67%	3
3	22.22%	4
4	5.56%	1
5	5.56%	1
6	5.56%	1
Totals	100%	18

Activity 23: WBT - Charged particle deflected by a magnetic field

Activity 24: PET - Charged particle deflected by electric field

Activity 25: PET - Charge particle in electric and magnetic fields

The results for these three activities results are tabulated together. The response for each question is given individually and then following small group discussion. Note that in all cases, more correct responses were given following small group discussion. The

students did very well on determining the charge based on the deflection in the magnetic field and predicting the correct deflection for the charge in the electric field. However, when predicting the result of opposite deflections from the two fields, most students had seemed to have an idea that the charge would undulate.

1.) What is the sign of the charge?

	Responses (percent)	(count)
+	60%	12
-	40%	8
Insufficient Information		0% 0
Totals	100%	20

2.) What is the sign of the charge?

	Responses (percent)	(count)
+	90%	18
-	10%	2
Insufficient Information	0%	0
Totals	100%	20

3.) Predict the direction the charge will be deflected by the electric field

	Responses (percent)	(count)
Up	20%	4
Down	80%	16
Totals	100%	20

4.) Predict the direction the charge will be deflected by the electric field

Responses	(percent)	(count)
Up	5%	1
Down	95%	19
Totals	100%	20

5.) Predict the path of the charge when both fields are

Responses	(percent)	(count)
Will wiggle back and forth	20%	4
Will deflect first one direction then the other	30%	6
Will go straight	40%	8
Some other answer	10%	2
Totals	100%	20

6.) Predict the path of the charge when both fields are

Responses	(percent)	(count)
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Will wiggle back and forth	25%	5
Will deflect first one direction then the other	40%	8
Will go straight	25%	5
Some other answer	10%	2
Totals	100%	20

Activity 26: CT - Two moving light clocks with light pulses perpendicular to travel  
 Activity 27: CT - Two moving light clocks with light pulses in direction of travel  
 The results for these two activities will be tabulated together. Not too surprisingly students had a lot of difficulties with time dilation. For a light clock where the pulse was transverse to the direction of propagation, the students, after small group discussion, predicted it would keep the same time as a stationary clock. For the light clock with the pulses parallel to the direction of travel, the students were about evenly split about whether the clock would run fast or slow. It seems that mid-instruction students' ideas about time dilation were quite muddled.

Questions 1) and 2) are for the transverse clock and question 3) and 4) are for the parallel clock.

1.) When the green clock moves with respect to the red clock it will

Responses	(percent)	(count)
Keep the same time as the red clock	36.36%	8
Run faster than the red clock	31.82%	7
Run slower than the red clock	27.27%	6
Cannot be determined	4.55%	1
Totals	100%	22

2.) When the green clock moves with respect to the red clock it will

Responses	(percent)	(count)
Keep the same time as the red clock	72.73%	16
Run faster than the red clock	22.73%	5
Run slower than the red clock	4.55%	1
Cannot be determined	0%	0
Totals	100%	22

3.) When the green clock moves with respect to the red clock it will

Responses	(percent)	(count)
Keep the same time as the red clock	28.57%	6
Run faster than the red clock	52.38%	11
Run slower than the red clock	19.05%	4
Cannot be determined	0%	0
Totals	100%	21

4.) When the green clock moves with respect to the red clock it will

Responses

	(percent)	(count)
Keep the same time as the red clock	8.70%	2
Run faster than the red clock	43.48%	10
Run slower than the red clock	47.83%	11
Cannot be determined	0%	0
Totals	100%	23

### **Planned Improvements in the Activities**

Experience using activities in class have definitely pointed to some future improvements. Several of the activities were not well suited to the level of the conceptual physics course, at least as the initial activity. In particular the WWT on charge and the WBT task on Faraday's law were more suited to the calculus-based course. In the future I will replace these activities in the Conceptual Physics course, although I intend to use them in the calculus-based course.

Another lesson that recurred throughout this project is that these types of activities place a premium on carefully and clearly worded questions. One activity that this was particularly evident with the questions on color where I didn't take into account that students will interpret adjectives such as bright as being a description of shade. Another activity where this was particularly important was the photoelectric effect, where students were confused between immediacy of an effect and amount. The photoelectric effect activity can be improved by splitting the issues of current vs. no current, and immediacy into separate questions. Also since the new clicker system only allows for five distractors, splitting each part of the photoelectric effect task into two questions will fit that system better.

Another area of improvement is that for some topics additional activities are needed. This was particularly true in DC circuits. The activities developed worked well, but did not adequately bridge to cases where the resistors were not identical, nor where there were branches in parallel with different number of resistors. Additional tasks are needed to bridge to more complicated circuits. I developed tasks for both changing the wavelength and slit spacing for the double slit pattern, but only had an activity on changing the slit width for the single slit pattern. This seems a silly oversight, and in the future an activity examining the effect of changing the wavelength on the single slit pattern will also be developed. One other area where additional activities are needed concerns the ordering tasks on image formation. In order to get an interesting arrangement, I included both object that would result in both real and virtual images. This proved to be too large a step. In the future a sequence with only real images, only virtual images, and then both real and virtual images should be given.

### **Dissemination**

Several efforts have been made to disseminate the ideas and activities developed in this project. At the end of the project I decided that the most effective way to organize the material for use by other instructors would be to build a website. Building the website proved to be an enormous undertaking and has dragged on interminably. Nevertheless, at this point 2/3 of the materials have been organized in what I hope is a quite user friendly format. The website can be found at <http://www.austincc.edu/nrgpsc/phys1407/tiperProject/tiperProjectIndex.htm>

For each activity, the website includes descriptions of the activities, target conceptual difficulties, links to the PowerPoint files and simulations, notes on using the simulations, a link to the pen and paper version of the activity, and a link to additional related pen and paper activities.

In addition to the website, I have disseminated the activities developed for this project in several other ways. I wrote an article for the ATE Program for Physics Faculty electronic newsletter, PWEN, on using the “Using PhET Simulations to Implement DC Circuit Tipers”. This article can be found at the link <http://physicsworkshops.org/PWEN/PWEN1.pdf>

I have also given several presentations on these activities at various AAPT meetings. At the Spring, 2007 Meeting of the Texas Section of AAPT I gave a contributed talk titled “Technology Based Tipers as an In-class Small Group Activity”. At the Summer, 2007 Meeting of the AAPT I gave an invited talk titled “Conceptually Rich Uses of Clickers” which included - in part - discussion of these activities. I additionally shared the ideas with a poster in the TYC idea sharing session at Greensboro titled “Incorporating Simulations into Technology Based Tipers”. At the Fall, 2007 Meeting of the Texas Section of the AAPT I co-presented a workshop with Tom O’Kuma and Regina Barrera titled “Using PhET Simulations in Your Physics Class”. All of these sessions were well attended with 24 attendees at the workshop, and at least 20 attendees at each of the AAPT sessions.

## **Conclusions**

The project had a number of goals. A common complaint about the Conceptual Physics course is that it is too easy. Often instructors deal with the difficulty issue by adding a problem solving component to the course, which somewhat defeats the idea of the course being Conceptual Physics. One goal of this project was to increase the cognitive level of the Conceptual Physics in a way that didn’t rely on algebraic problem solving. Incorporation of the TIPERs certainly accomplished that. The activities themselves provided an excellent in class activity which definitely engaged and pushed the students. Since the students had been exposed to TIPERs in class, I could reasonably add them to homework assignments, test review, and tests. Each homework assignment given the students had at least two TIPERs, and each test also had at least one TIPER. The TIPERs were routinely the lowest scoring items on student tests, but not unacceptably so.

A second goal was to demonstrate that TIPERs could be delivered via a clicker system and thus demonstrate that Clickers could be used for things other than concept tests. Eight different TIPER formats were adapted successfully to clickers. Certainly individual activities can be improved as detailed above, but this project definitely demonstrates a novel and valuable use of clickers.

I ended up experimenting with different class models for delivering these activities. I used a model with students individually responding followed by class discussion, a model where students discussed the activities in small groups before responding followed by class discussion, and a “Peer Instruction” model consisting of individual response followed by small group discussion then response and finally class discussion. The “Peer Instruction” model definitely promoted the most class discussion and highest level of

engagement, and as indicated by the data in the results section above was used almost exclusively for the activities later in the semester.

Finally, I have long believed in the value of TIPERs, but this project was my most extensive effort to incorporate them into a class in a systematic way. Encouraged by the results of this project, I have included TIPERs – both pen and paper and clicker – in a more systematic way in other classes. I also was extremely impressed with the PhET website as a teaching resource. Not only have I used simulations from it for TIPERs, but I have also used it as a lecture demonstration tool and have included simulations from it in lab activities, and in one case a homework assignment.

## References

1. Randall D. Knight, *Five Easy Lessons*, Addison Wesley, 2002.
2. Arnold B. Aarons, *Teaching Introductory Physics*, Wiley, 1996.
3. Wolfgang Christian and Mario Belloni, *Physlets: Teaching Physics with Interactive Curricular Material*, Prentice Hall, 2001.
4. Thomas L. O’kuma, David P. Maloney, and Curtis J. Hieggelke, *Ranking Task Exercises in Physics*, Prentice Hall, 2000.
5. Curtis J. Hieggelke, Stephen E. Kanim, David P. Maloney, and Thomas L. O’kuma *E&M TIPERs: Electricity & Magnetism Tasks Inspired by Physics Education Research*, Prentice Hall, 2006.
6. Wolfgang Christian and Mario Belloni, *Physlet Physics: Interactive Illustrations, Explorations, and Problems for Introductory Physics*, Prentice Hall, 2004.
7. R. E. Scherr, P. S. Shaffer, and S. Vokos, “The Challenge of Changing Deeply Held Student Beliefs about the Relativity of Simultaneity,” *Am. J. Phys.* **70**, 1238 (2002).
8. Paul Williams, “Using PhET Simulations to Implement DC Circuit Tipers”, *Physics Workshop Electronic Newsletter (PWEN)*  
<http://physicsworkshops.org/PWEN/PWEN1.pdf>
9. The Physics Education Technology (PhET) simulations can be found at  
<http://phet.colorado.edu/new/index.php>
10. Documentation, examples and the Java Jar files for Physlets can be found at  
<http://webphysics.davidson.edu/Applets/Applets.html>
11. The simulations used for emission and absorption spectra were drawn from the Visual Quantum Mechanics website. Previous simulations from this group have been converted to a commercial product; however as of this date these are still available on the web. <http://phys.educ.ksu.edu/vqm/index.html>