Reinforcing Critical Thinking Skills Using a Homework Layout in Engineering Physics Course

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Abstract

Practice is the key to success. Homework problems play a crucial part of that practice. Unfortunately, in our classrooms, the trend is to use a web-based system to assign and grade homework problems. Web-based systems present many advantages. For instances, they save instructor’s time on grading, randomized values on problems may discourage cheating, students can use links to the related electronic text before solving a problem, etc. However, web-based systems are focused on the answer only. Students become careless of their work and even try trial and error method just to get the correct answer.

In this study, the author presents the assessment of hand-written homework layout used in engineering physics course. A web-based system was also used along with the hand-written homework layout. The purpose was to reinforce students’ critical thinking skills by focusing on the process of how to obtain an answer instead of the answer itself. Critical thinking skill takes time to develop, but with the layout most students showed their thinking process when solving problems. More and more, the students accepted the layout as their approach to any problems, became more organized, made less mistakes or easily found their mistake, and got used to the layout with time.

Background

Nowadays, online homework sites have replaced the old-school hand-written homework assignments. There are pros and cons of online homework assignments and several studies
focused on comparing the effect of online vs. hand-written homework assignments on students’ understanding of physics concepts. The conclusion drawn was that there is no significant difference between these two types\textsuperscript{1-3}, the key factor was that increased student understanding occurred when homework was graded\textsuperscript{3}.

In 1949, Burke defined critical thinking in a way that a person’s behavior would describe if they exhibit the skill\textsuperscript{4}. A few exemplary behaviors that constitute critical thinking skill are differentiation between reliable and less reliable sources, criticizing faulty deductive reasoning, drawing valid inferences from given information, recognizing assumptions to be made, estimating probability of an interference and criticizing given estimates, and recognizing the existence of errors of measurement\textsuperscript{4}. In 1987, Murugesan\textsuperscript{5} defined not being able to think critically as “students have the greatest difficulty in distinguishing and connecting various concepts and formulae”. Although Murugesan claimed that it was up to the students to overcome not being able to think critically, Edmiston\textsuperscript{6} blames the teachers. Not only the teachers at school but the first teachers a child has in their life - parents. He stated that “Children are usually not taught to think critically by their parents, by their kindergarten teacher, by any teachers. Most likely, the majority of their teachers are not critical thinkers.”

After several decades, we still face the same issue in our classrooms - how to teach our students to be critical thinkers. This study focuses on reinforcing critical thinking skills using hand-written homework assignments.

**Design/Method**

Engineering physics courses, Mechanics and Electricity and Magnetism (E&M), are among the fundamental courses that students build their engineering career on. During these
courses it is important to reinforce students’ critical thinking skills. Most students tend to accept the information given as it is, without questioning it. Although students are exposed to more activities and assignments in the upper level classes where they are required to show their critical and analytical skills, the stronger the foundation the more prepared they are for the future challenges. For this reason, in the E&M course students were asked to submit their handwritten homework in a structured layout where they had to: First, state what is given and what has been asked of them to find with a detailed figure; second, provide assumptions, a plan and an estimate and, finally, submit step-by-step solution of the problem with a brief discussion at the end. With this layout students identify the problem, create a methodology to solve the problem, apply the methodology to the problem and evaluate the result by considering its limitations, how reasonable it is, and the dimensions and units of the answer.

The engineering physics courses are 5-credit and the E&M course has lecture and lab hours separated. There were two sections of this course in the Fall 2016 with about 35 students in each section. Since the number of students are high relative to other classes (18-20 students), two instructors were present during lectures. While one instructor had the leading role throughout the semester, the other instructor’s main role was to help students during question or problem sessions. The concepts were introduced briefly using powerpoint slides. 5-10 conceptual questions were asked in each lecture and students used electronic clicker remotes to answer quickly. Simulations, demonstrations and video clips were also used frequently. After introducing a concept, usually a simple example problem was solved with the class to illustrate the application of the concepts and equations. In addition, after each chapter 4-5 extra problems were provided to students as handouts. Students were given time to solve a few of them in class with
the guidance of the instructors. Labs were separated into 4 sections with approximately 18 students in each section. One instructor was present in each lab section.

There were a total of ten homework assignments and six exams. Homework assignments were assigned on WileyPLUS (WP) which is an additional online source for the Fundamentals of Physics, Halliday textbook used for engineering physics classes. The assignments were separated into two parts. The first part consisted of multiple-choice questions to measure conceptual understanding and the second part consisted of open-ended problems to practice problem solving. Separating multiple-choice questions from open-ended problems helped manage grading more effectively on WP. While the attempts on multiple-choice questions were limited to 3 with a penalty after each attempt, open-ended problems had unlimited attempts with no penalty. Students were asked to submit hand-written solutions to open-ended problems only. Each assignment had about 10 open-ended problems and students were asked to solve each problem using the hand-written homework layout. The majority grading was done by the WP. Multiple-choice questions were out of 12-15 points whereas problems were out of 100 points. The latter was counted as the correctness score in the hand-written homework. The grading of the hand-written homework was done by the lead-instructor only. For that reason, only 4 assignments were graded. Students obtained maximum of 42 points as the format score from the rubric for the layout to be added to the correctness score (only when the assignment was graded for the format). They were not told which assignments were going to be graded so they assumed each assignment was likely to be graded.
Students were expected to improve on using the structured layout by getting feedback from the instructor on homework and exams. Assessment of this method was done in three different ways:

1. Handwritten homework
2. Exams
3. Feedback from students

Feedback from students was collected three times:

3.1. Anonymous feedback collection on Moodle in the first weeks of the semester.

3.2. Small group instructional diagnosis (SGID) in the middle of the semester.

3.3. Final anonymous feedback collection on Moodle in the last weeks of the semester.

In 2016 academic year, students submitted their homework assignments two ways - online and hand-written in Engineering Physics: Mechanics (Spring) and E&M (Fall) courses. Initially, in the Mechanics course, they were not required to follow a structure in their hand-written homework assignment other than showing work by starting from the original equations and showing several steps before reaching the answer. There are several advantages of collecting both online and hand-written submission. Mainly, students can benefit from all the pros an online system provides. They get immediate but brief feedback whether their answer is correct from the online submission. Whereas creating handwritten solutions in structure that promotes thinking about the problem helps them to be better critical thinkers. Einstein said “It is not that I’m so smart, it is just that I stay with problems longer”. The main goal of the hand-written
The layout is to have students think about a problem a little longer than usual. Most students only focus on what the answer is rather than the ways to get to the answer and whether the answer makes sense.

The first calculus based physics course, mechanics, uses an active learning textbook\(^7,\,8\). The layout used in homework assignments was emphasized in this textbook with in-class or supplemental example problems in the Spring semester. Except a few transfer students, all others were familiar with the layout. However, the students in the mechanics class were not asked to apply the layout in hand-written homework. As a result, most of their homework submissions lacked organization, neat solutions, good spacing, and, more importantly, the evidence of their thought process. In the Fall semester, students were provided format rules and directions to complete their hand-written homework assignment along with online submission. The layout and instructions used in E&M course is as follows: Given, Find, Figure, Assumptions, Plan, Estimate, Solution, and Discussion. The full homework format rules are provided in Appendix A. Students were also required to attach homework coversheet shown in Appendix B where they go through a checklist for the format and provide their online homework score (correctness score) for each problem. Their total homework grade was based both on the correctness score obtained from the online system and the layout format score which was easily calculated with a simple rubric.

**Results and Discussions**

Initial anonymous Moodle feedback results, summarized in Appendix C, revealed that about 49% of the students had used a similar format before this course and 86% find it of average or easy difficulty to follow the structure. Although 22% did not see the benefit of it right
away, 58% realized that the layout forces them to be more organized with 75% stating that it required a great deal of time/work. The bright side is that 19% confirmed that they make fewer mistakes since all the work should be shown and it is easier to figure out their mistake with the layout.

Feedback collected during SGID in the middle of the semester is provided in Appendix D. Students were complaining about the layout even more. No one really liked to do “extra” work, as expected. Some were asking for changes and they thought assumption, estimation, and discussion parts were time consuming and unnecessary. However, those are important sections of the layout, especially for an engineering physics course. Students needed to be encouraged to have a habit of being organized and structured so when the program gets harder or when they find a job they would know how to separate the given problem into parts and critically analyze it to reach an answer.

Homework assignments improved from the beginning to the end of the semester. Although the layout is not used very efficiently by everyone, the majority showed their work more clearly which helped them collect more points on the assignments. Good and poor hand-written homework examples are provided in Appendix F and G, respectively.

In exams, there were a few multiple choice questions for concepts and two open-answered problems. In one of the problems they had to use the homework layout to obtain full credit. In the other they did not have to use it. Starting with the fourth exam, I was very pleased to see some students were using the homework layout on the problem in which the layout was not mandatory. They must have had started to make a habit of using it. Also, students were getting more points on the problems where the homework layout was required, mostly because
they showed more work, earning more partial credit, and they double-checked their answers with their estimation. The “discussion” section in the layout was not only used for comparing the answer obtained from the solution with the estimation but also for student’s self reflection. Students were also asked to talk about what was challenging about the problem and what mistakes they had done before reaching a correct answer. This might help when studying for the final exam by reading the discussion section and remembering their mistakes and learning from them. Overall, about 65% thought that using the layout helped them obtain more credit on exams.

Using this layout to solve any problem takes more time. As expected, students did not like doing “extra” work, especially in the cases where they can find an answer with scribbling a few letters or numbers. The instructor was aware that they were going to complain about it but was hopeful that they would see the benefit after a (short) while. Initially, most of them were not focused on the physics part of the problem which required a lot of thinking and analyzing, instead they were jumping into conclusions and doing poor work. This resulted in not understanding the concepts very well.

The layout is very common in our department with slight modifications. However, in some other classes students are asked to use a structure which includes only “given”, “find” and “solution”. Usually students are fine showing work for those three sections without complaining but to reinforce critical thinking “assumption”, “estimation” and “discussion” sections were necessary and were emphasized. Physics is the logical thinking process after all and these latter sections encourage thinking about the problem in different ways.
Assumptions are important before starting to solve a problem and they help clear the problem. One of the reasons students do not get the correct answer to a problem is either not reading or not understanding the problem very well. To be able to write down assumptions, students need to make sure they understand the problem, consider the rules or conditions they learned during lecture, and even compare it with other similar problems. For example, for a projectile motion question if they are able to assume that there are no other external forces except gravity, they probably understand that if there was another external force the acceleration would be different than what we use in projectile motion which would change the entire solution.

Estimations are usually the hardest to make and students, in general, do not like to invest extra time or effort. Also, in some problems estimations are almost impossible without solving the problem. Once in a while we had such problem. However, some sort of an estimation could be made in most problems. My main goal was to have them think about the problem in another perspective. For example, if it was an electrostatic force problem between point charges, they could easily use what they know about vectors and try to estimate the direction of the net force using graphical method. Then, they could compare their answer with their estimation and double check their solution and estimation if the two do not match.

Initially, a majority of students already realized the benefit of writing “given”, “find” and “solution” explicitly but very few appreciated the sections like “assumption”, “estimation” and “discussion” which were the hardest to do. After the final anonymous feedback collection on Moodle, the number of students who found the layout useful increased. In the first weeks only 5.1% used the layout as an approach to any problem they encounter. This ratio went up to 24% towards the end of the semester. Similarly, at the end of the semester 78% thought it forced them...
to be more organized (20% increase); 22% thought they made less mistakes since all the work needed to be shown (3.4% increase); 30% said it was easier to find their mistake with the layout (11% increase); 52% thought it was hard in the beginning but it got easier with time (21% increase); 61% said that applying the layout took so much work/time (13% decrease); and finally only 9.3% found it useless (13% decrease).

Unfortunately, not everyone used the layout effectively. There were students who really wasted their time. A comment form the SGID summarizes this well: “No! Because everybody in our group will either complete the problem & fill it out for the format after the fact, or section the pages out for the format without writing anything except “Find, Given, Discussion, Estimation” etc. and not actually fill them out until after the problem is completed. The format helps not!”.

The instructor emphasized the importance of effective usage of the layout. For example, for the estimation sections, some were doing the calculations to estimate a value of the desired quantity. However, the point was either to find it in the order of magnitude or, if that is not possible, they could make estimations like the result being less than some value or it is negative/positive etc. A few also mentioned that assumptions and estimations are the same thing and it is unnecessary to have them both. They simply do not understand each section well. A few wrote the same thing in estimation and assumption. The difference between them was explained in class in more detail than the written format rules.

**Conclusions**

Considering all the feedback collected, there are some modifications made for the 2017 academic year. The points for following the layout format was reduced to 20% of overall homework points from approximately 30%. Despite complaints on sections like “assumption”,
“estimation” and “discussion”, the instructor was persistent in keeping them. The layout is being used for the homework assignments in the Mechanics course (freshman year).

WP was problematic time to time and many interruptions occurred during the semester. It was stressful for both the instructor and students to have interruptions right before the homework deadline. Another issue was the tolerance assigned on each problem. Each student had randomized values for a given problem to prevent copying someone else’s work but sometimes the tolerance was either too high or low for a problem. Depending on the rounding, students sometimes struggled to get the exact answer. Instead of using the online system, in the current Mechanics course, the instructor provides answers to problems and students need to follow the format and step-by-step solutions to obtain those answers. The step-by-step solution strategy was explained in the active learning textbook used for the Mechanics course. The strategy prevents equation hunting. In addition to these changes, each homework set has its own cover sheet. The format rubric on the cover sheet was also simplified and points were reduced to 20. The grading is not done by WP anymore and each assignment still has about 10 problems. The instructor is grading only 2 problems which are not announced to students before turning in their hand-written homework assignment.

The road to critical thinking is not straight forward and it is challenging for both student and instructor. Students are ready to quit “extra” work and jump to conclusions without showing their thought process. Instructors need to be persistent and encouraging so students turn this process into a habit. Students might resent us for having them do more work and that is alright because it will take time for them to develop the skill and it is hard to see its benefits right away. Along the way some encouragement helps keep students motivated. Collaboration between
instructors is also important for consistency and permanency of the skill, so it is favorable if the students are using similar layouts throughout their program.

The author is planning to collect follow-up feedback from the same students before they graduate. Starting this new academic year, the author is also using the Force Concept Inventory to assess students’ learning more quantitatively.


APPENDIX A - Homework Format Rules

In doing your homework, you are required to follow the instructions listed below:

- Use a pencil - Do NOT use a pen.
- Completely erase any extraneous material - NO scratched out material should appear on the solutions.
- Show all the pertinent details of how you obtained your solution.
- Staple your assignment together - Do NOT use paper clips or other means to assemble your homework.
- Write legibly, in print large enough to be read easily.
- Use 8 ½ by 11-inch paper. Do NOT use paper torn from a spiral binder unless it is perforated and you can neatly remove the ragged edge.
- Use straight edges to draw diagrams, schematics, etc.

Each homework problem must follow the structure given below:

Given: Concisely state the problem, including relevant sketches, units, etc.
Find: State what is the goal of the problem (i.e. what is unknown).
Figure: Show a large, neat, and complete figure that embodies the problem.
Assumptions: List all assumptions used in solving the problem.
Plan: A sentence or two on how you plan to attack the problem.
Estimate: Estimate what you think the answer might be.
Solution: Give a step-by-step solution of the problem, including explanatory sentences. **You must have units for every number, show your units calculations, and put a box around your final answers.**
Discussion: Comment on your solution, note if your answer makes sense, problems you had, how good your estimate was, etc. Talk about what was challenging about that problem.

Additional features of a GOOD homework

**Figures.** Each problem should have a neatly drawn figure. If you are not a true artist, you should use a straight edge. Also, the figure should be large enough to be easily read and important variables associated with the problem should be labeled on the figure. A well-drawn figure will greatly help you solve the problem and help me understand your solution.

**Organization.** Each solution should be well organized. Labels for parts (a), (b), (c) etc. should be easy to locate and the solution should be placed in the proper section.

**Neatness.** Don’t cram your solutions into a small space. There should be lots of “white space” in your solution. Leave blank lines between steps; this makes it much easier to grade and gives me room to make comments. Start each problem on a new page.

**Details.** A homework solution should be capable of being “read” just like a textbook example problem. This means that you include all the pertinent details of the solution as well as text to help the reader follow your analysis. (Include sentences in your solutions not just equations.) Explain what you are doing, tell where you have taken an equation from, etc.

**Approach.** For nearly every problem your approach should be:
1. While you are writing the given & find think about the problem. Think about what you know and don’t know; think about which fundamental law might relate the quantities; form a strategy!
2. Start your solution with a very general equation. The equation should be written with symbols only.
3. Simplify the equation and state why you have made your simplifications.
4. Once the equation is simplified, then plug in the numbers. Take care of conversions before plugging.
5. Calculate the final answer and double-check the final units.
6. Ask yourself if the answer makes sense. Use your estimation and any other limitations if applicable.
APPENDIX B - Homework Cover Sheet

*Directions:* In the left hand column of the table below, fill in the individual problem numbers that were assigned (e.g. 22.14). In the right hand column mark your WileyPLUS assigned score for each problem. Also complete the Student Solution Checklist Table and the lower portion of the form. Grey areas will be completed by the instructor.

<table>
<thead>
<tr>
<th>WileyPLUS Grade (Problems ONLY)</th>
<th>Student Solution Checklist</th>
<th>√ 3 2 1 0 Wt Tot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem #</td>
<td>Score*</td>
<td>Proper setup (given, find, etc.)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Neatly drawn figure</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Neat solutions w/ good spacing</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Detailed solutions w/ descriptions</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Units shown and used</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Box around final answers</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Cover page filled out</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Stapled</td>
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<td>8</td>
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<tr>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal:</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Correctness score is your Subtotal as long as the value matches the one on WileyPLUS. If not, WileyPLUS score will be used. In the case of system fault, student has the responsibility to inform the instructor in a timely manner. If necessary, score will be adjusted by the instructor. The individual points for each problem is adjusted so that the maximum score is 100 points for each assignment.*

**Format score will be calculated from the rubric shown in grey area next to the checklist. The weights for individual items are given. If you are submitting perfect homework assignment, you will gain 42 points for the format score.**

***Total score is the sum of the Correctness score and the Format score. For example, if your correctness score is 100 points (you got all the problems correct) and you provide all items on the checklist you get 42 points for format and the total score is 142 points.***

Please list below the names of other students who you worked with while doing this assignment (i.e. if you worked the problems in a group setting, list the names of those who were present). If you received help on a specific problem (e.g. if there was a particular part that you could not figure out and someone helped you), you must also cite that assistance within the particular problem solution.

_____________________________  _______________________  _____________________
_____________________________  _______________________  _____________________

*Honor Pledge:* I attest that the work contained herein is my own, original work. Any assistance I received from others has been cited within the homework solutions and above. In working the problems I have developed my final answers through analysis of the problems and have NOT forced/forged the problem to match the given answers. I understand that failure to follow these rules constitutes an act of academic dishonesty and is punishable in accordance with the college policies described in the College Catalog and noted on the course syllabus. I have also followed the homework format guidelines.

*Signature: ________________________________
APPENDIX C - First Weeks Anonymous Moodle Feedback

Submitted answers: 59  
Questions: 22

1. What is your background on Electricity and Magnetism (E&M)  
   - I took a low intensity high school E&M physics class: 14 (23.73 %)  
   - I took an intense high school E&M physics class: 11 (18.64 %)  
   - I have taken a general (non engineering) college E&M physics class: 4 (8.78 %)  
   - I have taken engineering E&M physics at York College or elsewhere but did not pass: 1 (1.69 %)  
   - I have not taken an E&M physics course before: 29 (49.15 %)

2. What is your major?  
   - Mechanical Engineering: 36 (61.02 %)  
   - Electrical Engineering: 11 (18.64 %)  
   - Computer Engineering: 6 (10.17 %)  
   - Engineering Management: 3 (5.08 %)  
   - Math or Math Education: 0  
   - Science (Chemistry, Biology, Computer): 1 (1.69 %)  
   - Other: 2 (3.39 %)

3. How many hours do you spend outside of class studying and doing homework?  
   - 0 – 2.5 hours/week: 2 (3.39 %)  
   - 2.5 – 5 hours/week: 15 (25.42 %)  
   - 5 – 7.5 hours/week: 23 (38.98 %)  
   - 7.5 – 10 hours/week: 12 (20.34 %)  
   - More than 10 hours/week: 7 (11.86 %)

11. Choose the best answer on how you like WileyPLUS? (consider e-text, orion, the struggles with submission, etc.)  
   - I love it - nice addition to the text book: 0  
   - I like it - no problems so far: 8 (13.58 %)  
   - I like it - most of the struggle was due to my own mistakes (e.g. algebra, ignoring signs, etc.): 24 (40.68 %)  
   - I don’t like it but some features are useful (e.g. e-text, orion, etc.): 17 (28.81 %)  
   - I don’t like: 10 (16.95 %)

14. How familiar were you with the handwritten homework format before this course?  
   - I used similar format in my other course(s) last year.: 29 (49.15 %)  
   - I use similar format in my other course(s) this semester.: 7 (11.86 %)  
   - First time doing homework in this structure.: 23 (38.98 %)

15. How hard is to follow the structure for the handwritten homework assignments?  
   - Easy: 20 (33.90 %)  
   - Average: 31 (52.54 %)  
   - Hard: 8 (13.56 %)

16. What do you think about the structure of handwritten problems overall? (You can choose multiple answers)  
   - That is my approach on every problem: 3 (5.08 %)  
   - It forces me to be more organized: 24 (40.68 %)  
   - I make less mistakes since all the work should be shown: 34 (57.63 %)  
   - It is easier to figure out my mistake this way: 11 (18.64 %)  
   - It was hard in the beginning but it gets easier overtime: 18 (30.51 %)  
   - So much time/work is needed: 44 (74.58 %)  
   - It is useless: 13 (22.03 %)

22. Any other thoughts you want to share?  
   - Everything is going well so far. I am actually understanding concepts much better this time around and I think I did really well on the test. One thing I am sincerely grateful for is the unlimited attempts on the Homework Problems. When I previously took this class, we used a similar online site called Mastering Physics. There was a 30% point deduction for every wrong answer inputted. This discouraged me from actually trying my own answers, and I instead tried to look up solutions on the internet to avoid losing massive amounts of points on this homework.  
   - I find that the estimation step of the homework is a little unnecessary.  
   - Give more time on the homework. I need it all!
- Less formatting for the homework.
- I think the handwritten homework should be given a due date of the next class following the due date of the homework. This would allow those who didn't understand the time and ability to ask questions and to correct their mistakes and maintain more points on their homework.
- Homework layout is challenging for some problems, especially on the easy ones. There do not seem to be assumptions to be made, and sometimes conclusions do not warrant much discussion.
APPENDIX D - SGID - Mid Semester - AM Section

1. How hard is it to follow the structure for the handwritten homework assignments?

   Please explain with examples to back up your response.

   6 responded to Easy

   6 responded to Average

   • Estimates are hard to make

   • The problems that don’t use numbers can be hard to follow

   • It is hard to understand what is asked of us in the discussion section

   • Layout helps toward solution. Sometimes assumptions and estimates are hard to make

   • Assumptions are sometimes confusing as to what it should be or how to put into words.

   • Estimates are difficult to figure out

   • The format itself is not too hard but doing it for 10 or so problems just feels like a waste of time in which we could be learning material. It also doesn’t mesh well with the problems without numbers especially the estimation part. The estimation also just feels like a waste of time especially for problems we aren’t as familiar with.

   • As long as I follow the format as specified on the handout, it’s straightforward

   • The steps are logical and easy to follow
• Overall, the structure seems easy but I’m not always sure what to put in the estimate and assumptions sections. Especially when the problems are simple plug and chug problems.
• But some steps are pointless but if it’s for the better than okay
• It is relatively easy to follow the homework structure. The most difficult part is the estimation. We do not have the same experiences to give a general answer before the solution
• Just time consuming
• The given and find portions are easy but the plan and estimation seem tedious and don’t provide understanding of the topics.

2. What do you think about the structure of handwritten problems overall? (Circle all that apply. Add comments to back up your answers.)

1 responded to: That is my approach on every problem
8 responded to: It forces me to be more organized
3 responded to: I make fewer mistakes since all the work should be shown
3 responded to: It is easier to figure out my mistakes this way
4 responded to: It was hard in the beginning but it gets easier overtime
11 responded to: So much time/work is needed
0 responded to: It is useless

• Most of the homework assignments can be done faster if we weren’t forced to spend so much time setting up the problems.
• Without even a more simplified version, I get confused, mess up which equation to use, etc.

• We feel that the organization is worth too much as opposed to the questions themselves

• The structure works great for some problems but some problems take a minute to do and then we waste time writing it all out.

• The way the tests are structured where some of the problems require it and some don’t is alto better

• The format really forces you to be more organized, which leads to fewer mistakes but it is very time consuming. Usually the first few problems of the homework are fairly simple and take 5-10 minutes to actually solve but writing every step out for the format takes an extra half hour to an hour

• Layout creates organization

• Get used to the steps overtime

• Very time consuming

• I think that there are too many sections. I really only use the given, figure and find sections of the structure

• It is a helpful organizational tool, but it takes a lot more time to finish the problems when including discussions and assumptions, etc.

• Always used to write givens, and finds, figure/FBD. See the other section as extra/not vital sections
• The addition of the find, plan, assumption, and estimation sections clutter up the workplace. Also, the format allows for no flexibility so if the work is not done exactly according to the format rules, you won’t be able to get full credit.

3. Consider problems when you used and not used the homework layout. Do you think that using the homework layout encourages you to think more about the problem before you start solving it compared to not having the layout where you were just aiming for the answer? Explain.

• Yes, I believe that writing everything out about what the problem is and what I’ll do helps when starting to solve.

• Doing setup makes us more confused sometimes and causes me to make mistakes

• Yes, getting the givens laid out and conversions identified helps the process without it I often get lost and make mistakes

• Sometimes on more complex problems it makes me think but on problems that are easy it just uses up time

• For the bigger more complex problems, it works well and is useful but for the smaller, simpler problems it is useless and a big waste of time

• Yes, it forces me to think through each problem and discourages lazy mistakes

• No, solve the problem first then place in layout afterwards
• I don’t think that using the homework layout has changed anything except making the problem take longer to solve
• The layout doesn’t help with the problems. There should be other ways to do this.
• It is about the same. Last semester we only needed to write given, find, and draw a picture if needed. This new format did not really change how we thought about the problem it just takes more time
• We can see why the instructor wants us to do it but time consuming, maybe less stuff to do
• The new layout forces you to focus specifically on what the question is asking instead of jumping right in and starting to crunch numbers right away

4. Do you feel like your note taking skills improved at all after practicing problem solving using the homework layout? Explain
• Yes, I have found my notes for all of the classes more legible since I spread my writing out
• I see no correlation
• Kind of, note taking tends to be class dependent. I develop my system during class
• Usually there isn’t enough time to do this format in class. Slightly more time on in class problems would be nice
No correlation. 2/3 people have been good note takers whereas the other does not take great notes but this trend has been before this class. The most helpful thing about the homework is using equations.

No, they have very little correlation

Yes, because after completing a practice problem, I see the purpose of what is in the notes and I realize what topics I absolutely need to take notes on and what topics are for review

Not really, notes and homework layout are separate. Usually just write equation for notes.

No, they have not changed

No, the layout hasn’t improved my note taking skills, if anything it made me think about that part of the problem caused me issues.

No, they have not. The homework does not affect how we take notes in class.

Stayed the same – maybe wrote more concisely.

No, the homework layout has not influenced my note taking skills. I feel the two are unrelated.

5. What other comments can you add about the homework layout?

It is often hard to come up with assumptions and estimates. I have never applied them to my problem solving technique and just throw anything in, in order to get credit for it. I see no value in them.

Be more lenient
• Good homework load overall
• Frustrating when we do it and it’s not always checked but doing this forces us to practice more and practice thinking through problems
• After spending 5+ hours on a homework assignment, I am burnt out and don’t have the energy to study the material I need to study.
• Maybe don’t require all steps for each problem or make it optional and if you get the problem wrong you can rewrite it in the layout to get some credit back.
• I think that the homework layout should be changed to only include a given, find, figure, and plan section.
• I don’t think the discussion is necessary. Some parts of the layout like writing the givens is helpful and the rest like guessing on answers is useless since most of the time I have no clue what my answer might be before I do the problem.
• Assumptions and estimations are really not needed for us to improve our homework problem solving.
• We can see why you make us do the format. It is time consuming with all other classes
1. How hard is it to follow the structure for the handwritten homework assignments?

Please explain with examples to back up your response.

2 responded to Easy

6 responded to Average

1 responded to hard

- We normally follow the structure in order to complete homework problems, so following guidelines takes away from time actually doing problems. Estimating on some problems is impossible. Extra writing makes problems take long without being any harder

- It’s easier to write side notes when they are necessary ex.) estimates –not necessary

- Easy to follow but a lot of it is pretty unnecessary. Assumptions and estimates are kind of redundant and wasted time

- The structure is not hard to follow, but Wiley Plus is frustrating sometimes

- Most problems impossible to have a hypothesis or estimations

- A number of problems are so simple, no discussion or elaboration is possible

- Easy to follow but seems excessive

- A little much but it helps understand the problems and adds time

- Very annoying to follow the structure. We want bonus points. We don’t see the point in assumptions and estimates because it’s just homework
• If we had to write given, find, equations needed, and solve it would be much easier

2. What do you think about the structure of handwritten problems overall? (Circle all that apply. Add comments to back up your answers.)

  2 responded to: That is my approach on every problem

  6 responded to: It forces me to be more organized

  2 responded to: I make fewer mistakes since all the work should be shown

  1 responded to: It is easier to figure out my mistakes this way

  3 responded to: It was hard in the beginning but it gets easier overtime

  7 responded to: So much time/work is needed

  3 responded to: It is useless

• Make formatting required on first few assignments and then allow us to choose what works for us

• Writing out the given, the equation, and drawing a picture helps and usually everything else is just helpful for review. We don’t think a plan, estimate, and discussion should be mandatory because some problems are straight forward or hard to estimate.

• It is my approach because I’m forced to or I will lose points. Given, find, plan, solution, all make sense and I do them regardless but everything else is pointless and takes more time away from me actually getting work done.
• It helps, but for some problems it is excessive when the problem is easy. I feel only a few points helpful, like drawing the picture and stating the given. The plan, estimate, and assumptions I find I waste my time and usually B.S. most of it to get points.

• Sometimes no drawings or diagrams given, word choice is confusing which leads to improper set of the problem

• Being organized or following someone else’s fixed format does NOT blow in any way how good or bad we are in Physics. We are ALWAYS and already are stressed for time and adding in extra written work on top of having already solved the problem and completing it, is a waste of our precious time. We all understand we need to be organized and neat for our jobs, but does that mean we have to do more work than we need to before we even start our real jobs?

• The structure gives a clear path for thinking

• Seems like more work than actually needed

• We only are given and find but never assumptions or estimates. Given, Find, Figure, Solution: The only useful ones

3. Consider problems when you used and not used the homework layout. Do you think that using the homework layout encourages you to think more about the problem before you start solving it compared to not having the layout where you were just aiming for the answer? Explain.

• Sometimes solving the problem helps in understanding the concept
• Kind of – just for the given and find sections

• The layout helps to think about it if I didn’t have any idea of how to start the problem. Given and Find help you to narrow down what you are solving for and Plan gives you a place to write the equation you are going to use. Solution of course make sense but everything else is wasted time.

• Sometimes it is hard to prepare for the problem so we just solve it anyway

• No! Because everybody in our group will either complete the problem & the fill it out for the format after the fact, or section the pages out for the format without writing anything except “Find, Given, Discussion, Estimation” etc. and not actually fill them out until after the problem is completed. The format helps not!

• The only useful steps are Given, Figure, Solution and Discussion. The estimate answer portion is useless because it is hard to get a good estimate.

• We get the same answer either way

• We usually aim for the answer then go back and format it afterwards. Format slows the process down by a lot.

• The layout helps more with organization of the problem. It is easier to work through the problems to solve it. Writing the needed equations for plan/assume is one of the only things about the layout that helps us solve the problem.

4. Do you feel like your note taking skills improved at all after practicing problem solving using the homework layout? Explain
• Practicing writing always improves your skills. Some of us don’t have the time so it adds stress

• Stayed the same—having those large workout problem sets before tests and reviewing them together is more helpful than the homework layout; discussing problems in class improves my note taking skills more

• For in class practice problems all I write is given and find and the I solve it because that is all I need

• Not at all, because note taking involves me formulating my ideas in a way that I can understand them later, whereas the homework format is just forcing us to apply their problems in their form, completely unrelated topics

• No. It has nothing to do with notes

• No, the homework style is not necessary for note taking because we tend to go over each step and that can be used for review

• It didn’t affect my notes at all

• No, taking notes in class is more about the concepts than the homework problems/how to set up problems

5. What other comments can you add about the homework layout?

• Long, wastes actual problem solving time. I spend 20-30 minutes on a 1-step problem because of all the other stuff I have to write out that doesn’t even help me. Also, formula sheets should be provided at the beginning of each chapter so we can start homework right away
• Time consuming, but sometimes helpful when the problem is tough or has a lot of parts

• Estimate and assume are very similar. Are both really required?
## APPENDIX E - Last Weeks Anonymous Moodle Feedback

### Submitted answers: 54  
### Questions: 12

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you think that using homework layout helped on exams to obtain more credits?</td>
<td>7 (12.96 %)</td>
<td>28 (51.85 %)</td>
<td>15 (27.78 %)</td>
<td>4 (7.41 %)</td>
<td>0</td>
</tr>
</tbody>
</table>

- **Any comments on your previous answer?**
  - Only on the parts where the layout was required
  - my own method compared to the homework layout, but was not exact. so i felt the homework layout we had to use had unnecessary steps
  - Nope, it was good.
  - I still feel that even with the homework layout not enough partial credit is given to help do well on exams
  - I thought just writing the given and what to find was effective enough, like last semester.
  - I used a similar method to the homework layout which included providing the givens and knowing what I'm solving for, along with giving what I think the answer should be, and this did help to solve most of the problems
  - The layout definitely helped getting more partial credit on the exams
  - I don't find the format helpful or detrimental. It just takes more time.
  - The only thing that helps on a test is knowing the test material. If part of the test is to do the homework format, knowing how to apply the homework format helps... but nothing about the homework layout is related to the actual material we are learning
  - I always showed work, layout was not a big deal to me
  - Na
  - Helps me remember example problems
  - It helped when there were steps to aim us in the right direction
  - It was just something I did because it said if I do not, I will not get full credit.
  - I feel like the practice helped but I still did not do the homework layout completely correct most of the time on homework
  - It helped me become better at solving problems one step at a time
  - I don’t think the layout helped me on the exams, but I think it does help overall because it forces us to be more organized.
  - It does keep me more organized but not every question needs such structure.
  - not bad but can be really time consuming on questions that don’t really need that much work
  - It offered more opportunities to obtain points
  - I always show my work on exams anyways
  - It made it easier for you to see what our ideas were and where our answers were coming from.
  - Very good layout
  - Forces you to think through the problem before attempting to solve it.
  - Made me think about what I was looking for

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you think that you have used the homework layout effectively?</td>
<td>11 (20.37 %)</td>
<td>27 (50.00 %)</td>
<td>10 (18.52 %)</td>
<td>6 (11.11 %)</td>
<td>0</td>
</tr>
</tbody>
</table>
Any comments on your previous answer?
- I did not always use the homework layout as I should of but I did always include the givens and what's being solved for which I found to be most helpful for me, but I should have always used the full homework layout.
- It's not entirely the same way I address problems but I am still learning how to address problems so some guidance is nice. Also, I write all the problems down in this format ahead of time before I start the problem which helps ease into the homework.
- The plan step has helped me a lot
- Just something I had to do
- I skip over estimations a lot because I'm sure how the answer should turn out.
- When needed yes
- I didn't use it to its full potential because I would complete the problems beforehand and put them into the homework layout after completing all of the problems.
- Sometimes I still had trouble determining what to put for both the assume and estimate section but I don't think that's a problem with the format, just a me problem.
- I feel that the homework layout was helpful. If you were committed to using it the right way it would benefit but if you just wanted to fill in something without thought to get credit it makes it feel like it just wastes time. It depends on if the student
- It kept me organized.
- I didn't think parts of the homework layout where nessasary. In many problems the estimations and assumptions where difficult to figure out or think of.
- Practice makes perfect
- No
- The only thing that bothered me about the format was the plan, assumptions, estimation and discussion. At the point of time I am starting the homework the material has not completely settled in yet and I don't know enough to come to those conclusions.
- Sometimes I would skip the estimate and discussion until I finish the entire HW
- Sometimes I was lazy about it but overall it was good.
- I have done it but there are to many steps for the homework layout for it to be effective. Most of us just skip the first few steps and go back to them when we finish the problem
- It's hard to make predictions and such, but I did my best to use it
- Carefully thinking each step out, I believe I have used it effectively.

Do you think using the homework layout got easier with time?
- Strongly agree: 11 (20.37 %)
- Agree: 30 (55.56 %)
- Neutral: 8 (14.81 %)
- Disagree: 5 (9.26 %)
- Strongly disagree: 0

What do you think about the structure of handwritten problems overall? (You can choose multiple answers)
- That is my approach on every problem: 13 (24.07 %)
- It forces me to be more organized: 42 (77.78 %)
- I make few mistakes since all the work should be shown: 12 (22.22 %)
- It is easier to figure out my mistake this way: 16 (29.63 %)
- It was hard in the beginning but it gets easier overtime: 28 (51.85 %)
- So much time/work is needed: 33 (61.11 %)
- It is useless: 5 (9.26 %)
Chapter 21 problem 17

Given: 3 point charges and the distance between them

Find: Magnitude of electrostatic force on particle 1 due to particles 2 and 3

Figure:

```
  △
  3.7m
  △
  3.7m

51 μC

-3 - 51 μC → x
```

Assume: Distances from center of charges and angles of equilateral triangle = 60°

Plan: \[ F = k \left( \frac{|q_1||q_2|}{r^2} \right) \]

\[ k = 8.99 \times 10^9 \text{ Nm}^2/\text{C}^2 \]

\[ F_{\text{net magnitude}} = \sqrt{F_x^2 + F_y^2} \]

Estimate: Large answer, unit of newtons

\[ (8.99 \times 10^9) \times \left| \frac{5.1 \times 10^5}{3.7} \right| = 1.71 \text{ N} \uparrow \]

Solving for Force between particles 1/2 using Coulomb's Law. Because both charges are positive, particle 1 is repelled in the positive y direction. Since there is only one direction for this vector, it is by default the magnitude.
Part B: \[ \text{Free body diagram of particle 1} \]

we already know the force vector on particle 1 by particle 2 is 1.71 \text{ N} along the force vector on particle 3, and add the vectors to find the net force.

\[ \overrightarrow{F_{12}} = 1.71 (\cos 30^\circ) \text{ N} \hat{x} + 1.71 (\cos 60^\circ) \text{ N} \hat{y} \]

\[ \overrightarrow{F_{13}} = 1.71 (\cos 30^\circ) \text{ N} \hat{x} + 1.71 (\cos 60^\circ) \text{ N} \hat{y} \]

\[ \overrightarrow{F_{\text{net}} = F_{12} + F_{13} = -1.48 \text{ N} \hat{x} + 2.57 \text{ N} \hat{y}} \]

Now, we find the magnitude of the vector by using \[ \sqrt{F_{x}^2 + F_{y}^2} \]

\[ \sqrt{(-1.48 \text{ N})^2 + (2.57 \text{ N})^2} = 2.97 \text{ N} \]

Discussion: Because all of the charges were identical, Coulomb's Law only needed to be used once. The part that was tricky was the fact that \( \mu C \) were used in the original, so they needed to be converted to C. Also, basic geometry was needed, as the angles of the equilateral triangle are all 60°. This was needed in order to find the components of \( \overrightarrow{F_{13}} \).
APPENDIX G - Poor Example of A Homework Problem Solution

17) a) \[ F_2 = K\left(\frac{q_1q_2}{r^2}\right) = 8.99 \times 10^9 \left(\frac{2.8 \text{ mC} \times 2.8 \text{ mC}}{1.8 \text{ m}^2}\right) = 2.175 \times 10^4 \text{ N} \]

b) \[ F_1 = K\left(\frac{q_1q_2}{r^2}\right) + K\left(\frac{q_2q_3}{r^2}\right) = 8.99 \times 10^9 \left(\frac{2.8 \text{ mC} \times 2.8 \text{ mC}}{1.8 \text{ m}^2}\right) + 8.99 \times 10^9 \left(\frac{2.8 \text{ mC} \times 1.8 \text{ mC}}{2.01 \text{ m}^2}\right) = 3.92 \text{ N} \]