Syllabus Physics 21, Fall Semester 2020

https://lehigh.edu/inphy21/

Lecture
Remote **Asynchronous**,
with **synchronous Q&A meetings** during the official class times
Tuesday and Thursday, 10:45-11:35

Recitations
Remote **Synchronous**
Wednesday and Friday, various times

Instructor

Prof. Ivan Biaggio, LL 407
phy21@lehigh. edu
Office Hours: Before each lecture starting at 10:00am, during each lecture time, plus other times to be determined.

Recitation Leaders / Teaching Assistants

Christopher Angyal	Joseph (Zhiyu) Jiang	Jing Su	Andrew Venzie
cka217@lehigh.edu	zhj216@lehigh.edu	jis614@lehigh.edu	adv319@lehigh.edu

Your primary contact should be your recitation leader, a.k.a your teaching assistant (TA). If you have questions or need more help with an assignment, ask during recitations, or get a meeting with your TA. Office hours will be set independently. Your professor's office hours are given above.

Ask questions, we are here to answer them. But do not just ask something like "can you give me some hints about this problem?" The most efficient way to ask questions is to always first try yourself, determine the places where you have difficulties, and then make a list and come ask questions about those. Remember that in this class there will be many things that cannot be codified in simple rules and recipes. So ask questions about anything that seems strange.

In-person meetings

These are extraordinary times, but keep in mind that even though we do remote classes, we are not remote. We are right here on campus. We started by planning the zoom meetings, but we can also make ourselves available for in-person meetings. Such meetings can be one-on-one while wearing masks and maintaining the appropriate distance, and we could also arrange group meetings in large enough classrooms so that social distancing can be enforced at all times. We will talk about such opportunities going forwards. Drop in into zoom meetings during office hours, and email to enquire about in-person meetings.

Initial Competences Required for this course (what you should know already)

How to describe and predict, quantitatively, the movement of bodies in terms of the forces acting on them. Vectors and how to use them. Ability to write and solve algebraic equations. Familiarity with derivatives and integrals, and ability to write and use integrals. Knowledge of the simplest differential equations.

Course contents (what we will teach in this course)

Electric and magnetic fields, their origins, and their effects. How those fields arise, and what they do to electric charges, electric currents, and to each other. The origin of electro-magnetic waves, how they relate to light, how light propagates through systems consisting of lenses and mirrors, and how images are formed. How electric circuits work. What happens when one uses conducting wires to connect together such elements as "resistors", "capacitors", and "inductors" in various configurations, and then sends an electric current through them.

Competences expected after this course (what you will be able to do when done)

After this course, students should be be able to quantitatively calculate electromagnetic fields in some simple situations. They should know about the origin and properties of the speed of light, and they should be able to analyze both conceptually and quantitatively simple situations involving charges, currents, electric fields, magnetic fields, resistors, capacitors, inductors, electro-magnetic waves, light, and the phenomena of electromagnetic induction, diffraction, and interference. Students will be able to derive algebraic expressions that allow to calculate the value of physical quantities as they are determined by other physical quantities in specific situations. For example, students will be able to calculate, algebraically and numerically, the magnitude and direction of a magnetic field at a certain point in space when given the values and the coordinates of specific current distributions, or the time dependence of an electric field. As another example, students will be able to design a system that uses lenses or mirrors to form the image of an object, and to determine the light intensity pattern on a screen as it is affected by diffraction or interference. Students will be able to quantitatively determine the currents and voltages that will appear over various circuit elements as voltages are applied, currents are forced through the circuits, or switches are flipped.

CLASSES

Plan for four 1-hour sessions every week for Lectures and Recitations. All Lectures are remote and asynchronous, but your Professor will be available during official class times on Tuesdays and Thursdays via zoom. Go to coursesite and view the corresponding lecture **BEFORE** you then attend the class meeting to discuss and ask questions about what you viewed. All student then meet in smaller groups with their TA on Wednesdays and Fridays, synchronous meetings via zoom. Lecture times are at 10:45am in LL270. Check the time or your recitation section.

REQUIRED MATERIALS AND CLASS ACTIVITIES

Course website
A quick access point to all you need is at http://www. lehigh. edu/inphy21/, with a summary of how this course will work, instructions on how to sign up for *masteringphysics,* and a link to this syllabus.

CourseSite
Class material is available there.

Textbook
Randall D. Knight, "Physics for Scientists and Engineers: A Strategic Approach", 3d Edition,
We will cover chapters 20 to 37, available in the paperback as *Volumes 3 and 4*.

Note that this is an older edition, allowing you to get pre-owned printed books for cheap. Our course will cover the same material as in chapter 20 to 37 of the textbook, *but not in the same sequence*. In addition to this textbook, there are also plenty of free resources online, see for example https://openstax.org/details/books/university-physics-volume-2 (unit 2), or http://www.humanismweb.net, or even https://www.feynmanlectures.caltech.edu/II_01.html.

This course will use *masteringphysics* for homework assignments, and you must specify the above textbook when signing up (see below).

Mastering physics
Online homework assignments, must be submitted twice a week, on Tuesday night and Thursday night. You must sign up for the masteringphysics that is attached to correct edition of Knight's textbook (see above). For instructions on how to sign up, go to http://www. lehigh. edu/inphy21/. Note that if you want you can also sign up for access to the electronic version of the textbook.

Class Plan
On coursesite: It lists when each activity takes place, when each topic is taught, and where it is found in the textbook.

Lecture summaries
On coursesite: I'll be posting typeset summaries of each week of lectures. You **must** read them.

Learning homework
On coursesite: Weekly homework assignments that are meant to stimulate critical and creative thinking and to provide a different way to learn a subject by working on it. This is an important complement to *masteringphysics*. Don't do them because of the homework points they allow you to collect. Do them for the training and understanding that you receive from them, or at least study the solutions (see below).

Full, detailed solutions of each learning homework
On coursesite: These are teaching solutions, going into details of the particular problem, with additional information and explanations. You must read them even if you happen to not have done the corresponding homework.

Quizzes
Every week during the Friday recitation that will be a short quiz, mostly on topics that have just been taught or discussed in past homework. It serves to check your progress and highlight some questions that can then be discussed in recitation.

READING MATERIAL
There are several resources that you can use to help you along. The class plan posted on coursesite details the material that will be discussed in every lecture, and the corresponding sections in the textbook. I will also post my own short class summaries of the material that is presented every week. In addition, I will provide a full, detailed solution of the Learning Homework, and I also have some notes about the solutions to masteringphysics problems. Sometimes solutions will go beyond what was asked in the original problem, providing more explanations on related topics.

You must make sure you read the textbook, the weekly-summaries, and the homework solutions. Reading assignments are an integral part of the course

HOMEWORK ASSIGNMENTS AND QUIZZES
On-line Homework (MP)
Masteringphysics will allow you to practice and review the material as it is being taught, and it is the system that lets you collect the largest amount of points towards the final grade. A new homework assignment will be made available on masteringphysics by each Tuesday (**MPa**, due Thursday night) and each Thursday (**MPb**, due Tuesday night the next week). Every MP homework counts on average more than *8 points*, for a total of 16 points each week. You don't need to answer every single questions to get the maximum amount of HW points.

Have a quick look at each assignment the day *before* recitation, so that you can ask questions if you don't understand a problem. **MPa** (the Tuesday homework) must be submitted on-line *two days* later by Thursday at midnight, so that its solution can be discussed on Friday. **MPb** (the Thursday homework) must be submitted on-line *five days* later by Tuesday at midnight, the following week, and its solution will be discussed in recitation the day after. The submission deadline is strict. The system does not allow for late submissions and late submissions won't be accepted.

Learning Homework (LHW)

The purpose of the learning homework is to stimulate critical and creative thinking and to provide an additional way to learn a topic. The aim is not even necessarily to obtain a full solution. The aim is often to try to solve the problem, but get stuck somewhere, fail to solve it immediately, but then use the experience to generate more questions and more understanding. This provides an alternative to the shorter masteringphysics problems that often give the impression that there is just a recipe that one must know. Such recipes do not exist for real problems! LHW assignments provide both open questions and more explanations about their topics. Use them for discussions and to generate questions and answers. For each LHW, thing first about what it is asking, what are the physical effects that come into play, and put together all ideas that you think might be useful for developing a solution. Start working on a solution only after you have done that.

LHW assignments will require to hand in solutions in **two steps**. First, you hand in a *short narrative* in English describing what you see as the physical principles that are at play in the problem, and the steps you intend to take towards solving the problem, but without any calculations. Then, a week later, you hand in a *final solution*. This is designed to help you develop problem solving skills and to stimulate discussions and questions. The most difficult part about physics is to integrate what one learns in a way that one can then analyze physical situations such as those described in homework assignments. And so when working with LHW assignments we will try to explicitly separate the important problem-solving step of analyzing what is going on and determining a way towards a solution, and the second-step of actually working through a solution.

A learning homework assignment will be posted on coursesite at the beginning of every week.

The *short narrative* must be submitted by Thursday night, so that it can be discussed in recitation the next day. This gives you a few days to think about it and ask questions. You will get your narrative back bt the following Wednesday. But in the meantime you can keep working and start developing the mathematical portions of a solution.

The *final solution*, must be submitted as a PDF scan of your work by Thursday night the week after. (one week after you submitted the narrative). Once the semester is on its way, you will regularly submit, by each Thursday night, the narrative for the new LHW, and the solution for the LHW from the previous week.

Use the fact of giving your recitation leader a PDF scan of your work to also add any written questions you might have!

The narrative and final solution will be graded on a scale from 0 to 4 points, delivering *8 extra homework points* per week that will count towards the total homework points mentioned above. Late homework will not be accepted.

Detailed solutions of each LHW are added to coursesite at the beginning of every week, together with new assignments. LHW solutions often go beyond what was asked. You must read the solutions and compare them to what you did. It is not the responsibility of the grader to go through and find all your mistakes for you. Going through the solutions yourself and comparing to what you did is a very important and helpful way to learn the material.

If you find somewhere somehow a solution of any homework assignment, **do not use it**. Using it robs you of the opportunity to learn from problem solving practice and from understanding what is going on. The fact is that we learn by struggling to do something. You need to struggle to do something in order to the understand it better. Do not look at the solution before you try to do this. Also, if you find such a solution and you copy it, do not submit it. Doing so would waste the time of your TA, it is disrespectful, and goes against academic integrity. But most importantly, it is a waste of *your time* to just copy down a solution.

Note also that the LHW assignments and their solutions are still useful, even if you were to choose to not submit your work. But then you should do what you must always do with the solution of a physics problem: look at it, see if you understand it, look up everything you need until you understand it. Then hide it somewhere, take a new sheet of paper, and try solving the problem based on what you remember.

Quizzes

There will be one short quiz every week during Friday's recitation. Of all the quizzes, only the best 70% will count towards the 75 Quiz points that contribute to the final grade. There won't be any make-up quizzes.

A TYPICAL WEEK

w i, day 1	Tuesday	Submit **MPb$_{i-1}$**	**MPa$_i$** available	**LHW$_i$** available
w i, day 2	Wednesday			Discuss **LHW$_{i-1}$, LHW$_i$, and MPa$_i$**
w i, day 3	Thursday	Submit **MPa$_i$**	**MPb$_i$** available	
w i, day 4	Friday	Hand in **LHW$_i$** narrative	Hand in **LHW$_{i-1}$**	**Quiz.** Discuss **LHW$_i$ and MPb$_i$**

EXAMS

Exams are closed book, but an equation sheet will be provided. You don't need to memorize any complicated formula. When doing paper exams, I allowed people to add handwritten notes between the line of the equation sheet. I still suggest that you do it if you want, because it may help you. If you do it, upload your modified equation sheet together with the exam.

Mid-Term Hour Tests

There will be two hour-tests that should take place according to the plan issued by the Registrar's office. There won't be any make-up tests. If you miss a test because of an accident or illness documented with the office of the Dean of Students, you will be able to substitute the grade for the Hour Test you missed with the partial grade obtained in the corresponding section of the final exam.

Final Exam

There will be one comprehensive final exam. The date and time of the final exam are set by the Registrar.

COURSE GRADING

The final grade of the course will be determined from the total number of "points" collected by the students. These points are obtained in the two hour tests, the final exam, homework, and quizzes as follows:

Exams	300	(60 each from the two hour tests, and 180 from the final exam)
Homework	150	(accumulated by adding homework points up to a maximum of 150)
Quizzes	75	(obtained from the grades of the best 7 quizzes)
Total	**525**	

Additional extra-credit points that can also contribute to the above total will be given based on attendance and participation in the zoom meetings for recitations and lectures, at the discretion of recitation leaders and lecture instructor, but they will be limited to a maximum of 50 points.

The 300 exam points, as described above, will be determined by adding the points obtained in the two hour tests and in the final exam. The two hour tests together contribute a maximum of 120 points, and the final exam contributes a maximum of 180 points, for a total of 300.

ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES

Lehigh University is committed to maintaining an equitable and inclusive community and welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact Disability Support Services (DSS), provide documentation, and participate in an interactive review process. If the documentation supports a request for reasonable accommodations, DSS will provide students with a Letter of Accommodations. Students who are approved for accommodations at Lehigh should share this letter and discuss their accommodations and learning needs with instructors as early in the semester as possible. For more information or to request services, please contact Disability Support Services in person in Williams Hall, Suite 301, via phone at 610-758-4152, via email at indss@lehigh.edu, or online at https://studentaffairs.lehigh.edu/disabilities.

THE PRINCIPLES OF OUR EQUITABLE COMMUNITY

Lehigh University endorses The Principles of Our Equitable Community [http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf]. We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.

A NOTE ON ACADEMIC INTEGRITY

Academic integrity applies to all we do. See the links in the top-left corner when you enter coursesite, which opens some slides/vignettes. Don't cheat on exams or quizzes, don't copy homework assignments. Taking care of academic integrity works to your advantage. When doing homework, some nice discussions among friends are always a good way to learn, but do try to also work on the assignments alone. Always relying on help from others will work against you because it will not allow you to identify the areas where you have more difficulties.

Lehigh University Undergraduate Student Senate Statement on Academic Integrity

We, the Lehigh University Student Senate, as the standing representative body of all undergraduates, reaffirm the duty and obligation of students to meet and uphold the highest principles and values of personal, moral and ethical conduct. As partners in our educational community, both students and faculty share the responsibility for promoting and helping to ensure an environment of academic integrity. As such, each student is expected to complete all academic course work in accordance to the standards set forth by the faculty and in compliance with the University's Code of Conduct.

HOW THE VARIOUS ELEMENTS FIT TOGETHER, AND OTHER GENERAL COMMENTS

What is this really about?

Many different students take this course. Some of you may be interested in physics. Some of you may have to take this course as a prerequisite and don't see the reason why. Some of you may hate the fact of having to take physics. Others may love it. Maybe you will encounter some problems (especially as part of the learning homework) that seems to be too esoteric or appear to be totally useless to you. Or you may find problems that seem too easy or boring. There may be some of you who will only be interested in their grade, or a few who don't care too much about the grade but just want to be done with this course and move on to other things. Some others will be happy to learn something about how the universe works, others won't care, and others still will love physics.

Because of the diversity of interests in the students taking the course, we need to cover all backgrounds. What I will try to do with this course is help everyone, no matter what their aim is: give something to the physics lovers to go beyond what's in the standard textbooks, while not bothering the other students too much. Provide a structure that allows to get a decent grade even if you are not a physics fan – if you are willing to do the work. But most of all, the important question is what will remain after the course is over at the end of the semester.

Part of what is developed during this course is the ability to *calculate* and *solve problems*. This is a valuable skill that will be useful whatever you do in the future. Such a skill is built through *practice*. It is the same as in music or in athletics. Practice is what allows you to master something, and developing problem-solving skills requires doing many problems, alone. There is no other way. We help you to do this by providing homework assignments and discussing them with you.

Another part of what is developed during this course is the *knowledge* of some things that happen in the universe and an *understanding* of how they work. Or how one can use them to do something new. This kind of understanding and knowledge is achieved only when one acquires the ability to see how various things related to each other. Imagine that what we will learn is represented by some big photograph. It is possible to go through a course like this one and only do the equivalent of analyzing some selected clusters of pixels and their colors. But true understanding is only reached after you are able to take a step back, see the whole picture produced by all pixels together, and learn how different parts relate to each other. It is important to achieve this ability to see the whole picture, while at the same time we work on some details by zooming into it. This is what is very difficult to achieve by just reading a textbook sequentially, and where my role in the lectures and in the design of the course comes in. By stressing the ***fundamental qualitative principles*** of the physics we are teaching I will take a spotlight and illuminate the various parts of the picture and guide you through it. Tell you how some physical effects are related to each other, highlight which parts of the textbook are really important, and help you distinguish them from the parts that are just additional descriptions or examples.

The ultimate aim is not just to be able to solve problems in a test. It is to obtain some background knowledge and some work habits and strategies that will be useful for you later on.

The work that needs to be done

It is important to realize that this is a fast-paced course which does require a lot of work. *The rule of thumb is that for every credit hour you need to work three credit hours on your own.* This course is a 4 credit course, and therefore it is totally normal and expected that you work an additional 12 hours a week to learn all the required material and keep up with the coursework. It is critical that you digest the material presented during one week before the next week starts.

The material to be learned in this course will come from multiple sources (lectures, recitations, textbooks, homework, reading-assignments). Lectures on Tuesdays and Thursdays will serve to introduce new concepts and as a guide to the connections between different topics. They will also highlight the most important ideas. Examples will be discussed in Recitations, where you ask questions, and exercise problem-solving. Homework assignments solidify what has been introduced in lectures by allowing the students to apply the concepts and techniques they just learned.

Do not just read the textbook, do not just come to class: this course is designed for you to learn the material through a combination of reading, attending classes, and the practice in problem-solving that you get by doing the weekly homework assignments. *The lecture and the other activities are integrated. I designed how the material that you will learn is transmitted to you via lecture, recitations, reading assignments, various kinds of homework assignments, the corresponding solutions, and the examples discussed in class*.

Therefore, to profit from this course you must do everything. Sometimes it is useful to introduce a new concept in a homework, other times this happens in a reading assignments or in class. Sometimes there is a deeper explanation of a particular technique in the solutions to the "learning homework". Sometimes we calculate through an example in class, but often you should do your own math, working through examples outside of class. Our limited class time is better used for explaining and connecting concepts instead of detailed number-crunching.

At the end of the course, **students will be expected to know the material that is exercised in the homework and that is presented in the corresponding chapters of the textbook even if it is not explicitly discussed in class**. It is worth stressing that, given the time-constraints, it is impossible for me alone to tell you in lectures everything that you need to learn, but I can guide you by highlighting the most important things.

SOME ADDITIONAL ADVICE

You cannot learn physics without doing lots of independent homework, in particular problem solving. It's the practice of using the concepts that makes you learn and understand them.

Practice problem solving

Getting into the habit of needing "hints" or any other initial help on a homework assignment before trying to do it yourself **is the absolute worst thing you can do**. The most difficult part of solving a problem is finding the right path to work through it. That's what you need to exercise (the *narrative* that is part of the weekly learning homework is meant to help with this).

The basic trap many people fall into because of various reasons, including former training and the way people are tested in school, is the big bear trap of thinking that knowing the material is equivalent to solving the standard problems, with the associated belief that in order to solve a problem one needs to find and use a particular formula.

This doesn't work. This has never worked. The very first thing you need to do to solve a problem is visualize it, **make a sketch** of what is going on, or what you think may happen, decide what basic principles can be used to understand the issues, set up some basic relationships, *and then, once you have an idea about what to do*, start thinking about equations. Equations are the mathematical description of a *relationship*. Don't look for formulas with the thing you are interested in on the left-hand side. Also, when solving any problem use algebra for as long as you can. At the end you will get a formula that represents your solution, but it will be an algebraic expression that you derived yourself. Only plug-in numbers at the end.

Lecture plan and textbook

My advice is not just to read a textbook sequentially. Instead,read questions or summaries, and then keep going back to the textbook over and over again to look at explanations and details. Read the questions at the end of the chapters, and then go back to look for information based on what you can answer and what you can't. In this class I will follow an optimized path through the material, described in the plan made available on coursesite. This path has been designed to highlight the relationships that may not be seen just by following the textbook sequentially. A counterintuitive advantage that follows from this is also that the reading assignments will not be necessarily sequential, which will help you access the book in an efficient way, and get a feeling of the different ways each topic or physical effect can be associated together. This will in turn be very helpful for general understanding, and will make you better at solving problems because it trains you in seeing relationships. But in addition to the textbook, do also consider any other source material that you can find, from openstax, to wikipedia to anything else that you might find useful (see the last section below).

Homework points that count towards your grade

Homework points can be collected towards the *150 homework points* that count for the final grade. Do the math: two MP assignments each week of at least 8 points each give (at least) *16 MP points per week*. Over 12 weeks this already gives 192 points. In addition, the LHW provides up to 8 points per week, that is up to 96 points over 12 weeks. So you can collect up to 288 points per week thanks to both MP and LHW homework, but you only need 150 to maximize the homework contribution to the final grade. But in addition to this, the MP assignments will always be some short questions to quickly collect points, and I will also generally provide more than 8 points for each MP assignment. This means that it won't be an issue if you miss out on one homework because you are sick or because of any other problems, and it also means that you don't have to stress to do every single problem or question that is offered in each weekly homework assignment!

Note that the LHW counts towards only 8 of the 24 (or more) weekly homework points you can collect. You should do it because it is promotes understanding and discussion, and will help you in the long run. So it is not a big deal if you don't solve it all, but you must try to do as much as you can, and there will be solutions to discuss! Some LHW will have some more challenging parts that are attractive to the most interested students, but they are also useful as review materials and alternative explanations for all students d.

Copying

In addition to the academic integrity issues, copying your homework is a guaranteed way to *not* learn the material and to get a bad final grade. And **don't go look for "hints" about solving problems. You must exercise finding your own way to the solution of a problem.** There are no "hints" in exams on in real problems you may face later on. If you go to tutoring ask a tutor if you need help in understanding what the homework is about, but try doing the problems alone first!! Going to a tutoring class where they give you a recipe for solving a problem that let you skip the step of actually finding the way towards a solution will leave you with only the math to complete. This is bad because then you don't train problem-solving. Working like this defeats the purpose of doing homework and will work against you in the tests and in anything else.

Also, I must underline that I don't want to be responsible for trying to impede you from going out and finding old versions of homework that come with solutions, or some other pre-made, pre-canned solution. But you **will** be worse off if you do it. Same story: if you do that, you will not learn problem-solving, you will miss important practice, and you will not learn the material. If somebody gives you an old version of a homework with solutions, throw them away or store them for future checks, and try to attack the problem yourself first. If you have troubles, look for info in the textbook, describe your difficulties to your TA, come ask questions.

Additional ways to help you learn

To develop a general understanding where relationships between sub-topics start to emerge, it is necessary to develop an understanding of how things "work" in general terms, of how different effects are related to each other, or can be described in a similar way, etc. I will try to give an intuitive feeling in the lecture whenever I can, but you should also look for other sources beyond our classes or the textbook. You can find lots of things just on the web. Or there are popular science descriptions that will give you a good background about what we will do without using a single equation. There are many resources like this, from newspaper or magazine articles to books. As an example, a cheap, short, well-written booklet that you can look at is Asimov's *"Understanding Physics: Volume 2: Light, Magnetism and Electricity,"* which is available for something like $5 (check on-line).

How to practice physics

In many areas, it has been shown how "deliberate practice" can be essential, and the following is what I think is a good way to do physics practice in a similar way. Clearly, everyone needs to find their own way, and some things may work better for you than others. But the suggestions below should still be useful.

I suggest **four activities** that all start by looking at old questions and problems. These activities can be done while studying, or in addition to anything else you normally like to do. Which one of these activities you keep doing depends on your personal needs. Here a list, ordered according to the time they require, from least time to more time:

1. Look at old questions/problems and see if you understand the question. If you don't, or if there is one work you don't understand, look up the material in the textbook and check what it is that you are missing.
2. Look at old questions/problems and see if you understand what are the physical principles that you could use. If you cannot do this, look up the material in the textbook and find out what you are missing.
3. Look at old questions/problems and see if you can plan how to solve them without actually doing so. If feel you are missing something, or you are confused about which path to take, look up the material in the textbook or elsewhere. At this stage, if you don't plan to go to try to (4), you can check the solution.
4. Look at old questions/problems and solve them. If you encounter problems along the way, go back to the textbook and other similar examples to see where the difficulty is. Once your solution is done check it against the solutions that are available. See if you did it right. Understand your mistakes, and why you made them, or what the correct way would have been. Go back to textbook or other materials to get help.

The idea is to build up from (1) to (4), but to do (1) quickly many times before doing (2), and then do (2) many times before doing (3), and so on. This method is a more efficient use of time: it is better to dedicate some whatever available time you have to look at more problems as described in points (1) to (3) without calculating a full solution, when compared to the alternative of always trying to solve a problem. Because the latter automatically means that you can look at fewer problems. Using this method will also ensure that you are not missing out on some important piece of knowledge or definition. To implement these steps, use the conceptual questions in the book, use the any of the problems there, use the additional exercise packs, or use old learning homework assignments and their solutions.

Here what I expect to happen: at the beginning, if your knowledge of the material still needs to be built up, you will find yourself doing point (1) over and over again. Keep doing (1) until you don't need to go back to the textbook or other material anymore and then move to (2). Students with less knowledge-gaps will move quicker to (2). Keep doing (2) until you see that you don't need to go back to other material anymore. Then do (3) and see if the plan you come up with is the one that makes you confident that you can work this out, and exercise doing (4) for some problems.

Once you are further along in your studying, doing points (1) or (2) will take no time at all, and doing point (3) will also become faster.

Note that this is not about doing less problem solving (point 4). It is about doing the same amount of problem solving, but then *deliberately* building up the skills that are part of points (1) to (3) and that are often neglected when studying because standard solutions often focus too much on the math and too little on the physical understanding that allows to arrive at the correct algebra in the first place.

Important: The above only works if you try to answer those questions, and do those problems by yourself. Only after you have tried by yourself (in the variants described in points 1 to 4 above), go seek help or maybe do some of the activities with a colleague. But you can't find out about what you really do not understand if you do not exercise facing those challenges alone.

Naturally, the activities listed above also serve as a springboard to dive into the book (and any other material that helps you), which, as I am sure I already said, is much better than just reading the textbook sequentially.