How To
Give College the Old College Try

by Michael Kupferschmid

"The old college try" is a colloquialism used to describe one's very best effort to perform a difficult task.

Disclaimer.

The suggestions in this document have been helpful to students in the past and are offered here in the sincere hope that they might be helpful to students in the future. They are, however, merely opinions of the author, and if you follow any of them it will be *on your own initiative.* The author offers no guarantee that his advice will be helpful to anyone, and you take it *at your own risk.* He disclaims liability for any adverse outcome that might result, including but not limited to the following: bad grades, disciplinary action by a university, monetary loss, damage to reputation, anxiety or nervous breakdown, and wasted time.

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Introduction

Some of the ideas in these chapters are simple common sense that you probably already know, while others were suggested by my experience as a student or as a teacher and might never have occurred to you. I studied engineering and mathematics and later taught courses in those subjects so that is the perspective from which I write, but much of the advice could apply to other majors as well.

I currently teach a course over Zoom, so I want to begin by discussing a few issues that are unique to remote learning.

Speak only when it is your turn. In normal conversation it is possible for several people to talk at the same time and still be understood, or for one person to interrupt another, but doing this on Zoom yields gibberish. Normally your microphone should be muted. Plan what you are going to say, wait for the current speaker to pause, press the space bar to temporarily unmute yourself, and say just what you had planned. Avoid introducing placeholder sounds like "uh" and "um" or mumbling to yourself during or after what you want the others to hear, because this prevents anyone else (such as the instructor) from getting a word in edgewise. Try to minimize the background noise that gets picked up when you unmute to speak. If you are using a Windows computer, to avoid feedback you should disable the option that plays back your own microphone's audio through its speakers; see `https://www.zoom.com/en/blog/troubleshooting-audio-feedback-zoom`.

Show your face. Your instructor uses visual cues to decide whether you are understanding the lesson or not, and might subconsciously read your lips to help understand what you are saying. Displaying a picture instead, or focusing the camera at the ceiling, signals to everyone that you do not wish to participate in the class.

Give your undivided attention. You might need to absent yourself from Zoom briefly for the same reasons that you would temporarily leave an in-person class, but watching television or preparing lunch during class is an insult to the people who are actually engaging with the material. It might or might not be appropriate to *eat* lunch during class, so you should ask the instructor before you do.

Take notes as you would in an in-person class. Even if the zoom session is being recorded and you will watch it again, it is worthwhile to take notes for all of the reasons that are outlined in Chapter 2. If the instructor shares the screen to display text or pictures, try to get a hardcopy of that material ahead of time to follow along with and mark up.

1

How To Be a College Student

Motivation. To master any significant body of knowledge is hard, so you will succeed only if you're convinced that it's really worth the work. Most students are motivated by the prospect of finding an interesting job and earning enough money to have a decent life after graduation. Many students are motivated by the fun and excitement of learning new things. Some students are motivated by the challenge of succeeding at a difficult task. A few students are just determined not to disappoint their parents. Think carefully about your deepest personal reasons for going to college, and periodically remind yourself of them. If you keep the ultimate reward in mind, it will be easier for you to sustain the effort required to earn it. If your only real motivation for going to college is to have fun and meet people, you should really stop reading now and begin doing exactly those things instead.

Background. Many students at a selective college arrive exquisitely prepared. That means that even if you were a very good student in high school you might be missing some of the skills that your classmates have. If you are offered advanced placement, *decline it.* High-school courses are much easier than college courses having the same names, so you need to learn the material again. In the unlikely event that you find a course easy, keep working at it anyway to improve your grasp of the subject. If you find that you lack the background expected in a course, *get help* right away from your instructor or learning assistance center.

Planning. Meet with your academic advisor to work out an official Plan of Study. This will ensure that you take prerequisites before you need them and satisfy any complicated technical requirements for graduating on schedule. To do this you will need to decide on an academic major, so if you are uncertain you need to shop around right away and make up your mind. Interview faculty and seniors in programs you are considering, to find out what their work is like, and search the web for information on the occupations for which graduates are qualified. Waiting to pick a major, or changing your major after a year or two, will probably require you to take extra courses and delay your graduation.

Focus. Many people get along by default through high school, without making any important decisions for themselves. Now you must adopt a more intentional and deliberate way of life. You are embarking upon a huge investment of time, effort, and money for only one reason: to successfully complete your degree program. Build a little play time into your schedule for the sake of your mental health, but prove that you can handle the school work *before* you get involved in television, video games, music, sports, clubs, a fraternity, or an extensive social life. Most students need to focus exclusively on academics at least until their second or third semester, and very few can maintain good grades unless they continue to put

work first and play second. Go to class, study, learn, and monitor your grades so that you always know how you are doing in every course. Meet all of your professors and teaching assistants in person. Start collecting textbooks and class notes for the reference library that you will need as a professional. No, it is not all on the web.

Order your life. Put sleeping, eating, bathing, doing laundry, getting your hair cut, and the other overhead functions of your life on a regular schedule that doesn't interfere with your work. Having these things on autopilot will let you concentrate on school. Sleep at night, no less than six hours per night. Develop a reliable system for keeping track of all your commitments and managing your time, such as logging your activities in a computer file and keeping a list of tasks you must accomplish ordered by due date. Your life at college will be too complicated to keep in your head, and knowing that your schedule is under control will help you to relax and enjoy the ride.

Manage your personal growth. In your coursework and socialization you might encounter assertions and ideas so different from anything you already knew that it feels as though accepting them would make you into an entirely different person. Someone who exclaims "That's just so not *me*!" is expressing this sort of discomfort. Skepticism is a healthy instinct, especially in academia where ideology sometimes colors the wisdom that is on offer. You should certainly guard your moral integrity, and you should reconsider your philosophical convictions only in the face of compelling argument.

But some unfamiliar assertions really are facts, and many unfamiliar ideas are worth considering. The act of learning modifies the neural connections in your brain, so *it cannot happen without changing you.* Studying any subject can make you good at it even if you were never good at it before, but only if you permit that change to take place. As you encounter each challenge to your ignorance or preconception, make a conscious decision about how welcoming of it you will be.

Get a whole education. Professional training prepares you to make a living, but to make a life requires cultural literacy and interpersonal skills as well. A liberal arts education prepares you to make a life, but to make a living requires practical skills sufficient to a career. If there are gaps in either part of your formal education, try to fill them by choosing elective courses outside of your major and by seeking life experiences that will broaden your knowledge. Pay more attention to the fundamental and permanent in whatever you study and experience than you do to the superficial and transient.

Education is a lifelong project, so the most important thing you will learn in college is how to learn on your own. Chapters 3 and 6 of this book are about skills that are key to that objective.

2

How To Attend a Class

Show up. Each credit you register for is costing someone a lot of money in tuition, so you're throwing away many dollars every time you skip a class. You will learn things by reading textbooks and doing homework, but most of the course will happen in class and you will earn most of your grade in class. Sleep at night, so that you can be alert for your morning classes. Some teachers are better than others, but you can learn from all of them if you try. Show up every time, on time, even if you don't much feel like it. If some compelling reason makes it impossible for you to attend a class, see the instructor ahead of time or as soon as possible afterward to get a copy of the class notes and handouts. Here are some reasons that might be sufficiently compelling to make you miss a class.

- University policy requires it because you have tested positive for an infectious disease.
- Your attendance is required at the funeral of an immediate family member.
- Your observance of a religious holiday requires you to be elsewhere.

Meet people. In many courses it will be necessary to work with your classmates in teams, and you might get to pick your teammates. In every course it will be helpful to know your classmates so that you can help each other learn the material. Get to know as many of them as you can, as soon as you can.

Be polite. Turn off your cellphone and any other personal electronics you are carrying, except for a computer if using it is part of the class. Never record a class without permission. Participate in the class, but don't interrupt the instructor or have private conversations with other students.

Take notes. Pay attention to the instructor and the other students, and to what you think in response to them, and write it down on paper in a form that will be useful to you later. Summarize in your own words what the instructor says and writes, rather than just taking dictation or copying verbatim. This process of taking notes will help you understand and remember the material that is being presented. You will want to study your notes when you review the material, so make them neat and orderly. Use a pencil, and bring a big eraser so that you can make corrections without crossing things out. If you are worried about the pencil blurring when the pages rub together, use thin HB leads instead of wide #2 ones. Read the class handouts, and add notes to them. You will want to integrate your class notes chronologically or by topic with the many handouts that will be distributed, so punch everything (don't just poke holes in the pages) and use a looseleaf binder (*not* a spiral notebook and folder) to hold and organize all of your papers for the course.

Ask questions. You can't take useful notes if you aren't understanding the material, so if you don't follow what the instructor is saying or writing raise your hand and ask a specific question about it. If you are not getting it, probably many other students are not getting it either, so nobody will think you are stupid for asking. If the students are not getting it, the instructor wants to know, so he or she will be grateful to you for asking.

Answer questions. The instructor will ask questions of the whole class, which anybody can answer, and might also ask questions of you individually, which you should try to answer. Take a moment if you need to think over the question before answering. The instructor will wait until it seems clear that you're not going to get it before asking somebody else. If you get the answer wrong, the instructor will just give another student a chance. There is no penalty for giving a wrong answer in class.

Work! Learning new things is exciting and fun, but if it does not also seem like hard work then you are not working hard enough. Try to develop your ability to focus on the task at hand, and always be asking yourself "What should I be doing right now to get the most I can out of this class?" Even good students can get to be much better by consciously trying to improve.

3

How To Read a Textbook

Get the book. Some courses have no textbook, but if your instructor went to the trouble of choosing one then you're probably going to need it. In most courses you will be expected to learn, by reading the textbook, some material that is never even mentioned in class. Some college textbooks are useful in more than one course, and for reference after graduation. Used books cost less than new ones and are suitable if they are of the right edition and have not been marked in. If you are using a book that has been marked in, or that you share with other students, it will be difficult to do your own highlighting.

Study the table of contents. Parts of the book other than those assigned might turn out to be useful too. Look over the whole book so you know what's in it. Figure out how to use the index.

Read before class. Do each assigned reading *before* the class in which that material is discussed. That will make it easier to follow the instructor's presentation, and allow you to ask questions in class about the reading. This *first reading* can be rather casual, just passing your eyes over the words and figures so that you know what is being discussed and how the material is organized. Don't make any marks in the book this time.

Reread after class. After the class, reread the relevant pages. This *second reading* should be much more careful than the first one. Have pencil and paper handy so that you can figure out missing steps, verify results, and make notes, but don't put any marks in the book this time either. What story is the author trying to tell? In your head, as you are reading, try to rephrase it in your own words. Are there parts that seem to be missing, or that don't fit together? If there is anything you can't figure out or don't understand, write down questions and plan to get help finding the answers. Other students can often help, but if they can't then see the instructor during office hours or ask your questions in class.

Reread to highlight. A few days after the second reading, when you've answered all of your questions about the material, go through the pages again and annotate the book. In pencil, write notes to yourself in the margins wherever you found that some extra explanation was required to understand the material. Highlight very selectively, marking only the most fundamental and important concepts. This is the *third reading*.

Reread to summarize. After you understand the material in the book, the challenge becomes remembering it so that you can put the ideas to use. Go through the pages again and summarize what they say, in your own words, on a separate sheet of paper. If it isn't

obvious how to do that, try making an outline (you probably learned to do this in grade school). This is the *fourth reading*.

Review the summary. Before each exam, review the textbook summary you made along with your class notes, returned assignments, and other materials relevant to the topics that will be on the exam.

4

How To Do Graded Homework

Do your homework. In most technical courses, working problems is the only way you can learn the subject. The assigned homework has been carefully designed to help you understand the material, *but that will happen only if you actually work the problems.* Never even think about skipping this essential part of the course.

Follow these simple rules. On many occasions in your professional career you will be required to communicate technical information in writing. You can learn how to do that by preparing homework, so your instructors will encourage you to be careful with both its technical content and its presentation. Homework that is late or sloppy, even if it is correct, betrays a careless and disrespectful attitude towards both the reader of the paper and the subject matter of the course. Your adherence to the minimal standards outlined below will make it clear that you take homework seriously, by being deliberate rather than casual, paying attention to the details, and striving always for clarity and precision. Following these simple rules will make your work more likely to be right, less likely to be misunderstood, and easier for the grader to correct. If you find them absurd, arbitrary, an intolerable infringement on your freedom of expression, or just too much trouble to bother with, then you must be prepared to lose credit as the price of your philosophical conviction or laziness.

Know what is due when. Find out from the course schedule what is in each homework and when each homework is due. Start working on each assignment as soon as it is given, or when you turn in the preceding one, so that you will have time before the due date to get help from the instructor or teaching assistant if you discover that you need it. In most courses late work is penalized, and in some it is refused, so the best strategy is usually to turn in each assignment on time even if it is incomplete.

Work the problems. It is not enough that you know how to *copy* the solution from an answer book, the internet, a social club file, or another student. In some courses you might be allowed to work in teams (in which case the team will turn in a single paper) or collaborate on individual work, but copying is always a violation of academic integrity. If you or your team get help in understanding a problem, you must independently reproduce the solution on your own. It is not even enough that you know how to solve the problem yourself; *you must also demonstrate that to the grader,* by showing the details of your work and explaining what you are doing. Define any variables you introduce, and describe your reasoning so that the grader can follow your train of thought. Doing this will also help you get the problems right. If you don't know how to start a problem, review the assigned reading and your

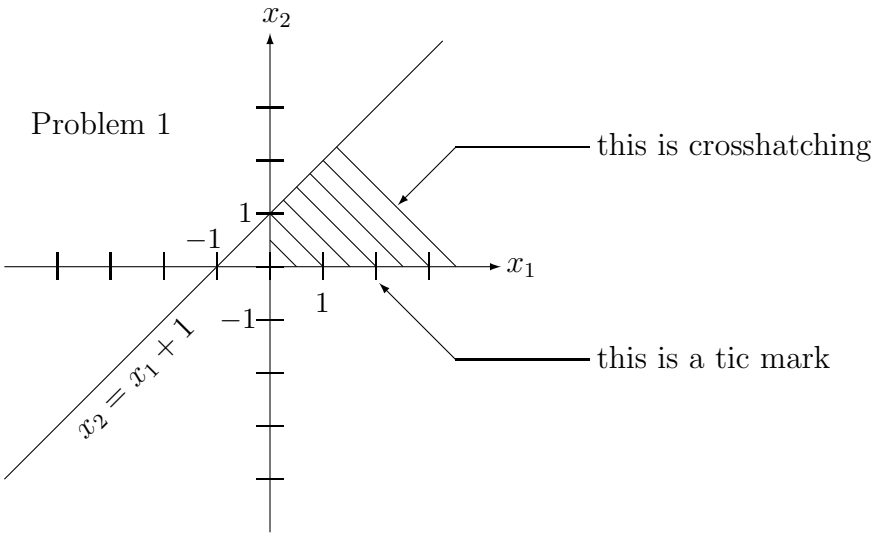
class notes for a general technique that might apply. Homework problems are always related somehow to what you have been studying.

Write up your work. Use paper that has actual (not just advertised) dimensions of $8\frac{1}{2} \times 11$ inches and that does not have fringes along its edge; pages torn from a spiral notebook are never suitable. Print your name on the front side of each sheet. Label each solution with the number of the problem it solves. If you write up your work by hand, use pencil rather than pen so that you can erase your mistakes rather than crossing them out. Avoid using a pencil of the color (probably red) that the grader will use for marking corrections. Print legibly, and present your work in a neat and orderly way. Line up the pages and fasten them together with a single staple in the upper left corner; dog-earing the pages together is not good enough. Make sure that when the stapled pages are turned, all of your work on each page is clearly visible.

Most technical courses do not require you to typeset homework, but you might find that easier than writing it up by hand, it is always desirable, and in some courses it is worth extra credit. Word is suitable for text but LaTeX is much better for mathematics and diagrams.

Plot readable graphs. Often you will be required to include a graph in your writeup of a problem, and a graph might be useful even if it is not required. You can prepare graphs using a computer application such as Excel or `gnuplot` or LaTeX `picture`, or you can draw them by hand on paper that has a printed grid, such as graph paper, quadrille pad paper, or engineering paper. A grid improvised by hand is seldom good enough even if you use a ruler to space the grid lines equally. Many websites offer graph paper that you can print for free. If you are graphing by hand, use a straightedge to draw the axes and any straight lines the graph contains. Draw an arrowhead on only *one* end of each axis, to show the direction in which that coordinate increases; a graph axis that has arrowheads on both ends does not make sense. Label each axis with the variable it measures, provide properly-spaced tic marks, and label enough of the tic marks so that the origin and scale are clear. If the quantity represented has units, indicate in the axis label or tic mark labels what those units are. Use crosshatching to indicate a region of interest. An example of a readable graph is shown on the next page.

Review corrected work. Study each paper when it is returned, so that if you made a mistake you can understand what it was and how to avoid making it again. If you don't understand what the grader wrote or why points were deducted, ask. Save returned homeworks so that you can refer to them later when you are studying for an exam.


Problem 1
x_2
x_1
1
−1
1
−1
$x_2 = x_1 + 1$
this is crosshatching
this is a tic mark

5

How To Manage Deadlines

Know how you are spending your time. Most students who begin keeping hour-by-hour records of what they do are astonished to discover how much of each day they have been wasting on activities that contribute nothing of real value to *any* aspect of their lives. If you make this discovery about yourself, consider not doing some of those things.

Know what is due when. Devise a reliable system for keeping track of homework assignments, labs, projects, papers, quizzes, tests, and exams. Combine all of your commitments in a single list, ordered by due date with the closest due date on top. Find out about deliverables as far ahead as possible. Keep your list of outstanding requirements up to date continuously, as you complete work and find out about new work.

Prioritize the tasks presently outstanding. When you chose the school, major, and courses that you are in, you elected to trust the experts who designed the curriculum to know what material it should contain and to ensure that your mastery of it is reflected accurately by the grades you earn. Your decision about which deliverables are most important should therefore be based on those grade values, rather than on your subjective appraisal of course content. It is important to do well in courses that are required for your major, but resist the temptation to focus only on subjects you like at the expense of those you hate; a B and a D are better than an A and an F. It is more important to pass an exam that counts for half the course grade than to get a few more points on a lab that counts for 1% of the course grade, unless doing the low-value assignment helps you prepare for the high-value one.

Decide the urgency of a task based on the time remaining and the work needed to complete it. A big project due tomorrow is more urgent than a simple one due next month. Work that is both urgent and important comes first. Work that is urgent but less important comes next. Work that is important but not urgent follows that. Work that is neither important nor urgent gets done last.

Plan the work. Many projects include tasks that need to be done right away and others that can be put off until later; in that case separate them. Figure out exactly what must happen when, in sufficient detail to convince yourself that it all *will* happen if you just carry out the steps. Schedule the pieces of each project in the order that minimizes wasted effort. Keep the plan continuously updated as requirements change.

Automate what you easily can. Mindless repetitive work is seldom demanded by college courses, so if that is what you are doing you might have misunderstood the assignment. If

tedious calculations really are necessary, consider having Excel, Maple, or MATLAB do them for you. Minutes spent learning how to use power tools can save hours of labor.

Get help. Fretting about deadlines makes it harder to meet them. If you are struggling, your instructor, advisor, roommate, counselor, and significant other need to know. Talking about it with them will make you feel better, and they might have useful suggestions. Investigate the possibility of getting deadlines extended; work that is turned in a little late has been known to receive only a little penalty.

Work your way out of the hole. The best way to deal with deadlines is to complete the work. All deadlines in college are short-term, and most students can sustain high levels of short-term effort without physical or psychic injury. Remove distractions and immerse yourself in the task instead of worrying about it. Getting things done will make you feel much better.

Shed load. Many worthy people find that they are unable to perform flawlessly in college; remember that perfect is the enemy of good and the mortal enemy of done. If you find yourself overwhelmed even after adjusting your expectations, you should consult with your academic advisor about dropping a strategically-chosen course, changing to a less-demanding major, or arranging for time off from school so that you can rethink what you have planned for your life.

6

How To Study

Figure out a method. Studying is *bringing your mind into contact with the material to be learned in such a way that you understand and remember it.* High school offers little intellectual content, so you might have learned it all without conscious effort. In college and at work you will need to learn more and faster, so it's essential to develop a systematic and deliberate approach. Always imagine you are taking an extra course called "How To Study," and work as hard at it as you do at your regular courses. Befriend the "A" student in your class who seems to have the best-developed study methods, and adapt them to fit your unique style and needs. Constantly improve your technique.

Put in enough time. Permanent learning requires multiple exposures to the material, separated by days or weeks, and cannot be rushed, squeezed into commercial breaks between television programs, or made to look effortless. Most students need $2\frac{1}{2}$ to 3 hours of study for every hour in class. A 16-credit load demands 40 to 48 hours of study time each week.

Plan your work. Try to maximize the lowest grade you expect to get. This means working more on your weaker subjects, rather than studying only the ones you like. Schedule your work in advance so that it all fits in the time you have. You can plan some events from the syllabus (classes, exams, labs, homework assignments) for the whole semester. Plan your other work as far ahead as you can, and revise the plan daily to account for changing circumstances. Use a calendar that shows at a glance precisely what you intend to do when.

Work alone, but in public. You will learn only if you do the studying yourself. Never copy anyone else's work. If you need help ask an expert to explain the theory or solution method, but then apply it on your own. You will be more inclined to act the part of a serious and responsible student if you know that someone is watching, so find a public place to study where you can work undisturbed but in clear view of other people.

Work together, but individually. Get your teammates to agree on a clear division of labor so that everyone can contribute and learn something. Teaching is the best way to consolidate your own knowledge, so seize any chance to teach someone else what you know.

Read, summarize, organize, memorize. Perfect the course notebook for use in the future, when you need to review the material in another course or at work. Read and make notes on the textbook. Annotate your class notes. Look up references. Organize and summarize all of the notes, and then annotate and summarize the summary. Write down any questions that come up along the way, and find answers to them. Identify the few things you must remember, and memorize them using flashcards or repeated copying.

Practice, practice, practice. Work the assigned problems, and the suggested problems, and problems that weren't even mentioned. Work old exam problems and problems from other books. Work each problem in several different ways, and generalize from your experience so that you can solve new problems easily. Strive for correctness, speed, and clarity.

7

How To Use Office Hours

Prepare. Office hours are a valuable resource that you should always consider using. Meeting with your instructor or TA in person for just a few minutes can often clarify something you have been trying for hours to understand, or get you going again on a homework problem that you have been trying for hours to solve. It takes time and effort on your part to go for help, so it's important to get as much as you can out of the experience. Here are some suggestions for maximizing the value of office hours.

Try to help yourself first. It is far better to discover something on your own than to have someone give it to you, so always try hard to master the material before seeking help. If you succeed you will forever own what you have learned, and if you don't succeed you will at least understand the material well enough to ask questions about it and make use of the answers you get.

Write down specific questions to ask. Office hours are not meant to be an opportunity for the instructor or TA to tutor you in the subject, so if you ask "Could you just review everything we've studied so far?" the answer will probably be "I'm sorry, but there isn't enough time." You should also not expect the instructor or TA to do your homework, because then you would not learn from doing it yourself. Instead of announcing "I don't understand *anything* about this problem" try to identify particular things that are confusing you and ask about those. Grading complaints should generally go to the TA, if there is one, rather than to the instructor. If you need help with an issue that is not specific to the course, prepare by thinking about what you want to discuss.

Bring everything you will need. That includes the textbook, your classnotes, a pencil, an eraser, and some blank paper. If you need to show the instructor a program you wrote, or to demonstrate some difficulty you are having with a program you are using, bring your computer, and have it ready to use when you arrive. If you need to ask about a homework or quiz problem, be sure to bring the corrected paper.

Allow enough time. Open office hours are always conducted on a walk-in basis. If you show up five minutes before you have to be at a class or five minutes before the end of office hours with a question that will take ten minutes to explain and an equal time to answer, the instructor or TA might have to suggest that you come back at another time. If you think this might happen because you can't arrive early enough, consider scheduling an appointment rather than going to the open office hours.

Find the communication channel that works best. Different people react in different ways to text messages, email, and phone messages, so you should ask each instructor which to use. To answer your question it might be necessary to exchange more information than can easily be communicated in any of those ways, so it usually works best to meet in person or ask your question in class.

8

How To Take An Exam

Plan. The syllabus for each course probably includes exam dates, so you can and should plan your preparations far in advance. Exams tend to come in clusters, so careful scheduling might be needed to ensure that you get ready for all of them. Ask the instructor exactly what you need to know, and what references, if any, you may bring. Open-book exams are typically harder than closed-book exams and require more preparation. Study over several (perhaps many) days, not just the night before. "Pulling an all-nighter" to study for an exam, in addition to being childish and uncomfortable, does not work.

Prepare. Get all of your open questions answered. Make summary notes combining everything you need to know. If you will be allowed to use a reference page, carefully prepare one. Memorize the things that you will have to remember, including definitions, proofs, laboratory procedures, and plain facts, but know how to derive formulas appropriate to each problem. Get old exam questions from the instructor and work them for practice. Attend any review sessions that might be offered, or organize a review session with your classmates. Study and practice in the room where the exam will occur, so that it will feel familiar when you take the exam. Your preparations should give you an attitude of responsible confidence, so that you are relaxed about the exam and look forward to showing what you have learned.

Show up. Bring everything you will need, including writing implements, an eraser, a watch, a blue book if required, a calculator if one is allowed, your reference sheet if one is allowed, and any references you can use if the exam is open book. Make sure the calculator is charged. Show up early to pick a seat and get organized. As soon as the exam begins, write down any memorized things that you are worried about forgetting. Then read the whole exam, so that your mind can start subconsciously working on all of the problems. Work the problems in order of increasing difficulty, carefully organizing and explaining your work. If you know anything about a problem you can probably get partial credit, but only if you *write something down.* Answer every part, even if you don't know how to solve the whole problem. When you've finished, check your work. If possible solve each problem in a different way to prove that your answer is right. If you get two answers and aren't sure which is right, cross one out with a simple $\times$ so the grader can see both calculations. Keep checking and reviewing your work until the time limit expires; never leave early. It is better to be late for your next class, if you must, than to leave before you are finished if it is possible to stay and keep working.

Postmortem. It's all right to discuss the exam with your classmates, but don't take what they say very seriously; they probably got it wrong. If you remember troublesome problems, try to work them out. Pay attention when the exam is reviewed in class, and study the

corrections written on it when the paper is returned. Always appeal for extra credit if you can think up any credible basis at all. If an optional re-test is offered, take it if (a) you failed the first try or (b) the re-test is no-risk, in that the highest grade will be retained or (c) you are confident you know the material much better than you did the first time.

Never cheat. Cheating is personally degrading, risks an F in the course, takes more work than learning the material, and seldom helps. Assume that every instructor knows all of the tricks.

9

How To Cope With Performance Anxiety

Recognize the problem. Many students react to criticism, overwork, and deadlines, especially in time-limited exams, by worrying so much that it interferes with their performance. The physiological reason for this[1] is that worries compete for working memory. That makes the problem worse, leading to a vicious cycle of overload and inability to function. It's important to have a way of coping with this natural phenomenon, for both your happiness and your academic success. Here are some things to think about as you devise your own personal strategy.

Avoid needless stress. The high-stakes exam is an artificial construct of the academic environment; seldom in real life does everything depend on a single performance of any kind. To make your life as a student less unrealistic, take the course with many little quizzes rather than the course in which your grade will be determined by a single heart-stopping test. Choose take-home projects you can do at your own pace over in-class projects. In some courses you can take a retest or raise your grade by doing extra work of a less-stressful kind; always find out if alternatives are available in case you need them.

Be prepared. If you are convinced you know the material that will be covered by the exam, or that you have the slides ready for your in-class presentation, then you can be confident instead of worried.

Keep things in perspective. How important is this one performance in the grand scheme of your life? Ten per cent of your grade in one course does not count for much even at the small scale of an academic semester. Your life might involve marriage, children, a thirty-year professional career, or military service, all of which will make tomorrow's quiz seem not very significant. It's important to do your best, but even if you fail a test it will not be the end of the world or prove that you are a failure in life.

Focus on the mission. The exam or presentation is *not about you.* Your job is to work the problems or write the essay or give the talk, not to defend your ego. The instructor's job is to tell you what you did wrong so that you can get it right next time, not to pass judgment on your worth as a human being. An exam grade is a part of the standard machinery of taking a course, not a personal compliment or insult. Using exam grades to guide your learning process will keep you from taking offense at them. They are useful numbers.

[1] See Ramirez and Beilock, "Writing About Testing Worries Boosts Exam Performance in the Classroom," *Science* 331 p211-213, 14 Jan 11.

Be realistic. The objective of education is improvement, not perfection. Ignore both external and internal demands for a 4.0 grade-point average and concentrate instead on learning as much as you can. Set achievable goals, do a workmanlike job, and stop hating yourself for every tiny mistake.

Don't be embarrassed. Performance anxiety is not a moral failing or character flaw, and it often wears itself out through repeated exposure to stressful situations. It can also be diminished by learning how to focus on the educational mission rather than on your feelings. College is for personal growth of that sort as well as for learning a profession.

Consider getting help. Intractable performance anxiety can stem from earlier life experiences that you do not recognize as the cause. A trained counselor (such as a psychologist or rabbi) might help you to understand the underlying reasons for your anxiety and thereby deprive them of power over your feelings.

10

How To Be a Graduate Student

Every student might find the suggestions given in Chapters 1–9 useful, but the topics discussed here will be of interest to graduate students in particular.

About Graduate Study

All graduate programs require additional and more-advanced coursework, and most require a thesis that reports findings from original research or a project that involves original innovation. A *terminal master's program* prepares you to seek employment in industry as a technical specialist or manager; a *doctoral program* prepares you to seek employment as a research scientist or university professor.

Before attempting a graduate program you should have completed a rigorous undergraduate curriculum and earned a degree in the graduate subject or a subject very closely related to it. If you lack any foundational coursework you should take it and do well before beginning your graduate program. To be admitted to a doctoral program you will need to pass examinations covering undergraduate-level material but from an advanced perspective, so you will need to study for them seriously and practice on old exams.

A graduate program has three goals. First, it should teach you how to do original work. This involves developing instincts, attitudes, and methods that facilitate innovation. Second, it should reveal whether you have the temperament to undertake your intended career as a professional in academia or industry. If you are unsuited to the work you will be miserable and unproductive when you try to do it for a living. Third, your work should yield some new knowledge that is valuable or interesting enough to merit dissemination. A master's thesis or project should yield one conference paper or an article in a professional publication; a doctoral thesis should yield three articles in refereed scientific or engineering journals.

Expect to succeed. Many students learn how to do research, complete a successful thesis or project, get the degree, and go on to happy careers. Other students get the degree but then discover that research is not their life's work after all. Some students complete a doctoral program just so that they can work at an undergraduate teaching college, where publishing only a few papers might be sufficient to get tenure. Some students decide before finishing that they would be happier doing something else altogether. It is not uncommon for a doctoral student to complete all of the degree requirements except for the thesis, and to leave content with the informal title of AbD, which means "all but dissertation." In each of these cases the process worked and the outcome should be regarded as success.

Be prepared in case you fail. Sometimes a student who has the capacity to succeed in his or her intended career gives up angry or is denied the degree. The advisor might demand too much or provide insufficient mentoring. The student might work too little or try hard but prove unequal to the task. The problem might turn out to be tougher than anybody thought, or somebody else might publish a solution first, or the answer might turn out to be so uninteresting that it does not merit publication. The student might run out of time or money before finishing the work. The student might have a falling out with the advisor. The advisor might die, be denied tenure, or find a better job at another school, and the student not be able to find a replacement. The project might fall victim to some other sort of bad luck. Enough students fail to receive the doctorate that many universities provide a safety net by awarding a master's degree if the requirements for one are met along the way.

Rarely a student who does *not* have the capacity to succeed is awarded the degree anyway and then has a bad experience at work, such as failing to publish or find research funding or earn tenure at a university. This can happen because the advisor demanded too little or the student borrowed too much from the work of others.

Before you begin a graduate program you should write yourself a letter outlining what you will do if disaster strikes or you decide that it was a mistake to enroll. Seal it in an envelope labeled JUST IN CASE, put it in a safe place, and then forget about it. You can burn it on the day you receive your doctorate.

How To Get Started

Find the right research advisor. Most students have no trouble completing the additional coursework required for a graduate degree and many pass the preliminary exams for admission to a doctoral program, but very few find research easy. You will learn how to do research by apprenticeship to your advisor, so it is essential to have one who is willing to be your mentor. Identify those tenure-track faculty members, working in the general area that interests you, *who are able to fund you* through the entire process of getting your degree. How many students has each of them graduated, and how many candidates have failed? Interview former students of both kinds, if you can. What is the training method used by each faculty member? Try to find one who will not simply throw you in the deep end to sink or swim on your own. How many students does each advisor already supervise, and how much access do they get? Most students need at least 1 hour per week of the advisor's undivided attention. What are the personalities of the faculty? Doing research can be an emotionally fraught experience, and you must be able to get along with your advisor through times that are trying for both of you. Get to know prospective advisors by taking courses from them, reading their papers, and attending any talks they give. When you know enough to rank the candidates, approach them in order of desirability and try to get adopted as a student. It is a lot of work to teach a student how to do research, so most faculty members would rather advise a doctoral student, who might be around for long enough to share significant

discoveries, than a master's student who will soon be gone. Once you have found an advisor, work out the support arrangements, an official Plan of Study, and a tentative schedule for completing the degree.

Find the right research problem. With your advisor, find some next step that it seems likely you can take. It is essential that your advisor be interested in and know about your project, so *let the advisor pick the research topic.* You will have opportunities to work on other things after you have your degree. Avoid problems that are too easy to merit the degree, too hard to finish in the time you have, or fashionable enough to be solved by somebody else first. It is likely that as you follow your nose into the problem you will discover unexpected questions worth pursuing, so the project you end up doing might be quite different from the one you first imagine, but it is essential to start with a tentative goal that is definite.

Read, but not too much. Published works are the forum for scholarly discourse and embody the accumulated experience of the research community, so it is important to master what others have already written. Search the literature on your problem and read the classic books and papers. Try to reproduce the results published there, but don't be too much in awe of experts or abandon an idea just because they didn't think of it. If possible attend conferences and meet people doing relevant work.

Always be writing. *Start writing the thesis now,* using the software that will produce the final product in the required format, rather than waiting to have everything "finished" in some other form first. Make a preliminary table of contents, and figure out how the work it describes will fit into the time you have. Begin the bibliography, and get into the habit of recording the precise citation of every reference you use or think you might use.

Summarize each day's work at some appropriate place in the thesis draft. Writing about what you have done is the only way to figure out what to do next, so it is essential that you pause to write every day. Describing what you did, any questions that occur to you, and everything you learn will help you get ideas. Putting the ideas into words, pictures, and equations will reveal your mistakes and the open questions you need to investigate. Keeping accurate notes about what you have tried will keep you from revisiting dead ends and help you reconstruct ideas that merit further study. When you get stuck, explaining precisely *how* you are stuck, in writing intended for a naïve reader, will help you find a way to get unstuck.

Refine the table of contents as you describe your discoveries. Plan on throwing away 90% of what you write as the price of getting the 10% that will comprise the final draft. Your audience includes the students who will follow you, so make your thesis a teaching document that explains how you got to your results. Back up your computer frequently.

Acquire any special skills you need. This might involve taking additional courses, reading textbooks, participating in a seminar, or practicing analytical techniques that are of particular value in addressing your problem. Arrange the computing environment that

you will use for your work based on the needs of the project rather than on your immediate comfort. This might involve learning an unfamiliar operating system, software package, or programming language.

Acquire smart friends. Get to know fellow students whose skills are complementary to your own, and solicit their advice when you need it. Being this kind of resource to someone else is the secret to winning their help in return, and can lead to a lifelong professional connection and personal friendship.

If you are a doctoral student, work with your advisor to arrange a thesis committee that meets all the bureaucratic requirements and includes people who can actually help you. Some departments require formal approval of your research plans in a candidacy exam, while in other departments the candidacy exam is a dress rehearsal for the defense. Whether a formal presentation is required at this stage or not, you should explain your thesis outline and research plans to your committee and get their consent. They will eventually be voting on whether or not you get the degree. Develop the habit of talking with them about aspects of your project that overlap with their areas of special expertise.

How To Do Research

Cultivate habits of thought that lead to discovery. Doing research requires sound preparation in the discipline and better-than-average common sense, but a thesis project is *not* an IQ test. Instead it is an exercise in the development of certain character traits that have been found to be essential to the work of scientific discovery and technological invention, including self-confidence, humility, independence, creativity, organization, and, most important of all, persistence. To think deeply enough to do anything original you must learn how to focus, shutting out all distractions. To discover anything important you must abandon your ego, which is the biggest distraction, and be willing to make many mistakes in exchange for each insight. Allow your imagination to generate lots of ideas, but be skeptical of them all until you sift out the ones worth keeping. Research is an iterative, nonlinear process that can't be predicted or planned perfectly in advance, so you must develop a high tolerance for ambiguity and uncertainty. Revise your strategy constantly as you learn how to do research, but revise your problem only if your advisor agrees that the unexpected thing you have turned up is really interesting. Always be planning future work.

Research is often described as "what I am doing when I don't know what I am doing" and successful researchers often can't explain exactly how they do it, so there is no sure-fire recipe. However, there seem to be some common tactics that work for many people at least some of the time. My list, inspired in several places by[1] "An Algorithm for Discovery" by David Paydarfar and William J. Schwartz, begins on the next page.

[1] *Science* 292, 06 Apr 01, page 13

- The still small voice of discovery is hard to hear in a tumult. *Cultivate a relaxed yet attentive and prepared state of mind* that is free of the meetings, deadlines, and other exigencies of the workday schedule. Resist the temptation to settle for quick closure and instead actively search for deviations, inconsistencies, and peculiarities. Hidden among the anomalies might be clues that challenge accepted wisdom. *Question your assumptions,* especially the implicit ones that you have stopped thinking about. Investigate every surprising coincidence in the hope that it might turn out not to be a coincidence at all, but abandon leads that don't soon show at least some promise.

- *Try not to make the project harder than it is.* What is the essence of the problem? Strip away superfluous details and ornamentation before you start; there is less to most things than meets the eye. Some results that appear anomalous really aren't.

- *Use all the skills you have,* especially mathematics and logic. Algebra, geometry, and calculus still work even in unfamiliar territory, and all the theorems you know are true wherever their hypotheses are satisfied. The laws of nature are universal.

- If a general theory applies to your specific problem, use it; if not study specific examples and try to generalize from them. *Look for patterns.*

- *Try to formally prove statements* that you suspect to be true. Often this process turns up aspects of the problem you had overlooked. When a plausible conjecture turns out to be false, rejoice in your good fortune and study the counterexamples in detail.

- *Consider a simpler case,* and then a simpler one, until you get to one you understand. If necessary, go all the way back to first principles. Consider extreme cases for hints, and to sanity-check your theories. Always try to make a picture or a graph.

- Use problem-specific results that you have already established. *Reason by analogy* to things you have seen before.

- *Search the literature* for answers to specific questions that arise in your writing. This is quite different from speculative reading without a particular motive. Read critically.

- Look for ways to *be more precise* in your thinking and writing. Clarify the notation. Nondimensionalize the formulation. Remember that simplicity is the seal of truth.

- Use symbolic calculation, numerical methods, computer graphics, and other power tools to *automate your work* and to investigate the problem in different ways. Time spent refining analytic, computational, and experimental methods is seldom wasted. Rigorous attention to detail helps to avert the premature rejection or acceptance of hypotheses. Sometimes the process of perfecting one's approach leads to an unexpected

discovery.[2] Meticulous checking helps ensure results that are actually reliable enough to reveal something new.

- There is no substitute for first-hand knowledge of the mathematical analysis or numerical algorithm or experimental data that you are using, whether it came from someone else's prior work or your own. *Review the algebra and the source code and the numbers.* Often it is necessary to rely for the heavy lifting on published theorems, laboratory instruments, Maple, MATLAB, or software you inherited, but how well do you understand the inner workings of those black boxes? Inspecting their inputs and their visible parts, and viewing their outputs with a wary eye, helps to guard against error and against the automated averaging-out of precisely the unusual, subtle, or contradictory phenomena that you seek.

- *Be skeptical* of your results and cross-check them every way you can think of. If possible compute numbers that you can check for plausibility or symbolic results that you can check analytically in some independent way.

- *Sleep on it.* Sometimes letting a question simmer in your subconscious for a while lets a new insight dawn on you.

- Be fearless, ruthless, and relentless. Dare to have wild ideas even though most of them will be wrong, and weed out the wrong ones without nostalgia. *Never give up.*

Enter the professional culture. Write papers about your work and present them at conferences. Go to lunch with your colleagues. Try to meet the leading researchers in your field and learn from them. Watch your advisor write research proposals and manage contracts. Learn how to select graduate students of your own when the time comes. Learn to teach efficiently as well as effectively, so that when you are a faculty member you will have time for research. Network, welcome opportunities for collaboration, and find out what will be involved in getting a job once you have your degree.

Have a life too. Play hard and rest completely when you are not at work. Spend quality time with your partner and family. Look after your physical and emotional health. Practice your religion. Be nice to people even when you are having a bad day. When the research threatens to consume you, find ways to shed your frustrations and put your professional work back into perspective as one part of a whole life.

[2] An example of this is the background radiation attributed to the Big Bang, which was identified by Penzias and Wilson while they were pursuing the source of noise in the signal from a radio telescope.

How To Teach Undergraduates

Welcome the opportunity. It is easier to learn how to teach when you are a graduate student than on your first day in front of a class as a faculty member. If you hope to become a professor, teaching undergraduates is an important part of your doctoral training.

Know your students and care about them as individuals. Make photo flashcards so that you can memorize all of their names before the first class. Call on every student, if possible, during each class. Encourage them to come to your office hours, and get to know them as people. Learning odd facts about them, such as where they went to high school or what their sister does for a living, will help you tell them apart and remember their idiosyncrasies. Want them all to succeed. Pay attention to their physical and emotional health, and intervene or refer if that seems appropriate. Try to meet each student's individual needs, but treat them all the same. Give one-on-one help to students who are floundering, whether they ask for it or not, and to any student who asks. Suggest that those who lack academic skills read the first 9 chapters of this book, and provide personalized help if they still can't figure it out. Be a positive role model, and convince the students that if you could do it they can too.

Provide structure and leadership but without being noticed. Learning is a process that cannot be commanded or directly controlled, so teaching is like tending a garden rather than like managing employees. You must help students learn for themselves, so it is all about *them,* never about you. They need to be confident that you know what you are doing and that they know what is expected of them. Make sure you have a deep understanding of the course material yourself, and prepare functional notes to prompt you as you lead each class. Begin the first class with a description of the course schedule and organization, including the topics to be discussed each day, the assigned reading, all of the deliverables, the grading scheme, and your contact information and office hours. Once the rules are clear try to get out of the way, and help them to feel that *they* are the primary owners of the class. What they get out of it will depend mainly on what *they* put into it. Don't require attendance, but if someone is missing find out why because their absence might indicate a problem you can fix. Give mid-course student evaluations, report the results in class, and adjust your delivery if necessary. Appoint a committee of the weaker students to tell you what you are doing wrong, and try to take their advice about how to fix it. Promote mutual respect.

Facilitate access to the material. Give class notes so clear, concise, and well-organized that students in other sections will ask to borrow them from your students. Never use PowerPoint; a class is not a presentation of static facts but a highly interactive conversation about ideas, and its exact trajectory cannot be predicted in advance. Always write out the notes by hand as you teach, so that the students can keep up and so that you can continuously adjust your presentation in response to the questions they ask and the answers they give to

your questions. Insist that they take notes, and encourage them to put what you are saying into their own words as they write it down. Provide paper handouts that they can write on in class as they are being discussed. Teach each class as though it included one student who is deaf and another who is blind. Get volunteers from among the stronger students to tutor the weak ones. Use computing, video, and other technical means, but only when they actually help the students learn the material. Always ask yourself "What value am I adding beyond what the student could get by spending this time in the library studying alone?"

Provide motivation. Always introduce a new idea with an example, by asking a question designed to pique the curiosity and interest of the class. Call on people by name, and give them time to think before answering. Pick realistic examples that are relevant to the academic majors and personal interests of your students, and explain how the things they are learning will be of value to them later on. Reward correct answers, but never embarrass a student who gives a wrong one. Use grades as a way of encouraging students to work at learning, not as a gate-keeping mechanism to cull the herd. Give exams that are straightforward and unambiguous, that can be done in the time allowed, and that teach as well as measuring. Allow partial credit. Return graded work promptly, and make sure the students always know how they are doing in the course. Be lenient or strict according to the situation, depending on which strategy will extract more effort from the student. Retest, if necessary, until they get it. Set an achievable absolute standard of performance, rather than grading on a curve, so it is crystal clear what is necessary to pass the course and so it is theoretically possible for everybody to get an A. Always allow a student to get a better grade by doing more work. Measure your performance as a teacher by how successfully you can engage the least interested student in the class.

Let the students discover what you want them to learn. Your students will learn something in class only if they get to *discover* the facts and *have* the ideas. A teacher is not an authority who dispenses knowledge to be passively absorbed, but a skillful and involved guide who works along with the students as they figure out the subject for themselves. Reveal just enough to set the students up to discover the next idea, and then ask them questions designed to elicit that discovery. If you notice students talking to each other, ask them if they have a question or to share what they were discussing. Call on people by name to get them to talk, and then really listen to what they are saying. Remember the strengths and weaknesses of each student and phrase your questions and explanations with their personalities in mind. When most of the class finally "gets it," reinforce that discovery and start setting them up for the next idea. At the beginning of the course, explain this process to the students so they understand what you expect them to do.

Continuously improve your performance. After each class, review how it went and make notes on what you will do differently the next time you teach and the next time you teach that material. If you told the students anything wrong, plan to issue a correction.

Learn how to refer students in emotional trouble. Undergraduates sometimes experience personal problems such as the death of a friend, parents divorcing, accidents involving someone they know, serious illness, bullying, worries about relationships, alcohol or drug abuse, anxiety, insomnia, depression, and thoughts of suicide. Any of these distractions can lead to bad grades, bad attendance, a bad attitude, or self-destructive behavior such as cutting, so as an instructor you might be the first to notice the evidence. Usually the right response is to get the student an appointment with the university counseling service, but sometimes a kind word is enough and on rare occasion the campus police should be involved. To learn what to do in each case, attend all of the training you are offered.