

Olympiad Training for Individual Study: Syllabus

OTIS Year V (2019-2020)

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It's hard to do a really good job on anything you don't think about in the shower.

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§1 Overview

§1.1 Prerequisites

- You should be comfortable qualifying for your country's national olympiad and be able to read and write proofs.
- You must have submitted a complete application by the deadline (August 1).
- It is a good investment¹ to learn \LaTeX well in the summer before OTIS begins; it will pay back in spades when writing up solutions.
- Students can participate at most two full years in either the Weekly or Biweekly format.² Also, note that practice exams repeat every two years, so in a third year the practice exams would become redundant.
- You should be prepared to work very hard. OTIS is serious businessTM, and its rigor is comparable to that of MOP.

A crude estimate for the total time commitment might be **5-10 hours per week**, though this varies substantially between different people and between units.

§1.2 Components

OTIS is based on the following components.

- Every two weeks, a **unit** consisting of a couple worked examples, plus a **problem set** of approximately 9-15 olympiad problems (of which you solve some subset), most of which focus in one particular topic. See Section 3 for details.
- Prompt communication (via email, Facebook, Hangouts, etc.) for questions etc. See Section A.1 for a long speech on this.
- A set of ten full-length **mock olympiads** (3.5 hours and 3 problems, USAMO/IMO style) and eight brief short-answer quizzes (for computation practice). These are graded in full. See Section 4 for details about practice exams.
- Online meetings, as described in Section 1.3 and Section 5.

§1.3 Meeting formats

For Year V, there are *four* different lecture formats possible.

Biweekly Lectures are held **every two weeks** and are **0.7 hours** (42 minutes) each. The k th meeting would cover the k th unit ($k \geq 1$), and the corresponding problem set is due by the start of the $(k + 1)$ st meeting.

See Section 5 for details about what happens in a meeting.

Weekly Lectures are held **every week** and are **0.7 hours** (42 minutes) each. The $(2k - 1)$ and $2k$ th meeting would discuss the k th unit ($k \geq 1$), and the corresponding problem set is due by the start of the $(2k + 1)$ st meeting. This option is usually only offered to a few returners.

See Section 5 for details about what happens in a meeting.

¹This suggestion is actually from one of my past participants, so I'm not just making this up.

²This is both for fairness, as well as limitations on my materials.

External You would be paired with an **instructor other than me** for lectures. These instructors are usually OTIS alumni who have won USAMO or attended IMO.

Scheduling and payment for meetings would be done entirely with the instructor. In particular, parameters like how often / how long are up to you — anything is fine by agreement. In particular, you have longer meetings!

Correspondence The Correspondence format has **no meetings** at all. You submit problem sets as you complete them (and would notify me as you did so).

Thus you could actually pick your own pace, and you can move through as many or as few units as you have time for. This is recommended only if you are really motivated (but has been done before).

§1.4 Dates

We follow the MIT academic calendar.

Fall Early September to early-mid December.

Spring Mid-late January to mid-April (just before USAMO).

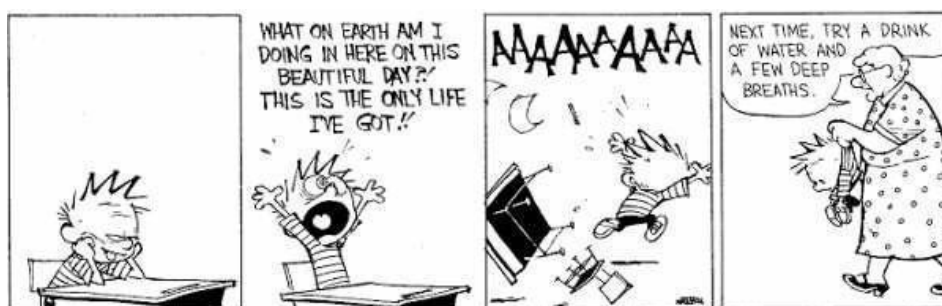
In Weekly and Biweekly, expect about **twelve weeks of lectures** per semester (barring unexpected conflicts, snow days, apocalypse, etc.).

Since students often will work through materials outside these dates (e.g. during the long winter break), progressing through **six to eight units per semester** is a good baseline.

§1.5 Payment information

The rate is $\$80(H + 4)$ each semester where H is the number of hours of meetings with me.³ Assuming six units as advertised, participants will have $H \in \{0, 4.2, 8.4\}$ each semester.

Once enrolled, you'll get a "Parent Information" handout with details on payment methods and the like (the boring stuff).



³The +4 term is for grading, answering questions, administration, and preparing materials. And, uh, server costs.

§2 Curriculum and Materials

§2.1 Units

The page <http://web.evanchen.cc/static/otis-samples/synopsis.html> contains a catalog of possible units (which is always changing, so may be slightly out of date).

The choice of which units to cover each year is entirely up to you. Usually, it's a bit of an overwhelming task to try and pick from such a long list, so the way I do it now is that at acceptance there will be a preference form, and then I will give you some sort of selection by default. But you can and should request changes at any time, see Section A.2.

§2.2 Lecture notes (walkthroughs)

The lecture notes for every unit includes some “walkthroughs”: example problems together with a sequence of parts intended to take you step by step through the problems. Here is an example of what that might look like.

Problem (IMO 2003/6). Let p be a prime number. Prove that there exists a prime number q such that for every integer n , the number $n^p - p$ is not divisible by q .

Walkthrough. (a) Show that if $q \not\equiv 1 \pmod{p}$ then this fails. So we will restrict our attention to $q = pk + 1$.

(b) Prove that it's sufficient to have $p^k \not\equiv 1 \pmod{q}$, for the k in (a).

... and so on.

During meetings, I will probably pick one or two of the walkthroughs to work through with you. But even in Weekly format we more than likely won't get to finishing all the written walkthroughs, and in that case you can (and should) read through the rest of the walkthroughs on your own time. Full solutions to all the walkthroughs are provided in an appendix at the end of each unit.

§2.3 OTIS-WEB

OTIS has now moved onto its own dedicated website; details about this are sent to accepted participants.

The website is sort of the central hub for all materials It will be used to manage the following:

- Materials (notes and problem set) for each unit,
- Transcripts of meetings, and
- Your submissions to the problem sets.

Mock olympiads and quizzes are submitted separately, see below. (They are still listed on OTIS-WEB.)

Note that lecture notes for meetings are uploaded well in advance, and you are encouraged to skim through these beforehand. In particular, for Weekly/Biweekly participants, certain lectures may have associated **reading you will need to do before-hand**; these will be clearly indicated in the lecture notes PDF, under a section titled “Reading”.

All materials are *internal use* only.

§3 Problem sets

The most important part of the training is the regular problem sets.

§3.1 Solving instructions

Each problem set has 10-15 problems, but you're not expected to solve all of them: each problem has a weight (like [5♣]) attached to it, and you are aiming to solve a certain target score or more. This will be self-explanatory once you see your first problem set.

You are expected to communicate with me throughout the week about any problems you have difficulty with (this should happen every week). A good rule of thumb is to **ask for hints after an hour with no progress**. When asking for hints, please describe the progress you've made so far, or approaches that you've tried and didn't work. See Section A.1 for more on that.

§3.2 Write-ups and submission

For regular problem sets, **you only need to submit outlines of solutions** (although full write-ups are certainly welcome if you have the time). This way I can see which problems you have solved and roughly by what method, and also sanity-check that there are no obvious errors in the solution. An "outline" is just 2-5 sentences that capture the main idea.

Here is an example of what I mean:

Problem (HMMT 2016 Guts 17). Compute the sum of all integers $1 \leq a \leq 10$ with the following property: there exist integers p and q such that p , q , $p^2 + a$ and $q^2 + a$ are all distinct prime numbers.

Solution. Odd a fail for parity reasons and $a \equiv 2 \pmod{3}$ fail for mod 3 reasons. This leaves $a \in \{4, 6, 10\}$, for which we can take $(p, q) = (3, 5)$, $(5, 11)$, $(3, 7)$, respectively. Thus $4 + 6 + 10 = 20$. \square

For each unit's problem set, you should write up solutions⁴ and submit problem sets by uploading a single PDF to OTIS-WEB. You should upload it under the "**File Uploads**" page for that unit.

§3.3 Due dates

To reiterate Section 1.3, problem sets are due differently depending on which format of OTIS you are taking.

- For the Weekly and Biweekly formats, problem sets are due each two weeks. In particular:
 - In the Weekly case, the $(2k - 1)$ st and $2k$ th meeting would cover the k th unit ($k \geq 1$), so the corresponding problem set is due by the start of the $(2k + 1)$ st meeting.

⁴As I mentioned in the beginning, I suggest typesetting your problem sets in L^AT_EX. The output is very pretty, you learn how to use L^AT_EX (useful later), and you now have digital copies of all your work. After all, given how much time you're spending on my problems, don't you want to keep records of them?

- In the Biweekly case, the k th meeting would cover the k th unit ($k \geq 1$), and the corresponding problem set is due by the start of the $(k + 1)$ st meeting.

That said, if you are on Weekly or Biweekly, I encourage you to go faster than this pace if you are able to. The units are actually now designed for self-study thanks to the Correspondence option, so it is entirely possible to decide, hey, this unit looks easy, I'll just do this one myself and ask Evan to do something different next lecture. See Section A.2 for more on that.

- In the External case, you should talk to your instructor about pacing.
- In the Correspondence case, you are self-paced: there are no hard due dates. Each time you submit a problem set, you should then contact me to review your submissions; I will then advance your counter (unlocking further units).

For transparency, I should say now: **the regular problem set submissions are NOT graded**⁵. Sorry, there are just too many. Usually, I am willing to read through the solutions to sanity-check them and point any obvious issues I can see (wrong final answer, common pitfalls, etc.). But I will probably not notice typos or more subtle errors. (The practice exams are graded fully, though.)

§4 Mock olympiads and quizzes

Both the mock olympiads and the short quizzes will be **graded through the GradeScope program**. (You'll be set up for GradeScope after acceptance.) The exams (and solutions) themselves will be shared on OTIS-WEB. The solutions are actually available immediately, so you can read them right after taking the test, without waiting for grading.

§4.1 Strategy

Once you are registered for OTIS, you will find on the portal a handout about meta-strategies for test taking on olympiads (with respect to write-ups, problem ordering, etc.). I strongly recommend reading through this before taking your first mock olympiads, since this will give you a chance to practice these strategies on many practice tests before the first one.

§4.2 Dates

There will be 10 tests (mock olympiads) in the school year, which come in pairs. The short quizzes are short-answer practice, each with 5 much quicker short-answer problems. The dates for the practice exams are specified in Table 1.

I run grading at the beginning of each calendar month for the test that just finished.,

§4.3 Instructions for tests (mock olympiads)

Here are some instructions for submissions.

- Each test is three problems, 7 points per problem.
- There are **three levels: JMO, USAMO, and TST**. You should pick one of them to take.

⁵This is part of why I only ask for outlines of solutions.

Test Name	Released	Due
Tests 1 and 2	Aug 15	Oct 1
Tests 3 and 4	Sep 15	Nov 1
Quiz A	Oct 2	Nov 1
Tests 5 and 6	Oct 15	Dec 1
Quizzes B and C	Nov 2	Dec 1
<i>Fall bonus final (optional)</i>	Dec 14	
Quizzes D, E, F	Jan 2	Feb 1
Tests 7 and 8	Jan 15	Mar 1
Quizzes G and H	Feb 2	Mar 1
Tests 9 and 10	Feb 15	Apr 1
<i>Spring bonus final (optional)</i>	Mar 14	

Table 1: Schedule for OTIS practice exams

- The time limit is **only 3.5 hours**. (This is deliberately shorter than the 4.5 hours used for JMO / USAMO; to help you get used to working under time pressure, and to make it easier to fit in your schedule.)
- Like a real olympiad, submit complete solutions on the given answer sheets. You can download the answer sheets from OTIS-WEB.
- You are encouraged to do the problems on the olympiad that you didn't take, but please do not submit those solutions on GradeScope; leave them blank.⁶
- When submitting mock olympiads, be careful to submit the right papers to the right problems. There are five distinct questions among the tests, of which you will only submit three.
- Even if you do not think you solved any problems, submit whatever progress you made. This helps me with record-keeping so I can adjust tests in the future. In any case, if you are following my advice you should have tried every problem for some time, so it is better to avoid leaving anything blank.

§4.4 Instructions for quizzes (short answer)

These are intended to give you bit of short-answer practice during the school year, to help prepare you for AIME, HMMT, PUMaC, MP4G, et cetera. (Indeed, you can expect most of the problems to come from there.)

- Each quiz is **45 minutes long**, and features **5 short answer problems**. Think of it like $\frac{1}{3}$ of an AIME, except probably harder and faster.
- Use the answer sheet provided on OTIS-WEB. You will only submit short answers for grading. (Thus your score will be one of $\{0, 1, \dots, 5\}$.)

§4.5 Bonus final olympiads

You can request a final at the date in Table 1 if you have completed most of the previous OTIS exams due before then. So, it serves as sort of an end-of-semester present, which is

⁶It seems that the GradeScope now lets you omit submissions for problems; this was not true before.

why it comes out around Christmas in the fall semester! The final problems are supposed to be especially nice (or at least I think so, seeing as I save them all year). I hand-design these for each individual.

The bonus finals are totally optional. You can do these as a mock exam if you really want to, or you can also just work on the problems for fun. (But if you do want to take it under exam conditions, then email me your solutions and I will grade them.)

§5 Meetings with Evan

This section describes meetings for those in the Weekly or Biweekly formats. If you are in the External format, you can expect something similar to what's below, but the exact details might be slightly different.

§5.1 Logistics

We will use [Google Hangouts](#) for meetings. My Gmail address is

chen.evan6@gmail.com

Please be online on Hangouts at the scheduled meeting time. **All meetings are one-on-one.**

§5.2 Transcripts

Typically, I will have a \LaTeX document (in real time⁷) which serves as a sort of “white board” for the class. So problem statements, partial progress, etc. will all appear there.

Here is an example of part of a transcript from last year (which is also posted in full on my website for download).⁸

IMO 2014 Problem 6

Example (IMO 2014/6)

Prove that for all sufficiently large n , in any set of n lines in general position it is possible to colour at least \sqrt{n} lines blue in such a way that none of its finite regions has a completely blue boundary.

Strategy

Color lines blue until stuck.

Proof this strategy works.

Look at a maximal configuration. Claim that in here, at least \sqrt{n} lines are blue.

So suppose there k blue lines and $n - k$ red lines. Then there are $\binom{k}{2}$ intersections of two blue lines. Moreover every red line is part of an almost-blue polygon. So can associate every red line to a blue intersection. By “geometry”, at most two red lines per blue vertex. Thus

$$\binom{k}{2} \geq \frac{1}{2}(n - k) \implies k \geq \sqrt{n}.$$

Putnam example

The advantage of this setup is that we get a full transcript of the class that you can review on your own time. I usually upload these immediately after your class.

You can review the transcripts at any time later; the transcripts will be under the link “File Uploads” for each unit.

⁷This means a lot of me typing furiously and getting angry at \LaTeX compilation errors. I always forget the `fragile` option when using Asymptote in Beamer.

⁸Yes, I really type \LaTeX that fast.

§5.3 What happens in a meeting?

Examples of things we can do in a meeting on the n th unit (all flexible):

- Present solutions to problems from the previous $(n - 1)$ st unit.
- Work together through the examples/walkthroughs for the n th unit.
- Work together through any practice problems from the n th unit (for example, things you've tried and are stuck on).
- Questions about reading or lecture notes (or anything else).

§5.4 Scheduling

As described already, participants meet every one or two weeks. The meetings are **0.7 hours** long.

The exact time of day is usually coordinated close to the start of each semester.⁹

§6 Miscellaneous

§6.1 Surveys and feedback

Throughout the year, I send three OTIS surveys by email.

- The first (longest) survey¹⁰ is sent around the third unit or so.
- The second survey will be sent around the end of the fall semester.
- The third (shortest) survey will be sent at the end of the year.

You need not worry about these until you see them, but when you do, I really appreciate your feedback. Of course if you have comments at other times of the year, I am more than happy to take those as well.¹¹

§6.2 T-shirt

exist?

⁹Fair warning: There are a lot of you, so I re-schedule classes often. I apologize in advance.

¹⁰The nice thing about having a start-of-year survey (rather than an end-of-year survey like the rest of the world) is that your feedback will actually be used right away this year, rather than just helping future instances of OTIS.

¹¹In particular, if you run into a problem you think would fit well on one of my units, please send it to me! (Or if you run into a nice problem in general.) Many of the problems you see in OTIS were forwarded to me by participants and friends.

§7 Your to-do checklist

Here is a checklist of what's expected of you, to help keep track of the many parts.

- After acceptance:
 - Register for an account on OTIS-WEB and GradeScope
 - Agree on a schedule for the school year
 - Read the handout on test-taking strategy (before first practice olympiad)
- Before each unit:
 - Do any reading specified in the notes for that unit
- During each unit:
 - Meet with me/instructor at scheduled times
 - Work through the walkthroughs
 - Solve the problem set for that unit
 - Keep me updated on your progress on the problems (see Section [A.1](#))
 - Submit outlines of solutions to OTIS-WEB (under “file uploads”)
- Before the deadlines in Table [1](#), submit:
 - Practice olympiads (usually two per month)
 - Quizzes (in selected months)
 - Request a bonus final (optional)
- Throughout the year:
 - Respond to surveys
 - Send me good problems

§A Some advice and words of encouragement

§A.1 Talk to me, I don't bite

I want to really stress the importance of keeping in contact with me, and in particular the importance of asking for pointers when stuck.¹² The problem sets are meant to help you learn through practice, rather than for me to measure anything (skill, time spent, or whatever). A problem will usually teach you a lot more in the first one or two hours than in the six hours after that. So it's much better to ask for feedback on your approaches once you've hit a barrier, rather than being stuck for hours on problem 5 and then not reading problems 6-10.

On any unit, a rough estimate is that you will need help on at least 1/3 of the problems, in the sense that you're unlikely to solve the problem no matter how much time you spend. (The actual constant varies a lot by person and unit.) That means that in expectation you should be writing to me 3+ times per unit. This is a lot!¹³ Put more concisely, **the problem sets should feel interactive**. This only works if you reach out to me.

Some pointers on asking questions:

- *Do it*. Really. I want to hear from you.
- You can contact me through Facebook messenger, email, or Google Hangouts. I recommend the first two since I'll see those on my phone¹⁴, but I'll eventually notice and respond to Google Hangouts as well.
- *Timing*: I try to respond to OTIS messages as soon as I see them, since I consider this to be one of the most important parts of my job. However I tend to sleep early (sometimes as early as 10PM ET), so if you message me late at night I will probably not get it until next morning. But if you message me during daylight hours, you might typically expect a response within about 6 hours. If I don't respond to something within 24 hours, please remind me.
- It's more convenient for me if you refer to problems by source e.g. "USAMO 2010/6" (instead of "problem 10", say). I have a lot of the contest years memorized by now.
- Describing what you've tried so far (even things that didn't work) is helpful, so I can give more refined suggestions.
- Don't be afraid to ask for further directions if the first answer I give isn't sufficient!

That +4 term in the semester payment is there for a reason. Make use of it!

§A.2 Flexibility of units

I want to stress that the curriculum is malleable. You can and should **request changes or additions to your chosen units, at any time, for any reason**. There are many, many, valid reasons to do so. If I *really* think that something is a bad idea, then I will warn you in advance, but in general this is supposed to be a one-on-one learning experience and so I want to really give you a lot of say.

¹²Here's another long digression: people often call this "asking for hints", but I don't like this phrasing and try to avoid it when possible. The reason is that hints are seen as things that you only take if you can't do something yourself. This is only true during the "big game" when you're being scored. Training is not like that: long delays in feedback actually make learning slower.

¹³If you find you're consistently able to solve nearly all the problems, consider asking me to make your curriculum more difficult.

¹⁴Hooray for technology in education?

Here is a list of examples of good reasons (by no means exhaustive) that you should request changes to curriculum:

- (a) I made a mistake¹⁵ and accidentally gave you a unit that you’ve already done¹⁶, or didn’t give you a unit that you specifically requested.
- (b) Your preferences have changed since last June, and now you want to work on less geometry and more combinatorics.
- (c) A little bird told you that the Anti-Problems unit is *hilarious*.
- (d) You cleared that Euclidean Algorithm unit in three days, and want another unit to work on for the other eleven days. This applies even if you are weekly or biweekly.
- (e) More generally, if you work through units faster than one every two weeks, you should add some more.¹⁷ As an extreme example, Anant Mudgal holds the program record with *44 units* completed in one year.¹⁸
- (f) That Z-level Analysis or Extreme Graph unit just isn’t clicking. You want to downgrade the difficulty, or skip it altogether.
- (g) You find a D-level of a unit too easy and want to do the Z-level one instead.
- (h) You saw Evan nuke a problem with homography, and are now curious.
- (i) You’ve realize you’ve seen most of the problems on the Linear Algebra unit already so you’d rather work on something else.

In short: this is an **all-you-can-eat buffet** with 100% satisfaction guarantee™. The “one unit per two weeks” is meant as a baseline and shouldn’t be taken too seriously.

§A.3 Hints on scanning files

If you have a iPhone/Android/whatever, there are quite a few apps that will let you take pictures with your phone, and then automatically apply the correct linear transformation to get a scan of the page. For many of you this will be more convenient.

The one I use is called “Tiny Scanner” on iPhone (free if you put up with a few annoyances). Others have used “Cam Scanner” as well.

§A.4 OTIS documents are on Dropbox

Almost all OTIS content (e.g. handouts) is actually hosted on Dropbox, so whenever I make changes to documents on my computer, they are updated online in real-time. Thus **problems and documents change (or disappear) frequently for this reason**. If you don’t like this behavior, save local copies of the documents as you get them, and check for updates time to time.

Also plan accordingly if you plan on being in China, since without a VPN you cannot access Dropbox content.

¹⁵Seriously, happens all the time. When I set the curriculums at the beginning of the year, I try to do the whole thing within maybe three or four hours, and there are 50 of you. Do the math.

¹⁶There are some units that have multiple disjoint versions so that you can do them more than once, though.

¹⁷I’ll probably notice this, too, so you may not even have to say anything.

¹⁸If you do this, I might have a hard time finding units for you the next year.

§B Mission statement (not meant to be read)

I want to have an official mission statement here, but it's more for completeness and my own reference. You do not need to read it unless you really really want to.

OTIS is built with **four goals**. These are the metrics which I use to measure my “success” each year, and guide all my design decisions. For each goal, I give a brief description and my plans to achieve it.

- *Systematic hard work.* First and foremost, I want students to learn work ethic. The focus is squarely placed on problem sets, with lectures minimal or nonexistent. You will do a large number of problems: there is no way around this.

The program's structure is set in a fairly explicit way, with individual units and concrete deliverables. Thus students work in a systematic and organized fashion. I like to think that the careful planning and design of OTIS (and even the sheer amount of material) helps set a good example as well.

- *Learning how to learn.* OTIS is my attempted answer to “how should people learn?”, in the context of math olympiads. Yes, you have to spend a lot of time, but there's more to it than that.¹⁹ How do you know you really understand something? What should you be thinking about after you've done each problem? How do you prioritize approaches? Why are philosophy and intuition so important? And so on.

During OTIS, these ideas are addressed indirectly through examples and explicitly through discussion. I don't claim my answers are the best or only ones. But I hope it's one helpful viewpoint. My intention is that the seeing olympiad math from the OTIS perspective gives insight into these nuances.

- *Enjoyable and worthwhile experience.* In the short-term, I want OTIS to be fun. In the long-term, I want students to be able say, “*hey, I really enjoyed OTIS and learned a lot from it, and I'm glad that I joined*”, even if they didn't do as well on USAMO as they hoped. I think this kind of maturity and appreciation is important later on in life (for example in trying new things without excessive fear of failure).

This is where the human face of OTIS comes in. Part of it is in design: point-based problem sets, picking fun problems, keeping a human voice in writing.

The other part is just being available. During the school year, I see a lot of students who are left to float around and fend for themselves. My hope is that I can be a good mentor for students: being there to answer questions, giving guidance and encouragement, just being enthusiastic, etc. It's hard to learn math in a vacuum; I hope to fix that.

- *Olympiad math itself:* after completing OTIS, students should have learned a lot of olympiad math. Hopefully, the mechanism for this is self-explanatory!

Optimizing all four metrics simultaneously is hard enough. And so, to take a page from Ravi Vakil: **there are no other goals.**²⁰

¹⁹To quote Palmer Mebane: “It's always discouraging to see people say that they're planning to do every problem in PSS or every IMO SL, because it sounds like they're more intent on being able to say they've done that than actually doing the problems as thoroughly as they should.”

²⁰I follow Unix philosophy: “write programs that do one thing and do it well”.