

## **Beyond Math 1: Which math course is for you?**

If you have completed the through Math 1b at Harvard or if you have had the equivalent material elsewhere, you may be wondering what additional Math courses to take. The mathematics department provides a variety of options which you should consider based on your academic interests and your background. With exceedingly rare exceptions, students in your position are advised to take one of Math 19a, 21a, 21b, 22a, 25a, 55a. You can also take Math 101 concurrently with any of Math 19a-21. (The School of Engineering and Applied Sciences also offers Applied Math 22a which covers selected topics from Math 21a and Math 21b with some focus on coding.) What is written below describes the Mathematics Department's offerings and to help you decide which course is right for you.

- **MATH 19A:** Math 19a is given in just the fall; it teaches multivariable calculus and differential equations for applications to the life sciences. It is recommended by those taking the Life Science 1a,b courses and by the life science concentrations (this means Biological Anthropology, Chemical and Physical Biology, Human Evolutionary Biology, Molecular and Cellular Biology, Neurobiology, Organismic and Evolutionary Biology, and Social and Cognitive Neuroscience.) In particular, the focus is on modeling via differential equations, both linear and non-linear in one or more variables. Math 19a has a second focus which is mathematical modeling for life science problems. This course is preferable to Math 21a for those majoring in a life science except for students who plan to take Physics 11/12 or 15/16. Math 21b can be taken before or after Math 19a.
  
- **MATH 21A:** This course covers the basics of multivariable calculus in two and three dimensions: Curves and surfaces, functions and their derivatives, the calculus of variations, multi-variable integration, integration on curves and surfaces, multivariable generalizations of the fundamental theorem of calculus. In short: Math 21a teach the tools and intuition for dealing with basic multivariable problems. Math 21a is given in both the fall and spring semester. It is a generic multi-variable calculus course that is appropriate for any concentration.
  
- **MATH 21B:** This course covers the basics of linear algebra in dimensions 2, 3 and higher. A significant part of the course then used the linear algebra to study ordinary and partial differential equations and Fourier series. Math 21a and Math 21b can (in principle) be taken in either order, but Math 21a first is the recommended order.
  
- **MATH 22A,B:** This course covers multivariable calculus and linear algebra for students interested in theoretical sciences. It covers the same linear algebra topics as Math 21a,b but with more rigor. In this regard, students in Math 22a are taught techniques of proof and mathematical reasoning whereas these techniques are not taught in Math 21a,b. (But note that Math 21b does cover significantly more by way of differential equations than Math 22a,b.) The workload in Math 22a,b is

comparable with the 21 sequence. But in contrast to the order of topics in the Math 21a,b sequence, Math 22a focus on linear algebra whereas Math 22b focuses on multivariable calculus. For this reason, Math 22b cannot be taken after Math 21a, and vice-versa. Likewise, Math 21b cannot be taken after Math 22a and vice-versa.

- **MATH 25A,B** and **MATH 55A,B**: These are theory courses that should be taken only by students who have a particular interest in and enjoyment of abstract mathematics, as well as a solid understanding of one-variable calculus. (Even so, these courses are not just for people planning for the Mathematics concentration; more than half of the students in these courses go on to concentrate in other sciences.) These courses assume a willingness to think rigorously and abstractly about mathematics; and they require a willingness to work hard. Both courses study multivariable calculus and linear algebra plus many very deep, related topics. These courses come with an iron clad guarantee that you will be learning beautiful mathematics. Math 25a and Math 55a are fall courses and Math 25b, 55b are in the spring. Students from Math 25a or Math 55a can go on to take Math 22b or Math 21a (not Math 21b) instead of Math 25b or Math 55b.

- \* **CHOOSING BETWEEN MATH 22, 25 OR 55**: Math 25 differs from Math 22 by virtue of the work load in Math 25 being significantly more; but then Math 25 covers more material. (In particular, Math 25 covers material in the 100-level courses Math 112 and Math 121.) Even so, any given course that asks for Math 25 as a prerequisite accepts Math 22 as well. Math 55 differs from Math 25 and Math 22 in that the former assumes an extremely strong proof oriented mathematics experience; and, as with Math 25, a willingness to spend much extra time on mathematics during the semester (Math 55 covers even more 100-level course material.)

- \* **SKIPPING MATH 25/55**: Every so often, a first year person with an extremely advanced background hopes to skip Math 25 and Math 55 and start with a 100- or 200- level course. Based on many years of experience, we discourage this. Here is why: These courses teach more than just a body of mathematics; they teach how to 'be' a research mathematician (as opposed to one who only does well in math courses). If, in spite of this warning, you think that taking a higher level course as a first year student would best serve your needs, you should speak to the Director of Undergraduate Studies in Mathematics first.

- **Applied Math 22a**: This is a spring term course that teaches topics in multivariable calculus and linear algebra with some focus on applications and coding. The topics chosen for Applied Math 22a are for the most part in Math 21b and Math 22b. Applied Math 22a is taught in a single lecture hall, whereas Math 21a,b are taught in small sections that are designed to maximize student/ teacher interactions. (Mathematics concentrators can use Applied Math 22a as a 'related field' course for concentration credit if Math 21b or Math 22a or Math 25a or Math 55a is not taken. Applied Math concentrators can take Math 21a,b or Math 22a,b or one of Math 22a,b and Math 55a,b.)

#### OTHER COURSES:

- Math 101: Math 101 (offered both fall and spring semesters) is designed to give people with a Math 1b level background and with interest in mathematics a taste of what modern mathematics is all about. This course can be taken concurrently with Math 21a or 21b. It is not to be taken with Math 25 or 55 (without special permission). Math 101 also gives a good background for writing and following mathematical proofs. This skill will be needed for most higher level math courses. This skill is also taught in Math 22 and Math 25, and (to a lesser extent) in a few other 100 level courses.