

12th Grade Assignment – Week #32

GROUP WORK – TUESDAY / After L1 and Before L2:

There are two parts to this assignment, *Discussion* and *Solving a Cubic Equation*. You can freely choose to skip either section, skip parts of a given section, or let aspects carry over into your next group meeting. Just make sure everyone has a voice in the decision(s), and you decide together.

[I] *Discussion*

- Ⓐ Before considering what follows, survey the group to see if questions are already alive there. Give your questions priority. Help each other make sense of our study and its implications.
- Ⓑ What follows is an extended quotation from *Anxiety is the Dizziness of Freedom*, a short story by Ted Chiang included in the 2019 collection Exhalation. The story itself is science fiction, but the excerpt below is factual. Be social, and have a volunteer or two read it aloud.

(It is through this story that I came to know of Michael Berry's work. It (the story, not the quote) contains some violence, and references drug addiction. That said, I find it beautifully human and truly inspiring. I highly recommend it.)

“ Set up a rack of billiard balls and execute a flawless break. Imagine the table has no pockets and is frictionless, so the balls just keep rebounding, never coming to a stop; how accurately can you predict the path of any given ball as it collides against the others? In 1978, the physicist Michael Berry calculated that you could predict only nine collisions before you would need to account for the gravitational effect of a person standing in the room. If your initial measurement of a ball's position is off by even a nanometer, your prediction becomes useless within a matter of seconds.

The collisions between air molecules are similarly contingent and can be affected by the gravitational effect of a single atom a meter away. The difference is imperceptible at first, but when air is turbulent, it takes roughly a minute for a perturbation at the microscopic level to become macroscopic, affecting eddies one centimeter in diameter.

For same scale atmospheric phenomena, the effects of perturbations double in size every couple of hours. In terms of prediction, that means that an error one meter wide in your initial measurements of the atmosphere will lead to an error a kilometer wide in your prediction of the weather on the following day. At larger scales, the propagation of errors slows down due to factors like topography and the stratification of the atmosphere, but it doesn't stop; eventually errors on the kilometer scale become errors hundreds or thousands of kilometers in size. Even if your initial measurements were so detailed that they included data about every cubic meter of Earth's atmosphere, your prediction of the future weather would cease to be useful within a month's time. Increasing the resolution of the initial measurements has a limited benefit; because errors propagate so rapidly at the small scale, starting with data about every cubic centimeter of the atmosphere would prolong the accuracy of the prediction by only a matter of hours. ”

Was all that obvious to you or is it surprising? Does an unconscious understanding of this underpin our actions and choices, or do we act as though things were otherwise? Share your thoughts about all this, and in particular, what it may mean to you personally.

12th Grade Assignment – Week #32 (continued)

GROUP WORK – TUESDAY / After L1 and Before L2: • *Discussion (continued)...*

Ⓒ Here is a quote from the [1988 interview with Michael Berry](#) that was on your [reading list](#).

“ I now take the ... view ... that there's no piece of worthwhile mathematics that has been— or will be —invented which cannot and will not some day be of use in describing some aspect of the universe. I've found the most surprising pieces of mathematics ... to be just what I needed for particular physical problems. That's the practical reason why I'm forced to this view. But even theoretically, when you think about it, it's fairly obvious. After all the whole universe, which it's the object of science to describe, is more complicated than the inside of one's head and that's where mathematics comes from. ”

Do you agree or disagree with Berry's conclusion in general? What about his final statement about where mathematics comes from? You've studied the Philosophy of Math. Are there arguments for or against Berry's position which could be made?

(Describing the pool ball scenario in this interview, Berry put the number of collisions at six or seven, whereas Chiang gives the number as nine. Chiang speaks of an analysis Berry did regarding just *one person*, whereas in the interview Berry speaks of *people* milling about.)

Ⓓ Discuss this quote from 1976 where Robert May refers to how students were (then) educated.

“ The mathematical intuition so developed ill equips the student to confront the bizarre behavior exhibited by the simplest nonlinear systems, such as [the logistic function]. Yet such nonlinear systems are surely the rule, not the exception, outside the physical sciences.

Not only in research, but also in the everyday world of politics and economics, we would all be better off if more people realized that simple nonlinear systems do not necessarily possess simple dynamical properties. ”

Ⓔ This quote is from the prologue of James Gleick's 1988 book *Chaos: Making a New Science*.

“ As the revolution in chaos runs its course, the best physicists find themselves returning without embarrassment to phenomena on a human scale. ... They feel that they are turning back a trend in science toward reductionism, the analysis of systems in terms of their constituent parts: quarks, chromosomes, or neurons. They believe that they are looking for the whole. ”

What is science (or math) on a human scale? What has science gained through reductionism, and what has it lost? Where in society is reductionism rightly applied, and where are we in need of a greater holism? What is “the whole”? Discuss anything else that comes to mind.

[II] *Solving a Cubic Equation*

Here is a cubic equation you can solve. It is laborious. You may choose to allow it to span both your group sessions this week. Or you may prefer to devote your limited time elsewhere.

$$3x^3 + 27x^2 - 36x - 480 = 0$$

[Here is a link to a Google Sheet](#) that can provide you all the key waypoints along the path to the solution, including the final answers. The roots of this cubic are all integers. You may also find it helpful to refer to [the document giving the solution to the cubic from last week's tutorial](#).

12th Grade Assignment – Week #32 (continued)

GROUP WORK – THURSDAY / After L2:

As before, the first two parts of this assignment are *Discussion* and *Solving a Cubic Equation*, and you are free to decide together how to use your time. That means that you can give priority to your own questions, skip around as suits, and return to anything from your last session you wish to work with further. No matter what, however, leave time for the final section, *Goodbyes*.

[III] *Discussion*

Ⓕ Here is another quote from the prologue of James Gleick’s *Chaos: Making a New Science*.

“ To some physicists chaos is a science of process rather than state, of becoming rather than being. ”

Can you say more about this difference? Can you provide examples which demonstrate it? In education, when we encourage students to adopt a “growth mindset”, we are guiding them to focus on becoming more than being. Do you think that humanity at large focuses more on becoming or on being? And where in society might a shift in mindset be of benefit?

Ⓖ And here is yet another quote from the aforementioned prologue.

“ Believers in chaos— and they sometimes call themselves believers, or converts, or evangelists —speculate about determinism and free will, about evolution, about the nature of conscious intelligence. ”

People were speculating about these things long before mathematical chaos theory entered the scene. And they still are. Questions don’t get much bigger than this. So... how does our little main lesson connect to your own thinking about these things?

[IV] *Solving a Cubic Equation*

Here is another cubic with integer solutions. (For limited support, see links below prior cubic.)

$$2x^3 - 30x^2 + 36x + 208 = 0$$

[V] *Goodbyes*

This is your last formal Math Academy group meeting. Don’t let it evaporate without giving everyone the opportunity to share their future plans, thank each other, and say their goodbyes.

INDIVIDUAL WORK

- ★ For this week’s tutorial, you will need scissors, a ruler, (optionally a 45°-45°-90° triangle if you have one handy), and a piece of paper twice as long as it is wide, so when folded in half, it will become a square. You can trim 3” from the short side of letter size (8½”×11”) paper to create a 5½”×11” rectangle, but if you have bigger paper to start with that would be nicer. Legal paper (8½”×14”) makes a 7”×14” rectangle, and tabloid (11”×17”) can do 8½”×17”.
- Read. Keep up with the published [list of readings](#). If you have the time, read more than just what is “expected”. Everything on the reading list, even items labeled as “optional”, are worth reading. That said, their value does not expire with the conclusion of our course. You can certainly read them at your leisure later on.
- Handwork. Find a way to get some of the ideas we have studied out of your head and into the physical world. Make them manifest. Make them yours. Create something. ☺