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• Conceptually understanding the operation of the Fourier transform (and eigen-things) via mathematical animations: "What is the Fourier transform? A visual introduction."

tinyurl.com/WS-3b1b-FT
3blue1brown.com
youtube.com/user/EugeneKhutoryansky/videos /
tinyurl.com/WS-3b1b-linalg

I continue to be stunned by the conceptual insights made possible for learning mathematics via animated visualizations made with computer software; these videos will enrich your life by learning cool new mathematical insights. To me, the future for standard conceptual mathematics education and mathematical physics education *must* include visualization software; had I been exposed to these ideas, I might have pursued mathematical physics as a career. This month's knock-my-socks-off encounter came courtesy of Grant Sanderson of the "3 Brown 1 Blue" (3b1b) YouTube channel, who uses visualization software and mechanics analogies to conceptually explain the mathematical mechanism underlying the Fourier transform (FT). Sanderson animates a "winding graph" in which he graphs a sinusoidal plot "wrapped" in a circle around the origin (like a clock hand, where the hand angle varies uniformly in time and the amplitude varies the length of the hand of the clock) and then varies the period of the winding (clock hand speed). The resulting visually compelling patterns are then analyzed as if they defined a planar object cut from a uniform mass plate; examining the location of the center of mass for the resulting cutout in the x- and y-coordinate gives an approximation for the resulting amplitude and phase in frequency space. The procedure is suggestively reminiscent of Feynman's "QED photon clock hand" analogies.

The idea is hard to describe in words but beautifully compelling in animation, particularly when Grant starts winding snippets of mixed sinusoidal signals representing audio signals—e.g., voltage (time) signals while continuously indicating the "center of mass" of the planar object. As the period of the winding hands is varied, the CM bounces around zero on the (x,y) plane—actually the (frequency, phase) plane—but there are clear values of the winding period for which there are x-axis extrema corresponding to local peaks on an amplitude (frequency) plot. The video is a tour-de-force of the power of computer visualization and animation to make a conceptually complex procedure approachable. Quite stunning, and bravo Mr. Sanderson.

Previously my favorite visualization for introductory mathematical physics had been the eigen-vectors and eigen-values video of Eugene Khutoryansky (whose standalone video is great for visualizing what's conceptually going on when we calculate eigen-things) and it comes as no surprise that 3b1b also has an online linear algebra course with an integral video on eigen-stuff (Chapter 10 of 11). Like many physics students, I memorized mathematical tools and procedures like calculating Fourier transforms and inverse FTs, eigen-vectors and eigen-values without really developing an insight into what was happening; I just knew this was the algorithmic recipe for my physical solutions. To me, the algorithm was a black box that I could monitor inputs to and outputs from intuitively. Watching what the algorithms do by continuously varying variables and animating the process seems extraordinarily insightful to me. And of course Eugene has excellent videos on Fourier synthesis and transforms as well. It's a brave new world for visualizing mathematical procedures and we are remiss in our responsibilities to our physics students if we and they are not exposed to, if not conversant with, this powerful new tool.

• Three new simulations and games for teaching electrostatics and circuits: Craig's "Metal Leaf Electroscope Simulator," Blackman's "Crack the Circuit," and Kortemeyer's "Kirchhoff's Revenge"

newsletter.oapt.ca/files/Electroscope-Simulator.html
theuniverseandmore.com/
msu.edu/user/kortemey/kirchhoff.html

Matt Craig describes his new Java-based Grade 9-10 electroscope applet as "a very simple simulation that can be used to show induced charge separation, charging by contact, charging by induction and grounding." It is reminiscent of the PET/CPU simulators for electrostatics. His site has many Java simulations across several pages.

Matt Blackman's "The Universe and More" site continues to expand with worthwhile physics games, including his new circuit mystery puzzle box web game "Crack the Circuit," which gameifys the old standard activity of analyzing hidden simple circuits with batteries, bulbs, and switches. Connections are hidden, and the viewer must solve the puzzle by drawing a correct schematic given the behavior of bulbs when visible switches are opened and thrown, bulbs are removed, etc.

Gerd Kortemeyer writes of his new Mac and PC downloadable animated graphics-intensive puzzle-solving introductory circuits game "Kirchhoff's Revenge"—though better graphics give better play, "the game is playable in under an hour by students on our lab machines."