Boston QuarkNet Center

2021-2022 Annual Report

We had no fall meeting in 2021.

**Winter Meeting - January 27, 2022**

Our winter meeting at Roxbury Latin School featured teachers presenting favorite physics lessons. We had a hybrid meeting with Mike Hamblin, David Kurtz, Jamison Smith, Ayo Awobode, Mike Hirsh, Tim Fitzgibbon, and Rick Dower, attending in person and Mike Wadness, Matt Heising (Mike’s student teacher associate), Jon Kelley, and Nicole Preiser, and our Northeastern Mentor, Darien Wood joining via Zoom. After some initial difficulty trying to share his screen for his PowerPoint presentation, Rick showed a derivation of Newton’s gravitation law by combining Kepler’s planetary laws with Newton’s laws of motion. Matt Heising showed complimentary geometric derivation showing, as Newton had done, that elliptical orbits are produced by a 1/r2 force. Details can be found at <https://researchgate.net/publication/243714958_Elliptical_Orbit_1r2_Force>

Nicole described using the QuarkNet Z Mass exercise in her development of momentum conservation. Mike Wadness used a related approach when he asked his students to analyze data from the QuarkNet Top Quark exercise to examine momentum conservation. They were frustrated to see that momentum was not conserved. The Mike introduced the idea, a la Pauli, of the neutrino to account for the missing momentum in the proton-antiproton collisions.

Finally, Rick demonstrated a Stirling heat engine model powered by the temperature difference between the lower plate sitting on a thermos of hot water and the upper plate at room temperature. The meeting was recorded by Zoom and made available to others not present. Also, Rick sent out a copy of his slides after the meeting.

**Spring Meeting - May 19, 2022**

We had our spring meeting as usual at Roxbury Latin School and continued our presentations of favorite class presentations, demonstrations, and lab projects. Jamison Smith, Michael Hamblin, Michael Hirsh, George Odell, Jonathan Kelley, and Rick Dower attended in person. Mike Wadness, whose family was coping with COVID, and Matt Heising joined on Zoom.

Jonathan showed an example of a project he devised for his classes that involved constructing a cardboard model of a house with lights (Christmas LEDs), fan, switches (binder clips), and a doorbell powered by a 6-volt battery and properly wired to function appropriately.

Mike Hirsh showed a tall vertical resonance tube (originally constructed by Mike Hamblin) with a small speaker at the top that was connected to a variable frequency audio source and an inlet port at the bottom through which water could be introduced to change the length of the resonating air column above it. We had a nice discussion of the apparently anomalous results that Mike got when trying to determine nodes and antinodes at various frequencies.

George Odell showed his favorite circular standing wave pattern in water in a beaker and the analogy with electron standing wave patterns in H atoms.

Jamison discussed some materials about gravitational lensing of astronomical sources from Perimeter Institute that he uses with his classes. He extoled that variety of free material for physics classroom exercises that are available from Perimeter Institute.

Mike Wadness and Matt discussed their successful use of a limited menu of projects available for students rather than a completely open-ended project assignment. Students could be much more focused and pleased with their outcomes.

Rick presented the beginning of a slide set on early evidence for atoms. He finished with a white-board derivation of the fundamental result of kinetic theory:
average molecular KE in a gas = (3/2) x Boltzmann constant x absolute temperature
and the comment that when first derived this result gave a meaning to temperature.

**Summer Workshop - August 10-11, 2022**

The topic for this summer’s QuarkNet Workshop was Nuclear Fusion, as suggested by George Odell. For the Wednesday session, Amanda Harnden, Mike Hirsh, Mike Wadness, Scott Carlson, Jon Kelley, Gerry Gagnon, Mark Hermano (a new member teaching at St. Paul’s School in New Hampshire), Rick Dower, and our Northeastern Mentor, Darien Wood, joined us. We had a nice discussion of energy units from therm to BTU to kWh to GeV/c2 before tackling some calculations that students could do to support the idea that the Sun’s power source is hydrogen fusion rather than chemical combustion, radioactive decay, or uranium fission. We also did some sample calculations of the binding energy of various nuclei, looked at the overall curve of binding energy per nucleon for the elements with a peak near Fe-56 and the consequences of that curve for element formation, energy generation, and lifetime of stars.

In the afternoon, a tour of the MIT Plasma Science and Fusion Center included a look at the test chamber for the SPARC high temperature superconducting magnet prototype. The magnet successfully reached a 20 T B-field last September when operated with several thousand amps of current flowing through the 1-micron thick layer of high temperature superconductor encased in the copper clad tape used for the magnet windings. Our grad student guide during the visit explained his devotion to the project as motivated by the need to develop usable non-CO2 -producing power sources soon to avoid the worst consequences of climate change. Before the visit we enjoyed lunch at the near-by Flour Bakery and Cafe. After the visit we returned to the Flour Bakery for conversation about the visit and tasty snacks.

For the Thursday session, we examined several YouTube videos that talked about the development of magnets at MIT, the development of the SPARC concept for a compact tokamak fusion reactor using high temperature superconductor ribbon for the magnets of the tokamak, and the importance of the development of fusion power for meeting the world’s increased demand for energy over the next two decades. We also snuck in a little astrophysics with conversation about heavy element formation in supernova explosions and neutron star mergers.

Conversations during the breaks suggested that a discussion of student projects and descriptions of their use in our physics classes would be a fruitful topic for our fall meeting.

Once again we appreciated the use of the Roxbury Latin Physics Lab for our meeting, and we look forward to the next one.

Rick Dower