ED42A-06

Non-traditional Instructional Approaches and Assessment of Graduate Plasma Physics Courses at West Virginia University

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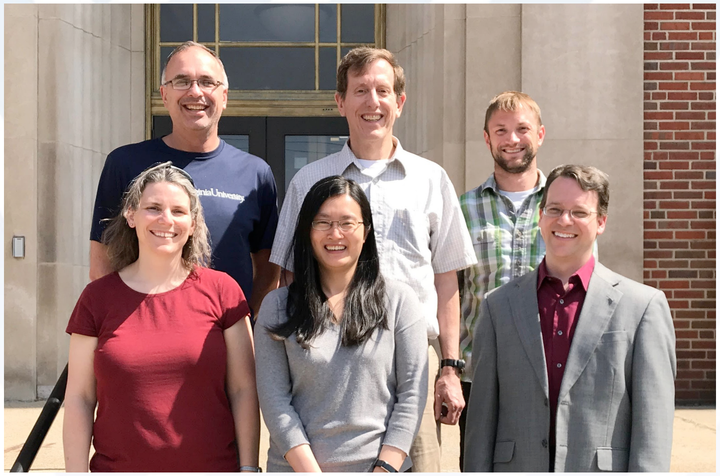
2019 Fall American Geophysical Union
December 12, 2019

Plasma and Space Physics @ WVU

- WVU has a long history in plasma and space physics:
  - The C layer of the ionosphere was discovered in 1936 by Robert Colwell, a long-time department chair [Colwell and Friend, 1936]
  - In 1966, WVU Physics professor Oleg Jefimenko wrote down equations for retarded electric and magnetic fields that are crucial to electromagnetic radiation theory [Jefimenko, 1966]; these are now called the “Jefimenko equations” or the “Feynman-Jefimenko equations” [e.g., Jackson, 1998]
- More recently:
  - Mark Koepke (1987), Experiment - Aurora, Plasma Waves and their space applications
  - Earl Scime (1995), Experiment, Cubesats, Observations - Ion heating for solar corona and solar wind applications, satellite development
  - Paul Cassak (2008), Theory, Computation - Magnetic reconnection in solar corona/magnetosphere
  - Weichao Tu (2015), Computation, Observations - Radiation belt diffusion and particle acceleration
  - Fang Fang (2017), Computation - Solar dynamo, flux emergence
  - Adam Kobelski (2017), Observations - Solar flares, magnetospheric analogies
  - FDSS Hire (Presumably will start in 2020), Instrumentation/Experiment - ???



Front left is Amy Keesee (not shown - Fang Fang)

Plasma and Space Physics Courses

Course #	Course Name	Cadence
Phys 481	Plasma Physics (undergrad)	Sporadically, often co-listed with Phys 781
Phys 493S	Sounding Rocket Payload Development (undergrad)	Taught 2009 – 2015
Phys 781	Principles of Plasma Physics	Every 2 years
Phys 782	Computer Simulation of Plasma	Was every 2 years, last taught Fall 2014
Phys 783	Advanced Kinetic Theory of Plasmas	Every 2 years
Phys 784	Advanced Magnetohydrodynamic Theory of Plasmas	Every 2 years
Phys 793B	Special Topics: Partially Ionized Plasma	Once: Fall 2015
Phys 793A	Special Topics: Solar and Space Physics	Once: Fall 2018
Phys 593C	Special Topics: Plasma Diagnostics	Once: Spring 2019

Flipped Classrooms

- “Flipped” or “inverted” classroom
  - Students do traditional “lecture” activities at home
    - For undergraduate courses, the lectures are often filmed and students watch at home
    - Flipped MHD and Kinetic Theory classes; give students lecture notes and have them read and take notes on them
    - Challenge! - For the student to do this right, it takes *a lot* of time (>2x the time for in-class lectures)
  - Class time reserved for discussions/questions/group problem solving
    - The idea - students get to talk out the material with colleagues, teach and learn from each other in their own words at their own pace; instructor can go around and help on problems in real time
    - Challenge! - Group problems shouldn’t just be busy work; they need to strategically address sticking points, misconceptions, overarching concepts, etc. There is no repository for this; often have to create things yourself!

Worksheet Examples - Kinetic Theory

- Pendulum in Phase Space - develops intuition of time evolution in phase space
- Qualitative Evolution of the Distribution Function - motivates that Vlasov equation describes convection of f in phase space
- Quantitative Evolution of the Distribution Function - gets exact solution, agrees with qualitative result
- Physics of Plasma Oscillations in Phase Space, Physics of Landau Damping of Plasma Oscillations in Phase Space - novel worksheet developing an understanding of Landau damping in the kinetic description (not configuration space!)
- Landau Theory for Negative Wavenumber - redo of Landau theory with negative k, reinforces understanding of contour integration
- The Weibel Instability - math and physics of the Weibel instability
- Quasi-linear theory of Drift Waves - reinforces physics and math of quasi-linear theory

Worksheet Examples - MHD

- Scaling arguments
- Convection - Suppose a region of water has salt concentration (salinity) S that increases linearly with distance in the x direction on a length scale of L, so that $S(x, t = 0) \simeq S_0(1 + x/L)$, where S_0 is a positive constant. The water flows in the +x direction at a uniform and constant speed V . Consider the salinity of a particular fluid element initially at the origin. Assume there are no external sources of salt for the water.
  - (a) Sketch the system. (b) What is the salinity of the fluid element in question at time t = L/2V if the Lagrangian description is employed? (c) What is the salinity of the fluid element in question at time t = L/2V if the Eulerian description is employed? (d) If an external source of salt increases the salinity at a rate of vS_0 everywhere in space (where v is a positive constant), what is the salinity at time t = L/2V at the fluid element at the origin (in the Eulerian description)? (e) In the latter scenario, what is the rate of salinity increase at time t = L/2V at the fluid element at the origin (in the Eulerian description)?
- de Laval Nozzle/Parker solar wind solution
- Firehose instability derivation and physics

Pre- and Post-Testing

- Assessing instruction is notoriously challenging;
  PER community has utilized pre- and post-testing (Hake 1998)
  - Assesses conceptual understanding (as distinguished from ability to perform calculations)
  - Typically for introductory courses; not aware of resources for technical (graduate-level) classes
  - Important - students typically get participation credit, not credit based on their scores!
- Developed a pre- and post-test for “Advanced Kinetic Theory of Plasmas” (Phys 783) class
  - Called the “Kinetic Theory Concept Achievement Test (KiTCAT)”

Kinetic Theory Concept Achievement Test (KiTCAT)

- 20 multiple choice conceptual questions + 3 “demographics” questions about past experience with kinetic theory in courses or research
- Notes on its development:
  - Validated the test against “experts” in the field
    - Six people at WVU - one faculty member, one research professor, two postdocs, and two graduate students who had previously taken the course
  - Two problems were ambiguous and were thrown out; they were fixed in subsequent years

KiTCAT Examples

- 12. In the absence of collisions, the evolution of a distribution function in phase space can be thought of as
  (a) turbulent.
  (b) laminar.
  (c) incompressible.
  (d) stochastic.

- 7. Linear Landau damping of electron plasma oscillations is caused predominantly by
  (a) passing electrons.
  (b) trapped electrons.
  (c) passing and trapped electrons equally.
  (d) None of the above.

Results

- Table shows the results from the experts and three iterations of classes
  - The Hake gain is defined as the increase in score relative to the amount possible to increase
- Interpretations
  - The difference between student pre-tests was consistently ~two standard deviations below the experts
    - Suggests that the test does a reasonable job of distinguishing between novices and experts
  - Hake gains were quite consistent year to year at ~55-60%.
  - Absolute post-test results are consistent with expert scores
    - Suggests the course was successful in bringing students up to the expert level
  - Important comment - these results are all for “flipped” classes
  - Important comment - results are remarkably similar year-to-year, but this may result from the course instructor both creating the test and teaching the class; there is no data on whether the results transfer to other instructors

Group (N)	Pre-Test Score	Pre-Test σ	Post-Test Score	Post-Test σ	Hake Gain
Experts (6)	N/A	N/A	13.67/18 = 75.9%	1.63	N/A
1 (7)	8.57/18 = 47.6%	2.51	14.33/18 = 79.6%	1.51	61.1
2 (7)	10.14/20 = 50.7%	2.48	15.57/20 = 77.9%	2.44	55.1
3 (8)	10.50/20 = 52.5%	2.98	15.75/20 = 78.8%	2.25	55.3

Conclusions

- WVU has a broad array of plasma and space physics research supported by a diverse set of graduate and undergraduate courses
- Have used novel instructional approaches in graduate plasma and space physics courses
    - Used “flipped” classrooms in graduate MHD and Kinetic Theory courses
        - Has many benefits (emphasizes concepts, classes are more than just stenography, more opportunity for students to internalize and verbalize course material), some drawbacks (time consuming for students, retention, supports learning for only certain types of learners)
    - Created and implemented pre- and post-test for graduate Kinetic Theory course
        - Allows for more meaningful assessment of instruction
        - Validation and three years experience reveal that students come in with knowledge less than experts but gain expert conceptual knowledge through the course