Syllabus PY521 Spring 2025

- Demo: blue, polarized scattering. [ch 1] Newtonian gravi. Grav multipole expansion. When a dipole can/cannot be eliminated. Grav. quadrupole field.
- Python intro.
- [ch 2-3] Electrostatics. Integrability lemma reduces from 4 eqns in 3 unknown functions to 1 eqn in 1 unknown. Green function solution and multipole revisited. Intermolecular interactions. Visualization by contour plots. Numerical differentiation. Visualization by arrow plots.
- [ch 4] FRET
- [ch 5] Curvilinear coordinates and separation of variables.
- [ch 6] Capacitors. Polarization and bound charge. Physical analogy between polarization and two springs in series. Huge static polarizability of liquid water versus not-huge for ice versus not-huge at optical frequency. Langevin function and how to measure permanent molecular dipole moments. Solubility of an ionic solid.
- What is Physics, anyway? Energy in a capacitor. [ch 8] Continuity equation. Ohmic behavior of salt water. Quasi-static regime. Electrocardiogram.
- :[ch 13] Tensors of rank > 2. Aside on spherical harmonics. Cross product and its relatives as a rank-3 tensor. Levi-Civita tensor and some identities. Aside on nematic liquid crystals. [ch 14] Tensors from Heaven.
- [ch 15] Magnetic field as a tensor, and as a pseudovector. Poincaré lemma as the origin of both electric and magnetic potentials. Gauge invariance. Coulomb gauge choice. Green function solution to magnetostatics. Biot-Savart.
- Numerical integration in Python. [ch 16] SI vs gaussian. Dimensional shortcut for eddy currents. [ch 17] Magnetostatic multipole expansion: No monopole. Dipole. Quadrupole.
- Force and torque on a current distribution in an external B field. Paramagnetism and diamagnetism. Diamagnetic levitation without superconductivity. Mathematical inconsistency of static field equations with nonstatic current motivates Maxwell's modification to the Ampère law.
- Faraday law. Stored magnetic energy proportional to volume.
- Complex exponential notation. Plane wave solutions. Linear and circular polarization. : Microwave demo. Potentials beyond statics. Simplification in restricted Coulomb gauge. [Assigned but no lecture: [ch 20] Energy and momentum transport by waves.]
- [ch 25] Green function solution to inhomogeneous D'Alembert equation. Radiation from a current loop.
- [ch 26] Newtonian interlude: symmetry (active) vs invariance (passive) as two sides of a coin. Principle of Relativity. Galilean invariance hardwires P of R in newtonian physics. Galilean group. Wave equation does NOT have Galilean invariance, but it does when we acknowledge the possible motion of the medium.

- [ch 27] Local energy density and flux, and their continuity equation, for vibrating spring. Animation in Python. [ch 28] If there's no elastic medium, what happens to the P of R? Lorentz invariance of wave equation.
- [ch 29] Fizeau experiment. Complete the specification of Lorentz boosts. [ch 30] Aberration. CMBR anisotropy. [ch 31] Rela energy/mom. Other experimental tests.
- [ch 32] Review 3-tensor principle. The Rules in 3D. Lorentz group and its discrete subgroups. 4-velocity. 4-momentum and its consequences. Quantitative confirmation in the very first linear accelerator.
- [ch 33] Four-tensors and their Rules. "Einstein thinking." Lorentz force law needs a tweak to be Lorentz invariant. From cyclotrons to synchrotrons. Transformation of fields. Point charge in uniform motion.
- [ch 34] Maxwell equations in invariant form. The 4-vector potential. Gauge invariance. Uniform motion again. Qualitative view of bremsstrahlung.
- [ch 35] "E-thinking" everywhere: Gravitational lensing. Energy-momentum flux tensor of electromagnetic fields. Poynting theorem. [ch 36] Plane waves revisited. Energy-momentum flux of plane waves. Two polarizations do not interfere. Equation of state for the radiation-dominated early Universe.
- [ch 38] Green revisited. Lienard-Weichert.
- [ch 39] Variational
- [ch 42] Dipole rad. [ch 46] Scattering
- [ch 47,51] Simple media. Energy in media.
- [ch 52] Scattering in media.