Basic knowledge for Georgia Tech Geophysical and Planetary Science students

This document serves as a summary of the background knowledge expected of PhD students in Geophysical and Planetary Sciences at Georgia Tech. Outside of the additional knowledge identified for specific subdisciplines (denoted by **bold*** abbreviations), the information listed here will mostly be covered in a few "core courses", short courses, individual research, or can be gained through via participation in group and departmental seminars or through undergraduate studies. The graduate-level "core courses" include *Geodynamics*, *Seismology*, *Physics of Planets*, and *GeoFluids*. These courses are not meant for all, but are ones most graduate students will take.

Basic Knowledge:

- Plate tectonics theory: kinematic and dynamic processes, major current plate organization
- Planetary atmospheric structure (P, T, ρ) and dominant species
- Fundamentals of heat transfer (conductive, radiative and convective)
- Major earth materials (silicate, salt, oxide mineral classes; rock types), base compositions, density and location
- 1D mechanical (G, ρ) and compositional Earth models (differentiating ocean/continental lithospheres)
- Fluid and solid mechanics: real-earth elastic and viscous moduli, stresses, flow and strain values
- Gravity: Universal law of gravity, the geoid, and structural anomalies
- Scaling, self-similarity and power-laws in nature
- Simplified phase diagrams
- Basic understanding of continuum mechanics
- Basic understanding of radioactive nuclide decay
- Electromagnetism: Basic (E/M relationship, potentials, etc.)
- Statistics and error analysis: T-,F-tests, χ^2 , random vs. systematic error
- Basic scientific paper writing and presentation skills
- Tools for geophysical exploration: seismic, remote-sensing, gravity, magnetism, geodesy, LiDAR, spectroscopy
- Earth history (planet formation, differentiation, continental growth, climatic and biotic evolution)

Math Skills

- Taylor, Fourier series
- Mathematical background: scalars, vectors, and tensor, matrix algebra, vector calculus
- Classification of differential equations (DE), homogeneous DE, linear DE and general strategies for solutions.
- Non-dimensionalize equations

Seismology

- Elastic wave propagation
- Snell's law (including Fermat's and Huygens' principles)
- Types of seismic waves, controls on velocity, important seismic phases within the Earth
- Geometric spreading, anelastic and scattering attenuation (**S**)
- Seismic anisotropy (**Gd, Gf, S**)
- Time series analysis: digital signal processing, FFT, f-domain, filtering, convolution, correlation (**Gd, S**)

Geodesy

- Okada models of slip induced deformation (**Gd, S**)
- Mogi model of spherical source deformation (**Gd**, **V**)
- Limitations of analytic vs. numerical models of deformation (**Gd**)
- Basic theory of InSAR and GPS data reduction (**Gd**)

Earthquakes and Faults

- Elastic rebound theory
- Fault characterization using geologic, geophysical, and lab studies (**Gd, Gm, S**)
- Controlling factors for earthquake occurrence (**Gd, S**)
- Characteristics of earthquake rupture, afterslip, slow earthquakes and creep events (**Gd, S**)
- Earthquake rupture properties: directivity, length, width, slip and strength (**Gd**, S)
- Magnitude-types and calculations, seismic moment, stress drop (**Gd, S**)
- Corner frequency, and radiated energy (**S**)
- Focal mechanisms, moment tensors, Anderson's Theory of Faulting, deviations (**Gd, S**)
- Mohr-Coulomb failure, slip-weakening, Coulomb/Amonton friction, rate- and state friction (**Gd, S**)
- Omori's law of aftershock occurrence (**Gm, Gd, S**)
- Modified Mercalli Intensity scale, contributing factors in ground shaking intensity (**Gd, S**)
- Hazard assessment of earthquakes and tsunami (**Gd, S**)

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* *Additional* knowledge necessary for: (**Gd**) Geodesy, (**Gf**) Geophysical Fluid Dynamics, (**Gm**) Geomorphology, (**P**) Planetary Sciences, (**S**) Seismology, and (**V**) Volcanology.

Fluid Dynamics

- Conservation relationships for thermal energy, mass and momentum
- Fluid through porous media: Darcy's law
- Boundary layer analysis (**Gf, P, V**)
- Reynolds number, Stokes number, Froude number, particle flow and forces (**Gf, Gm, V**)
- Plumes, jets and gravity currents (analytic models and scaling) (**Gf, V)**
- Turbulent flows and Kolmogorov theories (and transition from laminar to turbulent flow) (**Gf, Gm, P, V**)
- Familiarity with compressible fluid dynamics (shock relations and choked flow) (**Gf, P**, **V**)
- Kinetic theory of gases (**Gf, V**)
- Basic understanding of convection/melting and source terms (radionuclides, linear melting models) (**Gf, V**)
- Fluid dynamics with interfaces (bubbles or particles) – boundary conditions (**Gf, P, V**)
- Rheology (Newtonian, Bingham, shear thinning and shear thickening) (**Gd, Gf, V**)
- Permeability structure in the crust, structural controls on permeability (**Gd, Gf, S, V**)
- Potential flows (**Gf, V**)

Volcanology and Magma Dynamics

- Mantle melting relations (wet and dry)
- Basic understanding of compositional variation in magmas (basalt – rhyolite) and their physical properties
- Volcanic system types, eruption styles and mechanisms (**Gm, V**)
- Fragmentation criteria for magma in volcanic conduits, and its relation to eruptive style (**V**)
- Fundamentals of heat transfer in crust and magmatic systems (**V**)
- Volcanic hazards (**V)**

Planetary and Rock Magnetism

- Magnetic dipole field, basic dynamo theory, magnetic reversals (field evidence)
- Curie point and magnetic susceptibility
- Space weather (sun-earth connection)
- General understanding of magnetic reconnection (**P**)
- Magnetospheric/Auroral generation and dynamics (**P**)
- Electromagnetism: Plasma, and wave dynamics (**P**)

Geomorphology and Geology

- Basic understanding of geochronologic/thermochronologic techniques
- Feedbacks between mountain building, erosion, chemical weathering, and climate
- Fundamentals of field methods and geologic mapping (**Gd, Gm, S, V**)
- Influence of crustal structure on surface geology and topography (**Gm, S**)
- Paleoseismology and observations of faulting (**Gd, Gm, S, V**)
- Channel incision and sediment transport by rivers and debris flows (**Gf, Gm**)
- Hillslope characteristics, processes, and evolution (**Gd, Gm**)
- Hydrologic and geochemical evolution of the Earth's surface and near subsurface (**Gm**)
- Glacier dynamics and erosion (**Gd, Gm**)
- Aeolian sediment transport and landforms (**Gm**)
- Biotic influences on surface processes (**Gm**)

Planetary Science

- Planet formation
- Basic orbital and physical parameters of major solar system planetary bodies
- Characteristics of habitable planetary environments
- Two-body and restricted three-body orbits (**P**)
- Tidal forces and dissipation (**P**)
- Impact crater formation, morphology, and utility for age estimation (**P**)
- Remote sensing techniques used in planetary science – thermal inertia, gamma/X/neutron spectroscopy (**P**)

Space Plasma Physics

- 1D compositional and mechanical models of planetary bodies (**P**)
- Kinetic plasma theory, Boltzmann's and Vlasov's equations, distribution functions in space plasmas (**P**)
- Waves in plasmas: magnetohydrodynamic waves, cold plasma waves, Friedrichs diagrams, CMA diagram (**P**)
- Discontinuities in plasma fluids, Rankine-Hugoniot relations, basic physics of shocks (**P**)

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