NASSP NATIONAL ASTROPHYSICS AND SPACE SCIENCE PROGRAMME

UNIVERSITY OF KWAZULU-NATAL ™

INYUVESI YAKWAZULU-NATALI

NATIONAL ASTROPHYSICS AND SPACE SCIENCE PROGRAMME HONOURS MODULES OUTLINE

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MODULE NAME: **Computational Physics Module Outline**

MODULE CODE: **PHYS766 W1**

NUMBER OF CREDITS: **8**

LECTURER: Prof. Jonathan Sievers

Email: sieversj@ukzn.ac.za

Course Content

1. Introduction to Linux and basic Unix commands
2. Introduction to version control, in particular git.
3. Introduction to Python programming, including mathematical and plotting functions.
4. Introduction to numerical integration, including Simpson's rule.
5. FFTs and applications, including convolutions, correlations, and the shift theorem.
6. Intermediate Python, including classes and operator overloading.
7. N-body simulations. Direct n^2 methods plus introduction for FFT-based gravity solvers.
8. Introduction to partial differential equations, including conservation and stability analysis.
9. Model fitting, including chi^2, linear least-squares, and MCMC.
10. Introduction to Gaussian random fields, including generations of random field realizations via the FFT, and applications such as Kriging.

MODULE NAME: **Mathematical Methods**

MODULE CODE: **PHYS769 W1**

NUMBER OF CREDITS: **8**

LECTURER: Dr. Ilya Sinayskiy

Email: ilsinay@gmail.com

Course Content

Part 1: Finite-dimensional Analysis:

sets, metric and inner product spaces, linear transformations, dual spaces, operators, spectral decomposition theorem.

Part2: Basics of Infinite-dimensional Analysis:

Introduction to space of the square-integrable functions, Hilbert and Banach spaces, Fourier transform and integral, orthogonal polynomials as a basis in infinite dimensional space, classical orthogonal polynomials, elements of the theory of generalised functions.

Part 3: Elements of the Complex Analysis:

Complex functions, Cauchy-Riemann conditions, Cauchy integral formula, Taylor and Laurent series, Calculation of Residues, Evaluation of the Definite integrals using residue theorem, meromorphic functions, analytic continuation, method of the steepest descent.

MODULE NAME: **Classical Field Theory**

MODULE CODE: **PHYS769W1**

NUMBER OF CREDITS: **8**

LECTURER: Prof. Sivakumar Venkataraman

Email: venkataramans@ukzn.ac.za

Course Content

Classical Field Theory: Part 2

1 EM waves

1.1 Separate equations for $\vec{E}$ and $\vec{B}$

1.2 Plane waves in non-conducting medium

1.3 Plane waves in a conducting medium

1.4 Plane waves in arbitrary direction

1.5 Time averaged energy relations

1.6 Polarization

2 Reection and Refraction of EM Waves

2.1 Snell's law

2.2 Fresnel's equations

3 Waveguides

3.1 Boundary conditions at the surface of a conductor

3.2 Propagation characteristics of waveguides

3.3 Fields in a waveguide

3.4 Rectangular waveguides

3.4.1 TE modes

3.4.2 TE10 mode

3.5 TEM modes

MODULE NAME:	**Classical Field Theory**
MODULE CODE:	**PHYS769W1**
NUMBER OF CREDITS:	**8**
LECTURER:	Prof. Francesco Petruccione
Email:	petruccione@ukzn.ac.za

Course Content

Classical Field Theory: Part 2

- Special Relativity
- Relativistic Formulation of Electrodynamics
- Lagrangian formulation of Electrodynamics
- Radiation from relativistic sources
- Basics of General Relativity

MODULE NAME:	**Ordinary Differential Equations [ODE]**
MODULE CODE:	**MATH 714 W1**
NUMBER OF CREDITS:	**16**
LECTURER:	Dr. Rivendra Narain
Email:	narain@ukzn.ac.za

Course Content

Historical introduction; symmetry; Lie symmetry; differential equations; and symmetry; classification of equations; solution of equations; algebras of integrals, partial differential equations; systems of equations; generalized symmetries; Noether's theorem.

Introduction to dynamical system analysis of nonlinear systems (1D flows, Phase plane diagrams, Stability analysis, 2D flows, Bifurcation theory, Applications to real world problems) and Singularity analysis (odes and system of odes)

The course in on Nonlinear ODEs.

MODULE NAME:	**Fluid Dynamics**
MODULE CODE:	**MATH732W1**
NUMBER OF CREDITS:	**16**
LECTURER:	Dr. Anne Marie
Email:	anne.nzioki@gmail.com

Course Content

- Fundamental equations of fluids
- External forces and source terms
- Accretion and shocks
- Fluid instabilities (Rayleigh-Taylor, Kelvin-Helmholtz, Jeans)
- Numerical methods and simulations (finite differences, Lagrangian and Eulerian approaches to fluid simulation)
- Viscous accretion disks
- Magnetohydrodynamics

MODULE NAME:	**Cosmology**
MODULE CODE:	**MATH703W2**
NUMBER OF CREDITS:	**16**
LECTURER:	Prof. Ray Subharthi
Email:	rays@ukzn.ac.za

Course Content

- General Introduction - Length scales – Epochs of the Universe.
- Robertson-Walker Metric - Einstein Universe – Expanding Universe – Assumptions in Cosmology – Redshift
- Hubble Law – Angular Size – Apparent Magnitude
- Friedmann Models - Field equations in Cosmology – Energy-Momentum tensors – Solution of the Friedmann's
- Equations – Luminosity Distance – Angular size – The term
- Thermal History of the Universe - Creation of Photons – Adiabatic Expansion – The Radiation era – Decoupling of Photon and Lepton – Big Bang Nucleosynthesis
- Physical Cosmology - Introduction to Structure Formation – Jeans Theory in Collisional and Collisionless fluids – Growth – Observational Constraints.

MODULE NAME:	**Space Physics**
MODULE CODE:	**PHYS773W1**
NUMBER OF CREDITS:	**8**
LECTURER:	Dr. Judy Stephenson
Email:	stephens@ukzn.ac.za

Course Content

The sun, solar wind, Earth's magnetosphere, plasmasphere, and ionosphere.

Particles in the earth's magnetic field, the aura.

MODULE NAME:	**Plasma Physics**
MODULE CODE:	**PHYS771W1**
NUMBER OF CREDITS:	**8**
LECTURER:	Dr. Suleman Moolla
Email:	moollas@ukzn.ac.za

Definition of a plasma, quasi-neutrality, collective behavior Debye shielding, the plasma parameter.

Single Particle motion Applied to uniform and non-uniform electric and magnetic fields Time varying electric and magnetic fields Curvature drifts Plasmas as fluids
The convective derivative, stress tensor Waves in Plasmas Electrostatic and electromagnetic waves, ion acoustic waves.

Dispersion relations.
Cut offs and resonances.

MODULE NAME:	**Honours Project in Applied Mathematics**
MODULE CODE:	**MATH798W2**
NUMBER OF CREDITS:	**32**
LECTURER:	**TBD**

Content

Some aspect of applied mathematics is considered under the guidance of a "supervisor", a report is written and an oral presentation given, both which are graded. It could be a survey, a synthesis or an application of a known method to a new problem. Original research is not expected but the appropriate research methodology is demanded.