PH5011 - General Relativity

Credits:	15.0	**Semester:**	1
Number of Lectures:	27	**Lecturer:**	Dr Martin Dominik
Academic Year:	2018-19		

Overview
The module provides an introduction to Einstein's theory of General Relativity. We lay the necessary grounds of differential geometry and tensor analysis with familiar concepts and non-relativistic mechanics before discussing the fundamental ideas behind Einstein's theory. We show how Newton's forces are being eliminated in favour of curvature of space-time, where matter and curvature are being related by Einstein's gravitational field equations. We find Schwarzschild's solution and discuss implications such as perihelion precession of planets, bending of light, gravitational redshift, time delay, black holes, and gravitational waves. Moreover, we show how General Relativity plays a role in current technology such as satellite navigation.

Aims & Objectives
The module should provide an introduction and applications to the theory of General Relativity, covering the following topics:

- the "need" for General Relativity and its historic evolution - fundamental principles of General Relativity
- the advanced mathematics required in order to apply the theory - derived predictions and their experimental tests
- application of general relativity in science and technology

Learning Outcomes
Students are expected to be able to

- understand the fundamental concepts of the theory of General Relativity
- practice tensor analysis to describe physical phenomena in curved space-time - derive the equations of motion from a given metric tensor
- compute the general-relativistic effects relevant to astronomy
- compute the effects of general relativity in modern technology

Synopsis
Curvilinear coordinates: basis and coordinates, reciprocal basis, metric, vector fields, tensor fields, coordinate tranformations, affine connection;
Tensor analysis: covariant derivative, Riemann tensor, Einstein tensor;
Classical mechanics (review): principle of stationary action, Hamilton's equations, Hamilton-Jacobi formalism;
Mechanics in curved space: equations of motion, embedding, geodesics, stationary paths, conserved quantities, Hamilton-Jacobi equation;
Special Relativity: Minkowski space, light cone, proper time, relativistic mechanics, energy-momentum tensor;
General Relativity: principles, Einstein's field equations, cosmological constant, time and distance, synchronisation, Schwarzschild solution;
Consequences: relativistic Kepler problem, bending of light, gravitational redshift, time delay, satellite navigation, black holes, gravitational waves.

Pre-requisites
PH3081 or PH3082 or (MT2506 and MT2507). Recommended PH4032 and PH4038.

Anti-requisites
None

Assessment
2 Hour Examination = 100%

Recommended Books
Please view University online record: http://resourcelists.st-andrews.ac.uk/modules/ph5011.html

General Information
Please also read the general information in the School's honours handbook.