# Plasma Physics

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<tr>
<th>Module Code</th>
<th>PHYS96031</th>
<th>FHEQ Level</th>
<th>Level 6</th>
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<tbody>
<tr>
<td>Pre-requisites</td>
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<tr>
<td>Primary Department</td>
<td>Physics</td>
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<tr>
<td>Module Leader</td>
<td>Prof Jeremy Chittenden</td>
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<td>Additional Teaching Departments</td>
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<tr>
<td>Teaching Staff</td>
<td>Prof Jeremy Chittenden + Associate</td>
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<td>Programmes on which the Module is delivered</td>
<td>All UG Physics programmes (F300, F303, F309, F325, F390, F3W3)</td>
<td>Core/Elective</td>
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## Learning Outcomes

On completing the Plasma Physics course, students will:

- Understand the broad range of physical phenomena which determine the behaviour of plasmas and the importance of collective effects.
  - Qualitative understanding
  - Theoretical models (often have to be simplified)
- Start learning how to think like a plasma physicist
  - Develop intuition for plasma behaviour
  - Pin-point the key physics/phenomena for a particular system/application
  - Understand conditions spanning over 20 orders of magnitude.
  - Simplification of theoretical models.
- Learn problem-solving skills for plasma physics
  - Linearization of PDEs
  - ...to facilitate tractable, quantitative solutions
  - Enhance their analytical abilities and physics problem-solving, in general
- Understand the principles and challenge involved in energy generation by thermonuclear fusion.
- Understand the role of plasma in a range of naturally occurring phenomena and laboratory application.

## Description of Content

### Basic properties of plasmas
- Definition, occurrence & importance of plasmas, Debye shielding
- Quasi-neutrality, plasma parameter, plasma frequency, Larmor orbits (basics)
- Non-ideal plasmas

### Thermonuclear fusion
- Nuclear reactions & cross sections, ignition & break-even

### Single particle motion
- Guiding centre drifts; $E\times B$, curvature, gradient
- Magnetic moment ($\mu$), conservation of $\mu$, magnetic mirrors

### Collisions
- Coulomb collisions; mean-free-path and collision time (single & cumulative collisions)
- Resistivity, particle diffusion, bremsstrahlung

**Magnetohydrodynamics (MHD)**
- MHD equations; mass continuity, momentum, energy, Ohm’s law
- The convective derivative, MHD validity & assumptions
- B-field dynamics; flux freezing, resistive diffusion, magnetic Reynolds number
- Magnetic pressure & tension

**Waves**
- Electromagnetic, Langmuir, MHD (Alfvén, magnetosonic)

**Magnetic confinement**
- MHD equilibria; flux surfaces, Z-pinches
- -MHD instabilities & the safety factor, energy confinement in tokamaks
- Tokamak requirements – summary

**Kinetic theory**
- Vlasov & Boltzmann equations, obtaining fluid/MHD equations from Boltzmann
- Langmuir waves, resonant particles & trapping, Landau damping
- Laser-Plasma particle accelerators

**Main approaches to controlled fusion**
- Overviews; magnetic confinement fusion (MCF) & tokamaks, inertial confinement fusion (ICF)

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