Indian Institute of Technology Guwahati
Proposal for a New Course

Course Number & Title: **ME 622 Fundamentals of Fusion Energy Generation and Tokamaks**
L-T-P-C: **3-0-0-6**
Type of Letter Grading (Regular Letter Grades / PP or NP Letter Grades): **Regular Letter Grades**
Kind of Proposal (New Course / Revision of Existing Course): **New Course**
Offered as (Compulsory / Elective): **Elective**
Offered to: **UG** (3rd & 4th Year), **PG** and **PhD;** also open to students of **Physics department** and **School of Energy Science and Engineering**
Offered in (Odd/ Even / Any): **Any**
Offered by (Name of Department/ Center): **Mechanical Engineering**
Pre-Requisite: **None**

Preamble / Objectives (Optional):

The proposed course offers insights into the science and engineering of Fusion energy, a potentially promising source of safe, emission-free and sustainable baseload power. With over 70yrs of continued research, the field has matured enormously and is now at an inflexion point. This is evident from stronger national and international fusion programs, entry of several private investors with growing levels of funding towards fusion, to several new fusion startups coming up swiftly and the large number of universities involved in teaching and research in fusion worldwide.

In this context, it is important to equip future engineers and researchers with the existing know-how, so that they can positively contribute to the Indian fusion program and to India's goal of carbon neutrality in the coming decades. The course content is structured so as to serve as a first course in fusion energy, suitable for both bachelor and master/PhD students. A broad spectrum of topics are covered from basics of fusion reactions, reactor design and high-temperature plasmas, extending to fluid modeling, tokamak plasma equilibria and stability and state-of-the-art challenges.

Course Content/ Syllabus

World energy landscape, climate change quantified, fusion energy and its role; Fusion reactions, fusion versus chemical and fission reactions, binding energy curve; Historical perspective of fusion energy: from hydrogen bomb to ITER; Fusion cross-section, mean-free path and collision frequency, reaction rate and fusion power density, radiation losses and Bremsstrahlung; Power balance in a fusion reactor, concept of energy confinement time, ignition and gain, Lawson criterion, thermal stability; Basic design of a fusion reactor: configuration, engineering and physics constraints, reactor parameters; Fusion plasma: principles of Debye shielding, AC shielding, collective effects; Larmor radii and frequencies; Particle motion in a plasma: gyro motion, ExB drift, grad B and curvature drifts; Coloumb collisions in a plasma: derivation and physical consequences; Two-fluid model: conservation of mass, momentum and energy, coupling to Maxwell's equations; Magnetohydrodynamic (MHD) model: plasma equilibrium and general properties, toroidal force balance; Fusion devices: tokamaks and stellarators, their properties; the

Grad-Shafranov equation; MHD stability: general picture, linear stability and the energy principle, Ideal MHD modes: kink modes and vertical displacement events (VDE), Resistive MHD stability and tearing modes; Disruptive instabilites in tokamak plasmas, current state-of-the-art and key challenges to fusion energy realization.

References: (Format: Authors, *Book Title in Italics font,* Volume/Series, Edition Number, Publisher, Year.)	
1.	J. Freidberg, *Plasma Physics and Fusion Energy*, Cambridge University Press, 2007
2.	J. Wesson, *Tokamaks*, 4th edition, Oxford University Press, 2011
3.	H. Zohm, *Magnetohydrodynamic Stability of Tokamaks*, Wiley-VCH, 2015
4.	J. Freidberg, *Ideal MHD*, Cambridge University Press, 2014
5.	H.P. Goedbloed and S. Poedts, Principles of *Magnetohydrodynamics*, Cambridge University Press, 2004

Detailed Course Content (Optional)
It will not be included in the Courses of Study Booklet

S. No.	**Broad Titles/Topics**	**No. of Lectures**
1	Energy-mix, climate change, alternative pathways & relevance of fusion energy	1
2	Fusion reactions	2
3	Evolution of fusion science and technology	1
4	Fusion power generation	2
5	Power balance, confinement and thermal stability	3
6	Fusion reactor design	3
7	Plasma basics, field shielding and collective effects	3
8	Particle motion in a plasma and drifts	4
9	Coloumb collision theory, physical effects	4
10	Two-fluid model	2
11	MHD model, plasma equilibrium, properties	4
12	Tokamaks and stellarators	1
13	Linear stability and energy principle	2
14	Ideal MHD stability in tokamaks; kinks & VDEs	4
15	Resistive MHD stability and tearing modes	3
16	Disruptive instabilites	2
17	State-of-the-art and open problems in fusion	1
	Total No. of Lectures	**42**