Optical Wave Propagation & Metamaterials			
Course Code:		**Semester:**	
Credit Hours:		**Pre-requisite Codes:**	Electromagnetic Field Theory
Instructor:	Dr. M. Qasim Mehmood	**E-mail:**	qasim.mehmood@itu.edu.pk
Office:	4^{th} floor, Arfa Soft Tech Park	**Telephone:**	+923360502237
Department:	Physics & Engineering	**Discipline:**	Physics & Engineering
Lecture/Lab Days:	As Per Time Table	**Consulting Hours:**	By Appointment via Tel / Email

Reference Books:	
Text Books:	1. Engineering Electromagnetics and Waves by Umran S. Inan, Aziz S. Inan, Ryan K. Said 2. Introduction to Optics By Frank L. Pedrotti, S.J., Leno M. Pedrotti, Leno S. Pedrotti 3. Optics by E. Hecht and A. R. Ganesan 4. Concise Optics Concepts, Examples, and Problems By Ajawad I. Haija, M. Z. Numan, W. Larry Freeman 5. Electromagnetic Metamaterials: Transmission Line Theory And Microwave Applications: The Engineering Approach by Christophe Caloz and Tatsuo Itoh 6. Electromagnetic Metamaterials and Metasurfaces: From Theory To Applications By Long Li, Yan Shi, Tie Jun Cui 7. Electromagnetic Metasurfaces Theory and Applications by Karim Achouri, Christophe Caloz

Weekly Lecture Breakdown : (Each Lecture Duration 1.5 Hours)			
Week 1:	Light Waves, Properties, and Propagation	Week 10:	Introduction to Metamaterials
Week 2:	Light Waves, Coherence, Superposition, and Interference	Week 11:	Fundamentals of Left-handed (LH) Metamaterials
Week 3:	Light Diffraction	Week 12:	Introduction to Electromagnetic Metasurface
Week 4:	Light Diffraction, Fourier Optics	Week 13:	Theory Models of Electromagnetic Metamaterials and Metasurfaces
Week 5:	Fourier Optics	Week 14:	Analysis and Design Methods of Metamaterials and Metasurfaces
Week 6:	Geometric Optics	Week 15:	Overview of Computational Electromagnetic (CEM) Techniques
Week 7:	Geometric Optics	Week 16:	Finite Difference Methods
Week 8:		Week 17:	Design and Simulation of Metamaterials and Metasurfaces on FDTD Lumerical and CST
Week 9:	**Mid Term**	Week 18:	**Final Exam**

<table>
<tr><th>Reference Materials</th><th>Topics</th><th>Lectures (Lecture Duration 1.5 Hours)</th></tr>
<tr><td colspan="3">Physical and Geometric Optics</td></tr>
<tr><td rowspan="6">Introduction to Optics by Frank L. Pedrotti, S.J., Leno M. Pedrotti, Leno S. Pedrotti

Optics by E. Hecht and A. R. Ganesan

Concise Optics Concepts, Examples, and Problems
By
By Ajawad I. Haija, M. Z. Numan, W. Larry Freeman</td><td>Light Waves, Properties, and Propagation
▪ Maxwell’s Equations
▪ Wave Equation
▪ Types and Properties of Electromagnetic Wave Equations
▪ Electromagnetic Wave Equations in Dielectrics
▪ Photon Flux Density</td><td>2</td></tr>
<tr><td>Light Waves, Coherence, Superposition, and Interference
▪ Superposition of Two and Multiple Waves of Arbitrary Phases and of a Slightly Different Frequency: Group Velocity
▪ Young’s Double-Slit Experiment
▪ Lloyd’s Mirror
▪ Newton’s Rings
▪ Interference of Light In Thin Films
▪ Multiple-Beam Interference
▪ Fringes of Equal Inclination:
▪ Fizeau Fringes
▪ Michelson Interferometer</td><td>2</td></tr>
<tr><td>Light Diffraction
▪ Single-Slit Diffraction
▪ Fraunhofer Diffraction
▪ Diffraction From Rectangular Apertures
▪ Double-Slit Diffraction
▪ Diffraction Gratings
▪ Angular Dispersion And Power Of A Grating
▪ Layout And Assumptions: Obliquity Factor</td><td>3</td></tr>
<tr><td>Fourier Optics
▪ Single-Slit Diffraction
▪ Fraunhofer Diffraction
▪ Diffraction From Rectangular Apertures
▪ Double-Slit Diffraction
▪ Diffraction Gratings
▪ Angular Dispersion And Power of a Grating
▪ Layout And Assumptions: Obliquity Factor</td><td>3</td></tr>
<tr><td>Geometric Optics
▪ Reflection and Refraction
▪ Image Formation via Refraction
▪ Paraxial Rays and Lenses
▪ Matrix Optics for Paraxial Rays</td><td>4</td></tr>
<tr><td colspan="3">Mid-Term Exam</td></tr>
<tr><td colspan="3">Optical Metamaterials and Metasurafecs</td></tr>
<tr><td></td><td>Introduction to Metamaterials
▪ Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs
▪ Theoretical Speculation by Viktor Veselago
▪ Experimental Demonstration of Left-Handedness</td><td>2</td></tr>
</table>

Electromagnetic Metamaterials: Transmission Line Theory And Microwave Applications by Christophe Caloz and Tatsuo Itoh	▪ Further Numerical and Experimental Confirmations ▪ Conventional” Backward Waves and Novelty of LH MTMs ▪ Terminology ▪ Transmission Line (TL) Approach ▪ Composite Right/Left-Handed (CRLH) MTMs ▪ MTMs and Photonic Band-Gap (PBG) Structures ▪ Historical “Germs” of MTMs	
	Fundamentals of Left-handed (LH) Metamaterials ▪ Left-Handedness from Maxwell’s Equations ▪ Entropy Conditions in Dispersive Media ▪ Boundary Conditions ▪ Reversal of Doppler Effect ▪ Reversal of Vavilov- ˇ Cerenkov Radiation ▪ Reversal of Snell’s Law: Negative Refraction ▪ Focusing by a “Flat LH Lens” ▪ Fresnel Coefficients, ▪ Reversal of Goos-H¨anchen Effect ▪ Reversal of Convergence and Divergence in Convex and Concave Lenses ▪ Subwavelength Diffraction	2
Electromagnetic Metamaterials and Metasurfaces: From Theory To Applications by Long Li, Yan Shi, Tie Jun Cui	**Introduction to Electromagnetic Metasurface** ▪ Introduction ▪ Features and Classifications of Electromagnetic Metamaterials/Metasurfaces ▪ Brief History of Electromagnetic Metamaterials/ Metasurfaces	2
	Theory Models of Electromagnetic Metamaterials and Metasurfaces ▪ The Electrodynamics of Double Negative Metamaterials ▪ Generalized Snell’s Law ▪ Digital Coding Metamaterials/Metasurfaces ▪ Group Theory of Metamaterials	2
	Analysis and Design Methods of Metamaterials and Metasurfaces ▪ Local Resonant Cavity Cell Model for EBG Metamaterials ▪ Equivalent Medium Theory for Metamaterials ▪ Equivalent Circuit Model for Metasurfaces ▪ Fast Full-Wave Algorithm Simulation for Periodic Array	2
Computational Modeling and Simulation of Metamaterials and Metasurfaces		
	Overview of Computational Electromagnetic (CEM) Techniques ▪ Analytical Methods ▪ The finite difference time domain (FDTD) method ▪ The method of moments (MoM) ▪ Overview of other methods ▪ The finite element method ▪ The transmission line method ▪ The method of lines	2

Multiple Sources	▪ Ray tracing methods ▪ The modelling process; verification and validation; accuracy, convergence consistency and stability;	
	Finite Difference Methods ▪ Finite differences ▪ The lossless transmission line as an 1D problem; FDTD solution ▪ Obtaining wideband data using FDTD ▪ Numerical dispersion ▪ Courant stability criterion ▪ The 2D FDTD algorithm: formulation, sources, meshing, absorbing boundary conditions ▪ The PML absorbing boundary condition ▪ The 3D FDTD algorithm: The Yee cell	2
	Design and Simulation of Metamaterials and Metasurfaces on FDTD Lumerical and CST ▪ Materials Engineering ▪ Meta-atom level design and optimization ▪ Metamaterial/Metasurfaces-level Design and Optimization ▪ Results extraction and Analysis	3
Final Exam		

Course Assessment Distribution:	
Quizez:	10 %
Assignments:	15 %
Term Project:	15%
Mid-term Exam:	20 %
Final Exam:	40.00 %