M. Tech. DEGREE IN

NON - DESTRUCTIVE TESTING

SYLLABUS FOR

CREDIT BASED CURRICULUM

(From the academic year 2024-25 onwards)

DEPARTMENT OF PHYSICS

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI - 620 015

TAMIL NADU, INDIA.

THE INSTITUTE

Vision

To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

Mission

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

THE DEPARTMENT

Vision

- Provide a world class scientific platform for scientists and engineers.

Mission

- Establish the department as a global player in Science and Technology.
- Excel in scientific R&D and consultancy.
- Create an environment for society aimed at knowledge enhancement.

Programme Educational Objectives (PEOs)

PEO1	Postgraduates of the program will become effective non-destructive evaluation engineers in government, industry and other sectors. Involving engineering and technology to become effective innovators and entrepreneurs in addressing engineering challenges in the field of non-destructive testing.
PEO2	To prepare the graduates to work in an interdisciplinary background and contribute significantly to quality research and reliability for the safety of life.
PEO3	To develop graduates with strong industrial training, practical knowledge, interpersonal skills with integrity and ethical values so that they become successful professionals and responsible NDT engineers for society.

Programme Outcomes (POs)

PO1	An ability to independently carry out research /investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery over the area of non-destructive evaluation and related topics.

CURRICULUM

The total credits required for completing the M.Tech. programme in Non-Destructive Testing is **80**.

SEMESTER I

CODE	COURSE OF STUDY	L	T	P	C
PH601	Surface NDE Methods	3	1	0	4
PH603	Ultrasonic Testing	3	1	0	4
PH606	Fabrication Technology	3	1	0	4
	Elective I	3	0	0	3
	Elective II	3	0	0	3
	Elective III	3	0	0	3
PH607	Conventional NDE Laboratory	0	0	4	2
	TOTAL CREDITS				**23**

SEMESTER II

CODE	COURSE OF STUDY	L	T	P	C
PH602	Advanced NDE Techniques	3	1	0	4
PH604	Advanced Ultrasonic Techniques	3	1	0	4
PH605	Radiographic Testing and Radiation Safety	3	1	0	4
	Elective IV	3	0	0	3
	Elective V	3	0	0	3
	Elective VI	3	0	0	3
PH608	Advanced NDE Laboratory and Fieldwork	0	0	4	2
PH622	Radiography and Computational Laboratory	0	0	4	2
	TOTAL CREDITS				**25**

SUMMER TERM (Evaluation in the III Semester based on attached academic institute)

CODE	COURSE OF STUDY	C
PH621	Internship/ Academic Attachment	2
	TOTAL CREDITS	**2**

SEMESTER III

CODE	COURSE OF STUDY	C
PH609	Project Work – Phase I	12
TOTAL CREDITS		**12**

SEMESTER IV

CODE	COURSE OF STUDY	C
PH610	Project Work – Phase II	12
TOTAL CREDITS		**12**

OPEN ELECTIVE/ONLINE COURSES

CODE	COURSE OF STUDY	L	T	P	C
	Open Elective/Online Course#	3	0	0	3
	Open Elective/Online Course*, #	3	0	0	3
	TOTAL CREDITS				**6**

* A Student may register for one 2-credit course and one 1-credit course instead of one 3 credit course.

Every semester, a list of **approved** online courses will be made available to the students to register.

LIST OF ELECTIVES*

	CODE	COURSE OF STUDY
1.	**PH611**	Digital Signal and Image Processing
2.	**PH613**	Basics of Engineering Materials
3.	**PH615**	Material Characterization Techniques
4.	**PH617**	Composite Technology
5.	**PH619**	Electrical, Magnetic and Optoelectronic Materials
6.	**PH612**	Digital Radiography and Computed Tomography
7.	**PH614**	Fracture Mechanics and Failures of Materials
8.	**PH616**	Probability, Statistics, Quality and Reliability
9.	**PH618**	Introduction to Data Analytics
10.	**PH620**	Neutron Radiography
11.	**PH680**	Computational Techniques
12.	**PH685**	Sensors and Transducers
13.	**PH687**	Physics and Technology of Thin Films

* Electives are not limited to the given list. Courses from other PG programmes can also be chosen as subjects of study. The courses will be offered based on the availability of the faculty concerned.

PH601 SURFACE NDE METHODS

COURSE OBJECTIVES:

1. *To introduce the basic concepts of visual testing and acquire knowledge on codes, standards and specifications in NDT.*
2. *To understand the basic principles and application of liquid penetrant testing.*
3. *To understand the basics of magnetism and its application in the field of NDT.*
4. *Introduce the basics of electromagnetics and apply them in eddy current testing.*

Visual Testing

Fundamentals of Visual Testing – vision, lighting, material attributes, environmental factors, visual perception, direct and indirect methods – mirrors, magnifiers, boroscopes and fibroscopes – light sources and special lighting – calibration- computer-enhanced system – Employer defined applications, metallic materials including raw materials and welds – Drone based inspection- Inspection objectives, inspection checkpoints, sampling plan, inspection pattern – classification of indications for acceptance criteria - Codes, Standards and Specifications (ASME, ASTM, AWS etc.)

Liquid Penetrant Testing

Principles – types and properties of liquid penetrants – developers – advantages and limitations of various methods - Preparation of test materials – Application of penetrants to parts, removal of excess penetrants, post cleaning – Control and measurement of penetrant process variables – selection of penetrant method – solvent removable, water washable, post emulsifiable – Units and lighting for penetrant testing –calibration- Interpretation and evaluation of test results - dye penetrant process- applicable codes and standards.

Magnetic Particle Testing

Theory of magnetism – ferromagnetic, paramagnetic materials – characteristics of magnetic fields – magnetic hysteresis – magnetization by means of direct and alternating current – magnetic flux leakage - surface strength characteristics – Depth of penetration factors – Circular and longitudinal magnetization techniques, current calculation –– field produced by a current in a coil, shape and size of coils, field strength, Magnetic Barkhausen Noise Analysis (MBN) – advantages and limitations,

Magnetic Particle Testing

Selecting the method of magnetization, inspection materials, wet and dry particles – portable, mobile and stationary equipment – calibration- capabilities of equipment – magnetic particle inspection of castings and welding – Dry continuous method, wet residual method – Interpretation and evaluation of test indications – Principles and methods of demagnetization – Residual magnetism – applicable codes and standards.

Eddy Current Testing

Basics of electromagnetics - Generation of eddy currents – effect of change of impedance on instrumentation – properties of eddy currents – eddy current sensing elements, probes, type of coil arrangement – absolute, differential, lift off, operation, applications, advantages, limitations – Through encircling coils, type of arrangements –absolute, differential fill factor, operation, application, advantages, limitations - Factors affecting sensing elements and coil impedance - test part and test system – Signal to noise ratio – equipment's, reference samples, calibration, inspection of tubes, cylinders, steel bars, welded tubing, plates and pipes, Remote Field Sensing

- Interpretation/Evaluation –Applicable codes and standards.

Textbooks

1. *ASM Handbook, Volume 17: Non-destructive Evaluation of Materials, ASM International (2018).*
2. *J. Prasad and C. G. K. Nair, Non-Destructive Test and Evaluation of Materials, Tata McGraw-Hill Education, 2nd edition (2017).*
3. *B. Raj, T. Jayakumar and M. Thavasimuthu, Practical Non Destructive Testing, Alpha Science International Limited, 3rd edition (2007).*
4. *T. Rangachari, J. Prasad and B.N.S. Murthy, Treatise on Non-destructive Testing and Evaluation, Navbharath Enterprises, Vol.3, (1983).*
5. *Ed. Peter.J. Shull, Non-destructive Evaluation : Theory, Techniques, and Applications, Marcel Dekker (2002).*

Reference Books and Standards:

1. *C. Hellier, Handbook of Non-Destructive Evaluation, McGraw-Hill Professional, 1st edition (2001).*
2. *J. Thomas Schmidt, K. Skeie and P. Maclntire, ASNT Non Destructive Testing Handbook: Magnetic Particle Testing, American Society for Non-destructive Testing, American Society for Metals, 2nd edition (1989).*
3. *V. S. Cecco, G. V. Drunen and F. L. Sharp, Eddy current Manual: Test method, Vol.1, Chalk River Nuclear Laboratories (1983).*
4. *B.P.C. Rao, Practical Eddy Current Testing, Alpha Science International Limited (2006).*
5. *N. A. Tracy, P. O. Moore, Non-Destructive Testing Handbook: Liquid Penetrant Testing, Vol. 2, American Society for Non-destructive Testing, 3rd edition (1999).*
6. *Don E. Bray and Roderic K. Stanley, Non-destructive Evaluation: A Tool in Design, Manufacturing and Service, CRC Press (1996).*
7. *ASTM/ASME/API standards for Visual, Liquid Penetrant Testing, Magnetic particle Inspection and Eddy Current Testing.*

COURSE OUTCOMES:

After successful completion of this course, the students will be able to:

1. *have a basic knowledge of surface NDE techniques, which enables to carry out various inspection in accordance with the established procedures.*
2. *differentiate various defect types and select the appropriate surface NDT methods for better evaluation.*
3. *communicate their conclusions clearly to specialist and non-specialist audiences.*
4. *document the testing and evaluation of the results for further analysis. Understand how to read and understand specific Codes and Standards in each technique.*

PH603 ULTRASONIC TESTING

COURSE OBJECTIVES:

1. *Introduce ultrasonic wave propagation in other engineering materials.*
2. *Understand ultrasonic wave generation and transducer operation.*
3. *Familiarize with the procedure of ultrasonic inspection and relevant calibration.*
4. *Obtain knowledge of how to evaluate the test results.*

Fundamentals of Ultrasonic Waves

Nature of sound waves,**–** modes of sound wave **–** longitudinal waves, transverse waves, surface waves, lamb waves **–**Velocity, frequency and wavelength of ultrasonic waves **–** Ultrasonic pressure, intensity and impedance **–** Attenuation of ultrasonic waves **–** reflection, refraction and mode convection **–** Snell's law and critical angles **–** Fresnel and Fraunhofer effects **–** ultrasonic beam split – wave propagation in other engineering materials.

Generation of Ultrasonic Waves

Methods of ultrasonic wave generation **–** piezoelectric effect, piezoelectric materials and their properties **–** crystal cuts and mode of vibration **–** Ultrasonic search Unit (transducers), types (straight, angle, dual) **–** Construction materials and shapes **–** Beam intensity, characteristics, sensitivity, resolution and damping **–** Transducer operation, manipulations.

Ultrasonic Inspection Methods and Equipment

Principle of pulse-echo method, through transmission method, resonance method **–** Advantages, limitations **–** contact testing, immersion testing, couplants **–** Data presentation A, B and C scan displays, comparison of contact and immersion method. Pulse Echo instrumentation, controls and circuits, pulse generation, signal detection, display and recording methods, gates, alarms and attenuators.

Calibration of Testing Equipment

Basic instrument calibration **–** calibration blocks (IIW Block, ASTM Blocks, Distance Amplitude Block, Area Amplitude Block, etc.), cables, connectors, test specimens etc. Reference reflectors for calibration (side drilled holes, notches, etc.) **–** Inspection calibration, comparison with reference blocks, reference for planned tests (straight beams angle beam. etc.), transmission factors **–** factors affecting the performance of ultrasonic tests.

Testing/Evaluation/Interpretation

Weld body examination with normal and angle beam by DAC and DGS methods **–** Ultrasonic testing and evaluation of base material product forms (a) Ingot, (b) Plate and Sheet (c) Bar and Rod (d) Castings (e) Forgings (f) Pipe and Tubular products, Ultrasonic test indications, Variables affecting ultrasonic test results- case studies in metals and composites- weld geometries, root inspection - types, origin and typical orientation of discontinuities - response of discontinuities to ultrasound – safety precautions, Test Procedure- Scan plan/technique sheets, Applicable codes and standards, specifications (ASME, ASTM, AWS, BS. etc.).

Textbooks

1. *J. Krautkramer and H. Krautkramer, Ultrasonic Testing of Materials, Springer, 4^{th} edition (1990).*
2. *B. Raj, C.V. Subramanian and T. Jayakumar, Non Destructive Testing of Welds, Woodhead Publishing, 1^{st} edition (2000).*
3. *L. Schmerr and J. Song, Fundamentals of Ultrasonic Non-destructive Evaluation, Springer, (1998).*

Reference Books:

1. *P. J. Shull, Non-destructive Evaluation: Theory, Techniques, and Applications, CRC Press, 1^{st} edition (2002).*
2. *C.V.Subramanian, Practical Ultrasonics, Alpha Science International, (2006).*
3. *A.S. Birks and R.E. Green, Ultrasonic Testing, Non-destructive Handbook, Vol. 7, American Society for Non-destructive Testing, 2^{nd} edition (1991).*
4. *ASME Sec V 2001 (Boiler & Pressure Vessel Code), ASME Intl. (2017).*

COURSE OUTCOMES:

After successful completion of this course, the students will be able to:

1. *understand basic knowledge of ultrasonic techniques and equipment. Calibrate the instrument and evaluate the component for imperfections.*
2. *independently analyze after performing an inspection of defective samples.*
3. *differentiate various defect types and select the appropriate procedure for the specimen.*
4. *document the reports and classify written procedures, paving the way for further training in specific techniques.*

PH606 FABRICATION TECHNOLOGY

COURSE OBJECTIVES:

1. *To understand the basic concepts of metal casting, forming and joining technology in order to produce new materials.*
2. *To know the concepts of metal joining technology and apply them for various manufacturing processes.*
3. *To explore the different welding defects formed during the joining process.*
4. *To gain knowledge on inspection and case studies.*

Casting and Forging Processes
Casting- definition- different types of casting – sand casting – shell mould casting - permanent mould casting – die casting – centrifugal casting – continuous casting – plaster mould casting – investment casting – ceramic mould casting – shaw process – unicast process – Slush casting and composites mould casting. Classification of Metal forming processes- Forging- definition- different types of forging -open die, closed die and flashless die forging - Forging hammers, presses and dies - Rotary swaging.

Fusion Welding
Heat sources - Shielding gas and flux – *Gas Welding* – flame characteristics, different kinds of flame and applications – *Arc Welding* – Types of electrodes- Power sources- Polarity- Different types of arc welding- Manual metal arc welding - Submerged arc welding – Gas Metal arc welding (MIG welding), Gas Tungsten arc welding (TIG welding) - *Resistance welding*- advantages and limitations.

Solid State Welding
Diffusion welding - Friction welding- Friction stir welding:- Concepts – Metal flow phenomena, tools, process variables and applications - Advantages and limitations.- Ultrasonic welding.

Welding Defects
Classification of welding defects - *External welding defects* - different types (Weld Crack, Undercut, Spatter, Porosity, Overlap etc..) - Causes and remedies- *Internal welding defects*- different types (Slag inclusion, Incomplete fusion, Incomplete penetration, Neckless cracking, etc.) – Causes and remedies- Effect of metallurgical parameters – Concept of weldability- Factors affecting on weldability.

Other Engineering Processes
Brazing, soldering, cutting, surfacing, adhesive joints, bolted and riveted- processes – joining materials, advantages and limitations- applications – inspection of the joints – case studies.

Textbooks

1. *R. W. Heine, C. R. Loper P. C. Rosentha, Principles of Metal Casting, McGraw -Hill, 2nd edition, (1967).*
2. *P. L. Jain, Principles of Foundary Technology, McGraw Hill, 5th edition, (1995).*
3. *R. S. Parmer, Welding Engineering and Technology, Khanna Publishers, 2nd edition, (2010).*
4. *M. P. Groover, Fundamentals of Modern Manufacturing: Materials, Process and Systems, 4th Edn., John Wiley (2010).*

Reference Books:

1. *N. K. Srinivasan, Foundry Technology, Khanna Publications, (1986).*
2. *H. B. Carry and S. Helzer, Modern Welding Technology, Prentice Hall, 6th edition, (2004).*
3. *R. S. Mishra, M.V. Mahoney,Y. Sato and Y. Hovanski, Friction Stir Welding and Processing, John Wiley & Sons, (2013).*
4. *M. D. Jackson, Welding Methods and Metallurgy, Grffin, (1967).*

COURSE OUTCOMES:

At the end of this course, the students will be able to:

1. *design a new pattern or mould for the required application.*
2. *classify the different welding processes with their inherent merits and limitations.*
3. *solve the material problems and minimise the welding defects in the metal joining processes in the industries.*
4. *provide the low cast manufacturing possibilities by appropriate selection of the joining process.*

PH607 CONVENTIONAL NDE LABORATORY

COURSE OBJECTIVES:

1. *To demonstrate knowledge and understanding of conventional non-destructive evaluation (CNDE) techniques for defect detection in mechanical components.*
2. *To provide a strong hands-on experience with CNDE methods for inspecting and evaluating components according to industry specifications.*
3. *To identify and evaluate the different types of defects in the weld components through CNDE systems.*
4. *To understand the advantages and limitations of CNDE techniques and their field of applications.*

List of Practicals

1. Visual inspection of welded tubes.
2. Inspection of welds using solvent removable visible dye penetrant test (PT)
3. Inspection of welds using solvent removable fluorescent dye penetrant test.
4. Inspection of welds by Magnetic Particle Testing - Dry method.
5. Inspection of welds by Magnetic Particle Testing- Wet method.
6. Familiarization of Ultrasonic Flaw Detectors
7. Calibration of Ultrasonic Flaw Detector using stranded reference blocks.
8. Determination of mechanical properties of materials using ultrasonic pulse-echo method.
9. Inspect the metal thickness of ship hulls, piping, and structural steel using an ultrasonic thickness gauge.
10. Leak testing- pressure vessel
11. Leak testing- vacuum vessel
12. Familiarization and calibration of Eddy Current Flaw Detector.
13. Inspection of non-magnetic/magnetic materials by Eddy Current Flaw Detector.

COURSE OUTCOMES:

After completing these experiments, the students will be able to:

1. *handle the CNDE techniques independently and inspect the components according to industrial standards.*
2. *evaluate and differentiate the surface imperfections using the penetrant testing method.*
3. *inspect subsurface defects using magnetic particle and eddy current testing methods.*
4. *evaluate and interpret the results of ultrasonic flaw detectors and radiographs for defect analysis.*

PH605 RADIOGRAPHIC TESTING AND RADIATION SAFETY

COURSE OBJECTIVES:

The course is intended to:

1. *understand the sources of radiation and their interaction with matter.*
2. *identify the suitability of the radiographic testing method for the material inspection and exposure.*
3. *interpret and evaluate radiographic images according to applicable standards, codes and procedures.*
4. *provide information on safe practices in handling radiographic techniques and equipment.*

Basic Principles of Radiography
Geometric exposure principles, shadow formation, shadow sharpness – Radio isotopic sources – types and characteristics – Production and processing of radioisotopes – radiographic cameras - X-ray source generation and properties – industrial X-ray tubes – target materials and characteristics – change of mA and kVp effect on "quality" and intensity of X-rays – High energy X-ray sources – linear accelerators.

Film Radiography
X-ray film – structure and types for industrial radiography – latent image formation on film-sensitometric properties – characteristic curves (H & D curve) –– radiographic exposure, reciprocity law, photographic density – X-ray and gamma ray exposure charts – exposure time calculations – film handling and storage – Effect of film processing on film characteristics – Processing defects and their appearance on films – control and collection of unsatisfactory radiographs – Automatic film processing.

Radiographic Image Quality and Radiographic Techniques
Radiographic sensitivity – Radiographic Contrast, film Contrast, Subject Contrast, Definition, Radiographic density – penetrameters or Image Quality Indicators – Intensifying screens – intensification factor, control of scattered radiation, filters, diaphrams, masks – Radiography of weldments – single and double wall Radiography – panoramic radiography-procedure shootingsketch/technique sheets.

Radiation Detectors and Safety
Special and SI Units of radiation – Principle of radiation detectors – ionization chamber, proportional counter, G. M. counters, scintillation counters, solid state detectors – Biological effectof ionizing radiation – Operational limits of exposures – Radiation hazards evaluation and control – Design of radiography installation and shielding calculations. Atomic Energy Regulatory Board (AERB) regulations for industrial Radiography.

Special Radiographic Techniques and Interpretation of Radiographs
Principles and applications of Fluoroscopy/Real-time radioscopy – advantages and limitations – recent advances, intensifier tubes, vidicon tubes – Principle of neutron radiography - attenuation of neutrons - direct and indirect technique - advantages and limitations – Principle and applicationof in-motion and flash radiography.

Interpretation of radiographs:- Interpretation for welds, castings etc, applications, various case studies, Inspection standards - applicable codes, standards and specifications (ASME, ASTM, AWS, BS, IBR etc.)

Textbooks

1. *L. E. Bryant and P. McIntire, Non-Destructive Testing Hand Book: Radiography andRadiation Testing, Vol.3, American Society for Non-Destructive Testing, 2nd edition (1985).*
2. *R. Halmshaw, Industrial Radiography: Theory and Practice, Springer, 2nd edition (1995).*
3. *Non-Destructive Examination and Quality Control, ASM International, Vol.17, 9th edition(1989)*

Reference Books:

1. *R. H. Bossi, F. A. Iddings and G.C. Wheeler, Radiographic Testing, American Society forNon-destructive Testing, 3rd edition (2002).*
2. *B. Raj, T. Jayakumar and M. Thavasimuthu, Practical Non-Destructive Testing, Alpha Science International Limited, 3rd edition (2002).*
3. *Richard A. Quinn and Claire C. Sigl, Radiography in modern industry, Eastman Kodak Co, 4th edition, (1980).*
4. *https://www.aerb.gov.in/english/publications/codes-guides*
5. *C. J. Hellier, Handbook of Non-destructive Evaluation, McGraw Hill (2003).*

COURSE OUTCOMES:

By successful completion of this course, the students will able to:

1. *have a complete theoretical and practical understanding of the radiographic testing, interpretation and evaluation.*
2. *select an appropriate technique and exposure time for a better imaging.*
3. *differentiate various defect types and characterize them.*
4. *follow proper safety precautions to avoid radiation hazards. Understand regulatory requirements in Industrial Radiography by general reading.*

PH602 ADVANCED NDE TECHNIQUES

COURSE OBJECTIVES:

1. *To introduce a basic understanding of various advanced non-destructive evaluation (NDE) techniques.*
2. *To demonstrate a comprehensive understanding of advanced NDE techniques for quality control in manufacturing engineering components.*
3. *To develop proficiency in inspecting engineered components and materials using various NDE methods, including acoustic emission inspection, leak testing, thermography, terahertz imaging, and advanced optical image testing techniques.*
4. *To create the ability to select appropriate NDE testing techniques for designed, engineered systems.*

Acoustic Emission (AE) Inspection

Principles and Theory, Signal Propagation, Physical and Time Considerations, AE Parameters, The AE Process Chain, The AE Measurement Chain, AE Source Measurements Methods, and Types of Measurement Parameters and Data Analysis. Advantages and Limitations, Comparison to other NDE testing methods, Applications: Practical uses of AE inspection, including inspecting health conditions in pressure vessels, examining weld joints and pipelines, Monitoring steam turbines and power transformers, and assessing composite materials.

Leak Testing

Basic knowledge of leaks and leakage, Tracer fluids, Characteristics of methods and techniques of leak testing, Different techniques for the application of leak tests: Bubble test, Testing using pressure, Test by detection of halogens, Ultrasonic leak testing, Acoustic emission leak testing, Vacuum box leak testing techniques, Halide torch testing, and Helium mass spectrometer leak testing, Choosing the Optimum Leak Testing Method, System response in leak testing, Common errors in Leak testing, Codes and standards, Safety aspects, and Leak testing for special applications.

Infrared Thermographic

Introduction and fundamentals to infrared and thermal testing, Heat transfer methods, Thermomechanical behavior of materials, Types of Thermography Inspection: Passive and Active techniques, Lock-In and Pulse thermography, Flash- and Vibro-thermography, Heat sensitive paints and papers, Other temperature-sensitive inspection methods, Infrared radiation and infrared detectors, Applications: Electrical Inspections, Building Diagnostics, Moisture Detection, Mechanical Inspections, Aircraft Maintenance, Medical Diagnostics, Case studies.

Terahertz Imaging Technique

Fundamentals of Terahertz imaging, THz Generation and detection methods, Terahertz Spectroscopy, Time and Frequency domain Spectroscopy, Refractive index measurement, THz NDT instruments, and Applications of THz in NDE.

Strain Gauge Testing and Optical NDT Methods

Principle, Types of Strain Gauges, Instrumentation, and Integrate strain gauging with other NDT methods.

Optical NDT Methods

Laser Shearography, Holographic Interferometry, Holographic Shearing Interferometry, Speckle Pattern Interferometry, Speckle Pattern Shearing interferometry, and Microwave holography.

Textbooks

1. *X. P. V. Maldague, Non-destructive evaluation of materials by infrared thermography, Springer-Verlag, 1st edition, (1993).*
2. *A. S. Paipetis,T. E Matikas and D. G. Aggelis, Emerging Technologies in Non-Destructive Testing, CRC Press, (2012).*
3. *C. U. Grosse, Acoustic Emission Testing, Springer, (2008).*
4. *Kai-Erik Peiponen, Axel Zeitler, Makoto Kuwata-Gonokami, Terahertz Spectroscopy and Imaging, Springer (2013).*

Reference Books:

1. *X. P.V. Maldague, Non-Destructive Testing Handbook; Infrared and Thermal Testing, Vol-3, series III, American Society for Non-Destructive Testing, 3rd edition (2001).*
2. *C. N. Jackson and N.Sherlock , Non-Destructive Testing Handbook; Leak Testing , Vol -1, series VI, American Society for Non-Destructive Testing, 3rd edition, (1998).*
3. *R. K.Miller and V.K.Hill, Non-Destructive Testing Handbook; Acoustic Emission Testing, Vol-6, series V, American Society for Non-Destructive Testing, 3rd edition, (2005).*

COURSE OUTCOMES:

Upon successful completion of this course, the students will be able to:

1. *identify and explain various advanced NDE techniques used for quality control engineering.*
2. *understand recent NDE developments and their applications in various industries.*
3. *select appropriate advanced NDE technique(s) for improved inspection and evaluation of components.*
4. *apply and analyze various NDE methods to a component and compare the effectiveness of different techniques for specific applications.*

PH604 ADVANCED ULTRASONIC TECHNIQUES

COURSE OBJECTIVES:

To introduce students to the recent advances in the field of ultrasonic and

1. *introduce advanced ultrasonic techniques with the knowledge of different process.*
2. *understand instruments and probe design for a better evaluation of complex geometries.*
3. *obtain knowledge of advanced ultrasonic inspection and applicable code.*
4. *familiarize with Structural Health Monitoring and application.*

Phased Array Techniques

Principles of phased array inspection – phased array probes and their characteristics – Phased array wedges – Focal law – Beam shaping, steering –Scanning with phased array probes- linear, sectorial, A, B, C, D and S scan.

Instrumentation – phased array instruments, calibration methods, TCG plotting– beam angles and beam shape - data acquisition, defect detection, sizing, interpretation and characterization – dynamic depth focusing, Delay law applications, Advanced PAUT probes Full matrix capture (FMC) and Total Focusing Method (TFM) and - Codes in PAUT.

Time of Flight Diffraction

Theory and principles of Time of Flight Diffraction (TOFD) –Data acquisition and interpretation – TOFD techniques – selection of probe angle – calibration– flaw location and sizing – types of scan, equipment requirements – advantages of TOFD inspections interpretation, evaluation, applications, case studies. *Introduction to Synthetic Aperture Focusing Technique (SAFT).* Codes and standards – in TOFD.

Ultrasonic Guided Waves

Basics of guided waves – Generation of guided waves – Dispersion curves –Modes in guided waves –advantages and limitations – Applications, few case studies. Long Range Guided Waves - Applications, SHM Methods - EMAT, Optical Methods in EMAT sensors, Laser Ultrasonic –lamb wave generation mechanisms, optical detection of ultrasound – Structural Health Monitoring (SHM)- Automatic deformation monitoring system.

Textbooks

1. *J. L. Rose, Ultrasonic waves in solid media, Cambridge University Press, (2004).*
2. *T. Kundu, Ultrasonic Non-Destructive Evaluation: Engineering and Biological Material Characterization, CRC Press, 1st edition, (2003).*
3. *L. W. Schmerr, Fundamentals of Ultrasonic Phased Arrays, Springer, (2014)Phased Array Testing: Basic Theory for Industrial Applications, Olympus NDT, (2004).*
4. *Introduction to Phased Array Ultrasonic Technology Applications, R/D Tech, (2004).*

Reference Books:

1. *Z. Shu and L. Ye, Identification of Damage Using Lamb Waves: From Fundamentals to Applications, Springer, (2009).*

2. *Advances in Phased Array Ultrasonic Technology Applications, Olympus NDT, (2007).*
3. *J. A. Ogilvy and A.G. Temple, Diffraction of elastic waves by cracks: Application to Time of Flight Inspection, Ultrasonics, volume 7, 259-269, (1983).*
4. *G. Baskaran, K. Balasubrmaniam and C. L. Rao, Shear wave time of flight diffraction (S-TOFD) technique, NDT&E International, volume 39, 458-467, (2005).*
5. *S. Mondal, An overview of TOFD method and its mathematical model, www.ndt.net/rticle/v05n04/mondal*
6. *L.J. Busse, Three dimensional imaging using a frequency domain synthetic aperture focusing technique, IEEE Transac.UFFC 39, 174-179, (1992)*
7. *Phased array techniques-Olympus NDT, (1999).*
8. *C. B. Scruby and L. E. Drain, Laser Ultrasonics: Techniques and Applications, CRC Press, (1990).*
9. *R. Keith Mobley, Vibration Fundamentals, Newnes (1999).*

COURSE OUTCOMES:

After successful completion of this course, the students will be able to:

1. *understand the workings of advanced ultrasonic equipment for independently Performing inspection of defective samples.*
2. *calibrate the instrument and evaluate the component for imperfections by selecting proper codes and standards.*
3. *analyze with appropriate cutting-edge testing methods for real-time measurement.*
4. *classify and Document the reports and create written procedures, paving the way for further training in specific techniques.*

PH608 ADVANCED NDE LABORATORY AND FIELD WORK

COURSE OBJECTIVES:

1. *To demonstrate knowledge of the Advanced Non-destructive Evaluation (ANDE) techniques and their calibration methods.*
2. *To provide strong hands-on experience in ANDE methods and data interpretation training through Matlab software.*
3. *To identify different types of defects in the components and validate the obtained results using simulation tools.*
4. *To understand the real-time application of ANDE techniques in industries and manufacturing processes.*

List of Experiments

1. Calibration and Plotting DAC curves using Ultrasonic Flaw Detector using by normal and angle beam probes.
2. Inspection of welds in plates by ultrasonic angle beam testing.
3. Inspection of butt welds in pipes by ultrasonic angle beam testing.
4. Weld inspection using Ultrasonic Immersion Systems (C- Scan).
5. C -Scan imaging of metal samples using an ultrasonic immersion transducer.
6. Characterization of defects in honeycomb structure using Infrared (IR) Thermography.
7. Inspection of composite laminate structures using the NDT technique
8. Calibration of Phased Array Ultrasonic Testing (PAUT) equipment for defect detection.
9. Inspection of IOW blocks using Phased Array calibration (PAUT).
10. Calibration and weld inspection using time-of-flight diffraction (TOFD) .
11. Infrared (IR) Thermography: i) thickness measurement and ii) diffusivity measurement of advanced composites.
12. Inspection of welded plates by Eddy Current Flaw Detector.
13. Field visit - Evaluation of manufacturing process (Pipes, valves, tubes, etc).
14. Field visit – Testing and calibration of materials using various advanced NDE techniques.

COURSE OUTCOMES:

After completing these experiments, the students will be able to:

1. *handle the ANDE instruments and perform inspections of weldments with unknown defects.*
2. *evaluate the A, B, and C scan profiles using ultrasonic immersion testing and operate a phased array of equipment for effective defect detection.*
3. *inspect and identify delamination in the composite structures using infrared thermography (IRT).*
4. *understand the application of ANDE techniques in manufacturing industries and the testing and calibration of materials as per industrial standards.*

PH 622– RADIOGRAPHY AND COMPUTATIONAL LABORATORY

COURSE OBJECTIVES:

1. *To introduce the basic concept of radiation physics behind X-ray radiography, Gamma-ray spectrometer, and GM counter.*
2. *To provide hands-on experience and training with radiation-based NDE methods and analysis of defect characteristics in the components.*
3. *To demonstrate the basics of MATLAB programming for signal and image processing.*
4. *To understand the application of radiation NDE techniques in the manufacturing industry and their software skills.*

List of Experiments

1. X-ray radiography: density analysis
2. X-ray radiography: penetration depth analysis
3. Gamma-ray spectrometer: isotope analysis
4. Gamma-ray spectrometer: penetration depth analysis
5. GM counter: half-life analysis
6. MATLAB-1: acoustic emission signal analysis
7. MATLAB-2: Time-series analysis using Fourier transform
8. MATLAB-3: Image and data analysis
9. Radiography analysis Python programming
10. Ultrasonic analysis Python programming
11. Eddy current analysis of Python programming
12. Inspection of a welded plate by radiographic single wall single image technique- X-rays.
13. Inspection of a welded pipe by Panoramic Technique- Gamma rays.
14. Inspection of a welded pipe by double wall single image technique - Gamma rays.
15. Simulation and Modelling of NDT Techniques
16. Ultrasonic modelling simulator

Reference Books

1. *MATLAB Programming Fundamentals – © COPYRIGHT 1984–2021 by The MathWorks, Inc.*

COURSE OUTCOMES:

After completing these experiments, the students will be able to:

1. *handle the radiation-based NDE techniques to inspect the various components as per the industrial specifications.*
2. *use MATLAB programming to analyze the signal (time and frequency domain) and image processing.*
3. *analyze the ultrasonic and radiography data using Python programming.*
4. *inspect the welded plates and pipes through radiation-based NDE techniques and evaluate defect characteristics in the components.*

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Elective papers

PH611 DIGITAL SIGNAL AND IMAGE PROCESSING
(Elective)

COURSE OBJECTIVES:

1. *Introduce discrete signal and image processing concepts and their application.*
2. *To understand the basic mathematics necessary for signal processing and image processing.*
3. *Know different techniques for designing digital filters.*
4. *Have knowledge of different Image enhancement techniques and analysis.*

Discrete Time signal and systems
Basics of signals **–** Periods, frequency, phase **–** Mathematical representation of signals **–**Discrete time signals, data acquisition **–** Sequences **–** Linear shift-invariant systems **–** Stability and Causality **–** Linear constant Co-efficient difference equations **–** Frequency-domain **–** Representation of Discrete-time systems and signals **–** Representation of discrete-time signals by Fourier transform – signal analysis - time-domain analysis- determination of signal power and energy – gating methods – time gate – peak determination- echo detection – time-frequency analysis – short time Fourier transform – wavelet.

Transform analysis of linear time invariant systems
Z-transform **–** Region of convergence **–** Relation between Z- transform and Fourier Transform **–** Frequency response **–**Phase distortion and delay **–** system functions **–** Frequency response of rational system functions**–**first-order systems **–** Basic Digital filter structures **–** FIR and IIR filters.

Filter Design Techniques and Fast Fourier Transform
Signal noise – inherent noise, EMI noise, random noise, speckle noise, process induced noises etc – Design of FIR filters by window method **–** Rectangle **–** Hanning **–** Hamming **–** Kaiser **–** IIR Filters design **–** Bilinear Transformation **–** Discrete Fourier Transform **–** Computation of DFT- Applications in NDT.

Continuous and Digital Image Characterization
Image representation - 2D-systems - 2D-Fourier Transform - Light perception - Eye Physiology - Visual phenomena - Monochrome vision model - 2D Image sampling & reconstruction - Image sampling systems - Aliasing effects - Image reconstruction systems - Vector-space Image representation - Image Quantization.

Linear Image Processing methods and Image Enhancement
Introduction to image representation – spatial and frequency domain –. Generalized 2D Linear operator - Superposition – Filtering – Convolution and De-convolution - Unitary transformations - Fourier Transform - Cosine Transformation - Image reconstruction and Enhancement - Contrast manipulation - Histogram modification - Noise cleaning – Image analysis – Edge detection and crispening –contour quantification –texture analysis– statistical analysis- Applications in NDT.

Textbooks

1. *A.V. Oppenheim and R. W. Schafer, Discrete-Time Signal Processing, Pearson India (2014).*
2. *Vinay K. Ingle and John G. Proakis*, Digital Signal Processing Using MATLAB®: A Problem Solving Companion Paperback – Cengage India Private Limited (2017*).*
3. *W. K. Pratt, Digital Image Processing, John Wiley & Sons,4th edition, (2010).*
4. *R. C. Gonzalez and R. E. Woods, Digital Image Processing, Pearson Education,4th edition. (2018).*

Reference Books:

1. *L.R. Rabiner and B. Gold, Theory and Applications of Digital Signal Processing, Pearson India, (2015).*
2. *T. Bose, Digital Signal and Image Processing, Wiley student edition (2010).*
3. *A.V. Oppenheim, A. S. Will Sky and S. H. Nawab, Signals and Systems, Prentice-Hall of India, 2nd edition, (2008).*
4. *N. Efford, Digital image processing: a practical introduction using Java, Addison-Wesley, (2000).*

<u>COURSE OUTCOMES:</u>

Upon completion of the course, the students will be able to:

1. *understand basic principles of discrete-time signals and systems.*
2. *design and analyse various types of frequency digital filters.*
3. *use different Digital image processing techniques for specific applications.*
4. *apply signal processing to ultrasonic signals and image processing to radiographic images.*

PH613 BASICS OF ENGINEERING MATERIALS
(Elective)

COURSE OBJECTIVES:

This introductory course is aimed to:

1. *obtain knowledge on basics of metals, dislocations, reactions and phase diagrams.*
2. *familiarize heat treatment of steels, TTT and CCT diagrams.*
3. *understand the mechanical properties and testing of materials.*
4. *introduce non-ferrous metals, ceramics, light weight structures.*

Structure of Metals

Crystal structure– Imperfections in crystals – dislocation theory - Principles of Alloying – Solid solutions– Gibbs phase rule and equilibrium diagram - types of binary phase diagrams – Eutectic – Peritectic and eutectoid reactions.

Steel and Heat Treatment of Steels

The Iron-carbon system – structural changes on slow and rapid cooling - martensitic transformation –concept of hardenability – TTT and CCT diagrams. Effects of carbon and alloying elements – Classification of steels. *Heat Treatment of Steels:* Annealing -normalizing, quenching and tempering – Case hardening, Austempering and martempering – Solidification of Metals and alloys – Nucleation and crystal growth from the liquid phase –Segregation effects and grain size control – strength mechanisms – solute, dispersion and precipitation hardening.

Mechanical behaviour of materials

Elements of elastic and plastic deformation – stress-strain relation-work hardening, recovery, re-crystallization and grain growth. Fracture-ductile fracture, brittle fracture, Griffith's criterion-toughness- fatigue, creep fracture- - Failure analysis and testing.

Non-Ferrous Metals & Ceramics

Significance of light metals in engineering industries, Aluminum, Aluminum alloys, strengthening mechanism of aluminum alloys and heat treatment methods- Copper & Copper Alloys- Titanium & Titanium Alloys, Advantages & Applications. Industrial importance of engineering ceramic materials, refractories and their application. Cement and concrete, damages and degradation of concrete.

Composites

Importance of composites – constituents – functions of fiber and matrix –types of fibers-glass fiber, carbon fiber, metallic fibers, ceramic fibers-Matrix materials – Metallic and Polymer matrix composites – Manufacture methods – hand lay up & prepeg techniques pulforming, therforming, resin-transfer moulding, injection moulding.

Textbooks

1. *W. D. Callister, Materials Science and Engineering: An Introduction, Wiley, 7th edition, (2006)*
2. *V. Raghavan, Materials Science and Engineering, Prentice Hall of India, 5th edition (2013).*
3. *G.E. Dieter, Mechanical Metallurgy, Mc-Graw Hill, 3rd edition (2004).*
4. *A.V.K. Suryanarayana, Testing of Metallic Materials, Prentice -Hall of India, 2nd edition (2007).*
5. *V. B. John, Introduction to Engineering Materials, Palgrave Macmillan Limited, 3rd edition, (1992).*

Reference Books:

1. *Robert E. Reed Hill and R. Abbaschian, Physical Metallurgy Principles, PWS-Kent Publishing Company 3rd edition (1992).*
2. *L. H. Van Vlack, Elements of Materials Science and Engineering, Addison Wesley, 6th edition (1989).*
3. *I. J. Polmear, Light Alloys: Metallurgy of the Light Metals, Wiley, 3rd edition (1995).*
4. *V. Raghavan, Physical Metallurgy: Principles and Practice, PHI Learning Private Limited, 2nd edition (2006).*

COURSE OUTCOMES:

Upon completion of the course, the students will be able to:

1. *acquire knowledge on various materials and emphasis the need of modern materials other than conventional metals and alloys for specific engineering applications.*
2. *understand the heat treatment of steels, TTT and CCT diagrams.*
3. *evaluate mechanical properties and to analyze the various metallurgical factors influencing the performance of materials for different structural engineering applications.*
4. *appreciate the non-ferrous metals, ceramics, light weight structures and their properties for engineering applications.*

PH615 MATERIAL CHARACTERIZATION TECHNIQUES

(Elective)

COURSE OBJECTIVES:

1. *To familiarize the fundamental principles.*
2. *To familiarize common material characterization methods.*
3. *To determine the structure and composition of solids.*
4. *To know the different characterization equipment and their working principles.*

Optical Metallographic Techniques

Importance of material characterization **–** classification of material characterization techniques **–** mechanical characterization process **–** measurement of hardness **–** fracture toughness through nano indentation **–**Optical microscopic techniques.– metallurgical microscope – principle, construction and working, metallographic specimen preparation – optical properties – magnification, numerical aperture, resolving power, depth of focus, depth of field, various illumination techniques – bright field , dark field, phase-contrast polarized light illuminations, interference microscopy

Surface Analysis Techniques

Importance of surface characterization techniques**–**principle, working and applications of AFM, Surface area, pore volume measurements by B.E.T. method, Mercury porosimetry - Particle size measurement, Principle and working of SEM, STEM, TEM, imaging dark and bright field**–** specimen preparation techniques**–**merits and demerits- applications.

X Ray Diffraction Techniques

Characteristic X**–**ray spectrum-Bragg's Law**–**Diffraction methods-Laue method, rotating crystal method, powder method – X ray diffractometer **–** determination of crystal structure**–**lattice parameter-measurement of residual stress.

Analytical Techniques:

Principles, working and application of DTA, TGA and DSC**–** UV**–**Visible (UV**–**VIS), IR & Raman spectroscopy**–**FTIR, NMR, X-ray fluorescence spectroscopy **–** Optical emission spectroscopy

Terahertz Spectroscopy

Introduction Terahertz basics- generation detection and instrumentation - Terahertz spectroscopy – Terahertz time-domain spectroscopy- Terahertz imaging- Applications in material science and industry

Textbooks

1. *K. R. Hebbar, Basics of X-Ray Diffraction and its Applications, I.K. International Publishing House Pvt Ltd, (2007)*
2. *V. A. Phillips, Modern Metallographic Techniques and their Applications, John Wiley & Sons, 1st edition, (1972).*
3. *V. T. Cherepin and A. K. Mallic, Experimental Techniques in Physical Metallurgy, Asia Publishing Compny, (1967).*
4. *Terahertz Spectroscopy: Principles and Applications edited by Susan L. Dexheimer CRC Press, (2017).*

Reference Books:

1. *B. D. Cullity, Elements of X-ray Diffraction, Prentice Hall, 3rd edition, (2001).*
2. *A. Mammoli, C. A. Brebbia and A. Klemm, Materials Characterisation, WIT Press, 1st edition, (2011).*
3. *V. Voort, Metallography: Principle and practice, ASM International, (1999).*

COURSE OUTCOMES:

By successful completion of this course, the students will be able to:

1. *have an understanding of the basic physics, mechanisms and applications of the characterization methods commonly used in materials engineering.*
2. *know the principles of metallurgical microscope, X-ray Diffractometer (XRD), scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Thermal analysis and dilatometer.*
3. *determine the crystal structure, lattice parameter, surface topography using different methods.*
4. *select appropriate tool to characterize the material by knowing its merits and demerits.*

PH612 DIGITAL RADIOGRAPHY AND COMPUTED TOMOGRAPHY

COURSE OBJECTIVES:

1. *To introduce the basics of digital radiography terminologies.*
2. *To know the different radiography technique's and detectors.*
3. *To know the different image processing techniques in digital radiography.*
4. *To apply in NDT defect characterization.*

Digital Radiography Terminologies

Basics of Digital Imaging-Contrast and Noise, Specific Contrast, Scatter influence, SNR, CNR, basic spatial resolution and measurement, pixel size, optimization of image quality, scatter protection, MTF, digitization of X-ray films, DQE.

Computed Radiography and Radiographic Detectors

Computed Radiography (CR), Direct Radiography (DR), Imaging Plates, CR scanner principle, Image formation in CR, CR phantoms, Exposure conditions and diagrams, Digital Detector Arrays (DDA)-Introduction and design-indirect and direct converting, Charge Coupled devices (CCD), amorphous silicon and CMOS detectors, Detector calibration, Linear Detector Arrays (LDA), Intensifiers, Fluoroscopes and applications, Comparison of film, CR and DR Methods.

Digital Imaging

Image Structure, Quantization (bits and bytes), picture element(pixel), grey value, Point Operations-Contrast, brightness, gamma correction, Histogram, Look Up Table(LUT), Matrix Operations, Filters-Smoothing, improvement of SNR, Edge Enhancement, Line extraction, Median, Measurement Tools-calibration, Line profile, Measurement of flaw length, areas, Depth.

Computed Tomography

Concept of Computed Tomography and its difference from conventional radiography, CT slice, Fan beam CT, Cone Beam CT, Helical CT, Computed laminography, Typical Components of a CT system, Sources of penetrating radiations for CT, Detectors for CT imaging

Principal of Image Reconstruction in Computed Tomography

Reconstruction Methods-Transform Methods, Radon Transform, Back Projection Methods, Direct Fourier algorithm, Feldkamp Reconstruction algorithm, Contrast Discrimination Function (CDF), Contrast Detail Diagram, Artifacts in CT- Beam Hardening, Scattered Radiation, Edge Artifacts, Cone Beam artifacts, Reconstruction Artifacts, Codes and Standards, Applications.

Textbooks

1. *Euclid Seeram, Digital Radiography: Physical Principles and Quality Control, Springer (2019).*
2. *Jiang Hsieh, Computed Tomography: Principles, Design, Artifacts, and Recent Advances, Third Edition, (2015).*

Reference Books:

1. *Industrial Radiography- Image forming Techniques,* GE Inspection Technologies, (2008).
2. *ASTM E1441-19-Computed Tomography.*

COURSE OUTCOMES:

Upon completion of this course, students will gain knowledge about:

1. *digital terminology and different detectors.*
2. *different computer Radiography methods and their importance.*
3. *concepts of Computed Tomography.*
4. *understand the necessary codes and standards for CT.*

PH617 COMPOSITE TECHNOLOGY

COURSE OBJECTIVES:

1. *To give an introduction to the basic theory, properties and applications of composite materials.*
2. *To expose the Manufacturing Process concepts of composites.*
3. *Understand the different defect formations during the manufacturing process.*
4. *Inspect the composites for the defects.*

Introduction to Composites

Importance of composites- constituents – functions of fiber and matrix – properties of fibers: aligned and random fiber composites-types of fibers-glass fiber, carbon fiber, metallic fibers, ceramic fibers and various types of fibers – Matrix materials –Metallic, polymer and ceramic matrix materials, Polymer matrix composites -Thermosetting and thermoplastic polymers, properties of polymers like epoxies, phenolics, polyester peek etc.

Manufacturing of Composites

Manufacturing Process – hand lay up and curing technique, prepeg technique, open and closed mould processes – pressure bag and vacuum bag molding techniques, pultrusion, pulforming, therforming, resin-transfer moulding, injection moulding, Bulk moulding compound, sheet moulding compound.

Sandwich structures and Joining of Composites

Sandwich Structures:- Face and core materials–Honeycomb types, properties, manufacturing–Adhesive materials–Honeycomb process–sandwich fabrications– Design aspects-Laminate lay.
Joining Process: - Bonded joints–joint design–tooling for composites–Failure criteria.

Defects and Inspection of Composites

Production Defects:- Porosity, fiber orientation, waviness, breakage, fiber misalignment, shrinkage, fiber volume fraction, resin rich and resin starved, inclusions, voids, disbonds, ply misalignment – ***In service Defects:-*** Delaminations, Impact damage, Heat damage, Stress Rupture, matrix cracking, matric-fiber debonding, fiber breakage.

Inspection methods: NDI techniques – Ultrasonics – choice of frequency, defect detection, characterization and imaging– acoustic emission, acousto ultrasonics and ultrasonic spectroscopy- Thermal methods – pulsed and lock In thermogrphy and IR imaging, shearography and laser Doppler vibrometry – simulation and modelling .

Applications and case studies

Standards- specifications- Various structural applications of composites in aerospace, automobiles, marine industries and concrete structures– safety precautions– merits and demerits-few case studies.

Textbooks

1. *M. Balasubramanian, Composite materials and processing, CRC Press, (2014)*
2. *K. K. Chawla, Composite Material: Science and Engineering, Springer, 3rd edition, (2012).*
3. *D. Hull and T. W. Clyne, An Introduction to Composite Materials, Cambridge University Press, 2nd edition (1996).*

Reference Books:

1. *L. J. Broutman and R. H. Krock, Modern Composite Materials, Addison-Wesley, 1st edition (1967).*
2. *Vistap M. Karbhari, Non-Destructive Evaluation (NDE) of Polymer Matrix Composites, Woodhead Publishing, 1st edition (2013).*

COURSE OUTCOMES:

After the successful completion of this course, the students will be able to:

1. *understand about fibers, matrix and resins in a composite material.*
2. *fabricate different varieties of composite materials and find its properties.*
3. *implement various inspection methods to find its imperfections and its application in various industries.*
4. *structural applications of composites in aerospace.*

PH619 ELECTRICAL, MAGNETIC AND OPTOELECTRONIC MATERIALS
(Elective)

COURSE OBJECTIVES:

1. *To understand the fundamentals and applications of electrical, magnetic and optical properties of materials.*
2. *Apply a multi-disciplinary approach to plan and design these materials.*
3. *To know different single crystal growth techniques.*
4. *Identify and address future needs of all novel materials.*

Electrical and Dielectric Materials

Review of electrical conduction – discussion on specific materials used as conductors (OFHC, Ag, Al, other alloys) – temperature-dependent resistivity of Copper and CuNi alloy – Nordheim rule – CuAu alloy – dielectric phenomena – concept of polarization – effects of composition, frequency and temperature on these properties – discussion on specific materials used as dielectrics (ceramics and polymers) – $BaTiO_3$ – dielectric loss, dielectric breakdown – ferro electricity – piezo and pyroelectricity.

Magnetic Materials

Introduction to dia, para, ferri and ferro magnetism – hard and soft magnetic materials – iron-silicon alloys – iron, nickel alloys – ferrites, garnets and LCMO – rare earth alloys – Pt alloys – fine particle magnetism – applications of hard and soft magnetic materials – Giant Magneto Resistance – magnetocaloric effect – spintronics – multiferroics – nanomagnetic materials.

Superconducting and Semiconducting Materials

Concept of superconductivity – theories and examples for high-temperature superconductivity – discussion on specific superconducting materials – Nb_3Sn – YBCO – MgB_2 – Carbon based – comments on fabrication and engineering applications – review of semiconducting materials – concept of doping – simple and compound semiconductors – amorphous semiconductor – oxide semiconductors – organic semiconductor – low dimensional semiconductor – materials for solar cell applications – Hall effect – homojunction – schottky barrier – heterojunction – materials and applications.

Production of Electronic Materials

Binary alloy phase diagram (PbSn and CuNi) – homogeneous and heterogeneous nucleation – methods of crystal growth for bulk single crystals – Czochralski – Bridgman – low and high-temperature solution growth – floating zone method - synthesis of epitaxial films by LPE, VPE, PVD, MBE and MOCVD techniques – lithography – production of silicon – applications.

Optical and Optoelectronic Materials

Principles of photoconductivity – simple models – effect of impurities – principles of luminescence – types and materials, Laser Principles – ruby, He-Ne, injection, Nd-YAG and Dye lasers – LED materials – binary, ternary photo electronic materials – Optical storage materials – LCD materials - photo detectors – applications of optoelectronic materials – introduction to optical fibers – light propagation – electro optic effect – electro optic modulators – Kerr effect – Pockel's effect.

Textbooks

1. *C. Kittel, Introduction to Solid State Physics, John Wiley and Sons, 7th edition, New Delhi, (2004).*
2. *A. J. Dekker, Electrical Engineering Materials, Prentice Hall, NJ, (1959).*
3. *L. H. Van Vlack, Elements of Materials Science and Engineering, Addison –Wesley, 6th edition, New York, (1989).*

Reference Books:

1. *V. Raghavan, Materials Science and Engineering, Prentice Hall of India, 5th edition, New Delhi, (2013).*
2. *B. G. Yacobi, Semiconductor Materials: An Introduction to Basic Principles, Springer, 1st edition, New York, (2013).*
3. *S. Kasap and P. Capper (eds.), Handbook of Electronic and Photonic Materials, Springer, New York, (2007).*
4. *Ed. Charles P. Poole, Jr., Handbook of Superconductivity, Academic Press (2000).*
5. *Nicola. A. Spaldin, Magnetic Materials: Fundamentals and Applications, 2nd Edn., Cambridge Univ. Press. (2002).*

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1. *obtain knowledge about the electrical, magnetic and optoelectronic materials, their properties and applications.*
2. *successfully apply advanced concepts of materials engineering for the design, development and analysis of materials and devices.*
3. *develop novel materials from the fundamental understanding of materials and apply them to societal needs.*
4. *know the materials required for LASERS, LED and photodetectors.*

PH614 FRACTURE MECHANICS AND FAILURES OF MATERIALS
(Elective)

COURSE OBJECTIVES:

1. *Introduction to fatigue of materials.*
2. *To exposure to the concepts of failure mechanism of materials on structural application.*
3. *To provide a valuable roadmap for investigating, analyzing and solving current materials failure issues.*
4. *To understand the basics principles of corrosion, testing and prevention.*

Fracture of Materials
Types of fractures in metals– Ductile and brittle fractures – Cohesive strength of metals, Griffith theory of brittle fracture, metallographic aspects of fracture, dislocation theories of brittle fracture, ductile fracture, fracture under combined stresses.

Fracture Mechanics
Introduction to Linear elastic fracture mechanics (LEFM) and elasto-plastic fracture mechanics (EPFM) – Strain energy release rate, stress intensity factor, fracture toughness, fracture toughness testing– Anelastic deformation at the crack tip, Notch bar fracture mechanics and the micro mechanics of cleavage fracture. CTOD – Relation between CTOD, KI and G1. J–integral & R- curve.

Fatigue of Materials
Introduction to fatigue of materials, stress cycles. S-N curve, Low-cycle fatigue, stress life & strain life equations, fatigue crack propagation, concepts of damage tolerance under fatigue cracks, cumulative damage concepts, modifiers in fatigue – stress concentration, temperature, corrosion, defects, surface effects, residual stresses.

Corrosion
Basic principles – different forms of corrosion – atmospheric corrosion, galvanic corrosion, general biological corrosion – Localized corrosion - pitting corrosion- mechanism of stress corrosion cracking- Hydrogen embrittlement – prevention and control of corrosion – Corrosion monitoring-erosion, wear induced corrosion- case studies.

Failure Analysis
Failure mechanism-effect of variables-part shape, type of loading, stress concentration, wear failure-adhesive, abrasive -elevated temperature failures, creep, thermal fatigue, oxidation-Cause of failure in components - misuse, assembly errors, manufacturing defects, improper maintenance- design errors, improper material, improper heat treatment, operating conditions, inadequate quality assurance, and discontinuities.

Textbooks

1. *G.E. Dieter, Mechanical Metallurgy, Mc-Graw-Hill Book Company, 3rd edition (2004).*
2. *P. Kumar, Elements of Fracture Mechanics, Tata McGraw-Hill Education, 1st edition (2009).*

3. A. *K. Das, Metallurgy of Failure Analysis, McGraw Hill Professional, 1st edition (1997).*
4. *P. Roberge, Corrosion Engineering: Principles and Practice, McGraw - Hill Professional, 1st edition (2008).*

Reference Books:

1. *N. E. Dowling, Mechanical Behavior of Materials;* Engineering Methods for *Deformation, Fracture, and Fatigue, Pearson Prentice Hal, 3rd edition (2007).*
2. *S. R. Lampmn and N. D. DiMatteo, Fatigue and Fracture, Vol.19, ASM Handbook, ASM International, (1996).*
3. *S. D. Cramer and B. S. Covino, ASM Handbook Volume 13B: Corrosion: Materials, ASM International,(2005).*
4. *D. A. Jones, Principles and Prevention of Corrosion Pearson Education, 2nd edition (2013).*
5. *D. Broek, Elementary engineering in fracture mechanics, Springer, 4th edition, (1986).*
6. *S. Suresh, Fatigue of materials, Cambridge University Press, 2nd edition, (1998).*

<u>COURSE OUTCOMES:</u>

Upon completion of the course, the students will be able to:

1. *find the life assessment of engineering materials and analyze various factors affecting fatigue and corrosion.*
2. *provide suitable remedial measures to prevent premature failure and reduction in performance.*
3. *ascertain the failure by proper technique.*
4. *describe the failure modes and root cause of the materials failure based on fracture mechanics and fractography approach.*

PH616 PROBABILITY, STATISTICS, QUALITY AND RELIABILITY
(Elective)

COURSE OBJECTIVES:

1. *To strengthen and improve the ability to use theory, design and techniques of quality control.*
2. *Improve statistical analysis of reliability.*
3. *Utilization of reliability considerations in engineering design for a improved safety life.*
4. *To learn statistical tools and quality philosophy in order to control the quality in manufacturing and production engineering components.*

Probability and Random Variable
Concepts of probability – Random variables – Baye's Theorem – Standard Probability Distributions – Binomial, Poisson, Normal, Geometric, Exponential distributions – Correlation and Regression.

Statistical Quality Control
Statistical basis for control charts – control limits – control charts and types – control charts for variables, defective and defects – introduction to six sigma – inspections by sampling – OC curves – acceptance sampling plans.

Quality
Basics of quality – Quality philosophy – quality control – quality assurance – design for quality management system – Quality certification and accreditation schemes – total quality management and Taguchi's method – quality standards and procedures – ISO 9000 Series –14000 Series

Reliability
Basic concepts of reliability – Reliability Vs Quality – Hazard and failure rate analysis – mean time between failures (MTBF) – mean time to failure (MTTF) – Mathematical models for reliability studies – Normal, Exponential and Weibull failure laws – Reliability of systems –Series system, Parallel system, Series-Parallel system

NDE Reliability
Applications of reliability to systems - General Considerations: NDE response, NDE systems management and schedule – Procedure selection/development of NDE Engineering – System/process – performance characteristics - Conditional probability in NDE discrimination Signal/ noise relationships, reference standards personnel – Modeling of NDE reliability– PoD – Benefits of PoD – approaches to modeling PoD – Applications (case studies) – Air frames – gas turbine engines – Space shuttle - Statistical nature of NDE process

Textbooks

1. *D. C. Montgomery, Introduction to Statistical Quality Control, John Wiley & Sons, 6th edition, (2009).*
2. *S. C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand, 10th edition, (2000).*
3. *A. Birolini, Reliability Engineering: Theory and Practice, Springer, 6th edition, (2010).*

Reference Books:

1. *Thomas Pyzdek, The Six Sigma Handbook, McGraw-Hill, (2000).*
2. *C. E. Ebeling, An introduction to Reliability and Maintainability engineering, Waveland, 2nd edition, (2009).*
3. *J. S. Oakland, Total Quality Management, Butterworth–Hcinemann Ltd., 3rd edition, (2003).*
4. *R. S. Leavenworth and E. L. Grant, Statistical Quality Control, Tata McGraw –Hill Education, 7th edition, (2000).*
5. *Don E. Bray and Roderic K. Stanley, Non-destructive Evaluation: A Tool in Design, Manufacturing and Service, CRC Press (1996).*

COURSE OUTCOME:

On successfully completing this course, the students will be able to:

1. *understand the key concepts of life-cycle cost analysis and to make considered judgements regarding optimal maintenance and/or repair strategies.*
2. *apply simulation and sampling techniques to evaluate the reliability of structural components or systems qualitatively.*
3. *perform simple calculation in SQC and reliability to real applications.*
4. *evaluate the nominal probability of failure of a structure using a time-independent reliability formulation.*

PH618 INTRODUCTION TO DATA ANALYTICS
(Elective)

COURSE OBJECTIVES:

1. *To introduce the language and core concepts of probability theory.*
2. *To understand basic principles of statistical inference.*
3. *To perform linear regression and apply various classification techniques using software.*
4. *To apply resampling methods to enhance model performance.*
5. *To introduce tree-based methods and foundational concepts in deep learning, including neural networks and convolutional networks.*

Tools of Probability
Concept of Probability, Random variables, central limit theorem, conditional probability, total probability theorem, Bayes theorem, Collecting Data, Summarizing and Exploring Data

Statistical Inference
Basic Concepts of Inference, Inferences for Single Samples, Interference for two samples, z-test, student's t-test, implementation in R.

Linear Regression
Simple linear regression, Multiple linear regression, qualitative predictors, few applications using a programming language. Classifications; qualitative variables, logistic regression, linear discriminant analysis, quadratic logistic regression, naive Bayes, and K-nearest neighbors.

Resampling methods
validation approach, leave out cross validation, boot strap. Linear model selection and regularization; subset selection, stepwise selection, shrinkage methods. Nonlinear regression; Polynomial, step function and splines.

Tree base methods
Decision trees, bagging. Deep learning; single layer neural networks, multilayer neural networks, convolution neural networks

Text Books

1. Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, An Introduction to Statistical Learning with applications in R (2^{nd} Edition), Springer, 2021

COURSE OUTCOMES:

After successful completion of the course, the students will be able to:

1. *gain a foundational understanding of probability concepts and apply these concepts to real-world data problems.*
2. *develop skills in summarizing and exploring data, and perform basic inferential statistics to draw conclusions from samples.*

3. *apply regression analysis and classification methods to solve practical data analysis problems.*
4. *learn and implement various resampling methods, such as validation approach, cross-validation, and bootstrapping, to evaluate model performance.*
5. *build and interpret decision trees, and gain an introduction to neural networks and deep learning.*

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PH680 COMPUTATIONAL TECHNIQUES

COURSE OBJECTIVES:

1. *To learn the MATLAB environment and its basic commands.*
2. *To learn how MATLAB can be used for basic mathematical applications and machine learning techniques.*
3. *To learn the principle of the finite element method and its types.*
4. *Learn how to solve physical problems using the finite element method.*

Introduction to MATLAB
MATLAB environment – working with data sets – data input/output – logical variables and operators – array and X-Y Plotting – simple graphics – data types: matrix, string, cell and structure– file input and output – MATLAB files – simple programs.

Applications of MATLAB
Matrices and array operation – elemental matrix functions – file functions – application of MATLAB – solving linear algebraic equations – curve fitting – interpolation – numerical integration – basic 2D Plots – overlay plots – specialized 2D plots – 3D plots – view.

Specialized Applications using MATLAB
Fast Fourier Transform - Fuzzy Logic - Artificial Neural Network (ANN): Neural Net Fitting, Neural Net Pattern Recognition, Neural Net Time Series.

Finite Element Method
Introduction to FEM: Method of Weighted Residuals – Galerkin's Finite Element Formulation – Variational Method – Rayleigh-Ritz Finite Element Method.

Application of FEM
Structural mechanics and wave propagation problems in 2D - solving ordinary and partial differential equations - Fluid-structure interaction.

Textbooks

1. *R. Pratap, Getting Started with MATLAB: A Quick Introduction for Scientist andEngineers, Oxford University Press (2010).*
2. *D. W. Pepper and J. C. Heinrich, The Finite Element Method: Basic Concepts and Applicationswith MATLAB, MAPLE, and COMSOL, 3rd edition, CRC Press (2017).*
3. *H. Bang and Y. W. Kwon, The Finite Element Method Using MATLAB, CRC Press (2018).*

Reference Books

1. *Introduction to COMSOL Multiphysics – © 1998–2020 COMSOL*
2. *MATLAB Programming Fundamentals – © 1984–2021 by The MathWorks, Inc.*

COURSE OUTCOMES:

Upon completion of this course, the students will be able to:

1: Identify and describe the syntax of MATLAB.
2: Solve different mathematical problems and demonstrate basic machine learning techniques in MATLAB.
3: Describe and explain the finite element method principle and its different variants.
4: Solve different physical problems using FEM.

PH620: NEUTRON RADIOGRAPHY

COURSE OBJECTIVES:

The objective of this course is to:

1. *familiarize with the basics of neutron radiography.*
2. *expose various techniques for carrying out neutron radiography.*
3. *understand various imaging techniques.*
4. *expose to applications in various industries.*

Basic Principles and Theory of Neutron Radiography

Basic concepts of neutron interaction with matter, Neutron Sources, nuclear cross sections, Neutron moderations, attenuation coefficients, utilisation of attenuation for radiography, collimators.

Imaging Techniques

Direct exposure techniques, Transfer Techniques, Dynamic Imaging methods, neutron tomography, comparison of various imaging techniques, image recorders, converters.

Radiographic Techniques, Interpretation and Evaluation

Geometry of exposure, Exposure factors, Image-object relationships, Material considerations, Codes, standards, and specifications, Image Quality Indicators.

Codes and Standards, Safety and Health

National Standards, ASTM Standards, International Standards, Exposure hazards, Methods of controlling radiation exposure, Operation and emergency procedures.

Applications

Industrial Applications, Non-industrial applications, Nuclear Applications, NR facilities for various applications.

COURSE OUTCOMES:

By successful completion of this course, the students will:

1. *acquire a complete theoretical knowledge of neutron radiography, interpretation and evaluation.*

2. *have a basics understanding of code and standards to be followed.*
3. *follow proper safety precautions to avoid radiation hazards.*
4. *understand the applications of neutron radiography in industry.*

Textbooks

1. *Practical Neutron Radiography, J C Dominus. Springer (2012).*
2. *ASM Handbook Vol. 17, NDE and QC, ASM International, (2018).*

Reference Books

1. *NDT Handbook, Third Edition: Volume 4, Radiographic Testing, ASNT (2002).*
2. *J.P. Barton, Neutron Radiography – An Overview, Practical Applications of Neutron Radiography and Gauging. ASTM STP 586, American Society of Testing and Materials, (1976).*
3. *Commission of the European Communities. Neutron Radiography Handbook. Edited by P. von der Hardt and H. Röttger, D. Reidel Publishing Company, Dordrecht, (1981).*

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