Ph.D. Course work

Pre-Ph.D. Examination Syllabus

DEPARTMENT OF PHYSICS,
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BOS - Approved

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PHY-PhD-1 Spectroscopic Studies on Transition metal ions

1. INTRODUCTION:

The concept of ligand field - The scope of ligand field theory – The'd' and other orbital's.The physical properties affected by ligand fields.

2. QUANTITAVIVE BASIS OF CRYSTAL FIELDS:

Crystal field theory – The octahedral crystal field potential on the'd' wave function – The evaluation of 10 Dq – The tetrahedral potential.

3. FREE ION IN WEAK, MEDIUM AND STRONG CRYSTAL FIELDS:

The effect of a cubic crystal field on S and P terms – on D terms – on F terms – on G, H and I terms – Strong field configurations – Transition from weak to strong crystal fields – term energy level diagrams – Tanabe-Sugano diagrams.

4. BASIC THEORY g-FACTOR:

The g-factor – the general Hamiltonian – The crystal field and orbital symmetry – Symmetry of p and d orbitals – Effect of crystal field – Jahn-Teller distortion and Kramer's theorem – Magnitude of the crystal field – Calculation of g-factors – Ti3+ in octahedral field – The spin-Hamiltonian – effect of field orientation – Fine structure – Zero-field splitting – The Spin-Hmiltonian for V3+ and $FeO4^{2-}$ - S-state ions – Mn^{2+} ion.

5. NUCLEAR HYPERFINE STRUCTURE:

Introduction – General treatment – Isotropic hyperfine interaction – The spin-Hamiltonian – energy levels – Interpretation of isotropic hyperfine coupling constant – Unpaired spin density – Anisotropic hyperfine interaction – The Spin-Hamiltonian energy levels – Interpretation of anisotropic hyperfine coupling constants – the term $\langle(1 - 3\ Cos2 / r3)\rangle_{av}$

TEXT BOOKS:

1. Introduction to Ligand Fields.
B.N.Figgis, Wiley – Eastern Ltd., New Delhi (1976).
2. Electron Spin Resonance in Chemistry.
Peter B.Ayscough. Methuen and Co.Ltd., London (1964).
3. Instrumental Methods and Analysis.
H.Willard, L.Merritt, J.Dean,F.Settle, CBS publishers and distributors (1986).
4. Fundamentals of Molecular Spectroscopy.
C.N.Banwell, Tata-McGraw-Hill publishing company Ltd, New Delhi (1990).

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PHY-PhD-1 MODEL QUESTION PAPER

Spectroscopic Studies on Transition metal ions

Time: 3hrs Max. **Marks: 100**

Answer any five of the following questions. All questions carry equal marks

1. Explain the effect of octahedral crystal field on the d wave functions and compare the corresponding effect by a tetrahedral field.
2. Describe the effect of cubic crystal field on S, P, D terms in detail.
3. Distinguish between static and dynamic Jahn-Teller effects and their role in the electronic spectra of complex molecules.
4. Explain the energy levels and g-factor for Ti3+ in an octahedral field.
5. Explain how spin-orbit coupling is evaluated from the experimental studies on atomic spectroscopy and ESR spectra of crystals.
6. Distinguish between isotropic and anisotropic hyperfine interaction and explain the corresponding spin-Hamiltonian energy levels.
7. Write the spin-Hamiltonian for S-state ions explain each term in it. Give the energy level diagram of Mn2+ ion.
8. Write notes on any two of the following.

(a) Zero-field splitting

(b) Tanabe-Sugano diagrams.

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PHY-PhD-2 Spectroscopic Studies on Rare Earth ions

1. **ATOMIC SPECTROSCOPY:**

The free ion: Free ion terms for d2 and f2 configurations; Spin-orbit coupling; Ground states for fn configurations; Coulomb and spin-orbit energies; Intermediate coupling.

2. **ABSORPTION CHARACTERISTICS OF RARE EARTH IONS:**

Intra-configurational f-f transitions; magnetic dipole, electric dipole and induced electric dipole transitions; Intensity of absorption bands; Judd-Ofelt theory for induced electric dipole transitions and evaluation of Judd-Ofelt parameters.

3. **LUMINESCENCE CHARACTERISTICS OF RARE EARTH IONS:**

Radiative transition rates, Emission cross-sections and Branching ratios, relaxiation process: Non-radiative relaxiation: Multi-phonon, Radiative quantum efficiencies of rare earth ion energy levels.

4. **ENERGY TRANSFER IN RARE EARTHS:**

Possible mechanisms of energy transfer: Resonance energy transfer; Process of IR to Visible upconversion; Energy transfer from lanthanides to other species.

5. **RARE EARTH DOPED LASERS:**

Principle of laser action: typical rare earth lasers- Nd: YAG: Energy level diagram of Nd(III) ion in YAG laser.

TEXT BOOKS:

1. Introduction to Ligand Fields.
B N Figegis, Wiely Eastern Ltd, New Delhi.
2. Optical Spectra of Transparent Rare Earth Compounds.
S Hufner, Academic Press, London.
3. Lasers and excited states of Rare Earths.
R Reisfield and C K Jorgensen, Springer-Verlag, New York.

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PHY-PhD-2 MODEL QUESTION PAPER

Spectroscopic Studies on Rare Earth ions.

Time: 3hrs Max. **Marks: 100**

Answer any five of the following questions. All questions carry equal marks

1. Obtain the free-ion terms of d2 configuration. Explain diagrammatically the splitting of these terms in spin-orbit coupling.
2. Derive the free-ion terms of f2 configuration. Explain how to obtain ground states and what are the ground states for the trivalent lanthanides?
3. Explain magnetic dipole and electric dipole transitions in lanthanide absorption spectra. How do you measure the intensity of the spectral lines from absorption bands?
4. Give the Judd-Ofelt theory for the analysis of intensities of induced electric dipole transitions. Derive the expression for the intensity parameters ($\Omega\lambda$).
5. Write down the various expressions for the luminescence characteristics like radiative transition rates, radiative lifetimes, branching ratios, emission crosssections and quantum efficiencies.
6. Explain the relaxation process. Discuss the non radiative multiphonon relaxiation phenomena in rare earth ions.
7. What are the different possible mechanisms of energy transfer? Explain the phenomenon visible of upconversion in detail.
8. What are the various principles involved in laser action. Illustrate the Nd:YAG laser with its energy level diagram.

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PHY-PhD-3 NANO SCIENCE AND TECHNOLOGY

Unit I

Introduction: Importance of Nano science &technology, Emergence of Nano-technology, Types of Nano materials, Bottom-up and Top-down approaches,, Applications of Nano Technology in Science and technology.

Unit II

Zero Dimensional Nano-structures: Nano particles through homogenous nucleation; Growth of nuclei, synthesis of metallic nano particles, Nano particles through heterogeneous nucleation; Fundamentals of heterogeneous nucleation and synthesis of nano particles using micro emulsions and Aerosol.

Unit III

One Dimensional Nano-structure, Nano wires and nano rods: Spontaneous growth: Evaporation and condensation growth, Casting method, vapor-liquid-solid growth, Electrochemical deposition and Electro spinning.

Unit IV

Two dimensional nano-structures: Fundamentals of film growth. Physical vapour Depostion(PVD): Chemical Vapour Depostion (CVD) Characterization of nano materials by using spectroscopic and microscopic techniques-XRD,FTIR,DSC,SEM and TEM. Electrical measurements of nano composite materials by using fourprobe method.

Unit V

Introduction to Carbon Nano Tubes(CNTs), Properties, Preparation of CNTs-Laser ablation method, Arc method, chemical vapor deposition (CVD), Sol-Gel method, Carbon nanotube Polymer Nano composites ,Applications of Nano in drug delivery system.

Text books:

1.Introduction to Nano technologyby Charles P.Poole.Jr.& Frank J.ownes John wielly&sons Inc. Publishers -2006

2. Nano structures and Nano materials: Synthesis, properties and applications Guozhong Cao- Imperial College press.

Reference Book:" Nano structured Materials" by Jackie Ying academic press, 2001

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PHY-PhD-3 MODEL QUESTION PAPER

NANO SCIENCE AND TECHNOLOGY

Time:3hrs **Max Marks:100**

Answer any FIVE of the following Questions. Each Question carries Equal Marks.

1. a) What are nano materials? Explain different types of nano materials?

   b)Discuss the size effects on nano materials.

2. (a) List out few methods of Synthesis of nano particles.

   (b) Explain how can you prepare the silver metal nano particles by using Physical Vapour Synthesis method with neat sketch?

3. (a) Mention different methods used to produce carbon nano tubes.

   (b) Mention the properties and applications of carbon nano tubes

4. What is meant by SEM? Explain the construction and working of SEM? Give its applications?

5. Explain how you can Fabricate Nickel metal nano particles by using Chemical Vapour Deposition (CVD) method with neat sketch?

6. Briefly explain about Bottom-up and Top-down approaches. Explain the synthesis of nano particles using aerosol method.

7. How can characterize a nano composite material by using XRD ,DSC and SEM

8. Briefly explain the following

i) Nano wires and nano rods

ii) Physical vapour Deposition (PVD)

iii) Distinguish between SEM and TEM

iv) Applications of carbon Nanotubes in engineering

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PHY-PhD-4 SOLID STATE IONICS

UNIT 1:- Introduction
Classification of solids – crystalline, amorphous materials and its processing techniques, structural characterization by IR, XRD, DSC/TGA and SEM methods

UNIT 2:- Ionic Materials
Introduction to polymeric materials – Blends, Composites and polymer electrolytes, Solid conducting polymer electrolytes – Fast ion conductors, Characterization. Solid conducting polymer electrolytes composites – Synthesis, processing and characterization and their device applications – Electrochemical cells, Rechargeable polymer battery, electro chromic devices, electro chemical solar cells, sensors.

UNIT 3:- Nano materials
Introduction to nano particles and nano composites, synthesis and processing technologies for nanostructure materials – Chemical co-precipitation method, soldzer method, hydrothermal method, copolymerization method – Chemical oxidative polymerization method, structural, mechanical, optical and electrical studies of nano composites conductivity and electrical transport properties of processable nano
materials – Applications.

UNIT 4:- Electrochemical cell Devices
Introduction to Electro chemical cells, sensors and fuel cells – Types– Synthesis and development of solid electrolyte membranes – Characterization by XRD, Differential scanning calorimetry (DSC), SEM(Scanning Electron Microscopy)

UNIT-V: Measurements:
Measurement of electrical conductivity of solid electrolyte membranes – Determination of transference number by Wagner's polarization method, water balance in membranes – Fabrication and working principles of Electro chemical cell, fuel cell, sensors– Calculation of open circuit voltage (OCV), short circuit current, resistivity, current density, power density and estimation of efficiency, V-I characteristics of fuel cells, Application of fuel cells in transportation and low temperature electronic devices .

Prescribed Books: 1.Solid state Ionics for Batteries By M. Tatsumisago,M. Wakihara etc., Springer Publishers
2. Solid state Ionics by B.V.R. Chowdary,Wenji.B .World Scientifics Ltd.

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PHY-PhD-4 MODEL QUESTION PAPER

SOLID STATE IONICS

Time: 3hrs Max **Marks:100**

Answer any FIVE of the following Questions. Each Question carries Equal Marks

1. (a) Explain briefly the different types of Solid Polymer Electrolytes.

(b) Describe the working mechanism of a Polymer battery?.How can you estimate the efficiency of an Electrochemical cell?

2. (a) What is meant by Carbon Nano Tube? Give different Synthesizing Methods.

(b) How can you synthesize a Carbon Nano Tubes by using RF Plasma method.

3. (a) Define Transition Temperature and Melting Temperature of Polymeric Material.

(b) Explain the Mechanical Properties of Polymers by stiffness, strength and toughness with neat diagrams.

4. (a Discuss the Transport properties of Solid Electrolyte Membranes.

(b) How can you determine the Transferce Number of a given Solid Electrolyte Membrane by using Wagner's Polarization method.

5. (a). What is meant by a Solid Polymer Nano composite? Mention its Characteristics.

(b) Discuss the Complexzation in Polymer Composites .How can you Study or Analyse the Complexation Mechanism by using different IR,XRD, Spectroscopic Techniques.

6. (a).Define a Fuel Cell. Discuss different types of Fuel Cells.

(b) What is PEM Fuel Cell? Explain the working of PEM Fuel Cell with neat Diagram.What is the role of Electrolyte in PEM Fuel Cell?

7. a) Explain transport phenomenon in polymer electrolytes?

b)Determine transference number by using Wagner polarization method

c)Explain V-I characterstics of fuel cells

8. Write a brief note on the Following.

(i) Structural Characterisation of a material by XRD

(ii) Electrochemical Solar Cells.

(iii) Synthesis Methods for Nanostructured Materials.

(iv) Fabrication of a PEM Fuel cell

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PHY-PhD-5 Remote Sensing Techniques

CHAPTER 1: Introduction
Definition - SONAR, Satellite Images Vs Maps, Remote Sensing Vs GIS, Remote Sensing Vs Aerial Photography / Photogrammetry, Remote Sensing Vs SONAR, Spatial data acquisition-ground based and remote sensing methods, application of remote sensing-Agriculture, Forestry, Geology, Hydrology, Sea Ice, Land Cover & Land Use, Mapping, Oceans & Coastal Monitoring.

CHAPTER 2: Electromagnetic Radiation
Electromagnetic energy, Interaction mechanisms, Laws regarding the amount of energy radiated from an object, Planck Radiation Law, Wien's displacement law, Black body concept, Emissivity and Radiant Temperature, Electromagnetic Spectrum, Wavelength bands, Atmosphere effects, Scattering, Absorption, Reflectance spectra, Mixtures, Grain Size Effects, The Continuum and Band Depth, Continuum-Removed
Spectral Feature Comparison, Viewing Geometry

CHAPTER 3: SENSORS and PLATFORMS
Introduction, Sensors – passive sensors, active sensors – radar, principles of imaging radar, geometric properties of radar, data formats, distortions in radar images, interpretation of radar images, applications of radar, Airborne remote sensing, Space borne remote sensing, Image data characteristics, Data selection criteria.

CHAPTER 4: RADIO METRIC CORRECTIONS
Introduction, From satellite to ground radiances: atmospheric correction, Atmospheric correction in the visible part of the spectrum – cosmetic corrections, relative AC methods based on ground reflectance, Absolute AC methods based on atmospheric processes.

CHAPTER 5: THERMAL REMOTE SENSING
Introduction, principles of thermal remote sensing- physical laws, blackbodies and emissivity, Radiant and kinetic temperatures, Processing of thermal data – band ratios and transformations, determining kinetic surface temperatures, Thermal applications – rock emissivity mapping, thermal hot spot detection.

Ref: Principles of remote sensing by Wim H.Bakker, Karl A.Grabmaier, GerritC.huumeman, FreekD.Vander Meer, AnupmaPrakash, Klaus tempfli, Ambro S.M. Gieske, chrisA.Hecker,Lucas L.F.Janseen,GabrielN.parodi, colinV.Reeves, MichaelJ.C.weir, Ben G.H.Gorte,JohnA.Hom,Normankerle, Christine pohl, Frank J.VanRuitenbeek, TsehaieWoldai.

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PHY-PhD-5 MODEL QUESTION PAPER

Remote sensing techniques

Time: 3hrs **Max Marks:100**

Answer any 5 of the following:

1. Explain or give an example how ground based and remote sensing methods may complement each other?
2. List three possible limitations of remote sensing data and also discuss their implications?
3. List and describe the two models used to describe electromagnetic energy?
4. What is the electromagnetic spectrum and explain why the microwave band has been utilized most by the community?
5. List and define the three types of atmospheric scattering with pictorial representations?.
6. What specific interaction takes place at different levels of atmospheric regions of the Earth when EM energy from the sun hits the Earth's surface.
7. Explain the sensor-platform concept
8. Mention two types of passive and active sensors and Explain the sensor-platform concept.

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PHY-PhD-6 Upper atmospheric science

CHAPTER 1

Introduction, survey of atmosphere, physical properties of the upper atmosphere – atmospheric composition, atmospheric dynamics, atmospheric energetics, atmospheric layers and relation to temperature.

CHAPTER 2

Earth System & Interaction of energetic solar photons with the upper atmosphere History of Climate and the Earth System, Components of the Earth System, Hydrologic & carbon cycles, Solar irradiance, optical depth, photoionization, photo dissociation, photoelectrons.

CHAPTER 3

Atmospheric Thermodynamics Gas Laws, Hydrostatic Equation, First Law of Thermodynamics, Adiabatic Processes, Water Vapor in Air, Static Stability, Second Law of Thermodynamics and Entropy

CHAPTER 4

Radiative Transfer Spectrum of Radiation, Quantitative Description of Radiation, Blackbody Radiation, Physics of Scattering and Absorption and Emission, Radiative Transfer in Planetary Atmospheres, Radiation Balance at the Top of the Atmosphere

CHAPTER 5

Atmospheric Chemistry Composition of Tropospheric Air, Sources,Transport, and Sinks of Trace Gases, Some Important Tropospheric Trace Gases, Tropospheric Aerosols, Air Pollution, Tropospheric Chemical Cycles, Stratospheric Chemistry

References

Physics and chemistry of the Upper atmosphere By M.H.Rees

Atmospheric Science By John M.Wallace, Peter V. Hobbs & CHAPTER2 from Physics and chemistry of the Upper atmosphere By M.H.Rees

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PHY-PhD-7 THIN FILM TECHNOLOGY AND APPLICATIONS

Unit - I

Preparation of Thin-films Kinetic aspects of Gases in a vacuum chamber - Classifications of vacuum ranges Production of vacuum - Pressure measurement in vacuum systems - Physical vapour deposition - Evaporation Techniques - Sputtering (RF & DC) - Pulsed Laser deposition- Liquid Phase Epitaxy- Vapour Phase Epitaxy- Molecular Beam Epitaxy.

Unit – II

Film growth and measurement of thickness, Thermodynamics and Kinetics of thin film formation - Film growth – five stages - In corporation of defects and impurities in films - Deposition parameters and grain size - structure of thin films - Microbalance technique - quartz crystal monitor photometric - Ellipsometry and interferometers - Measurement of rate of deposition using ratemeter - cleaning of substrate.

Unit - III

Characterization, X-ray Diffraction(XRD) - SEM, Photoluminescence(PL) - Raman Sepectroscopy, UV-Vis-IR Spectrophotometer – AFM - Hall effect – SIMS - X-ray Photoemission Spectroscopy (XPS) - Vibrational Sample Magnetometers, Rutherford Back Scattering (RBS).

Unit - IV

Properties of thin films Dielectric properties - Experimental techniques for dielectric film - annealing effect, effect of film thickness on dielectric properties – determination of optical constants – Experimental techniques for determination of optical parameters - Magnetic and mechanical properties - Hall effect compilations - Adhesion, stress, strength, Raleigh surface waves - Ferromagnetic properties of Thin films - Experimental methods for measurement of mechanical properties of thin films.

Unit – V

Applications, Micro and optoelectronic devices, quantum dots, Data storage, corrosion and wear coatings - Polymer films, MEMS, optical applications - Applications in electronics – electric contacts, connections and resistors, capacitors and inductances - Applications of ferromagnetic and super conducting films - active electronic elements, micro acoustic elements using surface waves - integrated circuits - thin films in optoelectronics and integrated optics.

Reference

1. K.L. Chopra, Thin film phenomena, McGraw- Hill book company New York, 1969

2. Ludminla Eckertova, 'Physics of thin films', Plenum press, New York 1977.

3. A. Goswami, Thin Film Fundamentals, New Age international (P) Ltd. Publishers, New Delhi (1996).

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PHY-PhD-7 MODEL QUESTION PAPER

THIN FILM TECHNOLOGY AND APPLICATIONS

Time: 3hrs **Max Marks:100**

Answer any 5 of the following

1. Discuss about different Vacuum techniques.
2. Discuss about Kinetics of thin film formation and Film growth.
3. Explain the Thin film characterization technique and discuss about optical characterization.
4. Explain the physical properties of thin films.
5. Explain the optoelectronic properties of TCO thin films.
6. Discuss the magnetic and electrical properties of thin films.
7. Discuss about experimental methods for measurement of mechanical properties of thin films.
8. Discuss about Sputtering (RF), Pulsed Laser deposition, Liquid Phase Epitaxy, Molecular Beam Epitaxy.

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PHY-PhD-8 NUCLEAR PHYSICS-1

UNIT – I

Basic nuclear properties: size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Liquid drop model; Fission and fusion;

UNIT – II

Two nucleon problem, Elementary ideas of alpha, beta and gamma decays and their selection rules; Nuclear Forces: Characteristics of nuclear forces – Ground state of Deuteron – Proton – Proton scattering – Neutron – Proton scattering – Meson theory of nuclear forces.

UNIT – III

Nuclear Models: Introduction – The liquid drop model – Bethe-Weizacker semi-empirical binding energy equation and its applications – Nuclear shell model – Shell Model: Single particle model with square well, harmonic oscillator and spin-orbit potentials, Collective model, Nilsson model. Energy levels and calculation of angular momentum – Collective model.

UNIT –IV

Nuclear Reactions: Types of nuclear reactions – Compound nuclear reactions – Nuclear cross section – Resonance theory – Briet Wigner formula.

UNIT – V

Nuclear interactions: Direct and compound nuclear reaction mechanisms- cross sections in terms of partial wave amplitudes–compound nucleus–Scattering Matrix–Reciprocity theorem–Breit-Wigner one – level formula- Resonance scattering.

References

1) Concepts of Nuclear Physics, B. L. Cohen (Tata McGraw Hill)

2) Nuclear Physics - An Introduction, S. B. Patel

3) Subatomic Physics, Frauenfelder and Hanley (Prentice-Hall)

4) Nuclear Physics, I. Kaplan

5) Nuclei and Particles, Emilio Segre

6) Nuclear Radiation Detectors, S. S. Kapoor, V. S. Ramamurthy

7) Techniques for Nuclear and Particle Physics Experiments, W R Leo

8) Radiation Detection and Measurement, G F Knoll

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PHY-PhD-8 MODEL QUESTION PAPER

Nuclear Physics-I

Time: Three Hours Answer any 5 (5x20 = 100) Maximum: 100 marks

1. Explain the predictions of Shell model. How the discrepancies caused in shell model is overcome in collective model.
2. Explain the types of nuclear fission. Discuss Bhor and Wheeler's tjeory of nuclear fusion.
3. What are nuclear forces? List the properties of nuclear forces. Describe in detail Meso theory of nuclear forces.
4. What is meant by Q value of a nuclear reaction? Obtain an expression for it. Write the laws of nuclear reactions.
5. (a). Prove that nuclear absorption cross-section varies inversely proportional to the velocity of the incident neutron for low energy neutrons.
   (b) Discuss briefly various types of the direct reactions for low energy neutrons.
6. (a)Explain how the L.S. interaction helps us to reproduce the magic number in Shell model?
   (b) Discuss the salient features of the Collective model.
7. (a) Describe the classification of the elementary particles, fundamental Interactions and conservation laws.
   (b) Describe neutron-proton scattering at low energies.
8. (a)With a square well potential, derive an expression for the binding energy of a deuteron, as a function of the depth and width of the potential.
   (b) With a square well potential, derive an expression for the binding energy of a deuteron, as a function of the depth and width of the potential.

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PHY-PhD-9 NUCLEAR PHYSICS - II

UNIT – I

Nuclear Decays: Nuclear transformations – Radioactive decay – Alpha decay – Gamow"s theory – Beta decay – Fermi theory –Selection rules – Interaction of gamma radiation with matter – Photo electric effect – Compton scattering – Pair production.

UNIT – II

Nuclear Accelerators: Introduction – Linear accelerators – Drift tube and Wave guide accelerators – Low energy circular accelerators – Cyclotron and Betatron – High energy circular accelerators – Synchrotron and Microtron

UNIT – III

Nuclear Reactors: Nuclear fission and fusion reactions – Nuclear chain reactions – Four factor formula – The critical size of a reactor – General aspects of reactor design – Classification of reactors – Power reactors (elementary aspects only)

UNIT – IV

Nuclear Structure: Problem of Nucleon Nucleon Interactions and Nuclear Forces, Nuclear Models and Nuclear Matter, Electromagnetic and Weak Interactions.

UNIT – V

Experimental methods: Gamma-ray spectroscopy, conversion-electron and charged-particle spectroscopy associated with nuclear reactions and Coulomb excitation, Compton-suppressed Ge detectors, multiplicity filter, Neutron detectors, Sector field electron spectrometer, mini-range spectrometer, Recoil mass-separator, Advanced detector arrays-INGA, GAMMASPHERE and EUROBALL etc.

References:

1) Concepts of Nuclear Physics, B. L. Cohen (Tata McGraw Hill)

2) Nuclear Physics - An Introduction, S. B. Patel

3) Nuclear Physics, I. Kaplan

4) Nuclei and Particles, Emilio Segre

5) Nuclear Radiation Detectors, S. S. Kapoor, V. S. Ramamurthy

6) Techniques for Nuclear and Particle Physics Experiments, W R Leo

7) Radiation Detection and Measurement, G F Knoll

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PHY-PhD-9 MODEL QUESTION PAPER

Nuclear Physics-II

Time: Three Hours answer any 5 (5x20 = 100) Maximum: 100 marks

1. (a) Discuss Fermi's theory of beta decay and explain the continuous beta spectrum.

   (b). What are the selection rules for gamma decay? Illustrate with examples.

2. (a) Describe the reactor design with reference to

   i) Fuel

   ii) Moderators and Reflectors

   iii) Reactor Coolants

   iv) Control Materials

   v) Reactor Shielding

   (b) Explain constructions and working of proportional counter. Mention its applications

3. (a) Describe the working and principle of a Cyclotron.

   (b) Describe semi-conductor detectors, working of a Germanium detector.

4. (a) Write detailed nuclear energy state scheme for the decay of ThC nuclide to the ground state with emission of alpha and gamma particles.

   (b) Derive the expression for alpha disintegration energy?

5. Describe the interaction of neutron with matter in detail.

6. (a) Explain three processes involved in interaction of gamma rays with matter

   (b) What is artificial radioactivity? Explain the alpha neutron reaction.

7. Give an account on studies of nuclear structure and describe INGA detector setup.

8. Explain neutron cycle in a nuclear reactor. Obtain the four factor formula for nuclear fission

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PHY-PhD-10 LIQUID CRYSTALS-I

1. **Chemical Construction:**

Thermo tropic liquid crystals, Nematics, Smectics, Cholestrics, and Disc like molecules, linear molecules, lyotropic liquid crystals, monolayer and bilayer arrangements, monotropic and enatiotropic liquid crystals, bridging groups.

2. **Microscopic investigations including basic concepts:**

Phenomenology and morphology –polymorpholism-boundary effects-textures-homogeneous and homeotropic textures of nematic and smectic phases.

3. **Theories of liquid crystalline state:**

Swan theory- Continuem theory -Maier-Sauté theory (Mean field theory) – Landau-de Gennes theory –Pre transitional effects-Mc Millan theory of septic A phase and its developments.

4. **Electric and Magnetic field effects:**

Elastic deformations (Fredrick's deformation) – Magnetic field effects (temperature) on nematics and smetics – Electric field effects- Domains – DSM _ Loops –Electro hydrodynamic instabilities.

5. **Polarizing Microscopy:**

The Polarizing Microscope, Basic Liquid Crystal Optics, Uniaxial Phases, Biaxiality, Conoscopy

Books:

1. Introduction to Liquid Crystals:Editors E.P.Priestley et. Al.,Plenum Press,N.Y.
2. Hand book of Liquid Crystals: Hans Kelker et. Al.
3. The molecular Physics of Liquid Crystals: G.W.Gray et.al.
4. Liquid Crystals: S. Chandrasekhar.
5. Textures of Liquid Crystals: Ingo Dierking

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PHY-PhD-10 MODEL QUESTION PAPER

Liquid Crystals – I

Time 3 Hours **Max. Marks: 100**

Answer any Five Questions

1. Explain the classification of liquid crystals with specific examples.
2. Explain monolayer and bilayer arrangements in liquid crystals and discuss the effect of bridge groups.
3. Explain the homogeneous and homeotropic textures of the nematic and smectic phases in liquid crystals.
4. Discuss the phenomenology and morphology of liquid crystals and describe polymorphism.
5. Discuss in detail about Landau-de Gennes theory of nematic Liquid Crystals
6. Explain Mc Millan theory of smectic liquid crystals and discuss its developments.
7. Explain the effect of magnetic field in liquid crystals
8. Write about electric field effects, domains and DSM loops.

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PHY-PhD-10 LIQUID CRYSTALS-II

1. **Thermodynamic Properties:**
   Theories of phase transitions-pre transitional phenomena – Calorimetric measurements – Molar heat – Transitional entropy and enthalpy.

2. **Optical Properties:**
   Birefringence –Rayleigh's scattering – UV and Visible absorption spectroscopy.

3. **Liquid Crystal displays:**
   Electro optic phenomena – Field induced birefringence – Twisted nematic – Guest – Host effect – Cholestrics to nematic trastion – Storage mode – Display life – Alignment of liquid crystal, homogeneous and homeotropic.

4. **Technical Applications :**
   Thermography – Elecro optic display devices – Holography – Interferometry and other a

5. **Twist Grain Boundary Phases:**
   The TGBA Phase, Textures of planar anchoring conditions, hometropic anchoring conditions, Suppression of TGBA texture, TGBC and $TGBC_A$ phases.

Books:

1. Introduction to Liquid Crystals:Editors E.P.Priestley et. Al., Plenum Press, N.Y.
2. Hand book of Liquid Crystals: Hans Kelker et. Al.
3. The molecular Physics of Liquid Crystals: G.W.Gray et.al.
4. Liquid Crystals: S. Chandrasekhar.
5. Textures of Liquid Crystals: Ingo Dierking

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PHY-PhD-11 MODEL QUESTION PAPER

Liquid Crystals – II

Time 3 Hours **Max. Marks: 100**

Answer any Five Questions

1. Write about the chemical constitution of liquid crystals and describe the effect of bridging groups.
2. Explain in detail about pre-transitional phenomenon and calorimetric measurements.
3. Discuss the different theories of phase transitions.
4. Explain in detail birefringence – Rayleigh Scattering.
5. How the order parameter of nematic liquid crystals is determined by IR spectroscopy.
6. Discuss in detail Guest-host interactions in nematic liquid crystals.
7. Write short note on a) Liquid Crystal Interferometers b) Entropy and enthalpy in liquid crystals
8. Discuss in detail thermographic applications of liquid crystals.

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PHY-PhD-12 Molecular Modeling

1. **An Introduction to Computational Quantum Mechanics:** One-electron Atoms, Polyelectronic Atoms and Molecules, Molecular Orbital Calculations, The Hartree-Fock Equations, Basis sets, Calculating Molecular Properties Using ab initio Quantum Mechanics, Approximate Molecular Orbital Theories, Semi-empirical Methods, Huckel Theory, Performance of Semi-empirical Methods Advanced ab initio Methods, Density functional theory and solid-state quantum Mechanics: Opens-shell systems, Electron Correlation, Practical Considerations when performing ab initio Calculations, Energy Component Analysis, Valance Bond Theories, Density Functional Theory, Quantum mechanical methods for studying the solid state, The future role of quantum mechanics: Theory and Experiment working together
2. **Empirical Force Field Models: Molecular Mechanics:** General features of molecular mechanics, Bond stretching, Angle bending, Torsional Terms, Improper Torsions and out-of-plane bending motions, Cross terms, Non-bonded interactions, Electrostatic Interactions, Van der Waals Interactions, Many-body effects in empirical potentials, effective pair potentials, Hydrogen bonding in molecular mechanics, Force field Models for the simulation of liquid water, united atoms force fields and reduced representations, derivatives of the molecular mechanics energy function, Calculating thermodynamic properties, Force field parametrisation, Transferability of force field parameters, delocalized pi systems, force fields for inorganic molecules and solid state systems, empirical potentials for metals and semiconductors.
3. **Energy minimization and related methods for exploring the energy surface:** Non-derivative and derivative minimization methods, First order minimization methods, Second derivative methods: Newton Raphson Method, Quasi-Newton Methods, Applications of energy Minimization, Determination of Transition structures and reaction pathways, Solid state systems: Lattice statics and lattice dynamics. Conformational analysis: Systematic methods for exploring conformational space, mode-building approaches, random search methods, distance geometry, exploring conformational space using simulation methods, Variations on the standard methods, Finding the Global energy minimum, Solving protein structures using restrained MD and simulated annealing, Structural databases, Molecular fitting, Clustering algorithms and pattern recognition techniques, reducing the dimensionality of data set, covering conformational space: Poling, prediction of crystal structures.
4. **Protein structure prediction, sequence analysis and protein folding:** Some basis principles of protein structure, First principles methods for predicting protein structure, comparative modelling sequence alignment, Constructing and evaluating a comparative model, predicting protein structures by 'Threading', A comparison of protein structure prediction methods: CASP, protein folding and unfolding.
5. **Four Challenges in molecular modelling:** Free energies, solvation, reactions and solid-state defects: Free energy calculations and free energy differences, application of methods for calculating free energy differences, Calculation of enthalpy and entropy differences, Partitioning the free energy, Potential pitfalls with free energy calculations, Potentials of Mean force, Approximate/rapid free energy methods, continuum representations of solvent, the electrostatic contribution to the free energy solvation- The Born and Onsager models, Modelling chemical reactions, Modelling solid state defects.

References:

1. Molecular modelling: Principles and Applications, Andrew R. Leach, PEARSON Education Ltd.
2. Modern quantum chemistry Introduction to advances electronic structure theory by Attillo szabo, Neil S. Ostlund, Dover publications, Inc. Mineola, New York.
3. Molecular quantum mechanics, 4th edition, peter Atkins, Ronald Friedman, oxford university press.

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Department of Physics

K L UNIVERSITY

(Deemed to be University U/S 3 of UGC act 1956)

Minutes of the
First Board of Studies Meeting

K L University
Greenfields, Vaddeswaram,
Guntur District, Andhra Pradesh

2012-2014

COR-NSM-STD-REC-1	**Standard for issuing the Notices for BOS meetings**

Meeting Particulars

Type of Meeting	**Board of Studies,**
Department Conducting the meeting	Department of Physics
Number of the Meeting	01
Date of Meeting	11-04-2012
Time of Meeting	10 :00 am
Venue of Meeting	FED conference hall, K.L.University

Persons to Meet

Serial Number	Name of the Person	Institution	Department of the Person	Designation of the person	Position of the person in the meeting	Primary Responsibility if any
1	Dr. A Srinivasa Rao	K L University	Dept. of Physics	Professor	Chairmen	To Recommend the Syllabus for Engineering Physics, Engineering Materials Courses and recommend the course structure for M.Sc Physics along with Lab
2	Dr. P Madhusudana Rao	J N T U, Hyderabad	Dept. of Physics	Professor & HOD	External Member	-do-
3	Dr. R Ramakrishna Reddy	S K University College of Engineering	Dept. of Physics	Professor	External Member	-do-
4	Dr. K Vijaya Kumar	K L University	Dept. of Physics	Professor	Internal Member	-do-
5	Dr. G Ramakrishna	K L University	Dept. of Physics	Professor	Internal Member	-do-
6	Dr. K S Ramesh	K L University	Dept. of Physics	Professor	Internal Member	-do-
7	Dr. K Srinivasa Ravi	K L University	Dept. of Physics	Professor	Internal Member	-do-
8	Dr. K S N Murthy	K L University	Dept. of Physics	Professor	Internal Member	-do-
9	M V V K Srinivas Prasad	K L University	Dept. of Physics	Asst. Professor	Internal Member	-do-

Agenda Items to Discuss.

Item Number	Agenda Item
PHY-BOS-1201	To resolve and recommend the syllabus of Engineering Physics course (11-BS 103) with Lab for I/IV B.Tech all branches.
PHY-BOS-1202	To resolve and recommend the syllabus of Engineering Materials course (11-ES 103) for I/IV B.Tech all branches.
PHY-BOS-1203	To resolve and recommend the syllabus of M.Sc Physics (Semester I, II, III, IV) along with Lab as per Annexure – I.
PHY-BOS-1204	To resolve and recommend the introduction of Ph.D programmes in the areas: Glass Science and Technology, Nanoscience and Technology, Solid State Ionics, Thin films and Atmospheric Sciences.

Notice Acknowledgement

Serial Number	Name of the Person	Designation	Institution	Signature
1	Dr. A Srinivasa Rao	Professor	K L University	A. Srinivasa Rao 1/4/12
2	Dr. P Madhusudana Rao	Professor	J N T U, Hyderabad	P. Madhusudana Rao
3	Dr. R Ramakrishna Reddy	Professor	S K University College of Engineering Anantapur	– ABSENT –
4	Dr. K Vijaya Kumar	Professor	K L University	
5	Dr. G Ramakrishna	Professor	K L University	–
6	Dr. K S Ramesh	Professor	K L University	
7	Dr. K Srinivasa Ravi	Professor	K L University	K. S. Ravi
8	Dr. K S N Murthy	Professor	K L University	
9	M V V K Srinivasa Prasad	Asst. Professor	K L University	Srinivas

Authorized Signatory: **Signature:**

COR-NSM-STD-REC-2	Standard for Recording the Minutes of the Meetings

Particulars of the Meeting conducted

Type of Meeting	**Board of Studies,**
Department Conducting the meeting	Department of Physics
Number of the Meeting	01
Date of Meeting	11-04-2012
Time of Meeting	10 :00 am
Venue of Meeting	FED conference hall, K.L.University, Guntur

Persons Present

Serial Number	Name of the Person	Institution	Department of the Person	Designation of the person	Position of the person in the meeting	Primary Responsibility if any
1	Dr. A Srinivasa Rao	K L University	Dept. of Physics	Professor	Chairmen	To Recommend the Syllabus for Physics Courses and recommend the course structure for M.Sc Physics
2	Dr. P Madhusudana Rao	J N T U, Hyd	Dept. of Physics	Professor & HOD	External Member	-do-
3	Dr. K Vijaya Kumar	K L University	Dept. of Physics	Professor	Internal Member	-do-
4	Dr. G Ramakrishna	K L University	Dept. of Physics	Professor	Internal Member	-do-
5	Dr. K S Ramesh	K L University	Dept. of Physics	Professor	Internal Member	-do-
6	Dr. K Srinivasa Ravi	K L University	Dept. of Physics	Professor	Internal Member	-do-
7	Dr. K S N Murthy	K L University	Dept. of Physics	Professor	Internal Member	-do-
8	M V V K Srinivas Prasad	K L University	Dept. of Physics	Asst. Professor	Internal Member	-do-

Resolutions

Agenda Item Number	Agenda Item Description	Important Objections	Resolution	Feedback Reference if any
PHY-BOS-1201	To resolve and recommend the syllabus of Engineering Physics course (11-BS 103) with Lab for I/IV B.Tech all branches.	—	It has been resolved that the syllabus is recommended by the BOS members for approval.	DEP-ACC-YRSRL
PHY-BOS-1202	To resolve and recommend the syllabus of Engineering Materials course (11-ES 103) for I/IV B.Tech all branches.	—	It has been resolved that the syllabus is recommended by the BOS members for approval.	
PHY-BOS-1203	To resolve and recommend the syllabus of M.Sc Physics (Semester I, II, III, IV) along with Lab as per Annexure – I.	—	It has been resolved that the syllabus is recommended by the BOS members for approval.	
PHY-BOS-1204	To resolve and recommend the introduction of Ph.D programmes in the areas: Glass Science and Technology, Nanoscience and Technology, Solid State Ionics, Thin films and Atmospheric Sciences.	—	It has been resolved that the syllabus is recommended by the BOS members for approval.	

Circulation and acknowledgements

Serial Number	Name of the Person	Designation	Institution	Signature
1	Dr. A Srinivasa Rao	Professor	K L University	A. Srinivasa Rao 11/4/12
2	Dr. P Madhusudana Rao	Professor	J N T U, Hyderabad	P. Madhusudana Rao
3	Dr. K Vijaya Kumar	Professor	K L University	11/4/2012
4	Dr. G Ramakrishna	Professor	K L University	
5	Dr. K S Ramesh	Professor	K L University	
6	Dr. K Srinivasa Ravi	Professor	K L University	K. S. Ravi
7	Dr. K S N Murthy	Professor	K L University	
8	M V V K Srinivasa Prasad	Asst. Professor	K L University	

Authorized Signatory: **Signature:**

K L UNIVERSITY

Department of Physics

First year 2012 - 2013 L-P-T: 3-0-1

Course Title	:	**Engineering Physics**
Course Code	:	**11-BS 103**
Branch	:	Common to all branches

Course content and overview:

This course is offered for first year B.Tech (all branches) in a semester as one of the courses in basic Sciences (BS). Students are exposed to wave optics covering the aspects of interference and diffraction. The study of polarization helps the students to understand electromagnetic wave propagation in communications and also in stress analysis. Study on lasers like spontaneous and stimulated emission make the student to understand the distinction between a normal source and laser source. The types of lasers like ruby, He-Ne and semiconductor help the student to understand the light sources used in modern technology. The study on ultrasonics mainly the production, detection and Non Destructivre Testing including the study of SONAR makes the student to understand the applications in the field of Industry and Medicine. The study on electrostatics mainly the calculation of electric field intensity using coulombs law and Gauss law gives an insight for the student to go into Electromagnetics. Similarly, Students are introduced to magnetostatics to understand the Gauss law and its applications. They are exposed to Amperes law and Biot-Savart's law to calculate magnetic field intensity for current carrying conductors of various of symmetric ans unsymmetric systems. The study on Lorentz force on moving charges, and its usage to understand how to produce high energy particles in circular accelerators. The study on the phenomenon of Hall Effect finds application in science technology. Students are exposed to certain basic laws of electrical technology like Faraday's laws, Lenz's law. He will be exposed to Maxwell's equations, which are the fundamental laws used to solve the problems related to electromagnetism. Students are introduced to understand the physics part behind light emitters like LED and light detectors like photo diode and photo transistor. Students are introduced to the significance of alternate energy sources and exposed to one such an alternate source of energy namely SOLAR. The

A. Srinivasa Rao 11/4/12

P. Ramachandra 11/4/12

11/4/12

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Scope and Objective of the course:

This course explores the fundamental principles and concepts of Physics from different topics such as wave optics, ultrasonic's, electromagnetism, superconductivity, lasers and optoelectronic devices needed for all engineering students, which they can readily relate to the engineering problems that they would be addressing in their course work.

Prescribed Text Books

Text Books:

1. University Physics, 6th edition, Francis W.Sears, Mark W Zemansky, Hugh D Young, Norsa Publishing House.
2. Engineering Physics, 8th Edition, R K Gaur and S L Gupta, Dhanpat Rai Publications.

Reference Books:

1. Solid State Physics, 6th Edition, S.O.Pillai, Newage International Publishers.
2. Applied Physics, P.K.Palanisamy, Scitech publications (India) Pvt.Ltd, Chennai.
3. Physics Volume II 5th Edition, Resnick, Halliday and Krane.
4. Engineering Physics, 2nd edition, P. K Palanisamy, Sci Tech publications (India) Pvt.Ltd, Chennai.

P. Madhusudana Rao 11/4/12

A. Srinivasa Rao 11/4/12

11/4/12

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Engineering Physics (11-BS103)

List of Experiments

Expt. No.	Name of the Experiment
1	Frequency of A.C. supply using sonometer
2	Hall Effect
3	L C R series resonant circuit
4	Haidinger fringes
5	Diffraction Grating by Normal Incidence
6	Newton's Rings
7	Planck's constant
8	Solar Cell
9	Field along the axis of the coil
10	Laser diffraction grating
11	p-n junction diode characteristics
12	Determination of velocity of ultrasconic waves by Interferometer

Note: A student has to complete 10 experiments out of 12 experiments.

P. Prabhakara Rao 11/4/12

A. Srinivasa Rao 11/4/12

11/4/12

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K L UNIVERSITY

Department of Physics

First year 2012 - 2013 **L-P-T: 3-0-0**

Course Title : **Engineering Materials**

Course Code : **11-ES 103**

Branch : Common to all branches

Course content and overview:

This course mainly deals with the fundamental principles, Phenomena's, laws and Properties of Engineering materials as relevant to engineering applications for modern day technologies. There is a symbiotic relation between Engineering Materials and Engineering. Broadly speaking without engineering materials there is no engineering. The main Concepts are magnetic materials-classification of materials, soft and hard magnetic materials, Hysteresis phenomena, magnetic materials for transformers, motors, magnetic recording, data storage, relays and sensors. Electrical materials types, electrical conduction mechanism, dielectric polarization methods, Ferro electricity and Piezo electricity and applications of electrical materials. This course is highly useful for mechanical as well as Civil engineers for focusing the concepts on Mechanical and thermal properties of materials-basic properties like stress, strain, ductility toughness, relationship between stress and strain, elasticity, Plasticity, fatigue-fracture, specific heat and thermal conductivity. Classification of ferrous and non-ferrous materials, types of steels and super alloys for automotive engine parts. Classification of construction materials like cement, bricks, stones, wood, glasses and paints. And also deals with composite materials-Laminates, filler resign, copper foil, polyesters for potential applications. Finally this course explores emerging materials such as Nano materials classification of nano materials and their Properties, different synthesis methods like physical vapour, sol –gel technique, CVD technique and their characterization and their potential applications in modern day technologies.

A. Srinivasa Rao 11/4/12

11/4/12

11/4/2012

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Syllabus:

Magnetic Materials: Basic concepts – magnetic moment, susceptibility, permeability; Types of magnetic materials – Diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic and ferromagnetic materials, structure of ferrites, domain theory of ferromagnetism, magnetostriction effect, Hysteresis of ferromagnetic and ferromagnetic materials; Soft and hard magnetic materials; Applications - Magnetic materials for transformers, motors, magnetic storage, magnetic memories, magnetic tapes, magnetic recorder, relays, sensors and electromagnets.

Electrical Materials: Properties of materials – Ohm's law, electrical conductivity, electrical resistivity – conducting materials, semiconducting materials, insulating materials, dielectric materials; Electrical conduction – Ohm's law, electrical conductivity, resistivity:

Dielectric materials: Dielectric polarization – electronic, ionic, orientation or dipolar and space charge polarizations (qualitative treatment), frequency and temperature dependence of polarization, ferro electricity – spontaneous polarization and structure of barium tiatianate; definition of piezoelectricity.

Mechanical and Thermal properties of materials: Definitions – elasticity, plasticity, stress, strain, strength, hardness, brittle, ductility, creep, fatigue, fracture, malleability and toughness; relationship between stress and strain; deformation. Qualitatively treatment of temperature, specific heat and thermal conductivity.

Classification of ferrous and nonferrous materials: Metals classification, steel manufacturing process by Basic oxygen process and electric arc furnace process ; classification of carbon steels, Alloy steels; general affects of alloy steels ; Ni-steels, Cr-steels, Ni-Cr Steels; manufacturing process of cast iron, classification , properties and uses ; Aluminium extraction, properties, uses and alloys; Copper extraction, properties, uses and alloys

Construction materials: Refractories for furnaces. Composite materials: Laminates, properties of laminates, phenolic laminates, epoxy laminates, silicon laminates.

Nano materials and Nanotechnology: Basic concepts of nanotechnology. Properties and technological advantage of nano materials. Carbon nano tubes and applications. Nano material preparation by sol-gel method and chemical vapor deposition.

A. Srinivasa Rao 11/4/12

P. Madhusudhana Rao 11/4/12

11/4/2012

Scope and Objective of the course:

- This course is designed to enable the students to appreciate the different aspects of engineering materials for their potential device applications in engineering and science and technology. The Students will be exposed to understand the significance of electric and magnetic forces on a moving charged particle and its usage to understand how to produce high magnetization materials like ferrites and how to use these materials in designing of transformers, motors, data storage, recording, relays and sensors for certain applications in science and technology.

- Students will be exposed to understand the basic conduction mechanism in conducting, semi conducting, Insulating and dielectric materials for electronic device applications. Students will know what are mechanical and thermal properties of materials by different synthesizing methods and its role in science and technology. He will come to know about types of alloys, their structures and their applications in automotive engine parts.

- This course is intended to provide for engineering students with background important basic concepts, manufacturing methods and applications of various metals, alloys for industrial applications. And also the students should learn the chemistry of construction materials such as cement bricks wood, paints and refractories and their potential applications, The primary object of this course how collectively engineering materials is important in engineering and also form a bridge of materials knowledge basic sciences and engineering disciplines.

- Finally the Students are exposed for certain emerging materials like Nano materials, CNTs and their fabrication methods, characterization and their potential applications in science and technology.

11/4/12

11/4/12

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Books:

Notes will be made available

Prescribed Text Books:

T1. Material Science and Engineering by W. D. Callister, Jphn Wiely and Sons Company, 2007.

T2. Elements of material science and engineering, 6th Edition, by Van Vlack L.H.,Adisson Wesley, 1989.

T3. Material Science by Dr. Arumugam, Anuradha Publications.

T4. Modern magnetic materials, by O'Handley R.C, John Wiley & Sons, 2000.

T5.Engineering materials by R.K.Rajput,laxmi publications new Delhi-2006.

Reference Books:

R1. Material Science by V Raghavan (TMH).

R2. Material Science by K M Gupta Umesh Publications.

R3. Material Science by O P Khanna Publications.

R4. Solid State Physics, 6th Edition, S.O.Pillai, Newage International Publishers.

R5. Building Materials by B.C punmia Lakshmi publications.

R7.Engineering Material Science by S.C Rangawala Charotor publications.

P. Mahalingam 11/4/12

A. Srinivasa Rao 11/4/12

11/4/2012