ES 301: Atomic and Molecular Physics

1. Structure of Atom (5 Hours)

Various atomic models - survey-brief ideas with assumptions, postulates and shortcomings, Quantum states of an electron in an atom, Quantum numbers, Electron spin, Stern-Gerlach experiment, Spectrum of Hydrogen, Helium and alkali atoms, Relativistic corrections for energy levels of hydrogen, Vector atom model - its need/important.

(Reference books:-
1. Introduction to atomic and nuclear physics (Van Norstrand Reinhold (east-West Press) by H. E. White)
3. Atoms and Molecules: An introduction for students of Physical chemistry (W. A. Benjamin Inc. New York) by Martin Karplus and Richard N. Porter)

2. Atom model for two valance electron (8 Hours)

Various coupling schemes: LL, SS, LS and jj, Pauli exclusive principle, Coupling principle, factors for LS coupling, Lande interval rule, JJ branching rule, selection rules, intensity relations, magnetic moment of atom, Lande g factor, determination of g factor by electron spin resonance, Zeeman effect, intensity rules, calculation of Zeeman pattern, Paschen Back effect-LS and jj coupling and Paschen Back effect, Breits scheme for derivation of spectral terms, Pauli's exclusive principle

(Reference books:-
Introduction to atomic spectra (Mc. Graw hill, International Edition) by H. E. White))

3. Complex spectra (5 Hours)

Displacement law, alternation law of multiplicities, vector model for more valance electrons, Lande interval rule, inverted terms, Hund’s rule, Zeeman effect and magnetic quantum numbers in complex spectra, magnetic energy and Lande g factor, Paschen back effect in complex spectra.

(Reference books:-
Introduction to atomic spectra (Mc. Graw hill, International Edition) by H. E. White))
4. **Hyperfine structure**  

   Introduction, hyperfine structure and Lande interval rule, nuclear interaction with one valance electron, hyperfine structure of two or more electron, Zeeman effect in hyperfine structure, Back Gouldsmit effect in hyperfine structure.

   (Reference books:-  

5. **Pure rotational structure**  

   Rotation of linear system (classical and quantum mechanical), rigid rotator, rotational energy levels and their populations, interaction of rotation with rotating molecules, rotational spectra of rigid rotators, selection rules for linear molecules, determination of moment of inertia and bond length from rotational spectra, relative intensities of spectral lines, Stark effect in molecular rotational spectra, molecular rotation-nuclear coupling.

   (Reference books:-  

6. **Pure vibrational spectra**  

   Vibration of single particle, vibrations of two particles connected by spring (classical), Harmonic oscillators, vibrational energies of diatomic molecules, interaction of radiation with vibrating molecules, anharmonic oscillator, deduction of molecular properties from vibrational spectra of diatomic molecules.

   (Reference books:-  

7. **Rotation and vibration spectra**  

   Diatomic vibrating rotator coupling of rotation and vibration, rotation-vibration spectra, selection rules and transition for vibrating rotator, intensities in rotation and vibration spectrum, parallel and perpendicular bands of linear molecules, Isotope effect-vibration, rotation.
8. **Electronic spectra of Diatomic molecules** (7 Hours)

Electronic energy curves, potential energy curves stable and unstable molecular states, vibration structure of electronic transitions, general formula, graphical representation, isotopes effect, rotational structure of electronic spectar, the branches of band, band head formation, shading of bands: Fortrat diagram, Isotope effect, intensities in electronic bands-Vibrational structure-Frank Condon principle, absorption and emission, rotational structure, transition.

(Reference books:-
ES 302: CONDENSED MATTER PHYSICS

1. **Defects in solids**  
   (6 Hours)  
   Mechanical properties, Types of defects: Point defects, Schottky and Frankel defects, defects and thermodynamic equilibrium, diffusion and it’s temperature dependence, color centers, Line defects: type of dislocations, burger vector, Surface defects: Stacking faults, low angle grain boundary.

2. **Specific heat and lattice vibrations**  
   (7 Hours)  
   Classical theory of specific heat and it’s drawbacks, Einstein theory of specific heat, vibrational modes of a continuous medium, Debye approximation, The Born cut-off procedure, Vibrational modes of a finite one-dimentional lattice of identical and diatomic lattice.

3. **Free electron theory of metals**  
   (7 Hours)  
   The free electron theory of metals, electronic specific heat, Response and relaxation phenomena, Drude model of electrical and thermal conductivity, the Fermi surface, electrical conductivity; effects of the Fermi surface, thermoelectric power.

4. **Dielectric and optical properties of Insulators**  
   (10 Hours)  
   Static fields: Macroscopic description of the static dielectric constant, The static electronic and ionic polarizabilities of molecules, Oriental polarization, The internal field according to Lorentz and the Clausius-Mosotti formula.  

5. **Magnetism and Ferroelectrics**  
   (10 Hours)  
   Origin of permanent magnetic dipoles, Dimagnetism and Larmor precession,  
   The static paramagnetic susceptibility: Classical and Quantum theory of paramagnetism,  
   Ferromagnetism: The Weiss molecular field, The Weiss molecular field and it's interpretation, Temperature dependence of spontaneous magnetization,  
   Ferroelectricity: General properties of ferroelectric materials, classification, ferroelectric domains.

6. **Superconductivity**  
   (8 Hours)  
   Introduction, Meissner effect, The critical field, Thermodynamics of superconducting transition: The heat capacity and stability of superconducting state, Electrodynamics of superconductors: The London equation, coherence length and penetration depth, BCS theory of superconductivity, the condensate,  
   The Josephson Tunneling: DC and AC effect, Introduction to high Temperature superconductivity.

References:  
2. Charles Kittel, Introduction to Solid State Physics, , John Wiley and Sons.  
1. Solar Photovoltaics
   (a) Introduction (2 Hours)
   The Photovoltaic effect, Photovoltaic cells and power generation, some important definitions, Characteristics of Solar Cell: Photocurrent and quantum efficiency, dark current and open circuit voltage, efficiency, parasitic resistances, non-ideal diode behaviour

   (b) Basic Principles of Solar Photovoltaics (4 Hours)

   Reference: The Physics of Solar Cells: Jenny Nelson, Imperial College Press

2. Solar Cell: Materials and Technology (6 Hours)
   Material Properties and synthesis techniques, solar cell and module properties, status and future prospects of: Silicon, cadmium telluride, copper indium diselenide
   Tandem cells and concentrating systems, dye-sensitized cells and organic solar cells

   Introduction: Stand alone SPV systems: consumer applications, solar home systems, Residential systems, hybrid systems; Grid connected SPV systems: decentralised and central grid connected SPV systems (2 Hours)
   System Wiring: cable sizing, line losses, circuit protection; steps in design and installation, system maintenance (4 Hours)
   Reference: The Solar Entrepreneur’s Handbook: Geoff Stapleton, Gunaratne, Konings, Bandyopadhyay, WISE publication

4. Wind Turbine Power (12 Hours)
Energy and Torque, Power output from an ideal turbine, aerodynamics, power output from practical turbines, transmission and generator efficiencies, energy production and capacity factor, torque at constant speeds, turbine shaft power and torque at variable speeds.
Reference: Wind Energy Systems by Dr. Gary L. Johnson

5. Electric Network

(12 Hours)

Synchronous power: methods of generation, few concepts of ac circuits, the synchronous generator; asynchronous generators: systems, Dc shunt generators with battery load, permanent magnet generator
Reference: Wind Energy Systems by Dr. Gary L. Johnson
## ES 401: NUCLEAR PHYSICS

<table>
<thead>
<tr>
<th>1. <strong>Nuclear properties</strong> (4 hours)</th>
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<tbody>
<tr>
<td>The nuclear radius, mass and abundance of nuclides, energy of nucleons in the nucleus, nuclear binding energy, nuclear angular momentum and parity, nuclear electromagnetic moments, nuclear excited states.</td>
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<th>2. <strong>Nuclear models</strong> (8 hours)</th>
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<tr>
<td>Constitution of the nucleus; neutron-proton hypothesis, Nature of nuclear force, Inventory of stable nuclides, Liquid drop model: Semi-empirical mass formula, applications of semi-empirical mass formula, limitations of liquid drop model, Nuclear Shell model: The Shell-theory potential, effective mass, Allowed orbits in the Shell-theory potential, Filling of allowed orbits in the shell-theory potential, separation energies of nucleons, energy spacings between shells, non spherical nuclei. Limitations of shell theory.</td>
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<th>3. <strong>Radioactivity</strong> (10 hours)</th>
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<tr>
<td>Radioactive disintegration and displacement law, Nuclear decay laws, half life, successive disintegrations, radioactivity equilibrium, radioactive dating methods. Alpha-decay: kinematics of alpha decay: alpha particle energy, Virtual levels: a stationary approach to alpha-decay, penetration through the Coulomb barrier(Geiger-Nutall law) Beta-decay: The old beta decay theory and the neutrino hypothesis, Energy relations and Q-values in beta-decay, The Fermi theory of beta-decay, angular momentum and parity-selection rules, comparative half-lives and forbidden decays, neutrino physics, non conservation of parity, Gamma decay: passage of gamma rays through matter, gamma ray spectra and nuclear energy levels, radiative transitions in nuclei.</td>
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<th>4. <strong>Detection of nuclear radiation and their measurement</strong> (6 hours)</th>
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<tr>
<td>Interaction of radiations with matter, gas filled counters, scintillation detectors, semiconductor detectors, counting statistics, energy measurements, coincidence measurement and time resolution, measurement of nuclear lifetimes.</td>
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<th>5. <strong>The acceleration of charged particles:</strong> (6 hours)</th>
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<td>The van de Graff machine, cyclotron, frequency-modulated cyclotron, the betatron and the electron synchrotron, The proton synchrotron, Linear accelerators, The alternating gradient synchrotron.</td>
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<th>6. <strong>Nuclear fission and fusion</strong> (6 hours)</th>
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<tr>
<td>Characteristics of fission, Energy in fission, energy distribution between the fission fragments, energetic of fission process, Bohr-Wheeler theory of nuclear fission, cross section of neutron induced fission, controlled fission reactions, Q-value calculations, fission reactor, fission explosives, Basic fusion process, cross section of fusion reaction, critical temperature, Lawson criterion, different methods of satisfying Lawson criterion.</td>
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<th>7. <strong>Elementary particles:</strong> (8 hours)</th>
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<tr>
<td>Classification of elementary particles, conservation laws, fundamental interactions in nature. Elementaary idea of CP and CPT invariance.</td>
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</table>
Quark hypothesis: Classification, Quark structure of mesons and baryons, Gellman-Okubo mass formula.

References:
5. Basic ideas and concepts in Nuclear Physics, K. Heyde, IOP publishing limited, 2005.
1. **SOLAR RADIATION** (7 Hours)
The Sun, the solar constant, spectral distribution of extra-terrestrial radiation, variation of extra-terrestrial radiation, definitions, direction of beam radiation, angles for tracking surfaces, extra-terrestrial radiation on a horizontal surface


2. **AVAILABLE SOLAR RADIATION:** (7 Hours)
Instruments for measuring solar radiation and sunshine: pyrheliometer, pyranometer, sunshine recorder, apparent motion of the Sun, sunrise, sunset and the day length, local apparent time, atmospheric attenuation of solar radiation, empirical equations for predicting the availability of solar radiation, solar radiation on a tilted surface

References:
Solar Engineering of Thermal Processes: John A. Duffie and William A. Beckmann
Solar Energy: S.P. Sukhatme

3. **SELECTED HEAT TRANSFER TOPICS** (8 Hours)
The electromagnetic spectrum, the blackbody, Planck's law and Wien's displacement law, Stephan-Boltzmann equation, Fourier's law, IR radiation exchange between grey surfaces, sky radiation, radiation heat transfer coefficient, Natural convection between flat parallel plates and between concentric cylinders, wind convection coefficient


4. **LIQUID FLAT PLATE COLLECTOR** (10 Hours)
Introduction, Energy balance equation, transmittivity of cover systems, trasmissivity-absorptivity product, overall loss coefficient and heat transfer correlations, collector efficiency factor, collector heat removal factor, testing procedure, the evacuated tube collectors, Introduction to concentrating collectors: classification and types

Reference: Solar Energy: S.P. Sukhatme

5. **DESIGN METHODS** (5 Hours)
Design of active systems by utilizability methods: Hourly utilizability and daily utilizability.

6. **THERMAL ENERGY STORAGE** (5 Hours)
   Introduction, sensible heat storage: liquids, solids, analysis of a liquid storage tank;
   Latent heat storage

   Reference: Solar Energy: S.P. Sukhatme

7. **ECONOMIC ANALYSIS** (6 Hours)
   Initial and annual costs, definitions, present worth calculations, repayment of loan in equal annual instalments, annual solar savings, cumulative solar savings and life cycle savings, payback period.

   Reference: Solar Energy: S.P. Sukhatme
ES 403: ENERGY AUDIT AND MANAGEMENT

1. **ENERGY AUDITING BASICS**  
   (3 Hours)  
   Introduction, types of energy audits, the audit process, pre-site work, post-site work, the audit report  

2. **ENERGY ACCOUNTING AND ANALYSIS**  
   (5 Hours)  
   Introduction, electric demand, load factor, analyzing energy data, identifying potential measures, industrial audit opportunity  

3. **Economic Analysis and Life Cycle Costing**  
   (10 Hours)  
   Introduction, Costs: categories, cash flow diagrams and tables, simple payback period cost analysis, economic analysis using the time value of money, discounted cash flow analysis, discounted cash flows: basics and single sum analysis, methodology using discounted cash flows, cost effectiveness measures using discounted cash flows, Life cycle costing  

4. **Electric Energy Management**  
   (10 Hours)  
   Introduction, Power supply, motor and motor related terms, power factor, formulas and rules of thumb, electric motor operating loads, power meter, electric motor efficiency, comparing motors, motor efficiency management,  

5. **Lighting**  
   (10 Hours)  
   Introduction, components of the lighting system, lamp characteristics, lamp types, ballasts, Luminaries, determining lighting needs, the lighting survey, safety issues, identifying potential EMOs.  

6. **Process Energy Management**  
   (10 Hours)  
   Introduction, steps for process improvement, motors and adjustable speed drives, air compressors, examples of process energy improvements, common energy management opportunities  