

SAR 5133	SUSTAINABILITY IN BUILDING MATERIALS AND TECHNIQUES	L	T	P	Credits	Total Marks
		2	1	0	3	100

COURSE OBJECTIVES

1. To give a comprehensive overview of sustainable building materials and construction techniques.
2. To understand the concept of embodied energy of materials in construction industry.
3. To synthesize the innovative applications of primary, secondary and tertiary waste as building materials in construction

COURSE OUTCOMES:

1. Ability to classify the materials based on the thermal properties, embodied energy and availability.
2. Ability to analyze the various methods adopted to calculate the embodied energy through case studies.
3. Understand the concept of life cycle costing analysis of building materials.
4. Critically appreciate the alternative construction techniques.
5. Learn various innovative methods of using waste materials in constructing both permanent and temporary shelters.
6. Understand the ways through which the salvaged materials are used in construction.

UNIT 1 INTRODUCTION TO SUSTAINABLE BUILDING MATERIALS**10 Hrs.**

Introduction to sustainable building materials, qualities, use, examples - Natural building materials, locally available and locally manufactured materials, bio materials - Salvaged and recycled materials - Non toxic materials: low VOC paints, coating and adhesives.

UNIT 2 CONCEPT OF EMBODIED ENERGY AND CARBON FOOTPRINT**16 Hrs.**

Idea of embodied energy - Development of the concept, factors to be considered, calculation techniques for embodied energy - Data sets available for calculation of embodied energy - Case studies of embodied energy calculations- Sample embodied energy calculations for a material - Concept of embodied carbon or carbon footprint of material, calculation techniques, methods to off-set high embodied energy - Cradle to cradle material, whole life cycle and life cycle costing analysis techniques.

UNIT 3 SUSTAINABLE CONSTRUCTION TECHNIQUES**12 Hrs.**

Alternative construction techniques such as SMB, CSEB, and steam cured blocks, composite beam and panel, funicular shells, filler slabs, reinforced concrete masonry, vaulted roofs, ferro-cement wallsetc., -Case studies

UNIT 4 INNOVATIVE USE OF MATERIALS**10 Hrs.**

Use of waste materials such as paper, glass bottles, tires, shipping containers - Use of post consumer and industrial waste such as fly-ash, bags, building demolition waste –use of salvaged materials from flooring, columns, beams, timber, glass, etc.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. Sustainable Building - Design Manual Pt 1 & 2, The Energy and Resources Institute, TERI, 2004
2. GROSS Spiegel, Green Building Materials A Guide to Product Selection and Specification, 3rd Edition by, John Wiley & Sons, 2010
3. K.S. Jagadish, Alternative Building Materials and Technologies, New age International Pvt Ltd Publishers, 2008
4. Traci Rose Rider, Stacy Glass, Jessica McNaughton, Understanding Green Building Materials, W.W.Norton and Company, 2011
5. Johan van Lengen, The Barefoot Architect: A Handbook for Green Building, Shelter Publication, 2008

WEBSITES

1. <http://www.ijsrp.org/research-paper-1112/ijsrp-p1154.pdf>
2. <http://www.sustainablebuild.co.uk/ecofriendlyconstructionmethodsmaterials.html>
3. <http://www.epa.gov/greenhomes/SmarterMaterialChoices.htm>
4. <http://inhabitat.com/tag/sustainable-building-materials/>

End semester examination question paper pattern
(To be distributed uniformly among all the units)

Max. Marks: 100**PART A : 2 questions from each unit, each carrying 4 marks.****PART B : 2 questions from each unit with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**

SAR 5135	TECHNOLOGY FOR ENERGY EFFICIENT BUILDINGS	L	T	P	Credits	Total Marks
		3	0	0	3	100

Course objectives:

1. To understand the various aspects of natural and mechanized ventilation.
2. To give a comprehensive introduction and the principles of natural and artificial lighting.
3. To explore the fundamentals of integrating services in buildings.

Course Outcomes:

1. Understand the various types of cooling and heating systems.
2. Explore the principles of day lighting systems.
3. Ability to comprehend the ventilation requirements as per ASHRAE/ECBC.
4. Critical understanding of the differences between cooling and heating system.
5. An overview of various methods to integrate automation of building systems in buildings.
6. Comparative analysis of strategies to integrate services adopted in green buildings through case studies.

UNIT 1 HVAC TECHNOLOGIES**10 Hrs.**

Factors affecting HVAC Design - Types of Cooling systems air cooled, water cooled, chilled beams, chilled slabs, pre-cooling, free-cooling, VFD drives, etc. - Individual controls and VAV boxes - Natural refrigerants, combined heat power systems- Types of heating systems, radiant heating, solar heating -Conservatory design.

UNIT 2 DAYLIGHTING & ARTIFICIAL LIGHTING**12 Hrs.**

Principles of day lighting design - Day lighting requirements, daylight protractor, day lighting sensors - Glare reduction systems and devices - Day lighting pipes - Shading design - Artificial lighting - Principles of lighting systems, lighting design systems - Occupancy sensors - Glare reduction techniques.

UNIT 3 VENTILATION TECHNIQUES**14 Hrs.**

Requirements of ventilation as per ASHRAE/ECBC - Natural ventilation: stack effect, courtyard effect, air changes, ventilation requirement calculations, cross ventilation - Artificial ventilation techniques: forced ventilation, fresh air systems, pre-cooling of fresh air - Heat recovery through economizers and desiccant wheels - Humidity control systems, demand controlled ventilation

UNIT 4 BUILDING SERVICES INTEGRATION**12 Hrs.**

Integration of various building systems- Building automation systems and intelligent building systems - Integration of HVAC systems with water supply and treatment systems - Occupant responsive buildings - Building information modelling - Green building case studies - Cost analysis of green buildings and ordinary buildings- Capital investment vs. maintenance/operating costs.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. Martin Evans, Housing, Climate and comfort, Architectural Press, London 1980
2. Handbook of functional requirements of Buildings, Bureau of Indian standards SP41, 1987
3. David Egan, Concepts in Thermal comfort, Prentice Hall, 1975
4. Energy Conservation Building Code of India, User manual, 2007
5. ASHRAE 90.1 User Manual, 2007
6. Brian Atkin, Intelligent Buildings: Applications of IT and Building Automation to High Technology Construction Projects, Kogan Page limited, London, 1988
7. Peter Tregenza and Michael Wilson, Daylighting: Architecture and Lighting Design, Routledge, 2011
8. Francis Allard, Natural Ventilation in Buildings: A Design Handbook (BEST (Buildings Energy and Solar Technology)), Routledge, 1998
9. H.B. Awbi, Ventilation of Buildings, Routledge, 2013

WEBSITES

1. <http://www.wbdg.org/resources/daylighting.php>
2. <http://www.wbdg.org/resources/efficientlighting.php>
3. http://www.wbdg.org/resources/hvac_humidclimates.php

END SEMESTER EXAMINATION QUESTION PAPER PATTERN**(To be distributed uniformly among all the units)****Max. Marks : 80****Exam Duration : 3 Hrs.****PART A : 2 questions from each unit, each carrying 4 marks.****08 x 04 = 32 Marks****PART B : 2 questions from each unit with an internal choice, each carrying 12 marks.****04 x 12 = 48 Marks**

SAR 5136	PERFORMANCE ANALYSIS OF BUILDINGS	L	T	P	Credits	Total Marks
		2	1	0	3	100

Course objectives:

1. To introduce the need for performance analysis of buildings and the emergent outcomes.
2. To comprehend the fundamentals of shading devices and the tools for shading analysis.
3. To analyze energy use through open source soft ware.

Course Outcomes:

1. Ability to investigate the performance of buildings through calculations.
2. Comprehensive understanding to the parametric and empirical building simulation for analysis.
3. Skill to develop building models for shading analysis, thermal performance of built forms.
4. An overview of the various factors which influence accuracy of energy modeling of buildings.
5. An insight to the analysis of various parameters to assess the building performance.

UNIT 1 PERFORMANCE OF BUILDINGS**8 Hrs.**

Need for performance analysis of buildings- Investigation and assessment, energy audit procedures - Design investigations- Energy conservation measure calculations - Modelling systems: cognitive, empirical and analytical assessment of buildings.

UNIT 2 WHOLE BUILDING ENERGY SIMULATION**16 Hrs.**

Modelling the Building form - Parametric and empirical building simulation - Factors affecting accuracy of energy model- Thermal performance criteria of buildings- Envelope considerations, climatic analysis, weather data- Heating and cooling systems modelling, ventilation systems modelling - Energy use analysis through open source software such as EQUEST

UNIT 3 DAYLIGHTING AND SHADING SIMULATIONS**14 Hrs.**

Day lighting simulation models- Day lighting simulation criteria- Factors affecting accuracy of day lighting model - Day lighting simulation exercises using daylight modelling tools - Shading simulations- Principles of shading design- Tools for shading analysis- Tools for shading design - Shading design exercises using open source shading software - BIM Integration.

UNIT 4 ANALYSIS OF BUILDING PERFORMANCE**10 Hrs.**

Metering systems - Analysis of collected data from existing buildings - Economic aspects of energy simulation results: LCA, payback analysis, break even analysis, benefit cost analysis, present worth analysis, etc. - Selection of appropriate ECM from modelling results-Recalibration of the model from actual performance data.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. Teaming for Efficiency: technologies, design, performance analysis and building industry trends, American Council for an Energy-Efficient Economy, 2002
2. James P. Waltz, Computerized Building Energy Simulation Handbook, Fairmont PR, 1997
3. Joseph Clarke, Energy Simulation in Building Design, Routledge, 2007
4. Giuliano Dall'O', Green Energy Audit of Buildings: A guide for a sustainable energy audit of buildings, Springer, 2013
5. ASHRAE Press, The ASHRAE Green Guide, Butterworth- Heinemann, 2006
6. Energy Conservation Building Code of India- User manual, 2007

WEBSITES

1. http://doe2.com/download/equest/eQ-v3-63_Introductory-Tutorial.pdf
2. <http://ocw.mit.edu/courses/architecture/4-430-daylighting-spring-2012/>
3. http://www.photosolar.dk/userfiles/file/Dokumenter/Guideline%20to%20daylight%20calculation_2013.pdf

END SEMESTER EXAMINATION QUESTION PAPER PATTERN**(To be distributed uniformly among all the units)****Max. Marks : 80****Exam Duration : 3 Hrs.****PART A : 2 questions from each unit, each carrying 4 marks.****08 x 04 = 32 Marks****PART B : 2 questions from each unit with an internal choice, each carrying 12 marks.****04 x 12 = 48 Marks**

SAR 5137	SUSTAINABLE WATER MANAGEMENT	L	T	P	Credits	Total Marks
		3	0	0	3	100

Course objectives:

1. To understand the traditional knowledge of managing water in various contexts.
2. To introduce the fundamentals of technology for effective water management.
3. To comprehend the strategies to reduce water consumption in buildings.

Course Outcomes:

1. Acquire knowledge on the ways to manage water from different climatic zones in Indian context.
2. Explore the importance of water management from the social, environmental and economical perspectives.
3. Comprehensive knowledge of incorporating sustainable principles of watershed development in large campuses.
4. Ability to incorporate the various methods to reduce, recycle and recharge water at the building level.
5. Understandings the rationale behind water pricing and regulations
6. An introduction to the fundamentals of renewable power sources.

UNIT 1 WATER MANAGEMENT – HISTORICAL PERSPECTIVE 8Hrs.

Traditional community wisdom regarding water management from different climatic zones of the world - Traditional Architecture of wells in Rajasthan, Gujarat, Tamilnadu– Stepped Wells, Baoris, Tankas, etc.

UNIT 2 WATER MANAGEMENT – MACRO LEVEL 12 Hrs.

Management of the water cycle as a single system - Management of water supply, sanitation and drainage - Social imperatives, environmental considerations and economic challenges - Technological options for water management, recycling, reuse, conservation and treatment - Planning of settlements and large campuses based on principles of sustainable watershed development with water as a priority resource.

UNIT 3 WATER MANAGEMENT – MICRO LEVEL 14Hrs.

Design for water conservation – Building and products - Designing building services, plumbing and sanitary design for effective water reuse, recycling, and recharge - Strategies for water pricing and its regulation - Rain water harvesting techniques – Basic Concepts, piping techniques and pit design for groundwater recharge wells.

UNIT 4 STRATEGIES TO REDUCE WATER CONSUMPTION IN BUILDINGS 14Hrs.

Low flow plumbing fixtures for water efficient appliances - Rain water harvesting - Reuse of grey water for non potable uses - Wetlands for natural waste water treatment, use of wetlands for natural storm water and vegetated roof tops, (natural) renewable power source such as photo voltaic, solar hot water fuel cells etc.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. John Briscoe, R.P.S. Malik (Ed.), Handbook of Water Resources in India: Development, Management, and Strategies, Oxford University Press, 2007
2. Ramaswamy R. Iyer, Water and the laws in India, Sage Publications India Pvt. Ltd, 2009
3. Hydrology and Water Resources of India, Water Science and Technology Library, Vol. 57, Jain, Sharad K., Agarwal, Pushpendra K., Singh, Vijay P. Springer, 2007
4. Guy Honore (Ed.), Principles and Practices of Integrated Watershed Management in India, Indo-German Bilateral Project, 2002
5. K. Nageswara (Ed.), Water Resources Management: Realities and Challenges, Eastern Book Corpn., 2006
6. Dr B C Punmia, Ashok Kr Jain, Arun Kr Jain; Water Supply Engineering, Laxmi, Cunliffe, D. (ed) (2011), Water safety in buildings, World Health Organization, Geneva, Switzerland, 2011
7. P.K. Singh, Rainwater Harvesting: Low cost indigenous and innovative technologies, Macmillan Publishers India, 2008
8. R.N. Athavale, Water Harvesting And Sustainable Supply In India, Rawat Publications, 2003

WEBSITES

1. http://www.unepfi.org/fileadmin/publications/water/chief_liquidity1_India.pdf
2. <http://wrmin.nic.in>
3. http://www.unicef.org/india/Final_Report.pdf

END SEMESTER EXAMINATION QUESTION PAPER PATTERN**(To be distributed uniformly among all the units)****Max. Marks : 80****Exam Duration : 3 Hrs.****PART A : 2 questions from each unit, each carrying 4 marks.****08 x 04 = 32 Marks****PART B : 2 questions from each unit with an internal choice, each carrying 12 marks.****04 x 12 = 48 Marks**

SAR 5210	SUSTAINABLE URBAN PLANNING	L	T	P	Credits	Total Marks
		2	1	0	3	100

COURSE OBJECTIVE

1. To emphasize the importance of sustainable design practices and strategies in urban planning and settlement design.
2. To understand the sustainable approaches in traditional settlements and the impacts of post industrial settlements.
3. To explore the emerging sustainable urban design concepts and strategies.

COURSE OUTCOMES:

1. Understand the sustainability principles at urban scale in selected cities.
2. Learn traditional sustainable principles at settlement level with case examples.
3. Critically analyze and assess the impacts of the post-industrial urban built form on the environment
4. Outline the sustainable urban design strategies with case examples.
5. Comprehend the emerging sustainable urban design concepts and strategies.
6. Evaluate the suitability, strength and weaknesses of sustainable urban design strategies and concepts in different contexts.

UNIT 1 PRE HISTORIC SETTLEMENTS**12 Hrs.**

Traditional design strategies of human habitats in India and other parts of the world with special focus on resource management and built forms in response to harsh climatic conditions - Concepts and principles related to Eco-Village.

UNIT 2 POST INDUSTRIAL REVOLUTION SETTLEMENTS**12 Hrs.**

Urban pollutants and their impact on air, water, land and micro climate - Impact of built form density, building footprint, urban form including height and geometry, orientation of streets, etc. on micro climate especially light, ventilation and temperature.

UNIT 3 URBAN DESIGN STRATEGIES**12 Hrs.**

Improving environmental quality, energy efficiency, efficient resource management (soil, water, waste and materials) through appropriate site selection, effective neighbourhood planning and Urban design strategies - Transport planning, land-use zoning strategies, landscape planning etc. - Study of zero discharge sites and communities.

UNIT 4 EMERGING IDEAL AND CONCEPTS**12 Hrs.**

Concepts related to urban renewal namely inner city regeneration, revitalization of the "townships" and informal settlement / slum upgrading - Integrating renewable energy at neighbourhood scale, smart grids, concept of solar cities, smart cities, eco cities.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. CIRIA, TheSuDs Manual, CIRIA C 697, Edited by CIRIA, London, 2007
2. Emmanuel.R., An urban approach to climate sensitive design: strategies for the tropics, Span Press, Taylor and Francis, 2005
3. Farr, Douglas, Sustainable Urbanism: Urban Design with Nature, John Wiley & Sons, 2008
4. Beatley, Timothy, Biophilic Cities: Integrating Nature into Urban Design and Planning, Island Press, 2010
5. Register, Richard, Ecocities - Rebuilding Cities in Balance with Nature, New Society Publishers, 2006

WEBSITES

1. http://www.nmun.org/ny_archives/ny13_downloads/BGGU13UNHABITAT.pdf
2. <http://Planning%20Sustainable%20Cities%20UN-HABITAT%20Practices%20and%20Perspectives.pdf>
3. <http://www.newurbanism.org>

END SEMESTER EXAMINATION QUESTION PAPER PATTERN**(To be distributed uniformly among all the units)****Max. Marks : 80****PART A : 2 questions from each unit, each carrying 4 marks.****PART B : 2 questions from each unit with an internal choice, each carrying 12 marks.****Exam Duration : 3 Hrs.****08 x 04 = 32 Marks****04 x 12 = 48 Marks**

SAR 5211	SUSTAINABLE WASTE MANAGEMENT	L	T	P	Credits	Total Marks
		3	0	0	3	100

COURSE OBJECTIVES

1. To expose the students to the need, importance, types and management of solid waste.
2. To understand the laws/ rules governing waste management and the strategies adopted in India and other countries
3. To comprehend the innovative practices of utilizing waste in as resources in construction industry.

COURSE OUTCOMES:

1. Comprehend the various types of wastes generated in human habitats.
2. Construct an overview and critically analyze rules governing waste management in India and other countries.
3. Understand the challenges of waste management in environmentally sensitive areas in specific and diverse contexts.
4. Overview of contemporary technologies and infrastructure adopted for waste management.
5. Appreciate the ways through which the wastes are addressed as resources in various domains.
6. Learn the challenges in utilizing recycled materials in construction field.

UNIT 1 INTRODUCTION TO WASTE MANAGEMENT**8Hrs.**

Introduction to waste management - Wastes generated by human habitat: solid, liquid and gaseous - Types of wastes: municipal, industrial, post consumer, agricultural, toxic, bio-medical, hazardous, electronic, radioactive etc. - Overview of laws /rules governing waste management in India - Importance of community participation in waste management - Impact on health and sanitation.

UNIT 2 SOLID WASTE MANAGEMENT IN INDIA**14Hrs.**

Cradle to Cradle cycle of municipal waste – Segregation at source, storage, transportation, disposal and processing - Waste management in India– Current scenario, challenges, responses and pitfalls - Waste management in difficult terrains: hilly areas, high rain fall areas, water fronts, etc., - Grey water recycling in Singapore city regions.

UNIT 3 SOLID WASTE MANAGEMENT IN OTHER COUNTRIES**14Hrs.**

Overview of wastemanagement from other parts of the world - Contemporary technologies and infrastructure for waste management - Designing infrastructure for efficient and effective solid waste management from generation point to final disposal: waste bins, cold rooms, transport mechanisms, landfill sites, incinerators, composting, etc. - Designing collection system for waste in different types of building structure - Financial models for waste management - Role of NGOs in effective waste management, sanitation and health.

UNIT 4 WASTE AS A RESOURCE**12 Hrs.**

Recycling industrial, agricultural and municipal waste - Recycling waste as alternative material for buildings, landscape and other products - Study of innovative practices for use of recycled material, specifications and construction methods for using recycled waste - Demonstrative architecture and landscape using waste, vermi-composting, biological and thermal energy options - Energy from sanitary landfills, refuse derived fuel and other options.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. William McDonough, Michael Braungart, "Cradle to Cradle: Remaking the way we make things", North Point Press, 2002.
2. ERM.UK Municipal Solid waste Management, Study for the MMA-Vol-1 Interim Report, August-1995

WEBSITES

1. http://roing.nic.in/NHPC_Docs/EMP/EMPDocs/C12_SWM.pdf
2. http://www.indiawaterportal.org/sites/indiawaterportal.org/files/Manual%20on%20municipal%20solid%20waste%20management_%20MoUD_GOI_2000.pdf
3. http://www.tn.gov.in/dtp/publications/SWM/SWM_161to184.pdf
4. <http://www.environment.tn.nic.in/SoE/images/WasteManagement.pdf>
5. http://planningcommission.nic.in/reports/publications/pub95_hghpwr.pdf

END SEMESTER EXAMINATION QUESTION PAPER PATTERN**(To be distributed uniformly among all the units)****Max. Marks : 80****PART A : 2 questions from each unit, each carrying 4 marks.****PART B : 2 questions from each unit with an internal choice, each carrying 12 marks.****Exam Duration : 3 Hrs.****08 x 04 = 32 Marks****04 x 12 = 48 Marks**

S89 INT	PROFESSIONAL TRAINING	L	T	P	Credits	Total Marks
		0	0	0	5	200

COURSE OBJECTIVES:

1. To give practical exposure and provide a learning opportunity for students in a professional context.

COURSE OUTCOMES:

1. Apply the knowledge and skills acquired in the classroom to a professional context.
2. Demonstrate an enhanced knowledge about practical aspects of the field.
3. Develop professional skills.
4. Ability to prepare a portfolio of the academic and professional design work.

The candidate has to join an architectural or environmental design practice and work on the design/ documentation of a sustainable architecture, environmental site planning project for a minimum of 30 working days during their summer vacation. A comprehensive report shall be submitted at the end of the summer internship.

SAR6512	SUSTAINABLE DESIGN STUDIO III	L	T	P	Credits	Total Marks
		0	0	18	9	300

COURSE OBJECTIVE

1. To design a residential, institutional, manufacturing, corporate, healthcare, hospitality or SEZ campus based on environmental site planning, programmatic constraints- opportunities and socio- cultural parameters

COURSE OUTCOMES:

1. Understand the climatic, cultural and environmental characteristics of the selected climatic zone to evolve an approach to environmentally sensitive design.
2. Critically analyze the strategies adopted in case studies incorporating the ECBC and GRIHA guidelines.
3. Evolve design strategies and solutions to meet the ECBC and GRIHA guidelines.
4. Generate a comprehensive sustainable design that optimize, conserve, or reuse resources and reduce the environmental impact through climate responsive and energy efficient design.
5. Understand, apply, document and present energy, water savings, daylight and embodied energy calculations for a design.
6. Apply open source software to analyze the performance of the sustainable strategies incorporated in the design.

STUDIO BRIEF

1. The student shall select a campus type : Example
Residential/ Commercial/ Institutional/ Industrial-manufacturing/Corporate/ Healthcare/ Hospitality
Note: Scale of the selected building shall not be less than 5000sqm of floor area
2. Students shall select any one climatic zone from ECBC's climatic zone classification.
3. They shall select any city from a zone and research local bye laws and regulations.
4. They shall analyze site fit and program brief
5. They shall evaluate cultural, environmental factors and inspirations for environmental design from local vernacular and nature.
6. They shall design a building which shall function as per GRIHA and ECBC guidelines
7. The building should highlight at least one local material and one material which has low embodied energy as compared to conventional technology.
8. The Building should make use of at least one sustainable building service technology in HVAC.
9. The student shall design an energy model using an open source software such as Equest which gives comprehensive energy use analysis of the building.

DELIVERABLES

1. Detailed description of building typology selected and reasons for the same.
2. Climatic and microclimatic analysis of the site.
3. A case study of a similar building in a similar climatic zone with respect to sustainability features, etc.
4. Study report and story board incorporating site fit, zoning and program brief, contextual adaptations from vernacular/ nature responses, conceptual design.
5. Preliminary energy analysis
6. Architectural documentation including 2D drawings and 3D models
7. Detailing and modelling of green building features including passive design features, hybrid features, active features, etc.
8. Detailed description of HVAC system and its sustainability feature.
9. Summary of detailed energy, water savings, daylight and embodied energy calculations and summary

TEXT / REFERENCE BOOKS

1. Joseph Clarke, Energy Simulation in Building Design, Routledge, 2007
2. The ASHRAE Green Guide- ASHRAE Press, Butterworth-Heinemann, 2006
3. Energy Conservation Building Code of India- User manual, 2007
4. Willie Weber, Simod Yannas (ed.), Lessons from Vernacular Architecture, Routledge, 2013
5. Arvind Krishen, Nick Baker (ed.), Climate responsive architecture: A design handbook for energy efficient buildings, McGraw Hill Education (India) Pvt. Ltd, 1999
6. Jeanne Gang, Reveal : Studio Gang Architects, Princeton Architectural Press, 2011

SAR 5212	ENVIRONMENTAL IMPACT ASSESSMENT TECHNIQUES	L	T	P	Credits	Total Marks
		2	1	0	3	100

Course objectives:

1. To introduce the various aspects of environmental impact assessment.
2. To understand the components and impacts of EIA and socio economic systems.
3. To give an insight to sectoral EIA in diverse contexts.

Course Outcomes:

1. An overview of EIA, legal and regulatory aspects in India.
2. A comprehensive understanding of the components, methods, tools and documentation involved in EIA.
3. An insight to EIA methods in other countries.
4. Acquire knowledge about the various parameters in social impact assessment with examples.
5. Explore the aspects and issues related to various sectoral EIA ranging from micro to macro level.

UNIT 1 INTRODUCTION**8 Hrs.**

Historical development of environmental impact assessment (EIA) - EIA in project cycle, legal and regulatory aspects in India – Types and limitations of EIA – Cross sectoral issues and terms of reference in EIA – Public Participation in EIA - EIA process, screening, scoping, setting, analysis, mitigation.

UNIT 2 COMPONENTS AND METHODS**14Hrs.**

Matrices – Networks – Checklists – Connections and combinations of processes - Cost benefit analysis – Analysis of alternatives – Software packages for EIA – Expert systems in EIA – Prediction tools for EIA – Mathematical modelling for impact prediction – Assessment of impacts: air, water, soil, noise, biological — Cumulative Impact Assessment – Documentation of EIA findings, planning, organization of information and visual display materials – Report preparation - EIA methods in other countries.

UNIT 3 IMPACT ON SOCIO-ECONOMIC SYSTEMS**14Hrs.**

Definition of social impact assessment - Social impact assessment model and the planning process - Rationale and measurement for SIA variables - Relationship between social impacts and change in community and institutional arrangements - Individual and family level impacts - Communities in transition - Neighbourhood and community impacts, selecting, testing and understanding significant social impacts - Mitigation and enhancement in social assessment - Environmental costing of projects.

UNIT 4 SECTORAL EIA**12 Hrs.**

Ethical and Quality aspects of environmental impact assessment, sectoral EIA -EIA related to the following sectors – Infrastructure, construction and housing, mining, industrial, thermal power, river valley and hydroelectric, coastal projects-Nuclear Power, hill area development and CRZ -EIA for coastal projects.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. Lawrence D.P., Environmental Impact Assessment – Practical solutions to recurrent problems, Wiley-Interscience, New Jersey, 2003
2. Environmental Assessment Source book-Vol. III: Guidelines for environmental assessment of energy and industry projects, World Bank, 1998
3. Petts J., Handbook of Environmental Impact Assessment, Vol., I and II, Blackwell Science, London, 1999
4. Canter L.W., Environmental Impact Assessment, McGraw Hill, New York, 1996
5. Nick Harvey, Beverley Clarke, Environmental Impact Assessment: Procedures and Practices, Oxford University Press, USA, 2012

WEBSITES

1. <https://www.cbd.int/doc/nbsap/EIA/India.pdf>
2. <http://coe.mse.ac.in/Guidelines.asp>
3. http://www.planning.nsw.gov.au/rdaguidelines/documents/emp_guideline_publication_october.pdf
4. http://www.gpcb.gov.in/pdf/Nuclear_Power_Corpo_of_India_Exe_Summ_Eng.pdf
5. http://www.tnpcb.gov.in/pdf/EIA_Perambalur_%20SEZ%20Eng.pdf
6. <https://www.env.go.jp/earth/coop/coop/document/10-eiae/10-eiae-2.pdf>

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SAR 5601	MAINTENANCE AND REHABILITATION OF STRUCTURES	L	T	P	Credits	Total Marks
		3	0	0	3	100

Course objectives:

1. To understand the need and importance of structural maintenance, extending the serviceability and durability of structures.
2. To explore the techniques for repairing of structures, selection of suitable materials and enhancement of strength of structural elements.

Course Outcomes:

1. Understanding of the requirements for governance of good serviceability and longevity of structures.
2. Exposure to various types of engineering maintenance and evaluation of damaged structures.
3. Identify suitable materials for repair and selection of appropriate techniques to mitigate the faulty structures.
4. Knowledge about various types of special concrete to meet specific requirements of structures.
5. Identifying enhancement techniques for structural strengths of different members and knowledge about the modern demolition techniques.

UNIT 1 INFLUENCE ON SERVICEABILITY AND DURABILITY**10 Hrs.**

Effects due to climate, temperature, chemicals, wear and erosion - Design and construction errors, corrosion mechanism - Effects of cover thickness and cracking - Methods of corrosion protection, corrosion inhibitors, corrosion resistant steels, coatings, cathodic protection.

UNIT 2 MAINTENANCE AND REPAIR STRATEGIES**14 Hrs.**

Definitions: Maintenance, repair and rehabilitation - Facets of Maintenance importance - Maintenance Preventive measures on various aspects – Inspection - Assessment procedure for evaluating a damaged structure - Causes of deterioration - testing techniques.

UNIT 3 MATERIALS AND TECHNIQUES FOR REPAIR**14 Hrs.**

Special concretes and mortar, concrete chemicals - Special elements for accelerated strength gain, expansive cement, polymer concrete, sulphur infiltrated concrete, ferrocement, fibre reinforced concrete. Rust eliminators and polymers coating for rebars during repair foamed concrete, mortar and dry pack, vacuum concrete - Guniting and shotcrete epoxy injection, mortar repair for cracks, shoring and underpinning.

UNIT 4 EXAMPLES OF REPAIR TO STRUCTURES**10 Hrs.**

Repairs to overcome low member strength - Deflection, cracking, chemical disruption, weathering wear, fire, leakage, marine exposure - Engineered demolition techniques for dilapidated structures - Case studies

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. Denison Campbell, Allen and Harold Roper, Concrete Structures, Materials, Maintenance and Repair, Longman Scientific and Technical UK, 1991
2. Allen R.T. and Edwards S.C., Repair of Concrete Structures, Blahie and Sons, UK, 1993
3. Shetty M.S., Concrete Technology- Theory and Practice, Chand and Company, New Delhi, 2000
4. Verghese P.C., Maintenance, Repair & Rehabilitation & Minor Works of Buildings, Prentice Hall, 2014
5. Samuel Y. Harris, Building Pathology- Deterioration, Diagnostics and Intervention, John Wiley & sons, 2001.

**End semester examination question paper pattern
(To be distributed uniformly among all the units)**

Max. Marks: 100**Exam Duration: 3 Hrs.****PART A : 2 questions from each unit, each carrying 4 marks.****: 08 x 05 = 40 Marks****PART B : 2 questions from each unit with an internal choice, each carrying 15 marks****: 04 x 15 = 60 Marks**

SAR 5622	GREEN BUILDING RATING SYSTEMS	L	T	P	Credits	Total Marks
		3	0	0	3	100

Course Objectives:

1. To get a complete overview of various kinds of green building rating systems and how they are used in the industry.
2. To understand the purpose and application of green building rating system.

Course Outcomes:

1. Understanding of the various green rating systems and practices across the globe and Indian Context
2. Critically inquire the merits and demerits of Green rating Systems, Material Certification & stewardship, and their necessity
3. Application of Green Rating Systems in projects and analytical knowledge of various green points required for projects towards achieving Green Rating
4. Appraising the role of a green building consultant and the process of Green accreditation examination.
5. Analyzing and evaluating the basics of energy modeling and auditing.

UNIT 1 INTRODUCTION TO GREEN RATING SYSTEMS**10 Hrs.**

History of green Rating systems- LEED, GRIHA, BREEAM, IGBC- Need and use of green rating systems - Structure of the rating systems- Market response to various rating systems- Selection of the appropriate rating system.

UNIT 2 GREEN RATING SYSTEMS IN INDIA**16 Hrs.**

In-depth study of the requirements of IGBC, LEED and GRIHA rating systems - Cross comparisons between the various requirements, their intents and ability of a project to meet the requirements - Other rating systems such as Eco House, Green Mark, Green Pearl, Living Building Challenge.

UNIT 3 APPLICATION OF RATING SYSTEM REQUIREMENTS**10 Hrs.**

Applying the Green rating systems in a project - Role of Green building consultant- Determining the various green points- Green Accreditation examinations.

UNIT 4 THE FUTURE OF RATING SYSTEMS**10 Hrs.**

Upcoming rating systems- Auditing after rating, Material certifications and stewardships - Energy modeling and energy auditing in green building ratings - Consultancy scope and services for green rating systems.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. Linda Reeder, Guide to Green Building Rating Systems: Understanding LEED, Green Globes, 2010
2. Jerry Yudelson, The Green Building Revolution, Island Press, 2007

WEBSITES

1. www.usgbc.org
2. www.igbc.org
3. www.grihaIndia.org
4. living-future.org/lbc

End semester examination question paper pattern
(To be distributed uniformly among all the units)

Max. Marks: 100**PART A : 2 questions from each unit, each carrying 4 marks.****PART B : 2 questions from each unit with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**

SAR 5624	SUSTAINABLE LANDSCAPE PLANNING	L	T	P	Credits	Total Marks
		3	0	0	3	100

Course objectives:

1. To introduce the history and fundamentals of landscape ecology.
2. To understand the concepts and approaches by pioneers of landscape.
3. To give an insight to the various aspects of landscape planning and management.

Course Outcomes:

1. Acquire knowledge on the history of landscape and the interaction between the landscape, structure and function.
2. Explore the various phases involved in landscape planning.
3. Ability to incorporate the various strategies explored through case studies in design.
4. Understand the diverse dimensions to be addressed in identifying preferences and suitability in design.
5. Comprehensive overview of the landscape management practices in different contexts.
6. An understanding of the policies of landscape and horticulture practices.

UNIT 1 LANDSCAPE ECOLOGY**12 Hrs.**

Introduction to landscape ecology – Formation of various landforms – Landforms and landscape process – Pattern and structure of landscapes– Concepts of patch, corridor and matrix - Landscape dynamics and function – Topological and chorological process within landscape - Concept of landscape metrics – Understanding dynamic interaction between landscape structure and function – Ecological services of landscape - History and Ecology.

UNIT 2 LANDSCAPE PLANNING**12 Hrs.**

Relationship between man and nature – Analytical aspects of landscape - The natural and cultural setting - Evolution of landscape planning – Concepts and projects of McHarg, Carl Steinert, Warren Manning, Augustus Hills, Phil Lewis – Ian Kenton, Ervin Zube - Landscape planning models.

UNIT 3 PROCESS IN LANDSCAPE PLANNING**12 Hrs.**

The purpose of landscape planning – Domain and context for landscape planning – Principles of planning – Procedure in landscape planning - Problem defining, goal setting, inventory and analysis - Basics of collecting and analyzing, projecting and presenting data in landscape planning, visual assessment and aesthetic dimension– Suitability analysis – Techniques for identifying preferences - Planning options – Proposing landscape plan.

UNIT 4 CASE STUDIES: LANDSCAPE MANAGEMENT**12 Hrs.**

Reclamation and restoration of derelict landscapes - Conservation and preservation of ecological fragile areas such as wetlands, creeks etc. - Conservation ordinances - Case studies on landscape regional planning - Policies and landscape - Landscape management at regional scale - Management practices with emphasis on urban forest, urban ecology, river front development green belt - Regional open spaces, national parks, reserved forests, wet lands, coastal areas - Horticultural practices.

Max. 48 Hours**TEXT / REFERENCE BOOKS**

1. Richard T.T. Forman and Michel Godron, Landscape Ecology, John Wiley & Sons, 1986
2. Tom Turner, Landscape Planning and Environmental Impact Design, UCL Press, London, 1998
3. Ervin H. Zube, Robert O Brush, Julius G.Y. Fabos, Landscape assessment – values, perceptions, 1975
4. G. Tyler Miller Jr., Living in the Environment: Principles, Connections, and Solutions, Brooks / Cole publisher's co., 2004
5. William M. Marsh, Landscape planning – Environmental Application, John Wiley and sons Inc., 1997

WEBSITES

1. http://www.gardenwriters.org/html/meetings/presentations_11/presentations/schweyer.pdf
2. http://www.wbcsdpublications.org/cd_files/datas/business_applications/uii/pdf/SolutionsLandscapeGujarat-FullReport.pdf
3. <http://sustainable landscape construction.pdf>

End semester examination question paper pattern
(To be distributed uniformly among all the units)

Max. Marks: 100**PART A : 2 questions from each unit, each carrying 4 marks.****PART B : 2 questions from each unit with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**

SARA5132	BUILDING ENERGY CODES AND STANDARDS	L	T	P	Credits	Total Marks
		2	1	0	3	100

COURSE OBJECTIVES:

- To understand the importance and basics of ECBC and SP41.
- To devise the applicability of the methodologies prescribed in the codes
- To comprehend the compliance approaches

INTRODUCTION**6 Hrs.****UNIT 1**

National policies on sustainable and energy efficient development, The Energy Conservation (Amendment) Act, 2010, National policies on sustainable and energy efficient development. Introduction and Guidelines of ECBC – Energy Efficiency Performance levels, Energy Performance Index, Compliance approaches – prescriptive method, whole building performance method (Energy simulation), Compliance requirements, Building Envelope – Fenestration, opaque construction, Daylighting, building envelope sealing, Roof - Skylights, Building envelope trade off method.

UNIT 2 ECBC – COMFORT SYSTEMS AND CONTROLS**12 Hrs.**

Ventilation - Minimum Space Conditioning Equipment Efficiencies -Unitary, Split, Packaged Air-Conditioners, Variable Refrigerant Flow, Air Conditioning and Condensing Units Serving Computer Rooms. Controls – Temperature control, air conditioning control, occupancy control, fan controls. Piping and duct work. System Balancing. Condensers, Service water heating, cooling towers, Economizers, Variable Flow Hydronic Systems, Energy recovery. Low-energy Comfort Systems. Lighting and controls, electrical and renewable energy systems. Calculation of energy requirements of a proposed and standard design

Suggestive Assignment – Manual calculation – lighting, fenestration efficiency calculation and lighting power allowance calculation.

UNIT 3 FUNCTIONAL EFFICIENCY OF BUILDINGS – HEAT INSULATION AND VENTILATION**12 Hrs.**

SP41 – Climate, Thermal comfort, Shading devices, energy requirement for cooling and heating. Heat Insulation - introduction, terminology, requirements, heat transmission through building sections, thermal performance of building sections, orientation of buildings, building characteristics for various climates, thermal design of buildings, influence of design parameters, mechanical controls. Ventilation - introduction, terminology, ventilation requirements, minimum standards for ventilation, ventilation design, energy conservation in ventilating systems.

UNIT 4 FUNCTIONAL EFFICIENCY OF BUILDINGS - LIGHTING**9 Hrs.**

Lighting –standards, general, illumination requirement, day lighting analysis, supplementary artificial lighting design, artificial lighting design, energy conservation.

Suggestive Assignment – Work out examples on thermal insulation, method of calculating solar load on vertical surfaces of different orientation, orientation on the basis of solar road

UNIT 5 COMPREHENSIVE LEARNING**6 Hrs.**

Arriving at Comfort band and passive strategies for a particular city using Mahoney table, calculating overheated period and deriving the shadow mask for fenestrations

Max. 45 Hours**COURSE OUTCOME:**

- CO1** Explore about the national policies on sustainable and energy efficient development
- CO2** Understand the prescriptive method and whole building performance method.
- CO3** Analyse the available comfort systems and controls.
- CO4** Categorise the various parameters in heat insulation and ventilation.
- CO5** Acquire knowledge about the lighting requirement.
- CO6** Integrate the aspects learnt in the codes for effective application in design

TEXT / REFERENCE BOOKS

- Bureau of Energy Efficiency, G. o. (2017). Energy Conservation Building Code. New Delhi: Bureau of Energy Efficiency.
- Standards, B. o. (1987). SP.41 Handbook on Functional requirements of buildings. New Delhi: Bureau of Indian Standards.
- Standards, B. o. (2016). National Building Code . India: ureau of Indian Standards.

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 100****PART A : 2 questions each from unit 1 to unit 4, each carrying 5 marks****PART B : 1 question each from unit 1 to unit 4 with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**

SARA6131	BUILDING PERFORMANCE ANALYSIS STUDIO		L	T	P	Credits	Total Marks
			0	1	2	3	100

COURSE OBJECTIVE:

- To introduce Simulation software like EQuest, Sefaira, Design Builder, IES VE and Envi Met and upcoming software to learn the techniques and substantiate the design.
- To understand the various simulation strategies and applications related to building sensitivity analysis, i.e. understanding the impact of equipment load in the building.
- To determine the building performance through parameters like thermal comfort of spaces, daylighting analysis, wind analysis, energy optimization and quantification.

STUDIO BRIEF**PART 1**

To understand the basics of Software through Hands-on experience and introductory parameters and their studies like Climatic analysis, Shadow analysis, volumetric zoning, mutual shading, building sensitivity analysis and material selection.

- To comprehensively study the behavior of building components through simulation strategies for better performance.
- To understand the climate responsive design strategies through daylighting analysis, solar radiation analysis, wind analysis, volumetric zoning of spaces and through performing iterations for one particular design.
- To perform Calculations and derive inferences for day lighting, ventilation and solar heat gain and loss with its analysis.
- Understanding the impact of design through multiple strategies & their behaviour from multiple results to determine the optimum design solutions
- Understanding the Behaviour of Building Components-through simulation
- To determine the behaviour of building in the aspects of Energy, CO2 footprint, resources footprint, etc.

PART 2

- Understanding of Thermal Behaviour of Spaces, Calculations for thermal comfort of spaces, for various climate and conditions and its associated parameters like heat gains-losses, temperature profiles, fabric gains-losses, Ventilation etc
- Learning the Life Cycle of the Built environment through software like OpenLCA, Revit, etc.
- Add on software and Hands-on with allied and compatible software like Radiance, PMV, Solar Tool etc

COMPREHENSIVE LEARNING

Report with individual exercises for various parameters of the taught software as per break-up of module.

COURSE OUTCOME:

- CO1** Ability to investigate the performance of buildings through calculations
- CO2** Understand the basics of simulation software to analyse building performance
- CO3** Demonstrate skills and techniques for substantiating design through various analysis – daylighting, wind, solar radiation
- CO4** Critically analyse and perform calculations, prepare graphs and analyse the thermal performance
- CO5** Applying various software tools to analyse sustainability in the built environment.
- CO6** Acquired knowledge on calculations for thermal comfort, Ventilation, modelling for energy performance

TEXT/ REFERENCES BOOKS

1. Help Manuals
2. Video Tutorials
3. Trainers or Expert's Guest Lectures

SARA9131		SUSTAINABLE DESIGN STUDIO I		L	T	P	Credits	Total Marks
				0	0	12	6	300
Continuous Assessment				University Viva			Min Pass Marks	
200				100			150	

COURSE OBJECTIVE:

- To identify contemporary relevance of sustainable principles in vernacular buildings and to compare/ contrast the same with recent buildings.
- To understand the difference in the sustainable principles adapted in vernacular buildings against contemporary buildings and the significance of passive techniques
- To understand and apply the climate responsive passive strategies on a small-scale building design

STUDIO BRIEF 01**CASE STUDY 1**

To identify and document a building or a group of buildings from a pre-industrial, vernacular, traditional settlement in India and

- To comprehensively study the building in terms of its layout, use of materials, spatial and environmental concepts, user comfort, ambience, distinct features etc.,
- Understand its climate responsive design strategies, sustainable practices and their contemporary relevance.

CASE STUDY 2

To identify a modern building or a group of buildings built within the last decade and

- document and analyze their layouts, use of materials, spatial and environment concepts, ambience, user comfort etc.,

COMPARISON OF CASE STUDIES 1 AND 2

- To compare and contrast case studies 1 and 2 to understand the shift in societal values and their subsequent effect on sustainability

PROPOSAL

Propose changes or modifications (Façade modifications / passive strategy application) to the 'lesser performing case' and prove its enhanced climate responsiveness.

DELIVERABLES

Students shall submit case study documentation sheets with requisite sketches, photographs, models, cognitive analysis diagrams, empirical documentation, detailed narratives and proposal for modification and enhancement of one of the cases based on the analysis.

STUDIO BRIEF 02

1. The students shall design a residential building which shall function as per ECBC guidelines
2. Students shall select any one climatic zone from ECBC's climatic zone classification.
3. They shall select any city from a zone and research local bye laws and regulations.
4. They shall analyse site fit and program brief
5. They shall evaluate cultural, environmental factors and inspirations for environmental design from local vernacular architecture and nature.
6. The building should highlight at least one local material and one material which has low embodied energy as compared to conventional technology.

DELIVERABLES

1. Study report on climatic and microclimatic parameters that will guide environmental site development.
2. Study report and story board incorporating site fit, zoning and program brief, contextual adaptations from vernacular/ nature responses, conceptual design.
3. Residential typology precedent analysis and Preliminary energy analysis
4. Architectural documentation including 2D drawings and 3D models
5. Detailing and modelling of green building features emphasizing passive design features.
6. Detailed calculations as per ECBC standards.

COURSE OUTCOME:

- CO1** Understand and document the sustainable principles and practices, and passive design strategies in a built environment.
- CO2** Demonstrate a heightened awareness of sustainability as a multidimensional concept and awareness of the environmental factors influencing the built environment and vice versa.
- CO3** Critically analyze, evaluate and make informed judgment on the working of sustainable design strategies in vernacular and contemporary buildings
- CO4** Develop design strategies that optimize and conserve resources and provide comfortable environment for the occupants in a building in a particular climate
- CO5** Ability to use software tools to analyze sustainability in the built environment.
- CO6** Applying Passive strategies and finding solution for development of sustainable practices in a small-scale building.

TEXT / REFERENCE BOOKS

1. Deulgaonkar, A. (2015). *Laurie Baker, Truth in Architecture*. New Delhi: Jyotsna Prakashan.
2. Kainth, G. S. (2011). *Climate Change, Sustainable Development and India*. New Delhi: LAP Lambert.
3. Lengen, J. V. (2007). *The Barefoot Architect: A Handbook for Green Building*. California, USA: Shelter Publication.

4. Spiegel, R. (2010). *Green Building Materials: A Guide to Product Selection and Specification, 3rd Edition*. -: John Wiley & Sons.
5. TERI. (2004). *Sustainable Building - Design Manual Pt 1 & 2*. New Delhi: Teri Press, The Energy And Resources Institute.

SARA5232	TECHNOLOGY FOR ENERGY EFFICIENT BUILDINGS	L	T	P	Credits	Total Marks
		3	0	0	3	100

COURSE OBJECTIVES:

- To understand the influence of HVAC technology on energy efficient buildings.
- To give a comprehensive introduction and the principles of natural and artificial lighting.
- To explore the fundamentals of integrating services in buildings.

UNIT 1 HVAC TECHNOLOGIES**9 Hrs.**

Factors affecting HVAC Design - Types of Cooling systems air cooled, water cooled, chilled beams, chilled slabs, pre-cooling, free-cooling, VFD drives, etc.- ducting design, Individual controls and VAV boxes - Natural refrigerants, types of air conditioning- combined heat power systems- Types of heating systems, radiant heating, solar heating -Conservatory design.

UNIT 2 DAYLIGHTING & ARTIFICIAL LIGHTING**12 Hrs.**

Principles of day lighting design - Day lighting requirements, daylight protractor, day lighting sensors - Glare reduction systems and devices – Daylight harnessing systems -Daylight system with shading design - Artificial lighting - Principles of lighting systems, lighting design systems - Occupancy sensors - Glare reduction techniques.

UNIT 3 VENTILATION TECHNIQUES**9 Hrs.**

Requirements of ventilation as per ASHRAE/ECBC - Natural ventilation: stack effect, courtyard effect, air changes, ventilation requirement calculations, cross ventilation - Artificial ventilation techniques: forced ventilation, fresh air systems, pre-cooling of fresh air - Heat recovery through economizers and desiccant wheels - Humidity control systems, demand controlled ventilation.

UNIT 4 BUILDING SERVICES INTEGRATION**9 Hrs.**

Integration of various building systems - Building automation systems and intelligent building systems - Integration of HVAC systems with water supply and treatment systems - Occupant responsive buildings - Building information modelling- Case studies explaining various building systems.

UNIT 5 COMPREHENSIVE LEARNING**6 Hrs.**

Exercise to work out cooling load, dehumidifying and heat load estimate. Comparative cost analysis (Capital investment vs maintenance/operating costs) against green buildings and ordinary buildings.

Max.45 Hours**COURSE OUTCOME:**

- CO1** Comprehend the various types of air conditioning
CO2 Understanding the principles of day lighting systems.
CO3 Acquire knowledge on adopting the various daylight harnessing systems.
CO4 Ability to categorize the ventilation requirements as per ASHRAE/ECBC.
CO5 Evaluate the various methods to integrate automation of building systems in buildings.
CO6 Develop the strategies to integrate services adopted in buildings through case studies.

TEXT / REFERENCE BOOKS

1. Allard, F. (1998). *Natural Ventilation in Buildings: A Design Handbook (BEST (Buildings Energy and Solar Technology))*. London: Routledge.
2. ASHRAE. (2007). *ASHRAE 90.1 user manual*. Atlanta: ASHRAE.
3. Brian Atkin. (1988). *Intelligent Buildings: Applications of IT and Building Automation to High Technology Construction Projects*. London: Kogan page limited.
4. David Egan, I. (1975). *Concepts in Thermal comfort*. Prentice: Prentice Hall.
5. Evans, M. (1980). *Housing, Climate and comfort*. London: Architectural Press.
6. Power, M. o. (2007). *Energy Conservation Building Code of India, User manual*. New Delhi: Ministry of Power.
7. standard, B. o. (1987). *Handbook of functional requirements of Buildings*. New Delhi: Bureau of Indian standard.
8. Wilson, P. T. (2011). *Daylighting: Architecture and Lighting Design*,. London: Routledge.

WEBSITES

1. <http://www.wbdg.org/resources/daylighting.php>
2. <http://www.wbdg.org/resources/efficientlighting.php>
3. http://www.wbdg.org/resources/hvac_humidclimates.php

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 100****PART A : 2 questions each from unit 1 to unit 4, each carrying 5 marks****PART B : 1 question each from unit 1 to unit 4 with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**

SARA5233	PERFORMANCE ANALYSIS OF BUILDINGS	L	T	P	Credits	Total Marks
		2	0	1	3	100

COURSE OBJECTIVES:

- To introduce the need for performance analysis of buildings and the emergent outcomes.
- To comprehend the fundamentals of shading devices and the tools for shading analysis.
- To analyze energy use through open source software.

UNIT 1 PERFORMANCE OF BUILDINGS**9 Hrs.**

Need for performance analysis of buildings - Soft Computation - Investigation and assessment, energy audit procedures - Design investigations- Energy conservation measure calculations - Modelling systems: cognitive, empirical and analytical assessment of buildings – Parametric and empirical building simulations.

UNIT 2 WHOLE BUILDING ENERGY SIMULATION**12 Hrs.**

Modelling the Building form - Parametric and empirical building simulation - Factors affecting accuracy of energy model- Thermal performance criteria of buildings- Envelope considerations, climatic analysis, weather data- Heating and cooling systems modelling, ventilation systems modelling. Computing energy required for heating/ cooling needs through open source software's.

UNIT 3 DAYLIGHTING AND SHADING SIMULATIONS**12 Hrs.**

Shading simulations- Principles of shading design- Tools for shading analysis- Tools for shading design - Shading design exercises using open source shading software - Day lighting simulation models- Day lighting simulation criteria- Factors affecting accuracy of day lighting model - Day lighting simulation exercises using daylight modelling tools - BIM Integration.

UNIT 4 ANALYSIS OF BUILDING PERFORMANCE**6 Hrs.**

Metering systems - Analysis of collected data from existing buildings - Economic aspects of energy simulation results: LCA, payback analysis, break even analysis, benefit cost analysis, present worth analysis, etc. - Selection of appropriate ECM from modelling results-Recalibration of the model from actual performance data.

UNIT 5 COMPREHENSIVE LEARNING**6 Hrs.**

Based on understanding of above Units the students are expected to perform Whole building computation of a small project emphasizing on the material selection.

Max.45 Hours**COURSE OUTCOME:**

- CO1** Ability to investigate the performance of buildings through calculations
- CO2** Acquired knowledge on whole building energy simulation.
- CO3** Comprehensive understanding of the parametric and empirical building simulation.
- CO4** Skills to develop building models for shading analysis and understand thermal performance of built forms.
- CO5** Evaluate the various factors which influence energy modeling of buildings.
- CO6** Understanding the various parameters to assess the building performance.

TEXT / REFERENCE BOOKS

1. ASHRAE. (2006). *The ASHRAE Green Guide*. Butterworth- Heinemann: ASHRAE Press.
2. Clarke, J. (2007). *Energy Simulation in Building Design*. Routledge: Architectural Press.
3. GiulianoDall'O'. (2013). *Green Energy Audit of Buildings: A guide for a sustainable energy audit of buildings*. New York: Springer.
4. Power, M. o. (2007). *Energy Conservation Building Code of India, User manual*. New Delhi: Ministry of Power.
5. Waltz, J. P. (1997). *Computerized Building Energy Simulation Handbook*. Fairmont: Fairmont PR.
6. Wilson, P. T. (2011). *Daylighting: Architecture and Lighting Design*,. London: Routledge.

WEBSITES

- 1.http://doe2.com/download/equest/eQ-v3-63_Introductory-Tutorial.pdf
- 2.<http://ocw.mit.edu/courses/architecture/4-430-daylighting-spring-2012/>
- 3.http://www.photosolar.dk/userfiles/file/Dokumenter/Guideline%20to%20daylight%20calculation_2013.pdf

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 100****PART A : 2 questions each from unit 1 to unit 4, each carrying 5 marks****PART B : 1 question each from unit 1 to unit 4 with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**

SARA5234	SUSTAINABLE WATER MANAGEMENT	L	T	P	Credits	Total Marks
		3	0	0	3	100

COURSE OBJECTIVES:

- To understand the traditional knowledge of managing water in various contexts.
- To familiarize the fundamentals of technology for effective water management.
- To comprehend the strategies to reduce water consumption in buildings.

UNIT 1 WATER MANAGEMENT – HISTORICAL PERSPECTIVE 9 Hrs.

Traditional community wisdom regarding water management from different climatic zones of the world - Traditional Architecture of wells in Rajasthan, Gujarat, Tamil Nadu– Stepped Wells, Baoris, Tankas, etc.

UNIT 2 WATER MANAGEMENT – MACRO LEVEL 12 Hrs.

Management of the water cycle as a single system - Management of water supply, sanitation and drainage - Social imperatives, environmental considerations and economic challenges - Technological options for water management, recycling, reuse, conservation and treatment - Planning of settlements and large campuses based on principles of sustainable watershed development with water as a priority resource.

UNIT 3 WATER MANAGEMENT – MICRO LEVEL 9 Hrs.

Design for water conservation – Building and products - Designing building services, plumbing and sanitary design for effective water reuse, recycling, and recharge - Strategies for water pricing and its regulation - Rain water harvesting techniques – Basic Concepts, piping techniques and pit design for groundwater recharge wells.

UNIT 4 STRATEGIES TO REDUCE WATER CONSUMPTION IN BUILDINGS 9 Hrs.

Low flow plumbing fixtures for water efficient appliances - Rain water harvesting - Reuse of grey water for non-potable uses - Wetlands for natural waste water treatment, use of wetlands for natural storm water and vegetated roof tops, (natural) renewable power source such as photo voltaic, solar hot water fuel cells etc.

UNIT 5 COMPREHENSIVE LEARNING 6 Hrs.

Submission of reports by interviewing those involved in rainwater harvesting and water management system. Critically analyse water management strategy adopted in any particular case study.

Max.45 Hours**COURSE OUTCOME:**

- CO1** Understand the basic concepts on the ways to manage water in different climatic zones specific to Indian context.
- CO2** Summarize the importance of water management from the social, environmental and economic perspectives.
- CO3** Construct knowledge of incorporating sustainable principles of watershed development in large campuses.
- CO4** Ability to analyze the various methods to reduce, recycle and recharge water at the building level.
- CO5** Criticize the fundamentals of renewable power sources.
- CO6** Develop a strategy that can be achieved from practical knowledge in the water management system.

TEXT / REFERENCE BOOKS

- (Ed.), K. N. (2006). *Water Resources Management: Realities and Challenges*, ..2006. India: Eastern Book Corpn.
- Athavale, R. (2003). *Water Harvesting And Sustainable Supply In India*. India: Rawat Publication.
- Dr B C Punmia, A. K. (2011). *Water Supply Engineering, Water safety in buildings*. Geneva: World Health Organization,.
- Honore(Ed.), G. (2002). *Principles and Practices of Integrated Watershed Management in India*,. -: Indo-German Bilateral Project.
- Iyer, R. R. (2009). *Water and the laws in India*. Chennai: Sage Publications India Pvt. Ltd.,
- Jain, S. K. (2007). *Hydrology and Water Resources of India, Water Science and Technology Library, Vol. 57*, . New York: Springer.
- John Briscoe, R. M. (2007). *Handbook of Water Resources in India: Development, Management, and Strategies* . Chennai :)Oxford University Press.
- Singh, P. (2008). *Rainwater Harvesting: Low cost indigenous and innovative technologies*. India: Macmillan Publishers.

WEBSITES

- http://www.unepfi.org/fileadmin/publications/water/chief_liquidity1_India.pdf
- <http://wrmin.nic.in>
- http://www.unicef.org/india/Final_Report.pdf

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 100****PART A : 2 questions each from unit 1 to unit 4, each carrying 5 marks****PART B : 1 question each from unit 1 to unit 4 with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**

SARA9231	SUSTAINABLE DESIGN STUDIO II	L	T	P	Credits	Total Marks
		0	0	14	8	300
Continuous Assessment		University Viva			Min Pass Marks	
200		100			150	

COURSE OBJECTIVES:

- To incorporate the sustainable principles and approaches to the identified typology in the site, built form and the environment.
- To develop the design skills with respect to larger scale project
- To gain and apply knowledge for detailed calculations on energy and water saving.

STUDIO BRIEF 01

1. The student shall select a Campus type: Example Residential/ Commercial/ Institutional/ Industrial-manufacturing/Corporate/ Healthcare/ Hospitality
2. Students shall select any one climatic zone from ECBC's climatic zone classification.
3. They shall select any city from a zone and research local bye laws and regulations.
4. They shall analyse site fit and program brief
5. They shall evaluate cultural, environmental factors and inspirations for environmental design from local vernacular and nature
5. They shall design buildings which shall function as per GRIHA and ECBC guidelines
6. The building should highlight material which has low embodied energy as compared to conventional technology and at least one sustainable building service technology in HVAC
7. The student shall design an energy model using an open source software such as eQUEST, IESVE, which gives comprehensive energy use analysis of the building

DELIVERABLES

1. Detailed description of building typology selected and reasons for the same.
2. Climatic analysis and microclimatic analysis of the site.
3. A case study of a similar building in a similar climatic zone with respect to sustainability features, etc.
4. Study report on climatic and microclimatic parameters that will guide environmental site development.
5. Study report and story board incorporating site fit, zoning and program brief, contextual adaptations from vernacular/ nature responses, conceptual design.
6. Preliminary energy analysis and Architectural documentation including 2D drawings and 3D models
7. Detailing and modelling of green building features including passive design features, hybrid features, active features, etc.
8. Detailed calculations to show energy and water savings and daylight calculations
9. Detailed embodied energy calculation
10. Final energy analysis

STUDIO BRIEF 02

Retrofitting of building – Any Building type – Focus on building Envelope design

1. To understand Building and Climatic variables through field study analysis- measurements on-site, photos etc
2. The students will make a team and are to discover a single design strategy that will meet multiple design objectives.
3. Examine the elements in a building that mediate between the interior and exterior environment
4. To initiate energy conservation retrofits to reduce energy consumption and explore the building performance
5. To improve indoor environmental quality, decreasing moisture penetration, and reducing mold for occupant health and productivity.
6. The design major renovations and retrofits for existing buildings should include sustainability to reduce operation costs and environmental impacts, and can increase building adaptability, durability, and resiliency.
7. They shall follow the ECBC guidelines

DELIVERABLES

1. Detailed description of building typology selected and reasons for the same.
2. Climatic analysis and microclimatic analysis of the site.
3. Case studies to understand envelope design, various measures to retrofit with respect to sustainability features, etc
4. Alternative strategies for improving thermal comfort.
5. Base case and Design case analysis
6. Final Design with details and simulations
7. Summary of detailed energy, water savings, daylight and embodied energy calculations and conclusions.
8. Report of the entire exercise as group work to be submitted.

COURSE OUTCOME:

- CO1** Explore the sustainable principles relevant to the design typology and the context
- CO2** Ability to incorporate the sustainable principles and practices, and passive design strategies and analyze the same in the identified typology.
- CO3** Acquired knowledge on Energy models and calculations
- CO4** Develop design strategies that optimize and conserve resources and provide comfortable environment for the occupants in a building
- CO5** Simulating by use software tools to analyze the incorporated sustainable ideals in the emergent outcome.
- CO6** Critically analyse, evaluate and make informed judgment on the working of sustainable design strategies in design.

TEXT / REFERENCE BOOKS

1. ArvindKrishen, N. B. (1999). *Climate responsive architecture: A design handbook for energy efficient buildings*. New Delhi: McGraw Hill Education (India) Pvt. Ltd.,
2. B.V Venkatarama Reddy and K.S Jagadish, s. . (2003). *Embodied energy of common and alternative building materials and technologie*. Vol. 35 (pp129-137): Energy and Buildings.
3. Egan, D. (1975). *Concepts in Thermal comfort*. Prentice: Prentice Hall.
4. Lengen, J. v. (2007). *The Barefoot Architect: A Handbook for Green Building* . UK: Shelter Publication.
5. Power, M. o. (2007). *Energy Conservation Building Code of India, User manual*. New Delhi: Ministry of Power.
6. Willie Weber, S. (. (2002). *Lessons from Vernacular Architecture*. -: Routledge.

S89APT		PROFESSIONAL TRAINING		L	T	P	Credits	Total Marks
				0	0	0	3	300
Continuous Assessment		University Viva				Min Pass Marks		
50		50				50		

COURSE OBJECTIVES:

- To undergo professional training in a firm to get experience of handling various environmental design practice, Sustainable developments and learn latest software trending in the market.
- To utilize the forum to discuss key issues in the projects, keep track of the different sustainable approaches, communicate with the stakeholders and get an overall view of the contract administration.
- The final project report will comprise of an in-depth research and analysis of activities in the form of drawings & relevant details, schematic charts & reports, photographs, documentation of the project, comments, suggestions, etc to appraise the efficiency in progress of work.

PROCEDURE

1. The candidate has to join an Architectural or Environmental design practice or organization and work on the design/documentation of projects related to Sustainable Architecture and or Environmental site planning projects for a minimum of 30 working days during their summer vacation.
2. Weekly report has to be sent to the concerned Year Coordinator by the student duly signed by the head of the firm, which needs to be compiled in the comprehensive report later.
3. This comprehensive report shall be submitted at the end of the summer internship along with the Joining letter and experience letter.
4. The evaluation of report and viva voce examination shall be conducted as per norms for the Institution Semester examination.

COURSE OUTCOME:

- C01** Accumulate concepts or skills with access to leading experts with specialized knowledge and experience.
- C02** Obtain enhanced knowledge, develop communication skills and learn practical application aspects in the field.
- C03** Manage projects using proven, effective performance measurement techniques.
- C04** Analyze and recommend project decisions concerning scope, design, cost and other project parameters faster, effectively and confidently.
- C05** Ability to prepare a portfolio of the academic and professional design work.
- C06** Develop knowledge of the new software, materials, costing and documentation prevalent in Sustainable Architecture projects.

SARA5431	ENVIRONMENTAL IMPACT ASSESSMENT TECHNIQUES		L	T	P	Credits	Total Marks
			3	0	0	3	100

COURSE OBJECTIVES:

- To introduce the various aspects of environmental impact assessment.
- To understand the components and impacts of EIA and socio-economic systems.
- To give an insight to sectoral EIA in diverse contexts.

UNIT 1 INTRODUCTION**9 Hrs.**

Historical development of environmental impact assessment (EIA) - EIA in project cycle, legal and regulatory aspects in India – Types and limitations of EIA – Cross sectoral issues and terms of reference in EIA – Public Participation in EIA - EIA process, screening, scoping, setting, analysis, mitigation.

UNIT 2 COMPONENTS AND METHODS**10 Hrs.**

Matrices – Networks – Checklists – Connections and combinations of processes - Cost benefit analysis – Analysis of alternatives – Software packages for EIA – Expert systems in EIA – Prediction tools for EIA – Mathematical modelling for impact prediction – Assessment of impacts: air, water, soil, noise, biological — Cumulative Impact Assessment – Documentation of EIA findings, planning, organization of information and visual display materials – Report preparation - EIA methods in other countries.

UNIT 3 IMPACT ON SOCIO-ECONOMIC SYSTEMS**10 Hrs.**

Definition of social impact assessment - Social impact assessment model and the planning process - Rationale and measurement for SIA variables - Relationship between social impacts and change in community and institutional arrangements - Individual and family level impacts - Communities in transition - Neighborhood and community impacts, selecting, testing and understanding significant social impacts - Mitigation and enhancement in social assessment - Environmental costing of projects.

UNIT 4 SECTORAL EIA**10 Hrs.**

Ethical and Quality aspects of environmental impact assessment, sectoral EIA -EIA related to the following sectors – Infrastructure, construction and housing, mining, industrial, thermal power, river valley and hydroelectric, coastal projects- Nuclear Power, hill area development and CRZ -EIA for coastal projects.

UNIT 5 COMPREHENSIVE LEARNING**6 Hrs.**

To make a report on the role of government and government agencies in emphasizing the adoption of EIA

Max.45 Hours**COURSE OUTCOME:**

- CO1** Explore about the legal and regulatory aspects overview of EIA in India.
- CO2** Understanding of the components, methods, tools and documentation involved in EIA.
- CO3** Analyse the impact of socio-economic systems and an insight to EIA methods in other countries.
- CO4** Acquire knowledge about the various parameters in social impact assessment with examples.
- CO5** Categorizing the ethical and quality aspects of EIA.
- CO6** Identify the aspects and issues related to various sectoral EIA ranging from micro to macro level.

TEXT / REFERENCE BOOKS

1. book, E. A. (1998). *Guidelines for environmental assessment of energy and industry projects*,. Vol. III: World Bank.
2. D.P., L. (2003). *Environmental Impact Assessment – Practical solutions to recurrent problems*,. New Jersey: Wiley-Interscience.
3. J, P. (1999). *Handbook of Environmental Impact Assessment*, . London: Blackwell Science - Vol., I and II.
4. L.W, C. (1996). *Environmental Impact Assessment*,. New York: McGraw Hill,.
5. Nick Harvey, B. C. (2012). *Environmental Impact Assessment: Procedures and Practices*,. USA: Oxford University Press.

WEBSITES

1. <https://www.cbd.int/doc/nbsap/EIA/India.pdf>
2. <http://coe.mse.ac.in/Guidelines.asp>
3. http://www.planning.nsw.gov.au/rdaguidelines/documents/emp_guideline_publication_october.pdf
4. http://www.gpcb.gov.in/pdf/Nuclear_Power_Corpo_of_India_Exe_Summ_Eng.pdf
5. http://www.tnpcb.gov.in/pdf/EIA_Perambalur_%20SEZ%20Eng.pdf
6. <https://www.env.go.jp/earth/coop/coop/document/10-eiae/10-eiae-2.pdf>

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 100****PART A : 2 questions each from unit 1 to unit 4, each carrying 5 marks****PART B : 1 question each from unit 1 to unit 4 with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**

SARA7433	ADAPTIVE REUSE AND RETROFIT	L	T	P	Credits	Total Marks
		3	0	0	3	100

COURSE OBJECTIVES:

- To give a comprehensive overview on how existing buildings can be adapted and retrofitted to function sustainably.
- To analyze the technologies which can be adopted for improving the energy efficiency of existing buildings
- To understand the various strategies adopted to conserve heritage buildings.

UNIT 1 SUSTAINABLE RETROFIT FOR EXISTING BUILDING**9 Hrs.**

Retrofitting options for existing buildings: structural retrofit, facade, services, interior retrofit - Performance analysis of existing buildings - Physical audits - Building Simulation - Metering and tracking options - Analysis the building's current performance- Decision influencers for retrofit- economic, social and environmental issues.

UNIT 2 ADAPTIVE REUSE OF OLD BUILDING**10 Hrs.**

Need for adaptive reuse - Issues to be explored in building adaption- Economic, social, environmental, and assessment models for adaptive reuse - Case studies of buildings with adaptive reuse.

UNIT 3 TECHNOLOGIES FOR ENERGY EFFICIENCY IN EXISTING BUILDINGS**10 Hrs.**

Improving energy efficiency in existing buildings- Facade improvements, HVAC improvements, Indoor Environment Improvements - Monitoring the performance of retrofits - Case studies on energy efficiency improvements in existing buildings.

UNIT 4 SUSTAINABLE CONSERVATION OF HERITAGE STRUCTURES**10 Hrs.**

Conservation of heritage structures - Sustainability in heritage structures - Adaptive reuse of heritage structures - Issues in adapting a heritage structure - Use of sustainable conservation techniques - Improving the energy performance of heritage structures - Case studies of sustainable conservation in heritage structures.

UNIT 5 COMPREHENSIVE LEARNING**6 Hrs.**

Select a historic building (more than 100 years old) / abandoned modern building (less than 50 yearsold). Study the current state and performance of the building in terms of environment, social & economic aspects. Based on the results of the study, provide a suitable solution to improve the structure, façade, function of the building, which in turn will reflect on the three pillars of sustainability.

Max.45 Hours**COURSE OUTCOME:**

- CO1** Understanding the various types and methods of validating existing building for retrofitting.
- CO2** Comprehending the ways to enhance the performance of existing building for retrofitting through audits, metering and simulation.
- CO3** Interpreting the strategies adopted from various 'adaptive reuse' case studies
- CO4** Critically analyzing the approaches adopted in improving the energy efficiency in different contexts.
- CO5** Ability to integrate energy efficient technologies to augment the performance of existing buildings.
- CO6** Exploring the issues involved in sustainable conservation of heritage structures.

TEXT / REFERENCE BOOKS

1. Sara J. Wilkinson, Hilde Remoy, Craig Langston, Sustainable Building Adaptation: Innovations in Decision-making, John Wiley and sons, 2014
2. John Krigger, Residential Energy: Cost Savings and Comfort for Existing Buildings, Prentice Hall, 2009
3. William H. Clark, Retrofitting for Energy Conservation, McGraw Hill Professional, 1997
4. Paul Apple, Sustainable Retrofit and Facilities Management, Routledge, 2013
5. Zeynep Aygen, International Heritage and Historic Building Conservation: Saving the World's Past, Routledge, 2013

WEBSITES

1. http://www.wbdg.org/resources/retro_sustperf.php
2. <http://www.intach.org/about-charter-guidelines.php>
3. <http://cpwd.gov.in/Publication/ConservationHertBuildings.pdf>
4. <http://www.sciencedirect.com/science/article/pii/S0378778812004227>

END SEMESTER EXAM QUESTION PAPER PATTERN**Max. Marks : 100****PART A : 2 questions each from unit 1 to unit 4, each carrying 5 marks****PART B : 1 question each from unit 1 to unit 4 with an internal choice, each carrying 15 marks****Exam Duration: 3 Hrs.****: 08 x 05 = 40 Marks****: 04 x 15 = 60 Marks**