M.Tech. Program on "E-waste Resource Engineering & Management"
(to be jointly executed by IIT Hyderabad and C-MET)

Background: With rapid change in technology and more digitalization in the world, there is an explosive growth in electronics industry and subsequently that has led to enormous growth in electronic waste (e-waste). E-waste contains many hazardous and toxic substances which have serious health and environmental effects, if not managed properly. Therefore, it becomes essential to learn about various technological interventions to manage, reduce and recycle e-waste for its safe disposal.

Objectives: This proposed M.Tech. program on E-waste resource engineering &management is not only very timely but also a very unique with joint participation from IIT Hyderabad and Centre for Materials for Electronics Technology (C-MET), Hyderabad. This M.Tech. program will first discuss the Waste management in general and e-waste management in particular including E-waste management rules. Various technologies for recycling of e-waste including the recovery of metals, plastics will be studied in detail followed by understanding life cycle analysis and carbon foot print calculations. Chain and supply management including the role of Artificial intelligence based techniques to develop an effective recycling system will also be covered. Few case studies will be taken in seminar course while the thesis work will facilitate in developing new technological and viable solutions to meet the challenges in E-waste management.

Recycling of e-waste needs expertise in three areas: (1) collection, recycling and / or reuse of Waste Electrical and Electronic Equipment (WEEE) and its sub-assemblies (2) expertise over the entire life cycle of electronic devices and lastly (3) Non-ferrous and precious metals recovery in an environmentally friendly manner. Similarly, the life cycle management needs (a) analysis of the life cycle logistics (manufacturing, distribution, collection, dismantling, recovery), (b) analysis of manufacturing products and substitutes within the framework of e-waste (management) rules 2016 regulations with a focus on resource efficiency and lastly and(c) the carbon footprint generated by the electronic products for generation as well as recovery.

This M.Tech. program will catalyse the efforts towards E-waste management in the country and worldwide and will provide a necessary support for several of Government initiatives in this direction such as Skill India, Swachh Bharat, Waste-to-Wealth initiatives.

Eligibility:
B.Tech. in Chemical Engg./Materials Sci. & Metallurgical Engg./Civil Engg./Environmental Engg./Electrical Engg./Mechanical Engg./Engineering Sciences/Engineering Physics/Minerals Engineering and affiliated areaswith GATE qualification OR M.Sc. in Physics/Chemistry with NET/GATE qualified

GATE paper qualified: CE/CH/CY/EC/EE/IN/ME/MN/MT/PH/PI/XE-C/XE-F/XE-H/XL-P/

Note: NET/GATE qualification is exempted for industry sponsored candidates with a minimum two years' experience OR for IIT Undergraduates with minimum CGPA of 8.0.

Intake: 05

Program Structure:

Total: 49 credits (Theory 24+1 credits; Thesis: 24 credits)
Theory: 14 Core credits + 10 Elective credits + 1 Core credit Institute courses + 0 Core credit Institute course

Semester wise credit requirements:

Semester	Theory		Thesis	Total
	Core	Elective		
I	6 (3+3)+ 1	5 (3+2)	Nil	11+1 (12)
II	9 (2+3+2+1+1)+1	5 (3+2)	Nil	14+1 (15)
III	Nil	Nil	12	12
IV	Nil	Nil	12	12
Total (I-IV)			24	49+2 (51)

Semester wise Theory courses:

Semester I (12 credits)
Core Courses (7 credits; 3+3+1):

1. Introduction to waste management (3 credits)(CMET) EW5010
2. Advanced Concepts in Process Metallurgy (3 credits) (IITH) MS5640
3. English communication (1 credit) (IITH) LA5180

A. Elective Courses (3 credits) - Choose anyone
A1: Electrometallurgy (3 credits) (IITH) MS5390
A2: Computational Methods for Chemical Engineers (3 credits) (IITH) CH5010

B. Elective Courses (2 credits) - Choose anyone
B1: Design concepts of project capacity to a viable scale (2 credits) (IITH) EW5100
B2: SWOT analysis and risk management (2 credits) (CMET) EW5120

Semester II (13 credits)
Core Courses (8 credits; 2+3+1+1+1+0):

4. Instrumentation and Characterization (2 credits) (CMET) EW5070
5. E-waste Recycling Methods (3 credits) (CMET) EW5020
6. Trace metal Analysis (2 credit) (IITH) EW5060 – changed from 1 to 2
7. Supply Chain Management and Circular Economy (1 credit)(IITH) EW5090
8. Machine Learning for Process Systems Engineering (1 credit)(IITH) CH6870
9. **Industrial Lectures Series (1 credit) (IITH) EW5106**

C. Elective Courses (2 credits) - Choose anyone
C1. Life Cycle Analysis in Waste Management (2 credits) (IITH) EW5030
C2: Molecular Thermodynamics (2 credits) (IITH) CH5030

D. Elective Courses (3 credits) - Choose anyone
D1: Global Government Policies on E-waste Mgmt & Business calculations EW5110
D2: Instrumentation for efficient recycling and automation EW5130

Theory credits: 27 (equally distributed to IITH and CMET)

Course Details:

Semester I - Core Courses

1. EW5010 - Introduction to Waste Management (3 credits)

Waste Electrical and Electronic Equipment (WEEE): Flows, Quantities and Management, a Global Scenario; The Importance of Waste Management; Types of Waste- Solid and Liquid; Criteria for EEE/E-Waste Classification; Multivariate Model for E-Waste Estimation; Environmental and Health Effects of Waste Management, Inventorisation of E-Waste and Emerging trends in E-waste disposal with bench marks for depollution - global scenario; Dumping, Burning and Landfill: Impact on the Environment; Effective Waste Management and Disposal Strategies; Legislative Influence on Electronics Recycling; Waste Management Rules and Their Amendments; Electronic Waste: Public Health Implications; Restriction of Hazardous Substances (RoHS) Directives in Electrical and Electronic Equipment; 3R's of Managing Solid Waste: Reduce, Recycling and Reuse; 4R;s in e-waste management:

Electronic Waste Management Rules 2016; E-Waste management (Amendment rules) 2018. Extended Producer Responsibility (EPR) in E-Waste Management; The Role of Collective versus Individual Producer Responsibility in E-Waste Management; Recycling and Resource Management: Ecological and Economical Valuation; Life Cycle Assessment (LCA) Approach to Waste Management System; Environmental Incentives for Recycling and Life Cycle Analysis of Materials Recycling . Overview of Indicators for Evaluating the Performance of E-Waste Treatment; Best -of-2-Worlds (Bo2W) Approach for E-Waste Treatment

Resource efficiency and circular economy: Resources; wastes, resource efficiency in e waste management. waste hierarchy, waste audit, sustainable resource management, resource management laws, zero waste concepts, The Circular Economy System and definitions; Materials Flow; Environmental and economic benefits; Circular Economy and social benefits Sectorial opportunities – examples, Circular Economy case studies;

Text book:

i) Electronic Waste Management and Treatment Technology, Editors: MajetiNarasimhaVara Prasad MeththikaVithanage
ii) Electronic Waste Management, Edited by R. E. Hester, R. M. Harrison, RSC Publishing 2009
iii) Solid Waste Technology & Management, Christensen, T., Ed., Wiley and Sons., 2011
iv) Electronics Waste Management: An India Perspective. Front Cover. Sandip Chatterjee. Lap Lambert Academic Publishing GmbH KG, 2010 - Electronic
v) Handbook of Electronic Waste Management, International Best Practices and Case studies, Elsevier, 2019
vi) E-waste: Implications, regulations, and management in India and current global best practices. Author(s): Rakesh Johri, TERI Press
vii) The global impact of e-waste: Addressing the challenge by Karin Lundgren, Publications of the International Labour Office Geneva, Switzerland, 2012
viii) E-Waste in Transition: From Pollution to Resourceedited by Florin-Constantin Mihai, InTech, Croatia 2016

Reference Book:

i) Electronic Waste Management and Handling Rules, Ministry of Environment and Forests, Government of India, New Delhi, 2011
ii) Guidelines and criteria for hazardous waste landfills and hazardous waste treatment disposal facilities, Central Pollution Control Board, New Delhi, 2010

Outcome of this course: Overall understanding about E-waste Management rules 2016 and strategies for e-waste management.

2. Advanced Concepts in Process Metallurgy (3 credits)

Principles of extraction, unit operations, material and heat balance of processes, thermodynamics of processes; introduction to laws, thermochemistry, thermodynamic equilibrium; Genesis, construction and analysis of Ellingham diagram, predominance area diagram, Eh-pH diagram and its application in extraction of various metals.

Introduction to chemical kinetics and rate processes, Process kinetics: Heterogeneous kinetics, gas-solid reactions (progressive conversion, shrinking core, shrinking particle model), liquid-liquid reactions (mass transfer models), concepts of reactor design.

Structure & properties of aqueous solution and molten melts (metals, slags, salts, and matte). Unit processes in pyro and hydrometallurgy.

Ore Dressing; Fine separation technologies, Dry beneficiation techniques, Ironmaking; RIST model for BF and DRI, Steelmaking; concept of physical modelling & simulations, inclusion engineering in steels, construction, and analysis of inclusion stability diagram, flux design for liquid steel refining.

Sustainable metallurgy; Novel use of hydrogen and CO_2 in metallurgical processes, Thermodynamics and Kinetics of hydrogen and CO_2 reactions, Hydrogen plasma smelting and other novel reactors, strip casting and challenges.

Lunar metal/material processing; molten oxide electrolysis; thermodynamics, kinetics, and challenges in development of inert anode. Solar metallurgy; Concept, design and principle of solar concentrator/furnace and simulator for material processing.

Introduction to life cycle analysis of metallurgical processes and case study.

Recommended reference books:

1. Principles of Extractive Metallurgy, Terkel Rosenqvist, McGraw-Hill Book Company.
2. Stoichiometry and Thermodynamics of Metallurgical Processes: Y K Rao, Cambridge University Press.
3. Handbook of Extractive Metallurgy: Fathi Habashi; Wiley-VCH.
4. Chemical Reaction Engineering, 3ed (WSE); Octave Levenspiel, Wiley publication, 2006
5. Life Cycle Assessment Theory and Practice; Michael Z. Hauschild, Ralph K. Rosenbaum, Stig Irving Olsen, Springer publications, 2018.
6. Advanced Physical Chemistry for Process Metallurgy; Nobuo Sano, Wei-Kao Lu, Paul V. Riboud, Academic Press, 1997.
7. Theory and Methods of Metallurgical Process Integration; Ruiyu Yin, Academic Press, Elsevier Inc., 2016.

Semester – I: Elective Courses

A1.MS 5390 Electrometallurgy (3 credits)

(A) Fundamental aspects of Electrometallurgy: Introduction (Electrometallurgy, Electrochemical principles and basic concepts, Evolution of electrometallurgy), Pourbaix diagrams, Transport properties of electrolytes (aqueous, molten and ionic solutions), Solution models (Debye-Hückel-aqueous, Temkin-molten salts), Electrode-electrolyte interface, Equilibrium electrode potential, and Potential Applications (Electronics, Automotive, Aerospace, Biomaterials & Medical Devices)
(B) Electrochemical Kinetics: Electrochemical reaction kinetics and mechanism of electrodeposition, Mass transport and interfacial processes, Aspects of cementation, electrocrystallization and surface morphology of metal electrodeposits (through mathematical approach, physical model, and a realistic system), Current distribution in electrochemical cells, Electrodeposition at a periodically changing rate, Effects of additives
(C) Various Electrometallurgical Processes: Electrowinning (melts electrolysis and aqueous solution electrolysis), Electrorefining (from impure metal anodes), Electroplating (metals, alloys and composites) from aqueous electrolytes, ionic liquids, & molten salts, Electroforming, Surface finishing (Electropolishing, Electromachining)
(D) Electroless Deposition (Displacement deposition, Contact deposition and Autocatalytic deposition)
(E) Structure, Properties and Characterization of Electrodeposits
(F) Case Studies, Industrial Practices & Challenges (energy utilization, chemical stability, productivity, and safety), Materials and Environmental issues, Industrial/Electrochemical Effluents/Wastewater Treatment
(G) Electroplating: Numerical Modelling and Simulation
(H) New age Electrodeposits (nanostructures, multilayers, multicomponent, etc)

Books/References
(1) Fundamental aspects of electrometallurgy, by K.I. Popov, S.S. Djokic and B.N. Grgur, Kluwer, Academic Publishers, 2002
(2) Fundamentals of electrochemical deposition, by M. Paunovic and M. Schlesinger, Wiley Interscience, 2006
(3) Modern Electrochemistry (Volume 1), by J.O'M. Bockris and A.K.N. Reddy, Plenum Press, London, 1970
(4) Understanding Voltammetry (Third Edition), by R.G. Compton, E. Laborda and K.R. Ward, World Scientific Publishing Europe Ltd., 2018
(5) Understanding Voltammetry: Simulation of Electrode Processes, by R.G. Compton and C.E. Banks, World Scientific Publishing Europe Ltd., 2018

A2: Computational Methods for chemical engineers (3 credits);

Review of computer programming; solutions of simultaneous linear/ non-linear equations; Newton's interpolation formula ; Quadratic formula; Systems of first order ordinary differential equations (ODEs), Stability analysis; Variable step size algorithms (Gear's algorithm etc.), Finite difference methods for ODEs (IVPs & BVPs) and PDEs (hyperbolic, parabolic, elliptic). Numerical solutions of chemical engineering problems e.g. separation processes, reaction engineering, fluid mechanics, process control, thermodynamics etc.

Reference:

1. Gupta S.K., Numerical Methods for engineers , 5-th Ed., New age international (2010).

2. Pushpavanam, S. Mathematical methods in Chemical Engineering, Prentice- Hall of India, New Delhi (2004).
3. Chapra, S.C., Canale, R.P. Numerical methods for engineers, Tata-McGraw- Hill, New Delhi (2006).
4. Hoffman, J.D. Numerical methods for engineers & Scientists, Taylor & Francis, Boca Raton (2001)
5. Conte SD & de Boor C, Elementary Numerical analysis- an algorithmic approach, 3rd Ed, SIAM publishing, 2018.

B1: EW5100: Design concepts of project capacity to a viable scale (2 credits)

Concept of Technology Readiness Levels (TRL); Project Management; Technology Commercialization: Role of Incubator, Cluster, Research Park and Consortia; Intellectual Property Protection and Management; Technology Assessment: Valuation and Pricing; Technology Development and Management; Measuring Commercialization Capability: Capital expenses, Revenue calculation; Building Commercialization Capability; Technology fusion; Sustainable Production Technologies; Case Study: Spent PCB recycling, Scale-up to Commercial Scale Recycling, Case Study: Rare Earth Recovery from Spent Permanent Magnets; Case Study: Recycling of Li ion Batteries; Availability of Raw Material and Consistency

Reference books:

i) Technology Commercialization Manual: Strategy, Tactics, and Economics for Business Success edited by Melvin Joseph DeGeeter
ii) E-Waste in Transition: From Pollution to Resourceedited by Florin-Constantin Mihai, InTech, Croatia 2016

B2: EW 5120: SWOT analysis and risk management (2 credits)

SWOT Analysis: Steps for Success with The SWOT Analysis; Influencing Factors; SWOT analysis of E-Waste sector in India; Strength: Statistics of E-Waste Generation, Demand and Need of Recycled Materials, Business Opportunities; Weakness: E-waste channelization, consumer unawareness, lack of research, poor implementation of E-waste management rules, high capital expenses for setting-up recycling facilities; Opportunity: Environment Friendly E-waste recycling, Difference between E-waste generated and recycled, start-ups in various fields of E-waste management, formalization of informal sectors; Threats: lack of E-waste awareness, Illegal processing of E-waste, health hazard and unhygienic working conditions, cost competence with informal route recycling, Effluents Management

Risk Management: Risk Assessment Standards and Definitions; Risk Assessment Fundamentals; Fundamental Hazard Analysis and Risk Management: Informal Methods, Formal Methods; Industrial Hygiene Risk Assessment: Occupational Health Risk, Health Risk Assessment and Prioritization; Machine Risk Assessment: Machine Safety Standards, Machine Safeguarding, Assessment of Machine Maintenance and Service

Reference books:

i) The SWOT Analysis: A key tool for developing your business strategy by Christophe Seth, Published by 50MINUTES.com
ii) Risk Assessment: A Practical Guide to Assessing Operational Risks, edited by Georgi Popov, Bruce K. Lyon, Bruce Hollcroft, WILEY

Semester 2: Core Courses

Instrumentation and Characterization

Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES); Atomic Absorption Spectroscopy (AAS); Energy Dispersive X-ray Fluorescence (EDXRF); Ion chromatography (IC); Gas chromatography–mass spectrometry (GC-MS); Ultraviolet–visible spectroscopy (UV-Vis); Inductively Coupled Plasma – Mass Spectroscopy (ICP-MS); Sample preparation-Microwave Digestion System (MDS)

X-ray Diffraction (XRD):Crystal structure, Interaction of X-ray and atoms, Absorption, Laue's equation, Bragg's condition of diffraction;Fourier-transform infrared spectroscopy (FTIR); Laser Raman Spectroscopy (LRS)

Thermal analysis techniques: Differential scanning calorimetry (DSC), Differential thermal analysis (DTA), Dilatometry, Thermogravimetric analysis (TGA)

Scanning Electron Microscopy (SEM): Basic principles of scanning electron microscopy, energy dispersive spectroscopy (EDS), Electron backscattered diffraction (EBSD)

Reference:

1. Elements of X-ray Diffraction By B. D. Cullity.
2. Goodhew, P.J., Humphreys, J. and Beanland, R., "ElectronMicroscopy and Analysis", 3rd Edition, Taylor and Francis
3. Goldstein, J., Newbury, D.E., Joy, D.C., Lyman, C.E., Echlin, P., Lifshin, E., Sawyer, L. and Michael, J.R., "Scanning ElectronMicroscopy and X-ray Microanalysis", 3rd Edition, Springer
4. Speyer, R., "Thermal Analysis of Materials", CRC Press

EW5020 - E-waste Recycling Methods (3 credits)

Recycling Electronic Waste: Challenges and Opportunities for Sustainable Management; Resource Recovery from E-waste: Materials Used in Manufacturing Electrical and Electronic Products; Integrated Approach to E-Waste Recycling: Recycling and Recovery Technologies, Emerging Recycling and Recovery Technologies, Printed Circuit boards; Sector-based Eco-Design; Characterizations and Classification of E-Waste: Sampling Techniques; Technical and Societal Aspects of E-Waste Treatment;

Theory of Metallurgical Processes: Ellingham Diagrams, Pyrometallurgical Process for E-waste Recycling: Pyrolysis, Depopulation, Calcination, Smelting; Flux Chemistry for Separation of Metals; Hydrometallurgical Process for E-waste Recycling, Separation and Purification of Metals; Fundamental Principle and Practices of Solvent Extraction for Extraction and Separation. Physical and Powder Separation Techniques: wet and cold grinding, density separation. Separation in the presence of magnetic field, Electrostatic separation

Recycling methods for PCBs for metal recovery; Permanent Magnets Scraps Treatment for Rare Earth Metal(s) Recovery; Lithium Ion Batteries: from Devices to Recycling; Rare Earth Metal(s) Extraction from Florescent Lamps; Recycling methods for solar panels

Management of Effluents: Solids, Liquids and Gases, generation of effluents, handling/treatment, neutralization; CPCB guidelines for the disposal of effluents; design and development of pollution control systems

Text book:

i) Electronic Waste Management and Treatment Technology, Editors: MajetiNarasimhaVara Prasad MeththikaVithanage
ii) Electronic Waste Management, Edited by R. E. Hester, R. M. Harrison, RSC Publishing 2009
iii) The Complete Technology Book on E-Waste Recycling, Asia Pacific Business Press Inc, 2018
iv) Electronic Waste Management: Edition 2Editors: G H Eduljee, R M Harrison, Royal Society of Chemistry.
v) Extractive metallurgy of copper by AK Biswas, W.G. Davenport
vi) E-Waste in Transition: From Pollution to Resourceedited by Florin-Constantin Mihai, InTech, Croatia 2016

Reference Book:

i) Handbook of Electronic Waste Management: International Best Practices and Case Studies 1st Edition, Eds. MajetiNarasimhaVara Prasad, MeththikaVithanage, Anwesha Borthakur

Outcome of this course: Understanding about various e-waste recycling methods and strategies, resource efficiency and circular economy

Trace Metal Analysis (1 Credit):

Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES); Atomic Absorption Spectroscopy (AAS); Energy Dispersive X-ray Fluorescence (EDXRF); Ion chromatography (IC); Inductively Coupled Plasma – Mass Spectroscopy (ICP-MS); X-ray Diffraction; X-ray Absorption;

(Among these instruments few were practically demonstrated by the lab technicians to have more depth and clarity on the same).

EW 5060: Supply Chain Management and Circular Economy(1 credit)

Introduction to Supply Chain Management - Logistics Network Configuration - Inventory Models - Value of Information - Circular Economy - IT & Decision Support - Mathematical Models

Text / Reference Books:

1. Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies by David Simchi-Levi, Edith Simchi-Levi, and Philip Kaminsky, McGraw Hill Education; 3rd edition (2007).
2. Operations Research: An Introduction by HamdiTaha, Pearson; 9th edition (2010).
3. A Circular Economy Handbook for Business and Supply Chains By C. Weetman, KoganPage; 1st edition (2016).

Machine learning for process system engineering (1 credit):

Introduction to ML: Supervised Learning (ANN/Surrogate Optimization) & Unsupervised Learning (Clustering). Process Systems Engineering deals with the process design for the purpose of converting raw goods to usable end products and focuses on the design, operation, control, optimization and intensification of several processes such as chemical, physical, and biological, waste management, climate change etc.

. PSE examples/Assignments
a. ANN/Optimization toolboxes (Matlab/R)

Reference:

1. Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow by Aurelien Geron.

6.

Semester 2: Elective Courses

Life Cycle Analysis in Waste Management and Resource Recovery (2 credits)

Waste Management in transition. Material flow analysis – energy balance - Environmental Impact of Processing waste – health effects – key issues and challenges – quantity and quality assessment. Life cycle impact analysis - reuse and recycle – metal recovery processes – plastics recovery options – secondary and tertiary contamination – water, air and land – challenges and opportunities. Lifetime of recovered substances – use of secondary plastics in products –- product lifetime extension – theory to practice – feasibility assessment - supply chain in its applications.

References

Surjya Narayana Pati, Life Cycle Assessment Future Challenges, CRC Press 2022

Guido Sonnemann Francesc Castells Marta Schuhmacher, Integrated Life-Cycle And Risk Assessment For Industrial Processes, CRC publications, 2004

Jawad Khan, Electronic waste management – Alife cycle approach applicable to e-waste, Lambert Publications, 2022

Florin-Constantin Mihai, E-Waste In Transition - From Pollution to Resource 2016

Molecular Thermodynamics (2 credits):

Introductory Probability, Quick Glance on Thermodynamics: Relooking the Basics with Applications, Extremum Conditions, Free Energy & Entropy, 3rd Law & Boltzmann Distribution, Simple Gasses, Temperature & Heat Capacity, Solutions, Different Ensembles, Dynamics & Fluctuations, Example Applications.

Reference:

1. Molecular Driving Forces, Dill & Bromberg, 2nd Ed., 2011, CRC Press.
2. Thermodynamics & Statistical Mechanics, M. Scott Shell, 2015, Cambridge University Press.

3. Other Relevant Books: a] Huang, b] Kardar, c] Stowe, d] Widom, e] Reif

Global Government policies on E-waste management and Business calculations (3 credits):

Policy trends of e-waste management in Asia:China, India, Japan, Bangladesh, Pakistan, Malaysia, Thailand, Vietnam; Updated policies on E-waste management in India;

E-waste Management in East Africa Community: Uganda, Kenya, Tanzania, Rwanda and Burundi; E-waste management in Sub-Saharan Africa

E-Waste Management in Americas: United States, Canada, Latin America; European regulation of electronic waste management; E-Waste Management in Oceania

Energy Considerations and Economic Incentives for Recycling and Resource Recovery;Evaluating and Managing Financial Performance;

Capital expenses: Land, Plant and Machinery; Installation and Commissioning of Equipment and/or Process;

Operational expenses: Human resource, Raw Material, E-Waste for Recycling, Utilities, Logistics, Marketing, Contingency, Spares and consumables;

Revenue calculation for recycling of different Waste Electrical and Electronic Equipment (WEEE): Resource economics

Reference:

1. Handbook of Electronic Waste Management: International Best Practices and Case Studies 1st EditionEds. MajetiNarasimhaVara Prasad, MeththikaVithanage, AnweshaBorthakur
2. E- Waste (Management) Amendment Rules, 2016 & 2018
3. Small Business Management: Launching and Growing New Ventures by Justin GooderlLongenecker

Instrumentation for efficient recycling and automation (3 credits):

Basic principles of instrumentation, automation. Definition, principles of sensing and transduction, classification, Mechanical and Electromechanical sensors, Capacitive sensors, Tachometers, piezoelectric effects, Industrial weighing systems, Thermal sensors – types and principles, Magnetic sensors, radiation detectors, smart sensors,; measurement of flow

Introduction to Analytical Instrumentation: Classification, types of Instrumental methods Measurement of Humidity, moisture, viscosity, density; Oxygen Analysis, Liquid analysis: ion selective electrodes, Ph electrode, polarography, colorimetry, Fire assay

Introduction to plant machinery for Efficient approaches for resource recovery; disassembly, automation: imaging, recognition, robotics, laser, IR heating desoldering, pulse ejection; self-disassembly; segregation line: automation, Depopulation systems, rotary, vibrational, principles, machinery; Comminution systems-shredder, crusher, ball mill, hammer mill, planetary mill.

Separators: Vibrational screens, density separators, electrostatic separator- types, magnetic separator, cyclone separator, bag filters

Integrated mechanical processing line: Weighing, classification (removal of hazardous substance WEEE directive), dismantling, depopulation, shredding, crushing, plastic recovery, classifiers, metal recovery

Pyrometallurgy processing machinery: Types of furnaces:electrical- resistive, microwave and induction furnaces, Gas fired furnace – bottom fired, top blown; industrial smelters – principles, copper smelter, zinc smelter, blast furnace, kaldo furnace, rotary furnace. Anode casting furnace, furnaces for pure metals, gasifier, incinerator

Hydrometallurgy processing machinery: Leaching systems, Chemical reactors, Precipitation systems, Types of solvent extraction systems, Ion exchange, Types filtration systems-principle, Filtration, Precipitation, Solvent extraction, Rectifier, Electro refining/winning machinery.

Effluent treatment: Scrubber, wet scrubber, dry scrubber, bag filter, gas cleaning system for dioxins and furans as per CPCB guidelines, liquid effluents, land filling..

Reference:

1. Principles of Industrial Instrumentation, D. Patranabis, TMH New Delhi
2. D Patranabis, Sensors and Transducers, PHI, 2nd ed.
3. E. A. Doebelin, Measurement Systems: Application and Design Mc Graw Hill, New York
4. H. K. P. Neubert, Instrument Transducers, Oxford University Press, London and Calcutta
5. Combustion Engineering and fuel technology, A.K.Shaha,Oxford and IBH Publ. Co. Calcutta,1974
6. Mineral Processing Technology by Barry A. Wills
7. The Complete Technology Book on E-Waste Recycling, Asia Pacific Business Press Inc, 2018
8. Principles of Industrial Instrumentation- D.C. Patranabis, Publisher: Tata McGraw Hill
9. Principles of Instrumental Analysis- Skoog, Holler, Nieman, Publisher: Thomson Brooks/Cole.