INDIAN INSTITUTE OF TECHNOLOGY GANDHINAGAR

Norms for e-Masters Programme in Industrial Safety Engineering

(As approved by the Senate in its 61st meeting held on 15th November 2022)

Overall Structure of the Programme:
[Approx. 10 full course equivalents of 4 credits, 1 credit equivalent to 10 hrs.]
[Min. 400 hrs of engagement required for e-Master's degree]

No.	Course Title	Type	Credits	Engagement (h)
1	Process Principles and Calculations	Foundation	4	40
2	Basic Topics of Engineering	Foundation	4	40
3	Hazard Identification and Risk Assessment	Core	4	40
4	Chemical Process Safety and Management	Core	4	40
5	Fire Protection and Emergency Response	Core	4	40
6	Industrial Safety & Health Legislations	Core	4	40
7	Industrial Hygiene & Occupational Safety	Core	4	40
8	Electrical and Maintenance Safety	Core	4	40
9	Accident Investigation and Forensics	Core	2	20
10	Sustainable Environment	Core	2	20
11	Economics of Safety	Core	2	20
12	Emerging Technologies in Safety Engineering	Core	2	20
13	Behavioral Safety	Core	2	20
14	Capstone Project 1	Core	4	40
15	Capstone Project 2	Core	4	40
16	Writing & Leadership	HSS	4	40
	Total		54	540

Break-up of courses:

Course Type	List of Courses from the Program Structure	Engagement (h)
Foundation (8 Credits)	(1) Process Principles and Calculations (2) Basic Topics of Engineering	80
Core (42 Credits) [6 Courses with 40 h each (24 Credits) and 5 Courses with 20 h each (10 Credits) and One Capstone project (4 credits]	(1) Hazard Identification and Risk Assessment, (2) Chemical Process Safety and Management, (3) Fire Protection and Emergency Response, (4) Industrial Safety & Health Legislation, (5) Industrial Hygiene & Occupational Safety, (6) Electrical and Maintenance Safety (7) Industrial Accident Investigation and Forensics, (8) Sustainable Environment, (9) Economics of Safety	420

	(10) Emerging Technologies in Safety Engineering (11) Behavioral Safety (12 & 13) Two Capstone Project Courses	
Communication/Leadership (4 Credits)	(1) Writing & Leadership	40
Total 54 Credits	**Total Engagement (h)**	**540**

Course contents:

1. **Process Principles & Calculations [40 h of Engagement]**

Course Objective: It is a foundational course. At the end of the course, the student will refresh and rebuild the fundamentals in the domain, develop basic problem-solving skills, and know the various processes, principles and operations in the industries covering mass transfer, heat transfer and reaction, including key separation processes.

Course Content:
Unit conversions, Stoichiometry; material and energy balances; multiphase process, material and energy balances with chemical reactions; purge and recycle; thermophysics and thermochemistry; first law of thermodynamics and its applications, Energy calculation for industrial operations, Basics of Mass Transfer, Heat Transfer operation and Reaction Engineering; Basics of key separation processes in industries such as Gas absorption, Distillation, Drying, Humidification operations, Crystallization etc.

Mode of conduct: The course will have lectures followed by practice problems covering various processes. Students will solve problems through assignments and discuss various case studies in problem-solving sessions on mass balance and energy calculations. The course will have quizzes and semester exam.

References:

i. Elementary Principles of Chemical processes, Felder, R. M. and Rousseau, Ronald W., New Delhi: Wiley India., 2000
ii. Unit Operations of Chemical Engineering, McCabe, Warren L, Harriott, Peter, Smith, Julian C., Boston: McGraw-Hill Higher Education, 2005

2. **Basic Topics of Engineering [40 h of Engagement]**

Course Objective: A foundational course to refresh the basics topics of engineering including probability, statistics and data handling. At the end of the course, the student will refresh the basic topics in Engineering including hydraulics and compression, instrument calibration and measurements, fatigues in metals, thermodynamics, process control, various transport processes.

Course Content:
Engineering data; Elementary probability and statistics (random variables, distribution, central limit theorem); population sampling, confidence intervals; Basics of Transport

Phenomena Unidirectional flows: steady and unsteady; Governing equations of heat transfer Governing equations of mass transfer Basics of phase equilibrium, Ideal Solutions Raoult's Law, Henry's law, Vapor - Liquid - Equilibrium. Non-ideal solutions; . Basics of Process Control, Basics of machine tools, Hydraulics and pneumatics comparison, Pressure, Flow and direction control valves; Temp & pressure compensation; Actuators accumulators and intensifiers; Process parameter measurements and calibration of various instruments, Corrosion and its influence by various environmental factors, Fatigue of metals – Stress cycle, S-N curve, cyclic stress-strain curve, fatigue crack propagation, effect of metallurgical variables, corrosion fatigue; creep and stress rupture, superplasticity, fracture at elevated temperature; Properties of concrete and reinforcing steel, design philosophies

Mode of conduct: The course will have lectures followed by practice problems covering various processes. Students will solve problems through assignments. The course will have quizzes and semester exam.

References:

i. Applied Statistics and Probability for Engineers, Douglas C. Montgomery, G. C. Runger, , John Wiley and Sons, 2003.
ii. Transport Phenomena, Bird, R. B., Stewart, W.E. and Lightfoot, E.N., 2nd ed., Wiley, 2006
iii. Introduction to Chemical Engineering Thermodynamics, Smith, J.M. , Van Ness H.C. and Abbott, M.M. 6th ed., McGraw-Hill, 2001.
iv. Chemical Process Control: An Introduction to Theory and Practice, Stephanopoulos, G. Prentice Hall, New Delhi, 1984

3. Hazard Identification and Risk Assessment [40 h of Engagement]

Course Objective: The student will learn to identify Hazard, HAZOP studies, and risk and consequence analysis through risk assessment using various failure mode analyses. The student will also learn Quantitative Risk Analysis hands-on.

Course Content: Hazards Identification, Methodology for carrying out a HAZID, HAZID application, Process Hazards Checklists, Hazards Surveys, Hazards and Operability Studies (HAZOP), HAZOP exercise, Safety reviews and Major accident Hazard scenarios, Dow index, Mond's index, Consequence analysis, frequency, Risk Analysis, and estimation, Bow tie analysis, tolerability and acceptability, risk perception, Risk Assessment & Risk Reduction, Common Mode Failures, Failure Mode and Equipment Analysis (FMEA study), Event Trees, Fault Trees, Quantitative calculations using the Fault Tree, Quantitative Risk Analysis (QRA) and Layer of Protection Analysis (LOPA), Developing scenario for LOPA and risk decision using LOPA, Safety Instrumented Systems (SIS), Related software and hands-on

Mode of conduct: The course will have lectures and followed by case studies and group discussion. Students are going to do QRA and solve problems through assignments. The course will have quizzes and semester exam.

References:

i. Layer of protection analysis: simplified process risk assessment: Series: A CCPS concept book, by Center for Chemical Process Safety (CCPS), New York: John Wiley & Sons, 2001
ii. Guidelines for chemical process quantitative risk analysis, 2nd ed. by Center for Chemical Process Safety (CCPS), New York John Wiley & Sons 2000
iii. Evaluating process safety in the chemical industry: a user`s guide to quantitative risk analysis : Series: A CCPS concept book by Arendt, J. S, Lorenzo, D. K., New York John Wiley & Sons 2000

4. Chemical Process Safety and Management [40 h of Engagement]

Course Objective: The course will cover the elements of Process Safety Management and inherently safer design. The student will learn the fundamentals of runaway reactions and aspects of reactor safety, including handling, storage, and transportation of reactive chemicals, petroleum products, dust etc. The student will learn various National and International guidelines on compliance.

Course Content: Hazardous and reactive chemicals, reactor safety and runaway reaction, Toxic release and various dispersion models at various scenario, inherently safer design, Relief Scenarios and its design considerations, Relief Sizing, Fire and explosion, Domino effect, Vapor Cloud Explosions, Flash Fires, and BLEVEs, Case studies. Safety in storage and transportation of petroleum products, underground storages, loading and unloading, venting and relief, atmospheric vent, flame arrestors, fire relief - fire prevention. Dust explosion and various explosibility characteristics, Dust ignition sources – Dust explosion prevention and protection.
Elements of Process Safety Management - Guidelines for Compliance (OSHA 3133), OISD guidelines, Process Safety Management (PSM) system implementation and its actual process safety performance. Guidelines for plant commissioning, inspection and operations, Review of International safety audits, safety audit report

Mode of conduct: The course will have regular lectures and case studies will be discussed in the class along with some design problems. The students are going to take assignments and quizzes, along with the semester exams.

References:

i. Chemical Process Safety: Fundamentals with applications, Daniel A. Crowl, Joseph F. Louvar, Upper Saddle River, NJ Prentice Hall 2011
ii. Lees` Loss Prevention in the Process Industries: hazard identification, assessment and control, edited by Sam Mannan, Oxford Butterworths Heinemann 2012
iii. Guidelines for Process Safety Fundamentals in general Plant Operations, Center for Chemical Process Safety, by Center for Chemical Process Safety, New York : American Institute of Chemical Engineers, 1995

5. Fire Protection and Emergency Response [40 h of Engagement]

Course Objective: The course will provide design aspects and fundamentals of Fire Science. It will also provide a guideline and good practices for emergency preparedness for industrial disasters.

Course Content: Fires and Explosions, Detonation and Deflagration, Fire Triangle, Flammability diagram and characteristics of liquids and vapors and its mixtures, ignition, autoignition, auto-oxidation, Alarm and detection systems, Principles of fire suppression for various class of fire, active and passive fire protection systems, Fire hydrant and Hydraulic calculation, foam generators, Sprays and Mists, Confined Explosions, TNT equivalent and Blast damage due to overpressure, Structures under fires, Design aspects to prevent fires and explosions, Inserting and purging, advanced firefighting technics and media, Designs for preventing fires and explosions.
Emergency and disaster planning (onsite and offsite - natural / man-made), roles and responsibility and communications in emergency, rescue, relief and rehabilitation plan, mitigation, preparedness and evacuation plan, critical equipment handling, Various codes and standards related to fire, adequacy check.

Mode of conduct: The course will have regular lectures and followed by case studies and group discussion. Students are going to solve assignment problems. The course will have quizzes and semester exam.

References:

i. Principles of Fire Behavior by Quintiere, James G., New York: Delmar Cengage Learning, 1998
ii. Handbook of fire and explosion protection engineering principles : for oil, gas, chemical and related facilities by Dennis P. Nolan., Westwood, N.J: Noyes Publications, 1996
iii. Engineering analysis of fires and explosions by Randall K. Noon, Boca Raton CRC Press c1995

6. Industrial Safety & Health Legislations [40 h of engagement]

Course Objective: The student will learn factories act and other legislation related to Industrial safety. Also, it will provide the OSHA, National and International conventions, including ILO.

Course Content: ILO convention and recommendation, manufacture storage and import of hazardous chemical rules, 1989, Factories act and rules, OHSAS, 18001, national policy on occupational safety health and environment at workplace, the factories act, 1948, air (prevention & control of pollution) act, 1981 and amended, 1986, water (prevention & control of pollution) act, 1974 an rules, Indian explosive act, Indian petroleum act and rules, Environmental pollution act, Indian Electricity act and rules, workmen's compensation acts, 1923, the employee's state insurance act, 1948, the mines act, 1952 and rules, the dockworkers act, 1986 and the dockworkers regulations, 1990, Employees' Compensation Act, Explosives Act, Water Act and Air Act, Overview of ISO45001 and ISO 14000, OISD guidelines, Contract Labor Act and Central Rules-Registration of Establishments, Licensing of Contractors, Welfare and Health provisions in the Act and the Rules, Penalties, Rules regarding wages.

Mode of conduct: The course will have lectures, case studies and group discussion. The course project will be designed based on various scenarios and presentation will be evaluated. In addition, there will be quiz.

References:

i. Factories Act, 1948.
ii. Explosives Act and related Rules.
iii. Petroleum Act and Rules.
iv. Environmental Acts & relevant Rules

7. **Industrial Hygiene Occupational Safety [40 h of Engagement]**

Course Objective: The course will expose the students to industrial exposure and its health effects. The student will be able to analyse physical, chemical and biological hazards associated with occupational health and maintain industrial hygiene.
Course Content: Physical Hazards, Chemical hazards, Biological and Ergonomic hazards, Occupational health and toxicology, Occupational physiology, Threshold Limit Value (TLV), Hazards of VOC's and control measures, Biological indicators of chemical dosage and monitoring, Body defense mechanism to toxicant exposure - membrane defenses and non-membrane defenses, Occupational and work-related diseases, Notifiable occupational diseases and its effects and prevention. Industrial toxicology. Local and systemic effects. Chronic and acute effects. Chemical hazards: dust, fume, gas etc. Recognition of chemical hazards. Controlled work environment, prevention and mitigation of accidental chemical releases, General methods for the control of airborne hazards, dilution ventilation, Local exhaust ventilation, monitoring, and troubleshooting of existing ventilation systems, personal protective clothing, respiratory protection.
Mode of Conduct: The course will have lectures, case studies and group discussion. The course project will be designed based on various scenarios and presentation will be evaluated. In addition, there will be quizzes / semester exam.
References:
i. Patty's Industrial Hygiene and Toxicology, Volume III, Lewis J. Cralley & Lester V. Cralley, Second edition, John Wiley & Sons, New York, 1985.
ii. Chemical Process Safety: Fundamentals with applications, Daniel A. Crowl, Joseph F. Louvar, Upper Saddle River, NJ Prentice Hall 2011
iii. Fundamentals of Industrial Hygiene by Barbara A. Plog and Patricia J. Quinlan, 6th Edition, National Safety Council, USA, 2012.

8. Electrical and Maintenance Safety [40 h of engagement]

Course Objective: The course will cover the fundamentals of electrical safety and safety during maintenance work in the industry. The student will be able to assess electrical and maintenance risks associated with various areas of the industry and plan mitigation strategies.

Course Content: Static charge, charge accumulation, energy from electrostatic discharges, electrostatic ignition sources, electrostatic voltage drops, charged capacitors, controlling static electricity, design consideration to prevent electrostatic ignitions, electrical safety hazards, safety precautions of various electrical devices, grounding, protection system using fuse, circuit breakers and overload relays, overload and short circuit protection-no load protection, earth fault protection, grounding-equipment, safety in handling hand held electrical appliances tools and medical equipments. Electrical safety in extreme weather conditions, protection from dirt & water as IEC standard, electrical hazard and statutory requirements, overview of Indian Electricity rules of safety, standard safety procedures for electrical equipment, classification of hazardous zones -intrinsically safe and explosion-proof electrical

apparatus (IS, API and OSHA standard); Safety in operation and maintenance of equipment at the construction site, risk associated with construction and maintenance work, access and working in confined space, works at height, plant maintenance, modification and emergency planning; reliability engineering and OEM management.

Mode of conduct: The course will have lectures and followed by case studies and group discussion. Students are going to do solve problems through assignments. The course will have quizzes and semester exam.

References:

i. Electrical Safety Handbook, 4th Edition, John Cadick, Mary Capelli-Schellpfeffer, Dennis Neitzel, Al Winfield, McGraw-Hill Education, (2012)
ii. Principles of Electrical Safety (IEEE Press Series on Power and Energy Systems), Peter E. Sutherland, Wiley-IEEE Press (2015)
iii. Industrial Safety and Maintenance Management, M.P. Poonia, S.C. Sharma, Khanna Publishing House (2018)

9. Industrial Accident Investigation and Forensics [20 h of engagement]

Course Objective: The course will provide basic strategy to investigate industrial accidents and various forensic techniques to evaluate the cause of incidents. Analyzing various data and preparing investigation report.

Course Content: Incident reporting, Accident investigations, route cause analysis, Learning from accidents, Investigation process, Interviewing and analysis techniques, team and planning, workflow and stages in an accident/incident investigation, loss pattern, collection of evidence, Interviewing the person(s) involved and witnesses, type of injury and illness, causality, site visit and critical observations, recognition of evidence and organize the evidence, time and event sequence, cause and analysis, human factor, Pre and post-accident management, analysis of organizational safety culture, documentation, Investigation summary, diagnosis aids, Fires, explosions and sources of ignition, Pressure effects, medical evidence, aids for recommendations, developing the recommendation, ethical issues and insurance aspects, Case studies, Use of risk assessment methods in the investigation

Mode of conduct: The course will have lectures and followed by case studies and group discussion. Students are going to do QRA and solve problems through assignments. The course will have quizzes and semester exam.

References:

i. Accident Investigation Techniques: Basic Theories, Analytical Methods, and Applications, Jeffrey S. Oakley, Amer Society of Safety Engineers (2003)
ii. Accidents: Causes, Investigation and Prevention, James Thornhill, Ingram short title (2011)
iii. Modern Accident Investigation and Analysis, 2nd Edition, Ted S. Ferry, Wiley (2007)

10. Sustainable Environment [20 h of Engagement]

Course Objective: The students will be exposed to environmental impact assessment and its implication for the environment and community. It will enable students to prepare mitigation and management plan, including rehabilitation.
Course Content: Environmental Impact Assessment (EIA) in project lifecycle and report

preparation, legal and regulatory aspects, Impact identification and prediction, Prediction tools for EIA, Assessment of impacts – air, water, soil, noise, biological — cumulative Impact Assessment. ISO 14000, Social impact assessment and implication on community, communities in transition, environmental management plan, mitigation and rehabilitation plans, ethical and quality aspects of Environmental Impact Assessment, Case studies with examples from Air pollution, Water pollution and Hazardous waste Management, Sustainability reporting

Mode of conduct: The course will have lectures and followed by case studies and group discussion. The course project will be designed to cover various aspects of sustainability and used for evaluation. The assignment will be designed such that student can identify an area in their neighborhood and perform environmental impact assessment and present the findings in the class. In addition, there will be normal assignment and quizzes.

References:

i. Environmental Impact Assessment, Canter, L.W., McGraw Hill, New York. 1996
ii. Environmental Impact Assessment – Practical solutions to recurrent problems, Lawrence, D.P., Wiley-Interscience, New Jersey. 2003

11. Economics of Safety [20 h of Engagement]

Course Objective: The student will learn cost and economic aspects of safety. The course will provide perspective of productivity against cost of safety. The course will expose the student to various techniques to evaluate the cost of safety in various risk level.

Course Content: Productivity and Safety, Operational Risk, Operational Safety and Economics, Economic Assessment Techniques, Decision-making Processes for Investing in Safety, Safety Demand and Long-term Average Cost of Production, Safety Value Function, Expected Value Theory, Value at Risk, and Safety Attitude, Safety Utilities, Preferences of Safety Management – Safety Indifference Curves, Budget Constraint and n-Dimensional Maximization Problem Formulation, Safety and Profitability, Methods for influencing safety level,

Mode of conduct: The course will have lectures and case studies and group discussion. Student will be evaluated based on Project and presentation which will be designed such that it involves identification of various accidents and cost evaluation and economic aspect of the accident. In addition, there will be scenario based assignments and quizzes.

References:

i. Cost-Benefit Analysis, Edited by Richard Layard and Stephen Glaister, Cambridge University Press (1994)
ii. The Economics of Safety and Physical Risk, Jones - Lee, Wiley–Blackwell (1989)
iii. Preventing Industrial Accidents, Carsten Busch, Routledge (2021)
iv. Operational Safety Economics by Genserik L. L. Reniers, H. R. Noel Van Erp, Wiley, (2016)

12. Emerging Technologies in Safety Engineering [20 h of Engagement]

Course Objective: The student will learn various advanced technologies and its application in improving industrial safety. The course will explore the implementations of some of the advanced and emerging technologies and its benefit in safety applications to improve workplace safety, including public safety in general.

Course Content: Mapping technology solutions for workplace safety, Overview of various technologies and its possible of application in Safety Engineering. Some of the technologies (but not limited) - Robotics and automation, wearables and smart PPE, Artificial intelligence, Machine Learning, Computer Vision, Deep Learning, Computational Photography, Real-time data analysis and process monitoring, Big Data and accident prediction, Eye tracking in industrial operation, Virtual Reality, Sensor Technology, Various Simulators, GPS, Mobile and Drone technology, Real-time video feeds through 5G and prediction on critical incidents, 5G facilitated information access and exchange for emergency responses.

Mode of conduct: The course will have lectures and case studies and group discussions. Experts from various technology will provide lectures and demonstrations (wherever possible). The student will be asked to prepare the project, followed by a presentation on the use case of different technologies for different safety solutions. The student will be evaluated based on the course project and presentation, including any prototype preparation. In addition, there will be assignments on applications of various technologies.

References:

i. Workplace Safety Futures: The impact of emerging technologies and platforms on work health and safety and workers' compensation over the next 20 years, Horton J, Cameron A, Devaraj D, Hanson RT, Hajkowicz SA, CSIRO, Canberra (2018).
ii. Safety Technology 2020: Mapping Technology Solutions for Reducing Serious Injuries and Fatalities in the Workplace, National Safety Council (2019).

13. Behavioral Safety [20 h of Engagement]

Course Objective: The student will learn the impact of behavior on the industrial incident. The course will expose the student to various safe and unsafe behavior and its implication for industrial safety.

Course Content: Behaviors and attitudes, positive and negative reinforcement as well as antecedents, implementation of safe behavior program, behavior-based safety practices in industry, different roles and responsibilities among employee, factors cause incidents, the influence of behavior on incidents, unsafe acts and unsafe conditions, behaviors and attitudes towards safety, the theory behavior modification, positive reinforcement, components of a behavioral safety program and the behavioral safety observation, implementation of behavior based safety practices.

Mode of conduct: The course will have lectures and case studies and group discussion. Student will be evaluated based on Project and presentation which will be designed such that it involves identification of unsafe environments and come up with solutions (based on behavioral aspects) to turn them into safe environments. In addition, there will be scenario based assignments and quizzes.

References:

i. Behavioral Safety: A Framework for Success, Dominic Cooper, BSMS; 1st edition (September, 22, 2009)
ii. A Definitive Guide to Behavioural Safety, Tim Marsh, Routledge, 2017
iii. The Behavior-Based Safety Process: Managing Involvement for an Injury-Free Culture, Thomas R. Krause, Wiley; 2nd edition (1996)

14. Two Capstone Projects on Safety Engineering [Semester/Module long Engagement: 8 Credits]

Course Objective: The project course will expose the student to solving a small problem by applying the fundamentals covered in various courses. It may require data generation/data collection, modeling, analysis, and hypothesis validation.

Course Content: Students will work on various safety engineering topics and present at the semester's or module's end. They will meet faculty members separately during the semester for their project course. Students will also be encouraged to use some lab facilities during their visit to the IITGN campus.

Mode of conduct: The student should be connected with faculty members for regular progress of the project through multiple discussion session throughout the semester. They should present the progress and get evaluated during mid semester as well as end semester. In addition to the presentation, student should prepare a project report and submit the it before end semester evaluation.

15. Writing & Leadership

Course Objective: The student will develop professional writing skills and leadership qualities

Course Content: Existing Institute course modules

Mode of conduct: To be added

References: To be added