Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MNO302	Sea Bed Mining and Asteroid Mining	3	0	0	9

MODULE I : SEA BED MINING (2-0-0)

Course Objective

In order to meet the ever changing technological, social and economic demands of Indian and Global mineral industry, this innovative and futuristic course in Mining is focused mainly in the non-conventional areas such as deep sea mining or ocean mining, asteroid mining, mining of rare earth elements from beach sand and rock dredging for port deepening. The objective is mainly to address the rising demand for strategic and scarce minerals/metals, dwindling mineral resources on land as well as rising concerns on environmental impacts/climate change. This is also in line with the inter-disciplinary courses recommended under new National Education Policy 2020 of Govt. of India.

Course Outcomes

Students will learn the new frontiers of mining of minerals and metals which are scarce on land. They will also appreciate the advanced technologies such as vertical lift systems, underwater robotics, environmental impacts and mitigation. An interdisciplinary thought process will also be inculcated.

Unit No.	Topics to be Covered	Lecture Hours	Teaching Dept.	Learning Outcome
Deep Sea Mining				
1.	Introduction and value chain, Mining Potential: Reserves and Life (Global and Indian)	1	MNE	Various geological processes, mineral resources, mining potential and legal aspects.
2.	Legal Framework for deep sea and placer mining, Social Perspective,	1	MNE	
4.	Geological aspects: Morphology of Ocean floor, Data acquisition and evaluation, Genesis, Types, Composition, Minerals, Beneficiation capacity	2	AGL	
5.	Exploration: Methods, Limitations, Analysis of Data for Feasibility	2	AGP	
6.	Capacity in deep sea mining technology: Organisations; Exploitation: Equipment and Methods; Limitations	2	MNE	Technological, Economic and safety aspects of Deep sea mining, including recent advances.
7.	Economics: Costs of exploration and Extraction; Mining Safety Risks and Mitigation	1	MNE	
8.	Advances in deep sea mining Methodologies for resource potential assessment, 3D modelling, strategic mine planning and mining systems, Hyperbaric cutting of rock, Vertical hydraulic transport of solid particles, Processing of marine minerals, Applied mineralogy and its link to mineral processing with special reference to marine minerals, Underwater Robotics	3	MNE	
9.	Robotic Applications: Introduction to mining robots, Underwater Arm forward and Inverse kinematics. Control of robotic arms with external disturbances, Introduction to Industry 4.0 Simulation and Modelling: Vertical Lift, Plume dissipation	3	ME	Remote operation procedures including robotics.
Placer Mining and Rock Dredging				
10.	Placer Mining: Introduction, Industrial Applications, Mining Methods	2	MNE	Geological and mining aspects covering placer mining and rock dredging for sea bed deepening.
11.	Geological processes, Exploration	1	AGL	
12.	Introduction, Need and Importance, Port deepen-	1	MNE	

Unit No.	Topics to be Covered	Lecture Hours	Teaching Dept.	Learning Outcome
	ing and Widening, Geotechnical characterization			
13.	Underwater drilling and blasting systems: Design and Execution, Dredging systems and Equipment	2	MNE	
14.	Mechanical cutting using drum cutters	1	MNE	
15.	Processing: Methods for ¾ metal extraction for deep sea minerals Mineral Separation Plant, Tailing Disposal, Land Reclamation and Rehabilitation for beach placers	3	FMME	Mineral processing and environmental aspects governing placer and sea bed mining.
16.	Environmental impacts and control measures for deep sea and placer mining.	3	MNE	

Books

1. Deep-Sea Mining: Resource Potential, Technical and Environmental Considerations, Editors: Sharma, Rahul (Ed.)
2. Deep Sea Mining and the Law of the Sea by Alexandra Merle Post
3. Deep Marine Mineral Resources: Editors: Fouquet, Yves, Lacroix, Denis (Eds.)
4. Handbook of Placer Mineral Deposits, G. Victor Rajamanickam, New Academic Publishers, 2001 - Placer deposits

Reference Books

1. Handbook of Marine Mineral Deposits, Edited By David Spencer Cronan
2. The Indian Ocean Nodule Field, 2nd Edition: Geology and Resource Potential, Authors:R. Mukhopadhyay Anil Kumar Ghosh Sridhar Iyer
3. Ocean Floor Mining (Ocean Technology Review), December 1975, by John S. Pearson

MODULE II : ASTEROID MINING (1-0-0)

Course Objective
With ever-growing world economy and technology, the mental resources to develop modern technologies and industries could be depleted in the next 40-50 years. Besides meeting the metal demands for Technology, the Asteroid Mining is expected to play a key role in Space Industrialization which is high on the agenda of human development. The objective of the course is to introduce Asteroid Mining in the course curriculum of IIT-ISM.

Learning Outcomes
Upon successful completion of this course, the students will be able to develop a deeper understanding about the space resources in general and Asteroids in particular. Different types of Asteroids, their tracking, exploration and exploitation techniques, environmental and safety aspects, and international laws governing the exploration and exploitation of space resources. Miner Operation etc.

Unit no.	Topics to be covered	Lecture Hours	Teaching Deptt.	Learning Outcome
1	Introduction to Asteroid Mining: • Fundamentals of Space Resources and Space Technology. • What are Asteroid? Types of Asteroids, Physical Properties of Asteroids etc. • Asteroid Mining: Advantages and disadvantages • Space operations for Asteroid Mining • Economics of Asteroid mining.	2	MNE	The students will be exposed to the fundamentals of space resources in general and Asteroid Mining.

Unit no.	Topics to be covered	Lecture Hours	Teaching Deptt.	Learning Outcome
2	Knowing more about Asteroids: • Planetary Geo-Physics • Geology of Asteroids • Geo-chemistry and geo-mechanics of Asteroids • Tracking and targeting of Asteroids • Remote Sensing Techniques to know about the Asteroids: Spectrophotometry, Radiometry, Spectro Polarimetry, Hyperspectral Imaging, Thermal Modelling. • Modelling of Asteroid Resources.	4 (1+3)	AGL/ AGP	The students will be exposed to the basic principles of planetary geophysics, geology, geochemistry, physical and mechanical properties of Asteroids. The students would also expose to few techniques of tracking of Asteroids and modelling of resources of Asteroids.
3	Mining of Asteroids: • Targeting of Asteroids • Mining and Processing of Asteroids: Tether anchoring to the asteroid, Asteroid motion control, Body/fragment restraint system placement, Operations platform construction, Bag construction, Auxiliary and support equipment placement, Mining operations, Processing operations, Product transport to markets. • Mining Infrastructure in the space (includes Machinery and Instrumentation) • Economic Feasibility	3	MNE	The students will be exposed to the mining techniques and mining infrastructures for Asteroid Mining.
4	Automations and Robotics for mining in space • Introduction to Remote Manipulator System and Serial chain robots. • Challenges to robotics arm used for space exploration and asteroid mining. • Introduction to Remotely Operated Vehicle (ROV) for space.	2	ME	The students will be able to know about the Robotics and Automation aspects of Asteroid Mining.
5	Environmental and safety aspects of Asteroid Mining	1	MNE	The students will be exposed Environmental and safety issues related with Asteroid Mining
6	Legal and ethical considerations of Asteroid Mining: 3. Regulatory framework for mining in space: International Space Laws 4. Ethical issues associated with Asteroid Mining	2	MNE	The students will be exposed to Regulations (Local and International) and Ethical Aspects of Asteroid Mining.

Text Books and Periodicals

1) Asteroid Mining 101 – Wealth for New Space Economy by John S Lewis
2) Space Mining and Manufacturing by David Sivolella