CENTRAL UNIVERSITY OF PUNJAB

M. Sc. Geology

(Two Years)

3 semester Course work and one Semester of Research (3 + 1)

Batch 2025 - 2027

Department of Geology

School of Environment and Earth Sciences

Graduate Attributes

The graduates of this MSc Geology program will develop deep level of disciplinary knowledge and ability to apply/practice this knowledge in multidisciplinary or multi-professional context to tackle the future challenges. They will be able to acquire, analyze and interpret data generated from the laboratory or field, and can decipher the result to the scientific community. Graduates shall be capable of expanding their knowledge boundary through research and training; and take lead in cross-disciplinary studies. After completion of these programs, graduates will possess critical, creative and evidence-based thinking to solve local/regional/global problems; attain good communication skills and professionalism with ethical competency to work individually as well as in a team; will be capable enough to become an efficient entrepreneur and to take up leadership role. Additionally, they will be self-aware about the recent developments and emerging challenges; and to be a responsible global citizen. Graduates will be competent and technically adept geoscientists for building careers in research, teaching, government, industry and non-governmental organizations.

Program Outcomes

M.Sc. geology program provides the holistic knowledge about the Earth System Science and its relationship with other branches of science. Thus, by studying this program, students are prepared to pursue higher research in different field of geosciences. The program also makes them ready to prepare for different National and International level competitive examination for different scientific, professions and other posts related to civil and administration, etc. This program trains the students to be ready to become a professional geologist, to assume in different responsible positions in industry or in government agencies; to serve as academician; to pursue research as a career at universities and certain scientific organizations of Nation and International level; and further to become a global citizen.

Course Structure of the M.Sc. Geology Program with 3 semester Course work and one Semester of Research (3 + 1)

Semester – I

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.401	Mineralogy and Crystallography	*Discipline Specific Core*	3	0	0	3
MEGS.402	Mineralogy and Crystallography (Practical)	*Practical / Skill based*	0	0	4	2
MEGS.403	Structural Geology and Geotectonics	*Discipline Specific Core*	3	0	0	3
MEGS.404	Structural Geology (Practical)	*Practical / Skill based*	0	0	2	1
MEGS.405	Applied Paleontology	*Discipline Specific Core*	3	0	0	3
MEGS.406	Applied Paleontology (Practical)	*Practical / Skill based*	0	0	2	1
MEGS.407	Geological Time and Stratigraphy	*Discipline Specific Core*	3	0	0	3
MEGS.596	Field Training	*Ability Enhancement*	0	0	4	2
	Tutorial	*Remedial class*	0	2	0	0
Select any one from the following Discipline Elective course$						
MEGS.408	Geomorphology	*Discipline Elective*	3	0	0	3
MEGS.409	Natural Resource Management		3	0	0	3
MEGS.410	Meteorites & Planetary Sciences		3	0	0	3
		Total	**15**	**2**	**12**	**21**

Semester-II

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.411	Igneous and Metamorphic Petrology	*Discipline Specific Core*	3	0	0	3
MEGS.412	Igneous and Metamorphic Petrology (Practical)	*Practical's/ Skill Based*	0	0	4	2
MEGS.516	Geochemistry and Isotope Geology	*Discipline Specific Core*	3	0	0	3
MEGS.517	Hydrogeology, Remote sensing and GIS	*Discipline Specific Core*	3	0	0	3
MEGS.518	Hydrogeology, Remote sensing and GIS (Practical)	*Practical's/ Skill Based*	0	0	4	2
MEGS.519	Analytical Techniques and Geo-Statistics	*Ability Enhancement*	3	0	0	3
MEGS.520	Entrepreneurship in Geosciences	*Entrepreneurship*	2	0	0	2
	Tutorial	*Remedial class*	0	2	0	0
Select any one from the following Discipline Elective course[$]						
MEGS.521	Mineral Exploration and Petroleum Geology	*Discipline Elective*	3	0	0	3
MEGS.522	Oceanography		3	0	0	3
MEGS.523	Watershed Management		3	0	0	3
Interdisciplinary course (IDC)						
	Interdisciplinary course#	*IDC*	2	0	0	2
		Total	**19**	**2**	**8**	**23**

Interdisciplinary course offered by the Department						
MEGS.506	Introduction to Disaster Management	*IDC*	2	0	0	2
MEGS.507	Introduction to Earth System Science	*IDC*	2	0	0	2
MEGS.508	Geoheritage and Geotourism	*IDC*	2	0	0	2

Students, who opt to exit the program with PG-Diploma in Geology at the end of the 1st year, need to complete internship/mini project/industrial training/MOOC course of minimum 2 credits in addition to above courses in the same academic year.

Semester – III

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.535	Research Methodology	*Ability Enhancement*	2	0	0	2
MEGS.536	Solid Earth Geophysics	*Discipline Specific Core*	3	0	0	3
MEGS.537	Sedimentology and Engineering Geology	*Discipline Specific Core*	3	0	0	3
MEGS.538	Sedimentology (Practical)	*Practical's/ Skill Based*	0	0	3	1.5
MEGS.539	Ore Geology	*Discipline Specific Core*	3	0	0	3
MEGS.540	Ore Geology (Practical)	*Practical's/ Skill Based*	0	0	3	1.5
Select any one from the following Discipline Elective course[$]						
MEGS.541	Environmental Geology	*Discipline Elective*	3	0	0	3
MEGS.542	Quaternary Geology		3	0	0	3
MEGS.543	Geomagnetism		3	0	0	3
	Tutorial	*Remedial class*	0	2	0	0
Select Any One Value Added Course (VAC)[$]						
MEGS.511	Geological Mapping	*VAC*	2	0	0	2
MEGS.512	Environmental Magnetism	*VAC*	2	0	0	2
		Total	**16**	**2**	**6**	**19**

Semester – IV

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.599	Dissertation	Dissertation	0	0	40	20
		Total	**0**	**0**	**40**	**20**
Grand total for all semester (I+II+III+IV)			**50**	**6**	**66**	**83**

L: Lectures, **T:** Tutorial, **P:** Practical, **Cr:** Credit (Two Practical credit hours = One credit)

Students may opt any Inter disciplinary course offered by other departments. Students are not allowed to take IDC course offered by the parent department.

$ Based on the availability of infrastructural facility and faculty, limited course(s) will be offered to the batch.

- ➔ Students may opt any internship/ academic or industrial training during semester break with approval from department. Above experiential learning/internship equivalent to 40–45 contact hours will be considered as one credit (as per NCrF guidelines).

- ➔ MOOCs may be taken up 40% of the total credits (excluding dissertation credits). MOOC may be taken in lieu of any course but content of that course should match minimum 70%. However, students need to consult with the Head of the department prior to the registration of the MOOC.

- ➔ Students, who opt to exit the program with PG-Diploma in Geology at the end of the 1st year, need to complete internship/mini project/industrial training/MOOC course of minimum 2 credits in addition to above courses.

- ➔ Students will have an option to carryout dissertation work in industry, national institutes or Universities in the top 100 NIRF ranking. Group dissertation may be opted, with a group consisting of a maximum of four students. These students may work using single approach or multidisciplinary approach. Research project can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.

Evaluation Criteria for Theory Courses: Total Marks 100

A. Continuous/Internal Assessment: [25 Marks]
   [Internal assessment for different courses will be conducted using any two or more of the following given methods: Surprise Tests, in-depth interview, unstructured interview, Jigsaw method, Think-Pair Share, Students Teams Achievement Division (STAD), portfolios, case based evaluation, video based evaluation, Kahoot, Padlet, Directed paraphrasing, Approximate analogies, one sentence summary, Pro and con grid, student generated questions, case analysis, simulated problem solving, media assisted evaluation, Application cards, Minute paper, open book techniques, classroom assignments, homework assignments, term paper]

B. Mid Semester Test: Based on Subjective Type Test [25 Marks]
C. End Semester (50 Marks): Subjective Test up to 100%, Objective up to 30% [15 marks].

Evaluation Criteria for Practical Courses: Total Marks 100

End semester exam (50 marks)
Continues assessment (30 marks)
Lab record (10 marks)
Viva (10 marks)

Evaluation Criteria for Entrepreneurship Course: Total Marks 100

Mid Semester Test (50 Marks): Subjective test up to 100%, Objective up to 30% and Preparing a business plan/innovative idea.
End semester exam (50 marks): Subjective Test up to 100%, Objective up to 30% [15 marks]

Evaluation Criteria for Dissertation/ Field training / specialized courses are given in the detailed syllabus.

Examination pattern from 2025-2026 sessions onwards:

Core, Discipline Elective, and Compulsory Foundation Courses			IDC, VAC, Entrepreneurship, Innovation and Skill Development Courses (≤2 credits) or any other theory course of ≤2 credits	
	Marks	Evaluation	Marks	Evaluation
Internal Assessment	25	Various methods	-	-
Mid-semester test (MST)	25	Descriptive	50	Descriptive (up to 100%) Objective (up to 30%)
End-semester exam (ESE)	50	Descriptive (up to 100%) Objective (up to 30%)	50	Descriptive (up to 100%) Objective (up to 30%)

Dissertation (Fourth Semester)		
	Marks	Evaluation
Supervisor/ co-supervisor(s)	50	Continuous assessment (regularity in work, mid-term evaluation) dissertation report, presentation, final viva-voce
External expert	50	Report of dissertation (25), presentation (10), novelty/originality (5) and final viva-voce (10).

Marks for internship shall be given by the supervisor/internal mentor and external mentor.

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MEGS.402	Mineralogy and Crystallography (Practical)	*Practical / Skill based*	0	0	4	2
MEGS.403	Structural Geology and Geotectonics	*Discipline Specific Core*	3	0	0	3
MEGS.404	Structural Geology (Practical)	*Practical / Skill based*	0	0	2	1
MEGS.405	Applied Paleontology	*Discipline Specific Core*	3	0	0	3
MEGS.406	Applied Paleontology (Practical)	*Practical / Skill based*	0	0	2	1
MEGS.407	Geological Time and Stratigraphy	*Discipline Specific Core*	3	0	0	3
MEGS.596	Field Training	*Ability Enhancement*	0	0	4	2
	Tutorial	*Remedial class*	0	2	0	0
Select any one from the following Discipline Elective course[$]						
MEGS.408	Geomorphology	*Discipline Elective*	3	0	0	3
MEGS.409	Natural Resource Management		3	0	0	3
MEGS.410	Meteorites & Planetary Sciences		3	0	0	3
		Total	**15**	**2**	**12**	**21**

Course Code: MEGS.401

Course Title: Mineralogy and Crystallography

L	T	P	Credits
3	0	0	3

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Apprise how the internal structure of minerals affects the external structure and physical properties of minerals and crystals.

CLO2: Compare the mineralogical concepts of polymorphism, solid solution and exsolution.

CLO3: Interpret the basic properties and chemistry of common rock-forming minerals.

CLO4: Solve the difficulties of mineral identification and mineralogical assemblage by applying polarizing microscope, x-ray diffraction and electron microprobe.

Unit/ Hour	Contents	Mapping with CLO
I/10	**Mineralogy:** Introduction to mineralogy, broad classification, properties of minerals & environments of formation. Crystal chemistry: bonding and packing in mineral, coordination number and Pauling's Rules, chemical analysis of minerals, general and structural mineral formulae. Rules of substitution, Introduction to phase diagram and solid solution series. **Learning Activities:** Hands on exercise of mineral specimens, Use of stick-ball model to check bonding and packing.	**CLO1 CLO4**
II/11	**Crystallography:** Crystal Morphology, Crystal Symmetry, Crystallographic Axes, Crystal systems, Introduction to symmetry, 32 classes of symmetry; 2D and 3D lattice, 14 Bravais lattice; Introduction to space group. Study of stereogram and stereographic projections. Twinning, Polymorphism, Polytypism, Pseudomorphism, Crystal defects, twinning and twin laws: common types of twins and their examples in minerals. Introduction to X-ray crystallography, and Bragg's equation. **Learning Activities:** Hands on exercise of crystal models, drawing of stereographic projections, Powder XRD data analysis.	**CLO2 CLO4**
III/12	**Optical Mineralogy:** Petrological microscope; Introduction to optics, Isotropic and anisotropic minerals, Interference	**CLO4**

	Phenomena, Compensation, and Optic Sign, optical crystallography of uniaxial and biaxial crystals, indicatrix, pleochroism, interference figures, crystal orientation, determination of optic sign, 2V and 2E. **Learning Activities:** Use of petrological microscope and analyzing each parameters.	
IV/12	A detailed study of the important silicates (listed below) mineral (a) Nesosilicates/Orthosilicates: olivine group, garnet group, aluminosilicate group, humite group, zircon. (b) Sorosilicates: melilite, axinite and epidote group. (c) Cyclosilicates: beryl, tourmaline, cordierite, eudialyte (d) Inosilicates: pyroxene group, amphibole group and wollastonite (e) Phyllosilicates: mica group, kaolinite-serpentine group, talc-pyrophyllite, chlorite, smectite. (f) Tectosilicates: silica group, feldspar group, zeolite and feldspathoid **Learning Activities:** Mini project and student presentation on different silicate and non-silicate minerals, Group discussion	**CLO2** **CLO3** **CLO4**

Transactional Modes: Lecture, Demonstration, Tutorial, Problem solving, Tools used: PPT, Video, Animation, Whatsapp, Software Tool: Mineralogical interactive software, crystal maker, XRD data analysis tool, website: Mindat, Web minerals.

Suggested Readings:

1. Dyar M. D., Gunter M. E., and Tasa D., 2020. *Mineralogy and Optical Mineralogy*, Mineralogical, Society of America, ISBN 978-1-946850-02-7.
2. Perkins Dexter, 2012. *Mineralogy*, Pearson Education.
3. William E. Ford, 2006. *Dana's Textbook of Mineralogy (With Extended Treatise on Crystallography and Physical Mineralogy*), CBS Publishers & Distributors Pvt. Ltd., ISBN 10: 8123908091.
4. Bloss, 1999. *Optical Crystallography*, Mineralogical Society of America.
5. Bloss, 1994. *Crystallography and Crystal Chemistry*, Mineralogical Society of America.
6. William Nesse, 2011. *Introduction to Mineralogy*, Oxford University Press, ISBN: 9780199827381.
7. William Nesse, 2012. *Introduction to Optical Mineralogy*, Oxford University Press, ISBN: 9780199846276.
8. Cornelius Klein, 2007. *Minerals and Rocks-Exercises in Crystallography, Mineralogy and Hand Specimen Petrology*, Wiley publisher.

9. Berry, L.G., Mason, B. and Dietrich, R.V., 2004.*Mineralogy*, CBS Publishers, ISBN 10: 8123911483, ISBN 13: 9788123911489.
10. Introduction to the Rock-Forming Minerals by Deer W.A., Howie R.A. and Zussman, J., 2013, Mineralogical Society of America.
11. Gribble, 2005. *Rutley's Elements of Mineralogy*, CBS Publishers, ISBN-10: 8123909160.
12. Ram.S. Sharma and Anurag Sharma, 2013. *Crystallography and Mineralogy Concepts and Methods*, Geological society of India, Bengaluru.

Web Resources: http://webmineral.com/
https://www.mindat.org/
http://www.jsu.edu/depart/geography/mhill/earthsci/mine ralID /virtualminlab.html
https://sketchfab.com/tags/minerals
http://www.minsocam.org/

Course Code: MEGS.402

L	T	P	Credits
0	0	4	2

Course Title: Mineralogy and Crystallography (Practical)

Total hours: 60

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Demonstrate the different minerals in hand specimen and under petrological microscope.
CLO2: Interpret the crystal parameter and to identify the mineral phase
CLO3: Compare the different crystals system in hand specimen and under petrological microscope.
CLO4: Solve mineralogical and crystallographic problems using XRD data.
CLO5: Formulate empirical formula of the mineralogical phases and the impurities present in the minerals.

Unit/ Hour	Contents	Mapping with CLO
I/60	Identification of rock-forming minerals in hand specimens	**CLO1**
	Identification of crystal model using symmetry elements	**CLO2 CLO3**
	Use of Goniometer to measure interfacial angle of crystals and calculation of axial ratio.	
	Representation of symmetry elements of crystals belonging to 32 classes of symmetry using stereonet	
	Scheme of pleochroism and absorption of a given mineral in thin section	**CLO1 CLO3**
	Determination of extinction angle, Determination of order of interference colours, length fast and length-slow characters of minerals	

	Study of interference figures of uniaxial and biaxial crystals, determination of optic signs	
	Identification of rock forming minerals using optical properties	
	Analysis of powder XRD spectrum of minerals	**CLO2 CLO4**
	Empirical formula of the mineralogical phases and the impurities present in the minerals	**CLO5**

Transactional Modes: Demonstration, practical with real specimens, Problem solving, Group discussion, Tools used: PPT, Video, Animation, Software Tool: Mineralogical interactive software, crystal maker, website: Mindat, Web minerals.

Evaluation Criteria: Total Marks – 100,
End semester exam (50 marks), Continuous assessment (30marks), Lab record (10marks), Viva (10marks).

Suggested Readings:

1. Cornelius Klein, 2007. *Minerals and Rocks-Exercises in Crystallography, Mineralogy and Hand Specimen Petrology*, Wiley.
2. Perkins Dexter, 2012. *Mineralogy*, Pearson Education.
3. William E. Ford, 2006. *Dana's Textbook of Mineralogy (With Extended Treatise on Crystallography and Physical Mineralogy)*, CBS Publishers & Distributors Pvt. Ltd.
4. Dyar M. D., Gunter M. E., and Tasa, D., 2008. *Mineralogy and Optical Mineralogy*, Mineralogical, Society of America.
5. Bloss, 1999.*Optical Crystallography*, Mineralogical Society of America.
6. Bloss, 1994.*Crystallography and Crystal Chemistry*, Mineralogical Society of America.
7. William Nesse, 2011. *Introduction to Mineralogy*, Oxford University Press.
8. William Nesse, 2012. *Introduction to Optical Mineralogy*, Oxford University Press.
9. Berry, L. G., Mason, B. and Dietrich, R. V., 2004. *Mineralogy*, CBS Publishers.
10. Deer, W. A., Howie, R. A. and Zussman, J., 2013.*Introduction to the Rock-Forming Minerals*, Mineralogical Society of America.

Web Resources: http://webmineral.com/
https://www.mindat.org/
https://sketchfab.com/tags/minerals
http://www.minsocam.org/

Course Code: MEGS.403

L	T	P	Credits
3	0	0	3

Course Title: Structural Geology and Geotectonics

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Determine the geological structures related to stress and strain.

CLO2: Develop the idea regarding rock failures in compressional and extensional regime.

CLO3: Understand about the structural features formed due to folding and faulting.

CLO4: Build concepts on crust building process in various geological time.

CLO5: Differentiate between the various elements of plate tectonics.

CLO6: Recognize the elements of paleomagnetism and appreciate the geodynamic evolution of the Great Himalaya.

Unit/ Hour	Contents	Mapping with CLO
I/10	Structural elements and measurements, Stress and analysis of stress in two and three dimension; Plane stress analysis and Mohr stress circle, and its relationship with faulting and fracture mechanics; Theory of rock failure: brittle failure – shear and tensile failures. Fault plane solution; Fault related folds; Ductile deformation; Dynamic recrystallization; Pure shear vs. simple shear deformation; Strain analysis– finite and infinitesimal, homogeneous and inhomogeneous strains; Progressive deformation. **Learning Activities:** Determination of strain in naturally deformed rocks. Hands on exercises on the stress and strain analysis of deformed rocks, assignment and group discussion.	CLO1 CLO2
II/15	Mechanism of folding, Classification of folds, fold development and distribution of strains in folds; Buckling and shearing process; Analysis and interpretation of superimposed folding. Mechanics and geometric aspects of thrust, normal and strike-slip faults, and associated structural features. Planar and linear fabrics (Foliation and Lineation) in deformed rocks: description, classification, genesis and significance. Brittle and ductile shear zones, Geometry and products of shear zones, Mylonites and Cataclasites. **Learning Activities:** Assignment, student Seminar, group discussion on rock deformation patterns at different regimes.	CLO2 CLO3
III/10	Crustal evolution: Crust building process during Archean and Proterozoic Era; Archean Nuclei and their geotectonic appraisal; Concepts of Mobile Belts; Indian Mobile Belts; Major tectonic features of the oceanic and continental crust; Seafloor spreading and plate tectonics.	CLO4 CLO5

	Learning Activities: Assignment, Group discussions, seminars on the geotectonic features of different cratons and mobile belts in India.	
IV/10	Extensional tectonics: Mantle convection cells, block rotation models, Basin and ridge provinces, fault scarp retreat; Magnetic polarity on the ocean floor; Transform and transcurrent faults; Euler pole and its significance; Concepts of declination and inclination; Apparent polar wandering path; Pull-apart basins; Compressional tectonics: Flip-flop subduction, Passive and active continental margin, Magmatic polarity at the subduction zone; Stability of Triple junction; Geodynamic Evolution of Himalaya through time. Geodynamics of the Indian plate. **Learning Activities:** Student seminar, group discussion on global geodynamics and orogeny.	CLO5 CLO6

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, flipped learning, focused group discussion, Team teaching, Field visit, Brain storming, Mobile teaching, Collaborative learning, E-tutoring, Problem solving.

Suggested Readings:

1. Marland P. Billings, 2016. *Structural Geology*, Phi Learning, 3rd edition.
2. Robert J. Twiss and Eldridge M. Moores, 2006. *Structural Geology*, W. H. Freeman publisher.
3. Haakon Fossen, 2016. *Structural Geology*, Cambridge University Press.
4. Donal M. Ragan, 2009. *Structural Geology: An Introduction to Geometrical Techniques, Cambridge University Press*.
5. Ramsay, J.G. and Huber, M.I., 1983. *Techniques of Modern Structural Geology. Vol. I. Strain Analysis*, Academic Press.
6. Ramsay, J.G. and Huber, M. I., 1987. *Techniques of Modern Structural Geology. Vol. II. Folds and Fractures, Academic Press*.
7. Ramsay, J. G.,1967. *Folding and Fracturing of Rocks, McGraw-Hill*.
8. Stephen Marshak and Gautam Mitra, 1988. Basic Methods of Structural Geology, Prentice Hall.
9. Hobbs, B.E., Means, W. D. and Williams, P. F., 1976. *An outline of Structural Geology*, John Wiley and Sons. New York.
10. Ghosh, S.K., 2014. *Structural Geology: Fundamental and Modern Developments*, Kidlington: Elsevier Science.
11. Condie, K. C., 1997. *Plate Tectonics and Crustal Evolution*, Butterworth-Heinemann.
12. Alan E. Mussett, M. Aftab Khan, 2000. Looking Into the Earth: An Introduction to Geological Geophysics, Cambridge University Press.
13. *Passchier, C. W. & Trouw, R. A. J. 2006.* Microtectonics*,: 2nd ed. xvi + 366 pp. Berlin, Heidelberg, New York: Springer-Verlag.*

Web Resources:

https://www.gsi.gov.in/webcenter/portal/OCBIS/pageQuickLinks/pageTIStructuralGeology?_afrLoop=21149378600749056&_adf.ctrlstate=zil7ujw74_38#!%40%40%3F_afrLoop%3D21149378600749056%26_adf.ctrl-state%3Dzil7ujw74_42

http://www.geo.cornell.edu/geology/classes/RWA/GS_326/

https://serc.carleton.edu/NAGTWorkshops/structure/index.html

https://onlinecourses.nptel.ac.in/noc21_ce37/previewhttps://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-113-structural-geology-fall- 005/

https://uh.edu/~jbutler/anon/anoncoursestructure.htm (1233) STRUCTURAL GEOLOGY (Prof. Santanu Misra, IIT Kanpur) - YouTube

Course Code: MEGS.404

Course Title: Structural Geology (Practical)

L	T	P	Credits
0	0	2	1

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Solve the stratum contours, V-rule, geometric, and borehole problems related to Structural geology.

CLO2: Solve various stereo net problems and construct stereographic projections of the field data.

CLO3: Interpret various maps and identify the geological structures of deformed continental regimes with microstructural analysis.

Unit/ Hour	Contents	Mapping with CLO
I/30	Study of stratum contours and their relation with the dip of the beds	**CLO1**
	Relation between true thickness and width of outcrop of a bed using 'V' rule	**CLO1**
	Graphical solution of structural problems using geometrical methods	**CLO1**
	Bore-hole problems (Three-pin problems)	**CLO1**
	Structural problems based on orthographic and stereographic projections, concerning the economic deposit	**CLO2**
	Preparation and interpretation of Geological maps and sections	**CLO3**
	Recording and plotting of the structural data on base map	**CLO3**

Transactional Modes:

Demonstration, practical with real specimens, Problem-solving, Group discussion, Tools used: PPT, Video, Animation, Software Tool: Sedilog, Photoshop.

Evaluation Criteria:
Total Marks–100,
End semester exam (50 marks), Continues assessment (30 marks),
Labrecord (10 marks), Viva (10 marks).

Suggested Readings:

1. Stephen Marshak and Gautam Mitra. 1988.Basic Methods of Structural Geology, Prentice Hall.
2. Ghosh, S.K., 1993. *Structural Geology: Fundamental and Modern Developments*, Pergamon Press.
3. Ramsay, J.G. and Huber, M.I., 1987. *Techniques of Modern Structural Geology. Vol. II. Folds and Fractures, Academic Press.*
4. Ramsay, J. G. and Huber, M.I., 1983. *Techniques of Modern Structural Geology. Vol. I. Strain Analysis*, Academic Press.
5. Donal M. Ragan, 2009. *Structural Geology: An Introduction to Geometrical Techniques, Cambridge University Press*. Structural analysis of Metamorphic Tectonites by Turner, F.J. & Weiss, L.E. 1963, McGraw-Hill.

Web Resources:

https://serc.carleton.edu/NAGTWorkshops/structure/index.html
https://onlinecourses.nptel.ac.in/noc21_ce37/preview
https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-113-structural-geology-fall-2005/
https://uh.edu/~jbutler/anon/anoncoursestructure.html
https://iah.org/education/
https://www.routledge.com/Hydrogeology
https:// www.youtube.com/watch?v=G7CnE5NBxZs
https://geologyscience.com/applied-geology/hydrogeology/(1233)
STRUCTURAL GEOLOGY (Prof. Santanu Misra, IIT Kanpur) - YouTube

Course Code: MEGS.405

Course Title: Applied Palaeontology

L	T	P	Credits
3	0	0	3

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 Interpret the basic idea about process of fossilization, biodiversity and understanding diversification of life.
CLO2 Knowledge of important invertebrate fossils fauna.
CLO3 Basic ides about evolution of vertebrate life and important fossil flora of India.
CLO4 Understanding important group of microfossils, their significance in understanding paleoecology, paleoclimate and paleoenvironments.

CLO5 Application of fossils in solving geological problems in space and time.
CLO6 Application fossils in climate studies and hydrocarbon exploration.

Units	Contents	Mapping with CLO
I/10	i. Taphonomy and its application ii. Conditions and modes of fossilization iii. Biodiversity in time iv. Concept of species and speciation v. Precambrian microbiota and its significance vi. Shell morphology, geological distribution and evolutionary trend of, Bivalvia, Gastropoda, Brachiopoda, Cephalopoda, Echinoidea, and Trilobites. **Learning Activities:** Sessions on the evolution of life, assignments, take-home exercises, peer learning, seminars, and group discussions.	**CLO1** **CLO2**
II/10	i. Vertebrate life through the ages ii. Evolution and extinction of dinosaurs with emphasis on Indian dinosaurs iii. Evolution of *Homo* and Indian record. iv. Major extinction events and their role in changing biodiversity. v. Pre-Gondwana and Gondwana flora and significance of Gondwana flora in paleoclimatic studies. vi. Floral diversity in the Paleogene **Learning Activities:** Mini projects on vertebrate life, assignment, home exercise, peer learning, seminar, and group discussion.	**CLO3**
III/15	i. Types of Microfossils ii. Introduction to phytoliths and their significance in geosciences. iii. Foraminifera: morphology of foraminifers and their role in understanding palaeoceanography, paleoclimate and biostratigraphy. iv. Basic morphology of spores/pollen. v. Introduction to dinoflagellates and their significance in stratigraphy and shoreline studies vi. Introduction to ostracodes and their significance in geoscience. vii. Calcareous nanoplanktons and their significance in paleoecological studies. **Learning Activities:** Assignment, take-home exercise, peer learning, seminar, and group discussion.	**CLO4**
IV/10	i. Micro and macroevolution ii. Phylogenetic analysis	**CLO5&6**

	iii. Dendrochronology and its application. iv. Application of plants in paleoclimate interpretation v. Application of oxygen and carbon isotopes in climate studies vi Paleoclimate and Milankovitch and Wolf Gleissberg solar cycles. **Learning Activities:** Exercise on the application of fossils and correlation with other co-relatable sections, student seminar.	

Transactional Modes: Lecture, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Team teaching, Brain storming, Mobile teaching, Collaborative learning, Case based study, Through SOLE (Self Organized Learning Environment).

Suggested Readings

1. Clarksons, E.N.K. (1998) *Invertebrate Paleontology and Evolution*, Allen and Unwin, London.
2. Raup, D.M. and Stanley, S.M. (1985) *Principles of Paleontology*, CBS Publishers, New Delhi 2. Taylor, T.N., E.L. Taylor and M. Krings. 2009. *Palaeobotany- The Biology and Evolution of Fossil Plants*. Elsevier.
3. Anis Kumar Ray (2016) *Fossils in Earth Sciences* PHI learning Pvt ltd, pp 443
4. Alfred Traverse, 2008. *Paleopalynology*. Springer, 3rd Edition.
5. Willis, K.J., and J.C. McElwain. 2002. *The Evolution of Plants*. Oxford University Press, New York.
6. Jones, T.P. and Rowe, N.P. 1999. *Fossil Plants and Spores: Modern Techniques*. The Geological Society, London.
7. Stewart, W.N. and Rothwell, G.W. 1993. *Paleobotany and the Evolution of Plants*. Cambridge University Press; 2nd edition
8. Agashe, S.N. and Andrews, H.N. 1997. *Paleobotony: Plants of the Past, Their Evolution, Paleoenvironment and Application in Exploration of Fossil Fuels*. Science Publishers, U.S.
9. Stoermer, E.F. and Smol, J.P. (1999)(Eds.) *The Diatoms: Applications for the Environmental and Earth Sciences*, Cambridge University Press, 469p
10. Kathal, P.K. (4011) *Applied Geological Micropaleontology*, Scientific Publishers, Jodhpur.
11. Saraswati, P.K. and Srinivasan, MS (2016) *Micropaleontology Principles and Application*, Springer. pp 219.
12. Braiser, M. D., 1980. *Microfossils*, George Allen and Unwin.
13. Shrock, N., 2005. *Principles of Invertebrate Paleontology*, CBS publication.

Web Resource

https://www.ucl.ac.uk/GeolSci/micropal/welcome.html
https://www.sciencedaily.com/news/fossils_ruins/paleontology
https://sites.google.com/site/paleoplant/home
http://lifeofplant.blogspot.com/2011/03/paleobotany.html
http://www1.biologie.uni-hamburg.de/bonline/kerp/links.html

http://www.equisetites.de/palbot/teach/palbotteach.html
https://www.floridamuseum.ufl.edu/paleobotany/resources/link
https://www.priweb.org/science-education-programs-and-resources/digital-atlas-of-ancient-life

Course Code: MEGS.406

Course Title: Applied Palaeontology (Practical)

L	T	P	Credits
0	0	2	1

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Understand techniques in the extraction of microfossils and apply the sample preparation methods for the separation of fossils. Cataloguing of samples for research and industrial applications.

CLO2: Understand modes of preservation of fossils.

CLO3: Understanding the morphology of important microfossils.

CLO4: Knowing the morphology of important fossils of invertebrates and plants for paleoenvironment and paleoclimatic interpretation

CLO5: Correlate the fossils with extant fauna, flora, and lithostratigraphy to know the palaeoenvironment and palaeobiogeography

Unit/hour	Contents	Mapping with CLO
I/15	Techniques in the processing of microfossils	**CLO 1**
	Study of modes of preservation of fossils.	**CLO 2**
	Morphology and description of foraminifera	**CLO 3, CLO 5**
	Morphology and description of pollen and spores	**CLO 3, CLO 5**
II/15	Study of the Morphology of Gastropods and Bivalves	**CLO 4, CLO 5**
	Study of the Morphology of Cephalopods and Trilobites	**CLO 4, CLO 5**
	Study of Morphology of Brachiopods and Echinoids.	**CLO 4, CLO 5**
	Study of important plant fossils	**CLO 4**

Transactional Modes: Demonstration, practical with real specimens, Problem solving, Group discussion, Tools used: PPT, Video, Animation, Software Tool: Sedilog, Gradistat, Photoshop

Suggested Readings:

1.Henry Wood, 2004. *Paleontology Invertebrate*, CBS Publication
2. Bignot, G., 1985. *Elements of Micropaleontology*, Graham and Trottman, London.

3. Haq and Boersma, 1978.*Introduction to Marine Micropaleontology*, Elsevier.
4. Smith, A. B., 1994. *Systematics & Fossil Record-Documenting Evolutionary Patterns*, Blackwell publisher.
5. Jones, R. W., 1996. *Micropaleontology in Petroleum exploration*, Clarendon Press Oxford.
6. Saraswati, P.K. and Srinivasan, MS (2016) Micropaleontology Principles and Application, Springer. pp 219.
7. Kathal, P.K. 2011 *Applied Micropaleontology*, Scientific Publishers, Jodhpur.
8. Agashe, S.N. and Andrews, H.N. 1997. *Paleobotony: Plants of the Past, Their Evolution, Paleoenvironment and Application in Exploration of Fossil Fuels*. Science Publishers, U.S.

Web Resources:

https://serc.carleton.edu/research_education/paleontology/general.html
https://www.palaeontologyonline.com/?doing_wp_cron=1621058580.7671799659729003906250
https://www.priweb.org/blog-post/learn-at-home
https://www.nationalgeographic.org/encyclopedia/paleontology/
https://naturalhistory.si.edu/education/teaching-resources/paleontology
https://www.priweb.org/science-education-programs-and-resources/digital-atlas-of-ancient-life

Course Code: MEGS.407

L	T	P	Credits
3	0	0	3

Course Title: Geological Time and Stratigraphy

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO7 Construct stratigraphic cross sections into a historical summary that expresses environmental states and changes.

CLO8 Design appropriate nomenclature.

CLO9 Adapt the base level concept in reasoning through the succession of paleogeographic changes during which a series of strata accumulated.

CLO10 Discuss multiple variables that contribute to the accumulation of strata (e.g., tectonic subsidence, sediment supply, sea level change) in deducing plausible scenarios.

CLO11 Makeup: reasoning to construct one or more hypotheses for the paleogeographic and environmental histories that produced a series of strata.

CLO12 Appraise an understanding of stratigraphic sequence mapping and interpretation to a variety of data types typical of surface geological and subsurface geological analysis (i.e., outcrop, well log, seismic).

Unit/ Hour	Contents	Mapping with CLO
I/10	**Principle of Stratigraphy:** Geological time scale and History, development of stratigraphy; stratigraphic procedures (surface and subsurface), concept of lithofacies and biofacies; stratigraphic correlation (litho, bio-, and chronostratigraphic correlation). Study of standard stratigraphic code (lithostratigraphic, biostratigraphy, and chronostratigraphic); Concepts of magneto stratigraphy, chemo-stratigraphy, event stratigraphy, and sequence stratigraphy. **Learning Activities**: Discussion and practical exercises on the preparation of lithologs and their correlations.	CLO1 CLO2
II/13	**Precambrian stratigraphy of India:** Precambrian stratigraphic framework of India; Classification, structure and tectonics of the Indian cratons; Mobile belts; Ancient supracrustal (Sargur Type); Gold bearing schist belts of Eastern Karnataka (Kolar Type); Younger schist belts (Dharwar Type); Gneiss complex, granulites, charnockites; Structure, tectonics and stratigraphy of the OMG, OMTG, Iron Ore Group (Singbhum Craton); Stratigraphy of the Sukma, Bengpal, and Bailadila series from Central India; Stratigraphy, geology, tectonics and evolution of the Proterozoic basins/Purana formations in India. **Learning Activities**: Group Discussion on Archean-Precambrian geology of India. Exercise on mapping certain geological formations, assignment.	CLO3 CLO4 CLO5 CLO6
III/12	**Palaeozoic stratigraphy**: Magmatic provenances and palaeogeography during the Palaeozoic Era. Stratigraphy, facies, and fossil contents of the Palaeozoic rock formations of Peninsular and extra-peninsular India. Permian-Triassic (P-T) boundary. **Gondwana stratigraphy:** Concepts, classification, fauna, flora, and age limits of Gondwana Supergroup and related palaeogeography, palaeoclimate, depositional characteristics, igneous activity, and formation. **Mesozoic stratigraphy:** Classification, depositional characteristics, fauna and flora, age limits, correlation of Triassic, Jurassic and Cretaceous systems in principal basins of Peninsular and extra-peninsular India. Stratigraphy of the Deccan volcanic province (DVP); Cretaceous-Palaeogene (C-P) boundary. **Learning Activities**: Assignment, student presentation, and brainstorming sessions.	CLO3 CLO4 CLO5 CLO6
IV/10	**Cenozoic stratigraphy**: Classification, depositional characteristics, fauna and flora of the Palaeogene and Neogene systems in their type localities and their	CLO3 CLO4 CLO5

	equivalents in India. Epoch boundaries of the Cenozoic in India. Quaternaries of Peninsular India; Neogene-Quaternary boundary. Stratigraphy and tectonics of the Siwalik Formation. Quaternary relative sea level changes. **Learning Activities**: Take-home exercises and brainstorming sessions, student seminar, and group discussion.	CLO6

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Seminar, Group discussion, Co-operative learning, Flipped learning, Focused group discussion, Team teaching, Field visit, Mobile teaching, Collaborative learning, Case analysis, Case study, Case based study.

Suggested readings:

1. Ravindra Kumar, 2018. *Fundamentals of historical geology and stratigraphy of India,* New Age, ISBN-13:978-0852267455
2. Sam Boggs, Jr., 2016. *Principles of sedimentology & stratigraphy*, Prentice Hall.
3. Ramakrishnan, M. and Vaidyanathan, R., 2008. *Geology of India Vol. 1 & 2*, Geological Society of India, Bangalore, ISBNNo:978-81-85867-98-4.
4. Naqvi, S.M. and Rogers, J.J.W., 1987. *Precambrian Geology of India, Oxford University Press*.
5. Krishnan, M.S., 1982. *Geology of India and Burma*, C.B.S. Publishers & Distributors, Delhi.
6. Gary Nichols, 2009. Sedimentology *and Stratigraphy*, Wiley-Blackwell, ISBN:978-1-4051-3592-4.
7. Bolli, H. M. and Saunders, J.B., 1977. Introduction *to stratigraphy and paleontology, in Indian Ocean geology and biostratigraphy (eds. J.R. Heirtzler, H.M. Bolli, T.A. Davies, J.B. Saunders and J.G. Sclater), American Geophysical Union*, Washington, D.C.
8. Pascoe, E.H., 1968.A *Manual of the Geology of India & Burma (Volume I–IV),* Govt. of India Press, Delhi
9. Pomerol, C., 1982. The Cenozoic Era*? Tertiary and Quaternary, Ellis Harwood Ltd., Halsted Press*.
10. Schoch, R.M., 1989. *Stratigraphy: Principles and Methods*, Van Nostrand Reinhold, New York.
11. Doyle, P., and Bennett, M. R., 1996.Unlocking *the Stratigraphic Record, John Wiley*.

Web Resources:

http://www.sepmstrata.org/page.aspx?pageid=15https://www.gsi.gov.in/webcenter/portal/OCBIS/pageQuickLinks/pageEducationalVideos?

Course Code: MEGS.596

Course Title: Field Training

L	T	P	Credits
0	0	4	2

Total hours: 60

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 Apply theoretical knowledge to ground observation in the field and to learn essential observational and practical skills.

CLO2 Identification of rocks and interpreting the physical (including tectonic) processes that may have been involved in their formation.

CLO3 Divide different rock types, different deformational structures, such as fold, fault, lithology, and depositional features, etc., in the field.

CLO4 Assess how to prepare a geological map and a geological cross-section.

Unit/ Hour	Contents	Mapping with CLO
I/30	Field training will be conducted in small groups/ whole classes during this semester or in the semester break between I and II and III at a suitable time. Geological field training and field work will be carried out according to the guidelines of the University at selected sites for a period of 10 days.	CLO1 CLO2 CLO3 CLO4

Transactional Modes: During the fieldwork, students will do the geological mapping of an areas (depend on the prospective mining or continental elevated region); will learn different rock type, fossils, different deformational structures, such as fold, fault, lithology and depositional features; will visit mining/drilling sites; sample and fossils collections if available in the area.
Evaluation of this course will be based on the field activity, daily field report, final report submission presentation during the end semester exam. Prior to fieldwork, a literature review on the selected/proposed field area will be carried out by the students, and basic information will be provided to students.
Due to any unavoidable circumstance, if the fieldwork is not conducted in the allocated semester or before, then the students will be assigned a seminar, report writing, and partial lab work/mathematical modelling work to fulfill the credit requirement, and a separate evaluation criterion will be used for assessment.

Evaluation Criteria: Full Marks–100
Field activity (10 marks), Evaluation of field dairy during every day of fieldwork and final submission (20 marks), Final field report (40 marks), Presentation (30 marks) – Presentation will be evaluated using rubrics: Speak clearly (4 marks), Posture and Eye contact (3 marks), Content (4 marks), Preparation (5marks), stay in topic (4 marks); Response to questions (10 marks).

Suggested readings:

1. Angela L.C., 2010.*Geological field techniques*, Blackwell Publishing Ltd.
2. Lisle, R.J., Brabham, P. and Barnes, J.W.,2011. *Basic Geological Mapping (Geological Field Guide)*, Wiley-Blackwell.
3. Mathur, S.M., 2001. *Guide to Field Geology*, PHI Learning Private Limited, New Delhi.
4. Maley, T.S., 1994. *Field Geology (Illustrated), Mineral Land Publications*.
5. Lahee, F.H.,1961. *Field Geology*, McGraw-Hill.

Additional material will be provided to the students prior to the field visit based on the locality/geological sites selected for that year.

Tutorial/ Remedial Class

L	T	P	Credits
0	2	0	0

A two-hour non-credit tutorial class is designed for remedial teaching. Scheduled classes will be assigned in the timetable. As per the requirement of students, remedial classes will be conducted in these periods.

Discipline Elective course

Course Code: MEGS.408

L	T	P	Credits
3	0	0	3

Course Title: Geomorphology

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1 : Demonstrate the principal theories and models for landscape evolution.

CLO2 : Assess the mode of formation, age, and history of landforms in India.

CLO3 : Distinguish landforms and their processes of formation in different climate zones and tectonic regimes.

CLO4 : Develop a relevant solution to elucidate geomorphologic problems.

Unit/ Hours	Content	Mapping withCLO
I/11	Historical development in geomorphology, geomorphic processes: weathering, sediment production, mass movement, erosion, transportation and deposition, landforms: Characterization and process involved in their formation.	CLO1, CLO2

	Learning Activities: Design a note on the concept of origin, the evolution of landforms, historical development, scope, etc.	
II/12	Geomorphic processes and landforms- fluvial, glacial, aeolian, coastal, and karst. River forms and processes- streamflow, Environmental change- causes, effects on processes and landforms. **Learning Activities:** Brainstorming on geomorphic processes for landform development, landforms under different environments, etc.	CLO3
III/12	Definition and scope of tectonic geomorphology. Landscape evolution and the involved process. Concept of Form-Process relationship in landscape evolution. Applications of geomorphology in mineral prospecting, civil engineering, hydrology, and environmental studies. **Learning Activities:** Design a conceptual model on the importance of topography, DEM, and maps in geomorphology.	CLO1, CLO4
IV/10	Physiographic division of India, Submarine relief, Quaternary geomorphology, Eustatic sea-level change and impact of coastal geomorphology, recent advancements in geomorphological research, extra-terrestrial geomorphology and morphometry **Learning Activities:** Student seminar on recent advancements in geomorphological studies.	CLO2

Transactional Modes: Lecture, Demonstration, Problem-solving, Seminar, Assignment, Group discussion, Tools used, ICT, PPT, Video, Animation.

Suggested Readings:

1. Thornbury, W.D., 2004.*Principles of Geomorphology, CBS Publisher & Distributor Private Ltd.*
2. Philip Kearey, Keith A.K., Frederick J.V., 2009. Global Tectonics, Wiley-Blackwell.
3. Richard John Huggett, 2007.Fundamentals of Geomorphology, Taylor & Francis.
4. AngelaL. Coe (edt), 2010.*Geological Field Techniques, by Wiley-Blackwell.*
5. Richard J.L., Peter B., and John W.B., 2011. *Basic Geological Mapping (Geological Field Guide),* Wiley-Blackwell; ISBN-13:978-0470686348.
6. Michael A. Summerfield (Editor), 2000. *Geomorphology and Global Tectonics*, Wiley, ISBN: 978-0-471-97193-1.

7. P. Mc L.D. Duff, 1993. *Holmes ' Principles of Physical Geology, Chapman and Hall*, London.
8. R.J. Allison, 2002. *Applied Geomorphology: Theory and Practice*, Wiley.
9. Douglas W.B., and Robert S.A., 2011. *Tectonic Geomorphology*, Wiley-Blackwell; ISBN-13:978-1444338867
10. Robert S.A., and Suzanne P.A., 2010.Geomorphology: The Mechanics and Chemistry of Landscapes, Cambridge University Press.
11. Paul R.B., and David R.M., 2013. *Key Concepts in Geomorphology, W.H. Freeman.*
12. Sharma, H.S., 1991. *Indian Geomorphology*, Concept Publishing Co., New Delhi.
13. Mahapatra, G.B., 2008. *Textbook of Physical Geology, CBS Publishers & Distributors Private Ltd.*

Web Resources:

https://www.geomorphology.org.uk/https://www.nature.com/subjects/geomorphology
https://www.usgs.gov/centers/umid-water/science/fluvial-geomorphologyhttps://onlinecourses.nptel.ac.in/noc20_ce28/preview

Course Code: MEGS.409

L	T	P	Credits
3	0	0	3

Course Title: Natural Resource Management

Total Hours: 45

Course Learning Outcomes (CLO):

Upon successful completion of this course, the student will be able to integrate and apply technical knowledge in the following key areas.

CLO1 : Appraisal of the types of natural resources available and their relation to geological processes
CLO2 : Invention of new ideas to conserve, manage, and develop the Earth's natural resources available
CLO3 : Evaluation of the validity and limitations of new scientific theories and their claims about the environment.
CLO4 : Appraising the interactions among physical, biological, chemical, and human components of our environment.

Units/ Hours	Content	Mapping with CLO
I/11	Natural resources: Classification of natural resources; natural resource degradation and conservation; Environmental impacts of resource depletion. Forest	**CLO1, CLO2**

	Resources: Forest cover of India and world; forest types, Conservation of forests, Exploitation of forest resources, Afforestation, Desertification, Forest policy **Learning Activities:** Develop a sustainable model on the natural resources of India. Presentation on the forest resources of India	
II/12	Water Resources: Surface, groundwater, resources assessment and utilization; Rivers and Lakes in India; hydrological cycle; Groundwater depletion; Water logging and salinity; Water Conservation and management techniques; Rainwater harvesting; Watershed management; Restoration of Lakes; Interlinking of rivers; conflicts over water. **Learning Activities:** Design a concept model on water resources, drought, flood issues of India, restoration etc.	**CLO1, CLO2**
III/12	Land resources: Land degradation due to mining, exploration, industrialization, irrigation, and natural disasters; Soil erosion, loss of soil fertility, Soil conservation methods; **Learning Activities:** Group discussion on organic farming, green manuring, etc., to highlight the salient points	**CLO2, CLO3**
IV/10	Mineral resource: Type of mineral resources, reserve, policy, and management. Rock and other building materials. Ocean resources, International territorial policy, and geopolitics. Mineral resource management using geospatial technologies. SDG goals. **Learning Activities:** Group discussion on the ocean resources of India. Student seminar.	**CLO1, CLO2, CLO4**

Transactional Modes: Lecture, Demonstration, Tutorial, Problem-solving, Seminar, Assignment, Group Discussion, Tools Used: PPT, Video, Animation.

Suggested Readings:

1. David A., 2013. *Environmental economics and natural resource management,* Routledge.
2. Gurdev Singh and Vinod Ahuja, 1992. Land resource management, Oxford & IBH Pub. Co.
3. Kathy Wilson Peacock, 2008. *Natural resources and sustainable developments, Facts on File Inc.*
4. Daniel R.L., 2009. *Sustainable natural resource management for scientists and engineers*, Cambridge University Press
5. Jaidev Somesh, 2010. Natural *Resources in the 21st Century, ABD Publisher.*

6. Panday, S.N. and Misra, S.P. (Eds.), 2008. *Essential Environmental Studies*, CRC Press.

Web Resources:

https://www.icar.org.in/content/natural_resource_management_division
https://www.india.gov.in/topics/environment-forest/natural-resources
https://www.youtube.com/watch?v=ZFD13WoyUGw

Course Code: MEGS.410

L	T	P	Credits
3	0	0	3

Course Title: Meteorites and Planetary Science

Total Hours: 45

Course Learning Outcomes (CLO):

Upon successful completion of this course, the student will be able to:

CLO1: Understand thoroughly the different types of meteorites, their classification, composition, and physical characteristics.

CLO2: insights into the processes that govern the formation and evolution of planetary bodies, including asteroids and other celestial objects.

CLO3: learn how meteorites provide valuable geological records of early solar system history and planetary differentiation processes.

CLO4: enhance their critical thinking abilities by evaluating the significance of meteorite research in addressing broader questions in planetary science and geology.

Unit/Hour	Contents	Mapping with CLO
I/12	Introduction to meteorites, Classification of meteorites, Oxygen isotopes, Asteroids, Asteroid-meteorite connection, chondritic and differentiated meteorites **Learning Activities:** Assignment, take-home exercise, and student seminar.	**CLO1 CLO3 CLO4**
II/12	Chondrules and Calcium-aluminum-rich inclusions (CAIs), Volatility and metal fractionation in the solar nebula, Early timescales, Formation of Moon. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO1 CLO2 CLO3 CLO4**
III/11	Stellar life cycles and nucleosynthesis, pre-solar grains, Organic matter in meteorites, Differentiation **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO2 CLO3 CLO4**

IV/10	Thermal models, Impacts and collisions, Lunar meteorites, Martian meteorites, Lunar Geology, Martian Geology. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO2** **CLO3** **CLO4**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, flipped learning, Focused group discussion, Team teaching, Brain storming, Mobile teaching, Collaborative learning, E-tutoring, Problem solving.

Suggested Readings:

1. Krot A.N., K. Keil, E.R.D. Scott, C.A. Goodrich and M.K. Weisberg (2014) Classification of meteorites and their genetic relationships. In Treatise on Geochemistry, 2nd Ed., Elsevier, pp. 1-63.
2. Gaffey M.J., E.A. Cloutis, M.S. Kelley and K.L. Reed (2002) Mineralogy of asteroids. In Asteroids III (eds. W.F. Bottke, Jr., A. Cellino, P. Paolicchi, and R. Binzel), pp. 183-204.
3. Burbine T.H., T.J. McCoy, A. Meibom, B. Gladman and K. Keil (2002) Meteoritic parent bodies: Their number and identification. In Asteroids III (eds. W.F. Bottke, Jr., A. Cellino, P. Paolicchi, and R. Binzel), pp. 653-667.
4. Hewins R.H. (1997) Chondrules. In Ann. Rev. Earth Planet. Sci. 25, 61-83. A short review of evidence pertaining to chondrules and what they might tell us about the solar nebula.
5. MacPherson G. J., S.B. Simon, A.M. Davis, L. Grossman and A.N. Krot (2005) Calcium-aluminum-rich inclusions: major unanswered questions. In Chondrites and the Protoplanetary Disk (eds. A.N. Krot, E.R.D. Scott, and B. Reipurth), pp. 225-250. ASP Conference Series, vol. 341. Astronomical Society of the Pacific: San Francisco.
6. Jones R.H., T. Lee, H.C. Connolly Jr., S.G. Love and H. Sheng (2000) Formation of chondrules and CAIs: Theory vs. observation. In Protostars and Planets IV (eds. V. Mannings, A.P. Boss, S.S. Russell), pp. 927-962.
7. Davis A. (2006) Volatile evolution and loss. In Meteorites and the Early Solar System II (eds. D.S. Lauretta and H.Y. McSween Jr.), pp. 295-307.
8. Wood J. (2005) The chondrite types and their origins. In Chondrites and the Protoplanetary Disk (eds. A.N. Krot, E.R.D. Scott, and B. Reipurth), pp. 953-971. ASP Conference Series, vol. 341. Astronomical Society of the Pacific: San Francisco.
9. Dauphas N. and M. Chaussidon (2011) A perspective from extinct radionuclides on a young stellar object: The sun and its accretion disk. In Ann. Rev. Earth Planet. Sci. 39, 351-386.
10. Lugmair G.W. and A. Shukolyukov (2001) Early solar system events and timescales. Meteorite. Planet. Sci. 36, 1017-1026.
11. Huss G.R., A.E. Rubin and J.N. Grossman (2006) Thermal metamorphism in chondrites. In Meteorites and the Early Solar System II (eds. D.S. Lauretta and H.Y. McSween Jr.), pp. 567-586. University of Arizona Press: Tucson.
12. Brearley A. (2006) The action of water. In Meteorites and the Early Solar System

II (eds. D.S. Lauretta and H.Y. McSween Jr.), pp. 587-624. University of Arizona Press: Tucson.
13. Clayton D.D. and L.R. Nittler (2004) Astrophysics with presolar stardust. In Annu. Rev. Astron. Astrophys. 42, 39-78.
14. Gilmour I. (2005) Structural and isotopic analysis of organic matter in carbonaceous chondrites. In Meteorites, Comets, and Planets (ed. A.M. Davis), Ch. 1.10, pp. 269-290. Elsevier: Amsterdam.
15. McSween H.Y.Jr. (1989) Achondrites and igneous processes on asteroids. Ann. Rev. Earth Planet. Sci. 17, 119-140.
16. Wasson J.T. (1985) Iron meteorites: Evidence for and against core origins. In Meteorites- Their Record of Early Solar-system History, Ch. IV, pp.76-99. W.H. Freeman & Co.: New York.
17. McSween H.Y., Jr, A. Ghosh, R.E. Grimm, L. Wilson, E.D. Young (2002) Thermal evolution models of asteroids. In Asteroids III (eds. W.F. Bottke, Jr., A. Cellino, P. Paolicchi, R.P. Binzel, pp. 559-571. University of Arizona Press: Tucson.
18. Stöffler D., A. Bischoff, V. Buchwald and A.E. Rubin (1988) Shock effects in meteorites. In Meteorites and the Early Solar System (eds. J.F. Kerridge and M.S. Matthews), pp. 165-202.
19. Scott E.R.D. and R.S. Rajan (1981) Metallic minerals, thermal histories and parent bodies of some xenolithic, ordinary chondrite meteorites. Geochim. Cosmochim. Acta 45, 53-67.
20. Udry A. et al. (2020) What martian meteorites reveal about the interior and surface of Mars. JGR Planets 125, https://doi.org/10.1029/2020JE006523.

Web Resources:

https://meteorites.pdx.edu/

https://web.pdx.edu/~ruzickaa/meteorites/gallery/gallery.html

Semester-II

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.411	Igneous and Metamorphic Petrology	*Discipline Specific Core*	3	0	0	3
MEGS.412	Igneous and Metamorphic Petrology (Practical)	*Practical's/ Skill Based*	0	0	4	2
MEGS.516	Geochemistry and Isotope Geology	*Discipline Specific Core*	3	0	0	3
MEGS.517	Hydrogeology, Remote sensing and GIS	*Discipline Specific Core*	3	0	0	3
MEGS.518	Hydrogeology, Remote sensing and GIS (Practical)	*Practical's/ Skill Based*	0	0	4	2
MEGS.519	Analytical Techniques and Geo-Statistics	*Ability Enhancement*	3	0	0	3
MEGS.520	Entrepreneurship in Geosciences	*Entrepreneurship*	2	0	0	2
	Tutorial	*Remedial class*	0	2	0	0
Select any one from the following Discipline Elective course[$]						
MEGS.521	Mineral Exploration and Petroleum Geology	*Discipline Elective*	3	0	0	3
MEGS.522	Oceanography		3	0	0	3
MEGS.523	Watershed Management		3	0	0	3
Interdisciplinary course (IDC)						
	Interdisciplinary course#	*IDC*	2	0	0	2
		Total	**19**	**2**	**8**	**23**

Interdisciplinary course offered by the Department						
MEGS.506	Introduction to Disaster Management	*IDC*	2	0	0	2
MEGS.507	Introduction to Earth System Science	*IDC*	2	0	0	2
MEGS.508	Geoheritage and Geotourism	*IDC*	2	0	0	2

Course Code: MEGS.411

L	T	P	Credits
3	0	0	3

Course title: Igneous and Metamorphic Petrology **Total Hours: 45**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Evaluate key textural/microstructural features of Igneous rocks and their genesis.
CLO2: Do the nomenclature of Igneous rocks using IUGS recommendations.
CLO3: Understand the Magmatic and Metamorphic processes using multiple proxies.
CLO4: Understand the petrogenesis of Igneous and metamorphic rocks using phase diagrams and thermodynamics.
CLO5: Evaluate key textural/microstructural features of Metamorphic rocks and their genesis.
CLO6: Understand the geochemical behavior during the Igneous and Metamorphic processes.

Unit/ Hour	Contents	Mapping with CLO
I/12	Magma: nature and evolution, Magmatic and allied process: Partial melting, fractional crystallization, assimilation, liquid immiscibility, double diffusion, and magma-mixing, Introduction to thermodynamics and its application in Igneous petrology, The phase equilibrium of unary, binary and ternary systems and its relation to magma genesis and crystallization, Nucleation and crystal growth, Igneous textures. **Learning Activities:** Assignment, Take-home exercise, mini projects.	**CLO1 CLO3 CLO4**
II/11	IUGS classification of the Igneous rocks, CIPW Norm, Petrology and petrogenesis of ultramafic, basaltic, granitic, alkaline igneous rocks, layered igneous complex, Geochemical modelling and its application to magmatic and allied processes. **Learning Activities:** Group discussion and take-home exercise.	**CLO2 CLO3 CLO4 CLO6**
III/11	Mineralogical phase rule for closed and open systems. Laws of Thermodynamics, Gibbs Free Energy, Entropy, Δ G of Metamorphic Reactions. Nature of metamorphic reactions, concept and classification of metamorphic facies, Graphical representation of minerals in ACF, AKF, AFM, and A'FM' diagrams; Time relation between phases of deformation and metamorphic crystallization. Introduction to ultrahigh temperature and ultrahigh pressure metamorphism, description of each facies of low–Pressure, medium to high–pressure and very high pressure with special reference to	**CLO3 CLO4 CLO5 CLO6**

	characteristic minerals, subdivision into zones/sub-facies, Metamorphism of shale, mafic and calcareous rocks Mineral assemblages, Metamorphic reactions and pressure–temperature conditions of metamorphism. **Learning Activities:** Assignment, take-home exercise, and student presentation	
IV/11	Isograds and reaction isograds, Schrienemakers rule and construction of petrogenetic grids, Metamorphic differentiation, anatexis and origin of migmatites in the light of experimental studies, regional metamorphism and paired metamorphic belts with reference to the theory of plate tectonics, Geothermobarometry Pressure – temperature – time paths. **Learning Activities:** Student seminar, assignment, and mini projects.	**CLO3** **CLO4** **CLO5** **CLO6**

Transactional Modes: Lecture, Demonstration, Seminar, Group discussion, Cooperative learning, Blended learning, flipped learning, focused group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching and tutoring, Problem solving, Self-learning, Case-based study, etc.

Suggested readings:

1. Winter, J.D., 2001. An Introduction to Igneous and Metamorphic Petrology, Prentice Hall.
2. Philpotts, A.R. 1994. *Principles of Igneous and Metamorphic Petrology*, Prentice Hall.
3. Cox, K.G., Bell, J.D. and Pankhurst, R.J., 1993. *The Interpretation of Igneous Rocks, Chapman & Hall*, London.
4. Turner, F.J., and Verhoogen, J., 1987. *Igneous and Metamorphic Petrology*, CBS.
5. Myron G., 2002. Igneous *and Metamorphic Petrology, Blackwell Science*.
6. Faure, G., 2001. Origin of Igneous Rocks–The Isotopic Evidence, Springer.
7. HallA.,1997. *Igneous Petrology*, Longman.
8. LeMaitre, R.W., 2002. Igneous Rocks: A Classification and Glossary of Terms, Cambridge University Press.
9. McBirney, 1994. *Igneous Petrology*, CBSPublishers, Delhi.
10. Sood, M.K., 1982. *Modern Igneous Petrology, Wiley-Interscience Publ., New York*.
11. Srivastava Rajesh, K., Chandra, R. and Balkema, A.A., 1997. *Magmatism in Relation to Diverse Tectonic Settings, Oxford University Press*.
12. Bucher, K. and Martin, F., 2002. *Petrogenesis of Metamorphic Rocks*, Springer–Verlag.
13. Yardley, B.W.D., 1989. *An Introduction to Metamorphic Petrology, Longman Scientific & Technical, New York*.

14. Spear, F.S. 1993. Mineralogical Phase Equilibria and Pressure–Temperature–Time Paths, Mineralogical Society of America.
15. Powell, R.1978. *Equilibrium Thermodynamics in Petrology: An Introduction, Harper & Row Publishers*, London.
16. Bose, M.K.,1997. *Igneous Petrology, World Press*, Kolkata.
17. Sharma, Ram. S., 2016. Metamorphic Petrology: Concepts and Methods, Geological Society of India

Web Resources:

https://www.southalabama.edu/geography/allison/gy303/GY303Lectures.html
http://www1.mans.edu.eg/FacSciM/english/courses/geology/Dr_Mahrous/Abu%20El-nen%20Metamorphic%20Petrology%20Course/Metamorphic%20Petrology%20-%20Lecture%20I.ppt
http://academic.sun.ac.za/natural/geology/undergraduate/modules/G214_course_notes_e.htm
https://serc.carleton.edu/resources/22102.html
http://eps.mcgill.ca/~courses/c212/Igneous14/IgPetClass/IntoPet212-14.pptx
http://www.geosciences.fau.edu/Resources/CourseWebPages/Spring2012/GLY4310_S12/index.4310_S10.htm
https://ocw.mak.ac.ug/courses/earth-atmospheric-and-planetary-sciences/12-479-trace-element-geochemistry-spring-2013/lecture-notes/
http://www.tulane.edu/~sanelson/eens212/

Course Code: MEGS.412

L	T	P	Credits
0	0	4	2

Course Title: Igneous and Metamorphic Petrology (Practical)

Total Hours: 60

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 : Identify and inspect key textural/microstructural features of igneous and metamorphic rocks in hand specimens as well as under the microscope.

CLO2 : Assign an Igneous or metamorphic rock on the basis of its mineralogical and textural characteristics, and appreciate the environment (s) of formation.

CLO3 : Classify the igneous and metamorphic rocks using a different scheme.

Unit/ Hour	Contents	Mapping with CLO
I/15	Following exercise will be conducted in the lab • Megascopic and microscopic study of different igneous rocks • Calculation of CIPW Norms • Preparation of classificatory and variation diagrams and their interpretation • AdetailedstudyoftexturesinrockSectionswithreferencetotimerelationsbetweenthephasesofdeformationandrecrystallizationofminerals	CLO1 CLO2
II/15	• Calculation of ACF, AKF, and AFM values from chemical and structural formulation of minerals and their graphical representation • Study of Metamorphic Rocks in hand specimens and thin sections belonging to different facies with emphasis on texture/structure, mineral composition, parent rock, metamorphic facies/subfacies	CLO2 CLO3

Transactional Modes: Demonstration, Group discussion, Problem solving, Case analysis, Case study, Self-learning, Case-based study, Through SOLE (Self-Organized Learning Environment), Experimentation.

Evaluation Criteria: Total Marks–100, End semester exam (50 marks), Continuous assessment (30 marks), Lab record (10 marks), Viva (10 marks).

Suggested readings:

1. LeMaitre, R.W., 2002. Igneous Rocks: A Classification and Glossary of Terms, Cambridge University Press.
2. Winter, J.D., 2001.*An Introduction to Igneous and Metamorphic Petrology, Prentice Hall.*
3. Philpotts, A.R., 1994.*Principles of Igneous and Metamorphic Petrology, Prentice Hall.*
4. Cox, K.G., Bell, J.D., and Pankhurst, R.J., 1993. *The Interpretation of Igneous Rocks, Chapman & Hall*, London.
5. Myron G., 2002. Igneous and Metamorphic Petrology, Blackwell Science.
6. Faure, G., 2001. Origin of Igneous Rocks–The Isotopic Evidence, Springer.
7. HallA.,1997. *Igneous Petrology*, Longman.

Web Resources:

http://academic.sun.ac.za/natural/geology/undergraduate/modules/G214_course_notes_e.htm
https://serc.carleton.edu/resources/22102.html
http://eps.mcgill.ca/~courses/c212/Igneous14/IgPetClass/IntoPet212-

14.pptx
https://ocw.mak.ac.ug/courses/earth-atmospheric-and-planetary-sciences/12-479-trace-element-geochemistry-spring-2013/lecture-notes/
http://www.tulane.edu/~sanelson/eens212/

Course Code: MEGS.516
Course Title: Geochemistry and Isotope Geology

L	T	P	Credits
3	0	0	3

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 : Appraise behaviors of elements in the formation of primary and secondary rocks
CLO2 : Formulate the basics of isotope systematics and radioactive decay.
CLO3 : Design the geochemical aspects for the assessment of elements in and on Earth.
CLO4 : Discuss the principles and applications of radiogenic isotope systems to study geological processes and date rock-forming events.
CLO5 : Adapt the principles and applications of stable isotope systematics.

Unit/ Hour	Contents	Mapping with CLO
I/11	Introduction to geochemistry and cosmochemistry. The abundance of elements in the solar system and the chemical composition and properties of Earth's layers. Atmosphere: its layers, chemical composition, and evolution of the atmosphere. Meteorites, classification, mineralogy, origin, significance, and phenomena of fall. **Learning Activities:** Assignments, Take-home exercises, and Group discussions.	**CLO1 CLO2**
II/10	Geochemical classification of elements. Chemical Bonds, Ionic Radii, and Crystals, Distribution coefficient; Behavior of major and trace, including rare earth elements during magmatic crystallization, Oddo-Harkins rule. Elemental mobility in surface environment, Eh-pH diagram. Concept of geochemical-biogeochemical cycling: Minor cycle and major cycle. Chemical weathering of minerals and rocks. **Learning Activities:** Take-home exercise, peer learning, and plotting of Eh-pH diagram for stability of different species/complexes of elements.	**CLO3**

III/12	**Isotope Geology:** The law of radioactive decay; principles of mass spectrometry; Principles, methods, and applications of K-Ar method, Ar-Ar method, Rb-Sr method, Sm-Nd Method, U-Th-Pb Method: decay schemes, U-Pb isochron, U-Pb mineral dating, and application. **Learning Activities:** Hands-on exercise during class, take-home exercise, assignment, and student seminar.	**CLO4** **CLO5**
IV/12	Stable isotopes and their fractionation; ratio Mass Spectrometry; principles of oxygen, carbon, and sulphur isotope geochemistry and their application in Geology. Application of Cosmogenic radionuclides in the geosciences. Principles and application of Fission Track and Radiocarbon methods of dating. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO4** **CLO5**

Transactional Modes: Lecture, Project Method, Seminar, Co-operative Learning, Focused Group Discussion, Team Teaching, Mobile Teaching, Collaborative Learning, E-tutoring, Problem-solving, Case Analysis, Self-learning, Case-based Study, Experimentation.

Suggested readings:

1. Gunter Faure, 1998. *Principles and Applications of Geochemistry, Prentice Hall.*
2. John V. Walther, 2010.*Essentials of Geochemistry, Jones and Bartlett Publications*.
3. Claude Allegre, 2008. *Isotope Geology, Cambridge University Press*.
4. Dickin, A.P., 2005.*Radiogenic Isotope Geology*. Cambridge University Press.
5. Jochen Hoefs, 2015. *Stable Isotope Geochemistry*, Springer International Publishing.
6. Gunter Faure, 1986.*Principles of Isotope Geology*, Wiley.
7. Gunter Faure and Teresa M. M, 2004. *Isotopes: Principles and Applications*, Wiley.
8. Francis Albarede, 2003. *Geochemistry: An Introduction, Cambridge University Press*.
9. William M. W.,2013. *Geochemistry*, Wiley-Blackwell.
10. Mc Sween Jr., H. Y., Richardson, S. M., and Uhle, M. E.,2003. *Geochemistry: Pathways and Processes*, Columbia University Press,
11. Mason, B., and Moore, C.B., 1991.*Introduction to Geochemistry, Wiley Eastern.*
12. Krauskopf, K.B., 1967. *Introduction to Geochemistry, McGraw-Hill.*

Web Resources:

https://www.uvm.edu›GEOL195-Geochemistryhttp://www.geo.cornell.edu/geology/classes/Geo656/656notes03.html

https://wwwrcamnl.wr.usgs.gov/isoig/isopubs/itchch2.html
https:/www.southalabama.edu/geology/haywick/GY112/ppt/112-pp8a.pdf
https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-742-marine-chemistry-fall-2006/lecture-notes/lecture_2_notes.pdf

Course Code: MEGS.517

L	T	P	Credits
3	0	0	3

Course Title: Hydrogeology, Remote Sensing and GIS

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Appraise the role of groundwater in the hydrological cycle, groundwater flow pattern in different terrains.

CLO2: Estimate quantity and assess quality aspects of groundwater for better management.

CLO3: Formulate the evolution of water chemistry through hydro-geochemical processes across different terrains.

CLO4: Develop utilization of satellite data in various applications such as geology, hydrogeology, climatology, forestry, town planning, etc.

CLO5: Maximize digital image processing techniques of satellite data for various applications such as land use/land cover, digital elevation model (DEM).

Unit/ Hour	Contents	Mapping with CLO
I/11	Hydrosphere and groundwater system: hydrological cycle; groundwater origin, type, and occurrences. Scope and importance of hydrogeology. Principles of groundwater flow: Darcy's law and its validity, concept of permeameter, water table, and piezometer. Tracing of groundwater movement with flow nets; Pumping tests: principles, types of pumping tests, procedures, data analysis. **Learning Activities:** Design a model of the hydrologic cycle and the concept of Darcy's law.	**CLO1** **CLO2**
II/12	Occurrence, distribution, and quality of groundwater: vertical distribution of groundwater. Hydrologic properties of rocks: porosity, permeability, hydraulic conductivity, storativity. Types of aquifers: unconfined and confined aquifers. Behavior of sedimentary, crystalline, and volcanic rocks as aquifers. Groundwater quality assessment: hydrochemical parameters; hydrochemical data presentation and data analysis. Concept and evaluation of hydrochemical facies. Use of environmental isotopes in groundwater studies.	**CLO1** **CLO2** **CLO3**

	Learning Activities: Group discussion on local major aquifer types and groundwater occurrence.	
III/11	**Fundamentals of Remote Sensing:** Electromagnetic spectrum; scattering, absorption, refraction, path radiance, reflection, transmission, absorption. Energy-Earth interaction. Atmospheric windows. types of satellites: Polar sun-synchronous, geo-stationary. Platforms: types and their orbital characteristics; sensor types: active and passive; sensor systems: whiskbroom and push broom. Characteristics of resolutions of sensor: spatial, spectral, radiometric, and temporal; Basics of digital Image Processing; image enhancement, radiometric correction, image classification. **Learning Activities:** Group discussion on recent developments in satellite technology, exercises on satellite data mining from open sources, and development of different thematic layers using open data sources.	**CLO4 CLO5**
IV/11	**Applications of Remote Sensing and GIS in Geology:** Concept and applications of GIS. Geographic information database management system: datatypes (map, attributes, image data) and structure; spatial and non-spatial data. Applications of remote sensing: in geological mapping; in groundwater exploration; in geomorphic mapping, in identification of rocks, structures, and drainages; in mineral exploration. **Learning Activities:** Brainstorming on the impacts of engineering projects on the environment and their importance to highlight the salient points, student seminar.	**CLO4, CLO5**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Seminar, Group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching, Collaborative learning, Case analysis, Case study, Case-based study, Through SOLE (Self-Organized Learning Environment).

Suggested readings:

1. Todd D.K., 2007. *Groundwater Hydrology*, John Wiley and Sons
2. Gupta, S.K., 2011. *Modern Hydrology and Sustainable Water Development*, Wiley-Blackwell.
3. Raghunath, H.M., 1985.*Groundwater*, Wiley Eastern Ltd.
4. Karanth, K.R.,1987. *Groundwater Assessment Development and Management, McGraw-Hill* Publishers
5. Freeze and Cherry, 1979. *Groundwater*, Prentice-Hall.
6. Singh, C.K. (2018). *Geospatial Applications for Natural Resources Management, CRC Press*.

7. Shellito, B. (2017). *Geospatial Technologies,4thedition, W. H. Freeman Publisher*.
8. Shamsi, U.M. (2012). *GIS Applications for Water, Wastewater, and Stormwater Systems, CRC Press*.
9. Bhatt, B. (2011). *Remote Sensing and GIS, New Delhi: Oxford University Press*.
10. Skidmore, A. (2010). *Environmental Modeling with GIS and Remote Sensing, New Delhi, CRC Press*.
11. Abbasi, T. (2010). *Remote Sensing, GIS and Wetland Management, Discovery Publishing House*.
12. Lillisand,T.M.,Keifer,R.W.(2007).*Remote Sensing and Image Interpretation, USA: John Wiley and* Sons.
13. Joseph, G. (2003). *Fundamentals of Remote Sensing,* Hyderabad: Universities Press.
14. Chang, K. (2002). *Introduction to Geographic Information Systems, USA: Tata McGraw-Hill*.
15. Barrett, E.C. and Curtis, L.F. (1999). *Introduction to Environmental Remote Sensing, USA: Chapman and Hall Publishers*.
16. Curran, P.J. (1988). *Principles of Remote Sensing, ELBS: Harlow, Longman Scientific and Technical*.

Web Resources:

https://iah.org/education/
https://www.routledge.com/Hydrogeologyhttps://www.youtube.com/watch?v=G7CnE5NBxZshttps://geologyscience.com/applied-geology/hydrogeology/
https://bhuvan.nrsc.gov.in/bhuvan_links.php
https://landsat.gsfc.nasa.gov/data
https://www.esri.com/en-us/home

Course Code: MEGS.518

L	T	P	Credits
0	0	4	2

Course Title: Hydrogeology,Remote Sensing and GIS (Practical) **Total Hours: 60**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO.1 : Construct water table maps for evaluation of groundwater flow and discharge site identification
CLO.2 : Maximize exploration of groundwater resources using hydrogeology and GIS GIS-integrated approach
CLO.3 : Assess the quality of groundwater for different uses and top propose the development and management of groundwater resources

CLO.4 : Design various experiments for familiarization with satellite images, mapping, and layout.
CLO.5 : Apply remote sensing and GIS software for image interpretation
CLO.6 : Develop the analytical skills for pre-processing, image classification, and post-processing.

Unit/ Hour	Contents	Mapping with CLO
I/30	The following exercise will be conducted in the lab • Water table contour mapping • Interpretation of flow network: groundwater flow movement, delineation of recharge and discharge areas • Representation of hydrochemical data in Stiff plot and interpretation • Evaluation of hydrochemical facies in the Trilinear diagram and interpretation. • Analysis of hydrochemical facies in Durov diagram	**CLO1** **CLO2** **CLO3**
II/30	• Photogeology: Interpretation of aerial photographs. • Stereoscopic Vision: The Process of perceiving stereoscopic vision using a stereoscope. • Types of Stereoscopes: Use of the Pocket and Mirror stereoscope • Satellite data mining: downloading and familiarization of satellite imagery, reading metadata, and basic characteristics of images. • Preprocessing: geometric and radiometric correction, FCC generation, mosaicking, subletting, and atmospheric correction • GIS database mining: point, polygon, and line features capture, editing and manipulation, topology building, joining attribute table with spatial data.	**CLO4** **CLO5** **CLO6**

Transactional Modes: Demonstration, Group discussion, Problem solving, Case analysis, Case study, Self-learning, Case-based study, Through SOLE (Self-Organized Learning Environment), Experimentation.

Evaluation Criteria: Total Marks–100,
End semester exam (50 marks), Continuous assessment (30 marks), Lab record (10 marks), Viva (10 marks).

Suggested readings:

1. Todd D.K., 2007. *Groundwater Hydrology*, John Wiley and Sons
2. Gupta, S.K., 2011. *Modern Hydrology and Sustainable Water Development*, Wiley-Blackwell.

3. Raghunath, H.M., 1985. *Groundwater*, Wiley Eastern Ltd.
4. Karanth, K. R., 1987. *Groundwater Assessment Development and Management,* McGraw-Hill Publishers
5. Freeze and Cherry,1979. *Groundwater*, Prentice-Hall.
6. Singh, C.K. (2018). *Geospatial Applications for Natural Resources Management, CRC Press*.
7. Shellito, B. (2017). *Geospatial Technologies,4th edition,W. H. Freeman Publisher*.
8. Shamsi, U.M. (2012). *GIS Applications for Water, Wastewater, and Stormwater Systems, CRC Press*.
9. Bhatt, B. (2011). *Remote Sensing and GIS, New Delhi: Oxford University Press*.
10. Skidmore, A. (2010). *Environmental Modeling with GIS and Remote Sensing, New Delhi, CRC Press*.
11. Abbasi, T. (2010). *Remote Sensing, GIS and Wetland Management, Discovery Publishing House*.
12. Lillisand, T.M., Keifer, R.W. (2007). *Remote Sensing and Image Interpretation,* USA: John Willey and Sons.
13. Joseph, G. (2003). *Fundamentals of Remote Sensing,* Hyderabad: Universities Press.
14. Chang, K. (2002). *Introduction to Geographic Information Systems,* USA: Tata McGraw-Hill.
15. Barrett, E.C. and Curtis, L.F. (1999). *Introduction to Environmental Remote Sensing,* USA: Chapman and Hall Publishers.
16. Curran, P.J. (1988). *Principles of Remote Sensing,* ELBS: Harlow Longman Scientific and Technical.

Web Resources:

https://iah.org/education/https://www.routledge.com/Hydrogeology
https://www.youtube.com/watch?v=G7CnE5NBxZshttps://geologyscience.com/applied-geology/hydrogeology/
http://www.tulane.edu/~sanelson/eens212/https://bhuvan.nrsc.gov.in/bhuvan_links.phphttps://landsat.gsfc.nasa.gov/data
https://www.esri.com/en-us/home

Course Code: MEGS.519

L	T	P	Credits
3	0	0	3

Course title: Analytical techniques and geostatistics

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Explain principle, instrumentation and application of instruments

CLO2: Distinguish steps and working principle of electrochemical, and spectrometric

CLO3: Describe the types, principle and applications of chromatographic techniques

CLO4: Solve quantitative problems of geosciences

Unit/ Hour	Contents	Mapping with CLO
I/11	Electrochemical methods: pH meter, Conductivity meter, TDS meter, DO meter, Salinity meter used in field/in-situ. Voltammetry method: Anode stripping voltammetry. Introduction to mass spectrometry, Spectrometric Methods for elemental analysis: U.V. spectrophotometer, Flamephotometry, Atomic absorption spectrophotometry (AAS), Microwave-plasma Atomic Emission Spectroscopy (MP-AES); Inductive Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) and optical emission Spectroscopy (ICP-OES). **Learning Activities:** Hands on exercise, assignment and student seminar.	**CLO1** **CLO2**
II/12	Introduction to working principles, concepts, sample preparation, applications and limitations of X-ray Diffractions (XRD), Scanning Electron Microscope(SEM), X-ray fluorescence(XRF), Energy-dispersive X-ray spectroscopy (EDS, EDX, or XEDS), Electron Probe Micro Analyzer (EPMA), Proton Induced X-ray Emission (PIXE). **Learning Activities:** Assignment, take home exercise and student seminar.	**CLO3** **CLO4**
III/11	Principle and applications of Chromatography techniques; Inductive Coupled Plasma Mass Spectroscopy (ICP-MS): Quadruple and magnetic sector; Multicollector Mass spectrometer like TIMS, MC-ICP-MS, LA-MC-ICP-MS; Optical simulation Luminescence (OSL) dating techniques; Accelerator mass spectrometer; other supporting analytical methods like: Thermo gravimetric Analysis (TGA,DTA), Total Organic Carbon analyzer, Particle size analyzer, Magnetic separator. **Learning Activities:** Assignment, take home exercise, seminar	**CLO3** **CLO4**
IV/11	Application of different statistical tool to interpret the geological data such as sampling, descriptive statistics, central tendency of data, probability function,	**CLO3** **CLO4**

	hypothesis testing, Anova, exponential smoothing, regression and correlations, cross correlation, sampling, moving average for time-series data, Fourier transformation, matrix, PCA analysis and Eigen value, intrapolation, Markovchain, segmenting sequences, splines and semi variograms. **Learning Activities:** Assignment, take home exercise and student seminar	

Transactional Modes: Lecture, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Co-operative learning, Blended learning, Flipped learning, Team teaching, Brain storming, Mobile teaching, Collaborative learning, Problem solving, Self-learning, Case based study, Through SOLE (Self Organized Learning Environment).

Suggested readings:

1. Bruce, L.B. 2001. *Qualitative Research Methods for Social Sciences*, Allyn and Bacon, Boston.
2. John,W.C.,2011.*ResearchDesign:Qualitative,QuantitativeandMixedMethods Approaches*, Sage Publications, Thousand Oaks.
3. Potts,P.J.,1997.*Silicaterockanalysis*
4. Reed, S.J.B.,1990. *Recent developments in geochemical microanalysis: Chemical Geology*, Volume. 83, PP.1-9.
5. FrankA.Settle,1997.*Handbook of Instrumental Techniques for Analytical Chemistry*, Prentice Hall, Upper Saddle River, NJ.
6. Hussain, C. H., Kecili, R (2020). *Modern Environmental Analysis Techniques for Pollutants*, Elsevier Book, ISBN:9780128169346.
7. AhluwaliaV.K.(2015).*InstrumentMethodsofchemicalanalysis,*AneBooksPvt. Ltd.
8. Holler F.J., Crouch, S.R.(2014).*Skoog & West's Fundamental of Analytical Chemistry,* 9th edition, CENGAGE learning.
9. Chatwal,G.R.,Anand, S.K.(2013).*Instrumental Methods of Chemical Analysis,* Himalaya Publishing House, NewDelhi
10. Patnaik,P.(2010).*Hand book of environmental analysis,* CRC Press, USA
11. Rouessac, F., Roussac, A. (2008). *Chemical analysis: modern instrumentation and techniques*, Wiley, England.
12. Skoag, D.A., Holler, F.J., Crouch, S.R.(2007).*Principles of Instrumental Analysis,* CENGAG ELearning.
13. Skoog D. A., Holler, F. L., Crouch, S. R. (2007). *Principles of instrumental analysis,* USA: Thomson Brooks/Cole Publishers.
14. Rajvaidya,N.,Markandey,D.(2005).*EnvironmentalAnalysisandInstrumentation,*APHPublisher.
15. Eaton, A. D., Clesceri, L. S., Rice, E. W., Greenberg, A.E. (2005).*Standard methods for examination of water and waste water,* 21st Edition. American Public Health Association, American Water Worker Association, Water Environment Federation, USA.

16. Wiersma, G. (2004). *Environmental monitoring,* CRC Press, UK.
17. Svehla, G. (1996). *Vogel's qualitative inorganic analysis, 7th Edition,* Prentice Hall, USA
18. Shukla,S.K.,Srivastava,P.R.(1992).*Methodology for environmental monitoring and assessment,* New Delhi: Commonwealth Publishers.
19. Ewing, G.W.(1985).*Instrumental methods of chemical analysis, 5th edition,* USA: McGraw Hill Publications
20. Harris, D.C. (1948). *Exploring Chemical Analysis,* 3rd edition. W.H Freeman & Company.

Web Resources:

https://pubs.acs.org/doi/10.1021/acsnano.9b05157https://serc.carleton.edu/research_education/geochemsheets/techniques/XRF.html
http://www.ecs.umass.edu/eve/facilities/equipment/ICPMS/ICPMS%20quick%20guide.pdf
https://www.eag.com/techniques/spectroscopy/particle-induced-x-ray-emission-pixe/
https://serc.carleton.edu/research_education/geochemsheets/techniques/TIMS.htmlhttps://web.njit.edu/~gilhc/EE495/TIMS.htm
https://www.thermofisher.com/blog/microscopy/edx-analysis-with-sem-how-does-it-work/
https://serc.carleton.edu/research_education/geochemsheets/techniques/MCICPMS.html
https://serc.carleton.edu/research_education/geochemsheets/browse.#xray

Course Code: MEGS.520

L	T	P	Credits
2	0	0	2

Course Title: Entrepreneurship in Geosciences

Total hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, students will be able to

CLO1 : Understand the basic concepts of entrepreneurship, its importance.

CLO2 : Aware of the issues, challenges, and opportunities in entrepreneurship.

CLO3 : Develop the capabilities of preparing proposals for starting small businesses.

CLO4 : Know the availability of various institutional/industrial supports for making a new start-up.

Unit/ Hour	Contents	Mapping with CLO
I/7	Introduction to entrepreneurship and entrepreneurship; Characteristics of an entrepreneur; Characteristics of entrepreneurship; entrepreneurial traits and skills; innovation and entrepreneurship; Types of entrepreneurial ventures; enterprise and society in the Indian context; Importance of women entrepreneurship. **Learning Activities:** Group discussion and student seminar.	**CLO1** **CLO2**
II/8	Opportunity analysis, external environment analysis, legal requirements for establishing a new unit, raising of funds, and establishing the venture - Project report preparation – format for a preliminary project report, format for a detailed/final project report. **Learning Activities:** Brainstorming session and case study.	**CLO3** **CLO4**
III/8	Scope and opportunities in the field of mineral exploration, groundwater exploration, geotechnical solutions, and geo-consultancy. Basic requirements for establishing a small business, Possible avenues for developing Geo-entrepreneur; Requirements and demand for geo-consultancy. **Learning Activities:** Student seminars and proposal on development and scope of possible Geo-entrepreneur	**CLO3**
IV/7	Preparation of IAR/CHR/ Modelling Reports as per the guidelines issued by Central Ground Water Authority, Ministry of Jal Shakti: A) Impact Assessment Report For Infrastructure Projects Involving Dewatering, B) Comprehensive Hydro Geological Report On Ground Water Conditions In Both Core And Buffer Zones For Mining Projects. **Learning Activities:** Mini projects, Case studies, and live interaction with the young and dynamic Geo-entrepreneur	**CLO2** **CLO3** **CLO4**

Transactional Modes: Lecture, Project Method, Inquiry Training, Seminar, Group Discussion, Co-operative Learning, Blended Learning, Flipped Learning, Team Teaching, Brainstorming, Mobile Teaching, Collaborative Learning, Self-learning, Case-based Study, Through SOLE (Self-Organized Organized Environment)

Suggested readings:

1. Arora, Renu (2008). *Entrepreneurship and Small Business, Dhanpat Rai & Sons Publications*.
2. Chandra, Prasaaan (2018). *Project Preparation, Appraisal, Implementation*, Tata McGraw-Hill.
3. Desai, Vasant (2019). *Management of a Small-Scale Industry, Himalaya Publishing House*.
4. Jain, P.C. (2015). *Handbook of New Entrepreneurs, Oxford University Press*.
5. Srivastava, S.B. (2009). *A Practical Guide to Industrial Entrepreneurs*, Sultan Chand & Sons.

Web Resources:

http://cgwb.gov.in/AR/Final-Guideline-IA-AR-Studies-submitted-website-hosting.pdf
https://cgwb.gov.in/Documents/GEC97.pdf
https://www.dalmiacement.com/wp-content/themes/DalmiaCement/assets/pdf/Final-CHG-Dalmia-Kottameta_03.06.22.pdf

Tutorial/ Remedial Class

L	T	P	Credits
0	2	0	0

Two hours non-credit tutorial class is designed for remedial teaching. Scheduled classes will be assigned in the timetable. As per the requirement of students, remedial classes will be conducted in these periods.

Discipline Elective: Select any one

Course Code: MEGS.521

L	T	P	Credits
3	0	0	3

Course Title: Mineral Exploration and Petroleum Geology **Total Hours: 45**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 : Evaluates ore deposit types, including genesis and exploration requirements;
CLO2 : Designing an understanding of petroleum geology, exploration techniques, and resource evaluation;
CLO3 : Explain the concept-oriented approaches in the analysis of geological data.
CLO4 : Assess and apply geochemical exploration methods and geochemical data presentation/analysis;
CLO5 : Discusses the role of geology in mine design and operation.
CLO6 : Evaluate the range of surface and underground mining techniques

Unit/ Hour	Contents	Mapping with CLO
I/10	Distribution of mineral resources in India: Gas hydrates and coal bed methane. Introduction to mineral exploration, stages of exploration, and types of exploration. **Transactional Modes:** Assignment, Take-home exercise, peer learning.	**CLO1 CLO2 CLO5**
II/12	**Mineral Exploration Methods:** Geological, geophysical, geochemical, and geobotanical methods of surface and sub-surface exploration on different scales; Sampling, assaying, and evaluation of mineral deposits; Methods of petroleum exploration. **Transactional Modes:** Assignment, take-home exercise, group discussion.	**CLO3 CLO4 CLO5**
III/12	**Occurrence and Source rocks:** Classification and composition of Petroleum; Physical properties of petroleum; Occurrence of petroleum; Nature of source rock, composition of biomass; Kerogen: Composition and types; Reservoir rocks, pore space and fluids; Reservoir Traps; Origin, migration and accumulation of petroleum. Basin Analysis. **Transactional Modes:** A case study by a different group followed by discussion and assignment.	**CLO1**

IV/11	**Indian Oil Fields- Prospecting and Drilling:** Oil bearing basins of India and the world; India's position regarding petroleum and natural gas future prospects; Geophysical prospecting for petroleum; Drilling, logging, and subsurface correlation. Importance of micropaleontology in the field of petroleum exploration. **Transactional Modes:** Student seminar and brainstorming.	**CLO2** **CLO5** **CLO6**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, flipped learning, Focused group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching, Collaborative learning, Case-based study.

Suggested readings:

1. Leverson, 2006. *Geology of Petroleum*, CBS.
2. Selley, R.C., 1997. *Elements of Petroleum Geology, Atlantic Publishers & Distribution Pvt*. Ltd, Delhi.
3. Emmons, W.H., 2015. *Geology of Petroleum*, Sagwan Press.
4. Dobrin, M.B., and Savit, C.H., 1988. *Introduction to Geophysical Prospecting, McGraw-Hill Inc*.
5. Kearey, P., Brooks, M. and Hill, I., 2002.*An Introduction to Geophysical Exploration,* Wiley-Blackwell.
6. Parasnis, D. S., 1986. *Principles of Applied Geophysics, Chapman and Hall*.
7. Hawkes, H.E., Webb, J.S., 2012. *Geochemistry in mineral exploration, Literary Licensing*, LLC.
8. Haldar, S.K., 2013. Mineral Exploration: Principles and Application, Elsevier.
9. Moon C.J., Whateley, M.K.G., and Evans, A.M., 2005. *Introduction to Mineral Exploration*, Blackwell Science.
10. Dobrin, M.B., and Savit C.H., 1988. *Introduction to Geophysical Prospecting, McGraw-Hill Inc*.
11. Kearey, P., Brooks, M., and Hill, I., 2002. *An Introduction to Geophysical Exploration*, Wiley-Blackwell.

Web Resources:

https://pubs.usgs.gov/of/1995/ofr-95-0831/CHAP3.pdfhttps://www.osti.gov/servlets/purl/895050
http://faculty.washington.edu/dersh/Files/Geophysics2006.pdfhttps://eclass.uoa.gr/modules/document/file.php/GEOL312/Geophysical%20methods/Forte_L1_Introduction%20to%20geophysical%20methods.pdf
https://www.gsi.ie/en-ie/programmes-and-projects/minerals/activities/mineral-exploration/Pages/Geophysical-Methods.aspx

Course Code: MEGS.522

L	T	P	Credits
3	0	0	3

Course Title: Oceanography

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

- **CLO1** : Explain the theories related to the origin and evolution of the oceans.
- **CLO2** : Understand the various topographical features associated with the ocean systems.
- **CLO3** : Describe the process, causes, and effects of ocean water circulation.
- **CLO4** : Grasp the concepts of ocean currents and their distribution in all the major oceans of the Earth's surface.
- **CLO5** : Develop an understanding of the Indian Monsoon and its impacts.
- **CLO6** : Learn the important concepts related to the waves, tides, and tsunamis.
- **CLO7** : Expand their knowledge in the field of ocean chemistry and sedimentation.

Unit/ Hour	Contents	Mapping with CLO
I/11	Origin and evolution of ocean basins; Importance of oceans; Paleoceanography: Theories, proxies and significance; Hydrological cycle; Hypsometric Curve; Ocean bottom relief; Bottom relief of Pacific, Atlantic and Indian Ocean; Salinity of the ocean: Sources, factors and distribution; Salt budget. **Learning Activities:** Assignment, take-home exercise, peer learning on oceanic topography.	**CLO1** **CLO2**
II/12	Ocean water circulation; Convection cells of the Earth; Coriolis forces: Its cause and effects; Wind drags; Ekman Spiral; Mechanism of Hurricanes and its difference from Tornadoes; Storm surges; Gyres; Geostrophic currents; Western Intensifications. **Learning Activities:** Exercise on the mechanics of atmospheric and oceanic circulation.	**CLO3**
III/11	Ocean currents: causes and impacts; Currents of Pacific, Atlantic, and Indian Ocean; Gulf Stream; Concepts of Indian Monsoon; Retreat Monsoon; Walker Circulation; Southern Oscillation; El Niño and La Niña; El Niño Southern Oscillation (ENSO); Indian Ocean Dipole (IOD). **Learning Activities:** Group discussions, Assignments, Term papers.	**CLO4** **CLO5**

IV/11	Ocean waves: Wave dynamics, deep water waves, shallow water waves, progressive waves, wave interference, wave dispersion, wave transformation and wave breaks; Tsunami; Tides; chemical properties of seawater; Principal of constant proportion; Ocean acidification and pH buffer; Ocean sediments and marine deposits; Coral reefs: Origin, distribution and significance; Coral bleaching; Exclusive Economic Zone (EEZ); India's Exclusive Economic Zone (EEZ)..; **Learning Activities:** Assignment on wave dynamics and ocean chemistry, group discussion on EEZ of the Indian Ocean.	**CLO6** **CLO7**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry Training, Seminar, Group discussion, Blended learning, flipped learning, Focused group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching, Collaborative learning, Case-based study, Through SOLE (Self-Organized Learning Environment).

Suggested readings:

1. Garrison, T., 1996.*Oceanography-An invitation to Marine Science*, Wadsworth Publishing Company
2. Gross, M.G.,1972. *Oceanography: A View of the Earth*, Prentice-Hall.
3. Thurman, B.Y., 1978. *Introductory Oceanography*, Charles E. Merrill Publishing Company.
4. Kale, V.S. and Gupta, A., 2001.*Introduction to Geomorphology, Orient Longman*, Bangalore.
5. Singh, S., 2011.*Physical Geography, Prayag Pustak Bhavan*, Allahabad.
6. Strahler, A.N. and Strahler, 1996.*An Introduction to Physical Geography, John Wiley & Sons*, UK.
7. S. Davis, R.A. Jr., 1972.*Principles of Oceanography, Addison-Wesley Publishing Company*.
8. Roonwal, G.S.,1986. *The Indian Ocean: Exploitable Mineral and Petroleum Resources, Narosa Publishing House*.
9. Francis P. Shepard, 1977. Geological Oceanography: Evolution of Coasts, Continental Margins & the Deep-Sea Floor, Pan Publication.
10. Bhatt J.J., 1978. *Oceanography–Exploring the Planet Ocean, D. van Nostrand Company*.

Web Resources:

https://www.nationalgeographic.org/https://www.nio.org/
https://science.nasa.gov/earth-science/focus-areas/oceanography

Course Code: MEGS.523

L	T	P	Credits
3	0	0	3

Course Title: Watershed Management

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to integrate and apply technical knowledge in the following key areas

CLO1: exploration of water resource through watershed management and exploration methods
CLO2: Evaluation of the validity and limitations of scientific theories and claims about the watershed management
CLO3: Appraisal of the interactions among the physical, biological, chemical, and human components controlling the watershed area.

Units/ Hours	Content	Mapping with CLO
I/11	Introduction to water shed management concept, different stakeholders and their relative importance. Fundamental policies for watershed management and decision making. Issues related to watershed management, approach and components. Role of structure, relief, physiography, drainage systems in watershed management. **Learning Activities:** Group discussion on watershed management policies in India, to highlight the salient points.	**CLO1**
II/12	Importance of rivers and lakes in India; hydrological cycle; Water conservation and management techniques; Wetland–definition, classification, functions, ecological importance and conservation. Rainwater harvesting; concept of Micro Watershed Management; Watershed Management using Geo-spatial technologies. **Learning Activities:** Prepare a note on watershed management plan of India, followed by student presentation on that note.	**CLO2, CLO3**
III/11	Community participation, private sector participation, Institutional issues, Socio-economy, Integrated development; Watershed Management in India, Water legislation and implementations, policies and decision making. **Learning Activities:** Group discussion on water legislation and implementations and its presentation.	**CLO3**

IV/11	Storm water management: design of drainage system, flood routing through channels and reservoir. Flood control and reservoir operation. Case studies onflooddamage.Droughtassessmentandclassification,droughtanalysistechniques,droughtmitigationplanning. **Learning Activities:** Mini project and student presentation on mechanism of Indian monsoon system and climatic regimes.	**CLO2, CLO3**

Transactional Modes: Lecture, Demonstration, Tutorial, Problem solving, Seminar, assignment, Group discussion, Tools used: PPT, Video, Animation.

Suggested Readings:

1. Murthy, K.S. 1998. *Watershed Management in India*, Wiley Eastern Ltd. /NewAge International Ltd.
2. Tideman, E.M.,1996. *Watershed Management: Guidelines for Indian Conditions*, Omega, NewDelhi.
3. Verghese,B.G.,1990. *Waterof Hope: Integrated Water Resource Development and Regional Co-operation within the Himalayan-Ganga-Brhamaputra-Barak Basin*, Oxford-IBH
4. Kathy Wilson Peacock, 2008. *Natural resources and sustainable developments*, Facts on file Inc.
5. Daniel R. L., 2009. *Sustainable natural resource management for scientists and engineers*, Cambridge University press
6. Panday, S.N. and Misra, S.P. (Eds.), 2008. *Essential Environmental Studies*, CRC Press.

Web Resources:

https://www.newworldencyclopedia.org/entry/Climate_of_India
https://www.weatheronline.co.uk/reports/climate/India.htm
https://www.india.gov.in/https://bhuvan.nrsc.gov.in/bhuvan_links.php

Interdisciplinary Course (IDC) offered by the department

L	T	P	Credits
2	0	0	2

Course Code: MEGS.506

Course Title: Introduction to Disaster Management **Total hours: 30**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Define key terms in disaster management and explain the disaster management cycle.

CLO 2: Classify types of natural and human-made disasters, with emphasis on those affecting India.

CLO 3: Describe the main national and international disaster management frameworks and policies.

CLO 4: Identify the roles and responsibilities of institutions and stakeholders in disaster management.

Unit/ Hour	Contents	Mapping with CLO
I/7	Disaster Management: definition, scope, Objectives and Approaches, Definitions and concepts of Hazard, Vulnerability, Risk, Resilience, Concept of Disaster Management Cycle – Response, Recovery, Mitigation and Preparedness. **Learning Activities:** Group Discussion and brainstorming session on disaster and hazards.	**CLO1**
II/9	Introduction to various Hazards both Natural and Man-Made Hazards- earthquake, volcanoes landslide, flood, cyclone, tsunami, droughts, forest fires, industrial accidents, biological disasters, climate change, global warming etc. **Learning Activities:** Student seminar, discussion and brain storming session	**CLO2**
III/8	Introduction to National Disaster Management Plan-2019, PM's Ten-Point Agenda for Disaster Risk Reduction, Main Pillars of NDMP, Global Frameworks— Disasters, Sustainable Development and Climate Change, objectives of the National Policy on Disaster Management, Disaster Management Act, Disaster mitigation: Concept, importance, tools, strategies with reference to specific disasters; **Learning Activities:** Student presentation and group discussion on the case study on Indian disasters, and their mitigation and preparedness techniques.	**CLO3** **CLO 4**

IV/7	Basic Institutional Framework- national, state-level disaster management, Key National-Level Decision-Making Bodies for Disaster Management, Role and responsibility of Central, State, District, and Local Administration, Armed Forces, NGOs, media, etc. Disaster relief; Reconstruction planning; **Learning Activities:** Student Seminar and brainstorming session on the disaster management system of India.	**CLO3** **CLO4**

Transactional Modes: Lecture, Project Method, Inquiry Training, Seminar, Group Discussion, Blended Learning, Flipped Learning, Focused Group Discussion, Mobile Teaching, Collaborative Learning, Case-Based Study.

Suggested reading:

1. Srivastava, A.K. 2021. Textbook of disaster management. Scientific Publishers.
2. Coppola, D. 2015. Introduction to International Disaster Management. Elsevier. 3rd Edition.
3. Ahmad, A., 2010.*Disaster Management: Through the New Millennium, Anmol Publications, New Delhi*.
4. Ahmed, Shaik Iftikhar, 2008. Disaster Management in the Wake of a Flood, Twenty-First Century Publications, Patiala.
5. Bilham, R. 2009. *The seismic future of cities, Bulletin of Earthquake Engineering*.
6. Bryant, E.,2005. *Natural Hazards, Cambridge University Press*, U.K.
7. Bureau ofIndian Standards (2002). Indian Standards: Criteria for Earthquake-Resistant Design of Structures, Part I, Fifth Revision.
8. Burton, I., Kates, R.W., and White, G.F.,1993. *Environment as Hazard, 2nd edition, Guilford Press, New York*.

Web Resource:

http://www.onlinenidm.gov.in/
https://ndma.gov.in/
https://ndmindia.mha.gov.in/#
https://www.mha.gov.in/division_of_mha/disaster-management-division
https://www.undp.org/
https://library.wmo.int

Course Code: MEGS.507

L	T	P	Credits
2	0	0	2

Course Title: Introduction to Earth System Science **Total hours: 30**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1 : Develop a basic understanding of the origin of Earth, major components and processes of the Earth systems, and the Evolution of life.

CLO2: Develop the essential properties of Earth's components, including its core, mantle, asthenosphere, lithosphere, cryosphere, hydrosphere, atmosphere, and biosphere.

CLO3: Explain the plate tectonic theory and its relationship to earth processes; identify common rocks and minerals and interpret their genesis; recognize the events in geologic history using geological shreds of evidence and discover how Earth works as a system of interacting components across geological timescales.

CLO4: Demonstrate how the oceans are connected to the atmosphere and plate tectonics.

Unit/ Hours	Contents	Mapping with CLO
I/7	Branches and scopes of Earth Sciences; General characteristics and origin of the Universe, solar system and its planets; Concepts of Meteorites its classification and implications to solar system formation; Planet Earth: Origin, size, shape, mass, density, rotation and revolution parameters; Origin of atmosphere, ocean and life; Mechanical layering of the Earth and its internal composition; Concepts of Convection currents and Earth's magnetic field. **Learning Activities:** Student seminar, discussion and brain storming session	**CLO1, CLO2**
II/8	Concept of isostasy and geothermal gradient of the Earth; Plate tectonics: Continental drift and Sea floor spreading; Plates and plate boundaries: Convergent, Divergent and Transform Plate Boundaries; Seismic Waves and Earthquakes; Volcanoes and volcanic landforms. **Learning Activities:** Take-home exercise on isostasy, finding earthquake epicenters, and online monitoring the intensity map of earthquakes.	**CLO2, CLO3**
III/8	Cosmic abundance of elements: Distribution of elements in solar system and in Earth; Geochemical cycles; Concepts of uniformitarianism, catastrophism and neptunism; Laws of superposition and faunal succession; Concept of Geological Time Scale and Mass Extinction; Minerals and their characteristics; Rocks: Classification, origin and characteristics; Soils: types, soil profile, processes of formation of soil; Concept of weathering and erosion.	**CLO2, CLO3**

	Learning Activities: Group discussion on important geochemical cycles and theories.	
IV/7	Hydrologic cycle and groundwater system; Concepts of eustasy and Land-air-sea interaction; Ocean and atmospheric circulations; Bathymetry of the ocean floor; Oceanic current system and effect of Coriolis force; Natural resources and their management; Global Carbon Cycle. **Learning Activities:** take-home exercise, budgeting of carbon in the different systems	**CLO4**

Transactional Modes: Lecture, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Mobile teaching, Collaborative learning, Case-based study.

Suggested reading:

1. Bangar, K.M., 2020, Principles of Engineering Geology. Standard Publishers Distributors, ISBN: 978-8180141157.
2. Mahapatra, G.B., 2019, A Textbook of Geology. CBS Publishers, ISBN: 978-0824794446.
3. McConnell, D., Steer, D., Knight, C., Owens, K., and Park, L., 2016, The Good Earth: Introduction to Earth Science. McGraw Hill Publication, 1st Ed., ISBN: 978-0-07-301847-8.
4. Christiansen E.H., and Hamblin, W.K., 2015, Dynamic Earth: An Introduction to Physical Geology. 1st Ed., Jones and Bartlett Publishers, Inc., ISBN: 9781449659844.
5. Dasgupta, A., 2013, An Introduction to Earth Science. World Press, ISBN: 978-9382878001.
6. Mukherjee, P.K., 2013, Textbook of Geology. World Press, ISBN: 978-8187567547.
7. Grotzinger, J., Jordan, T.H., Press, F., and Siever, R., 2007, Understanding Earth (Fifth Edition). W. H. Freeman and company, New York.
8. Kump, L.R., Kasting, J.F., and Crane, R.G., 2004 The Earth System, Prentice Hall, 2nd Ed., ISBN 0-13-142059-3.
9. Jacobson, M. C., Charlson, R. J., Rodhe, H., and Orians, G. H., 2000, Earth System Science: San Diego, CA, Academic Press, 523 p., ISBN 0-12-379370-X
10. Patwardhan, A.M., 2004, The Dynamic Earth System, Prentice Hall India Learning Private Limited, New Delhi. ISBN -978-81-203-1496-2.
11. Duff, P.M.D., and Duff, D., (Eds.) 1993. Holmes' principles of physical geology. Taylor and Francis.

Web Resources:

https://open.uci.educourses/ess_1_introduction_to_earth_system_science.html
https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-001-introduction-to-geology-fall-2013/lecture-notes-and-slides/
https://cosmolearning.org/courses/introduction-earth-system-science/
https://www.tulane.edu/~sanelson/Natural_Disasters/struct&materials.htm

https://www.eolss.net/sample-chapters/C12/E1-01-02.pdf
https://www.soas.ac.uk/cedep-demos/000_P500_ESM_K3736-Demo/module/pdfs/p500_unit_01.pdf
https://ucdavis.mediaspace.kaltura.com/media/Lecture+1+-+Intro+to+Earth+System+Science+-+ESM+120+%28Winter+2021%29/1_th0lfkw5

Course Code: MEGS.508

L	T	P	Credits
2	0	0	2

Course Title: Geoheritage and Geotourism

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Familiar with the general concepts of the world's geological heritage and India.
CLO2: Understand the major contemporary evolutionary trends in Geoheritage and Geotourism.
CLO3: Know the different institutional figures of nature conservation areas and their importance in Geoheritage and Geotourism.
CLO4: Curate and communicate geoheritage inventory.

Unit/Hour	Contents	Mapping with CLO
I/15	Concepts of geodiversity, geosites, geoheritage, geoconservation, geotourism, and geoparks. Classification and significance. International geoconservation designations: World Heritage Sites, Ramsar Sites, European Designations **Learning Activities:** Assignment, take-home exercise, and student seminar.	**CLO1 CLO3 CLO4**
II/15	Geoheritage elements across the Indian sub-continent. National Geological Monuments (NGM). Aspiring and prospective geopark localities of India. Organizational efforts towards geoconservation. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO1 CLO2 CLO3 CLO4**
III/15	Definition of geoparks. Objectives of geoparks. History of development of geoparks: role of UNESCO, international promotional events. Infrastructural elements of geoparks: geoguides and georangers, geopaths, georoutes, information panels and signages, geomuseums, geoshops, geohotels, geoproducts. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO2 CLO3 CLO4**

IV/15	Geotourism routes: inventory, evaluation, conservation, and enhancement of Geoheritage. Case studies of the Geoheritage sites of India and the world. International Geopark Networks. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO2** **CLO3** **CLO4**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Team teaching, Brain storming, Mobile teaching, Collaborative learning, E-tutoring, Problem solving.

Suggested Readings:

1. C. Anze, L. Yunting and C.Y. Ng. Young (2015). The Principles of Geotourism, Science Press, Beijing
2. C.V. Burek and C.D. Prosser (2008). The History of Geoconservation, The Geological Society, London, Special Publications, 300
3. D.R. Reddy (2020). A Monograph on Potential Geoparks of India, INTACH, New Delhi
4. 36th IGC (2016). Geotourism Hotspots of Indian Subcontinent, GSI, New Delhi
5. C. Sharples (2002). Concepts and Principles of Geoconservation, Tasmanian Parks and Wildlife Service, Australia
6. R.K. Dowling and D. Newsome (2006). Geotourism – Sustainability, Impacts and Management, Elsevier Butterworth-Heinemann, Oxford
7. R, Crofts, J.E. Gordon, J. Brilha, M. Gray, J. Gunn, J. Larwood, V.L. Santucci, D. Tormey and G.L. Worboys (2020). Guidelines for Geoconservation in Protected and Conserved Areas, Best Practice Protected Area Guidelines, Series No. 31, IUCN, Switzerland
8. M.H. Henriques, R.P. dos Reis, J. Brilha, T. Mota (2011). Geoconservation as an Emerging Geoscience. Geoheritage, 3, 117–128.

Web Resources:

http://www.globalgeopark.org/homepageaux/tupai/6513.htm
IUGS | International Commission on Geoheritage
Geodiversity, World Heritage and IUCN | IUCN
IUGS Geological Heritage sites | UNESCO
UNESCO Global Geoparks | UNESCO
International Geoscience and Geoparks Programme | UNESCO
Guardians of GEOHERITAGE:-A 'THE SOCIETY OF EARTH SCIENTISTS' Initiative

Semester – III

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.535	Research Methodology	*Ability Enhancement*	2	0	0	2
MEGS.536	Solid Earth Geophysics	*Discipline Specific Core*	3	0	0	3
MEGS.537	Sedimentology and Engineering Geology	*Discipline Specific Core*	3	0	0	3
MEGS.538	Sedimentology (Practical)	*Practical's/ Skill Based*	0	0	3	1.5
MEGS.539	Ore Geology	*Discipline Specific Core*	3	0	0	3
MEGS.540	Ore Geology (Practical)	*Practical's/ Skill Based*	0	0	3	1.5
Select any one from the following Discipline Elective course$						
MEGS.541	Environmental Geology	*Discipline Elective*	3	0	0	3
MEGS.542	Quaternary Geology		3	0	0	3
MEGS.543	Geomagnetism		3	0	0	3
	Tutorial	*Remedial class*	0	2	0	0
Select Any One Value Added Course (VAC)$						
MEGS.511	Geological Mapping	*VAC*	2	0	0	2
MEGS.512	Environmental Magnetism	*VAC*	2	0	0	2
		Total	**16**	**2**	**6**	**19**

Course Code: MEGS.535

L	T	P	Credits
3	0	0	3

Course title: Research Methodology

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Choose and propose appropriate research methods according to their research aims and objectives
CLO2: Aware of the limitations of particular research methods
CLO3: Justify knowledge of the selection of various instruments and sample preparation techniques for addressing the specific research problem
CLO4: Develop skills in qualitative and quantitative data analysis and presentation
CLO5: Design advanced critical thinking skills and enhanced writing skills

Unit/ Hour	Contents	Mapping with CLO
I/11	Concept and definition of Research: academic research, basic and fundamental research, applied research, theoretical, conventional, and experimental research. Concepts and needs of the research hypothesis. Research proposal and concepts; developing a research proposal in the field of geosciences; research approach and identifying gap areas from the literature review; problem formulation and statement of research objective. **Learning Activities:** Assignment, take-home exercise on identifying research gaps from different selected topics, and discussion.	**CLO1** **CLO2**
II/11	Literature survey and review, use of digital library, online resources; Problem formulation and statement of research objective; Development of bibliography. Research Ethics, Concepts on plagiarism, ISSN and ISBN numbers, impact factors, and citation index of research articles, and assessing the quality of research articles. **Learning Activities:** Assignments and exercises on developing bibliography, referencing.	**CLO4** **CLO5**
III/12	Pre-field preparations: field mapping and documentation, procedure of sampling, Introduction to field mapping and section measurement. Recent advancements in analytical techniques, field gear, data sciences, and AI in the field of Earth Sciences. **Learning Activities:** Assignment, take-home exercise, and student seminar.	**CLO1** **CLO2** **CLO3** **CLO4**
IV/11	Types of data: primary and secondary data, source, and authenticity of secondary data. Introduction to analytical data treatment and Geochemical modelling. Application of software in Earth science. Writing a scientific paper, abstract and summary writing, organizing a thesis, and project reports. **Learning Activities:** Assignment, take-home exercise, and student seminar.	**CLO1** **CLO2** **CLO3**

Transactional Modes: Lecture, Lecture cum demonstration, Project Method, Seminar, Group discussion, Co-operative learning, Blended learning, Flipped learning, Team teaching, Brainstorming, Mobile teaching, Collaborative learning, Self-learning, Through SOLE (Self Organized Learning Environment).

Suggested readings:

1. Bruce, L.B. 2001.*Qualitative Research Methods for Social Sciences, Allyn and Bacon*, Boston.
2. John, W.C., 2011. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, Sage Publications, Thousand Oaks*.
3. Blaxter, L.; Hughes, C. and Tight, M. (1996): How to Research.Open University Press, Buckingham.
4. Paltridge, B., Starfield, S. (2019). *Thesis and Dissertation Writing in a Second Language, Routledge Publisher*.
5. Hofmann, A.H. (2019). *Scientific Writing and Communication: Papers, Proposals, and Presentations,* Oxford Univ Pr; 4th edition, USA.
6. Kothari, C.R., Garg, G. (2019).*Research Methodology: Methods and Techniques, New Age* International Publishers; Fourth edition, India.
7. Prathapan, K. (2019).*Research Methodology for Scientific Research*, Dreamtech Press, India
8. Kothari, C.R. (2008). *Research methodology (s)*. New Age International, New Delhi.
9. Lester, James, D. and Lester Jr. J.D., 2007. *Principles of Writing Research Papers, Longman, New York*.
10. Potts, P.J.,1997. *Silicate rock analysis*
11. Reed, S.J.B., 1990.*Recent developments in geochemical microanalysis: Chemical Geology, Volume* 83, PP.1-9.
12. Frank A. Settle, 1997. *Handbook of Instrumental Techniques for Analytical Chemistry, Prentice Hall, Upper Saddle River*, NJ.

Web Resources:

https://prog.lmu.edu.ng/colleges_CMS/document/books/EIE%20510%20LECTURE%20NOTES%20first.pdf
https://iare.ac.in/sites/default/files/MTECH-CAD.CAM-R18-RM-IP-NOTES.pdfhttp://14.139.185.6/website/SDE/sde578.pdfhttps://www.modares.ac.ir/uploads/Agr.Oth.Lib.17.pdf
https://fac.ksu.edu.sa/sites/default/files/introduction-to-research-and-research-methods.pdf

Course Code: MEGS.536

Course Title: Solid Earth Geophysics

L	T	P	Credits
3	0	0	3

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of course, the student will be able to

CLO1 : Adapt modern field instrumentation, theory, programming/or advanced analysis on geophysical problems

CLO2 : Evaluate and assess data quality and different information sources in geophysics

CLO3 : Formulate, process, and implement strategies for data and theoretical analysis.

CLO4 : Develop the ability to perform geophysical data analysis, interpretation, and use seismological data for understanding the Earth's subsurface.

Unit/ Hour	Contents	Mapping with CLO
I/11	Introduction to geophysics; shape and size of the Earth; gravitational field of the Earth; variation of gravity on the Earth's surface; principles of gravity methods and instruments used; gravity field surveys; corrections applied to gravity data; The Bouguer anomaly; regional and residual anomalies; gravity anomaly maps and their interpretation. Relative motion of plates, Stability of triple junction. **Learning Activities:** Assignment, take-home exercise, group discussion.	CLO1
II/11	Geomagnetic field of the earth; magnetic properties of rocks; principles of magnetic methods; Variation of magnetic fields over earth's surface, Densities and magnetic susceptibilities of rocks and minerals. Instruments of magnetic surveying; Field procedure in conducting magnetic surveys and data reductions; aeromagnetic surveys; profiling and sounding. **Learning Activities:** Problem solving after each method, take-home exercise.	CLO1 CLO2
III/12	Seismic methods: principles and instruments used; seismic velocity and interpretation of seismic data; Seismic refraction and reflection methods. Geometry of refraction and reflection paths in layered earth. Seismic noise, reflection, and refraction field methods. Conventional and modern (CDP) methods of acquisition of seismic reflection data. Applications of seismic methods to oil exploration. **Learning Activities:** Assignment, take-home exercise, lab-based exercise.	CLO3
IV/11	Electrical methods: basic principles and various types of electrode configuration: Wenner and Schlumberger; Electrical resistivity method, self-potential and resistive surveying; field procedures and interpretation of field data. Applications of electricity in groundwater exploration. Brief outline of various well logging techniques: self-potential and resistivity logs, radioactive logs, induction	CLO4

	logs, caliper logs, sonic logs, well logging applications in petroleum, groundwater, and mineral exploration. **Learning Activities:** Assignment, student's seminar, and a mini project.	

Transactional Modes: Lecture, Lecture cum demonstration, Project Method, Seminar, Group discussion, Team teaching, Brainstorming, Mobile teaching, Collaborative learning, Case analysis, Case study, Case-based study, Through SOLE (Self-Organized Learning Environment).

Suggested readings:

1. Lowrie, W., 1997. *Fundamentals of Geophysics, Cambridge Univ.* Press. London.
2. Fowler, 2005. *The Solid Earth: An Introduction to Global Geophysics, Cambridge University Press*.
3. Telford, W .M., Geldart, L.P. and Sheriff, R.E., 1990. Applied Geophysics, Cambridge University Press.
4. Peter Shearer,1999. *Introduction to Seismology, Cambridge University Press*, Cambridge.
5. Alan E. Mussett, M. Aftab Khan, 2000.*Looking into the Earth: An Introduction to Geological Geophysics, Cambridge University Press*.
6. Lillie, R.J., 1998. Whole Earth Geophysics: An Introductory Book for Geologists and Geophysicists, Pearson Education.
7. Parasnis, D.S., 1986. Principles of Applied Geophysics, Chapman and Hall.
8. Dobrin, M.B. and Savit, C.H., 2014. Introduction to Geophysical Prospecting, McGraw-Hill Exclusive.
9. Gadallah, Mamdouh R. and Fischer, R.L., 2009. Exploration Geophysics, Springer-Verlag Berlin Heidelberg.
10. AlbertTarantola,2005.InverseProblemTheoryandModelParameterEstimation.SIAM
11. Thorne Lay and Terry Wallace, 1995. Modern Global Seismology, Academic Press.

Web Resources:

https://www.ucl.ac.uk/EarthSci/people/lidunka/GEOL2014/Revised%20Course/OVERVIEW.htm
https://www.bu.edu/pasi/files/2011/01/MarcSpiegelman1-06-1330.pdf
https://www.irsm.cas.cz/ext/ethiopia/resources/lecture_notes.pdf
http://www-gpsg.mit.edu/12.201_12.501/
https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-201-essentials-of-geophysics-fall-2004/lecture-notes/

Course Code: MEGS.537

L	T	P	Credits
3	0	0	3

Course Title: Sedimentology and Engineering Geology **Total Hours: 45**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Interpret the processes responsible for the deposition of the sediment and formation of sedimentary textures and structures.
CLO2: Construct the depositional environment of certain sedimentary rock based on recognition of facies associations, lithology, textures, and structures.
CLO3: Formulate the sedimentary basin forming processes and their environmental and economic significance.
CLO4: Understand the engineering properties of rock and soil materials and engineering geological investigations.
CLO5: Understand the importance of engineering geology related to technical issues during construction, and conduct basic engineering geological assessments and analyzes

Unit/ Hour	Contents	Mapping with CLO
I/10	Important sedimentary bed forms and sedimentary structures– their genesis and stratigraphic significance. Application of sedimentary structures in palaeocurrent analysis; Diagenesis – Physical and chemical processes. Burial and Lithification. Evidence of diagenesis in sandstones, mudrocks, and carbonate rocks. Evaporites, siliceous, phosphatic, and ferruginous rocks. Heavy minerals and their importance in the determination of provenance. **Learning Activities:** Hands-on exercise and practice of sedimentary rock petrography and the separation of heavy minerals, assignment.	**CLO1**
II/11	Concept of facies and methods of their analysis and interpretation of depositional environments. Walther's Law of superimposition and its implication. Processes and characteristics of Aeolian, fluvial, barrier-beach, tidal-flats, and deep-sea environments. Tectonic and sedimentation; Review of concept of geosynclines and plate-margins, major types of basins and distribution of environments and litho-facies within basins, evolution of basins with time. Sedimentary basins of India and their economic importance. **Learning Activities:** Exercises on sedimentary facies identification, mapping the sedimentary basins of India, student seminar, and group discussion.	**CLO2** **CLO3**

III/13	Role of engineering geology in civil constructions. Various stages of engineering geological investigation for civil engineering projects. Slope stability, geological factors affecting the stability of a facility on and in the soil. Physical characteristics of building stones. Metal and concrete aggregates. **Learning Activities:** Mini project on vertebrate fossils, Exercises and brainstorming session on the evolution of life, demarcating the vertebrate fossils of India through the ages and their global comparison.	**CLO4**
IV/12	Geological considerations for evaluation of dams, reservoir sites, and foundation rock problems. Geotechnical evaluation of tunnel alignments and transportation routes, method of tunneling; classification of ground for tunneling purposes; various types of support. **Learning Activities:** Hands-on exercise on the application of fossils of different sections and their correlation with other co-relatable sections, student seminar.	**CLO5**

Transactional Modes: Lecture, Demonstration, Tutorial, Problem-Solving, Seminar, Assignment, Group Discussion, Tools Used: PPT, ICT, Video, and Animation, software: Google Class, Piazza, Padlet.

Suggested Readings:

1. Sam Boggs, Jr., 2016. *Principles of Sedimentology and Stratigraphy, Prentice Hall, 5th Edition*.
2. Donald R. Prothero and Fred Schwab, 2013. *Sedimentary Geology, W.H. Freeman*.
3. Tucker, M.E. and Wright, V.P., 1991. *Carbonate Sedimentology, Wiley Publisher*.
4. Reading, H.G., 1996. *Sedimentary Environments: Processes, Facies, and Stratigraphy*, Wiley-Blackwell.
5. Gary Nichols, 2009. *Sedimentology and Stratigraphy*, Wiley-Blackwell, ISBN:978-1-4051-3592-4.
6. Adams, A. E., MacKenzie, W.S., and Guilford, C., 1984. *Atlas of Sedimentary Rocks under the Microscope, Prentice Hall*.
7. Maurice E. Tucker, 2011. *Sedimentary Rock in the Field: A Practical Guide (Geological Field Guide)*, Wiley-Blackwell.
8. Miall, A.D., 2000. *Principles of Sedimentary Basin Analysis*, Springer-Verlag.
9. Einsele, G.,1992.*SedimentaryBasins*,SpringerVerlag.
10. Reineck, H. E. and Singh, I. B., 1980. *Depositional Sedimentary Environments*, Springer-Verlag.
11. Bell, F.G., 1992. *Fundamentals of Engineering Geology*, Aditya Books Pvt. Ltd., Indian Edn.
12. Krynine, D.H. and Judd, W.R., 1998. *Principles of Engineering Geology, C.B.S. Edition*. Delhi.

13. Jaeger J., Cook N. G. and Zimmerman R., 2007. *Fundamentals of Rocks Mechanics*, Wiley-Blackwell
14. Reddy, D.V.,1995. *Engineering Geology for Civil Engineers*, IBH Publishing Co. Pvt. Ltd.

Web Resources:

https://iah.org/education/
https://www.priweb.org/blog-post/learn-at-home
https://www.nationalgeographic.org/encyclopedia/
https://naturalhistory.si.edu/education/teaching-resources/

Course Code: MEGS.538

Course Title: Sedimentology (Practical)

L	T	P	Credits
0	0	3	1.5

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Classify the various sedimentary rocks.
CLO2: Analyze sedimentary rock samples for paleo-environment and paleoclimatic interpretation.
CLO3: Reconstruct paleoenvironmental setup based on sedimentological records.
CLO4: understand the properties of various building materials

Unit/ Hour	Contents	Mapping with CLO
I/ 45	Study of clastic and non-clastic rocks in hand specimens	**CLO1**
	Microscopic examination of important sedimentary rock types	**CLO2**
	Grain-sizeanalysisbysievingmethod:plottingofsize-distributiondataasfrequencyandcumulativecurves	**CLO1**
	Heavy mineral separation; their Microscopic characters, graphic representation, and interpretation	**CLO2 CLO3**
	Assemblagesofsedimentarystructuresandtheirpalaeo-environmentalsignificance	
	Palaeo-current analysis	
	Study of vertical profile sections of some selected sedimentary environments	
	Analysis of engineering properties of building materials and aggregate	**CLO4**

Transactional Modes: Demonstration, practical with real specimens, Problem-solving, Group discussion, Tools used: PPT, Video, Animation, Software Tool: Sedilog, Gradistat, Photoshop.

Evaluation Criteria: Total Marks–100,
End semester exam (50 marks), Continuous assessment (30 marks), Lab record (10 marks), Viva (10 marks).

Suggested Readings:

1. Adams, A. E., MacKenzie, W. S., and Guilford, C., 1984.*Atlas of Sedimentary Rocks Under the Microscope, Prentice Hall*.
2. Shrock, N., 2005. *Principles of Invertebrate Paleontology, CBS publication*.
3. Roy C. Lindholm, 1987.*A Practical Approach to Sedimentology, Allen and Unwin*, London.
4. Sengupta, S.,1997. *Introduction to Sedimentology*, Oxford-IBH.

Web Resources:

https://www.priweb.org/blog-post/learn-at-home
https://www.nationalgeographic.org/encyclopedia/
https://naturalhistory.si.edu/education/teaching-resources/

Course Code: MEGS.539

L	T	P	Credits
3	0	0	3

Course title: Ore Geology

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Improve their knowledge of the basic concepts of ore geology, ore localization and spatial and temporal distribution.
CLO2: Understand the various process associated with ore formation in specific environment.
CLO3: Elaborate overall geometry, texture, zonation, and alteration patterns of rock associations to specific classes of metallic mineral deposits.
CLO4: Describe the various types of ore metallogenesis and their overall assemblages.
CLO5: Explain the distribution pattern of ore minerals in India in terms of their strategic, critical, and essential perspectives.
CLO6: Build their concepts on Fuel geology, especially on coal, petroleum, and nuclear resources.
CLO7: Evaluate the importance and applications of fluid inclusion in ore geology.

Unit/ Hour	Contents	Mapping with CLO
I/11	Modern concept of ore genesis; mode of occurrence of ore bodies – morphology and relationship of host rock and migration, wall-rock alteration; Structural,	**CLO1 CLO2**

	physicochemical and stratigraphic controls of ore localization; processes of formations of ore mineral deposits; Spatial and temporal distribution of ore deposits – a global perspective. Ore deposits in relation to plate tectonics. **Learning Activities:** Assignment, take home exercise, seminars, Group discussions	
II/11	Texture, paragenesis and zoning of ores and their significance; Introduction to Ore microscopy: Qualitative and Quantitative methods in the identification of Ore minerals; Ore deposits and their distributions; VMS, SEDEX, MVT, Porphyry, Skarn, IOCG deposits; **Learning Activities:** Hands on exercise and group discussion.	**CLO3** **CLO4**
III/12	Study of ore minerals related to the following metals such as Fe, Mn, Cr, Cu, Pb, Zn, Al, Mg, Au, Sn, and W with special reference to their mineralogy, genesis, uses in important industries, and their distribution in India. Strategic, critical, and essential minerals. Fundamentals of coal petrology; Petroleum geology; Nuclear and Non-conventional source of energy. **Learning Activities:** Student seminar, assignment and take home exercise.	**CLO5** **CLO6**
IV/11	Principle of Fluid inclusion study and its applications in ore genesis: Basic definitions and history; Types of fluid inclusions; formation mechanism; Fluid inclusion petrography; Sample preparation techniques; Principles of micro-thermometry; Binary and ternary systems of related to fluid inclusion studies., . **Learning Activities:** Assignment, take home exercise, seminar.	**CLO7**

Transactional Modes: Lecture, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Focused group discussion, Team teaching, Mobile teaching, Collaborative learning, Problem solving, Case analysis, Self-learning, Case based study.

Suggested readings:

1. Robb, L., 2005. *Introduction to Ore-forming processes*, Blackwell Publ., Oxford.
2. Evans, A.M., 1992. *Oregeology and Industrial Minerals, Blackwell Science*.

3. Misra, K.C. 1999. *Understanding mineral deposits, Kluwer Academic Publishers*.
4. Sinha, R.K. and Sharma, N.L., 1970. *Mineral economics*, Oxford & IBH.
5. Jensen, M.L. and Bateman, A.M., 1981. *Economic mineral deposits*, John Wiley & Sons.
6. Stanton, R.L., 1972. *Ore Petrology*, McGraw-Hill.
7. Guilbert, J.M. and Park, Jr. C.F., 1986. *The Geology of Ore Deposits*, Freeman.
8. Barnes, H.L., 1979. *Geochemistry of Hydrothermal Ore Deposits*, John Wiley.
9. Umeshwar Prasad, 2014. *Economic Geology: Economic Mineral Deposits (Second Edition),* CBS Publishers & Distributors Pvt. Ltd., New Delhi.
10. T. J. Shepherd, A. H. Rankin, D. H. M. Alderton, 1985, *A Practical Guide to Fluid Inclusion Studies*, Publisher: Blackie, Page: 239. ISBN-0412006014, 9780412006012.

Web Resources:

https://www.southalabama.edu/geology/haywick/GY111/111-8.pdf
http://earthsci.org/mineral/mindep/class_dep/class_dep.html
https://pubs.usgs.gov/bul/0225/report.pdf
https://www.mlsu.ac.in/econtents/1911_Mineral%20Deposits%20in%20India.pdf
https://gsi.gov.in/webcenter/portal/OCBIS/pagePublications/pageViewGSIPublication?_adf.ctrl-state=w5w97un87_5&_afrLoop=2133991338489583 6#!

Course Code: MEGS.540

L	T	P	Credits
0	0	3	1.5

Course Title: Ore Geology (Practical)

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Identify and inspect common ore minerals in hand samples and under the microscope
CLO2: Get familiar with a wide range of mineral deposits, including recognizing the overall geometry, zonation, and alteration patterns, grade and tonnage associated with specific classes of metallic mineral deposits
CLO3: understand the methods to identify various fluid inclusions associated with minerals and their application in ore geology.

Unit/ Hour	Contents	Mapping with CLO
I/45	• Megascopic study of Indian metallic ores and industrial minerals in hand specimens • Study of optical properties and identification of important ore minerals under ore-microscope. • Preparation of maps showing distribution of metallic and industrial minerals in India and classical world mineral deposits • Estimation of grade, tonnage of ore deposits • Practical on fluid inclusion petrography	**CLO1** **CLO2** **CLO3**

Transactional Modes: Demonstration, Group discussion, Problem solving, Case analysis, Case study, Self-learning, Case-based study, Through SOLE (Self-Organized Learning Environment), Experimentation.

Evaluation Criteria: Total Marks–100, End semester exam (50 marks), Continuous assessment (30 marks), Lab record (10 marks), Viva (10 marks).

Suggested readings:

1. Evans, A.M. (1992). *Ore geology and industrial minerals*, Blackwell Science.
2. A.E. Annels, (1992). *Mineral deposit evaluation*, Chapman and Hall, London.
3. Sinha, R.K. and Sharma, N.L.,1970. *Mineral economics*, Oxford & IBH.
4. Umeshwar Prasad, 2014. *Economic Geology: Economic Mineral Deposits (Second Edition),* CBS Publishers & Distributors Pvt. Ltd., New Delhi
5. T. J. Shepherd, A. H. Rankin, D. H. M. Alderton, 1985, *A Practical Guide to Fluid Inclusion Studies*, Publisher: Blackie, Page: 239. ISBN-0412006014, 9780412006012.

Web Resources:

https://pubs.usgs.gov/bul/0225/report.pdf
https://www.mlsu.ac.in/econtents/1911_Mineral%20Deposits%20in%20India.pdf
https://gsi.gov.in/webcenter/portal/OCBIS/pagePublications/pageViewGSIPublication?_adf.ctrl-state=w5w97un87_5&_afrLoop=21339913384895836#!

Discipline Elective: Select any one

Course Code: MEGS.541

L	T	P	Credits
3	0	0	3

Course Title: Environmental Geology

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1 Discuss the role of geologic processes in assessment of environment
CLO2 Formulate the occurrence and formation of earth resources and significant environmental effects caused by their extraction, processing, and use
CLO3 Predict the major sources of water, soil, and sediment pollution and methods for their management;
CLO4 Evaluate the causes and effects of global climate change.

Unit/ Hour	Contents	Mapping with CLO
I/10	Introduction to Environmental Geology: Fundamental concepts of environmental geosciences, its scope and necessity; Definition, structure, composition and general characteristics of lithosphere, hydrosphere, atmosphere and biosphere; Concept of ecology, ecosystem; Biogeochemical cycles of carbon, nitrogen, phosphorus and sulfur; Physiography, drainage, climate, soils and natural resources of India. **Learning Activities:** Take home exercise and brain storming session on importance of environmental geology.	**CLO1 CLO2**
II/12	Environmental issues: Water pollution : types of water pollution, ground water pollution sources, pathways and mechanism, attenuation processes, case histories of natural (arsenic and fluoride poisoning) and man-made water pollution; water logging, causes, effects and remedial measures, aquifers; declining ground water tables, subsidence and compaction of aquifers; Soil pollution-sources, causes and effects; Soil pollution control measures; Air pollution : definition, terminology, sources and classification of air pollutants; effects of air pollution- acid rain, green house effects and ozone layer depletion; Air pollution control and management; waste management of energy resources. **Learning Activities:** Assignment and group discussion on environmental pollution.	**CLO2 CLO3**

III/12	Introduction to natural and manmade disasters; Dimensions of natural and anthropogenic disasters; Floods–nature and frequency of flooding, flood hazards, urbanization and flooding, flood hydrographs, Dams barrages and river diversions; Landslides; Coastal hazards – tropical cyclone, coastal erosion, sea level changes, coastal zone management; Earth quakes - Seismicwaves,quakeresistantbuildingsanddams;Tsunamis;Volcanoes;Wildfires;Oilspills;Urbanhazardsanddisasters. **Learning Activities:** Preparation of assessment reports, assignments and brain storming session on types of disasters and its management.	**CLO2** **CLO4**
IV/11	Risk Assessment and Preparedness for Natural Hazards; Hazard zonation maps; Recent Environmental Issue and possible solutions: Global warming, Sealevel rise, Acid rain, Ozone layer depletion. Acid Mine drainage (AMD), Ground water contamination, Water stress and water scarcity, River interlinking conflict in India, Soil Erosion, Deforestation. **Learning Activities:** Assignment and brainstorming session on disaster risk management.	**CLO1** **CLO4**

Transactional Modes: Lecture, Demonstration, Tutorial, Problem solving, Seminar, assignment, Group discussion, Tools used: PPT, Video, Animation, toposheet and maps.

Suggested Readings:

1. BarbarW.Murketal.,1996.*EnvironmentalGeology*,JohnWiley&Sons,NewYork.
2. EdwardA. K, 2011.*Introduction to Environmental Geology*, Pearson Education publisher.
3. Valdiya,K.S.,2013.*EnvironmentalGeology*,McGraw-HillEducation(India)
4. CollinsLarryR.andSchneidThomasD.,2000.*DisasterManagementandPreparedness*,TaylorandFrancis.
5. GrahamThompsonandJonTurk,2007.*EarthScienceandtheEnvironment*,ThomsonandBrooks/cole.
6. GoelS.L.andKumarRam,2001.*DisasterManagement*,DeepandDeepPublications.
7. Living with Risk: A global review of disaster reduction initiatives, 2004 Vision, United Nations.
8. ParasuramanS.,2004. *India Disasters Report: Towards a Policy Initiatives*, Oxford University Press.

Web Resources:

https://ndma.gov.in/
https://www.iwapublishing.com/news/disaster management
https://nidm.gov.in/
https://www.who.int/

Course Code: MEGS.542

L	T	P	Credits
3	0	0	3

Course Title: Quaternary Geology **Total hours: 45**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1 Know the main principles, concepts and approaches pertaining to the study of Quaternary sediments and landforms
CLO2 Knowledge of the Quaternary stratigraphic framework
CLO3 Knowledge of the basic applied glacial geology techniques
CLO4 Appreciation and basic knowledge of the complexity of changes that have occurred worldwide throughout the Quaternary Period

Unit/ Hour	Contents	Mapping with CLO
I/12	Quaternary time and its significance; Basic concept of Landform evolution; Geomorphology of Indo-Gangetic Plain and Himalaya; Climatic cycles during Quaternary: Milankovitch cycle; Terminal Pleistocene-Holocene climatic and sea level changes; Geomorphology and Quaternary climate studies of Thar Desert and Peninsular India; Exogenic processes: River basin and drainage network; Morphotectonics and associated landforms. **Learning Activities:** Exercises and brainstorming session and group discussion.	CLO1
II/11	Continental-marine correlation of Quaternary record. Quaternary geomorphic processes. Landscape evolution in Quaternary. Concept of tectonic geomorphology. Weathering and Erosion, Mass wasting; Geological works of glacier, wind, underground water, ocean and landforms produced by them. Wave erosion and beach processes. **Learning Activities:** Student seminar and group discussion.	CLO2

III/11	Radiometric dating techniques (e.g. 14C, K-Ar, OSL, cosmogenic dating), Incremental dating methods (Dendrochronology, varve chronology), Age-equivalent stratigraphic markers (e.g. paleomagnetism,), Use of Oxygen Isotopes in palaeoclimatic studies; **Learning Activities:** Assignments and take home exercise.	CLO3
IV/11	Significance of Quaternary studies; Quaternary Stratigraphy; Quaternary deposits in India; Neotectonics; Evolution of man and cultural stages; Criteria used for defining Pliocene-Pleistocene boundary; Pleistocene-Holocene boundary. **Learning Activities:** Student Seminar and group discussion.	CLO4

Transactional Modes: Lecture, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Team teaching, Brainstorming, Mobile teaching, Collaborative learning, Case based study.

Suggested readings:

1. Benn D.I., and Evans D.J.A. (2010) Glaciers & Glaciation. Second Edition, Hodder Education, 802 pages.
2. Lowe, J.J., and Walker, M.J.C. (1997) Reconstructing Quaternary environments. 2nd edition, Pearson, Prentice-Hall, 446 pages.
3. Menzies, J. (Ed.) (1996) Past glacial environments: Sediments, forms and techniques. Glacial Environments: Volume 2. Butterworth-Heinemann, Oxford, 598 pages.
4. Oerlemans, J. (2001) Glaciers and climate change,
5. A.A Balkema. Pomerol, (1982) The Cenozoic Era: Tertiary and Quaternary, Ellis Harwood Ltd

WebResources:

https://notendur.hi.is/oi/quaternary_geology.htm
https://www.ngu.no/en/topic/quaternary-landscape-development
https://www.youtube.com/watch?v=lQY5Oz_4JX0
https://www.ngu.no/en/topic/quaternary-landscape-development
https://www.youtube.com/watch?v=MMjXyCjDiBA
https://www.youtube.com/watch?v=e-cIDUu7j54
https://www.youtube.com/watch?v=vv2fu2bIyzw
https://opengeology.org/historicalgeology/case-studies/the-meghalayan-age/

L	T	P	Credits
3	0	0	3

Course Code: MEGS.543

Course Title: Geomagnetism **Total Hours: 45**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1 Understand about Earth's Magnetic Field and how it has changed in recent and ancient time and their importance in earth sciences.

CLO2 Understand the basics of the paleomagnetic theory and be able to determine the past magnetic field stored in different geological formation.

CLO3 Undertake the field, laboratory investigations independently and also able to do the data interpretation related to Geomagnetism & Paleomagnetism.

CLO4 Interpret the history of continental motion and able to established Magnetostratigraphy their correlation with Geomagnetic Polarity Time Scale.

Unit / Hour	Contents	Mapping with CLO
I /12	Introduction to geomagnetism, Early Measurements of the Earth's Magnetic Field, Origin of the magnetic field, Geocentric Axial Dipole Model, The Present Geomagnetic Field, Geomagnetic Secular Variation, Magnetic Properties of Solids- Diamagnetism, Paramagnetism, Ferro-, Antiferro-, and Ferrimagnetism. **Learning Activities:** Groupdiscussion on origin of Earth's magnetic field.	**CLO 1**
II /11	Basics of Paleomagnetism, Early Work in Paleomagnetism, Domain theory- Single, Pseudo-single & multi domain grains, types of magnetic remanence- Natural Remanent Magnetism, Thermoremanent Magnetism, Chemical Remanent Magnetism, Detrital Remanent Magnetism, Viscous Remanent Magnetism, Paleomagnetism and Plate Tectonics. **Learning Activities:** Prepare a note on primary magnetisation, followed by student presentation	**CLO 1** **CLO 2**
III /11	Sampling methods, Instruments and laboratory techniques, Statistical analysis of paleomagnetic data, Alternating field Demagnetisation, Thermal Demagnetisation, Chemical Demagnetisation, Identification of Magnetic Minerals, Curie Temperatures, Isothermal Remanent Magnetization, The Lowrie-Fuller Test, Hysteresis and Magnetic Grain Sizes. **Learning Activities:** Group discussion on suitable Demagnetisation techniques in different rock types and analytical methods used in paleomagnetism.	**CLO 2** **CLO 3**

IV / 11	Magnetic Field Reversals, Normal, Reverse & Intermediate magnetic polarity direction, Geomagnetic Polarity Time Scale (GPTS), Magneto-stratigraphy, Applications to paleogeography and Apparent Polar Wander Paths. **Learning Activities:** Understanding of Geomagnetic Polarity Time Scale (GPTS) and correlation of data at global level, Development of Magnetostratigraphy, Student presentation.	**CLO 4**

Transactional Modes: Lecture, Demonstration, Tutorial, Problem solving, Tools used: PPT, Video, Animation, Whatsapp, Software Tool: Remasoft, Anisoft, Paleomag.

Suggested readings:

1. D. H. Tarling, 1983. Palaeomagnetism. Principles and Applications in Geology, Geophysics and Archaeology. ix + 379 pp. London, New York: Chapman & Hall.
2. E.Irwing (1964), Paleomagnetism and its Applications to Geological and Geophysical Problems, Wiley, New York.
3. R.Thompson and F.Oldfield (1986), Environmental Magnetism, Allen and Unwin, London.
4. O'Reilly (1984), Rock and Mineral Magnetism, Chapman & Hall, New York.
5. Michael W Mc Elhinny and Philip L.Mc Fadden (2000), Paleomagnetism Continents and Oceans, Academic Press USA.
6. Robert F. Butler (1992); Paleomagnetism: Magnetic Domains to Geologic Terranes, Blackwell Science Inc.
7. R.Thompson and F.Oldfield (1986), Environmental Magnetism, Allen and Unwin, London.

Web Resources:

https://websites.pmc.ucsc.edu/~njarboe/pmagresource/ButlerPaleomagnetismBook.pdf
https://www.soest.hawaii.edu/GG/FACULTY/ITO/GG450/Lowrey_Geomagnetism.pdf
http://www-odp.tamu.edu/publications/190_IR/chap_05/c5_6.htm
https://www.degruyter.com/document/doi/10.1525/9780520946378-016/html
https://www.sciencedirect.com/science/article/abs/pii/S0074614296800027
https://www.researchgate.net/publication/23703966_On_Geomagnetism_and_Paleomagnetism
https://www.wgtn.ac.nz/scps/research/research-groups/enviro-phys-geo/geomagnetism
https://earth-planets-space.springeropen.com/articles/10.1186/s40623-019-1060-4
https://www.youtube.com/watch?v=jpp672BBknA
https://www.youtube.com/channel/UCRVhgDx1dphMVnTJhdKKDZQ
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2006RG000198
https://www.youtube.com/watch?v=yzgGHAoN_68&list=PLyqSpQzTE6M_OXWtn1RUnuZNSbSSy6Lys
https://www.youtube.com/watch?v=Pxk9q7gdR8M&list=PLsfizngNlx8suxYQjXSZiHxlarp8wwERG&index=17

Tutorial/ Remedial Class

L	T	P	Credits
0	2	0	0

Two hours non-credit tutorial class is designed for remedial teaching. Scheduled classes will be assigned in the timetable. As per the requirement of students, remedial classes will be conducted in these periods.

Value Added Course

L	T	P	Credits
2	0	0	2

Course Code: MEGS.511

Course Title: Geological Mapping **Total Hours: 30**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 : Aware the different field accessories in geosciences
CLO2 : Measure the equipment is confidently at field
CLO3 : Evaluate the processes and practices of geological mapping
CLO4 : Assess the processes of sampling techniques

Unit/ Hour	Contents	Mapping with CLO
I/10	Field Geology: Introduction to toposheets, Scale definition; small-scale and large-scale maps; reading various components of a toposheet. Geological map definition, various components of a geological map include scale, legend, structures, etc. Studies of outcrop pattern, topographic law, and rules of 'V'. **Learning Activities:** Take-home exercise, assignment, and group discussion.	**CLO1**
II/12	Instruments used in geological field studies; techniques and use of geological tools during fieldwork- use of clinometer, compass, Brunton compass, GPS, altimeter. Attitude measurements: measurement of true thickness and distance, section measurement techniques, and significance. **Learning Activities:** Hands-on exercise on the application of geological tools, section measurement, and group discussion.	**CLO2**
III/12	Geological mapping procedures: Geological mapping of	**CLO3**

	igneous terrains, geological mapping of sedimentary terrains. Geological mapping of metamorphic terrains and recording of structural information, preparation of Geological Cross-section. **Learning Activities:** Hands-on exercise on the geological mapping and cross-section preparations, assignments, and group discussion.	
IV/13	Techniques for sample collection: Sampling and oriented sampling, their significance; sampling for isotopic, geochronological, and geochemical studies, and their significance. Sampling strategies for micro-palaeontological and biostratigraphic studies and recording of palaeontological information. **Learning Activities:** Hands-on exercise on the sampling processes for certain geological analysis, assignments, and group discussion.	**CLO4**

Transactional Modes: Lecture, practical demonstration, Video demonstration, Lecture cum demonstration, ICT methods, web resource, Brainstorming session

Suggested readings:

1. Angela L. C. 2010.Geological field techniques, Blackwell Publishing Ltd.
2. Lisle, R.J., Brabham, P. and Barnes, J.W., 2011. Basic Geological Mapping (Geological Field Guide) 5th edition, Wiley-Blackwell.
3. Mathur, S.M., 2001. Guide to Field Geology, PHI Learning Private Limited-New Delhi.
4. Maley, T.S., 1994. Field Geology (Illustrated), Mineral Land Publications.
5. Lahee, F.H., 1961. *Field Geology, 6th edition,* McGraw-Hill.

Web Resource:

https://surveyofindia.gov.in/
https://www.usgs.gov/core-science-systems/national-cooperative-geologic-mapping-program
https://www.usgs.gov/products/maps/geologic-mapshttp://www.geosci.usyd.edu.au/users/prey/FieldTrips/BrokenHillOlary/Mapping.html
https://www.gsi.ie/en-ie/programmes-andprojects/minerals/activities/mineral-exploration/Pages/Geological-Mapping

Course Code: MEGS.512
Course Title: Environmental Magnetism

L	T	P	Credits
2	0	0	2

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 Understand the basics of Environmental Magnetism and Earth's Magnetic Field.

CLO2 Understand the magnetic mineralogy and use them as proxy for Environmental Magnetism in various geologic settings.

CLO3 Undertake the field & laboratory investigations independently and also able to do the data interpretation related to Environmental Magnetism.

CLO4 Comprehend the basic of soil & rock magnetism and their role in Earth's Environment.

Unit/ Hour	Contents	Mapping with CLO
I/07	Prospect of Environmental Magnetism, Basic Magnetic properties of solids, Effects of crystal size, shape and structure-anisotropy, domain behaviour, Critical grain sizes, Time dependence of magnetisation, Magnetic remanence, Natural magnetic remanences, Laboratory-imparted remanences, Magnetic susceptibility. **Learning Activities:** Hands on exercise on the application of Environmental Magnetism and group discussion.	**CLO 1**
II/07	Enviromagnetic Parameters, Enviromagnetic minerals- magnetic mineralogy, Earth's magnetic field, Description of the geomagnetic field, Secular variation, Origin of the geomagnetic field, Palaeomagnetism, Techniques of magnetic measurements, Magnetic cleaning techniques, A basic environmental magnetic kit. **Learning Activities:** Take home exercise assignment and group discussion.	**CLO 1** **CLO 2**
III/08	Magnetic minerals and environmental systems, Surface processes and magnetic minerals, Magnetism and Pollution, Soil contamination, Magnetic minerals and fluvial processes, Mineral magnetic studies of lake sediments, Magnetic minerals in the atmosphere, Mineral magnetism in marine sediments. **Learning Activities:** Hands on exercise on the application of Environmental Magnetism on road side soil & dust and group discussion.	**CLO 2** **CLO 3**
IV/08	Basics of rock & soil magnetism, Magnetic properties of soil minerals, Magnetic proxy parameters used in soil magnetic studies, Sampling methodology for magnetic studies, Laboratory instrumentation and methods, The temporal variability of rock magnetic properties, Applications of soil magnetism, Future challenges in soil magnetism studies.	**CLO 4**

	Learning Activities: Hand on exercise on the sampling processes for rock and soil related to Environmental Magnetic study, assignments and group discussion.	

Transactional Modes: Lecture, Demonstration, Tutorial, Problem solving, Tools used: PPT, Video, Animation, Whatsapp, Software Tool: Remasoft, Anisoft, Paleomag.

Suggested readings:

1. Robert F. Butler (1992); Paleomagnetism: Magnetic Domains to Geologic Terranes, Blackwell Science Inc.
2. Evans ME, Heller F (2003) Environmental magnetism. Principles and applications of enviromagnetics. Academic Press, Elsevier Science.
3. R. Thompson and F. Oldfield (1986), Environmental Magnetism, Allen and Unwin, London
4. O'Reilly (1984), Rock and Mineral Magnetism, Chapman & Hall, New York.
5 Neli Jordanova (2017), Soil Magnetism. Applications in Pedology, Environmental Science and Agriculture. Academic Press, Elsevier Science.
6. Liu, Qingsong & Roberts, Andrew & Larrasoaña, Juan & Banerjee, Subir & Guyodo, Yohan & Tauxe, Lisa & Oldfield, Frank. (2012). Environmental Magnetism: Principles and Applications. Reviews of Geophysics. 10.1029/2012RG000393.

Web Resources:

https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2012RG000393
https://link.springer.com/article/10.1023/A:1003122305503
https://www.geomorphology.org.uk/sites/default/files/chapters/1.4.1_EnvironmentalMagnetism.pdf
https://repositorio.usp.br/directbitstream/b50c2c8d-1141-4a69-bcd99b52c2f85c8e/3022611.pdf
https://www.meteo.be/en/research-v1/scope-of-research/kmi-te-dourbes/omgevingsmagnetisme
https://openresearchrepository.anu.edu.au/bitstream/1885/69216/2/01_Liu_Environmental_magnetism:_2012.pdf
https://www.witpress.com/Secure/elibrary/papers/AIR06/AIR06033FU1.pdf
https://www.youtube.com/watch?v=S37xEsdCEq4
https://www.youtube.com/watch?v=jpp672BBknA&t=279s
https://www.youtube.com/watch?v=2uIyUOAC1kU

Semester IV

Course Code	Course Title	Course Type	Credit Hours			Credit
			L	T	P	Cr
MEGS.599	Dissertation	Dissertation	0	0	40	20
		Total	**0**	**0**	**40**	**20**

Course Code: MEGS.599

L	T	P	Credits
0	0	40	20

Course Title: Dissertation / Internship / Industrial Training

Total hours: 600

Course Learning Outcomes (CLO): After completion of the course, students will be able to

CLO1 : Formulate a research problem and identify
CLO2 : Know the limitations and expected outcome
CLO3 : Synthesis and interpret the field and lab data
CLO4 : Draw the Inference from the result
CLO5 : Decipher the future direction of research from the result
CLO6 : Take-up research for solving local/regional/global challenges

Unit/ Hour	Contents	Mapping with CLO
I/600	Each candidate required to submit a dissertation based on his/her research work carried out towards the fulfillment of his/her M.Sc. dissertation. It will have the following components: (a) Origin of the research problem and literature review (b) Objective of the research work (c) Methodology of the work, field observations (if any), and data recorded by the candidate, (d) Details of laboratory investigation (if any) carried out by the candidate, (e) Synthesis of results and interpretation (f) Concluding remarks and future direction For those opting for Internship / Industrial Training in the fourth semester should submit their report to the department; and present his/her work and attended the viva-voce for the assessment.	**CLO1** **CLO2** **CLO3** **CLO4** **CLO5** **CLO6**

Evaluation Criteria: The evaluation of the dissertation in the fourth semester will carry 50% weightage by the supervisor and 50% by the external expert. Distribution of marks as per the table given below. Marks

for internship shall be given by the supervisor/internal mentor and external mentor. The final viva-voce will be through offline or online mode. The workload of one contact hour per student will be calculated for the dissertation in the fourth semester.

Dissertation (Fourth Semester)		
	Marks	**Evaluation**
Supervisor/ co-supervisor(s)	50	Continuous assessment (regularity in work, mid-term evaluation) dissertation report, presentation, final viva-voce
External expert	50	Report of dissertation (25), presentation (10), novelty/originality (5) and final viva-voce (10).

Students may opt for any internship/ academic or industrial training during the semester break with approval from the department. Above experiential learning/internship equivalent to 40–45 contact hours will be considered as one credit (as per NCrF guidelines). Students will have an option to carry out dissertation work in industry, national institutes, or universities in the top 100 NIR ranking. Group dissertation may be opted for, with a group consisting of a maximum of four students. These students may work using a single approach or a multidisciplinary approach. The research project can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.
