TRIBHUVAN UNIVERSITY
INSTITUTE OF SCIENCE AND TECHNOLOGY
MASTER OF SCIENCE IN GEOLOGY
(MSc Geology)

COURSE STRUCTURE

AND

CURRICULUM

(REVISED)

2080

Submitted by
Central Department of Geology
Tribhuvan University
Kirtipur, Kathmandu
Nepal

Introduction

The Central Department of Geology (CDG) was established in the Tribhuvan University in 1976. CDG has been offering international standard academic syllabus for the Master of Science in Geology since its establishment in 1976. CDG offers not only theoretical and laboratory based teching but also extensive field work techniques, in order to build students capacity to work in various fields, such as tunnels, roads, bridges, dams, mining industries, and groundwater. CDG has been known for producer of competitive geoscientists with outstanding academic results, Courses offered by CDG are designed to maximize employment propects through acquisition of subject knowledge and practical skills. The Geology Subject Committee regularly revises its courses to meet the new requirements in a changed context,

The CDG has decided to introduce Semester System from academic year (2013) to meet the contemporary needs of the country as well as to make the level of education at par with the international standards. Accordingly, the Geology Subject Committee prepared course structure and curriculum for four semesters. The course was revised in 2015 and 2017. Tribhuvan University started Master of Science in Engineering Geology at the CDG and Tri Chandra College from 2016. The Geology Subject Committee has decided to make appropriate revisions in the MSc Geology course and implement it from the 2080 batch.

Aims and Objectives

The main aim of the Course is to create professionals having in depth knowledge and skills in the field of geology. Apart from it, the course also aims at producing specialists able to follow integrated and multi disciplinary approaches in their profession. After the completion of the course in geology the students will be able to carry out the professional work, research and /or advance studies independently.

Eligibility for Admission

The candidates who have passed the B.Sc. course in Geology from the Tribhuvan University or the B.Sc. course in Geology from any other equivalent universities or institutions shall be considered eligible for admission to the M.Sc. course in Geology. They should have also attended the prescribed geological field training at the B.Sc. level.

Admission Criteria

The applicants will have to appear in an entrance examination conducted by the Institute of Science and Technology, Tribhuvan University. An applicant who fails to appear in the Entrance Examination or fails to obtain a minimum qualifying score will not be allowed admission. A merit list of the qualified applicants will be prepared based on the marks obtained by them it the Entrance Examination. Admission of the students will be based strictly on the merit list and the enrolment capacity of the Central Department of Geology.

Medium of Instruction

English

Duration of the program

Four semesters completed in two academic years (4 academic semesters). There will be common courses for all students in the first, second and third semesters. In the fourth semester, the students will be assigned one special course from four Elective Groups designed according to their proposal for dissertation topic in the third semester. A student should complete the course within 5 years (10 academic semesters).

Hours of Instruction and credit calculation

Working days: 90 days per semester
Semesters: 4
Total credits: 69
Full Marks: 1725

Theory

One credit = 15 hours and 25 marks
One theory paper of 1 credit will have one hour of lecture per week

Practical

One credit 45 lab work hours and 25 marks.
One practical paper of 1 credit will have 3 hours of practical per week

Field work

One credit 70 field work hours/week (10 hours/day) and 25 marks,
A fieldwork for a period of 8 weeks will be given to each student of the M.Sc. course in Geology. There will be two fieldworks each of four weeks duration (one in the First Semester and the other in the Third Semester) and each of them will carry 4 credits.

Dissertation

The dissertation carries 4 credits. The student shall have to prepare a dissertation in the 4^{th} semester. The dissertation will ordinarily include from 4 to 6 weeks of fieldwork

Evaluation

Theory paper
Forty percent (40%) marks as Internal Assessment is assessed by concerned teacher on the basis of seminar, term-paper or internal examination. 60% mark is allocated for Final examination. Without passing internal exam students will not be qualified to appear in the semester exam.

Practical

The Practical work is evaluated separately (100%)

Dissertation

The dissertation will be submitted to the Central Department of Geology. The dissertation will be forwarded to the Institute of Science and Technology (IOST), Tribhuvan University for examination. The external examiner will be assigned by the IOST and internal examiner will be assigned by the CDG. A committee of head of department of CDG, external examiner, internal examiner and dissertation supervisor will examine the dissertation. The student should compulsorily attend the viva voce examination of the dissertation.

Grading

Student must pass all compulsory papers separately. The pass marks for bout theory and practical is 50% the performance of student shall be made on a four point scale ranging from 0 to 4 grades. A student must secure a minimum Grade Point Average (GPA) of 2.7 or Grade B minus (B^-) in each course. The absolute grading scale will be as follows:

Grade	CGPA	Percentage Equivalent	Performance Remarks
A	4.0	90 and above	Distinction
A^-	3.7	80-89.9	Very Good
B^+	3.3	70-79.9	First Division
B	3.0	60-69.9	Second Division
B^-	2.7	50-59.9	Pass in individual Subject
F	0	Below 50	Fail

Certificate

The successful candidates, who have passed all the examinations in theoretical and practical subjects, fieldwork, and dissertation work, will obtain a certificate of Master of Science in Geology from Tribhuvan University.

MSc Geology Course Structure (2080)

Semesters	SN	Course code	Course name	Credits	Marks
First	1	GEO 511	Igneous Petrology	2	50
	2	GEO 512	Metamorphic Petrology	2	50
	3	GEO 513	Mineralogy	2	50
	4	GEO 514	Sedimentology	2	50
	5	GEO 515	Structural Geology	2	50
	6	GEO 516	Stratigraphy and Microplaeontology	2	50
	7	GEO 517	Pracctical of GEO 511 and GEO 512	2	50
	8	GEO 518	Pracctical of GEO 513 and GEO 514	2	50
	9	GEO 519	Pracctical of GEO 515 and GEO 516	2	50
	10	GEO 520	Field work	4	100
			Total	**22**	**550**
Second	1	GEO 551	Geology of Himalaya	2	50
	2	GEO 552	Quaternary Geology and Paleoclimate	2	50
	3	GEO 553	Environmental Sedimentology	2	50
	4	GEO 554	Remote Sensing and GIS	2	50
	5	GEO 555	Geology of Mineral Deposit	2	50
	6	GEO 556	Exploration Geophysics	2	50
	7	GEO 557	Practicals of GEO 551 and GEO 552	2	50
	8	GEO 558	Practicals of GEO 553 and GEO 554	2	50
	9	GEO 559	Practicals of GEO 555 and GEO 556	2	50
			Total	**18**	**450**
Third	1	GEO 611	Engineering Geology	2	50
	2	GEO 612	Mining Geology	2	50
	3	GEO 613	Hydrogeology	2	50
	4	GEO 614	Exploration Geochemistry	2	50
	5	GEO 615	Practicals of GEO 611 and GEO 612	2	50
	6	GEO 616	Practicals of GEO 613 and GEO 614	2	50
	7	GEO 617	Field work	4	100
			Total	**16**	**400**
Fourth			**Elective Group I**		
	1	GEO 651	Structural Analysis	2	50
	2	GEO 652	Basin Analysis	2	50
	3	GEO 653	Global Tectonics and Seismology	2	50
	4	GEO 654	Practicals of Elective Group I	3	75
			Elective Group II		
	1	GEO 661	Tunnel Engineering	2	50
	2	GEO 662	Geohazard	2	50
	3	GEO 663	Geological Construction Material	2	50
	4	GEO 664	Practicals of Elective Group II	3	75
			Elective Group III		
	1	GEO 671	Mineral Prospecting and Exploration	2	50
	2	GEO 672	Mineral Resources of Nepal	2	50
	3	GEO 673	Mineral Economics and Petroleum geology	2	50
	4	GEO 674	Practicals of Elective Group III	3	75
			Elective Group IV		
	1	GEO 681	Mountain Hydrogeology	2	50
	2	GEO 682	Water resource and Climate Change	2	50
	3	GEO 683	Hydrogeological Techniques	2	50
	4	GEO 684	Practicals of Elective Group IV	3	75
			Total	**9**	**225**
		GEO 691	Dissertation	4	100
			Total Credits 22+18+16+13 = 69	**69**	**1725**

SEMESTER III

SN	Course code	Course name	Credits	Marks
1	GEO.611	Engineering Geology	2	50
2	GEO.612	Mining Geology	2	50
3	GEO.613	Hydrogeology	2	50
4	GEO.614	Exploration Geochemistry	2	50
5	GEO.615	Practical of GEO.611 and GEO.612	2	50
6	GEO.616	Practical of GEO.613 and GEO.614	2	50
7	GEO.617	Field work	4	100
		Total	**16**	**400**

GEO.611: ENGINEERING GEOLOGY

Semester	III
Course Title	Engineering Geology
Course Code	GEO.611
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: To give in-depth knowledge and understanding of Foundations of engineering geology; properties of geological materials and tests; strength experiments and failure criteria; classification of geological materials site investigation and instrumentation; geological, engineering geological and geotechnical mapping; geotechnical investigations.

General Objective: This course provides the students with the concepts of Engineering Geology dealing with different engineering geological applications

Specific Objectives: To provide the students with in-depth knowledge and practical skills of engineering geological concept, investigations techniques related to various structures.

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hours
Introduction and Foundation of Engineering Geology	Formation and development of Engineering Geology as subject, Aims and achieving the aims of engineering geology, Engineering geological mass, geological materials and mass fabric, Environmental Factors, Engineering geological matrix and engineering behaviour of ground, and essential.	**2**
Properties of geological materials and tests	Engineering properties of rock and soil: Unit weight, density, porosity, permeability, void ratio, strength, deformability-elastic modulus, bulk modulus and modulus of rigidity, block punch test, Schmidt hammer test, velocity tests, Poisson's ratio, abrasiveness and environmental reactivity; Soil: particle size analysis: sieve and hydrometer analyses and consistency tests, hydraulic conductivity, consolidation. Properties and behaviour of coarse soils, silts and loess, clay deposits, sensitive clays, dispersive soils, organic soils: peat; properties and engineering aspects of rocks. Description of geological materials; rock mass fabric and properties, weathering, and ground description.	**4**
Strength experiments and failure criteria	Soil: shear strength of soil – direct shear box test and tri-axial test, effective stress Rock: Uniaxial tensile test, direct tensile strength test, point load test, Brazilian test, uniaxial compressive strength test, tri-axial strength test, poly-axial (True Tri-axial) compressive test; Scale effects and rock strength, classes of rock strength; shear strength of discontinuities. Rock failure types; Rock failure types, Rock failure criteria, Mohr-Coulomb criterion and Hoek-Brown criterion.	**4**

Classification of geological material	Classification of soil; application of soil classification; rock mass classification: Rock mass rating (RMR), Collection of field data, estimation of rock mass rating and its applications, Rock mass quality (Q-system), collection of field data, estimation of support pressures, Geological strength index (GSI), Rock mass number	**4**
Site investigation and instrumentation	Introduction of ground investigation, Planning of site investigation, Objectives of site investigation; Stages of Investigation; Design of Site Investigations, Quality of site investigation. Tests and sampling in boreholes: Methods of boring and drilling, Bore hole and core logging, Tests in boreholes - Penetration tests, Deformability tests, Vane shear test etc., Sampling and sample disturbance, Trial pitting. Tests in large diameter boreholes, adit, shaft or tunnel – stress, deformability, strength etc Instrumentation and measurements: Introduction, Instruments and applications, Choosing instrumentation; Instrumentation for water pressure, ground movement, ground vibration measurement etc. Instrumentation in boreholes, excavations and slopes, Geophysical investigation methods.	**6**
Geological, engineering geological and geo-technical mapping	Maps, maps making, geological and engineering geological maps, types of geological maps and engineering geological maps, Geological mapping, Engineering geological mapping, Discontinuity survey, Trench, tunnel, cave and cut slope mapping and logging, and Documentation	**2**
Geotechnical Investigation for -	Tunnel: terminology, tunnelling methods, geological condition of tunnelling, methods of site selection, Different stages of tunnel investigations i.e. feasibility, detailed and pre construction, Information and data density required in different stages. Dam: Dam site investigation, terminology and types of dam, problems and failures in dam, geological and geotechnical investigation for dam site, slope protection of dam site, foundation work for dam, grouting in dam site, site selection criteria for dam (preliminary investigation, detailed exploration, pre-construction stage). Road: Terminology and classification, road and pavement foundation, rigid and flexible pavement, geological and geotechnical investigation of mountain road, valley road, and road in plane area, road alignment survey and alignment selection. Railroad: terminology and classification, rail road foundation, geological investigation of railroad, rail road investigation in mountain and plane area. Bridge: Classification of bridge and parts of bridge, types of abutment, types of piers, bridge foundations, investigation of medium size bridge and large size bridge foundation. Building: Types of building foundation, Types of buildings - residential, commercial, industrial buildings, power plants and pumping stations, Selection of foundation types, foundation problems and exploratory programs, groundwater problems in foundations, building foundation on fills.	**8**

Text Books

1. Price, D. G. (2009). Engineering Geology: Principles and Practice. Springer, 450p.
2. Look, B. G. (2007). Handbook of Geotechnical Investigation and Design Tables, Taylor & Francis Group, London, UK, 356p
3. Krynine, D. P. and Judd W. R. (1957). Principles of Engineering Geology and Geotechniques, John Wiley and Sons, New York.
4. Bell, F. G. (1982). Fundamentals of Engineering Geology, Aditya Books Pvt. Ltd., New Delhi, 648p.

Reference Books

1. Bell, F. G. (1980). Engineering Geology and Geotechniques, John Wiley and Sons, New York.
2. Beavis F. C. (1985). Engineering Geology, Blackwell Scientific, Melbourne. 231 p
3. Monnet, J., (2015). In Situ Tests in Geotechnical Engineering, ISTE Ltd, UK and John Wiley & Sons, Inc., USA, 401P
4. Legget K. F. and Hatheway (1988). Geology and Engineering, John Wiley and Sons New York.

Geo.612: MINING GEOLOGY

Semester	III
Course Title	Mining Geology
Course Code	GEO.612
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: Mining geology is an applied science, which combines the principles of economic geology and mining engineering that deals with modern knowledge and techniques of mining.

General Objective: To provide an in-depth understanding of the modern methods of surface and underground mining.

Specific Objectives: To make the students able to understand:

- Mining terminologies, technologies, and methods of driving mine openings and associated operations,
- Organization and techno-economic characteristics of mine works, and
- Environmental issues associated with mining

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hours
Geology in the Mining Industry	Pure and applied geology, specialties in mining geology, importance of epigenetic deposits. Geology in Mining, company-staff geology. Geological economist.	**2**
Assembling Geological Data and Sampling Techniques	Interpretation of surface geological mapping for mining. Techniques of underground mapping, instruments, and equipment. Geophysical investigations to detect the ore body location, dimension, and other mining parameters. Sampling ore and calculating tonnage: general principles, channel sampling, and its uses. Other sampling methods. Averaging assays. Calculating grade and tonnage of ore. Ore sampled by drilling.	**3**
Application of Specific Phases of Mining	Field exploration, examining and developing prospects, valuing mining properties, geological work at an operating mine, and engineering geology in mining. Mine support: evaluation and implementation methods. Writing and reading reports.	**3**
Techniques of Mine Openings	Appraisal of exploration data for mining. Mining terminology, Mining Stages, Modes of entry to mineral deposits- adit or tunnel, incline, or vertical shaft. Exploratory surface mining of mineral and placer deposits. Open-pit mining methods, Classification of underground excavations and methods of excavations, techniques, high-speed driving of crosscuts and entries. Excavation of inclined workings. Support of junctions, shapes, cross-sectional dimensions of mine openings, and unit operations of mining.	**4**
Technical and Economic	Progress in machine driving of development openings.	**3**

Characteristics of driving development Workings	Rate of advance of development openings and labor productivity. Comparison of broad and narrow face driving. Underground mining methods for open-stopping sublevel open stopping, Longwall mining, Room, and pillar mining, shrinkage stopping, and caving. Cycles of operation drilling, blasting, mucking, support and lining, ventilation, illumination, and drainage.	
Tools of Mine Openings	Mine development tools, types of machinery, and equipment. Drilling and blasting in excavations of mine openings. Electric power supply. Aeration of faces and drives of development openings. Loading of blasted muck, haulage, and hoisting.	**3**
Organization of the drifting cycle	Patterns and methods of work organizations, Mines administration, Calculation of major parameters of the drifting cycle.	**2**
Technological Characteristics of Ores	Amenability of ore to treatment. Marketable forms of metals and ores: Smelters' payments, mineralogical nature, and commercial standard.	**2**
Environmental Issues	Nature and extent of environmental problems due to surface and underground mining. Mine waste management. Role of the geologist at operative mines.	**2**
Mine Planning	Mine planning for open pit mining: block models. Mine planning for underground excavations. Evaluation, risk, and feasibility. Geological parameters for mine planning. Technical and social parameters.	**6**

Text Books

1. Onika, D. (1978). Excavation of Mine Openings, Mir Publishers
2. Boky, B. (1967). Mining, Mir Publishers, 763p
3. Arogyaswami, R. N. P. (1988). Courses in Mining Geology. Third Edition, Oxford and IBH Publishing Company Limited, New Delhi, 695 p.
4. Peele, R. (1918). Mining Engineers Handbook, John Wiley & Sons, Inc . 2292p.
5. McKinsry, H. E. (1962). Mining Geology. Cambridge (1948). Asia Publishing House. Produced by Charles E. Tuttle Company and Printed in Japan (1962).
6. Craig, J. R. and Vaughan, D. J. (1981). Ore Microscopy and Ore Petrography, John Wiley and Sons Inc., New York, 190p.

Reference Books

1. Deshmukh, D. J. (2010). Elements of Mining Technology (8th Edition), Vol. I, Denett & Company, 424p.
2. Deshmukh, D. J. (2016). Elements of Mining Technology (9th Edition), Vol. II, Denett & Company, 323p.
3. Deshmukh, D. J. (2016). Elements of Mining Technology (8th Edition), Vol. III, Denett & Company, 368p.
4. Harman, H. L. and Mutmansky, J. M. (2002). Introductory mining engineering, second edition, 570p.

GEO.613: HYDROGEOLOGY

Semester	III
Course Title	Hydrogeology
Course Code	GEO.613
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: The course contains various topics related to hydrogeology, meteorology, and hydrological aspects so that the students will be holistically educated and skilled in data requirement, data analysis and interpretation in the subject.

General Objective: Understanding fundamentals of hydrogeology and water chemistry.

Specific Objective: Hydrogeological, meteorological, hydrological and chemical data analysis, presentation, and interpretation.

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hours
Introduction	Importance of water, physical and chemical properties of water, hydrological cycle, water balance equation.	**2**
Precipitation	Precipitation types, frequency, intensity and spatial distribution at different physiographic regions. Rainfall measurement, techniques of filling missing rainfall data, data analysis and interpretation.	**3**
Evaporation and Transpiration	Available energy, water supply, atmosphere, measurement of evaporation (Lysimeter, Penman etc.), estimation of evaporation (mass balance, canopy interception loss)	**2**
Runoff	Runoff mechanism, stream flow measurement, hydrograph analysis frequency analysis	**3**
Aquifers	Aquifer in different geological set up, especially in Terai Plain, intermontane basin and hard rocks. Types of natural spring; Groundwater hydrology of natural spring	**2**
Well Hydraulics	Darcy's law in porous media. Groundwater flow in different types of aquifer, recharge. Groundwater flow in wells, pumping test analysis in different scenario.	**2**
Water well drilling and design	Well drilling methods and problems encountered, well casing. Well screens: types of screens. Selection of screens, Determination of well depth, screen length, Installation of well screens, design for domestic wells, design for sanitary protections, conducting a pumping test, well efficiency, major causes of deteriorating well performance and well failure. Groundwater monitoring methods.	**4**
Groundwater chemistry	Property of water, inorganic and organic solutes, chemical reaction; isotopes (stable, radioactive and environmental isotopes) and its application in hydrogeology.	**5**
Groundwater quality and pollution	Chemical analysis, physical analysis and biological quality of water; quality, uses and standards (WHO, Nepal standards). Sources and types of pollution, distribution of contaminants in the subsurface, attenuation of pollution, mass transport of pollutants, contamination of soil and water.	**4**

Remediation of contaminants	Contaminant sources, contaminant plume, mass transfer processes in contaminant plume, redox zonations in contaminant plume, relevant physical and chemical properties of contaminants, isotopes fractionation of contaminants.	**3**

Text Books

1. Todd, D. K. and Mays, W. M. (2005). Groundwater Hydrology. John Wiley & Sons, NewYork, 636p.
2. Domenico, P. A. and Schwartz, F. W. (1990). Physical and Chemical Hydrogeology, J. Wiley & Sons, Chichester.
3. Driscoll, F. G. (1989). Groundwater and Wells, Johnson Filtration Systems lnc., Minnesota.
4. Fetter, C. W. (1990). Applied Hydrology (2nd ed), CBS Publishers India.
5. Raghunath, H. M. (2007). Groundwater 3rd edition.
6. Laura, L sanders (1998). Manual of Field Hydrogeology.
7. Pathak, D. (2021). Mountain Hydrogeology, Nepal Hydrogeological Association.

References

1. Journals of Nepal Geological Society.
2. Bulletins of the Department of Geology.
3. Jones, G. P. and Rushton, K.R. (1981). Pumping-test analysis, Groundwater Resources Evaluation (Lloyd).
4. Fetter, C. W. (1993). Contaminant Hydrogeology. - Macmillan Publishing Company, New York; 458p.
5. Schwarzenbach, R. P., Gschwend, P. M. and Imboden, D. M. (2002). Environmental Organic Chemistry. Wiley Interscience, 1200p.
6. Smith, J. A., Witkowski, P. J. and Fusillo (1988). Manmade organic compounds in the surface waters of the United States -A review of current understanding.-U.S. Geological Survey, Circular 1007.

Geo.614: EXPLORATION GEOCHEMISTRY

Semester	III
Course Title	Exploration Geochemistry
Course Code	GEO.614
Credits	2
Teaching hours	30 hrs.
Full Marks	50
Pass Marks	25
Nature of the course	Theory

Course Description: The course deals with fundamental principles of geochemistry and geochemical exploration methods applied in mineral exploration.

General Objective

To provide in-depth knowledge and practical skills on geochemical prospecting and exploration techniques applied to investigate and find out mineral deposits, and their evaluation.

Specific Objective

To provide in-depth knowledge and practical skills for the study, analysis and interpretation of

- Geochemical data
- Geochemical prospecting and exploration of mineral deposits
- Laboratory equipment used in geochemical analysis
- Geochemical sampling, sample treatment, and analysis

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hours
Fundamentals of geochemistry	Zonal structure of the earth, composition of the crust, composition of the earth as a whole, primary differentiation of elements, Goldschmidt's rule of geochemical classification of elements. Major elements, trace elements, Goldschmidt's rule of distribution of elements, compatible and incompatible elements, geochemical process, variation diagrams Stable and radioactive isotopes and their application in geology.	**4**
Introduction to exploration geochemistry	Definition and other terminologies, basis of geochemical exploration, types of geochemical survey, the geochemical environment, geochemical cycle, geochemical dispersion, mobility of the elements, natural association of the elements, indicator elements, pathfinder elements, pathfinder minerals, geochemical mapping, geochemical distribution pattern, geochemical anomaly, interpretation of geochemical data, relation between various elements.	**3**
The Primary Environment	Introduction, distribution of elements in the igneous rocks and minerals, primary halos and primary dispersion, geochemical provinces, geochemical association.	**2**
The Secondary Environment	Introduction, chemical weathering, physical weathering, environmental factors affecting weathering, application of Eh and pH, adsorption, mobility in the secondary environment, water (groundwater, river water, lake water and sediments)	**2**

Geochemical surveys	Bedrock, residual soil, ridge and spur soil, stream sediment samples, heavy mineral concentrate panning, biogeochemical, geobotanical, ground water and stream water sampling, gas/ vapor and other geochemical surveys (Introduction, orientation survey, detailed surveys, interpretation of geochemical data)	**3**
Dispersion patterns of deep seated origin (primary dispersion)	Syngenetic patterns: larger patterns (or geochemical provinces), local patterns, Epigenetic patterns: wall-rock anomalies, wall-rock alterations, leakage anomalies, compositional zoning etc.	**3**
Surficial dispersion patterns (dispersion)	Weathering, products of weathering, soil profile, factors affecting soil formation, mechanisms of dispersion: mechanical factors, surficial dispersion patterns, anomalies in residual Overburden.	**3**
Geochemical sampling and sample preparation	Sample size, methods of sampling, quality assurance, controls to sample collection, sample preparation: handling of sample, sample size reduction, separation and concentration, sample dividers, sample homogenization, contamination.	**4**
Laboratory methods of analysis	Criteria for selecting an analytical technique, important terminologies, introduction to analytical techniques: ion- exchange separation, fire assay, AAS, XRF, INAA, ICP- AES/OES, ICP-MS, TIMS, EPMA, LA-ICP-MS, SIMS, PIXE, X-ray Microprobe.	**3**
Statistical treatment of geochemical data	Introduction, geochemical parameters, frequency of samples, mean, median, mode, background values, threshold value, anomalous value, standard deviation, population, normal and abnormal distribution, histogram, cumulative frequency curve, regional/ local variation, correlation between elements, classification of samples, survey sampling, anomaly detection.	**3**

Text Books

1. Randive, K. R. (2012). Elements of geochemistry, geochemical exploration and medical geology. Research Publishing, 448p.
2. Levinson, A. A. (1974). Introduction to exploration geochemistry, second edition. The University of Michigan, 924p.
3. Mason, B. and Moore, C. B. (1966). Principles of geochemistry. Wiley Eastern Limited, 350p.
4. Hawkes, H.E and Webb, J. S., (1962). Geochemistry in Mineral Exploration, Harper's Geoscience series, 415p.

Reference Books

1. Pacal, Z. (ed.) (1977). Geochemical prospecting methods. GEOCHIM.CSSR.UNESCO Postgraduate training course. 83p.
2. Krauskopf, K. B. and Bird, D. K. (1995). Introduction to geochemistry. McGraw-Hill International editions, Earth Science and Geology Series, 645p.
3. Walther, J. V. (2010). Essentials of Geochemistry. Jones and Bartlet (Student Edition), 797p

GEO.615: PRACTICAL OF GEO.611 AND GEO.612

Semester	III
Course Title	Practical of Geo.611 and Geo.612
Course Code	GEO.615
Full Marks	50
Pass Marks	25
Nature of the course	Practical
Credit	2 (90 hrs.)

GEO.615a: ENGINEERING GEOLOGY

(Total credit: 1; FM: 25; Teaching hours: 45)

Course Contents

Lab 1: To Classify soil in Unified soil classification system.

Lab 2: To determine the unit weight of rock and soil specimens.

Lab 3: To determine tensile strength, point-load index, and classify strength of the rocks.

Lab 4: To determine uniaxial compressive strength, young's modulus and Poisson's ratio of rock.

Lab 5: To log drilled cores, determine RQD and study to measure structures in core from both oriented and non-oriented cores.

Lab 6: To estimate rock mass quality Q, basic rock mass rating (RMR) and Geological strength index (GSI).

Lab 7: Site investigation problem for bridge site selection from given maps.

Lab 8: Site investigation problem for road site selection from given maps.

Lab 9: Site investigation problem for dam site selection from given maps.

Lab 10: Prepare engineering geological map of a landslide.

GEO.615b: MINING GEOLOGY

(Total credit: 1; FM: 25; Teaching hours: 45)

Course Contents

Lab 1: Interpretation of surface geological maps for mining.

Lab 2: Interpretation of subsurface geological maps for mining.

Lab 3: Interpretation of geological logs for mining.

Lab 4: Interpretation of geophysical data for mining.

Lab 5: Interpretation of geochemical, petrography, and other laboratory data for mining.

Lab 6: Methods of computation of ore reserve, tonnage, and grade using different methods.

Lab 7: Design of support system in underground excavation

Lab 8: Study of mine development tools, types of machinery, and equipment.

Lab 9: Design of drilling and blasting in excavations of mine openings.

Lab 10: Methods of mine planning.

GEO.616: PRACTICAL OF GEO.613 AND GEO.614

Semester	III
Course Title	Practical of Geo.613 and Geo.614
Course Code	GEO.616
Full Marks	50
Pass Marks	25
Nature of the course	Practical
Credit	2 (90 hrs.)

GEO.616a: HYDROGEOLOGY

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Contents

Lab 1: Collection, analysis and interpretation of precipitation data

Lab 2: Analysis of discharge data, flow separation

Lab 3: Calculation of energy and heads

Lab 4: Groundwater flow, flow net maps, recharge assessment through various methods

Lab 5: Pumping test data analysis and aquifer characterization

Lab 6: Calculation of cone of depression, well efficiency, specific yield

Lab 7: Well design and development (Selection of screen, calculation of hydraulic conductivity, screen and their types, specification)

Lab 8: Calculation of solute concentration in water in different units.

Lab 9: Measurement, analysis, presentation of data and interpretation.

Lab 10: Characterization of contaminant plume

Lab 11: Representation of isotope data, analysis and interpretation in different hydrogeological setting.

GEO.616b: EXPLORATION GEOCHEMISTRY

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Contents

Lab 1: Familiarization with the Terms and Definitions related to Geochemistry.

Lab 2: Solar system showing all nine planets, Sun and Asteroid

Lab 3: Internal structure of the earth in detail showing thickness, and average density of crust, mantle and core.

Lab 4: (A) Isotopes of Hydrogen, Oxygen, Carbon, Uranium, Thorium, Rubidium, Lead (B) Daughter elements of 235U, 238U, 232Th, 87Sr, 40K and 14C.

Lab 6: Geochemical cycle: Primary dispersion and Secondary dispersion

Lab 7: Interpretation of EPMA data

Lab 8: Illite Crystallinity

Lab 9: Age determination of the rock from the given data

Lab 10: Statistical interpretation of geochemical data by plotting histogram and cumulative frequency curves and determine geochemical parameters (Median, Mode, Mean (X), Background (Bg) ,Threshold (Xth) values, Standard deviation (Sd), Anomalous and Highly/ distinct Anomalous values in (A) Stream sediment survey/ sampling (B) Ridge and spur soil survey, (C) Residual soil survey and (D) Heavy mineral concentrate sampling for placer gold and other heavy minerals.

GEO.617: FIELD WORK

Semester:	III
Course Title	Field work
Course Code	GEO.617
Full Marks	100
Pass Marks	50
Nature of the course	Field Work
Credit	4 (4 weeks)

Course description: Fieldwork is carried out to provide the field knowledge of structural analysis and tectonics; Engineering Geology; Mining Geology and Hydrogeology including related data collection, database preparation, data analysis, interpretation and discipline related map preparation.

General objective: To give the knowledge, techniques and skill of structural analysis and tectonics; Engineering Geology; Mining Geology and Hydrogeology in the field.

Specific objective: To provide the students with the techniques of:

- Structural analysis and tectonics
- Engineering Geology
- Mining Geology, and
- Hydrogeology.

Field work duration: The field work will carry a total of 28 days. One credit of field work will have 70 hours of teaching per week. One teacher will be assigned per 10 students in the field.

Location: The fieldwork will be carried out for four weeks in various locations in Nepal as suitable in order to address the specific objectives of the field work. The location may vary depending upon the criteria set by the Department and situation in the field sites.

Field work course content

S. N.	Title	Content
1	**Structural Analysis and Tectonics**	Structural Geological investigation, mapping, data collection techniques, preparation of required maps etc. Students will learn methods of structural geological, studies specific to various geological terrain and their tectonic interpretation. Application of geophysical investigation method as required.
2	**Engineering Geology**	Engineering Geological exploration, mapping, site investigation, data collection techniques, preparation of required maps etc. Students will learn methods of engineering geological studies specific to various engineering structures suitable in various conditions, e.g. landslide area, different project sites from the fieldwork. Application of geophysical investigation method as required.
3	**Mining Geology**	Mineral Prospecting, Exploration, Mining, and Mineral Processing Techniques: Students will learn methods of prospecting and exploration of metallic minerals, non-metallic minerals, gems, industrial rocks and minerals, dimension stones, and coal, gas, and petroleum. They will

		learn to prepare a mineral resource map of a region. They will also learn the methods of reserve calculation, sampling, mining, and processing of minerals. They will learn techniques of laboratory analysis of samples collected from the fieldwork. Application of geophysical investigation method as required.
4	**Hydrogeology**	Students will learn to prepare hydrogeological map in plain and mountainous terrains, hydrogeological parameter assessment through various means like pumping test, water quality test, groundwater exploration, hydrogeological mapping etc. as per site condition during the field work duration. Students will also learn data compilation, analysis, interpretation and hydrogeological mapping. Application of geophysical investigation method as required.

Evaluation

Students will submit field report incorporating all information collected in the field, database preparation, data analysis, map preparation, interpretation and conclusions. The report should be well formatted as prescribed by the department. In addition to the students' performance evaluated in the field, a formal presentation/Viva-voce will be a part of the examination.

SEMESTER IV

SN	Course code	Course name	Credits	Marks
Elective Group I				
1	GEO 651	Structural Analysis	2	50
2	GEO 652	Basin Analysis	2	50
3	GEO 653	Global Tectonics and Seismology	2	50
4	GEO 654	Practicals of Elective Group I	3	75
Elective Group II				
1	GEO 661	Tunnel Engineering	2	50
2	GEO 662	Geohazard	2	50
3	GEO 663	Geological Construction Material	2	50
4	GEO 664	Practicals of Elective Group II	3	75
Elective Group III				
1	GEO 671	Mineral Prospecting and Exploration	2	50
2	GEO 672	Mineral Resources of Nepal	2	50
3	GEO 673	Mineral Economics and Petroleum geology	2	50
4	GEO 674	Practicals of Elective Group III	3	75
Elective Group IV				
1	GEO 681	Mountain Hydrogeology	2	50
2	GEO 682	Water resource and Climate Change	2	50
3	GEO 683	Hydrogeological Techniques	2	50
4	GEO 684	Practicals of Elective Group IV	3	75
		Total for each Elective Group	**9**	**225**
	GEO 691	**Dissertation**	**4**	**100**

ELECTIVE GROUP I

GEO.651: STRUCTURAL ANALYSIS

Semester	IV
Course Title	Structural Analysis
Course Code	GEO.651
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: The course gives the necessary knowledge and skills of analysis and interpretation of geological structures.

General Objective: To give in-depth knowledge and understanding of structural analysis techniques.

Specific Objective: To provide the students with in-depth knowledge and practical skills of

- Microscopic, mesoscopic, and macroscopic analysis of structural data,
- Geometrical, kinematic, and dynamic interpretations,
- Their use in geology.

(Total Credit: 2; Full Marks: 50; Teaching hours: 30)

Title	Content	Teaching hours
Introduction	Historical Background. Structural analysis, scope of structural analysis, limitations of structural analysis	**2**
	Definition and purpose, factors in structural analysis, geometric, kinematic and dynamic analysis	**2**
Geologic bodies	Definition, Scale of geologic bodies, Homogenous and heterogenous geologic bodies, Fabric of geologic bodies, Fabric domain, Penetrative and non-penetrative discontinues in geologic bodies, Fabric elements and fabric data, Isotropic and anisotropic fabrics, concept of tectonite, componental movement, types of tectonite, Fabric elements of tectonite	**6**
Microtectonics: Deformation mechanism	Introduction, cataclastic flow, pressure solution, intracrystalline deformation, recovery, recrystallisation (grain boundary migration recrystallisation, subgrain rotation recrystallisation, competing processes during deformation), solid state diffusion creep, grain boundary sliding and super plasticity, grain boundary area reduction, static recrystallisation, deformation of some rock forming minerals (Introduction, Quartz, Calcite and Dolomite, Feldspar, Micas, Olivine, Orthopyroxene, Amphiboles), Deformation of polymineralic rocks (Introduction, Quartz-Feldspar aggregates, deformed ignimbrites), flow laws and deformation mechanics maps.	**6**
Microtectonics: Shear Zones	Introduction, brittle fault rocks (incohesive fault rocks, cohesive fault rocks, pseudotachylite), Mylonite (Introduction, characteristics fabric elements, mylonite classification, dynamic of mylonite development, mylonite and metamorphic conditions), complex fault	**6**

	rocks, sense of shear (Introduction, displacement and deflection of markers, foliation curvature), microscopic shear sense indicators in mylonite (Introduction, foliation orientation, oblique foliations, shear band cleavage, mantled porphyroblast, development of mantle porphyroblast, mica fish, quarter structures, lattice-preferred orientation, vergence of asymmetric fold sections, potential shear sense markers), shear sense indicators in brittle regime (Introduction, incohesive brittle fault rocks, cohesive brittle fault rocks, pseudotachylite)	
Stress strain relationship	Geological significance of strain ellipse, progressive deformation, relationship of finite and infinitesimal strain, coordinate transformation equations, relationship between stress and strain	**6**
Structural data collection	Techniques of structural data collection in the field and laboratory and their interpretation	**2**

Text Books

1. Ramsay, J. G. (1967). Folding and Fracturing of Rocks, McGraw Hill Inc., 568 p.
2. Turner, F. and Weiss, L. E. (1963). Structural Analysis of Metamorphic Tectonites, McGraw Hill Book Company, 545 p.
3. Passchier, C. W. and Trouw R. A. J. (2003). Micro-tectonics, Springer, 253 p.
4. Ramsay, J. G. and Huber, M. I (1983). The Techniques of Modern Structural Geology, Volume 1: Strain Analysis, Academic Press, 307 p.
5. Ramsay, J. G. and Huber, M. I (1987). The Techniques of Modern Structural Geology, Volume 2: Folds and Fractures, Academic Press, 309-700 p.

Reference Books

1. Bayly, B. (1991). Mechanics in Structural Geology, Springer-Verlag, 253 p
2. McClay, K. R. (1987). The Mapping of Geological Structures, John Wiley & Sons Inc., 161 p.
3. Ragan D. M. (1985). Structural Geology, An Introduction to Geometrical Techniques, 3rd edition, John Wiley & Sons Inc., 393 p.
4. Means W. D. (1985). Stress and Strain Basic concepts of continuum mechanics for geologists, Springer-Verlag New York, 339 p.

GEO.652: BASIN ANALYSIS

Semester	IV
Course Title	Basin Analysis
Course Code	GEO.652
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: Basin Analysis deals with regional to local scale entities of sedimentary basins distributed in the globe. This course provides skills and techniques of data acquisition, analysis and interpretation of sedimentary basins.

General Objective: To give in-depth knowledge and understanding of the structure of the Earth's sedimentary basins in various tectonic settings.

Specific Objectives: To provide the students with in-depth knowledge and practical skills of

- Classification of sedimentary basins
- Origin and occurrence of sedimentary basins
- Data analysis to reconstruct and interpret sedimentary basins

(Total Credit: 2; Full Marks: 50; Teaching hours: 30)

Title	Contents	Teaching hours
Types of Sedimentary Basins	Basins in Plate Tectonic Environment: Zonation of the Earth, Plate movements, Wilson Cycle. Mechanisms of basin subsidence.	**3**
	Tectonic basin classification: Continental or interior sag basins. Oceanic sag basins. Continental or interior fracture basins. Basins on passive continental margins. Basins related to subduction. Basin related to collision. Strike-slip/Wrench basins. Dickinson's Classification.	
Basin Evolution and Sediments	Rift Basins : Rift structures: Pure shear and simple shear. Other structural features. Examples of young rift zones: East African Rift Zone. Other young rift zones. Sediments of Rift Basins. Transition from Rift Basins to Continental Margin Basins.	**3**
	Continental Margin and Slope Basins: Types of continental margins. Basin morphology and sediments. Sediment successions of continental margin basins: Sediment buildup on Atlantic-type margins. Sediment-starved marginal basins. Submarine Marginal Plateaus. Sediment successions on continental slopes.	**3**
	Intracratonic Basins Associated wtih Mega-Rifting: Permian to Mesozoic Basin development in Europe. Mesozoic Sediments between the North Sea and the Western Tethys. Continental or Intracratonic Sag Basins: General Aspects. Sediments.	
	Deep-seaTrenches, Forearc and Backarc Basins: *Deep-seaTrenches*: General characteristics and sediment sources. Consequences for sediments in accretionary wedges. The Sunda Arc-Trench System. *Forearc Basins*: Types of Forearc Basins. Basin Evolution and sediment source. Ridged and Shelved Forearc Basins. Sediment Successions of Forearc Basins. Examples: The Great Valley-Forearc Basin of California. *Backarc Basins*: General	**3**

	characteristics. Sediment successions of Backarc Basins. Examples of Modern Backarc Basins. Ancient subduction Basins.	
	Remnant and Foreland Basins: *Remnant Basins with Flysch*: General. Basin evolution and sediments. *Foreland Basins with Molasses*: General. Modern Examples. Basin Evolution and Sediments. Pull-Apart Basins: Characteristics. Sediments of Pull-Apart Basins.	**3**
Basin Mapping Methods	Sedimentologic-Stratigraphic Database: *Describing Surface Sections:* Method of measuring and recording data, Types of field observation, graphic logging. *Describing Subsurface Stratigraphic Sections*: Method of measuring and recording data, Examination of well cutting and cores, Subdivision of section into descriptive units, Sampling plan. *Stratigraphic Procedures*: Mapping and correlation procedure, Surface mapping, and stratigraphic cross-section matching. 3-D panel diagram.	**3**
	Facies Analysis: Some general trends for sediment accumulation and facies. Meaning of facies, Recognition and definition of facies types, Example of facies scheme, Establishing a facies scheme, facies associations and sedimentary models, ordering of facies, Vertical profile analysis.	**3**
	Structure and Isopach contouring. *Construction of lithofacies Maps:* Multi-component map, Lithofacies maps, Single component maps. Clastic Petrographic Data*:* Petrofacies analysis, Provenance analysis. Paleocurrent Analysis: Types of paleocurrent indicators, Data collection and processing, Environment and paleoslope interpretation.	**3**
	Application of Log Data in Basin Evaluation: Petrophysical logs: Borehole logging, Borehole imaging. Log combination for effective interpretation.	**3**
Sedimentation and Accumulation Rates	Sedimentation rates. Accumulation rates. Short- and long-term sedimentation rates. Potential and actual sedimentation rates. Average Sedimentation Rates in various depositional environments. Sedimentation rates in relation to denudation, subsidence and sea level change.	**3**

Text Books

1. Miall, A. D. (1984). Principles of Sedimentary Basin Analysis. Third Edition, Springer Verlag, 616p.
2. Allen, P. A. and Allen, J. R. (1990). Basin Analysis: Principles and Applications. Blackwell Scientific Publications, London, 451p.
3. Einsele, G. (1992). Sedimentary Basins, Springer Verlag, 628p.
4. Tamrakar, N. K. (2011). Practical Sedimentology, Bhrikuti Academic Publication, Kathmandu, 232p.

Reference Books

1. Nichols, G. (2009). Sedimentology and Stratigraphy. 2nd edition. Wiley-Blackwell, 418p.
2. Reineck H. E. and Singh I. B. (1980). Depositional Sedimentary Environments, 2nd edition, Springer Verlag, 549 p.
3. Folk. R. L. (1980). Petrology of Sedimentary Rocks. Hemphill Publishing Company, Austin, Texas, 184p.

4. Pettijohn, F. J. (1984). Sedimentary Rocks. 3rd edition, CBS Delhi, 628p.
5. Yin, A. and Hrrison, T. M. (eds) (1996). The Tectonic Evolution of Asia. Cambridge University Press, 666p.

GEO.653: GLOBAL TECTONICS AND SEISMOLOGY

Semester	IV
Course Title	Global Tectonics and Seismology
Course Code	GEO.653
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: Concepts on global plate boundaries, seismic behavior of the plate boundaries.

General Objective: To give in-depth knowledge and understanding of the structure of the earth and its formation, particularly in relation to continental tectonics and mantle convection and give basic knowledge of seismology

Specific Objective: The course provides in-depth knowledge of large scale tectonics, thin skin tectonics and micro-tectonics**.** To provide students' knowledge of seismic wave propagation, seismic source characteristics, seismicity analysis.

(Total Credit: 2; Full Marks: 50; Teaching hours: 30)

Title	Content	Teaching hours
Global Tectonics		
Historical perspective	Continental drift, sea floor spreading and the birth of plate tectonics	**1.5**
The interior of Earth	Continental and oceanic crust, Crust mantle boundary, rheology of the crust and mantle, role of mantle in global tectonics, behaviour of the crust and lithosphere at plate boundaries	**1.5**
Continental drift	Continental drift: Continental reconstructions- Euler's theorem, geometric reconstructions of continents; geologic evidence for continental drift, paleoclimatology, paleontologic evidence for continental drift; paleomagnetism: rock magnetism, natural remnant magnetization, past and present geomagnetic field, apparent polar wander curves	**1.5**
Sea floor spreading and transform faults	Sea floor spreading: marine magnetic anomalies, geomagnetic reversals, seafloor spreading, Vine-Matthews hypothesis, magnetostratigraphy, dating the ocean floor; transform faults: ridge-ridge transform faults, ridge jumps and transform fault offsets	**1.5**
The framework of plate tectonics:	Plates and plate margins, distribution of earthquakes, relative plate motions, absolute plate motions, hotspots, true polar wander, cretaceous superplume, direct measurement of relative plate motions, finite plate motions, stability of triple junctions, present day triple junctions.	**1.5**
Continental rifts and rifted margins:	General characteristics of narrow rifts, general characteristics of wide rifts; volcanic activity: large igneous provinces, mantle upwelling beneath rifts; rift initiation; strain localization and delocalization processes: lithospheric stretching, buoyancy forces and lower crustal flow, lithospheric flexure, strain induced weakening, rheological stratification of lithosphere, magma assisted rifting; rifted continental margins: volcanic margins, non-volcanic margins, evolution of rifted margins; Case studies: the transition from rift to rifted margin: East African Rift System, The Wilson cycle.	**2**

Continental transforms and strike-slip faults	Fault styles and physiography; deep structure of continental transforms: The Dead Sea Trasform. The San Andreas Fault; Transform continental margins; continuous versus discontinuous deformation: relative plate motion and surface velocity fields; strain localization and delocalization mechanisms: lithospheric heterogeneity, strain softening feedbacks; Measuring the strength of transforms	**1.5**
Subduction zones	Ocean trenches, general morphology of island arc systems, gravity anomalies of subduction zones, structure of subduction zones from earthquakes, thermal structure of the downgoing slab, variations in subduction zone characteristics, accretionary prisms, volcanic and plutonic activity, metamorphism at convergent margins, backarc basins	**1.5**
Orogenic belts	Ocean–continent convergence: seismicity, plate motions and subduction geometry; compressional sedimentary basins: foreland basins, basin inversion, modes of shortening in foreland fold-thrust belts; continent–continent collision: relative plate motions and collisional history, surface velocity fields and seismicity, general geology of the Himalaya and Tibetan Plateau, deep structure, mechanism of continental collision; arc–continent collision, Terrane accretion and continental growth	**2.5**
Seismology		
Seismic wave propagation	Stress-strain and equation of motion, Seismic waves: seismic wave equation, body waves and surface waves, Seismogram and different seismic phases	**4**
Earthquake phenomenology	Seismic source: point source and finite fault source, Seismic wave radiation, attenuation, Radiation pattern of body waves and double couple source, Different magnitude scales of earthquake, saturation of magnitude scales, seismic energy and seismic moment. Seismic moment tensor.	**5**
Seismicity analysis	Global seismicity and plate tectonics, Focal mechanism solutions, Earthquake catalog, distribution of earthquakes in time and space, Background seismicity, foreshock, mainshock and aftershock, aftershock distribution and Omori's law, Interseismic period and coseismic activities, Earthquake magnitude and frequency, Richter-Gutenberg relation, Earthquake sequences, Seismotectonics of the Himalaya.	**6**

Textbooks

1. Philip Kearey, Keith A. Klepeis and Frederick J. Vine (2009). Global Tectonics, Third Edition. Wiley-Blackwell, Oxford, 496 p.
2. Frisch, W., Meschede, M. and Blakey, R. (2011). Plate Tectonics: Continental Drift and Mountain Building. Springer, 212p.
3. Shearer, Peter M. (2009). Introduction to Seismology Second Edition, Cambridge University Press, 412p.
4. Scholz, Christopher H. (2002). The Mechanics of Earthquake and Faulting Second Edition, Cambridge University Press, 471p.

Reference Books

1. Dhital, M. R. (2015). Geology of the Nepal Himalaya: Regional Perspective of the Classic Collided Orogen. Springer, 498p.

2. Lowrie, W. (1997). Fundamentals of Geophysics. Cambridge University Press, 354p.
3. Press, F., Siever, R., Grotzinger, J., Jordan, T. (2003). Understanding Earth. 4th edition. Freeman, New York, 568p.
4. Rob Van der Voo (1993). Paleomagnetism of the Atlantic, Tethys and Iapetus Oceans. Cambridge University Press, 416p.
5. Spencer, E. W. (1977). Introduction to the Structure of the Earth, McGraw Hill Kogakusha, 640 p.
6. Stuwe, K. (2007). Geodynamics of the Lithosphere: Quantitative of Geological Problems. 2nd Edition. Springer-Verlag, 493p.
7. Turcotte, D. L., Schubert, G. (2002). Geodynamics: Applications of Continuum Physics to Geological Problems. 2nd edition. Cambridge University Press, Cambridge, England, 456p.
8. Chapman, Chris H. (2004). Fundamentals of Seismic Wave Propagation, Cambridge University Press, 617p.
9. Aki, K. and Richards, P. G. (2009). Quantitative Seismology, University Science Books, 700p.
10. Stein, S. and Wysession, M. (2003). An Introduction to Seismology, Earthquakes and Earth Structure. Blackwell Publishing, 498p.

GEO.654: PRACTICAL OF ELECTIVE GROUP I

Semester	IV
Course Title	Practicals of Elective Group I
Course Code	GEO.654
Full Marks	75
Pass Marks	37.5
Nature of the course	Practical
Credit	3 (135 hrs.)

GEO 654a: Structural Analysis

(Total Credit: 1; Full Marks: 25; Teaching hours: 45)

Course Content

Lab 1: Principles of displacement and strain using simple shear of a card deck.

Lab 2: The strain ellipse concept – Distortation and Rotation.

Lab 3: Calculation of ellipticity from the distorted clast.

Lab 4: Displacement vector fields and strain.

Lab 5: Calculation of nature of strain by different methods

Lab 6: measurement of strain in extended and shortened feature

Lab 7: Projection of plane before and after deformation

Lab 8: Projection of a line before and after deformation

Lab 9: Classification of fold using Ramsay's classification

GEO 654b: Basin Analysis

(Total Credit: 1; Full Marks: 25; Teaching hours: 45)

Course Content

Lab 1: Drawing a synthetic chart of Basin Analysis. Drawing and describing a Wilson cycle. Drawing models of Isostasy.

Lab 2: Drawing models of sedimentary basin formative mechanisms. Drawing of the World's map to show existing sedimentary basins. Drawing classification schemes of Sedimentary Basins

Lab 3: Drawing models of Rift Basins

Lab 4: Drawing models of Continental Margin and Slope Basins, Intracratonic basins.

Lab 5: Drawing models of Deep Sea Trenches, Forearc and Backarc Basins;

Lab 6: Drawing models of Remnant Ocean and Foreland Basins;

Lab 7: Drawing models of Pull-apart Basins.

Lab 8: Constructing graphic and petrophysical logs from subsurface data, and correlation and interpretation.

Lab 9: Litho- and instrumental logs in interpretation of evolution of basin.

Lab 10: Facies analysis and interpretation of depositional models.

Lab 11: Constructing graphic logs and interpretation of depositional environment

Lab 12: Construction of Lithofacies map and interpretation of basin.

Lab 13: Analysis of clastic petrofacies data in interpreting detrital modes, provenance, and Himalayan Unroofing history.

Lab 14: Comprehensive review on studies to interpret evolution of basins.

GEO 654c: Global Tectonics and Seismology

(Total Credit: 1; Full Marks: 25; Teaching hours: 45)

Course Content

Lab 1: Tectonic reconstruction: Preparation of seismotectonic map of the Globe.

Lab 2: Tectonic reconstruction: Geophysical anomalies at different plate boundaries.

Lab 3: Fault plane solution: Fault plane solution of different mechanisms using polarity data.

Lab 4: Fault plane solution: Fault plane solution of different mechanisms using polarity data.

Lab 5: Earthquake Location: Velocity model of the Earth

Lab 6: Earthquake Location: Epicenter location of earthquake based on velocity model and first arrival data

Lab 7: Anatomy of seismogram: Seismic structure of the Earth

Lab 8: Anatomy of seismogram: Analysis of a seismogram and identification of different phases at regional distance

Lab 9: Analysis of seismicity: Seismicity map preparation

Lab 10: Analysis of seismicity: Analysis of clusters; b-value calculation

ELECTIVE GROUP II

GEO.661: TUNNEL ENGINEERING

Semester	IV
Course Title	Tunnel Engineering
Course Code	GEO.661
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: The course of Tunnel engineering gives the necessary knowledge of tunnel investigation, excavation techniques, support design and tunnel construction

General Objective: To make students capable of work in tunneling and underground environment

Specific Objective: To provide the students in-depth knowledge and practical skills of:

- - Tunneling methods and technology
- - Tunnel investigation and engineering
- - Tunnel support design
- - Tunnel construction, environment and management

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hour
Overview	Outline of tunneling, tunnel construction, application and classification; parts of tunnel; tunnel section and its parts; shafts; adit; portal; tunnel shapes; tunnel construction affecting factors; challenges of tunnel construction.	**2**
Equipment and approaches for tunneling	Types, function and efficiency of tunneling equipment; different methods of tunnel constructions; detail aspects of D&B and TBM methods, tunnel blasting and blasting design; special methods of tunneling.	**4**
Excavation type, size and techniques	Cavern, cavern construction, stress in cavern, cavern excavation methods; shaft, shaft construction, ground stress in shaft; Sequential Excavation Method (SEM); New Austrian Tunneling Method, other methods; tunneling in soft ground; tunneling in squeezing and swelling ground; micro tunneling.	**4**
Supports	Tunnel support and reinforcement principles, types of supports; rock bolts and dowels, their types and application; cable bolts; shotcrete support, introduction, shotcrete technology, dry mix and wet mix shotcrete, Steel fiber reinforced, micro-silica shotcrete; steel arches, principles, types; precast frame; ceiling cast; tunnel reinforcement, wire mesh, strap, spiles and forepoles; tunnel grouting types and method, ground freezing; tunnel lining; supports for shaft, portals and junction; support in cavern; face supports.	**6**
Geotechnical deliberations in tunneling	Geological structures and their influencing tunneling; intact and rock mass properties influencing tunneling; discontinuities characteristics and its role in tunneling; geological and engineering geological mapping; face mapping; tunnel logging during excavation; application of rock and ground testing data.	**2**
Ground characteristics	In-situ stress; stress distribution and failure prediction in tunnel; stability analysis in cavern; failure characteristics in underground	**2**

and excavation stability	excavation; tunnel shape, dimension and stability; structurally control instability; caving and subsidence; tunnel face stability.	
Tunnel environment during tunneling	Tunnel excavation method and environment; ventilation; dust suppression; lighting; communication; drainage and water control; fire protection; pollution and environment management.	**2**
Tunnel instrumentation and monitoring	Type of instruments and their function for tunneling and underground excavations; planning and designing the monitoring; recoding instrument data and analysis.	**4**
Tunneling hazards and construction risk management	Introduction; Potential hazards; Mechanization and automation; Occupational hazards; Risk analysis. Tunnel construction planning and risk; Risk sharing and management; Tunneling rate; Work condition classification for tunneling rate; Management classification; Tunnel construction performance management.	**4**

Text Books

1. Hoek, E, Kaiser, P.K. and Bawden, W. F. (2005). Support of Underground Excavations in Hard Rock. A. A. Balkema/Rotterdam/Brookfield, 225p.
2. Hoek, E. (2000). Rock Engineering: course note by E. Hoek. 313p.
3. Kolymbas, D. (2005). Tunelling and Tunnel Mechanics A Rational Approach to Tunnelling. Springer-Verlag Berlin Heidelberg. 311p.
4. Brady, B. H. G. and Brown, E. T. (2007). Rock Mechanics for Underground Mining, Ist Indian reprint, Springer International.

References

1. Singh, B., Goel, R. K. and Freng, J. A. H. (2006). Tunneling and weak rocks. Elsevier.489p.
2. Sinha, R.S. Underground Structures, (1991). Design and Construction, Elsevier, Amsterdam.
3. Mahtab, M. A. and Grasso, P. Geomechanics (1992). Principal in the Design of Tunnels and Caverns in Rock, Elsevier, Amsterdam.
4. Esex, E. J. (1997). Geotechnical Line Reports for Underground Construction: Guidelines and Practices, American Society of Civil Engineers Publication.
5. Hudson, J. A. (1993). Comprehensive Rock Engineering, Vol. 3 & 5, Pergamon Press, Oxford.

GEO.662: GEOHAZARD

Semester	IV
Course Title	Geohazard
Course Code	GEO.662
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: Geo-hazard deals with the stability of slopes and its hazards with methods for assessing this stability and with techniques for improving the stability of the slopes; seismic hazard and risk assessment; overview of flood and debris flow hazards, fundamentals of Glacial Lake Outburst Flood (GLOF), land subsidence, volcanic, settlement and water erosion hazards; and provides the knowledge of multi-hazard, vulnerability, and risk assessment.

General Objective: To give in-depth knowledge and understanding of the stability of slopes and landslide hazards particularly in relation to the characteristics of soil, rock mass and groundwater. The course of geological hazard gives the necessary knowledge and skills of analyzing, mapping and management of geological hazards and provide knowledge on understanding and management of geological hazards**.**

Specific Objectives:

- To provide assessment and management of slope and landslide stability and their hazards:
- To provide fundamental knowledge of geo-hazard like earthquake and volcanic hazard, flood, debris flow, GLOF, settlement and water erosion.
- To provides the knowledge of multi-hazard, vulnerability, and risk assessment basically in context of Nepal

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hour
Introduction to Natural Hazards	Usage of different terminologies: hazard, susceptibility, exposure, vulnerability, risk, disaster, catastrophe, resiliency, adaptation, multi-hazard. Types of hazards, their socioeconomic impact, hazards in Nepal. Introduction to disaster data portals and other relevant data sources.	**1**
Landslide and slope stability	Landslide classification and their causative factors: Classification based on materials and movement mechanism; Physical, geological, morphological, and anthropogenic causes of landslides Fundamentals of mass movement and slope failure: Stress and strain; Friction, cohesion and coherent; Shear strength of soil; Pore water pressure; behavior of materials; rock discontinuities and orientation; Slope failure criteria Methods of Slope stability analysis: Plane failure: General conditions for plane failure, plane failure, analysis, influence of groundwater on stability, critical tension crack depth and location, tension crack as an indicator of instability, analysis of failure on rough plane; reinforcement of a slope; Wedge failure: definition of wedge geometry, analysis of wedge failure, wedge analysis including cohesion, friction and water pressure, wedge stability analysis;	**8**

	Toppling failure: types of toppling failure, kinematics of block toppling failure; limit equilibrium analysis of toppling on stepped base, block geometry, block stability; Circular failure: conditions for circular failure and methods of analysis, shape slide surface, stability analysis procedure, use of circular failure chats; Rock fall: analysis of rock fall hazards, mechanics of rockfalls, possible measures to reduce rockfall hazards -reduction of energy levels and physical restraint rock fall control measures. Mitigation measures of slope instability.	
Landslide Hazard and Risk Assessment	Description of uncertainty, Estimation of hazard, decision under uncertainty Landslide investigation and inventory Landslide hazard mapping approaches: Deterministic, Heuristic, and Statistical Different statistical methods to prepare landslide susceptibility maps: Logistic regression, Analytical Hierarchy Process, Frequency ratio, Weight of evidence Application of remote sensing in landslide hazard mapping Hazards based on causes and assessments: Rainfall-induced, Earthquake-induced, and Anthropogenic landslide hazard	**4**
Seismic Hazard and Risk Assessment	Causes of earthquakes, prediction of earthquake; earthquake disasters, calculation of peak ground acceleration (PGA); shear wave velocity (Vs); Ground response and pre-dominant period; Seismic intensity; Stochastic modeling to show their distribution Seismic hazard assessment: Scenario earthquake model; Ground model; Probabilistic seismic hazard. Earthquake Risk Management Liquefaction susceptibility mapping: Factors affecting the liquefaction susceptibility; Calculation of liquefaction potential index; Spatial modeling of the liquefaction hazard	**4**
Flood Hazard	Hydrological study and flood frequency analysis Hydraulic modeling and flood mapping Integrated approach for flood hazard mapping: Geomorphic analysis and Participatory loss and damage assessment River training activities and flood hazard mitigation measures	**4**
Debris flows	Fundamental on debris flows, flash flood, and runout Application of remote sensing in debris flows inventory Morphometric analysis for debris flow susceptibility mapping	**2**
Subsidence, settlement and water erosion	Fundamentals and classification, causes of settlements and subsidence, investigation of settlement and subsidence, hazard and risk analyses and mapping for subsidence. Surface and Gully Erosion: Methodological insight for assessment of surface erosion and severe gully erosion	**2**
Glacial Lake Outburst Flood (GLOF)	Fundamentals- Glacial lakes: types, causes of lake creation, factors contributing GLOF, mitigation techniques, GLOF hazard and risk analysis techniques. GLOF hotspots in the Himalaya, distribution of glaciers in Nepal, potentially dangerous glacial lakes in Nepal, historical GLOFs in the Himalayas and case studies of some devastating GLOFs, glacier hazard in the Nepal Himalayas.	**2**
Volcanic Hazard	Fundamental- causes of volcanic eruption, disasters caused by volcanic eruptions, volcano hazard maps, volcano risk maps, prediction monitoring and management of volcanoes, Worldwide hotspots of volcanic eruption	**1**

Multi-Hazard, Vulnerability, and Risk Assessment	Cascading effect of hazards Multi-hazard composite assessment Multi-sectoral vulnerability and capacity assessment Assessment of physical vulnerability Calculation of risk	**2**

Text books

1. Wyllie, D. C. and Christopher W. M. (2004). Rock Slope Engineering (Civil and mining), Spon Press, 431p.
2. Hock, E. and Bray J. (1977). Rock Slope Engineering. Institute of Mining and Metallurgy, London, 358p.
3. Abramson, L. W., Lee, T. S., Sharma, S. and Boyce, G. M. (2002). Slope Stability and Stabilization Methods. John Wiley & Sons, Inc., 712p.
4. Bryant, E. (2005). Natural Hazards. Cambridge University press. 330p.
5. Montgomery, C. W. (2014). Environmental Geology, tenth edition, The McGraw-Hill Companies, Inc., New York, 564p.

References

1. Scawthorn, C., & Chen, W.-F. (Eds.). (2002) Earthquake Engineering Handbook, Edited By Wai-Fah Chen and Charles Scawthorn, III Series, CRC Press LLC, Washington, D.C, 1449p.
2. Davis, T. and Shroder, J. F. (2015). Landslide Hazards, Risks, and Disasters, First Edition. Elsevier, 473p.
3. Jakob, M. and Holm K. (2012). Risk Assessments for Debris Flows. In J.J. Clague and D. Stead (ed.) Landslides: Types, Mechanisms and Modeling. Cambridge University Press.
4. Deoja B., Dhital M., Thapa B., and Wagner A. (Principal Editors); 1991: Mountain Risk Engineering Handbook, International Centre for Integrated Mountain Development, 875 p.
5. Bass S., Ramasamy, S. DePryck, J.D., and Battista, F. (2008). Disaster Risk Management Systems Analysis- A Guide Book. FAO, 68p.
6. Pathak, D. (2016). Climate change and its impact in Nepal – an analysis from geological disaster perspective. Central Department of Geology, Tribhuvan University, Kathmandu, Nepal, 142p. ISBN 978-9937-0-0728-3.
7. Pathak, D. (2016). Geo-hazards along road corridor in Koshi basin – remote sensing and GIS based analysis. Nepal Landslide Society, Kathmandu, Nepal, 110p. ISBN 978-9937-0-1003-0.
8. Pathak, D. (2016). Water induced disaster management in Nepal – with special reference to geological disaster. Nepal Landslide Society, Kathmandu, Nepal, 125p. ISBN 978-9937-0-1004-7.
9. Nepal Disaster Risk Reduction Portal http://www.drrportal.gov.np/
10. Pathak, D. (2016). Water Induced Disaster Mitigation in Nepal – present approach and way forward for effective water induced disaster mitigation from geological perspective. Disaster Review 2015, Series XXIII, pp. 25-30.
11. Pathak, D. (2015). Use and Limitation of Landslide Hazard Map in Road Alignment Planning: Case Study of Wamitaksar-Rudrabeni Road Section, Gulmi District, West Nepal. Disaster Review 2014, Series XXII, pp. 20-24.
12. Pathak, D. (2014). Water Induced Disaster in Tamor River Sub-Basin, East Nepal. DWIDP Bulletin, Series XV, pp. 6-11.

GEO.663: GEOLOGICAL CONSTRUCTION MATERIAL

Semester	IV
Course Title	Geological Construction Material
Course Code	GEO.663
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: The course of geological construction material engineering gives the knowledge and skills of geological and geotechnical inputs necessary for investigation, and selection of construction materials for various engineering structures.

General Objective:

- To give knowledge and understanding of geological construction materials for various civil engineering structures.
- To highlight the role of a geologist in finding and assessing construction materials.

Specific Objectives: To provide the students in-depth knowledge and practical skills of description, classification, testing, and field investigating for construction materials.

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hours
Introduction to Geological Construction Materials	Definition and application of construction materials. Building stones. Large stones and ripraps. Natural and artificial aggregates. Cement. Gypsum, Clays for bricks and tiles.	**3**
Aggregates for Concrete	Definition of Aggregates. Categories of aggregates. Constituents of aggregates. Aggregate shapes and Aggregates types in concrete. Key properties of aggregates used in concrete. Aggregate gradation analysis. Flakiness and Elongation Indices, shape and surface textures. Water absorption, specific gravities, and unit weights of aggregates. Effect of grading on water absorption. Aggregate Impact Value. Aggregate Crushing Value. Los Angeles Abrasion. Point-load Strength Index. Unconfined Compressive Strength. Slake durability. Sulphate soundness. Alkali aggregate reactivity, Deleterious constituents. Specification for fine and coarse aggregates.	**3**
Pavement Construction Materials: Unbound Pavement Construction Materials:	Historical perspective. Pavement system Design and typical pavement types: Structural elements and functions. Pavement types.	**3**
	Desirable properties of aggregates for unbound pavement. Resistance to wear. Influence of aggregate properties on degradation. Influence of moisture content on degradation. Effects of degradation. Resistance to decay. Effect of water migration in pavement structure.	
Bituminous Bound Construction Materials	Flexible pavements. Asphalt, Bitumen and Tar. Types of aggregates used in bituminous composition. Desirable properties of aggregates. Influence of aggregates on engineering properties: crushing strength, resistance to abrasion, resistance to polishing, resistance to striping, resistance to weathering, ability to contribute to strength and stiffness of total mix. Detailed requirements for aggregates.	**3**

	Pavement distresses: Types of distresses. Roles of subgrade, structural design, aggregate selection, traffic and aging in distresses.	
Mortar and fine aggregates used in mortar	Introduction, types of mortars, description and classification of mortar sands and fillers. Types of fine aggregates used in mortars. Mineralogy of fine aggregates. Shape and grain size distribution of fine aggregates. Light weight aggregates used in mortars. Testing for fines. Influence of sand and fines characteristics on mortar properties. UK specifications. Specification and practice outside the UK.	**3**
Railway track ballast	Introduction. Ballast. Function of ballast. Structural elements of railway ballast. Rock types suitable for track ballast. Asphaltic track. Desirable properties: British practice. European practice.	**1.5**
Filter Media and Aggregates	Introduction. Principle functions of filters and drains. Key properties of filter aggregates. Testing of filter aggregates. Filter for civil engineering structures.	**1.5**
Large stones and Riprap	Definition of stones. Application of large stones. Application of ripraps. Desirable properties of armour stone and riprap. Rock types suitable for ripraps and armour stones, Specification. Important properties and tests: composition, physical properties. Toughness and Durability. Alteration and physical disintegration.	**3**
Dimension stones:	Introduction. Varieties of Dimension stones. Classification of Rock types used in Dimension stones. Surface characteristics of dimension stones. Basic Keys to selection of Stones. Rock types suitable for facing stones, flooring stones, and roofing stones. Specification.	**3**
Cement	Uses. Types of cements. Portland Cements. Production process. Ordinary Portland Cement. Portland Pozzolana Cement. Special purpose and blended cements. Other cements. Major constituents of Portland Cement. Hydration of Portland Cement. Composition of cement. Relative strengths of cement. Effect of cement on concrete properties. Factors affecting Strength of concretes. Specification (Clause 614) of Department of Roads	**3**
Sources and field investigation of Construction Materials	Rocks. Sediments (fluvial, glacial, coastal, marine, fans and talus). Residual soils. Field investigation: Prospecting (Regional geological mapping, aerial photo study). Exploration (detailed site mapping, geophysical investigation, drilling and pitting), sampling and quality assessment. Reserve estimation method.	**3**

Textbooks

1. Prentice, J. E. (1990). Geology of construction materials, Champman and Hall, London, 197p.
2. Smith, M. R. and Collis, L. (ed.) (1993). Aggregates: sand, gravel and crushed rock aggregates for construction purposes (second edition). Geological Society Engineering Geology Special Publication, No. 9, The Geological Society, 339p.
3. Krynine, D. P. and Judd W. R. (1957). Principles of Engineering Geology and Geotechniques, John Wiley and Sons, New York
4. Johnson, R. B. and DeGraff, J. V. (1988). Principles of Engineering Geology, John Wiley and Sons, New York, 497p.

References

1. The complete book on construction material, NIIR Project Consultancy Services. 672p.

2. Department of Road (2073). Standard specifications for road and bridge works. Ministry of Physical Infrastructure and Transport, Government of Nepal. 708p.
3. Bulletins of Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal.
4. Journals of Nepal Geological Society, Kathmandu, Nepal.

GEO.664: PRACTICAL OF ELECTIVE GROUP II

Semester	IV
Course Title	Practicals of Elective Group II
Course Code	GEO.664
Full Marks	75
Pass Marks	37.5
Nature of the course	Practical
Credit	3 (135 hrs.)

GEO.664a: Tunnel Engineering

(Total credit: 1; FM: 25; Teaching hours: 45)

Course Content

Lab 1: Preparation of tunnel alignment on the basis of given map field data.

Lab 2: Study and/or preparation of tunnel map and log and explain geotechnical condition of the tunnel.

Lab 3: Study of structurally failure analysis in jointed rock mass from given maps

Lab 4: Study of Failure in elastic rock failure analysis from given maps/data

Lab 5: Study on tunnel support design based on (a) Support pressure estimation (b) Rock mass classification and (c) Rock load approach

Lab 6: Study of rock bolt design in tunnel

Lab 7: Study of tunnel blasting and ground vibration

Lab 8: Estimation of ground stress and its impact in proposed tunnel based on given data.

Lab 9: Tunnel construction and management

Lab 10: Study of ventilation design in during tunnel construction

GEO.664b: Geohazard

(Total credit: 1; FM: 25; Teaching hours: 45)

Course Content

Lab 1: Plane failure stability analysis from kinematic, analytical and numerical approaches

Lab 2: Wedge failure stability analysis from kinematic, analytical and numerical approaches

Lab 3: Circular failure stability analysis from kinematic, analytical and numerical approaches

Lab 4: Topple failure stability analysis from kinematic and analytical approaches

Lab 5: Preparation of landslide inventory maps along a road alignment and within a watershed

Lab 6: Preparation of rainfall-induced landslide susceptible maps using statistical methods

Lab 7: Review and preparation of seismic hazard maps using different methods

Lab 8: Flood frequency analysis and flood hazard assessment using integrated approach

Lab 9: Flash flood and debris flow hazard assessment using image interpretation and morphometric analysis

Lab 10: Estimation of soil loss in a watershed using universal soil loss equation

GEO.664c: Geological Construction Material

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Content

Lab 1: Testing of coarse aggregates for grading.

Lab 2: Testing of fine aggregates for grading and fineness modulus.

Lab 3: Description of physical characteristics and classification of stones and aggregates. Specification of construction aggregates of Department of Road: Section 600: Materials and Testing materials. Clauses 609, 610, 611, 612, 613, 614; Section 1200: Subbase, base and wearing course: Clauses 1201 (1), (2) and (3); 1202 (1), (2) and (3); 1203 (1), (2) and (3); 1204 (1), (2) and (3); 1207 (1), (2) and (3); 1208 (1), (2) and (3); Section 1300: Bituminous surface and base course: Clauses 1303 (1) and (2b); 1304 (1) and (2); 1305 (1) and (3); 1306 (1) and (3); 1307 (1), (2a), (2b) and (2c); 1308 (1) and (2a to 2d); 1309 (1) and (2); 1310 (1) and (2); 1311 (1) and (2); 1313 (1), (2) and (3); 1314 (1), (2), (3a) and (3b); 1315 (1) and (2); 1316 (1) and (2a to 2e).

Lab 4: Determination of shape indices and texture of coarse aggregates.

Lab 5: Physical testing of coarse aggregates for specific gravity and water absorption.

Lab 6: Physical testing of fine aggregates for specific gravity and water absorption.

Lab 7: Sample preparation for aggregate crushing and impact values.

Lab 8: Determination of aggregate crushing and impact values.

Lab 9: Sample preparation for testing for abrasion resistance and durability.

Lab 10: Testing of aggregates for Los Angeles Abrasion Value.

Lab 11: Testing of aggregates/rock samples for Slake Durability.

Lab 12: Testing of mechanical strength of samples of construction material.

Lab 13: Determination of deleterious constituents and micropetrographic index for given rock/particle types.

Lab 14: Methylene blue adsorption value of rocks and aggregate samples.

Lab 15: Reserve estimation of construction material.

ELECTIVE GROUP III

GEO.671: MINERAL PROSPECTING AND EXPLORATION

Semester	IV
Course Title	Mineral Prospecting and Exploration
Course Code	GEO.671
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: Prospecting and Exploration Geology deals with the discovery and establishment of economic values of deposits.

General Objective: To provide in-depth knowledge and understanding of the modern methods of discovering economic deposits and evaluating them.

Specific Objectives: To make the students able to gain knowledge of

- Prospecting and exploration of mineral deposits
- Exploration system and equipment
- Sampling and reserve estimation of mineral deposits.

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hours
Conceptual Background of Mineral Prospecting	Theoretical concepts. Economic mineral deposits: prospecting and the principles of classifying workable deposits. Ferrous and non-ferrous metals and their alloys. Precious metals, radioactive elements, rare and rare earth elements, and scattered elements. Raw materials for the steel industry, chemical raw materials, other industrial minerals, building materials, and fossil fuels.	**4**
Prospecting criteria and guides	Geological criteria, climatic criteria, stratigraphic criteria, facies, lithological criteria, structural criteria, magmatic criteria, geochemical criteria, geomorphological criteria, and geophysical criteria. Geological conditions favorable to prospecting. Geological indicators: Primary dispersion haloes, secondary dispersion haloes, non-geological guides.	**4**
Prospecting methods	Classification, surface geological and mineralogical methods. geochemical methods, geophysical methods, Choice of prospecting method, prospecting, and geological surveying	**4**
Mineral Exploration	Main objectives and principles of exploration, variability of exploration, general mathematical expression of the variability of deposits, morphology and variability of ore bodies, mineral quality, and variability. Exploration methods and, stages. Tracing and outlining of deposits, exploration grids, analysis of grid density, classification of mineral reserves, general exploration conditions, and degree of exploration. Use of remote sensing and photogeology in mineral prospecting and exploration.	**6**
Exploration equipment and systems	The main types of exploration equipment. Factors affecting the choice of exploration system, technical and economic analysis of systems, the applicability of different systems to various types of deposits, and exploration records.	**4**

Sampling of deposits	Preliminary data, surface, underground, and borehole sampling, sampling methods, choice of sampling methods, spacing of samples, grading minerals without sampling, sampling placers.	**2**
Sample Treatment and Sampling Checks	Treatment of samples, methods of treating samples, testing of samples. Treatment and technological testing of placer samples. Sampling checks, sampling errors, checking sampling, and treatment. Assay checks.	**2**
Evaluation of mineral deposits and Mine Exploration	General concepts and classification of reserves, reference data for reserve estimation, determination of average block indicators, methods of estimating reserves, and accuracy of estimates. Evaluation of a deposit at the various stages of geological exploration, workability conditions. Mine exploration. Evaluation of a deposit during exploitation.	**4**

Textbooks

1. Marjoribanks, R. (2010). Geological Methods in Mineral Exploration and Mining, Springer-Verlag Berlin Heidelberg, 238p.
2. Kreiter, V. M. (2004). Geological Prospecting and Exploration, University Press of the Pacific, 384p.
3. Levinson, A. A. (1980). Introduction to Exploration Geochemistry, Applied Publishing Limited., 924p.

References

1. Barrett, W. M. et al. (2012). Introduction to mineral exploration, Blackwell Publication, 481p.
2. William, C. Peters (1978). Exploration and Mining Geology (Chapter 14, 15 & 16), pp. 397-488.
3. Babu, S. K. and Sinha, D. K. (1988). Practical Manual of Exploration and Prospecting, CBS Publishers India, 167 p.
4. Craig, J. R. and Vaughan, D. J. (1981). Ore Microscopy and Ore Petrography, John Wiley and Sons Inc., New York, 190 p.

GEO.672: MINERAL RESOURCES OF NEPAL

Semester	IV
Course Title	Mineral Resources of Nepal
Course Code	GEO.672
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description and General Objectives: To provide in-depth knowledge on the mineral resources of Nepal and its current status. Mineral resources of Nepal cover the geological setting, occurrences, reserve and exploitation status of the metallic and non-metallic minerals, major prospects and identified reserves, operating mines in Nepal**.**

Specific objectives:

To provide the students in-depth knowledge of

- geologic setting of various mineral deposits in Nepal
- mineral potential of Nepal
- present status and utilization of mineral resources

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hours
Introduction	Regional geological setting of Nepal, Gangetic plain, Sub-Himalaya, Lesser Himalaya, Higher Himalaya and Tethys Himalaya. Geological control on mineral resources of Nepal, distribution of mineral resources, mineral resource map of Nepal. History of mineral investigation in Nepal. Definition and classification of mineral resources and reserves.	**4**
Metallic minerals	Location, geology, reserve, quality, uses and production and consumption status of Antimony, Arsenic, Bismuth, Cadmium, Chromium, Cobalt, Copper, Gold, Iron, Lead, Lithium, Mercury, Molybdenum, Nickel, Silver, Tantalum-Niobium, Tin, Titanium, Tungsten, Uranium, Zinc.	**4**
Non-metallic Industrial minerals	Location, reserve, quality, uses and production and consumption status of cement-grade limestone and chemical, fertilizer, insulator, ceramic, refractory, and abrasive minerals.	**4**
Non-metallic gem minerals	Location, reserve, quality, uses and production and consumption status of Aquamarine, Beryl, Kyanite, Quartz and its varieties, Ruby, Sapphire and Tourmaline Garnet.	**4**
Non-metallic minerals: Decorative and dimension stones and construction materials	Location, reserve, quality, uses and production and consumption status of Granite, Marble, Quartzite, Slate, Gravel and Sand. Basic and Acidic Rocks (amphibolite, granite, pegmatite, gneisses).	**4**
Fuel minerals and thermal springs	Location, geology, reserve, quality, uses and production and consumption status of coal, petroleum and natural gas. Thermal springs of Nepal.	**2**

Potential minerals, Mineral-based industries and mineral economics of Nepal	Evaluation of identified potential minerals, feasibility study, (quality (grade & tonnage), appraisal & mine planning. Status of mining and mineral-based industries of Nepal. Mineral production, export-import status of mineral commodities. Contribution of mines and mineral sector to the national GDP.	**4**
Institutional and legal framework on mineral resource development and management	Concept of mineral resource management. Role of academic institutions for mineral prospecting, exploration, mining, and mineral development in Nepal. Minerals and Conflict: Case studies on mineral related conflicts, Potential mineral conflict in-between federal & provincial government, case study. Constitutional provisions. Acts and regulations: Mines and Minerals Act (1985); Mines and Minerals Rules (1999), Nepal Petroleum Act (1983), Petroleum Exploration Regulation (1984), Environment Protection Act (2019), Forest Act (2019). (Including amendments) Mine Administration and Licensing System. Provincial and Local acts for mineral and mine development. Institutional provisions: History of institutional development, Roles and responsibilities of DMG in the mineral resource development of Nepal. Role of National Natural Resources and Fiscal Commission. Comparative study of mineral and mineral-related acts of Nepal with the SARRC countries and some other developed countries like China, USA, Australia, Canada, and Africa. Recent trends and research gaps. Challenges and opportunities in mineral resources development in Nepal	**4**

Text Books and References

1. UN/ESCAP with HMG/MOI/ DMG (1993). Geology and Mineral Resources of Nepal, Explanatory Brochure, Atlas of Mineral Resources of the ESCAP Region Vol. 9, 107p.
2. Talalov, V. A. (1972). Geology and Ores of Nepal vol.2. UN/UNDP. Nepal Geo. Survey, unpub. Report, 483p.
3. लालुप्रसाद पौडेल (२०६८). नेपालका खनिज सम्पदा: एक विश्लेषणात्मक अध्ययन, १३३ पेज
4. Sah, R. B. and Paudyal, K. R. (2023). Mineral Resources of Nepal. Publisher: Stratigraphic Association of Nepal, 322p.
5. Paudyal, K. R. (2024). Mineral Resources of the Bhut Khola-Labdi Khola-Bandipur Areas of Tanahun District, Nepal. Publisher: Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal. ISBN: 978-9937-1-6776-5; 125 p.
6. DMG (2004). Mineral resources of Nepal, 154p.
7. हरिभक्त उपाध्याय (२०६४). नेपालका रत्न पत्थर, १२२ पेज

References

1. Sah, R. B., and Paudyal, K. R. (2023). Mineral Resources of Nepal; ISBN: 978-9937-8456-5-6 Publisher: Geo-Science Innovations Pvt. Ltd., 179 p.
2. Paudel, L. P. (2012). Mineral Resources of Nepal: An Analytical Study. Publication: Devi Dhakal. Distribution: Bidhyarthi Books and Stationery, Kirtipur, Kathmandu, Nepal; 135p.
3. Kaphle, K. P. (2020). Mineral Resources of Nepal and their present status. ngs.org.np.
4. Kansakar, D. R., Dorian, J. P. and Clark, A. L. (1986). The Minerals Potential of Nepal. GeoJournal, Vol. 12, No. 1, pp. 19-31.
5. Annual Reports of Department of Mines and Geology, Lainchaur, Kathmandu.
6. Journals of Nepal Geological Society and Bulletin of Department of Geology, Tribhuvan University.

GEO.673: MINERAL ECONOMICS AND PETROLEUM GEOLOGY

Semester	IV
Course Title	Mineral Economics and Petroleum Geology
Course Code	GEO.673
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: This course provides the fundamental principles of economic rules that Help understand economic and legislation issues associated with the production, use and sale of mineral commodities.

General Objective: To provide an in-depth understanding of mineral economics and marketing.

Specific Objectives: To make the students able to

- understand frequently used economic terminology
- comprehend particularities of the mining industry and mining processes
- discern mineral legislation and related policies
- acquire knowledge of mineral marketing.

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Content	Teaching hours
Conceptual Background and Fundamental Principles of Mineral Economics	Background, concept, objectives, and the scope of study. Classification of mineral deposits. World resources of minerals. Future sources of mineral supply.	**2**
Mining Economy	Special features of the mineral and mining industry. Tenor, grade, and specification. Strategic, critical, and essential minerals. Classification of minerals from a Military point of view. Future sources of mineral supply. Conservation, and Substitution. Changing patterns of mineral consumption.	**3**
Mine examination and valuation	Goal and strategies, Methods of investment analysis. Cost Benefit analysis, Risk analysis, Capital investment, and financing.	**2**
Mineral Processing and Mining Laws	National Mineral Policy, Mining, and Related Laws of Nepal. Mining laws of various lands: African countries, Asian countries, Australasia, European countries, Latin American countries, and North America. Marine mineral resources and the law of the sea. Exclusive economic zone. Mines and mineral legislation of India and China.	**6**
Economic evaluation and specification of the Important Mineral Commodities	Metallic mineral deposits: Precious Metals (Gold, Silver, Platinum), Ferrous and Allied Metals (Iron, Manganese, Chromium, Vanadium, Molybdenum, Tungsten, Nickel, Cobalt, Titanium). Non-ferrous and Allied Metals (Copper, Lead and Zinc, Tin, Antimony, Bismuth). Light Metals (Lithium, Magnesium, Beryllium, Aluminum). Radioactive Metals (Uranium and Thorium). Rare Metals (Tantalum and Columbium, Cadmium, Mercury, Palladium, Selenium and Tellurium, Rate Earth Group of Metals). Non-Metallic Minerals (Mineral fuels), Gemstones, Abrasive Minerals, Siliceous Abrasive, Soft Abrasive). Building materials and dimension stones (Granite, Marble, Limestone,	**8**

	Quartzite and Sandstone, Slate, Cement, Clay, Sand and Lime). Industrial Minerals (Mica, Asbestos, Barytes, Talc, Soapstone, and Steatite, Bentonite, Vermiculite). Metallurgical and Refractory Minerals (Fireclay, Graphite, Dolomite, Quartzite). Ceramic Minerals (Clay, Feldspar, wollastonite), Glass Manufacturing Materials like quartz and silica sand. Fertilizer Minerals like Phosphorite, Potash, Lime, Gypsum). Chemical Minerals (Rock salt, Borax, Fluorite, Sulphur, and Pyrites). Mineral Pigments (Ochre). Economic Evaluations: Statistic methods, profitability Quotient, Calculation of rent, Payback period, Dynamic methods, Sensitivity analysis, Breakeven calculations.	
Mineral Taxation and Incentive Measures	Incidence of taxes, incentive measures. Concessions in income tax, depreciation, rehabilitation allowance, expenditure on scientific research, and amortization of preliminary expenses. Deduction of expenditure in prospecting etc., tax holiday. Depletion allowance. Sinking fund. Financial participation. Simplification of taxation laws.	**3**
Mineral Marketing	Market structure, market organization, mineral demand and Forecasting, mineral price, and pricing. Port handling charges, customs duty, import duty. Quantitative techniques for estimating mineral demand: The general problems of estimation. Statistical techniques and judgmental analysis.	**2**
Petroleum Geology	Historical overview of petroleum production and exploration. Application of geology (study of earth materials, and processes) to the exploration and production of oil and natural gas). Petroleum occurrences. Petroleum generation. Petroleum reservoirs. Impermeable seals and caprock. Traps. Conditions for geologic accumulation of petroleum. Hydrocarbon composition and occurrence. Crude oil. Stages of petroleum exploration, production, and processing.	**4**

Text Books

1. Sinha, R. K. and Sharma, N. L. (1970). Mineral Economics: A textbook for university students. New Delhi: Oxford & IBH Pub. Co., 317 p.
2. Gocht, W. R., Zantop, H. & Eggert, R. G. (1988). International Mineral Economics. Springer-Verlag, Berlin.
3. Umeshwar Prasad (2014). Economic Geology (Economic Mineral Deposits). CBS Publishers & Distributors Pvt. Ltd. New Delhi, 319p.
4. Friedrich-Wilhelm Wellmer (1989). Economic Evaluations in Exploration. Springer-Verlag Berlin Heidelberg New York; 163p.
5. Jensen, M. L. and Bateman, A. M. (1981). Economic Mineral Deposits, John Wiley and Sons Inc., New York, 593p.

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1. Anderson, F.J. (ed.) (1987). Selected Readings in Mineral Economics. Pergamon Press, New York, USA.
2. Sobczyk, E.J. & Kicki, J. (eds.) (2008). International Mining Forum 2008: Economic Evaluation and Risk Analysis of Mineral Projects. Taylor & Francis Group, London, UK.
3. Maxwell, P. & Guj, P. (eds.) (2013). Australian Mineral Economics. Australasian Institute of Mining and Metallurgy, Carlton, Victoria, Australia.

4. Sah, R. B., and Paudyal, K. R. (2023). Geology of Mineral Resources (Decoding the Geological Marvel of Mineral Resources). Publisher: Geo-Science Innovations Pvt. Ltd; ISBN: 978-9937-8456-4-9, 192 p
5. Robb, L. (2005). Introduction to Ore Forming Processes. Blackwell Science Ltd.
6. Craig, J. R. and Vaughan, D. J. (1981). Ore Microscopy and Ore Petrography, John Wiley and Sons Inc., New York, 190 p.

GEO.674: PRACTICAL OF ELECTIVE GROUP III

Semester	IV
Course Title	Practicals of Elective Group III
Course Code	GEO.674
Full Marks	75
Pass Marks	37.5
Nature of the course	Practical
Credit	3 (135 hrs.)

GEO.674a: Mineral Prospecting and Exploration

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Content

Lab 1: Study of geological controls of important economic mineral deposits of Nepal Himalaya from geological maps and cross-sections.

Lab 2: Study on specification techniques and uses of metallic/non-metallic/gemstones and industrial rocks and minerals from the Nepal Himalayas.

Lab 3: Study of potential ore minerals from Nepal concerning ore texture and structure under an ore microscope and interpretation on genesis/mode of formation.

Lab 4: Evaluation of river sand from Nepal as silica sand.

Lab 5: Study of gemstones (precious and semi-precious stones) from the Nepal Himalayas.

Lab 6: Study of given dimension stones and construction materials from Nepal for specification and ranking for uses.

Lab 7: Specification of phosphorite minerals as well as color pigments in Nepal.

GEO.674b: Mineral Resources of Nepal

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Contents

Lab 1: Preparation of simplified geological and mineral potential map of Nepal

Lab 2: Study of Iron Deposits of Nepal: Phulchoki, Those and Dhaubadhi.

Lab 3: Study of Copper Deposit of Nepal: Wapsa, Kalitar and Dhusa.

Lab 4: Study of Pb-Zn Deposit of Nepal: Ganesh Himal.

Lab 5: Study of cement-grade limestone deposits of Nepal.

Lab 6: Study of coal deposits of Nepal.

Lab 7: Study of hot springs of Nepal.

GEO.674c: Mineral Economics and Petroleum Geology

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Contents

Lab 1: Techniques of economic evaluation of mineral deposits.

Lab 2: Various methods of reserve estimation of mineral deposits.

Lab 3: Study of coal, gas, and petroleum samples with emphasis on technical analysis and geological mode of formation.

Lab 4: Laboratory assessment of gold mineralization from the river terraces (for placer gold) and gold from basic rocks, veins, or other bedrocks.

Lab 5: Geological interpretation of mode of formation, and geological control (source-reservoir studies) for given samples of coal, petroleum, and natural gas.

Lab 6: Study of genesis and mode of occurrences of mineral resources using the ore microscopy under polished sections.

ELECTIVE GROUP IV

GEO.681: MOUNTAIN HYDROGEOLOGY

Semester	IV
Course Title	Mountain Hydrogeology
Course Code	GEO.681
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: This course provides the students with the concepts of mountain hydrogeology.

General Objective: To provide in-depth understanding of mountain hydrogeology covering both hard rock and unconsolidated aquifers.

Specific Objectives: To provide the students with in-depth knowledge and practical skills on mountain hydrogeology, specifically:

- Fundamental concepts on hydrogeological setups in the mountainous region
- Geomorphic evaluation and fracture mapping with respect to hard rock aquifer
- Assessment of recharge
- Delineation of groundwater potential areas

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Contents	Teaching hours
Fundamental Concepts	Multidisciplinary integrated approach to study the hydrogeological mountain system; Regional geology and geomorphology; regional climate	**4**
Groundwater modeling concept	Boundary conditions, interaction of surface/groundwater in different terrain condition, groundwater modeling concept	**3**
Hydrogeological Information for mountainous region	Hydrogeological inventory, hydropedology; hydromorphology; defining hydrogeological units, isotope hydrology and identification of aquifer recharge area; Developing conceptual model on mountain hdyrogeology; Karstified aquifer system	**4**
Superficial deposits	Significance of superficial deposits, interaction between superficial granular aquifer and bedrock aquifer, pollution transport	**2**
Geomorphic evaluation	Geomorphic mapping of the terrain (aerial photograph/ satellite image/field mapping); groundwater occurrence in different physiographic regions	**2**
Fracture mapping	Concept of fracture mapping; mapping through satellite image, aerial photo, maps and direct field measurement; presentation of fracture data; common fracture pattern; surface geophysical methods Likely to be of use in locating zones of intense fracturing at different terrain condition; Stress and fracture characteristics in relation to permeability of hard rock.	**4**
Well drilling in bedrock	Identification of drilling site, method of drilling in hard rock; drilling depth; borehole orientation	**2**

Water quality of mountain aquifer	Vulnerability and source protection at recharge area as well as at the discharge area; pollution related parameters; groundwater contamination in hard rock; Risk Reduction and Disaster prevention, Water management and strategy	**3**
Groundwater potential mapping	different parameters used for delineating groundwater recharge zones and groundwater potential zones; methods used to delineate recharge zone and potential zone	**3**
Exploiting mountain aquifer: Nepalese case	Importance of mountain aquifer; water availability (like spring/seepage) and livelihood; present practice of using mountain aquifer; issues related to changed availability through springs; way forward towards sustainable exploitation of groundwater in mountainous regions.	**3**

Text Book

1. Richard, W. Healy Estimating Groundwater Recharge. Cambridge university Press.
2. Banks, D. and Robins, N. (2002). An introduction to Groundwater in Crystalline bedrock. Norges geologiske undersøkelse, 64pp. ISBN 82 7386 100 1
3. Pathak, D, 2021. Mountain Hydrogeology, Nepal Hydrogeological Association
4. Willis, D. Weight (2008). Hydrogeology Field Manual (Second Edition). McGraw-Hill Companies, Inc.
5. Anderson, M. P., Woessner, W. W. (1992). Applied groundwater modeling - Simulation of flow and advective transport, Academic Press.

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1. Marques JE, Marques JM, Chaminé HI, Carreira PM, Fonseca PE, Santos FAM, Moura R, Samper J, Pisani B, Teixeira J, Carvalho JM, Rocha F, Borges FS, 2013. Conceptualizing a mountain hydrogeologic system by using an integrated groundwater assessment (Serra da Estrela, Central Portugal): a review, Geosciences Journal, Vol. 17, No. 3, p. 371 − 386, DOI 10.1007/s12303-013-0019-x.
2. Local water harvesting in mountain areas. ICIMOD News Letter, no. 36, 2000.
3. Water and mountains. ICIMOD Newsletter, no. 42, 2003.
4. Poudel D and Duex TW, 2017. Vanishing Springs in Nepalese Mountains: Assessment of Water Sources, Farmers' Perceptions, and Climate Change Adaptation. Mountain Research and Development Vol 37, No 1 pp. 35–46. DOI: http://dx.doi.org/10.1659/MRD-JOURNAL-D-16-00039.1.
5. Journal articles (like Journal of hydrogeology, Journal of hydrogeology etc.)
6. Otto J-C and Smith MJ, 2013. Geomorphological mapping. In Geomorphological Techniques (Chap 2, Sec 6) ISSN 2047-0371.
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8. Alberti & Fernando Rocha (2013) Hydrogeomorphological mapping as a tool in groundwater exploration, Journal of Maps, vol. 9, no. 2, pp. 263-273, DOI: 10.1080/17445647.2013.776506
9. Pathak, D. (2015). Groundwater Flow Modeling in an Intermontain Basin. Journal of Nepal Geological Society, vol. 49, pp. 7-15. DOI: https://doi.org/10.3126/jngs.v49i1.23137
10. Bhandari, R. and Pathak, D. (2019). Groundwater flow modeling in Chitwan Dun Valley (between Narayani River and Lothar Khola), Nepal. Journal of Institute of Science and Technology, vol. 24(2), pp. 30-38. http://doi.org/10.3126/jist.v24i2.27254

GEO.682: WATER RESOURCES AND CLIMATE CHANGE

Semester	IV
Course Title	Water Resources and Climate Change
Course Code	GEO.682
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: This course provides the students with the concepts of climate change and climate induced impact on groundwater occurrence and thereby help to adapt in the changed context

General Objectives: This course provides fundamental concept on how water resources, especially groundwater resources is related with climate change and how climate change impact on water resources in different regions, scales and sources.

Specific Objectives: To provide the ability of students with in-depth knowledge and practical skills on water resources and climate change, specifically:

- Build fundamental concept understanding water resources types and climate change impact
- Understand hydrometeorological processes and impact on groundwater resources.
- Develop knowledge on role of water resources and climate models
- Gather knowledge relating hydrological and hydrogeological with climate change
- Gain knowledge on basic techniques analysing hydrogeological, hydrometeorological, climate data analysis and interpretation

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Contents	Teaching hours
Fundamentals	Water resources, interactions and its nexus: Types of water sources, water budget and water balance, processes, distribution, surface water and groundwater, snow, glacier permafrost interactions various nexus of water, groundwater resources and its nexus, groundwater resources and UN sustainable development goals.	**3**
Groundwater resources	Types, occurrences, distribution, spatial, temporal, vertical distribution of groundwater and its sources, precipitation and groundwater resources connections, groundwater basin, groundwater recharge and recharge dynamics.	**3**
Mode of occurrences of groundwater resources	Types, seasonal fluctuations, precipitation linkages, provincial distribution and variations of groundwater resources in Nepal and its role in inter and interprovincial settings and groundwater nexus in provincial level.	**3**
Climate change	Fundamentals of climate change, Climate change and precipitation, surface water and groundwater, climate change trend and its impact on groundwater resources, climate change in water budget and balance, climate change and water resources of Nepal Himalaya.	**4**
Projected Future change: Direct Impact	Impacts on various sectors; Effects of climate change on groundwater resources; Effects of climate change on groundwater resources; Climatological cycles in groundwater levels; impact to	4

	springs due to climate change, Quantifying the impacts of climate change on groundwater in an unconfined aquifer; Transient response of groundwater systems to climate changes	
Projected Future change: Indirect Impact	Implications for groundwater dependent systems and sectors; Rural and urban communities; Urban pressure; Agriculture; Ecosystems; Uncertainties and knowledge gaps.	2
Adaptation to Climate Change	Concept of adaptation; preparing for adaptation; Framework for adaptation: Climate monitoring, Water demand analysis, Diversification of water sources, and Enhancing storages. Forms of adaptation, Adaptation options for risks to groundwater dependent systems from climate change and hydrological variability.	4
Vulnerability and adaptive capacity assessment	Adaptation options for risks to groundwater dependent systems from climate change and hydrological variability; Building adaptive capacity for groundwater management; Managing groundwater recharge; Protecting groundwater quality; Managing groundwater storages; Managing demand for groundwater; Management of groundwater discharge; Managing for increased groundwater recharge; Avoiding adaptation decision errors; Evaluation of adaptation options; Barriers to introduction of adaptations; Groundwater management strategies to reduce vulnerabilities	4
Climate change and groundwater resources	Climate change in groundwater occurrences, distribution, utilization, quality, recharge, sources and their distributions, groundwater basin, country level and provincial level.	**3**

Text Book

1. Ritter, D. F., Kochel, R. C., and Miller, J. R. (2006). Process Geomorphology, Boston: McGraw-Hill
2. Domenico, P. A. and F. W. Schwartz (1990). Physical and Chemical Hydrogeology.- J. Wiley & Sons, Chichester
3. Dragoni, W. & Sukhija, B. S. (eds) 2008. Climate Change and Groundwater. Geological Society, London, Special Publications, 288.
4. Treidel, H. J., Martin-Bordes, L. and Gurdak J. J. (Eds:) (2011). Climate Change Effects on Groundwater Resources - A Global Synthesis of Findings and Recommendations. International Association Of Hydrogeologists, CRC Press.

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1. Gosain, A. K., Shrestha, A. B., and Rao, S. (2010). Modelling climate change impact on the hydrology of the Eastern Himalayas; Climate change impact and vulnerability in the Eastern Himalayas – Technical report 4. Kathmandu: ICIMOD.
2. Pathak, D. (2016). Climate change and its impact in Nepal – an analysis from geological disaster perspective. Central Department of Geology, Tribhuvan University, Kathmandu, Nepal, 142p. ISBN 978-9937-0-0728-3
3. Pathak, D., Gajurel, A. P.; Mool, P. K. (2010). Climate change impacts on hazards in the Eastern Himalayas; Climate change impact and vulnerability in the Eastern Himalayas – Technical report 5. Kathmandu: ICIMOD

4. Water and Climate Change: Impacts on groundwater resources and adaptation options' Craig Clifton Rick Evans Susan Hayes Rafik Hirji Gabrielle Puz Carolina Pizarro. Water Working Notes no 25,June 2010.
5. Groundwater and Climate Change: Challenges and Possibilities. Groundwater Resource and management. BGR Geo Center Denmark
6. Various IPCC reports, UN reports, National reports from different federal and provincial governments of Nepal
7. Pathak, D. (2015). Groundwater Flow Modeling in an Intermontain Basin. Journal of Nepal Geological Society, vol. 49, pp. 7-15. DOI: https://doi.org/10.3126/jngs.v49i1.23137
8. Bhandari, R. and Pathak, D. (2019). Groundwater flow modeling in Chitwan Dun Valley (between Narayani River and Lothar Khola), Nepal. Journal of Institute of Science and Technology, vol. 24(2), pp. 30-38. http://doi.org/10.3126/jist.v24i2.27254

GEO.683: HYDROGEOLOGICAL TECHNIQUES

Semester	IV
Course Title	Hydrogeological Techniques
Course Code	GEO.683
Full Marks	50
Pass Marks	25
Nature of the course	Theory
Credit	2 (30 hrs.)

Course Description: The systematic and organised groundwater investigation in the various terrains might assure the desired quantity of water supply for various purposes. Groundwater investigation in hills, narrow valleys and mountains would be more crucial than in the huge alluvial plain like Indo-Gangatic alluvium. More sophisticated groundwater investigation techniques would be needed to investigate its likely potential. There are three major areas to investigate hydrogeology.

General Objectives: The main objective of the proposed course is to create a comprehensive understanding of Hydrogeological Investigation Techniques on a theoretical and practical basis.

Specific Objectives: The specific objective of the course is to enhance knowledge on:

- Surface and subsurface groundwater investigation techniques (well and spring inventory, surface geophysics, borehole geophysics, groundwater flow identification by tracer and other method)
- Laboratory investigation of hydrogeological parameters (such as aerial photo and remote sensing data interpretation, permeability test, porosity determination, fracture analysis, groundwater tracers, secondary porosity determination etc.).

(Total credit: 2; FM: 50; Teaching hours: 30)

Title	Contents	Teaching hour
Fundamentals of hydrogeological investigation	Definition, groundwater development and groundwater management, methods for estimating hydraulic conductivity.	**3**
Investigation methods	Surface investigation methods: geological and geomorphological; aerial methods; well and spring inventory, In-situ tools and techniques. Subsurface methods: application of different geophysical methods for groundwater investigation and groundwater pollution Borehole Geophysical logging: aquifer evaluation Investigation techniques in hard rock and soft sediments.	8
Environmental Isotope	Environmental isotopes in hydrogeology, application of isotopes in hydrogeological characterization, groundwater recharge, surface water and groundwater interconnection, groundwater pollution.	**5**
Groundwater recharge	Well and stream hydrographs, Rainfall hydrographs separation, recharge estimation methods, water budgets.	**4**
Aquifer characterization	Steady and transient pumping test in confined, unconfined and leaky aquifer; step-drawdown test; slug test; borehole flowmeter test; Direct Push Injection logging (DPIL).	**6**
Representation of hydrogeological data	Thematic map, groundwater contour map, flow nets, hydrogeological map.	**4**

Text Book

1. Fetter, C. W. (2001). Applied Hydrogeology. Fourth Edi\tion, Pearson Education Limited, UK.
2. Todd, D. K. and Mays, L. W. (2004). Groundwater Hydrology. Third Edition, Wiley. ISBN 978-0471059370.
3. Clark, D. and Fritz, P. (1997). Environmental Isotopes in hydrogeology. CRC Press LLC, USA, 312 p.

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2. Weight, W. D. (2008). Hydrogeology-Field Manual. Second edition, McGraw-Hill Professional Publishing.
3. Arden, D., Stetler, L. (2007). Pumping Well Test Analysis: Hell Creek Aquifer, North Cave Hills, Harding County, South Dakota. Report # 11-07 Department of Geology and Geological Engineering South Dakota School of Mines and Technology' Rapid City., SD 57701
4. Batu, V. (1998). Aquifer Hydraulics: A comprehensive guide to hydrogeologic analysis. John Wiley & Sons, New York, 727 p.
5. Dagan, G., 1978. A note on packer, slug, and recovery tests in unconfined aquifers, Water Resources Research, vol. 14, no. 5. pp. 929-934
6. Hyder, Z, J.J. Butler, Jr., C.D. McElwee and W. Liu, 1994. Slug tests in partially penetrating wells, Water Resources Research, vol. 30, no. 11, pp. 2945-2957.
7. USGS webpage.

GEO.684: PRACTICAL OF ELECTIVE GROUP IV

Semester	IV
Course Title	Practicals of Elective Group IV
Course Code	GEO.684
Full Marks	75
Pass Marks	37.5
Nature of the course	Practical
Credit	3 (135 hrs.)

GEO.684a: Mountain Hydrogeology

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Contents

Lab 1: Delineate different types of aquifers in the given watershed of mountainous region.

Lab 2: Preparation of geomorphological map from aerial photo/satellite image or topographic maps from groundwater perspective.

Lab 3: Fracture/lineament mapping from aerial photo/satellite image.

Lab 4: Interpret hydrogeology of the given area through the given spring location and geological map.

Lab 5: Identify recharge area and estimate groundwater recharge in the watershed using various methods.

Lab 6: Interpretation of groundwater quality in the given area with respect to geology and aquifer types.

Lab 7: Vulnerability assessment and protection at recharge area as well as at the discharge area.

Lab 8: Preparation of various thematic layers in GIS for hydrogeomorphological map.

Lab 9: Preparation of groundwater potential map in the mountainous region using GIS through various methods.

GEO.684b: Water Resource and Climate Change

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Contents

Lab 1: Scenarios analysis of various regions on water resources occurrences, distribution: local, region and global. Utilization of local and regional climate models

Lab 2: Review and draw diagram with the paleo-climate change and recent climate change (after 1960) trend: Global and national perspective.

Lab 3: Groundwater regime in Nepal at various physiographic regions and assess possible impact in the extent of climate change.

Lab 4: Assess spatial variation in mean annual rainfall and temperature in Nepal, 1960 onwards.

Lab 5: Analysis of surface water and groundwater monitoring data linking precipitation from Nepal

Lab 6: Estimate groundwater recharge in mountainous region with respect to rainfall before climate change and after climate change (in the mountain watershed where climate modeling has been done).

Lab 7: Estimate groundwater recharge in Terai with respect to rainfall before climate change and after climate change (where climate modeling has been done).

Lab 8: Propose adaptation and mitigation measures to ensure groundwater availability in those regions (Mountainous and Terai) with respect to best available techniqe and socio-economic condition.

Lab 9: Climate change Impact analysis on aquifers, springs, groundwater basin in local and regional scale

GEO.684c: Hydrogeological Techniques

(Total credit: 1; FM: 25; Teaching hours: 45)
Course Contents

Lab 1: Geological analysis: Use bedding, joints and fracture system data of particular terrain to investigate groundwater flow direction and estimate secondary porosity.

Lab 2: Permeability Test: Constant head permeameter test in the laboratory with calculations.

Lab 3: Porosity Test: Rock and sediments.

Lab 4: Rainfall hydrograph separation: Different methods used in hydrograph separation.

Lab 5: Isotope application: Provide isotopic data of groundwater and surface water and make interpretation.

Lab 6: Geophysical exploration: Provide geophysical data and make interpretations (Resistivity and seismic) with respective to aquifer delineation and characterization.

Lab 7: Hydrogeological Map: Incorporate all available above information and prepare comprehensive hydrogeological map of the terrain