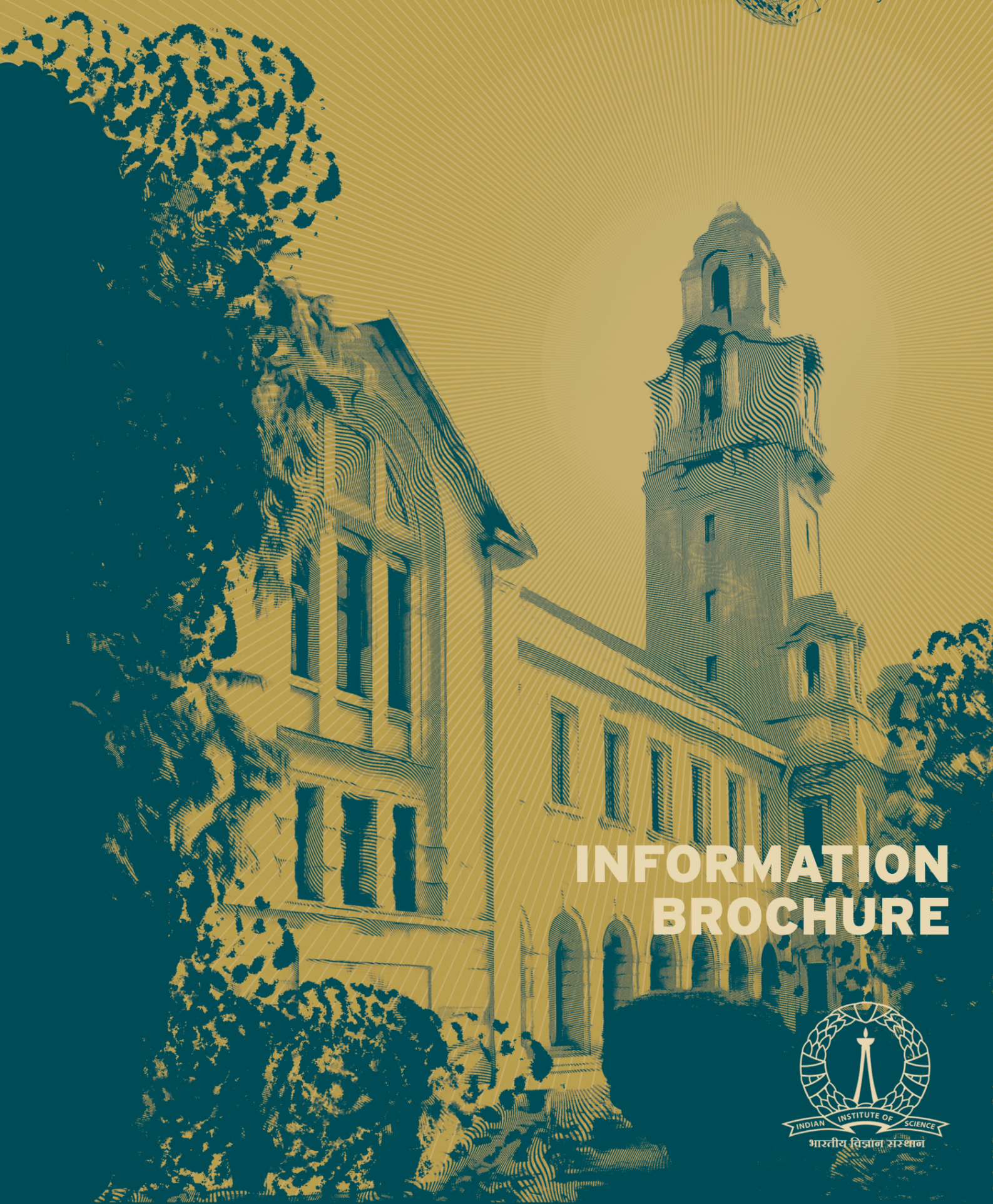
GRADUATE APTITUDE TEST IN ENGINEERING 2024

अभियांत्रिकी स्नातक अभिक्षमता परीक्षा २०२४

ORGANISING INSTITUTE: INDIAN INSTITUTE OF SCIENCE, BENGALURU

GATE 2024
IISc Bengaluru



INFORMATION BROCHURE

INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

EXAMINATION DATES: February 3, 4, 10, & 11, 2024

DATES FOR ONLINE REGISTRATION

Regular Period

Opening date: August 30, 2023

Closing date: September 29, 2023

Extended Period

Closing date with late fee: October 13, 2023

ANNOUNCEMENT OF RESULTS: March 16, 2024

Dates mentioned are liable to change.

APPLICATION FEES (per paper) in ₹

GENDER/CATEGORY	REGULAR PERIOD	EXTENDED PERIOD
FEMALE/SC/ST/PwD	900/-	1400/-
OTHER CANDIDATES	1800/-	2300/-

For two papers, the fee payable is twice that of a single paper.

GATE 2024

IISc Bengaluru

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Date of Release: August 26, 2023

1. List of Abbreviations

B.A.	Bachelor of Arts	IIT	Indian Institute of Technology
B.Arch.	Bachelor of Architecture	MCQ	Multiple Choice Questions
B.Com.	Bachelor of Commerce	M.E.	Master of Engineering
B.D.S.	Bachelor of Dental Surgery	MoE	Ministry of Education
B.E.	Bachelor of Engineering	M.Sc.	Master of Science
B.Sc.	Bachelor of Science	MSQ	Multiple Select Questions
B.Tech.	Bachelor of Technology	M.Tech.	Master of Technology
B.V.Sc.	Bachelor of Veterinary Science	NAT	Numerical Answer Type
CBT	Computer Based Test	NCB	National Coordination Board
CFTI	Centrally Funded Technical Institute	NIT	National Institute of Technology
EWS	Economically Weaker Section	OBC-NCL	Other Backward Class Non-Creamy Layer
GATE	Graduate Aptitude Test in Engineering	OI	Organising Institute
GOAPS	GATE Online Application Processing System	Ph.D.	Doctor of Philosophy
GoI	Government of India	PSU	Public Sector Undertaking
IB	Information Brochure	PwD	Person with Disability
ID	Identity Document	SC	Scheduled Caste
IISc	Indian Institute of Science	ST	Scheduled Tribe

2. Highlights of GATE 2024

- Indian Institute of Science (IISc) Bengaluru is the Organising Institute (OI) for GATE 2024. The website of GATE 2024 is https://gate2024.iisc.ac.in.

- Dates of examination: **February 3, 4, 10, and 11, 2024**. The exam will be held in two sessions on these dates — forenoon and afternoon.

- GATE 2024 will be conducted as a Computer Based Test (CBT).

- There will be a total of 30 test papers. GATE 2024 test papers will be in English and entirely of the objective type. The types of questions include Multiple Choice Questions (MCQ), Multiple Select Questions (MSQ), and Numerical Answer Type (NAT) questions. In MCQs, only one out of four options is correct. In MSQs, one or more than one out of four options is/are correct; and for NAT questions, the answer must be keyed in using a virtual keypad. The candidates must use only the on-screen virtual calculator provided for their calculations.

- GATE 2024 will have a new test paper on Data Science and Artificial Intelligence (DA). Please check out corresponding new two-test-paper combinations.

- Candidates are allowed to appear for one or two test papers only. The two-paper combinations must be chosen from the given list of combinations. If new two-paper combinations become available, the candidates will be given an opportunity to revise their selection and choose test papers with non-conflicting schedules. Candidates appearing for two test papers are required to fill out a single application form only.

- Examination for some test papers may be held in multiple sessions. However, a candidate will be required to appear for the examination in only one of the sessions of the test paper.

- A candidate who is currently studying in the third or higher years of any undergraduate degree program or who has already completed any government-approved degree program in Engineering/Technology/Architecture/Science/Humanities is eligible to appear for GATE 2024.

- There is no age limit to appear for GATE 2024.

- Applications will be accepted ONLINE through the GATE 2024 Application Portal, which can be accessed from the GATE 2024 website.

- GATE 2024 score card will remain valid for THREE years from the date of the announcement of results.

- Candidates with B.D.S, B.V.Sc. and B.Sc. (Agriculture, Horticulture, Forestry) degrees can also appear for GATE 2024.

- GATE 2024 will be held at several centres spread across more than 200 cities/towns in India only.

3. Important Dates

GATE Online Application Processing System (GOAPS) opens	August 30, 2023
Closing date of regular online registration/applications	September 29, 2023
End of extended period for online registration/application (with late fee)	October 13, 2023
Last date for change of Category, Paper and Examination City, adding a new test paper, and change of personal details (additional fee applicable per change)	November 11, 2023
Admit Cards available for download	January 3, 2024
GATE 2024 Examination Dates Forenoon: 9:30 AM to 12:30 PM Afternoon: 2:30 PM to 5:30 PM	February 3, 2024 (Saturday) February 4, 2024 (Sunday) February 10, 2024 (Saturday) February 11, 2024 (Sunday)
Announcement of results in the GATE Online Application Processing System (GOAPS)	March 16, 2024
Score Cards available for free download	March 23, 2024 to May 31, 2024
Score Cards available for download by paying a fee of Rs. 500 per test paper	June 1, 2024 to December 31, 2024

The dates mentioned above are liable to change.

4. Pattern of Examination

Particulars	Details
Mode of examination	Computer Based Test (CBT)
Duration	3 hours*
Number of papers	30 test papers
Sections	General Aptitude (GA) + Candidate's Selected Subject(s)
Types of questions	(a) Multiple Choice Questions (MCQ) (b) Multiple Select Questions (MSQ) (c) Numerical Answer Type (NAT)
Test of abilities	(a) Recall (b) Comprehension (c) Application (d) Analysis and Synthesis
Number of questions	10 (General Aptitude) + 55 (Subject) = 65 Questions
Distribution of marks in all papers except AR, CY, DA, EY, GG, MA, PH, ST, XH and XL	General Aptitude: 15 marks Engineering Mathematics**: 13 marks Subject Questions: 72 marks Total: 100 marks (**XE includes an Engineering Mathematics section XE-A of 15 marks)
Distribution of marks in papers AR, CY, DA, EY, GG, MA, PH, ST, XH and XL	General Aptitude: 15 marks Subject Questions: 85 marks Total: 100 marks
Marking scheme	Questions carry either 1 mark or 2 marks
Negative marking	For a wrong answer to an MCQ, there will be negative marking. For a 1-mark MCQ, 1/3 will be deducted for a wrong answer. Likewise, for 2-mark MCQ, 2/3 will be deducted for a wrong answer. There is no negative marking for wrong answers to MSQ and NAT questions. There is no partial marking for any question.

*PwD candidates with benchmark disability more than 40% are eligible for compensatory time of one hour. PwD candidates with less than 40% disability and having difficulty in writing are eligible for compensatory time subject to production of a certificate as stated in Appendix-I of the guidelines issued by the Ministry of Social Justice and Empowerment.

5. About GATE

Graduate Aptitude Test in Engineering (GATE) is a national-level examination conducted jointly by the Indian Institute of Science (IISc), Bengaluru, and seven Indian Institutes of Technology (IIT Bombay, IIT Delhi, IIT Guwahati, IIT Kanpur, IIT Kharagpur, IIT Madras, and IIT Roorkee) on behalf of the National Coordination Board (NCB)-GATE, Department of Higher Education, Ministry of Education (MoE), Government of India.

GATE is conducted as a computer-based test (CBT) and evaluates the comprehensive understanding of the candidates in various undergraduate subjects in Engineering, Technology, Science, and Architecture; and both undergraduate and post-graduate level subjects in Humanities and Science. GATE 2024 will feature 30 test papers, distributed over four days. The examination dates for GATE 2024 are February 3, 4, 10, and 11, 2024. GATE 2024 examination will be conducted in several cities across India. GATE 2024 will not be conducted in centres outside India.

The GATE score reflects the relative performance level of the candidate in a test paper. GATE 2024 score will be valid for THREE YEARS from the date of announcement of results. Qualifying in GATE is useful for seeking admission and/or financial assistance to:

(i) Master's programs and direct Doctoral programs in Engineering/Technology/Architecture; and
(ii) Doctoral programs in relevant branches of Engineering/Science/Technology/Architecture/Humanities, in institutions supported by MoE and other government agencies. Even in colleges and institutions that admit students without MoE scholarship/assistantship, GATE qualification may be useful. Further, many Public Sector Undertakings (PSUs) have been using the GATE score in their recruitment process.

5.1 GATE Administration

GATE is administered by Indian Institute of Science (IISc), Bengaluru, and seven Indian Institutes of Technology (IIT Bombay, IIT Delhi, IIT Guwahati, IIT Kanpur, IIT Kharagpur, IIT Madras, and IIT Roorkee), which are collectively referred to as zones. For administrative purposes, the examination cities in India are segregated into these eight zones. GATE operations in each zone are managed by the Zonal GATE Office. Each year, one of the eight zonal institutes is designated as the Organising Institute (OI), which will be responsible for the overall coordination and conduct of the exam. Indian Institute of Science (IISc), Bengaluru is the Organising Institute for GATE 2024. Table 1 gives the details of the zonal structure of GATE with contact details, and the examination cities where the test centres will be available.

Table 1: Zonal structure of GATE and tentative list of examination cities/towns.

Zonal GATE Office	Tentative List of Examination Cities/Towns
Zone-1 **IISc Bengaluru** **Bengaluru - 560 012** **Website:** https://gate2024.iisc.ac.in Email: helpdesk.gate@iisc.ac.in Phone nos.: 080-22932644 080-22933333 **Organising Institute for GATE 2024**	**Andhra Pradesh:** Ananthapuramu, Kurnool **Karnataka:** Bagalkot, Ballari (Bellary), Belagavi (Belgaum), Bengaluru North, Bengaluru South, Bidar, Chikkamagaluru, Chikkballapur, Davanagere, Hassan, Hubballi (Hubli)/ Dharwad, Kalaburagi (Gulbarga), Kolar, Mandya, Mangaluru, Manipal-Udupi, Mysuru (Mysore), Shivamogga (Shimoga), Tumakuru **Kerala:** Angamaly, Kannur, Kasaragod, Kozhikode, Malappuram, Palakkad, Pathanamthitta, Payyanur, Thrissur, Vatakara, Wayanad **Telangana:** Hyderabad, Medak, Nalgonda **Andaman and Nicobar:** Port Blair
Zone-2 **IIT Bombay** **Powai, Mumbai - 400 076** Email: gateoffice@iitb.ac.in Phone no.: 022-25767068	**Gujarat:** Ahmedabad, Anand, Bhavnagar, Bhuj, Gandhinagar, Jamnagar, Mehsana, Rajkot, Surat, Vadodara, Vapi **Maharashtra:** Ahmednagar, Akola, Amravati, Aurangabad, Baramati, Chandrapur, Dhule, Jalgaon, Kolhapur, Latur, Mumbai, Nagpur, Nanded, Nashik, Navi Mumbai-Thane, Panvel-Raigad, Pune, Ratnagiri, Sangamner-Loni-Shirdi, Sangli, Satara, Solapur, Vasai-Palghar, Wardha, Yavatmal **Goa:** Goa

Zone-3 **IIT Delhi** **Hauz Khas, New Delhi - 110 016** Email: gate@admin.iitd.ac.in Phone no.: 011-26591749	**Haryana:** Faridabad, Gurugram, Hisar **Jammu and Kashmir:** Jammu-Samba, Srinagar **Ladakh:** Leh **Madhya Pradesh:** Indore, Ujjain **New Delhi:** New Delhi **Rajasthan:** Ajmer, Alwar, Bikaner, Jaipur, Jodhpur, Kota, Sikar, Udaipur **Uttar Pradesh:** Greater NOIDA, Mathura
Zone-4 **IIT Guwahati** **Guwahati - 781 039** Email: gate@iitg.ac.in Phone nos.: 0361-2582751/2582755	**Arunachal Pradesh:** Itanagar **Assam:** Dibrugarh, Guwahati, Jorhat, Silchar, Tezpur **Bihar:** Bhagalpur, Muzaffarpur, Patna, Purnea **Jharkhand:** Bokaro Steel City, Dhanbad **Manipur:** Imphal **Meghalaya:** Shillong **Mizoram:** Aizawl **Nagaland:** Dimapur, Kohima **Sikkim:** Gangtok **Tripura:** Agartala **West Bengal:** Asansol, Durgapur, Burdwan, Kalyani, Siliguri
Zone-5 **IIT Kanpur** **Kanpur - 208 016** Email: gate@iitk.ac.in Phone nos.: 0512-2597412/2596962/2596963	**Madhya Pradesh:** Bhopal, Gwalior, Jabalpur, Sagar, Satna **Uttar Pradesh:** Agra, Aligarh, Allahabad, Bareilly, Gorakhpur, Jhansi, Kanpur, Lucknow, Varanasi
Zone-6 **IIT Kharagpur** **Kharagpur - 721 302** Email: gateonline@adm.iitkgp.ac.in Phone nos.: 03222-282091/282095	**Andhra Pradesh:** Eluru, Kakinada-Surampalem, Rajamahendravaram (Rajahmundry), Srikakulam, Tadepalligudem, Vijayawada, Visakhapatnam, Vizianagaram **Chhattisgarh:** Bhilai, Bilaspur, Raipur **Jharkhand:** Hazaribag, Jamshedpur, Ranchi **Odisha:** Balasore, Bhubaneswar, Brahmapur, Cuttack, Dhenkanal, Kakatpur (Puri), Rourkela, Sambalpur **West Bengal:** Bankura, Berhampur-Murshidabad, Hooghly, Howrah, Kharagpur-Midnapur, Kolaghat, Kolkata, Suri (Birbhum)
Zone-7 **IIT Madras** **Chennai - 600 036** Email: gate@iitm.ac.in Phone no.: 044-22578200	**Andhra Pradesh:** Chirala, Chittoor, Guntur, Kadapa, Nellore, Ongole, Tirupati **Kerala:** Alappuzha, Aluva-Ernakulam, Attingal, Chengannur, Kanjirapally, Kollam, Kothamangalam, Kottayam, Muvattupuzha, Thiruvananthapuram **Pondicherry:** Puducherry **Tamilnadu:** Chennai South, Chennai West, Coimbatore, Cuddalore, Dindigul, Kanyakumari-Nagercoil, Madurai, Namakkal, Ramanathapuram, Salem, Thanjavur, Theni, Thoothukudi, Tiruchirapalli, Tirunelveli, Vellore, Virudhunagar **Telangana:** Adilabad, Karimnagar, Khammam, Kodad, Kothagudem, Nizamabad, Suryapet, Warangal
Zone-8 **IIT Roorkee** **Roorkee – 247 667** Email: gate@iitr.ac.in Phone no.: 01332-284531	**Haryana:** Ambala, Kurukshetra **Himachal Pradesh:** Bilaspur, Hamirpur, Kangra, Mandi, Shimla-Solan **Punjab:** Amritsar, Bathinda, Jalandhar, Ludhiana, Mohali-Chandigarh, Patiala, Pathankot **Uttarakhand:** Dehradun, Haldwani, Roorkee **Uttar Pradesh:** Ghaziabad, Meerut, Moradabad, Muzaffarnagar, NOIDA, Saharanpur

6. Opportunities with GATE Qualification

To avail financial assistance (scholarship/assistantship) for a postgraduate program, the candidate must first secure admission to a program in one of the centrally funded institutes, through a process that may be specific to the institute. Depending on the norms adopted by the institute or a department of the institute, candidates may be admitted directly into a program, based on their performance in GATE only; or based on their performance in GATE and an admission test and/or interview conducted by the department to which they have applied and/or the candidate's academic record. The MoE guidelines prescribe a minimum of 70% weightage to the performance in GATE and the remaining for the candidate's performance in the test/interview and/or academic record. However, the admitting institutes could also prescribe a minimum passing mark in the test/interview.

Candidates are advised to seek complete details of the admission procedures and the availability of MoE scholarship/assistantship from the corresponding admitting institutes. The criteria for postgraduate admission with scholarship/assistantship varies from one institute to the other. The management of the postgraduate scholarship/assistantship is also the responsibility of the admitting institute. Reservation of seats for different categories will be as per the policies and norms of the admitting institute and Government of India rules. The admitting institute may also specify the number of candidates who will be provided financial assistance (scholarship), if admission is secured. Qualification in GATE is also a minimum requirement to apply for various fellowships awarded by many government organisations.

Different types of scholarships and sponsorship opportunities also exist for foreign nationals. Details may be obtained from nearby Indian Mission or from the website of Indian Council for Cultural Relations.

Several Public Sector Undertakings (PSUs) have been using GATE score to shortlist candidates for recruitment. During the past few years, the PSUs that have used GATE scores in their recruitment process are: Bharat Heavy Electricals Limited (BHEL), Bharat Sanchar Nigam Limited (BSNL), Coal India Limited (CIL), Centre for Railway Information Systems (CRIS), Chenab Valley Power Projects Limited (CVPPL), Damodar Valley Corporation (DVC), Electronics Corporation of India Limited (ECIL), Engineers India Limited (EIL), Gas Authority of India Limited (GAIL), Indian Oil Corporation Limited (IOCL), Mazagaon Dock Shipbuilders Limited (MDSL), National Aluminium Company Limited (NALCO), National Highways Authority of India (NHAI), NLC India Limited (NLCIL), National Mineral Development Corporation (NMDC), Nuclear Power Corporation of India Limited (NPCIL), National Thermal Power Corporation (NTPC), Oil and Natural Gas Corporation (ONGC), Power Grid Corporation of India (PGCIL), Power System Operation Corporation Limited (POSOCO), Rashtriya Ispat Nigam Limited (RINL).

Direct recruitment to Group-A level posts in the central government such as Senior Field Officer (Tele), Senior Research Officer (Crypto) and Senior Research Officer (S&T) in Cabinet Secretariat, Government of India, is now being done based on GATE score. The details of the scheme of recruitment are usually published in national newspapers/Employment News/Rozgar Samachar by the concerned authority.

Other organisations may also utilise GATE 2024 score in their recruitment process.

7. Pre-Examination Activities

- Candidates must register and fill the application via ONLINE mode ONLY at the GATE 2024 website. Uploading certificates/documents must also be done in the ONLINE mode only. Candidates should NOT send printed copies of their application forms or documents to IISc or any of the zonal GATE offices.
- The application fees must be paid electronically (credit card, debit card, NEFT, UPI, etc.). If a candidate wishes to appear for TWO test papers, the fees to be paid by the candidate will be TWICE of that mentioned for a single paper.
- Admit Cards for GATE 2024 would be available for download on the GATE 2024 website. Printed copies of the Admit Cards will not be posted to the candidates.
- The candidate must appear at the GATE Examination Centre on the date and time specified in the Admit Card.
- Requests for change in the Centre or Location or Date/Time specified in the Admit Card will not be entertained.
- In all matters concerning GATE 2024, the decision of the GATE 2024 Organising Institute will be final and binding on all the applicants.
- For candidates appearing for the Geology and Geophysics (GG) and Humanities and Social Sciences (XH) papers, separate score and ranking will be provided based on their selection of sections.
- Section-wise score and ranking will not be provided for the other test papers.

7.1 Eligibility for GATE 2024

Before filing the application, candidates must ensure that they meet the educational eligibility criteria of GATE 2024. A candidate who is currently studying in the third or higher years of any undergraduate degree program or who has already completed any government approved degree program in Engineering/Technology/Architecture/Science/Commerce/Arts/Humanities is eligible to appear for GATE 2024.

The following Professional Societies or Institutions conduct examinations in various fields of engineering:

- The Institution of Engineers (India) (IE)
- The Institution of Civil Engineers (ICE)
- The Institution of Electronics and Telecommunication Engineers (IETE)
- The Aeronautical Society of India (AeSI)
- The Indian Institute of Chemical Engineers, including Polymer and Environmental Group (IIChE)
- The Indian Institute of Metals (IIM)
- The Indian Institute of Industrial Engineers (IIIE)

Candidates who possess certification from any of the professional societies must ensure that those examinations are approved by MoE/AICTE/UGC/UPSC as equivalent to B.E./B.Tech./B.Arch./B.Planning.

Candidates who are pursuing their qualifying degree or obtained the degree from countries other than India must be currently in the third or higher years or must have completed their Bachelor's degree (of duration at least 3 years) in Engineering/Technology/Science/Architecture/Humanities. Details of eligibility criteria are given in Table 2. If a candidate is pursuing any higher degree or has already obtained a degree higher than that mentioned in the Table 2, the candidate will be allowed to appear for GATE 2024.

Candidates with B.Sc./B.A./B.Com. degrees desirous of seeking admission to Master's programs in IISc, IITs, NITs, and other CFTIs, may refer to JAM-2024 Examination organised by Indian Institute of Technology Madras.

Table 2: Eligibility Criteria for GATE 2024.

Degree/Program	Qualifying Degree/Examination	Description of Eligible Candidates
B.E./B.Tech./B.Pharm.	Bachelor's degree in Engineering / Technology (4 years after 10+2 or 3 years after B.Sc./ Diploma in Engineering/Technology)	Currently in the 3rd year or higher or already completed
B. Arch.	Bachelor's degree of Architecture (5- year course) /Naval Architecture (4- year course)/ Planning (4- year course)	Currently in the 3rd year or higher or already completed
B.Sc. (Research)/B.S.	Bachelor's degree in Science (Post-Diploma/ 4 years after 10+2)	Currently in the 3rd year or higher or already completed
Pharm. D. (after 10+2)	6 years degree program, consisting of internship or residency training, during third year onwards	Currently in the 3rd/4th/5th/ 6th year or already completed
M.B.B.S./B.D.S./B.V.Sc.	Degree holders of M.B.B.S./B.D.S./B.V.Sc. and those who are in the 5th/6th/7th semester or higher semester of such program.	5th/6th/7th or higher semester or already completed
M. Sc./M.A./M.C.A. or equivalent	Master's degree in any branch of Arts/Science/ Mathematics/Statistics/Computer Applications or equivalent	Currently in the first year or higher or already Completed
Int. M.E./M.Tech. (Post-B.Sc.)	Post-B.Sc Integrated Master's degree programs in Engineering/Technology (4-year program)	Currently in the 1st/2nd/3rd/ 4th year or already completed
Int. M.E./ M.Tech./M.Pharm. or Dual Degree (after Diploma or 10+2)	Integrated Master's degree program or Dual Degree program in Engineering/Technology (5-year program)	Currently in the 3rd /4th/ 5thyear or already completed
B.Sc./B.A./B.Com.	Bachelor's degree in any branch of Science / Arts / Commerce (3-year program)	Currently in the 3rd year or already completed
Int. M.Sc./Int. B.S./M.S.	Integrated M.Sc. or 5-year integrated B.S.-M.S. program	Currently in the 3rd year or higher or already completed
Professional Society Examinations (equivalent to B.E./B.Tech./B.Arch.)	B.E./B.Tech./B.Arch. equivalent examinations of Professional Societies, recognised by MoE/UPSC/ AICTE (e.g. AMIE by Institution of Engineers-India, AMICE by the Institute of Civil Engineers-India and so on)	Completed Section A or equivalent of such professional courses
B.Sc. (Agriculture, Horticulture, Forestry)	4-year program	Currently in the 3rd/4th year or already completed

*Enrolments with professional bodies and institutions as per MHRD OM (No. 11-15/2011-AR (TS.II)) with permanent recognition up to 31st May 2013, stand recognised. Kindly see circular F. No. 13-56/PC/ODL-Mode/ AICTE/2020, Dated 23rd November 2020 and Public Notice issued by AICTE for clarification.

8. List of GATE 2024 Test Papers

Table 3 shows the list of test papers and codes for GATE 2024. A candidate is allowed to appear in ONE or TWO test papers. However, the combination of two papers must be chosen from the list given in Table 4. For a paper conducted in multiple sessions, a candidate will be required to appear for the examination in one of the sessions only.

Table 3: List of GATE 2024 test papers and their corresponding codes.

Test Paper	Code	Test Paper	Code
Aerospace Engineering	AE	Geology and Geophysics	GG###
Agricultural Engineering	AG	Instrumentation Engineering	IN
Architecture and Planning	AR#	Mathematics	MA
Biomedical Engineering	BM	Mechanical Engineering	ME
Biotechnology	BT	Mining Engineering	MN
Civil Engineering	CE	Metallurgical Engineering	MT
Chemical Engineering	CH	Naval Architecture and Marine Engineering	NM
Computer Science and Information Technology	CS	Petroleum Engineering	PE
Chemistry	CY	Physics	PH
Data Science and Artificial Intelligence	DA	Production and Industrial Engineering	PI
Electronics and Communication Engineering	EC	Statistics	ST
Electrical Engineering	EE	Textile Engineering and Fibre Science	TF
Environmental Science & Engineering	ES	Engineering Sciences	XE*
Ecology and Evolution	EY	Humanities & Social Sciences	XH**
Geomatics Engineering	GE##	Life Sciences	XL***

*XE Paper Sections	Code	**XH Paper Sections	Code	***XL Paper Sections	Code
Engineering Mathematics (**Compulsory**) (15 marks)	A	Reasoning and Comprehension (**Compulsory**) (25 marks)	B1	Chemistry (**Compulsory**) (25 marks)	P
Any TWO optional sections (2x35 = 70 marks)		Any ONE optional section (60 marks)		Any TWO optional sections (2x30 = 60 marks)	
Fluid Mechanics	B	Economics	C1	Biochemistry	Q
Materials Science	C	English	C2	Botany	R
Solid Mechanics	D	Linguistics	C3	Microbiology	S
Thermodynamics	E	Philosophy	C4	Zoology	T
Polymer Science and Engineering	F	Psychology	C5	Food Technology	U
Food Technology	G	Sociology	C6		
Atmospheric and Oceanic Sciences	H				

#AR Paper Sections	##GE Paper Sections	###GG Paper Sections
Part-A (Compulsory)	Part-A (Compulsory)	Part-A (Compulsory)
Part-B1 (Architecture)	Part-B1 (Surveying and Mapping)	Part-B1 (Geology)
Part-B2 (Planning)	Part-B2 (Image Processing and Analysis)	Part-B2 (Geophysics)

The syllabus for the test papers is given on Pages 31-126 of this Information Brochure. Choosing the appropriate test paper while filing the GATE application is the responsibility of the candidate. Candidates are expected to appear in papers appropriate to the discipline of their qualifying degree. However, candidates are also free to choose any one or the allowed set of two papers of GATE 2024 as per their admission or employment plan, while keeping in mind the eligibility criteria laid out by the institutions in which they would like to seek admission or employment.

If a candidate files multiple applications for a test paper, only one of them will be considered, and the others will be rejected without any refund of application fee.

8.1 GATE 2024 Two-test Paper Combinations

Candidates opting to appear in TWO test papers must have a primary choice of paper and a secondary choice of paper, which can be chosen from the allowed combinations given in Table 4. Certain combinations listed in the table may be removed at a later date if there are scheduling constraints, in which case, the fee paid towards the second paper will be refunded to the candidates. If at a later date, new two-paper combinations are announced, candidates will be given an opportunity to add a test paper subject to payment of the requisite fee. In view of infrastructure and scheduling constraints, the examination centre for candidate to appear for the second paper may be different (but in the same city) than that for the first paper. No responsibility is assumed for any legal obligations arising out of this issue.

Table 4: Allowed two-paper combinations in GATE 2024.

Code of the Primary Paper	Codes of Papers Allowed as the Secondary Paper	Code of the Primary Paper	Codes of Papers Allowed as the Secondary Paper
AE	CE, ME, XE	GE	AR, CE, CS, ES, GG
AG	CE	GG	GE
AR	CE, GE	IN	BM, EC, EE, ME
BM	BT, IN	MA	CS, DA, PH, ST
BT	BM, XL	ME	AE, DA, IN, NM, PI, XE
CE	AE, AG, AR, ES, GE, NM, XE	MT	XE
CH	ES, PE, XE	NM	CE, ME
CS	DA, EC, GE, MA, PH, ST	PE	CH
CY	XE, XL	PH	CS, DA, EC, EE, MA, XE
DA	CS, EC, EE, MA, ME, PH, ST, XE	PI	ME, XE
EC	CS, DA, EE, IN, PH	ST	CS, DA, MA, XH
EE	DA, EC, IN, PH	XE	AE, CE, CH, CY, DA, ME, MT, PH, PI
ES	CE, CH, GE	XH	ST
EY	XL	XL	BT, CY, EY

9. Distribution of Marks

Total Marks: 100; Total Time: 3 hours*

Each test paper is for a total of 100 marks. All test papers have a General Aptitude (GA) section for 15 marks. The remaining 85 marks cater to the subject chosen by the candidate. Table 5 shows the distribution of marks in various test papers of GATE 2024.

Table 5: Distribution of marks in various test papers of GATE 2024.

Paper Code	General Aptitude (GA) Marks	Subject: Compulsory Section	Subject: Optional Section(s)	Total Marks
AE, AG, BM, BT, CE, CH, CS, EC, EE, ES, IN, ME, MN, MT, NM, PE, PI, TF; Subject marks in these papers include questions on Engineering Mathematics (13 marks), which are paper-specific.	15	85	—	100
CY, DA, EY, MA, PH, ST	15	85	—	100
AR: Part A is Common and Compulsory. Part B1/B2 can be selected during the exam. B1 - Architecture B2 - Planning	15	60	25	100
GE: Part A is Common and Compulsory. Part B1/B2 can be selected during the exam. B1 - Surveying and Mapping B2 - Image Processing and Analysis	15	55	30	100
GG: Part A is Common and Compulsory. Part B1/B2 must be chosen at the time of application. B1 - Geology B2 - Geophysics	15	25	60	100
XE: Section A (Engineering Mathematics) is Common and Compulsory. Applicants must select any TWO of the other sections during the exam.	15	15	2 x 35	100
XH: Section B1 (Reasoning and Comprehension) is Common and Compulsory. Applicants must select any ONE of the other sections at the time of application.	15	25	60	100
XL: Section P (Chemistry) is Common and Compulsory. Applicants must select any TWO of the other sections during the exam.	15	25	2 x 30	100

*PwD candidates with benchmark disability more than 40% are eligible for compensatory time of one hour. PwD candidates with less than 40% disability and having difficulty in writing are eligible for compensatory time subject to production of a certificate as stated in Appendix-I of the guidelines issued by the Ministry of Social Justice and Empowerment (F. No. 29-6/2019-DD-III, dated 10th August, 2022).

10. GATE 2024 Online Application

Table 1 gives a tentative list of the exam cities (zone-wise) in which GATE 2024 examination is scheduled to be held. A candidate can choose three cities from the list given in Table 1, with the three choices chosen from the same GATE 2024 zone. If a candidate chooses a particular city (in a particular zone) as the first choice, then the second and third choices of the city will also be restricted to the same zone as the first. Because of operational constraints, the GATE Organising Institute reserves the right to add a new city or remove an existing one and allot a city that may not be from any of the choices selected by the candidate.

10.1 Application Process

Application for GATE 2024 must be submitted online through GATE Online Application Processing System (GOAPS), accessible from the GATE 2024 website, by paying the prescribed application fee. The photograph, signature, photo ID, and certificates such as SC/ST/PwD/Dyslexia, wherever applicable, must be uploaded during the online application. The accepted photo identification cards are: Aadhaar-UID, Aadhaar Virtual ID, Government issued ID, Passport, PAN card, Voter ID card, and Driving License. Candidates must produce the same original valid photo identification card during the examination for verification purposes, failing which the candidate may not be allowed to appear for the examination.

10.2 GATE 2024 Application Fee

Details of the application fee per candidate per paper are given in Table 6. Payments must be made online by using net banking/debit card/credit card/wallet/UPI. Candidates are advised to ensure that E-COM transaction facility is enabled for their credit/debit cards before proceeding with fee payment. The application fee is not transferable. It is not refundable except when a certain two-paper combination is removed by GATE 2024 Organising Institute. There are no international centres in GATE 2024. Foreign nationals or Indian nationals desirous of appearing for the exam will have to travel to India to appear for the test.

Table 6: Details of application fee per test paper.

Category	Regular Period (August 30 to September 29, 2023)	Extended Period (September 30 to October 13, 2023)
Female/SC/ST/PwD* candidates	₹ 900	₹ 1400
All other candidates including foreign nationals	₹ 1800	₹ 2300

*PwD stands for Persons with Benchmark Disability. Only those candidates with benchmark disability (greater than 40%) are eligible for fee concession. For benchmark disabilities, please consult https://disabilityaffairs.gov.in/upload/uploadfiles/files/Guidelines-29_08_2018.pdf and https://disabilityaffairs.gov.in/upload/uploadfiles/files/Corrigendum-08-02-19.pdf

The application fee does not include service charges, processing fees, and any other charges that the banks may levy. For two papers, the fee payable will be twice that of a single paper.

10.3 GATE 2024 Website

Tentatively, by the last week of August 2023, GATE 2024 website (https://gate2024.iisc.ac.in) will contain the link to the GATE Online Application Processing System (GOAPS), which enables a candidate to

- Apply for the examination.
- Upload photograph, signature, photo ID, and category certificate (SC/ST/PwD) and/or Dyslexic certificate, as applicable.
- Pay the application fee through the listed electronic payment modes.
- Check the status of the application form: Received, Under scrutiny, Accepted, Defect status, Status after rectification, rejected with valid reasons, etc.
- Download Admit Card.
- View answers, marks, and GATE score.
- Download GATE Score Cards.

10.4 Registration

A candidate must first register by providing full name, valid e-mail address, mobile number and by choosing a password. All communication will be sent to this e-mail address and mobile number. Only one registration per email address is allowed. No change in email or mobile number will be entertained at a later stage.

10.5 Enrolment ID

Each registration will be provided with a unique Enrolment ID, which will be communicated to the candidate by e-mail. The Enrolment ID will be needed for reference in future communication pertaining to the examination.

10.6 Password

The candidate must choose a password during enrolment and will be needed to log in to the account. It is recommended to choose a password that cannot be guessed easily. The password must be kept confidential.

After registration, GATE 2024 application must be filled and submitted online only. Candidates are discouraged from filing applications through a third party. If the application is filled by a third party, it is the responsibility of the candidate to ensure that the data submitted is correct.

The following data will be required while filling the online application form:

- Personal details (name of the candidate, date of birth, mobile number, name and mobile number of parent or guardian, etc.). The name of the candidate in the application form must be exactly the same as that in the valid photo ID, which the candidate must produce in original while appearing for GATE 2024 examination at the centre. Candidates are advised to ensure that the date of birth provided in the application form matches exactly with that mentioned in the photo ID.
- GATE 2024 scorecard will be issued as per the name entered in the application form. Prefixes/titles such as Mr./Shri/Dr./Mrs./Smt./Prof./Capt./Maj./Lt./Col. etc. must not be used.
- Address for communication including PIN code
- Eligibility degree details
- College name and address with PIN code
- Choice of GATE paper(s)
- Choice of GATE examination cities
- Good quality image of the candidate's photograph conforming to the specifications
- Good quality image of the candidate's signature conforming to the specifications
- Scanned copy of valid photo Identity Document (ID)
- PDF copy of Category (SC/ST) certificate (if applicable)
- PDF copy of PwD Certificate (if applicable)
- PDF copy of Dyslexic Certificate (if applicable)
- Net-banking/debit card/credit card/UPI/wallet details for fee payment

GATE 2024 Application Processing System (GOAPS) allows the candidate to enter the data, save partially filled form, logout and resume filling the form by logging in again. The online application process is self-explanatory and user-friendly.

Before proceeding to payment, the candidate is advised to check the filled-in application form for any errors. Once the candidate clicks "**Submit and Proceed to Payment**" button, no changes can be made to the application. Before submitting the online application form, the candidate will be asked to read and accept a declaration that the details furnished are correct and that falsification of data will attract appropriate consequences.

10.7 Identity Proof/Photo ID

Candidates must specify one of the following valid photo Identity Documents (IDs) during the online application process and enter the document number: Aadhaar-UID, Aadhaar Virtual ID, Government issued ID, Passport, PAN Card, Voter ID or Driving License. On the day of the examination, the candidate must bring the original ID proof together with the GATE 2024 Admit Card. The photo ID must clearly show the name, photo, ID number, and date of birth.

For international candidates appearing at centres in India, ONLY a valid Passport/Government issued ID/Driving License will be accepted as the recognised identification document.

10.8 PwD Candidates and Scribe Related Guidelines

GATE 2024 will follow the government regulations with regard to PwD candidates: https://disabilityaffairs.gov.in/upload/uploadfiles/files/Guidelines-29_08_2018.pdf and https://disabilityaffairs.gov.in/upload/uploadfiles/files/Corrigendum-08-02-19.pdf

A Person with benchmark Disability (PwD) or a dyslexic candidate has the option of availing scribe assistance during the GATE 2024 examination. The candidate must exercise this option at the time of filing the application. PwD and Dyslexic candidates can either arrange their own scribe or request the GATE Organising Institute to arrange for a panel of scribes. The assistance that the scribe can render to the candidate is limited to reading the instructions and test paper displayed on the computer screen verbatim and in mouse-clicks, if the candidate is not able to do so. The scribe shall not translate/interpret/emphasise the Test Paper contents to the candidate.

10.9 Scribes arranged by Candidates

The scribe MUST NOT be a candidate for a test paper in GATE 2024. According to the Government of India (GoI) guidelines, in cases where the candidates have opted to bring their scribe, the qualification of the scribe should be one step below the qualification of the candidates taking the examination. If PwD/Dyslexic candidate have opted for their own scribe, but they do not bring their own scribe, then it will not be possible to arrange a new scribe. Honorarium will not be paid to the scribe arranged by the PwD/Dyslexic candidate.

10.10 Scribes arranged by the GATE Organising Institute

GATE scribes will be used for those PwD/Dyslexic candidates who have a priori opted for GATE scribes. The qualification of the scribe arranged by GATE will NOT be more than the minimum eligibility criteria of GATE. However, the qualification of the scribe must be matriculation (10^{th}) or above. If there are Y candidates who require scribe, a panel of (Y+1) scribes will be made available at the exam centre so that every candidate can have an alternative scribe to choose for the services. A PwD/Dyslexic (or similar learning disability) will be presented with TWO scribes from this panel. The candidate must choose one from these two scribes. Candidates will NOT be permitted to bring their own scribe if they have already opted for scribes to be arranged by GATE.

10.11 Assistive Devices

PwD candidates are permitted to use assistive devices such as Abacus, Braille slate, Wheelchair, etc. They may arrange for the devices on their own and bring them to the examination. GATE Organising Institute cannot provide any assistive devices. Candidates will be given an option to view the content on the computer screen in a magnified font (approximately 1.25x or 1.5x). PwD candidates are encouraged to visit the Exam Centre a day before the examination to familiarise themselves with the arrangements.

10.12 Compensatory Time

Candidates with a scribe can avail the compensatory time of one hour. As per GATE guidelines, PwD/Dyslexic (similar learning disabilities) candidates with Scribes are eligible for a compensatory time of 60 minutes. Compensatory time of 60 minutes will be provided automatically, which may be checked on the candidate's console.

PwD candidates, with certain benchmark disabilities that limit the speed of writing, can request for compensatory time during application. On-spot requests for compensatory time at the examination hall will not be entertained. For compensatory time, please consult https://disabilityaffairs.gov.in/upload/uploadfiles/files/Guidelines-29_08_2018.pdf, https://disabilityaffairs.gov.in/upload/uploadfiles/files/Corrigendum-08-02-19.pdf, and https://disabilityaffairs.gov.in/upload/uploadfiles/files/Vikash%20Kumar%20Guidelines%2010-8-22.pdf

10.13 Supporting Documents

- **Category (SC/ST/OBC/EWS) Certificate**

Candidates who belong to SC/ST category must upload a valid documentary proof (for availing concession in application fee). Certificates issued only by the authorised officials will be considered valid (refer to Appendix A for a list of Authorities Empowered to Issue SC/ST Certificate). Necessary legal action will be initiated for any wrongdoing or misinformation. The same document may be required to be submitted to the admitting institute,

which also has the onus of verifying the candidate's SC/ST certificate. OBC-NCL and EWS candidates are not required to submit/upload any category certificate while filling the online application form.

- **Person with Disability (PwD) Certificate**

To avail the application fee concession under the Person with Disability (PwD) category, the candidates should attach a recently obtained and valid PwD certificate issued by the competent authority. The same document may be required to be submitted to the admitting institute during admission.

- **Certificate of Dyslexia**

To avail the services of a scribe, dyslexic candidates should attach a valid dyslexic certificate issued by any authorised Dyslexia Association (refer to Appendix A for Authorities Empowered to Issue Certificate of Dyslexia).

- **Photograph and Signature Requirements**

GATE 2024 application requires that candidate's photograph and signature files be uploaded online according to the following specifications.

- **Photograph Requirements**
  - GATE 2024 Admit Card and Score Card will contain the same photograph that you have submitted at the time of application.
  - Upload a good quality, colour photograph of passport size (3.5 cm width × 4.5 cm height) with the face of the candidate covering 60-70% of the photograph.
  - The background of the photograph must be white and not contain any other objects or persons.
  - The photograph must show the frontal face view looking directly into the camera and must show the forehead, eyes, nose, and chin. The face in the photograph must not be covered with objects such as caps, hats, sunglasses, coloured glasses, etc. Normal spectacles for vision correction are allowed. If the candidate normally wears spectacles, a photograph with glare on the glasses is not acceptable. If the glare cannot be avoided, the spectacles must be removed.
  - Photograph can be in JPEG/JPG format with minimum aspect ratio of 0.66 and maximum aspect ratio of 0.89. After cropping the photograph, the face must cover 60-70% of the image.
  - The maximum pixel resolution is 530 x 690 pixels and the minimum resolution is 200 x 260 pixels. The file size must be minimum of 5 kB and a maximum of 1 MB.
  - The face must be visible clearly and not covered by any cloth or shadow.
  - Photographs not adhering to the specified criteria could lead to rejection of your GATE application, and the application fee will not be refunded.
  - Head coverings are not permitted except for religious reasons, but the facial features from bottom of chin to the top of forehead and both edges of the face must be clearly shown.

Table 7 shows samples of acceptable and unacceptable photographs.

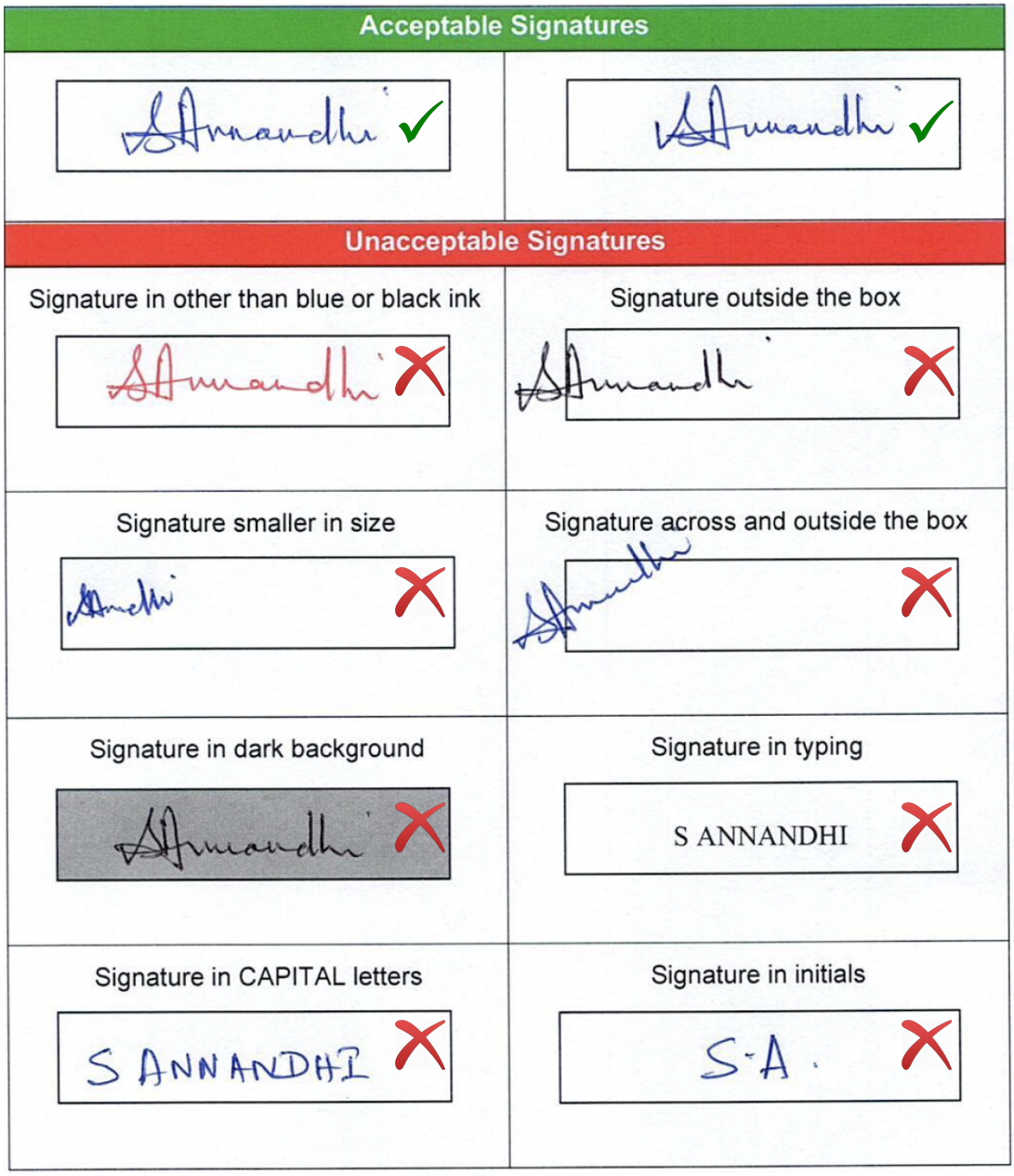
- **Signature Specifications**
  - Upload an image of your signature in JPEG/JPG format of size with an aspect ratio (height : width) of 1 : R, where the value of R can be between 2.75 and 3.75. After cropping to the mentioned size, the area of the signature must cover 70-80% of the image.
  - The signature of the candidate must be in black or dark blue colour ink only.
  - The file size must be a minimum of 3 kB and maximum of 1 MB.
  - The maximum pixel resolution is 580 × 180 pixels and the minimum resolution is 250 × 80 pixels.
  - The signature must be signed only by the applicant and not by any other person.
  - If the candidate's signature does not match with the signature at the time of the examination, the applicant could be disqualified.

Table 8 shows samples of signatures that are acceptable and unacceptable.

Table 7: Samples of acceptable and unacceptable photographs.



Table 8: Samples of acceptable and unacceptable signatures.



Before submitting the GATE 2024 Application Form, the candidate must ensure that all the details and all the necessary supporting documents are filled or uploaded. An application once submitted cannot be changed or edited.

10.14 Application Fee Payment Options

The GATE 2024 application portal directs candidates to the payment gateway, which provides options for fee payment — Net banking/debit card/credit card/wallet/UPI. The fee amount and bank charges will be shown to the candidate, and they will have to confirm and pay. Once the payment is successful, the candidate will be redirected to the GATE 2024 application portal, from where the pdf copy of the submitted application form can be downloaded.

If the candidate has a difficulty due to poor internet connection or power failure problems, for example, and the candidate is not certain whether the payment has been processed or not, then the candidate should check the status of transaction from the bank account and also login back to GATE 2024 application portal after some time and check the status of the payment.

If the payment was received, the candidate can continue printing the application form. If the payment is not received by GATE 2024, a fresh payment must be initiated. In case the fee amount has been debited/deducted

from the bank account, but an acknowledgement for fee payment has not been received from GATE 2024, then the money will be credited back to the candidate's account within 15 days.

In case of multiple payments made due to technical glitches, with respect to one application, the extra fee paid will be returned (credited) to the same bank account within 15 days. In case a payment confirmation has not been received, the candidate is advised to initiate a new payment without waiting for the refund of the earlier payment, to complete the application submission process within the deadline. Candidates are advised to apply and complete the payment well ahead of the closing date to avoid problems due to last-minute rush.

10.15 Application Scrutiny and Rectification

GATE 2024 applications will be scrutinised for accuracy of the data, which include verification against the uploaded supporting documents, clarity of the photograph and signature. If everything is found to be in order, the application will be accepted. Otherwise, the defects will be marked and intimated to the candidate by email or SMS for rectification within a stipulated time frame. The status of an application will be updated after scrutiny by the respective zonal GATE offices. The status of the candidate's application can be checked anytime by logging into the GATE 2024 account. Candidates must promptly rectify defects in their application within the stipulated time. Candidates are advised to login to the Application Portal and check the status of the defects from time to time.

10.16 Admit Card

Admit Cards can ONLY be downloaded from the GATE 2024 website in the first week of January 2024.
Admit Cards will NOT be sent by post or email.

Candidates must bring a printed copy of the Admit Card on A4 paper to the examination for verification along with a valid original photo Identity Document, specified during the filling up of the online application. The Admit Card is valid if and only if the candidate's photograph and signature are clear. Candidates are advised to print the Admit Card on A4 size paper using a laser printer, preferably in colour. GATE 2024 Admit Card and Original ID proof are essential for entry into the examination hall.

Candidates are advised to regularly check the GATE 2024 website for latest updates.

11. GATE 2024 Examination Related Information

A virtual scientific calculator will be available on the computer screen. Calculators, mobile phones, Blue-tooth devices, electronic/communication devices, wallets, books, papers, loose sheets, data or handbooks, tables, pen/pencil box/pouch, analog/digital/smart watches are strictly prohibited in the exam halls and candidates found in possession of such devices will be disqualified regardless of whether they use them or not. GATE 2024 Organising Institute will not be responsible for safe-guarding the candidates' personal belongings.

A scribble pad will be provided to the candidates for rough work. The candidates must write their name and registration number on the scribble pad before using it. A candidate can possess only one scribble pad at any point of time. Before taking the second scribble pad, the first scribble pad MUST be returned to the invigilator. The scribble pad in the candidate's possession must be returned to the invigilator at the end of the examination.

Syllabus for the test papers, previous years GATE question papers, and mock examination links together with the virtual scientific calculator will be accessible through GATE 2024 website.

All test papers of GATE 2024 will be of three hours duration (four hours in case of candidates availing compensatory time), consisting of 65 questions for a total of 100 marks. After the examination duration has elapsed, the examination will terminate automatically.

Candidates will be permitted to occupy their allotted seats 40 minutes before the scheduled start of the examination. Candidates can login and start reading the instructions 20 minutes before the start of examination. A candidate will not be permitted to login after 30 minutes from the scheduled start of the examination. Candidates will NOT be permitted to leave the examination hall before the scheduled end of the examination.

12. Details of GATE 2024 Test Papers

12.1 Types of Questions

GATE 2024 test papers contain questions of three types: Multiple Choice Questions (MCQs); Multiple Select Questions (MSQs); and Numerical Answer Type (NAT).

Multiple Choice Questions (MCQ) carry 1 or 2 marks each. Each MCQ will have choice of four answers, out of which ONLY ONE choice is correct. For a wrong answer chosen in a MCQ, there will be negative marking. For a 1-mark MCQ, 1/3 mark will be deducted for a wrong answer. Likewise, for 2-mark MCQ, 2/3 mark will be deducted for a wrong answer.

Multiple Select Questions (MSQ) carry 1 or 2 marks each. Each MSQ will have choice of four answers, out of which ONE or MORE than ONE choice(s) is / are correct. There is NO negative marking for a wrong answer in MSQ questions. However, there is NO partial credit for choosing partially correct combinations of answers.

Numerical Answer Type (NAT) questions carry 1 or 2 marks each. For NAT questions, the answer is a signed real number, which must be entered by the candidate using the virtual numeric keypad on the monitor (keyboard of the computer will be disabled). No choices will be shown for these types of questions. The answer can be a number such as 10 or -10 (an integer only). The answer may be in decimals as well, for example,10.1 (one decimal) or 10.01 (two decimals) or -10.001 (three decimals). The stem of the NAT question will indicate the number of decimal places that must be specified in the answer. Candidates are advised to round-off only at the end of the calculation and not at intermediate stages of the calculation. There is NO negative marking for a wrong answer in NAT questions.

12.2 Categories of Questions

The questions in a test paper are designed to assess the following abilities:

- **Recall:** These questions are based on facts, principles, formulae or laws of the discipline. The candidate is expected to be able to obtain the answer either from memory of the subject or at most from a short computation.
- **Comprehension:** These questions test the candidate's understanding of the basic concepts and require the candidate to draw simple conclusions from fundamental ideas.
- **Application:** These questions test the candidate's applicability of knowledge either through computation or by logical reasoning.
- **Analysis and Synthesis:** In these questions, the candidate is presented with data, diagrams, images, etc. that require analysis before answering a question. A Synthesis question might require the candidate to compare two or more pieces of information. Questions in this category could, for example, involve the candidate being able to recognise unstated assumptions, or separating useful information from irrelevant information.

The questions may be a mix of a single standalone statement/phrase/data based questions, combination of options, or match the given items type.

12.3 Distribution of Marks and Questions

Every test paper has 65 questions carrying a total of 100 marks, out of which 10 questions carrying a total of 15 marks will be on General Aptitude (GA), which is intended to test typically language and analytical skills.

In test papers AE, AG, BM, BT, CE, CH, CS, EC, EE, ES, GE, IN, ME, MN, MT, NM, PE, PI and TF, the General Aptitude section will carry 15 marks and the remaining 85 marks are devoted to the subject component, out of which Engineering Mathematics will carry 13 marks.

XE has a common and a compulsory section, namely, XE-A (Engineering Mathematics), which carries 15 marks.

In test papers AR, CY, DA, EY, GG, MA, PH, ST, XH and XL, the General Aptitude section carries 15 marks and the remaining 85 marks are devoted to the subject component.

• General Aptitude (GA) Questions

In all test papers, GA questions carry a total of 15 marks. The GA section includes 5 questions carrying 1 mark each and 5 questions carrying 2 marks each.

• Architecture and Planning (AR) Test Paper

Apart from the General Aptitude (GA) section, the test paper consists of two parts: Part A (60 marks) and Part B (25 marks). Part A is compulsory for all the candidates. Part B contains two parts: Part B1 (Architecture) and Part B2 (Planning). Candidates will have to attempt questions in Part A and questions in either Part B1 or Part B2. The choice of Part B1 or Part B2 can be made during the examination.

Part A consists of 39 questions carrying a total of 60 marks: 18 questions carrying 1 mark each and 21 questions carrying 2 marks each. Part B1 (Architecture) and Part B2 (Planning) consist of 16 questions each carrying a total of 25 marks: 7 questions carrying 1 mark each and 9 questions carrying 2 marks each.

• Geomatics Engineering (GE) Test Paper

Apart from the General Aptitude (GA) section, the question paper consists of two parts: Part A (55 marks) and Part B (30 marks). Part A — Engineering Mathematics and Basic Geomatics is compulsory for all the candidates. Part B contains two components: Part B1 (Surveying and Mapping) and Part B2 (Image Processing and Analysis). Candidates will have to attempt questions in Part A, and questions in either Part B1 or Part B2. The choice of Part B1 or Part B2 can be made during the examination.

Part A consists of 36 questions carrying a total of 55 marks: 17 questions carrying 1 mark each and 19 questions carrying 2 marks each. Part B1 (Surveying and Mapping) and Part B2 (Image Processing and Analysis) consist of 19 questions each, carrying a total of 30 marks: 8 questions carrying 1 mark each and 11 questions carrying 2 marks each.

• Geology and Geophysics (GG) Test Paper

Apart from the General Aptitude (GA) section, the GG question paper consists of two parts: Part A (25 marks) and Part B (60 marks). Part A is compulsory for all the candidates. Part B contains two components: Part B1 (Geology) and Part B2 (Geophysics). Candidates will have to attempt questions from Part A and questions from either Part B1 or Part B2. **The choice of Part B1 or Part B2 must be made at the time of filling the online application form and cannot be made in the examination hall.**

Part A consists of 16 questions carrying a total of 25 marks: 7 questions carrying 1 mark each and 9 questions carrying 2 marks each. Part B1 (Geology) and Part B2 (Geophysics) consists of 39 questions each, carrying a total of 60 marks: 18 questions carrying 1 mark each and 21 questions carrying 2 marks each.

• Engineering Sciences (XE) Test Papers

A candidate appearing in the XE paper must answer the following:

- **General Aptitude (GA)** carrying a total of 15 marks.
- **Section A – Engineering Mathematics (Compulsory):** This section contains 11 questions carrying a total of 15 marks: 7 questions carrying 1 mark each, and 4 questions carrying 2 marks each.
- **Any two of XE Sections B through H:** The choice of two sections from B to H can be made during the examination after viewing the questions. Only two optional sections can be answered at a time. A candidate wishing to change the optional section during the examination must first deselect one of the previously chosen optional sections (B through H). This step will clear the answers, but there will be a message warning the candidate that the answers to the section being deselected will be deleted. Only after the candidate confirms will the answers be deleted and the section deselected. Each of the optional sections of the XE paper (Sections B through H) contains 22 questions carrying a total of 35 marks: 9 questions carrying 1 mark each (sub-total 9 marks) and 13 questions carrying 2 marks each (sub-total 26 marks).

• Humanities and Social Sciences (XH) Test Papers

A candidate appearing in the XH paper must answer the following:

- **General Aptitude (GA)** carrying a total of 15 marks

- **Section B1 – Reasoning and Comprehension (Compulsory):** This section contains 16 questions carrying a total of 25 marks: 7 questions carrying 1 mark each (sub-total 7 marks) and 9 questions carrying 2 marks each (sub-total 18 marks).
- **Any one of XH Sections C1 to C6: The choice of section from C1 to C6 must be made at the time of filling the online application form.** Candidates cannot request for a change of section during the examination. Each of the optional sections of the XH paper (Sections C1 through C6) contains 39 questions carrying a total of 60 marks:18 questions carrying 1 mark each and 21 questions carrying 2 marks each. A candidate wishing to change the optional section during the examination must first deselect one of the previously chosen optional sections (C1 through C6). This step will clear the answers, but there will be a message warning the candidate that the answers to the section being deselected will be deleted.

• Life Sciences (XL) Test Papers

A candidate appearing in the XL paper must answer the following:

- **General Aptitude (GA)** carrying a total of 15 marks.
- **Section P – Chemistry (Compulsory):** This section contains 17 questions carrying a total of 25 marks: 9 questions carrying 1 mark each (sub-total 9 marks) and 8 questions carrying 2 marks each (sub-total 16 marks).
- **Any two of XL Sections Q through U:** The choice of two sections from Q to U can be made during the examination after viewing the questions. Only TWO optional sections can be answered at a time. A candidate wanting to change the optional section must first deselect one of the chosen optional sections (Q to U). Each of the optional sections of the XL paper (Sections Q through U) contains 19 questions carrying a total of 30 marks: 8 questions carrying 1 mark each and 11 questions carrying 2 marks each. A candidate wishing to change the optional section during the examination must first deselect one of the previously chosen optional sections (Q through U). This step will clear the answers, but there will be a message warning the candidate that the answers to the section being deselected will be deleted.

Question papers from previous GATE exams (2007 to 2023) can be downloaded from the Downloads tab of the GATE 2024 website.

13. Post-Examination Related Information

After the GATE 2024 examinations conclude, the candidates' responses will be available in their GATE 2024 account for download. The answer keys will also be displayed on the GATE 2024 website. Candidates may submit their contests against the answer keys during the specified dates subject to payment of a fee. Once the evaluation is finalised, GATE 2024 results will be announced. Qualified candidates can download the Score Card from their GATE 2024 account.

13.1 GATE Score

After evaluating the answers, the actual (raw) marks obtained by a candidate will be considered for computing the GATE score. For multi-session test papers, the raw marks obtained by the candidates in different sessions will be converted to normalised marks for that particular test paper. Thus, raw marks (for single session papers) or normalised marks (for multi-session test papers) will be used for computing the GATE score, based on the qualifying marks.

13.2 Calculation of Normalised Marks for Multi-Session Papers

In GATE 2024, some test papers may be conducted in multiple sessions. For such papers, a suitable normalisation is applied to take into account any variation in the difficulty levels of the question papers across sessions. The normalisation is done based on the assumption that in multi-session GATE papers, the distribution of abilities of candidates is the same across the sessions. This assumption is reasonable since the number of candidates appearing in multi-session papers will be large and the procedure for allocation of candidates to sessions is random. Further, the number of candidates allotted in each session of the multi-session paper is comparable.

Based on these considerations, the following formula is used for calculating the normalised marks for the multi-session papers.

The normalised marks of the j^{th} candidate in the i^{th} session, denoted by $\widehat{M}_{ij}$, are computed as

$$\widehat{M}_{i,j} = \frac{\overline{M}_t^g - M_q^g}{\overline{M}_{ti} - M_{iq}}(M_{ij} - M_{iq}) + M_q^g$$

where

M_{ij} is the actual marks obtained by the j^{th} candidate in the i^{th} session;

$\overline{M}_t^g$ is the average marks of the top 0.1% of the candidates considering all sessions;

M_q^g is the sum of mean and standard deviation marks of the candidates in the paper considering all sessions;

$\overline{M}_{ti}$ is the average marks of the top 0.1% of the candidates in the i^{th} session; and

M_{iq} is the sum of the mean marks and standard deviation marks of the i^{th} session.

13.3 Calculation of GATE Score for All Papers

The GATE 2024 score will be computed using the formula given below.

$$\text{GATE Score} = S_q + (S_t - S_q)\frac{M - M_q}{\overline{M}_t - M_q}$$

where

M is the marks obtained by the candidate (actual marks for single session papers and normalised marks for multi-session papers);

M_q is the qualifying marks for the General Category candidate in the paper;

$\overline{M}_t$ is the mean of marks of top 0.1% or top 10 (whichever is larger) of the candidates who appeared in the paper (in case of multi-session papers including all sessions);

S_q = 350 is the score assigned to M_q ; and

S_t = 900 is the score assigned to $\overline{M}_t$.

In GATE 2024, the qualifying marks M_q for the general category candidate in each subject will be 25 marks (out of 100) or $\mu + \sigma$, whichever is larger, where μ is the mean and σ is the standard deviation of positive marks of all the candidates who appeared for the test paper.

13.4 GATE 2024 Results and Score Cards

GATE 2024 results will be announced on the GATE 2024 website. GATE 2024 Score Cards will be available for download by the qualified candidates. Hard copies of the score card will not be issued. It is recommended that an electronic version of the Score Card be preserved by the candidates for future use. After May 31, 2024 and until December 31, 2024, a fee of ₹ 500 (Rupees five hundred only) per test paper per candidate will be levied for obtaining the Score Card. From January 1, 2025 onward, Score Cards will not be issued for GATE 2024 qualified candidates.

13.5 Contact Information

Candidates are assigned a zone at the time of application, based on the first choice of the exam city. The zonal GATE office contact details are available in Table 1. Any queries regarding the application, examination centre, Admit Card, and results are handled by the respective GATE 2024 zonal institute in consultation with the Organising Institute. Candidates are encouraged to look up the frequently asked questions (FAQs) on the website. If a query is not resolved even after going through the FAQs, then they may contact the zonal GATE office.

Appendix A: Certificate Issuing Authorities

Authorities Empowered to Issue SC/ST Certificates

- District Magistrate/Additional District Magistrate/Collector/Deputy Collector/Deputy Commissioner / Additional Deputy Commissioner/1st Class Stipendiary Magistrate/City Magistrate/Sub-Divisional Magistrate/ Taluk Magistrate/Executive Magistrate/Extra Assistant Commissioner.
- Chief Presidency Magistrate/Additional Chief Presidency Magistrate/Presidency Magistrate.
- Revenue Officer not below the rank of Tahsildar.
- Sub-Divisional Officer of the area where the Candidate and/or her/his family normally resides.
- Administrator/Secretary to Administrator/Development Officer (Lakshadweep Islands). Certificate issued by any other official will NOT be accepted.

Person with Disability (PwD) Category

In order to avail application fee concession under the PwD category, the candidates should attach a recently obtained proper PwD certificate, which is required to be submitted to the admitting institute at the time of admission. Benefit would be given to those who have benchmark disability i.e. not less than 40% impairment irrespective of the type of disability. The onus of verifying PwD certificate lies with the admitting institute. The GATE Committee is NOT responsible for any incorrect declaration of the PwD status of candidates.

Authorities Empowered to Issue 'Certificate of Dyslexia'

A copy of the certificate of Dyslexic condition should be uploaded at the time of online registration to avail the services of scribe. Such a certificate can be obtained from any Dyslexia Association. Some of them are listed below:

- Dyslexia Trust of Kolkata, Divya Jalan, Aruna Bhaskar 3, Dover Park, Kolkata – 700019.
- Dyslexia Association of Andhra Pradesh (DAAP), 3-4-494/1, 1st Floor, Macherla Gastrology Hospital, Reddy College Road, Barkatpura, Hyderabad, Telangana, 500027.
- Madras Dyslexia Association, 94 Park View, 1st Floor, G.N. Chetty Road, T. Nagar, Chennai –600017.
- Maharashtra Dyslexia Association, 003, Amit Park Bldg, L J Road, Deonar, Mumbai 400088.
- The Dyslexia Association of India, MZ-47, The Center Stage Mall, Plot No 01, Block L, Sector 18, NOIDA, 201303.

PwD candidates may consult Unique Disability ID scheme of Ministry of Social Justice and Empowerment, Government of India for more information.

Appendix B: Code of Conduct for GATE 2024 Examination

Candidates appearing for GATE 2024 must strictly comply with the following code of conduct:

- Candidates appearing for GATE 2024 examination must carry Admit Card and original valid photo-identity proof (used at the time of registration) inside the examination hall.
- Scribble pad will be provided to the candidate for rough work in the examination hall by the invigilator. Candidates must write their name and registration number on the scribble pad before they start using it. The candidate can possess only one scribble pad at any point of time. Before taking the next scribble pad, the previous scribble pad must be returned to the invigilator. Any scribble pad in the possession of the candidate must be returned to the invigilators after the end of the examination.
- Carrying mobile phones (even in the switched-off mode), watches of any form and calculators inside the examination hall is strictly prohibited.
- Carrying any electronic/communication devices, wallets, papers, loose sheets, pen/pencil box/pouch, and printed or hand-written textual materials, inside the examination hall is strictly prohibited.
- All means and modes of communication, verbal or otherwise, among the candidates inside the examination hall are strictly prohibited.
- If any of the prohibited acts or items listed above is detected during the examination, it will automatically lead to cancellation of candidature. Results will not be declared for such candidates.
- The GATE Examination Body comprising Organising Institute and Zonal Institutes will not take any responsibility regarding safety and security of mobile phones/electronic devices/any kind of valuables belonging to candidates.
- Candidates must not tamper with the computer and the related hardware provided in the examination hall. Candidates found tampering the computers will have their candidature cancelled summarily. In addition, appropriate legal action may be initiated against such candidates.
- Candidates found using unfair means and not complying with the code of conduct and ethics of GATE 2024 will have their candidature cancelled regardless of whether they have been allowed to complete their examination or not. Appropriate legal action may be initiated against all such candidates.

14. Syllabus of Test Papers

GA General Aptitude

Verbal Aptitude

Basic English grammar: tenses, articles, adjectives, prepositions, conjunctions, verb-noun agreement, and other parts of speech Basic vocabulary: words, idioms, and phrases in context.

Reading and comprehension, Narrative sequencing.

Quantitative Aptitude

Data interpretation: data graphs (bar graphs, pie charts, and other graphs representing data), 2- and 3-dimensional plots, maps, and tables Numerical computation and estimation: ratios, percentages, powers, exponents and logarithms, permutations and combinations, and series Mensuration and geometry Elementary statistics and probability.

Analytical Aptitude

Logic: deduction and induction, Analogy, Numerical relations and reasoning.

Spatial Aptitude

Transformation of shapes: translation, rotation, scaling, mirroring, assembling, and grouping paper folding, cutting, and patterns in 2 and 3 dimensions.

AE Aerospace Engineering

In each of the following subjects, the topics have been divided into two categories – Core Topics and Special Topics. The corresponding sections of the question paper will contain 90% of the questions on Core Topics and the remaining 10% on Special Topics.

Section1: Engineering Mathematics

Core Topics

Linear Algebra: Vector algebra, Matrix algebra, systems of linear equations, rank of a matrix, eigen values and eigen vectors.

Calculus: Functions of single variable, limits, continuity and differentiability, mean value theorem, chain rule, partial derivatives, maxima and minima, gradient, divergence and curl, directional derivatives. Integration, Line, surface and volume integrals. Theorems of Stokes, Gauss and Green.

Differential Equations: First order linear and nonlinear differential equations, higher order linear ODEs with constant coefficients. Partial differential equations and separation of variables methods.

Special Topics

Fourier Series, Laplace Transforms, Numerical methods for linear and nonlinear algebraic equations, Numerical integration and differentiation. Complex analysis. Probability and statistics.

Section 2: Flight Mechanics

Core Topics (Basics)

Atmosphere: Properties, standard atmosphere. Classification of aircraft. Airplane (fixed wing aircraft) configuration and various parts. Pressure altitude; equivalent, calibrated, indicated air speeds; Primary flight instruments: Altimeter, ASI, VSI, Turn-bank indicator. Angle of attack, sideslip; Roll, pitch & yaw controls. Aerodynamic forces and moments.

Airplane performance: Drag polar; take-off and landing; steady climb and descent; absolute and service ceiling; range and endurance, load factor, turning flight, V-n diagram. Winds: head, tail and cross winds.

Static stability: Stability and control derivatives; longitudinal stick fixed and free stability; horizontal tail position and size; directional stability, vertical tail position and size; lateral stability. Wing dihedral, sweep & position; hinge moments, stick forces.

Special Topics

Dynamic stability: Euler angles; Equations of motion; Decoupling of longitudinal and lateral-directional dynamics; longitudinal modes; lateral-directional modes.

Section 3: Space Dynamics

Core Topics

Central force motion, determination of trajectory and orbital period in simple cases. Kepler's laws; escape velocity.

Special Topics: None

Section 4: Aerodynamics

Core Topics

Basic Fluid Mechanics: Conservation laws: Mass, momentum and energy (Integral and differential form); Dimensional analysis and dynamic similarity;

Potential flow theory: sources, sinks, doublets, line vortex and their superposition. Elementary ideas of viscous flows including boundary layers.

Airfoils and wings: Airfoil nomenclature; Aerodynamic coefficients: lift, drag and moment; Kutta-Joukoswki theorem; Thin airfoil theory, Kutta condition, starting vortex; Finite wing theory: Induced drag, Prandtl lifting line theory; Critical and drag divergence Mach number.

Compressible Flows: Basic concepts of compressibility, One-dimensional compressible flows, Isentropic flows, Fanno flow, Rayleigh flow; Normal and oblique shocks, Prandtl-Meyer flow; Flow through nozzles and diffusers.

Special Topics

Wind Tunnel Testing: Measurement and visualization techniques. Shock - boundary layer interaction.

Section 5: Structures

Core Topics

Strength of Materials: Stress and strain: Three-dimensional transformations, Mohr's circle, principal stresses, Three-dimensional Hooke's law, Plane stress and strain. Failure theories: Maximum stress, Tresca von Mises. Strain energy. Castigliano's principles. Statically determinate and indeterminate trusses and beams. Elastic flexural buckling of columns.

Flight vehicle structures: Characteristics of aircraft structures and materials. Torsion, bending and shear of thin-walled sections. Loads on aircraft.

Structural Dynamics: Free and forced vibrations of undamped and damped SDOF systems. Free vibrations of undamped 2-DOF systems.

Special Topics

Vibration of beams. Theory of elasticity: Equilibrium and compatibility equations, Airy's stress function.

Section 6: Propulsion

Core Topics

Basics: Thermodynamics, boundary layers, heat transfer, combustion and thermo chemistry.

Aerothermodynamics of aircraft engines: Thrust, efficiency, range. Brayton cycle.

Engine performance: Ramjet, turbojet, turbofan, turboprop and turboshaft engines. After burners.

Turbomachinery: Axial compressors: Angular momentum, work and compression, characteristic performance of a single axial compressor stage, efficiency of the compressor and degree of reaction, multi-staging.

Centrifugal compressor: Stage dynamics, inducer, impeller and diffuser.

Axial turbines: Stage performance.

Rockets: Thrust equation and specific impulse, rocket performance. Multi-staging. Chemical rockets. Performance of solid and liquid propellant rockets.

Special Topics

Aerothermodynamics of non-rotating propulsion components such as intakes, combustor and nozzle. Turbine blade cooling. Compressor-turbine matching, Surge and stall.

AG Agricultural Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrices and determinants, linear and orthogonal transformations, Caley Hamilton theorem; Eigen values and Eigen vectors, solutions of linear equations.

Calculus: Limit, continuity and differentiability; partial derivatives; homogeneous function – Euler's theorem on homogeneous functions, total differentiation; maxima and minima of function with several independent variables; sequences and series – infinite series, tests for convergence; Fourier, Taylor and MacLaurin series.

Vector Calculus: Vector differentiation, scalar and vector point functions, vector differential operators – del, gradient; divergence and curl; physical interpretations-line, surface and volume integrals; Stokes, Gauss and Green's theorems.

Differential Equations: Linear and non-linear first order Ordinary Differential Equations (ODE); homogeneous differential equations, higher order linear ODEs with constant coefficients; Laplace transforms and their inverse; Partial Differential Equations - Laplace, heat and wave equations.

Probability and Statistics: Mean, median, mode and standard deviation; random variables; Poisson, normal and binomial distributions; correlation and regression analysis.

Numerical Methods: Solutions of linear and non-linear algebraic equations; numerical integration - trapezoidal and Simpson's rule; numerical solutions of ODEs.

Section 2: Farm Machinery

Machine Design: Design and selection of machine elements – gears, pulleys, chains and sprockets and belts; overload safety devices used in farm machinery; measurement of force, stress, torque, speed, displacement and acceleration on machine elements - shafts, couplings, keys, bearings and knuckle joints.

Farm Machinery: Soil tillage; forces acting on a tillage tool; hitch systems and hitching of tillage implements; functional requirements, principles of working, construction and operation of manual, animal and power operated equipment for tillage, sowing, planting, fertilizer application, inter-cultivation, spraying, mowing, chaff cutting, harvesting and threshing calculation of performance parameters - field capacity, efficiency, application rate and losses; cost analysis of implements and tractors.

Section 3: Farm Power

Sources of Power: Sources of power on the farm — human, animal, mechanical, electrical, wind, solar and biomass; bio-fuels.

Farm Power: Thermodynamic principles of I.C. engines; I.C. engine cycles; engine components; fuels and combustion; lubricants and their properties; I.C. engine systems – fuel, cooling, lubrication, ignition, electrical, intake and exhaust; selection, operation, maintenance and repair of I.C. engines; power efficiencies and measurement; calculation of power, torque, fuel consumption, heat load and power losses; performance index, cost analysis of implements and tractors.

Tractors and Power tillers: Type, selection, maintenance and repair of tractors and power tillers; tractor clutches and brakes; power transmission systems – gear trains, differential, final drives and power take-off; mechanics of tractor chassis; traction theory; three point hitches - free link and restrained link operations;

steering and hydraulic control systems used in tractors; tractor tests and performance; human engineering and safety considerations in design of tractor and agricultural implements.

Section 4: Soil and Water Conservation Engineering

Fluid Mechanics: Ideal and real fluids, properties of fluids; hydrostatic pressure and its measurement; continuity equation, kinematics and dynamics of flow; Bernoulli's theorem; laminar and turbulent flow in pipes, Darcy-Weisbach and Hazen-Williams equations, Moody's diagram; flow through orifices, weirs and notches; flow in open channels, dimensional analysis – concepts of geometric dimensionless numbers.

Soil Mechanics: Engineering properties of soils; fundamental definitions and relationships; index properties of soils; permeability and seepage analysis; shear strength, Mohr's circle of stress, active and passive earth pressures; stability of slopes, Terzaghi's one dimensional soil consolidation theory.

Hydrology: Hydrological cycle and measurement of its components; meteorological parameters and their measurement; analysis of precipitation data; runoff estimation; hydrograph analysis, unit hydrograph theory and application; stream flow measurement; flood routing, hydrological reservoir and channel routing, Infiltration – indices and equations, drought and its classification.

Surveying and Leveling: Measurement of distance and area; instruments for surveying and levelling; chain surveying, methods of traversing; measurement of angles and bearings, plane table surveying; types of levelling; the odolite traversing; contouring; total station, introduction to GPS survey, computation of areas and volume.

Soil and Water Erosion: Mechanics of soil erosion - wind and water erosion: soil erosion types, factors affecting erosion; soil loss estimation; biological and engineering measures to control erosion; terraces and bunds; vegetative waterways; gully control structures, drop, drop inlet and chute spillways; earthen dams.

Watershed Management: Watershed characterization and land use capability classification; water budgeting in watershed, rainwater harvesting, check dams and farm ponds.

Section 5: Irrigation and Drainage Engineering

Soil-Water-Plant Relationship: Water requirement of crops; consumptive use and evapotranspiration; measurement of infiltration, soil moisture and irrigation water infiltration.

Irrigation Water Conveyance and Application Methods: Design of irrigation channels and underground pipelines; irrigation scheduling; surface, sprinkler and micro irrigation methods, design and evaluation of irrigation methods; irrigation efficiencies.

Agricultural Drainage: Drainage coefficient; planning, design and layout of surface and sub-surface drainage systems; leaching requirement and salinity control; irrigation and drainage water quality and reuse; non-conventional drainage system.

Groundwater Hydrology: Groundwater occurrence; Darcy's Law, steady and unsteady flow in confined and unconfined aquifers, groundwater exploration techniques; overview of groundwater recharge estimation and artificial recharge techniques.

Wells and Pumps: Types of wells, steady flow through wells; design and construction of water wells; classification of pumps; pump characteristics; pump selection and installation.

Section 6: Agricultural Process Engineering

Engineering properties of agriculture produce: Physical, thermal, frictional, rheological and electrical properties.

Evaporation and Drying: Concentration and drying of liquid foods – evaporators, tray, drum and spray dryers; hydrothermal treatments; drying and milling of cereals, pulses and oilseeds; drying kinetics; psychrometry – properties of air-water vapor mixture.

Size Reduction and Material Handling: Mechanics and energy requirement in size reduction of agriculture produce; particle size analysis for comminuted solids; size separation by screening; fluidization of granular solids-pneumatic, bucket, screw and belt conveying; cleaning and grading; effectiveness of separation; centrifugal separation of solids, liquids and gases; homogenization; filtration and membrane separation.

Processing of Agriculture Produce: Processing of seeds, spices, fruits and vegetables; value addition of agriculture produce.

Storage Systems: Controlled and modified atmosphere storage; perishable food storage, godowns, bins and grain silos, packaging material and machines.

Section 7: Dairy and Food Engineering

Heat and Mass Transfer: Steady state heat transfer in conduction, convection and radiation; transient heat transfer in simple geometry; working principles of heat exchangers; diffusive and convective mass transfer; simultaneous heat and mass transfer in agricultural processing operations; material and energy balances in food processing systems; water activity, sorption and desorption isotherms.

Preservation of Food: Kinetics of microbial death – pasteurization and sterilization of milk and other liquid foods; preservation of food by cooling and freezing; refrigeration and cold storage basics and applications.

AR Architecture and Planning

Part A: Common

Section 1: Architecture, Planning and Design

Architectural Graphics; Visual composition in 2D and 3D; Computer application in Architecture and Planning; Anthropometrics; Organization of space; Circulation- horizontal and vertical; Space Standards; Universal design; Building byelaws; Codes and standards.

Section 2: Construction and Management

Project management techniques e.g. PERT, CPM etc.; Estimation and Specification; Professional practice and ethics; Form and Structure; Principles and design of disaster resistant structures; Temporary structures for rehabilitation.

Section 3: Environmental Planning and Design

Natural and man-made ecosystem; Ecological principles; Environmental considerations in Planning and design; Environmental pollution- types, causes, controls and abatement strategies; Sustainable development, goals and strategies; Climate change and built environment; Climate responsive design.

Section 4: Urban Design, landscape and Conservation

Historical and modern examples of urban design; Elements of urban built environment – urban form, spaces, structure, pattern, fabric, texture, grain etc.; Concepts and theories of urban design; Principles, tools and techniques of urban design; Public spaces, character, spatial qualities and Sense of Place; Urban design interventions for sustainable development and transportation; Development controls – FAR, densities and building byelaws; Urban renewal and conservation; heritage conservation; historical public spaces and gardens; Landscape design; Site planning.

Section 5: Planning process

Salient concepts, theories and principles of urban planning; concepts of cities - Eco-City, Smart City; Concepts and theories by trendsetting planners and designers; Ekistics; Urban sociology; Social, Economic and environmental cost benefit analysis; Methods of non-spatial and spatial data analysis; Development guidelines such as URDPFI.

Section 6: Housing

Housing typologies; Concepts, principles and examples of neighbourhood; Residential densities; Affordable Housing; Real estate valuation.

Section 7: Services and Infrastructure

Fire fighting Systems; Building Safety and Security systems; Building Management Systems; Water treatment; Water supply and distribution system; Water harvesting systems; Principles, Planning and Design of storm water drainage system; Sewage disposal methods; Methods of solid waste management - collection, transportation and disposal; Recycling and Reuse of solid waste; Land-use – transportation - urban form inter-relationships; Design of roads, intersections, grade separators and parking areas; Hierarchy of roads and level of service; Para-transits and other modes of transportation, Pedestrian and slow moving traffic planning.

Part B1: Architecture

Section B1.1: History and Contemporary Architecture

Principles of Art and Architecture; World History of Architecture: Egyptian, Greco-Roman classical period, Byzantine, Gothic, Renaissance, Baroque-Rococo, etc.; Recent trends in Contemporary Architecture: Art nouveau, Art Deco, Eclecticism, International styles, Post Modernism, Deconstruction in architecture, etc.; Influence of Modern art and Design in Architecture; Indian vernacular and traditional Architecture, Oriental Architecture; Works of renowned national and international architects.

Section B1.2: Building Construction and Structural systems

Building construction techniques, methods and details; Building systems and prefabrication of building elements; Principles of Modular Coordination; Construction planning and equipment; Building material characteristics and applications; Principles of strength of materials; Alternative building materials; Foundations; Design of structural elements with different materials; Elastic and Limit State design; Structural systems; Principles of Pre-stressing; High Rise and Long Span structures, gravity and lateral load resisting systems.

Section B1.3: Building Services and Sustainability

Solar architecture; Thermal, visual and acoustic comfort in built environments; Natural and Mechanical ventilation in buildings; Air-Conditioning systems; Sustainable building strategies; Building Performance Simulation and Evaluation; Intelligent Buildings; Water supply; Sewerage and drainage systems; Sanitary fittings and fixtures; Plumbing systems; Principles of internal and external drainage system; Principles of electrification of buildings; Elevators and Escalators - standards and uses.

Part B2: Planning

Section B2.1: Regional and Settlement Planning

Regional delineation; settlement hierarchy; Types and hierarchy of plans; Various schemes and programs of central government; Transit Oriented Development (TOD), SEZ, SRZ etc.; Public Perception and user behaviour; National Housing Policies, Programs and Schemes; Slums, Squatters and informal housing; Standards for housing and community facilities; Housing for special areas and needs.

Section B2.2: Planning Techniques and Management

Application of G.I.S and Remote Sensing techniques in urban and regional planning; Tools and techniques of Surveys – Physical, Topographical, Land use and Socio-economic Surveys; Urban Economics, Law of demand and supply of land and its use in planning; Graphic presentation of spatial data; Local self-governance, Panchayatiraj institutions; Planning Legislation and implementation – Land Acquisition Act, PPP etc.; Decision support system and Land Information System; Urban geography and econometrics; Management of Infrastructure Projects; Demography and equity in planning.

Section B2.3: Infrastructure Planning

Process and Principles of Transportation Planning and Traffic Engineering; Road capacity and Travel demand forecasting; Traffic survey methods, Traffic flow Analysis; Traffic analyses and design considerations; Traffic and transport management and control in urban areas; Mass transportation planning; Intelligent Transportation Systems; Urban and Rural Infrastructure System Network.

BM Biomedical Engineering

Engineering Mathematics

Linear Algebra: Matrix algebra, systems of linear equations, Eigenvalues and Eigenvectors.

Calculus: Mean value theorems, theorems of integral calculus, partial derivatives, maxima and minima, multiple integrals, Fourier series, vector identities, line, surface and volume integrals, Stokes, Gauss and Green's theorems.

Differential equations: First order linear and nonlinear differential equations, higher order linear differential equations with constant coefficients, method of separation of variables, Cauchy's and Euler's equations, initial and boundary value problems, and solution of partial differential equations.

Analysis of complex variables: Analytic functions, Cauchy's integral theorem and integral formula, Taylor's and Laurent's series, residue theorem.

Probability and Statistics: Sampling theorems, conditional probability, mean, median, mode and standard deviation, random variables, discrete and continuous distributions: normal, Poisson and binomial distributions. Tests of Significance, statistical power analysis, and sample size estimation. Linear Regression and correlation analysis;

Numerical Methods: Matrix inversion, numerical solutions of nonlinear algebraic equations, iterative methods for solving differential equations, numerical integration.

Electrical Circuits

Voltage and current sources - independent, dependent, ideal and practical; v-i relationships of resistor, inductor and capacitor; transient analysis of RLC circuits with dc excitation; Kirchoff's laws, superposition, Thevenin, Norton, maximum power transfer and reciprocity theorems; Peak, average and rms values of ac quantities; apparent, active and reactive powers; phasor analysis, impedance and admittance; series and parallel resonance, realization of basic filters with R, L and C elements, Bode plot.

Signals and Systems

Continuous and Discrete Signal and Systems - Periodic, a periodic and impulse signals; Sampling theorem; Laplace and Fourier transforms; impulse response of systems; transfer function, frequency response of first and second order linear time invariant systems, convolution, correlation. Discrete time systems - impulse response, frequency response, DFT, Z - transform; basics of IIR and FIR filter.

Analog and Digital Electronics

Basic characteristics and applications of diode, BJT and MOSFET; Characteristics and applications of operational amplifiers - difference amplifier, adder, subtractor, integrator, differentiator, instrumentation amplifier, buffer, filters and waveform generators. Number systems, Boolean algebra; combinational logic circuits - arithmetic circuits, comparators, Schmitt trigger, encoder/decoder, MUX/DEMUX, multi-vibrators; Sequential circuits - latches and flip flops, state diagrams, shift registers and counters; Principles of ADC and DAC; Microprocessor- architecture, interfacing memory and input- output devices.

Measurements and Control Systems

SI units, systematic and random errors in measurement, expression of uncertainty - accuracy and precision index, propagation of errors; PMMC, MI and dynamometer type instruments; DC potentiometer; bridges for measurement of R, L and C, Q-meter. Basics of control system - transfer function.

Sensors and Bioinstrumentation

Sensors - resistive, capacitive, inductive, piezoelectric, Hall effect, electro chemical, optical; Sensor signal conditioning circuits; application of LASER in sensing and therapy. Origin of bio potentials and their measurement techniques - ECG, EEG, EMG, ERG, EOG, GSR, PCG, Principles of measuring blood pressure, body temperature, volume and flow in arteries, veins and tissues, respiratory measurements and cardiac output measurement. Operating principle of medical equipment-sphygmomanometer, ventilator, cardiac pacemaker, defibrillator, pulse oximeter, hemodialyzer Electrical Isolation (optical and electrical) and Safety of Biomedical Instruments.

Human Anatomy and Physiology

Basics of cell, types of tissues and organ systems; Homeostasis; Basics of organ systems - musculoskeletal, respiratory, circulatory, excretory, endocrine, nervous, gastro-intestinal and reproductive.

Medical Imaging Systems

Basic physics, Instrumentation and image formation techniques in medical imaging modalities such as X-Ray, Computed Tomography, Single Photon Emission Computed Tomography, Positron Emission Tomography, Magnetic Resonance Imaging, Ultrasound.

Biomechanics

Kinematics of muscles and joints - free-body diagrams and equilibrium, forces and stresses in joints, biomechanical analysis of joints, Gait analysis; Hard Tissues - Definition of Stress and Strain, Deformation Mechanics, structure and mechanical properties of bone - cortical and cancellous bones; Soft Tissues - Structure, functions, material properties, visco elastic properties, Maxwell & Voight models; Biofluid mechanics - Flow properties of blood in the intact human cardiovascular system.

Biomaterials

Basic properties of biomaterials - Metallic, Ceramic, Polymeric and Composite; Fundamental characteristics of implants - biocompatibility, bioactivity, biodegradability; Basics of drug delivery; Basics of tissue engineering. Biomaterial characterization techniques - Rheology, Atomic Force Microscopy, Electron Microscopy, Transmission Electron Microscopy Fourier Transform Infrared Spectroscopy.

BT Biotechnology

Section 1: Engineering Mathematics

Linear Algebra: Matrices and determinants; Systems of linear equations; Eigen values and Eigen vectors.

Calculus: Limits, continuity and differentiability; Partial derivatives, maxima and minima; Sequences and series; Test for convergence.

Differential Equations: Linear and nonlinear first order ODEs, higher order ODEs with constant coefficients; Cauchy's and Euler's equations; Laplace transforms.

Probability and Statistics: Mean, median, mode and standard deviation; Random variables; Poisson, normal and binomial distributions; Correlation and regression analysis.

Numerical Methods: Solution of linear and nonlinear algebraic equations; Integration by trapezoidal and Simpson's rule; Single step method for differential equations.

Section 2: General Biology

Biochemistry: Biomolecules - structure and function; Biological membranes - structure, membrane channels and pumps, molecular motors, action potential and transport processes; Basic concepts and regulation of metabolism of carbohydrates, lipids, amino acids and nucleic acids; Photosynthesis, respiration and electron transport chain. Enzymes - Classification, catalytic and regulatory strategies; Enzyme kinetics - Michaelis-Menten equation; Enzyme inhibition - competitive, non-competitive and uncompetitive inhibition.

Microbiology: Bacterial classification and diversity; Microbial Ecology - microbes in marine, fresh water and terrestrial ecosystems; Microbial interactions; Viruses - structure and classification; Methods in microbiology; Microbial growth and nutrition; Nitrogen fixation; Microbial diseases and host-pathogen interactions; Antibiotics and antimicrobial resistance.

Immunology: Innate and adaptive immunity, humoral and cell mediated immunity; Antibody structure and function; Molecular basis of antibody diversity; T cell and B cell development; Antigen-antibody reaction; Complement; Primary and secondary lymphoid organs; Major histocompatibility complex (MHC); Antigen processing and presentation; Polyclonal and monoclonal antibody; Regulation of immune response; Immune tolerance; Hypersensitivity; Autoimmunity; Graft versus host reaction; Immunization and vaccines.

Section 3: Genetics, Cellular and Molecular Biology

Genetics and Evolutionary Biology: Mendelian inheritance; Gene interaction; Complementation; Linkage, recombination and chromosome mapping; Extra chromosomal inheritance; Microbial genetics - transformation, transduction and conjugation; Horizontal gene transfer and transposable elements; Chromosomal variation; Genetic disorders; Population genetics; Epigenetics; Selection and inheritance; Adaptive and neutral evolution; Genetic drift; Species and speciation.

Cell Biology: Prokaryotic and eukaryotic cell structure; Cell cycle and cell growth control; Cell-cell communication; Cell signalling and signal transduction; Post-translational modifications; Protein trafficking; Cell death and autophagy; Extra-cellular matrix.

Molecular Biology: Molecular structure of genes and chromosomes; Mutations and mutagenesis; Regulation of gene expression; Nucleic acid - replication, transcription, splicing, translation and their regulatory mechanisms; Non-coding and micro RNA; RNA interference; DNA damage and repair.

Section 4: Fundamentals of Biological Engineering

Engineering Principles Applied to Biological Systems: Material and energy balances for reactive and non-reactive systems; Recycle, bypass and purge processes; Stoichiometry of growth and product formation; Degree of reduction, electron balance and theoretical oxygen demand.

Classical Thermodynamics and Bioenergetics: Laws of thermodynamics; Solution thermodynamics; Phase equilibria, reaction equilibria; Ligand binding; Membrane potential; Energetics of metabolic pathways, oxidation and reduction reactions.

Transport Processes: Newtonian and non-Newtonian fluids, fluid flow - laminar and turbulent; Mixing in bioreactors, mixing time; Molecular diffusion and film theory; Oxygen transfer and uptake in bioreactor, k_La and its measurement; Conductive and convective heat transfer, LMTD, overall heat transfer coefficient; Heat exchangers.

Section 5: Bioprocess Engineering and Process Biotechnology

Bioreaction Engineering: Rate law, zero and first order kinetics; Ideal reactors - batch, mixed flow and plug flow; Enzyme immobilization, diffusion effects - Thiele modulus, effectiveness factor, Damkoehler number; Kinetics of cell growth, substrate utilization and product formation; Structured and unstructured models; Batch, fed-batch and continuous processes; Microbial and enzyme reactors; Optimization and scale up.

Upstream and Downstream Processing: Media formulation and optimization; Sterilization of air and media; Filtration - membrane filtration, ultra filtration; Centrifugation - high speed and ultra; Cell disruption; Principles of chromatography - ion exchange, gel filtration, hydrophobic interaction, affinity, GC, HPLC and FPLC; Extraction, adsorption and drying.

Instrumentation and Process Control: Pressure, temperature and flow measurement devices; Valves; First order and second order systems; Feedback and feed forward control; Types of controllers – proportional, derivative and integral control, tuning of controllers.

Section 6: Plant, Animal and Microbial Biotechnology

Plants: Totipotency; Regeneration of plants; Plant growth regulators and elicitors; Tissue culture and cell suspension culture system - methodology, kinetics of growth and nutrient optimization; Production of secondary metabolites; Hairy root culture; Plant products of industrial importance; Artificial seeds; Somaclonal variation; Protoplast, protoplast fusion - somatic hybrid and cybrid; Transgenic plants - direct and indirect methods of gene transfer techniques; Selection marker and reporter gene; Plastid transformation.

Animals: Culture media composition and growth conditions; Animal cell and tissue preservation; Anchorage and non-anchorage dependent cell culture; Kinetics of cell growth; Micro & macro-carrier culture; Hybridoma technology; Stem cell technology; Animal cloning; Transgenic animals; Knock-out and knock-in animals.

Microbes: Production of biomass and primary/secondary metabolites - Biofuels, bioplastics, industrial enzymes, antibiotics; Large scale production and purification of recombinant proteins and metabolites; Clinical-, food- and industrial- microbiology; Screening strategies for new products.

Section 7: Recombinant DNA technology and Other Tools in Biotechnology

Recombinant DNA technology: Restriction and modification enzymes; Vectors - plasmids, bacteriophage and other viral vectors, cosmids, Ti plasmid, bacterial and yeast artificial chromosomes; Expression vectors; cDNA and genomic DNA library; Gene isolation and cloning, strategies for production of recombinant proteins; Transposons and gene targeting.

Molecular tools: Polymerase chain reaction; DNA/RNA labelling and sequencing; Southern and northern blotting; In-situ hybridization; DNA fingerprinting, RAPD, RFLP; Site-directed mutagenesis; Gene transfer technologies; CRISPR-Cas; Biosensing and biosensors.

Analytical tools: Principles of microscopy - light, electron, fluorescent and confocal; Principles of spectroscopy - UV, visible, CD, IR, fluorescence, FT-IR, MS, NMR; Electrophoresis; Micro-arrays; Enzymatic assays; Immunoassays - ELISA, RIA, immunohistochemistry; immunoblotting; Flow cytometry; Whole genome and ChIP sequencing.

Computational tools: Bioinformatics resources and search tools; Sequence and structure databases; Sequence analysis - sequence file formats, scoring matrices, alignment, phylogeny; Genomics, proteomics, metabolomics; Gene prediction; Functional annotation; Secondary structure and 3D structure prediction; Knowledge discovery in biochemical databases; Metagenomics; Metabolic engineering and systems biology.

CE Civil Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra; Systems of linear equations; eigen values and eigen vectors.

Calculus: Functions of single variable; Limit, continuity and differentiability; Mean value theorems, local maxima and minima; Taylor series; Evaluation of definite and indefinite integrals, application of definite integral to obtain area and volume; Partial derivatives; Total derivative; Gradient, Divergence and Curl, Vector identities; Directional derivatives; Line, Surface and Volume integrals.

Ordinary Differential Equation (ODE): First order (linear and non-linear) equations; higher order linear equations with constant coefficients; Euler-Cauchy equations; initial and boundary value problems.

Partial Differential Equation (PDE): Fourier series; Separation of variables; solutions of one- dimensional diffusion equation; first and second order one-dimensional wave equation and two-dimensional Laplace equation.

Probability and Statistics: Sampling theorems; Conditional probability; Descriptive statistics – Mean, median, mode and standard deviation; Random Variables – Discrete and Continuous, Poisson and Normal Distribution; Linear regression.

Numerical Methods: Error analysis. Numerical solutions of linear and non-linear algebraic equations; Newton's and Lagrange polynomials; numerical differentiation; Integration by trapezoidal and Simpson's rule; Single and multi-step methods for first order differential equations.

Section 2: Structural Engineering

Engineering Mechanics: System of forces, free-body diagrams, equilibrium equations; Internal forces in structures; Frictions and its applications; Centre of mass; Free Vibrations of undamped SDOF system.

Solid Mechanics: Bending moment and shear force in statically determinate beams; Simple stress and strain relationships; Simple bending theory, flexural and shear stresses, shear centre; Uniform torsion, Transformation of stress; buckling of column, combined and direct bending stresses.

Structural Analysis: Statically determinate and indeterminate structures by force/ energy methods; Method of superposition; Analysis of trusses, arches, beams, cables and frames; Displacement methods: Slope deflection and moment distribution methods; Influence lines; Stiffness and flexibility methods of structural analysis.

Construction Materials and Management: Construction Materials: Structural Steel – Composition, material properties and behaviour; Concrete - Constituents, mix design, short-term and long-term properties. Construction Management: Types of construction projects; Project planning and network analysis - PERT and CPM; Cost estimation.

Concrete Structures: Working stress and Limit state design concepts; Design of beams, slabs, columns; Bond and development length; Prestressed concrete beams.

Steel Structures: Working stress and Limit state design concepts; Design of tension and compression members, beams and beam- columns, column bases; Connections - simple and eccentric, beam-column connections, plate girders and trusses; Concept of plastic analysis -beams and frames.

Section 3: Geotechnical Engineering

Soil Mechanics: Three-phase system and phase relationships, index properties; Unified and Indian standard soil classification system; Permeability - one dimensional flow, Seepage through soils – two - dimensional flow, flow nets, uplift pressure, piping, capillarity, seepage force; Principle of effective stress and quicksand condition; Compaction of soils; One- dimensional consolidation, time rate of consolidation; Shear Strength, Mohr's circle, effective and total shear strength parameters, Stress-Strain characteristics of clays and sand; Stress paths.

Foundation Engineering: Sub-surface investigations - Drilling bore holes, sampling, plate load test, standard penetration and cone penetration tests; Earth pressure theories - Rankine and Coulomb; Stability of slopes – Finite and infinite slopes, Bishop's method; Stress distribution in soils – Boussinesq's theory; Pressure bulbs, Shallow foundations – Terzaghi's and Meyerhoff's bearing capacity theories, effect of water table; Combined footing and raft foundation; Contact pressure; Settlement analysis in sands and clays; Deep foundations – dynamic and static formulae, Axial load capacity of piles in sands and clays, pile load test, pile under lateral loading, pile group efficiency, negative skin friction.

Section 4: Water Resources Engineering

Fluid Mechanics: Properties of fluids, fluid statics; Continuity, momentum and energy equations and their applications; Potential flow, Laminar and turbulent flow; Flow in pipes, pipe networks; Concept of boundary layer and its growth; Concept of lift and drag.

Hydraulics: Forces on immersed bodies; Flow measurement in channels and pipes; Dimensional analysis and hydraulic similitude; Channel Hydraulics - Energy-depth relationships, specific energy, critical flow, hydraulic jump, uniform flow, gradually varied flow and water surface profiles.

Hydrology: Hydrologic cycle, precipitation, evaporation, evapo-transpiration, watershed, infiltration, unit hydrographs, hydrograph analysis, reservoir capacity, flood estimation and routing, surface run-off models, ground water hydrology - steady state well hydraulics and aquifers; Application of Darcy's Law.

Irrigation: Types of irrigation systems and methods; Crop water requirements - Duty, delta, evapo-transpiration; Gravity Dams and Spillways; Lined and unlined canals, Design of weirs on permeable foundation; cross drainage structures.

Section 5: Environmental Engineering

Water and Waste Water Quality and Treatment: Basics of water quality standards – Physical, chemical and biological parameters; Water quality index; Unit processes and operations; Water requirement; Water distribution system; Drinking water treatment.

Sewerage system design, quantity of domestic wastewater, primary and secondary treatment. Effluent discharge standards; Sludge disposal; Reuse of treated sewage for different applications.

Air Pollution: Types of pollutants, their sources and impacts, air pollution control, air quality standards, Air quality Index and limits.

Municipal Solid Wastes: Characteristics, generation, collection and transportation of solid wastes, engineered systems for solid waste management (reuse/ recycle, energy recovery, treatment and disposal).

Section 6: Transportation Engineering

Transportation Infrastructure: Geometric design of highways - cross-sectional elements, sight distances, horizontal and vertical alignments.

Geometric design of railway Track – Speed and Cant.

Concept of airport runway length, calculations and corrections; taxiway and exit taxiway design.

Highway Pavements: Highway materials - desirable properties and tests; Desirable properties of bituminous paving mixes; Design factors for flexible and rigid pavements; Design of flexible and rigid pavement using IRC codes.

Traffic Engineering: Traffic studies on flow and speed, peak hour factor, accident study, statistical analysis of traffic data; Microscopic and macroscopic parameters of traffic flow, fundamental relationships; Traffic signs; Signal design by Webster's method; Types of intersections; Highway capacity.

Section 7: Geomatics Engineering

Principles of surveying; Errors and their adjustment; Maps - scale, coordinate system; Distance and angle measurement - Levelling and trigonometric levelling; Traversing and triangulation survey; Total station; Horizontal and vertical curves.

Photogrammetry and Remote Sensing - Scale, flying height; Basics of remote sensing and GIS.

CH Chemical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra, Systems of linear equations, Eigen values and eigenvectors.

Calculus: Functions of single variable, Limit, continuity and differentiability, Taylor series, Mean value theorems, Evaluation of definite and improper integrals, Partial derivatives, Total derivative, Maxima and minima, Gradient, Divergence and Curl, Vector identities, Directional derivatives, Line, Surface and Volume integrals, Stokes, Gauss and Green's theorems.

Differential Equations: First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Cauchy's and Euler's equations, Initial and boundary value problems, Laplace transforms, Solutions of one-dimensional heat and wave equations and Laplace equation.

Complex Variables: Complex number, polar form of complex number, triangle inequality.

Probability and Statistics: Definitions of probability and sampling theorems, Conditional probability, Mean, median, mode and standard deviation, Random variables, Poisson, Normal and Binomial distributions, Linear regression analysis.

Numerical Methods: Numerical solutions of linear and non-linear algebraic equations. Integration by trapezoidal and Simpson's rule. Single and multi-step methods for numerical solution of differential equations.

Section 2: Process Calculations and Thermodynamics

Steady and unsteady state mass and energy balances including multiphase, multi-component, reacting and non-reacting systems. Use of tie components; recycle, bypass and purge calculations; Gibb's phase rule and degree of freedom analysis.

First and Second laws of thermodynamics. Applications of first law to close and open systems. Second law and Entropy. Thermodynamic properties of pure substances: Equation of State and residual properties, properties of mixtures: partial molar properties, fugacity, excess properties and activity coefficients; phase equilibria: predicting VLE of systems; chemical reaction equilibrium.

Section 3: Fluid Mechanics and Mechanical Operations

Fluid statics, surface tension, Newtonian and non-Newtonian fluids, transport properties, shell-balances including differential form of Bernoulli equation and energy balance, equation of continuity, equation of motion, equation of mechanical energy, Macroscopic friction factors, dimensional analysis and similitude, flow through pipeline systems, velocity profiles, flow meters, pumps and compressors, elementary boundary layer theory, flow past immersed bodies including packed and fluidized beds, Turbulent flow: fluctuating velocity, universal velocity profile and pressure drop.

Particle size and shape, particle size distribution, size reduction and classification of solid particles; free and hindered settling; centrifuge and cyclones; thickening and classification, filtration, agitation and mixing; conveying of solids.

Section 4: Heat Transfer

Equation of energy, steady and unsteady heat conduction, convection and radiation, thermal boundary layer and heat transfer coefficients, boiling, condensation and evaporation; types of heat exchangers and evaporators and their process calculations; design of double pipe, shell and tube heat exchangers, and single and multiple effect evaporators.

Section 5: Mass Transfer

Fick's laws, molecular diffusion in fluids, mass transfer coefficients, film, penetration and surface renewal theories; momentum, heat and mass transfer analogies; stage-wise and continuous contacting and stage efficiencies; HTU & NTU concepts; design and operation of equipment for distillation, absorption, leaching, liquid-liquid extraction, drying, humidification, dehumidification and adsorption, membrane separations (micro-filtration, ultra-filtration, nano-filtration and reverse osmosis).

Section 6: Chemical Reaction Engineering

Theories of reaction rates; kinetics of homogeneous reactions, interpretation of kinetic data, single and multiple reactions in ideal reactors, kinetics of enzyme reactions (Michaelis-Mentenand Monod models), non-ideal reactors; residence time distribution, single parameter model; non-isothermal reactors; kinetics of heterogeneous catalytic reactions; diffusion effects in catalysis; rate and performance equations for catalyst deactivation.

Section 7: Instrumentation and Process Control

Measurement of process variables; sensors and transducers; P&ID equipment symbols; process modeling and linearization, transfer functions and dynamic responses of various systems, systems with inverse response, process reaction curve, controller modes (P, PI, and PID); control valves; transducer dynamics; analysis of closed loop systems including stability, frequency response, controller tuning, cascade and feed forward control.

Section 8: Plant Design and Economics

Principles of process economics and cost estimation including depreciation and total annualized cost, cost indices, rate of return, payback period, discounted cash flow, optimization in process design and sizing of chemical engineering equipments such as heat exchangers and multistage contactors.

Section 9: Chemical Technology

Inorganic chemical industries (sulfuric acid, phosphoric acid, chlor-alkali industry), fertilizers (Ammonia, Urea, SSP and TSP); natural products industries (Pulp and Paper, Sugar, Oil, and Fats); petroleum refining and petrochemicals; polymerization industries (polyethylene, polypropylene, PVC and polyester synthetic fibers).

CS Computer Science and Information Technology

Section 1: Engineering Mathematics

Discrete Mathematics: Propositional and first order logic. Sets, relations, functions, partial orders and lattices. Monoids, Groups. Graphs: connectivity, matching, colouring. Combinatorics: counting, recurrence relations, generating functions.

Linear Algebra: Matrices, determinants, system of linear equations, eigenvalues and eigenvectors, LU decomposition.

Calculus: Limits, continuity and differentiability, Maxima and minima, Mean value theorem, Integration.

Probability and Statistics: Random variables, Uniform, normal, exponential, Poisson and binomial distributions. Mean, median, mode and standard deviation. Conditional probability and Bayes theorem.

Section 2: Digital Logic

Boolean algebra. Combinational and sequential circuits. Minimization. Number representations and computer arithmetic (fixed and floating point).

Section 3: Computer Organization and Architecture

Machine instructions and addressing modes. ALU, data-path and control unit. Instruction pipelining, pipeline hazards. Memory hierarchy: cache, main memory and secondary storage; I/O interface (interrupt and DMA mode).

Section 4: Programming and Data Structures

Programming in C. Recursion. Arrays, stacks, queues, linked lists, trees, binary search trees, binary heaps, graphs.

Section 5: Algorithms

Searching, sorting, hashing. Asymptotic worst case time and space complexity. Algorithm design techniques: greedy, dynamic programming and divide-and-conquer. Graph traversals, minimum spanning trees, shortest paths.

Section 6: Theory of Computation

Regular expressions and finite automata. Context-free grammars and push-down automata. Regular and context-free languages, pumping lemma. Turing machines and undecidability.

Section 7: Compiler Design

Lexical analysis, parsing, syntax-directed translation. Runtime environments. Intermediate code generation. Local optimisation, Data flow analyses: constant propagation, liveness analysis, common sub expression elimination.

Section 8: Operating System

System calls, processes, threads, inter-process communication, concurrency and synchronization. Deadlock. CPU and I/O scheduling. Memory management and virtual memory. File systems.

Section 9: Databases

ER-model. Relational model: relational algebra, tuple calculus, SQL. Integrity constraints, normal forms. File organization, indexing (e.g., B and B+ trees). Transactions and concurrency control.

Section 10: Computer Networks

Concept of layering: OSI and TCP/IP Protocol Stacks; Basics of packet, circuit and virtual circuit-switching; Data link layer: framing, error detection, Medium Access Control, Ethernet bridging; Routing protocols: shortest path, flooding, distance vector and link state routing; Fragmentation and IP addressing, IPv4, CIDR notation, Basics of IP support protocols (ARP, DHCP, ICMP), Network Address Translation (NAT); Transport layer: flow control and congestion control, UDP, TCP, sockets; Application layer protocols: DNS, SMTP, HTTP, FTP, Email.

CY Chemistry

Section 1: Physical Chemistry

Structure: Postulates of quantum mechanics. Operators. Time dependent and time independent Schrödinger equations. Born interpretation. Dirac bra-ket notation. Particle in a box: infinite and finite square wells; concept of tunnelling; particle in 1D, 2D and 3D-box; applications. Harmonic oscillator: harmonic and anharmonic potentials; Hermite polynomials. Rotational motion: Angular momentum operators, Rigid rotor. Hydrogen and hydrogen-like atoms: atomic orbitals; radial distribution function. Multi-electron atoms: orbital approximation; electron spin; Pauli exclusion principle; slater determinants. Approximation Methods: Variation method and secular determinants; first order perturbation techniques. Atomic units. Molecular structure and Chemical bonding: Born-Oppenheimer approximation; Valence bond theory and linear combination of atomic orbitals – molecular orbital (LCAO-MO) theory. Hybrid orbitals. Applications of LCAO-MO theory to H_2^+, H_2; orbital theory (MOT) of homo- and heteronuclear diatomic molecules. Hückel approximation and its application to annular π – electron systems.

Group theory: Symmetry elements and operations; Point groups and character tables; Internal coordinates and vibrational modes; symmetry adapted linear combination of atomic orbitals (LCAO-MO); construction of hybrid orbitals using symmetry aspects.

Spectroscopy: Atomic spectroscopy; Russell-Saunders coupling; Term symbols and spectral details; origin of selection rules. Rotational, vibrational, electronic and Raman spectroscopy of diatomic and polyatomic molecules. Line broadening. Einstein's coefficients. Relationship of transition moment integral with molar extinction coefficient and oscillator strength. Basic principles of nuclear magnetic resonance: gyromagnetic ratio; chemical shift, nuclear coupling.

Equilibrium: Laws of thermodynamics. Standard states. Thermochemistry. Thermodynamic functions and their relationships: Gibbs-Helmholtz and Maxwell relations, Gibbs-Duhem equation, van't Hoff equation. Criteria of spontaneity and equilibrium. Absolute entropy. Partial molar quantities. Thermodynamics of mixing. Chemical potential. Fugacity, activity and activity coefficients. Ideal and Non-ideal solutions, Raoult's Law and Henry's Law, Chemical equilibria. Dependence of equilibrium constant on temperature and pressure. Ionic mobility and conductivity. Debye-Hückel limiting law. Debye-Hückel-Onsager equation. Standard electrode potentials and electrochemical cells. Nernst Equation and its application, relationship between Electrode potential and thermodynamic quantities, Potentiometric and conduct metric titrations. Phase rule. Clausius- Clapeyron equation. Phase diagram of one component systems: CO_2, H_2O, S; two component systems: liquid- vapour, liquid-liquid and solid-liquid systems. Fractional distillation. Azeotropes and eutectics. Statistical thermodynamics: micro canonical, canonical and grand canonical ensembles, Boltzmann distribution, partition functions and thermodynamic properties.

Kinetics: Elementary, parallel, opposing and consecutive reactions. Steady state approximation. Mechanisms of complex reactions. Unimolecular reactions. Potential energy surfaces and classical trajectories, Concept of Saddle points, Transition state theory: Eyring equation, thermodynamic aspects. Kinetics of polymerization. Catalysis concepts and enzyme catalysis. Kinetic isotope effects. Fast reaction kinetics: relaxation and flow methods. Diffusion controlled reactions. Kinetics of photochemical and photo physical processes.

Surfaces and Interfaces: Physisorption and chemisorption. Langmuir, Freundlich and Brunauer–Emmett–Teller (BET) isotherms. Surface catalysis: Langmuir-Hinshelwood mechanism. Surface tension, viscosity. Self-assembly. Physical chemistry of colloids, micelles and macromolecules.

Section 2: Inorganic Chemistry

Main Group Elements: Hydrides, halides, oxides, oxoacids, nitrides, sulfides – shapes and reactivity. Structure and bonding of boranes, carboranes, silicones, silicates, boron nitride, borazines and phosphazenes. Allotropes of carbon, phosphorous and sulphur. Industrial synthesis of compounds of main group elements. Chemistry of noble gases, pseudohalogens, and interhalogen compounds. Acid-base concepts and principles (Lewis, Brønsted, HSAB and acid-base catalysis).

Transition Elements: Coordination chemistry – structure and isomerism, theories of bonding (VBT, CFT, and MOT). Energy level diagrams in various crystal fields, CFSE, applications of CFT, Jahn-Teller distortion. Electronic spectra of transition metal complexes: spectroscopic term symbols, selection rules, Orgel and Tanabe-Sugano diagrams, nephelauxetic effect and Racah parameter, charge-transfer spectra. Magnetic properties of transition metal complexes. Ray-Dutt and Bailar twists, Reaction mechanisms: kinetic and thermodynamic stability, substitution and redox reactions. Metal-metal multiple bond.

Lanthanides and Actinides: Recovery. Periodic properties, spectra and magnetic properties.

Organometallics: 18-Electron rule; metal-alkyl, metal-carbonyl, metal-olefin and metal- carbene complexes and metallocenes. Fluxionality in organometallic complexes. Types of organometallic reactions. Homogeneous catalysis - Hydrogenation, hydroformylation, acetic acid synthesis, metathesis and olefin oxidation. Heterogeneous catalysis - Fischer- Tropsch reaction, Ziegler-Natta polymerization.

Radioactivity: Detection of radioactivity, Decay processes, half-life of radioactive elements, fission and fusion processes.

Bioinorganic Chemistry: Ion (Na^+ and K^+) transport, oxygen binding, transport and utilization, electron transfer reactions, nitrogen fixation, metalloenzymes containing magnesium, molybdenum, iron, cobalt, copper and zinc.

Solids: Crystal systems and lattices, Miller planes, crystal packing, crystal defects, Bragg's law, ionic crystals, structures of AX, AX_2, ABX_3 type compounds, spinels, band theory, metals and semiconductors.

Instrumental Methods of Analysis: UV-visible, fluorescence and FTIR spectrophotometry, NMR and ESR spectroscopy, mass spectrometry, atomic absorption spectroscopy, Mössbauer spectroscopy (Fe and Sn) and X-ray crystallography. Chromatography including GC and HPLC. Electroanalytical methods- polarography, cyclic voltammetry, ion-selective electrodes. Thermoanalytical methods.

Section 3: Organic Chemistry

Stereochemistry: Chirality and symmetry of organic molecules with or without chiral centres and determination of their absolute configurations. Relative stereochemistry in compounds having more than one stereogenic centre. Homotopic, enantiotopic and diastereotopic atoms, groups and faces. Stereoselective and stereospecific synthesis. Conformational analysis of acyclic and cyclic compounds. Geometrical isomerism and optical isomerism. Configurational and conformational effects, atropisomerism, and neighbouring group participation on reactivity and selectivity/specificity.

Reaction Mechanisms: Basic mechanistic concepts – kinetic versus thermodynamic control, Hammond's postulate and Curtin-Hammett principle. Methods of determining reaction mechanisms through kinetics, identification of products, intermediates and isotopic labelling. Linear free-energy relationship – Hammett and Taft equations. Nucleophilic and electrophilic substitution reactions (both aromatic and aliphatic). Addition reactions to carbon-carbon and carbon-heteroatom (N and O) multiple bonds. Elimination reactions. Reactive intermediates — carbocations, carbanions, carbenes, nitrenes, arynes and free radicals. Molecular rearrangements.

Organic Synthesis: Synthesis, reactions, mechanisms and selectivity involving the following classes of compounds – alkenes, alkynes, arenes, alcohols, phenols, aldehydes, ketones, carboxylic acids, esters, nitriles, halides, nitro compounds, amines and amides. Uses of Mg, Li, Cu, B, Zn, P, S, Sn and Si based reagents in organic synthesis. Carbon-carbon bond formation through coupling reactions - Heck, Suzuki, Stille, Sonogoshira, Negishi, Kumada, Hiyama, Tsuji-Trost, olefin metathesis and McMurry. Concepts of multistep synthesis - retrosynthetic analysis, strategic disconnections, synthons and synthetic equivalents. Atom economy and Green Chemistry, Umpolung reactivity – formyl and acyl anion equivalents. Selectivity in organic synthesis – chemo-, regio- and stereoselectivity. Protection and deprotection of functional groups. Concepts of asymmetric synthesis – resolution (including enzymatic), desymmetrization and use of chiral auxiliaries, organocatalysis. Carbon-carbon and carbon-heteroatom bond forming reactions through enolates (including boron enolates), enamines and silyl enol ethers. Stereoselective addition to C=O groups (Cram, Prelog and Felkin-Anh models).

Pericyclic Reactions and Photochemistry: Electrocyclic, cycloaddition and sigmatropic reactions. Orbital correlations - FMO and PMO treatments, Woodward-Hoffmann rule. Photochemistry of alkenes, arenes and carbonyl compounds. Photooxidation and photoreduction. Di-π-methane rearrangement, Barton-McCombie reaction, Norrish type-I and II cleavage reaction.

Heterocyclic Compounds: Structure, preparation, properties and reactions of furan, pyrrole, thiophene, pyridine, indole, quinoline and isoquinoline.

Biomolecules: Structure, properties and reactions of mono- and di-saccharides, physicochemical properties of amino acids, chemical synthesis of peptides, chemical structure determination of peptides and proteins, structural features of proteins, nucleic acids, lipids, steroids, terpenoids, carotenoids, and alkaloids.

Experimental Techniques in Organic Chemistry: Optical rotation (polarimetry). Applications of various chromatographic techniques such as thin-layer, column, HPLC and GC. Applications of UV-visible, IR, NMR and Mass spectrometry in the structural determination of organic molecules.

DA Data Science and Artificial Intelligence

Probability and Statistics: Counting (permutation and combinations), probability axioms, Sample space, events, independent events, mutually exclusive events, marginal, conditional and joint probability, Bayes Theorem, conditional expectation and variance, mean, median, mode and standard deviation, correlation, and covariance, random variables, discrete random variables and probability mass functions, uniform, Bernoulli, binomial distribution, Continuous random variables and probability distribution function, uniform, exponential, Poisson, normal, standard normal, t-distribution, chi-squared distributions, cumulative distribution function, Conditional PDF, Central limit theorem, confidence interval, z-test, t-test, chi-squared test.

Linear Algebra: Vector space, subspaces, linear dependence and independence of vectors, matrices, projection matrix, orthogonal matrix, idempotent matrix, partition matrix and their properties, quadratic forms, systems of linear equations and solutions; Gaussian elimination, eigenvalues and eigenvectors, determinant, rank, nullity, projections, LU decomposition, singular value decomposition.

Calculus and Optimization: Functions of a single variable, limit, continuity and differentiability, Taylor series, maxima and minima, optimization involving a single variable.

Programming, Data Structures and Algorithms: Programming in Python, basic data structures: stacks, queues, linked lists, trees, hash tables; Search algorithms: linear search and binary search, basic sorting algorithms: selection sort, bubble sort and insertion sort; divide and conquer: mergesort, quicksort; introduction to graph theory; basic graph algorithms: traversals and shortest path.

Database Management and Warehousing: ER-model, relational model: relational algebra, tuple calculus, SQL, integrity constraints, normal form, file organization, indexing, data types, data transformation such as normalization, discretization, sampling, compression; data warehouse modelling: schema for multidimensional data models, concept hierarchies, measures: categorization and computations.

Machine Learning: (i) Supervised Learning: regression and classification problems, simple linear regression, multiple linear regression, ridge regression, logistic regression, k-nearest neighbour, naive Bayes classifier, linear discriminant analysis, support vector machine, decision trees, bias-variance trade-off, cross-validation methods such as leave-one-out (LOO) cross-validation, k-folds cross-validation, multi-layer perceptron, feed-forward neural network; (ii) Unsupervised Learning: clustering algorithms, k-means/k-medoid, hierarchical clustering, top-down, bottom-up: single-linkage, multiple-linkage, dimensionality reduction, principal component analysis.

AI: Search: informed, uninformed, adversarial; logic, propositional, predicate; reasoning under uncertainty topics — conditional independence representation, exact inference through variable elimination, and approximate inference through sampling.

EC Electronics and Communication Engineering

Section 1: Engineering Mathematics

Linear Algebra: Vector space, basis, linear dependence and independence, matrix algebra, eigen values and eigen vectors, rank, solution of linear equations - existence and uniqueness.

Calculus: Mean value theorems, theorems of integral calculus, evaluation of definite and improper integrals, partial derivatives, maxima and minima, multiple integrals, line, surface and volume integrals, Taylor series.

Differential Equations: First order equations (linear and nonlinear), higher order linear differential equations, Cauchy's and Euler's equations, methods of solution using variation of parameters, complementary function and particular integral, partial differential equations, variable separable method, initial and boundary value problems.

Vector Analysis: Vectors in plane and space, vector operations, gradient, divergence and curl, Gauss's, Green's and Stokes' theorems.

Complex Analysis: Analytic functions, Cauchy's integral theorem, Cauchy's integral formula, sequences, series, convergence tests, Taylor and Laurent series, residue theorem.

Probability and Statistics: Mean, median, mode, standard deviation, combinatorial probability, probability distributions, binomial distribution, Poisson distribution, exponential distribution, normal distribution, joint and conditional probability.

Section 2: Networks, Signals and Systems

Circuit Analysis: Node and mesh analysis, superposition, Thevenin's theorem, Norton's theorem, reciprocity. Sinusoidal steady state analysis: phasors, complex power, maximum power transfer. Time and frequency domain analysis of linear circuits: RL, RC and RLC circuits, solution of network equations using Laplace transform.

Linear 2-port network parameters, wye-delta transformation.

Continuous-time Signals: Fourier series and Fourier transform, sampling theorem and applications.

Discrete-time Signals: DTFT, DFT, z-transform, discrete-time processing of continuous-time signals. LTI systems: definition and properties, causality, stability, impulse response, convolution, poles and zeroes, frequency response, group delay, phase delay.

Section 3: Electronic Devices

Energy bands in intrinsic and extrinsic semiconductors, equilibrium carrier concentration, direct and indirect band-gap semiconductors.

Carrier Transport: Diffusion current, drift current, mobility and resistivity, generation and recombination of carriers, Poisson and continuity equations.

P-N junction, Zener diode, BJT, MOS capacitor, MOSFET, LED, photo diode and solar cell.

Section 4: Analog Circuits

Diode Circuits: Clipping, clamping and rectifiers.

BJT and MOSFET Amplifiers: Biasing, AC coupling, small signal analysis, frequency response. Current mirrors and differential amplifiers.

Op-amp Circuits: Amplifiers, summers, differentiators, integrators, active filters, Schmitt triggers and oscillators.

Section 5: Digital Circuits

Number Representations: Binary, integer and floating-point- numbers. Combinatorial circuits: Boolean algebra, minimization of functions using Boolean identities and Karnaugh map, logic gates and their static CMOS implementations, arithmetic circuits, code converters, multiplexers, decoders.

Sequential Circuits: Latches and flip-flops, counters, shift-registers, finite state machines, propagation delay, setup and hold time, critical path delay.

Data Converters: Sample and hold circuits, ADCs and DACs.

Semiconductor Memories: ROM, SRAM, DRAM.

Computer Organization: Machine instructions and addressing modes, ALU, data-path and control unit, instruction pipelining.

Section 6: Control Systems

Basic control system components; Feedback principle; Transfer function; Block diagram representation; Signal flow graph; Transient and steady-state analysis of LTI systems; Frequency response; Routh-Hurwitz and Nyquist stability criteria; Bode and root-locus plots; Lag, lead and lag-lead compensation; State variable model and solution of state equation of LTI systems.

Section 7: Communications

Random Processes: Auto correlation and power spectral density, properties of white noise, filtering of random signals through LTI systems.

Analog Communications: Amplitude modulation and demodulation, angle modulation and demodulation, spectra of AM and FM, super heterodyne receivers.

Information Theory: Entropy, mutual information and channel capacity theorem.

Digital Communications: PCM, DPCM, digital modulation schemes (ASK, PSK, FSK, QAM), bandwidth, inter-symbol interference, MAP, ML detection, matched filter receiver, SNR and BER. Fundamentals of error correction, Hamming codes, CRC.

Section 8: Electromagnetics

Maxwell's Equations: Differential and integral forms and their interpretation, boundary conditions, wave equation, Poynting vector.

Plane Waves and Properties: Reflection and refraction, polarization, phase and group velocity, propagation through various media, skin depth.

Transmission Lines: Equations, characteristic impedance, impedance matching, impedance transformation, S-parameters, Smith chart. Rectangular and circular waveguides, light propagation in optical fibers, dipole and monopole antennas, linear antenna arrays.

EE Electrical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix Algebra, Systems of linear equations, Eigen values, Eigen vectors.

Calculus: Mean value theorems, Theorems of integral calculus, Evaluation of definite and improper integrals, Partial Derivatives, Maxima and minima, Multiple integrals, Fourier series, Vector identities, Directional derivatives, Line integral, Surface integral, Volume integral, Stokes's theorem, Gauss's theorem, Divergence theorem, Green's theorem.

Differential Equations: First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Method of variation of parameters, Cauchy's equation, Euler's equation, Initial and boundary value problems, Partial Differential Equations, Method of separation of variables.

Complex Variables: Analytic functions, Cauchy's integral theorem, Cauchy's integral formula, Taylor series, Laurent series, Residue theorem, Solution integrals.

Probability and Statistics: Sampling theorems, Conditional probability, Mean, Median, Mode, Standard Deviation, Random variables, Discrete and Continuous distributions, Poisson distribution, Normal distribution, Binomial distribution, Correlation analysis, Regression analysis.

Section 2: Electric circuits

Network Elements: Ideal voltage and current sources, dependent sources, R, L, C, M elements; Network solution methods: KCL, KVL, Node and Mesh analysis; Network Theorems: Thevenin's, Norton's, Superposition and Maximum Power Transfer theorem; Transient response of DC and AC networks, sinusoidal steady-state analysis, resonance, two port networks, balanced three phase circuits, star-delta transformation, complex power and power factor in AC circuits.

Section 3: Electromagnetic Fields

Coulomb's Law, Electric Field Intensity, Electric Flux Density, Gauss's Law, Divergence, Electric field and potential due to point, line, plane and spherical charge distributions, Effect of dielectric medium, Capacitance of simple configurations, Biot-Savart's law, Ampere's law, Curl, Faraday's law, Lorentz force, Inductance, Magnetomotive force, Reluctance, Magnetic circuits, Self and Mutual inductance of simple configurations.

Section 4: Signals and Systems

Representation of continuous and discrete time signals, shifting and scaling properties, linear time invariant and causal systems, Fourier series representation of continuous and discrete time periodic signals, sampling theorem, Applications of Fourier Transform for continuous and discrete time signals, Laplace Transform and Z transform. R.M.S. value, average value calculation for any general periodic waveform.

Section 5: Electrical Machines

Single phase transformer: equivalent circuit, phasor diagram, open circuit and short circuit tests, regulation and efficiency; Three-phase transformers: connections, vector groups, parallel operation; Auto-transformer, Electromechanical energy conversion principles; DC machines: separately excited, series and shunt, motoring and generating mode of operation and their characteristics, speed control of dc motors; Three-phase induction machines: principle of operation, types, performance, torque-speed characteristics, no-load and blocked-rotor tests, equivalent circuit, starting and speed control; Operating principle of single-phase induction motors; Synchronous machines: cylindrical and salient pole machines, performance and characteristics, regulation and parallel operation of generators, starting of synchronous motors; Types of losses and efficiency calculations of electric machines.

Section 6: Power Systems

Basic concepts of electrical power generation, AC and DC transmission concepts, Models and performance of transmission lines and cables, Economic Load Dispatch (with and without considering transmission losses), Series and shunt compensation, Electric field distribution and insulators, Distribution systems, Per-unit quantities, Bus admittance matrix, Gauss- Seidel and Newton-Raphson load flow methods, Voltage and Frequency control, Power factor correction, Symmetrical components, Symmetrical and unsymmetrical fault analysis, Principles of over-current, differential, directional and distance protection; Circuit breakers, System stability concepts, Equal area criterion.

Section 7: Control Systems

Mathematical modelling and representation of systems, Feedback principle, transfer function, Block diagrams and Signal flow graphs, Transient and Steady-state analysis of linear time invariant systems, Stability analysis using Routh-Hurwitz and Nyquist criteria, Bode plots, Root loci, Lag, Lead and Lead-Lag compensators; P, PI and PID controllers; State space model, Solution of state equations of LTI systems.

Section 8: Electrical and Electronic Measurements

Bridges and Potentiometers, Measurement of voltage, current, power, energy and power factor; Instrument transformers, Digital voltmeters and multi-meters, Phase, Time and Frequency measurement; Oscilloscopes, Error analysis.

Section 9: Analog and Digital Electronics

Simple diode circuits: clipping, clamping, rectifiers; Amplifiers: biasing, equivalent circuit and frequency response; oscillators and feedback amplifiers; operational amplifiers: characteristics and applications; single stage active filters, Active Filters: Sallen Key, Butterwoth, VCOs and timers, combinatorial and sequential logic circuits, multiplexers, demultiplexers, Schmitt triggers, sample and hold circuits, A/D and D/A converters.

Section 10: Power Electronics

Static V-I characteristics and firing/gating circuits for Thyristor, MOSFET, IGBT; DC to DC conversion: Buck, Boost and Buck-Boost Converters; Single and three-phase configuration of uncontrolled rectifiers; Voltage and Current commutated Thyristor based converters; Bidirectional ac to dc voltage source converters; Magnitude and Phase of line current harmonics for uncontrolled and thyristor based converters; Power factor and Distortion Factor of AC to DC converters; Single-phase and three-phase voltage and current source inverters, sinusoidal pulse width modulation.

ES Environmental Science and Engineering

Section 1: Mathematics Foundation

Linear Algebra: Determinants and matrices, Systems of linear equations, Eigenvalues and eigenvectors.

Calculus: Functions, Limit, Continuity, Differentiability, Local maxima and minima, Taylor series, Tests for convergence, Definite and indefinite integrals, Application of definite integral to obtain area and volume, Partial and total derivatives.

Differential Equations: Linear and non-linear first order ordinary differential equations (ODE), Higher order linear ODEs with constant coefficients, Cauchy's and Euler's equations, Laplace transform and its application in solving linear ODEs.

Probability and Statistics: Descriptive statistics, Measurement of central tendency, Dispersion, Skewness and kurtosis, Probability concepts, Conditional probability, Bayes theorem, Risk and reliability, Probability distributions, Correlation, Single and multiple regression models, Hypothesis testing (t-test, F-test, chi-square test).

Section 2: Environmental Chemistry

Fundamentals of Environmental Chemistry: Covalent and ionic bonding; Chemical equations, concentration and activity; Structure and chemistry of organic molecules; Radioactivity of elements; Chemical equilibria; Thermodynamics and kinetics of chemical reactions.

Principles of Water Chemistry: Water quality parameters and their measurement; Acid-base equilibria; Buffer solution; Carbonate system; Solubility of gases in water; Complexation, precipitation, and redox reactions; Inorganic and organic contaminants in water and their speciation.

Soil Chemistry: Organic matter, nitrogen, phosphorous, potassium, cation exchange capacity, base saturation, and sodium absorption ratio.

Atmospheric Chemistry: Composition of the atmosphere; Reactivity of trace substances in the atmosphere; Urban atmosphere—smog and particulate pollution; Chemistry of ozone formation; Chemistry of stratosphere.

Section 3: Environmental Microbiology

Prokaryotic and Eukaryotic Microorganisms: Characteristics of diverse groups of microorganisms; Classification of microorganisms; Microbial diversity; Plant-microbe and soil-microbe interactions; Role of microorganisms in wastewater treatment, bioremediation and biogeochemical cycling.

Cell Chemistry and Cell Biology: Structure of proteins, nucleic acid (DNA & RNA), lipids and polysaccharides; Bonds in biomolecules; Stereoisomerism in biomolecules; Structure of cell; Structure and function of cytoplasmic membrane, cell wall, outer membrane, glycocalyx, chromosomes, endospores, storage products, mitochondria and chloroplasts.

Microbial Metabolism: Anabolism and catabolism; Phosphorylation; Glycolysis; TCA cycle; Electron transport chain; Fermentation; Anaerobic respiration; Energy balances; Enzymes and Enzyme kinetics.

Growth and Control of Microorganisms: Bacterial nutrition and growth; Specific growth rate and doubling time; Monod's model; Types of culture media; Batch and continuous culture; Effects of environmental factors on growth; Control of microbes using physical and chemical methods.

Microbiology and Health: Pathogens and modes of transmission; Indicator organisms; Quantification of coliforms using MPN and membrane filtration techniques.

Section 4: Water Resources and Environmental Hydraulics

Global Water Resources: Structure, properties and distribution of water; Water quality; Threats to water resources; Water conservation.

Surface Water Resources: Hydrological cycle and water balance - precipitation, infiltration, evapotranspiration, runoff; Flow hydrographs; Unit hydrographs; Stage-discharge relationship; Reservoir capacity; Reservoir and channel routing; Surface run-off models; Surface water management; Rain water harvesting and storage.

Groundwater Resources: Geologic formations as aquifers; Vadose and saturated zones; Confined and unconfined aquifers and their parameters - porosity, permeability, transmissivity and storage coefficient; Darcy's law and applications; Steady state well hydraulics.

Environmental Hydraulics: Concepts of mechanics; Properties of fluids; Pressure measurement; Hydrostatic force on surfaces; Buoyancy and flotation; Laminar and turbulent flow; Flow through pipes; Pipe networks; Boundary layer theory; Forces on immersed bodies; Flow measurement in channels and pipes; Kinematics of flow; Continuity, momentum and energy equations; Channel hydraulics - specific energy, critical flow, hydraulic jump, rapid and gradually varied flow; Design of lined and unlined channels.

Section 5: Water & Wastewater Treatment and Management

Water and wastewater quality parameters; Eutrophication and thermal stratification in lakes; River pollution - Oxygen sag curve.

Water treatment methods — screening, sedimentation with and without coagulation, filtration, desalination, disinfection; Water distribution and storage

Point and non-point sources of wastewater; Population forecasting methods; Design of sewer and storm water sewers; Sewer appurtenances; Preliminary, primary, secondary and tertiary sewage treatment; Sludge generation, processing and disposal methods; Sewage farming.

Sources and characteristics of industrial effluents; Concept of Common Effluent Treatment Plants (CETP); Wastewater recycling and zero liquid discharge.

Kinetics and reactor design: Mass and energy balance, Order and rate of reactions, Batch reactors, Completely mixed flow reactors, Plug flow reactors.

Section 6: Air and Noise Pollution

Structure of the atmosphere; Natural and anthropogenic sources of pollution; Atmospheric sources, sinks, transport; Indoor air pollution; Effects on health and environment; Air pollution: gases and particulate matter; Air quality standards; Primary and secondary pollutants; Criteria pollutants, ambient and source standards, air quality indices, visibility.

Particulate Pollutants: Measurement and control methods; Control of particulate air pollutants using gravitational settling chambers, cyclone separators, wet collectors, fabric filters (Bag-house filter), electrostatic precipitators (ESP).

Gaseous Pollutants: Measurement and control methods; Control of gaseous contaminants: absorption, adsorption, condensation and combustion; Control of sulphur oxides, nitrogen oxides, carbon monoxide, and

hydrocarbons; Vapour-liquid and vapour-solid equilibria; Diffusion, Fick's law and interfacial mass transfer. Automotive emission controls, fuel quality, diesel particulate filters, catalytic convertors.

Air Quality Management: Point, line and area sources; Inventory; Influence of meteorology - wind rose diagrams, stability, mixing height, topography, dispersion modelling, monitoring.

Noise Pollution: Sources; Health effects; Standards; Measurement and control methods.

Section 7: Solid and Hazardous Waste Management

Integrated solid waste management; Waste hierarchy; Rules and regulations for solid waste management in India.

Municipal solid waste management: Sources, generation, characteristics, collection and transportation, waste processing and disposal (including reuse options, biological methods, energy recovery processes and landfilling).

Hazardous waste management: Characteristics, generation, fate of materials in the environment, treatment and disposal. Soil contamination and leaching of contaminants into groundwater.

Management of biomedical waste, plastic waste and E-waste: Sources, generation and characteristics; Waste management practices including storage, collection and transfer.

Section 8: Global and Regional Environmental Issues

Global effects of air pollution: Greenhouse gases, global warming, climate change, urban heat islands, acid rain, ozone hole.

Ecology and various ecosystems; Biodiversity; Factors influencing increase in population, energy consumption, and environmental degradation.

Section 9: Environmental Management and Sustainable Development

Environmental Management Systems; ISO14000 series; Environmental Auditing: Environmental Impact Assessment; Life cycle assessment; Human health risk assessment.

Environmental Law and Policy: Objectives; Polluter pays principle, Precautionary principle; The Water and Air Acts with amendments; The Environment (Protection) Act (EPA) 1986; National Green Tribunal Act, 2010; National Environment Policy; Principles of International Law and International treaties.

Energy and Environment: Energy Sources: Overview of resources and reserves; Renewable and non-renewable energy sources; Energy-Environment nexus.

Sustainable Development: Definition and concepts of sustainable development; Sustainable development goals; Hurdles to sustainability; Environment and economics.

EY Ecology and Evolution

Section 1: Ecology

Fundamental Concepts: Abiotic and biotic components; scales (population, species, community, ecosystems, biomes); niches and habitats.

Population Ecology: Population growth rates (density dependent/independent); meta population ecology (colonization, persistence, extinction, patches, sources, sinks); age-structured populations.

Interactions: Types (mutualism, symbiosis, commensalism, competition, parasitism, predation, etc); ecophysiology (physiological adaptations to abiotic environment); prey-predator interactions (Lotka-Voltera equation, etc.)

Community Ecology: Community assembly, organization and succession; species richness, evenness and diversity indices, species-area relationships; theory of island biogeography

Ecosystems Structure and Function: Trophic levels and their interactions; nutrient cycles; primary and secondary productivity

Section 2: Evolution

History of Evolutionary Thought: Lamarckism; Darwinism; Modern Synthesis

Fundamentals: Variation; heritability; natural selection; fitness and adaptation; types of selection (stabilizing, directional, disruptive)

Diversity of Life: Origin and history of life on earth; diversity and classification of life; systems of classification (cladistics and phenetics)

Life History Strategies: Allocation of resources; tradeoffs; r/K selection; semelparity and iteroparity

Interactions: Co-evolution (co-adaptations, arms race, Red Queen hypothesis, co-speciation); prey-predator interactions (mimicry, crypsis, etc)

Population and Quantitative Genetics: Origins of genetic variation; Mendelian genetics; Hardy-Weinberg equilibrium; drift; selection (one-locus two-alleles model); population genetic structure (panmixia, gene flow, F_{ST}); polygenic traits; gene-environment interactions (phenotypic plasticity); heritability

Molecular Evolution and Phylogenetics: Neutral theory; molecular clocks; rates of evolution; phylogenetic reconstruction; molecular systematics

Macroevolution: Species concepts and speciation; adaptive radiation; convergence; biogeography

Section 3: Mathematics and Quantitative Ecology

Mathematics and Statistics in Ecology: Simple functions (linear, quadratic, exponential, logarithmic, etc); concept of derivatives and slope of a function; permutations and combinations; basic probability (probability of random events; sequences of events, etc); frequency distributions and their descriptive statistics (mean, variance, coefficient of variation, correlation, etc).

Statistical Hypothesis Testing: Concept of p-value; Type I and Type II error, test statistics like t-test and Chi-square test; basics of linear regression and ANOVA.

Section 4: Behavioural Ecology

Classical Ethology: Instinct; fixed action patters; imprinting; learnt behavior; proximate and ultimate questions.

Sensory Ecology: Neuroethology; communication (chemical, acoustic and visual signaling); recognition systems.

Foraging Ecology: Foraging behaviour; optimal foraging theory.

Reproduction: Cost of sex; sexual dimorphism; mate choice; sexual selection (runaway selection, good-genes, handicap principle, etc); sexual conflict; mating systems; parental care.

Social Living: Costs and benefits of group-living (including responses to predators); effect of competition (scramble and contest) on group formation; dominance relationships; eusociality; kin selection; altruism; reciprocity; human behaviour.

Section 5: Applied Ecology & Evolution

Biodiversity and Conservation: Importance of conserving biodiversity; ecosystem services; threats to biodiversity; invasive species; *in-situ* conservation (endemism, biodiversity hotspots, protected areas); *ex-situ* conservation; conservation genetics (genetic diversity, inbreeding depression); DNA fingerprinting and DNA barcoding.

Disease Ecology and Evolution: Epidemiology; zoonotic diseases; antibiotic resistance; vector Control Plant and animal breeding: Marker assisted breeding; genetic basis of economically important traits.

Global Climate Change: Causes; consequences; mitigation.

GE Geomatics Engineering

Part-A (Common): Engineering Mathematics and Basic Geomatics

Engineering Mathematics: Surveying measurements, Accuracy, Precision, Most probable value, Errors and their adjustments, Regression analysis, Correlation coefficient, Least square adjustment, Statistical significant value, Chi square test.

Remote Sensing: Basic concept, Electromagnetic spectrum, Spectral signature, Resolutions-Spectral. Spatial, Temporal and Radiometric, Platforms and Sensors, Remote Sensing Data Products - PAN, Multispectral, Microwave, Thermal, Hyperspectral, Visual and digital interpretation methods

GNSS: Principle used, Components of GNSS, Data collection methods, DGPS, Errors in observations and corrections.

GIS: Introduction, Data Sources, Data Models and Data Structures, Algorithms, DBMS, Creation of Databases (spatial and non-spatial), Spatial analysis - Interpolation, Buffer, Overlay, Terrain Modeling and Network analysis.

Part-B1: Surveying and Mapping

Maps: Importance of maps to engineering projects, Types of maps, Scales and uses, Plotting accuracy, Map sheet numbering, Coordinate systems- Cartesian and geographical, map projections, map datum – MSL, Geoid, spheroid, WGS-84.

Land Surveying: Various Levels, Levelling methods, Compass, Theodolite and Total Station and their uses, Tachometer, Trigonometric levelling, Traversing, Triangulation and Trilateration.

Aerial Photogrammetry: Types of photographs, Flying height and scale, Relief (height) displacement, Stereoscopy, 3-D Model, Height determination using Parallax Bar, Digital Elevation Model (DEM), Slope.

Part-B2: Image Processing and Analysis

Data Quantization and Processing: Sampling and quantization theory, Principle of Linear System, Convolution, Continuous and Discrete Fourier Transform.

Digital Image Processing: Digital image characteristics: image histogram and scattergram and their significance, Variance-Covariance matrix, Correlation matrix and their significance.

Radiometric and Geometric Corrections: Registration and Resampling techniques.

Image Enhancement: Contrast Enhancement: Linear and Non-linear methods; Spatial Enhancement: Noise and Spatial filters

Image Transformation: Principal Component Analysis (PCA), Discriminant Analysis, Colour transformations (RGB - IHS, CMYK), Indices (Ratios, NDVI, NDWI).

Image Segmentation and Classification: Simple techniques.

GG Geology and Geophysics

Part-A: Common Section

Earth and planetary system – terrestrial planets and moons of the solar system; size, shape, internal structure and composition of the earth; concept of isostasy; elements of seismology – body and surface waves, propagation of body waves in the earth's interior; Heat flow within the earth; Gravitational field of the Earth; geomagnetism and paleomagnetism; continental drift; plate tectonics – relationship with earthquakes, volcanism and mountain building; continental and oceanic crust – composition, structure and thickness.

Weathering and soil formation; landforms created by river, wind, glacier, ocean and volcanoes.

Basic structural geology - stress, strain and material response; brittle and ductile deformation; nomenclature and classification of folds and faults.

Crystallography – basic crystal symmetry and concept of point groups. Mineralogy – silicate crystal structure and determinative mineralogy of common rock forming minerals.

Petrology of common igneous, sedimentary and metamorphic rocks.

Geological time scale; Geochronology and absolute time. Stratigraphic principles; major stratigraphic divisions of India.

Mineral, coal and petroleum resources of India.

Introduction to remote sensing.

Engineering properties of rocks and soils.

Elements of hydrogeology.

Principles and applications of gravity, magnetic, electrical, electromagnetic, seismic and radiometric methods of prospecting for oil, mineral and ground water; introductory well logging.

Part-B1: Geology

Geomorphology: Geomorphic processes and agents; development and evolution of landforms in continental and oceanic settings; tectonic geomorphology.

Structural Geology: Forces and mechanism of rock deformation; primary and secondary structures; geometry and genesis of planar and linear structures (bedding, cleavage, schistosity, lineation); folds, faults, joints and unconformities; Stereographic projection; shear zones, thrusts and superposed folding; basement-cover relationship. Interpretation of geological maps.

Crystallography and Mineralogy: Elements of crystal symmetry, form and twinning; crystallographic projection; crystal chemistry; classification of minerals, physical and optical properties of rock- forming minerals.

Geochemistry: Cosmic abundance of elements; meteorites; geochemical evolution of the earth; geochemical cycles; distribution of major, minor and trace elements in crust and mantle; elements of high temperature and low temperature geochemical thermodynamics; isotopic evolution of the crust and the mantle, mantle reservoirs; geochemistry of water and water-rock interaction.

Igneous Petrology: Classification, forms, textures and genesis of common igneous rocks; magmatic differentiation; binary and ternary phase diagrams; major and trace elements as monitors of partial melting and magma evolutionary processes. Mantle plumes, hotspots and large igneous provinces.

Sedimentology: Texture, structure and sedimentary processes; petrology of common sedimentary rocks; Sedimentary facies and environments, cyclicities in sedimentary succession; provencance and basin analysis. Important sedimentary basins of India.

Metamorphic Petrology: Structures and textures of metamorphic rocks. Physico-chemical conditions of metamorphism and concept of metamorphic facies, grade and baric types; chemographic projections; metamorphism of pelitic, mafic and impure carbonate rocks; role of bulk composition including fluids in metamorphism; thermobarometry and metamorphic P-T-t paths, and their tectonic significance.

Paleobiology: Diversity of life through time, mass extinctions- causes and effects; taphonomy - processes of fossilization. Taxonomy. Morphology and functional morphology of invertebrates (bivalves, brachiopods, gastropods, echinoids, ammonites); microfossils (foraminifera, ostracoda, conodonts, bryozoa); Vertebrate paleonology (Equus, Probicidea, Human); Paleobotany (plant, spores, pollens). Basic concepts of ecology/ paleoecology; classification - ecological and taxonomic schemes (diversity and richness). Fossils and paleoenvironments.

Stratigraphy: Principles of stratigraphy and concepts of correlation; Lithostratigraphy, biostratigraphy and chronostratigraphy. Principles of sequence stratigraphy and applications. Stratigraphy of peninsular and extra-peninsular India. Boundary problems in Indian stratigraphy.

Resource Geology: Ore-mineralogy; ore forming processes vis-à-vis ore-rock association (magmatic, hydrothermal, sedimentary, supergene and metamorphogenic ores); fluid inclusions as ore genetic tools. Coal and petroleum geology; marine mineral resources. Prospecting and exploration of economic mineral deposits - sampling, ore reserve estimation, geostatistics, mining methods. Ore dressing and mineral economics. Distribution of mineral, fossil and nuclear fuel deposits in India.

Global Tectonics: Plate motions, driving mechanisms, plate boundaries, supercontinent cycles.

Applied Geology: Physico-mechanical properties of rocks and soils; rock index tests; Rock failure criteria (Mohr-Coulomb, Griffith and Hoek-Brown criteria); shear strength of rock discontinuities; rock mass classifications (RMR and Q Systems); in-situ stresses; rocks as construction materials; geological factors in the construction of engineering structures including dams, tunnels and excavation sites. Analysis of slope stability.

Natural hazards (landslide, volcanic, seismogenic, coastal) and mitigation. Principles of climate change.

Hydrogeology: Groundwater flow and exploration, well hydraulics and water quality.

Basic Principles of Remote Sensing: energy sources and radiation principles, atmospheric absorption, interaction of energy with earth's surface, aerial-photo interpretation, multispectral remote sensing in visible, infrared, thermal IR and microwave regions, digital processing of satellite images. GIS – basic concepts, raster and vector mode operations.

Part-B2: Geophysics

Soild-Earth Geophysics: The earth as a planet; different motions of the earth; gravity field of the earth, Clairaut's theorem, size and shape of earth; geomagnetic field, paleomagnetism; Geothermics and heat flow; seismology and interior of the earth; variation of density, velocity, pressure, temperature, electrical and magnetic properties of the earth.

Geodesy: Gravitational Field of the Earth; Geoid; Ellipsoid; Geodetic Reference Systems; Datum; Everest (1830) and WGS 84 (1984) systems; GPS and DGPS; Levelling and Surveying.

Earthquake Seismology: Elements of elasticity theory- stress and strain tensors, Generalized Hooke's Law; Body and Surface Waves; Rotational, dilatational, irrorational and equivolumnal waves. Reflection and refraction of elastic waves; Inhomogenous and evanescent waves and bounded waves; Eikonal Equation and Ray theory; earthquakes-causes and measurements, magnitude and intensity, focal mechanisms; earthquake quantification, source characteristics, seismotectonics and seismic hazards; digital seismographs, Earthquake statistics, wave propogation in elastic media, quantifying earthquake source from seismological data. Elements of Seismic Tomography.

Potential and Time Varying Fields: Scalar and vector potential fields; Laplace, Maxwell and Helmholtz equations for solution of different types of boundary value problems in Cartesian, cylindrical and spherical polar coordinates; Green's theorem; Image theory; integral equations in potential and time-varying field theory.

Gravity Methods: Absolute and relative gravity measurements; Gravimeters; Land, airborne, shipborne and bore-hole gravity surveys; Tensorial Gravity sensors and surveys; various corrections for gravity data reduction – free air, Bouguer and isostatic anomalies; density estimates of rocks; regional and residual gravity separation; principle of equivalent stratum; data enhancement techniques, upward and downward continuation; derivative maps, wavelength filtering; preparation and analysis of gravity maps; gravity anomalies and their interpretation – anomalies due to geometrical and irregular shaped bodies, depth rules, calculation of mass.

Magnetic Methods: Elements of Earth's magnetic field, units of measurement, magnetic susceptibility of rocks and measurements, magnetometers and magnetic gradiometers, Land, airborne and marine magnetic and magnetic gradiometer surveys, Various corrections applied to magnetic data, IGRF, Reduction to Pole transformation, Poisson's relation of gravity and magnetic potential field, preparation of magnetic maps, upward and downward continuation, magnetic anomalies due to geometrical and irregular shaped bodies; Image processing concepts in processing of magnetic anomaly maps; Depth rules; Interpretation of processed magnetic anomaly data; derivative, analytic signal and Euler Depth Solutions. Applications of gravity and magnetic methods for mineral and oil exploration.

Electrical Methods: Conduction of electricity through rocks, electrical conductivities of metals, non- metals, rock forming minerals and different rocks, concepts of D.C. resistivity measurement and depth of investigation; Apparent Resistivity and Apparent Chargeability, Concept of Negative Apparent Resistivity and Negative Apparent Chargeability; Theory of Reciprocity, Sounding and Profiling, Various electrode arrangements, application of linear filter theory, Sounding curves over multi-layered earth, Dar-Zarrouk parameters, reduction of layers, Triangle of anisotropy, interpretation of resistivity field data, Principles of equivalence and suppression, self-potential method and its origin; Electrical Resitivity Tomography (ERT); Induced polarization, time and frequency domain IP measurements; interpretation and applications of SP, resistivity and IP data sets for ground-water exploration, mineral exploration, environmental and engineering applications.

Electromagnetic Methods: Geo-electromagnetic spectrum; Biot Savart's Law; Maxwell's Equation, Helmotz Equation, Basic concept of EM induction in the earth, Skin-depth, elliptic polarization, in-phase and quadrature components, phasor diagrams; Response function and response parameters; Ground and Airborne Methods, measurements in different source-receiver configurations; Earth's natural electromagnetic methods-tellurics, geomagnetic depth sounding and magnetotellurics; Electromagnetic profiling and Sounding, Time domain EM method; EM scale modelling, processing of EM data and interpretation; Ground Penetrating Radar (GPR) Methods; Effect of conducting overburden; Geological applications including groundwater, mineral environmental and hydrocarbon exploration.

Seismic Methods: Elastic properties of earth materials; Reflection, refraction and CDP surveys; land and marine seismic sources, generation and propagation of elastic waves, velocity – depth models, geophones, hydrophones, digital recording systems, digital formats, field layouts, seismic noise and noise profile analysis, optimum geophone grouping, noise cancellation by shot and geophone arrays, 2D, 3D and 4D seismic data acquisition, processing and interpretation; CDP stacking charts, binning, filtering, static and dynamic corrections, Digital seismic data processing, seismic deconvolution and migration methods, attribute analysis, bright and dim spots, seismic stratigraphy, high resolution seismics, VSP, AVO, multi-component seismics and seismic interferometry.

Reservoir Geophysics: Rock Physics and Petrophysics. Geophysical Survey Design.

Geophysical Signal Processing: Sampling theorem, Nyquist frequency, aliasing, Fourier series, periodic waveform, Fourier and Hilbert transform, Z-transform and wavelet transform; power spectrum, delta function, auto correlation, cross correlation, convolution, deconvolution, principles of digital filters, windows, poles and zeros.

Geophysical Well Logging: Principles and techniques of geophysical well-logging, SP, resistivity, induction, gamma ray, neutron, density, sonic, temperature, dip meter, caliper, nuclear magnetic resonance- longitudinal and transverse relaxation, CPMG sequence, porosity characterization, cement bond logging, micro-logs. Pulsed Neutron Devices and Spectroscopy Multi-Array and Triaxial Induction Devices; Quantitative evaluation of formations from well logs; Logging while drilling; High angle and horizontal wells; Clay Quantification; Lithology and Porosity Estimation; Saturation and Permeability Estimation; application of bore hole geophysics in ground water, mineral and oil exploration.

Radioactive Methods: Prospecting and assaying of mineral (radioactive and non-radioactive) deposits, half-life, decay constant, radioactive equilibrium, G M counter, scintillation detector, semiconductor devices, application of radiometric for exploration, assaying and radioactive waste disposal.

Geophysical Inversion: Basic concepts of forward and inverse problems, Ill-posedness of inverse problems, condition number, non-uniqueness and stability of solutions; L1, L2 and Lp norms, over determined, underdetermined and mixed determined inverse problems, quasi-linear and non-linear methods including Tikhonov's regularization method, Singular Value Decomposition, Backus-Gilbert method, simulated annealing, genetic algorithms, swarm intelligence, machine learning and artificial neural networks. Statistics of misfit and likelihood, Bayesian construction of posterior probabilities, sparsity promoting L1 optimization. Ambiguity and uncertainty in geophysical interpretation.

IN Instrumentation Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra, systems of linear equations, consistency and rank, Eigenvalue and Eigenvectors.

Calculus: Mean value theorems, theorems of integral calculus, partial derivatives, maxima and minima, multiple integrals, Fourier series, vector identities, line, surface and volume integrals, Stokes, Gauss and Green's theorems.

Differential Equations: First order equation (linear and nonlinear), second order linear differential equations with constant coefficients, method of variation of parameters, Cauchy's and Euler's equations, initial and boundary value problems, solution of partial differential equations: variable separable method.

Analysis of Complex Variables: Analytic functions, Cauchy's integral theorem and integral formula, Taylor's and Laurent's series, residue theorem, solution of integrals.

Probability and Statistics: Sampling theorems, conditional probability, mean, median, mode, standard deviation and variance; random variables: discrete and continuous distributions: normal, Poisson and binomial distributions.

Numerical Methods: Matrix inversion, solutions of non-linear algebraic equations, iterative methods for solving differential equations, numerical integration, regression and correlation analysis.

Section 2: Electricity and Magnetism

Coulomb's Law, Electric Field Intensity, Electric Flux Density, Gauss's Law, Divergence, Electric field and potential due to point, line, plane and spherical charge distributions, Effect of dielectric medium, Capacitance of simple configurations, Biot-Savart's law, Ampere's law, Curl, Faraday's law, Lorentz force, Inductance, Magnetomotive force, Reluctance, Magnetic circuits, Self and Mutual inductance of simple configurations.

Section 3: Electrical Circuits and Machines

Voltage and Current Sources: Independent, dependent, ideal and practical; v-i relationships of resistor, inductor, mutual inductance and capacitor; transient analysis of RLC circuits with dc excitation.

Kirchoff's laws, mesh and nodal analysis, superposition, Thevenin, Norton, maximum power transfer and reciprocity theorems.

Peak-, average- and rms values of AC quantities; apparent-, active- and reactive powers; phasor analysis, impedance and admittance; series and parallel resonance, locus diagrams, realization of basic filters with R, L and C elements. transient analysis of RLC circuits with ac excitation.

One-port and two-port networks, driving point impedance and admittance, open-, and short circuit parameters.

Single Phase Transformer: Equivalent circuit, phasor diagram, open circuit and short circuit tests, regulation and efficiency; Three phase induction motors: principle of operation, types, performance, torque-speed characteristics, no-load and blocked rotor tests, equivalent circuit, starting and speed control; Types of losses and efficiency calculations of electric machines.

Section 4: Signals and Systems

Periodic, aperiodic and impulse signals; Laplace, Fourier and z-transforms; transfer function, frequency response of first and second order linear time invariant systems, impulse response of systems; convolution,

correlation. Discrete time system: impulse response, frequency response, pulse transfer function; DFT and FFT; basics of IIR and FIR filters.

Section 5: Control Systems

Feedback principles, signal flow graphs, transient response, steady-state-errors, Bode plot, phase and gain margins, Routh and Nyquist criteria, root loci, design of lead, lag and lead-lag compensators, state-space representation of systems; time-delay systems; mechanical, hydraulic and pneumatic system components, synchro pair, servo and stepper motors, servo valves; on-off, P, PI, PID, cascade, feed forward, and ratio controllers, tuning of PID controllers and sizing of control valves.

Section 6: Analog Electronics

Characteristics and applications of diode, Zener diode, BJT and MOSFET; small signal analysis of transistor circuits, feedback amplifiers. Characteristics of ideal and practical operational amplifiers; applications of opamps: adder, subtractor, integrator, differentiator, difference amplifier, instrumentation amplifier, precision rectifier, active filters, oscillators, signal generators, voltage controlled oscillators and phase locked loop, sources and effects of noise and interference in electronic circuits.

Section 7: Digital Electronics

Combinational logic circuits, minimization of Boolean functions. IC families: TTL and CMOS. Arithmetic circuits, comparators, Schmitt trigger, multi-vibrators, sequential circuits, flipflops, shift registers, timers and counters; sample-and-hold circuit, multiplexer, analog-to-digital (successive approximation, integrating, flash and sigma-delta) and digital-to-analog converters (weighted R, R-2R ladder and current steering logic). Characteristics of ADC and DAC (resolution, quantization, significant bits, conversion/settling time); basics of number systems, Embedded Systems: Microprocessor and microcontroller applications, memory and input-output interfacing; basics of data acquisition systems, basics of distributed control systems (DCS) and programmable logic controllers (PLC).

Section 8: Measurements

SI units, standards (R, L, C, voltage, current and frequency), systematic and random errors in measurement, expression of uncertainty - accuracy and precision, propagation of errors, linear and weighted regression. Bridges: Wheatstone, Kelvin, Megohm, Maxwell, Anderson, Schering and Wien for measurement of R, L, C and frequency, Q-meter. Measurement of voltage, current and power in single and three phase circuits; ac and dc current probes; true rms meters, voltage and current scaling, instrument transformers, timer/counter, time, phase and frequency measurements, digital voltmeter, digital multimeter; oscilloscope, shielding and grounding.

Section 9: Sensors and Industrial Instrumentation

Resistive-, capacitive-, inductive-, piezoelectric-, Hall effect sensors and associated signal conditioning circuits; transducers for industrial instrumentation: displacement (linear and angular), velocity, acceleration, force, torque, vibration, shock, pressure (including low pressure), flow (variable head, variable area, electromagnetic, ultrasonic, turbine and open channel flow meters) temperature (thermocouple, bolometer, RTD (3/4 wire), thermistor, pyrometer and semiconductor); liquid level, pH, conductivity and viscosity measurement. 4-20 mA two-wire transmitter.

Section 10: Communication and Optical Instrumentation

Amplitude- and frequency modulation and demodulation; Shannon's sampling theorem, pulse code modulation; frequency and time division multiplexing, amplitude-, phase-, frequency-, quadrature amplitude, pulse shift keying for digital modulation; optical sources and detectors: LED, laser, photo-diode, light dependent resistor, square law detectors and their characteristics; interferometer: applications in metrology; basics of fiber optic sensing. UV-VIS Spectrophotometers, Mass spectrometer.

MA Mathematics

Calculus: Functions of two or more variables, continuity, directional derivatives, partial derivatives, total derivative, maxima and minima, saddle point, method of Lagrange's multipliers; Double and Triple integrals and their applications to area, volume and surface area; Vector Calculus: gradient, divergence and curl, Line integrals and Surface integrals, Green's theorem, Stokes' theorem, and Gauss divergence theorem.

Linear Algebra: Finite dimensional vector spaces over real or complex fields; Linear transformations and their matrix representations, rank and nullity; systems of linear equations, characteristic polynomial, eigen values and eigen vectors, diagonalization, minimal polynomial, Cayley-Hamilton Theorem, Finite dimensional inner product spaces, Gram-Schmidt orthonormalization process, symmetric, skew-symmetric, Hermitian, skew-Hermitian, normal, orthogonal and unitary matrices; diagonalization by a unitary matrix, Jordan canonical form; bilinear and quadratic forms.

Real Analysis: Metric spaces, connectedness, compactness, completeness; Sequences and series of functions, uniform convergence, Ascoli-Arzela theorem; Weierstrass approximation theorem; contraction mapping principle, Power series; Differentiation of functions of several variables, Inverse and Implicit function theorems; Lebesgue measure on the real line, measurable functions; Lebesgue integral, Fatou's lemma, monotone convergence theorem, dominated convergence theorem.

Complex Analysis: Functions of a complex variable: continuity, differentiability, analytic functions, harmonic functions; Complex integration: Cauchy's integral theorem and formula; Liouville's theorem, maximum modulus principle, Morera's theorem; zeros and singularities; Power series, radius of convergence, Taylor's series and Laurent's series; Residue theorem and applications for evaluating real integrals; Rouche's theorem, Argument principle, Schwarz lemma; Conformal mappings, Mobius transformations.

Ordinary Differential Equations: First order ordinary differential equations, existence and uniqueness theorems for initial value problems, linear ordinary differential equations of higher order with constant coefficients; Second order linear ordinary differential equations with variable coefficients; Cauchy-Euler equation, method of Laplace transforms for solving ordinary differential equations, series solutions (power series, Frobenius method); Legendre and Bessel functions and their orthogonal properties; Systems of linear first order ordinary differential equations, Sturm's oscillation and separation theorems, Sturm-Liouville eigenvalue problems, Planar autonomous systems of ordinary differential equations: Stability of stationary points for linear systems with constant coefficients, Linearized stability, Lyapunov functions.

Algebra: Groups, subgroups, normal subgroups, quotient groups, homomorphisms, automorphisms; cyclic groups, permutation groups, Group action, Sylow's theorems and their applications; Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domains, Principle ideal domains, Euclidean domains, polynomial rings, Eisenstein's irreducibility criterion; Fields, finite fields, field extensions, algebraic extensions, algebraically closed fields

Functional Analysis: Normed linear spaces, Banach spaces, Hahn-Banach theorem, open mapping and closed graph theorems, principle of uniform boundedness; Inner-product spaces, Hilbert spaces, orthonormal bases, projection theorem, Riesz representation theorem, spectral theorem for compact self-adjoint operators.

Numerical Analysis: Systems of linear equations: Direct methods (Gaussian elimination, LU decomposition, Cholesky factorization), Iterative methods (Gauss-Seidel and Jacobi) and their convergence for diagonally dominant coefficient matrices; Numerical solutions of nonlinear equations: bisection method, secant method, Newton-Raphson method, fixed point iteration; Interpolation: Lagrange and Newton forms of interpolating polynomial, Error in polynomial interpolation of a function; Numerical differentiation and error, Numerical integration: Trapezoidal and Simpson rules, Newton-Cotes integration formulas, composite rules, mathematical

errors involved in numerical integration formulae; Numerical solution of initial value problems for ordinary differential equations: Methods of Euler, Runge-Kutta method of order 2.

Partial Differential Equations: Method of characteristics for first order linear and quasilinear partial differential equations; Second order partial differential equations in two independent variables: classification and canonical forms, method of separation of variables for Laplace equation in Cartesian and polar coordinates, heat and wave equations in one space variable; Wave equation: Cauchy problem and d'Alembert formula, domains of dependence and influence, non-homogeneous wave equation; Heat equation: Cauchy problem; Laplace and Fourier transform methods.

Topology: Basic concepts of topology, bases, subbases, subspace topology, order topology, product topology, quotient topology, metric topology, connectedness, compactness, countability and separation axioms, Urysohn's Lemma.

Linear Programming: Linear programming models, convex sets, extreme points; Basic feasible solution, graphical method, simplex method, two phase methods, revised simplex method ; Infeasible and unbounded linear programming models, alternate optima; Duality theory, weak duality and strong duality; Balanced and unbalanced transportation problems, Initial basic feasible solution of balanced transportation problems (least cost method, north-west corner rule, Vogel's approximation method); Optimal solution, modified distribution method; Solving assignment problems, Hungarian method.

ME Mechanical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra, systems of linear equations, eigen values and eigen vectors.

Calculus: Functions of single variable, limit, continuity and differentiability, mean value theorems, indeterminate forms; evaluation of definite and improper integrals; double and triple integrals; partial derivatives, total derivative, Taylor series (in one and two variables), maxima and minima, Fourier series; gradient, divergence and curl, vector identities, directional derivatives, line, surface and volume integrals, applications of Gauss, Stokes and Green's theorems.

Differential Equations: First order equations (linear and nonlinear); higher order linear differential equations with constant coefficients; Euler-Cauchy equation; initial and boundary value problems; Laplace transforms; solutions of heat, wave and Laplace's equations.

Complex Variables: Analytic functions; Cauchy-Riemann equations; Cauchy's integral theorem and integral formula; Taylor and Laurent series.

Probability and Statistics: Definitions of probability, sampling theorems, conditional probability; mean, median, mode and standard deviation; random variables, binomial, Poisson and normal distributions.

Numerical Methods: Numerical solutions of linear and non-linear algebraic equations; integration by trapezoidal and Simpson's rules; single and multi-step methods for differential equations.

Section 2: Applied Mechanics and Design

Engineering Mechanics: Free-body diagrams and equilibrium; friction and its applications including rolling friction, belt-pulley, brakes, clutches, screw jack, wedge, vehicles, etc.; trusses and frames; virtual work; kinematics and dynamics of rigid bodies in plane motion; impulse and momentum (linear and angular) and energy formulations; Lagrange's equation.

Mechanics of Materials: Stress and strain, elastic constants, Poisson's ratio; Mohr's circle for plane stress and plane strain; thin cylinders; shear force and bending moment diagrams; bending and shear stresses; concept of shear centre; deflection of beams; torsion of circular shafts; Euler's theory of columns; energy methods; thermal stresses; strain gauges and rosettes; testing of materials with universal testing machine; testing of hardness and impact strength.

Theory of Machines: Displacement, velocity and acceleration analysis of plane mechanisms; dynamic analysis of linkages; cams; gears and gear trains; flywheels and governors; balancing of reciprocating and rotating masses; gyroscope.

Vibrations: Free and forced vibration of single degree of freedom systems, effect of damping; vibration isolation; resonance; critical speeds of shafts.

Machine Design: Design for static and dynamic loading; failure theories; fatigue strength and the S-N diagram; principles of the design of machine elements such as bolted, riveted and welded joints; shafts, gears, rolling and sliding contact bearings, brakes and clutches, springs.

Section 3: Fluid Mechanics and Thermal Sciences

Fluid Mechanics: Fluid properties; fluid statics, forces on submerged bodies, stability of floating bodies; control-volume analysis of mass, momentum and energy; fluid acceleration; differential equations of continuity and momentum; Bernoulli's equation; dimensional analysis; viscous flow of incompressible fluids, boundary layer,

elementary turbulent flow, flow through pipes, head losses in pipes, bends and fittings; basics of compressible fluid flow.

Heat Transfer: Modes of heat transfer; one dimensional heat conduction, resistance concept and electrical analogy, heat transfer through fins; unsteady heat conduction, lumped parameter system, Heisler's charts; thermal boundary layer, dimensionless parameters in free and forced convective heat transfer, heat transfer correlations for flow over flat plates and through pipes, effect of turbulence; heat exchanger performance, LMTD and NTU methods; radiative heat transfer, Stefan- Boltzmann law, Wien's displacement law, black and grey surfaces, view factors, radiation network analysis

Thermodynamics: Thermodynamic systems and processes; properties of pure substances, behavior of ideal and real gases; zeroth and first laws of thermodynamics, calculation of work and heat in various processes; second law of thermodynamics; thermodynamic property charts and tables, availability and irreversibility; thermodynamic relations.

Applications: *Power Engineering*: Air and gas compressors; vapour and gas power cycles, concepts of regeneration and reheat. *I.C. Engines*: Air-standard Otto, Diesel and dual cycles. *Refrigeration and air-conditioning*: Vapour and gas refrigeration and heat pump cycles; properties of moist air, psychrometric chart, basic psychrometric processes. *Turbomachinery*: Impulse and reaction principles, velocity diagrams, Pelton-wheel, Francis and Kaplan turbines; steam and gas turbines.

Section 4: Materials, Manufacturing and Industrial Engineering

Engineering Materials: Structure and properties of engineering materials, phase diagrams, heat treatment, stress-strain diagrams for engineering materials.

Casting, Forming and Joining Processes: Different types of castings, design of patterns, moulds and cores; solidification and cooling; riser and gating design. Plastic deformation and yield criteria; fundamentals of hot and cold working processes; load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal forming processes; principles of powder metallurgy. Principles of welding, brazing, soldering and adhesive bonding.

Machining and Machine Tool Operations: Mechanics of machining; basic machine tools; single and multi-point cutting tools, tool geometry and materials, tool life and wear; economics of machining; principles of non-traditional machining processes; principles of work holding, jigs and fixtures; abrasive machining processes; NC/CNC machines and CNC programming.

Metrology and Inspection: Limits, fits and tolerances; linear and angular measurements; comparators; interferometry; form and finish measurement; alignment and testing methods; tolerance analysis in manufacturing and assembly; concepts of coordinate-measuring machine (CMM).

Computer Integrated Manufacturing: Basic concepts of CAD/CAM and their integration tools; additive manufacturing.

Production Planning and Control: Forecasting models, aggregate production planning, scheduling, materials requirement planning; lean manufacturing.

Inventory Control: Deterministic models; safety stock inventory control systems.

Operations Research: Linear programming, simplex method, transportation, assignment, network flow models, simple queuing models, PERT and CPM.

MN Mining Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrices and Determinants; Inverse and Rank of matrix; Systems of linear equations; Eigen values and Eigen vectors. Cayley-Hamilton Theorem.

Calculus: Limit, continuity and differentiability; Partial Derivatives; Mean value theorems; Indeterminate forms and L' Hospital's rule; Maxima and minima; Taylor's theorem; Sequences and series; Test for convergence; Fourier series.

Vector Calculus: Gradient; Divergence and Curl; Line; surface and volume integrals; Stokes, Gauss and Green's theorems.

Differential Equations: Linear and non-linear first order ODEs; Higher order linear ODEs with constant coefficients; Cauchy's and Euler's equations.

Probability and Statistics: Measures of central tendency and dispersion; hypothesis testing; Binomial, Poisson, exponential and normal distributions; Correlation and regression analysis.

Numerical Methods: Solutions of linear algebraic equations; Interpolation; Integration of trapezoidal and Simpson's rule; Single and multi-step methods for differential equations.

Section 2: Mining Geology, Mine Development and Surveying

Mining Geology: Minerals, Rocks and their Origin, Classification, Ore Genesis; Structural Geology.

Mine Development: Methods of access to deposits; Underground drivages; Drilling method and machines; Explosives and energetics, blasting devices, blast design practices; Rock-Tool Interaction applicable to mechanical cutting systems and their selection.

Mine Surveying: Levels and levelling, theodolite, tacheometry, triangulation; Contouring; Errors and adjustments; Correlation; Underground surveying; Curves; Photogrammetry; EDM, Total Station, GPS, Basics of GIS and remote sensing.

Section 3: Geomechanics and Ground Control

Engineering Mechanics: Equivalent force systems; Equations of equilibrium; Two dimensional frames and trusses; Free body diagrams; Friction forces; Particle kinematics and dynamics; Beam analysis.

Geomechanics: Geo-technical properties of rocks; Rock mass classification; Instrumentation and in-situ stress measurement techniques; Theories of rock failure; Ground vibrations; Stress distribution around mine openings; Subsidence; Slope stability.

Ground Control: Design of pillars; Roof supporting systems; Mine filling. Strata Control and Monitoring Plan.

Section 4: Mining Methods and Machinery

Mining Methods: Surface mining: layout, development, loading, transportation and mechanization, continuous surface mining systems; highwall mining; Underground coal mining:bord and pillar systems, room and pillar mining, longwall mining, thick seam mining methods, Underground metal mining: open, supported and caved stoping methods, stope mechanization, ore handling systems.

Mining Machinery: Generation and transmission of mechanical, hydraulic and pneumatic power; Materials handling: wire ropes, haulages, conveyors, face and development machinery, hoisting systems, pumps; comminution methods and machinery.

Section 5: Surface Environment, Mine Ventilation and Underground Hazards

Surface Environment: Air, water and soil pollution: Standards of quality, causes and dispersion of contamination and control; Noise pollution and control; Land reclamation; EIA.

Mine Ventilation: Underground atmosphere; Heat load sources and thermal environment, air cooling; Mechanics of airflow, distribution, natural and mechanical ventilation; Mine fans and usage; Auxiliary ventilation; Ventilation survey and planning; Ventilation networks.

Underground Hazards: Mine Gases, Methane drainage; Underground hazards from fires, explosions, dust and inundation; Rescue apparatus and practices; Safety management plan; Accident data analysis; assessment; Mine lighting; Mine legislation; Occupational health and safety.

Section 6: Mineral Economics, Mine Planning, Systems Engineering

Mineral Economics: Mineral resource classification; Discounted cash flow analysis; Mine valuation; Mineral taxation.

Mine Planning: Sampling methods, practices and interpretation; Reserve estimation techniques: Basics of geostatistics and quality control; Optimization of facility location; Mine planning and its components, Determination of mine size and mine life; Ultimate pit configuration and its determination, Optimum mill cut-off grade and its determination, Stope planning, Design of haul road, Selection of mining system vis-à-vis equipment system.

Systems Engineering: Concepts of reliability; Reliability of simple systems; Maintainability and availability; Linear programming, transportation and assignment problems; Network analysis; Inventory models; Queuing theory; Decision trees.

MT Metallurgical Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrices and Determinants, Systems of linear equations, Eigen values and Eigen vectors.

Calculus: Limit, Continuity and Differentiability; Partial derivatives; Maxima and minima; Sequences and series; Test for convergence; Fourier series.

Vector Calculus: Gradient; Divergence and Curl; Line, Surface and volume integrals; Stokes, Gauss and Green's theorems.

Differential Equations: Linear and non-linear first order ODEs; Higher order linear ODEs with constant coefficients; Cauchy's and Euler's equations; Laplace transforms; PDEs –Laplace, one dimensional heat and wave equations.

Probability and Statistics: Definitions of probability and sampling theorems, conditional probability, Mean, median, mode and standard deviation; Random variables; Poisson, normal and binomial distributions; Analysis of experimental data; linear least squares method.

Numerical Methods: Solutions of linear and non-linear (Bisection, Secant, Newton- Raphson methods) algebraic equations; integration by trapezoidal and Simpson's rule; single and multi-step methods for differential equations.

Section 2: Metallurgical Thermodynamics

Laws of Thermodynamics: First law – energy conservation, Second law - entropy; Enthalpy, Gibbs and Helmholtz free energy; Maxwell's relations; Chemical potential; Applications to metallurgical systems, solutions, ideal and regular solutions; Gibbs phase rule, phase equilibria, binary phase diagram and lever rule, free-energy vs. composition diagrams; Equilibrium constant, Activity, Ellingham and phase stability diagrams; Thermodynamics of point defects, surfaces and interfaces, adsorption and segregation phenomena.

Electrochemistry: Single electrode potential, Electrochemical cells, Nernst equation, Potential-pH diagrams.

Section 3: Transport Phenomena and Rate Processes

Momentum Transfer: Concept of viscosity, shell balances, Bernoulli's equation, mechanical energy balance equation, flow past plane surfaces and through pipes.

Heat transfer: Conduction, Fourier's Law, 1-D steady state conduction.

Convection: Heat transfer coefficient relations for forced convection.

Radiation: Black body radiation, Stefan-Boltzman Law, Kirchhoff's Law.

Mass Transfer: Diffusion and Fick's laws, Mass transfer coefficients.

Dimensional Analysis: Buckingham Pi theorem, Significance of dimensionless numbers.

Basic Laws of Chemical Kinetics: First order reactions, reaction rate constant, Arrhenius relation, heterogeneous reactions, oxidation kinetics.

Electrochemical Kinetics: Polarization.

Section 4: Mineral Processing and Extractive Metallurgy

Comminution techniques, Size classification, Flotation, Gravity and other methods of mineral beneficiation; Agglomeration: sintering, pelletizing and briquetting.

Material and Energy balances in metallurgical processes; Principles and processes for the extraction of non-ferrous metals – aluminium, copper and titanium.

Iron and Steel Making: Material and heat balance in blast furnace; Structure and properties of slags and molten salts – basicity of slags - sulphide and phosphate capacity of slags; Production of metallurgical coke. Other methods of iron making (COREX, MIDRE)

Primary Steel Making: Basic oxygen furnace, process dynamics, oxidation reactions, electric arc furnace.

Secondary Steel Making: Ladle process – deoxidation, argon stirring, desulphurization, inclusion shape control, principles of degassing methods; Basics of stainless steel manufacturing.
Continuous Casting: Fluid flow in the tundish and mould, heat transfer in the mould, segregation, inclusion control.

Section 5: Physical Metallurgy

Chemical Bonding: Ionic, covalent, metallic, and secondary bonding in materials, Crystal structure of solids – metals and alloys, ionic and covalent solids, and polymers.
X-ray Diffraction: Bragg's law, optical metallography, principles of SEM imaging.
Crystal Imperfections: Point, line and surface defects; Coherent, semi-coherent and incoherent interfaces.
Diffusion in Solids: Diffusion equation, steady state and error function solutions; Examples- homogenenization and carburization; Kirkendall effect; Uphill diffusion; Atomic models for interstitial and substitutional diffusion; Pipe diffusion and grain boundary diffusion.
Phase Transformation: Driving force, Homogeneous and heterogeneous nucleation, growth Kinetics Solidification in isomorphous, eutectic and peritectic systems, cast structures and macrosegregation, dendritic solidification and constitutional supercooling, coring and microsegregation.
Solid-state Transformations: Precipitation, spinoidal decomposition, ordering, massive transformation, discontinuous precipitation, eutectoid transformation, diffusionless transformations; Precipitate coarsening, Gibbs-Thomson effect.
Principles of heat treatment of steels, TTT and CCT diagrams; Surface hardening treatments; Recovery, recrystallization and grain growth; Heat treatment of cast iron and aluminium alloys.
Electronic, magnetic and optical properties of materials.
Basic forms of corrosion and its prevention.

Section 6: Mechanical Metallurgy

Strain tensor and stress tensor, Representation by Mohr's circle, elasticity, stiffness and compliance tensor, Yield criteria, Plastic deformation by slip and twinning.
Dislocation Theory: Edge, screw and mixed dislocations, source and multiplication of dislocations, stress fields around dislocations; Partial dislocations, dislocation interactions and reactions.
Strengthening Mechanisms: Work/strain hardening, strengthening due to grain boundaries, solid solution, precipitation and dispersion.
Fracture behaviour, Griffith theory, linear elastic fracture mechanics, fracture toughness, fractography, ductile to brittle transition.
Fatigue: Cyclic stress strain behaviour - low and high cycle fatigue, crack growth. Mechanisms of high temperature deformation and failure; creep and stress rupture, stress exponent and activation energy.

Section 7: Manufacturing Processes

Metal Casting: Mould design involving feeding, gating and risering, casting practices, casting defects.

Hot, Warm and Cold Working of Metals: Metal forming – fundamentals of metal forming processes of rolling, forging, extrusion, wire drawing and sheet metal forming, defects in forming.

Metal Joining: Principles of soldering, brazing and welding, welding metallurgy, defects in welded joints in steels and aluminium alloys.

Powder Metallurgy: production of powders, compaction and sintering.

Non-destructive Testing (NDT): Dye-penetrant, ultrasonic, radiography, eddy current, acoustic emission and magnetic particle inspection methods.

NM Naval Architecture and Marine Engineering

Section 1: Engineering Mathematics

Determinants and matrices, Systems of linear equations, Eigen values and eigen vectors. Functions, gradient, divergence, curl, chain rules, partial derivatives, directional derivatives, definite and indefinite integrals, line surface and volume integrals, theorems of Stokes, Gauss and Green. Linear, non-linear, first and higher order ordinary and partial differential equations, separation of variables.

Laplace transformation, analytical functions of complex variables, Fourier series, numerical methods for differentiation and integration, complex analysis, probability and statistics.

Section 2: Applied Mechanics and Structures

Engineering Mechanics: Free-body diagrams and equilibrium; trusses and frames; virtual work; kinematics and dynamics of particles and rigid bodies in plane motion; impulse and momentum (linear and angular) and energy formulations.

Mechanics of Materials: Stress and strain, elastic constants, Poisson's ratio; Mohr's circle for plane stress and plane strain; shear force and bending moment diagrams; bending and shear stresses; torsion; Euler's theory of columns; energy methods; theories and failure, material testing methods.

Vibrations: Free and forced vibration of damped and undamped systems, single and multi DOF systems.

Machine Design: Design for static and dynamic loading; Design of machine elements such as shafts, gears, rolling and sliding contact bearings; Joining techniques such as bolting, riveting and welding.

Section 3: Fluid Mechanics and Marine Hydrodynamics

Fluid Mechanics: Fluid properties; fluid statics, stability of floating bodies; Conservation laws: Mass, momentum and energy (Integral and differential form); Dimensional analysis and dynamic similarity; sources, sinks, doublets, line vortex and their superposition; Stoke's integral theorem. Generalised Bernoulli's equation, sources, sinks, dipole, Flow with circulation, potential flow with rotational symmetry, hydrodynamical lift, Kutta-Joukowski theorem. Vortex motion- Fundamental concepts, vortex analogy to Biot-Savart's law, straight parallel vortex filaments, vortex sheets. Viscous flow - Navier-Stokes equations, Couette flow, Plane poiseuille flow. Equation of continuity, Euler's equation, Bernoulli's equation, Viscous flow of incompressible fluids, elementary turbulent flow, boundary layer, flow through pipes.

Boundary layer theory- Prandtl's boundary layer equations, criterion for separation, Blasius solution, Skin friction, displacement thickness, momentum thickness, Turbulent boundary layer, Boundary layer control. Airfoils- Lift, drag, circulation, pressure distribution-theory of thin aerofoils, wings of infinite and finite span, circulation distribution, Cavitation.

Vorticity and Kelvin's theorem, Potential flow theory, Sources, Sinks and Doublets, hydrodynamic forces in potential flow, D'Alembert's paradox, added-mass, slender-body theory, hydrodynamic model testing, scaling laws, application of potential theory to surface waves, energy transport, wave/body forces, linearised theory of lifting surfaces.

Section 4: Naval Architecture and Ocean Engineering

Ship geometry and physical fundamentals - Archimedes' principle, buoyancy and weight of ship, laws of flotation, heel and trim, stable and unstable equilibrium of ships, importance of streamlined hull shape, ship main particulars, hydrostatic calculations,

Stability and Trim of Ships: Statical stability at small angles of heel, Inclining experiment. Shift of centre of gravity due to addition or removal of mass, transverse movement of mass and effect, Free surface effect, Effect of suspended mass, Stability at large angles of heel, angle of loll, curves of statical stability, dynamical stability, Probabilistic and deterministic Damage Stability Different Characteristic curves of dynamic stability. Floodable length calculations and curves. Loss of stability due to grounding, docking stability.

Resistance and Propulsion: Components of ship resistance, form factor, hull roughness, model testing and ship resistance prediction methods, tank wall effects, determination of ship resistance different series test results, resistance of advanced vehicles, appendage and added resistance. Geometry of screw propeller, propeller theories, hull-propeller interactions, different propulsive efficiency definitions. Propeller cavitation and effects. Propeller design and series. Open water and self-propulsion model tests. Different types of propellers and their working principles. Propeller material, strength and manufacturing. Unconventional propellers.

Ship Manoeuvring and Motions: Ship path keeping and changing, equations of motion, linearised equations and control fixed stability indexes, model tests. Stability and control in the horizontal and vertical planes – definitive manoeuvres and sea trials. Rudder hydrodynamics, design and operation. Influence of propeller, hull, appendages etc. on rudder performance. Experimental methods for the determination of hydrodynamic derivatives.

Ocean waves – regular, irregular, trochoidal. Wave spectrum, encounter frequency. Types of ship motions, coupled and non-coupled motions, equations of motion. Dynamic effects of ship motion in seaway. Different ship motion stabilisers – passive and active. Different numerical and experimental methods to determine ship motions – strip theory, BEM, FEM. Seakeeping features of high-performance marine vehicles.

Ship Structures and Strength: Shipbuilding materials, joining techniques, ship structural and framing systems – bottom, side, deck, bulkhead, end structures, and structural connections. Primary and secondary structural members, superstructure, hatch covers, machinery foundations, cargo handling systems and support structures.

Loads acting on ships in seaway, longitudinal and transverse strength considerations and estimation methods. Strength of hull girder, stiffened plate analysis, torsion of hull girder, deformation and stresses, local strength analysis; Reliability analysis and ultimate strength of hull girder, structural vibrations, fatigue and fracture.

Physical Oceanography: Physical properties of seawater, Different types of ocean waves - tides and wind waves, and their importance. Offshore Structures: Fixed offshore platforms - Jackets, Gravity platforms; Floating platforms - semi-submersibles, jack-ups, TLPs, FPSOs; Mooring, station keeping. Port and Harbour Engineering: Ports and Harbours, Port structures - Jetties, Dolphins, Liquid berths, Dredging, Navigation.

Section 5: Thermodynamics and Marine Engineering

Thermodynamics: First law of thermodynamics - Closed system undergoing a cycle; closed system undergoing a change of state; Internal energy of a system; Expansion work; Process using ideal gas - constant pressure, constant volume, isothermal; adiabatic and polytropic process -work done and heat added in different process; First law applied to one - dimensional steady flow process, flow energy, steady flow energy equation (ID). Second law of Thermodynamics - Different statements; Reversible and irreversible process; Corollaries of second law - Absolute temperature scale; Carnot cycle - Carnot engine, refrigerator and heat pump. Clausius inequality and definition of entropy, change of entropy of an ideal gas; Gas power cycles and I.C.Engines; Gas power cycles: Carnot cycle, Brayton cycle, Erricson cycle, Sterling cycle etc.; Air standard cycles- Otto- Diesel, Dual and Joule cycle; Evaluation of thermal efficiency and mean effective pressure; Internal Combustion engine - Classification of I.C. engines -Principle of operation of spark Ignition and Compression Ignition engines both two stroke and four stroke; Stages of combustion in S.I. and C.I. engines; Knocking and detonation-factors controlling knock and detonation, methods of preventing Knocking and detonation; Refrigeration - principle of operation of Simple vapour compression system, Comparison with vapour compression systems; Air conditioning principles - Sensible heating and cooling, Humidification and dehumidification, Cooling and humidification, Cooling and dehumidification- Heating and humidification, Heating and dehumidification, Adiabatic mixing of air streams –cooling and heating load calculation.

Marine Diesel Engines: General engine principles, Low speed and medium speed diesel engines, Two and Four stroke engines, Scavenging and turbo charging, Fuel oil system, Lubricating oil systems, cooling systems, torque and power measurement, Starting air systems and reversing systems, controls and safety devices, Couplings and Gearboxes, Specific Fuel Consumption. Waste heat recovery system, MARPOL regulations and Energy Efficiency Design Index (EEDI), Ship Energy Efficiency Management Plan (SEEMP).

Marine Steam Turbines: Types of turbines, compounding, reheat, turbine construction, rotors, blades, casing, Gland sealing, diaphragms, nozzles, bearings etc. Lubrication systems, expansion arrangements, Gearings. Marine gas turbines – fundamentals of G.T, Structure of gas turbines, gearing, operational features, controls, combined cycles. Nuclear propulsion –physical principles of the operation of nuclear reactors – use of nuclear propulsion on seagoing vessels, Electrical Propulsion,

Marine Boilers: Types - fire tube, water tube boilers, Package boilers, Cochran Boilers, Composite boilers, steam to steam generators, double evaporation boilers, exhaust gas heat exchangers, auxiliary steam plant systems, exhaust gas boilers, composite boilers. Boiler mounting, combustion, feed system, feed water treatment.

Engine Dynamics: Torsional vibration of engine and shafting, axial shaft vibration, critical speeds, engine rating, rating corrections, trial tests etc. Relationship of engine to the propeller classification society rules on engine construction, Engine room arrangement. Automation of ship propulsion plants, Maintenance requirements and reliability of propulsion plants.

Marine Auxiliary Machinery & Systems: Different types of pumps and piping systems in ships - hot water, drinking water, cooling water and seawater, fuel oil systems, lubricating oil system filters, coolers, centrifuges, purifiers and clarifiers, bilge and ballast systems, sewage disposal, oily water separator, air compressors, boilers, heat exchangers, waste heat recovery systems; Heat, ventilation and air conditioning systems; Dech machinery and cargo handling systems; Propulsions and steering gear systems.

PE Petroleum Engineering

Linear Algebra: Matrix algebra, Systems of linear equations, Eigen values and eigen vectors.

Calculus: Functions of single variable, Limit, continuity and differentiability, Taylor series, Mean value theorems, Evaluation of definite and improper integrals, Partial derivatives, Total derivative, Maxima and minima, Gradient, Divergence and Curl, Vector identities, Directional derivatives, Line, Surface and Volume integrals, Stokes, Gauss and Green's theorems.

Differential Equations: First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Cauchy's and Euler's equations, Initial and boundary value problems, Laplace transforms, Solutions of one dimensional heat and wave equations and Laplace equation.

Complex Variables: Complex number, polar form of complex number, triangle inequality.

Probability and Statistics: Definitions of probability and sampling theorems, Conditional probability, Mean, median, mode and standard deviation, Random variables, Poisson, Normal and Binomial distributions, Linear regression analysis.

Numerical Methods: Numerical solutions of linear and non-linear algebraic equations. Integration by trapezoidal and Simpson's rule. Single and multi-step methods for numerical solution of differential equations.

Petroleum Exploration: Classification and description of some common rocks with special reference to clastic and nonclastic reservoir rocks. Origin, migration and accumulation of Petroleum. Petroleum exploration methods.

Oil and Gas Well Drilling Technology: Well planning. Drilling method. Drilling rigs Rig operating systems. Drilling fluids function and properties. Drilling fluid maintenance equipment. Oil & gas well cementing operations. Drill bit types and their applications. Drill string & Casing string function, operations, selection & design. Drilling problems, their control & remedies. Directional drilling tools. Directional survey. Application of horizontal, multilateral, extended reach, slim wells.

Reservoir Engineering: Petrophysical properties of reservoir rocks. Coring and core analysis. Reservoir fluid properties. Phase behaviour of hydrocarbon system. Flow of fluids through porous media. Water and gas coning. Reservoir pressure measurements. Reservoir drives, drive mechanics and recovery factors. Reserve estimation & techniques.

Petroleum Production Operations: Well equipments. Well completion techniques. Well production problems and mitigation. Well servicing & Workover operations. Workover & completion fluids. Formation damage. Well stimulation techniques. Artificial lift techniques. Field processing of oil & gas. Storage and transportation of petroleum and petroleum products. Metering and measurements oil & gas. Production system analysis & optimization. Production testing. Multiphase flow in tubing and flow-lines. Nodal system analysis. Pressure vessels, storage tanks, shell and tube heat exchangers, pumps and compressors, LNG value chain.

Offshore Drilling and Production Practices: Offshore oil and gas operations & ocean environment. Offshore fixed platforms, Offshore mobile units, Station keeping methods like mooring & dynamic positioning system. Offshore drilling from fixed platform, jack-up, ships and semi submersibles. Use of conductors and risers. Offshore well completion. Deep water applications of subsea technology. Offshore production: Oil processing platforms, water injection platforms, storage, SPM and SBM transportation and utilities. Deep water drilling rig. Deep water production system. Emerging deep water technologies.

Petroleum Formation Evaluation: Evaluation of petrophysical of sub-surface formations: Principles applications, advantages and disadvantages of SP, resistivity, radioactive, acoustic logs and types of tools used. Evaluation of CBL/VDL, USIT, SFT, RFT. Production logging tools, principles, limitations and applications. Special type of logging tools. Casing inspection tools (principles, applications and limitations), Formations micro scanner (FMS), NMR logging principles. Standard log interpretation methods. Cross-plotting methods.

Oil and Gas Well Testing: Diffusivity equation, derivation & solutions. Radius of investigation. Principle of superposition. Horner's approximation. Drill Stem Testing. Pressure Transient Tests: Drawdown and build up-test analysis. Wellbore effects. Multilayer reservoirs. Injection well testing. Multiple well testing. Interference testing, Pulse testing, well-test analysis by use of type curves. Gas well testing.

Health Safety and Environment in Petroleum Industry: Health hazards in Petroleum Industry: Toxicity, Physiological, Asphyxiation, respiratory and skin effect of petroleum hydrocarbons, sour gases. Safety System: Manual & automatic shutdown system, blow down systems. Gas detection system. Fire detection and suppression systems. Personal protection system & measures. HSE Policies. Disaster & crisis management in Petroleum Industry. Environment: Environment concepts, impact on eco-system, air, water and soil. The impact of drilling & production operations on environment, Environmental transport of petroleum wastes. Offshore environmental studies. Offshore oil spill and oil spill control. Waste treatment methods.

Enhanced Oil Recovery Techniques: Basic principles and mechanism of EOR, Screening of EOR process. Concept of pattern flooding, recovery efficiency, permeability heterogeneity. Macroscopic and microscopic displacement efficiency. EOR methods: Chemical flooding, Miscible flooding, Thermal recoveries (steam stimulation, hot water & steam flooding, in-situ combustion), Microbial EOR.

Latest Trends in Petroleum Engineering: Coal bed methane, shale gas, oil shale, gas hydrate, and heavy oil.

PH	Physics

Section 1: Mathematical Physics

Vector Calculus: Linear vector space: basis, orthogonality and completeness; matrices; similarity transformations, diagonalization, eigen values and eigen vectors; linear differential equations: second order linear differential equations and solutions involving special functions; complex analysis: Cauchy-Riemann conditions, Cauchy's theorem, singularities, residue theorem and applications; Laplace transform, Fourier analysis; elementary ideas about tensors: covariant and contravariant tensors.

Section 2: Classical Mechanics

Lagrangian Formulation: D'Alembert's principle, Euler-Lagrange equation, Hamilton's principle, calculus of variations; symmetry and conservation laws; central force motion: Kepler problem and Rutherford scattering; small oscillations: coupled oscillations and normal modes; rigid body dynamics: interia tensor, orthogonal transformations, Euler angles, Torque free motion of a symmetric top; Hamiltonian and Hamilton's equations of motion; Liouville's theorem; canonical transformations: action-angle variables, Poisson brackets, Hamilton-Jacobi equation.

Special Theory of Relativity: Lorentz transformations, relativistic kinematics, mass-energy equivalence.

Section 3: Electromagnetic Theory

Solutions of electrostatic and magnetostatic problems including boundary value problems; method of images; separation of variables; dielectrics and conductors; magnetic materials; multipole expansion; Maxwell's equations; scalar and vector potentials; Coulomb and Lorentz gauges; electromagnetic waves in free space, non-conducting and conducting media; reflection and transmission at normal and oblique incidences; polarization of electromagnetic waves; Poynting vector, Poynting theorem, energy and momentum of electromagnetic waves; radiation from a moving charge.

Section 4: Quantum Mechanics

Postulates of quantum mechanics; uncertainty principle; Schrodinger equation; Dirac Bra-Ket notation, linear vectors and operators in Hilbert space; one dimensional potentials: step potential, finite rectangular well, tunneling from a potential barrier, particle in a box, harmonic oscillator; two and three dimensional systems: concept of degeneracy; hydrogen atom; angular momentum and spin; addition of angular momenta; variational method and WKB approximation, time independent perturbation theory; elementary scattering theory, Born approximation; symmetries in quantum mechanical systems.

Section 5: Thermodynamics and Statistical Physics

Laws of thermodynamics; macrostates and microstates; phase space; ensembles; partition function, free energy, calculation of thermodynamic quantities; classical and quantum statistics; degenerate Fermi gas; black body radiation and Planck's distribution law; Bose-Einstein condensation; first and second order phase transitions, phase equilibria, critical point.

Section 6: Atomic and Molecular Physics

Spectra of one-and many-electron atoms; spin-orbit interaction: LS and jj couplings; fine and hyperfine structures; Zeeman and Stark effects; electric dipole transitions and selection rules; rotational and vibrational spectra of diatomic molecules; electronic transitions in diatomic molecules, Franck-Condon principle; Raman effect; EPR, NMR, ESR, X-ray spectra; lasers: Einstein coefficients, population inversion, two and three level systems.

Section 7: Solid State Physics

Elements of crystallography; diffraction methods for structure determination; bonding in solids; lattice vibrations and thermal properties of solids; free electron theory; band theory of solids: nearly free electron and tight binding models; metals, semiconductors and insulators; conductivity, mobility and effective mass; Optical properties of solids; Kramer's-Kronig relation, intra- and inter-band transitions; dielectric properties of solid; dielectric function, polarizability, ferroelectricity; magnetic properties of solids; dia, para, ferro, antiferro and ferri-magnetism, domains and magnetic anisotropy; superconductivity: Type-I and Type II superconductors, Meissner effect, London equation, BCS Theory, flux quantization.

Section 8: Electronics

Semiconductors in Equilibrium: Electron and hole statistics in intrinsic and extrinsic semiconductors; metal-semiconductor junctions; Ohmic and rectifying contacts; PN diodes, bipolar junction transistors, field effect transistors; negative and positive feedback circuits; oscillators, operational amplifiers, active filters; basics of digital logic circuits, combinational and sequential circuits, flip-flops, timers, counters, registers, A/D and D/A conversion.

Section 9: Nuclear and Particle Physics

Nuclear radii and charge distributions, nuclear binding energy, electric and magnetic moments; semi-empirical mass formula; nuclear models; liquid drop model, nuclear shell model; nuclear force and two nucleon problem; alpha decay, beta-decay, electromagnetic transitions in nuclei; Rutherford scattering, nuclear reactions, conservation laws; fission and fusion; particle accelerators and detectors; elementary particles; photons, baryons, mesons and leptons; quark model; conservation laws, isospin symmetry, charge conjugation, parity and time-reversal invariance.

PI Production and Industrial Engineering

Section 1: Engineering Mathematics

Linear Algebra: Matrix algebra, Systems of linear equations, Eigen values and Eigen vectors.

Calculus: Functions of single variable, Limit, continuity and differentiability, Mean value theorems, Evaluation of definite and improper integrals, Partial derivatives, Total derivative, Maxima and minima, Gradient, Divergence and Curl, Vector identities, Directional derivatives; Line, Surface and Volume integrals; Stokes, Gauss and Green's theorems.

Differential Equations: First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Cauchy's and Euler's equations, Initial and boundary value problems, Laplace transforms.

Complex Variables: Analytic functions, Cauchy's integral theorem, Taylor series.

Probability and Statistics: Definitions of probability and sampling theorems, Conditional probability, Mean, median, mode and standard deviation, Linear regression, Random variables, Poisson, normal, binomial and exponential distributions.

Numerical Methods: Numerical solutions of linear and nonlinear algebraic equations, Integration by trapezoidal and Simpson's rules, Single and multi-step methods for differential equations.

Section 2: General Engineering

Engineering Materials: Structure, physical and mechanical properties, and applications of common engineering materials (metals and alloys, semiconductors, ceramics, polymers, and composites – metal, polymer and ceramic based); Iron-carbon equilibrium phase diagram; Heat treatment of metals and alloys and its influence on mechanical properties; Stress-strain behavior of metals and alloys.

Applied Mechanics: Engineering mechanics – equivalent force systems, free body concepts, equations of equilibrium; Trusses; Strength of materials – stress, strain and their relationship; Failure theories; Mohr's circle (stress); Deflection of beams, bending and shear stresses; Euler's theory of columns; Thick and thin cylinders; Torsion.

Theory of Machines and Design: Analysis of planar mechanisms, cams and followers; Governors and fly wheels; Design of bolted, riveted and welded joints; Interference/shrink fit joints; Friction and lubrication; Design of shafts, keys, couplings, spur gears, belt drives, brakes and clutches; Pressure vessels.

Thermal and Fluids Engineering: Fluid mechanics – fluid statics, Bernoulli's equation, flow through pipes, laminar and turbulent flows, equations of continuity and momentum, capillary action; Dimensional analysis; Thermodynamics – zeroth, first and second laws of thermodynamics, thermodynamic systems and processes, calculation of work and heat for systems and control volumes; Air standard cycles; Heat transfer – basic applications of conduction, convection and radiation.

Section 3: Manufacturing Processes I

Casting: Types of casting processes and applications; Sand casting: patterns – types, materials and allowances; molds and cores–materials, making, and testing; design of gating system and riser; casting techniques of cast iron, steels, and nonferrous metals and alloys; analysis of solidification and microstructure development; Other casting techniques: Pressure die casting, Centrifugal casting, Investment casting, Shell mold casting; Casting defects and their inspection by non-destructive testing.

Metal Forming: Stress-strain relations in elastic and plastic deformation; von Mises and Tresca yield criteria, Concept of flow stress; Hot, warm and cold working; Bulk forming processes – forging, rolling, extrusion and wire drawing; Sheet metal working processes – blanking, punching, bending, stretch forming, spinning and deep drawing; Ideal work and slab analysis; Defects in metal working and their causes.

Joining of Materials: Classification of joining processes; Principles of fusion welding processes using different heat sources (flame, arc, resistance, laser, electron beam), Heat transfer and associated losses; Arc welding processes - SMAW, GMAW, GTAW, plasma arc, submerged arc welding processes; Principles of solid state

welding processes - friction welding, friction stir welding, ultrasonic welding; Welding defects - causes and inspection; Principles of adhesive joining, brazing and soldering processes.

Powder Processing: Production of metal/ceramic powders, compaction and sintering of metals and ceramic powders, Cold and hot isostatic pressing.

Polymers and Composites: Polymer processing – injection, compression and blow molding, extrusion, calendaring and thermoforming; Molding of composites.

Section 4: Manufacturing Processes II

Machining: Orthogonal and oblique machining, Single point cutting tool and tool signature, Chip formation, cutting forces, Merchant's analysis, Specific cutting energy and power; Machining parameters and material removal rate; tool materials, Tool wear and tool life; Thermal aspects of machining, cutting fluids, machinability; Economics of machining; Machining processes - turning, taper turning, thread cutting, drilling, boring, milling, gear cutting, thread production; Finishing processes – grinding, honing, lapping and super-finishing.

Machine Tools: Lathe, milling, drilling and shaping machines – construction and kinematics; Jigs and fixtures – principles, applications, and design.

Advanced Manufacturing: Principles and applications of USM, AJM, WJM, AWJM, EDM and Wire EDM, LBM, EBM, PAM, CHM, ECM; Effect of process parameters on material removal rate, surface roughness and power consumption; Additive manufacturing techniques.

Computer Integrated Manufacturing: Basic concepts of CAD and CAM, Geometric modeling, CNC; Automation in Manufacturing; Industrial Robots – configurations, drives and controls; Cellular manufacturing and FMS - Group Technology, CAPP.

Section 5: Quality and Reliability

Metrology and Inspection: Accuracy and precision; Types of errors; Limits, fits and tolerances; Gauge design, Interchangeability, Selective assembly; Linear, angular, and form measurements (straightness, flatness, roundness, runout and cylindricity) by mechanical and optical methods; Inspection of screw threads and gears; Surface roughness measurement by contact and non-contact methods.

Quality Management: Quality – concept and costs; Statistical quality control – process capability analysis, control charts for variables and attributes and acceptance sampling; Six sigma; Total quality management; Quality assurance and certification - ISO 9000, ISO14000.

Reliability and Maintenance: Reliability, availability and maintainability; Distribution of failure and repair times; Determination of MTBF and MTTR, Reliability models; Determination of system reliability; Preventive and predictive maintenance and replacement, Total productive maintenance.

Section 6: Industrial Engineering

Product Design and Development: Principles of product design, tolerance design; Quality and cost considerations; Product life cycle; Standardization, simplification, diversification; Value engineering and analysis; Concurrent engineering; Design for "X".

Work System Design: Taylor's scientific management, Gilbreths's contributions; Productivity – concepts and measurements; Method study, Micro-motion study, Principles of motion economy; Work measurement – time study, Work sampling, Standard data, PMTS; Ergonomics; Job evaluation and merit rating.

Facility Design: Facility location factors and evaluation of alternate locations; Types of plant layout and their evaluation; Computer aided layout design techniques; Assembly line balancing; Materials handling systems.

Section 7: Operations research and Operations management

Operation Research: Linear programming – problem formulation, simplex method, duality and sensitivity analysis; Transportation and assignment models; Integer programming; Constrained and unconstrained nonlinear optimization; Markovian queuing models; Simulation – manufacturing applications.

Engineering Economy and Costing: Elementary cost accounting and methods of depreciation; Break-even analysis; Techniques for evaluation of capital investments; Financial statements; Activity based costing.

Production Control: Forecasting techniques – causal and time series models, moving average, exponential smoothing, trend and seasonality; Aggregate production planning; Master production scheduling; MRP, MRP-II and ERP; Routing, scheduling and priority dispatching; Push and pull production systems, concepts of Lean and JIT manufacturing systems; Logistics, distribution, and supply chain management; Inventory – functions, costs, classifications, deterministic inventory models, quantity discount; Perpetual and periodic inventory control systems.

Project Management: Scheduling techniques – Gantt chart, CPM, PERT and GERT.

ST Statistics

Calculus: Finite, countable and uncountable sets; Real number system as a complete ordered field, Archimedean property; Sequences of real numbers, convergence of sequences, bounded sequences, monotonic sequences, Cauchy criterion for convergence; Series of real numbers, convergence, tests of convergence, alternating series, absolute and conditional convergence; Power series and radius of convergence; Functions of a real variable: Limit, continuity, monotone functions, uniform continuity, differentiability, Rolle's theorem, mean value theorems, Taylor's theorem, L'Hospital rules, maxima and minima, Riemann integration and its properties, improper integrals; Functions of several real variables: Limit, continuity, partial derivatives, directional derivatives, gradient, Taylor's theorem, total derivative, maxima and minima, saddle point, method of Lagrange multipliers, double and triple integrals and their applications.

Matrix Theory: Subspaces of $\mathbb{R}^n$ and $\mathbb{C}^n$, span, linear independence, basis and dimension, row space and column space of a matrix, rank and nullity, row reduced echelon form, trace and determinant, inverse of a matrix, systems of linear equations; Inner products in $\mathbb{R}^n$ and $\mathbb{C}^n$, Gram-Schmidt orthonormalization; Eigen values and eigen vectors, characteristic polynomial, Cayley-Hamilton theorem, symmetric, skew-symmetric, Hermitian, skew-Hermitian, orthogonal, unitary matrices and their eigen values, change of basis matrix, equivalence and similarity, diagonalizability, positive definite and positive semi-definite matrices and their properties, quadratic forms, singular value decomposition.

Probability: Axiomatic definition of probability, properties of probability function, conditional probability, Bayes' theorem, independence of events; Random variables and their distributions, distribution function, probability mass function, probability density function and their properties, expectation, moments and moment generating function, quantiles, distribution of functions of a random variable, Chebyshev, Markov and Jensen inequalities.

Standard Discrete and Continuous Univariate Distributions: Bernoulli, binomial, geometric, negative binomial, hypergeometric, discrete uniform, Poisson, continuous uniform, exponential, gamma, beta, Weibull, normal.

Jointly distributed random variables and their distribution functions, probability mass function, probability density function and their properties, marginal and conditional distributions, conditional expectation and moments, product moments, simple correlation coefficient, joint moment generating function, independence of random variables, functions of random vector and their distributions, distributions of order statistics, joint and marginal distributions of order statistics; multinomial distribution, bivariate normal distribution, sampling distributions: central, chi-square, central t, and central F distributions.

Convergence in distribution, convergence in probability, convergence almost surely, convergence in r-th mean and their inter-relations, Slutsky's lemma, Borel-Cantelli lemma; weak and strong laws of large numbers; central limit theorem for i.i.d. random variables, delta method.

Stochastic Processes: Markov chains with finite and countable state space, classification of states, limiting behaviour of n-step transition probabilities, stationary distribution, Poisson process, birth-and-death process, pure-birth process, pure-death process, Brownian motion and its basic properties.

Estimation: Sufficiency, minimal sufficiency, factorization theorem, completeness, completeness of exponential families, ancillary statistic, Basu's theorem and its applications, unbiased estimation, uniformly minimum variance unbiased estimation, Rao-Blackwell theorem, Lehmann-Scheffe theorem, Cramer-Rao inequality, consistent estimators, method of moments estimators, method of maximum likelihood estimators and their properties; Interval estimation: pivotal quantities and confidence intervals based on them, coverage probability.

Testing of Hypotheses: Neyman-Pearson lemma, most powerful tests, monotone likelihood ratio (MLR) property, uniformly most powerful tests, uniformly most powerful tests for families having MLR property, uniformly most

powerful unbiased tests, uniformly most powerful unbiased tests for exponential families, likelihood ratio tests, large sample tests.

Non-parametric Statistics: Empirical distribution function and its properties, goodness of fit tests, chi-square test, Kolmogorov-Smirnov test, sign test, Wilcoxon signed rank test, Mann-Whitney U-test, rank correlation coefficients of Spearman and Kendall.

Multivariate Analysis: Multivariate normal distribution: properties, conditional and marginal distributions, maximum likelihood estimation of mean vector and dispersion matrix, Hotelling's T^2 test, Wishart distribution and its basic properties, multiple and partial correlation coefficients and their basic properties.

Regression Analysis: Simple and multiple linear regression, R^2 and adjusted R^2 and their applications, distributions of quadratic forms of random vectors: Fisher-Cochran theorem, Gauss-Markov theorem, tests for regression coefficients, confidence intervals.

TF Textile Engineering and Fibre Science

Engineering Mathematics

Linear Algebra: Matrices and Determinants; Systems of linear equations; Eigen values and Eigen vectors.

Calculus: Limit, continuity and differentiability; Successive differentiation; Partial differentiation; Maxima and minima; Errors and approximations; Definite and improper integrals; Sequences and series; Test for convergence; Power series; Taylor series.

Differential Equations: First order linear and non-linear differential equations; Higher order linear differential equations with constant coefficients; Euler-Cauchy equation; Partial differential equations; Wave and heat equations; Laplace's equation.

Probability and Statistics: Random variables; Poisson, binomial and normal distributions; Mean, mode, median, standard deviation; Confidence interval; Test of hypothesis; Correlation analysis; Regression analysis; Analysis of variance; Control charts.

Numerical Methods: Numerical solutions of linear and non-linear algebraic equations; Numerical integration by trapezoidal and Simpson's rules; Single-step and multi-step numerical methods for differential equations.

Textile Engineering and Fibre Science

Section 1: Textile Fibres

Classification of textile fibres; Essential requirements of fibre forming polymers; Gross and fine structures of natural fibres like cotton, wool, silk; Introduction to bast fibres; Properties and uses of natural and man-made fibres including carbon, aramid and ultra-high molecular weight polyethylene fibres; Physical and chemical methods of fibre and blend identification and blend analysis.

Molecular architecture, amorphous and crystalline phases, glass transition, plasticization, crystallization, melting, factors affecting T_g and T_m; Polymerization of nylon-6, nylon-66, poly (ethylene terephthalate), polyacrylonitrile and polypropylene; Melt spinning processes for PET, polyamide and polypropylene; Preparation of spinning dope; Principles of wet spinning, dry spinning, dry-jet-wet spinning and gel spinning; Spinning of acrylic, viscose and other regenerated cellulosic fibres such as polynosic and lyocell; Post spinning operations such as drawing, heat setting, tow-to-top conversion; Spin finish composition and applications; Different texturing methods.

Methods of investigating fibre structure such as density, x-ray diffraction, birefringence, optical and electron microscopy such as SEM and TEM, I.R. spectroscopy, thermal methods such as DSC, DMA, TMA and TGA; Structure and morphology of man-made fibres; Mechanical properties of fibres; Moisture sorption of fibres; Fibre structure-property correlation.

Section 2: Yarn Manufacture, Yarn Structure and Properties

Principles of ginning; Principles of opening, cleaning and blending; Working principles of modern blow room machines; Fundamentals of carding; Conventional vs. modern carding machine; Card setting; Card clothing; Periodic mass variation in card sliver; Card auto leveller; Principles of roller drawing; Roller arrangements in drafting systems; Periodic mass variation in drawn sliver; Draw frame auto leveller; Principles of cotton combing; Combing cycle and mechanisms; Recent developments in combing machine; Principles of drafting, twisting, and bobbin building in roving formation; Modern developments in roving machine; Principles of drafting, twisting and cop building in ring spinning; Causes of end breakages; Modern developments in ring spinning machine; Working principles of ring doubler and two-for-one twister; Relationship between single yarn twist and folded yarn twist; Principles of compact, rotor, air-jet, air-vortex, friction, core, wrap and twist-less spinning processes.

Influence of fibre geometry, fibre configuration and fibre orientation in yarn; Fibre packing density of yarn; Yarn diameter; Yarn twist and its relation to yarn strength; Helical arrangement of fibres in yarns; Yarn contraction; Fibre migration in yarns; Stress-strain relation in yarn; Mass irregularity of yarn; Structure-property relationship in ring, compact, rotor, air-jet and friction spun yarns.

Section 3: Fabric Manufacture, Structure and Properties

Principles of winding processes; Classification of winding methods; Patterning mechanism; Yarn clearers and tensioners; Different systems of yarn splicing; Warping objectives and classification; Different types of warping creels; Features of beam and sectional warping machines; Different sizing systems; Sizing of spun and filament yarns;Drawing-in process; Principles of pirn winding.

Primary and secondary motions of loom; Shedding motion; Positive and negative shedding mechanisms; Type of sheds; Tappet, dobby and jacquard shedding; Weft insertion; Mechanics of weft insertion with shuttle; Shuttle picking and checking; Beat-up; Kinematics of sley; Loom timing diagram; Cam designing; Effect of sley setting and cam profile on fabric formation; Take-up and Let-off motions; Warp and weft stop motions; Warp protection; Weft replenishment; Principles of weft insertion systems of shuttle-less weaving machines such as projectile, rapier, water-jet and air-jet; Principles of functioning of multiphase and circular looms; Types of selvedges.

Basic woven fabric constructions and their derivatives; Crepe, cord, terry, gauze, leno and double cloth constructions; Drawing and lifting plans.

Fundamentals of weft knitting; Classification of weft knitting technologies; Weft knitted constructions such as plain, rib, interlock and purl; Different knit stitches such as loop, tuck and float.

Principle of warp knitting; Classification of warp knitting technologies; Swinging and shogging motion of guide bar; Basic warp knit construction such as pillar, tricot, atlas, inlay and nets.Fibre preparation processes for nonwovens; Web formation and bonding processes;Spun-bonding and melt-blowing technologies; Applications of nonwoven fabrics.

Principles of braiding; Type of braids; Maypole braiding technology.

Peirce's equations for plain woven fabric geometry; Elastic a model of plain-woven fabric; Thickness, cover and maximum set of woven fabrics; Geometry of plain weft knitted loop; Munden's constants and tightness factor for plain weft knitted fabrics; Geometry of tubular braids.

Section 4: Textile Testing

Sampling techniques for fibres, yarns and fabrics; Sample size and sampling errors.

Moisture in textiles; Fibre length, fineness, crimp, maturity and trash content; Tensile testing of fibres; High volume fibre testing.

Linear density of sliver, roving and yarn; Twist and hairiness of yarn; Tensile testing of yarns; Evenness testing; Fault measurement and analysis of yarns.

Fabric thickness, compressibility, stiffness, shear, drape, crease recovery, tear strength, bursting strength, pilling and abrasion resistance; Tensile testing of fabrics; Objective evaluation of low stress mechanical characteristics; Air permeability; Wetting and wicking; Water-vapour transmission through fabrics; Thermal resistance of fabrics.

Section 5: Chemical Processing

Impurities in natural fibre; Singeing; Chemistry and practice of preparatory processes for cotton; Preparatory processing of wool and silk; Mercerization of cotton; Preparatory processes for manmade fibres and their blends; Optical brightening agent.

Classification of dyes; Dyeing of cotton, wool, silk, polyester, nylon and acrylic with appropriate classes of dyes; Dyeing of polyester/cotton and polyester/wool blends; Dyeing machines; Dyeing processes and machines for cotton knitted fabrics; Dye-fibre interaction; Introduction to thermodynamics and kinetics of dyeing; Brief idea about the relation between colour and chemical constitution; Beer-Lambert's law; Kubelka-Munk theory and its application in colour measurement; Methods for determination of wash, light and rubbing fastness.

Methods of printing such as roller printing and screen printing; Preparation of printing paste; Various types of thickeners; Printing auxiliaries; Direct styles of printing of (i) cotton with reactive dyes, (ii) wool, silk, nylon with acid and metal complex dyes, (iii) polyester with disperse dyes; Resist and discharge printing of cotton, silk and polyester; Pigment printing; Transfer printing of polyester; Inkjet printing; Printing faults.

Mechanical finishing of cotton; Stiff, soft, wrinkle resistant, water repellent, flame retardant and enzyme (bio-polishing) finishing of cotton; Milling, decatizing and shrink resistant finishing of wool; Antistatic and soil release finishing; Heat setting of synthetic fabrics; Minimum application techniques.

Pollution control and treatment of effluents.

XE-A | Engineering Mathematics (Compulsory for all XE candidates)

Section 1: Linear Algebra

Algebra of real matrices: Determinant, inverse and rank of a matrix; System of linear equations (conditions for unique solution, no solution and infinite number of solutions); Eigen values and eigen vectors of matrices; Properties of eigen values and eigen vectors of symmetric matrices, diagonalization of matrices; Cayley-Hamilton Theorem.

Section 2: Calculus

Functions of Single Variable: Limit, indeterminate forms and L'Hospital's rule; Continuity and differentiability; Mean value theorems; Maxima and minima; Taylor's theorem; Fundamental theorem and mean value theorem of integral calculus; Evaluation of definite and improper integrals; Applications of definite integrals to evaluate areas and volumes (rotation of a curve about an axis).

Functions of Two Variables: Limit, continuity and partial derivatives; Directional derivative; Total derivative; Maxima, minima and saddle points; Method of Lagrange multipliers; Double integrals and their applications.

Sequences and Series: Convergence of sequences and series; Tests of convergence of series with non-negative terms (ratio, root and integral tests); Power series; Taylor's series; Fourier Series of functions of period 2π.

Section 3: Vector Calculus

Gradient, divergence and curl; Line integrals and Green's theorem.

Section 4: Complex variables

Complex numbers, Argand plane and polar representation of complex numbers; De Moivre's theorem; Analytic functions; Cauchy-Riemann equations.

Section 5: Ordinary Differential Equations

First order equations (linear and nonlinear); Second order linear differential equations with constant coefficients; Cauchy-Euler equation; Second order linear differential equations with variable coefficients; Wronskian; Method of variation of parameters; Eigen value problem for second order equations with constant coefficients; Power series solutions for ordinary points.

Section 6: Partial Differential Equations

Classification of second order linear partial differential equations; Method of separation of variables: One dimensional heat equation and two dimensional Laplace equation.

Section 7: Probability and Statistics

Axioms of probability; Conditional probability; Bayes' Theorem; Mean, variance and standard deviation of random variables; Binomial, Poisson and Normal distributions; Correlation and linear regression.

Section 8: Numerical Methods

Solution of systems of linear equations using LU decomposition, Gauss elimination method; Lagrange and Newton's interpolations; Solution of polynomial and transcendental equations by Newton-Raphson method; Numerical integration by trapezoidal rule and Simpson's rule; Numerical solutions of first order differential equations by explicit Euler's method.

XE-B | Fluid Mechanics

Section 1: Flow and Fluid Properties

Fluid Properties: Density, viscosity, surface tension, relationship between stress and strain-rate for Newtonian fluids.

Classification of Flows: Viscous versus inviscid flows, incompressible versus compressible flows, internal versus external flows, steady versus unsteady flows, laminar versus turbulent flows, 1-D, 2-D and 3-D flows, Newtonian versus non-Newtonian fluid flow.

Hydrostatics: Buoyancy, manometry, forces on submerged bodies and its stability.

Section 2: Kinematics of Fluid Motion

Eulerian and Lagrangian descriptions of fluid motion. Concept of local, convective and material derivatives. Streamline, streakline, pathline and timeline.

Section 3: Integral Analysis for a Control Volume

Reynolds Transport Theorem (RTT) for conservation of mass, linear and angular momentum.

Section 4: Differential Analysis

Differential equations of mass and momentum for incompressible flows.

Inviscid flows - Euler equations and viscous flows - Navier-Stokes equations.

Concept of fluid rotation, vorticity, stream function and circulation.

Exact solutions of Navier-Stokes equations for Couette flow and Poiseuille flow, thin film flow.

Section 5: Dimensional Analysis

Concept of geometric, kinematic and dynamic similarity.

Buckingham Pi theorem and its applications.

Non-dimensional parameters and their physical significance - Reynolds number, Froude number and Mach number.

Section 6: Internal Flows

Fully developed pipe flow.

Empirical relations for laminar and turbulent flows: friction factor, Darcy-Weisbach relation and Moody's chart.

Major and minor losses.

Section 7: Bernoulli's Equation and its Applications, Potential Flows

Bernoulli's Equation: Assumptions and applications.

Flow measurements - Venturi meter, Pitot-static tube and orifice meter.

Elementary Potential Flows: Velocity potential function.

Uniform flow, source, sink and vortex, and their superposition for flow past simple geometries.

Section 8: External Flows

Prandtl Boundary Layer Equations: Concept and assumptions.

Boundary Layer Characteristics: Boundary layer thickness, displacement thickness and momentum thickness.

Qualitative idea of boundary layer separation, streamlined and bluff bodies, and drag and lift forces.

XE-C Materials Science

Classification and Structure of Materials

Classification of Materials: Metals, ceramics, polymers and composites.

Nature of Bonding in Materials: Metallic, ionic, covalent and mixed bonding; structure of materials: fundamentals of crystallography, symmetry operations, crystal systems, Bravais lattices, unit cells, primitive cells, crystallographic planes and directions; structures of metals, ceramics, polymers, amorphous materials and glasses.

Defects in Crystalline Materials: 0-D, 1-D and 2-D defects; vacancies, interstitials, solid solutions in metals and ceramics, Frenkel and Schottky defects; dislocations; grain boundaries, twins, stacking faults; surfaces and interfaces.

Thermodynamics, Kinetics and Phase Transformations

Extensive and intensive thermodynamic properties, laws of thermodynamics, phase equilibria, phase rule, phase diagrams (unary and binary), basic electrochemistry.

Reaction kinetics, fundamentals of diffusion, Fick's laws, their solutions and applications.

Solidification of pure metals and alloys, nucleation and growth, diffusional solid-state phase transformations (precipitation and eutectoid), martensitic transformation.

Properties and Applications of Materials

Mechanical properties of metals, ceramics, polymers and composites at room temperature; stress-strain response (elastic, anelastic and plastic deformation).

Electronic Properties: Free electron theory, Fermi energy, density of states, elements of band theory, semiconductors, Hall effect, dielectric behaviour, piezo- and ferro-electric behaviour.

Magnetic Properties: Origin of magnetism in materials, para-, dia-, ferro- and ferri-magnetism.

Thermal Properties: Specific heat, heat conduction, thermal diffusivity, thermal expansion, and thermoelectricity.

Optical Properties: Refractive index, absorption and transmission of electromagnetic radiation.

Examples of materials exhibiting the above properties, and their typical/common applications.

Characterization and Measurements of Properties

X-ray diffraction; spectroscopic techniques such as UV-Vis, IR and Raman; optical microscopy, electron microscopy, composition analysis in electron microscopes. Tensile test, hardness measurement. Electrical conductivity, carrier mobility and concentrations. Thermal analysis techniques: thermogravimetry and calorimetry.

Processing of Materials

Heat treatment of ferrous and aluminium alloys; preparation of ceramic powders, sintering; thin film deposition: evaporation and sputtering techniques, and chemical vapour deposition, thin film growth phenomena.

Degradation of Materials

Corrosion and its prevention; embrittlement of metals; polymer degradation.

XE-D Solid Mechanics

Section 1: Mechanics of rigid bodies

Equivalent force systems; free-body diagrams; equilibrium equations; analysis of determinate trusses and frames; friction; principle of minimum potential energy; particle kinematics and dynamics; dynamics of rigid bodies under planar motion; law of conservation of energy; law of conservation of momentum.

Section 2: Mechanics of deformable bodies

Stresses and strains; transformation of stresses and strains, principal stresses and strains; Mohr's circle for plane stress and plane strain; generalized Hooke's Law; elastic constants; thermal stresses; theories of failure.

Axial force, shear force and bending moment diagrams; axial, shear and bending stresses; combined stresses; deflection (for symmetric bending); torsion in circular shafts; thin walled pressure vessels; energy methods (Castigliano's theorems); Euler buckling.

Section 3: Vibrations

Free vibration of undamped single degree of freedom systems.

XE-E Thermodynamics

Section 1: Basic Concepts

Continuum and macroscopic approach; thermodynamic systems (closed and open); thermodynamic properties and equilibrium; state of a system, state postulate for simple compressible substances, state diagrams, paths and processes on state diagrams; concepts of heat and work, different modes of work; zeroth law of thermodynamics; concept of temperature.

Section 2: First Law of Thermodynamics

Concept of energy and various forms of energy; internal energy, enthalpy; specific heats; first law applied to elementary processes, closed systems and control volumes, steady and unsteady flow analysis.

Section 3: Second Law of Thermodynamics

Limitations of the first law of thermodynamics, concepts of heat engines and heat pumps/refrigerators, Kelvin-Planck and Clausius statements and their equivalence; reversible and irreversible processes; Carnot cycle and Carnot principles/theorems; thermodynamic temperature scale; Clausius inequality and concept of entropy; microscopic interpretation of entropy, the principle of increase of entropy, T-s diagrams; second law analysis of control volume; availability and irreversibility; third law of thermodynamics.

Section 4: Properties of Pure Substances

Thermodynamic properties of pure substances in solid, liquid and vapor phases; PvT behaviour of simple compressible substances, phase rule, thermodynamic property tables and charts, ideal and real gases, ideal gas equation of state and van der Waals equation of state; law of corresponding states, compressibility factor and generalized compressibility chart.

Section 5: Thermodynamic Relations

TdS relations, Helmholtz and Gibbs functions, Gibbs relations, Maxwell relations, Joule-Thomson coefficient, coefficient of volume expansion, adiabatic and isothermal compressibilities, Clapeyron and Clapeyron-Clausius equations.

Section 6: Thermodynamic Cycles

Carnot vapor cycle, ideal Rankine cycle, Rankine reheat cycle, air-standard Otto cycle, air-standard Diesel cycle, air-standard Brayton cycle, vapor-compression refrigeration cycle.

Section 7: Ideal Gas Mixtures

Dalton's and Amagat's laws, properties of ideal gas mixtures, air-water vapor mixtures and simple thermodynamic processes involving them; specific and relative humidities, dew point and wet bulb temperature, adiabatic saturation temperature, psychrometric chart.

XE-F Polymer Science and Engineering

Section 1: Chemistry of High Polymers

Monomers, functionality, degree of polymerizations, classification of polymers, glass transition, melting transition, criteria for rubberiness, polymerization methods: addition and condensation; their kinetics, metallocene polymers and other newer methods of polymerization, copolymerization, monomer reactivity ratios and its significance, kinetics, different copolymers, random, alternating, azeotropic copolymerization, block and graft copolymers, techniques for polymerization-bulk, solution, suspension, emulsion. Concept of intermolecular order (morphology) – amorphous, crystalline, orientation states. Factor affecting crystallinity. Crystalline transition. Effect of morphology on polymer properties.

Section 2: Polymer Characterization

Solubility and swelling, Concept of molecular weight distribution and its significance, concept of average molecular weight, determination of number average, weight average, viscosity average and Z-average molecular weights, polymer crystallinity, analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA), microscopic (optical and electronic) techniques, Molecular wt. distribution: Broad and Narrow, GPC, Mooney viscosity.

Section 3: Synthesis, Manufacturing and Properties

Commodity and general purpose thermoplastics: PE, PP, PS, PVC, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, PC, PBT, PSU, PPO, ABS, Fluoropolymers Thermosetting polymers: Polyurethane, PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds. Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex; SBR, Nitrile, CR, CSM, EPDM, IIR, BR, Silicone, TPE, Speciality plastics: PEK, PEEK, PPS, PSU, PES, etc. Biopolymers such as PLA, PHA/PHB.

Section 4: Polymer Blends and Composites

Difference between blends and composites, their significance, choice of polymers for blending, blend miscibility-miscible and immiscible blends, thermodynamics, phase morphology, polymer alloys, polymer eutectics, plastic-plastic, rubber-plastic and rubber-rubber blends, FRP, particulate, long and short fibre reinforced composites. Polymer reinforcement, reinforcing fibres – natural and synthetic, base polymer for reinforcement (unsaturated polyester), ingredients / recipes for reinforced polymer composite.

Section 5: Polymer Technology

Polymer compounding-need and significance, different compounding ingredients for rubber and plastics (Antioxidants, Light stabilizers, UV stabilizers, Lubricants, Processing aids, Impact modifiers, Flame retardant, antistatic agents. PVC stabilizers and Plasticizers) and their function, use of carbonblack, polymer mixing equipments, cross-linking and vulcanization, vulcanization kinetics.

Section 6: Polymer Rheology

Flow of Newtonian and non-Newtonian fluids, different flow equations, dependence of shear modulus on temperature, molecular/segmental deformations at different zones and transitions. Measurements of rheological parameters by capillary rotating, parallel plate, cone-plate rheometer. Visco-elasticity-creep and stress relaxations, mechanical models, control of rheological characteristics through compounding, rubber curing in parallel plate viscometer, ODR and MDR.

Section 7: Polymer Processing

Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, filament winding, SMC, BMC, DMC, extrusion, pultrusion, calendaring, rotational molding, thermoforming, powder coating, rubber processing in two-roll mill, internal mixer, twin screw extruder.

Section 8: Polymer Testing

Mechanical-static and dynamic tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact, toughness. Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity, swelling, ageing resistance, environmental stress cracking resistance, limiting oxygen index. Heat deflection temperature – Vicat softening temperature, Brittleness temperature, Glass transition temperature, Co-efficient of thermal expansion, Shrinkage, Flammability, dielectric constant, dissipation factor, power factor, Optical Properties - Refractive Index, Luminous Transmittance and Haze, Melt flow index.

Section 9: Polymer Recycling and Waste management

Polymer waste, and its impact on environment, Sources, Identification and Separation techniques, recycling classification, recycling of thermoplastics, thermosets and rubbers, applications of recycled materials. Life cycle assessment of polymer products (case studies like PET bottles, packaging bags).

XE-G Food Technology

Section 1: Food Chemistry and Nutrition

Carbohydrates: Structure and functional properties of mono-, oligo-, & poly- saccharides including starch, cellulose, pectic substances and dietary fibre, gelatinization and retrogradation of starch.

Proteins: classification and structure of proteins in food, biochemical changes in post mortem and tenderization of muscles.

Lipids: Classification and structure of lipids, rancidity, polymerization and polymorphism.

Pigments: carotenoids, chlorophylls, anthocyanins, tannins and myoglobin.

Food Flavours: Terpenes, esters, aldehydes, ketones and quinines. Enzymes: specificity, simple and inhibition kinetics, coenzymes, enzymatic and non- enzymatic browning.

Nutrition: Balanced diet, essential amino acids and essential fatty acids, protein efficiency ratio, water soluble and fat soluble vitamins, role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, nutrient deficiency diseases.

Chemical and Biochemical Changes: Changes occurring in foods during different processing.

Section 2: Food Microbiology

Characteristics of Microorganisms: Morphology of bacteria, yeast, mold and actinomycetes, spores and vegetative cells, gram-staining.

Microbial Growth: Growth and death kinetics, serial dilution technique.

Food Spoilage: Spoilage microorganisms in different food products including milk, fish, meat, egg, cereals and their products.

Toxins from Microbes: Pathogens and non-pathogens including Staphylococcus, Salmonella, Shigella, Escherichia, Bacillus, Clostridium, and Aspergillus genera.

Fermented Foods and Beverages: Curd, yoghurt, cheese, pickles, soya-sauce, sauerkraut, idli, dosa, vinegar, alcoholic beverages and sausage.

Section 3: Food Products Technology

Processing Principles: Thermal processing, chilling, freezing, dehydration, addition of preservatives and food additives, irradiation, fermentation, hurdle technology, intermediate moisture foods. Food pack aging and storage: packaging materials, aseptic packaging, controlled and modified atmosphere storage. Cereal processing and products: milling of rice, wheat, and maize, parboiling of paddy, bread, biscuits, extruded products and ready to eat breakfast cereals.

Oil Processing: Expelling, solvent extraction, refining and hydrogenation.

Fruits and Vegetables Processing: Extraction, clarification, concentration and packaging of fruit juice, jam, jelly, marmalade, squash, candies, tomato sauce, ketchup, and puree, potato chips, pickles.

Plantation crops processing and products: Tea, coffee, cocoa, spice, extraction of essential oils and oleoresins from spices.

Milk and Milk Products Processing: Pasteurization and sterilization, cream, butter, ghee, ice- cream, cheese and milk powder. Processing of animal products: drying, canning, and freezing of fish and meat; production of egg powder.

Waste Utilization: Pectin from fruit wastes, uses of by-products from rice milling.

Food Standards and Quality Maintenance: FPO, PFA, A-Mark, ISI, HACCP, food plant sanitation and cleaning in place (CIP).

Section 4: Food Engineering

Mass and energy balance.

Momentum Transfer: Flow rate and pressure drop relationships for Newtonian fluids flowing through pipe, Reynolds number. Heat transfer: heat transfer by conduction, convection, radiation, heat exchangers.

Mass Transfer: Molecular diffusion and Flick's law, conduction and convective mass transfer, permeability through single and multilayer films.

Mechanical Operations: Size reduction of solids, high pressure homogenization, filtration, centrifugation, settling, sieving, mixing & agitation of liquid. Thermal operations: thermal sterilization, evaporation of liquid foods, hot air drying of solids, spray and freeze-drying, freezing and crystallization.

Mass Transfer Operations: Psychometric, humidification and dehumidification operations.

XE-H Atmospheric and Oceanic Sciences

Section A: Atmospheric Science

Vertical Structure and Composition of the Atmosphere; Blackbody Radiation and Radiation Balance; Modes of Heat Transfer in the Atmosphere; Greenhouse Effect; Cloud Types; Laws of Thermodynamics; Gas Laws; Hydrostatic Equation; Clausius Clapeyron Equation; Adiabatic Processes, Humidity in the Atmosphere, Atmospheric Stability; Weather and Climate.

Navier-Stokes and Continuity Equations; Compressible and Incompressible Fluids; Pressure Gradient, Centripetal, Centrifugal and Coriolis Forces; Geostrophic, Gradient and Cyclostrophic Balances; Circulations and Vorticity, General Circulation of the Atmosphere. Broad Features of Indian Monsoons, Monsoon Depressions; Tropical Convergence Zones; Tropical Cyclones.

Section B: Ocean Sciences

Vertical Profiles of Temperature and Salinity; Stability and Double Diffusion; Equation of State, Equations for Conservation of Mass, Momentum, Heat and Salt; Inertial Currents; Geostrophic Motion; Air-Sea Surface Fluxes; Wind-driven Circulation, Ekman and Sverdrup Transports; Storm Surges, Tides, Tsunamis and Wind Waves; Eddies and Gyres; Eastern and Western Boundary Currents, Equatorial Currents, Indian Ocean Current Systems; Thermohaline Circulation.

Chemical Properties of Seawater, Major and Minor Elements, Ocean Acidification, Biochemical Cycling of Nutrients, Trace Metals and Organic Matter. Biological Pump; Primary and Secondary Biological Productivity; Air-sea Exchange of Biogenic Dissolved Gases; Marine Ecology.

XH-B1	Reasoning and Comprehension (Compulsory for all XH candidates)

This part is to test the candidate's ability to comprehend and interpret written information – skills that are critical to research in the Humanities and Social Sciences. The section will not directly test language competence in terms of grammar, vocabulary etc. The focus is instead on critical reasoning (similar to what is often found in exams like LSAT, GRE, GMAT etc.) and analysis of the text and its stylistic and rhetorical structure.

Questions of this section XH-B1 will test the following skills:

Reading Comprehension: Ability to understand complex language material in short paragraphs and answer questions regarding them.

Expression: Questions on stylistic and rhetorical aspects of a short passage including corrections or modifications of particular sentences.

Analytical Reasoning: ability to understand relationships in statements or short passages and being able to draw reasonable conclusions/inferences from them.

Logical Reasoning: Thinking critically to evaluate or to predict an argument, identify the main and supporting arguments, predict outcomes etc.

XH-C1 Economics

C1.1 Microeconomics: Theory of Consumer Behaviour: Cardinal Approach and Ordinal Approach; Consumer Preferences; Nature of the utility function; Marshallian and Hicksian demand functions; Duality Theorem. Slutsky equation and Comparative Statics. Homogeneous and Homothetic Utility Functions; Euler's Theorem. The Theory of Revealed Preference: Weak Axiom of Revealed Preference and Strong Axiom of Revealed Preference, Theory of Production and Costs: Short-run and Long-run Analysis, Existence, Uniqueness and Stability of Market Equilibrium: Walrasian and Marshallian Stability Analysis. The Cobweb Model, Decision making under uncertainty and risk. Asymmetric Information: Adverse Selection and Moral Hazard. Theory of Agency costs. The Theory of Search, Non-Cooperative games: Constant sum game, Mixed Strategy & Pure Strategy, Bayesian Nash Equilibrium, SPNE, Perfect Bayesian Equilibria., Theory of Firm: Market Structures — Competitive and Non-competitive equilibria and their efficiency properties. Structure-Conduct-Performance Paradigm, Factor Pricing: Marginal productivity Theory of Distribution in Perfectly Competitive markets; Theory of Employment in Imperfectly Competitive Markets — Monopolistic Exploitation, General Equilibrium Analysis. Welfare Economics: Fundamental Theorems, Social Welfare Function. Efficiency Criteria: Pareto-Optimality.

C1.2 Macroeconomics: National Income Accounting: Closed Economy Concepts and Measurement and Open Economy Issues, Determination of output and employment: Classical & Keynesian Framework, Theories of Consumption: Absolute Income Hypothesis, Relative Income Hypothesis, Life Cycle Hypothesis, Permanent Income Hypothesis and Robert Hall's Random Walk Model; Investment Function Specifications - Dale Jorgenson's Neoclassical Theory of Capital Accumulation and Tobin's, Keynesian Stabilization Policies, (Autonomous) Multipliers and Investment Accelerator, Demand and Supply of Money, Components of Money Supply, Liquidity Preference and Liquidity Trap, Money Multiplier, Interest Rate determination, Central Banking, Objectives, Instruments (Direct and Indirect) of Monetary Policy, Prudential Regulation, Quantitative Easing (Unconventional Monetary Policy), Commercial Banking, Non-Banking Financial Institutions, Capital Market and its Regulation, Theories of Inflation and Expectations Augmented Phillips Curve, Real Business Cycles, Adaptive Expectations Hypothesis, Rational Expectation Hypothesis and its critique. Closed Economy IS – LM Model and Mundell Fleming Model: Monetary and Fiscal Policy Efficacy. The Impossible Trinity.

C1.3 Statistics, Econometrics and Mathematical Economics: Probability Theory: Concepts of probability, Probability Distributions [Discrete and Continuous], Central Limit Theorem, Index Numbers and Construction of Price Indices, Sampling Methods & Sampling Distribution, Statistical Inferences, Hypothesis Testing, Linear Regression Models and the Gauss Markov Theorem, Heteroscedasticity, Multicollinearity and Autocorrelation, Spurious regressions and Unit roots, Simultaneous Equation Models – recursive and non-recursive. Identification Problem, Differential Calculus and its Applications, Linear Algebra – Matrices, Applications of Cramer's Rule, Static Optimization Problems and Applications, Input-Output Model, Linear Programming, Difference equations and Differential equations with applications

C1.4 International Economics: Theories of International Trade, International Trade under Imperfect Competition, Gains from Trade, Terms of Trade, Trade Multiplier, Tariff and Non-Tariff barriers to trade; Dumping and Anti-Dumping Policies, GATT, WTO and Regional Trade Blocks; Trade Policy Issues, Balance of Payments: Composition, Equilibrium and Disequilibrium and Adjustment Mechanisms, Foreign Exchange Market and Arbitrage, Exchange rate determination, IMF & World Bank.

C1.5 Public Economics: Market Failure and Remedial Measures: Asymmetric Information, Public Goods, Externality, Regulation of Market – Collusion and Consumers' Welfare, Public Revenue: Tax & Non-Tax Revenue, Direct & Indirect Taxes, Progressive and non-Progressive Taxation, Incidence and Effects of Taxation, Public expenditure, Public Debt and its management, Public Budget and Budget Multiplier, Tax Incidence, Fiscal Policy and its implications, Environment as a Public Good, Market Failure and Coase Theorem, Cost-Benefit Analysis.

C1.6 Development Economics: Theories of Economic Development: Adam Smith, David Ricardo, Karl Marx, J. Schumpeter, W. Rostow, Balanced & Unbalanced Growth, Big Push Approach, Indicators of Economic Development: HDI, SDGs, MDGs, Poverty and Inequalities – Concepts and Measurement Issues, Social Sector

Development: Health, Education, Gender, Fertility, Morbidity, Mortality, Migration, Child Labor, Age Structure, Demographic Dividend, Models of Economic Growth: Harrod-Domar, Solow, Ramsey, Technical progress – Disembodied & Embodied, Endogenous Growth Models.

C1.7 Indian Economy: Economic Growth in India: Pattern and Structure, Agriculture, Industry & Services Sector: Pattern & Structure of Growth, Major Challenges, Policy Responses, Rural & Urban Development – Issues, Challenges & Policy Responses, Flow of Foreign Capital, Trade Policies, Infrastructure Development: Physical and Social; Public-Private Partnerships, Reforms in Land, Labour and Capital Markets, Poverty, Inequality & Unemployment, Functioning of Monetary Policy in India, Fiscal Policy in the Indian context: Structure of Receipts and Expenditure, Tax reforms-Goods and Services Tax, Issues of Growth and Equity, Fiscal Federalism, Centre-State Financial Relations and Finance Commissions of India; Sustainability of Deficits and Debt, The Fiscal Responsibility and Budget Management Act 2003, Demonetization and aftermath. India's balance of payments, Composition of India's Trade, Competitiveness of India's exports, India's exchange rate policy.

XH-C2 English

C2.1 Multi-genre literatures in English—poetry, the novel and other forms of fiction including the short story, drama, creative non-fiction, and non-fiction prose—with emphasis on the long 19th and 20th centuries.

C2.2 Especially in a comparative context, anglophone and in English translation, literatures from India and, extending to some degree, the larger Indian subcontinent.

C2.3 Literary criticism and theory; critical and cultural intellectual-traditions and approaches widely referred to and used in the discipline of English.

C2.4 History of English literature and English literary studies.

C2.5 Research approaches and methodologies, including interpretive techniques responsive to literary forms, devices, concepts, and genres.

Note:
(i) The five units above list aspects that the question paper will include rather than signal separate modules or sections. These five units listed are not necessarily exclusive to each other either. The question paper will also not be divided into sections corresponding to the above aspects; and
(ii) While the paper will test candidates for a reasonable breadth of disciplinary knowledge, it would prioritize conceptual depth and methodological sensitivity demonstrative of disciplinary training over information, wherever possible.

XH-C3 Linguistics

C3.1 Language and Linguistics

Language spoken, written and signed; description and prescription; language and cultural heritage; language and social identity; language as an object of inquiry – its structure, units and components; design features; writing systems; biological foundations and language faculty; linguistic competence and performance; levels of grammar; contrast and complementation; rules - context dependent and context free; levels of adequacy for analysis; interdisciplinary approaches; schools of linguistic thought (European, American) and the Indian Grammatical Tradition.

C3.2 Levels of Grammar and Grammatical Analysis

A. Phonetics and Phonology: Vocal tract anatomy; phonation; articulatory parameters; classification of sounds; gestural theory of speech production; cardinal vowels; secondary and co-articulation; suprasegmentals - length, stress, tone, intonation and juncture; IPA; basic physics of sound and of phonation and articulation; acoustic cues for speech sounds; organisation of phones into phonemes; phoneme inventories and cross-linguistic properties; syllable structure and phonological properties; principles of phonological analysis - phonetic similarity, contrastive and complementary distribution, free variation, allophones; linear and non-linear approaches; levels of representation; phonological rules; distinctive features (major class, manner, place, etc.); feature geometry; rule ordering, markedness and unspecified featural values; core principles of lexical phonology, optimality theory, autosegmental phonology and prosodic morphology.

B. Morphology: Concepts of morpheme, morph, allomorph, zero allomorph, conditions on allomorphs; lexeme and word; types of morphemes – structural and functional; affixes vs clitics; grammatical categories; morphological theories – generative, lexicalist, process and distributed morphology; identification of morphemes and parts of speech; alternation; morphophonology; inflection vs. derivation; conjugation and declension; word creation and word formation rules and processes; creativity and productivity, blocking, bracketing paradoxes, constraints on affix ordering; mental lexicon; lexical categories; valency changing operations.

C. Syntax: Basic syntactic units and their types: word, phrase, clause, sentence and their description and generation; grammatical and case relations; key ideas fromsyntactic theories, Generative Grammars including Minimalist Program, HPSG, Relational Grammar and Lexical Functional Grammar; phrase structure rules (including X-bar theory); universal grammar and cross-linguistic properties; idea of grammaticality judgements; solving the language acquisition problem; diagnostics of structure; syntactic phenomena such as movement, binding, ellipses, case-checking, islands, argument structure etc.; unergatives and unaccusatives.

D. Semantics and Pragmatics: Types of meaning, lexical and compositional; syntax-semantics interface (semantic roles, binding, scope, LF etc.); sense and reference, connotation and denotation, lexical semantic relations (homonymy, hypo/hypernymy, antonymy, synonymy, ambiguity); prototype theory and componential analysis; sentence meaning and truth conditions, contradictions, entailment; basic set theory; propositions, truth values, sentential connectives; arguments, predicates, quantifiers, variables; in/definiteness, mood and modality; language use in context; sentence meaning and utterance meaning; speech acts; deixis; presupposition and implicature: Gricean maxims; information structure; politeness, power and solidarity; discourse analysis.

C3.3 Historical Linguistics

Neogrammarian laws of phonetic change such as Grimm's, Verner's, Grassmann's Laws; genesis and spread of sound change; split and merger; conditioned vs. unconditioned change; lexical diffusion of sound change; analogical changes and paradigm levelling; relative chronology of different changes; study of sound change in

progress; morphosyntactic (syncretism, grammaticalisation and lexicalisation) and semantic change (extension, narrowing, figurative speech); linguistic reconstruction - external vs. internal: the comparative method; lexicostatistics; language contact and dialect geography – borrowing and impact of borrowing; pidgins and creoles; bi- and multilingualism as the source for borrowing; dialect geography - dialect atlas; isogloss, focal, transition and relic areas.

C3.4 Sociolinguistics

Micro-and macro approaches to language in society; linguistic repertoire language, dialect, sociolect, idiolect; diglossia; taboo, slang and euphemism; elaborated and restricted codes; speech community and communicative competence; ethnography of speaking; lingua franca; diasporic language; linguistic variables and their co-variation along linguistic/social dimensions; language policies and development (especially inIndia); language contact and outcomes (language loss, pidginization and creolization); code-mixing and code-switching; language movements – state and societal interventions; script development and modifications; linguistic minorities; language ecology and endangerment linguistic vitality, language endangerment (EGIDS scale), parameters of endangerment, documentation and revitalisation.

C3.5 Areal Typology, Universals, Cross-linguistic Features

Morphological types of languages agglutinative, analytical (isolating), synthetic fusional (inflecting), polysynthetic (incorporating) languages; formal and substantive universals, absolute and statistical universals; implicational and non-implicational universals (Greenberg); linguistic relatedness—genetic, typological and areal classification of languages; universals and parametric variation; word order typology; salient features of South Asian languages - Indo-Aryan, Dravidian, Austro-Asiatic, and Tibeto-Burman language families; Linguistic Survey of India; contact induced typological change.

C3.6 Methods of Analysis

Experimental and non-experimental methods; sampling and tools; identification of variables and their variants; data processing and interpretation; quantitative analysis of data; ethnomethodology; participant observation; field methods and elicitation; document creation; ethics.

C3.7 Applied Linguistics: Psycholinguistics — the study of how humans learn, represent, comprehend, and produce language. Topics include word recognition and storage, sentence production and comprehension, reading, speech perception, language acquisition, neural representation of language, bilingualism, and language disorders.

XH-C4 Philosophy

C4.1 Classical Indian Philosophy

C4.1.1 Orthodox Systems: **Sānkhya**- Puruṣa, Prakṛti, Guṇas, Satkāryavāda, Mokṣa (Kaivalya), Pramāṇas and Theory of Error, **Yoga** – Pramāṇas, Theory of Error, Iśvara, Citta, Kleśa, Aṣṭānga-yoga, Kaivalya (Mokṣa), **Nyāya** – Pramāṇas, Hetvābhāsa, Iśvara, Asatkāryavāda, Theory of Error, Navya-Nyāya, **Vaiśeṣika** – Parataḥprāmāṇya, Padārthas (categories), Theory of Atomism (paramāṇuvāda), **Mīmāmsā**– Dharma, Apūrva, Mokṣa, Pramāṇas (both in Kumārila and Prabhākara), Anyathākhyāti, and, **Vedānta**– Advaita (Adhyāsa, Brahman, Iśvara, Ātman, Jīva, Mokṣa, Viśiṣṭādvaita (Tattva-traya, Mokṣa, and Refutation of Māyāvāda), Dvaita, Dvaitādvaita, Śuddhādvaita, Pramāṇa in Advaita and Viśiṣṭādvaita.

C4.1.2 Heterodox Systems: **Cārvāka** – Pramāṇa, Indian marerislism and Hedonism, **Jainism**- Pramāṇas, Syādvāda, Anekāntavāda, Padārtha (categories), Jīva and Ajīva, Mokṣa, Mahāvrata, Aṇuvrata, and, **Buddhism** – Ti-piṭaka, Sarvāstivāda, Sautrāntika, Mādhyamika, Yogācāra-Vijñānavāda, Pañca-skandha, Anityavāda, Anātmavāda, Doctrine of Momentariness, Doctrine of Dependent Origination, Pramānas, Doctrine of Two Truths, Doctrine of Tri-kāya, Ṣaḍ-pāramitās, Brahmavihāras, Pāñcaśīla, and Bodhisattva Ideal, and Upāyakauśalya.

C4.1.3 Upaniṣads, Bhagavadgītā, and Dharmaśāstras: Philosophy of the Upaniṣads – Pure Monism, Brahmam and Ātman, Pañca-kośa, Parā-vidyā and Aparā-vidyā, Meaning of Dharma, Ṛta, Purusārtha, Śreyas and Preyas, Varṇāśrama-dharma, Dharma- Svadharma and Sādhāraṇa Dharma, Ṛna, Yajña, Karma-yoga, Sthitaprajña, Lokasaṃgraha, and Law of Karma.

C4.1.4 KāṣmiraŚaivism, Śaivasiddhānta, VīraŚaivism, Śāktism and Vaiṣṇavism: KāṣmīraŚaivism – Pratyābhijña school, Śiva and Śakti, and Conception of Kriyā, Śaivasiddhānta – God (pati) and Divine Power (śakti), Proofs for God's Existence, Bondage and Liberation, VīraŚaivism – Philosophical basis of VīraŚaivism, Śāktism - Philosophical basis of Śāktism, and Vaiṣṇavism – Philosophical basis of Vaiṣṇavism.

C4.2 Contemporary Indian Philosophy

C4.2.1 Vivekananda: Notion of God, Freedom and Karma, Nature of Soul/self, Practical Vedanta, and Universal Religion. **Aurobindo**: World Process – Involution and Evolution, Four Theories of Existence, The Supermind, Integral Yoga, and Gnostic Being. **Iqbal**: Nature of Intuition, Nature of Self, and Notion of God. **Tagore**: Humanism and Nature of Man, Notion of Religion, and Nationalism. **K. C. Bhattacharyya**: Concept of Absolute and Its Alternative Forms, and Notion Subjectivity and Freedom. **Radhakrishnan:** Nature of Ultimate Reality, Religious Experience, Intellect and Intuition, Hindu View of Life. **J. Krishnamurti**: Notion of Freedom, Choiceless Awareness, Truth is a Pathless Land, and Notion of Education. **Gandhi**: Notion of Truth, Non-violence, Satyagraha, Swaraj, and Trusteeship. **Ambedkar:** Annihilation of Caste, Neo-Buddhism, Democracy, and Natural Rights and Law. **M. N. Roy**: Radical Humanism and Materialism.

C4.3 Classical and Modern Western Philosophy

C4.3.1 Metaphysics: Pre-Socratic Philosophy of Thales, Anaxagoras, Anaximenies, Ionians, Pythagoras, Parmenides, Heraclitus and Democritus. Metaphysics of Plato and Aristotle**:** The question of Being (to on/ousia): Being as Idea in Plato's Phaedo, Republic and the Sophist, Being as synthesis of hyle [matter] and morphe [form] in Aristotle's Metaphysics and Physics. Problem of evil and existence of God in St. Augustine, St. Anselm, and St. Thomas Aquinas Metaphysics in Modern Philosophy: Substance, Mind-Body Dualism, Attribute, Parallelism, Pre-established harmony, the existence of God, Problem of Solipsism, Self and Personal Identity, Rejection of Metaphysics, Phenomena and Noumena, Transcendental Deduction of Categories, Being and Becoming, Absolute Idealism

C4.3.2 Epistemology: Plato and Aristotle's Theory of Knowledge, *Doxa*, *Episteme*, and Sophia, Method of Dialectics, Theoretical and Practical Reason, Theory of Causation, Descarte's Method of Doubt, cogito ergo sum, Innate Ideas and its refutation, Principle of Non-contradiction, Sufficient Reason, and Identity of Indiscernible, Locke's Three Grades of Knowledge, Berkeley's Critique of Abstract Ideas, Hume's Impressions and Ideas, Induction and Causality, Kant's Copernican Revolution, Forms of Sensibility, Possibility of Synthetic a priori Judgments. Hegel's Dialectics, Spirit, and Absolute Idealism.

C4.3.3 Ethics: Concepts of Good, Right, Justice, Duty, Obligation, Cardinal Virtues, *Eudaemonism*; Intuition as explained in Teleological and Deontological Theories; Egoism, Altruism, Universalism, Subjectivism, Cultural Relativism, Super-naturalism, Ethical realism and Intuitionism, Kant's moral theory, Postulates of Morality, Good-will, Categorical Imperative, Duty, Means and ends, Maxims; Utilitarianism: Principle of Utility, Problem of Sanction and Justification of Morality, Moral theories of Bentham, J. S. Mill, Sidgwick; Theories of Punishment; Ethical Cognitivism and Non-cognitivism, Emotivism, Prescriptivism, Descriptivism.

C4.3.4 Social and Political Philosophy: Plato's theory of Justice and State, Aristotle's definition of State and Political Naturalism; Classical Liberalism and Social Contract Theory (Hobbes, Rousseau, Locke); Marx's Dialectical Materialism, Alienation, and critique of Capitalism.

C4.3.5 Logic: Truth and Validity, Nature of Propositions, Categorical Syllogism, Laws of Thought Classification of Propositions Square of Opposition, Truth-Functions and Propositional Logic, Quantification and Rules of Quantification; Symbolic Logic: Use of symbols; Truth Table for testing the validity of arguments; Differences between Deductive and Inductive Logic, Causality and Mill's Method.

C4.4 Contemporary Western Philosophy

C4.4.1 Frege's Sense and Reference; Logical Positivism's Verification theory of meaning, Elimination of Metaphysics; Moore's Distinction between Sense and Reference, Defense of common-sense, Proof of an External World; Russell's Logical Atomism, Definite Descriptions, Refutation of Idealism; Wittgenstein on Language and Reality, the Picture Theory, critique of private language, Meaning and Use, Forms of life; Gilbert Ryle on Systematically Misleading Expressions, critique of Cartesian dualism; W.V.O. Quine's Two Dogmas of Empiricism; P.F. Strawson's concept of Person; Husserl's Phenomenological Method, Philosophy as a rigorous science, Intentionality, Phenomenological Reduction, Inter-subjectivity; Heidegger's concept of Being (*Dasein*), Being in the world; Sartre's Concept of Freedom, Bad-faith, Humanism; Merleau-Ponty on Perception, Embodied Consciousness; William James's Pragmatic Theories of Meaning and Truth, Varieties of Religious experience; John Dewey on Pragmatist Epistemology with focus on Inquiry, fallibilism and Experience, Education; Nietzsche on the Critique of Enlightenment, Will to Power, Genealogy of Moral; Richard Rorty's Critique of Representationalism, Against Epistemological method, Edifying Philosophy, Levinas: Ethics as a first philosophy, Philosophy of 'other'; Rawls' Veil of Ignorance, Principle of Justice; Nozick's critique of Rawls, Libertarianism: Charles Taylor's Communitarianism, critique of the Liberal Self, Politics of recognition; Martha Nussbaum's Liberal Feminism and Capability Approach; Simone de Beauvoir on Situated Freedom and Ethics of Ambiguity; Code and Harding on Situated Knowledge and Strong and Weak Objectivity; Gilligan and Noddings on Ethics of Care, Debate between Care and Justice.

XH-C5 Psychology

C5.1 Research Methods and Statistics

C5.1.1 Approaches to Research: Philosophical worldviews & criteria involved in approach. Research design: quantitative & qualitative, mixed methods.

C5.1.2 Designing Research: Research problems, purpose statement, Variables and Operational Definitions, Hypothesis, Sampling.

C5.1.3 Nature of Quantitative & Qualitative Research: Structured, semi-structured interviewing, self-completion questionnaires (Survey), observation, Experimental, Quasi-experimental, Field studies, Focus groups discussions, Narratives, Case studies, Ethnography.

C5.1.4 Ethics in conducting and reporting research.

C5.1.5 Statistics in Psychology: Measures of Central Tendency and Dispersion. Normal Probability Curve. Parametric and Non-parametric tests Effect size and Power analysis.

C5.1.6 Correlational Analysis: Correlation [Product Moment, Rank Order], Partial correlation, multiple correlation. Special Correlation Methods: Biserial, Point biserial, tetrachoric, phi coefficient. Regression: Simple linear regression, Multiple regression. Factor analysis: Assumptions, Methods, Rotation and Interpretation.

C5.1.7 Experimental Designs: ANOVA [One-way, Factorial], Randomized Block Designs, Repeated Measures Design, Latin Square, Cohort studies, Time series, MANOVA, ANCOVA. Single-subject designs.

C5.2 Psychometrics: Foundations of Psychological measurement; Basic components: scales and items' Construction and analysis of items: Intelligence test items, performance tests, Ability & Aptitude test, Personality questionnaires. Method of test construction, Standardization of measures: Reliability, Validity, Norms, Application of assessment and measurements in Tests— Applications of psychological testing in various settings-educations, counselling and guidance, clinical, organizational and developmental.

C5.3 Biological and Evolutionary Basis of Behaviour: Heredity and behaviour Evolution and natural selection, Nervous system, structures of the brain and their functions, Neurons: Structure, functions, types, neural impulse, synaptic transmission. Neurotransmitters. Hemispheric lateralization, The endocrine system types and functions, Biological basis of Motivation: Hunger, Thirst, Sleep and Sex. Biological basis of emotion: The Limbic system, Hormonal regulation of behaviour. Methods of Physiological Psychology: Invasive methods – Anatomical methods, degeneration techniques, lesion techniques, chemical methods, microelectrode studies, Non-invasive methods – EEG, Scanning methods, Muscular and Glandular system: Genetics and behaviour: Chromosomal anomalies; Nature-Nurture controversy [Twin studies and adoption studies]

C5.4 Perception, Learning, Memory and Forgetting: What is sensation, sensory thresholds and sensory adaptations, Vision, hearing, touch and pain, smell and taste, kinesthesis and vestibular sense, Perception: role of attention; organizing principles of perception, gestalt perception, depth perception and illusions, Theories of learning: classical conditioning, operant conditioning, social learning theory, cognitive learning, Memory: encoding, storage, retrieval, Information processing theories of memory, Retrieval in Long term memory, reconstructive nature of long-term memory, Forgetting: encoding failure, interference theory, memory trace decay theory, the physical aspects of memory.

C5.5 Cognition: Thinking, Intelligence and Language: Basic elements of though: Concepts, Propositions, Imagery. Current paradigms of cognitive psychology – Information processing approach, ecological approach, Problem solving: Methods of problem solving, Strategies and obstacles, Role of Metacognitive processing, decision-

making: choosing among alternatives, Intelligence: Theories of intelligence (Spearman; Thurstone; Jensen; Cattell; Gardner; Stenberg) and Emotional Intelligence; Measuring intelligence, Individual differences in Intelligence; Role of heredity and environment, Difference between Intelligence, Aptitude and Creativity.

C5.6 Personality: Theories of personality: Psychoanalytic, behaviourist, social cognitive view, humanism and trait and type theories, Biology of personality and Assessment of personality.

C5.7 Motivation, Emotion and Stress and Coping: Approaches to understanding motivation: instinct, drive-reduction, arousal, incentive, humanistic, Achievement motivation, Intrinsic motivation, aggression, curiosity and exploration, Emotions: nature of emotions; biological basis of emotions, Theories of emotions: James-Lange, Canon-Bard, Schachter and Singer, Lazarus, Definition of stress; what are stressors; cognitive factors in stress, Factors in stress reaction: General adaptation syndrome; effect of stress, Coping with stress: problem-focused coping; emotion-focused coping, REBT and meditation

C5.8 Social Psychology: Social perception: Attribution; impression formation; social categorization, implicit personality theory, Social influence: conformity, compliance and obedience, Attitudes, beliefs and values: Evaluating the social world, attitude formation, attitude change and persuasion, cognitive dissonance, Prejudice, discrimination, Aggression, power and prosocial behaviour, Belief systems and value patterns. Group dynamics, leadership style and effectiveness, Theories of intergroup relations and conflicts.

C5.9 Development Across the Life Span: Nature versus nurture in human development, Prenatal development: Chromosomes, Genes and DNA. Physical, cognitive and psychosocial development in infancy, childhood, adolescence and adulthood, Theories of aging, Moral development.

C5.10 Applications of Psychology: Psychological disorders: Conceptions of mental disorders; Assessment and diagnosis, DSM and Other tools, PTSD and Trauma; Psychotherapies: Psychodynamic, Phenomenological/ Experiential therapy; Behaviour therapy; cognitive therapy; biological therapy, Applications of theories of motivation and learning in School: Factors in educational achievement; counselling & guidance in schools, Application of theories of motivation, learning, emotions, perceptions, group dynamics & leadership to organizational set up, Issues of Personal space, crowding, and territoriality.

XH-C6	Sociology

C6.1 Sociological Theory

C6.1.1 Classical Sociological Traditions: Emile Durkheim (Social Solidarity, Social Facts, Religion, Functionalism, Suicide, Anomie, Division of Labour, Law; Max Weber (Types of authority, Social action, Protestant ethic and the spirit of capitalism, Bureaucracy, Ideal type, Methodology); Karl Marx: Class and class conflict, dialectical and historical materialism, capitalism, surplus value, alienation).

C6.1.2 Structural-Functionalism and Structuralism: Bronislaw Malinowski; A.R. Radcliffe- Brown, Talcott Parsons (AGIL, Systems approach), Robert K. Merton (Middle range theory, reference groups, latent and manifest function), Claude Levi Strauss (Myths, Structuralism).

C6.1.3 Hermeneutic and Interpretative Traditions: G.H. Mead, Alfred Schutz (Phenomenology); Harold Garfinkel (Ethnomethodology); Erving Goffman (Symbolic interaction, dramaturgy); Clifford Geertz (Culture, thick description).

C6.1.4 Post-Modernism, Post-Structuralism and Post-Colonialism: Pierre Bourdieu, Michel Foucault, Jurgen Habermas, Anthony Giddens, Frankfurt School.

C6.1.5 Conflict Theory: Ralf Dahrendorf; C Wright Mills.

C6.1.6 Indian Thinkers: M.K. Gandhi, B.R. Ambedkar, Radha Kamal Mukherjee, G. S. Ghurye, M.N. Srinivas, Irawati Karve.

C6.2 Research Methodology and Methods

C6.2.1 Conceptualizing Social Reality: Philosophy of Science; Scientific Method and Epistemology in Social Science; Hermeneutic Traditions; Objectivity and Reflexivity in Social Science; Ethics and Politics of research.

C6.2.2 Research Design: Reading Social Science Research, Data and Documents; Induction and Deduction; Fact, Concept and Theory; Hypotheses, Research Questions, Objectives.

C6.2.3 Quantitative and Qualitative Methods: Ethnography; Survey Method; Historical Method; Comparative Method.

C6.2.4 Research Techniques: Sampling; Questionnaire and Schedule; Statistical Analysis; Observation, Interview and Case study; Interpretation, Data Analysis and Report Writing.

C6.3 Sociological Concepts

C6.3.1 Sociological Concepts: Social Structure; Culture; Network; Status and Role; Identity; Community; Socialization; Diaspora; Values, Norms and Rules; Personhood, Habitus and Agency; Bureaucracy, Power and Authority; Self and society.

C6.3.2 Social Institutions: Marriage, Family and Kinship; Economy; Polity; Religion; Education; Law and Customs.

C6.3.3 Social Stratification: Social Difference, Hierarchy, Inequality and Marginalization: Caste and Class; Status and Power; Gender, Sexuality and Disability; Race, Tribe and Ethnicity.

C6.3.4 Social Change: Evolution and Diffusion; Modernization and Development; Social Transformations and Globalization; Social Mobility –Sanskritization, Educational and Occupational change.

C6.4 Agrarian Sociology and Rural Transformation: Rural and Peasant Society; Caste-Tribe Distinction and Continuum; Agrarian Social Structure and Emergent Class Relations; Land Ownership and Agrarian Relations; Decline of Agrarian Economy, De-Peasantization and Agrarian Change; Agrarian Unrest and Peasant Movements; Feudalism, Mode of production debate; Land reforms; Panchayati Raj; Rural development programmes and community development; Green revolution and agricultural change; Peasants and farmers movements.

C6.5 Family, Marriage and Kinship; Theoretical Approaches: Structural-Functionalist, Alliance and Cultural; Gender Relations and Power Dynamics; Inheritance, Succession and Authority; Gender, Sexuality and Reproduction; Children, Youth and Elderly; Emotions and Family; Emergent Forms of Family; Changing Marriage Practices; Changing Care and Support Systems; Family Laws; Domestic Violence and Crime against Women; Honour Killing.

C6.6 Indian Society/Sociology of India: Colonial, Nationalist, Indological perspectives (G.S. Ghurye); Structural-Functional approach (M.N. Srinivas); Dialectical approach (A.R. Desai); Subaltern studies (R. Guha); Non Brahmin perspectives (Phule, Dr. Babasaheb Ambedkar); Feminist perspectives (LeelaDube, SharmilaRege); Social Institutions – Family, Kinship, Household, Village and Urban Settings; Social Stratification – Caste, Class, Tribe and Gender; Tradition and Modernity (M.N. Srinivas, Yogendra Singh, Dipankar Gupta); Peasants and agrarian sociology (Andre Beteille, A.R. Desai, D.N. Dhanagare); Village studies; Communalism and Secularism.

C6.7 Social Movements

C6.7.1 Introduction to Social Movements: Nature, Definitions, Characteristics; Social Movement and Social Change; Types of social movements (Reform, Rebellion, Revival, Revolution, Insurrection, Counter Movement).

C6.7.2 Theories of Social Movements: Structural–functional; Marxist; Resource Mobilization Theory; New Social Movements.

C6.7.3 Social Movement in India with Specific Reference to Social Basis, Leadership, Ideology and Actions: Peasant movement; Labour movement; Dalit movement; Women's movement, Environmental movement.

C6.7.4 Social Movements, Civil Society and Globalization: Social movement and its relationship with state and civil society; Social movements and impact of globalization: Debates; Issues of citizenship.

C6.8 Sociology of Development

C6.8.1 Perspectives on the Study of Development: Definitions and Indices; Liberal, Marxist, and Neo-Marxist Perspectives (Dependency theory, World Systems); Epistemological Critiques of Development.

C6.8.2 State and Market: Institutions and ideologies: Planned Development and Society; Globalisation and Liberalization.

C6.8.3 The Micro-Politics of Development: Transforming Communities: Maps and Models; Knowledge and Power in Development; Re-inventing Development: Subaltern Movements; Post-colonial development; Decentralization and devolution; Participatory approaches.

C6.8.4 Sustainable Development: Post-sustainable development; Development, violence and inequality; Post-structural perspectives (Escobar); Alternative development paradigms; Feminist critique; Human development.

XL-P	Chemistry (Compulsory for all XL candidates)

Section 1: Atomic Structure and Periodicity

Planck's quantum theory, wave particle duality, uncertainty principle, comparison between Bohr's model and quantum mechanical model of hydrogen atom, electronic configuration of atoms and ions. Hund's rule and Pauli's exclusion principle. Periodic table and periodic properties: ionization energy, electron affinity, electronegativity and atomic size.

Section 2: Structure and Bonding

Ionic and covalent bonding, MO and VB approaches for diatomic molecules, VSEPR theory and shape of molecules, hybridization, resonance, dipole moment, structure parameters such as bond length, bond angle and bond energy, hydrogen bonding and van der Waals interactions. Ionic solids, ionic radii and lattice energy (Born-Haber cycle). HSAB principle.

Section 3: s, p and d Block Elements

Oxides, halides and hydrides of alkali, alkaline earth metals, B, Al, Si, N, P, and S. General characteristics of 3d elements. Coordination complexes: valence bond and crystal field theory, colour, geometry, magnetic properties and isomerism.

Section 4: Chemical Equilibria

Osmotic pressure, elevation of boiling point and depression of freezing point, ionic equilibria in solution, solubility product, common ion effect, hydrolysis of salts, pH, buffer and their applications. Equilibrium constants (K_c, K_p, and K_X) for homogeneous reactions.

Section 5: Electrochemistry

Conductance, Kohlrausch law, cell potentials, EMF, Nernst equation, thermodynamic aspects and their applications.

Section 6: Reaction Kinetics

Rate constant, order of reaction, molecularity, activation energy, zero, first and second order kinetics, catalysis and elementary enzyme reactions. Reversible and irreversible inhibition of enzymes.

Section 7: Thermodynamics

Qualitative treatment of state and path functions, First law, reversible and irreversible processes, internal energy, enthalpy, Kirchoff equation, heat of reaction, Hess's law, heat of formation. Second law, entropy and free energy. Gibbs-Helmholtz equation, free energy change and spontaneity, Free energy changes from equilibrium constant.

Section 8: Structure-Reactivity Correlations and Organic Reaction Mechanisms

Acids and bases, electronic and steric effects, Stereochemistry, optical and geometrical isomerism, tautomerism, conformers and concept of aromaticity. Elementary treatment of SN1, SN2, E1, E2 and radical reactions, Hoffmann/Saytzeff rules, addition reactions, Markownikoff rule and Kharasch effect. Elementary hydroboration reactions. Grignard's reagents and their uses. Aromatic electrophilic substitutions, orientation effect as exemplified by various functional groups. Identification of common functional groups by chemical tests.

Section 9: Chemistry of Biomolecules

Amino acids, proteins, nucleic acids and nucleotides. Peptide sequencing by chemical and enzymatic proteolytic methods. DNA sequencing by chemical and enzymatic methods. Carbohydrates (upto hexoses only). Lipids (triglycerides only). Principles of biomolecule purification-Ion exchange and gel filtration chromatography. Identification of these biomolecules and Beer-Lambert's law.

XL-Q	Biochemistry

Section 1

Organization of life; Importance of water; Structure and function of biomolecules: Amino acids, Carbohydrates, Lipids, Proteins and Nucleic acids; Protein structure, folding/misfolding and function; Myoglobin, Hemoglobin, Lysozyme, Ribonuclease A, Carboxypeptidase and Chymotrypsin.

Section 2

Enzyme kinetics, regulation and inhibition; Vitamins and Coenzymes; Bioenergetics and metabolism; Generation and utilization of ATP; Metabolic pathways and their regulation: glycolysis, TCA cycle, pentose phosphate pathway, oxidative phosphorylation, gluconeogenesis, glycogen and fatty acid metabolism; Metabolism of Nitrogen containing compounds: nitrogen fixation, amino acids and nucleotides. Photosynthesis, Calvin cycle.

Section 3

Biochemical separation techniques: Ion exchange, size exclusion and affinity chromatography, centrifugation; Characterization of biomolecules by electrophoresis; DNA- protein and protein – protein interactions; UV-visible and fluorescence spectroscopy; Mass spectrometry.

Section 4

Cell structure and organelles; Biological membranes; Action potential; Transport across membranes; Membrane assembly and Protein targeting; Signal transduction; Receptor-ligand interaction; Hormones and neurotransmitters.

Section 5

DNA replication, transcription and translation; DNA damage and repair; Biochemical regulation of gene expression; Recombinant DNA technology and applications: PCR, site directed mutagenesis, DNA-microarray; Next generation sequencing; Gene silencing and editing.

Section 6

Immune System: Innate and adaptive; Cell of the immune system; Active and passive immunity; Complement system; Antibody structure, function and diversity; B cell and T Cell receptors; B cell and T cell activation; Major histocompatibilty complex; Immunological techniques: Immuno diffusion, immune-electrophoresis, RIA and ELISA, flow cytometry; monoclonal antibodies and their applications.

XL-R	Botany

Section 1: Plant Systematics

Botanical nomenclature, history of plant taxonomy, diversity and classification of plants, APG system of plant classification; phylogenetics and cladistics, molecular taxonomy and DNA barcoding; Centers for plant taxonomy and herbaria in India.

Section 2: Plant Anatomy

Anatomy of root, stem and leaves, floral organs, embryo and young seedlings, Primary and secondary meristems, stellar organization, vascular system and their ontogeny, xylem and phloem structure, secondary growth in plants and wood anatomy, plant cell structure and differences from animal cells.

Section 3: Plant Development; Cell and Tissue Morphogenesis

Life cycle of an angiosperm, development of male and female gametophyte; cell fate determination and tissue patterning; spacing mechanisms in trichomes and stomata. Embryogenesis, organization and function of shoot and root apical meristems. Transition to flowering: photoperiodism and vernalization, ABC model of floral organ patterning, pollen germination, double fertilization, seed development; Xylem and phloem cell differentiation, photomorphogenesis; phytochrome, cryptochrome, phototropin. Role of auxin, cytokinin, gibberellins, and brassinosteroids on plant development.

Section 4: Plant Physiology and Biochemistry

Plant water relations, mechanisms of uptake and transport of water, ions, solutes from soil to plants, apoplastic and symplastic transport mechanisms. Mechanism of stomatal movements, nitrogen metabolism, photosynthesis; C3, C4 and CAM cycles, photorespiration, respiration: glycolysis, TCA cycle and electron transport chain. Plant responses and mechanisms of abiotic stresses including drought, salinity, freezing and heat stress, metal toxicity; role of abscisic acid in abiotic stresses. Structure and function of biomolecules (proteins, carbohydrates, lipids, nucleic acid), enzyme kinetics. Structure and biosynthesis of major plant secondary metabolites (alkaloids, terpenes, phenylpropanoids, flavonoids). Biosynthesis, mechanism of action and physiological effects of auxin, cytokinin, gibberellic acids, brassinosteroid, ethylene, strigolactone, abscisic acid, salicylic and jasmonic acid. Senescence and programmed cell death.

Section 5: Genetics and Genomics

Cell cycle and cell division. Principles of Mendelian inheritance, linkage, recombination, genetic mapping; extra chromosomal inheritance; Introduction to epigenetics; gene silencing- transgene silencing, post transcriptional gene silencing, miRNA and siRNA; evolution and organization of eukaryotic genome structure, gene expression, gene mutation and repair, chromosomal aberrations (numerical: euploidy and aneuploidy and structural: deletion, duplication, inversion, translocation), transposons. Model organisms for functional genetics and genomics; Introduction to transcriptomics, proteomics and metabolomics.

Section 6: Plant Breeding, Genetic Modification, Genome Editing

Principles, methods – selection, hybridization, heterosis; male sterility, genetic maps and molecular markers, embryo rescue, haploid and doubled haploids, plant tissue culture: micropropagation, embryo culture and in vitro regeneration, somatic embryogenesis, artificial seed, cryopreservation, somaclonal variation, somatic cell hybridization, marker-assisted selection, gene transfer methods viz. direct and vector-mediated, generation of transgenic plants; Introduction to genome editing: CRISPR/Cas9, Cre-Lox system to generate chimeras; plastid transformation; chemical mutagenesis.

Section 7: Economic and Applied Botany

A general account of economically and medicinally important plants- cereals, pulses, plants yielding fibers, timber, sugar, beverages, oils, rubber, pigments, dyes, gums, drugs and narcotics. Economic importance of algae, fungi, lichen and bacteria. Major Indian cash crops. Effect of industrialization on agricultural botany such as plastic on fiber economy. Genetically modified crops and its regulation, e.g. Bt cotton, Bt brinjal, golden rice etc.

Section 8: Plant Pathology

Nature and classification of plant diseases, diseases of important crops caused by fungi, bacteria, nematodes and viruses, and their control measures (chemical and biological) mechanism(s) of pathogenesis, resistance: basal, systemic, induced systemic resistance, gene for gene concept. Molecular detection of pathogens; plant-microbe interactions: symbionts and mycorrhiza, pathogens and pests. Signaling pathways in plant defence response; salicylic acid (SA) and jasmonic acid (JA) in plant-pathogen and plant-herbivore interaction, necrosis; host-parasitic plant interaction (such as Cuscuta).

Section 9: Ecology and Environment

Ecosystems – types, dynamics, degradation, biogeochemical cycles, ecological succession; food webs and energy flow through ecosystem; vegetation types of the world, Indian vegetation types and biogeographical zones, climate and flora endemism; pollution and global climate change, speciation and extinction, biodiversity and conservation strategies, ecological hotspots, afforestation, habitat restoration; plant interactions with other organisms; epiphytes, parasites and endophytes.

XL-S	Microbiology

Section 1: Historical Perspective

Discovery of microbial world; Landmark discoveries relevant to the field of microbiology; Controversy over spontaneous generation; Role of microorganisms in transformation of organic matter and in the causation of diseases.

Section 2: Methods in Microbiology

Pure culture techniques; Principles of microbial nutrition; Enrichment culture techniques for isolation of microorganisms; antigen and antibody detection methods for microbial diagnosis; Light-, phase contrast-, fluorescence- and electron-microscopy; PCR, real-time PCR for quantitation of microbes; Next generation sequencing technologies in microbiology.

Section 3: Microbial Taxonomy and Diversity

Bacteria, Archea and their broad classification; Eukaryotic microbes: Yeasts, molds and protozoa; Viruses and their classification; Molecular approaches to microbial taxonomy and phylogeny.

Section 4: Prokaryotic Cells: Structure and Function

Prokaryotic Cells: Cell walls, cell membranes and their biosynthesis, mechanisms of solute transport across membranes, Flagella and Pili, Capsules, Cell inclusions like endospores and gas vesicles; Bacterial locomotion, including positive and negative chemotaxis.

Section 5: Microbial Growth

Definition of growth; Growth curve; Mathematical expression of exponential growth phase; Measurement of growth and growth yields; Synchronous growth; Continuous culture; Effect of environmental factors on growth; Bacterial biofilm and biofouling.

Section 6: Control of Micro-organisms

Disinfection and Sterilization: Principles, methods and assessment of efficacy.

Section 7: Microbial Metabolism

Energetics: redox reactions and electron carriers; Electron transport and oxidative phosphorylation; An overview of metabolism; Glycolysis; Pentose-phosphate pathway; Entner-Doudoroff pathway; Glyoxalate pathway; The citric acid cycle; Fermentation; Aerobic and anaerobic respiration; Chemolithotrophy; Photosynthesis; Calvin cycle; Biosynthetic pathway for fatty acids synthesis; Common regulatory mechanisms in synthesis of amino acids; Regulation of major metabolic pathways.

Section 8: Microbial Diseases and Host Pathogen Interaction

Normal microbiota; Classification of infectious diseases; Reservoirs of infection; Nosocomial infection; Opportunistic infections; Emerging infectious diseases; Mechanism of microbial pathogenicity; Nonspecific defense of host; Antigens and antibodies; Humoral and cell mediated immunity; Vaccines; passive immunization; Immune deficiency; Human diseases caused by viruses, bacteria, and pathogenic fungi.

Section 9: Chemotherapy/Antibiotics

General characteristics of antimicrobial drugs; Antibiotics: Classification molecular mechanism of mode of action and resistance; Antifungal and antiviral drugs.

Section 10: Microbial Genetics

Types of mutation; UV and chemical mutagens; Selection of mutants; Ames test for mutagenesis; Bacterial genetic system: transformation, conjugation, transduction, recombination, plasmids, transposons; DNA repair; Regulation of gene expression: repression and induction; Operon model; Bacterial genome with special reference to *E.coli*; Phage λ and its life cycle; RNA ; mutation in virus genomes, virus recombination and reassortment; Basic concept of microbial genomics.

Section 11: Microbial Ecology

Microbial interactions; Carbon, sulphur and nitrogen cycles; Soil microorganisms associated with vascular plants; Bioremediation; Uncultivable microorganisms; basic concept of metagenomics and metatranscriptomics.

XL-T	Zoology

Section 1: Animal Diversity

Distribution, systematics and classification of animals, phylogenetic relationships (based on classical and molecular phylogenetic tools).

Section 2: Evolution

Origin and history of life on earth, theories of evolution, natural selection, adaptation, speciation.

Section 3: Genetics

Basic Principles of inheritance, molecular basis of heredity, sex determination and sex-linked characteristics, cytoplasmic inheritance, linkage, recombination and mapping of genes in eukaryotes, population genetics, genetic disorders, roles of model organisms in understanding genetic principles.

Section 4: Biochemistry and Molecular Biology

Nucleic acids, proteins, lipids and carbohydrates; replication, transcription and translation, Krebs cycle, glycolysis, enzyme catalysis, hormones and their actions, roles of vitamins and minerals.

Section 5: Cell Biology

Basic principles of cellular microscopy, structure of cell, cytoskeletal organization, cellular organelles and their structure and function, cell cycle, cell division, chromosomes and chromatin structure.

Section 6: Gene expression in Eukaryotes

Eukaryotic genome organization and regulation of gene expression, transposable elements.

Section 7: Animal Anatomy and Physiology

Comparative physiology, the respiratory system, Muscular system, circulatory system, digestive system, the nervous system, the excretory system, the endocrine system, the reproductive system, the skeletal system.

Section 8: Parasitology and Immunology

Nature of parasite, host-parasite relation, protozoan and helminthic parasites, the immune response, cellular and humoral immune response.

Section 9: Development Biology

Gametogenesis, Embryonic development, cellular differentiation, organogenesis, metamorphosis, Model organisms used in developmental biology, genetic and molecular basis of development, stem cells.

Section 10: Ecology

The ecosystem, Animal distribution, ecological niche and its contribution to ecological diversity, the food chain, population dynamics, species diversity, zoogeography, biogeochemical cycles, conservation biology, ecotoxicology.

Section 11: Animal Behaviour

Type of behaviours, courtship, mating and territoriality, instinct, learning and memory, social behaviour across the animal taxa, communication, pheromones, evolution of behavior in animals.

XL-U	Food Technology

Section 1: Food Chemistry and Nutrition

Carbohydrates: Structure and functional properties of mono-, oligo-, & poly- saccharides including starch, cellulose, pectic substances and dietary fibre, gelatinization and retrogradation of starch. Proteins: classification and structure of proteins in food, biochemical changes in post mortem and tenderization of muscles. Lipids: classification and structure of lipids, rancidity, polymerization and polymorphism. Pigments: carotenoids, chlorophylls, anthocyanins, tannins and myoglobin. Food flavours: terpenes, esters, aldehydes, ketones and quinines. Enzymes: specificity, simple and inhibition kinetics, coenzymes, enzymatic and non-enzymatic browning. Nutrition: balanced diet, essential amino acids and essential fatty acids, protein efficiency ratio, water soluble and fat soluble vitamins, role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, nutrient deficiency diseases. Chemical and biochemical changes: changes occur in foods during different processing.

Section 2: Food Microbiology

Characteristics of Microorganisms: Morphology of bacteria, yeast, mold and actinomycetes, spores and vegetative cells, gram-staining. Microbial growth: growth and death kinetics, serial dilution technique. Food spoilage: spoilage microorganisms in different food products including milk, fish, meat, egg, cereals and their products. Toxins from microbes: pathogens and non-pathogens including Staphylococcus, Salmonella, Shebelle, Escherichia, Bacillus, Clostridium, and Aspergillums genera. Fermented foods and beverages: curd, yoghurt, cheese, pickles, soya-sauce, sauerkraut, idly, dose, vinegar, alcoholic beverages and sausage.

Section 3: Food Products Technology

Processing Principles: Thermal processing, chilling, freezing, dehydration, addition of preservatives and food additives, irradiation, fermentation, hurdle technology, intermediate moisture foods. Food pack aging and storage: packaging materials, aseptic packaging, controlled and modified atmosphere storage. Cereal processing and products: milling of rice, wheat, and maize, parboiling of paddy, bread, biscuits, extruded products and ready to eat breakfast cereals. Oil processing: expelling, solvent extraction, refining and hydrogenation. Fruits and vegetables processing: extraction, clarification, concentration and packaging of fruit juice, jam, jelly, marmalade, squash, candies, tomato sauce, ketchup, and puree, potato chips, pickles. Plantation crops processing and products: tea, coffee, cocoa, spice, extraction of essential oils and oleoresins from spices. Milk and milk products processing: pasteurization and sterilization, cream, butter, ghee, ice- cream, cheese and milk powder. Processing of animal products: drying, canning, and freezing of fish and meat; production of egg powder. Waste utilization: pectin from fruit astes, uses of by-products from rice milling. Food standards and quality maintenance: FPO, PFA, A-Mark, ISI, HACCP, food plant sanitation and cleaning in place (CIP).

Section 4: Food Engineering

Mass and energy balance: Momentum transfer: Flow rate and pressure drop relationships for Newtonian fluids flowing through pipe, Reynolds number. Heat transfer: heat transfer by conduction, convection, radiation, heat exchangers. Mass transfer: molecular diffusion and Flick's law, conduction and convective mass transfer, permeability through single and multilayer films. Mechanical operations: size reduction of solids, high pressure homogenization, filtration, centrifugation, settling, sieving, mixing & agitation of liquid. Thermal operations: thermal sterilization, evaporation of liquid foods, hot air drying of solids, spray and freeze-drying, freezing and crystallization. Mass transfer operations: psychometric, humidification and dehumidification operations.

15. Disclaimer

Zonal GATE offices never sell or advertise any GATE examination test papers or syllabus. Candidates are advised to stay alert about fraud, spam or fake emails, text messages promising to offer services in the name of GATE. Any individual or organisation claiming to sell or distribute GATE papers in the name of IISc and IITs will attract appropriate legal action.

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The data provided by the candidates during the application process as well as their GATE results may be shared for admission or recruitment purposes.

PwD and Dyslexia certificates may be verified by the admitting institute. The GATE Organising Institute will not be responsible for incorrect declaration of the dyslexic status.

The dates mentioned here are subject to change due to unforeseen circumstances. In rare cases, it may become necessary to postpone the GATE 2024 examination because of situations beyond the control of the GATE Organising Institute. All updates will be available on the GATE 2024 website: https://gate2024.iisc.ac.in/

Candidates found using unfair means and not complying with the code of conduct and ethics of GATE 2024 will have their candidature cancelled regardless of whether they have been allowed to complete their examination or not. Appropriate legal action may be initiated against all such candidates.

In all matters concerning GATE 2024, the decision of the GATE 2024 Organising Institute will be final and binding on all the applicants.

Although GATE 2024 will be held at different centres across the country, Indian Institute of Science (IISc), Bengaluru, is the Organising Institute and has the overall responsibility of conducting GATE 2024. In case of any claims or disputes arising in respect of GATE 2024, the High Court of Karnataka in Bengaluru shall have the exclusive jurisdiction to entertain and settle such disputes and claims.

Zone	Contact Address	Phone Number	E-mail ID
Zone-1	GATE Office Indian Institute of Science Bangalore Bengaluru 560 012	080-22932392 080-23601227	gate@gate.iisc.ac.in
Zone-2	GATE Office Indian Institute of Technology Bombay Powai, Mumbai 400 076	022-25767068 022-25767022	gateoffice@iitb.ac.in
Zone-3	GATE Office Indian Institute of Technology Delhi Hauz Khas, New Delhi 110 016	011-26591749	gate@admin.iitd.ac.in
Zone-4	GATE Office Indian Institute of Technology Guwahati Guwahati 781 039	0361-2582751 0361-2582755	gate@iitg.ac.in
Zone-5	GATE Office Indian Institute of Technology Kanpur Kanpur 208 016	0512-2596962 0512-2596963	gate@iitk.ac.in
Zone-6	GATE Office Indian Institute of Technology Kharagpur Kharagpur 721 302	03222-282091 03222-282095	gateonline@adm.iitkgp.ac.in
Zone-7	GATE Office Indian Institute of Technology Madras Chennai 600 036	044-22578200	gate@iitm.ac.in
Zone-8	GATE Office Indian Institute of Technology Roorkee Roorkee 247 667	01332-284531	gate@iitr.ac.in

Contact Hours: Monday to Friday 10:00 AM to 1:00 PM, 2:00 PM to 5:30 PM (Government working days only)