Aeronautics and Astronautics	**Biological Engineering**	**Brain and Cognitive Sciences**	**Chemical Engineering**
Choose Two Core Classes: 16.422; 16.423; 16.453 *Select remaining requirements from Core Classes or Additional Classes:* 16.470; 16.456J; 2.183J; 16.413; 16.89; 16.895; 16.893; 22.55J	*choose BOTH* *20.420J and 20.440*	*choose ONE* 9.011 or HST.131	*choose at least TWO* 10.40; 10.50; 10.65
	choose at least ONE [20.C51J + 6.C51], 20.201; 20.405J; 20.410J; 20.415; 20.430J; 20.463J; 20.490	*choose at least ONE* 9.012; 9.013J; 9.014; 9.015J; 9.017	10.34; 10.524; 10.531J; 10.537J; 10.538J; 10.539J; 10.542; 10.545; 10.546J; 10.55; 10.562J; 10.566; 10.568; 10.569; 10.595; 10.643J; 10.668J
	20.203J; 20.215; 20.409; 20.446J; 20.452J; 20.465; 20.470J; 20.475; HST.507J; HST.508; HST.522J; HST.523J HST.537J; HST.538J	9.021J; 9.073J; 9.123J; 9.181J; 9.285J; 9.301J; 9.422J; 9.520J; 9.611J; 9.660; HST.562J; HST.580J; HST.582J	**Electrical Engineering**
			choose TWO from one group and ONE from each of two additional groups. <u>*System Science and Control Eng.*</u> 6.C67; 6.3010; (6.7000 or 6.7010 or 6.8800J); (6.7100J or 6.7940);(6.7200J or 6.7210J); 6.8810J; HST.584J <u>*Circuits and Electronic Systems*</u> 6.4861J; 6.6000; 6.6010; 6.6220 <u>*Information Science and Communication*</u> 6.7410; 6.7420; 6.7470; 6.7700J; 6.7710; (6.7800 or 6.7810); 6.7900; 6.8300 <u>*Electromagnetics*</u> 6.4832J; 6.6280; 6.6300; (6.6310 or 2.710); 6.6340J <u>*Physical Science and Engineering:*</u> 6.4812J; 6.6400; 6.6500J; 6.6510 <u>*Other*</u> (6.7300J or 6.7330J)
Chemistry	**Computer Science**		
42 UNITS required, may need 5 subjects	*choose TWO from one group and ONE from each of the other groups*		
5.05; 5.061; 5.062; 5.068; 5.44 5.45; 5.46; 5.511; 5.512; 5.52; 5.53; 5.54J; 5.56; 5.64J; 5.68J; 5.698J; 5.70J; 5.72; 5.73; 5.74; 5.78; 5.83; 7.51; 10.569; [20.C51J + 6.C51]; 20.201; 20.420J; 20.463J; 20.465; BCMP 250 (HU); CHEM 170 (HU)	<u>*Algorithms*</u> 6.1220J; 6.5210J; 6.5220J; 6.5250J; 6.7310J; 6.7320J <u>*Probability/Statistics*</u> 6.7300J; 6.7700J; 6.7800; 6.7810; 6.7900; 6.S898 (FALL 2023 only); 9.520J; 15.077J; 16.391; HST.460J; STAT 211 (HU) <u>*Applications*</u> 2.740, 6.4812J; 6.7920[J]; 6.8200; 6.8210; 6.8300; 6.8420; (6.8610J or 6.8620J or 6.8630J); 6.8700J; 6.8710J; 6.8800J; 6.8810J; 8.591J; 18.417; HST.508; HST.538J; HST.956J; BioPhys 205 (HU)		

Materials Science and Engineering	**Mechanical Engineering**	**Nuclear Science and Engineering**	**Physics**
Choose BOTH *3.20* ***and*** *3.21*	choose at least TWO from the first group; if you choose more you may include from sets marked with *	*42 UNITS required, may need 5 subjects*	No more than TWO from the first group
3.22; 3.23; 3.40J; 3.46; 3.941J; 3.942; (3.963J or 3.971J)	2.032; 2.066; (2.071 or 2.072 or 2.080J)*; (2.097J or 2.29)*; (2.140 or 2.151 or 2.153)*; 2.25; 2.37; 2.42; 2.55; 2.675, (2.710 or 6.6310); 2.75J; (2.720 or 2.77); (2.794J; 2.795J or 2.798J)*	22.11; 22.12; 22.13; 22.14; 22.15; 22.51J; 22.55J	8.591J; 8.592J; 8.593J
	2.174; 2.183J; 2.341J; 2.740, (2.782J or 2.785J or 2.79J or 3.963J); 3.23; HST.537J; HST.582J		8.311; 8.321; 8.322; 8.333; 8.334; 8.351J; 8.421; 8.422; 8.511; 8.512; 8.613J; 8.701

HST MEMP TQE Concentration Area Subjects

Aeronautics and Astronautics

Choose Two Core Classes:

16.422: Human Supervisory Control of Automated Systems
16.423: Aerospace Biomedical and Life Support Engineering
16.453: Human Systems Engineering

Select your remaining requirements from either the Core Classes or the Additional Classes below:

16.470: Statistical Methods in Experimental Design
16.456J: Biomedical Signal and Image Processing
2.183J: Biomechanics and Neural Control of Movement
16.413: Principles of Autonomy and Decision Making
16.89: Space Systems Engineering
16.895: Engineering Apollo: The Moon Project as a Complex System
16.893: Engineering the Space Shuttle
22.55J Radiation Biophysics

Biological Engineering

You must choose both 20.420J and 20.440.

20.420J Principles of Molecular Bioengineering **AND**
20.440 Analysis of Biological Networks

Choose at least one:

[20.C51J Machine Learning for Molecular Engineering **AND** 6.C51 Modeling with Machine Learning: from Algorithms to Applications] – *co-reqs*
20.201 Fundamentals of Drug Development
20.405J Principles of Synthetic Biology
20.410J Molecular, Cellular, and Tissue Biomechanics
20.415 Physical Biology
20.430J Fields, Forces, and Flows in Biological Systems
20.463J Biomaterials Science and Engineering
20.490 Computational Systems Biology: Deep Learning in the Life Sciences

Other approved subjects:

20.203J Neurotechnology in Action
20.215 Macroepidemiology, Population Genetics & Stem Cell Biology of Human Clonal Diseases
20.409 Biological Engineering II: Instrumentation and Measurement
20.446J Microbial Genetics and Evolution
20.452J Principles of Neuroengineering
20.465 Engineering the Immune System in Cancer and Beyond
20.470J Cellular Neurophysiology and Computing
20.475 Applied Developmental Biology and Tissue Engineering
HST.507J Advanced Computational Biology: Genomes, Networks, Evolution
HST.508 Evolutionary and Quantitative Genomics
HST.522J Biomaterials: Tissue Interactions
HST.523J Cell-Matrix Mechanics
HST.537J Fluids and Diseases
HST.538J Genomics and Evolution of Infectious Disease

HST MEMP TQE Concentration Area Subjects

Brain and Cognitive Sciences

Choose one *(not both):*

(9.011 Systems Neuroscience Core I **OR** HST.131 Neuroscience)

Choose at least one:

9.012 Cognitive Science
9.013J Molecular and Cellular Neuroscience Core II
9.014 Quantitative Methods and Computational Models in Neurosciences
9.015J Molecular and Cellular Neuroscience Core I
9.017 Systems Neuroscience Core II

Other approved subjects:

9.021J Cellular Neurophysiology and Computing
9.073J Statistics for Neuroscience Research
9.123J Neurotechnology in Action
9.181J Developmental Neurobiology
9.285J Audition: Neural Mechanisms, Perception and Cognition
9.301J Neural Plasticity in Learning and Memory
9.422J Principles of Neuroengineering
9.520J Statistical Learning Theory and Applications
9.611J Natural Language and the Computer Representation of Knowledge
9.660 Computational Cognitive Science
HST.562J Pioneering Technologies for Interrogating Complex Biological Systems
HST.580J Data Acquisition and Image Reconstruction in MRI
HST.582J Biomedical Signal and Image Processing

Chemical Engineering

Choose at least two:

10.40 Chemical Engineering Thermodynamics
10.50 Analysis of Transport Phenomena
10.65 Chemical Reactor Engineering

Other approved subjects:

10.34 Numerical Methods Applied to Chemical Engineering
10.524 Pharmaceutical Engineering
10.531J Macromolecular Hydrodynamics
10.537J Molecular, Cellular, and Tissue Biomechanics
10.538J Principles of Molecular Bioengineering
10.539J Fields, Forces, and Flows in Biological Systems
10.542 Biochemical Engineering
10.545 Fundamentals of Metabolic and Biochemical Engineering: Applications to Biomanufacturing
10.546J Statistical Thermodynamics
10.55 Colloid and Surfactant Science
10.562J Pioneering Technologies for Interrogating Complex Biological Systems
10.566 Structure of Soft Matter
10.568 Physical Chemistry of Polymers
10.569 Synthesis of Polymers
10.595 Molecular Design and Bioprocess Development of Immunotherapies
10.643J Future Medicine: Drug Delivery, Therapeutics, and Diagnostics

10.668J Statistical Mechanics of Polymers

Chemistry

Your TQE course selections must total at least 42 units, so it may be necessary to take five classes instead of the usual four.

5.05 Principles of Inorganic Chemistry III
5.061 Principles of Organometallic Chemistry
5.062 Principles of Bioinorganic Chemistry
5.068 Physical Inorganic Chemistry
5.44 Organometallic Chemistry
5.45 Heterocyclic Chemistry
5.46 NMR Spectroscopy and Organic Structure Determination
5.511 Synthetic Organic Chemistry I
5.512 Synthetic Organic Chemistry II
5.52 Tutorial in Chemical Biology
5.53 Molecular Structure and Reactivity
5.54J Advances in Chemical Biology
5.56 Molecular Structure and Reactivity II
5.64J Frontiers of Interdisciplinary Science in Human Health and Disease
5.68J Kinetics of Chemical Reactions
5.698J Computational Chemistry
5.70J Statistical Thermodynamics
5.72 Statistical Mechanics
5.73 Introductory Quantum Mechanics I
5.74 Introductory Quantum Mechanics II
5.78 Biophysical Chemistry Techniques
5.83 Advanced NMR Spectroscopy
7.51 Principles of Biochemical Analysis
10.569 Synthesis of Polymers
[20.C51J Machine Learning for Molecular Engineering AND 6.C51 Modeling with Machine Learning: from Algorithms to Applications] – *co-reqs*
20.201 Fundamentals of Drug Development
20.420J Principles of Molecular Bioengineering
20.463J Biomaterials Science and Engineering
20.465 Engineering the Immune System in Cancer and Beyond
BCMP 250 Biophysical and Biochemical Mechanisms of Protein Function (Harvard)
CHEM 170 Chemistry & Chemical Biology (Harvard)

Computer Science

Select two courses from one group and one from each of the other groups.

Algorithms

6.1220J Design and Analysis of Algorithms
6.5210J Advanced Algorithms
6.5220J Randomized Algorithms
6.5250J Distributed Algorithms
6.7310J Introduction to Numerical Methods
6.7320J Parallel Computing and Scientific Machine Learning

HST MEMP TQE Concentration Area Subjects

Probability and/or Statistics

6.7300J Introduction to Modeling and Simulation
6.7700J Fundamentals of Probability
6.7800 Inference and Information
6.7810 Algorithms for Inference
6.7900 Machine Learning
6.S898 Special Topic: Deep Learning *(fall 2023 only, subject expected to get new permanent number in fall 2024)*
9.520J Statistical Learning Theory and Applications
15.077J Statistical Machine Learning and Data Science
16.391 Statistics for Engineers and Scientists
HST.460J Statistics for Neuroscience Research
STAT 211 Statistical Inference I (Harvard)

[Students without a strong background in probability are encouraged to take 6.3702 Introduction to Probability before attempting one of the TQE classes listed above.]

Applications

2.740 Bio-inspired Robotics
6.4812J Cellular Neurophysiology and Computing
6.7920[J] Reinforcement Learning: Foundations and Methods
6.8200 Sensorimotor Learning
6.8210 Underactuated Robotics
6.8300 Advances in Computer Vision
6.8420 Computational Design and Fabrication
(6.8610 Quantitative Methods for Natural Language Processing **OR** 6.8620J Spoken Language Processing **OR** 6.8630J Natural Language and the Computer Representation of Knowledge)
6.8700J Advanced Computational Biology: Genomes, Networks, Evolution
6.8710J Computational Systems Biology: Deep Learning in the Life Sciences
6.8800J Biomedical Signal and Image Processing
6.8810J Data Acquisition and Image Reconstruction in MRI
8.591J Systems Biology
18.417 Introduction to Computational Molecular Biology
HST.508 Evolutionary and Quantitative Genomics
HST.538J Genomics and Evolution of Infectious Disease
HST.956J Machine Learning for Healthcare
Biophys 205 Computational and Functional Genomics (Harvard)

- You may not choose more than one class of the following: 6.8610J, 6.8620J, 6.8630

Electrical Engineering

Select two courses from one group and one from each of two additional groups.

System Science and Control Engineering:

6.C67 Computational Imaging: Physics and Algorithms
6.3010 Signals, Systems and Inference
(6.7000 Discrete-Time Signal Processing **OR** 6.7010 Digital Image Processing **OR** 6.8800J Biomedical Signal and Image Processing)
(6.7100J Dynamic Systems and Control **OR** 6.7940 Dynamic Programming and Reinforcement Learning)
(6.7200J Optimization Methods **OR** 6.7210J Introduction to Mathematical Programming)
6.8810J Data Acquisition and Image Reconstruction in MRI
HST.584J Magnetic Resonance Analytic, Biochemical, and Imaging Techniques

HST MEMP TQE Concentration Area Subjects

Circuits and Electronic Systems
6.4861J Medical Device Design
6.6000 CMOS Analog and Mixed-Signal Circuit Design
6.6010 Analysis and Design of Digital Integrated Circuits
6.6620 Power Electronics

Information Science and Communication
6.7410 Principles of Digital Communication
6.7420 Heterogeneous Networks: Architecture, Transport, Protocols, and Management
6.7470 Information Theory
6.7700J Fundamentals of Probability
6.7710 Discrete Stochastic Processes
(6.7800 Inference and Information **OR** 6.7810 Algorithms for Inference)
6.7900 Machine Learning
6.8300 Advances in Computer Vision

Electromagnetics
6.4832J Fields, Forces, and Flows in Biological Systems
6.6280 Electric Machines
6.6300 Electromagnetics
(6.6310 Optics and Photonics **OR** 2.710 Optics)
6.6340J Nonlinear Optics

Physical Science and Engineering
6.4812J Cellular Neurophysiology and Computing
6.6400 Applied Quantum and Statistical Physics
6.6500J Integrated Microelectronic Devices
6.6510 Physics for Solid-State Applications

Other
(6.7300J Introduction to Modeling and Simulation **OR** 6.7330J Numerical Methods for Partial Differential Equations)

Materials Science and Engineering
Choose both:
3.20 Materials at Equilibrium **AND** 3.21 Kinetic Processes in Materials
Other approved subjects:
3.22 Structure and Mechanics of Materials
3.23 Electrical, Optical, and Magnetic Properties of Materials
3.40J Modern Physical Metallurgy
3.46 Photonic Materials and Devices
3.941J Statistical Mechanics of Polymers
3.942 Polymer Physics
(3.963J Biomaterials Science and Engineering **OR** 3.971J Molecular, Cellular, and Tissue Biomechanics)

HST MEMP TQE Concentration Area Subjects

Mechanical Engineering

Choose at least two *(if you choose three or four from this group, you may include classes from the same set marked with *):*

2.032 Dynamics
2.066 Acoustics and Sensing
(2.071 Mechanics of Solid Materials **OR** 2.072 Mechanics of Continuous Media **OR** 2.080J Structural Mechanics)
(2.097J Numerical Methods for Partial Differential Equations **OR** 2.29 Numerical Fluid Mechanics)
(2.140 Analysis and Design of Feedback Control Systems **OR** 2.151 Advanced System Dynamics and Control **OR** 2.153 Adaptive Control and Connections to Machine Learning)
2.25 Fluid Mechanics
2.37 Fundamentals of Nanoengineering
2.42 General Thermodynamics
2.55 Advanced Heat and Mass Transfer
2.675 Micro/Nano Engineering Laboratory
(2.710 Optics **OR** 6.6310 Optics and Photonics)
2.75J Medical Device Design
(2.720 Elements of Mechanical Design **OR** 2.77 FUNdaMENTALS of Precision Product Design)
(2.794J Cellular Neurophysiology and Computing **OR** 2.795J Fields, Forces, and Flows in Biological Systems **OR** 2.798J Molecular, Cellular, and Tissue Biomechanics)
2.810 Manufacturing Processes and Systems

Other approved subjects:

2.174 Advancing Mechanics and Materials via Machine Learning
2.183J Biomechanics and Neural Control of Movement
2.341J Macromolecular Hydrodynamics
2.740 Bio-inspired Robotics
(2.782J Design of Medical Devices and Implants **OR** 2.785J Cell-Matrix Mechanics **OR** 2.79J Biomaterials: Tissue Interactions **OR** 3.963J Biomaterials Science and Engineering
3.23 Electrical, Optical, and Magnetic Properties of Materials
HST.537J Fluids and Diseases
HST.582J Biomedical Signal and Image Processing

Nuclear Science and Engineering

Your TQE course selections must total at least 42 units, so it may be necessary to take five classes instead of the usual four.

22.11 Applied Nuclear Physics,
22.12 Radiation Interactions, Control, and Measurement
22.13 Nuclear Energy Systems
22.14 Materials in Nuclear Engineering
22.15 Essential Numerical Methods
22.51J Quantum Technology and Devices
22.55J Radiation Biophysics

HST MEMP TQE Concentration Area Subjects

Physics

No more than two:

8.591J Systems Biology
8.592J Statistical Physics in Biology
8.593J Biological Physics

Other approved subjects:

8.311 Electromagnetic Theory I
8.321 Quantum Theory I
8.322 Quantum Theory II
8.333 Statistical Mechanics I
8.334 Statistical Mechanics II
8.351J Classical Mechanics: A Computational Approach
8.421 Atomic and Optical Physics I
8.422 Atomic and Optical Physics II
8.511 Theory of Solids I
8.512 Theory of Solids II
8.613J Introduction to Plasma Physics I
8.701 Introduction to Nuclear and Particle Physics