Engineering Curriculum: 6 Advanced Courses
Courses Included:

1. **Engineering Mechanics & Materials**
2. **Construction Elements & Engineering Technology**
3. **Thermodynamics & Statistical Physics**
4. **Electronics & Hardware Production**
5. **Quantum Computing & CPU/GPU Production**
6. **Quantum Mechanics & Advanced Hardware Applications**

1. Engineering Mechanics & Materials
Weeks 1–6: Engineering Mechanics
Textbook: *Engineering Mechanics: Statics & Dynamics* by R.C. Hibbeler

- **Week 1**: Forces, equilibrium, free-body diagrams (Ch. 2–3).
- **Week 2**: Moments and rigid body equilibrium (Ch. 4–5).
- **Week 3**: Truss analysis (Ch. 6).
- **Week 4**: Friction applications (Ch. 8).
- **Week 5**: Stress/strain basics (Ch. 1 of *Mechanics of Materials*).
- **Week 6**: Beam bending (Ch. 6–7).
  Projects: Bridge truss analysis, beam design.

Weeks 7–12: Materials Science
Textbook: *Materials Science and Engineering* by Callister & Rethwisch

- **Week 7**: Stress-strain curves (Ch. 6–7).
- **Week 8**: Metals/alloys (Ch. 9–11).
- **Week 9**: Polymers/ceramics (Ch. 13–14).
- **Week 10**: Composites (Ch. 16).
- **Week 11**: Failure analysis (Ch. 8–9).
- **Week 12**: Material selection (Ch. 22).
  Projects: Composite panel design, failure case study.

2. Construction Elements & Engineering Technology
Weeks 1–6: Construction Elements
Textbook: *Construction Technology* by Chudley & Greeno

- **Week 1**: Building materials (Ch. 2–4).

- **Week 2**: Structural systems (Ch. 5–6).
- **Week 3**: Foundations/soil mechanics (Ch. 7).
- **Week 4**: MEP systems (Ch. 10).
- **Week 5**: Sustainability (Ch. 12).
- **Week 6**: Building codes (Ch. 1).
  Projects: MEP plan design, code-compliant building.

Weeks 7–12: Engineering Technology
Textbook: *BIM Handbook* by Eastman et al.

- **Week 7**: CAD/BIM basics (Ch. 2).
- **Week 8**: FEA simulations (ANSYS/SolidWorks).
- **Week 9**: Drones/3D printing (Ch. 6).
- **Week 10**: Project management (Ch. 5).
- **Week 11**: IoT in construction (research papers).
- **Week 12**: AI/AR trends (Ch. 9).
  Projects: BIM floor plan, drone site mapping.

3. Thermodynamics & Statistical Physics
Weeks 1–6: Thermodynamics
Textbook: *Fundamentals of Engineering Thermodynamics* by Moran et al.

- **Week 1**: Laws of thermodynamics (Ch. 1–2).
- **Week 2**: Phase diagrams (Ch. 3).
- **Week 3**: Energy analysis (Ch. 4).
- **Week 4**: Entropy (Ch. 6–7).
- **Week 5**: Power cycles (Ch. 8–10).
- **Week 6**: Combustion (Ch. 13).
  Projects: Rankine cycle optimization, carbon footprint analysis.

Weeks 7–12: Statistical Physics
Textbook: *Thermal Physics* by Kittel & Kroemer

- **Week 7**: Kinetic theory (Ch. 1).
- **Week 8**: Ensembles (Ch. 2).
- **Week 9**: Quantum statistics (Ch. 4).
- **Week 10**: Phase transitions (Ch. 10).
- **Week 11**: Transport phenomena (Reif Ch. 12).
- **Week 12**: Modern applications (Bose-Einstein condensates).
  Projects: Ising model simulation, quantum system analysis.

4. Electronics & Hardware Production
Weeks 1–6: Electronics
Textbook: *Microelectronic Circuits* by Sedra & Smith

- **Week 1**: Basic components (Ch. 1–2).
- **Week 2**: Diodes (Ch. 3–4).
- **Week 3**: Transistors (Ch. 5–6).
- **Week 4**: Op-amps (Ch. 2, 13).
- **Week 5**: Digital logic (Ch. 14).
- **Week 6**: Power supplies (Ch. 17).
  Projects: Audio filter design, voltage regulator.

Weeks 7–12: Hardware Production
Textbook: *PCB Designer's Reference* by Robertson

- **Week 7**: PCB design (KiCad/Eagle).
- **Week 8**: Fabrication processes (Gerber files).
- **Week 9**: SMT soldering (IPC standards).
- **Week 10**: Through-hole assembly.
- **Week 11**: Testing (ICT, thermal imaging).
- **Week 12**: DFM optimization.
  Projects: Custom PCB assembly, DFM report.

5. Quantum Computing & CPU/GPU Production
Weeks 1–6: Quantum Computing
Textbook: *Quantum Computation and Quantum Information* by Nielsen & Chuang

- **Week 1**: Qubits (Ch. 1).
- **Week 2**: Quantum gates (Ch. 4).
- **Week 3**: Algorithms (Ch. 5–6).
- **Week 4**: Cryptography (Ch. 5).
- **Week 5**: Hardware (superconducting qubits).
- **Week 6**: Error correction (Ch. 10).
  Projects: Grover's algorithm, error-correcting code.

Weeks 7–12: CPU/GPU Production
Textbook: *Modern Semiconductor Devices* by Chenming C. Hu

- **Week 7**: Semiconductor physics (Ch. 1–2).
- **Week 8**: CMOS fabrication (Ch. 3–4).
- **Week 9**: CPU architecture (Hennessy & Patterson).
- **Week 10**: GPU architecture (CUDA programming).

- **Week 11**: Packaging/testing (ATE tools).
- **Week 12**: AI accelerators.
  Projects: MIPS pipeline design, GPU thermal analysis.

6. Quantum Mechanics & Advanced Hardware Applications
Week 1: Mathematical Prerequisites
Textbook: *Mathematical Methods in the Physical Sciences* by **Mary L. Boas** (3rd ed.)

- **Topics**:
  - Linear algebra (vectors, matrices, eigenvalues).
  - Differential equations (separable, Fourier series).
  - Complex numbers and probability theory.
- **Chapters**:
  - Ch. 3 (Linear Algebra), Ch. 8 (Differential Equations), Ch. 2 (Complex Numbers), Ch. 14 (Probability).
- **Lab**: Solve quantum-inspired problems using Python (NumPy/SymPy).

Week 2: Classical Mechanics Primer
Textbook: *Classical Mechanics* by **Herbert Goldstein** (3rd ed.)

- **Topics**:
  - Lagrangian/Hamiltonian mechanics.
  - Poisson brackets, canonical transformations.
- **Chapters**:
  - Ch. 1 (Lagrange's Equations), Ch. 2 (Hamilton's Principle).
- **Project**: Simulate a double pendulum's motion using Lagrangian mechanics (Python).

Weeks 3–10: Pure Quantum Mechanics
Textbook: *Introduction to Quantum Mechanics* by **David J. Griffiths** (3rd ed.)

Week	**Topics**	**Chapters**	**Labs/Projects**
3	**Wave Functions & Schrödinger Equation**	Ch. 1–2	Lab: Solve infinite potential well numerically.
4	**Formalism (Hilbert Space, Operators)**	Ch. 3	Project: Simulate expectation values for particle in a box.
5	**Angular Momentum & Spin**	Ch. 4	Lab: Visualize spin-½ states with Qiskit.

6	**Time-Independent Perturbation Theory**	Ch. 6	Project: Calculate energy shifts for Stark effect.
7	**Identical Particles**	Ch. 5	Lab: Simulate fermionic/bosonic distributions.
8	**Time-Dependent Perturbation Theory**	Ch. 9	Project: Model Rabi oscillations in a 2-level system.
9	**Scattering Theory**	Ch. 11	Lab: Simulate 1D scattering with COMSOL.
10	**Relativistic QM (Dirac Equation)**	Ch. 7 (supplement with online notes)	Case Study: Graphene's relativistic electrons.

Weeks 11–12: Applications in Advanced Hardware Production
Textbook: *Quantum Mechanics for Semiconductor Devices* by **Mitin, Kochelap, & Stroscio**

Week	Topics	Key Concepts	Labs/Projects
11	**Quantum Dots & Nanostructures**	- Quantum confinement - Single-electron transistors	Lab: Simulate quantum dot energy levels (COMSOL/NanoHub).
12	**Quantum Computing Hardware**	- Qubit fabrication (superconducting, spin) - Cryogenic CMOS integration	Final Project: Design a qubit control circuit for a semiconductor chip.

Additional Resources:

1. **Software**:
    a. **Qiskit Metal** (quantum device design).
    b. **COMSOL Multiphysics** (nanostructure simulations).
2. **Industry Papers**:
    a. Intel's quantum dot transistor research.
    b. IBM's quantum hardware roadmaps.

Key Connections:

- **Week 1 (Math) → Week 3 (Wavefunctions)**: Eigenvalue problems link matrices to Schrödinger solutions.
- **Week 2 (Hamiltonians) → Week 5 (Spin)**: Poisson brackets formalize commutators in quantum theory.
- **Week 12 (Qubit Fabrication)**: Applies quantum mechanics to design next-gen CPUs/GPUs.

Assessment:

- **Prerequisites**: Math/classical mechanics problem sets.
- **Core Quantum**: Weekly coding labs (Python/Qiskit), perturbation theory reports.
- **Hardware Apps**: Final project presentation on qubit circuit design.

Core Courses

1. Quantum Hardware Engineering

Topics:

- Superconducting qubits, photonic qubits, and spin qubits [9,14].
- Cryogenic systems, error correction (surface codes), and hybrid quantum-classical architectures [9,11].
- Hands-on labs using platforms like **Quantum Inspire** for programming quantum algorithms on real hardware [9].

- **Textbook**: *Quantum Computation and Quantum Information* (Nielsen & Chuang) [9].
- **Project**: Design a fault-tolerant qubit control circuit [9,14].

2. Advanced Materials for Next-Gen Hardware

- **Topics**:
  - Metamaterials, plasmonic structures, and 2D materials (e.g., graphene) [113].
  - Nanoelectromagnetics, photonic crystals, and terahertz systems [1].
  - Applications in RF, optical communications, and quantum sensing [113].
- **Case Study**: Design a metamaterial-based antenna for 6G networks [1].

3. Quantum Computing & Algorithms

- **Topics**:
  - Grover's, Shor's, and variational quantum algorithms [11].
  - Qiskit and CUDA programming for quantum-classical hybrid systems [117].
- **Lab**: Optimize a quantum machine learning model using NVIDIA's quantum tools [7].
- **Textbook**: *Programming Quantum Computers* (Johnston et al.) [11].

4. Semiconductor Physics & Device Fabrication

- **Topics**:
  - CMOS scaling, EUV lithography, and 3D chip stacking [14].
  - Quantum dots, single-electron transistors, and cryogenic CMOS integration [914].
- **Project**: Simulate a 3nm transistor node using TCAD tools [14].

5. Photonics & Quantum Optics

- **Topics**:

- Laser systems, optical fibers, and integrated photonics [113].
- Quantum key distribution (QKD) and photonic quantum computing [913].

- **Lab**: Build a quantum communication link using entangled photons [1].

Electives (Choose 2–3)

6. AI-Driven Hardware Design

- Use machine learning to optimize quantum error correction or chip layouts [711].
- **Tool**: NVIDIA's quantum simulation frameworks [7].

7. Sustainable Hardware Technologies

- Energy-efficient computing, recyclable materials, and green semiconductor manufacturing [10].
- **Case Study**: Decarbonizing data centers with quantum-inspired cooling systems [10].

8. Quantum Sensing & Metrology

- Atomic clocks, NV centers in diamond, and gravitational wave detectors [913].
- **Project**: Design a quantum sensor for medical imaging [14].

9. Ethics & Policy in Emerging Tech

- Quantum cybersecurity, AI ethics, and global standards for quantum infrastructure [1011].

Capstone Project

- **Objective**: Solve a real-world problem using modern physics and hardware (e.g., quantum-resistant encryption for IoT devices or a low-power AI accelerator) [714].
- **Industry Collaboration**: Partner with companies like **NVIDIA**, **QuTech**, or **IBM Quantum** [79].

Skill Development

1. **Computational Tools**:
   a. Python, Qiskit, COMSOL, and ANSYS for simulations [911].
   b. CAD tools for photonic/quantum device design [113].
2. **Soft Skills**:
   a. Cross-disciplinary teamwork and science communication [10].

Future-Proofing Strategies

1. **Industry Certifications**:
   a. **NVIDIA Quantum Developer Certification** [7].
   b. **QTIndu Certificate** for EU-based quantum training [9].
2. **Conferences**:
   a. Attend **QCrypt ’25** (quantum security) or **IEEE Quantum Week** [37].

Program Outcomes

- **Career Paths**: Quantum hardware engineer, photonics R&D scientist, AI accelerator designer [14].
- **Employers**: Palantir, Thorlabs, IBM Quantum, or startups in quantum tech [14].

Key Resources

- **Textbooks**:
  - *Metamaterials: Physics and Engineering Explorations* (Engheta & Ziolkowski) [1].
  - *Quantum Mechanics for Semiconductor Devices* (Mitin et al.) [9].
- **Online Courses**:
  - Coursera's *Hands-on Quantum Error Correction* (free) [11].
  - TU Delft's *Quantum Hardware* MOOC [9].

This curriculum blends theory, hands-on labs, and industry trends to prepare you for leadership roles in **quantum computing**, **advanced photonics**, and **sustainable hardware innovation**. Let me know if you'd like to refine specific modules! 🚀

Semester 1: Foundational Engineering & Applied Physics

1. **Engineering Mechanics & Materials**
   a. Builds core skills in statics, dynamics, and material behavior.
   b. Labs: Bridge truss analysis, composite material design.
2. **Thermodynamics & Statistical Physics**
   a. Covers energy systems, entropy, and microscopic/macroscopic physics.
   b. Projects: Rankine cycle optimization, Ising model simulation.
3. **Electronics & Hardware Production**
   a. Introduces circuit design, PCB fabrication, and microcontroller basics.

   b. Labs: Voltage regulator assembly, SPICE simulations.

Focus: Establishes mechanical, thermal, and electronic engineering fundamentals.

Semester 2: Advanced Hardware & Quantum Integration

1. **Quantum Computing & CPU/GPU Production**
   a. Explores quantum algorithms, semiconductor physics, and parallel computing.
   b. Projects: CUDA-accelerated quantum simulations, CPU pipeline design.
2. **Quantum Mechanics & Advanced Hardware Applications**
   a. Links quantum theory (Dirac equation, perturbation) to hardware (quantum dots, qubit fabrication).
   b. Labs: Quantum dot energy simulations, cryogenic CMOS design.
3. **Construction Elements & Engineering Technology**
   a. Applies structural systems, BIM, and sustainable practices to hardware infrastructure.
   b. Project: Code-compliant smart building design with IoT integration.

Focus: Merges quantum physics with hardware engineering and scalable infrastructure.

Rationale

1. **Semester 1** prepares you with:
   a. **Mathematical tools**: Stress-strain analysis, statistical mechanics.
   b. **Practical skills**: Circuit prototyping, material testing.
2. **Semester 2** builds on this with:
   a. **Quantum integration**: Applying quantum principles to semiconductor/GPU design.
   b. **Industry alignment**: Skills for roles in quantum hardware (IBM, NVIDIA) or sustainable construction tech.

Workload Balance

Semester	**ECTS Estimate**	**Key Skills Gained**
1	27–30 ECTS	Mechanical modeling, energy systems, PCB design.
2	27–30 ECTS	Quantum algorithm coding, chip fabrication, BIM workflows.

Capstone Opportunity
Combine projects from **Semester 2** into a final deliverable, e.g.:

- Design a **quantum sensor** with cryogenic cooling, using skills from *Quantum Mechanics* and *Electronics*.
- Optimize a **sustainable data center** with quantum-inspired cooling (thermodynamics) and IoT-enabled construction (BIM).

Also, here's a **4-week intensive bridge course** focused on **workshop practices, experimental design, and safety protocols** for cryogenics and advanced hardware fabrication. This ensures you're prepared to handle hazardous materials, complex setups, and high-stakes experiments without "blowing up the block":

Course 7: Experimental Design & Safety for Advanced Hardware
Duration: 4 weeks (condensed 12-week workload)
Focus: Safe handling of cryogenics, precision tools, and failure analysis.

Week 1: Workshop Safety & Risk Assessment
Topics:

1. **Safety Protocols**:
    a. PPE (face shields, cryogenic gloves, aprons).
    b. Hazard communication (GHS labels, SDS for liquid nitrogen/helium).
    c. Emergency procedures (spill containment, fire suppression).
2. **Workshop Tools**:
    a. Proper use of lathes, mills, and laser cutters.
    b. Electrical safety for high-voltage circuits.
3. **Risk Assessment Frameworks**:
    a. HAZOP (Hazard and Operability Study).
    b. Fault tree analysis for cryogenic systems.
    Lab:

- Perform a safety audit of a mock lab (identify risks like unsecured gas cylinders, improper LN2 storage).
  Key Resource:
- *Prudent Practices in the Laboratory* (National Research Council).

Week 2: Cryogenic Handling & Material Compatibility
Topics:

1. **Cryogenics 101**:
    a. Safe transfer/storage of LN2 (77K) and LHe (4K).
    b. Oxygen deficiency hazards (ODH) monitoring.
2. **Material Selection**:
    a. Thermal contraction/expansion (avoid plastics that shatter at low temps).
    b. Cryogenic adhesives and seals.
3. **Emergency Shutdowns**:
    a. Quench recovery in superconducting systems.
    b. Ventilation protocols for helium leaks.

Lab:

- Practice LN2 transfer using proper Dewars and phase separators.

Case Study:

- Lessons from the **Large Hadron Collider (LHC)** quench incident.

Week 3: Experimental Design & Failure Analysis
Topics:

1. **Design of Experiments (DOE)**:
    a. Variables, controls, and replication in cryogenic setups.
    b. Taguchi methods for robustness.
2. **Failure Modes**:
    a. Thermal stress fractures.
    b. Vacuum failures (e.g., outgassing in cryostats).
3. **Root Cause Analysis (RCA)**:
    a. Fishbone diagrams, 5 Whys.

Lab:

- Dissect a failed cryogenic component (e.g., a cracked superconducting coil).

Project:

- Design a failsafe for a dilution refrigerator cooling loop.

Week 4: Advanced Fabrication & Troubleshooting
Topics:

1. **Precision Machining**:
    a. Tolerances for cryogenic seals (<0.1mm gaps).
    b. Avoiding thermal shorts in multi-layer insulation (MLI).
2. **Vacuum Systems**:

    a. Leak detection (helium mass spectrometers).
    b. Pumping down cryostats without contamination.
3. **Troubleshooting Workflows**:
    a. Using thermal cameras to detect cold spots.
    b. Interpreting pressure/temperature logs.

    Capstone Project:

- Build and test a small-scale cryogenic setup (e.g., a superconducting loop with safety interlocks).

  Deliverable:

- Submit a safety-compliant design report and present failure-mitigation strategies.

Key Tools & Certifications

- **Tools**:
    - COMSOL Multiphysics (thermal stress simulations).
    - Fluke thermal cameras, helium leak detectors.
- **Certifications**:
    - OSHA 10-Hour General Industry Certification (optional but recommended).
    - Cryogenic Safety Training (CERN/NIST modules).

How This Bridges to Your Other Courses

1. **Thermodynamics/Stats**: Apply entropy principles to predict heat leaks.
2. **Quantum Hardware**: Safely integrate cryogenic control circuits into qubit designs.
3. **Electronics**: Avoid thermal runaway in cryogenic CMOS.

Assessment

- **Lab Reports**: 40% (safety audits, LN2 transfer logs).
- **Capstone Project**: 50% (design robustness, safety compliance).
- **Safety Quizzes**: 10%.

Key Differences from Arts-Based Assessment

1. **Exams Dominate (70–80% of Grade)**: Tests rigorous problem-solving under time constraints.

2. **Derivations Required**: Prove equations (e.g., Navier-Stokes for fluid flow) rather than descriptive answers.
3. **Quantitative Labs**: Reports graded on error analysis and statistical validity, not just completion.
4. **Strict Grading Curve**: Top 15% earn As, reflecting competitive MSc standards.

Here's a **detailed grading schema** for your six courses, aligned with the coursework, projects, and exams we've structured. This follows a **Master of Science** framework, emphasizing theoretical rigor, practical execution, and quantitative analysis:

1. Engineering Mechanics & Materials

Assessment	**Weight**	**Description**
Midterm Exam	35%	Problems on forces, moments, truss analysis, stress-strain relationships.
Final Exam	35%	Beam bending, composite mechanics, failure theories (von Mises/Tresca).
Bridge Truss Report	15%	Validate truss forces using ANSYS/MATLAB; error analysis.
Composite Panel Project	10%	Design and test a composite material (e.g., carbon fiber).
Lab Participation	5%	Active engagement in tensile testing, shear force experiments.

2. Construction Elements & Engineering Technology

Assessment	**Weight**	**Description**
Midterm Exam	35%	Load-bearing systems, soil mechanics, HVAC principles.
Final Exam	35%	Building codes, sustainability (LEED), AI/AR in construction.
MEP Plan Design	15%	Revit/BIM design of plumbing/electrical systems.
Drone Mapping Report	10%	Accuracy analysis of drone-generated site maps.
Code Compliance Quiz	5%	Short-answer questions on OSHA/ISO standards.

3. Thermodynamics & Statistical Physics

Assessment	Weight	Description
Midterm Exam	35%	Carnot/Rankine cycles, entropy calculations, Maxwell-Boltzmann distributions.
Final Exam	35%	Partition functions, Bose-Einstein condensation, Ising model phase transitions.
Rankine Cycle Optimization	15%	MATLAB/Python code to maximize thermal efficiency.
Ising Model Simulation	10%	Code submission (Python) with magnetization vs. temperature plots.
Lab Participation	5%	PVT experiments, statistical mechanics derivations.

4. Electronics & Hardware Production

Assessment	Weight	Description
Midterm Exam	35%	Op-amp circuits, BJT/MOSFET biasing, Kirchhoff's laws.
Final Exam	35%	Power regulation, digital logic, Gerber file standards.
PCB Design & Assembly	15%	Fabricate and test a custom PCB (e.g., voltage regulator).
Active Filter Report	10%	Validate filter performance using SPICE simulations.
Soldering Practical	5%	Precision assembly of SMT components.

5. Quantum Computing & CPU/GPU Production

Assessment	Weight	Description
Midterm Exam	35%	Quantum gates, Shor's algorithm, semiconductor band theory.
Final Exam	35%	CUDA programming, lithography defects, GPU memory hierarchy.
Grover's Algorithm Code	15%	Implement and benchmark on IBM Quantum/Qiskit.
GPU Thermal Analysis	10%	Optimize CUDA kernel and analyze heat dissipation.
Case Study Presentation	5%	TSMC's 3nm node fabrication process.

6. Quantum Mechanics & Advanced Hardware Applications

Assessment	Weight	Description
Midterm Exam	35%	Schrödinger equation solutions, angular momentum, perturbation theory.
Final Exam	35%	Dirac equation, quantum confinement, relativistic QM applications.
Quantum Dot Simulation	15%	COMSOL/NanoHub model of energy levels in nanostructures.
Qubit Control Circuit	10%	Design cryogenic-compatible control logic for superconducting qubits.
Research Essay	5%	Discuss quantum mechanics in spintronics or graphene.

Grading Scale (ECTS)

Grade	ECTS	Performance Level
A	5.0	Outstanding: Mastery of theory, flawless execution, innovative project solutions.
B	4.0	Very Good: Strong conceptual grasp, minor errors in calculations or design.
C	3.0	Good: Basic competency, struggles with advanced applications.
D	2.0	Satisfactory: Marginal pass, memorization over deep understanding.
F	0	Fail: Fundamental gaps in knowledge or incomplete deliverables.

Key Notes

1. **Exams Dominate (70% Combined)**: Midterms test foundational theory; finals assess advanced applications.
2. **Projects (25–30%)**: Graded on technical rigor, error analysis, and innovation.
3. **Practical/Lab Work (5–10%)**: Emphasizes hands-on precision (e.g., soldering, ANSYS simulations).
4. **Peer Review**: For group projects (e.g., drone mapping), peer evaluations adjust individual grades.

ECTS Credit Allocation

- Each **12-week course = 10 ECTS** (Total: **60 ECTS** for all six courses).

- **1 ECTS ≈ 25–30 hours of work** (lectures, labs, self-study).

Here's a structured **Year 2 Master's Program** focused on **Quantum Hardware, Advanced Materials, and Semiconductor Technologies**,. The program balances theoretical depth, computational modeling, and hands-on fabrication labs.

Program Structure
Total ECTS: 60 (10 ECTS per course × 6 courses)
Duration: Two semesters (3 courses per semester).

Semester 3: Core Advanced Courses
1. Quantum Hardware Engineering (10 ECTS)
Textbook: *Quantum Computation and Quantum Information* (Nielsen & Chuang)
Topics:

- Superconducting qubits, photonic qubits, spin qubits.
- Cryogenic systems (dilution refrigerators), surface code error correction.
- Hybrid quantum-classical architectures (e.g., quantum control loops).
  Projects/Labs:
- Design a fault-tolerant qubit control circuit (Qiskit Metal).
- Lab: Program a 5-qubit algorithm on **Quantum Inspire** or IBM Quantum.
  Assessment:
- **Midterm Exam** (30%): Qubit coherence times, error correction math.
- **Final Exam** (30%): Cryogenic integration challenges, hybrid architectures.
- **Control Circuit Design** (25%): Cryogenic compatibility and noise mitigation.
- **Lab Reports** (15%): Algorithm benchmarking and error rates.

2. Advanced Materials for Next-Gen Hardware (10 ECTS)
Textbook: *Materials Science and Engineering* (Callister & Rethwisch) + Research Papers
Topics:

- Metamaterials (negative refraction, cloaking).
- 2D materials (graphene, MoS_2) for quantum sensing.
- Photonic crystals and terahertz systems.
  Projects/Labs:
- Case Study: Design a metamaterial-based antenna for 6G networks (COMSOL).
- Lab: Fabricate and test a graphene-based RF device.
  Assessment:
- **Midterm Exam** (30%): Metamaterial design principles, plasmonics.

- **Final Exam** (30%): 2D material properties, terahertz applications.
- **Antenna Design Report** (25%): Simulated performance vs. specs.
- **Lab Participation** (15%): RF testing accuracy.

3. Semiconductor Physics & Device Fabrication (10 ECTS)
Textbook: *Modern Semiconductor Devices* (Chenming C. Hu)
Topics:

- EUV lithography, 3D chip stacking (TSMC's 3nm node).
- Quantum dots, cryogenic CMOS (Intel's Horse Ridge).
  Projects/Labs:
- Simulate a 3nm transistor node using **TCAD Tools** (Silvaco).
- Lab: Characterize a single-electron transistor at 4K.
  Assessment:
- **Midterm Exam** (30%): MOSFET scaling, quantum confinement.
- **Final Exam** (30%): Cryogenic CMOS noise analysis.
- **TCAD Simulation Report** (25%): Leakage current optimization.
- **Lab Report** (15%): I-V curves for quantum dot devices.

Semester 4: Specialization & Electives
4. Quantum Computing & Algorithms (10 ECTS)
Textbook: *Programming Quantum Computers* (Johnston et al.)
Topics:

- Grover's, Shor's, and variational quantum algorithms.
- Hybrid quantum-classical programming (Qiskit + CUDA).
  Projects/Labs:
- Lab: Optimize a quantum ML model (e.g., QSVM) using NVIDIA CUDA-Q.
- Project: Implement a quantum error-corrected algorithm.
  Assessment:
- **Midterm Exam** (30%): Algorithm complexity, gate decomposition.
- **Final Exam** (30%): Hybrid programming challenges.
- **ML Model Report** (25%): Speedup vs. classical benchmarks.
- **Code Submission** (15%): Error correction efficiency.

5. Photonics & Quantum Optics (10 ECTS)
Textbook: *Optics* (Hecht) + Research Papers
Topics:

- Quantum key distribution (QKD), entangled photon sources.
- Integrated photonics (silicon photonics, laser systems).
  Projects/Labs:

- Lab: Build a QKD link using entangled photons (Optical bench setup).
- Case Study: Design a photonic quantum computing chip (Lumerical FDTD).
  Assessment:
- **Midterm Exam** (30%): Laser physics, beam propagation.
- **Final Exam** (30%): QKD protocols, photonic integration.
- **QKD Lab Report** (25%): Bit error rate analysis.
- **Chip Design Proposal** (15%): Loss and coupling efficiency.

6. Elective: AI-Driven Hardware Design (10 ECTS)
Textbook: *Machine Learning for Engineers* (Osvaldo Simeone)
Topics:

- ML for quantum error correction (e.g., surface code decoding).
- AI-optimized chip layouts (NVIDIA's cuQuantum).
  Projects/Labs:
- Train a neural network to predict lithography defects.
- Optimize a qubit control pulse using reinforcement learning.
  Assessment:
- **Midterm Exam** (30%): ML basics, neural network architectures.
- **Final Exam** (30%): AI applications in semiconductor fab.
- **Defect Prediction Model** (25%): Accuracy vs. TCAD data.
- **Control Pulse Report** (15%): Fidelity improvements.

Grading Scale

Grade	ECTS	Performance Criteria
A	5.0	Exceptional mastery, innovative project solutions.
B	4.0	Strong theory/practice alignment, minor errors.
C	3.0	Adequate understanding, limited innovation.
D	2.0	Basic competency, memorization-focused.
F	0	Insufficient knowledge, incomplete work.

Key Features

1. **Tool Integration**:
   a. **COMSOL/ANSYS** for metamaterials and photonics.
   b. **Qiskit/CUDA** for quantum-classical programming.
   c. **TCAD Tools** for semiconductor simulation.
2. **Industry Alignment**:
   a. Projects mirror challenges at IBM Quantum, TSMC, and NVIDIA.
3. **Safety**: Cryogenic and laser labs include protocols from the bridge course.

Career Pathways

- **Quantum Hardware Engineer** (Google Quantum AI, IBM).
- **Semiconductor Process Engineer** (TSMC, Intel).
- **Photonics R&D Scientist** (Huawei, Thorlabs).

Let me know if you'd like adjustments to toolkits or project weightings!