KAUST Physical Science and Engineering – Assessment Examinations

All incoming M.Sc. and Ph.D. (Type I) students are required to take the following THREE Assessment Examinations before commencing their studies in the Division.

The THREE Assessment Examinations to be taken are:

1. **Engineering Mathematics**
2. **Physics and Mechanics**
3. **Chemistry and Thermodynamics**

Each examination is 25 minutes long, consists of 12 multiple choice questions, and are taken one after the other in the week before the semester formally starts. All examinations are taken online using your KAUST Blackboard account.

In what follows, an outline of the material covered in each of these examinations is given.

1. Engineering Mathematics

1. Concept of the limit and its properties. The calculation of limits. One- and two-sided limits. Continuity. The Intermediate Value Theorem.
2. Definition of the derivative. Differentiation from first principles. Derivatives for standard functions including the exponential, logarithmic, trigonometric, and hyperbolic functions. Product, quotient, and chain rules. Higher-order derivatives. Derivatives of inverse functions. Implicit and parametric differentiation. The Mean Value Theorem and Rolle's theorem. Differentiability.
3. Application of the derivative to finding the gradient of a tangent to a curve. Stationary points. Maxima and minima problems. The differential and its application to errors. Rates of change problems.
4. The primitive function and anti-differentiation. The indefinite integral. Techniques of integration including substitution, parts, partial fractions, trigonometric substitutions, and t-substitutions.
5. The definite integral and Riemann integration. Application of the integral to area and volume. The first and second Fundamental Theorems of Calculus. Improper integrals.
6. Sequences and infinite series. The geometric and telescoping series. Alternating series. Convergence and divergence of an infinite series. Test for convergence including the nth term test, direct and limit comparison tests, the integral test, ratio and root tests, alternating series test. Absolute and conditional convergence. The Alternating Series Estimation Theorem.
7. Power series. Properties of power series. Radius of convergence. Taylor and Maclaurin series. Application of power series. Taylor polynomials.
8. Complex numbers, Argand diagram, modulus-argument and polar forms, de Moivre's theorem, exponential form.
9. Vectors. Vector addition and multiplication by a scalar. Properties of vectors. Unit vectors and direction angles. The scalar dot and vector cross products and their associated properties. The scalar triple product. Vector identities. Application of vectors to three-dimensional analytic geometry. Equations of lines and planes in space.

Recommended Reading Material

1. *Calculus*, J. Stewart. Eight Edition (2015, Cengage Learning).
2. *How to Integrate It: A Practical Guide to Finding Elementary Integrals*, S. M. Stewart (2018, Cambridge University Press).

2. Physics and Mechanics

Physics component

1. Electric charge. Electric fields. Coulomb's law.
2. Gauss' law and applications of this law.
3. Electric potential. Capacitance and dielectrics.
4. Current, resistance, and resistivity.
5. Direct current circuits. Voltmeters and ammeters (both ideal and real). RC circuits.
6. Magnetic fields. Gauss' law for magnetism.
7. Magnetic forces. Sources of the magnetic field. The Biot-Savart law and Ampère's law.
8. Electromagnetic induction. Faraday's law. Lenz' law.
9. Displacement current. Maxwell's equations.

Mechanics component

1. Statics of particles. Forces and moments (torques).
2. Equilibrium of rigid bodies. Centres of mass and centroids
3. Moments of inertia.
4. Stress and strain due to axial loading. Torsion
5. Pure bending. Beam analysis
6. Kinematics of particles (using energy and momentum methods). Newton's second law.
7. Planar kinematics of rigid bodies.
8. Planar kinetics of rigid bodies (using equations of motion and energy and momentum methods).

Recommended Reading Material

1. *Sears and Zemanskys University Physics: With Modern Physics*. Young, H. D., Freedman, R. A., Ford, A. L., and Sears, F. W. (Addison-Wesley, 2021).
2. *Vector Mechanics for Engineers: Statics and Dynamics* (Twelfth edition). Ferdinand P. Beer, E. Russell Johnston, David F. Mazurek, Phillip J. Cornwall, and Brian P. Self (McGraw-Hill, 2019).

3. Chemistry and Thermodynamics

Chemistry component

1. Matter and energy. What is chemistry? Atoms, molecules, and ions. Substances, elements, and mixtures. Changes and properties of matter. Periodic Table, Periodic Law. Chemistry divisions. The International Union of Pure and Applied Chemistry (IUPAC).
2. Scientific method: observation, law, hypothesis, experiment, data, results, and theory. Accuracy and precision. Significant figures. Scientific notation. Basic experimental quantities. Unit conversion. Basic statistics for data analysis.
3. Timeline of atomic theories and models. Elementary particles. Quantum numbers for different orbitals. Electron configuration of atoms. Valence electrons and the octet rule.
4. Atomic/ionic radius. Electron affinity. Electronegativity. Ionization energy. Polarizability. Isoelectronic configurations.
5. Lewis structures. Covalent, ionic, and metallic bonds.
6. Molecular geometry. The valence shell electron pair repulsion (VSEPR) theory.
7. Intermolecular interactions. Phase changes. Gaseous, liquid, and solid states.

Thermodynamics component

1. Fundamentals of thermodynamics.
2. Work and heat. The zeroth and first laws of thermodynamics.
3. Pure substances.
4. The second law of thermodynamics.
5. An ideal gas.
6. Carnot cycle.
7. Entropy.

Recommended Reading Material

1. Denniston, K. J.; Topping, J. J.; Dorr, D. R. Q.; Caret, R. L., *General, Organic, and Biochemistry*, McGraw-Hill, 10th edition, 2020.
2. Smoot, R. C.; Smith, R. G.; Price, J., *Chemistry: A Modern Course*, Merrill Publishing Company, 1990.
3. Chang, R.; Overby, J., *Chemistry*, McGraw-Hill, 13th edition, 2019.
4. Goldberg, D. E., *Fundamentals of Chemistry*, McGraw-Hill, 5th edition, 2007.
5. Gaffney, J.; Marley, N., *General Chemistry for Engineers*, Elsevier, 1st edition, 2018.
6. Çengel, Y. A.; Boles, M. A., *Thermodynamics*: *An Engineering Approach*, McGraw-Hill, 5th edition, 2006.