CENTER FOR CURRICULUM REDESIGN

Draft Mechanical Engineering Standards

Note: These standards are designed to be used alongside the Next Generation Science Standards.

Standards design philosophy: These standards are designed to produce students who understand how machines work, including how to manage the heat they generate and the friction that causes wear. They also enable students to predict when simple machines or objects will fail mechanically under load, a necessary step in designing mechanical objects.

Subjects	Topics	Standards	Grades 3-5 Benchmarks	Grades 6-8 Benchmarks	Grades 9-12 Benchmarks
Machines	Force, Pressure, Mechanical motion	CCR-ME MCH 1. Understand forces and how simple mechanical machines operate.	CCR-ME MCH 3-5, 1.1. Identify examples of a force (e.g. pulling, pushing, throwing, squeezing, stretching) (Grade 4). [CAN-QU UO 1-6, 6.4.] CCR-ME MCH 3-5, 1.2. Describe the effects of a force on an object (e.g. sets it in motion, changes its motion, stops it) (Grade 4). [CAN-QU UO 1-6, 6.5.] CCR-ME MCH 3-5, 1.3. Describe the effects of a force on a material or structure (Grade 4). [CAN-QU UO 1-6, 6.6.] CCR-ME MCH 3-5, 1.4. Recognize simple machines (e.g., lever, inclined plane, screw, pulley, winch, wheel) used in an object (e.g. lever in seesaw, inclined plane for an access ramp) (Grade 4). [CAN-QU UO 1-6, 6.7.] CCR-ME MCH 3-5, 1.5. Describe the uses of certain simple machines (to adjust the force required) (Grade 4). [CAN-QU UO 1-6, 6.8.]	CCR-ME MCH 6-8, 1.1. Recognize the transformations of energy from one form to another in various devices (e.g. flashlight: chemical to light; electric kettle: electrical to heat). [CAN-QU UO 1-6, 6.9.] CCR-ME MCH 6-8, 1.2. Recognizes two types of motion (i.e., rotation and translation). [CAN-QU UO 1-6, 6.12.] CCR-ME MCH 6-8, 1.3. Describe a simple sequence of mechanical parts in motion. [CAN-QU UO 1-6, 6.13.] CCR-ME MCH 6-8, 1.4. Identify the main function of some machines (e.g. cart, waterwheel, wind turbine). [CAN-QU UO 1-6, 6.14.] CCR-ME MCH 6-8, 1.5. Recognizes various manifestations of pressure (e.g. inflatable balloon, atmospheric pressure, airplane wing). [CAN-QU UO 1-6, 6.18.] CCR-ME MCH 6-8, 1.6. Describe the effects of pressure on an object (e.g. compression, displacement, increase in temperature). [CAN-QU UO 1-6, 6.19.]	CCR-ME MCH 9-12, 1.1. Have, as a prerequisite, benchmarks CCR-ME MCH 3-5, 1.1-1.5 and CCR-ME MCH 6-8, 1.1-1.6.
	Common mechanical components	CCR-ME PT 2. Recognize and use common mechanical components.		CCR-ME PT 6-8, 2.1. Identify the mechanical parts in a manufactured object (e.g. gears, cams, springs, simple machines, connecting rods). [CAN-QU UO 1-6, 6.15.] CCR-ME PT 6-8, 2.2. Use simple mechanical parts (e.g., levers, gears, pulleys, springs) in creating, moving, or fixing objects. CCR-ME PT 6-8, 2.3. Describe typical uses of common mechanical components. [CAN-QU UO 1-6, 6.8.]	CCR-ME PT 9-12, 2.1. Have, as a prerequisite, benchmarks CCR-ME PT 6-8, 2.1-2.2.
	Disassembly and Repair	CCR-ME RE 3. Understand how a machine works by disassembly and examination.			CCR-ME RE 9-12, 3.1. Understand complex applications of mechanical subsystems and mechanisms by handling an object or system and, if necessary, take them apart. [CAN-QU UT 9-11, 10.3.] CCR-ME RE 9-12, 3.2. Determine the overall function of a more complex mechanical object and how it works by examining it and, if necessary, take it apart. [CAN-QU UO 7-8, 6.1. (Modified).] CCR-ME RE 9-12, 3.3. Describe the operating principles of a mechanical object using relevant scientific and technological concepts. [CAN-QU UO 7-8, 6.2.] CCR-ME RE 9-12, 3.4. Conduct maintenance and repairs of mechanical objects and mechanical systems, including complete or partial disassembly, defect identification, conducting the needed repair/maintenance, and correctly reassembling the object or system. [CAN-QU RE 9-11, 11.1. (Modified)]
Heat Transfer	Convection, Conduction and Radiation	CCR-ME HT 4. Understand convection, conduction, and radiation.		CCR-ME HT 6-8, 4.1. Understand the concepts of convection, conduction and radiation and give practical examples of each. CCR-ME HT 6-8, 4.2. Understand the concept of blackbody radiation and relate examples illustrating how an object that is absorbing light can re-emit it as heat (e.g., object left in the sun gets warm). CCR-ME HT 6-8, 4.3. Identify the conditions for "heat always rises" to be true (i.e., unforced convection).	CCR-ME HT 9-12, 4.1. Distinguish between convection, conduction, and radiation, and explain how materials are designed to prevent heat transfer.
	Atomistic mechanisms of heat transfer, Absolute Zero, Temperature vs. Heat	CCR-ME TMP 5. Understand the atomic mechanisms by which heat transfer occurs and the relationship between temperature and heat.		CCR-ME TMP 6-8, 5.1. Describe what temperature looks like on an atomic scale including how the atoms move as the temperature rises. CCR-ME TMP 6-8, 5.2. Explain and restate the concept of absolute zero (i.e., atoms perfectly fixed and not moving at all, the lowest possible temperature) (Grade 8). CCR-ME TMP 6-8, 5.3. Explain that in conduction, atoms transfer heat by transferring their vibration to the atoms next to them. CCR-ME TMP 6-8, 5.4. Describe the difference between temperature and heat.	CCR-ME TMP 9-12, 5.1. Illustrate what temperature looks like on an atomic scale (i.e., atoms inside the object vibrating in their positions more and more as an object gets hotter). CCR-ME TMP 9-12, 5.2. Explain and give examples of conduction, absolute zero, and the relationship between temperature and heat.
	Thermal conductivity, insulation	CCR-ME INS 6. Understand thermal conductivity and insulation.		CCR-ME INS 6-8, 6.1. Understand thermal conductivity and measure it in both an insulating and conducting material. CCR-ME INS 6-8, 6.2. Experiment with how insulation works in order to understand heat transfer (example 1: insulation containing air pockets, such as down coats or fiberglass, prevents heat transfer because one molecule has to bump into another molecule to transfer heat, and in air, the molecules are far apart. Example 2: a ceramic tile like those on the space shuttle or a kitchen trivet prevents heat transfer by conduction because the molecules in a ceramic don't vibrate much when they are heated and therefore can't pass the vibration along to the next molecule in the solid well, which is what gives these materials their low thermal conductivity and ability to insulate). CCR-ME INS 6-8, 6.3. Design an insulating material and test its ability to block heat transfer.	CCR-ME INS 9-12, 6.1. Explain and demonstrate the role of thermal insulation materials and how they reduce heat transfer by conduction.
	Volume-to-surface area ratio	CCR-ME HTR 7. Understand the role of volume-to-surface area ratio in determining the time required for an object to heat up or cool down.			CCR-ME HTR 9-12, 7.1. Demonstrate that the time for something to reach to a certain temperature (e.g., to freeze or to melt) goes up as the volume-to-surface area ratio increases. CCR-ME HTR 9-12, 7.2. Generate daily life examples using the concept of increasing the exposed surface area to raise or lower temperatures quickly (e.g. the convoluted shape of house or machine radiators; the use of crushed vs. cubed ice in drinks). CCR-ME HTR 9-12, 7.3. Use the scaling relationship $t \sim (v/sa)^2$ to solve practical problems in conductive heat transfer, (e.g., calculating the cooking time for brownies in an odd-shaped pan, given the original cooking time for a rectangular pan of specific dimensions; calculating the freezing time of a casting (i.e., Chvorinov's rule)).
Friction	Origins	CCR-ME FR 8. Understand the micro-level origins of friction.		CCR-ME FR 6-8, 8.1. Demonstrate the concept of friction (e.g., high and low friction) by rubbing together surfaces (e.g., two blocks covered with sandpaper; two Teflon blocks) and compare the results. CCR-ME FR 6-8, 8.2. Understand the origin of friction (i.e., microscopic irregularities in two surfaces getting caught on each other as the two surfaces rub against each other). CCR-ME FR 6-8, 8.3. Explain why polishing surfaces helps to reduce friction.	CCR-ME FR 9-12, 8.1. Explain the difference between static and kinetic friction and why it is important to know as it relates to mechanical properties of objects.
	Methods for eliminating.	CCR-ME LUB 9. Know practical methods for eliminating friction.		CCR-ME LUB 6-8, 9.1. Know methods engineers use to overcome friction (e.g., lubricants, polished surfaces, wheels, ball bearings) and give examples of each from everyday life. CCR-ME LUB 6-8, 9.2. Design and conduct an experiment using WD-40 and bearing grease to demonstrate which reduces friction the most effectively. CCR-ME LUB 6-8, 9.3. Understand why wheels reduce friction forces (i.e., only a small spot on the wheel is in contact with the other surface at any point in time). CCR-ME LUB 6-8, 9.4. Refurbish a rusted mechanism (e.g., through cleaning, grinding, chemical polishing, lubrication) to eliminate or reduce friction.	CCR-ME LUB 9-12, 9.1. Restate and summarize practical methods of eliminating friction and the best methods to use for common mechanical objects or machines.
	Coefficient of Friction	CCR-ME MU 10. Understand coefficients of friction and how to measure them.			CCR-ME MU 9-12, 10.1. Measure the force required to slide two objects past each other under both high and low friction conditions and convert those forces to approximate coefficients of friction (m). CCR-ME MU 9-12, 10.2. Understand the concept of air drag (i.e., friction between solid and gas) and how this influences the design of aircraft and vehicles. CCR-ME MU 9-12, 10.3. Identify materials having abnormally low coefficients of friction and list some situations in which they are used.

Mechanics of Materials	Force and Stress, Newton's second law, Energy and Work, Potential and Kinetic Energy, Force Equilibrium	CCR-ME FRC 11. Calculate forces and stresses in static and moving objects.			CCR-ME FRC 9-12, 11.1. Understand conceptually, and solve practical problems using, the relationship between force, stress (pressure), and area (e.g., calculate stress under a man's heel vs. woman's stiletto). CCR-ME FRC 9-12, 11.2. Convert forces at angles into easier-to-manipulate orthogonal components using trigonometry (e.g., force of a bat hitting a baseball; which angle of hitting the baseball has largest "x" component and would therefore send the baseball the farthest; compare the answer to actual photos of baseball players at bat). CCR-ME FRC 9-12, 11.3. Understand conceptually, and solve practical problems using, the relationship between force, mass, and acceleration (e.g., Newton's Second law). CCR-ME FRC 9-12, 11.4. Understand, and solve practical problems using, the relationship between force and work. CCR-ME FRC 9-12, 11.5. Understand the equivalence between energy and work and solve practical problems requiring a conversion from one to the other (e.g., roller coasters). CCR-ME FRC 9-12, 11.6. Understand conceptually, and solve practical problems using, relationship between potential and kinetic energy. CCR-ME FRC 9-12, 11.7. Understand and use the concept of force equilibrium to solve simple problems involving lever arms, springs, dashpots, beams, or trusses. CCR-ME FRC 9-12, 11.8. Calculate the stresses inside an object resulting from the forces calculated via all of the above methods and situations (Example 1: whether snow loads on a sloped roof will cause it to fail. Example 2: whether knowing the initial velocity of a car and the length by which it is shortened as a result of a crash (i.e., the deceleration distance) and determine if the force on car occupants during the crash would have been enough to kill them).
	Elastic Modulus, Yield Stress, Fracture Stress, Stress-strain relationships, Brittle Fracture, Fatigue, Finite Element Modeling	CCR-ME STR 12. Calculate when failure will occur in an object from the stresses involved.			CCR-ME STR 9-12, 12.1. Understand the concepts of elastic modulus, yield stress and fracture stress. CCR-ME STR 9-12, 12.2. Identify load-bearing applications that require high stiffness (i.e., elastic modulus), high stiffness-to-weight ratio, and high strength-to-weight ratio. CCR-ME STR 9-12, 12.3. Calculate the internal stresses of hypothetical or real objects under load (e.g., snow on a structure, water in a water tank, floors above a steel frame, vehicles on a bridge) and determine whether the stresses are sufficient to cause failure by yielding. CCR-ME STR 9-12, 12.4. Understand and explain that yield stresses decrease with increasing temperature and demonstrate this is why metal forming operations, such as forging or extrusion, are conducted at high temperature. CCR-ME STR 9-12, 12.5. Understand brittle materials (e.g., ceramics, glasses) do not yield, and that their failure is instead
					CCR-ME STR 9-12, 12.7. Understand the concept of glass transition temperature and its practical importance in the safe use of plastics and glasses (e.g., O-ring failure in Challenger shuttle crash). CCR-ME STR 9-12, 12.8. Understand the relationship between stress and strain, and use strain gauges to measure stress inside an everyday object. CCR-ME STR 9-12, 12.9. Understand shear stresses, how to calculate them from applied forces, and their relevance to specific phenomena, such as earthquake damage and plastic deformation of metals. CCR-ME STR 9-12, 12.10. Calculate the stress conveyed by moving winds, such as hurricanes, onto structures by converting wind speed to pressure. CCR-ME STR 9-12, 12.11. Understand that sharp corners act as stress concentrators, and catastrophic failure can initiate at these locations under what are otherwise low applied forces/stresses (e.g., See de Havilland comet). CCR-ME STR 9-12, 12.12. Understand and demonstrate (e.g., by breaking a coat hanger by bending it back and forth repeatedly) fatigue failure, as well as understand how fatigue impacts airplane safety.
					CCR-ME STR 9-12, 12.13. Estimate the force and stress experienced by objects or occupants during the crash of moving objects, and then measure the force experimentally (e.g., using a home-built pendulum accelerometer). CCR-ME STR 9-12, 12.14. Understand finite element analysis and how it is used by engineers to solve complex problems of stress and temperature distribution inside objects.