Sloan Career Cornerstone Center

Mechanical Engineering Overview

The Field - Spectrum

The Field

Mechanical engineering is one of the largest, broadest, and oldest engineering disciplines. Mechanical engineers use the principles of energy, materials, and mechanics to design and manufacture machines and devices of all types. They create the processes and systems that drive technology and industry. The technical interests and contours of the mechanical engineering profession are reflected in the professional groups and technical divisions that make up the American Society of Mechanical Engineers (ASME).

The key characteristics of the profession are its breadth, flexibility, and individuality. The career paths of mechanical engineers are largely determined by individual choices, a decided advantage in a changing world.

Mechanics, energy and heat, mathematics, engineering sciences, design and manufacturing form the foundation of mechanical engineering. Mechanics includes fluids, ranging from still water to hypersonic gases flowing around a space vehicle; it involves the motion of anything from a particle to a machine or complex structure.

Analysis, design, and synthesis are the key functions of mechanical engineers. The question is often how devices and processes actually work. The first step is to visualize what is happening and clearly state the problem. A mechanical engineer will then use computer-based modeling, simulation, and visualization techniques to test different solutions.

Design is one of the most satisfying jobs for a mechanical engineer. To design and build a new car, you must reckon with power, weight, size and shape, materials, reliability, and safety. "Synthesis" is when you pull all the factors together in a design that can be successfully manufactured. Design problems are challenging because most are open-ended, without a single or best answer. There is no best mousetrap -- just better ones.

The field is notable for emphasizing versatility. A mechanical engineering education is an excellent foundation for work in other fields. Some mechanical engineers work on medical problems, such as the mechanics of bones and joints, or the fluid dynamics of the circulatory system. Mechanical engineers deal with economic issues, from the cost of a single component, to the economic impact of a manufacturing plant. M.E.'s can be found in sales, engineering management, and corporate management. Versatility is a decided asset in a world that is undergoing constant economic, political, industrial, and social change. Mechanical engineers are educated and positioned, not only to adapt, but to define and direct change.

Spectrum

The diversity of the field of mechanical engineering is represented by ASME Technical Groups & Divisions.

Basic Engineering

Fundamentally, mechanical engineers are involved with the mechanics of motion and the transfer of energy from one form to another or one place to another. ME's design and build machines for industrial and consumer use -- virtually any machine you find, had a mechanical engineer involved with its development and production. They design heating, ventilation, and air conditioning systems to control the climate in homes, offices, and industrial plants, and develop refrigeration systems for the food industry. ME's also design heat exchangers, key components in high-tech mechanical and electronic computer equipment.

Applied Mechanics: Mechanics can be applied to almost anything -- metal bars, rocks, water, the human skeleton, or complex systems such as buildings, automobiles, and machines. The basic question is how things work and whether they work well. To find the answers, a mechanical engineer uses a knowledge of shock and vibration, dynamics and motion, fracture and failure in components, and the behavior of high-tech materials. New computer applications make it possible to model and visualize all of these processes.

Fluids Engineering: There's a mechanical process involved in anything that flows -- air, water, heat and cold, even the sand along our shores. Whatever the substance may be, M.E.'s know how to describe and control its movement. M.E.'s design fluid machines and systems -- pumps, turbines, compressors, valves, pipelines, biological devices, hydraulic systems, and the fluid systems in car engines. The fluids engineer can be found in industries ranging from aerospace to food, manufacturing, medicine, power, and transportation.

Heat Transfer: Heat is generated and moved by any use of energy, in everything from computers to automobiles and ventilating systems in buildings. This is an issue in all modern technology, given today's emphasis on conservation and wise use of resources. This field touches on combustion, power generation and transmission systems, process equipment, electronic devices, thermal controls in manufacturing, environmental controls, biotechnology, aerospace applications, transportation equipment, and even cryogenics (for those who like to freeze things).

Bioengineering: Mechanical engineering principles are used to design and perfect biomechanical devices or systems. Almost any part of the human organism can be described mechanically, whether it's a knee joint or the circulatory system. This field involves artificial organs, biomechanics, biomaterials, bio-instrumentation, biotransport processes, human factors, medical devices, biomedical modeling, and biological systems. Bioprocess Engineering focuses on the processes, systems, and equipment used in the biotechnology and pharmaceutical industries -- everything from cell cultures, to bioprocessing, to unit operations. M.E.'s in this field work closely with biologists, chemists, and chemical engineers.

Tribology: Tribology may not be a familiar term, but if you are designing an artificial hip socket, a laser printer, or a locomotive, you will have to think about friction, heat, wear, bearings, and lubrication. Otherwise your product probably won't run well or for very long. By reducing wear, the tribologist prevents the failure of everything from computer disk drives to the seals used in space vehicles.

Energy Conversion

We live in a world of dependent on the production and conversion of energy into useful forms. Mechanical engineers are involved in all aspects of the production and conversion of energy from one form to another. We design and operate fossil fuel, hydroelectric, conventional, nuclear and cogeneration power plants. We design and develop internal combustion engines for automobiles, trucks and marine use and also for electrical power generation.

Internal Combustion Engines: Mechanical engineers design and manufacture IC engines for mobile, marine, rail, and stationary applications. Engine design requires a broad knowledge base, including mechanics, electronics, materials, and thermal sciences. Problems must be solved in fuels and combustion, intake systems, ignition, instrumentation and controls, lubrication, materials, and maintenance.

Fuels & Combustion Technologies: Mechanical Engineers may specialize in the understanding of fuels and combustion systems in modern utility and industrial power plants or in internal combustion, gas turbine or other engines. These ME's work with combustion systems, fuel properties and characteristics, fuel processing and alternative fuels, and fuel handling transportation and storage.

Nuclear Engineering: M.E.'s in Nuclear Engineering use their knowledge of mechanics, heat, fluids, machinery and controls. They develop advanced reactors and components, heat exchangers, pressure vessels and piping, radwaste systems, and new fuel technologies.

Power Engineering: Power Engineering focuses on electricity, produced by steam and water-driven turbines. Power M.E.'s design and develop these systems, as well as industrial and marine power plants, combustion equipment, and the equipment that goes into power plants -- condensers, cooling towers, pumps, piping, heat exchangers, and the controls to make it all work.

Energy Resources

Mechanical engineers are experts on the conversion and use of existing energy sources and in developing the equipment needed to process and transport fuels . At the same time, mechanical engineers are active in finding and developing new forms of energy. In that effort, ME's deal with the production of energy from alternate sources, such as solar, geothermal, and wind.

Advanced Energy Systems: Most energy has come from the conversion of chemical or thermal energy into electrical and mechanical energy. M.E.'s are developing alternatives to thermal energy, power cycle devices, fuel cells, gas turbines, and innovative uses of coal, wind, and tidal flows.

Solar Engineering: M.E.'s in Solar Energy are finding new ways to produce mechanical and electrical power for heating, refrigeration, and water purification. They design devices and structures to collect solar energy, and they work with architects to design buildings that use solar energy for heating, cooling, and lighting.

Petroleum: Mechanical engineers play important roles in the petroleum industry, working in oil and gas drilling and production, offshore and arctic operations, hydrocarbon processing, synfuels and coal technology, materials, equipment design and manufacture, fuel transport, new fuel technologies, and pollution control.

Ocean, Offshore & Arctic Engineering: Much of our energy already comes from offshore sources. M.E.'s design and build ocean structures, systems, and equipment -- hyperbaric chambers, life support equipment, marine vehicles, submersibles and ROV's, propulsion systems, remote sensing systems, moorings and buoys, ship structures, and ocean mining equipment. Any given project may call for expertise in acoustics, construction and salvage technologies, corrosion, and high-tech materials. Offshore Mechanics differs from Ocean Engineering in that it focuses more on the science of mechanics. An M.E. specialist in this field deals with hydrodynamics, structural mechanics, computational methods, offshore materials science, materials fatigue and fracture, hydrodynamic forces and motion, fluid-solid-soil interactions, deepwater platforms, cable and pipeline dynamics, sensors and measurements, robots and remote control, and the mechanics of offshore drilling operations. The arctic engineer deals with a unique set of problems, such as ice mechanics, pipeline operations, and the behavior of materials in cold climates.

Environment & Transportation

Transportation is a large and growing field for mechanical engineers. Existing modes of air and surface transport require continuous improvement or replacement. ME's work at the cutting edge of these efforts. Wherever machines are made or used, you will find mechanical engineers. They are instrumental in the design, development and manufacturing of machines that transmit power. They are also critically involved with the environmental impact and fuel efficiency of the machines they develop and with any by-products of the fuels used to power those machines.

Aerospace & Automotive: They used to be called "flying machines." Very true. Aircraft are, in fact, flying "machines." One of the major activities of mechanical engineers is in the design, development and manufacture of things that move on land, sea, air and in space. M.E.'s design propulsion engines and structural component systems, crew and passenger accommodations and life support systems. M.E.'s also develop the equipment used to build automotive, aircraft, marine and space vehicles.

Environmental Engineering: Most environmental conditions involve a mechanical process -- the movement of heat, noise, or pollutants in air, soil, or water. M.E.'s deal with questions about environmental impact and recyclability in the design of products and systems. They use modeling techniques to understand air, ground, and water pollution and to develop effective controls. For example, M.E.'s analyzed and modeled the mechanical relationship between power plant emissions and acid rain in the northeastern states.

Noise Control & Acoustics: Sound is a mechanical phenomenon -- the movement of waves or vibrations through solids, liquids, or space. Acoustics is the art and science of producing, analyzing, and controlling sound. A mechanical engineering background can help to solve problems in noise control, flow-related noise and vibration, industrial acoustics, instrumentation, acoustical materials, and structures.

Rail Transportation: All aspects of mechanical engineering can be applied to the design, construction, operation, and maintenance of rail and mass-transit systems. Technologies developed in aerospace and energy conversion are being applied to a new generation of locomotives and cars for freight, passenger, and transit services.

Solid Waste Processing: Solid waste processing is a key aspect of environmental protection and energy conservation. M.E.'s are involved in the design and construction of solid waste processing facilities, and in work related to recycling, resource recovery, and the new technologies for waste-to-energy and biomass conversion.

Engineering & Technology Management

Working in project teams is a way of life for mechanical engineers. Deciding which projects to undertake and leading those projects to a successful conclusion is the job of experienced engineers who move into management. On the safety front, all projects involve safety issues. By its very nature mechanical engineering involves the harnessing and channeling of the forces of nature, forces which are often extremely powerful. Consider the contained "explosion" that inflates an automobile air bag or the mechanical forces involved in bringing an airplane load of people to a safe and comfortable landing, or the safety and reliability of an elevator, a power plant, or an incubator for pre-maturely born infants.

Management: Mechanical engineering careers often lead to project, division, or corporate management, on a domestic or international scale. M.E. managers deal with a variety of issues -- quality control, safety, teamwork and productivity, communications, finance, professional development and training, product and market analysis, sales and service, and computer systems.

Manufacturing

In contemporary manufacturing companies, mechanical engineers play a key role in the "realization" of products, working closely with other engineers and specialists in corporate management, finance, marketing, and packaging. ME's design products, select materials and processes, and convert them to finished products. They design and manufacture machine tools -- literally the machines that make machines and design entire manufacturing processes, aided by the latest technologies in automation and robotics. Finally, the finished products are transported in equipment designed by mechanical engineers. This is the largest area of employment for mechanical engineers, especially when the process and textile industries are included. A finished product requires the right materials, a viable plant and equipment, and a manufacturing system. This all comes within the purview of mechanical, manufacturing and industrial engineers.

Manufacturing Engineering: About half of all M.E.'s work in companies that manufacture "something," such as consumer goods, transportation, or industrial equipment. Another 16% work in the process industries, like petrochemical or pharmaceutical. The challenges are as diverse as the products -- from miniature devices used by surgeons, to disk drives, or massive pieces of industrial equipment. This work calls for a knowledge of materials, manufacturing processes, thermal processes, controls, electronics, and, as in all of engineering --- teamwork skills.

Materials Handling Engineering: Materials must be delivered at the right time, place, and in the right form -- a challenge with the costly, exotic, and sometimes hazardous materials used in some industries. Some M.E.'s specialized in materials transportation, handling equipment and procedures, hazard control technologies, and in the training of employees who will work with these materials.

Plant Engineering & Maintenance: Competitive industries must often update their plants, manufacturing equipment, and operating procedures. This must be done quickly and with the least possible disruption. M.E.'s in plant engineering focus on systems, equipment, processes, and facilities. They provide creative solutions that allow companies to meet their goals for quality, safety, and cost.

Process Industries: The M.E. `process engineer' changes materials from one form to another or gives them new properties. They can then be used in manufacturing components and finished products. The M.E. `process engineer' designs and builds the systems and machines that heat, cool, soften, harden, or liquefy substances -- anything from industrial fluids and gases, to metals, or even food products and pharmaceuticals.

Textile Engineering: Textile manufacturing is a global industry that depends on automated equipment to prepare and handle fibers, weave or knit fabrics, manufacture finished apparel, and handle finished products. Multinational textile industries turn to M.E.'s for expertise in plant design and construction, equipment installation, programming and control techniques, operations, and maintenance.

Materials & Structures

In order to arrive at the best design for a product, mechanical engineers use a wide variety of metal, plastic, ceramic materials. They also use composites made up of more than one type of material. Once designed, built and in service, elements like pipeline welds and sections, gears and other drive-train elements may need inspection for structural integrity or the effects of mechanical wear. Non-Destructive Evaluation, as its name implies, allows ME's to use X-ray, magnetic particle, ultrasound and other techniques to examine the internal condition of structural and machine parts, without causing them to fail or without removing them from service. This analysis is particularly important in assuring the reliability and safety of pressure vessels and piping systems.

Materials Engineering: Materials has grown into a distinct and important technology. Mechanical engineers focus on the behavior and selection of materials -- preferably before they become part of machines or complex structures. The Materials M.E. focuses on the properties of materials and their effect on design, fabrication, quality, and performance. M.E.'s find ways to give materials specific properties -- strength, ductility, and resistance to fracture, fatigue, and corrosion. The goal is to have materials that can be casted, forged, stamped, rolled, machined, or welded. Mechanical engineers are interested in many aspects of plant engineering, including the pressure vessels and piping that are an essential part of many industrial plants and processes.

Non-Destructive Evaluation: The manager of a large petrochemical plant needs to know whether a massive pressure vessel and two pumps are maintaining their structural integrity. There's a 50-50 chance that it won't be possible to reassemble the equipment once it's taken apart, and replacement will force a month-long shutdown. It's time to call in a mechanical engineer who specializes in Non-Destructive Evaluation -- materials testing, non-destructive testing, pressure vessel research, welding technologies, equipment design, and repair strategies.

Pressure Vessels & Piping: Many industries depend on pressure vessels and piping to perform critical functions. These vessels must be durable and safe when subjected to high-temperatures, pressure, corrosion, or undersea conditions. Mechanical engineers develop materials that will resist fatigue and fracture, plan the fabrication of equipment, perform inspections and tests, and design components using computer visualization and modeling techniques.

Systems & Design

Most mechanical engineers work in the design and control of mechanical, electromechanical and fluid power systems. As a mechanical engineer functioning as a design engineer it is likely that you would be involved with one or more technical specialties, for example: Robotic System Design; Computer Coordinated Mechanisms; Expert Systems in Design; Computer-Aided Engineering; Geometric Design; Design Optimization; Kinematics and Dynamics of Mechanisms; Cam Design/Gear Design; Power Transmission; or Design of Machine Elements.

Design engineers take into account a truly wide number of factors in the course of their work, such as: product performance, cost, safety, manufacturability, serviceability, human factors, aesthetic appearance, durability, reliability, environmental impact and recycleability.

Dynamic Systems & Control: Where there is movement there must be control. A modern production line is a dynamic system, because its movement and speed can be controlled. M.E.'s create the software, hardware, and feedback devices that form control and robotic systems. This requires a knowledge of heat and mass transfer, fluid and solid mechanics, the plants or processes to be controlled, elements of electronics and computers. Controls are needed everywhere -- in aerospace and transportation, biomedical equipment, production machinery, energy and fluid power systems, expert systems, and environmental systems.

Fluid Power Systems & Technology: You have been asked to design a massive vehicle to transport rocket boosters around the Kennedy Space Center. A conventional transmission won't work because of the weight and sheer inertia that the vehicle must overcome. You need to apply a lot of power very gradually, so you employ a fluid power coupling. These technologies are used in automotive, aerospace, manufacturing, and power industries, in situations that call for a flexible and precise application of power in large amounts.

Design Engineering: M.E.'s design components, entire machines, complex structures, systems and processes. This work requires a knowledge of the basic sciences, engineering principles, materials, computer techniques, manufacturing methods, and even economics. New and challenging problems come along with regularity. If you are working for an aircraft company, today's problem may be vibration in an engine; tomorrow it may be wind noise, stress on the landing gear, or a need to increase lift at low speeds.

Computers in Engineering: Mechanical engineers have developed a wealth of computer applications software, based on their knowledge of mechanics, fluids, heat, kinetics, and manufacturing. Some of the interests in this area include computer-aided design and simulation; computer-aided manufacturing; finite element analysis; visualization techniques; robots and controls; computer vision and pattern recognition; systems (hardware, software, and networks); and management information systems.

M.E.'s in the Electrical & Computer Industries: There are mechanical components in electrical, electronic, and computer equipment, all of which is manufactured through automated and mechanical processes, all components must fit precisely, and unwanted heat must be transferred elsewhere. All of these activities are in the domain of mechanical engineering. The PC is very largely a mechanical device. Consider disk drives, circuit boards, keyboards, the chasis structure, and, of course, the mouse!

Electrical & Electronic Packaging: A large number of mechanical engineers work for the manufacturers of electrical, electronic, and computer equipment. The major focus for M.E.'s in this area is the physical design and manufacture of these products in such a way that unwanted heat is removed and desired heat is retained where and to the degree it is needed.

Information Storage & Processing Systems: Quite a few mechanical engineers work for companies that manufacture computer peripherals. Any storage device on your computer -- the CD, DVD, diskette, or hard drives -- has electrical, electronic, and mechanical components. M.E.'s help to design and manufacture these precision devices. Their interests touch on hard disk technologies, data storage and equipment, wear and lubrication in data storage devices, micro-sensors, and controls.

Microelectromechanical Systems: Micro-electromechanical systems (MEMS) combines computers with tiny mechanical devices such as sensors, valves, gears, and actuators embedded in semiconductor chips. A MEMS device contains micro-circuitry on a silicon chip into which a mechanical device such as a mirror or a sensor has been constructed. Among the presently available uses of MEMS or those under study are: 1) Sensors built into the fabric of an airplane wing so that it can sense and react to air flow by changing the wing surface resistance; effectively creating a myriad of tiny wing flaps, 2) Sensor-driven heating and cooling systems that dramatically improve energy savings, and 3) Building supports with imbedded sensors that can alter the flexibility properties of a material based on atmospheric stress sensing.