SUPPLEMENTARY READING
Unit 1
Mechanisms and theory
Metallic microstructure

The key to understanding the mechanism behind hardness is understanding the metallic microstructure, or the structure and arrangement of the atoms at the atomic level. In fact, most important metallic properties critical to the manufacturing of today’s goods are determined by the microstructure of a material. At the atomic level, the atoms in a metal are arranged in an orderly three-dimensional array called a crystal lattice. In reality, however, a given specimen of a metal likely never contains a consistent single crystal lattice. A given sample of metal will contain many grains, with each grain having a fairly consistent array pattern. At an even smaller scale, each grain contains irregularities.

There are two types of irregularities at the grain level of the microstructure that are responsible for the hardness of the material. These irregularities are point defects and line defects. A point defect is an irregularity located at a single lattice site inside of the overall three-dimensional lattice of the grain. There are three main point defects. If there is an atom missing from the array, a vacancy defect is formed. If there is a different type of atom at the lattice site that should normally be occupied by a metal atom, a substitutional defect is formed. If there exists an atom in a site where there should normally not be, an interstitial defect is formed. This is possible because space exists between atoms in a crystal lattice. While point defects are irregularities at a single site in the crystal lattice, line defects are irregularities on a plane of atoms. Dislocations are a type of line defect involving the misalignment of these planes. In the case of an edge dislocation, a half plane of atoms is wedged between two planes of atoms. In the case of a screw dislocation two planes of atoms are offset with a helical array running between them.[5]

Dislocations provide a mechanism for planes of atoms to slip and thus a method for plastic or permanent deformation. Planes of atoms can flip from one side of the dislocation to the other effectively allowing the dislocation to traverse through the material and the material to deform permanently. The movement allowed by these dislocations causes a decrease in the material's hardness.

The way to inhibit the movement of planes of atoms, and thus make them harder, involves the interaction of dislocations with each other and interstitial atoms. When a dislocation intersects with a second dislocation, it can no longer traverse through the crystal lattice. The intersection of dislocations creates an anchor point and does not allow the planes of atoms to continue to slip over one another. A dislocation can also be anchored by the interaction with interstitial atoms. If a dislocation comes in contact with two or more interstitial atoms, the slip of the planes will again be disrupted. The interstitial atoms create anchor points, or pinning points, in the same manner as intersecting dislocations.

By varying the presence of interstitial atoms and the density of dislocations, a particular metal's hardness can be controlled. Although seemingly counter-intuitive, as the density of dislocations increases, there are more intersections created and consequently more anchor points. Similarly, as more interstitial atoms are added, more pinning points that impede the movements of dislocations are formed. As a result, the more anchor points added, the harder the material will become.

Unit 2

Engineering education

Most engineering programs involve a concentration of study in an engineering specialty, along with courses in both mathematics and the physical and life sciences. Many programs also include courses in general engineering. A design course, sometimes accompanied by a computer or laboratory class or both, is part of the curriculum of most programs. Often, general courses not directly related to engineering, such as those in the social sciences or humanities, also are required.

Graduate training is essential for engineering faculty positions and some research and development programs, but is not required for the majority of entry-level engineering jobs. Many experienced engineers obtain graduate degrees in engineering or business administration to learn new technology and broaden their education. Numerous high-level executives in government and industry began their careers as engineers.

How is the title of an engineer limited?

In many countries, engineering tasks such as the design of bridges, electric power plants, industrial equipment, machine design and chemical plants, must be approved by a licensed professional engineer. Most commonly titled Professional Engineer is a license to practice and is indicated with the use of post-nominal letters; PE or P.Eng. These are common in North America, European Engineer (Eur Ing) in Europe. The practice of engineering **in the UK** is not a regulated profession other than the control of the titles of Chartered Engineer (CEng) and Incorporated Engineer (IEng). The title CEng is in use in much of the Commonwealth. Many engineers in the UK also include semi skilled trades to engineering technicians. This is seen by some as a misuse of the title, giving a false image of the profession. A growing movement in the UK is to legally protect the title 'Engineer' so that only professional engineers can use it, a DirectGov petition, has been started to further this cause.

In the United States, licensure is generally attainable through combination of education, pre-examination (Fundamentals of Engineering exam), examination (Professional Engineering Exam),[15] and engineering experience (typically in the area of 5+ years). Each state tests and licenses Professional Engineers. Currently most states do not license by specific engineering discipline, but rather provide generalized licensure, and trust engineers to use professional judgement regarding their individual competencies; this is the favoured approach of the professional societies. Despite this, however, at least one of the examinations required by most states is actually focused on a particular discipline; candidates for licensure typically choose the category of examination which comes closest to their respective expertise.

In Canada, the profession in each province is governed by its own engineering association. For instance, in the Province of British Columbia an engineering graduate with four or more years of post graduate experience in an engineering-related field and passing exams in ethics and law will need to be registered by the Association for Professional Engineers and Geoscientists (APEGBC) [16] in order to become a Professional Engineer and be granted the professional designation of P.Eng allowing one to practice engineering.

In Continental Europe, Latin America, Turkey and elsewhere the title is limited by law to people with an engineering degree and the use of the title by others is illegal. In Italy, the title is limited to people who both hold an engineering degree and have passed a professional qualification examination (*Esame di Stato*). In Portugal, professional engineer titles and accredited engineering degrees are regulated and certified by the *Ordem dos Engenheiros*. In the Czech Republic, the title "engineer" (Ing.) is given to people with a (masters) degree in chemistry, technology or economics for historical and traditional reasons. In Greece, the academic title of "Diploma Engineer" is awarded after completion of the five-year engineering study course and the title of "Certified Engineer" is awarded after completion of the four-year course of engineering studies at a Technological Educational Institute (TEI).

Public perception of engineering

The perception of engineering varies across countries and continents. In the United States, continental western Europe, eastern Europe, Asia, the Middle East, Latin American and Canada engineering and engineers are held in very high esteem. The perception and definition of engineering in some English speaking countries is confused. The contemporary British public perceive engineers as skilled or semi skilled maintenance workers but this is a recent development. British school children in the 1950s were brought up with stirring tales of 'the Victorian Engineers', chief amongst whom were the Brunels, the Stephensons, Telford and their contemporaries but now British people often incorrectly use the term 'Engineer' to describe Plumbers and Mechanics. "Engineer" may sometimes be appended to titles for roles requiring no actual engineering qualification, such as Combat Engineers and, colloquially, "Domestic Engineers". The UK Royal Air Force describe a maintenance mechanic as an aeronautical engineer. British Gas refer to their gas repair mechanics as registered "professional engineers". In Canada, a 2002 study by the Ontario Society of Professional Engineers revealed that engineers are the third most respected professionals behind doctors and pharmacists.

In the Indian subcontinent, Russia and China, engineering is one of the most sought after undergraduate courses, inviting thousands of applicants to show their ability in highly competitive entrance examinations. In Egypt, the educational system makes engineering the second-most-respected profession in the country (after medicine); engineering colleges at Egyptian universities require extremely high marks on the General Certificate of Secondary Education (Arabic: الثانوية العامة *al-Thānawiyyah al-`Āmmah*)—on the order of 97 or 98%—and are thus considered (with colleges of medicine, natural science, and pharmacy) to be among the "pinnacle colleges" (كليات القمة *kullīyāt al-qimmah*).

The different definitions of engineering in different countries

The definition of what engineering is varies across countries. **In the UK** "engineering" is defined as an industry sector consisting of employers and employees loosely termed as "engineers" who range from semi skilled trades to chartered engineers. **In the US and Canada**, engineering is defined as a regulated profession whose practice and practitioners are licensed and governed by law. **In some English speaking countries** engineering has been seen as a somewhat dry, uninteresting field in popular culture and has also been thought to be the domain of nerds. For example, the cartoon character Dilbert is an engineer. In science fiction, engineers are often portrayed as highly knowledgeable and respectable individuals who understand the overwhelming future technologies often portrayed in the genre. Several *Star Trek* characters are engineers. One difficulty in increasing public awareness of the profession is that average people, in the typical run of ordinary life, do not ever have any personal dealings with engineers, even though they benefit from their work every day. By contrast, it is common to visit a doctor at least once a year, the accountant at tax time, the pharmacist for drugs, and, occasionally, even a lawyer.

In companies and other organizations in the UK there is a tendency to undervalue people with advanced technological and scientific skills compared to celebrities, fashion practitioners, entertainers and managers. In his book *The Mythical Man-Month*,[19] Fred Brooks Jr says that managers think of senior people as "too valuable" for technical tasks, and that management jobs carry higher prestige. He tells how some laboratories, such as Bell Labs, abolish all job titles to overcome this problem: a professional employee is a "member of the technical staff." IBM maintain a dual ladder of advancement; the corresponding managerial and engineering / scientific rungs are equivalent. Brooks recommends that structures need to be changed; the boss must give a great deal of attention to keeping his managers and his technical people as interchangeable as their talents allow.

Unit 3
Causes of conductivity
Conductivities of metals

A metal consists of a lattice of atoms, each with a shell of electrons. This is also known as a positive ionic lattice. The outer electrons are free to dissociate from their parent atoms and travel through the lattice, creating a 'sea' of electrons, making the metal a conductor. When an electrical potential difference (a voltage) is applied across the metal, the electrons drift from one end of the conductor to the other under the influence of the electric field.

Near room temperatures, the thermal motion of ions is the primary source of scattering of electrons (due to destructive interference of free electron waves on non-correlating potentials of ions), and is thus the prime cause of metal resistance. Imperfections of lattice also contribute into resistance, although their contribution in pure metals is negligible.

The larger the cross-sectional area of the conductor, the more electrons are available to carry the current, so the lower the resistance. The longer the conductor, the more scattering events occur in each electron's path through the material, so the higher the resistance. Different materials also affect the resistance.[1]

Semiconductors and insulators

In metals, the Fermi level lies in the conduction band (see Band Theory, below) giving rise to free conduction electrons. However, in semiconductors the position of the Fermi level is within the band gap, approximately half-way between the conduction band minimum and valence band maximum for intrinsic (undoped) semiconductors. This means that at 0 kelvins, there are no free conduction electrons and the resistance is infinite. However, the resistance will continue to decrease as the charge carrier density in the conduction band increases. In extrinsic (doped) semiconductors, dopant atoms increase the majority charge carrier concentration by donating electrons to the conduction band or accepting holes in the valence band. For both types of donor or acceptor atoms, increasing the dopant density leads to a reduction in the resistance. Highly doped semiconductors hence behave metallic. At very high temperatures, the contribution of thermally generated carriers will dominate over the contribution from dopant atoms and the resistance will decrease exponentially with temperature.

Ionic liquids/electrolytes

In electrolytes, electrical conduction happens not by band electrons or holes, but by full atomic species (ions) traveling, each carrying an electrical charge. The resistivity of ionic liquids varies tremendously by the concentration - while distilled water is almost an insulator, salt water is a very efficient electrical conductor. In biological membranes, currents are carried by ionic salts. Small holes in the membranes, called ion channels, are selective to specific ions and determine the membrane resistance.

Superconductivity

The electrical resistivity of a metallic conductor decreases gradually as temperature is lowered. In ordinary conductors, such as copper or silver, this decrease is limited by impurities and other defects. Even near absolute zero, a real sample of a normal conductor shows some resistance. In a superconductor, the resistance drops abruptly to zero when the material is cooled below its critical temperature. An electric current flowing in a loop of superconducting wire can persist indefinitely with no power source.

In 1986, it was discovered that some cuprate-perovskite ceramic materials have a critical temperature above 90 K (−183 °C). Such a high transition temperature is theoretically impossible for a conventional superconductor, leading the materials to be termed high-temperature superconductors. Liquid nitrogen boils at 77 K, facilitating many experiments and applications that are less practical at lower temperatures. In conventional superconductors, electrons are held together in pairs by an attraction mediated by lattice phonons. The best available model of high-temperature superconductivity is still somewhat crude. There is a hypothesis that electron pairing in high-temperature superconductors is mediated by short-range spin waves known as paramagnons.

Unit 4
Motion

Universe Spacetime (the fabric of the universe) is actually expanding. Essentially, everything in the universe is stretching like a rubber band.

The Milky Way Galaxy is hurtling through space at an incredible speed. Many astronomers believe the Milky Way is moving at approximately 600 km/s relative to the observed locations of other nearby galaxies.

Solar System The Milky Way is rotating around its dense galactic center, thus the solar system is moving in a circle within the galaxy's gravity.

The Earth is rotating or spinning around its axis, this is evidenced by day and night, at the equator the earth has an eastward velocity of 0.4651 km/s (1040 mi/h). The Earth is orbiting around the Sun in an orbital revolution. A complete orbit around the sun takes one year or about 365 days; it averages a speed of about 30 km/s (67,000 mi/h).[13]

Internal body and its motions

The human heart is constantly contracting to move blood throughout the body. Through larger veins and arteries in the body blood has been found to travel at approximately 0.33 m/s.[17] Though considerable variation exists, and peak flows in the venae cavae have been found between 0.1 m/s and 0.45 m/s.[18]

The smooth muscles of hollow internal organs are moving. The most familiar would be peristalsis which is where digested food is forced throughout the digestive tract. Though different foods travel through the body at rates, an average speed through the human small intestine is 2.16 m/h (0.036 m/s).[19]

Typically some sound is audible at any given moment, when the vibration of these sound waves reaches the ear drum it moves in response and allows the sense of hearing.

The human lymphatic system is constantly moving excess fluids, lipids, and immune system related products around the body. The lymph fluid has been found to move through a lymph capillary of the skin at approximately 0.0000097 m/s.[20]

Motion inside the cells

The cells of the human body have many structures which move throughout them. Cytoplasmic streaming is a way which cells move molecular substances throughout the cytoplasm. Various motor proteins work as molecular motors within a cell and move along the surface of various cellular substrates such as microtubuless. Motor proteins are typically powered by the hydrolysis of adenosine triphosphate (ATP), and convert chemical energy into mechanical work. Vesicles propelled by motor proteins have been found to have a velocity of approximately 0.00000152 m/s.

Motions of particles

According to the laws of thermodynamics all particles of matter are in constant random motion as long as the temperature is above absolute zero. Thus the molecules and atomswhich make up the human body are vibrating, colliding, and moving. This motion can be detected as temperature; higher temperatures, which represent greater kinetic energy in the particles, feel warm to humans whom sense the thermal energy transferring from the object being touched to their nerves. Similarly, when lower temperature objects are touched, the senses perceive the transfer of heat away from the body as feeling cold.

Simple harmonic motion

The simplest mechanical oscillating system is a mass attached to a linear spring subject to no other forces. Such a system may be approximated on an air table or ice surface. The system is in an equilibrium state when the spring is static. If the system is displaced from the equilibrium, there is a net *restoring force* on the mass, tending to bring it back to equilibrium. However, in moving the mass back to the equilibrium position, it has acquired momentum which keeps it moving beyond that position, establishing a new restoring force in the opposite sense. If a constant force such as gravity is added to the system, the point of equilibrium is shifted. The time taken for an oscillation to occur is often referred to as the oscillatory *period*.

The specific dynamics of this spring-mass system are described mathematically by the simple harmonic oscillator and the regular periodic motion is known as simple harmonic motion. In the spring-mass system, oscillations occur because, at the static equilibrium displacement, the mass has kinetic energy which is converted into potential energy stored in the spring at the extremes of its path. The spring-mass system illustrates some common features of oscillation, namely the existence of an equilibrium and the presence of a restoring force which grows stronger the further the system deviates from equilibrium.

Harmonic oscillator

All real-world oscillator systems are thermodynamically irreversible. This means there are dissipative processes such as friction or electrical resistance which continually convert some of the energy stored in the oscillator into heat in the environment. This is called damping. Thus, oscillations tend to decay with time unless there is some net source of energy into the system. The simplest description of this decay process can be illustrated by oscillation decay of the harmonic oscillator.

In addition, an oscillating system may be subject to some external force, as when an AC circuit is connected to an outside power source. In this case the oscillation is said to be *driven*.

Some systems can be excited by energy transfer from the environment. This transfer typically occurs where systems are embedded in some fluid flow. For example, the phenomenon offlutter in aerodynamics occurs when an arbitrarily small displacement of an aircraft wing (from its equilibrium) results in an increase in the angle of attack of the wing on the air flow and a consequential increase in lift coefficient, leading to a still greater displacement. At sufficiently large displacements, the stiffness of the wing dominates to provide the restoring force that enables an oscillation.

Continuous system - waves

As the number of degrees of freedom becomes arbitrarily large, a system approaches continuity; examples include a string or the surface of a body of water. Such systems have (in theclassical limit) an infinite number of normal modes and their oscillations occur in the form of waves that can characteristically propagate.

In physics, a force is any influence that causes an object to undergo a certain change, either concerning its movement, direction, or geometrical construction. In other words, a force is that which can cause an object with mass to change its velocity(which includes to begin moving from a state of rest), i.e., to accelerate, or which can cause a flexible object to deform. Force can also be described by intuitive concepts such as a push or pull. A force has both magnitude and direction, making it a vectorquantity. Newton's second law, F = *m*a, was originally formulated in slightly different, but equivalent terms: the original version states that the net force acting upon an object is equal to the rate at which its momentum changes.

Related concepts to force include: thrust, which increases the velocity of an object; drag, which decreases the velocity of an object; and torque which produces changes in rotational speed of an object. Forces which do not act uniformly on all parts of a body will also cause mechanical stresses,[2] a technical term for influences which cause deformation of matter. While mechanical stress can remain embedded in a solid object, gradually deforming it, mechanical stress in a fluid determines changes in its pressure and volume.

The concept of force

Philosophers in antiquity used the concept of force in the study of stationary and moving objects and simple machines, but thinkers such as Aristotle and Archimedes retained fundamental errors in understanding force. In part this was due to an incomplete understanding of the sometimes non-obvious force of friction, and a consequently inadequate view of the nature of natural motion.[5] A fundamental error was the belief that a force is required to maintain motion, even at a constant velocity. Most of the previous misunderstandings about motion and force were eventually corrected by Sir Isaac Newton; with his mathematical insight, he formulated laws of motion that were not improved-on for nearly three hundred years.[4]By the early 20th century, Einstein developed a theory of relativity that correctly predicted the action of forces on objects with increasing momenta near the speed of light, and also provided insight into the forces produced by gravitation and inertia.

With modern insights into quantum mechanics and technology that can accelerate particles close to the speed of light, particle physics has devised a Standard Model to describe forces between particles smaller than atoms. The Standard Model predicts that exchanged particles called gauge bosons are the fundamental means by which forces are emitted and absorbed. Only four main interactions are known: in order of decreasing strength, they are: strong, electromagnetic, weak, and gravitational. High-energy particle physics observations made during the 1970s and 1980s confirmed that the weak and electromagnetic forces are expressions of a more fundamental electroweak interaction.

Newton's laws of motion

Sir Isaac Newton sought to describe the motion of all objects using the concepts of inertia and force, and in doing so he found that they obey certain conservation laws. In 1687 Newton went on to publish his thesis *Philosophiae Naturalis Principia Mathematica*.[4][10] In this work Newton set out three laws of motion that to this day are the way forces are described in physics.

Newton's First Law of Motion states that objects continue to move in a state of constant velocity unless acted upon by an external net force or *resultant force*. This law is an extension of Galileo's insight that constant velocity was associated with a lack of net force (see a more detailed description of this below). Newton proposed that every object with mass has an innate inertia that functions as the fundamental equilibrium "natural state" in place of the Aristotelian idea of the "natural state of rest". That is, the first law contradicts the intuitive Aristotelian belief that a net force is required to keep an object moving with constant velocity. By making *rest* physically indistinguishable from *non-zero constant velocity*, Newton's First Law directly connects inertia with the concept of relative velocities. Specifically, in systems where objects are moving with different velocities, it is impossible to determine which object is "in motion" and which object is "at rest". In other words, to phrase matters more technically, the laws of physics are the same in every inertial frame of reference, that is, in all frames related by a Galilean transformation.

For instance, while traveling in a moving vehicle at a constant velocity, the laws of physics do not change from being at rest. A person can throw a ball straight up in the air and catch it as it falls down without worrying about applying a force in the direction the vehicle is moving. This is true even though another person who is observing the moving vehicle pass by also observes the ball follow a curving parabolic path in the same direction as the motion of the vehicle. It is the inertia of the ball associated with its constant velocity in the direction of the vehicle's motion that ensures the ball continues to move forward even as it is thrown up and falls back down. From the perspective of the person in the car, the vehicle and everything inside of it is at rest: It is the outside world that is moving with a constant speed in the opposite direction. Since there is no experiment that can distinguish whether it is the vehicle that is at rest or the outside world that is at rest, the two situations are considered to be physically indistinguishable. Inertia therefore applies equally well to constant velocity motion as it does to rest.

The concept of inertia can be further generalized to explain the tendency of objects to continue in many different forms of constant motion, even those that are not strictly constant velocity. The rotational inertia of planet Earth is what fixes the constancy of the length of a day and the length of a year. Albert Einstein extended the principle of inertia further when he explained that reference frames subject to constant acceleration, such as those free-falling toward a gravitating object, were physically equivalent to inertial reference frames. This is why, for example, astronauts experience weightlessness when in free-fall orbit around the Earth, and why Newton's Laws of Motion are more easily discernible in such environments. If an astronaut places an object with mass in mid-air next to himself, it will remain stationary with respect to the astronaut due to its inertia. This is the same thing that would occur if the astronaut and the object were in intergalactic space with no net force of gravity acting on their shared reference frame. This principle of equivalence was one of the foundational underpinnings for the development of the general theory of relativity.

Static equilibrium

Static equilibrium was understood well before the invention of classical mechanics. Objects which are at rest have zero net force acting on them.

The simplest case of static equilibrium occurs when two forces are equal in magnitude but opposite in direction. For example, an object on a level surface is pulled (attracted) downward toward the center of the Earth by the force of gravity. At the same time, surface forces resist the downward force with equal upward force (called the normal force). The situation is one of zero net force and no acceleration.

Pushing against an object on a frictional surface can result in a situation where the object does not move because the applied force is opposed by static friction, generated between the object and the table surface. For a situation with no movement, the static friction force *exactly* balances the applied force resulting in no acceleration. The static friction increases or decreases in response to the applied force up to an upper limit determined by the characteristics of the contact between the surface and the object.

A static equilibrium between two forces is the most usual way of measuring forces, using simple devices such as weighing scales and spring balances. For example, an object suspended on a vertical spring scale experiences the force of gravity acting on the object balanced by a force applied by the "spring reaction force" which equals the object's weight. Using such tools, some quantitative force laws were discovered: that the force of gravity is proportional to volume for objects of constant density (widely exploited for millennia to define standard weights); Archimedes' principle for buoyancy; Archimedes' analysis of the lever; Boyle's law for gas pressure; and Hooke's law for springs. These were all formulated and experimentally verified before Isaac Newton expounded his Three Laws of Motion.

Dynamic equilibrium

Dynamic equilibrium was first described by Galileo who noticed that certain assumptions of Aristotelian physics were contradicted by observations andlogic. Galileo realized that simple velocity addition demands that the concept of an "absolute rest frame" did not exist. Galileo concluded that motion in a constant velocity was completely equivalent to rest. This was contrary to Aristotle's notion of a "natural state" of rest that objects with mass naturally approached. Simple experiments showed that Galileo's understanding of the equivalence of constant velocity and rest were correct. For example, if a mariner dropped a cannonball from the crow's nest of a ship moving at a constant velocity, Aristotelian physics would have the cannonball fall straight down while the ship moved beneath it. Thus, in an Aristotelian universe, the falling cannonball would land behind the foot of the mast of a moving ship. However, when this experiment is actually conducted, the cannonball always falls at the foot of the mast, as if the cannonball knows to travel with the ship despite being separated from it. Since there is no forward horizontal force being applied on the cannonball as it falls, the only conclusion left is that the cannonball continues to move with the same velocity as the boat as it falls. Thus, no force is required to keep the cannonball moving at the constant forward velocity.

Moreover, any object traveling at a constant velocity must be subject to zero net force (resultant force). This is the definition of dynamic equilibrium: when all the forces on an object balance but it still moves at a constant velocity.

A simple case of dynamic equilibrium occurs in constant velocity motion across a surface with kinetic friction. In such a situation, a force is applied in the direction of motion while the kinetic friction force exactly opposes the applied force. This results in zero net force, but since the object started with a non-zero velocity, it continues to move with a non-zero velocity. Aristotle misinterpreted this motion as being caused by the applied force. However, when kinetic friction is taken into consideration it is clear that there is no net force causing constant velocity motion.

Gravity

What we now call gravity was not identified as a universal force until the work of Isaac Newton. Before Newton, the tendency for objects to fall towards the Earth was not understood to be related to the motions of celestial objects. Galileo was instrumental in describing the characteristics of falling objects by determining that the acceleration of every object in free-fall was constant and independent of the mass of the object. Today, this acceleration due to gravity towards the surface of the Earth is usually designated as $\vec{g}$ and has a magnitude of about 9.81 meters per second squared (this measurement is taken from sea level and may vary depending on location), and points toward the center of the Earth. This observation means that the force of gravity on an object at the Earth's surface is directly proportional to the object's mass.

Unit 8

Electric motor

An electric motor is an electromechanical device that converts electrical energy into mechanical energy.Most electric motors operate through the interaction of magnetic fields and current-carrying conductors to generate force. The reverse process, producing electrical energy from mechanical energy, is done by generators such as an alternator or a dynamo; some electric motors can also be used as generators, for example, a traction motor on a vehicle may perform both tasks. Electric motors and generators are commonly referred to as electric machines.

Electric motors are found in applications as diverse as industrial fans, blowers and pumps, machine tools, household appliances, power tools, and disk drives. They may be powered by direct current, e.g., a battery powered portable device or motor vehicle, or by alternating current from a central electrical distribution grid or inverter. The smallest motors may be found in electric wristwatches. Medium-size motors of highly standardized dimensions and characteristics provide convenient mechanical power for industrial uses. The very largest electric motors are used for propulsion of ships, pipeline compressors, and water pumps with ratings in the millions of watts. Electric motors may be classified by the source of electric power, by their internal construction, by their application, or by the type of motion they give.

The physical principle behind production of mechanical force by the interactions of an electric current and a magnetic field, Faraday's law of induction, was discovered by Michael Faraday in 1831. Electric motors of increasing efficiency were constructed from 1821 through the end of the 19th century, but commercial exploitation of electric motors on a large scale required efficient electrical generators and electrical distribution networks. The first commercially successful motors were made around 1873.

Some devices convert electricity into motion but do not generate usable mechanical power as a primary objective, and so are not generally referred to as electric motors. For example, magnetic solenoids and loudspeakers are usually described as actuators and transducers, respectively, instead of motors. Some electric motors are used to produce torque or force.

Operating principle

At least 3 different operating principles are used to make electric motors: magnetic, electrostatic and piezoelectric. By far the most common is magnetic.

Magnetic

Nearly all electric motors are based around magnetism (exceptions include piezoelectric motors and ultrasonic motors). In these motors, magnetic fields are formed in both the rotor and the stator. The product between these two fields gives rise to a force, and thus a torque on the motor shaft. One, or both, of these fields must be made to change with the rotation of the motor. This is done by switching the poles on and off at the right time, or varying the strength of the pole.

Categorization

The main types are DC motors and AC motors, although the ongoing trend toward electronic control somewhat softens the distinction,[citation needed][dubious – discuss] as modern drivers have moved the commutator out of the motor shell for some types of DC motors.

Considering all rotating (or linear) electric motors require synchronism between a moving magnetic field and a moving current sheet for average torque production, there is a clear distinction between an asynchronous motor and synchronous types. An asynchronous motor requires slip - relative movement between the magnetic field (generated by the stator) and a winding set (the rotor) to induce current in the rotor by mutual inductance. The most ubiquitous example of asynchronous motors is the common AC induction motor which must slip to generate torque.

In the synchronous types, induction (or slip) is not a requisite for magnetic field or current production (e.g. permanent magnet motors, synchronous brush-less wound-rotor doubly fed electric machine).

Rated output power is also used to categorize motors. Those of less than 746 watts, for example, are often referred to as fractional horsepower motors (FHP) in reference to the old imperial measurement.