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Young's modulus measures how stiff a material is when it gets stretched or squished.The formula for Young's modulus uses stress and strain to calculate a material's resistance to bending. Young's modulus(E or Y) is a measure of a solid's stiffness or resistance to elastic deformation under load. It relates stress (force per unit area) to strain (proportional deformation) along an axis or line. The basic principle is that a material undergoes elastic deformation when it is compressed or extended, returning to its original shape when the load is removed. More deformation occurs in a flexible material compared to that of a stiff material. In other words: A low Young's modulus value means a solid is elastic.A high Young's modulus value means a solid is inelastic or stiff. The equation for Young's modulus is: E = / = (F/A) / (L/L0) = FL0 / AL Where:E is Young's modulus, usually expressed in Pascal (Pa) is the uniaxial stress is the strainF is the force of compression or extensionA is the cross-sectional surface area or the cross-section perpendicular to the applied force L is the change in length (negative under compression; positive when stretched)L0 is the original length While the SI unit for Young's modulus is Pa, values are most often expressed in terms of megapascal (MPa), Newtons per square millimeter (N/mm2), gigapascals (GPa), or kilonewtons per square millimeter (kN/mm2). The usual English unit is pounds per square inch (PSI) or mega PSI (Mpsi). The basic concept behind Young's modulus was described by Swiss scientist and engineer Leonhard Euler in 1727. In 1782, Italian scientist Giordano Riccati performed experiments leading to modern calculations of the modulus. Yet, the modulus takes its name from British scientist Thomas Young, who described its calculation in hisCourse of Lectures on Natural Philosophy and the Mechanical Artsin 1807. It should probably be called Riccati's modulus, in light of the modern understanding of its history, but that would lead to confusion. The Young's modulus often depends on the orientation of a material. Isotropic materials display mechanical properties that are the same in all directions. Examples include pure metals and ceramics. Working a material or adding impurities to it can produce grain structures that make mechanical properties directional. These anisotropic materials may have very different Young's modulus values, depending on whether force is loaded along the grain or perpendicular to it. Good examples of anisotropic materials include wood, reinforced concrete, and carbon fiber. This table contains representative values for samples of various materials. Keep in mind, the precise value for a sample may be somewhat different since the test method and sample composition affect the data. In general, most synthetic fibers have low Young's modulus values. Natural fibers are stiffer. Metals and alloys tend to exhibit high values. The highest Young's modulus of all is for carbyne, an allotrope of carbon. MaterialGPaMpsiRubber (small strain)0.010.11.4514.5103Low-density polyethylene0.110.861.66.5102Diatom frustules (silicic acid)0.352.770.050.4PTFE (Teflon)0.50.075HDPE0.80.116Bacteriophage capsids130.150.435Polypropylene1.520.220.29Polycarbonate22.40.29-0.36Polyethylene terephthalate (PET)22.70.290.39Nylon240.290.58Polystyrene, solid33.50.440.51Polystyrene, foam2.57x10-33.610.2x10-4Medium-density fiberboard (MDF)40.58Wood (along grain)111.60Human Cortical Bone142.03Glass-reinforced polyester matrix17.22.49Aromatic peptide nanotubes19272.763.92High-strength concrete304.35Amino-acid molecular crystals21443.046.38Carbon fiber reinforced plastic30504.357.25Hemp fiber355.08Magnesium (Mg)456.53Glass50907.2513.1Flax fiber588.41Aluminum (Al)6910Mother-of-pearl nacre (calcium carbonate)7010.2Aramid70.5112.410.216.3Tooth enamel (calcium phosphate)8312Stinging nettle fiber8712.6Bronze9612013.917.4Brass10012514.518.1Titanium (Ti)110.316Titanium alloys1051201517.5Copper (Cu)11717Carbon fiber reinforced plastic18126.3Silicon crystal13018518.926.8Wrought iron19021027.630.5Steel (ASTM-A36)20029Yttrium iron garnet (YIG)193-20028-29Cobalt-chrome (CoCr)22025829Aromatic peptide nanospheres23027533.440Beryllium (Be)28741.6Molybdenum (Mo)32933047.747.9Tungsten (W)4004105859Silicon carbide (SiC)45065Tungsten carbide (WC)4506506594Osmium (Os)52556276.181.5Single-walled carbon nanotube1,000+150+Graphene (C)1050152Diamond (C)10501210152175Carbyne (C)321004660 A modulus is literally a "measure." You may hear Young's modulus referred to as the elastic modulus, but there are multiple expressions used to measure elasticity:Young's modulus describes tensile elasticity along a line when opposing forces are applied. It is the ratio of tensile stress to tensile strain.The bulk modulus (K) is like Young's modulus, except in three dimensions. It is a measure of volumetric elasticity, calculated as volumetric stress divided by volumetric strain.The shear or modulus of rigidity (G) describes shear when an object is acted upon by opposing forces. It is calculated as shear stress over shear strain. The axial modulus, P-wave modulus, and Lam's first parameter are other modulii of elasticity. Poisson's ratio may be used to compare the transverse contraction strain to the longitudinal extension strain. Together with Hooke's law, these valuesdescribe the elastic properties of a material.ASTM E 111, "Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus". Book of Standards Volume: 03.01.G. Riccati, 1782,Delle vibrazioni sonore dei cilindri, Mem. mat. fis. soc. Italiana, vol. 1, pp 444-525.Liu, Mingjie; Artyukhov, Vasilii I; Lee, Hoonkyung; Xu, Fangbo; Yakobson, Boris I (2013). "Carbyne From First Principles: Chain of C Atoms, a Nanorod or a Nanorope?". ACS Nano. 7 (11): 1007510082. doi:10.1021/nn404177rTruesdell, Clifford A. (1960).The Rational Mechanics of Flexible or Elastic Bodies, 16381788: Introduction to Leonhardi Euleri Opera Omnia, vol. X and XI, Seriei Secundae. Orell Fussli. The TANSCHE curriculum for first year B.Sc. Physics practical emphasizes experiments that enhance theoretical knowledge through practical experience. A key experiment in this curriculum is measuring Young's Modulus through non-uniform bending with a pin and microscope. This experiment allows students to assess the elasticity of a material by observing how a beam bends evenly when a load is applied. In this blog post, we will provide a step-by-step guide to help you carry out the experiment correctly. From setting up the equipment to interpreting the results, this guide offers a thorough approach for students to accurately determine the Youngs modulus of a material using the non-uniform bending technique.Young's modulus - Non uniform Bending (Pin and Microscope method)Aim:To determine the Young's modulus of the material of a given bar by the method of non-uniform bending using a pin and microscope.Apparatus required:Uniform bar, wait hanger, weights, knife edges vernier microscope, screw gauge, vernier caliper etcFormula:Here,E is the Young's modulus of the material of the bar N/m2m is the load added in the weight hanger kgg is the acceleration due to gravity m/s2L is the length of the bar between the knife edges mb is the breadth of the bar md is the thickness of the bar my is the depression of the midpoint of the bar due to a load m mProcedure:The given bar is placed symmetrically on two knife edges separated by L length (say 60 cm). A weight hanger is suspended at the centre of the bar. A pin is fixed vertically at the centre of the bar using wax.The tip of the pin is made to coincide with the crosswire in the microscope. The initial reading of the microscope on its vertical scale is noted.Load weight m (50 gm) on the weight hanger. Adjust the microscope so that the inverted image of the pin tip is again aligned with the horizontal crosswire and record the microscope readings. Then, add weights in m (50 gm) increments until the maximum load is reached. Eachtime, take the microscope readings. The weights are then removed in equal steps and the microscope readings are recorded each time. The average value of load is obtained. From these readings, the average elevation of the midpoint of the bar due to the load m applied is determined. From these measurements (m/y) can be calculated. This ratio can also be calculated by plotting a graph, with depression y along the x-axis and the mass m along the y-axis. This leads to a straight line. The slope of this line will give (m/y).The breadth (b) and the thickness (d) of the bar are measured with the help of vernier caliper and screw gauge respectively. The experiment can be repeated with different values of L.Tabular Column 1: To find the elevation corresponding to load using vernier microscopeLeast count (LC) = 0.001 cmLoad m gmMicroscope readingsMeancmDepression corresponding to 100 gm ycmLoadingUnloadingMSR cmVSR cmTR cmMSR cmVSRcmTR cmww+50w+100w+150w+200w+250Tabular Column 2: To find the breadth of the beam using vernier caliperThe procedure of usingVernier caliper and its table can be found here.Tabular Column 3: To find the thickness of the beam using screw gaugeThe procedure of usingScrew gauge and its table can be found here.The Youngs modulus of the material of the given beam = _____ N/m2You can simulate this experiment hereVirtual lab.A student investigates the relationship between the force on a wire and its extension. They set up the experiment by keeping the string taut with a 100 g mass. Adding on an extra 100 g each time and measuring the extension, they obtain the following table of resultsThe following additional data for the wire is:Calculate the value of the Young Modulus of the wire.Answer:Step 1: Plot a graph of the load (force) against the extensionMake sure the axes are properly labelled and the line of best fit is drawn with a rulerStep 2: Calculate the gradient of the graphStep 3: Substitute values into the Young Modulus EquationOriginal length of wire, L = 1.382 mCross-sectional area, A = 6.03 10-8 m2Gradient = 2812.5 N m-1Page 2The graph below shows the stress-strain graph for a copper wire.Use the graph to calculate the Young Modulus of copper.Answer:Step 1: Determine the stress and strain where the linear region ends The Young Modulus is the gradient of the linear region of a stress-strain graphStep 2: Calculate the gradient of the graph in this regionPage 3Which equation is used to calculate the Young Modulus of a material?E =E =k = Did this page help you?The Young Modulus can be found using the equation, E = .What are the units of stress and strain?stressstrainAPaNBPano unitsCNPaDno unitsno unitsDid this page help you?The stress-strain graph for carbon is shown.Which property of the graph gives the Young Modulus of carbon?The gradient of the whole graphThe gradient of the straight section of the graphThe Young Modulus cannot be calculated from the graphDid this page help you?A student uses the following apparatus to determine the Young modulus of copper.The student wishes to plot a stress-strain graph for the copper wire.What two additional pieces of apparatus would be required to determine values for stress and strain? stressstrainAmicrometermetre rulerBmicrometervernier calipersCdigital scalesvernier calipersDmetre rulermicrometerDid this page help you?What direct measurements would a student make in an experiment to find the Young Modulus?diameter of the wire being testedcross sectional area of the wire being testedapplied loadthe amount of massDid this page help you?The graph shows the stress-strain curve for a length of constantan wire.What is the ultimate tensile stress (UTS) of the wire?5.3 103 mDid this page help you?An experiment was carried out to find the Young Modulus of copper, using copper wire.The uncertainties in the measurements are given below.measurementuncertaintyapplied loadcross-sectional areaWhat is the percentage uncertainty in the stress applied to the wire?Did this page help you?A metal wire that is supported vertically from a hook has a cross sectional area of 0.5 10-6 m2.Weights totalling 1.5N are suspended from the wire, which extends by 2.0%.What is the Young Modulus of this wire?Did this page help you?A student performs the Young Modulus experiment.Which line in the table correctly matches up the best choice of equipment for a particular measurement, and the precision of the measurement?quantityinstrumentprecisionAoriginal lengthmetre ruler 0.1 mmBextensionmetre ruler 1 mmCdiametermicrometer 0.1 mmDmassforce meter0.1 gDid this page help you?A student has plotted the graph below, after carefully investigating the extension produced by different loads applied to a wire.What calculation based on the graph will give the Young Modulus?gradient gradient Did this page help you?An experiment was carried out to find the Young Modulus of copper, using copper wire.The uncertainties in the measurements are given below.measurementuncertaintyapplied loaddiameter of wireextensionoriginal length of wireWhat is the percentage uncertainty in the Young Modulus applied to the wire?Did this page help you?A metal tube with a thin wall thickness w is shown in the diagram. The thickness of the wall is small when compared to the diameter of the tube.A force T applied parallel to the axis of the tube puts the tube under tension. It is proposed that making the wall thicker would reduce the stress on the tube.If the tube diameter and the tension remain the same, which wall thickness would half the stress?Did this page help you?A steel metal wire has the following properties: diameter = 5.0 104 m Young modulus = 2.0 1011 Pa tension = 20 NThe string snaps and contracts elastically.By what percentage does a length of a piece of the string contract?Did this page help you?The Young modulus of a metal wire is dependent on which property?Did this page help you?The Young modulus E and the force per unit extension k describes the behaviour of a wire under tensile stress.For a wire of length L and cross-sectional area A, what is the relationship between E and k?Did this page help you?A steel bar, shown in the diagram, has a circular cross-section that is under tension T.The diameter of the thinner portion is half the wider portion.What is the value of ?Did this page help you?A student wanted to find the young modulus of a wire. The equation for the young modulus E is: The student extended the wire with a known force and made a series of measurements.Which measurement has the largest effect on the uncertainty in the value of the calculated Young modulus?measurementsymbolvalueAlength of wire before force appliedl2.043 0.002 mBforce appliedF19.62 0.01 NCextension of wire with force applied5.2 0.2 mmDdiameter of wired0.54 0.02 mmDid this page help you?Which unit cannot be used for the Young Modulus?Did this page help you?The stress-strain graph for carbon is shown.What is the Young Modulus of the carbon?Did this page help you?A steel wire X has a length L and a circular cross-section of radius r. When X hands vertically and a load is attached to the bottom end, it extends by e.Another wire Y is made from the same material and has the same load attached to it.Which length and radius for Y will produced an extension of ?length of YRadius of YA16L2rB4L0.5rC0.5L2rD2L0.5rDid this page help you?A construction site crane has a steel lifting cable with diameter 36 mm and length 27.0m. The steel used has a Young modulus of 200 GPa.Calculate the extension when the crane is used to lift materials with weight 28 kN.Did this page help you?Steel has a Young Modulus of 2 Pa and a breaking strain of 0.1 %.What is the force needed to break a steel wire of diameter 1 mm?Did this page help you?The graph shows the behaviour of a copper alloy when it is stressed.Which of the following shows a second line for a material which;is brittle,has a Young modulus lower than the copper alloyfractures at a strain of 2.6 x ?Did this page help you?Two springs are connected in series as shown. The values of the spring constants are different, where k1 = 25 N cm1 and k2 = 35 N cm1.The spring has a circular cross-sectional area of 707 mm2 and before the 50 N load is placed, the combination have a length of 5.0 cm.What is the young modulus of the material that the spring is made from?Did this page help you?An A Level Physics student carries out an investigation into the Young Modulus of a copper wire and plots her graph as shown.How would the graph be different if she repeated the experiment, first with thinner wire, and then using thicker wire?thinner wirethicker wireAlimit of proportionality would be at a higher forcesteeper gradientBlimit of proportionality would be at a lower forcesteeper gradientCsteeper gradientlimit of proportionality would be at a lower forceDshallower gradientlimit of proportionality would be at a lower forceDid this page help you?A popular playground ride is a rocking horse on a spring, as shown. The toy is designed to be used by children aged between 2-5 years old.When the child sits on the horse, the spring should compress a little but not too much for play to be both fun, and safe.Clinical data from childcare professionals suggests that 2 year old children have average weight of 12.0 kg, while five-year old children average 19.0 kg.Which spring constant would be most suitable?1.15 N1.03 X103 N1 020 X106 N10 X108 NDid this page help you?The system below shows a composite rod made from two different materials.The dimensions and Young Modulus for each rod are as follows:For Rod 1For Rod 2Young modulus, E1=20GPa.Young modulus, E2=40GPaWhat is the ratio of ?Did this page help you?The supporting cable of a suspension footbridge if the cable has a diameter of 55 mm, and it exerts an upwards force on the footpath of 5.2kN.If the Young Modulus of the steel the cable is made from is 2.0 GPa, and the maximum strain the cable can withstand before breaking is 5.0 %, then what is the breaking stress?operating stress / Pabreaking stress / PaA2.21.00 x108B2.2 x1061.00 x108C2.21.00 x106D2.2 x1061.00 x106Did this page help you?A uniform, heavy chain of Young Modulus, E, length, L, mass per unit length, , cross-sectional area, A is supported by a thin rope with negligible mass.Find an expression for the extension, L, when the chain is fully suspended above the ground.Did this page help you?A copper wire of length 1.80 m and cross-sectional area of 1.6 xm2 is put under a tensile stress of 2.45N. The length of the wire increases by 2mm.The experiment has been done using the following equipment:metre ruler to measure lengthvernier scale with precision of 0.1 mm to measure extensionmicrometer to measure diameter of the wireWhat is the Young Modulus of copper? You can assume the value for applied force is correct.(1.4 0.06) x108N(1.4 0.09) x108 N(1.4 0.06) x1011N(1.4 0.09) x1011NDid this page help you?Page 4Single Slit Diffraction, The Diffraction GratingRefraction at a Plane Surface, Snell's Law, Fibre OpticsScalars & Vectors, Resolving VectorsMoments, Couples, Centre of MassBrightness & Apparent Magnitude, Inverse Square Law of Radiation, Astronomical Distances, Absolute Magnitude, Wiens Displacement Law, Stefan's Law, Emission & Absorption Spectra in Stars, Stellar Spectral Classes, Star Formation, Life Cycle of a Low Mass Star, Life Cycle of a High Mass Star, Supernovae & Gamma Ray Bursts (GRBs), Supernovae as Standard Candles, Neutron Stars & Black Holes, The Hertzsprung-Russell DiagramECG MachinesThe First Law of Thermodynamics, pV Diagrams, Thermodynamic Processes, Petrol Engine Cycle, Diesel Engine Cycle, Comparing Petrol & Diesel Engines, Power Output of an Engine, Engine Efficiency, The Second Law of Thermodynamics, Heat Engines, Limitations of Real Heat Engines, Reversed Heat Engines, Coefficients of PerformanceTheories of Light, Young's Double Slit Interference, Maxwell's Wave Equation, Hertz's Discovery of Radio Waves, Fizeau's Speed of Light Experiment, UV Catastrophe & Black-Body Radiation, The Discovery of Photoelectricity, De Broglie's Hypothesis, Electron Diffraction, Transmission Electron Microscope, Scanning Tunnelling MicroscopeMechanical property that measures stiffness of a solid materialYoung's modulus is the slope of the linear part of the stressstrain curve for a material under tension or compression.Young's modulus (or the Young modulus) is a mechanical property of solid materials that measures the tensile or compressive stiffness when the force is applied lengthwise. It is the modulus of elasticity for tension or axial compression. Young's modulus is defined as the ratio of the stress (force per unit area) applied to the object and the resulting axial strain (displacement or deformation) in the linear elastic region of the material.Although Young's modulus is named after the 19th-century British scientist Thomas Young, the concept was developed in 1727 by Leonhard Euler. The first experiments that used the concept of Young's modulus in its modern form were performed by the Italian scientist Giordano Riccati in 1782, pre-dating Young's work by 25 years.[1] The term modulus is derived from the Latin root term modus, which means measure.Young's modulus, E {\displaystyle E} , quantifies the relationship between tensile or compressive stress {\displaystyle \sigma } (force per unit area) and axial strain {\displaystyle \varepsilon } (proportional deformation) in the linear elastic region of a material:[2] E = {\displaystyle E={\frac {\sigma }{\varepsilon }}} Young's modulus is commonly measured in the International System of Units (SI) in multiples of the pascal (Pa) and common values are in the range of gigapascals (GPa).Examples:Rubber (increasing pressure: large length increase, meaning low E {\displaystyle E})Aluminium (increasing pressure: small length increase, meaning high E {\displaystyle E})Main article: Linear elasticityA solid material undergoes elastic deformation when a small load is applied to it in compression or extension. Elastic deformation is reversible, meaning that the material returns to its original shape after the load is removed.At near-zero stress and strain, the stressstrain curve is linear, and the relationship between stress and strain is described by Hooke's law that states stress is proportional to strain. The coefficient of proportionality is Young's modulus. The higher the modulus, the more stress is needed to create the same amount of strain; an idealized rigid body would have an infinite Young's modulus. Conversely, a very soft material (such as a fluid) would deform without force, and would have zero Young's modulus.Material stiffness is a distinct property from the following:Strength: maximum amount of stress that material can withstand while staying in the elastic (reversible) deformation regime;Geometric stiffness: a global characteristic of the body that depends on its shape, and not only on the local properties of the material; for instance, an I-beam has a higher bending stiffness than a rod of the same material for a given mass per length;Hardness: relative resistance of the material's surface to penetration by a harder body;Toughness: amount of energy that a material can absorb before fracture.The point E is the elastic limit or the yield point of the material within which the stress is proportional to strain and the material regains its original shape after removal of the external force.Young's modulus enables the calculation of the change in the dimension of a bar made of an isotropic elastic material under tensile or compressive loads. For instance, it predicts how much a material sample extends under tension or shortens under compression. The Young's modulus directly applies to cases of uniaxial stress; that is, tensile or compressive stress in one direction and no stress in the other directions. Young's modulus is also used in order to predict the deflection that will occur in a statically determinate beam when a load is applied at a point in between the beam's supports.Other elastic calculations usually require the use of one additional elastic property, such as the shear modulus G {\displaystyle G} , bulk modulus K {\displaystyle K} , and Poisson's ratio {\displaystyle u } . Any two of these parameters are sufficient to fully describe elasticity in an isotropic material. For example, calculating physical properties of cancerous skin tissue, has been measured and found to be a Poissons ratio of 0.430.12 and an average Youngs modulus of 52 KPa. Defining the elastic properties of skin may become the first step in turning elasticity into a clinical tool.[3] For homogeneous isotropic materials simple relations exist between elastic constants that allow calculating them all as long as two are known: E = 2 G (1 +) = 3 K (1 2) . {\displaystyle E=2G(1+u)=3K(1-2u).} Young's modulus represents the factor of proportionality in Hooke's law, which relates the stress and the strain. However, Hooke's law is only valid under the assumption of an elastic and linear response. Any real material will eventually fail and break when stretched over a very large distance or with a very large force; however, all solid materials exhibit nearly Hookean behavior for small enough strains or stresses. If the range over which Hooke's law is valid is large enough compared to the typical stress that one expects to apply to the material, the material is said to be linear. Otherwise (if the typical stress one would apply is outside the linear range), the material is said to be non-linear.Steel, carbon fiber and glass among others are usually considered linear materials, while other materials such as rubber and soils are non-linear. However, this is not an absolute classification: if very small stresses or strains are applied to a non-linear material, the response will be linear, but if very high stress or strain is applied to a linear material, the linear theory will not be enough. For example, as the linear theory implies reversibility, it would be absurd to use the linear theory to describe the failure of a steel bridge under a high load; although steel is a linear material for most applications, it is not in such a case of catastrophic failure.In solid mechanics, the slope of the stressstrain curve at any point is called the tangent modulus. It can be experimentally determined from the slope of a stressstrain curve created during tensile tests conducted on a sample of the material.Young's modulus is not always the same in all orientations of a material. Most metals and ceramics, along with many other materials, are isotropic, and their mechanical properties are the same in all orientations. However, metals and ceramics can be treated with certain impurities, and metals can be mechanically worked to make their grain structures directional. These materials then become anisotropic, and Young's modulus will change depending on the direction of the force vector.[4] Anisotropy can be seen in many composites as well. For example, carbon fiber has a much higher Young's modulus (is much stiffer) when force is loaded parallel to the fibers (along the grain). Other such materials include wood and reinforced concrete. Engineers can use this directional phenomenon to their advantage in creating structures.Young's modulus is calculated by dividing the tensile stress, ( ) {\displaystyle \sigma (\varepsilon)} , by the engineering extensional strain, {\displaystyle \varepsilon } , in the elastic (initial, linear) portion of the physical stressstrain curve: E ( ) = F / A L / L 0 = F L 0 A L {\displaystyle E\equiv {\frac {\sigma (\varepsilon)}{\varepsilon }}={\frac {F/A}{\Delta L/L_{0}}}={\frac {FL_{0}}{A\,\Delta L}}} where E {\displaystyle E} is the Young's modulus (modulus of elasticity); F {\displaystyle F} is the force exerted on an object under tension; A {\displaystyle A} is the actual cross-sectional area, which equals the area of the cross-section perpendicular to the applied force; L {\displaystyle \Delta L} is the amount by which the length of the object changes (L {\displaystyle \Delta L} is positive if the material is stretched, and negative when the material is compressed); L 0 {\displaystyle L_{0}} is the original length of the object.Young's modulus of a material can be used to calculate the force it exerts under specific strain. F = E A L L 0 {\displaystyle F={\frac {EA\,\Delta L}{L_{0}}}} where F {\displaystyle F} is the force exerted by the material when contracted or stretched by L {\displaystyle \Delta L} .Hooke's law for a stretched wire can be derived from this formula: F = (E A L 0) L = k x {\displaystyle F=\left({\frac {EA}{L_{0}}}\right)\,\Delta L=kx} where it comes in saturation k E A L 0 {\displaystyle k\equiv {\frac {EA}{L_{0}}}\,} and x L . {\displaystyle x\equiv \Delta L.} Note that the elasticity of coiled springs comes from shear modulus, not Young's modulus. When a spring is stretched, its wire's length doesn't change, but its shape does. This is why only the shear modulus of elasticity is involved in the stretching of a spring. [citation needed]The elastic potential energy stored in a linear elastic material is given by the integral of the Hooke's law: U e = k x d x = 1 2 k x 2 . {\displaystyle U_{e}=\int {kx}\,dx={\frac {1}{2}}kx^{2}.} now by explicating the intensive variables: U e = E A L L 0 d L = E A L 0 L d L = E A L 2 2 L 0 {\displaystyle U_{e}=\int {\frac {EA\,\Delta L}{L_{0}}}\,d\Delta L={\frac {EA}{L_{0}}}\int \Delta L\,d\Delta L={\frac {EA\,\Delta L}^{2}}{2L_{0}}}} This means that the elastic potential energy density (that is, per unit volume) is given by: U e A L 0 = E L 2 2 L 0 2 = 1 2 E L L 0 L L 0 = 1 2 ( ) {\displaystyle {\frac {U_{e}}{AL_{0}}}={\frac {E\,\Delta L}^{2}}{2L_{0}^{2}}}={\frac {1}{2}}\times {\frac {E\,\Delta L}}{L_{0}}}\times {\frac {\Delta L}{L_{0}}}={\frac {1}{2}}\times \sigma (\varepsilon)\times \varepsilon } or, in simple notation, for a linear elastic material: u e ( ) = E d = 1 2 E 2 {\textstyle u_{e}(\varepsilon)=\int {E\,\varepsilon }\,d\varepsilon ={\frac {1}{2}}E{\varepsilon }^{2}} , since the strain is defined L L 0 {\textstyle \varepsilon \equiv {\frac {\Delta L}{L_{0}}}} .In a nonlinear elastic material the Young's modulus is a function of the strain, so the second equivalence no longer holds, and the elastic energy is not a quadratic function of the strain: u e ( ) = E ( ) d 1 2 E 2 {\displaystyle u_{e}(\varepsilon)=\int E(\varepsilon)\,\varepsilon \,d\varepsilon eq {\frac {1}{2}}E\varepsilon ^{2}} Influences of selected glass component additions on Young's modulus of a specific base glassYoung's modulus can vary somewhat due to differences in sample composition and test method. The rate of deformation has the greatest impact on the data collected, especially in polymers. The values here are approximate and only meant for relative comparison.Approximate Young's modulus for various materialsMaterialYoung's modulus (GPa)Megapound per square inch (Mpsi)[5]Ref.Aluminium (13Al)689.86[6][7][8][9][10][11]Amino-acid molecular crystals21443.056.38[12]Aramid (for example, Kevlar)70.5112.410.216.3[13]Aromatic peptide-nanospheres23027533.439.9[14]Aromatic peptide-nanotubes19272.763.92[15][16]Bacteriophage capsids130.1450.435[17]Beryllium (4Be)28741.6[18]Bone, human cortical142.03[19]Brass10615.4[20]Bronze11216.2[21]Carbon nitride (CN2)822119[22]Carbon-fiber-reinforced plastic (CFRP), 50/50 fibre/matrix, biaxial fabric30504.357.25[23]Carbon-fiber-reinforced plastic (CFRP), 70/30 fibre/matrix, unidirectional, along fibre18126.3[24]Cobalt-chrome (CoCr)23033.4[25]Copper (Cu), annealed11016[26]Diamond (C), synthetic10501210152175[27]Diatom frustules, largely silicic acid0.352.770.0510.058[28]Flax fiber588.41[29]Float glass47.783.66.9212.1[30]Glass-reinforced polyester (GRP)17.22.49[31]Gold77.211.2[32]Graphene1050152[33]Hemp fiber355.08[34]High-density polyethylene (HDPE)0.971.380.1410.2[35]High-strength concrete304.35[36]Lead (82Pb), chemical131.89[11]Low-density polyethylene (LDPE), molded0.2280.0331[37]Magnesium alloy45.26.56[38]Medium-density fiberboard (MDF)40.58[39]Molybdenum (Mo), annealed33047.9[40][7][8][9][10][11]Monel18026.1[11]Mother-of-pearl (largely calcium carbonate)7010.2[41]Nickel (28Ni), commercial20029[11]Nylon 662.930.425[42]Osmium (76Os)52556276.181.5[43]Osmium nitride (OsN2)194.99396.4428.357.5[44]Polycarbonate (PC)2.20.319[45]Polyethylene terephthalate (PET), unreinforced3.140.455[46]Polypropylene (PP), molded1.680.244[47]Polystyrene, crystal2.53.50.3630.508[48]Polystyrene, foam0.00250.0070.0003630.00102[49]Polytetrafluoroethylene (PTFE), molded0.5640.0818[50]Rubber, small strain0.010.10.001450.0145[12]Silicon, single crystal, different directions13018518.926.8[51]Silicon carbide (SiC)9013713.119.9[52]Single-walled carbon nanotube > {\displaystyle >} 1000 > {\displaystyle >} 140[53][54]Steel, A3620029[55]Stinging nettle fiber8712.6[29]Titanium (22Ti)11616.8[56][57][7][9][8][11][10]Titanium alloy, Grade 511416.5[58]Tooth enamel, largely calcium phosphate8312[59]Tungsten carbide (WC)6006868799.5[60]Wood, American beech9.511.91.381.73[61]Wood, black cherry910.31.311.49[61]Wood, red maple9.611.31.391.64[61]Wrought iron19328[62]Yttrium iron garnet (YIG), polycrystalline19328[63]Yttrium iron garnet (YIG), single-crystal20029[64]Zinc (30Zn)10815.7[65]Zirconium (40Zr), commercial9513.8[11]Bending stiffnessDeflectionDeformationFlexural modulusImpulse excitation techniqueList of materials propertiesYield (engineering)^ The Rational mechanics of Flexible or Elastic Bodies, 16381788: Introduction to Leonhardi Euleri Opera Omnia, vol. X and XI, Seriei Secundae. Orell Fussli.^ Jastrzebski, D. (1959). Nature and Properties of Engineering Materials (Wiley Internationaled.). John Wiley & Sons, Inc.^ Tilleman, Tamara Raveh; Tilleman, Michael M.; Neumann, Martino H.A. (December 2004). "The Elastic Properties of Cancerous Skin: Poisson's Ratio and Young's Modulus" (PDF). Israel Medical Association Journal. 6 (12): 753755. PMID15609889.^ Gorodtsov, V.A.; Lisovenko, D.S. (2019). "Extreme values of Young's modulus and Poisson's ratio of hexagonal crystals". Mechanics of Materials. 134: 18. Bibcode:2019MechM.134....1G. doi:10.1016/j.mechmat.2019.03.017. S2CID140493258.^ "Unit of Measure Converter". MatWeb. Retrieved May 9, 2021.^ "Aluminum, Al". MatWeb. Retrieved May 7, 2021.^ a b c Weast, Robert C. (1981). CRC Handbook of Chemistry and Physics (62nded.). Boca Raton, FL: CRC Press. doi:10.1002/jctb.280500215. ISBN978-0-84-930740-9.^ a b c Ross, Robert B. (1992). Metallic Materials Specification Handbook (4thed.). London: Chapman & Hall. doi:10.1007/978-1-4615-3482-2. ISBN9780412369407.^ a b c Nunes, Rafael; Adams, J. H.; Ammons, Mitchell; etal. (1990). Volume 2: Properties and Selection: Nonferrous Alloys and Special-Purpose Materials (PDF). ASM Handbook (10thed.). ASM International. ISBN978-0-87170-378-1.^ a b c Nayar, Alok (1997). The Metals Databook. New York, NY: McGraw-Hill. ISBN978-0-07-462300-8.^ a b c d e f g Lide, David R., ed. (1999). "Commercial Metals and Alloys". CRC Handbook of Chemistry and Physics (80thed.). Boca Raton, FL: CRC Press. ISBN978-0-84-930480-4.^ a b Azuri, Ido; Meirzadeh, Elena; Ehre, David; etal. (November 9, 2015). "Unusually Large Young's Moduli of Amino Acid Molecular Crystals" (PDF). Angewandte Chemie. 54 (46) (Internationaled.). Wiley: 1356613570. doi:10.1002/anie.201505813. PMID26373817. S2CID13717077 via PubMed.^ "Kevlar Aramid Fiber Technical Guide" (PDF). DuPont. 2017. Retrieved May 8, 2021.^ Adler-Abramovich, Lihi; Kol, Nitzan; Yanai, Inbal; etal. (December 17, 2010). "Self-Assembled Organic Nanostructures with Metallic-Like Stiffness". Angewandte Chemie. 49 (51) (Internationaled.). Wiley-VCH (published September 28, 2010): 99399942. doi:10.1002/anie.201002037. PMID20878815. S2CID44873277.^ Kol, Nitzan; Adler-Abramovich, Lihi; Barlam, David; etal. (June 8, 2005). "Self-Assembled Peptide Nanotubes Are Uniquely Rigid Bioinspired Supramolecular Structures". Nano Letters. 5 (7). Israel: American Chemical Society: 13431346. Bibcode:2005NanoL...5.1343K. doi:10.1021/nl0505896. PMID16178235 via ACS Publications.^ Niu, Lijiang; Chen, Xinyong; Allen, Stephanie; etal. (June 6, 2007). "Using the Bending Beam Model to Estimate the Elasticity of Diphenylalanine Nanotubes". Langmuir. 23 (14). American Chemical Society: 74437446. doi:10.1021/la7010106. PMID17550276 via ACS Publications.^ Ivanovska, Irena L.; de Pablo, Pedro J.; Ibarra, Benjamin; etal. (May 7, 2004). Lubensky, Tom C. (ed.). "Bacteriophage capsids: Tough nanoshells with complex elastic properties". Proceedings of the National Academy of Sciences of the United States of America. 101 (20). The National Academy of Sciences: 76007605. Bibcode:2004PNAS..101.7600I. doi:10.1073/pnas.0308198101. PMC419652. PMID15133147.^ Foley, James C.; Abeln, Stephen P.; Stanek, Paul W.; etal. (2010). "An Overview of Current Research and Industrial Practices of be Powder Metallurgy". In Marquis, Fernand D. S. (ed.). Powder Materials: Current Research and Industrial Practices III. Hoboken, NJ: John Wiley & Sons, Inc. p.263. doi:10.1002/9781118984239.ch32. ISBN978-1-11-898423-9.^ Rho, Jae Young; Ashman, Richard B.; Turner, Charles H. (February 1993). "Young's modulus of trabecular and cortical bone material: Ultrasonic and microtensile measurements". Journal of Biomechanics. 26 (2). Elsevier: 111119. doi:10.1016/0021-9290(93)90042-d. PMID8429054 via Elsevier Science Direct.^ "Overview of materials for Brass". MatWeb. Retrieved May 7, 2021.^ "Overview of materials for Bronze". MatWeb. Retrieved May 7, 2021.^ Chowdhury, Shafiul; Laugier, Michael T.; Rahman, Ismet Zakia (AprilAugust 2004). "Measurement of the mechanical properties of carbon nitride thin films from the nanoindentation loading curve". Diamond and Related Materials. 13 (48): 15431548. Bibcode:2004DRM....13.1543C. doi:10.1016/j.diamond.2003.11.063 via Elsevier Science Direct.^ Summerscales, John (September 11, 2019). "Composites Design and Manufacture (Plymouth University teaching support materials)". Advanced Composites Manufacturing Centre. University of Plymouth. Retrieved May 8, 2021.^ Kopeliovich, Dmitri (June 3, 2012). "Epoxy Matrix Composite reinforced by 70% carbon fibers". SubsTech. Retrieved May 8, 2021.^ Bose, Susmita; Banerjee, Dishary; Bandyopadhyay, Amit (2016). "Introduction to Biomaterials and Devices for Bone Disorders". In Bose, Susmita; Bandyopadhyay, Amit (eds.). Materials for Bone Disorders. Academic Press. pp.127. doi:10.1016/B978-0-12-802792-9.00001-X. ISBN978-0-12-802792-9.^ "Copper, Cu; Annealed". MatWeb. Retrieved May 9, 2021.^ Spear, Karl E.; Dismukes, John P., eds. (1994). Synthetic Diamond: Emerging CVD Science and Technology. Wiley. p.315. ISBN978-0-47-153589-8. ISSN0275-0171.^ Subhash, Ghatu; Yao, Shuhuai; Bellinger, Brent; Gretz, Michael R. (January 2005). "Investigation of mechanical properties of diatom frustules using nanoindentation". Journal of Nanoscience and Nanotechnology. 5 (1). American Scientific Publishers: 5056. doi:10.1166/jnn.2005.006. PMID15762160 via Ingenta Connect.^ a b Bodros, Edwin; Baley, Christophe (May 15, 2008). "Study of the tensile properties of stinging nettle fibres (Urtica dioica)". Materials Letters. 62 (14): 21432145. Bibcode:2008MatL...62.2143B. CiteSeerX10.1.1.299.6908. doi:10.1016/j.matlet.2007.11.034 via Elsevier Science Direct.^ "Float glass Properties and Applications". AZO Materials. February 16, 2001. Retrieved May 9, 2021.^ Kopeliovich, Dmitri (March 6, 2012). "Polyester Matrix Composite reinforced by glass fibers (Fiberglass)". SubsTech. Retrieved May 7, 2021.^ "Gold material property data". MatWeb. Retrieved September 8, 2021.^ Liu, Fang; Ming, Pingbing; Li, Ju (August 28, 2007). "Ab initio calculation of ideal strength and phonon instability of graphene under tension" (PDF). Physical Review B. 76 (6). American Physical Society: 064120. Bibcode:2007PhRvB..76f4120L. doi:10.1103/PhysRevB.76.064120 via APS Physics.^ Saheb, Nabi; Jog, Jyoti (October 15, 1999). "Natural fibre polym