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Thermal Expansion in One Dimension View the equipment Rationale: It is fairly intuitive to understand that when things are heated they expand. This effect is used in many devices such as thermostats and mercury thermometers. Although the results of thermal expansion are helpful many times, there are several times that the results are destructive such as roads buckling and railroad tracks bending in the hot summer. A good understanding of thermal expansion will better equip you when dealing with this phenomenon. Specific Objectives: By the time you finish this lab you should be able to (1) read a dial gauge; (2) calculate the linear coefficient of thermal expansion for three types of metal; (3) graph change in length versus temperature; and (4) convert resistance values to temperature values. Theory: We will be investigating a group of materials that are labeled isotropic. Isotropic materials thermally expand in all directions equally. After investigating the thermal expansion phenomenon, it is evident that the average atomic spacing increases with temperature in most substances. Figure 1 below illustrates how the overall length of a string of atoms, representing the atoms in our experimental tubes, will increase with temperature. Figure 1: Change in atomic spacing with increased temperature Keep in mind, the average atomic position is just an average. In reality the atoms oscillate around their average position. Given a few material parameters, we can predict how much the length, height, and width of an object will increase with temperature. Experimental observations suggest that the greater the temperature increase, the larger the increase in length. Also, the larger the original length of the object the greater the increase in length as it is warmed up. Mathematically we can state this using equation 1 below, where is a proportionality constant and is material dependent. Equation 1 Experimental Activity: Measuring the rod length: Length (L) is determined by measuring from the inner edge of the stainless steel pin on one end, to the inner edge of the angle bracket at the other end. Record in a table the length of the copper, aluminum, and steel tubes, respectively. Place the rod in the expansion base by placing the stainless steel pin into the slotted mounting block. The other end of the rod has an angle bracket mounted on its side. Now slide the dial gauge into the mounting block next to the angle bracket on the tube. Press the spring-loaded dial gauge against the angle bracket until it registers zero, then secure it with a small screw. Next, attach the thermistor lug to the middle of the tube using a threaded thunbscrew. Make sure the thermistor lug is aligned with the axis of the rod for maximum contact between lug and rod. (The lug has a saddle bend in it to ensure that the lug is properly aligned). Place the foam insulator over the thermistor lug for more accurate readings. Now connect your ohmmeter to the banana jacks labeled THERMISTOR in the expansion base. Record the room-temperature resistance value displayed on your ohmmeter in a table. Next connect the steam generator via a flexible hose to the end of the tube farthest from the dial gauge. Elevate this end of the expansion base by using the small wooden block. The elevation is needed to allow condensation to drain from the tube. Make sure that you place a Styrofoam cup at the other end to catch the draining water. Finally, turn on the steam generator and begin warming up the tube. Once the tube starts to expand it will take approximately 2 minutes to reach its maximum length. After the tube appears to stop expanding, wait an additional 2 minutes for equilibrium to be established and accurately record both resistance and dial gauge readings. Each increment on the dial gauge is equal to 0.01 mm. Make sure you record these values in a table for the respective tubes. Repeat this procedure for each tube. Analysis of Data: Convert each resistance reading to a temperature value using equation 2 below. T is calculated in degrees Celsius, and R must be in Ohms (). This equation is accurate to within one percent. Make sure these values are recorded properly in a table. Equation 2: Conversion of resistance to temperature. On one graph place two points for each material. The horizontal axis represents the temperature and the vertical axis represents the tube length. Plot one point for room temperature and one for the final temperature. Connect the two points with a straight line and determine the slope. Equation 1 tells us the slope equals L. From this slope value, calculate the linear expansion coefficient for each material. Final Results: Clearly indicate your values for linear expansion coefficient for each tube by using the slope of the graph. Report the percent difference between your calculated linear expansion coefficient value and the textbook value for each tube. Questions: Using a percent difference, compare your experimental values for linear expansion coefficient to values you find in your textbook. Is your experimental error consistently high or low? Using your results in question 1, comment on the source of error in this experiment. How would you improve the accuracy of this experiment? Explain the relationship between linear and volumetric coefficients of expansion. This topic is discussed in your textbook. Then for the 3 tubes, calculate the coefficient of volume expansion. Which material has the largest ? Using the graph, describe the relationship between the value of and the slope of each line. Close Window Materials scienceand engineering isinterdisciplinarand very important branch of study, which deals with the design and discovery of new materials, particularly solids.Materials scienceis one of the oldest forms of engineering and applied science and The material of choice of a given era is often a defining point (e.g. Stone Age, Bronze Age, Iron Age). The intellectual origins of materials science stem from the Enlightenment, when researchers began to use analytical thinking from chemistry, physics, and engineering to understand ancient, phenomenological observations in metallurgy and mineralogy. Sometimes it is useful to subdivide the discipline ofmaterials scienceand engineering intomaterials scienceandmaterials engineeringsubdisciplines. The discipline of materials science involves investigating the relationships that exist between the structures and properties of materials. In contrast, materials engineering is, on the basis of these structureproperty correlations, designing or engineering the structure of a material to produce a predetermined set of properties. Material propertiesareintensive properties, that means they areindependent of the amount of mass and may vary from place to place within the system at any moment. The basis of materials science involves studying the structure of materials, and relating them to their properties (mechanical, electrical etc.). Once a materials scientist knows about this structure-property correlation, they can then go on to study the relative performance of a material in a given application. The major determinants of the structure of a material and thus of its properties are its constituent chemical elements and the way in which it has been processed into its final form.About This ProjectMain purpose of this project is tohelp the public to learn some interesting and important information about chemical elements and many common materials. We realize that the basics in the materials science can help people to understand many common problems.Anyone canbe able to come here,learn the basicsofmaterials science, material properties and to compare these properties. Feel free to ask a question, leave feedback or take a look at one of our articles.Properties of chemical elements The following table provides a comprehensive list of volume thermal expansion coefficients for various liquids, taken at room temperature (approximately 20C or 68F) and 1 atmospheric (atm) pressure. (1 atm = 101,325 Pa) Click on the icon to switch between (1/C) and (1/F) units.Volume Thermal Expansion of LiquidsAcetic acid1.08 10-3Acetone1.46 10-3Aniline8.1 10-4Anisole9.51 10-4Benzene1.14 10-3Bromobenzene8.6 10-41-Bromobutane1.13 10-3Bromoethane1.31 10-31-Bromopentane1.04 10-3Butyl iodide1.02 10-3Carbon disulfide1.12 10-3Carbon tetrachloride1.14 10-3Chlorobenzene9.4 10-4Chloroform1.21 10-31-Chloropropane1.4 10-3Cyclohexane1.15 10-3Cyclopentane1.35 10-3Decane1.02 10-3Dibutyl phthalate8.6 10-41,1-Dichloroethane9.3 10-41,2-Dichloroethane1.14 10-3Dichloromethane1.39 10-3Diethylene glycol6.35 10-4Diethyl ether1.65 10-32,3-Dimethylbutane1.39 10-3Dodecane9.3 10-4Ethanol1.40 10-3Ethyl acetate1.35 10-3Ethylene glycol6.26 10-4Glycerol5.20 10-4Heptane1.26 10-3Hexane1.41 10-31-Hexanol1.03 10-3Mercury1.81 10-3Methanol1.49 10-3Nitrobenzene8.33 10-4Nonane1.08 10-3Octane1.16 10-31-Octanol8.27 10-4Pentane1.64 10-3Phosphorus trichloride1.9 10-31,3-Propanediol6.1 10-4Propylene glycol6.95 10-4Tetradecane8.7 10-4Toluene1.05 10-3Triacetin9.4 10-4Tribromomethane9.1 10-4Trichloroethylene1.17 10-3Tridecane9.0 10-4Undecane9.7 10-4m-Xylene9.9 10-4o-Xylene9.6 10-4p-Xylene1.00 10-3Water2.06 10-4 The thermal expansion of liquids can vary depending on factors like temperature, pressure, and impurities in the liquids. Density is the ratio of the mass to the volume of a substance:= m / V (1)where = density, units typically (g/cm3) or (lb/ft3) m = mass, units typically (g) or (lb) V = volume, units typically (cm3) or (ft3)Pure water has its highest density 1000 kg/m3 or 1.940 slug/ft3 at temperature 4C (=39.2F). Specific weight is the ratio of the weight to the volume of a substance: = (m g) / V = g (2)where = specific weight, units typically (N/m3) or (lbf/ft3) m = mass, units typically (g) or (lb) g = acceleration due to gravity, units typically (m/s2) and value on Earth usually given as 9.80665 m/s2 or 32.17405 ft/s2V = volume, units typically (cm3) or (ft3) = density, units typically (g/cm3) or (lb/ft3) Example 1: Specific weight of water In the SI system, specific weight of water at 4C will be: = 1000 (kg/m3) 9.807 (m/s2) = 9807 (kg/(m2 s2)) = 9807 (N/m3) = 9.807 (kN/m3)In the Imperial system the mass unit is the slug (sl) , and is derived from the pound-force by defining it as the mass that will accelerate at 1 foot per square second when a 1 pound-force acts upon it :1 (lbf) = 1 (sl) 1 (ft/s2) and 1 (sl) = 1 (lbf)/ (ft/s2)The density of water is 1.940 sl/ft3at 39 F (4 C), and the specific weight in Imperial units is = 1.940 (sl/ft3) 32.174 (ft/s2) = 1.940 (lbf)/((ft/s2) (ft3)) * 32.174 (ft/s2) = 62.4 (lbf/ft3)See more about the difference between mass and weight Online Water density CalculatorThe calculator below can be used to calculate the liquid water density at given temperatures. The output density is given as g/cm3, kg/m3, lb/ft3, lb/gal(US liq) and sl/ft3. Note! Temperature must be within the ranges 0-370 C, 32-700 F, 273-645 K and 492-1160 R to get valid values. The density of water depends on temperature and pressure as shown below:See Water and Heavy Water for thermodynamic properties at standard condtions. See also other properties of Water at varying temperature and pressure : Boiling points at high pressure, Boiling points at vacuum pressure, Dynamic and kinematic viscosity, Enthalpy and entropy, Heat of vaporization, Ionization Constant, pKw, of normal and heavy water, Melting points at high pressure, Prandtl number, Properties at Gas-Liquid Equilibrium Conditions, Saturation pressure, Specific gravity, Specific heat (heat capacity), Specific volume, Thermal conductivity, Thermal diffusivity and Vapour pressure at gas-liquid equilibrium . For other substances, see density and specific weight of acetone, air, ammonia, argon, benzene, butane, carbon dioxide, carbon monoxide, ethane, ethanol, ethylene, helium, hydrogen, methane, methanol, nitrogen, oxygen, pentane, propane and toluene . Density of crude oil , Density of fuel oils , Density of lubricating oil and Density of jet fuel as function of temperature. As shown in the figures, the change in density is not linear with temperature - this means that the volumetric expansion coefficient for water is not constant over the temperature range. Water density, specific weight and thermal expansion coefficient at temperatures given in degree Celsius:For full table with Specific Weight and Thermal Expansion Coefficient - rotate the screen! Water - Density, Specific Weight and Thermal Expansion Coefficients Temperature Density (0-100C at 1 atm, >100 C at saturation pressure) Specific weight Thermal expansion coefficient (C) (g/cm3) (kg/m3) (sl/ft3) (lbm/ft3) (lbm/gal(US liq)) (kN/m3) (lbf/ft3) (*10- 4K-1) 0.10.9998495999.851.940062.41868.34419.805262.419-0.6810.9999017999.901.940162.42188.34469.805762.422-0.5040.9999749999.971.940362.42648.34529.806462.4260.0010.9997000999.701.939762.40948.34299.803762.4090.8810.9991026999.101.938662.37198.33799.797862.3721.51200.9982067998.211.936862.31608.33049.789162.3162.07250.9970470997.051.934662.24368.32089.777662.2442.57300.9956488995.651.931962.15638.30919.764062.1563.03350.9940326994.031.928762.05548.29569.748162.0553.45400.9922152992.221.925261.94208.28049.730361.9423.84450.9902190990.211.921361.81688.26379.710661.8174.20500.9880498988.041.9171... Water density, specific weight and thermal expansion coefficient at temperatures given in degree Fahrenheit:For full table with Specific Weight and Thermal Expansion Coefficient - rotate the screen! Water - Density, Specific Weight and Thermal Expansion Coefficients Temperature Density (0-212F at 1 atm, >212 F at saturation pressure) Specific weight Thermal expansion coefficient (F) (lbm/ft3) (sl/ft3) (lbm/gal(US liq)) (g/cm3) (kg/m3) (lbf/ft3) (kN/m3) (*10- 4K-1) 32.262.421.94008.34410.99985999.862.429.805-0.683462.421.94028.34480.99993999.962.429.806-0.5039.262.431.94038.34520.99997100.062.439.8060.00314062.421.94028.34500.99995100.062.429.8060.015062.411.93978.34290.99970999.762.419.8040.886062.361.93838.33690.99898999.062.369.7971.597062.301.93648.32830.99796998.062.309.7872.188062.221.93388.31720.99662996.662.229.7732.729062.111.93068.30350.99498995.062.119.7573.211006 2.001.92698.28770.99308993.162.009.7393.661106 1.861.92278.26970.99093990.961.869.7184.081206 1.711.91818.24990.98855988.661.719.6944.461306 1.551.91318.22830.98597986.061... density and specific weight at 1000 psi and given temperatures:For full table with Specific Weight - rotate the screen! Water - Density, Specific Weight and Thermal Expansion Coefficients Temperature Density (at 1000 psi or 68.1 atm) Specific weight (C) (F) (g/cm3) (kg/m3) (sl/ft3) (lbm/ft3) (lbm/gal(US liq)) (lb/ft3) (kN/m3) 0.0321.00311003.11.94662.628.37162.629.8374.4401.00311003.11.94662.628.37162.629.8371 0.0501.00311003.11.94662.628.37162.629.83715.6601.00241002.41.94562.58.36662.589.83121.7011.00121001.21.94362.508.35562.509.81826.7800.99999999.91.94062.428.34462.429.80532.2900.99819981.91.93762.318.33062.319.78837.8100.99629996.21.93362.198.31462.199.76943.3110.99449994.41.92862.038.29262.039.74448.9120.99129991.21.92361.888.27261.889.72154.4130.98898988.91.91961.738.25261.739.69760.0140.98649861.41.91461.588.2... point Water density and specific weight at 10 000 psi and given temperatures:For full table with Specific Weight - rotate the screen! Water - Density, Specific Weight and Thermal Expansion Coefficients Temperature Density (at 10 000 psi or 681 atm) Specific weight (C) (F) (g/cm3) (kg/m3) (sl/ft3) (lbm/ft3) (lbm/gal(US liq)) (lbf/ft3) (kN/m3) 0.0321.03310332.00464.58.6264.510.134.4401.03210322.00364.48.6164.410.1210.0501.03110312.00064.48.6064.410.1115.6601.02910291.99764.38.5964.310.0921.1701.02810281.99464.18.5864.110.0826.7801.02610261.99064.08.5664.010.0632.2901.02410241.98663.98.5463.910.0437.81001.02110211.98263.88.5263.810.0243.31101.01910191.97763.68.5163.69.9948.91201.01710171.97363.58.4863.59.9754.41301.01410141.96863.38.4663.39.9460.01401.01110111.96263.18.4463.19.9265.61501.00810081.95763.08.4263.09.8971.11601.0051005195... per U.S. gallon is based on 7.48 gallons per cubic foot .1 gal(US liq) = 3.7854 l = 0.8327 gal(UK) = 0.8594 gal(US dry) = 0.1074 bu(US dry) = 0.4297 pk(US dry) = 4 qt(US liq) = 8pt(US liq) = 16 c(US) = 32 gi(US liq) = 128 fl oz(US) = 1024 fl dr(US) = 3.78541 0-3m3= 0.1337 ft3= 4.95110-3yd3To convert from density in kg/m3 to other density units - or between units - use the converting values below:1 kg/m3= 1 g/l = 0.001 kg/l = 0.000001 kg/cm3= 0.001 g/cm3= 0.99885 oz/ft3= 0.0005780 oz/in3= 0.16036 oz/gal(UK) = 0.1335 oz/gal(US liq) = 0.06243 lb/ft3= 3.6127x10-5 lb/in3= 1.6856 lb/yd3= 0.010022 lb/gal(UK) = 0.008345 lb/gal(US liq) = 0.0019403 sl/ft3= 0.0007525 ton(long)/yd3= 0.0008428 ton(short)/yd3See also density converter Example 2: Water Density in unit oz/in3Water density at temperature 20 oC is 998.21 kg/m3(table above). The density in units oz/in3 can with the converting value from above be calculated to998.21 (kg/m3) * 0.0005780 ((oz/in3)/(kg/m3)) = 0.5797 (oz/in3)Example 3: Mass of Hot WaterA tank with volume 10 m3contains hot water with temperature 190F. From the table above the density of water at 190F is 966.8 kg/m3. The total mass of the water in the tank can be calculated10 (m3) * 966.8 (kg/m3) = 9668 (kg)See also hydrostatic pressure in water and energy stored in hot water Online calculator, figures and tables showing density and specific weight of acetone at temperatures ranging from -95 to 275 C (-138 to 530 F) at atmospheric and higher pressure - Imperial and SI Units. Online calculator with figures and tables showing density and specific weight of ammonia for temperatures ranging -50 to 425 C (-50 to 800 F) at atmospheric and higher pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of argon, Ar, at varying temperature and pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of benzene, C6H6, at temperatures ranging from 5 to 325 C (42 to 620 F) at atmospheric and higher pressure - Imperial and SI Units. Online calculators, figures and tables showing density and specific weight of liquid and gaseous butane, C4H10, at varying temperature and pressure - Imperial and SI units. Online calculator, figures and tables showing density and specific weight of carbon dioxide, CO2, at temperatures ranging from -50 to 775 C (-50 to 1400 F) at atmospheric and higher pressure - Imperial and SI Units. Densities of common products - Imperial and SI-units. Online density converter with commonly used units. Density and specific volume of dry air and water vapor at temperatures ranging 225 to 900 degF (107 to 482 degC). Online calculator, figures and tables showing density and specific weight of ethane, C2H6, at varying temperature and pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of ethanol at temperatures ranging from -25 to 325 C (-10 to 620 F) at atmospheric and higher pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of ethylene, C2H4, at varying temperature and pressure - Imperial and SI Units. Diffusion flux [kg/m2s] tells how fast a substance solved in another substance flows due to concentration gradients. Diffusion constants [m2/s] for several gases in water. Thermodynamic properties of heavy water (D2O) like density, melting temperature, boiling temperature, latent heat of fusion, latent heat of evaporation, critical temperature and more. Online calculator, figures and tables showing density and specific weight of helium, He, at varying temperature and pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of hydrogen, H2, at temperatures ranging from -260 to 325 C (-435 to 620 F) at atmospheric and higher pressure - Imperial and SI Units. Depth and hydrostatic pressure. Online calculator, figures and tables with melting points of ice to water at pressures ranging from 0 to 29000 psia (0 to 2000 bara). Temperature given as C, F, K and R. Densities of common liquids like acetone, beer, oil, water and more. Densities and specific volume of liquids vs. pressure and temperature change. Mass vs. weight - the Gravity Force. Online calculator, figures and tables showing density and specific weight of methane, CH4, at temperatures ranging from -160 to 725 C (-260 to 1300 F) at atmospheric and higher pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of methanol,CH3OH, at varying temperature and pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of nitrogen, N2, at temperatures ranging from -175 to 1325 C (-280 to 2400 F) at atmospheric and higher pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of oxygen, O2, at varying temperature and pressure - Imperial and SI Units. Online calculator, figures and table showing density and specific weight of pentane, C5H12, at temperatures ranging from -130 to 325 C (-200 to 620 F) at atmospheric and higher pressure - Imperial and SI Units. Online calculator, figures and tables showing density and specific weight of propane, C3H8, at temperatures ranging from -187 to 725 C (-305 to 1300 F) at atmospheric and higher pressure - Imperial and SI Units. Seawater properties like density, saturation pressure, specific heat, electrical conductivity and absolute viscosity. Online calculator, figures and tables showing specific heat of liquid water at constant volume or constant pressure at temperatures from 0 to 360 C (32-700 F) - SI and Imperial units. Figures and tables showing thermal conductivity of water (liquid and gas phase) with varying temperature and pressure, SI and Imperial units. Density and specific weight of liquid toluene. Inclined and vertical u-tube manometers used to measure differential pressure in flow meters like pitot tubes, orifices and nozzles. Common converting units for Acceleration, Area, Density, Energy, Energy per unit mass, Force, Heat flow rate, Heat flux, Heat generation per unit volume and many more. Online calculator, figures and tables giving the boiling temperatures of water in varying vacuum, SI and Imperial units. Free online calculator - figures and tables with viscosity of water at temperatures ranging from 0 to 360C (32 to 675F) - Imperial and SI Units. Figures and tables showing the enthalpy and entropy of liquid water as function of temperature - SI and Imperial Units. Ionization constant (= dissociation constant = self-ionization constant = ion product = autoprotolysis constant) of water and heavy water, given as function of temperature (C and F) in figures and tables. Figures and tables showing how the properties of water changes along the boiling/condensation curve (vapor pressure, density, viscosity, thermal conductivity, specific heat, Prandtl number, thermal diffusivity, entropy and enthalpy). Liquid water properties at temperatures between melting point and boiling point and pressures of 14.7 psia, 1000 psia and 10000 psia (1 atm, 68.1atm and 681 atm). Figures and tables showing specific gravity of liquid water in the range of 32 to 700 F or 0 to 370C, using water density at four different temperatures as reference. Online calculator, figures and tables showing Specific Volume of water at temperatures ranging from 0-370 C and 32 - 700 F - Imperial and IS Units. Figures and tables with thermal diffusivity of liquids and gaseous water at varying temperatures and pressures - SI and Imperial units. Online calculator, figures and tables showing heat of vaporization of water, at temperatures from 0 - 370 C (32 - 700 F) - SI and Imperial units. Thermal properties of water, including density, specific heat capacity, thermal conductivity, and thermal expansion at different temperatures. Online calculator, figures and tables with water saturation (vapor) pressure at temperatures ranging 0 to 370 C (32 to 700F) - in Imperial and SI Units. Critical point is where vapor and liquid are indistinguishable and triple point is where ice, water and vapor coexist in thermodynamic equilibrium.Rudyard Kiplings short stories, novels, and poetry have established him as one of the premier authors of his generation. He was the first English writer to win the Nobel prize in literature, and remains the youngest ever to do so. As a child, one of my favorite characters from the Jungle Book was the story of Kotick, the white seal. Kotick had problems learning to swim at first, but later was able to glide easily around the icy waters in the Alaskan Bering Sea. Kipling wrote of the fish, walruses, sea lions, and killer whales that also inhabit the area. These creatures he wrote of so fondly owe their existence to a most peculiar property of water.Sea Lion: Matthew HullThermal Expansion of WaterMost solids and liquids expand with rising temperature. Water, the most common and most important liquid on Earth, has a limitation on this expansion. Ice water that is at a temperature of 0oC or 32oF will contract when it is heated. This contraction continues until after an increase beyond 4oC or 39.2oF. Then water that continues to be heated will finally begin to expand like other liquids until it reaches a gaseous state.At 4oC water has its smallest volume and also its greatest density. Water that is below 0oC has a larger volume and a smaller density. Therefore the reason why ice floats in your cup of soda is because ice is less dense or weighs less than water. This is also the reason why your water pipes may burst in the winter if you are not careful - the water inside increases in volume and weight as it cools from 4 to 0oCelsius.Why Should We Be Thankful for this Property?If not for this peculiar property, water in deep bodies such as ponds and lakes and oceans would begin freezing from the bottom up, eventually becoming completely frozen as the ice would never melt. As it is, water freezes from the top down; water that is very cold turns to ice and floats, leaving its warmer, still liquid form below. Normally for deep water, the thin layer of ice that does form on the top behaves as an insulator in that it slows down the rate of heat leaving the water beneath. This behavior of water coupled with temporary winters means deep waters rarely become completely frozen. This why life can exist in water even in artic climes.Resources Share copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. We observe thermal expansion every time we use a simple liquid-filled thermometer: Changing the temperature of a material changes its density and thus its volume. In a thermometer this forces the liquid to expand into a narrow tube, which is calibrated to show us the temperature. The same property applies to larger systemslike the water in the oceanand is one of the principal concerns of climate change. There is a coefficient of thermal expansion that is unique to each material that determines how much the material will change volume when heated. In this activity we calculate the coefficient of thermal expansion for tap water.Students will heat water in a long-necked glass bottle to explore the relationship between temperature and volume of water. Quantifying the initial volume, change in volume, and the initial and final temperatures allows students to calculate the coefficient of thermal expansion for tap water.6-8, 9-12, 13-14This activity can be completed by students from grades 8-14. The calculation requires the use of intro-level algebra, although younger students can perform the experiment non-quantitatively.Students willset up and conduct a quantitative experimentmeasure and record changes in a simple systemuse algebraic manipulation of their own data to calculate the coefficient of thermal expansion for waterexplore the relationship between temperature and volume changes in a liquid, and apply their experimental results to real-world systemsIn School: This is a lab activity. Ideally students will work in small groups although if the availability of equipment constrains group size, the experiment can be done as a class demonstration.Virtual Lab: With access to a few basic tools this activity can be done in a remote learning environment using a YouTube video for guidance. This activity requires one or two lab periods; the experiment itself will take one period, while discussion and analysis will require an additional class period.NGSS:Planning and Carrying Out InvestigationAnalyzing and Interpreting DataPS1.A: Structure & Properties of MatterESS3.C: Human Impacts on Earth SystemsESS3.D: Global Climate ChangeScale, Proportion & QuantityEnergy & MatterDr. Alexandra MoorePaleontological Research Institution, 1259 Trumansburg Rd., Ithaca NY 14850moore@priweb.orgDownload the Instructor Handout & Student Handout.The Instructor Handout duplicates all the content of the Student Handout, with additional context and directions for setting up and running the experiment.Set up and run the experiment yourself first, to gauge the range of behavior your students are likely to encounter. If you are limited by time or equipment for example not enough hot plates for students to work in small groups, or short class periods you can have one experimental set-up (saving time if youve set it up ahead) and have each team work independently with the group data. Decide what type of additional activities (if any) you would like the class to pursue.Materials (duplicate this list for each student group)Hot plate, stove top, or similar, to heat a pan of waterLong-necked bottle (ex: soda, wine)Graduated cylinder/beaker/measuring cup, to measure volume of water in bottleSmall grad cylinder/beaker/measuring cup to measure volume changeLarge beaker or sauce pan, to keep bottle from direct contact with stove/hot plateThermometer metal-stem digital kitchen thermometer or digital aquarium thermometerMasking tapeCalculator or computer spread sheetInstructionsThis experiment asks students to heat water in a bottle, a process that forces the warm water to expand into the bottle neck. Students measure the temperature change and volume change of the water, and use these values to calculate the coefficient of thermal expansion for tap water at room temperature. Once students have gained this expertise they can apply their knowledge to larger and more important systems; notably the projected sea level rise due to warming of the global oceans.When a material is heated, its change in volume is proportional to the amount of material present and to the change in temperature. That idea can be expressed mathematically:Here the constant of proportionality is the coefficient of thermal expansion, commonly designated with the Greek letter (sometimes), and with units of K, or per degree. The initial volume is designated V, the volume change is V, and the temperature change is T.[Note: this is a nice example that supports math literacy in that the verbal description of the concept translates directly word-for-word to the mathematical expression.]The step-by-step instructions for setting up the experiment are given in the teacher and student handouts.Students will add a known volume of water to the long-necked bottleenough to bring the water level to the bottom of the narrow neck. A thermometer is inserted into the bottle, and students mark the initial water level on the bottle and record the initial temperature. The bottle is placed in a larger heat-resistant water-filled container (to keep the bottle from direct contact with the heating element and prevent breakage) and the entire system is heated through a temperature change of ca. 40C (this will take approximately 10-20 minutes, depending on the power of the heating element). Students record the final temperature and remove the bottle from the water bath to mark the final volume on the bottle neck. At this point students will design a protocol for measuring the change in volume. Since they began with cold/room temperature water they will need to re-measure the new volume with water at the initial temperature, not the final warmer temperature. One method is to empty the warm water and re-fill the bottle to the new volume mark with cold water, then pour the new volume of water into a beaker/graduated cylinder, subtract the new volume from the initial volume to find the volume change. Data can be recorded on a table like the one below. Note that the boxes with green shading are those that require a calculation whereas unshaded boxes are direct measurements.SolutionThe coefficient of thermal expansion for water in this experiment should be ~0.0004/C. The coefficient of thermal expansion is not a universal constant. It varies as a function of the materials that we might examine, and for each material the coefficient varies as a function of the ambient temperature and pressure. For example, the coefficient of thermal expansion of the iron in the Eiffel Tower is different from that of fresh water, and the coefficient of thermal expansion is different for fresh water and for salt water.Photo: The Eiffel Tower in Paris is taller in the summer than in the winter due to the thermal expansion of its iron structure. Typical annual temperature variations cause the tower to increase in height by about 15 cm (6) in the summer as opposed to winter. Also, because the sun shines on one side at a time, the sunny side also expands with respect to the three shady sides, causing the tower to tilt, so that the summit actually moves in a circle (diameter ~15 cm) in opposition to the movement of the sun over the course of a day. (The temperature variation for the volumetric coefficient of expansion for fresh water and sea water is shown in the table below:Clearly thermal expansion is a sensitive parameterand it might seem like a messy quantity to introduce to studentsbut it is also a critically important one. And because it is so important, materials scientists and engineers have worked for centuries to figure out expansion coefficients for every possible material in every possible environment; thus these are quantities that we know very well. A walk across any bridge should reveal the expansion joints engineered into the construction to accommodate seasonal and diurnal temperature changes, and the expansion gaps between the steel rails on a railroad track give rise to the characteristic clickety-clack sound of moving trains. Thermal expansion in the built environment is all around us, even if we dont think a lot about it.Thermal expansion in the natural environment is equally important, and in the 21st century the thermal expansion of sea water is a parameter that will impact millions of people globally. More on that below.Tips & TricksSafety first. In the video I heated the water to 70C, which is scalding hot. The experiment will work just as well at lower temperatures. 50C = 120F, which is a safer temperature for inattentive students. Since both the temperature change and the initial volume of the water determine the amount of volume change, using a larger bottlea wine bottle as opposed to a soda bottlewill produce a larger and more visible increase in volume, especially if you choose to heat the water less. A digital thermometer is always easier to read than an analog thermometer. In this experiment the thermometer itself takes up some of the volume of the bottle, so it is important to make sure that the initial volume and final volume are recorded under the same conditions either with the thermometer in, or out, of the bottle. An aquarium thermometer is ideal for this experiment as it is easy to use with the bottle and has a big easily-read display.To calculate the coefficient of thermal expansion from the equation given here requires a simple algebraic manipulation. For students who do not have this background the equation can be re-arranged ahead. If students wish to compare their result with published values for the coefficient of thermal expansion they will need to consider the temperature range over which they heated the water, since changes as a function of temperature. For example, if the water was heated from 20 to 60C, the appropriate temperature to compare to is the midpoint of that range, 40C, where =0.000385.One final consideration; engineers tabulate the coefficients of thermal expansion for both volume expansion and linear expansion (ex: a piece of steel re-bar experiences mostly linear expansion). In this instance we are measuring the volumetric expansion of water, even though we will think about consequences such as sea level rise, which is a linear measurement. More below.Take it Beyond the ClassroomIn this experiment we use a very small volume of water and heat it over a very large temperature range. In the natural world it is more common for a large volume of water to be heated over a very small temperature range. The goal of this experiment is to give students experience with the concept of thermal expansion so that they can consider systems that are beyond their ability to measure directly. The most important such system is the change in volume of ocean water in response to changes in global temperature.In its 2021 Assessment Report (IPCC AR6) the Intergovernmental Panel on Climate Change presented five climate change scenarios, each based on a range of assumptions about anthropogenic greenhouse gas emissions over the next century. The scenarios range from very-low and low emissions through intermediate, high, and very high emissions. Each set of greenhouse gas emissions drives a temperature increase and subsequent sea level increase (along with other outcomes not discussed here, but which can be found in the AR6 Report.We can select representative temperature increases for sea water and use an appropriate coefficient of thermal expansion for the ocean to calculate the contribution to sea level rise from the thermal expansion of sea water. The calculation for a 0.2C increase in the temperature of the ocean is shown in the figure below. When projecting global sea level rise, thermal expansion accounts for just under half of the rise, while water inputs from melting ice caps and glaciers is a little more than half. So the results in the table above represent total sea level increases from 0.26-0.50 meters, ca. 1-2 feet. These results are well-aligned with the IPCC scenarios shown in the figure below. Additional discussion of climate, oceans and ice is found in the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.Figure: Results of three emissions scenarios from the IPCC Special Report on the Ocean and Cryosphere in a Changing ClimateWhy does this matter? The sea level rise projections might appear to be small, but they are in fact significant, for several reasons:Low-lying coastal zones are home to nearly one billion peopleThe impact of severe storms is exacerbated by higher sea levelsSea level rise is not uniform everywhere. Ocean currents distribute heat unevenly, causing a larger rise in some regions. Similarly, some land surfaces are gradually subsiding (ex. delta regions) and are more vulnerable to rising sea levelRising sea level contaminates ground water supplies with salt water and kills salt-intolerant coastal vegetationRising sea level impacts storm drains and wastewater systems in coastal urban areasRising sea level exacerbates normal high tide impacts, especially seasonal king tides, and recurrent El Nino eventsHundreds of millions of people will be displaced by even small increases in global sea level(References: Climate.gov Climate Change: Sea Level and IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, Summary for Policymakers) On the Atlantic and Gulf coasts of the US sea level is increasing everywhere. The tide gauge in the US capitol, Washington DC, shows an increase of over a foot of sea level rise in the last century, which had led to daily flooding around several national monuments.Click here for data from the Washington DC tide gauge. Temperature (C)Volume Expansion (relative to 0C)01.0000101.0021201.0043301.0064401.0086501.0107601.0129701.0150801.0172901.01931001.0215 Water thermal expansion is a fascinating and crucial phenomenon that impacts numerous aspects of our world, from everyday plumbing to global climate patterns. This guide will explore the intricacies of waters thermal expansion, its unique properties, and its wide-ranging implications. Thermal expansion is the tendency of matter to change in volume in response to a change in temperature. For most substances, an increase in temperature leads to an expansion in volume. However, water exhibits some unique behaviors that set it apart from other materials. Waters thermal expansion properties are exceptional and play a vital role in many natural and engineered systems: Density anomaly:Unlike most substances, water reaches its maximum density at 4C (39.2F), not at its freezing point3.This phenomenon is known as the density anomaly or negative thermal expansion. Non-linear expansion:Waters thermal expansion is not linear, meaning its rate of expansion changes with temperature. Expansion upon freezing:Water is one of the few substances that expands when it freezes, which has significant implications for life on Earth. To understand waters thermal expansion, we need to look at its molecular structure and behavior: Water molecules consist of one oxygen atom covalently bonded to two hydrogen atoms. The bent shape of the molecule and the uneven distribution of electrons create a polar molecule with a slight negative charge on the oxygen side and a slight positive charge on the hydrogen side. The polarity of water molecules allows them to form hydrogen bonds with each other. These bonds are responsible for many of waters unique properties, including its thermal expansion behavior. At low temperatures, water molecules form clusters held together by hydrogen bonds3.As temperature decreases, these clusters grow larger, increasing the space between molecules. This phenomenon is responsible for waters expansion as it approaches its freezing point. Waters density anomaly is perhaps its most intriguing thermal property: As water cools from room temperature, it contracts (like most substances) until it reaches 4C. Below 4C, water begins to expand as it cools further. At 0C, water freezes and expands significantly (about 9% by volume). This behavior is crucial for life on Earth. Its why ice floats on water and why lakes freeze from the top down, allowing aquatic life to survive in the liquid water below3. The volumetric thermal expansion of water can be calculated using the following formula:V = VTWhere: V is the change in volume is the coefficient of volumetric expansion V is the original volume T is the change in temperature However, its important to note that waters coefficient of thermal expansion () is not constant and varies with temperature2.For seawater at average ocean temperatures (around 17C), is approximately 2.23 10/C2. Waters thermal expansion behavior can be divided into three main temperature ranges: 0C to 4C:In this range, water exhibits negative thermal expansion, contracting as it warms. 4C to 100C:Above 4C, water expands as it warms, with the rate of expansion increasing at higher temperatures. Below 0C (ice):Ice has a different coefficient of thermal expansion than liquid water and expands slightly when heated. Waters unique thermal expansion properties have far-reaching consequences: As global temperatures rise, the thermal expansion of seawater contributes significantly to sea level rise. Even small temperature increases can result in substantial volume increases when considering the vast volume of the worlds oceans2. In residential and commercial plumbing, water thermal expansion in closed systems can lead to increased pressure, potentially causing damage to pipes, fixtures, and water heaters4.Expansion tanks are often used to accommodate this expansion and prevent pressure buildup. The density anomaly of water allows lakes and ponds to freeze from the top down, preserving liquid water underneath where aquatic life can survive winter3. Waters thermal properties play a crucial role in global heat distribution and weather patterns. The high heat capacity and expansion properties of water make oceans a significant factor in regulating Earths climate. Many industrial processes must account for waters thermal expansion, particularly in cooling systems, steam generation, and hydraulic systems. Understanding and managing waters thermal expansion is crucial in various applications: Expansion Tanks:These devices provide space for expanded water in closed systems, preventing pressure buildup. Pressure Relief Valves:These safety devices release excess pressure if it builds up beyond safe levels. Pipe Layout:Proper pipe layout can accommodate some expansion and contraction.Coastal Infrastructure:Designs must account for thermal expansion of seawater and resulting sea level changes. Offshore Structures:Thermal expansion of water can affect buoyancy and structural loads. Accurate representation of waters thermal expansion is crucial in climate models for predicting sea level rise and ocean circulation patterns. To put waters thermal expansion into context, lets compare it with other common substances: MaterialCoefficient of Volumetric Expansion (per C)Water (20C)207 10Ethanol750 10Mercury180 10Copper51 10Steel36 10 Note that waters coefficient varies significantly with temperature, unlike most other substances. Above its critical point (374C and 218 atm), water becomes supercritical and exhibits different thermal expansion behavior. This has implications for certain industrial processes and geological phenomena. Recent research has shown that water confined in nanoscale spaces can exhibit different thermal expansion properties than bulk water, which has implications for nanotechnology and biological systems. At very low temperatures, quantum effects begin to influence waters thermal expansion, leading to interesting phenomena that are still being studied by physicists. Accurate measurement of waters thermal expansion is crucial for scientific and engineering applications. Common methods include: Dilatometry:Uses precision instruments to measure volume changes with temperature. Interferometry:Employs laser interference patterns to detect minute dimensional changes. Density Measurements:Precise density measurements at different temperatures can be used to calculate thermal expansion. Ongoing research into waters thermal expansion properties is focusing on several areas: Improved Climate Models:Better understanding and modeling of ocean thermal expansion for more accurate climate predictions. Nanoscale Behavior:Exploring how water behaves in extremely confined spaces, relevant to nanotechnology and biological systems. Novel Materials:Developing materials that mimic or counteract waters thermal expansion properties for specific applications. Extreme Conditions:Studying waters behavior under extreme temperatures and pressures, relevant to geological and industrial processes. Waters thermal expansion properties are truly remarkable and play a crucial role in shaping our world. From the survival of aquatic life in frozen lakes to the rising sea levels affecting coastal communities, the implications of this seemingly simple phenomenon are vast and varied.Understanding waters thermal expansion is essential for a wide range of fields, including: Environmental science and climate studies Engineering and construction Plumbing and hydraulic systems Oceanography and marine biology Industrial processes and energy production As we continue to face challenges related to climate change, water management, and sustainable development, the importance of comprehending and accounting for waters unique thermal properties only grows. Whether youre a scientist, engineer, policymaker, or simply a curious individual, having a solid grasp of water thermal expansion provides valuable insights into the workings of our planet and the systems we build upon it. By appreciating the complexities and consequences of waters thermal expansion, we can better design our infrastructure, manage our resources, and prepare for the changes our warming world will bring. As research in this field progresses, we may uncover new applications and solutions that leverage this fundamental property of one of Earths most precious resources.

What is thermal expansion of water. Expansion water. Thermal expansion water pressure increase. Thermal expansion coefficient water.