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A primary source is one that has not been transformed or converted before use by the consumer. Example: coal burnt in a furnace to convert chemical PE into internal energy of the surrounding. A secondary source is energy that results from the transformation of a primary source. Example: electricity. Renewable energy source Non-renewable energy source Can be replenished in a relatively short time (human lifetime), or continually generated Can be replaced only over very long geological times Biomass, solar, wind, hydro (water), geothermal Coal, oil, natural gas, nuclear Our world in data - energy use Specific energy and energy density Specific energy is the number of joules that can be released by each kilogram of the fuel. Energy density is the number of joules that can be released from 1m3 of fuel. Energy density and specific energy table Sankey diagram The Sankey diagram is a visual representation of the flow of energy in a device or a process. Each energy source is represented by an arrow. The width of the arrow is proportional to how much energy it represents. Power stations Nuclear power plants A nuclear reactor is driven by the splitting of atoms, a process called fission, where a particle (a neutron) is fired at an atom, which then fissions into two smaller atoms and some additional neutrons. Some of the neutrons that are released then hit other atoms, causing them to fission too and release more neutrons. This is called a chain reaction.The fissioning of atoms in the chain reaction also releases a large amount of energy as heat. The generated heat is removed from the reactor by a circulating fluid, typically water. This heat can then be used to generate steam, which drives turbines for electricity production. In order to ensure the nuclear reaction takes place at the right speed, reactors have systems that accelerate, slow or shut down the nuclear reaction, and the heat it produces. This is normally done with control rods, which typically are made out of neutron-absorbing materials such as silver and boron. (World Nuclear Assosiation) Safety issues The reactor vessel is made of thick steel to withstand the high temperature and pressure. This also absorbs alpha and beta radiation. The vessel is encased in layers of concrete that absorbs neutrons and gamma rays. Nuclear reactor simulator Why Chernobyl exploded? (optional) Inside The Tunnels That Will Store Nuclear Waste For 100,000 Years (optional) Wind generators Kinetic energy of the air arriving at the turbine in one second: \begin{gather}P =\frac{1}{2} \rho Av^{3}\\\rho =density\ of\ air,\ A=blade\ area,\ v=speed\ of\ the\ wind otag\end{gather} The maximum theoretical power: \begin{gather} P=\frac{1}{2} \rho \pi r^{2} v^{3}\\ \rho =density\ of\ air,\ A=blade\ area,\ v=speed\ of\ the\ wind,\ r=blade\ radius otag \end{gather} Advantages Disadvantages No energy cost Variable output on a daily or seasonal basis No chemical pollution Site availability can be limited in some countries Cost can be high but reduce with economies of scale Noise pollution Easy to maintain on land Visual pollution How do Wind Turbines work? Pumped storage sources use gravitational potential energy of water held at a level above a reservoir is converted to electrical energy, as the water falls to the lower level. Maximum power from water: \begin{gather} P=\frac{m}{t} g\Delta h=\left(\frac{V}{t} \rho \right) g\Delta h\\ m=mass\ to\ move\ through\ generator,\ t=time\ taken,\ g=gravitational\ constant otag\\ h=height,\ V=volume\ of\ the\ water,\ \rho =density\ of\ the\ liquid otag \end{gather} World's Largest Batteries - (Pumped Storage) In a solar heating system, a collector (made up of flat-plate PV panels) collects solar energy from the sun. The air or water (or antifreeze) inside a pipe gets warmed up by the heat transferred by the collector. This heat is either carried directly to the interior space by a pump or a venting mechanism, or is stored in a storage system. Solar water heating history (optional) Solar photovoltaic panels The photovoltaic materials in the panel convert electromagnetic energy from the Sun into electrical energy. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity. (NASA) Power converted by the panel: \begin{gather} P=\eta IA\\ \eta =efficiency,\ I=intensity\ of\ radiation,\ A=area otag \end{gather} How do Solar cells work? Written explanation from NASA Thermal conduction is the diffusion of thermal energy (heat) within one material or between materials in contact. The higher temperature object has molecules with more kinetic energy; collisions between molecules distributions this kinetic energy until an object has the same thermal energy throughout. Convection is heat transfer by mass motion of a fluid such as air or water when the heated fluid is caused to move away from the source of heat, carrying energy with it. Convection above a hot surface occurs because hot air expands, becomes less dense, and rises (see Ideal Gas Law). Hot water is likewise less dense than cold water and rises, causing convection currents which transport energy. Thermal radiation is the transfer of energy by means of electromagnetic radiation. Radiation does not need a medium to propagate. It can travel through a vacuum, as it is a wave. Heat transfer video explanation Solving the heat equation (optional) Black-body radiation Intensity: \begin{gather}I=\frac{P}{A}\\I=intensity,\ P=power,\ A=area otag\end{gather} All objects with a temperature above absolute zero (0 K, -273.15 oC) emit energy in the form of electromagnetic radiation. A blackbody is a theoretical or model body which absorbs all radiation falling on it, reflecting or transmitting none. It is a hypothetical object which is a perfect absorber and a perfect emitter of radiation over all wavelengths. Wien's displacement law: \begin{gather} \lambda _{max} =\frac{b}{T}\\ \lambda _{max} =the\ wavelenght\ at\ which\ the\ intensity\ is\ maximum,\ T=absolute\ temperature otag\\ b=Wien's\ constant\ \left(2.9x10^{-3} mK\right) otag \end{gather} Stefan-Boltzmann law: \begin{gather} P=e\sigma A\left(T^{4} -T^{4}_{C}\right)\\ P=radiated\ power,\ A=radiating\ area,\ T=temperature\ of\ radiator otag\\ T_{C} =temperature\ of\ surroundings,\ \sigma =Stefan's\ constant\ \left(5.6703x10^{-8}\right) otag\\ e=emissivity\ of\ the\ object\ (e\ =\ 1\ for\ ideal\ radiator) otag \end{gather} In practice objects can be close to a black-body in behaviour, but not quite 100% perfect. These are called grey bodies. Emissivity: \begin{equation} e=\frac{power\ emitted\ by\ a\ radiating\ object}{power\ emitted\ by\ a\ black-body\ with\ the\ same\ proportions\ at\ the\ same\ temperature} \end{equation} Blackbody Radiation and the Ultraviolet Catastrophe The amount of energy that arrives at the top of the atmosphere is the solar constant. The solar constant is approximately 1366 Wm-2. Albedo When the energy from the sun arrives at ground level, some of it will get reflected by the Earth's surface, as the planet is not a black-body. The extent to which a surface can reflect is albedo (a). \begin{equation} a=\frac{energy\ reflected\ by\ the\ surface}{total\ energy\ incident\ on\ the\ surface} \end{equation} The average annual albedo for the Earth's surface is 0.35, thus 35% of the Sun ray's are reflected back into the atmosphere. The greenhouse effect and temperature balance The greenhouse effect is a process that occurs when gases in Earth's atmosphere trap the Sun's heat. This process makes Earth much warmer than it would be without an atmosphere. The "natural" greenhouse effect is due to the naturally occuring levels of gases. The enhanced greenhouse effect, in which increased concentration of gases, a result of human industrial processes, increases the Earth's average temperature. The energies of infra-red photons are much smaller than those of UV, and are not sufficient to break a molecule apart. When the frequency of a photon matches a vibrational state of a greenhouse gas molecule, then resonance occurs. Each vibrational mode of the CO2 has a characteristic frequency. If the frequency of the radiation matches this, then the molecule will vibrate. Global warming chain reaction: Ice and snow covers at the poles melt with increased temperature, which decreases albedo, which increases the rate at which heat is absorbed by the surface. A higher water temperature, reduces the extent to which CO2 is dissolved in seawater, which increases its presence in the atmosphere and therefore increases the heat absorbed by it. Global Warming 101 13 Misconceptions About Global Warming (recommended) The energy balance of the Earth Interactive energy balance (oversimplification) Number of correct answers: One or more of the following disciplines may be involved in solving a particular thermal engineering problem:ThermodynamicsA knowledge ofthermodynamicsis essential tonuclear engineers, who deal withnuclear power reactors. Thermodynamicsis the science that deals with energy production, storage, transfer and conversion. It studies the effects ofwork,heatandenergy on a system. Thermodynamicsis both a branch ofphysicsand anengineering science.The physicistis normally interested in gaining afundamental understandingof the physical and chemical behavior of fixed quantities of matter at rest and uses the laws of thermodynamics to relate the properties of matter.Engineersare generally interested in studyingenergy systemsand how they interact with their surroundings. Our goal here will be to introducethermodynamics as the energy conversion science, to introduce some of the fundamental concepts and definitions that are used in the study ofengineering thermodynamics. These fundamental concepts and definitions will be further applied to energy systems and finally tothermalornuclear power plants.Fluid MechanicsCFD numerical simulation Source: CFD development group hzdr.deFluid mechanics is the branch of thermal engineering concerned with the mechanics of fluids (liquids, gases, and plasmas) and the forces on them. It can be divided into fluid statics, the study of fluids at rest; and fluid dynamics. Fluid dynamicsis a subdiscipline offluid mechanics that deals with fluid flow.Fluid dynamicsis one of the most important of all areas of physics. Life as we know it would not exist without fluids, and without the behavior that fluids exhibit. The air we breathe and the water we drink (and which makes up most of our body mass) are fluids. Fluid dynamics has a wide range of applications, including calculating forces and moments on aircraft (aerodynamics), determining the mass flow rate of water through pipelines (hydrodynamics).Fluid dynamicsis an important part of most industrial processes; especially those involving thetransfer of heat.In nuclear reactorsthe heat removal from thereactor coreis accomplished by passing a liquid or gaseous coolant through the core and through other regions where heat is generated. The nature and operation of the coolant system is one of the most important considerations in the design of a nuclear reactor.Heat Transfer and Mass TransferHeat transfer is an engineering discipline that concerns the generation, use, conversion, and exchange of heat (thermal energy) between physical systems.In power engineering it determines key parameters and materials of heat exchangers. Heat transfer is usually classified into various mechanisms, such as:Heat Conduction.Heat conduction, also called diffusion, occurs within a body or between two bodies in contact. It is the direct microscopic exchange of kinetic energy of particles through the boundary between two systems. When an object is at a different temperature from another body or its surroundingsHeat Convection.Heat convection depends on motion of mass from one region of space to another. Heat convection occurs when bulk flow of a fluid (gas or liquid) carries heat along with the flow of matter in the fluid.Thermal Radiation.Radiation is heat transfer by electromagnetic radiation, such as sunshine, with no need for matter to be present in the space between bodies.In engineering, the term convective heat transfer is used to describe the combined effects of conduction and fluid flow. At this point, we have to add a new mechanism, which is known as advection (the transport of a substance by bulk motion). From the thermodynamic point of view, heat flows into a fluid by diffusion to increase its energy, the fluid then transfers (advects) this increased internal energy (not heat) from one location to another, and this is then followed by a second thermal interaction which transfers heat to a second body or system, again by diffusion. See the guide for this topic.1.1 Measurements in physics Fundamental SI unitsQuantitySI unitSymbolMassKilogramkgDistanceMetermTimeSecondsElectric currentAmpereAAmount of substanceMolemolTemperatureKelvinKDerived units are combinations of fundamental units. Some examples are:m/s (Unit for velocity)N (kg*m/s^2) (Unit for force)J (kg*m^2/s^2) (Unit for energy) In scientific notation, values are written in the form a*10^n, where a is a number within 1 and 10 and n is any integer. Some examples are:The speed of light is 300000000 (m/s). In scientific notation, this is expressed as 3*10^8A centimeter (cm) is 1/100 of ameter (m). In scientific notation, one cm is expressed as 1*10^-2 m.Metric multipliersPrefixAbbreviationValuepetaP10^15teraT10^12gigaG10^9megaM10^6kilok10^3hectoh10^2decada10^1decid10^-1centic10^-2millim10^-3micro10^-6nanon10^-9picop10^-12femtof10^-15 For a certain value, all figures are significant,except:Leading zerosTrailing zeros if this value does not have a decimal point, for example:12300 has 3 significant figures. The two trailing zeros are not significant.012300 has 5 significantfigures. The two leading zeros are not significant. The two trailing zeros are significant.When multiplying or dividing numbers, the number of significant figures of the result value should not exceed the least precise value of the calculation.The number of significant figures in any answer should be consistent with the number of significant figures of the given data in the question.FYIIn multiplication/division, give the answer to the lowest significant figure (S.F.).In addition/subtraction, give the answer to the lowest decimal place (D.P.). Orders of magnitude are given in powers of 10, likewise those given in the scientific notation section previously.Orders of magnitude are used to compare the size of physical data.DistanceMagnitude (m)Order of magnitudeDiameter of the observable universe10^2626Diameter of the Milky Way galaxy10^2121Diameter of the Solar System10^1313Distance to the Sun10^1111Radius of the Earth10^77Diameter of a hydrogen atom10^-1010Diameter of a nucleus10^-1515Diameter of a proton10^-1515MassMagnitude (kg)Order of magnitudeThe universe10^5353The Milky Way galaxy10^4141The Sun10^3030The Earth10^2424A hydrogen atom10^-27-27An electron10^-30-30TimeMagnitude (s)Order of magnitudeAge of the universe10^1717One year10^77One day10^55An hour10^33Period of heartheart10^00 Estimations are usually made to the nearest power of 10. Some examples are given in the tables in the orders of magnitude section.1.2 Uncertainties and errors Random errorSystematic error Caused by fluctuations in measurements centered around the true value (spread). Can be reduced by averaging over repeated measurements. Not caused by bias. Caused by fixed shifts in measurements away from the true value. Cannot be reduced by averaging over repeated measurements. Caused by bias.Examples: Fluctuations in room temperature The noise in circuits Human errorExamples: Equipment calibration error such as the zero offset error Incorrect method of measurement Physical measurements are sometimes expressed in the form xx. For example, 101 would mean a range from 9 to 11 for the measurement.Absolute uncertaintyxFractional uncertaintyx /xPercentage uncertaintyx/x*100%Calculating with uncertaintiesAddition/Subtractiony=aby=a+b (sum of absolute uncertainties)Multiplication/Divisiony=a*b or y=a/by/y=a/a+b/b (sum of fractional uncertainties)Powery=a^ny/y=|n|a/a (|n| times fractional uncertainty) Error bars are bars on graphs which indicate uncertainties. They can be horizontal or vertical with the total length of two absolute uncertainties. Line of best fit: The straight line drawn on a graph so that the average distance between the data points and the line is minimized.Maximum/Minimum line: The two lines with maximum possible slope and minimum possible slope given that they both pass through all the error bars.The uncertainty in the intercepts of a straight line graph: The difference between the intercepts of the line of best fit and the maximum/minimum line.The uncertainty in the gradient: The difference between the gradients of the line of best fit and the maximum/minimum line.1.3 Vectors and scalars ScalarVectorA quantity which is defined by its magnitude only.A quantity which is defined by both is magnitude and direction.Examples: Distance Speed Time EnergyExamples: Displacement Velocity Acceleration Force Vector addition and subtraction can be done by the parallelogram method or the head to tail method. Vectors that form a closed polygon (cycle) add up to zero.When resolving vectors in two directions, vectors can be resolved into a pair of perpendicular components.FYIThe relationship between two sets of data can be determined graphically.RelationshipType of GraphSlopey-intercepty=mx+cy against xmcy=kx^nlogy against logxnlogky=kx^n+c with n giveny against x^nkc The study of thermal physics covers macroscopic (whole systems) and microscopic (particles) processes. After studying this topic, you should be able to: Discussevidence for the atomic natureof materials Distinguishbetween temperature and heat Describe the relationship between heat added and temperatureincrease Understand whythe temperature of water doesn't change when itboils Recallthe gas lawsand their associated experiments Explain theuses of a pV diagram Suggest whereenergy goes when work is done against friction Key questions What are the main points in kinetic theory? Atoms and molecules are types of particle and are the smallest parts of matter.In this topic we will usually assume that the atoms or molecules are uncharged and do not interact,like a large number of very small perfectly elastic balls. Find out more. What is the relationship between temperature and heat? If two thermodynamic systems are each in thermal equilibrium with a third, then they are in thermal equilibrium with each other.In practical terms, temperature is the concentration of heat energy in a body. It dictates the overall direction in which heat energy will transfer (from hot to cold). Find out more. What is latent heat? The specific latent heat is the amount of heat required to change the state of one kilogram of asubstance. Find out more. What are the gas laws? Boyle's law states that the pressure of a fixed mass of gas at constant temperature is inversely proportional to its volume. The Pressure law states that the pressure of a fixed mass of gas with constant volume is directly proportional to its absolute temperature (in Kelvin).Charles' law states that the volume of a fixed mass of gas at a constant pressure is directly proportional to its temperature in Kelvin.Find out more. How do you draw a pV diagram? P,VandTcan be plotted on a 3-Dgraph.In practice, however,we draw justpandVwith the different temperaturesrepresented by isotherms. Find out more. To understand what happens to the energy we transfer to a body when we do work against friction we need to look inside the body.Because there are no forces between gas molecules, the gaseous state is the simplest to model. Internal Energy: The sum of the kinetic energy and potential energy of the molecules in a body. Temperature: The average kinetic energy of all particles. Heat: The transfer of internal energy Specific heat capacity (c): The heat required to raise 1 kg of a substance by one degree (K). Specific latent heat (L): The amount of heat required to change the state of 1kg of a substance without change in temperature. There are two types: fusion and vaporization Laws The pressure of a fixed mass of a gas at constant temperature in inversely proportional to its value. V=P Pressure law The pressure of a fixed mass of a gas with constant volume is directly proportional to its temperature. Heat transfer Name What it is What medium Examples Conduction When the molecules at one end of a solid object are given energy, they vibrate more. This disturbs the neighbouring molecules and passing the energy along. Conduction transfers energy through solid or liquid materials. Metals are usually the best conductor and plastics the best insulators. Heat will travel slowly through a pot on a stove. Convection The transfer of heat energy via liquid or gas.When heated a fluid expands marking it less dense, causing it to rise in the surrounding denser cooler fluid. Convection transfers energy through fluids such as gases and liquids. This is seen msot often in air or water. Radiator heats room by heating up the air. Radiation Direct transfer from one body to another via infrared radiation. Bodies of darker color both radiate and absorb the best. Radiation does not require any medium, unlike confuction and convection. Due to this, it is the only way to transfer heat in a vaccuum such as space. The sun emits radiation which heats up our planet. Specific heat capacity Acrynym:SHC Defintion: Amount of energy (joules) required to raise 1kg of a substance by one degree (Kelvin or Celcius) Symbol:c Si Unit:J/kgKor J/kgC Caclulating thermal energy changes Formula:Et=mct The change in thermal energy is equal to mass times specific heat capacity times by change in temperature. Example question and answer Jacob has 1500g of water which is at 17C . How much heat must he add in kj, for the water to begin to boil. The specific heat capacity of water is 4.2 kj/kgC. Answer: First pull out the values needed from the question: Change temperature = 100-17= 83C Mass = 1500g = 1.5kg SHC = 4.2 kj/gC. (The question asks for kj, so no need to convert to j) Then put into formula: Et=4.2*1.5*83Et=522.9kj What does the SHC tell us about the material? Specific heat capacity Meaning Insulator/conductor Examples