Zeroth law of thermodynamics

- thermal equilibrium
  - two systems are in thermal equilibrium if they have the same temp
- if system C is in thermal equilibrium with both system A & B, then systems A & B are also in thermal equilibrium with each other

Heat (SI: J)

- energy transfer that takes place solely because of a difference in temp is called heat flow/transfer
  - the energy itself that is transferred is HEAT
- better unit: calorie
  - 1 cal is the amount of heat required to raise the temp of 1g of water by 1°C
  - 1 kcal = 4186 J
  - 1 cal = 4.186 J
  - 1 kcal = 1 food cal = 1 Cal = 1000 cal
- specific heat (c)
  - amount of heat needed to raise the temp of 1kg of a material by 1°C or 1K
  - $C_{water} = 4190\ J/kg°C$
- $Q = mc\Delta T$
  - amount of heat Q needed to raise a temp from T_i to T_f
  - c = specific heat
  - $m_A c_A \Delta T_A = m_B c_B \Delta T_B$
    - used when 2 objects are in contact
    - energy gained by one object = energy lost by the other

Phase changes

- phase change is the change in the state of matter without altering its chemical composition
- terms
  - sublimation: solid to gas
    - ie. dried ice
  - condensation: gas to liquid
    - this is how distilled water is made
  - vaporization: liquid to gas
    - evaporation is the spontaneous change from liquid to gas since microscopic particles are at 100°C & get turned into water vapor
  - deposition: gas to solid
- $Q = \pm mL$
  - L = latent heat
    - amount of heat needed to change the phase of a specific amount of a substance
- L_f = latent heat of fusion = amount of heat needed to change phase from solid to liquid or vice versa
- L_v = latent heat of vaporization = amount of heat needed to change phase from liquid to gas or vice versa
- $L_{water} = 3.34 \times 10^5\ J/kg = 79.6\ cal/g$
- $L_{water} = 2.25 \times 10^6\ J/kg = 539\ cal/g$

Mechanisms of heat transfer

- conduction
  - heat transfer that occurs within a body or between 2 bodies in contact
- convection
  - heat transfer that depends on the motion of mass from one region to another
- radiation
  - heat transfer by electromagnetic radiation

Equations of state

- an equation which gives the relationship between pressure, volume, temp, & amount of the substance
- molar mass
  - 1 mole is the amount of a substance where it has exactly 6.022×10^{23} molecules inside of it
  - $n = m/M$
    - n = number of moles in a substance, m = mass in grams
    - M = molar mass ($^{mol}/_{g}$)
    - ATOMIC MASS = MOLAR MASS
    - ex.) having exactly 12.011 g of carbon means having 6.022×10^{23} atoms of carbon (AKA 1 mole of carbon)
- ideal gas equations
  - in an ideal gas, the molecules are so far apart that they don't interact with each other; they only interact with the wall
  - in real gases, the molecules interact with each other but are still far apart
  - $pV = nRT$
    - p = pressure
    - V = volume
    - n = number of moles
    - R = ideal gas constant = $8.314\ ^{J}/_{mol \cdot K}$
    - T = temperature in kelvin
  - $^{P_1V_1}/_{T_1} = {}^{P_2V_2}/_{T_2}$
    - equation for constant mass in a system

Thermodynamic processes

- processes where you change T, P, or V of the gas or ± heat to a particular gas
- adiabatic process
  - no heat is transferred
  - ex.) squeezing a balloon decreases V & increases p without ± heat
- isobaric process
  - process where pressure remains constant
  - ex.) heating up a balloon increases T & V, but P is constant
- isochoric process
  - process where volume remains constant
  - ex.) heating up gas tank makes V want to grow but it can't so P grows & could cause tank to explode
- isothermal process
  - process where temp remains constant
  - ex.) phase changes

The laws of thermodynamics

- (1) conservation of energy
  - the total energy of an isolated system is constant
  - if not acted upon by an external force, mass is also constant
- (2) entropy always increases
  - entropy is a quantitative measure of disorder or unpredictability
  - the entropy of an isolated system will always increase
    - if nothing is done to an isolated system, it will spontaneously go to thermal equilibrium which is a state of max entropy
    - an isolated system tends to be chaotic
- (3) entropy is 0 at absolute 0
  - the entropy of a system approaches its smallest value when the temp approaches absolute zero
  - absolute zero = 0K (impossible to reach)

Earths energy budget

- NOTION

Waves

- disturbance travelling in both space & time that transfers energy from one point to another without transporting matter
  - a disturbance is a change in a material that travels in space & time
- mechanical wave (physical wave)
  - wave created by the propagation of a deformation/disturbance within a physical object
  - ex.) sound waves, water ripples
- electromagnetic wave (physical wave)
  - wave formed by the propagation of varrying intensities of electromagnetic radiation
  - ex.) light waves
- wavelength is the distance between successive parts of the wave
- amplitude is from top to middle
- crest is highest point
- trough is lowest point

Period and frequency

- period is the time to complete 1 wavelength
- frequency is the number of wave cycles completed in a given amount of time
- $f = 1/T$

Wave motion

- transverse waves oscillate perpendicular to the direction of propagation
- longitudinal waves oscillate parallel to the direction of propagation
- $v = \lambda f$
  - v = wave speed
  - λ = wavelength
  - f = frequency

Interference

- occurs when waves overlap
- principle of superposition of waves
  - displacement adds at every point where they overlap
- constructive interference
  - when amplitude increases after waves collide (reinforcement)
- destructive interference
  - when amplitude decreases after collision (cancellation)
- waves are "in phase" when there is constructive interference

Standing waves

- product of wave interference of a wave & a reflected wave of the same frequency & amplitude (incident vs reflected wave)
- nodes are the points that dont move due to destructive interference
- antinodes are points that move maximally up & down due to constructive interference

Doppler effect

- the phenomenon when waves are compressed & drawn out when the source of the wave is moving at high speeds

Bow waves & shock waves

- bow waves
  - created when an object such as a boat on water travels as fast or faster than the wave it produces
  - there is constructive interference at the edges
- shock waves
  - similar to a bow wave but the overlapping waves are spheres instead of circles
  - a sonic boom is a loud bang produced when the source of the shock wave moves faster than sound
    - produces cone shaped pattern shock wave similar to V-shaped bow wave

Optics (electromagnetic wave)

- branch of physics which deals with the behavior of light & other electromagnetic waves
  - light itself is a category of electromagnetic waves that we can see
  - any object of temp > 0K emits infrared radiation
- light has both particle & wave properties, AKA wave-particle duality

Light as a wave

- the wave property of light is used to describe the propagation of light through a medium
  - since it is a wave, it exhibits properties like interference which was observed in young's double slit experiment

Light as a particle

- the particle property of light is used to describe the emission & absorption of light
- particles of light are called photons
- photoelectric effect
  - photons can knock away electrons from an atom if it has the exact amount of discrete energy

Light in a medium

↳ the speed of light in a vacuum is the maximum speed limit of anything (AKA universal speed limit)

↳ $c = 3.00 \times 10^8$ m/s

↳ light slows down when it travels through a medium

↳ $n = c/v$

↳ n = index of refraction, $n \geq 1$

↳ c = speed of light in a vacuum

↳ v = speed of light in the medium

↳ $n_{vacuum} \approx 1$

Color

↳ the perception of the human eye of visible light of varying wavelengths or frequencies

↳ different colors = diff frequencies & wavelengths

↳ $c = \lambda f$

↳ c = constant speed of light

↳ the higher the frequency = the higher the energy

↳ visible light

↳ red: 625-700 nm, 430-480 THz

↳ violet: 400-430 nm, 670-750 THz

Reflection

↳ reflection occurs when light bounces off the boundary between the mediums through which it passes

↳ in a mirror, most of the light is reflected to you

↳ law of reflection

↳ states that the angle of incidence is equal to the angle of reflection

↳ $\theta_i = \theta_o$ 

↳ periscope is a tube with mirrors that lets submarines see above water

Refraction

↳ refraction occurs when light travels from one medium to another with a different index of refraction, which bends the light

snells law / law of refraction

↳ describes relationship between the incident angle & incident medium index of refraction with refracted angle & outgoing medium index of refraction

↳ $n_i \sin\theta_i = n_o \sin\theta_o$

Total internal reflection

↳ phenomenon where all light is reflected when trying to pass from a medium with a higher index of refraction to a medium with a lower one ($n_i > n_o$)

↳ occurs at an incident critical where $\theta_o = 90°$

↳ TIR occurs at all $\theta_i \geq$ critical angle

Electromagnetism

↳ some sign charges repel each other

↳ atoms

↳ composed of 3 particles: electron (e^-), proton (p^+), & neutron (n^0)

↳ electron has charge $-e$, proton has charge $+e$

↳ $e = 1.602 \times 10^{-19} C$

↳ if a material is negatively charged, electrons from another object must've transferred to it

↳ **conductors** are materials that enable electrons or charges to freely pass through

↳ **insulators** are materials that do not permit electrons to pass through

↳ induced charge

↳ charging by induction is the process of producing net charge without actual contact between objects

↳ electric polarization is the phenomenon where positive & negatively charged particles shift in response to an electrical field

Coulombs law

↳ describes the amount of force applied by one charged particle on another

↳ $F = k\frac{|q_1 q_2|}{r^2}$

↳ $k = 8.988 \times 10^9\ N^{m^2}/_{C^2}$

↳ q_1 = charge in charged particle q_1

↳ q_2 = charge in charged particle q_2

↳ r = distance between particles

Electric field

↳ region where a charge experiences an electric force within that field

↳ the electric force on a charged body is exerted by the electric field created by other charged bodies

↳ the field produced by a charged body can only produce force on other charged particles, not on itself

isolated + charge

isolated - charge

↳ the **field lines** show the direction of the force exerted by the field of a **positively charged particle**

Electric potential (SI: V)

↳ potential energy per unit charge of a charged particle

↳ equipotential lines are regions where same charge would have the same amount of potential energy throughout the region

↳ voltage is the difference in potential between 2 points

↳ a positive charge always moves from a high potential to a low potential region

↳ a negative charge does the opposite

↳ electromotive force (emf) in a battery pushes the charges from the negative to the positive terminal to maintain current

Ohms law

↳ $V = IR$

↳ I = current; amount of charge passing through a point per unit time; (SI: A/ampere)

↳ R = resistance; property of a material to resist current; (SI: ohm/Ω)

↳ concerned with the relationship between the 3 in a **component** of a circuit

Circuit components & diagrams

- conductor with negligible resistance: ——————
- resistor: ——/\/\/\——
- source of emf: ——+ | V——
- voltmeter: ——(V)——
- ammeter: ——(A)——

Series & parallel circuits

- R_{eq} in series = $R_1 + R_2 + R_3$
- R_{eq} in parallel: $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3$