Measurements and Mathematics

* Units
  + A standard quantity that’s compared against in measurements
  + SI system
    - Fundamental
      * Length - meter (m), use a metric ruler
      * Mass - kilogram (kg), use a balance
      * Time - second (s), use a stopwatch
      * Electrical current - ampere (A)
      * Temperature - kelvin (K)
      * Amount of substance - mole (mol)
      * Luminous intensity - candela (cd)
    - Derived
      * Derived from combining multiple fundamental units
      * Frequency - hertz (Hz)
        + s-1
      * Force - newton (N), use a spring scale
        + mkgs-2
      * Energy - joule (J)
        + kgm2s-2
      * Electric charge - coulomb (C)
        + sA
      * Electric potential - volt (V)
        + m2kgs-3A-1
      * Power - watt (W)
        + m2kgs-3
      * Electrical resistance - ohm (Ω)
        + m2kgs-3A-2
      * Resistivity - ohm ⋅ meter (Ω⋅m)
        + kgs-1m3C-2
  + Units symbols in normal type
  + Quantities in formulas are in italic type
    - *t*: time (s)
    - *d*: displacement (m)
    - *F*: force (N)
    - *m*: mass (kg)
  + Dimensional analysis
    - Keep units when adding/subtracting/multiplying/dividing (basically, treat them as variables)
    - Only add/subtract when units are the same
    - When dividing, units can be simplified out (vertically + cross)
    - When multiplying, units can turn exponential when multiplied to the same unit
* Trigonometry
  + Sine (sin):
  + Cosine (cos):
  + Tangent (tan):
  + Pythagorean theorem: a2 + b2 = c2
* Uncertainty
  + Precise: an instrument is precise when it outputs very close measurements when measuring the same item
  + Accurate: an instrument is accurate when it outputs a measurement that’s very close to the accepted measurement
  + Significant figures
    - Keeps numbers accurate by indicating to which place value accuracy is guaranteed up to
    - Significant:
      * Nonzeros
      * Zeros between nonzeros
      * Trailing zeros if there’s a decimal
    - Not significant:
      * Leading zeros
      * Trailing zeros when there’s no decimal
    - adding/subtracting: Round answer at the place where the number with fewest significant figures after decimal ends the number
    - multiplying/dividing: Round answer to have the number of figures as in the number with the least significant figures
    - Propagation of error: When rounding 5, only round up when the previous digit is odd
* Scientific notation
  + A \* 10n, where A is a number [1, 10) and n is number of places to move the decimal (positive: to right, negative: to left)
  + add/subtract: Make the power of 10 terms have the same exponent, then add/subtract the non-power of 10 terms. Finally, readjust if necessary
  + Multiply/divide: Multiply/divide the non-power of 10 terms, then multiply/divide the power of 10 terms. Finally, readjust if necessary
* Data analysis
  + Range: the difference between the smallest and largest value
  + Mean: average
    - , where xi is the ith data point and fi is the number of occurrences of the ith data point
  + Variance:
  + Population standard deviation:
    - Normal distribution: 68% of data fall within 1 of the mean, 95% within 2 of the mean and 99.7% within 3 of the mean
* Percent error:
* Graphs
  + Independent variable: the factor that the experiment changes.
  + Dependent variable: the factor that changes due to the independent variable.
  + Axis are labeled their quantity and unit in parenthesis.
  + Title: dependent variable vs independent variable
  + Slope:
  + Relationships
    - Directly proportional: an increase in a quantity causes the other to increase
    - Inversely proportional: an increase in a quantity causes the other to decrease
    - Direct squared proportion: an increase in a quantity causes the other to have a squared increase
    - Inverse squared proportion: an increase in a quantity causes the other to have a squared decrease
* Vector quantity: has a magnitude (size: distance, time) and direction
* Scalar quantity: has only a magnitude
* Algebra
  + Axioms
    - If equals are added to equals, the sums are equal
    - If equals are subtracted from equals, the remainders are equal
    - If equals are multiplied by equals, the products are equal
    - If equals are divided by equals, the quotients are equal
    - A quantity may be substituted for its equal
    - Like powers or like roots of equals are equal
  + Order of operation
    - Parenthesis
    - Exponents
    - Multiplication/division
    - Addition/subtraction
* Linearization of graphs
  + Write an equation to model the existing graph
  + Manipulate the equation into y = mx + b (something equals something times something plus something; doesn’t have to be first degree terms)
  + Determine what the y and x would be
  + Graph that on the respective axis

Kinematics

* Distance: scalar quantity of length of the path traveled
* Displacement: vector quantity based on the net change in position
  + One dimensional: xf - xi where f is final, i is initial. Sign indicates direction
    - Linear motion: object changes position along a straight line
    - By convention, right is positive
    - Position-time graph
      * The x-axis is time, the y-axis is the position
      * Slope is velocity
    - Dot diagrams
      * Dots are drawn representing position at regular time intervals
      * If position didn’t change during the interval, stack the dot
      * Arrows are drawn to show the magnitude of the velocity
      * Number line labeled with position numbers
      * Arrows drawn above arrows to show the magnitude of acceleration
      * If dots are drawn at regular distance intervals and not time: change in velocity and time between intervals decreases as interval count increases. Acceleration makes objects fall faster, so less time passed between intervals. Less time passed between interval means less acceleration time, which means less change in velocity
  + Two dimensional (no air resistance)
    - Motion can be split into horizontal and vertical components, correlated only by time
    - Horizontal
      * No acceleration; velocity is constant
    - Vertical
      * Acceleration by gravity is always constant. Velocity is 0 at max point
      * Max point is a line of symmetry for velocities and time
    - Projectile launched at an angle
      * Y = asinx , where a is the launch velocity, x is angle of launch and y is vertical velocity
      * y=acosx, where a is the launch velocity, x is angle of launch, and y is the horizontal velocity
      * At 90 degrees, time of flight and max height are at max
    - Range: distance from launch to land
      * The range for an angle of projection is equal to the range of a projection of the complementary angle
      * Range is longest when angle of launch is 45 degrees
    - Projectile: object launched at an angle
    - Trajectory: path of projectile
* Velocity: is a vector quantity, average velocity is where *x* is displacement and *t* is time
  + Instantaneous velocity: the speed at a specific point
    - Calculate by finding velocity over a very small time frame that includes the point in question
    - Or can calculate by finding the slope of that point on a position-time graph
  + Velocity-time graph
    - time is x-axis, velocity is the y-axis
    - Slope is acceleration
    - The area under the curve is displacement
  + Relative velocity: from different reference frames, the perceived velocity of an object is different
    - The reference frame object is said to be at rest, while everything else is moving in relationship to the object at rest
    - If an object is moving in something and the reference is outside, the object inside has velocity of the thing it’s in plus its own velocity
    - If an object is moving in something and the reference is inside, the object inside has velocity of only itself
    - If the reference is moving towards something, then that something is moving towards the reference
    - If the reference is moving away from something, then that something is moving away from the reference
* Speed: is a scalar quantity, the average speed is where d is the distance
  + Uniform motion: constant speed
  + The average speed where acceleration is constant:
* Acceleration: vector quantity, average acceleration is
  + Acceleration of gravity (g): -9.81 m/s2
  + Free fall: object in motion only affected by gravity
* Formulas derived from velocity/speed and constant acceleration
  + Since and , so , then
  + Since and , so and , then
  + Since and , so and , then , then ,
* Kinematic variables: *x, v, a, t*
* Inertial reference frames
  + Kinematics should only be done in inertial reference frames
  + In inertial reference frames, both the observer and object being observed are governed by physical laws the same way
  + The easiest way to check is to determine if Newton’s 1st law holds true in that reference frame. It states that an object’s state of motion can’t be altered unless acted on by an unbalanced force. Make sure that everything observed follows this: every change in motion can be explained by an unbalanced force

Dynamics

* Concurrent forces-vector addition
  + 2+ forces affect an object at the same time
  + Resultant: the net force resulting from combining the concurrent forces
  + If 2 concurrent forces form an angle of 0o (same direction): *F*1+*F*2 and direction is the same as the vector components
  + If 2 concurrent forces form an angle of 180o (opposite direction): *F*1-*F*2 and direction is based on the vector component with the greater distance
  + If 2 concurrent forces form an angle between 0o and 180o
    - Triangle method
      * Keep one vector, but take the other and translate it so its tail is on the other vector’s head. Do not alter the direction
      * Vector drawn from object to head of the last vector to be translated is the resultant
    - Parallelogram method
      * Translate one vector so that its tail is on the other vector’s tail, do not alter the direction
      * Complete the parallelogram so that opposite sides are parallel
      * Vector drawn from object to opposite vertex of the parallelogram is resultant
    - Resolution of forces
      * To find the vectors components of resultant
      * Graphical method
        + Put the object on the origin and do not alter the resultant direction
        + One of the vector components is from the resultant head perpendicularly down to x-axis, the direction pointed as close as possible to resultant’s general direction
        + The other vector component is from the resultant head perpendicularly across to the y-axis, the direction pointed as close as possible to resultant’s general direction
      * Trigonomical method
        + Draw a perfectly horizontal line that meets the tail of resultant
        + The vector component that runs perfectly vertical is , where *A* is the force of the resultant and is the angle the resultant makes with the perfectly horizontal line. Direction points closest to the resultant’s general direction
        + The vector component that runs perfectly horizontal is . Direction points closest to the resultant’s general direction
      * When a vector is subtracted, it means to add the vector with opposite direction
* Force
  + Accelerates a mass
  + A push or pull that may change the motion of an object
  + Newton: the force required to make 1 kg accelerate 1 m/s2
  + balanced: when the net force is 0
  + Free Body diagram
    - sketch that shows all forces acting concurrently on an object
    - Arrows shows magnitude and direction of a force
    - Label of forces: Fentity receiving force, entity giving force
    - Circle the system. System is object receiving force, and environment outside the circle provides the forces
    - Mark Newton third law force pairs with “x”
  + No change in motion along an axis if forces on that axis are of equal magnitude and opposite direction
  + Gravity always exert a downwards force (from Earth)
  + Mass: amount of matter in an object
  + Weight: force of gravity
  + Normal force: a push exerted to prevent an object from passing through another. Also known as apparent weight. Measured by a scale
    - Normal means perpendicular, perp to the surface
  + Tension: a pull exerted by an object onto another through a string or a scale
    - Strings and scales have negligible mass, so they are considered to not receive or exert any force
    - Scales can also measure pulling force using its hook
      * The measured force is force of the attached object when force at the other end of the scale is of an equal magnitude to the force of the attached object
      * Otherwise, applied force is added to the measurement
  + Vertical and horizontal components of diagonal forces are independent, solvable by trig functions
* Newton’s First Law/Law of Inertia: An object maintains a state of equilibrium (constant velocity) unless acted upon by an unbalanced force (resulting in nonzero net force)
  + Inertia: object’s resistance to change in motion. Increases as mass increases
* Newton’s Second Law: when an unbalanced force acts on an object, the object accelerates in the same direction as the force
  + , where F is force and m is mass
* Newton’s Third Law: When an object exerts a force on a second object, the second object exerts a force of equal magnitude and opposite direction on the first object
* Systems
  + Dynamic systems
    - Scenario: a line of boxes being dragged together
    - Masses accelerate uniformly
    - Adding together the free body diagrams of each mass results in the free body diagram of the whole system
    - Force exerted on one mass isn’t necessarily applied to the other masses
  + Static equilibrium
    - Scenario: 2 strings hanging from the ceiling, makes angle with ceiling, meeting at a point that has a string connected to a mass. Net force of 0
    - Horizontal force from both strings are of equal magnitude
    - Vertical forces of both string sum to vertical force of mass
    - A string has less vertical tension if its angle with the ceiling is greater
  + Changing normal force
    - Normal force increases (add to FN of when was at rest) with positive acceleration
    - Normal force decreases (subtract from FN of when was at rest) with negative acceleration
    - ma = FN - Fg, and Fg, m remains constant
    - FN = Fg when object has 0 acceleration
  + Modified atwood machine
    - Draw the free body diagrams for both objects. Then, rotate the diagram for the hanging mass, so that both diagrams accelerate in the same direction. Then, treat as a dynamic system
    - Acceleration is maximized when hanging mass is greatest possible mass
    - Tension is maximized when hanging mass is equal to cart mass
  + Atwood machine
    - Draw the free body diagrams for both objects. Then, rotate them so that it’s like straightening out the string. Then, treat as a dynamic system
  + Masses on an incline
    - Force of gravity can be resolved into a component parallel to the incline, and another perpendicular to the incline
    - Force of gravity in the direction of the masses movement is mgsinx, where m is mass, g is gravity and x is angle of incline
    - Force of gravity perpendicular to the incline, is mgcosx, where m is mass, g is gravity and x is angle of incline
* Friction
  + Force that opposes the relative motion of 2 objects in contact
  + Is parallel to the 2 surfaces in contact
  + Acts in the direction opposite of the slipping motion
  + Coefficient of friction ()
    - ratio of frictional force to normal force, based on the 2 materials in contact
    - Coefficient of static friction is greater than of kinetic friction
  + Static friction
    - Opposes the start of motion
    - Equals applied force, but in opposite direction
    - Increases as applied force increases, until it reaches max static friction ()
  + Kinetic friction
    - Once it reaches max static friction, object starts moving and friction decreases down to a constant kinetic friction
  + Fluid friction: friction from moving through a fluid such as air
* Hooke’s law
  + , where is force applied, k is the spring constant and is the compression or elongation of a spring (m)
  + In a graph where force is the y-axis and change in length is the x-axis, the slope is k.
  + Larger k means stronger spring
  + K is the amount of force necessary to elongate by 1 m

Circular Motion and Gravitation

* When force is applied on a moving object and the force is perpendicular to the object’s motion, only the direction of the velocity changes (creating an acceleration), its magnitude is the same
* If the force in the previous bullet (but of sufficient magnitude) is constantly applied, the object moves in a circular path
* Tangential velocity: velocity of an object in circular motion at a given moment. Is straight and perpendicular to the centripetal acceleration
* Uniform circular motion: tangential velocity remains constant in magnitude
* Since the direction of the tangential velocity changes, there’s an acceleration
* Based on vector addition, this acceleration is towards the center of the circle (centripetal acceleration)
* This acceleration is , where v is tangential velocity and r is the radius of the circle
* This acceleration is caused by centripetal force (any type of force that causes circular motion)
* Newton’s Universal Law of Gravitation
  + Every mass in the universe attract each other with a force of gravitational attraction
  + Gravitational force , where G is the universal gravitational constant (6.67\*10-11 Nm2kg-2), m’s are the masses of the 2 objects, and r is the distance between the centers of the 2 objects in meter
  + The gravitational force that m1 and m2 exerts on each other are equal in magnitude and opposite in direction
  + Set that formula equal to m2ag, where m1 is the mass of the planet and r is height from center to solve for ag acceleration due to gravity
  + Gravitational force between a mass and an object orbiting that mass is the centripetal force
  + Technically, Earth orbits around another center of mass, so the moon doesn’t orbit the Earth. But we disregard this, as by doing so, it’s a close enough approximation
* Gravitational field
  + Space around every mass where a particle experiences a gravitational force
  + Mapped using a unit test mass and analyzing its vector
  + Direction of vectors from unit test mass are directed towards the center of the subject, and magnitude increase as unit mass gets closer to the center of subject
    - Vectors connected vertically is a field line
    - Magnitude decreases as distance increase following the inverse square law
    - There is a linear positive trend for when below a planet's surface
  + Gravitational field strength (g, a vector quantity): acceleration of unit mass due to gravity (since units are N/kg, which simplifies out to v/t2).
    - For short distances near Earth’s surface, g is constant for all masses (9.81 m/s2), but varies by crust composition
    - Describes gravitational force experienced per unit mass

Momentum

* Momentum (*p*), a vector quantity , describes how hard something moves
* Impulse (*J*): vector quantity, change in momentum
  + Is also the area under the curve of a force vs time graph
  + Is also a force applied over a period of time
* In a closed system (a group of objects that has no net external force (sum the force diagrams for each mass to check)), due to Newton’s 3rd law, objects exerting 3rd law internal force pairs will have impulses of equal magnitude and opposite direction
  + F1,2=-F2,1 internal 3rd law force pair
  + = m1a1=-m2a2
  + =
  + Since same time frame
  + =
    - Law of conservation of momentum: In a closed system, due to Newton’s 3rd law, the momentum in the system will remain the same
  + Since ,
* Since (Newton’s 2nd law) and ,
* In an open system, the net force of the system adds an impulse(Ft) to the system
* Due to J=Ft, a collision that last longer delivers less average impact force
* Momentum before + impulse = momentum after

Work and Energy

* Energy (*E*): ability to do work, a scalar quantity in ~~Juuls~~ Joules
  + Thermal: heat, total kinetic energy of an individual particle of an object
  + Chemical
  + Nuclear
  + Electromagnetic: associated with electric or magnetic fields (ex: light, microwave, radio)
    - Photocell: converts light to electricity
    - Motor: converts electricity to mechanical energy
    - Battery: converts chemical, thermal, nuclear or light energy to electricity
  + Sound
  + Nuclear: released from nuclear fission
  + Mechanical: energy that can change motion
    - Potential: energy possessed due to position or condition
      * Gravitational potential energy (Ug) is equal to the work done against gravity to lift an object, KE it can potentially fall back down with
        + *F* = *Fg,* and , so since , then if displacement is change in height ,
        + It’s a conservative force, meaning it’s path-independent: no matter what path an object took to reach that height, Ug is still the same

Increasing one decreases the other, K<->Ug convert

* + - * + Between 2 objects: -Gm1m2/d
      * Elastic potential energy is stored in a spring when compressed or elongated like my [redacted]
        + If increases uniformly, its average would be . Since work is , and ,
      * Electrical potential energy (learn more in the next unit)
    - Kinetic(K): energy of motion
    - Internal (Q): heat energy from friction
* Work (*W*): change in kinetic energy, J, scalar
  + F is net force, d is displacement, and is the angle between the the direction of motion and direction of net force
  + Positive work increases KE, negative work decreases KE
  + Positive work means work is in the same direction as displacement
  + Negative work means work is in the opposite direction of displacement
  + Work-energy theorem: net work = change in KE
* Power (*P*): scalar quantity, rate of which work is done:
  + Since , and , so , then , **∴**
* Energy flow
  + if the objects of the system are only affected by conservative forces within its system (law of conservation)
    - Conservative forces involves reversible conversions between KE and PE, and work done by these forces are path independent
  + Work done by forces from the environment and nonconservative forces =
  + Diagrams
    - Left side is a bar graph that shows amount of K, Ug and Us are initially in the system
    - Center is a circle that includes what’s in the system
    - Arrows are drawn pointing to the circle to indicate forces from environment and nonconservative forces that are working on/adding energy to the system
    - Arrows are drawn pointing away from the circle to indicate forces from environment and nonconservative forces that are working against/removing energy to the system
    - Right side is a bar graph that shows K, Ug, Us and (thermal energy - lost to friction) in the system in the end
  + Equation: initial energy + work done by nonconservative or external force = final energy

Electricity and Circuits

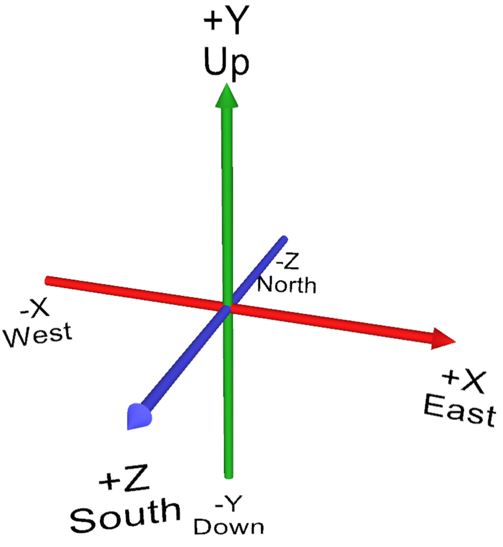
* Electrostatics
  + Study of stationary charge
  + Charges
    - Charges are like mass; mass describes how an object interacts through gravitational force, while charges describe how an object interacts through electrostatic force
    - Like charges repel and opposite charges attract
    - Charges are identified positive or negative to determine if they attract or repel, to determine the direction of electrostatic force
    - e: elementary charge
    - A proton has +e charge
    - An electron has -e charge
    - A neutron has 0e charge
    - Sum the elementary charges of the subatomic particles of a particle to get the net elementary charge of the particle
    - It is not feasible to count the number of subatomic particles in a particle, so conventionally, Coulombs (C) is used to measure charge
      * 1e = 1.6\*10-19C
      * Conversion formula: q=n(1.6\*10-19), where q is charge in C, and n is charge in e
    - Charge is quantized; meaning the number of electrons and protons a particle has is an integer, so it must have an integer value for number of elementary charges (or if in C, divisible by 1.6\*10-19)
  + Conductor
    - Material with low resistance, ideally 0
    - Ex: metals, due to sea of electrons
    - If a conductor receives a charge, the charge spreads out
  + Insulator
    - Material with high resistance, ideally infinite
    - Ex: glass, rubber, air
    - If an insulator receives a charge, the charge stays put
  + Ground
    - To send excess charge to Earth
    - Earth is good at dissipating charges
  + Charging
    - Only electrons are light enough to be transferred from particle to particle
    - When an object has a non-zero net charge, it likes to lose or gain electrons
    - Conduction
      * Electron transfer through direct physical contact
      * The 2 objects in contact ends up each having the charge equal to the average of the 2 original charges
    - Friction
      * An object with strong attraction for electrons is rubbed against an object with weak attraction for electrons
      * The object with stronger attraction will steal electrons from the other
    - Induction
      * Polarization
        + Since like charges repel, the electron cloud of one particle can be used to repel the electron cloud of the other. Since only the electrons are mobile, this would create temporary charges on the particles, causing attraction
        + The particles themselves individually are still neutral
      * One object connected to the ground. The other is placed close to the grounded object. Causes polarization, and the electrons of the grounded object ends up traveling to the ground
    - Conservation of charge: in a closed system, the charge before = the charge after
  + Electrostatic force
    - An attraction or repulsion due to charge
    - Coulomb's Law:
    - Looks like the one for gravitational force
    - Where k is the electrostatic constant (8.99\*109 Nm2/C2), q1 and q2 are the charges and r is the distance between the particles
    - Note whether the force is an attraction or repulsion to determine direction of the force
    - Force is a 3rd law force pair between the 2 objects
    - electrostatic force decreases inversely proportional to distance
    - The electrostatic force between 2 objects that are very close to each other is significantly larger than the gravitational force
    - The electrostatic force between two objects that are not very close to each other is significantly less than the gravitational force
      * Over that space, a lot of electrostatic forces cancel out each other
  + Electrostatic field
    - Field strength
      * Where E is the field strength, Feis electrostatic force and q is the charge of the object experiencing the electrostatic force
      * Describes how much electrostatic force a particle experience per C of charge it has
      * If Fe is substituted with Coulomb’s Law, , where Q is the source charge and r is the distance between source charge and particle experiencing the electrostatic force
    - Field map
      * Shows the direction of the electrostatic force a test particle would experience
        + The test particle is very light and is usually positive
      * Rules
        + Field lines point towards negative particles and away from positive particles (so opposite electron flow, since scientists used to not know that only electrons can travel)
        + Lines start perpendicular to the particle it’s coming out of
        + A greater magnitude of charge means a greater number of lines coming out of the particle
        + Lines are smooth
        + Lines never cross
        + Lines of one particle bends away from lines of a particle of a like charge
        + Lines of one particle bends towards lines of a particle of opposite charge
      * How to draw
        + Draw the source objects
        + At random locations, draw a dot to represent the test particle
        + For each dot, draw arrows to represent the direction and magnitude of the electrostatic force the test particle experiences from each source object
        + For each dot, draw the resultant from vector addition of the arrows drawn in the previous step
        + The resultant arrows are part of a path on the field map
  + Electric potential
    - A particle being in an electric field has the potential to be worked on by electrostatic force
    - In an area where electric field strength remains constant, the electrical potential energy is Fex, where Fe is the electrostatic force experienced and x is the distance the particle has the potential to travel due to Fe
    - A greater distance or a greater charge means greater electrical potential energy
    - Making charges do opposite of what it naturally does (separating opposite charges or pushing together like charges) increases electrical potential energy
    - Making charges do what it naturally does (pushing together opposite charges or separating like charges) decreases electrical potential energy
    - Since it is impractical to measure the charge in a circuit, we work with electric potential (aka voltage)
    - Voltage: electric potential energy stored per unit charge
      * Simplifies to V=Ex, where E is electrical field strength and x is the potential displacement due to Fe
      * Unit: volts
  + Batteries
    - Charged parallel plates
      * Electrical field strength is constant
      * the field map would be straight from the positive plate to the negative plate
      * A positive test particle would like to go to the negative plate
      * A positive test particle near the positive plate would have high voltage, since it’s farther from where it wants to be, and being near like charge is unnatural
      * A positive test particle near the negative plate would have low voltage, since it’s closer to where it wants to be, and being near opposite charge is natural
      * This means positive particles have a lot of potential to make it over from the positive plate to the negative plate
      * Chemicals can be used to create a wall between the positive and negative plates, forcing positive particles on the positive plate side to have to flow through a closed circuit to reach the negative plate side, which is where it wants to be, creating current
    - Electron flow is from the low voltage to high voltage terminal of battery
    - Conventional flow is the opposite direction
      * Scientists didn’t realize that positive particles are too heavy to flow until too late
* Current electricity
  + Resistance
    - Measured in Ohms
    - Measured by ohmmeter by putting one lead on each side of the resistor
    - Results from the loss of electrical potential energy due to electrons colliding with fixed atoms, leading voltage drops
    - Everything provides resistance
      * Longer wires have greater resistance because a longer path means more atoms for electrons to collide with
      * Wider wires have less resistance because like a wider hallway, there is more “freedom” for the electrons
    - Resistivity increases with temperature since more particles are excited and colliding
    - , where R is resistivity, L is length of the wire, A is the cross section area of the wire and is the resistivity constant of the wire’s material
    - Short circuit: when the voltage out of a battery equals voltage out of a battery, due to no resistance. This causes the battery to heat up, damaging the chemical wall between the positive and negative terminals, leading to shortened lifespan of the battery
      * Fuse: a wire that prevents short circuits by destroying itself when it detects too much voltage, creating an open circuit
    - A light bulb of more resistance is brighter, since more collision means more electrical potential energy being converted into light energy
  + Current
    - Measured in amps
    - Measured using an ammeter by making it part of the circuit at the location where current should be measured (current flows through it)
    - Represents the rate of which electrons flow through a cross section
    - More current through a light bulb means bulb is brighter
  + Voltage
    - Measured in volts
    - Measured using a voltmeter by putting one lead on each side of the item to read its voltage drop
    - Represents electrical potential energy per unit charge
    - A larger voltage drop across a light bulb means its brighter
  + Ohm’s Law
    - Only valid for ohmic conductors (meaning temperature stays constant)
    - V=IR
  + Circuits
    - Kirchoff current law: the current going into a junction equals the current splitting out of the junction
    - Kirchoff voltage law: the voltage drop across the resistors in a loop sums to the voltage gain by the battery
    - Series
      * One single pathway for current
      * Resistance: sum all in the loop
        + Proof:
        + There’s only one loop, so by Kirchhoff voltage law: VT=V1+V2+V3
        + By Ohm’s law, V=IR, so substitute: ITRT=I1R1+I2R2+I3R3
        + Current is constant throughout a series circuit, so cancel out the I’s: RT=R1+R2+R3
      * Current: stays the same anywhere in the loop, due to conservation, nowhere to split
      * Voltage: drops as electrons pass through resistors (Ue lost), Kirchoff voltage law
    - Parallel
      * Resistance: take the reciprocal of the sum of the reciprocals of each resistor’s resistance
        + Proof:
        + By Kirchoff current law, branches past one junction: IT=I1+I2+I3
        + By Ohm’s law, I=V/R: VT/RT=V1/R1+V2/R2+V3/R3
        + By Kirchoff voltage law, voltage drops in each branch/loop are the same since same battery: 1/RT=1/R1+1/R2+1/R3
      * Current: current splits at junctions into branches due to conservation. More splits into branches with less resistance
      * Voltage: total voltage drops in each loop are equal because Kirchoff voltage law
  + Electrical power
    - Unit of Watt
    - Rate of electrical energy being transformed into something else by a circuit
    - Since and , W=qV -> .
    - More power means light bulb is brighter
* (unit incomplete due to COVID-19)

Magnetism

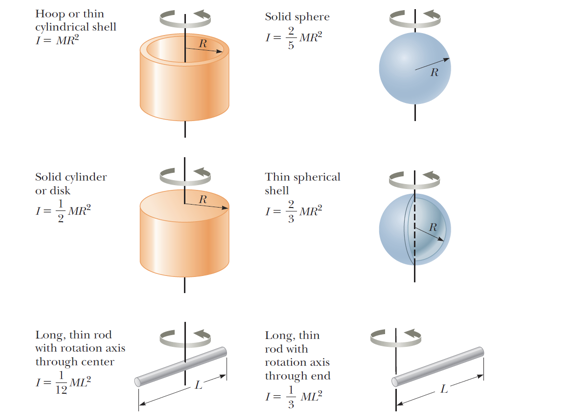
* (skipped due to COVID-19)

Torque and Rotations

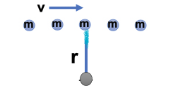
* Like how linear stuff are described in terms of meters, angular stuff are described in terms of radians
* Angular velocity: , where is angular speed, is angular displacement and t is time
  + Describes how fast something is moving in a circle
* Angular displacement is the angle in radians moved
* Radians: angle measurement in terms of number of radii in the arclength
  + , where l is length of arc and r is radius
* Angular acceleration:
* For kinematics, just take out the displacement stuffs and replace them with angle stuffs
* Conversions
  + Angular velocity (angle/time) to linear velocity (arc length/time)
    - , so
  + Angular acceleration to linear acceleration
    - , so
    - , so
  + Radial acceleration (acceleration along radius)
    - , so
* Torque
  + Like how a force causes linear acceleration, a torque creates angular acceleration
  + a twisting force that causes angular acceleration around a pivot point
  + Center of mass: summation of all the particles in a system, aka where all the mass is concentrated
    - Is the dot in a FBD
    - Center of a symmetrical system
    - Is the axis of rotation unless constrained otherwise
    - Is the point that gravitational force acts on (think: that’s where the object’s weight is)
    - Choose a reference point. COM distance from reference point = sum of (mass\*distance from reference point) for each part, divided by the sum of mass of each part
  + Units: N\*m
  + A force applied outside the axis containing the axis of rotation would cause torque
  + A greater lever arm (distance from pivot point to point of force applied) means greater torque
  + Force perpendicular to the lever arm causes torque
  + , where is torque, r is lever arm length and F is force applied on lever arm and is the angle in which that force is applied at, to get the perpendicular component of the force
  + Negative torque causes clockwise rotation, while positive torque causes counterclockwise rotation
  + Right hand thumb rule: wrap your hand around the axis of rotation so that your fingers (index to pinky) point in the direction of the applied force. The direction the thumb points is the direction of the torque. So someone looking at the same object from a different angle won’t have an argument whether it’s spinning positive or negative



* Moment of inertia
  + Like how the linear acceleration resulting from a force depends on mass, the angular acceleration resulting from a force depends on the moment of inertia
  + Mass =linear “mass”, moment of inertia = rotation “mass”
    - , where I is the moment of inertia
      * Proof:
        + Newton’s 2nd law: F=ma
        + To get torque, the force is multiplied by the length of the lever arm: rF=rma = =rma
        + a = r, as proved in the conversion section above: =rmr
        + = =r2m
        + = =I
  + Moment of inertia is related to the distribution of mass
  + Qualitatively describes how easy/hard it is to spin something, while mass is how easy/hard to move something
  + Moment of inertia increases as the more mass is distributed farther from the axis of rotation
  + Moment of inertia differs by the axis of rotation
  + I = mr2, where m is the mass and r is the distance from axis of rotation to the concentration of mass

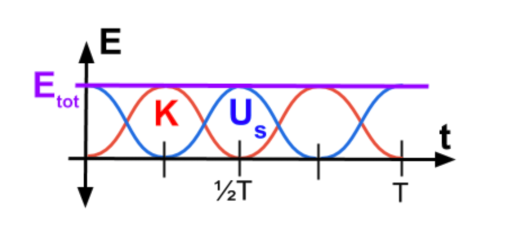


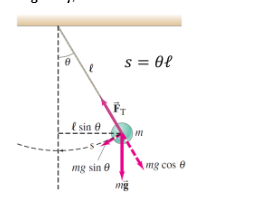
* Intermediate axis theorem
  + For objects with 3 different (meaning having different moment of inertia) axis of rotation
  + Of the 3 axes of rotations, rank them. Note the one in between. That’s the intermediate axis
  + If an object spins around it’s intermediate axis, it keeps on doing half twists while spinning
  + This is because the mass not on the intermediate axis experiences centripetal force and centrifugal force to keep them in place.
  + Then, let's say the object tilts a bit. The mass that was thought to be on the intermediate axis experiences centripetal and centrifugal forces
  + This causes tension within the spinning object, which makes the centripetal forces of the mass on the intermediate axis accelerate until the spinning object does a small flip
* Pulley problem solving
  + Get the torque of all the masses involved, so that net torque can be found
  + Find the moment of inertia caused by each mass involved. r is pulley radius
  + Net torque by everything == moment of inertia of everything in the system \* angular acceleration (whole system accelerates together)
* Momentum
  + Just like linear momentum
  + In a closed system (no net torque), momentum is conserved (momentum before = momentum after)
  + In an open system, just like how an external force applied over time causes impulse, an external torque applied over time causes a change in angular momentum () (momentum before + impulse = momentum after)
  + Scenarios
    - Figure skaters: as the skater spins, they’re not experiencing an external torque, so momentum is conserved. By pulling in their arms closer to themselves, the moment of inertia decreases, so angular velocity increases, making the skater spin faster. Spreading arms back out increases the moment of inertia, decreasing the angular velocity, allowing the skater to slow down and regain control
    - Holding a spinning wheel while on a spinning chair: In the beginning the wheel-person-chair system’s angular momentum is only the wheel’s angular momentum, since that’s the only thing rotating. If that wheel is flipped, lets say its original angular momentum was L. upside down, it’s -L. For the whole system to remain at L (original), -L +2L = L, so the spinning chair would need to spin at 2L when wheel goes -L to conserve angular momentum
    - Ski jump: once the person is about to fly off the ski jump, the person extends both arms as high as possible to shift up the person’s COM, to increase the person’s torque while in the air. That provides the person’s initial angular momentum. There are no external torques, so angular momentum is conserved. To do twists in the air, the person would bring closer only one arm, so that the person’s moment of inertia is lower on that side than the other. This causes a twist, as the different sides want to spin at different speeds.
    - Cats falling: Cat would bend its back in a V shape so that its front and back sides can rotate separately. Cat would extend its rear legs to increase moment of inertia there to slow the rotation there. The front legs would be brought closer to the body to decrease moment of inertia, so that it rotates faster there. Once the front side detects that it’s upright again, it would extend the front legs to increase the front’s moment of inertia to slow the front rotation, while bringing in the rear legs to decrease the moment of inertia in the rear to let the rear catch up. Once the body is leveled out, all legs and tail extend to increase the moment of inertia to slow the rotation and brace for impact.
  + Angular momentum of something moving in a straight line
    - For a mass moving at a straight line, it has linear momentum of p=mv
    - But it is moving in a straight line. How can it possibly have angular momentum? It’s not rotating about anything.
    - Well, let's say there exists a lever arm that rotates around an axis, and there’s a mass flying in a straight line. That mass then hits the lever arm. That lever arm will spin around the axis. That means the lever arm now has angular momentum. (IRL context: think of throwing a ball (mass) at your bedroom door (lever arm)) Where did it come from? Magic? Well, no, according to the law of conservation, that angular momentum must have come from somewhere. The only thing that the lever arm came in contact with was the mass going in a straight line. Therefore, that mass has transferred angular momentum to the lever arm, meaning the mass had angular momentum relative to that axis to begin with!
    - How to quantify angular momentum of a point mass: a derivation:
      * Angular momentum is
      * Moment of inertia (rotational “mass”) of a point mass is mr2
        + But since the mass isn’t going in a circular path, then doesn’t r change as it moves? No. Let’s define a system that only contains the lever arm. In order for it to change angular momentum, it must experience an external torque. The only part of a force that can cause torque is the component vertical to the lever arm. Therefore, r represents the distance between the axis of rotation and the point on the lever arm that would make perpendicular contact with the mass. Simply put, that is the closest distance the flying mass would ever be to the axis of rotation.



* + - * Angular velocity is also
      * Put everything together:
      * So basically the flying mass’ linear momentum \* the closest distance it would ever be to the axis of rotation = angular momentum of something going straight
  + Collisions: same thing as linear collisions: take inventory of all the initial angular momentums in the system. Add in the angular impulses. Set equal to the sum of the new angular momentums. (remember that when things stick or pop apart, recalculate their mass, er, moment of inertia)
* Kinetic energy
  + Just like how objects needs energy to slide, it needs energy to rotate too
  + Just like before, it’s just another form of energy that’s part of the whole system. If something’s both translating and rotating, system energy consists of the KE making translation, KE making rotation, and all other energies.
  + Scenario: a tic tac being dropped and bouncing to a height higher than it was dropped from
    - The amount of energy in the system is constant. If the tic tac was spinning as it was falling, its gravitational potential energy was converted into both rotational and translational kinetic energy. However, if it hits the ground in a way that generates just the right amount of torque to stop the tic tac’s rotation, then on its way up, all of its energy would go into translational kinetic energy, and not rotational kinetic energy. More translational kinetic energy on the way up means it could go higher than the height it was dropped from

Harmonics

* Period (*T*): time to complete 1 cycle/oscillation of motion, in s
  + Time it takes to return to start
* Frequency (*f*): number of periods in a unit time, in Hz
* Relationship:
* Restoring force: the force that attempts to bring a mass back to equilibrium
  + proportional to displacement, it follows F=cx model
* Simple harmonic oscillator
  + Simple means no friction
  + Harmonic means it’s cyclical
  + Oscillator is the object doing the simple harmonic motion
  + Graphing a quantity vs time produces a wave
* Quantities
  + Take this scenario: 
  + The spring is currently at its equilibrium position
  + Now, something either pulled or pressed the block, so that the spring’s length changed
  + By Hooke’s law, (F=-kx), as a result of that action, the spring is now exerting a force on the block, in attempt to get the block back to equilibrium position
  + Yay! The block eventually made it back to the equilibrium position (no force or acceleration, but greatest velocity here).
  + But wait. At equilibrium, x=0, so F from spring on block is 0. According to Newton’s 1st law, without a force, that block will still keep moving
  + Uh oh. The block kept moving and ended up changing the length of the spring again
  + F=-kx. Eventually, the spring would apply enough force to stop the momentum of the block. (max magnitude of force and acceleration, with no velocity here) Unfortunately, by the time that happens, the block won’t be at equilibrium anymore.
  + The spring has OCD (no, not really) and wants to get the block back to equilibrium again. As a result, this story would repeat itself over and over and over again. Creating an oscillation!
* Analysis
  + At the points where the spring finally got the block to stop momentarily
    - The block would be farthest from equilibrium (greatest x)
    - Hooke’s law: Fs=kx
    - This means at that point, the block is experiencing the most force
    - Newton’s 2nd law: F=ma
    - So most force means most acceleration there
    - >stopped momentarily
      * This means 0 velocity there
    - No velocity means no kinetic energy at that point
    - There’s no external work done, so energy must be conserved. When the block has no kinetic energy, that means its energy get stored in the spring as spring potential energy
  + At equilibrium
    - x=0, so no force there
    - By Newton’s 2nd law, no acceleration there
    - By the time the block reaches equilibrium, it would’ve experienced the acceleration for quite some time, so max velocity here.
    - Max here because once it passes equilibrium, by Hooke’s law, the block would begin to experience some force now, which causes impulse that takes away some momentum (which only over time would enough impulse be applied to stop motion)
      * Main takeaway: pass equilibrium point -> experience impulse -> momentum decrease so velocity decrease, so equilibrium must be max velocity
    - Max velocity means max kinetic energy at that point
    - Conservation of energy: no spring potential energy in the spring at this point
  + The block is the same distance from equilibrium at both momentary stops because conservation of energy. The amount of spring potential energy in the system in the first stop is the same as in the second stop. Since spring constant is constant, this means same displacement both times.
* Graph/equation modeling
  + Force or acceleration vs time: at one momentary stop, the force/acceleration is at max. Once it reaches equilibrium, it’s 0. Then, to the next momentary stop on the other side, the force/acceleration is at max, in the other direction. Once it reaches equilibrium, it’s 0. The next momentary stop brings us back to the first momentary stop, where the force/acceleration is at max in the same direction. Graph looks cosine!
  + Velocity vs time: at a momentary stop, velocity is 0. Then, at equilibrium, velocity is at max going one direction. Then at the next momentary stop, velocity is 0. Then, going back the other direction, at equilibrium, velocity is at max in the other direction. Then to another momentary stop, velocity is 0. Graph looks sine!
  + Position vs time: at one momentary stop, the block is as far as possible from equilibrium in that direction. Then, the block goes back to equilibrium, 0 distance from equilibrium. Then, the block goes to a momentary stop in the other direction, where its distance from equilibrium is max in the other direction. Then, the block goes back to equilibrium, 0 distance from equilibrium. Then, the block goes to the momentary stop in the first direction, at max distance in that direction. Graph looks cosine!
    - Why does this make sense? One cycle of cosine starts from max, down to min, then back to max again. It crosses 0 (equilibrium) twice. Just like one cycle of the block oscillating.
    - Modelling this graph with an equation:
      * So we know it’s cosine. Parent cosine is y=Acos(theta)
      * From rotations unit, , so
      * Plug in: (x is displacement, our output)
      * Since there’s a sinusoidal relationship between position and time, in period T, the wave would’ve gone 2pi radians. That means velocity is 2pi/T
      * Plug that in:
      * f=1/T, so
      * relates distance from equilibrium, amplitude of oscillation (max distance from equilibrium), frequency (oscillations per second) and time elapsed
  + Kinetic energy vs time
    - K=Csin2(2\*pi\*f\*t)
      * Why does this make sense? Parent sine goes above and below y=0. However, energy is a scalar quantity, so squaring sine removes direction. Therefore, the graph would look like 2 humps in one cycle.
      * The block starts at where it momentarily stops. No K there. Then, it goes to equilibrium, with max K. Then it goes to the other momentary stop, with no K. Then it goes to equilibrium, with max K. Finally, it returns to the first momentary stop location, with no K, finishing a cycle.
      * C=2m\*pi2\*f2\*A2
  + Spring potential energy vs time
    - Us=Ccos2(2\*pi\*f\*t)
      * Why does this make sense? Parent cosine goes above and below y=0. However, energy is a scalar quantity, so squaring cosine removes direction. Looks like a flipped version of sine squared
      * In a period, the block starts at its momentary stop, where it’s max U. Then, it goes to equilibrium, where there’s no U, as all of it became K. Once it reaches the second momentary stop, spring has max U. Then, back to equilibrium, for no U. Finally, to finish the period, block is back to the first momentary stop point, with max U in spring.
      * C=0.5kA2, where A=x
    - And energy is conserved!
* Horizontal oscillator
  + Like the setup I put in the story in the quantities section
  + Spring force is the restoring force
  + Period
    - Lets stretch/compress the spring x meters. If we were to then replace the block with a heavier one, the restoring force (F=kx) doesn’t change, but by F=ma, acceleration decreases. This means that a period would take longer. More mass = longer periods
    - Let's keep everything the same, but replace the spring with one that has a greater spring constant. This would increase the restoring force. (F=kx) By F=ma, this would increase the acceleration, allowing the oscillator to finish a period faster. Greater spring constant = shorter periods.
    - Equation for how long a period is
      * Circles are cyclical, so let's use a circle
      * v=x/t → t=x/v
      * In the context of a circle, x could be circumference and t could be period, or how long it took to travel a circumference
      * So, T=2pi(r/v)
      * All kinetic energy from equilibrium get converted into spring potential energy at the momentary stops, so 0.5mv2=0.5kx2
      * r in T=2pi(r/v) in trig would be the amplitude/radius, which in this scenario would be x, the stretch/compression of the spring during oscillation, so T=2pi(x/v)
      * In 0.5mv2=0.5kx2, x/v = sqrt(m/k)
      * So, the period of a horizontal oscillator is **T=2pi(sqrt(m/k))**
      * Checks out with the conceptual thoughts I mentioned above
      * Amplitude doesn’t play a role here. Greater amplitude would mean greater spring potential energy at the stops. Due to conservation of energy, the oscillator would have greater kinetic energy at equilibrium. This increase in kinetic energy increases velocity to make up for the fact that there’s more amplitude to cover
* Vertical oscillator
  + Similar to a horizontal oscillator
  + The equilibrium state for the system in this context would be when the mass is at equilibrium
    - Aka when mass hanging on a spring won’t move, which is when the mass’ weight == spring force
  + As a result, unlike the horizontal oscillator, it doesn’t always have max spring potential energy at momentary stops. Only the stop all the way on the bottom will have max spring potential energy, since no gravitational potential energy down there. The stop on the top has less, because some of it has to be given to gravitational potential energy
  + Also, at the equilibrium point of the oscillation, the spring does have spring potential energy, since it’s the mass’ equilibrium, not the spring’s. Therefore, there isn’t as much kinetic energy there as there could’ve been if it was horizontal.
* Pendulum
  + a bob (m), where all the mass is concentrated, attached to a string (l) (from pivot point to center of bob) of negligible mass
  + Like the other oscillators, but with spring potential energy replaced with gravitational potential energy
  + Equilibrium when perpendicular to the ground
    - *F*g (weight of bob) and *F*T (tension of string) are balanced at equilibrium
  + Displacement: since the bob travels in a circular path, it would be the arc length traveled by the bob. l\*theta
  + Restoring force is mgsin(theta)



Tangential to path to cause torque - rotation

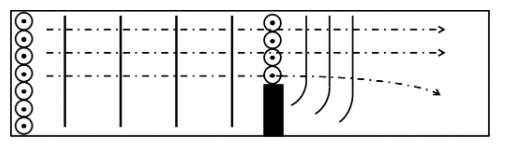
* + Amplitude (): angle created by string with equilibrium position
  + Since restoring force is proportional to displacement, F=cx → c=F/x → (mgsin(theta))/(lt\*theta)
    - Angles <15o in radians is very close to the sine of that angle (sin(theta)=theta), so, for pendulums with amplitude up to 15o, (mgsin(theta))/(lt\*theta) → (mg\*theta)/(l\*theta) → mg/l == c
  + For spring oscillators, F=kx was the restoring force, so k is the spring’s version of c. so, in , replace k with mg/l and you get...
  + Period:
    - Why does this make sense
      * Longer l means the circular path would have a longer radius, meaning a longer arc length to cover, making the period longer
      * More g means more restoring force, which would make a period shorter
      * Mass doesn’t affect the period for small amplitude pendulums. Think of dropping objects. Mass doesn’t affect when they hit the ground
      * Amplitude doesn’t affect the period. This gives more gravitational potential energy to convert into kinetic energy, meaning more velocity. Greater amplitude means more arc length to cover, but the extra velocity makes up for it

Waves and Sounds

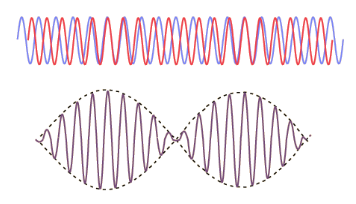
* Pulse: a disturbance, caused by net work
* Wave: pulses that causes a transfer of energy over a distance
* It’s currently accepted that nothing travels faster than light

Mechanical

* propagates (travels) through a medium that’s a matter
* Ball-spring model of matter: The particles that make up a piece of matter could be described as balls, with each ball attached to its neighboring balls using a spring. A pulse on one part of the matter would change the spring potential energy of the springs in that area. This change in energy would then transfer to a neighboring part when the previous part returns to its original state. The part that received the energy gets worked on (disturbed) by that energy until it passes the energy along to the next neighboring part, so it can return to normal, and so on.
* Transversal: particles vibrate perpendicular to the direction of the pulse travels in
* Longitudinal: particles vibrate on the same axis as the pulse’s velocity
  + Sound
    - travels at 331 m/s through the air at STP
    - Sound waves enter the ear, then get amplified by small bones. The resulting waves are passed to the cochlea, where it would disturb fluids, which will disturb hairs, and convert the sound into electrical signals for the brain.
    - Louder sounds have a greater amplitude
  + A longitudinal wave can be represented as a transverse wave by graphing density of particles vs distance from original pulse
* Waves travel faster through more rigid mediums, since particles are closer together, making it easier to transfer energy
* Amplitude (A): the amount of disturbance caused
  + The more energy the pulse, the greater the amplitude
* Crest: the high point of a transverse wave or the max density part of a longitudinal wave
* Trough: the low point of a transverse wave or the min density part of a longitudinal wave
* Wavelength (𝜆): length of a full cycle of the wave
* v=𝜆f
* Circular wavefronts
  + If the disturbance causing the wave is a single point, then the pulses travel outwards from that point in a sphere
  + 2D top view drawings only show where crests are
    - Useful for seeing wavelength, frequency, spread
  + 2D side view drawings show the crests and troughs in a cross section
    - Useful for seeing amplitude, energy
  + If multiple circular wave sources are put in a line, then the pulses along that line are canceled out
* Diffraction
  + When a wave travels through an opening, it becomes as if that opening is another circular wave source
  + The “new” wave source has the same amount of energy, but it spreads out to whatever area there is past that opening, which “weakens” the wave
  + When an object obstructs the path of a wave, it’s as if along the axis of the obstruction, there’s a line of circular wave sources, with the ones immediately next to the obstruction producing circularish wave



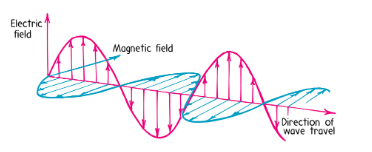
* + If the wavelength is smaller than the opening, the “new” wave doesn’t spread out as much
  + If the wavelength is greater than the opening, the “new” wave spreads out a lot
* Interference
  + Multiple waves superimposing (interacting with each other in the same place same time)
  + Constructive: when crests of multiple waves are in phase (aligned perfectly), the amplitudes add
  + Destructive
    - Partial: when a crest of a wave and a trough of another wave line up, they subtract in amplitude
    - Complete: when a crest of a wave and a trough of another wave of the same amplitude line up, they cancel each other out
      * 180° out of phase
      * This is how active noise cancelation works
  + Beats
    - When 2 waves of different frequencies interfere with each other, there will be both constructive and destructive interference, at regular intervals, creating beats



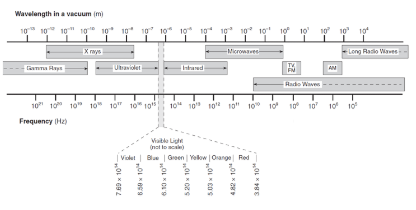
* + - The closer the 2 frequencies, the longer the beat period
* Reflection
  + Fixed end: trough becomes crest and vice versa when bouncing into the other direction
  + Loose end: trough remains trough, crest remains crest when bouncing into the other direction
  + When a wave is reflecting off of something, the wave arriving to the surface and the wave leaving the surface would interfere with each other
  + Places where such interference would lead to complete destructive interference are called nodes
  + A wave bouncing off a surface at higher velocity would cause more nodes
  + Antinode: crest between 2 nodes
  + Standing waves: a wave hitting a surface and bouncing off at constant velocity. nodes don’t move, and crests/troughs bop up and down. Looks as if there’s no horizontal movement
* Doppler
  + As the wave source gets closer to the receiver, the frequency appears to increase
  + As the wave sources gets farther from the receiver, the frequency appears to decrease
  + This is because the relative velocity and the frequency adds up
  + Uses
    - Speed radar
  + If relative velocity is greater than speed of sound, the receiver will hear a sonic boom
  + In terms of light, increasing frequency blueshifts, and decreasing frequency redshifts
* Resonance
  + String instrument
    - Plucking a string at different lengths create standing waves of different frequencies, since there would be a different number of nodes and antinodes
      * First harmonic: the longest wavelength that can fit on a string, which creates the sound of fundamental frequency
        + One antinode
      * Second harmonic: 2 antinodes, creating the sound of the first overtone
      * And so on
      * Wavelength = 2 \* string length / number of antinodes
      * Frequency = , where v is wave velocity, n is number of antinodes, L is length of string
    - Plucking a string isn’t perfect, causing other sounds to be mixed in
      * Fundamental frequency would give a note its pitch
      * Everything else gives it timbre
    - A string is thin, so it won’t be able to disturb much air to produce powerful enough sounds. It counts on the air disturbances it makes to go inside a hole in the body of the instrument. Then, once inside, it disturbs the body of the instrument, causing it to vibrate and disturb more air to create more powerful sounds (resonance)
    - Different sized bodies are better at resonating different frequencies. This means the resonance coming from inside the body would provide more constructive interference to some frequencies than other
      * Larger size is better for lower frequencies (such as bass)
      * Smaller size is better for higher frequencies (such as violin)
      * Now that’s why the same note of difference instruments sound different
  + Wind instrument
    - Don’t blow trumpets at 45° angles
    - Instead of fitting wavelengths onto a string, a wind instrument fits wavelengths into its air column
    - Open-close air columns: standing waves begin with a node, so there would be less antinodes, lower frequencies, than an open-open air column of same size
    - Open-open air columns: standing waves begin with an antinode, so there would be more antinodes, higher frequencies, than an open-close air column of the same size

Electromagnetic

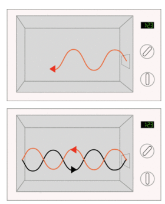
* Can travel through vacuum
* An oscillating electron generates an oscillating electric field
* This generates a magnetic field that also oscillates
* Field travels as wave



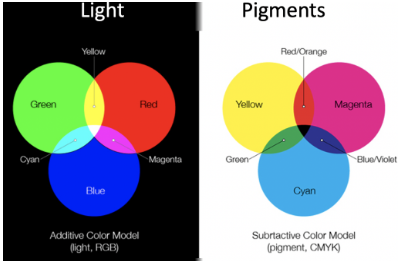
* Frequency reflects the amount of energy in the wave, since more energy means electron oscillates more
* Amplitude reflects the wave’s strength
* Spectrum
  + (not the ISP)
  + If you think 5G is giving you cancer, just know that the visible light reflecting off every object around you is about 1.25 million times more powerful than 5G. If 5G was that powerful, phones would have to be within eyesight of a cell tower to get a signal



* + Microwave
    - Weaker than visible light; your microwave isn’t gonna harm you (if you use it correctly)
    - Microwaves just happens to have the perfect frequency for dielectric heating of water
      * Water is a polar molecule
      * Water molecules attracted to the electric field of the wave
      * Whenever an antinode bops up and down, water molecules would follow suit, causing the water molecules to gain energy
    - One side of the microwave emit microwaves, which bounce off another side, creating standing waves



* + - The nodes would be the cold spots of your food are if your food wasn’t rotated. Rotation ensures that the cold spots get covered
    - To calculate the speed of light, use the nodes to find the microwave’s wavelength. Then, look up the frequency of the microwave model. Multiply them to get the speed of light
    - Looking at a microwave microwaving isn’t gonna microwave your vision. See the hole design of the microwave window? Microwaves are weaker than visible light, meaning that microwaves have a longer wavelength. Microwave wavelength is too big to fit through the hole, while visible light can. So you can see your food getting microwaved, without microwave escaping the microwave
  + Visible light
    - Color
      * Mixing color is not mixing light
        + Light is additive
        + Pigment (“color”) is subtractive



* + - * + Pigment is for things that don’t emit light

Crayons don’t emit light, so a yellow and cyan pigment mixed together would absorb all colored light except for green and reflect light with the frequency of green light

* + - * + Light is for producing light based on red, green, blue of certain intensities to trick the brain to interpret a certain color

To make light appear yellow, allow green light and red light to hit your eyes at the same time

* + - * + Basically, pigment: controlling what colors get absorbed. Light: controlling what colors hit your eyes
      * Dark mode > light mode
      * White: all the colors hitting your eyes together at once
      * Black: absence of light
      * LED bulbs tend to blend more blue in their “white”, while incandescent light tends to blend more red in their “white”
        + Screens are LED based, so light mode means shine blue light in your eyes
      * Plant looks green because it doesn’t use green light frequencies in photosynthesis
      * Vision
        + Rods detect brightness
        + Cones detect color

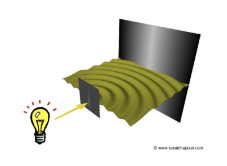
They specialize in either red, green or blue light frequencies

* + - * + Colors are seen by mixing the intensity of red, green and blue light detected by cones, then rods add in the brightness to generate an image
        + Screens

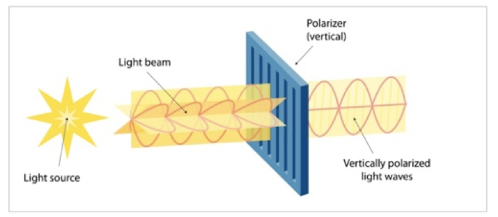
A backlight shines through sub pixels to emit red, green, blue lights. The subpixels control the intensity of backlight allowed to pass through its color filter. The different intensities tell the cones how much of what color it wants to blend, creating an image

With OLED displays, each subpixel has its own backlight, so that it’s the backlight adjusting intensities. This means that with black, instead of having subpixels block light, the subpixel’s backlight could just turn off instead

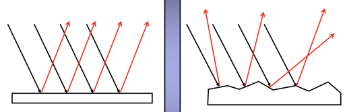
* + - Polarization and diffraction
      * Light behaves like a wave sometimes, and like a particle other times



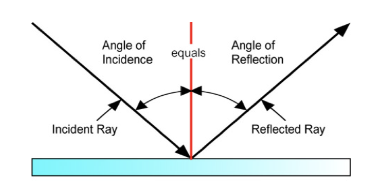
* + - * Naturally, light sources emit light waves that have their electric fields traveling in different random orientations
      * A polarizer creates polarized light by only allowing light waves containing electric fields of a certain orientation to go through



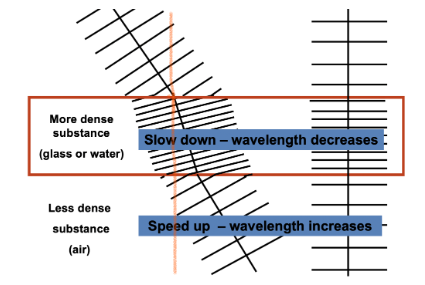
* + - That’s how sunglasses work
    - Reflection
      * Specular reflection
      * light waves reflect in a uniform fashion
      * Smooth surfaces
      * Allows us to see reflections
    - Diffuse reflection
      * Light waves reflect scattered
      * Rough surfaces
      * Can’t see reflections



* + - Law of reflection: the incident ray and the reflected ray must be of equal angle relative to the normal line



* + - Refraction
    - Change in speed and direction
    - Light ray refract every time it passes through a medium from another
    - The more “different” material 2 is from material 1, the greater the change
    - Light acting as a particle, a particle traveling through one medium would experience different resistance than traveling through another medium, changing its speed, possibly causing rotation
      * Index of refraction
      * Speed of light in vacuum (c) : 3\*108m/s
      * Light travels through a medium by being absorbed by an atom, then emitted by that atom, absorbed by another atom, emitted by that atom, and so on
      * The denser the material, the more atoms need to absorb and emit the light, slowing down the speed of the light
      * Index of refraction = speed of light in vacuum / speed of light in the medium
      * Snell’s law
      * If medium 2 has a higher index of refraction than medium 1, the refracted ray is closer to the normal line
      * If medium 1 has a higher index of refraction than medium 2, the refraction ray is farther away from the normal line



* + - * + where n1 is the index of refraction of medium 1, theta1 is the incident ray’s angle with the normal line, n2 is the index of refraction of medium 2, theta2 is the resulting ray’s angle with the normal line

Modern Physics (Regents)

* Atoms
  + Historic models
    - 1904 - JJ Thomson - Plum Pudding Model: uniformly positive sphere with negative particles embedded in it
    - 1909 - Earnest Rutherford - tested plum pudding model
      * Shot positive alpha particles at a thin gold foil
      * If the plum pudding model was correct, the alpha particles would pass straight through
      * Most alpha particles exhibited that prediction, but a small number of alpha particles were splayed randomly
      * This indicates that the atom is mainly empty space, and has a small, dense positive nucleus
    - Neils Bohr - quantized energy levels
      * Pointed out that electrons would be attracted to the nucleus, but somehow there’s still empty space
      * postulated that only certain radii are stable, and allow electrons there to not flop into the nucleus
      * There are only certain radii, or orbitals, allowed, meaning that the energy levels are quantized
    - Erwin Schrodinger - electron cloud
      * It’s impossible to locate an electron
      * Draw an electron cloud to represent the probability of finding an electron in a certain spot
  + Spectral emission
    - Ground state: the lowest energy level possible of an atom
    - Excited state: atom with more energy than ground state. Is not stable
    - To go from ground state to excited state, electrons must gain energy to move to energy levels farther away from the nucleus
    - When electrons fall back to ground state levels, electromagnetic radiation are released
    - Since only certain energy levels exist for different elements, the radiations emitted could be used to ID the element of a sample
* Mass & energy
  + Mass defect: the sum of the masses of the components that make up an atom does not equal to the mass of that atom
  + That mass became the energy required to hold the atom together
* Wave particle duality

Unit incomplete due to pandemic