PHY 1300 Lecture Reading Notes

January 7th, 2019
Reading: Introductory Lecture (L0)
Title: America's Science Problem

Gist: Anti-science is becoming a popular method of control by different political parties to enforce the organization's agenda.

Specific Notes:

- The Founding Fathers in America were science enthusiasts, but it is becoming overwhelmingly popular for the parties in the 21st century to take stances, about critical scientific issues, that have been proven wrong.
- Democrats believe that vaccines cause autism
- Republicans don't believe in climate change and evolution
- Quote by a Republican woman running: "If it is legitimate rape, then the female body has a way of shutting it down". Using fake science as a method of promoting certain laws (such as anti-abortion) lead to people being at risk and the future of technology and humanity uncertain
- All of this can lead to an authoritarian future
- The phrase, "there is no such thing as objectivity", has lead to people not researching all the truth to certain issues. This also gives the ability of people to choose either an opinion without facts associated with it, or the more scientific approach. But, those two options should not be emphasized at the same level; one is clearly the correct solution.

January 10th, 2019
Reading: Lecture 1
Title: Science and Pseudo-Science from Stanford Encyclopaedia of Philosophy Archive Winter 2015 Ed.
https://plato.stanford.edu/entries/pseudo-science/#SciPse

Terms:

- Demarcations: Differences
- Pseudoscience: Beliefs, theories, and ideologies that are considered scientific, but not based on scientific fact.
- *Parascience*: non scientific practices that are not pseudoscientific
- *Falsifiable*: statements or systems of statements, in order to be ranked as scientific, must be capable of conflicting with possible, or conceivable observations

Specific Notes:

- There are practical and theoretical differences between science and pseudoscience:

Application	**Science**	**Pseudoscience**
Healthcare	• Development and evaluating treatment according to evidence	• Ineffective and dangerous solutions that may not be backed up by tests and results
Expert Testimony	• In law, the truth must be presented based on the best available knowledge • Courts must be able to distinguish between real and delusions that people have over science as the case verdict rests upon it	• Pseudoscience explanations can lead to loopholes and ineffective justice delivered in court because the knowledge may not be correct
Environmental Policies	• Preventative measures must be taken to avoid environmental hazard • Decision makers in environmental policy must be able to distinguish between real and false claims	
Science Education	• School criteria and material must be protected against people who want to implement their opinions and force their beliefs on someone else	• Creationism is a belief that involves religions that should not mix with other people's understanding of reality
Journalism	• Differences of opinion must be explained relevantly in the media • Media portraying things in the wrong way has lead to movements that are uneducated and completely worthless which cause harm to general society (anti-vaccine movement)	

- Science refers to natural sciences and other fields of research that are similar
    - Political economy and sociology are counted as sciences, but history and literature are not
- *The community of knowledge* disciplines are increasingly interdependent
    - If fake information and beliefs are spread, there are harmful impacts in other fields of study as well
- There is a difference between the phrases "demarcation of science and demarcation of science from pseudoscience"

- Difference between un-scientific and pseudoscientific: Un scientific refers to mismeasurements and miscalculations who are trying and failing to produce "good science."
- Logical falsifiability can create issues with practical demarcations

January 14th, 2019
Reading: Lecture 1
Title: Kuhn: The Route to Normal Science from The World of Physics
Website: https://www.uky.edu/~eushe2/Pajares/Kuhn.html

Terms:
Paradigms: A typical example of a pattern

Specific Notes:
- Normal science refers to "research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice" - this is copy and pasted from the article!
- Normal science relies on two concepts:
    - Unprecedented activity
    - Open-ended understanding to allow for research to occur
- There is seldom disagreement among individuals in the science field over fundamentals as the students learn the same thing from the teachers, who learned it as students from their teachers.
- It remains an open question as to which parts of social science have acquired these paradigms
- Paradigms help scientists bound their discipline so that they can
    - Formulate questions
    - Create avenues of inquiry
    - Select methods on how to examine questions
    - Define areas of relevance
    - Establish or create meaning
- How are these paradigms created?
    - Early stages of inquiry
        - Different researchers confronting the same phenomena and there are multiple interpretations of this
    - Different schools of thought vie for preeminence
    - Then one theory is selected through all the patterns as the best suited because it is better than its competitors
    - As the paradigm grows in strength, the other competitors fade away and the old views are simply ignored

    - The paradigm will transform the way we view things and may create new job openings and specialized understanding leading to new journals and new curriculum

January 14th, 2019
Reading: Lecture 1 Continued
Title: "National Selection and the Emergence of Mind" Delivered at Darwin College, Cambridge, November 8, 1977
Website: http://www.informationphilosopher.com/solutions/philosophers/popper/

Terms:
Determinism: The idea that all the causes in the world are irrelevant to our ability to make choices, as we don't really have a choice. Everything we do is affected by external choices, where philosophers have argued that humans cannot be held accountable for their actions, because they aren't really theirs.

Gist: Scientists have argued with philosophers over what models a human's ability or inability to make decisions without external factors coming in the way and taking over that free will. The evolutionary model of free will suggests that we started developing free will and consciousness from discomfort and other emotions, and by the process of natural actions, our predicted thoughts become actions and we are able to dissociate ourselves from theories to see them through and to learn more from one another.

Specific Notes:
- Karl Popper came up with his own "evolutionary" model of free will
- The classic argument against free will: there is a stark choice between determinism and indeterminism
- Karl Popper did not believe in determinism
- The unpredictability of a quantum jump was being used as a model for the model of a human decision
    - The model consists of an amplifier which causes an explosion which was theorized to mirror someone taking a major decision
    - Karl Popper did not agree with this model
- "Some of our decisions are like penny tosses; they are snap-decisions, taken without deliberation, since we do not have time to deliberate sometimes"
- Popper compared new ideas to a variation in the gene pool due to random mutations followed by natural selection
    - Mutations are (it seems) brought about by quantum theoretical indeterminacy
    - Natural selection eliminates inappropriate mutations
    - A range of new ideas comes about by probabilistic and quantum mechanically characterized set of proposals

        - There is a selective approach that our brain takes on when looking at all the ideas which acts like natural selection
    - Model of free will
        - Popper's belief changed eventually and he started to believe that the choice process was a selection process and that selection could be random events, without being random in turn.

Audio Recording

1. Darwin's Natural Selection vs Paley's Natural Theology
    a. Paley had the argument of design (creationism)
    b. Darwin's theory was about evolutionism
    c. It is important to realize that science does not make assertions about ultimate questions and about the riddles of existence
    d. The counter-revolution against science is intellectually unjustifiable.
    e. Scientists should resist the temptations of scientism
2. Natural Selection and its scientific status
    a. Darwin's theory is not strictly universally true according to Popper
    b. Selectionist vs Instructionist
3. Huxley's Problem
    a. Huxley's Problem consisted of the idea that animals, including men, are automata
    b. He said that the action of the body upon the mind is one-sided; there is no mutual interaction
4. Remarks on the Emergence of Mind
    a. "Ecological conditions like those that favor the evolution of open behavioural programs sometimes also favour the evolution of the beginnings of consciousness, by favoring conscious choices"- copied directly!
    b. Stages of the emergence of consciousness:
        i. Centralized warning (pain or discomfort)
        ii. Natural selection will favor the organisms that try out the possible movements that might be adopted before they are executed
        iii. The beginning of more or less conscious aims or purposeful actions
        iv. The evolution of language
            1. Our human mind allows for us to dissociate ourselves from hypotheses and test them out
            2. We learn to kill our theories instead of killing eachother

January 15th, 2019
Reading: Lecture Two (L2)
Title: Is the Universe Leaking Energy?

Gist: The universe is expanding, which we can see because of the redshift of light. As the photons begin to slow down, the electromagnetic waves get longer and longer, becoming red. But, because of the uniform density of a membrane in space is constant, the number of photons remain the same in the membrane, which suggests that the region is becoming less energetic as space expands→ instead of losing photons (because that cannot happen).

Specific Notes:

- The law of conservation of NRG states that energy can neither be created nor destroyed.
- Light has the ability to be redshifted, meaning that the electromagnetic waves get stretched as they travel through space - discovered by Hubble in 1920
    - This assumption is based on Einstein's general theory of relativity: "*the laws of physics are the same for all non-accelerating observers, and that the speed of light in a vacuum was independent of the motion of all" observers. (https://www.space.com/17661-theory-general-relativity.html)*
- The longer the wavelength, the lower its energy → this principle violates the law of conservation because the energy dissipates without cause.
- FAKE NEWS! Einstein is never wrong and even the redshifted photons, light particles, will conserve energy. Fake news again? Energy doesn't apply to space lol
- Laws of nature have spacial and rotational symmetry, thus exhibiting continuous symmetry which is accompanied by the laws of conservation.
    - Examples:
        - Spatial symmetry= momentum is conserved
        - Rotational symmetry = angular momentum is conserved
        - Time symmetry = NRG is conserved
            - If this breaks down, then energy is not conserved
- The Doppler effect is the earth equivalent to red and blue shifting, but the two differ since the Doppler effect is the result of relative motion, instead of the change in the energy possessed by the photons.
    - BTW the Doppler effect is the NNNNEEEEEEEWWWW sound of a car and firetruck when it passes by you
        - When the car passes by you, the sound of the car is much louder than it was when it is far away from you (when it is coming towards you, and then when it passes you)
- Curved universe diagram
    - Time symmetry
- Evolving Geometry
    - Time symmetry is broken= energy is not conserved
- Red shifts occur without relative motion too, as occurs with tethered galaxies

- ***Comoving***: when two objects move farther away from each other in the universe as a result of stretching.
    - Results in a universal convention for time
- ***Peculiar motion*:** when an object has motion on top of the motion caused by the expansion of the universe
- Quantum mechanics: Matter loses NRG by slowing down + light loses NRG by increasing in wavelength
    - QM supports the idea that matter particles have mass as well as wave like properties
- Louis de Broglie - discovered that the larger the momentum of a particle, the smaller the wavelength and the greater the NRG.
- Since space is malleable, it is implied that it is not time-symmetric
- CONCLUSION: "the universe does not violate the conservation of energy; rather it lies outside that law's jurisdiction."hi bi

Quiz answers

1. C)
2. B)
3. D)
4. D)
5. B)

January 22nd, 2019
Reading: Lecture 3 (L3)
Title: The Self-Organizing Quantum Universe

TERMS:
General relativity: The geometrical theory of gravitation. Spacetime is curved by mass and energy.
Special relativity: Speed of light is the same in all situations, no matter where the observer is located. Leads to the concepts of time dilation and length contraction.
Causality: The principle that events occur in a specific temporal sequence of cause and effect. Is the reason why Euclidean quantum gravity does not work, and why special and general relativity work as theories.

Specific Notes:
- Main questions that need to be answered
    - How did space and time come about?
    - How did they form the smooth four-dimensional emptiness that serves as a backdrop for our physical world?
    - What do they look like at the very tiniest distances

- **Theory of Quantum Gravity**: sought-after unification of *Einstein's General Theory of Relativity* with *Quantum Theory*
    - Aims to describe the nature of spacetime on the very smallest of scales (the voids between the smallest known particles), by quantum laws and possibly explain it in terms of some fundamental constituents
        - **Superstring Theory** is described as the leading candidate to fill this role of a middle ground between Relativity Theory and Quantum Theory
            - But...has not provided an answer yet to answers above
- **Relativity Theory**: spacetime on large scales can take on countless different shapes, producing what we perceive as the force of gravity
- **Quantum Theory**: describes the laws of physics at atomic and subatomic scales, ignoring gravitational effects altogether
- History of Quantum Gravity
    - Rooted in Euclidean quantum gravity
        - Based on a fundamental principle from quantum mechanics - ***superposition***
            - Superposition states that any object is in a certain state, both classical objects or quantum ones (this characterizes its position and velocity)
        - State of a classical object can be described by a unique set of numbers
        - State of a quantum object is the sum (aka. superposition) of all possible classical states
            - FOR EXAMPLE:
                - A billiard ball moves in a straight line towards from point A to point B - this is a classical object (the position and velocity is precise at all times because it moves along a single trajectory)
                - When an electron travels from point A to point B, it does not move on a straight line, but all paths simultaneously
                    - This translates into quantum superposition, which is the weighted average of **ALL** of these distinct possibilities
                    - With this, you can find the probability of finding the electron in any range of velocities and positions
                    - These deviations from a single trajectory is called *quantum fluctuations*
        - Applies the superposition principle to the entire universe
        - Focuses on the different ways that the universe could evolve over time

    - Further simulations shows that Euclidean quantum gravity could not possibly work
- To determine how space sculpts itself, physicists first need to find a way to describe its shape
    - Use triangles and their higher-dimensional analogues, to create a mosaic that resembles a curved shape
- Scientists have speculated that wormholes (thin handles attached to the universe that provide a shortcut between regions that would otherwise be far apart) might find a justification within the still-unknown theory of quantum gravity
- **MISSING INGREDIENT IN THE THEORY**:
    - The universe must encode something called *causality*
    - Causality means that empty spacetime has a structure that allows us to distinguish unambiguously between cause and effect
    - In more simple terms: **causality is the principle that events occur in a specific temporal sequence of cause and effect**, rather than as a jumble of everything happening at once or in no particular order
    - **This is an integral part of the classical theories of special and general relativity**
- Euclidean quantum gravity does not take into account the notion of causality
    - Euclidean indicates that space and time are treated equally
    - Euclidean universes have no distinct notion of time, they have no structure to put events into a specific order
    - People living in these universes would not have the words “cause” and “effect” in their vocabulary **BECAUSE TIME WOULD NOT EXIST**
- Space keeps its overall form as time advances, it cannot break up into disconnected pieces or create wormholes
- There are four dimensions, but more specifically 4.02 ± 0.1
    - Putting back the causality is the only way to cure instabilities
- Needed to study the shape of spacetime over large distances to verify that it matched predictions of general relativity
    - Done with cosmological constant that exists in absence of matter and energy
- **De sitter geometry:** the solution for Einstein's equations which contains nothing but the cosmological constant
- One of the simulations involved a diffusion process where suitable analogies of an ink drop fall into the superposition of universes and they observe the spreading by quantum fluctuations.
    - Space time has a different number of dimensions when the ink spreads for a long time
- Fractal: where there is no concept of size in space
- Small = 10^-34
- As a result of the universes rapid expansion, matter will be so diluted that it will play little to no role

- On a shorter scale, quantum fluctuations have a stronger impact + number of dimensions drops to 2 + no more geometry
- The concept of distance exists in space
- To correctly decide the theory of quantum theory: the prediction of observable consequences derived from the microscopic quantum structure.

January 24th, 2019
Reading: Lecture 4 (L4)
Title: The Language of Fractals

GIST: Fractals are mathematical figures that retain and reproduce the same character in each part of its figure. It is used for imaging purposes to determine the shape of objects that would have been otherwise been difficult to determine.

TERMS:
Fractals: Mathematical figures that have fractional dimensions rather than the integral dimensions of familiar geometric figures (such as one-dimensional lines or two dimensional planes)
Scale invariance/self-similarity: Structures that have an underlying geometric regularity. The same fundamental patterns are repeated and noticed in objects at different scales.
Euclidean Geometry: Mathematical system that has a set of axioms and theorems that focus on shapes such as circles and lines

- "Pathological structures" have taken the form of fractals
- Fractals came into mathematician's curiosity after the groundbreaking book, "The Fractal Geometry of Nature" was published
- Fractals allow for a compact method for describing objects and formations
- Fractal geometry allows for natural shapes to be described better than Euclidean geometry
- **Contemporary Chaos Theory**
    - Many phenomena, even though certain rules are followed, are in principle unpredictable
    - Chaotic events show similar patterns of variation on different time scales just like scale-invariant objects show similar structural patterns on different places
        - Chaotic events include the beating of a human heart, or turbulence in the atmosphere
- **Fractal geometry is the geometry of chaos**
- Fractals are expressed in algorithms instead of primary shapes
    - Algorithms are translated into geometric forms with the aid of a computer
- Computer imaging is very important in the study of fractals
    - We are able to see the similarities between fractals and our world to prove the point of contemporary chaos theory

- Why would we ever need fractal geometry?
    - What if we want to find the shape of a cloud? Or some other irregular element? We must use fractal geometry to describe the shape
- Fractal geometry is comprised of many infinite elements that are unique and complete. These elements are defined by algorithms which all work together to produce a meaning much like the alphabet has 26 letters that we use to construct other words and produce meaning
- **Fractal language groups:** Linear and nonlinear
    - Infinite number of algorithms→ infinite number of possible fractal images
    - Nonlinear fractal language has more dialects and is more varied
    - Linear fractal geometry is the most basic
        - Called linear because the algorithms have the same form as lines on a mathematical plane in space
- **Multiple Reduction Copying Machine**
    - Imaginary image duplicator that helps explain how to explore the linear algorithms
    - Has several reduction lenses which copy the original image
    - The reduced images can be moved and altered in any way as long as the straight lines of the image are straight. The transformations associated with the images are based on the algorithm. A feedback loop processes the images and builds the fractal form
- **Sierpinski Triangle**
    - A fractal produced by a recursive algorithm
    - Every part of the image, no matter how small, can be zoomed in to see the same Sierpinski triangle in every part of the figure
- **Limiting image:** the final shape that begins to form that keeps being formed no matter how many cycles the copying machine goes through (hence like a limit that a function approaches)
    - Limiting image depends on reduction and displacement rules (algorithms) programmed into the machine
    - The original image becomes difficult to see after each copy is made, and so, the limiting image is the final image seen (the Sierpinski triangle)
- Small reconfigurations of the copying machine can make completely different limiting images
- Alfine-linear plane transformations: Transformations that maintain the straightness of lines but alter their positions, scale and overall orientation
- Any image can be coded using the best algorithm and linear transformation functions
- **Chaos Game**
    - Where a fractal image is produced by transformations being applied by a four-sided die (four transformations on each side)

    - Will take a very long time to make the image because the probability of each transformation is the same
- **Non-linear Quadratic Dialect**
    - Using complex numbers to create sequences and points on a plane
    - The sequence either roams freely to infinity when put into the transformation $g(x)=x^2+c$ or it is trapped within a certain complex-number plane
    - Is there an order principle that underlies the infinite variety of the non-linear quadratic dialect Julia sets?
        - The fractal that is formed with this algorithm maybe a connected piece or it may consist of an infinite number of disconnected points much like dust
- **Mandelbrot set**
    - Connect a control parameter c with a point on the connected Julia sets, and with the disconnected sets, you leave those parameters blank
    - Each portion of the Mandelbrot set is related to a family of Julia sets
    - Acts as a table of contents for the infinite number of Julia sets
- Random Fractals
    - Can be used to represent a mountain
    - Starts off as a triangle that is sliced at its midpoints to make more triangles. These are then shifted up and down on a plane to come up with the fractal image.
- **Fractal Dimension:** A characteristic number that measures the roughness, complexity or convolutedness of the fractal

January 24th, 2019
Reading: Lecture 4 (L4)
Title: The Principle of Uncertainty

- Light has a dual nature: it acts like a wave and like a particle
- Light is made up of discrete pockets of energy, called photons
    - Energy of the photons varied with the frequency of the light
- Electrons are guided by waves that accompany their motion
- Wave Mechanics
    - Theoretical tool in explaining the dynamics of the atom
- The distinction between waves and particles vanished - light waves behaved like particles and particles behaved like waves
- In the atomic world we can never overlook any disturbances caused by the introduction of a measuring apparatus
- Heisenberg considered the problem of trying to track the motion of a material particle
    - In the “physical world” (basically everything we can see with our eyes), we can follow the flight of a ping-pong ball without affecting its trajectory at all

    - Light exerts pressure on the ball but we do not have to play ping-pong in the dark because the pressure is too small to make any difference its trajectory
    - This situation becomes very different when you change the ping-pong ball into an atom
- Heisenberg's experiment: tracking the motion of a particle
    - In theory, if an electron is fired into a chamber, the particle will follow a trajectory known as a parabola
    - In practice, the moment a photon strikes it, the electron will recoil and change its velocity
        - By observing it in different points in motion, we can see that the electron takes a zig-zag shape instead of a smooth parabola because of the photon
    - By minimizing the photons impact (ie. decreasing the photons energy) by lowering the frequency of the light used, the impact on the electron is significantly small
    - **BUT**...the longer the wavelength of the light (low frequency, low energy photons), the less able we are to define the object because of the diffraction effect
        - This means we can no longer find the exact position of the electron at any given point anymore
    - **THEREFORE**...Heisenberg showed that the combined uncertainty in position and velocity (ie. product of two uncertainties) can **NEVER** be smaller than Planck's constant divided by the mass of the particle
- So, with very short waves we can define the positions of a moving particle sharply, but will interfere greatly with its velocity
- With very long waves, we can determine its undisturbed velocity but become very uncertain about its positions
- **MIDDLE GROUND**: use some optimal intermediate wavelength of light, we will disturb the particle's trajectory moderately and still be able to define its path to a fairly close approximation
    - The path will not be a sharp line, but it will be on a confined band
- Heisenberg concluded that we must give up the notion of the trajectory of an object to be on a thin line on an atomic level
- On the atomic level, we can only measure the **probability** that a photon will strike a certain point or that a particle will be found in a given place at a given instant

LAST 4 PAGES NOTES

- Heisenberg principle: Developed by Bohr, and helped to remove support for the wave-particle paradox
    - The uncertainty principle: the wave and particle ideas can be used to describe nature.
    - Albert Einstein did not agree with this and tried to find error with the uncertainty principle of quantum physics

- Einstein's thought experiment:
    - Time is the 4th coordinate of space-time and energy is the fourth component of momentum - mass x velocity
        - Uncertainty in time = uncertainty in energy → trying to prove that this was not the case
        - If an ideal box with perfect mirrors that could contain radiant energy forever released a single photon, then there would be an evident change in the mass of the box which revealed the energy of the photon → used to disprove the uncertainty principle
- Bohr's response to the Einstein thought experiment:
    - A spring scale with a with a pointer recording the weight is MEH, but if the box moved vertically, then the vertical velocity would be uncertain, and the height would be uncertain as well
    - The elevation above the earth's surface would also be uncertain, since the rate of the clock depends on the clocks relative position.

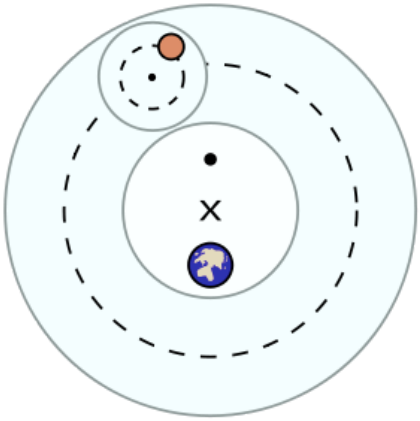
January 29th, 2019
Reading: Lecture 5 (L5)
Title: Copernicus and Tycho

Terms:
Conjunction: The alignment of the planets Mars, Jupiter and Saturn
Deferent: The large circular orbit followed by the center of the small epicycle in which a planet was thought to move in the Ptolemy model of the solar system
Epicycle: Small circle whose center moves around another circle

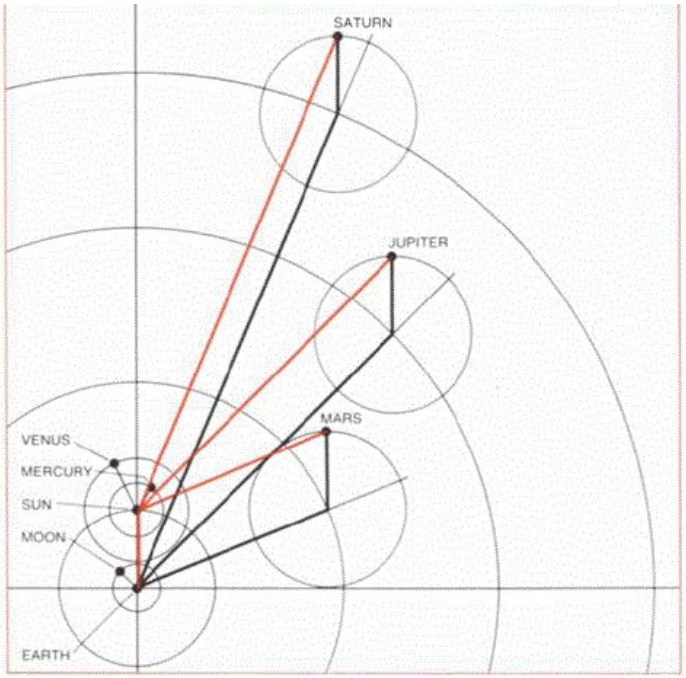
Gist: Tycho Brahe was an astronomer that was ridiculed for his Tychonic model of the solar system; however, in a new light, we see that his irregular model and learnings from Copernicus led to new findings that others used to build the foundations of astronomical physics.

Notes:
- Copernican system→ all planets revolve around the sun
    - Copernicus was delighted that his model fit with the order of the ranked planets (in terms of distance to the Sun) and their speeds, where the slowest planet had the largest orbit
- Tychonic Geocentric system→ the sun and moon travels around the fixed Earth, and the rest of the planets travel around the sun
    - Tycho had a bold plan for increasing the accuracy of observations places him far more securely in the mainstream of modern astronomy
    - Odd model that is not true, but was built off of Copernicus
    - Combined the Copernican system with the Ptolemy system

- The writer looked through an edition of Copernicus' *De revolutionibus orbium coelestium* and saw Tycho's cosmological notes
- In the Tychonic system, the laws of physics fit
    - This model had the immobile nature of Earth included whereas the Copernican model did not (the latter model did not fit with the laws of physics)
- Newton was the one that melded celestial physics with terrestrial physics
- **The ultimate goal of a planetary model is to predict the planets' position**
- Ptolemy
    - Geocentric epicyclic system
- Copernicus's tables were based off of Ptolemy so it was not a suitable base of observations
    - After Tycho came up with his systematic observations, the faultiness of Copernicus's tables were recognized
- **Back in the 16th century, the position of planets were predicted on the basis of the Alfonsine Tables which were made in the 13th century**
- Conjunctions of planets fascinated astronomers and could be observed accurately without instruments
- Copernicus watched the planets and found that the almanac predicts were off by about 10 days
- Copernicus wrote "Mars surpasses the numbers by more than two degrees; Saturn is surpassed by the numbers by 1 ½ degrees"
    - We didn't really know what this meant, but using computers and technology we can find out what he was trying to say
    - The actual positions of the planets were recomputed from 601 BC to 1649 AD which created a standard in which old almanacs could be compared to
    - It was determined that the longitude predicted by the Alfonsine Tables shows a characteristic periodic error
        - Determined to be a result of the unavailability of the knowledge about Earth's motion and the planet's motion (the ones they were looking at→ specifically Mars, Jupiter and Saturn)
    - Even though the almanacs were wrong, the errors that we can see with the super computer match exactly what Copernicus had said about Mars surpassing by more than 2 degrees and Saturn surpassing by 1 ½ degrees
        - Amazingly he was able to figure this out without having the technology we have now
- Ptolemaic system
    - Planet's position is predicted by computing its motion in the large orbital circle called a deferent, together with its motion in an epicycle or secondary cycle, centered on edge with the deferent
    - The Earth was placed near, but not exactly at the center of a set of the large deferent circles



    - In the Copernican model, the epicycle is seen as a result of the Earth's own orbital motion around the sun
    - Because of the irregularity of the planet's motion produced by the epicycle, a nonuniform motion of the center of the epicycle on the deferent was also required
        - To get this motion, Ptolemy suggest that there was something known as EQUANT
- **Equant: An axis of uniform motion off center within the deferent**
- Copernicus did not agree with Ptolemy and attacked the concept of the equant saying that it violated the principle of uniform circular motion
- **Rule of absolute motion:** Everything would move uniformly about its proper center
- A major theme of Copernicus's work became to prove that there was no equant
- Copernicus argued about his heliocentric theory by stating Earth has 3 movements
    - Revolution on its own axis
    - Orbit around the sun
    - Wobble that accounts for equinoxes
- Platonic-Pythagorean Concept
    - Celestial movements must be composed of uniform circular movements
- Osiander's belief → astronomy was only based on hypothesis
- Tychonic System



    - (Scroll to the beginning of the notes for a refresher on the Tychonic system)
    - Tycho's system retained many of the advantages offered by Copernicus
        - Planetary orbits were linked together in a coherent unit
        - Retrograde motions were "naturally" explained
- **In the Copernican system, the shorter the period of rotation for the planets, the closer the distance→ this opened the way for the mathematization and mechanization of the universe**
- Tycho's system was a step backwards and so he is rejected as a cosmologer
- Kepler's laws, however, were instigated by Tycho's findings
    - Elliptical orbits finally vanquished the ancient requirements of uniform circular components for celestial motions
    - Kepler saw the real possibility of celestial physics with Copernicus's model

January 29th, 2019
Reading: Lecture 5 (L5)
Title: Gravity

Gist: Through Newton and Galileo's tests to determine the various relationships between mass, gravity, and acceleration, it was determined that there is a special relationship called "Universal Gravitation". Universal gravitation is the attraction all objects have with one another, which was proved by Henry Cavendish. With this theory, Einstein's principle of equivalence came about that led to his theory on general relativity. As more research is done in this field, we continue to focus on the 4D aspect of spacetime, in particular looking into the various forces between electric and magnetic charges, and seeing if relations can be found with gravity.

Notes:

- Free fall was too fast to measure directly, so **Galileo** decided to study bodies on an inclined plane
    - Inclined planes would allow a ball to roll at an intermediate speed, depending on the angle of the incline
    - His experiments with the ball rolling down the incline indicated that ***speed increases in direct proportion to time (at any angle of incline)***
    - ***Distance covered increases in direct proportion to the square of time***
    - Performed the same experiments with a pendulum with varying weight and heights of release, which affect the period of oscillation.
- *Galileo's conclusion from his experiments*: regardless of weight, all object in free fall move in the same way.
- ***Newton's notions of force and inertial mass***: when force is applied to a material body, it changes the speed or direction of motion, or both
    - A homeostasis of types takes place and the inertial mass opposes the changes.
- ***Newton also discovered that:*** The rate of change of velocity (derivative of the velocity slope) is equivalent to the acceleration and also proportional to the force acting on it + inversely proportional to the mass
    - *Further relationships*
        - Doubling the mass halves the acceleration
        - Doubling both the force and mass will maintain the acceleration
- The gravitational pull on an object is proportional to the inertial mass.
- ***Newton considered gravitation in other terms:*** If he shot a bullet horizontally from the top of a mountain so that it rises above the atmosphere, the bullet will follow a curved trajectory and hit the surface of the earth some distance away from the base of the mountain
    - This led to the idea that the motion of the natural moon is also a free fall
- **Universal gravitation: All material bodies in the universe attract one another with forces determined by their masses and mutual distances**
    - Eg. The moon is suspended and rotates as a result of the earth's gravitational pull. The planets and earth are attracted to the sun's gravitational pull, and thus there is orbit.
    - RITA'S OPINION (@Nabeeha): universal gravitation is essentially the idea that gravity is acting on all things and we are also attracting each other so there is a force of attraction between all things in the universe attracting everything to everything else.
        - Also need to take into account the mass because that affects the force exerted on everything else in the universe.
    - Force of gravity decreases as the square of the distances between the attracting bodies
- ***Henry Cavendish:*** experimentally demonstrated that the law of universal gravitation held

    - the gravitational attraction between 2 bodies is proportional to the product of the masses
    - TORSION BALANCE EXPERIMENT
- **LAW OF UNIVERSAL GRAVITATION: :** F = G (Ml M2) / d^2
    - G is the constant of proportionality, or the gravitational constant
        - Approximately 6.6x10^8
- Laws of gravitation + the laws of motion = the rules governing planetary motion proposed by kepler
- Albert Einstein's theory: no observations made inside an enclosed chamber can answer the question of whether the chamber is at rest or moving along a straight line at a constant speed
- **Principle of equivalence:** Observers at the experiment site and those outside of the experiment location both have valid viewpoints of the observed action. This is the foundation of Einstein's relativistic theory of gravity.
- Light from distant universes should bend as they approach the sun → bc of principle of equivalence
- Inertia: when a person is inside a bus, the are travelling at the same speed as the bus, so when the bus abruptly stops, the person keeps moving.
    - RITA NOTE: An object in motion remains in motion unless acted upon by an unbalanced force
    - When you're in a bus and you throw up an apple and then catch it as the bus is moving, then a person outside the bus will observe it as a parabola, even if it looks like a straight line to you.
- Centrifugal Force: Force pushing objects out from the center of a circle
- Universal rotation: A body moving at constant speed on a circular path is accelerated because of its continuous change of direction.
    - Blind people on a merry go round will be aware of centrifugal force, which will push them outside to the rim of the merry go round
    - The effect of accelerated motion will be equivalent to that of a gravitational field
    - The force is directed away from the centre of the system, not towards it
- Time moves faster on the outside of a field
    - Aging will be more rapid when you're farther from the earth's surface
- Gravitational red-shift
    - If the natural clocks are slowed down, the light they emit should be shifted toward the low frequency- or red
- **Geodesics:** "Straightest" (shortest) lines between the points if one is confined to the surface in question (non 2D platform)
    - Suppose 3 geodesic lines form a triangle
        - If sum of angles is 180 degrees, the space is flat
        - If sum is more than 180 degrees, the space is spherelike
        - If sum is less than 180 degrees, the space is negatively curved

- The space around the sun is curved because astronomers have measured the angle of the light rays to be more than 180 degrees
- Newton's law of gravitational interaction between masses is quite similar to the law of electrostatic interaction between charges
- Einstein's theory of the gravitational field has many common elements with James Clerk Maxwell's theory of the electromagnetic field
- **Oscillating charges should give off oscillating waves**
- Gravitational waves are divided into discrete energy packets or quanta
- ***R. L. Moss-bauer*** found a way to produce nuclear gamma rays of pure frequency and measured small changes to the frequency.
- **Interactions of matter fall into distinct classes:**
    1. Strong Interactions (which include electromagnetic forces)
    2. Weak interactions (such as the 'beta decay' of a radioactive nucleus in which an electron and a neutrino are emitted)
    3. Gravitational interactions, which are vastly weaker than the ones called "weak"
- **The strength of an interaction is related to the rate, or probability of the emission or absorption of its quantum**
- Neutrinos→ particles with an extremely low probability of absorption (that is, with other types of matter)
    - They have no charge or no mass
- **Dirac→** proposed that the gravitational constant must be decreasing, and that this decrease may be associated with the expansion of the universe and the steady rarefaction of the material that fills it
- Question: If one can shield electric and magnetic forces, can you do the same with gravity?
- Gravitational polarization→ could make shielding against the force of gravity possible
    - Requires that matter be constituted into two kinds of particles:
        - Some with positive gravitational mass (which are attracted by earth)
        - Some with negative gravitational mass (which are repelled)
            - Particles with negative gravitational mass are as yet unknown
- Discovery of antigravity would make us choose between Newton's law of inertia and Einstein's equivalence principle
    - If antiparticles do have a negative gravitational mass then this would be the case
- CONCLUSIONS
    - Gravitational field clocks run slow, light rays bend in the direction of the field and a straight line is not the shortest distance between two points.
        - Space itself is curved LOL

January 31st, 2019
Reading: Lecture 6 (L6)
Title: Radiation Belts Around the Earth

- Earth is ringed by a region of high-energy radiation extending many thousand miles into space
- This is troubling news because it means that humans will have to be shielded by this radiation when they leave Earth's atmosphere (keep in mind this article is from **1959** so this is before the mission to the moon)
- The configuration of this region and the radiation it contains showcases a major phenomenon involving cosmic rays and solar corpulses
- Enormous reservoir of charged particles
- They are the middleman in the interaction between the Earth and the Sun
- This radiation also apparently plays some role in the Northern Lights
- Discovered that the radiation includes energetic protons (hydrogen nuclei) as well as electrons
- **BASICALLY**: space is radioactive !!
- Great intensity of radiation above altitudes of 500 miles over the entire region, 34 degrees north and south of the equator
- The radiation consists of charged particles-presumably protons and electrons-trapped in the magnetic field of the earth
- How the trapping mechanism works
    - When a fast-moving charged particle is injected into the earth's magnetic field, it describes a corkscrew-shaped trajectory, the center line of which lies along a magnetic line of force
    - The turns of the helical path are quite open over the equator but become tighter as the particle reaches the stronger magnetic field toward the poles
    - At the lower end of its trajectory the particle goes into a flat spiral and then winds back along a similar path to the other hemisphere, making the transit from one hemisphere to the other in a second or so
    - During this time its line of travel shifts slightly, so that the particle drifts slowly around the earth as it corkscrews from hemisphere to hemisphere
    - An electron drifts from west to east; a proton, in the opposite direction.
    - The particle descends into regions of higher atmospheric density
    - Collisions with the atoms of atmospheric gases causes it to gradually change its trajectory and lose energy
    - After a period of days or weeks, the particle is lost into the lower atmosphere
- **THIS IS WHY WE SEE ALL OF THESE PARTICLES SURROUNDING EARTH (THEY MAKE UP THE RADIATION RING)**
- Two belts of radiation rings exist
- A lot of these particles actually come from the Sun
- The radiation extends outward for many thousands of miles, with its maximum intensity no more than 10,000 miles above the earth

- The radiation completely disappears at about 40,000 miles beyond Earth
- Solar-Origin Theory
    - Scientists imagine that there is an imaginary “bucket” that fills with particles from the Sun
    - A particularly large influx of solar particles causes the bucket to "slop over," mainly in the auroral zone, generating visible auroras, magnetic storms and related disturbances
- Two problems with this theory
    - The energy of many of the particles they have observed is far greater than the presumed energy of solar corpuscles
    - It is difficult to explain how charged particles can get into the earth's magnetic field in the first place
- Another theory
    - Neutrons are released in large numbers in the earth's upper atmosphere by the impact of cosmic rays
    - These neutrons, being uncharged, can travel through the magnetic field without deflection
    - Some of them decay into electrons and protons, which are trapped
- Neither theory explains why there are two belts instead of one
- Space stations need to orbit below 400 miles or 30,000 miles from the Earth

January 31st, 2019
Reading: Lecture 6 (L6)
Title: Does Dark Matter Exist?

Gist: There is a discrepancy between how much mass there should be in the universe and how much there actually is. Physicists suggest that there could be something called dark matter and dark energy that account for the discrepancies. However, perhaps, if we look at it in a different way, one where we have to change the laws of physics, we can remove the requirement of dark matter and figure out what makes the rest of the mass of the galaxy. MOND is a new method of viewing the world of physics that takes into account different acceleration speeds and has been used to explain galaxy rotations, and why we see what we see in the universe.

- Where did the concept of dark matter even come from?
    - There is a mismatch in the masses of galaxies and larger cosmic structures
    - The laws of physics are able to tell us how much mass should be present in the universe to ensure that movements remain in check, but the mass accounted for falls short to what we actually observe
    - **MASS DISCREPANCY**
- **Before galaxies:** the universe was filled with plasma of atomic nuclei and subatomic particles
    - Radiation fused the plasma and kept it extremely smooth

    - After the plasma turned into a neutral gas, it started to grow and develop into galaxies→ doesn't react as strongly to radiation.
    - **Problem:** There wasn't enough time for the fluctuations in plasma to become the galaxies that we see today.
- Dark Matter
    - Neutral by definition→ it would not be homogenized by radiation→ it would be contracting this whole time→ **Dark matter would have had enough time to form galaxy-mass bodies**
- Dim Matter
    - Extra mass that consists of too little radiation for present technology to detect
    - **However,** this can only account for a tiny but of the missing mass that astronomers are seeing
- Dark Energy
    - An energy that would produce the observed accelerated expansion of the universe, a phenomenon that neither normal nor dark matter can explain
- **Summary 1:** The universe consists of:
    - 4% ordinary ("baryonic") matter
    - Around and less than 33% dark matter in some unknown forms
    - 66% of dark energy → even less understood
- If we stop looking at the laws of physics, then we can get rid of dark matter altogether
- The diverse appearances of the mass discrepancy are due to:
    - **Newtonian Physics formula combines:**
        - Newton's law of gravity
            - Which relates the force of gravity between bodies to the bodies' masses and separation
        - Newton's second law
            - Which relates force to acceleration
            - The acceleration of a body in orbit depends on the velocity and size of the orbit
- Changes to Newtonian physics
    1. Upgraded Newtonian dynamics to the theory of relativity (both the special theory and general theory)
        a. Special theory→ Changed Newton's second law
        b. General theory → Altered the law of gravity
    2. Second change led to quantum theory
        a. Accounts for the behaviour of microscopic systems and even macroscopic systems under certain circumstances
    - These two extensions of Newtonian dynamics comes into play during extreme conditions
        - Extreme speeds (special relativity)
        - Strong gravity (general relativity)

    - **Majority of the phenomena connected with galactic dynamics involves none of these particular conditions**
- What attributes of galactic systems are so extreme so that they might require yet another modification?
    1. Size?
        a. Perhaps gravity departs from the Newtonian law at large distances
        b. **James H. Jeans** proposed modifying the distance dependence of the law of gravity on galactic scales
            i. This was refuted because they were unrelated to dark matter
        c. **Arrigo Finzi** suggested another distance dependence as a possible solution to the dark matter problem in clusters.
            i. This was refuted as the distance dependence of gravity failed to reproduce the observations
- **Acceleration in galactic systems is many orders of magnitude smaller than in everyday experience**
- How do astronomers figure out how much matter fills the universe?
    1. They add up everything they see.
    2. Measure how fast the visible objects move.
    3. Apply the law of physics and deduce how much mass is needed to generate the gravity that restrains those objects.
    - The two methods give different answers!
    - Most astronomers conclude that some invisible mass also lurks out there- the infamous dark matter
- **MOND→** Modified Newtonian Dynamics; changes Newton's second law of motion at low accelerations
    - This alteration to Newton's laws may explain the discrepancy of mass in the universe
    - Still has some problems that may be unimportant or fatal
- **Important features of MOND**
    - New constant of nature with the dimensions of acceleration called a_0
    - When acceleration > a_0, Newton's second law applies as usual
        - Force is proportional to acceleration
    - When acceleration < a_0, Newton's second law is altered
        - Force becomes proportional to the square of acceleration
    - Using MOND: the force needed to impart a given acceleration is always smaller than Newtonian dynamics
    - MOND predicts a smaller force→ less gravity producing mass→ than Newtonian dynamics
    - MOND can eliminate the need for dark matter
    - The higher the mass, the farther out the effects of MOND set in
    - The acceleration produced by gravity decreases with distance and eventually goes below a_0
- MOND vs Newtonian dynamics (When looking at the universe)

- Newtonian dynamics
  - When the bulk of the mass in a region is found within a certain radius, the speed of orbits in circular orbits will decrease as you move further out
  - Eg. This is what happens in our solar system
    - Bulk of mass in Sun → the planets rotate around the Sun → orbital velocity of the planets decreases with distance… eg. Jupiter moves much slower than Earth around the Sun
- With MOND
  - At sufficiently large distances from the center of a galaxy, the orbital velocity should stop decreasing and reach a constant value
  - The constant velocity should be proportional to the fourth root of the galaxy's mass
- Tully-Fisher relation
  - Constant velocity is proportional to the fourth root of the galaxy's luminosity
  - This correlation is the relation that is observed
  - Assumption made: Luminosity is proportional to mass
- Successes of MOND
  1. Nature of low-surface brightness galaxies: Stellar agglomerations so wispy that they can barely be seen at all
     a. Acceleration in ordinary galaxies exceeds a_0 and drops below a_0 in the outskirts
     b. In low surface brightness galaxies, acceleration is smaller than a_0 everywhere
  2. Shape of galactic rotation curves: precise variation of orbital velocity with distance
     a. There is one parameter that MOND predicted must be adjusted for each galaxy→ conversion factor from starlight to mass
     b. For dark matter→ the comparisons involve at least two additional adjustable parameters per galaxy

- Even though MOND explains lots of stuff effectively, it still doesn't explain what happens when there are rich galaxy clusters→ there is still a discrepancy
- If we tried to do a physics experiment and test the effects of MOND, we would be unable to
  - The large background acceleration, caused by Earth's gravity, its rotation, its revolution around the sun and other factors would mask the effects of MOND
- MOND has not been incorporated into a theory that obeys the principles of relativity, either special or general
- **Cool fact:** For the acceleration near a black hole to be smaller than a_0, the hole would have to be larger than the observable universe
- a_0 is roughly the same number as the product of two important constants:

    1. The speed of light
    2. The Hubble Constant
- Mach's Principle
    - **MOND suggests that inertia, the responsiveness of a body to a force, is NOT an inherent property of bodies but is acquired by the body by dint of its interaction with the universe at large**
- Vacuum→ What is left when one annihilates all matter that can be annihilated
- **Interaction of the vacuum with particles might contribute to the inertia of objects**
- Galactic center→ what the stars in a galaxy orbit around
- Two effects determine the speed of a star orbiting:
    1. Distribution of mass
    2. Weakening of the force of gravity with distance

February 7th, 2019
Reading: Lecture 7 (L7)
Title: Giant Telescopes of the Future

- Very Large Telescope (VLT)
    - Most advanced set of telescopes in the world
- Other great telescopes include: Keck Observatory, Hubble Space Telescope and Very Large Array
- OWL Telescope → the proposed successor of the VLT, with good night vision→ $1.2 billion
- Why we need telescopes
    - To analyze Earth-like planets in other star systems
    - Looking for signs of life
    - Studying the first galaxies that formed
    - Understanding the nature of dark matter and dark energy
    - Imaging the multitude of bodies in our own solar system
- Thirty Meter Telescope (TMT) → $700 million
- 24-meter Giant Magellan Telescope (GMT) → $400 million
- **Moore's Law: Each generation of telescope is about twice as large as the preceding one and takes several decades to build**
- Reflecting telescope
    1. Light first bounces off a primary mirror
    2. Then strikes a secondary mirror which brings it to focus, where you can view the image with your eye
- When astronomers talk about the size of a telescope, they are talking about the diameter of the primary mirror
    - Doubling diameter→ lets you see celestial bodies one quarter as bright, or a body of a given brightness twice away
        - **Telescopes with bigger diameters are better to view more stuff into space**

- Detector efficiency has increased and has become nearly 100% efficient, so to make a better telescope, the mirror must become bigger (100m!)
- Why haven't we made a bigger telescope yet?
    - We have been limited by our ability to produce the mirror glass and make it to the proper shape and polish it
- Types of mirrors: paraboloidal, hyperboloid
    - Hyperboloid mirrors produce the sharpest possible focus
- **Problem with making telescopes:** Fabricating the glass itself
    - **Solution:** Guido Horn D'Arturo→ segmented mirror
        - Each segment has a different profile depending on its distance from the center of the mirror to ensure that there are no bumps or gaps (we want proper alignment)
        - **Downside:** You need to align the pieces with subwavelength precision… but what can you do? → **build fewer but larger segments**
- What do we want in a telescope?
    - Sensitivity to faint objects
    - Resolving power→ ability to discern fine details
- Larger telescope→ the less the images are degraded by diffraction
- **Diffraction:** The blurring of an image when the incoming waves get cut off at the outer edge of the mirror
- Parts of a telescope:
    - Primary Mirror → collects starlight
    - Secondary Mirror→ redirects the starlight into the corrector
    - Corrector→ Four smaller mirrors that remove image distortions
- What we need in the next level telescopes:
    - A combination of high resolution and high sensitivity
- **Coronagraph:** A small opaque disk that blocks out the star in the system of the planet that is being examined
    - **Problem:** If the disk is too big→ it hides the planet
    - **Solution:** A higher resolution will mean that the astronomers can use a smaller disc to get the same result (extending the range of their planet hunts)
- How can we make the telescope?
    - Rely on **adaptive optics** to undo distortions introduced by atmospheric turbulence
        - Create a reference star and adjust the shape of the mirror to keep this star in focus and make that mirror the secondary mirror or another smaller one
- The final construction of the telescope:
    - Build systems that operate at infrared wavelengths
        - Effect of turbulence is less severe at longer wavelengths
- **Multi Conjugate adaptive optics (MAO/MCAO)**: Corrects turbulence over a wide field of view so that systems are not limited to the small patches of sky around a reference star

    - VLT is using this method
- **Interferometry**
    - Technique that combines light from more than one telescope
    - **Limitations:** Can only observe a small field of view, only able to use a few percent of the light they collect through this method
        - Gives up sensitivity for resolution
- Skeletal Structure of large telescopes:
    - Mirrors are held by an open boxlike frame of 4 triangular trusses
    - When tilted, the frames flex and the mirrors shift laterally (but they stay aligned)
- How to make the OWL telescope cheaper:
    - Mass production of components to make a spherical primary mirror
    - **Problem:** this makes distortions in light so it would need a corrector

February 7th, 2019
Reading: Lecture 7 (L7)
Title: Dynamo-Electric Motors

- Example of an elevator:
    - Cage is suspended over two wire ropes, which pass over drums
    - Carry counterweights to balance the ordinary avg load
    - Only a little bit of additional power is needed to raise or lower the lift
        - Electric current is the additional power
        - Current comes from a dynamo-electric generator on the ground
        - It is conducted to a second dynamo machine attached to the carriage
        - Propulsion is affected by a metal ladder or rack
        - This runs up the middle of the shaft or passage of the lift
        - The rack works into two wheels carried by the lower part of the carriage
        - Wheels are driven by the revolving nature of the dynamo machine
        - The current is led from the stationary generator to the moving one by conductors running up the sides of the ladder
        - The return part of the circuit is formed of the metal wires by which the carriage is suspended

February 7th, 2019
Reading: Lecture 7 (L7)
Title: The First Electric Motor

- Abbe Salvatore dal Negro, Professor of Natural Philosophy at the University of Padua is credited with creating the very first electric motor in 1832
- The first motor

    - A magnet that would move around an axis situated at about one-third of its length
    - An upper part that was capable of oscillating between two branches of an electromagnet
    - A current being sent into the electromagnet would pass through an 8-cupped mercurial commutator that the oscillating magnet controlled through a rod and a fork
    - When the magnet had been attracted toward one of the poles of the electromagnet, this very motion of attraction, acting upon the commutator changed the direction of the current, and the magnet was repelled toward the other branch of the electromagnet
    - This apparatus contained one interesting thing
        - The movable magnet, when it touched the poles of the electromagnet, did not touch against the iron itself, but against the insulated wire that covered it
        - Either purposely or accidentally, the inventor avoided the inconveniences connected with remanent magnetism
- The second motor
    - Same general layout as the first one except it is controlled by a horizontal lever
    - Gives support above the electromagnet
    - Sets in motion a sort of wheel, that has rods with balls at the end
    - The motor produced a small amount of work
- Although this was a very basic structure of an electric motor it set the stage for other inventors to create more complex ones and eventually led to modern day electric motors

February 12th, 2019

Reading: Lecture 9 (L9)

Title: Nature's Color Tricks

- Many animals produce the intense colours on themselves through arrays of tiny structures that pick out particular wavelengths from the spectrum of light
    - The colours are produced through **reflection not absorption**
- The nanostructures on animals cause the phenomenon of **diffraction**
    - The incoming light rays reflect off the nanostructures and "constructively or destructively" interact
        - **Constructive Interference:** Wavelengths have the same period so when they interfere, they produce a wavelength with a greater amplitude
        - **Destructive Interference:** Wavelengths that have different periods so when they interfere, they produce a wave that cancels out almost indefinitely or produce a wave with a smaller amplitude (cancellation of light)

Layers on Animals

- Butterfly wings→ have natural polymer chitin → separated by air-filled voids within the hard outer surface
- Bird feathers→ layers are made of melanin and embedded in keratin
    - *Parotia lawesii* (a type of bird) has melanin that creates the reflections of orange-yellow light→ they ALSO have a V-Shaped cross section that reflects blue light as well (USED FOR MATING TO ATTRACT THE FEMALES)
- **Iridescent:** Slightly movements alter that position of the nanostructures, or barbells on animals which cause the colours to switch from one to another

The Christmas Tree Effect

- Butterflies→ have arrays of chitin that are shaped like Christmas trees (they diffract light)
    - Because the arrays are not flat, they reflect colours over a range of viewing angles
- **Things that can affect reflection of light:** Changing the structure of the arrays such as by running water over the structures
- **Key Point:** Different liquids have different indexes of refraction so there are different colour reflections
- **What are scientists doing?**
    - Creating chemical sensors that can identify a range of different liquids→ the sensor will change colour depending on the liquid they come into contact with (LIKE THE BUTTERFLY WING EFFECT TALKED ABOUT RIGHT ABOVE)
    - Use micro lithographic techniques to carve the structures into solids

Light-Bouncing Bowls

- **Sometimes what we see is not actually true!**
    - The bright green colour of the emerald swallowtail butterfly is not actually green!
        - The wings are covered in dimples and are lined with layers of chitin (these end up acting like selective mirrors)
            - Bottom of the layers reflect yellow
            - Sides of the bowls reflect blue
            - We can't differentiate between the yellow and blue combinations that are so small so we see green
- **What are scientists doing?**
    - They let water vapor condense as microscopic droplets on a polymer
    - The water droplets pack on rows and sink into the film
    - The droplets evaporate as the polymer sets and dimples are formed
        - THIS PROCESS LETS THEM MIMIC THE NATURAL LINING OF THE BUTTERFLY BOWLS SO THAT THEY CAN CREATE COLOUR
    - **Real life connection:** Using this method to create colours that look one way with our eyes, and different using a polarized filter can help create a simple green reflective coating that would hide the underlying blue and yellow light

which can be used to identify credit cards and real money (ABILITY TO DIFFERENTIATE BETWEEN REAL AND COUNTERFEIT MONEY)

Nanosponges

- Some other crystalline arrays of holes (**photonic crystals**) exclude light in particular wavelengths (causing that specific light to reflect)
- Photonic crystals → can confine light within narrow channels that can possible steer light around the tight spaces on computer chips
- **What are scientists doing?**
    - By creating the photonic crystals, we could make more low-cost solar cells
    - **Negative index of refraction:** Bending light "the wrong way"
        - Nanosponges made from metals such as silver could have this weird property
        - Can be used as superlenses that can image objects smaller than the wavelength of light

Crystal Fibers

- Light manipulating fibers are present in nature (such as in the spines of some marine worms)
- **What are scientists doing?**
    - Scientists are creating optical fibers with cladding that is impermeable to light within a particular band of wavelengths
        - Bundles of glass capillaries are made into thin fibers with hexagonally packed holes
    - Photonic crystal fibers "leak" less than conventional ones so they can replace the standard fibers in telecommunications networks

Deformed Matrices

- Disordered patterns→ the light scattering is diffuse; colours appear uniform when viewed from any angle (**DIFFUSE SCATTERING)**
- **What are scientists doing?**
    - Using this process of creating disordered sponges of films to create strong opaque coatings that are extremely thin

Reversible Proteins

- **Reflectin**→ a protein in squids that allow them to create and alter colors in their skin
    - Squids
        - Protein molecules are stacked into plates inside cells called **iridophores** which reflect specific colours
- **What are scientists doing?**
    - Studying how iridophores change colour
    - Scientists are using the protein and collapsing it into nanoparticles that can be tuned with salts and so we can control the interactions between charges on the proteins

    - Developed a polymer that switches from transparent to opaque in response to electrical voltages→ they want to use these materials to turn into fast shutters for infrared shutters

February 12th, 2019
Reading: Lecture 10 (L10)
Title: Laser Scissors and Tweezers

- Lasers: intense, pure beams of light
- Present in many commonplace items
- Strong lasers could potentially be used to perform surgery on delicate, fragile things
- Cell biologists use lasers as scissors and tweezers to perform invasive manipulations on livings cells and organelles

Laser Scissors

- Lasers scissors can produce a change within a chromosome deep within a cell
- They can inactivate a selected part of the organism in charge of dividing cells
- Laser changes the physical and chemical properties of the chromosome without destroying it
- Laser scissors manipulation is being in Europe for gametes (sperm and egg)
    - Can fertilize the eggs and then place them in the womb
    - Does not enable toxic chemicals to touch the embryo, which would otherwise harm it
- Associated Research Institute for Human Reproduction in Rome, reported a greater than 50 percent increase in pregnancy rates in more than 200 women whose embryos had undergone laser zona thinning compared with women who had not undergone the procedure
- Laser scissors can open a single cell to analyze it at any moment
- Side effect of laser scissors
    - Development of a minuscule cloud of ionized gas called a **microplasma** that forms when laser light is focused on or above the glass microscope slide on which the cell rests
    - Expansion and contraction of this microplasma generates mechanical stresses that, in turn, can rupture the cell
- Several factors make defining exact laser effects difficult
    - Various physical and chemical processes can potentially come into play when lasers interact with organic tissue
    - These processes can be triggered by the absorption of single photons or by the nearly simultaneous absorption of multiple photons
    - Photons of high energy may even break molecular bonds, tearing molecules apart
        - This is called **photoablation**
    - Multiple photons can be absorbed so closely in time as to be equivalent to a single, high-energy photon

    - Another key factor is the irradiance of the impinging light
        - **Irradiance of the impinging light**: the energy reaching a target's surface in a given time period, measured in watts per square centimeter
    - The irradiance can end up being enormous
- Laser scissors lead the way in our ability to perform microscopic surgery

Laser Tweezers

- Mid-1980s: Arthur Ashkin of AT&T Bell Laboratories discovered that a continuous-wave, low-power (under one watt) laser beam could "optically trap" individual bacteria
- Laser tweezers can also grip molecules
- A small enough object that is relatively transparent to laser light of a particular frequency, refracts incident laser beams, bending the light
    - Momentum is transferred from the light to the target
    - When the geometry of the arrangement of light beams and target is correct, the momentum imparted to the target pulls the target in the direction of the incident laser beam, and the beam can thus hold the target in place
    - By moving the beam, the laser operator can pull the target from place to place
- **Scissors employ short pulses of high irradiance, tweezers make use of continuous, low-irradiance beams**
- Target must be transparent to tweezers so that the beam will pass through the object without significant energy being absorbed
- Tweezers can grasp individual human sperm cells and manipulate them at will
    - One exciting discovery—sperm that swim in a zigzag pattern swim with greater force than straight swimmers—may explain clinical observations suggesting that men with a higher proportion of tacking sperm are more fertile than their counterparts who produce straight swimmers

February 14th, 2019
Reading: Lecture 11 (L11)
Title: Lasers General

Questions to answer:

- How do lasers work?
    - Stands for "Light Amplification by Stimulated Emission of Radiation"
    - ***First ruby laser:***
        - Created in 1960 by ***Theodore Maiman***
        - A ruby is composed of aluminum oxide with some Chromium - gives it a red colour.
            - When the ruby is formed into a cylinder with either a fully or partially reflective mirror on the ends and a high-intensity lamp provides a flash of white light, then lasers are triggered.

        - *Why does this work?*
            - The green and blue wavelength in the flash will excite the electrons in the chromium and they'll jump to a higher level. When the electrons return down then they'll emit red light
    - ***Extreme lasers***
        - *High-energy laser pulse*
            - 150 thousand joules in a single 10 nanosecond pulse
            - The energy produced will slam into a tiny pellet containing a form of hydrogen called deuterium
        - *Shortest laser pulse*
            - Works in just under a femtosecond
            - This pulse looks white to the eye
        - *High instantaneous power*
            - Just over a perawatt
            - The laser light is very condensed and the field is so strong that the electrons move at almost the speed of light
        - *Highest average power*
            - More than a megawatt of continuous output of power
            - Very powerful bursts of energy
        - *Baddest laser*
            - Produces MW-power pulses with duration of seconds and energies of MJ.
        - *Longest laser*
            - 1.3 Km long
        - *Shortest laser*
            - Several millionths of a meter in length
        - *Longest time of laser-cycle stability*
            - 13 seconds was the maximum amount of time that a laser could oscillate with the same frequency
        - *Most precise length measurement using a laser*
            - 1 attometre (10^-18m)
- What was the history of lasers?
    - ***Charles Townes*** created the precursor to the laser - the maser
        - ***Arthur Schawlaw*** worked with Charles as well to make the first laser
    - The maser
        - Microwave amplification by stimulated emission of radiation
        - Developed in 1954 at columbia university by ***charles townes*** and ***jim gordon*** and in Russia by ***Nicolav Basov*** and ***Alexandr Prokhorov.***
        - The ammonia masers were high energy and could withstand the oscillations and population inversions.
    - Laser patent war

        - ***Gould***, who was a graduate student at Columbia and the first to use the word laser, had filed a patent but lost to Townes and Gordon, but he won 30 years later for random other stuff.
        - 1974- barcode scanners were created
        - 1971 - laser printers
    - Nobel prize
        -
- ***Who were the laser pioneers?***
    - Robert e. Dicke
        - Filed a patent for an infrared laser with an open resonator, but there was a lack of publicity
    - Gordon Gould
        - First to use LASE
    - Charles Townes and Arthur Schawlow
        - Developed the first maser
    - Alexsandr M. Prokhorov and Nikolay Basov
    - Theodore maiman
    -