Science Monstrosity II: Science of the Lambs

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Tossups

1. Around the outside of one of these objects is an optically thick gas cloud known as a molecular torus. The most distant of them has a relativistic redshift of 6.4, and the spectra of many contain a region known as the Lyman-alpha forest. The suggestion that these objects are made from antimatter was countered by the accretion disk mechanism, although a recent experiment at Gemini North Telescope at Mauna Kea has shown that most of their host galaxies are too small to provide enough material for the accretion disk. Classified as radio-loud or radio-quiet, FTP, identify these galactic objects, probably supermassive black holes, which take their name from the fact that they resemble stars when viewed through optical telescopes.

Answer: **quasar** (or: **quasi-stellar radio source**)

2. One way of computing it is through the Mobius inversion formula, and when applied to a perfect square, it is equal to the square root of the argument times it applied to the square root. It can give the degree of a cyclotomic extension over the rational numbers and the prime number theorem sets bounds on its growth. In the generalized version of Fermat's Little Theorem, this function of n appears in the exponent of an integer relatively prime to n, and if the Goldbach conjecture is true, for every number m, there exist two prime numbers such that the sum of this function applied to each of them gives 2m. Equivalent to the number of elements in the ring of units of Z sub n, FTP, identify this function which gives the number of integers relatively prime to its argument.

Answer: **Euler phi function** (or **totient** function)

3. His inheritance of $300,000 after his father's death enabled him to become involved in politics by funding many left-wing causes. Receiving his Ph.D. at 22 under Max Born, in 1947 he became the director of the Institute for Advanced Studies, and during the 1930s and 40s, the FBI was greatly confused by the addition of a superfluous letter to his name. He lost his security clearance in 1953, in part due to testimony against him by Edward Teller, with whom he had disagreed regarding the wisdom of constructing a hydrogen bomb. Rumored to have said after seeing the test at Alamogordo, "I am become death, destroyer of worlds," FTP, identify this Caltech and Berkeley physicist, whose centennial was recently celebrated at Berkeley and who, with Born, is the namesake of a quantum-mechanical approximation.

Answer: J. Robert **Oppenheimer**

4. One assumption made in deriving it is that as long as the initial velocity is considered, the concentration of the product can be neglected. A physically meaningful limit of this equation is that of small initial velocities, in which case the velocity displays first-order kinetics, since it becomes proportional to the substrate concentration. In its full form, a plot of the velocity against the substrate concentration yields a rectangular hyperbola, whose horizontal asymptote represents saturation. Demonstrating that the substrate concentration that produces half the maximum reaction rate is equal to half its namesake constant, FTP, identify this equation which relates the reaction rates of reactions catalyzed by enzymes to the initial concentration as a function of the substrate concentration.

Answer: **Michaelis-Menten** equation

5. First observed at the Harvard Observatory in 1888, it is an active site of low-mass star formations and therefore provides a test for photodissociation models. The red glow often seen in pictures of it comes from the hydrogen gas behind it which is ionized by the star Sigma Orionis. Streams of gas leaving this structure are funneled away from it by a magnetic field and the streaks themselves are seen because this structure is located directly in front of an emission nebula IC 434. Lying just south of the bright star Zeta Orionis and also known as Barnard 33, FTP, what is this cosmic object, a cold, dark nebula located in the constellation Orion with an equine name?
     Answer: **Horsehead** nebula

6. In 1950, Motz proposed the basic structure of the device which makes it possible, but it was not until 1971 that Madey gave a full quantum-mechanical description. Unlike its more famous counterpart, the tunability of this device is limited only by the phase matching condition between the active medium and the magnetic field. The equivalent of population inversion is accomplished by a beam, and the radiation is produced when the beam particles interact with a static magnetic field. FTP, identify this type of laser, which derives its name from the fact that the lasing medium is a beam of unattached, negatively charged particles.
     Answer: **free electron laser** (or **FEL**)

7. It initially developed during a detailed examination of manganese oxide and copper chloride, and it cannot be applied to sulfides. The energy splitting predicted by it can be estimated by the fourth power of the mean d-orbital radius divided by the fifth power of the metal-ligand distance. That energy splitting can be classified as cubic, tetrahedral, linear, and square planar, among others, and compounds exhibiting octahedral field splitting can be classified as high-spin or low-spin in this theory. Developed by Hans Bethe in 1929 and extended by van Vleck to allow for some covalency, FTP, identify this theory of ionic compounds, which assumes that the interactions between the metal ion and the ligands are purely electrostatic in nature.
     Answer: **crystal field theory** (or **CFT**)

8. Five different types of it have been identified in the organism Arabidopsis thaliana, and it is a homodimer, one part of which is bonded to a non-protein pigment. It's A form is present only in angiosperms, and is responsible for the early events that take place during germination and seed etiolation. The interacting factor PIF3 is necessary for its proper function of photoinduced signal transduction, and depending on whether it absorbs light at 666 or 730 nanometers, it changes from the Pr form to the PFr form. Responsible for regulating circadian rhythms based in exposure to red light, FTP, what is this plant molecule joined to the chromophore?
     Answer: **phytochrome**

9. In 1999, Felix von Leitner published an article claiming that the consortium that had devised it could not have done anything more wrong than it had. Kevin Weinstein and MarcHorowitz at MIT broke it with just 7 lines of Perl code, defeating its scheme of encrypting a session key with 408 randomly generated player keys. The intial key used to break it came from a reverse-engineering of the Xing player, which took at most 17 hours on a single computer, and within days it was found that the hash value of the key can be used to retreive the key itself, making it useless. First reported as having been cracked by Jon Johansen, FTP, identify this failed encryption scheme for DVDs.
     Answer: **C**ontent **S**crambling **S**ystem

10. Depending on its clinical course, this disease may be classified as relapse-remitting, secondary progressive, progressive relapsing, and primary-progressive. Corticosteroids can be used to relieve the inflammatory response, during which leukocytes become drawn to regions of white matter. This inflammatory response

results in the death of oligodendrocytes and the formation of lesions on the neurons in the place of the myelin sheath, and can cause damage to the axonal membrane. FTP, identify this autoimmune disease which destroys neurons by demyelination.

Answer: **multiple sclerosis** (or **MS**)

11. Ian Shelton and Oscar Duhalde, in the Los Campanas station in the Andes, were the first people to observe it, and it has been proposed that neutrino losses were required for its core to contract sufficiently, leading to huge neutrino emissions that were detected in the Kamioka mine. 80 days after its initial observation, its magnitude peaked at 2.9, and by April, it was receiving most of its energy from the radioactive decay of nickel-56. One explanation for its small size is that the Large Magellanic Cloud is deficient in heavy elements, particularly objects, causing its progenitor, Sanduleak -69 202, to be more transparent and thus more likely to contract to a smaller size. First observed on February 23, FTP, identify this supernova, the closest to Earth since 1604.

Answer: **SN 1987A**

12. Using gold instead of more common dopants in these devices results in minority carrier suppression, lowering capacitance and enabling them to operate in high-frequency regimes. In the Gunn type, the formation of dipole domains allows for the building of high-frequency microwave oscillators, and the Esaki type exhibit regions of operation with negative resistance due to quantum tunneling. Ideal ones are described by the Shockley equation, which gives the current flowing through one as an exponential function of the bias current, and avalanche ones work by causing a wave of ionization at a well-defined current. Also existing in Zener and Schottky forms, FTP, identify these circuit elements formed from a single PN junction and best known in their light-emitting incarnations.

Answer: **diode**

13. A measure of the efficiency of this process can be found by computing the height equivalent of a theoretical plate, and the support for the condensate can be achieved by filling the dephlegmator with a high surface-to-volume packing material. The Le Bel-Henninger form uses a series of bulbs to achieve it and Young's pear-shaped forms are the most efficient, but most forms utilize a straight or spiral column. If it is applied to crude oil, the top of the column will contain petroleum gas, under which will be naptha and gasoline followed by kerosene. FTP, identify this method of separating mixtures in which a temperature gradient along the column separates consituents of the mixture according to their boiling points.

Answer: **fractional distillation** (or **fractionation**, or **rectification**)

14. The pull resulting from this phenomenon depends on the generation of a negative tension due to hydrophilic attraction. A measure of the efficient use of water is the ratio of this effect to photosynthesis, and some xerophytes reduce losses from it by using the CAM pathway. It can result in evaporative cooling, lowering the leaf temperature as much as 15 degree Celsius and its degree is regulated by guard cells around the stomata. Resulting in the drawing of water from the leaf xylem, FTP, what is this effect in plants, the loss of water vapor to the atmosphere through leaves?

Answer: **transpiration**

15. One of the environmental problems associated with the extraction of this mineral is that the water used collects aluminum suflates and becomes extremely acidic. This year, the Mars rover Opportunity discovered small spheres of it, hinting that Mars was once much wetter, since this mineral tends to form in basins of still water. Its Kidney Ore form is botryoidal, while the oolitic form is a sedimentary formation has a reddish-brown color and the Rose form appears as a circular arrangement of bladed crystals. With a Mohs hardness ranging from 5.5 to 7, FTP, identify this form of iron oxide, the most common source of iron with the chemical formula Fe2O3.

Answer: **hematite** (note to moderator: if anyone asks what "botryoidal" means, it means having the appearance of a cluster of grapes. Bet you didn't know that.)

16. The magnetic form of this phenomenon was discovered by Voight in 1902, who observed it in light propagating through a vapor. Celophane is a cheap example of a material that exhibits it, and an eponymous effect, in which refraction varies as the square of the electric field, exploits this phenomenon in such applications as high-speed camera shutters. In general, it arises in the cases when the rank-2 dielectric tensor is real and symmetric, with three eigenvalues along the orthongal polarizatoin axes. Demonstrated by the Kerr effect, FTP, identify this electro-optical phenomenon, in which a material exhibits different refractive indices for light polarized in the plane of the field and light polarized normal to it.
Answer: **birefringence** (or **double refraction**)

17. IOriginally, the denaturation phase of this process destroyed the key enzyme, but using a thermostable version from thermophilic bacteria allows denaturation to take place at 110 degrees. During denaturation, all enzymatic activities cease, and its second phase is annealing, during which the primers move around by Bronwnian motion with only the strongest bonds surviving. The primers that survive are thus strongly bonded to the template, allowing the extension phase to take place, during which its namesake enzyme makes copies of the DNA. FTP, identify this this process for copying DNA in vast amounts, invented by Kary Mullis.
Answer: **P**olymerase **C**hain **R**eaction

18. For the Ising model in the thermodynamic limit, its natural log is equal to the number of particles times the natural log of the largest eigenvalue of the transfer matrix. For N harmonic oscillators, it is equal to beta times h-bar times the frequency, all raised to the negative N power, and its natural log times the Boltzmann constant times the temperature gives the Helmholtz free energy. Its basic form can be derived from considering a system in equilibrium with a heat bath, and in the case of degenerate energy levels, each term in it must be multiplied by a weight factor. FTP, what is this basic quantity of statistical mechanics, the sum of the Boltzmann factors over all the energy states of the system?
Answer: **partition function**

19. The anti-sense version of it can inhibit its function in many eukaryotic cells and is thought to be a defense against retroposons. The removal of the gamma phosphate, the condensation of GTP, and the methylation of the terminal guanosine nucleotide in the 5-prime region are part of its capping process, and most eukaryotic forms have a special 3-prime tail consisting of adenine nucleotides. During transcription, RNA polymerase makes a copy from DNA to it, and polypeptide synthesis occurs during translation under its direction. FTP, identify this form of RNA, which takes its name from the fact that it carries information on protein synthesis to the ribosomes.
Answer: **m**essenger **R**ibo**n**ucleic **a**cid

20. Stephen Cook proved that the Boolean Satisfiability theorem is in it, and he also gave its best-known formal definition. Minimum multi-processor scheduling is in it, as is minimum broadcast time, and fixed-parameter algorithms can be used to find solutions for problems in it for special cases. Other problems in it are the subgraph isomorphism problem, as is the traveling salesman problem, and answers to problems in it can be verified by a non-deterministic Turing machine in polynomial time. FTP, identify this complexity class of problems which consists of all problems in NP such that every other problem in NP is reducible to them.
Answer: **NP-complete**

Bonuses

1. Identify the following stellar types, FTSNOPE.
[5 points] These objects have an upper mass limit of about 0.08 solar masses and radiate only from remaining internal heat. They result from failed stars that lack sufficient mass to initate fusion.
   Answer: **brown dwarf**
[10 points] Falling between brown dwarves and stars of about 1/3 of a solar mass are these stars, which burn helium so slowly that hey may remain on the main sequence for trillions of years. Proxima Centauri is one of these.
   Answer: **red dwarf**
[5 points] These are stars of a solar mass or greater which exhaust their core hydrogen begin burning hydrogen in a thin outer shell and enter helium burning stages in the core. As the star's luminosity increases, it expands in size and cools, leading to its name.
   Answer: **red giant**
[10 points] If a star exceeds 18 solar masses, it is classified as this. These types of stars are usually found in O-B associations and some examples are Rigel, Regulus, and Deneb.
   Answer: **blue giant**

2. Answer some questions about stellar physics FTPE.
[10 points] Combining the polytropic equation of state with the equation of hydrostatic equilibrium yields this non-linear differential equation which governs the macroscopic behavior of a star's interior.
   Answer: **Lane-Emden** equation
[10 points] Using an equation similar to the Lane-Emden equation when the index of the former is 3, it is possible to derive this limiting mass for a white dwarf.
   Answer: **Chandrasekhar** limit (or mass or value or whatever)
[10 points] The polytropic equation of state can be rewritten in terms of this index, which is the ratio of the specific heat at constant pressure to the specific heat at constant volume.
   Answer: **adiabatic** index

3. Answer some questions about the excretory systems of various animals, FTPE.
[10 points] This is the term for the excretory system of a flatworm, suggesting that it is a primitive form of kidney.
   Answer: **protonephridium**
[10 points] In insects, these excretory organs are responsible for removing nitrogenous wastes from the hemolymph and open up into the digestive tract.
   Answer: **Malpighian tubules**
[10 points] The vertebrate nephron consists of a single long tubule and this ball of capillaries, which is contained inside the Bowman's capsule.
   Answer: **glomerulus**

4. Answer some questions about topology, FTPE.
[10 points] This theorem states that a subspace of R-n is compact if and only if it is closed and bounded.
   Answer: **Heine-Borel** theorem
[10 points] Two objects are said to be this if they can be deformed into each other by a continuous, invertible mapping.
   Answer: **homeomorphic**
[10 points] This conjecture, recently proved by Perlman, states that every simply connected closed three-manifold is homeomorphic to the three-sphere.
   Answer: **Poincare** Conjecture

5. Answer some questions about computational models FTSNOPE.

[5 points] This is an eponymous compuational model consisting of a finite state machine, a read-write head, and an unbounded sequential tape.

Answer: **Turing** machine

[10 points] This is the term for a Turing machine (or any finite-state machine) which permits at most one next move at any step in a computation.

Answer: **deterministic**

[5 points] This term describes a Turing machine that can simulate any other Turing machine.

Answer: **universal**

[10 points] Also capable of universality are these collections of simple finite-state machines whose next state depends on their own state and on the state of their neighbors. The best known of these is Conway's Game of Life.

Answer: **cellular automata**

6. Answer some questions about a technical accomplishment, FTPE.

[10 points] The first attempt to install it was made by the the ships Niagara and Agamemnon at Valentia Harbor and Newfoundland, but it was not completely installed until the Great Eastern accomplished it in 1866.

Answer: **transatlantic cable** (accept logical equivalents; the words "atlantic" and some variation of "cable" must be present)

[10 points] Aboard the Great Eastern during both of its attempts to lay down the cable was this man, who was hired as the chief consultant on electricity. His description of electrical currents in cables as analogous to heat flow gave the theoretical justification for the cable's operation.

Answer: William **Thomson** (or Lord **Kelvin**)

[10 points] To measure current, Kelvin invented this device, in which a magnetic coil would manipulate a reflective surface to shine on a calibrated surface, allowing the magnitude to be read off the scale according to the degree of the deflection.

Answer: **mirror galvanometer**

7. Chemistry of solutions FTSNOPE.

[10 points] This eponymous factor gives the number of ions per molecule of solute that is dissolved in the solvent.

Answer: **van't Hoff** factor

[10 points] This process occurs when ions dissolve in a polar solvent, and consists of the surrounding and hydration of the ions by molecules of the solvent.

Answer: **solvation**

[10 points] Milk is an example of this kind of heterogenous mixture in which tiny particles are suspended in another material and in which the Tyndall effect can be observed.

Answer: **colloid**

8. Answer some questions about neurons, FTPE.

[10 points] This is the term for the mechanism which maintains ionic equilibrium across the plasma membrane, called after the two elements whose concentrations it regulates.

Answer: **sodium-potassium pump**

[10 points] When the depolarizatoin in the neuron reaches a certain level, this type of non-graded all-or-none response is triggered.

Answer: **action potential**

[10 points] If a second depolarizing trigger arrives too soon after the first one, it will have no effect because the neuron will still be in this regime, during which it is insensitive to depolarization.

Answer: **refractory period**

9. Identify these different types of years, FTPE.
[10 points] This is the time required for the sun to return to the same position with respect to the stars. It is 20 minutes and 24 seconds longer than the tropical year.
     Answer: **sidereal** year
[10 points] This is the time required for the sun, as seen from the Earth, to complete one revolution with respect to a node of the moon's orbit. It is equal to about 346.62 days.
     Answer: **eclipse** year
[10 points] This is the term for the time required for the Earth to complete one revolution with respect to its apsides. Although the shape of the orbit is not fixed, this year is slightly longer than the sidereal year.
     Answer: **anomalistic** year

10. Identify these parts of a cell, FTPE.
[10 points] This part of the non-dividing nucleus is responsible for the manufacture of ribosome components and their transport out into the cytoplasm.
     Answer: **nucleolus**
[10 points] Among the functions of this organelle, so named because its cytoplasmic surface lacks ribosomes, is the production of sex hormones in verterbrates, as well as detoxification in the liver.
     Answer: **smooth endoplasmic reticulum**
[10 points] Secretory proteins are "shipped" to the Golgi body in these specialized bubbles which bud from the transitional ER.
     Answer: **transport vesicles**

11. Answer some questions about glycolysis, FTPE.
[10 points] Under anaerobic conditions and in erythrocytes, pruvate is converted into this by this molecule's namesake dehydrogenase.
     Answer: **lactate**
[10 points] During aerobic glycolysis the electrons of cytoplasmic NADH are transferred to mitochondrial carriers of this pathway, generating a continuous supply of cytoplasmic NAD+.
     Answer: **oxidative phosphorylation**
[10 points] Most of the ATP used by cells to maintain homeostasis is produced during this cycle during which reduced NADH and FADH2 are also generated.
     Answer: **Tri**c**arboxylic **a**cid cycle

12. Answer some questions about the universe, FTPE.
[10 points] For the special case of a homogenous, isotropic fluid, the Einstein equations reduce to these two ordinary differential equations which involve only the radial coordinate and its time derivatives.
     Answer: **Friedmann** equations
[10 points] Einstein added this term to his equations, which would allow for a static, but unstable universe. It is currently believed that this term is small, but nonzero.
     Answer: **cosmological** constant
[10 points] At about 1.5 times 10 to the 10th degrees Kelvin, most of these lightest leptons undergo "freeze-out" and decouple from the rest of the universe, expanding afterwards adiabatically.
     Answer: **neutrinos**

13. Answer some questions about DNA, FTSNOPE.
[5 points] What is the generic term for enzymes which cut DNA molecules at specific locations?
     Answer: **restriction** enzymes

[10 points] Bonds between restriction fragments and complementary single-stranded stretches on DNA molecules cut with the same enzyme can be made permanent by this enzyme, which catalyzes the formation of photodiester bonds.

Answer: **DNA ligase**

[15 points] Extracting mRNA from an eukaryotic cell and using reverse transcriptase on it yields this form of DNA which contains no introns and can be attached to vector DNA for replication inside a cell.

Answer: **complimentary DNA**

14. Answer some questions about the philosophy of science FTPE.

[10 points] In his *Are Universes Thicker Than Blackberries*, Martin Gardner criticized this man's dismissal of induction in *The Problem of Induction*.

Answer: Karl **Popper**

[10 points] Popper rejected induction as logically unsound, favoring instead this concept, according to which only a single negative result is needed to prove an idea wrong.

Answer: **falsification**

[10 points] In devising falsification, Popper explicity rejected the teachings of Rudolf Carnap and this associated group.

Answer: **Vienna Circle**

15. Answer some questions about some widely-used devices in plasma physics, FTPE.

[10 points] Identify this device which uses a plasma current to generate the helical magnetic fields necessary for equilibrium.

Answer: **tokamak**

[10 points] More common in cylindrical plasmas, this technique can be used to contain a plasma in a tokamak by exploiting the adiabatic invariance of the magnetic moment.

Answer: **magnetic mirror**

[10 points] Unlike in a tokamak, in this earlier device all the magnetic fields necessary for containment were generated externally. It takes its name from the idea that it might be possible to harness the fusion power of the sun with it.

Answer: **stellerator**

16. Answer some questions about the geography of oceans, FTPE.

[10 points] Formed by turbidity currents that covered pre-existing topography, these regions are flat areas of the ocean basin floor which slope less than one part in 1000.

Answer: **abyssal plain**s

[10 points] An area of relatively shallow water found on the edges of continents, it merges with the ocean floor through its namesake slope. The largest of these is the Siberian, stretching about 1500 kilometers in width.

Answer: **continental shelf**

[10 points] This is the zone in ocean waters where the greatest temperature gradient is maintained. Polar oceans do not have permanent ones, but do have seasonal ones.

Answer: **thermocline** zone

17. Answer some questions about the chemistry of liquids, FTPE.

[10 points] Glass is often incorrectly classified as this type of liquid. This is the term for a meta-stable liquid whose temperature has been reduced below it's melting point but is above the glass transition temperature.

Answer: **supercooled** liquid

[10 points] For a pure liquid, this doubly-named equation can be used to determine the relationship between

a liquid's vapor pressure and its temperature, relating it to the enthalphy of vaporization.

Answer: **Clausius-Clayperon** equation

[10 points] For more complicated liquids, this equation, not named for St. Exupery, is a 3-parameter equation that fits the vapor pressure to the data over a limited temperature range.

Answer: **Antoine** equation

18. Identify the following concepts from circuit theory, FTPE.

[10 points] This theorem states that a linear network of voltage sources and resistances may be reduced to a single equivalent namesake voltage and resistance.

Answer: **Thevenin** theorem

[10 points] The frequency response of a circuit is described by this function, which gives the relative amplitudes of frequencies at the output of the circuit.

Answer: **transfer** function

[10 points] This is the principle which states that in a linear circuit containing multiple independent sources, currents and voltages in the network may be calculated as the algebraic sums of the individual contributions of each source acting alone.

Answer: **superposition** principle

19. Answer some questions about electrostatics, FTPE.

[10 points] In regions where there is no space charge, this simplified form of the Poisson differential equation can be solved to find the potential.

Answer: **Laplace** equation

[10 points] Attempting to solve the Laplace equation in cylindrical coordinates yields solutions that can be expanded in these eponymous functions.

Answer: **Bessel** functions (do not accept "Hankel" and "Neumann" functions unless they also mention "Bessel functions of the first kind")

[10 points] If the potential is sufficiently localized in a sphere around the origin, the potential outside the sphere may be found by means of this technique, in which that potential is written as an infinite sum of spherical harmonics.

Answer: **multipole** expansion

20. Organic chemistry, FTPE.

[10 points] Consisting of an organic molecule with a COOH group, this is the term given to a class of acids that includes formic and acetic acids.

Answer: **carboxylic acid**s

[10 points] This is the name given to carboxylic acids with long hydrocarbon side chains.

Answer: **fatty acid**s

[10 points] Carboxylic acids may be reduced by LiAlH4 to form these compounds, consisting of a hydroxyl group bound to another atom, which is itself bound to other hydrogens or carbons.

Answer: **alcohol**s