

2020 National Science Bee – Varsity and Junior Varsity Finals

1. This operation may be defined by summing n-fold products over the symmetric group of order n weighted by the sign of the permutation. The Leibniz formula defining this operation may also be written in terms of the Levi-Civita symbol. This operation is applied to the Jacobian when changing coordinates of multivariable integrals. This operation can be used to solve systems of linear equations by Cramer's Rule. A matrix is invertible if and only if this operation is nonzero. This operation is only defined on square matrices. For the point, name this matrix operation which when applied to a two by two matrix returns (read as letters) 'a' 'd' minus 'b' 'c'.

ANSWER: matrix **determinant**

2. In this type of cell, a paroxysmal nocturnal disease causes incorrect GPI linkage of decay-accelerating factor. These cells have phosphatidylserine primarily concentrated on their inner membrane that flips over as they age, serving as an "eat me" signal to macrophages after 120 days. Howell-Jolly bodies are a deformed type of these cells that are not properly processed by the spleen. Ht percentage is a measure of formed elements, which are primarily made up of these cells. A serine to valine mutation causes these cells to become misshapen, but possessing heterozygosity for that mutation confers resistance to malaria. These lobe-shaped cells contain no nucleus and have a high percentage of hemoglobin. For the point, name these cells that circulate through the blood system to deliver oxygen.

ANSWER: **red blood cells** [or **RBCs**]

3. According to a story, this theoretical physicist once sat on a committee for the DOE Joint Genomics Institute where a Motorola spokesperson's rambling answer to "What is Six Sigma" prompted this physicist to render the spokesperson completely silent with the question "Can you at least define one-sigma?" This scientist's QED work resulted in him lending his name to a perturbative series where each term is represented by Feynman diagrams. This scientist theorized a namesake genetically engineered tree capable of growing inside a comet. This scientist suggested searching for artificial stellar sources of infra-red radiation could result in finding civilization via looking for a type of megastructure named for this scientist built on top of stars. For the point, name this scientist who passed away in 2020 who developed the idea of capturing a star's energy with his namesake sphere.

ANSWER: Freeman (John) **Dyson**

4. This substance is formed via mobilization of iron and aluminum followed by their immobilization and stabilization in podzolization. The consolidation properties of this substance are measurable by Oedometers [[ee-DO-muh-ters]] which can help determine the Shrink-Swell index of this substance if its expansivity is a concern. The five factors of climate, organisms, relief, parent material, and time are the five CLORPT factors that help determine how this substance forms. The organic material of this substance forms the O horizon and humus accumulation makes up part of the A horizon. When the infiltration rate of water into this material is higher than the precipitation rate, runoff will occur. For the point, name this material which is enriched through crop rotation and fertilizer.

ANSWER: **soil** [accept **clay** soil]

5. The U.S. Government backed an Engineering Task Force for this technology which now works with the Reston, Virginia headquartered ISOC, a nonprofit "Society" centered around this technology whose motto is that this technology "is for everyone." Louis Pouzin led an early French effort into this technology that resulted in CYCLADES, an instance of this technology that used a distance vector to handle routing requests of data packets. So-called 'traffic flow' can be achieved through this technology via a three-way handshake using the Transmission Control Protocol build on top of IP, the standard protocol for this technology. For the point, name this technology, a system of interconnected computer networks that supports the World Wide Web.

ANSWER: the **Internet**

6. For integer values, the gaps in a process named by this distribution's namesake gives an Erlang distribution. This distribution was popularized by statistician Ladislaus Bortkiewicz in his book *The Law of Small Numbers*, using it to model the number of Prussian soldiers killed by horse kicks each month. The binomial distribution approaches this distribution as n tends to infinity for a probability p equal to a certain rate over n . This distribution gives the probability of a random variable evaluated at k as $e^{-\lambda} \frac{\lambda^k}{k!}$. This distribution models the number of arrivals over a given time interval. For the point, name this distribution named for a French mathematician.

ANSWER: **Poisson** distribution

7. The wavefunction of electrons inside one of these systems is given by a Bloch wave. Ewald's sphere describes momentum transfer in these systems by analyzing these systems' reciprocal spaces. Materials composed of many of these systems exhibit grain boundaries at their interfaces. Walter Schottky names a type of point defect in these systems created by excitations. Laue's equation improves on Bragg's law describing x-ray diffraction by these substances. According to the third law of thermodynamics, one of these systems at absolute zero will have zero entropy. For the point, name these well-ordered solids characterized by their periodic lattice structure.

ANSWER: **crystals** [accept lattices until mention; prompt on periodic system before mention]

8. This phenomenon is described in any homogeneous isotropic non-attenuating medium by the Jones vector. Depending on how much the ray undergoes this phenomenon the ray can be classified as ordinary or extraordinary with the latter being governed by a direction dependent index of refraction. A description of birefringence by Rasmus Bartholin suggests that the index of refraction of birefringent materials depends on this phenomenon. The change in irradiance of light with this property passing through a namesake device can be determined by multiplying the initial irradiance by cosine squared of the angle between the perpendicular axis of the device and the direction this phenomenon occurs according to Malus' law. For the point, name this property of materials that is sometimes used in sunglasses to reduce glare from the sun.

ANSWER: **polarization** [do not accept "polarity"]

9. This animal counteracts microbacterial transfer to its infants with a protein called MLP whose crystal structure has an unusually dense amount of loops. These mammals share a sex classification system similar to avian ZW chromosome classification which is accomplished with five X and Y chromosomes. The male members of these animals have venom glands on their hind legs which do not fully develop in females. Captain John Hunter first discovered this mammal and sent sketches to naturalist George Shaw. Shaw believed this mammal could be a "deceptive preparation by artificial means." This animal, scientifically known as *Ornithorhynchus anatinus*, has according to one scientist "the perfect resemblance of the beak of a Duck engrafted on the head of a quadruped." For the point, name this monotreme, endemic to Eastern Australia, with an iconic duckbill.

ANSWER: duck-billed **platypus** [UNTIL MENTIONED: accept Ornithorhynchus antanius]

10. Measures can be defined to assign a "size" to these objects which act as the elements of sigma algebras. These objects are called "path-connected" if a continuous function on these objects exists between any two points in one of these objects. The Cartesian product acts on two of these objects while Russell's paradox concerns a self-referential example of these objects. The cardinality of these objects is defined as the number of elements contained in these objects. De Morgan's laws can be used to change an expression of these objects in terms of complements, intersections and unions. For the point, name these basic mathematical objects defined as an unordered collection of elements.

ANSWER: **sets**

11. A modern day institute that pays homage to this location founded the International School of Information Science which promotes and carries out efforts to digitize documents and information. Once the head of this location, Aristarchus of Samothrace resigned his position and exiled himself to Cyprus after Ptolemy VIII Physcon purged several intellectuals from the city where it is located. Julius Caesar accidentally burnt part of this building during the Great Roman Civil War. For the point, name this library established in the Ptolemaic kingdom which attracted many Greek scholars to a certain Egyptian city.

ANSWER: the Great **Library of Alexandria** [accept answers indicating **Library** in or at **Alexandria** including **Alexandrian Library** and similar answers]

12. Typically, a compound containing aluminum and this element form the strong Lewis acid used in the Friedel-Crafts reactions. Oxygen and four moles of this element's acid react to form two moles of water and two moles of this element's dimer in the Deacon process. A common NMR solvent using a solvent containing four atoms of this element bound to a central carbon atom was banned by the Montreal Protocol. This element reacts less violently than the element above it on the periodic table, but is less selective than bromine when used in halogenation reactions. Nitric acid and this element's acid are used to make "aqua regia." For the point, name this element that forms an ionic bond with sodium to make table salt.

ANSWER: **chlorine**

13. Low mass analogs of HMCs in this process are termed hot corinos. This process is related to local gas surface density by an empirical relation named for Maarten Schmidt. This process begins occurring above the Bonnor-Ebert mass. The rate for this process is high in Pea galaxies and blue compact galaxies. The presence of a first hydrostatic core is thought to be detectable during this process which is also accepted to be the source of nebular ejections known as Herbig-Haro objects. Binary and multi-variants of the product of this process are commonly formed in systems in Bok globules. The elephant trunks of the Eagle Nebula were photographed undergoing this process in a photo named *Pillars of Creation*. For the point, name this process of forming astronomical objects like the sun.

ANSWER: (proto)**star formation** [or (proto)**stellar formation**; accept **formation** of **stars**; accept "forming" for formation and also logical equivalents like "birthing" "development", etc.]

14. The propagator can be used to find this object at all future times given an initial value. For the hydrogen atom this object is proportional to an associated Laguerre polynomial. For rotationally symmetric configurations, this quantity depends on a spherical harmonic. $i \hbar$ times the time derivative of this object equals the Hamiltonian acting on this object according to Schrödinger's equation. The probability of a particle can be found by integrating the square of the absolute value of this function, which collapses when a system is observed. For the point, name this function from quantum mechanics, symbolized ψ , that encodes the quantum state of the system.

ANSWER: **wavefunction**

15. An attack related to the mailing of these offspring-like structures could have originated from flask RMR-1029. Accumulation of Spo0A leads to a sigma cascade promoting the formation of these structures; a pathway upregulated by enzymes kinA and kinB in response to nutrient starvation. Dipicolinic acid helps provide heat resistance to a structure of this name. F Bacteria of the firmicute family produce non-reproductive structures of this name that are only formed under environmental stress to help the bacteria survive. For the point, identify this word that describes those bacteria structures as well as asexual reproductive structures produced by many plants and fungi.

ANSWER: **endospores** [accept Anthrax **endospores**; prompt on anthrax first line]

16. A good estimation of this property can be calculated by taking the square root of the cohesive energy density to obtain the Hildebrand parameter. That parameter of this property is useful for estimating the chi ("kai") parameter to determine this property for polymers in Flory-Huggins theory. This property's product constant can be determined for a salt via multiplication of this property for the dissociated ions in moles per liter. The ratio of this property for a substance in octanol versus in water is used to define the partition coefficient. Henry's Law gives a relation of partial pressure to this property of a gas in a liquid. For the point, name this property, the amount of solute that will dissolve in a given volume of solvent.

ANSWER: **solubility**

17. These objects can be "depressed" by a change of variables, which helped Lodovico Ferrari and Girolamo Cardano find formulas solving these objects. The Rodrigues formula can be used to compute members of an orthogonal set of these objects named for Adrien-Marie Legendre. The fundamental theorem of algebra guarantees that for the complex numbers the only irreducible examples of these objects are linear. The power rule is used to take the derivative of these functions. The Abel-Ruffini theorem proves that these functions are not generally solvable for degrees greater than or equal to five. For the point, name this class of functions which can be expressed as sums of monomial terms.

ANSWER: **polynomials**

18. This scientist's book *Through the Window* discusses a war between the Kasakala and Kahama communities with first hand accounts of non-human cannibalistic infanticide. Among the subjects described by this scientist in the book *In the Shadow of Man* were David Greybeard, Flint, Goliath, and Flo. After witnessing the use of spoon-like twigs being used to fish for termites, this anthropologist, who has been active for over sixty years, challenged the idea that humans were the only tool-making species. For the point, name this behavioral scientist whose studies at Gombe Stream National Park have made her a world leading expert in chimpanzees.

ANSWER: (Dame Valiere) Jane (Morris) (van Lawick-) **Goodall**

19. This letter sub one is used to represent a group formed of homotopic loops of a given base point in the topological space referred to as the fundamental group. Rabinowitz and Wagon developed a spigot algorithm for calculating a number represented with this letter. Parallel strips of wood of even width t are required for a set-up used to approximate a number related to this letter with a needle of length l ; a problem first formulated by the Comte de Buffon. The integral from negative one to one of dx over the square root of quantity one minus x squared, is equal to a transcendental number represented by this symbol. For the point, name this symbol used to represent a number equal to one half of tau or the ratio of a circle's circumference to its diameter.

ANSWER: **pi**

20. In regular expressions, this symbol indicates that the preceding letter may be repeated any number of times. In C, when this symbol is used with a value and a pointer, the size of the item the pointer currently points to is used to determine what sized blocks should be moved by. In Java, when both variables are of type string, this symbol can be used for the concatenation operation. Java also uses two tokens of this symbol after a variable to increment the variable's value by one. Bjarne Stroustrup created a programming language inspired by C that uses this symbol twice in its name. For the point, name this symbol used to represent addition in mathematics.

ANSWER: **plus** sign

21. Using chemical potential's equilibrium point as a proxy for this process was modeled by Michael Polanyi based on his potential theory. Molecular gases can be separated in a "pressure swing" technique that takes advantage of the target gas undergoing this process. BET theory models the multilayer possibility of this process. The first empirical model published for this process sets the fraction of molecules it occurs to equal to pressure raised to one over some constant; that model was published by Kuster and Freundlich. By assuming the molecule undergoing this process is an ideal gas at isothermal conditions, one can derive the Langmuir model. This process can be physical if the electrons on the surface only hold the gas by Van der Waals forces. For the point, name this process of molecules adhering to a surface.

ANSWER: **adsorption** [check that the answer given is not "absorption"]

22. This phenomenon is the primary natural source of Schumann resonance excitation. Unusually short duration instances of this phenomenon occurring in the upper atmosphere are classified as TLEs and include fantastically named types like ELVES, gnomes, and sprites. When this phenomenon comes in contact with the skin, it can leave behind a 2D fractal Lichtenberg figure, and when it comes in contact with the ground, it can fuse together soil and silicate material into a hollow glassy cylindrical material known as fulgurite. This phenomenon occurs when the local electric field exceeds the dielectric strength of the air. For the point, name this phenomenon that Benjamin Franklin empirically related to electricity by trials of his kite experiment.

ANSWER: thunderstorm **lightning**

23. The maximum k for which a k -core exists in a graph denotes the k -[this property] of a graph and encodes how sparse it is. In mathematical biology, this word refers to overlap between promoter sites. Semiconductors described by this adjective are so heavily doped that they begin to behave like metals. Matter described by this adjective can be modelled as an ideal Fermi gas and occurs in astrophysics problems due to gravitational pressure causing quantum mechanical effects. In molecular biology, codons have this property if they encode for the same amino acid. Two different quantum states are said to have this property if they give the same energy level upon measurement. For the point, name this concept that refers to overlap in states leading to simplification or to deterioration over time.

ANSWER: **degeneracy** [accept word forms like **degenerate** or **degeneration**]

24. This operation may be defined by summing n -fold products over the symmetric group of order n weighted by the sign of the permutation. The Leibniz formula defining this operation may also be written in terms of the Levi-Civita symbol. This operation is applied to the Jacobian when changing coordinates of multivariable integrals. This operation can be used to solve systems of linear equations by Cramer's Rule. A matrix is invertible if and only if this operation is nonzero. This operation is only defined on square matrices. For the point, name this matrix operation which when applied to a two by two matrix returns (read as letters) 'a' 'd' minus 'b' 'c'.

ANSWER: matrix **determinant**

25. In one example of this class of reactions, an encounter complex forms between a metal bound to six ligands and an incoming ligand whose rate can be determined by the Eigen-Wilkins mechanism. One type of this reaction begins with a carbon oxygen double bond on an acyl group being broken; that example of this class of reactions works best on acid halides since chlorine readily serves as a good leaving group. This class of reactions includes the Friedel-Crafts reactions performed on electrophilic aromatic compounds. A trigonal pyramidal intermediate is formed if the nucleophile attacks after the leaving group leaves in an S_N1 reaction, another example of this class of reactions. For the point, name this reaction where one or multiple components of molecules are replaced or swapped.

ANSWER: **substitution** [accept associative **substitution**; accept nucleophilic acyl **substitution**; accept electrophilic aromatic **substitution**; accept nucleophilic **substitution** 1 or 2; accept (double or single) **replacement**; prompt on S_NAC ; prompt on S_N1 ; prompt on S_N2 ; prompt on EAS]

26. Claude Cohen-Tannoudji proposed using two of these devices in the method of Sisyphus cooling. Arthur Schawlow and Charles Townes suggested a potassium lamp could serve as the basis for one of these devices. The Schawlow-Townes proposal for these devices was dismissed by Arthur Maiman in favor of a ruby crystal and a xenon flash lamp. Placing an attenuator can cause the Q factor of a component of this device to decrease while waiting for gain saturation and then turns off to allow for a high Q factor in the method of Q-switching to make giant pulses from these devices. For continuous wave operation, this device requires a pump source to maintain population inversion. For the point, name these devices that produce light via stimulated emission.

ANSWER: **lasers** [or **light amplification** by **stimulated emission of radiation**]

27. Quercetin and Genistein are naturally occurring inhibitors of the transport mechanism of this class of hormones that makes use of PGP proteins and PIN proteins. TIR1 is a receptor for this class of hormones that moves via a namesake polar transport. This class of hormones is responsible for the activation of expansins which causes an efflux of protons into the apoplast according to the acid growth hypothesis. The most abundant member of this class of hormones is indole-3-acetic acid. This class of hormones regulates phototropism and gravitropism. For the point, name this class of plant hormones responsible for apical dominance as well as stimulating stem growth alongside gibberellins.
ANSWER: **auxins**

28. A tree named for this algorithm can be constructed from a list of weighted nodes by finding three nodes x , y , and z such that x and y are less than z , creating a parent node $x + y$, and placing that to the right of the first value in the list greater than $x + y$. The Garcia-Wachs algorithm constructs a tree named after this algorithm, which cannot be modified in the static optimality problem. A tree with this algorithm's property has each node's children on the left smaller than the current node and each node's children on the right larger than the current node. A search algorithm with this name operates on a sorted list and compares the search element to the middle element before searching above or below. For the point, name this type of search where the search space is iteratively divided in two halves.
ANSWER: **binary search** [after reading "SEARCH" accept **binary**]

29. CODASYL used the network model of these constructs as the basis for developing languages for them. Systematic treatment of null values and non-subversion are part of twelve rules developed for these constructs developed by Edgar Codd. Mongo loads these constructs horizontally using shards. Atomicity, consistency, isolation and durability are the four ACID properties that must be kept during transactions of these constructions. Languages that interact with these constructs either use relational algebra or relational calculus during their query. JOIN, SELECT and INSERT are keywords used on these objects in languages like SQL. For the point, name these large pools of stored information.
ANSWER:(relational) **databases**

30. In 1916, Ma. et. al. outlined methods for extracting compounds that give off this property when it naturally occurs in silk, identifying it in compounds like all trans-lutein in NCS samples. Granulocytes in mast cells were discovered after they obtained this property from TBO. Back in 1855, before discovering his "magic bullet" to treat syphilis, Paul Ehrlich wrote a monograph on using alizarin and indophenol to give a cell this attribute in areas of high oxygen saturation. Paul Ehrlich also found a methylene compound that attributes this property to bacteria, which is used along with bromothymol and phenolphthalein in some titration techniques. For the point, name this property of staining reagents and dyes which helps with visualizing samples.
ANSWER: **color** [accept **pigmentation**; or **pigments**; BEFORE MENTIONED : accept **dyes**; accept **stains**; anti-prompt on blue, yellow, or pink "Can you be less specific?"]

31. This condition decreases GATA2 levels and promotes recruitment of p300/CPB and expression of ET-1 to form a namesake response complex. In addition to acidosis, this condition can trigger neutralization of the Von Hippel Lindau tumor suppressor protein. Elevated levels of EPO are associated with this cellular condition, which is regulated by namesake inducible factors. Kaelin Jr, Ratcliffe, and Semenza won the 2019 Nobel Prize in Physiology or Medicine for their work on how cells sense this condition. Freediving blackout can occur due to the cerebral form of this condition, which is also caused by hypocapnia, a related condition to a different respiratory molecule. For the point, name this condition of local or generalized deprivation of oxygen from tissue.
ANSWER: **hypoxia** [accept **low concentrations** of **oxygen**; accept **anoxia**]

32. In the Shockley model, P-MOS and N-MOS transistors are modelled with effective resistance and a circuit element measured with this quantity. The base and collector of transistors causes an amplification of this quantity's parasitic form due to the Miller effect. The impedance of the simple circuit element that is measured in this quantity is equal to the reciprocal of the imaginary number times angular frequency times this quantity. In the simplest geometry, this quantity, whose reciprocal is elastance, is equal to kappa times epsilon times area over distance where kappa is the dielectric constant and the geometry is parallel plates. This quantity's units can be written as coulombs per volt because this quantity equals charge over voltage. For the point, name this quantity whose SI unit is the Farad.

ANSWER: **capacitance**

33. Samuel Shenton founded an international research society for this position. Samuel Rowbotham's review of data published on the Bedford Level experiment resulted in him spreading the modern conception of this position with the creation of the *Zetetic Society*. The WCBD radio was originally founded by Wilbur Glenn Voliva to advocate for this position which he had pushed to have taught alongside creationism at Zion, Illinois Catholic Church schools. Explanations like "heat" and "photoshop" have been given against evidence of this position by placing a boat on water and watching indicators on the back of the boat disappear below the horizon as the boat travels farther away. For the point, name this position held by some where the earth is believed to be 2D rather than spherical.

ANSWER: **flat earth** [accept logical equivalents]

34. Most of these animals possess a bilobed sebaceous gland known as uropygial gland. For hematopoiesis, these animals make use of a specialized organ called the Bursa of Fabricius. The largest order of these animals, the passerines, is distinguished by the organization of the toes on the feet, with three facing forward and one facing backwards. Because some of these animals do not molt, the Humphrey-Parkes classification system was developed. All species of these animals use a ZW sex-determination system, as opposed to the mammalian XY system. Because they evolved from small theropods, some taxonomists consider these animals to be "living dinosaurs." For the point, name these feathered vertebrates who lay eggs, many of whom are capable of flight.

ANSWER: **birds** [accept **aves**; accept **avians**]

35. The Large Area Detector is designed for this phenomenon which records onto the Central Electronics Unit of the BATSE instrument. In 2017, after detection of gravitational waves from a neutron star merger nearby galaxy NGC 4993, this form of radiation was followed by a rapid fading UV signal and no x-rays detected by the Swift observatory. While searching for nuclear weapon signatures, a Ray Klebesadel-led Los Alamos team discovered an unusual signal caused by this radiation using Vela satellites. Magnetars are thought to be the source of "Soft Repeaters" of this radiation. The brightest events in the known universe are caused by "bursts" of this radiation. For the point, name this high frequency radiation named after a greek letter.

ANSWER: **gamma ray** [accept **gamma ray** bursts; prompt on GRB with "what form of radiation is involved?"]

Tiebreakers

36. Some quantum physicists are interested in this process in bacteria with focused study on energy transfer to the Fenna–Matthews–Olson complex. This process's cyclic and noncyclic phosphorylation reactions make use of iron-sulfur proteins called ferredoxins. The two systems of this process contain special molecule pair complexes referred to as P700 and P680. One part of this process makes use of the most abundant, and arguably most inefficient enzyme in the world, RuBisco in a carbon fixation step of the Calvin cycle portion of this process. Chloroplasts and stomata help with the conversion of carbon dioxide sourced products formed by this process. For the point, name this process that takes in light and carbon dioxide to produce glucose and other sugars.

ANSWER: **photosynthesis** [anti-prompt on Calvin cycle until Calvin Cycle is mentioned; anti-prompt on light dependent or light independent until light dependent is mentioned]

37. Cumrun Vafa and Andrew Strominger showed that solitonic states of these entities could explain Bekenstein-Hawking entropy. The winding number of these entities is equivalent in type IIA and type IIB theories by T-duality. Calabi-Yau manifolds are useful for creating an internal space on which these entities can reside. The holographic principle relieves the requirement of perturbation in the theory of these entities. These entities trace out worldsheets in spacetime and are branes with dimension one. Ed Witten noticed the dualities of five theories of these entities could lead to one overarching M-theory of them. For the point, name these hypothetical one-dimensional entities that replace particles in higher dimensional theories of physics.

ANSWER: **strings** [accept super**strings**]