

**Blind mathematician Bernard Morin described an intermediary step in the eversion of these objects. “Ricci flow with surgery” was used on one of these objects in Grigori Perelman’s proof of the Poincaré conjecture, which describes these objects in 4 dimensions. The Kepler conjecture gives the maximum (\*) packing density for these objects. A coordinate system named for these objects uses variables rho, phi, and theta to represent three-dimensional space. One of these objects is the boundary of any ball. Four-thirds-pi- $r^3$  gives the volume of, for 10 points, what three-dimensional analogs of circles?**

ANSWER: spheres [accept 3-spheres or 2-spheres]

<DB, Science - Other Science - Math>

**This planet’s moon Galatea causes its outermost Adams ring to feature clumps called arcs. This planet anomalously radiates more than twice as much energy as it receives from the sun, causing it to have winds that break the sound barrier. One moon of this planet has a frozen nitrogen surface and is the largest moon in the Solar System with a (\*) retrograde orbit. Johann Galle discovered this planet on the same night that he received Urban Le Verrier’s mathematical prediction of its existence. Since they were first observed in 1989, storms on this planet like the Scooter and the Great Dark Spot have disappeared. For 10 points, name this planet that is an ice giant like Uranus.**

ANSWER: Neptune

<DB, Science - Other Science - Astronomy>

**This particle was proven to exist using gamma rays from thallium-208. This particle was theorized as an unexpected positive solution to the Dirac equation. In the most common type of pair production, a high-energy photon is transformed into this positively-charged particle and its (\*) antiparticle. This particle is emitted when an up quark changes flavor into a down quark. This particle annihilates with its antiparticle in its namesake “emission tomography,” the PET scan. For 10 points, name this particle symbolized e-plus that has the same mass but opposite charge as an electron.**

ANSWER: positrons [or antielectrons or beta-plus; accept e-plus before mentioned]

<DB, Science - Physics>

**Johann Bernoulli solved the brachistochrone (“bruh-KISS-tuh-crone”) problem using the fact that this function of theta is inversely proportional to the square root of y for a cycloid. The Fourier decompositions of odd functions are sums of this function. The hyperbolic form of this function equals one half times the quantity e-to-the-x minus e-to-the-negative-x. This function’s Taylor series expansion is the (\*) alternating sum of odd powers of x over factorials of odd integers. The reciprocal of this function is cosecant, and the derivative of this function is cosine. For 10 points, name this trigonometric function that is equal to “opposite over hypotenuse.”**

ANSWER: sine [do not accept “cosine”; accept sin(x) or (“sine of x”) sin(theta) (“sine of theta”); accept sinh (“cinch” or “shine”) or hyperbolic sine]

<DB, Science - Other Science - Math>

**The intensity of this phenomenon in the near field can be evaluated with Cornu spirals. Two approximations for this effect are named for Fraunhofer and Fresnel (“fruh-NELL”). Huygens’s (“HIGH-guns-iz”) principle describes this phenomenon as the result of every point on a wavefront being a source of spherical waves. Two d sine theta equals n lambda according to (\*) Bragg’s law, which describes how x-rays exhibit this phenomenon. This phenomenon results in interference as photons travel through adjacent holes in Young’s double-slit experiment. For 10 points, name this phenomenon in which a wave bends around an obstacle.**

ANSWER: diffraction

<DB, Science - Physics>

**The six-factor formula for this process is used to determine an “effective multiplication factor” for this process. Geological dating can be performed by observing “tracks” left by this process. In this process, “fast”**

**particles are converted to “thermal” ones by graphite or (\*) heavy water, which are moderators that regulate neutron energies. If the critical mass is achieved, then neutrons colliding into other atoms will drive a chain reaction of this process, which is exploited by nuclear reactors. “Splitting the atom” refers to, for 10 points, what process, the opposite of nuclear fusion?**

ANSWER: nuclear **fission** [prompt on nuclear chain reaction or nuclear reaction; do not accept or prompt on “nuclear fusion”]

<DB, Science - Physics>

**Applying the Box–Cox transformation makes data follow this distribution. Data sets sampled from this distribution have high correlation coefficients on a default Q–Q plot. When values sampled from this distribution are squared, they follow a chi-square distribution. A large number of sample means follow this distribution via the (\*) central limit theorem. When population variance is unknown, the *t*-distribution is used instead of this distribution. The empirical rule states that 95% of values sampled from this distribution are within two standard deviations of the mean. For 10 points, name this bell-shaped distribution.**

ANSWER: **normal** distribution [or **Gaussian** distribution]

<DB, Science - Other Science - Math>

**The Relativistic Heavy Ion Collider used gold ions to detect this particle’s antiparticle in 2011. After protons, these particles are the most common type of cosmic ray. Stars with especially high temperatures perform fusion with three of these particles. These particles were fired through a (\*) zinc sulfide screen in Rutherford’s gold foil experiment. Uranium-238 decays to thorium-234 by emitting one of these particles, which are equivalent to the nucleus of a helium atom. For 10 points, name this particle consisting of two protons and two neutrons, named for the first letter of the Greek alphabet.**

ANSWER: **alpha** particles [accept **alpha** decay; prompt on helium 2+, helium (cat)ion, or helium-4 nucleus]

<DB, Science - Physics>

**A representation is characterized by a homomorphism of a group to a group of these objects, the general linear group. A set of *n* functions is differentiated *n*-minus-one times in one of these objects when calculating the Wronskian. These objects are orthogonal if their inverse equals their transpose. Pivot elements can be selected from these objects when simplifying them via methods like Gauss–Jordan (\*) elimination, which converts these objects to their reduced row echelon form. These objects are invertible if they have a non-zero value for their determinant. Linear algebra primarily concerns, for 10 points, what rectangular arrays of numbers?**

ANSWER: **matrices** [or **matrix**; accept specific types of **matrices**; accept **linear transformation** before “Wronskian”]

<DB, Science - Other Science - Math>

**These structures contain quiescent centers surrounded by pools of stem cells. Examples of these structures in *Rhizophora mangle* are described as “adventitious.” These structures are penetrated by arbuscular mycorrhiza (“mai-kaw-RYE-zuh”), which consist of an association of (\*) fungi with these structures. Rhizobia (“REE-zo-bee-uh”) mutualistically fix nitrogen while residing in the “nodules” of these structures. These structures connect members of the clonal colony pando, the heaviest organism on Earth. Monocots typically have a “fibrous” system of these structures, while the “tap” form of these structures is exemplified by carrots. For 10 points, name these plant structures that absorb water from the soil.**

ANSWER: **roots** [accept **root** nodules or **root** tips]

<DB, Science - Biology>

**Ehrenfest’s theorem relates the time derivative of the expectation of this quantity with potential energy. This quantity’s operator is equal to negative *i* times *h*-bar times the gradient. An object’s de Broglie (“duh BROY”) wavelength equals Planck’s constant divided by this quantity. Kinetic energy equals this quantity (\*)**

squared over two times mass. The Heisenberg uncertainty principle states that there is a tradeoff between precise knowledge of position and this quantity. The change in this quantity is often expressed with units of force times time, which equals impulse. For 10 points, name this quantity, symbolized  $p$ , that is equal to mass times velocity.

ANSWER: linear momentum [accept momentum operator]

<DB, Science - Physics>

**Excessive paging of this resource leads to thrashing, in which this resource is rapidly transferred between two sites. L1, L2, and L3 types of this resource are faster than the “main” form of this resource. A segmentation fault occurs when a program attempts to access this resource without permission. Garbage collection automatically deallocates this resource. (\*)** Pointers store addresses for this resource in the stack and are used to access this resource in the heap. The “cache” form of this resource is typically stored in the CPU as SRAM (“ess-ram”). For 10 points, name this computing resource whose “random access” type can be measured in gigabytes.

ANSWER: memory [accept virtual/computational/cache memory, accept random access memory; accept RAM before “SRAM”; prompt on RAM after “SRAM”]

<DB, Science - Other Science - Computer Science>

Impedance is analogous to this quantity for AC circuits. For 10 points each:

[10e] Name this quantity, measured in ohms, that is equal to voltage divided by current.

ANSWER: electrical resistance [prompt on R; do not accept “resistivity”]

[10m] The total resistance of resistors with this configuration equals the reciprocal of the sum of the reciprocals of the resistances. The total capacitance of capacitors in this configuration equals the sum of the capacitances.

ANSWER: in parallel

[10h] If the resistances of three resistors are already known, then the resistance of a fourth can be found by arranging the four resistors into two legs bridged by a galvanometer in this diamond-shaped circuit configuration.

ANSWER: Wheatstone bridge

<DB, Science - Physics>

This probability distribution is equivalent to a chi distribution with three degrees of freedom divided by a certain scale parameter. For 10 points each:

[10h] Name this doubly-eponymous distribution that describes the probabilities of particles in an ideal gas having certain velocities.

ANSWER: Maxwell–Boltzmann distribution [accept Maxwell–Boltzmann statistics]

[10m] The scale parameter of the Maxwell–Boltzmann can be calculated from the average temperature of the gas, the molar mass of particles in the gas, and this value. This value is equal to Boltzmann's constant multiplied by Avogadro's number.

ANSWER: ideal gas constant [accept R]

[10e] The ideal gas law holds that pressure times this quantity is equal to  $nT$  times the gas constant. Units for this quantity include liters and gallons.

ANSWER: volume [accept V]

<DB, Science - Chemistry>

The transition zone divides this layer of the Earth into its upper and lower regions. For 10 points each:

[10e] Name this layer of the Earth between the crust and the outer core.

ANSWER: **mantle**

[10m] Water stored in the transition zone may come from this process by which sections of the lithosphere sink into the mantle. This process's namesake "zones" have increased seismic and volcanic activity.

ANSWER: **subduction**

[10h] This process causes subducted slabs of the lithosphere to descend into the mantle. This process, by which hot matter travels to cooler areas, is primarily responsible for movement within the mantle.

ANSWER: mantle **convection**

<DB, Science - Other Science - Earth Science>

Vision is blurrier in the dark because this phenomenon is exacerbated when pupils expand to allow more light to enter the eye. For 10 points each:

[10h] Name this phenomenon in which a blurry image results from rays of light that do not all intersect at the same point.

ANSWER: **spherical aberration** [prompt on partial]

[10e] Spherical aberration can be avoided by using mirrors in the shape of this curve because all rays of light parallel to the principal axis will be reflected through the focal point. The graph  $y$  equals  $x$ -squared forms this curve.

ANSWER: **parabola** [accept **parabolic** mirror or **paraboloidal** mirror]

[10m] An object placed between a parabolic mirror and its focal point results in this type of image. This type of image, contrasted with a real image, is produced when light rays converge behind a mirror.

ANSWER: **virtual** image

<DB, Science - Physics>

Jurin's law states that the maximum height reached by this process in a tube is inversely proportional to the diameter of the tube. For 10 points each:

[10m] Name this process that is caused by adhesion and can result in the formation of a meniscus.

ANSWER: **capillary** action [accept **capillarity**, **capillary** motion, or **capillary** effect; prompt on **wicking**]

[10e] One form of this lab technique separates solutes as a solvent travels up a piece of paper via capillary action. This analytic technique is named for how it can separate components of a solute by color.

ANSWER: paper **chromatography**

[10h] In paper chromatography, the paper acts as this component. This component is a column with adsorbent material in HPLC, and is hydrophobic in reversed-phase chromatography techniques.

ANSWER: **stationary** phase [do not accept "mobile phase"]

<DB, Science - Chemistry>

Monte Carlo methods can be used to approximate this operation by randomly placing points in a region. For 10 points each:

[10e] Name this operation that yields the area under the curve of a function. It is the opposite of differentiation.

ANSWER: **integration** [accept (in)definite **integral**; prompt on **antiderivative**]

[10m] Definite integrals can also be estimated with this method, in which the combined areas of thin rectangles or trapezoids approximate the region under the curve of a function.

ANSWER: **Riemann** sum

[10h] A third way to estimate integrals is with this method. This method multiplies the values of the function by alternating coefficients of four and two, and then divides by three times the width of the interval of integration.

ANSWER: **Simpson's** rule

<DB, Science - Other Science - Math>

Answer the following about the 2020 Nobel Prize in Physics, for 10 points each.

[10e] Roger Penrose won half of the prize money for proving that these objects result from general relativity. Particles that enter these objects' event horizons cannot exit, so these objects emit no light.

ANSWER: **black holes**

[10h] Reinhard Genzel and Andrea Ghez won the other half of the prize money for studying the A-star region named for this constellation, which likely contains the supermassive black hole at the center of the Milky Way.

ANSWER: **Sagittarius** [or **Sgr**; accept **Sagittarius A-star**]

[10m] Genzel and Ghez concluded that the supermassive black hole is about four million times more massive than this object. The Chandrasekhar limit, which is the maximum stable mass of a white dwarf star, is about 1.4 times the mass of this object.

ANSWER: the **Sun** [or **Sol**; accept **solar** masses]

<DB, Science - Other Science - Astronomy>

An object's Mach number is the ratio of its speed to this quantity. For 10 points each:

[10e] Name this speed that characterizes transonic flow. Objects moving faster than this speed emit a sonic boom.

ANSWER: speed of **sound** [or **Mach 1**; prompt on **Mach** number]

[10m] The sound waves emitted by an object moving faster than the speed of sound form this shape, so its sonic boom can be heard along the boundary of this shape. Aircraft traveling near the speed of sound often become surrounded in a "shock collar" of water vapor in this shape.

ANSWER: **cone** [accept **Mach cone** or **vapor cone**]

[10h] The Kutta-Joukowski ("zhoo-KOV-skee") theorem describes the lift on an aircraft as the product of speed, air density, and circulation, which is the closed line integral of this quantity. This quantity is the curl of flow velocity.

ANSWER: **vorticity** [prompt on **omega**]

<DB, Science - Physics>

The order of a finite one of these algebraic structures must be equal to an integer power of a prime number. For 10 points each:

[10h] Name these structures that are less general than rings because they are closed over addition, subtraction, multiplication, and division.

ANSWER: **fields**

[10m] All algebraic number fields are extensions of the field containing these numbers. Assuming that the square root of two is one of these numbers leads to a contradiction.

ANSWER: **rational** numbers [or **fractions**; accept **field of rational(s)** numbers; prompt on **Q**]

[10e] Fields and rings must contain these values for both addition and multiplication. This value for addition is zero and this value for multiplication is one.

ANSWER: **identity** [or **identities**; accept additive **identity** or multiplicative **identity**]

<DB, Science - Other Science - Math>

Imagine that you are a software engineer. For 10 points each:

[10e] You would do your coding by using one of these entities, such as C or Java. A dynamically-typed example of these constructs called Python uses the "pandas" library.

ANSWER: **programming languages** [accept **computer languages** or **machine languages**; prompt on **languages**]

[10h] You likely type your code using one of these software applications, examples of which include PyCharm for Python and Eclipse for Java. These applications help software engineers to write, debug, and run their code.

ANSWER: **IDE** [or **integrated development environment**]

[10m] To share your code, you might use this version-control software developed by Linus Torvalds. This software allows developers to manage shared repositories of code with commands like "commit," "merge," and "push."

ANSWER: **Git** [accept **GitHub**]

<DB, Science - Other Science - Computer Science>

A transformer consists of a coupled pair of these circuit components. For 10 points each:

[10m] Name these circuit components, the "L" in an RLC circuit, that gradually store energy with a coiled wire.

ANSWER: **inductors**

[10e] Inductors commonly have iron cores placed inside the coiled wire in order to increase the strength of this entity. These entities, whose strength is measured in teslas, have lines that propagate from north to south poles.

ANSWER: **magnetic fields** [prompt on **B** or **H**]

[10h] Transformers are grouped into these two types based on whether they have a turns ratio less than one, and thus increases the voltage, or have a turns ratio greater than one, and thus decreases the voltage. Name either.

ANSWER: **step-up** OR **step-down** transformer [accept either]

<DB, Science - Physics>

In order for these particles to be consistent with general relativity, they would have to be massless and have a spin of two. For 10 points each:

[10h] Name these hypothetical particles. Experiments like LIGO ("lye-go") detect waves that may provide information about these particles.

ANSWER: **gravitons** [prompt on **G**]

[10e] While gravitons would be the quanta of the gravitational force, these particles are the quanta of the electromagnetic force. These massless particles are constantly traveling at the speed of light.

ANSWER: **photons**

[10m] Because gravitons and photons both have integer spin, they are this type of particle. These particles can become superfluids when cooled and are contrasted with fermions.

ANSWER: **bosons**

<DB, Science - Physics>

### **Not used**

Along with three constants named for scientists, this constant was added to the SI base units in 2019 such that this constant and one second define the value of one ampere. Hall resistance is quantized by Planck's constant divided by this constant squared. This value is equal to Faraday's constant divided by Avogadro's number. Replacing this value's units with Joules yields the value of one electronvolt. Atomized particles were ionized by an x-ray above an electric field to measure this constant in the Millikan oil drop experiment. The charge of a proton equals, for 10 points, what physical constant, symbolized "e," that is the quantum of charge?

ANSWER: **elementary charge** [or **elementary electric charge**; accept **charge** of an **electron** or **charge** of a **proton** before "proton" is read]

<DB, Science - Physics>

Ladner's theorem states that the "intermediate" subset of this set is empty. It is not a subset of BPP, but an example in which Merlin sends Arthur an unreliable message describes members of this set. The Cook-Levin theorem implies that any member of this set can be quickly reduced to the Boolean satisfiability problem because it is in the "-complete" subset of this set. The traveling salesman problem is in the "-hard" subset of this complexity class. An unsolved Millennium Prize Problem asks whether "P equals" this complexity class. For 10 points, give this name for a class of computational problems that stands for "non-deterministic polynomial."

ANSWER: **NP** <DB, Science - Computer Science>

In this physicist's namesake picture, operators remain constant while quantum states change over time. The only atomic orbital with an exact solution to this scientist's namesake equation is that of the hydrogen atom. That equation named for this scientist has time-dependent and time-independent versions, the latter of which equates the Hamiltonian of a wave function to its energy. A radioactive source and a flask of poison are placed in a box in a thought experiment that this scientist developed to illustrate quantum superposition, in which an animal is both dead and alive. For 10 points, what Austrian physicist names a hypothetical cat?

ANSWER: Erwin (Rudolf Josef Alexander) **Schrödinger** <DB, Science - Physics>