ESBOT

2023

DE11

Tossup

1) *Physics – Short Answer:* A viscous fluid is running through a circular pipe with a radius of 3 centimeters. If the fluid at the center of the pipe is flowing at 3 meters per second, what is the flow velocity of the fluid 2 centimeters from the center of the pipe?

ANSWER: 5/3

Bonus

1) *Physics – Short Answer:* Scientists are currently investigating whether the neutrino is a Majorana particle by looking for instances of the neutrinoless version of what radiochemical process?

ANSWER: Double Beta decay (DO NOT ACCEPT: Beta decay)

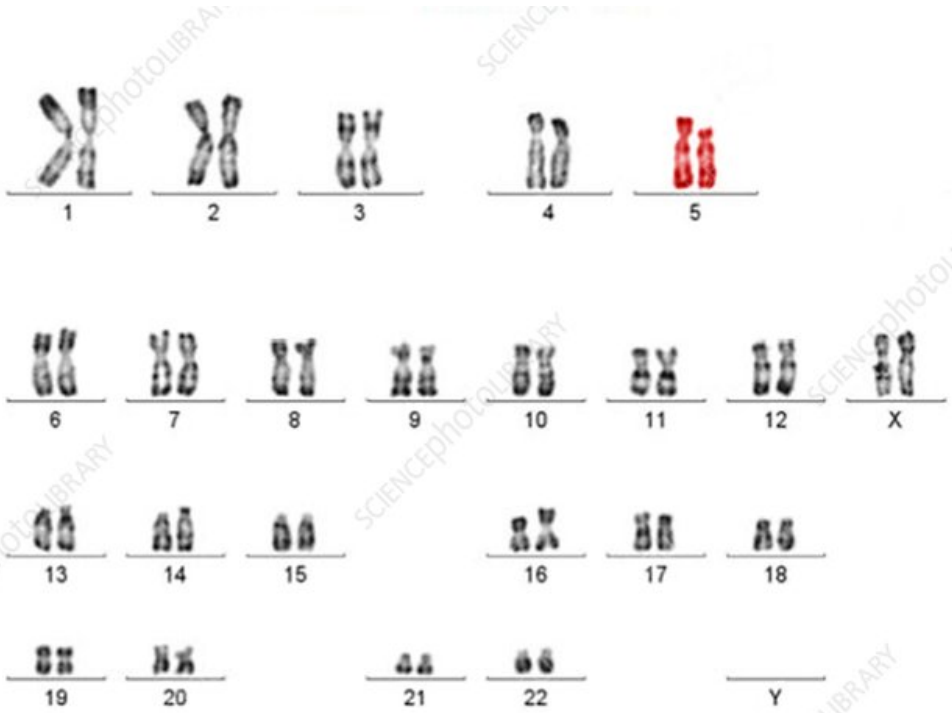
Tossup

2) *Biology – Short Answer:* In plants, the ABCDE model describes the development of floral organs. To what class of related sequences do the majority of the ABCDE model genes, as well as plant homeotic genes in general, belong to?

ANSWER: MADS box genes

Visual Bonus

2) *Biology – Short Answer:* Answer the following three questions about the karyotype shown below:



1) What subunit of chromosome 5 does this disorder affect?
2) What type of mutation is this disorder?
3) Characterized by high pitched cat-like crying in infants, what is the name of this disorder?

ANSWER: 1) 5p
2) chromosomal deletion
3) Cri du chat syndrome

Tossup

3) *Chemistry – Short Answer:* Order the following 3 compounds from most to least stable:

1) Cyclopentadienone **[cyclo penta die een own]**
2) Cyclobutadiene **[cyclo buta die een]**
3) 1,2-bromonaphthalene **[1 2 bromo naf thal een]**

ANSWER: 3, 1, 2

Bonus

3) *Chemistry – Multiple Choice:* Which of the following pairs of terms can describe a stabilized organic radical?

W) Delocalized and hyperconjugated
X) Resonance stabilized and nonbonding
Y) Kinetically persistent and thermodynamically stabilized
Z) Thermally deactivated and hindered

ANSWER: Y) Kinetically persistent and thermodynamically stabilized

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Tossup

4) *Earth and Space – Multiple Choice:* A glacier has recently retreated from an endorheic basin. What two drainage patterns would you expect to find exhibited?

W) Radial and Parallel
X) Radial and Deranged
Y) Centripetal and Parallel
Z) Centripetal and Deranged

ANSWER: Z) Centripetal and Deranged

Bonus

4) *Earth and Space – Short Answer:* Order the following 3 rocks in increasing P wave velocity:

1) Arkose
2) Quartz Sandstone
3) Mudstone

ANSWER: 3, 1, 2

Tossup

5) *Biology– Multiple Choice:* Autophagy is a process of clearing up worn-out and dysfunctional organelles. Mitophagy is the autophagy of worn-out mitochondria. Which of the following diseases is the dysfunction of mitophagy *most strongly* associated with?

W) Alzheimer's disease
X) Huntington's disease
Y) Parkinson's disease
Z) Multiple Sclerosis

ANSWER: Y) Parkinson's disease

Bonus

5) *Biology – Short Answer:* During different stages of sleep, different wave patterns primarily compose the EEG. Order the following 3 wave patterns found in EEGs during the different stages of sleep in order of increasing frequency:

1) Theta waves
2) Delta waves
3) Sleep spindles

ANSWER: 2, 1, 3

Tossup

6) *Math – Short Answer:* What is the least positive integer n such that $\sqrt{2023 \cdot n}$ **[square root of quantity 2023 times n]** is an integer?

ANSWER: 7

Bonus

6) *Math – Short Answer:* Assuming A and B are arbitrary constants, identify all of the following 3 expressions that are general solutions for y(x) that satisfy the differential equation y'' - y = 0 **[y double prime minus y equals 0]**

I) **[y equals A cosh x plus B e to the x]**
II) **[y equals A sinch x plus B e to the negative x]**
III) **[y equals A e to the x plus B e to the negative x]**

ANSWER: All

Tossup

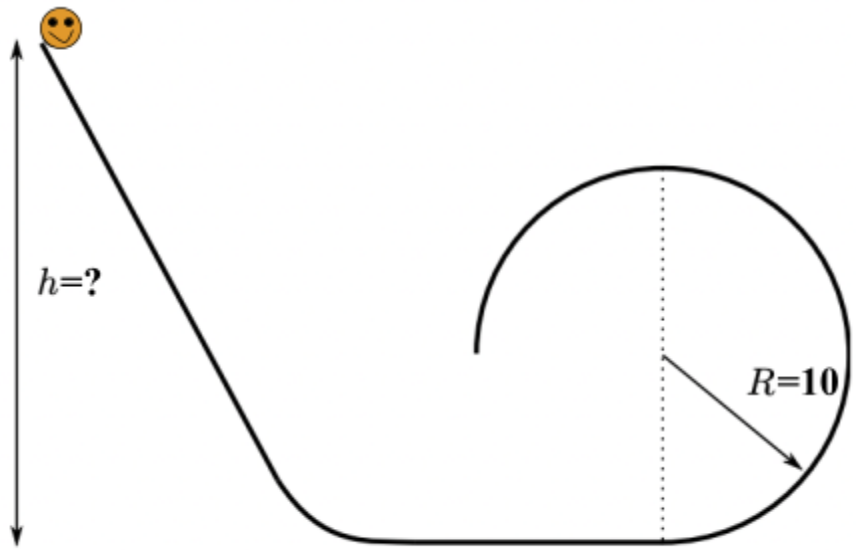
7) *Physics – Multiple Choice:* A hollow sphere has an inner radius of a, an outer radius of b, and a thermal conductivity of k. A constant temperature difference of T is maintained between the inner and outer radius of the shell. The rate of heat transfer between the inside and outside of the shell is proportional to which of the following?

W) ab
X) b^2/a^2 **[b squared over a squared]**
Y) ab/(b-a) **[a times b over the quantity b minus a]**
Z) ab/(a+b) **[a times b over the quantity a plus b]**

ANSWER: Y) ab/(b-a)

Visual Bonus

7) *Physics – Short Answer:* Thanush is giving Nikhil a new perspective on life, this time trying to roll him around a loop de loop so that he falls off. Nikhil can be approximated as a uniform sphere of radius 0.5 meters and mass 60kg. He starts at the top of a hill and rolls down to ground level before going around a circular loop with a radius of 10 meters. If Thanush wants Nikhil to fall off the loop at the top, what is the maximum height above ground level in meters from which Nikhil can start?



ANSWER: 27

Tossup

8) *Energy – Short Answer:* Scientists at Lawrence Berkeley National Lab are studying the spatial electron distribution of molecules. They are using a certain technique to do this, where a wavefunction of many particles is reduced to a single wavefunction parameterized by the density of particles. What is this technique called?

ANSWER: Density functional theory

Bonus

8) *Energy – Short Answer:* Researchers at Lawrence Livermore National Laboratory are studying adrenocortical carcinomas, which secrete elevated levels of adrenal cortex hormones. Identify of the following 3 options that would not occur if this cancer started secreting large amounts of adrenal cortex hormones:

I) Weight Loss
II) Water retention
III) Deepening voice

ANSWER: I only

Tossup

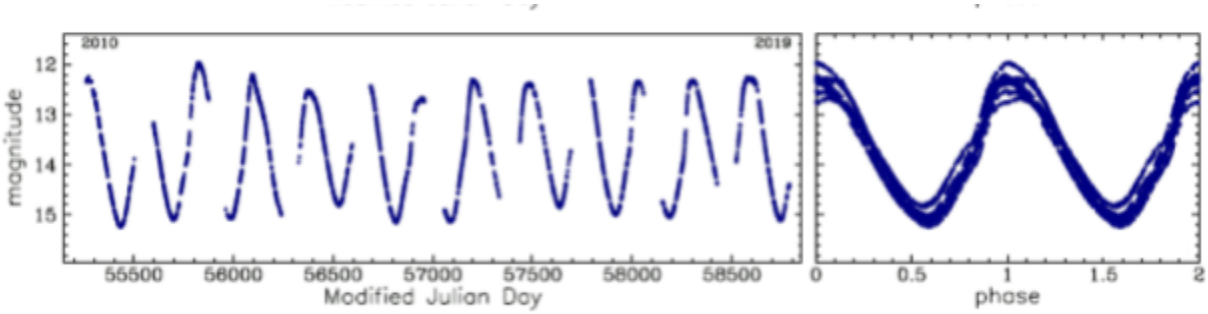
9) *Earth and Space – Multiple Choice:* Which of the following Galilean moons has the highest surface gravity?

W) Io
X) Europa
Y) Ganymede
Z) Callisto

ANSWER: W) Io

Visual Bonus

9) *Earth and Space – Short Answer:* The image below shows a light curve of a Variable Star in the milky way. Answer the following two questions about the image:



1) What type of variable star is most likely pictured in the graph below?
2) What is the name for the mechanism of this star's variability?

ANSWER: 1) Mira; 2) Dredge-ups

Tossup

10) *Math – Short Answer:* How many times do the functions sin(x) and cos(2x) cross each other from x = 0 to x = 2π, inclusive?

ANSWER: 3

Visual Bonus

10) *Math – Short Answer:* Thanush has strapped Nikhil to a bomb and the timer is ticking down, with the shape of each digit on the display shown at the top of the given image. Sukrith is trying to defuse it, but he needs to know the exact time on the clock to do so. Unfortunately, all of the segments marked with Xs on the display are broken and will not light up. If the bottom image shows the current time, how many seconds must Sukrith wait to be sure of the time on the display?





ANSWER: 18

Tossup

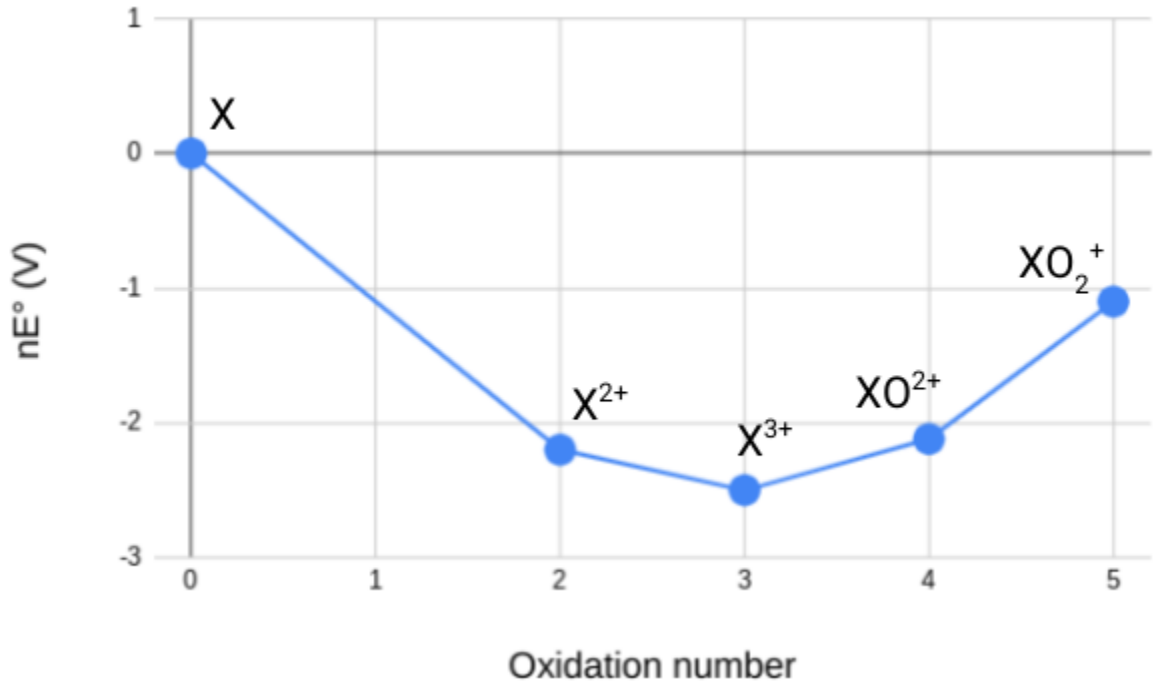
11) *Chemistry – Short Answer:* A 1,3 hydride rearrangement has a cyclic transition state. How many ring members does this transition state have?

ANSWER: 4

Visual Bonus

11) *Chemistry – Short Answer:* The given diagram is commonly used in inorganic chemistry to show the relative stability of different oxidation states of an element. Answer the following two questions about this diagram:

1) What is the name of this type of diagram?
2) What period 4 element is the most likely identity of element X?



ANSWER: Frost diagram; Vanadium

Tossup

12) *Earth and Space – Multiple Choice:* The distinction between phonolite and andesite is based on the concentrations of which of the following species?

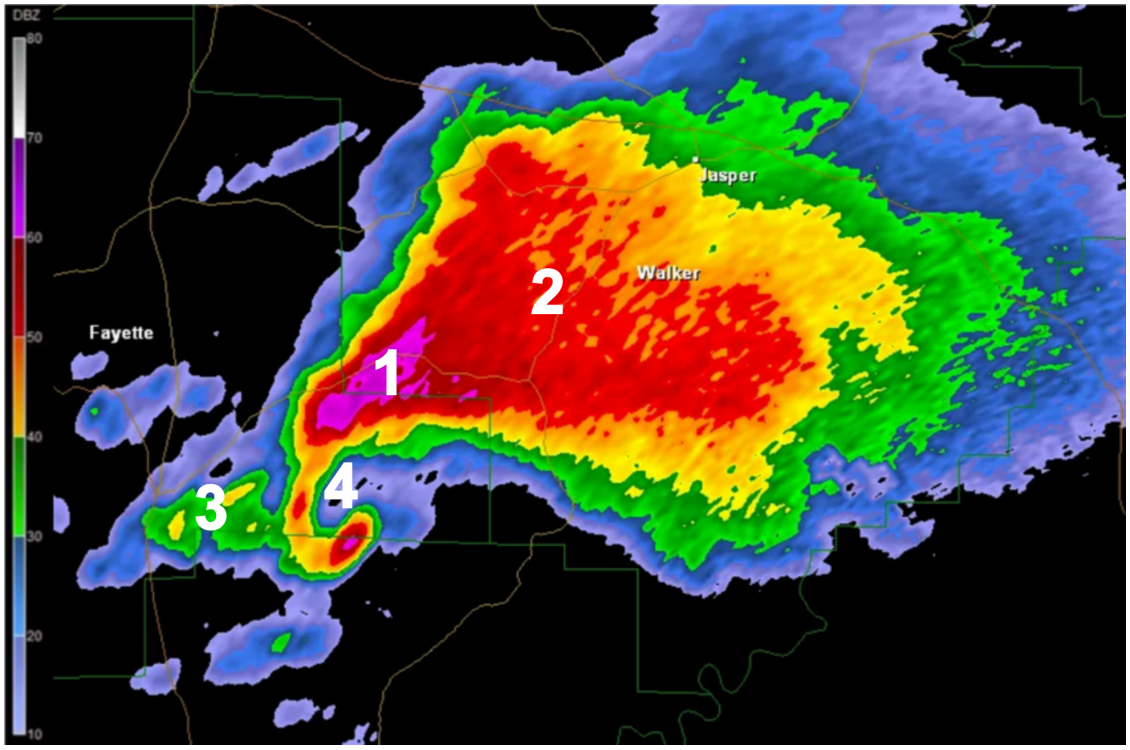
W) Acids
X) Alkalis
Y) Silica
Z) Alumina

ANSWER: X) Alkalis

Visual Bonus

12) *Earth and Space – Multiple Choice:* Pictured below is radar taken over Walker County, Alabama in 2011. Answer the following two questions about the figure:

1) What is the name of the weather phenomena present at point 4?
2) At which of the numbered points are the strongest downdrafts observed?



ANSWER: 1) Tornado 2) 2

Tossup

13) *Math – Short Answer:* In triangle ABC, the angle bisector of angle BAC intersects BC at point D and the circumcircle of triangle ABC at a point E not equal to A. Given that AD=7 and AE=10, then what is the value of BD times CD?

ANSWER: 21

Bonus

13) *Math – Short Answer:* The Mean of 5 numbers is 46. If two of the numbers are 20 and 43 and the median is seven less than the mode of the 5 numbers, what is the mode of the 5 numbers?

ANSWER: 58

Tossup

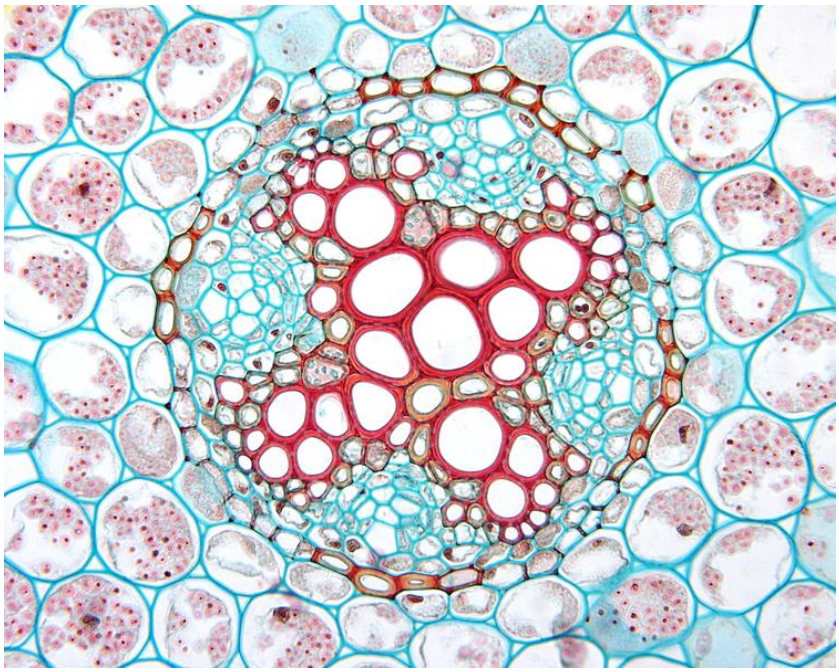
14) *Biology – Multiple Choice:* In eukaryotes, which of the following enzymes is responsible for synthesis of the mitochondrial DNA in DNA replication?

W) DNA polymerase alpha
X) DNA polymerase gamma
Y) DNA polymerase delta
Z) DNA polymerase epsilon

ANSWER: X) DNA polymerase gamma

Visual Bonus

14) *Biology – Short Answer:* Answer the following three questions about the cross section shown below:



1) Is this tissue cross section taken from a monocot or eudicot?
2) From what part of the plant is this tissue cross section taken?
3) What specific kind of tissue makes up the large red-stained circles shown in the center of the cross section?

ANSWER: 1) eudicot
2) root
3) metaxylem

Tossup

15) *Energy – Multiple Choice:* Scientists at Space Telescope Science Institute are using the Hubble Space telescope to study Cepheids **[se-fee-ids]** in open clusters to improve the calibration of cepheids as a standard candle. Order the following 3 types of type 2 cepheid from shortest to longest period of oscillation:

1) BL Herculis
2) RV Tauri
3) W Virginis

ANSWER: 1, 3, 2

Bonus

15) Energy– *Short Answer:* Scientists at Brookhaven National Lab are studying the extent to which cancer cell ATP production uses the citric acid cycle. Which of the following anaplerotic reactions is not one that occurs in the citric acid cycle?

W) Aspartate to malate
X) Adenyl Succinate to fumarate
Y) Pyruvate to oxaloacetate
Z) Glutamate to alpha ketoglutarate

ANSWER: Y) Pyruvate to oxaloacetate

Tossup

16) *Physics – Multiple Choice:* In a given thermodynamic system, each microstate of the system is equally likely to occur over a long period of time. Systems satisfying this constraint are said to be which of the following?

W) Auxetic
X) Ergodic
Y) Eutectic
Z) Parametric

ANSWER: X) Ergodic

Bonus

16) *Physics – Short Answer:* In solid-state physics, one assumption of many simple models is that atoms are fixed in place within the crystal lattice. In reality, the positions of atoms can be affected by electrons moving through the lattice. What is the name of the quasiparticle used to describe a moving electron and the effect it has on the lattice around it?

ANSWER: Polaron

Tossup

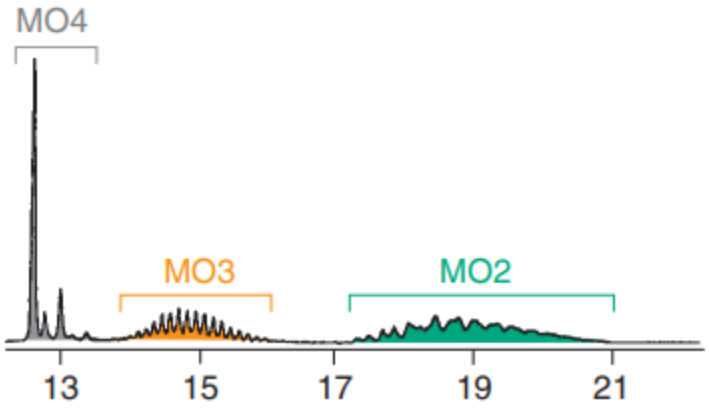
17) *Chemistry – Short Answer:* Cyclopentadienyl **[cyclo-penta-di-een-il]** is a common organometallic ligand. How many electrons does a neutral cyclopentadienyl ligand donate to the metal atom it coordinates with?

ANSWER: 5

Visual Bonus

17) *Chemistry – Short Answer:* The provided diagram shows the photoelectron spectroscopy results after analyzing water. Answer the following 2 questions about the diagram:

1) According to molecular orbital theory, how many nonbonding electrons are there in a water molecule?
2) What types of electron transitions are responsible for the fine structure peaks in the MO2 and MO3 orbitals?



ANSWER: 2; Vibrational

Tossup

18) *Biology – Short Answer:* Blood in a patient's heart is not able to flow properly from the left atrium to the left ventricle. Identify all of the following 3 heart valves that are definitely not affected:

I) Tricuspid
II) Pulmonary
III) Bicuspid

ANSWER: I and II

Bonus

18) *Biology – Multiple Choice:* Which of the following pairs of phi and psi angles, respectively, is indicative of the location of a right handed alpha helix on a Ramachandran plot?

W) negative phi angle, negative psi angle
X) negative phi angle, positive psi angle
Y) positive phi angle, negative psi angle
Z) positive phi angle, positive psi angle

ANSWER: W) negative phi angle, negative psi angle

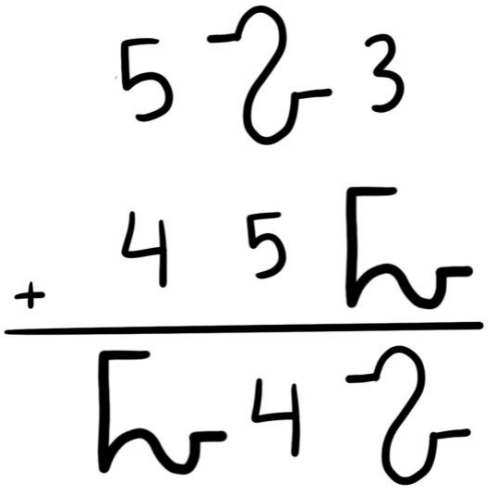
Tossup

19) *Math – Short Answer:* What is the sum of all positive integers m less than 13 such that 12m is a perfect square?

ANSWER: 15

Visual Bonus

19) *Math – Short Answer:* Sukrith is studying an endangered language as a linguist, and while looking at a whiteboard, he sees multiple equations. Confused, he realizes that they were written in another base with multiple unique symbols. He successfully translates some symbols into numerical values from 0 to 9 and replaces those symbols. He hasn't translated the rest yet, but he correctly assumes that the other symbols represent values greater than or equal to 10. Given the partially translated equation in the image shown and assuming that congruent symbols represent congruent numeric values, what base was most likely used?



ANSWER: 14

Tossup

20) *Physics – Short Answer:* The potential energy of two positive charges with charge Q placed 1 centimeter apart is 2 Joules. What is the potential energy in Joules of an octahedron of these charges with an edge length of 1 centimeter?

ANSWER: $8 + 3\sqrt{2}$

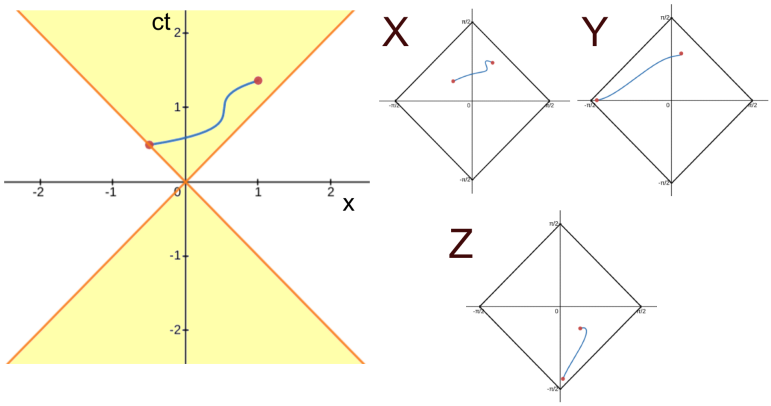
Visual Bonus

20) *Physics – Short Answer:* Shown below is a Minkowski diagram of the path taken between two events in spacetime. Answer the following 3 questions about the diagram:

A) A Penrose diagram compresses the infinite axes of a Minkowski diagram into a finite space, with distant spacetime placed on the left and right, and the far past and future placed on the top and bottom. Which of the labeled diagrams on the right is the correct Penrose diagram for this path?

B) Is the separation between the two events timelike, spacelike, or lightlike?

C) What is the term for the orange lines that bound the yellow shaded region on the Minkowski diagram?



ANSWER: X; spacelike; light cone

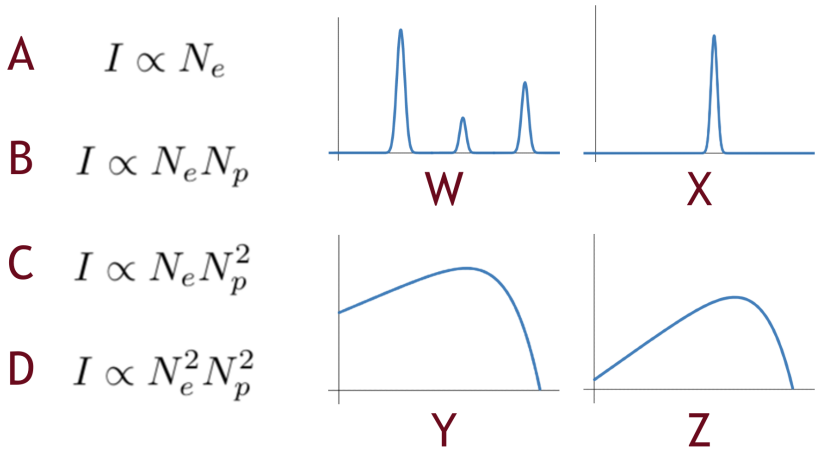
Tossup

21) *Energy – Short Answer:* Researchers at Enloe High School are using various machine learning algorithms to analyze the sentiment of human beings. In machine learning, what graphical tool is used to evaluate the performance of a binary classifier by plotting the true positive rate against the false positive rate at various threshold settings?

ANSWER: ROC curve (ACCEPT: Receiver Operating Characteristic curve)

Visual Bonus

21) *Energy – Short Answer:* Scientists at SLAC National Accelerator Facility are using the LINAC coherent light source to study the physics of photon interaction. Two of the most common methods of high energy photon production are undulators and free electron lasers. Using the given image and assuming **[N e]** is number of electrons and **[N p]** is the number of poles, provide the letters of the formula and the emission spectra for both undulators and free electron lasers



ANSWER: Undulator is C and W, free electron laser is D and X

Tossup - Rohit

22) *Earth and Space – Multiple Choice:* Which of the following can be used as a good predictor of the mass of a supermassive black hole at the center of a spiral galaxy?

W) Mass of the Galaxy
X) Luminosity of the galaxy
Y) Velocity dispersion of the galactic bulge
Z) Velocity dispersion of the galactic halo

ANSWER: Y) Velocity dispersion of the galactic bulge

Bonus

22) *Earth and Space – Short Answer:* Active galactic nuclei are often bright in the X-ray region resulting from what type of scattering through the hot corona around the accretion disk?

ANSWER: Inverse Compton (DO NOT ACCEPT: Compton)

Tossup

23) *Chemistry – Short Answer:* Identify all of the following 3 phenomena that are caused by relativistic effects on electron orbitals:

I) Gold and cesium's yellow color
II) Contraction of Mercury's 6s orbital
III) Technetium's High Melting Point

ANSWER: I and II

Bonus

23) *Chemistry – Short Answer:* Order the following 4 carbons of a carbon-13 NMR spectrum from least to most downfield:

1) Unsaturated carbons
2) Unsaturated carbons next to an oxygen
3) Saturated carbons
4) Saturated carbons next to an oxygen

ANSWER: 3, 4, 1, 2