

Science Bowl – Varied Team Round – 1/3/13

TOSS-UP

1) PHYSICS *Multiple Choice* If distance between an object and a concave parabolic mirror is less than one focal length, then the resulting image is

W) nonexistent

X) real, inverted, and smaller than the object

Y) virtual, upright, and smaller than the object

Z) virtual, upright, and larger than the object

ANSWER: Z) VIRTUAL, UPRIGHT, AND LARGER THAN THE OBJECT

BONUS

1) PHYSICS *Short Answer* If the focal length of a convex lens is 2 meters, the distance to an image is 5 meters, and the height of the image is 150 meters, what is the height of the object causing the image?

ANSWER: 100 METERS

TOSS-UP

2) CHEMISTRY *Short Answer* If the electron in a hydrogen atom transitions from $n=4$ to $n=3$ where n refers to the principal quantum number, an emitted photon will have a wavelength in what part of the electromagnetic spectrum?

ANSWER: INFRARED

BONUS

2) CHEMISTRY *Multiple Choice* Which of the following sets of quantum numbers is NOT possible for an electron in an atom?

W) [1, 0, 0, $-\frac{1}{2}$]

X) [3, 2, 1, $\frac{1}{2}$]

Y) [2, 1, -2, $-\frac{1}{2}$]

Z) [2, 0, 0, $\frac{1}{2}$]

ANSWER: Y) [2, 1, -2, $-\frac{1}{2}$]

TOSS-UP

3) BIOLOGY *Multiple Choice* Suppose a woman is carrying one X chromosome with the gene for a particular type of color blindness and her other X chromosome does not have this gene. If she is married to a man who does not have this gene on his X chromosome, what is the probability that their first child is color blind?

W) $\frac{1}{2}$

X) $\frac{1}{4}$

Y) $\frac{3}{4}$

Z) $\frac{2}{3}$

ANSWER: X) $\frac{1}{4}$

BONUS

3) **BIOLOGY** *Short Answer* Cystic fibrosis is an autosomal recessive genetic disorder. Mark and his old wife, Janet, have a child with cystic fibrosis. Mark's new wife, Ellen, had a brother with cystic fibrosis. Mark and Ellen, neither having cystic fibrosis, have a child named John. If John marries Janet (his father's old wife), who doesn't have cystic fibrosis, what is the probability that their child will have cystic fibrosis?

ANSWER: 3/16

TOSS-UP

4) **EARTH/SPACE** *Short Answer* By name or number, identify all of the following four which are TRUE concerning laccoliths.

1: it is a concordant pluton

2: there are many examples of possible laccoliths on the surface of the Moon

3: it can occasionally be detected by the lenticular bulge it may create at the surface

4: the magma generating a laccolith is less viscous than that of a sill

ANSWER: 1, 2, AND 3

BONUS

4) **EARTH/SPACE** *Short Answer* Suppose you observed a line in the Andromeda galaxy's spectrum with a wavelength of 1499 nm, but laboratory measurements show that the line should have a wavelength of 1500 nm. If the distance between the Milky Way and the Andromeda galaxy is 2.5×10^{22} m, in how much time will Andromeda collide with the Milky Way?

(Approximate the speed of light as 3×10^8 m/s.)

ANSWER: 1.25×10^{17} SECONDS (ACCEPT: APPROX. 4 BILLION YEARS)

TOSS-UP

5) **MATH** *Short Answer* A dog spots a cat 50 m away. At that instant, the cat begins running away from the dog at 6 m/s, and the dog begins running toward the cat at 8 m/s. If both of them accelerate instantaneously, how long does it take for the dog to reach the cat?

ANSWER: 25 SECONDS

BONUS

5) **MATH** *Short Answer* Once the dog reaches the cat, the dog consumes the cat at a rate directly proportional to the amount of cat left to be eaten. If the dog consumes half of the cat in 5 seconds, how long does it take the dog to consume 3/4 of the cat? (You may leave your answer in terms of the natural logarithm function.)

ANSWER: $5 \times \frac{\ln .25}{\ln .5}$ SECONDS or 10 SECONDS

TOSS-UP

6) **ENERGY** *Multiple Choice* By name or number, identify all of the following four types of processes that are part of the ideal Brayton cycle.

1: isentropic

2: isothermal

3: isochoric

4: isobaric

ANSWER: 1 AND 4

BONUS

6) ENERGY *Short Answer* By name or number, order the following four types of fuel cells from lowest to highest efficiency.

- 1: magnesium-air fuel cell
- 2: molten carbonate fuel cell
- 3: solid oxide fuel cell
- 4: direct carbon fuel cell

ANSWER: 2, 3, 4, 1 (MCFC, SOFC, DCFC, MAFC)

TOSS-UP

7) PHYSICS *Multiple Choice* You are given a standard kilogram mass and a tuning fork that is calibrated in Hz. You are also provided with a complete collection of laboratory equipment, but none of it is calibrated in SI units. You do not know the values of any fundamental constants. Which of the following quantities could you measure in SI units?

- W) the acceleration due to gravity
- X) the speed of light in a vacuum
- Y) the density of room temperature water
- Z) the spring constant of a given spring

ANSWER: Z) THE SPRING CONSTANT OF A GIVEN SPRING

BONUS

7) PHYSICS *Short Answer* Suppose you are in a hyperbolic orbit about the Earth, in which the semi-major axis of the hyperbola is 3000 km. Assuming your mass is negligible, what is your velocity at the point of closest approach to Earth? Leave your answer in terms of the gravitational constant G and mass of the Earth M .

ANSWER: $\frac{1}{1000}\sqrt{GM}$ METERS PER SECOND or $\frac{1}{1000000}\sqrt{GM}$ KM PER SECOND

TOSS-UP

8) CHEMISTRY *Short Answer* By name or number, order the following four crystal structures according to their atomic packing factor, from lowest to highest.

- 1: body-centered cubic
- 2: diamond cubic
- 3: face-centered cubic
- 4: simple cubic

ANSWER: 2, 4, 1, 3

BONUS

8) CHEMISTRY *Short Answer* By name or number, identify all of the following five which are TRUE concerning X-ray crystallography.

- 1: it is a form of elastic scattering
- 2: the directions in which secondary spherical waves add constructively can be determined by Bragg's law
- 3: the phase of a wave can be directly recorded during a diffraction experiment
- 4: as a crystal's unit cell becomes larger and more complex, the picture provided by X-RC becomes less well-resolved for a given number of observed reflections
- 5: the most useful X-ray source for an X-ray crystallographer is a synchrotron

ANSWER: 1, 2, 4, AND 5

TOSS-UP

9) BIOLOGY *Multiple Choice* Genetic engineers construct recombinant DNA molecules using two enzymes: restriction endonuclease and DNA ligase. What do these two enzymes do?

W) restriction endonuclease joins fragments into larger molecules; DNA ligase hydrolyses DNA into smaller fragments

X) restriction endonuclease hydrolyses DNA into smaller fragments; DNA ligase joins fragments into larger molecules

Y) restriction endonuclease hydrolyses bacterial plasmid DNA; DNA ligase hydrolyses DNA from eukaryotic cells

Z) They both hydrolyse DNA into smaller fragments and join fragments into larger molecules

ANSWER: X) RESTRICTION ENDONUCLEASE HYDROLYSES DNA INTO SMALLER FRAGMENTS; DNA LIGASE JOINS FRAGMENTS INTO LARGER MOLECULES

BONUS

9) BIOLOGY *Short Answer* A botanist received a specimen from a fellow scientist who noticed that the plant's stomates are closed during the day. The botanist observed that radioactive carbon in the form of carbon dioxide, fed to the plant at night, was first found in organic acids that accumulate in the vacuole. During the day it moved to sugars being manufactured in the chloroplast. What did the botanist conclude?

W) the plant is using mitochondria as chloroplasts

X) the plant is a C₄ plant

Y) the plant is a C₃ plant

Z) the plant fixes carbon by crassulacean acid metabolism

ANSWER: Z) THE PLANT FIXES CARBON BY CRASSULACEAN ACID METABOLISM

TOSS-UP

10) EARTH/SPACE *Short Answer* By name or number, identify all of the following four that are TRUE concerning air.

1: the slower rate of cooling caused by the addition of electromagnetic radiation from space is called the wet adiabatic rate

2: absolute stability prevails when the environmental lapse rate is less than the wet adiabatic rate

3: absolute instability prevails when the environmental lapse rate is greater than the dry adiabatic rate

4: the environmental lapse rate is a result of adiabatic temperature changes

ANSWER: 2 AND 3

BONUS

10) EARTH/SPACE *Short Answer* If the ratio of a star's luminosity to the Sun's luminosity is 81 and the ratio of the star's radius to the Sun's radius is 1/25, at what wavelength does the star emit the most intense radiation? Assume that the Sun's wavelength of maximum intensity is 3000 nm.

ANSWER: 200 NANOMETERS

TOSS-UP

11) MATH *Short Answer* What is the largest integer $n < 2013$ with four distinct digits?
ANSWER: 1987

BONUS

11) MATH *Short Answer* When flipped, coin A shows heads $1/3$ of the time, coin B shows heads $1/2$ of the time, and coin C shows heads $2/3$ of the time. You select one of the coins at random and flip it four times, yielding three heads and one tail. What is the probability that you flipped coin A?
ANSWER: $32/241$

TOSS-UP

12) ENERGY *Multiple Choice* Tsar Bomba, the most powerful nuclear weapon ever detonated, used which of the following types of nuclear weapon design?
W) gun-type assembly
X) implosion assembly
Y) Teller-Ulam design
Z) pure fusion
ANSWER: Y) TELLER-ULAM DESIGN

BONUS

12) ENERGY *Short Answer* By name or number, identify all of the following four which will necessarily lower the point of criticality of a mass of fissile material.
1: refining the shape of the mass toward a perfect sphere
2: lowering the temperature of the mass
3: increasing the density of the mass
4: using a neutron reflector or tamper
ANSWER: 1, 3, AND 4

[3) BONUS Explanation: “Although most people without CF have two working copies of the CFTR gene, only one is needed to prevent cystic fibrosis due to the disorder's recessive nature. CF develops when neither gene works normally and therefore has autosomal recessive inheritance.” - Wikipedia

Mark must have 1 copy of the rec. allele, since he does not have cystic fibrosis and his child does. The probability that he passes the allele to John is $1/2$. Since Ellen had a bro with CF, both of her parents had at least 1 rec. allele. and 1 or 0 dom. alleles. Given that Ellen doesn't have CF, in the case where both of her parents have only 1 rec. allele and the case where one parent had 2 rec. alleles and the other only had 1, the prob. that she carries 1 rec. allele is $1/2$. Thus, the probability that she passes the allele to Johnny is $1/4$. Following that, the prob. that John has CF is $1/8$.

Since Janet did not have CF but her child did, she must only have 1 copy of the rec. allele and the prob. that she passes it to her child is $1/2$.

There exists 3 ways by which John's/Janet's child can be born with CF: John has CF and passes the allele along with Janet's rec. allele, John only receives his mother's rec. allele and passes that along with Janet's rec. allele, or John only receives his father's rec. allele and passes that along with Janet's rec. allele. The prob. that John has CF and passes the allele along with Janet's rec. allele is $1/8 \times 1/2 = 1/16$. The prob. that John gets his father's rec. allele but not his mother's is $1/2 \times 3/4 = 3/8$, and the prob. that he sends the rec. allele along with Janet's is $1/2 \times 3/8 \times 1/2 = 3/32$. The prob. that John gets his mother's rec. allele but not his father's is $1/4 \times 1/2 = 1/8$, and the prob. that he sends the rec. allele along with Janet's is $1/2 \times 1/8 \times 1/2 = 1/32$. Summing these probabilities, $1/16 + 3/32 + 1/32 = 3/16$. Therefore, the probability that John's and Janet's child has cystic fibrosis is **$3/16$** .]