ESBOT

2023

DE13

Tossup

1) *Chemistry – Short Answer:* The formation of an unsaturated carbonyl from an allyl vinyl ether upon heating is known as what rearrangement?

ANSWER: Claisen rearrangement

Bonus

1) *Chemistry – Short Answer:* Two containers of equal volume and internal energy are filled with gas. The first has one mole of H_2 and the second has one mole of He. Assuming that the temperature is sufficiently low so as to not activate vibrational modes, what is the ratio of the average molecular velocity of the first container to the second container?

ANSWER: $\sqrt{6/5}$

Tossup

2) *Physics – Short Answer:* What force on moving electric particles, which opposes changes in acceleration, is the physical cause of radiation resistance in antennae?

ANSWER: Abraham-Lorentz Force (ACCEPT: Lorentz-Dirac Force, DO NOT ACCEPT: Lorentz Force)

Bonus

2) *Physics – Short Answer:* Identify all of the following 3 statements which are true of the Abraham-Lorentz force:

> I) It appears when a charged particle is in uniform circular motion
> II) It is proportional to charge squared times the acceleration of the charged particle
> III) The work done by the Abraham-Lorentz force does not always equal the energy radiated by the charged particle

ANSWER: I and III

Tossup

3) *Energy – Short Answer:* Researchers at Princeton Plasma Physics laboratory are studying magnetohydrodynamics in plasmas. When flowing, plasmas typically bunch together into strands or filaments due to magnetohydrodynamic forces. What is the term for the forces acting on a flowing current stream that compress it into a smaller stream?

ANSWER: Pinch

Bonus

3) *Energy – Short Answer:* Enloe Science Bowl is studying the Haber process. While doing so, they have proposed a possible surface catalyzed reaction, shown below in two parts. Answer the following question about these mechanisms.

1) Which step is less kinetically favorable?

2) During the final step of the process, nitrogen forms a cyclic transition state of how many members?

ANSWER: The first step is less favored by both, 3

Tossup

4) *Math – Short Answer:* If the expression $\sin(x)\cos(x) = 2/5$, what is the value of $(\sin(x) + \cos(x))^2$?

ANSWER: 9/5

Bonus

4) *Math – Short Answer:* What is the value of cos(2π/7) + cos(6π/7) + cos(10π/7)? **[cosine of 2 pi over 7 plus cosine of 6 pi over 7 plus cosine of 10 pi over 7]**?

ANSWER: -0.5

Tossup

5) *Earth and Space – Multiple Choice:* Along which of the following planes does fluorite display cleavage?

W) 100 **[one zero zero]**
X) 110 **[one one zero]**
Y) 210 **[two one zero]**
Z) 211 **[two one one]**

ANSWER: X) 110

Bonus

5) *Earth and Space – Short Answer:* Order the following three elements in increasing percent depletion from a basaltic rock during partial melting:

1) Potassium
2) Calcium
3) Cobalt

ANSWER: 1, 2, 3

Tossup

6) *Biology – Short Answer:* The thi operon in bacteria is responsible for the production of thiamine. The regulation of the thi operon is governed by the active form of thiamine, TPP, where TPP binds to the growing RNA transcript and changes its secondary structure, preventing transcription of the operon. What type of regulatory region of RNA does TPP bind to in order to prevent transcription?

ANSWER: Riboswitch

Visual Bonus

6) *Biology – Short Answer:* In dragons, scale color (R), eye color (Y), and wing size (L) are all controlled by genes on the 2nd chromosome. Red scales are dominant to white scales, yellow eyes are dominant to blue eyes, and long wings are dominant to short wings. A true breeding blue eyes white dragon with long wings is crossed with a true breeding yellow eyes red dragon with short wings. An offspring from the F1 generation is crossed with a dragon recessive for all traits, producing the results shown below. Answer the following three questions about the results

A) What are the two recombinant genotypes produced from a double crossover?
B) What is the recombination frequency between genes Y and L?
C) What is the order of the genes on the chromosome?

Genotype	Frequency
RYl	754
ryL	749
RYL	136
ryl	142
Ryl	97
rYL	96
RyL	13
rYl	13
Total:	2000

ANSWER: A) RyL, rYl
B) 0.2355
C) Y-R-L

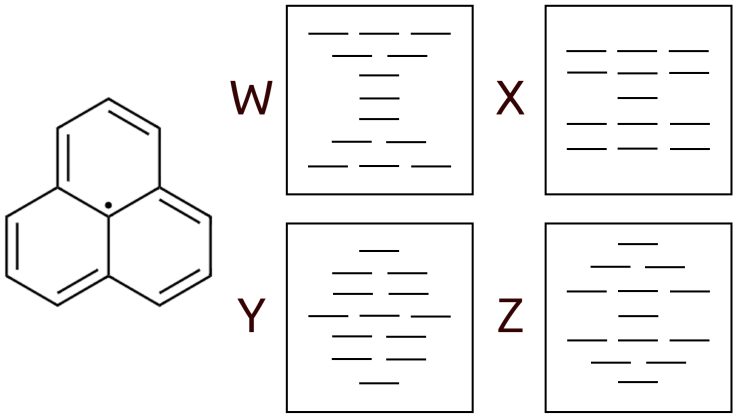
Tossup

7) *Chemistry – Short Answer:* An alcoholic derivative of propyne may be used to protect an alkyne during the Favorskii reaction. What is the name of the alkyl functional group derived from propyne?

ANSWER: Propargyl

Visual Bonus

7) *Chemistry – Short Answer:* The phenalenyl radical is shown on the left, along with four possible molecular orbital diagrams of the conjugated pi system. Answer the following 3 questions about the phenalenyl radical:



1) How many non-bonding electrons are in the phenylenyl radical?

2) By letter, identify the most correct molecular orbital diagram for the phenylenyl radical.

ANSWER: 1; Z

Tossup

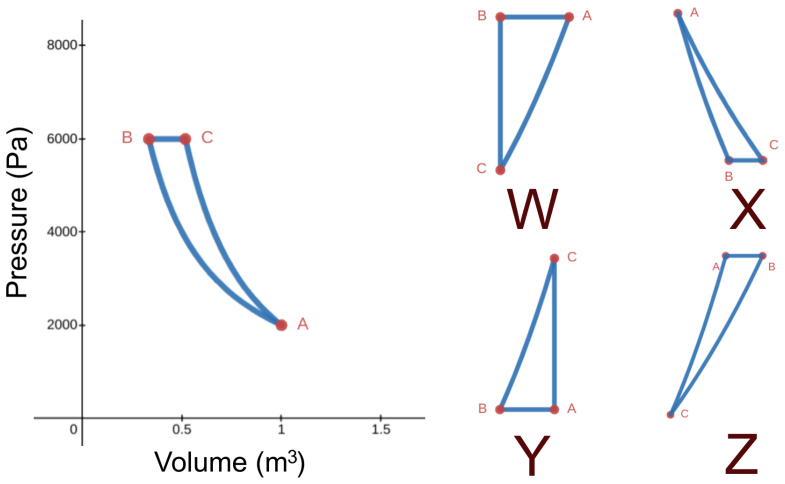
8) *Physics – Short Answer:* A planet is in circular orbit around a star at some distance R. The amount of heat the planet absorbs from the star's radiation over one orbital period is proportional to R raised to what power?

ANSWER: –1/2

Visual Bonus

8) *Physics – Short Answer:* Shown below is a PV diagram describing the state of one mole of gas as it goes through a thermodynamic cycle from A to B to C. Answer the following two questions about the diagram:

1) Which of the TS diagrams on the right correctly corresponds to the given PV diagram?
2) What is the entropy change of the system as it moves from point A to point B to the nearest Joule per Kelvin?



ANSWER: Y; -10

Tossup

9) *Earth and Space – Multiple Choice:* The dimensionless moment of inertia defined as the moment of inertia divided by the mass times the maximal radius squared of a body is used as a parameter to quantify radial homogeneity and degree of differentiation. Which of the following bodies has the lowest dimensionless moment of inertia?

W) Jupiter
X) Earth
Y) Mercury
Z) The Moon

ANSWER: W) Jupiter

Visual Bonus

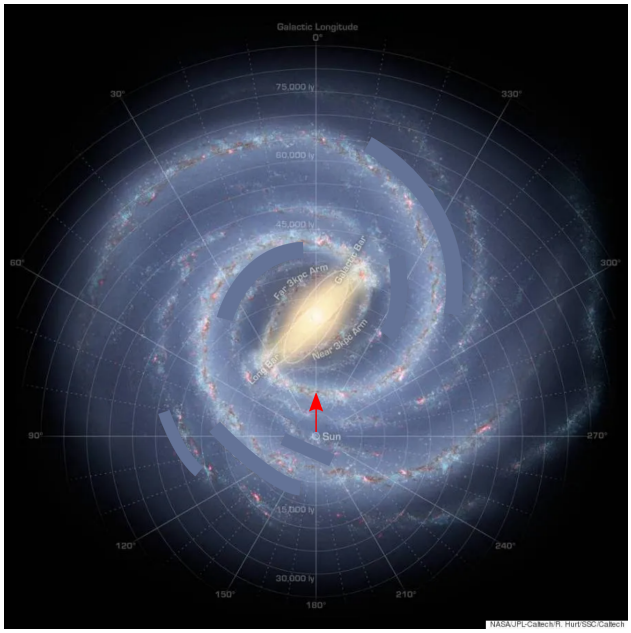
9) *Earth and Space – Short Answer:* Pictured is a map of the milky way galaxy. Answer the following two questions about the figure:

A) At the center of the milky way galaxy lies a supermassive black hole which is most likely increasing in mass despite the effect of hawking radiation. Hawking radiation is proportional to what power of the mass of a black hole?

B) Identify all of the following constellations which are visible by an observer on the earth looking in the direction marked by the arrow.

I) Sagittarius
II) Andromeda
III) Orion

ANSWER: –1; I only



Tossup

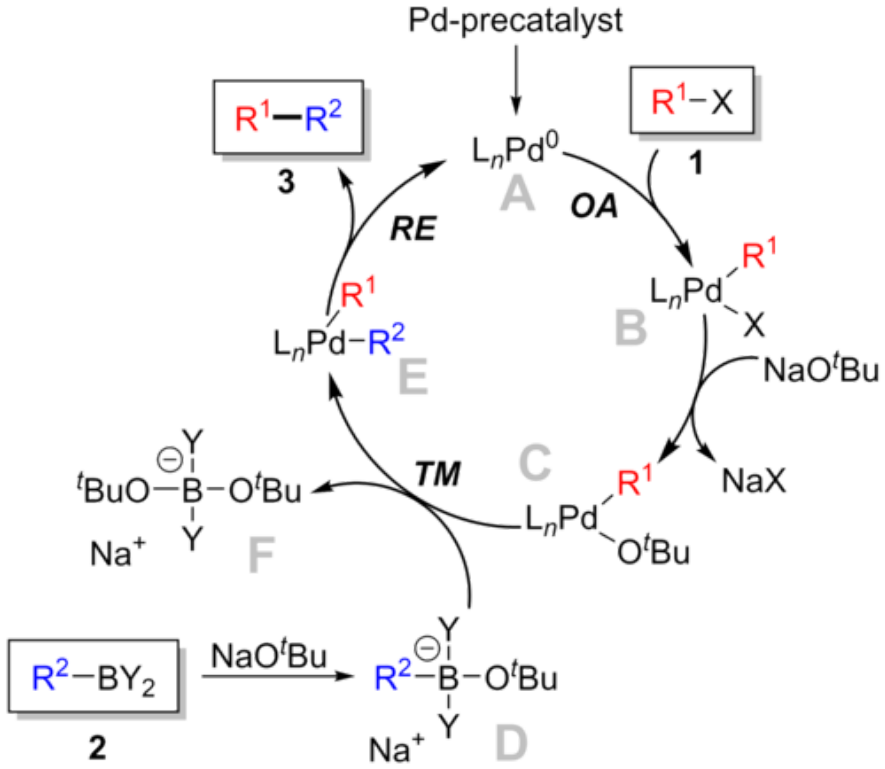
10) *Chemistry – Multiple Choice:* Which of the following describes how the position of the triple point on a phase diagram changes as a nonvolatile solute is added to a sample of the chemical at its triple point?

W) Shifts to the right and down
X) Shifts to the left and down
Y) Shifts to the right and up
Z) Shifts to the left and up

ANSWER: X) Shifts to the left and down

Visual Bonus

10) *Chemistry – Short Answer:* Shown below is the catalytic reaction cycle of a certain reaction. Answer the following three questions about this cycle.



1) What reaction is shown in this cycle?
2) What are the full names of the three main steps labeled OA, TM, and RE?
3) Which of these three main steps is the kinetically slowest step?

ANSWER: 1) Suzuki coupling; 2) Oxidative Addition, Transmetalation, Reductive Elimination; 3) TM (transmetalation);

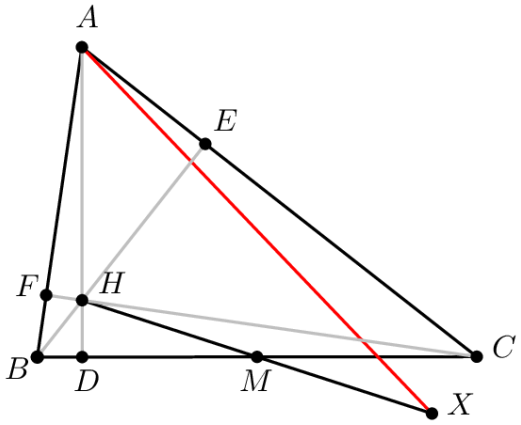
Tossup

11) *Math – Short Answer:* ABCD is a cyclic quadrilateral inscribed in circle O with AB=8, BC=1, CD=4, and DA=7. What is the diameter of circle O?

ANSWER: √65

Visual Bonus

11) *Math – Short Answer:* In triangle ABC, AB = 5, BC = 7, and CA = 8. Let H be the orthocenter of the triangle, and M be the midpoint of BC. If X is the reflection of H over M, then what is the square of the length of AX?



ANSWER: 196/3

Tossup

12) *Earth and Space – Short Answer:* Warm water from the pacific warm pool moves eastwards during the El Nino phase through what type of equatorially bound waves?

ANSWER: Kelvin Waves

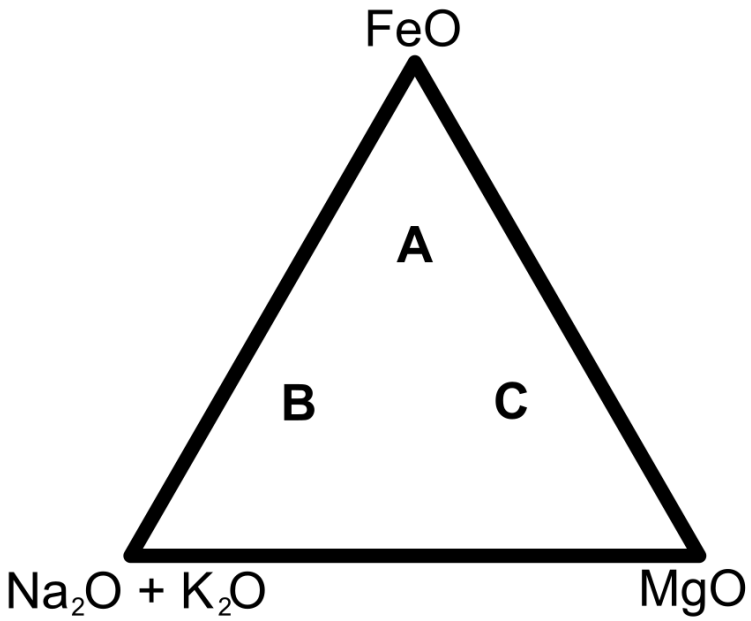
Visual Bonus

12) *Earth and Space – Short Answer:* Pictured below is an AFM diagram commonly used to graph a melt's evolution over time. Answer the following two questions about the figure.

A) Order the three points, A, B and C on the diagram from least to greatest degree of evolution for a tholeiitic basalt

B) Assuming the melt starts with a typical concentration of rare earth metals, at which of the points would the melt have the greatest concentration of lanthanum?

ANSWER: 1) CAB 2) B



Tossup

13) *Biology – Short Answer:* Which of the following are symptoms of a person with Cushing's syndrome?

I) Excess Mineralocorticoids
II) Excess Glucocorticoids
III) Osteoporosis
IV) Hypotension

ANSWER: II and III

Bonus

13) *Biology – Short Answer:* Select all of the following three statements that are true of phloem

I) The majority of callose embedded in sieve pores is in the form of callose platelets
II) In certain species, P-protein bodies do not disperse at maturity and form forisomes
III) In gymnosperms, specialized parenchyma cells called albuminous cells are found in phloem instead of companion cells

ANSWER: II, III

Tossup

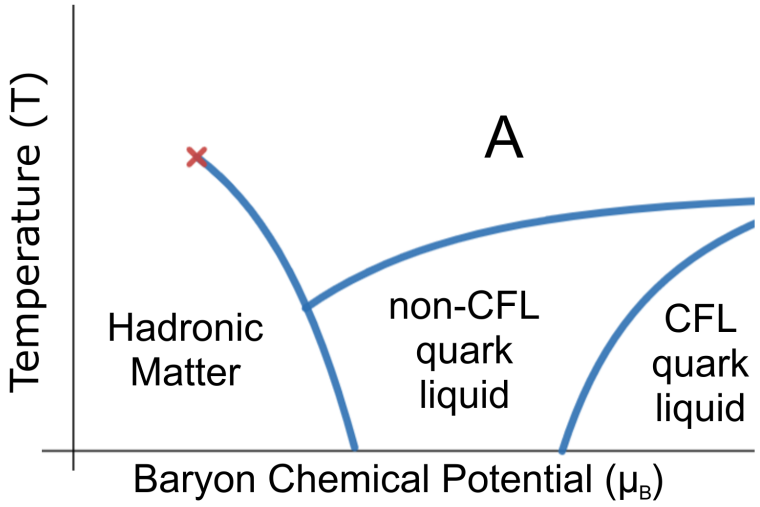
14) *Physics – Short Answer:* What phenomenon describes the effects of a moving mass, such as frame dragging, as a rough analogue to Maxwell's equations?

ANSWER: Gravitomagnetism

Visual Bonus

14) *Physics – Short Answer:* The given diagram shows a phase diagram for the theory of quantum chromodynamics. Answer the following 2 questions about this diagram:

A) What is the state of matter in the region labeled A?
B) What does the acronym CFL stand for?



ANSWER: Quark-gluon plasma; color-flavor locking

Tossup

15) *Energy – Short Answer:* Scientists at Brookhaven National Laboratory are studying the roots of plants to try and improve absorption of certain nutrients. Order the following 3 parts of a root from outermost to innermost.

1) Central Cells
2) Endodermal Cortical Layer
3) Parenchymatous Cortical Layer

ANSWER: 1, 3, 2

Bonus

15) *Energy – Short Answer:* Researchers at Argonne National Lab are studying superconductivity in low-temperature materials. According to the isotope effect, the critical temperature of a material is proportional to what power of the isotopic mass?

ANSWER: -1/2

Tossup

16) *Math – Short Answer:* How many subsets of the integers from 1 to 5 inclusive contain no pairs of consecutive integers?

ANSWER: 13

Bonus

16) *Math – Multiple Choice:* Consider the differential equation $6x^2y + 1 + 2x^3\, dy/dx = 0$. Which of the following is a general solution for $y(x)$?

W) $y = 2x^3 + x$
X) $y = 4x^3$
Y) $y = \frac{-1}{2x^2}$
Z) $y = 1/x - 1/x^3$

ANSWER: Y) $y = 1/x - 1/x^3$

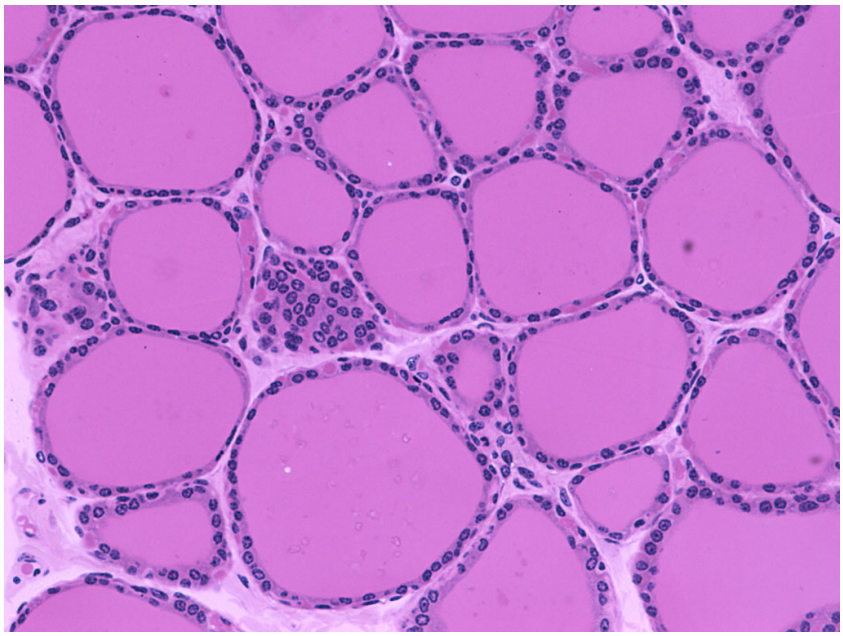
Tossup

17) *Biology – Short Answer:* Select all of the following four membrane phospholipids who have Phosphatidylethanolamine as its precursor:

I) Phosphatidylglycerol
II) Phosphatidylcholine
III) Phosphatidylserine
IV) Cardiolipin

ANSWER: II, III, and IV

Visual Bonus



17) *Biology – Short Answer:* The given image shows a microscopic view of a slice of tissue. Answer the following 2 questions about this image:

A) What organ of the body contains this tissue?
B) What are the pink circles called?

ANSWER: A) Thyroid (ACCEPT: Thyroid Gland)
B) Follicles (ACCEPT: Thyroid follicles)

Tossup

18) *Earth and Space – Multiple Choice:* Which of the following objects would have the highest Eddington luminosity?

W) Blue Supergiant
X) Supermassive Black Hole
Y) Neutron Star
Z) The Sun

ANSWER: X) Supermassive Black Hole

Bonus

18) *Earth and Space – Short Answer:* Although Venus has a very low orbital tilt, it shows periodic variations in atmospheric absorption due to variations in its energy budget. To the nearest year, what is the measured period of these atmospheric oscillations?

ANSWER: 11 years

Tossup - Colin

19) *Chemistry – Short Answer:* What quantity, defined as half the product of the concentration and the square of the charge of an ion, is commonly used to define activity coefficients for strong electrolytes in solution?

ANSWER: Ionic strength

Bonus

19) *Chemistry – Short Answer:* During the Wittig reaction, a cyclic intermediate is formed when the carbonyl pi bond attacks the phosphorus and the nucleophilic carbon attacks the electrophilic carbon of the carbonyl. How many members does this cyclic intermediate have, and what is its general name?

ANSWER: 4, oxaphosphetane

Tossup

20) *Biology – Short Answer:* Select all of the following 3 phyla of fungi that employ zygosporangium:

I) Mucoromycetes
II) Zoopagomycetes
III) Chytrids

ANSWER: I and II

Bonus

20) *Biology – Short Answer:* What set of differential equations models predator-prey dynamics under the assumption that predator consumption of prey is directly proportional to prey population, creating oscillating population curves

ANSWER: Lotka-Volterra Model

Tossup

21) *Physics – Short Answer:* 6 non-interacting identical fermions with spin 1/2 are placed into an infinite 2-dimensional well, filling each state from lowest to highest energy. What is the ratio between the average energy of the electrons and the ground state energy?

ANSWER: 4

Bonus

21) *Physics – Short Answer:* In orbital mechanics, what vector can be used to describe the orientation and shape of an orbit in a single value, and is always conserved within a certain orbit?

ANSWER: Laplace-Runge-Lenz vector (ACCEPT: Runge-Lenz vector)

Tossup

22) *Energy – Short Answer:* Researchers at Sandia National Laboratory are studying Fragile X syndrome and the genetic mutation that causes it. Fragile X syndrome is caused by too many repeats of what three nucleic acid sequence.

ANSWER: CGG (Accept: Cytosine Guanine Guanine)

Bonus

22) *Energy – Multiple Choice:* Researchers at Fermilab are studying possible mechanisms of CP violation. One remaining mystery in physics is the question of why CP symmetry is so close to being conserved, while not always being conserved. Which of the following would be an effect of large CP-violating interactions?

W) Change in boson spin
X) Nonconservation of color charge
Y) Large neutron dipole moment
Z) Existence of tetraquark fermions

ANSWER: Y) Large neutron dipole moment

Tossup

23) *Math – Short Answer:* The inner product of two arbitrary complex numbers w and v is equal to $1 + 2i$. What is the inner product of $2v$ and $2w$?

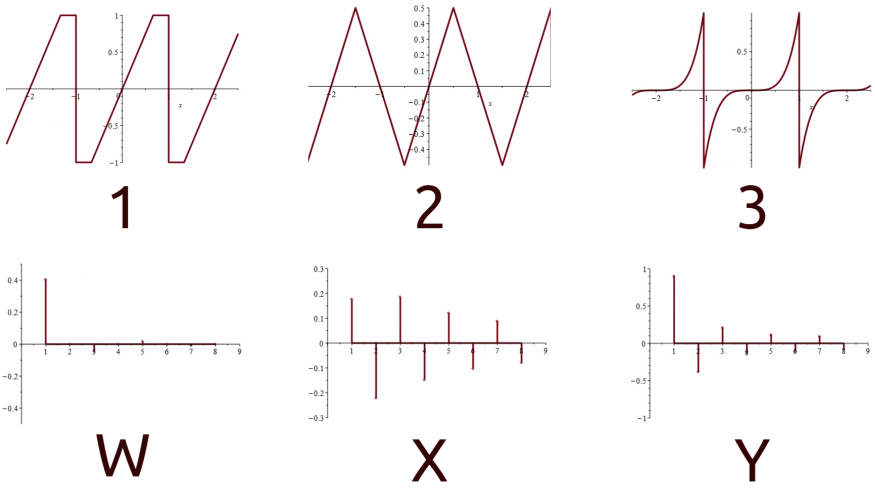
ANSWER: $4 - 8i$

Visual Bonus

23) *Math – Short Answer:* The given image shows three odd functions with a period of 2 and the first 8 coefficients of their sine Fourier series. Answer the following 2 questions about this image:

A) Which sets of Fourier coefficients match with functions 1, 2, and 3 respectively?

B) Function 3 is the odd periodic extension of x^4. What is the n = 0 coefficient in the cosine series of the even periodic extension of x^4?



ANSWER: A) 1 is Y, 2 is W, 3 is X
B) 1/5