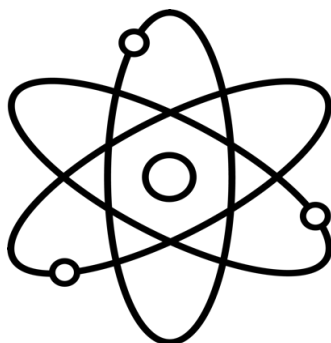




SCIENCE

District 2 • 2015



GENERAL DIRECTIONS:

- DO NOT OPEN EXAM UNTIL TOLD TO DO SO.
- Ninety minutes should be ample time to complete this contest, but since it is not a race, contestants may take up to two hours. If you are in the process of actually writing an answer when the signal to stop is given, you may finish writing that answer.
- Papers may not be turned in until 30 minutes have elapsed. If you finish the test in less than 30 minutes, remain at your seat and retain your paper until told to do otherwise. You may use this time to check your answers.
- All answers must be written on the answer sheet provided. Indicate your answers in the appropriate blanks provided on the answer sheet.
- You may place as many notations as you desire anywhere on the test paper except on the answer sheet, which is reserved for answers only.
- You may use additional scratch paper provided by the contest director.
- All questions have ONE and only ONE correct (BEST) answer. There is a penalty for all incorrect answers.
- If a question is omitted, no points are given or subtracted.
- On the back of this page is printed a copy of the periodic table of the elements. You may wish to refer to this table in answering the questions, and if needed, you may use the atomic weights and atomic numbers from the table. Other scientific relationships are listed also.
- Silent hand-held calculators that do not need external wall plugs may be used. Graphing calculators that do not have built-in or stored functionality that provides additional scientific information are allowed. Small hand-held computers are not permitted. Calculators that accept memory cards or memory sticks are not permitted. Each contestant may bring one spare calculator. All memory must be cleared.

SCORING:

All questions will receive 6 points if answered correctly; no points will be given or subtracted if unanswered; 2 points will be deducted for an incorrect answer.

Periodic Table of the Elements

1A 1																8A 18	
1 H 1.008											2 He 4.003						
2A 2												3A 13	4A 14	5A 15	6A 16	7A 17	
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)						

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Some Standard Properties of Water

property	symbol	value
density of water	ρ_{water}	1.000 g cm ⁻³
density of ice	ρ_{ice}	0.9167 g cm ⁻³
specific heats		
ice	C_{ice}	2.09 J g ⁻¹ K ⁻¹
water	C_{water}	4.184 J g ⁻¹ K ⁻¹
steam	C_{steam}	2.03 J g ⁻¹ K ⁻¹
heat of fusion	ΔH_{fus} or L_f	334 J g ⁻¹
heat of vaporization	ΔH_{vap} or L_v	2260 J g ⁻¹
index of refraction	n	1.33
autoionization	K_w	1.0×10^{-14}

Pressure
1 atm = 760 torr
= 101325 Pa
= 14.7 psi
1 bar = 10 ⁵ Pa
= 100 kPa

Energy
1 cal = 4.184 J
1 L atm = 101.325 J
1 Cal = 1 kcal
1 hp = 746 W
1 eV = 1.602 × 10 ⁻¹⁹ J

Various Physical Constants

property	symbol	value
universal gas constant	R	$8.314 \text{ J mol}^{-1} \text{ K}^{-1}$
		$62.36 \text{ L torr mol}^{-1} \text{ K}^{-1}$
		$0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$
		$1.987 \text{ cal mol}^{-1} \text{ K}^{-1}$
Planck's constant	h	$6.626 \times 10^{-34} \text{ J s}$
		$4.136 \times 10^{-15} \text{ eV s}$
Planck's reduced constant	$h/2\pi$	$1.054 \times 10^{-34} \text{ J s}$
		$6.582 \times 10^{-16} \text{ eV s}$
Boltzmann constant	k_B	$1.38 \times 10^{-23} \text{ J K}^{-1}$
Stefan-Boltzmann	σ	$5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
speed of light	c	$3.00 \times 10^8 \text{ m s}^{-1}$
speed of sound (at 20°C)	v_{air}	343 m s^{-1}
acceleration of gravity	g	9.80 m s^{-2}
gravitational constant	G	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Avogadro's number	N_A	$6.022 \times 10^{23} \text{ mol}^{-1}$
elementary charge	e	$1.602 \times 10^{-19} \text{ C}$
Faraday	F	96485 C mol^{-1}
Coulomb's law constant	k	$8.988 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
Rydberg constant	R	$2.178 \times 10^{-18} \text{ J}$

Some Other Conversion Factors

1 in	=	2.54 cm
1 lb	=	453.6 g
1 mi	=	5280 ft = 1.609 km
1 gal	=	4 quarts = 231 in ³ = 3.785 L

property	symbol	value
electron rest mass	m_e	$9.11 \times 10^{-31} \text{ kg}$
		0.000549 u
		0.511 MeV c ⁻²
proton mass	m_p	$1.6726 \times 10^{-27} \text{ kg}$
		1.00728 u
		938.3 MeV c ⁻²
neutron mass	m_n	$1.6749 \times 10^{-27} \text{ kg}$
		1.008665 u
		939.6 MeV c ⁻²
atomic mass unit	u	$1.6605 \times 10^{-27} \text{ kg}$
		931.5 MeV c ⁻²
earth mass		$5.972 \times 10^{24} \text{ kg}$
earth radius		$6.371 \times 10^6 \text{ m}$
moon mass		$7.348 \times 10^{22} \text{ kg}$
sun mass		$1.989 \times 10^{30} \text{ kg}$
distance earth-moon		$3.844 \times 10^8 \text{ m}$
distance earth-sun		$1.496 \times 10^{11} \text{ m}$
permittivity of free space	ϵ_0	$8.85 \times 10^{-12} \text{ F m}^{-1}$
permeability of free space	μ_0	$4\pi \times 10^{-7} \text{ T m A}^{-1}$

Some Average Bond Energies (kJ/mol)

C-H	413	C-C	346	C-Cl	339	C-N	305
O-H	463	C=C	602	C-Br	285	N=N	418
N-H	391	C≡C	835	O=O	498	H-H	436
C-O	358	C=O	799	C≡O	1072	Br-Br	193
H-Cl	432	S-H	347	N≡N	945	Cl-Cl	242
H-Br	366	H-I	299	C≡N	887	I-I	151

Biology Questions (1 – 20)

1. In eukaryotic cells, glycolysis occurs
 - A) In the same cellular location as in a prokaryotic cell
 - B) In a different cellular location than in a prokaryotic cell.
 - C) Glycolysis does not occur in eukaryotic cells.

2. Genetic engineering relies on the use of _____ which are enzymes that cut DNA at a limited number of specific locations.
 - A) restriction endonucleases
 - B) plasmid vectors
 - C) recombinant DNAses
 - D) DNA ligases
 - E) RNA ligases

3. What is the complementary RNA sequence for a segment of DNA with the sequence: 5' TTA GCG 3'
 - A) 5' AAT CGC 3'
 - B) 3' AAT CGC 5'
 - C) 5' AAU CGC 3'
 - D) 3' AAU CGC 5'
 - E) 5' CGC TAA 3'

4. Which of the following is true when a metabolic reaction is at equilibrium?
 - A) consumption of products is at a maximum
 - B) synthesis of reactants is at a minimum
 - C) no net release of free energy can occur
 - D) the reaction can power an endergonic reaction
 - E) the effect of inhibitors can be seen

5. Bryophytes are non-vascular land plants. Which trait do they all share?
 - A) use diffusion to move water and nutrients through the plant.
 - B) release diploid spores
 - C) are woody perennials
 - D) have a fibrous root system
 - E) lack mitochondria

6. Natural selection requires three basic conditions to occur. Which of the following is NOT required for a population to evolve by natural selection?
 - A) random mating
 - B) differential reproduction
 - C) heritable variation

7. Common characteristics of arthropods do not include which of the following?
 - A) Segmented bodies structure
 - B) Exoskeleton made of rigid protein called chitin
 - C) Jointed appendages
 - D) Body made of a head, abdomen, and thorax

8. Which of the following are the most abundant organisms by number on Earth?
 - A) insects
 - B) angiosperms
 - C) microbes
 - D) fungi

9. Which of the following terms are mismatched?
 - A) Spherical bacteria: Cocci
 - B) Rod-shaped bacteria: Linnelli
 - C) Spiral-shaped bacteria: Spirilli

10. Carbon is found in four main compartments on the Earth: the oceans, the atmosphere, fossil deposits and _____.
 - A) phytoplankton
 - B) thermal vents
 - C) terrestrial organisms
 - D) rock strata

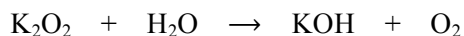
11. The presence of a _____ species has a strong positive effect on community diversity.
 - A) target
 - B) keystone
 - C) clutch
 - D) dominant
 - E) diverse

12. Alternating waves of contraction and relaxation in the smooth muscle lining the alimentary canal is called:
- secretion
 - peristalsis
 - excretion
 - osmostasis
 - interstitis
13. In animals, sheets of cells that cover the body and line organs and cavities are known as _____ tissue.
- connective
 - squamous
 - columnar
 - adipose
 - epithelial
14. Ventilation is the movement of air across a thin respiratory surface that promotes the diffusion of gases. Which of the following can function as a respiratory surface?
- tracheal systems
 - gills
 - skin
 - B and C
 - A, B and C
15. The transmission of traits from one generation to another may require which of the following?
- mitosis
 - meiosis
 - fertilization
 - B and C
 - A, B and C
16. Mendel's law of independent assortment can only be observed in:
- inheritance of alleles at the same locus
 - inheritance of alleles at two different loci on two different chromosomes
 - inheritance of alleles at two different loci on the same chromosome
 - inheritance of parental phenotypes
 - inheritance of homozygous alleles
17. The organelle that receives transport vesicles from the rough ER and is made up of flattened stacks of cisternae that differ in thickness and molecular composition is the:
- Golgi apparatus
 - Ribosome
 - Mitochondria
 - Smooth ER
 - ER lumen
18. The act of fusion of a vesicle containing a damaged organelle with a lysosome is known as:
- coprophagy
 - necrophagy
 - autophagy
 - phagocytosis
 - pinocytosis
19. The change in free energy of a system (ΔG) can be calculated as the difference between the change in the system's _____ and the change in the system's _____ at a given temperature (in K).
- energy; heat
 - enthalpy; entropy
 - entropy; enthalpy
 - entropy; heat
 - energy; enthalpy
20. The range of phenotypes observed for a particular genotype across a range of environment is known as?
- dominance
 - epistasis
 - norm of reaction
 - normal distribution
 - Chi-square distribution

Chemistry Questions (21 – 40)

21. What is the formula for copper(II) chromate?
- $\text{Cu}(\text{CrO}_4)_2$
 - CoCr_2O_7
 - CuCrO_4
 - CoCO_3
 - $\text{Cu}_2\text{Cr}_2\text{O}_7$

22. Balance the following reaction with whole numbers as coefficients.



What are the respective coefficients?

- A) 1 : 1 : 2 : 1
 B) 2 : 1 : 4 : 2
 C) 3 : 3 : 6 : 2
 D) 1 : 2 : 2 : 1
 E) 2 : 2 : 4 : 1
23. A laboratory bottle is labeled 3.75 M H_2SO_4 with a density of 1.251 g/mL. What is the molality of the H_2SO_4 ?

- A) 4.25 *m*
 B) 3.75 *m*
 C) 4.15 *m*
 D) 3.95 *m*
 E) 4.45 *m*

24. The solvent carbon tetrachloride is classified as _____.

- A) an ionic compound
 B) a nonpolar covalent compound
 C) a polar covalent compound
 D) an resonance compound
 E) a covalent metalloid compound

25. Write the proper line/dot structure for the sulfate ion. What is the formal charge on the sulfur atom in this ion?

- A) +2 C) -1 E) 0
 B) -2 D) +1

26. 355 g of chlorine gas is added to a 50-L evacuated container at 28°C. What is the pressure of this chlorine gas?

- A) 72.8 psi C) 23.9 psi E) 51.2 psi
 B) 3.38 psi D) 36.4 psi

27. The value for $\Delta H_{\text{solution}}$ under aqueous conditions is best thought of (and calculated) as a combination of what other two enthalpy changes?

- A) $\Delta H_{\text{hydration}}$ and ΔH_{fusion}
 B) $\Delta H_{\text{lattice}}$ and $\Delta H_{\text{hydration}}$
 C) $\Delta H_{\text{formation}}$ and $\Delta H_{\text{hydration}}$
 D) $\Delta H_{\text{lattice}}$ and $\Delta H_{\text{formation}}$
 E) $\Delta H_{\text{combustion}}$ and $\Delta H_{\text{hydration}}$

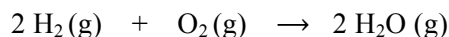
28. Lead(II) iodate has a K_{sp} value equal to 2.6×10^{-13} . A saturated solution of lead(II) iodate has an iodate concentration of 1.6×10^{-4} M. What is the concentration of lead(II) in this solution?

- A) 2.5×10^{-6} M
 B) 1.6×10^{-9} M
 C) 4.0×10^{-5} M
 D) 6.2×10^{-7} M
 E) 1.0×10^{-5} M

29. Which solution listed has the lowest vapor pressure?

- A) 1.7 *m* NaCl D) 1.2 *m* $\text{Sr}(\text{NO}_3)_2$
 B) 1.0 *m* CaCl_2 E) 0.50 *m* $\text{Al}(\text{NO}_3)_3$
 C) 0.80 *m* Na_3PO_4

30. Consider a system at 300 K with the following gas phase reaction occurring:



What is the amount of work done? Is the work done *on* the system or *by* the system?


- A) 7.5 kJ of work done on the system
 B) 2.5 kJ of work done by the system
 C) no work done on or by the system
 D) 7.5 kJ of work done by the system
 E) 2.5 kJ of work done on the system

31. Chloroform (CHCl_3) has the following phase data:

$$\begin{aligned} \Delta H_{\text{fusion}} &= 8.80 \text{ kJ/mol} & T_{\text{fp}} &= -63^\circ\text{C} \\ \Delta H_{\text{vaporization}} &= 30.8 \text{ kJ/mol} & T_{\text{bp}} &= 61^\circ\text{C} \\ C_{\text{p,liquid}} &= 114. \text{ J/mol K} \end{aligned}$$

How much heat must be added to 185 g of chloroform at 25°C in order to change all of it to gas state at 61°C?

- A) 69.7 kJ C) 74.2 kJ E) 61.0 kJ
 B) 54.1 kJ D) 20.0 kJ

32. Which example has $\Delta S < 0$ for the change given?
- a dash of salt dissolves into water
 - a cube of dry ice sublimates
 - a gas molecule splits into two other gas molecules
 - water vapor condenses on a cold windshield
 - an aluminum block is warmed from 20°C to 23°C
33. Consider the gas phase equilibrium:
- $$2 \text{ A (g)} + \text{ B (g)} \rightleftharpoons 3 \text{ C (g)}$$
- If the partial pressure of A is doubled, what happens to the reaction quotient, Q ?
- it drops to 1/4th its original value
 - it increases by a factor of 2
 - Q will not change
 - it increases by a factor of 4
 - it drops to 1/2th its original value
34. A sample of Al_2Cl_6 is put into a gas reaction chamber at 500K and allowed to equilibrate according to the reaction shown:
- $$3 \text{ Al}_2\text{Cl}_6(\text{g}) \rightleftharpoons 2 \text{ Al}_3\text{Cl}_9(\text{g})$$
- At equilibrium the partial pressure of Al_3Cl_9 is 5.0×10^{-3} atm and the Al_2Cl_6 is 1.1 atm. What is the value of the equilibrium constant, K ?
- 1.0×10^{-7}
 - 4.5×10^{-3}
 - 1.9×10^{-5}
 - 2.5×10^{-5}
 - 2.1×10^{-5}
35. An Olympic sized pool maintained at 25°C has one million gallons of water currently at a pH of 7.00. One pound of NaOH is added to the pool. Assuming that there is no buffering, approximate the new pH after all the NaOH has dissolved and mixed?
- 8.48
 - 7.56
 - 5.37
 - 8.63
 - 9.14
36. ~~What is approximate bond angle ($\angle \text{FIF}$) in the ion, IF_5^- ?~~
- ~~75°~~
 - ~~60°~~
 - ~~109.5°~~
 - ~~90°~~
 - ~~120°~~
37. Which of the following neutral atoms has the largest electron affinity?
- Be
 - Br
 - He
 - Rb
 - O
38. Consider the line structure for toluene shown. How many sp^3 hybridized atoms are there in this structure?
- 
- one
 - two
 - three
 - six
 - seven
39. A first order reaction takes 3 hours to fall from a concentration of 0.25 M to 0.015 M at a temperature of 310 K. What is the value of the rate constant, k ?
- $5.8 \times 10^{-3} \text{ s}^{-1}$
 - $1.1 \times 10^{-4} \text{ s}^{-1}$
 - $2.6 \times 10^{-4} \text{ s}^{-1}$
 - $6.8 \times 10^{-5} \text{ s}^{-1}$
 - $9.4 \times 10^{-1} \text{ s}^{-1}$
40. The equilibrium constant for a reaction is doubled when the temperature is changed from 25°C to 100°C. What is the value of ΔH for this reaction?
- 9.25 kJ
 - +8.55 kJ
 - +3.71 kJ
 - 341. J
 - +192. J

Physics Questions (41 – 60)

On this contest i, j and k are the unit vectors in the $+x$, $+y$ and $+z$ directions respectively, and unless otherwise indicated, you may neglect air resistance in every problem.

41. According to Tyson, which asteroid was discovered to have a moon placing doubt on the idea that only planets can have moons?
- Ceres
 - Dactyl
 - Hydra
 - Ida
 - Vesta
42. According to Tyson, what planetary astronomer suggested that “beyond the outermost planet in the solar system lies a reservoir of slowly orbiting debris”?
- Ann Harch
 - David Jewitt
 - Gerard Kuiper
 - Jane Luu
 - Clyde Tombaugh
43. According to Tyson, which of the following expert scientist did NOT appear onstage with the author, Neil DeGrasse Tyson, to debate the classification of Pluto?
- Johannes Anderson
 - Michael A’Hearn
 - David H. Levy
 - Jane Luu
 - Brian Marsden
44. According to Tyson, how did the Rose Center’s Cullman Hall of the Universe deal with the conundrum of Pluto’s placement in the universe?
- declared that the universe only has eight planets
 - listed Pluto as an asteroid
 - listed Pluto as a comet in the Oort cloud
 - listed Pluto as a planet
 - used a familial treatment of the solar system
45. Which of the following is NOT a base unit in the SI system?
- ampere
 - gram
 - meter
 - mole
 - seconds
46. A particle has a position vector given by $\mathbf{r}(t) = [(50t)\mathbf{i} + (20t - 12t^2)\mathbf{j}]$ m. What is the instantaneous velocity vector?
- $[10(29)^{1/2}]$ m/s
 - $[50\mathbf{i} + 20\mathbf{j}]$ m/s
 - $[-(24t)\mathbf{j}]$ m/s
 - $[50\mathbf{i} + (20 - 24t)\mathbf{j}]$ m/s
 - $[(25t^2)\mathbf{i} + (10t^2 - 4.0t^3)\mathbf{j}]$ m/s
47. Imagine that a car attached to the rim of a Ferris wheel undergoes uniform circular motion as it is rotated in a vertical circle. Which of the following is NOT a constant quantity for the car in this situation?
- magnitude of the acceleration of the car
 - magnitude of the force of gravity on the car
 - magnitude of the force on the car by the rim
 - magnitude of the net force on the car
 - magnitude of velocity of the car
48. A 110 kg man runs off of a horizontal river bank to land on a freely floating raft with mass of 175 kg that is initially at rest. After impact, the raft/man combo moves away from the bank with a horizontal speed of 3.50 m/s. What was the horizontal speed of the man as he left the river bank?
- 1.59 m/s
 - 2.07 m/s
 - 2.59 m/s
 - 5.57 m/s
 - 9.07 m/s

49. A 5.25 kg uniform cylinder with a radius of 12.0 cm and a height of 15.0 cm can freely rotate about an axis that runs along the symmetry axis passing through the center of mass. If an ideal string that is wrapped around the cylinder is used to apply a constant tangential force of 25.0 N, then what is the angular acceleration of the cylinder? You may assume that the string does not slip.
- A) 1.14 rad/s^2
 B) 1.59 rad/s^2
 C) 9.52 rad/s^2
 D) 39.7 rad/s^2
 E) 79.4 rad/s^2
50. A 4.50 kg particle moves due east with a constant speed of 5.00 m/s. What is the angular momentum of the particle about a point 7.50 m due north of the path of motion?
- A) $0.00 \text{ kg}\cdot\text{m}^2/\text{s}$
 B) $119 \text{ kg}\cdot\text{m}^2/\text{s}$, upward
 C) $119 \text{ kg}\cdot\text{m}^2/\text{s}$, downward
 D) $169 \text{ kg}\cdot\text{m}^2/\text{s}$, upward
 E) $169 \text{ kg}\cdot\text{m}^2/\text{s}$, downward
51. A planet orbits a massive star in an elliptical orbit such that at perihelion the planet is $1.5 \times 10^{15} \text{ m}$ from the star and at aphelion the planet is $2.7 \times 10^{15} \text{ m}$ away from the star. If the planet has an orbital speed of $7.3 \times 10^4 \text{ m/s}$ at perihelion, then what is the orbital speed of the planet at aphelion?
- A) $2.3 \times 10^4 \text{ m/s}$
 B) $4.1 \times 10^4 \text{ m/s}$
 C) $7.3 \times 10^4 \text{ m/s}$
 D) $1.3 \times 10^5 \text{ m/s}$
 E) $4.7 \times 10^5 \text{ m/s}$
52. A horizontal pipe narrows from 20 cm in diameter at point A to 10 cm in diameter at point B. How do the flow speeds at the two points compare if the pipe is filled with nonviscous, incompressible fluid with no turbulence?
- A) $v_A = (1/4)v_B$
 B) $v_A = (1/2)v_B$
 C) $v_A = v_B$
 D) $v_A = 2v_B$
 E) $v_A = 4v_B$
53. Suppose you have two mass-spring systems, A and B, which oscillate such that they have the same total mechanical energies. If the spring (or force) constant of A is twice that of B, then how does the amplitude of A, A_A , relate to the amplitude of B, A_B ?
- A) $A_A = A_B/2$
 B) $A_A = A_B/(2)^{1/2}$
 C) $A_A = A_B$
 D) $A_A = (2)^{1/2}A_B$
 E) $A_A = 2A_B$
54. A 5.50 m long string with a mass of 0.250 kg is fixed at both ends and has a tension of 50.0 N. What is the frequency of the 1st harmonic for transverse waves on this string?
- A) 3.02 Hz
 B) 4.26 Hz
 C) 6.03 Hz
 D) 100 Hz
 E) 365 Hz
55. A uniform line of charge with a constant linear charge density of $+6.5 \text{ nC/m}$ is on the x -axis between 0.0 and 10.0 m. Find the magnitude of the electric field on the x -axis at $x = 12.0 \text{ m}$.
- A) 24 N/C
 B) 47 N/C
 C) 97 N/C
 D) 290 N/C
 E) 580 N/C
56. A point particle has a $+5.0 \text{ }\mu\text{C}$ charge and is fixed at the origin. How much work is done by an external agent to bring a 2nd point particle with a charge of $+4.0 \text{ }\mu\text{C}$ from infinity to a distance of 6.0 m from the 1st charge?
- A) $+1.5 \times 10^{-7} \text{ J}$
 B) $+2.0 \times 10^{-4} \text{ J}$
 C) $+1.2 \times 10^{-3} \text{ J}$
 D) $+3.0 \times 10^{-2} \text{ J}$
 E) $+3.6 \times 10^4 \text{ J}$

57. A 20.0 μF capacitor and 25.0 μF capacitor are wired in series and this series combination is then connected across the terminals of a 12.0 V battery. What is the charge on each capacitor?
- A) $Q_{20} = 1.08 \mu\text{C}$ $Q_{25} = 1.08 \mu\text{C}$
 B) $Q_{20} = 133 \mu\text{C}$ $Q_{25} = 133 \mu\text{C}$
 C) $Q_{20} = 240 \mu\text{C}$ $Q_{25} = 300 \mu\text{C}$
 D) $Q_{20} = 500 \mu\text{C}$ $Q_{25} = 500 \mu\text{C}$
 E) $Q_{20} = 900 \mu\text{C}$ $Q_{25} = 1130 \mu\text{C}$
58. What is the magnetic force on an electron that has a velocity of $(3.0 \times 10^6 \mathbf{i} + 2.0 \times 10^6 \mathbf{j})$ m/s as it travels through a region with a uniform magnetic field given by $(0.65 \mathbf{i} - 0.45 \mathbf{j} + 0.35 \mathbf{k})$ T?
- A) $(-8.01 \times 10^{-15} \mathbf{i} + 1.12 \times 10^{-13} \mathbf{j} - 1.68 \times 10^{-13} \mathbf{k})$ N
 B) $(-1.12 \times 10^{-13} \mathbf{i} + 1.68 \times 10^{-13} \mathbf{j} + 8.01 \times 10^{-15} \mathbf{k})$ N
 C) $(1.12 \times 10^{-13} \mathbf{i} - 1.68 \times 10^{-13} \mathbf{j} - 8.01 \times 10^{-15} \mathbf{k})$ N
 D) $(-1.12 \times 10^{-13} \mathbf{i} + 1.68 \times 10^{-13} \mathbf{j} + 4.25 \times 10^{-13} \mathbf{k})$ N
 E) $(1.12 \times 10^{-13} \mathbf{i} - 1.68 \times 10^{-13} \mathbf{j} - 4.25 \times 10^{-13} \mathbf{k})$ N
59. A toroid with a radius of 30.0 cm is comprised of circular loops of radii 2.50 cm and is wound with a superconducting wire. If the wire has length of 1200 m and carries a current of 300 A, then what is the magnitude of the magnetic field strength at the center of the circular loops?
- A) 0.474 T
 B) 1.20 T
 C) 1.53 T
 D) 1.59 T
 E) 4.80 T
60. A 25 kW beam of electromagnetic radiation is normal to a surface that reflects half of the radiation. What force is exerted by the radiation on the surface?
- A) 8.3×10^{-8} N
 B) 4.1×10^{-8} N
 C) 2.5×10^{-7} N
 D) 1.3×10^{-4} N
 E) 7.5×10^4 N

UIL HIGH SCHOOL SCIENCE CONTEST

Contestant Answer Sheet

Contestant # _____

9 10 11 12
CONTESTANT GRADE LEVEL

A 2A 3A 4A 5A
CONFERENCE

PLEASE WRITE ANSWERS WITH CAPITAL LETTERS

- | | | |
|-----------|-----------|-----------|
| 1. _____ | 21. _____ | 41. _____ |
| 2. _____ | 22. _____ | 42. _____ |
| 3. _____ | 23. _____ | 43. _____ |
| 4. _____ | 24. _____ | 44. _____ |
| 5. _____ | 25. _____ | 45. _____ |
| 6. _____ | 26. _____ | 46. _____ |
| 7. _____ | 27. _____ | 47. _____ |
| 8. _____ | 28. _____ | 48. _____ |
| 9. _____ | 29. _____ | 49. _____ |
| 10. _____ | 30. _____ | 50. _____ |
| 11. _____ | 31. _____ | 51. _____ |
| 12. _____ | 32. _____ | 52. _____ |
| 13. _____ | 33. _____ | 53. _____ |
| 14. _____ | 34. _____ | 54. _____ |
| 15. _____ | 35. _____ | 55. _____ |
| 16. _____ | 36. _____ | 56. _____ |
| 17. _____ | 37. _____ | 57. _____ |
| 18. _____ | 38. _____ | 58. _____ |
| 19. _____ | 39. _____ | 59. _____ |
| 20. _____ | 40. _____ | 60. _____ |

BIOLOGY SCORE

CHEMISTRY SCORE

PHYSICS SCORE

OVERALL SCORE:

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY

DISTRICT 2 • 2015

- | | | | | | |
|-----|---|-----|--------------|-----|---|
| 1. | A | 21. | C | 41. | D |
| 2. | A | 22. | E | 42. | C |
| 3. | D | 23. | A | 43. | A |
| 4. | C | 24. | B | 44. | E |
| 5. | A | 25. | E | 45. | B |
| 6. | A | 26. | D | 46. | D |
| 7. | B | 27. | B | 47. | C |
| 8. | C | 28. | E | 48. | E |
| 9. | B | 29. | D | 49. | E |
| 10. | C | 30. | E | 50. | D |
| 11. | B | 31. | B | 51. | B |
| 12. | B | 32. | D | 52. | A |
| 13. | E | 33. | A | 53. | B |
| 14. | E | 34. | C | 54. | A |
| 15. | E | 35. | A | 55. | A |
| 16. | B | 36. | D | 56. | D |
| 17. | A | 37. | E | 57. | B |
| 18. | C | 38. | A | 58. | D |
| 19. | B | 39. | C | 59. | C |
| 20. | C | 40. | B | 60. | D |

PHYSICS KEY for Science Contest • District 2 • 2015

41. (D) “While examining the data, mission member Ann Harch discovered that Ida has a small (1.4-kilometer) orbiting moon that came to be named Dactyl.”
42. (C) “Gerard Kuiper had proposed that beyond the outermost planet in the solar system (perhaps in any star system) lies a reservoir of slowly orbiting debris...”
43. (A) “You couldn’t get more expert experts than the five scientists that joined me onstage:” Michael A’Hearn, David H. Levy, Jane Luu, Brian Marsden, and Alan Stern.
44. (E) “That’s when we decided to present the contents of the solar system as families of objects with similar properties...” “We knew that no matter how the Pluto debate would ultimately resolve, our familial treatment of the solar system was pedagogically and scientifically sensible – a kind of intellectual high road that sidestepped nomenclature altogether.”
45. (B) The SI base unit for mass is the kilogram.
46. (D) $\mathbf{v}(t) = (d/dt)[\mathbf{r}(t)] = [50\mathbf{i} + (20 - 24t)\mathbf{j}]$ m/s
47. (C) As the car undergoes vertical, uniform circular motion the magnitude of the force on the car by the rim will not be constant as can be seen by analyzing Newton’s second law at various points along the motion.
48. (E) By conservation of linear momentum: $110v_0 + 0 = (110+175)(+3.5) \Rightarrow v_0 = 9.07$ m/s
49. (E) By $\alpha = \Sigma \tau/I = (rF)/(1/2mr^2) = (2F)/(mr) = [2(25)]/[(5.25)(0.12)] = 79.4$ rad/s²
50. (D) With $\mathbf{L} = \mathbf{r} \times \mathbf{p} \Rightarrow L = rmv \sin\phi = (7.5)(4.5)(5) \sin 90^\circ = 169$ kg·m²/s & by the right hand rule the direction is upward
51. (B) By conservation of angular momentum: $L_a = L_p \Rightarrow r_a m v_a \sin\phi_a = r_p m v_p \sin\phi_p \Rightarrow v_a = (r_p/r_a)v_p = [(1.5E+15)/(2.7E+15)](7.3E+4) = 4.1E+4$ m/s
52. (A) For an incompressible fluid the volume flow rate, $Q = vA \cos\theta$, remains constant at any point along a pipe, thus $Q_A = Q_B \Rightarrow v_A (\pi/4)D_A^2 = v_B (\pi/4)D_B^2$ & with $D_B = 1/2 D_A \Rightarrow v_A = (1/4)v_B$
53. (B) By $E_{sho} = 1/2 k A^2 \Rightarrow 1/2 k_A A_A^2 = 1/2 k_B A_B^2$ & with $k_A = 2k_B \Rightarrow A_A = A_B/(2)^{1/2}$
54. (A) By $f = n[v/(2L)]$ & $v = [F_T/(m/L)]^{1/2} \Rightarrow f = (n/2)[F_T/(mL)]^{1/2} = (1/2)\{[(50)]/[(0.25)(5.5)]\}^{1/2} = 3.02$ Hz
55. (A) By $E = \int dE = \int (k dq/r^2)$ & $dq = \lambda dx$ & $r = (12-x) \Rightarrow E = k\lambda \int (12-x)^{-2} dx = k\lambda (12-x)^{-1}|_0^{10} = (8.99E+9)(6.5E-9)(1/2 - 1/12) = 24$ N/C
56. (D) By $W_{net} = W_{ext} + W_E = \Delta K = 0 \Rightarrow W_{ext} = -W_E = -(\Delta U_E) = +\Delta U_E = kq_1q_2/r - 0 = (8.99E+9)(+5E-6)(+4E-6)/(6) = 3.0E-2$ J
57. (B) For series combinations: $C_{eq} = [(20\mu F)^{-1} + (25\mu F)^{-1}]^{-1} = 11.11\mu F$ and since the charge is the same in series: $Q = Q_{20} = Q_{25} = C_{eq}V = (11.11E-6)(12) = 133$ μC
58. (D) By $\mathbf{F}_B = q\mathbf{v} \times \mathbf{B} = (-1.602E-19)[(3.0 \times 10^6\mathbf{i} + 2.0 \times 10^6\mathbf{j}) \times (0.65\mathbf{i} - 0.45\mathbf{j} + 0.35\mathbf{k})]$
 $= (-1.12E-13\mathbf{i} + 1.68E-13\mathbf{j} + 4.25E-13\mathbf{k})$ N
59. (C) By Ampère’s Law: $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{enc} \Rightarrow B = \mu_0 NI/(2\pi R)$ & $N = 1200/[2\pi(0.025)] = 7639$
 $\Rightarrow B = [(4\pi E-7)(7639)(300)]/[2\pi(0.3)] = 1.53$ T
60. (D) With $F = IA/c = P/c$ and double for reflection gives:
 $(1/2 P)/c + 2(1/2 P)/c = (3/2)(25000)/(3E+8) = 1.3E-4$ N