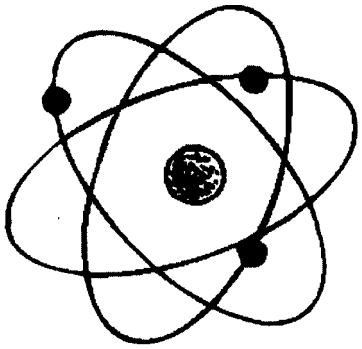
UIL

SCIENCE

State • 2009



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.
- Answers within 5% of the exact answer will be considered correct.

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																	8A
1 H 1.008	2A											3A	4A	5A	6A	7A	2 He 4.003
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 23.00	12 Mg 24.31	3B	4B	5B	6B	7B	8B			1B	2B	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	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 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Ha (262)	106 Unh (263)	107 Uns (262)		109 Une (267)									

Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinides	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	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 (260)

See Reverse Page for Other Useful Information

OTHER USEFUL INFORMATION

Avogadro's Number, $N_A = 6.022 \times 10^{23}$ mol^{-1}

Absolute zero = 0 K = -273.15°C

Atmospheric pressure, 1 atm = 1.013×10^5 N/m^2 = 101.3 kPa = 760.0 Torr = 760.0 mmHg

Standard temperature and pressure (STP) is 0°C and 1 atm

Gram molecular volume at STP = 22.4 L

Mechanical equivalence of heat, 1 kcal = 1 Cal = 1,000 cal = 4,186 J

Gas constant, R = 1.987 cal/mol•K = 0.08206 atm•L/mol•K = 8.314 J/mol•K

Dulong and Petit's constant = 6.0 amu•cal/gram•K

Faraday's constant, 1 F = 96,485 C/mol

Acceleration of gravity at Earth's surface, g = 9.80 m/s^2

Gravitational constant, $G = 6.67 \times 10^{-11}$ N•m^2/kg^2

Horsepower, 1 hp = 746 W = 550 ft•lbs/s

Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K

Stefan-Boltmann constant, $\sigma = 5.67 \times 10^{-8}$ W/m^2•K^4

Elementary charge, $e = 1.602 \times 10^{-19}$ C

Coulomb's law constant, $k = 1/4\pi\varepsilon_o = 8.988 \times 10^9$ N•m^2/C^2

Permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ C^2/N•m^2

Permeability of free space, $\mu_o = 4\pi \times 10^{-7}$ T•m/A

Electron volt, 1 eV = 1.602×10^{-19} J

Vacuum speed of light, $c = 3.00 \times 10^8$ m/s

Planck's constant, $h = 6.626 \times 10^{-34}$ J·s = 4.136×10^{-15} eV•s

Planck's reduced constant, $\hbar \equiv h/2\pi = 1.054 \times 10^{-34}$ J·s = 6.582×10^{-16} eV•s

Atomic mass unit, 1 amu = 1 u = 1.66×10^{-27} kg = 931.5 MeV/c^2

Electron rest mass, $m_e = 9.11 \times 10^{-31}$ kg = 0.000549 u = 0.511 MeV/c^2

Proton Mass = 1.6726×10^{-27} kg = 1.00728 u = 938.3 MeV/c^2

Neutron Mass = 1.6749×10^{-27} kg = 1.008665 u = 939.6 MeV/c^2

Some standard values for water:

- Mass density, $\rho = 1.00$ g/cm^3 = 1,000 kg/m^3
- Heat capacity or Specific heat, c = 1.00 cal/gram•C° = 1.00 kcal/kg•C° = 4186 J/ kg•C°
- Latent heats, $L_F = 79.7$ kcal/kg = 3.33×10^5 J/kg & $L_V = 539$ kcal/kg = 22.6×10^5 J/kg
- Index of refraction, n = 1.33

Biology Questions (1 – 20)

1. Which of the following is the primary function of a cell's nucleolus?
   A) to secrete hydrolytic enzymes
   B) to assemble ribosomes
   C) to transcribe DNA into RNA
   D) to synthesize DNA
   E) to store DNA

2. Which of the following is represented by the general formula CH_2O?
   A) sugars
   B) fats
   C) amino acids
   D) nucleic acids
   E) None of the above

3. If a human spermatocyte were to undergo meiosis without separate nuclear membranes forming around the chromosome sets produced, how many chromosomes would the single resulting cell contain?
   A) 23
   B) 46
   C) 92
   D) 184
   E) 368

4. How many turns of the Krebs cycle are needed to completely break down one glucose molecule?
   A) one
   B) two
   C) three
   D) four
   E) six

5. The puffs that appear on giant chromosomes are accumulations of
   A) DNA.
   B) repressor molecules.
   C) mRNA.
   D) tRNA.
   E) RNA.

6. Herpes viruses that produce latent infections include all but which of the following?
   A) hepatitis
   B) infectious mononucleosis
   C) genital herpes
   D) chicken pox
   E) cancer

7. Which of the following is NOT characteristic of diatoms?
   A) overlapping shells
   B) silica composition
   C) perforations in the shell
   D) meiosis
   E) flagella

8. Bryophytes differ from all other plants in that they
   A) have swimming sperm.
   B) have independent gametophytes and dependent sporophytes.
   C) were the first photosynthetic organisms to live on land.
   D) exhibit alternation of generations.
   E) have gametangia that produce sperm and eggs.

9. Which of the following is NOT true?
   A) The evolution of the coelom enabled animals to grow large.
   B) Segmentation allows increasing specialization of body parts.
   C) The evolution of an elongated gut allowed specialization of regions to carry out different digestive functions.
   D) Radial symmetry is associated with the greatest diversity and evolutionary success in animals.
   E) Cephalization allows concentration of sensory organs in that area of the body.

10. Which of the following elements has a role in electron transport and chlorophyll synthesis?
    A) iron
    B) manganese
    C) phosphorus
    D) zinc
    E) boron

11. Which color of light is most effective in producing phototropism?
    A) red
    B) blue
    C) yellow
    D) violet
    E) green

12. The characteristics of an apple are
    A) a blend of the characteristics of the parent plants that produced its seeds.
    B) determined by the genes of the plant it was produced on.
    C) determined by the genes of the pollinating plant.
    D) determined by the environmental conditions when the fruit was growing.
    E) 50% due to its genotype and 50% due to environment.

13. Which of the following is NOT a function of the liver?
    A) formation of urea
    B) formation of bile
    C) detoxification of poisons
    D) secretion of bicarbonate ions
    E) lipid metabolism

14. Normal bacterial inhabitants of the human body
    A) are naturally resistant to antibiotics.
    B) are able to outcompete some invading pathogens and thus are one of the body's defense mechanisms.
    C) can be transformed into pathogenic forms if a person's resistance to disease is low.
    D) are unable to survive the human body's defense mechanisms.
    E) neither harm nor help the body.

15. The membrane-bound system that maintains the resting membrane potential is the ___ pump.
    A) sodium-phosphorus
    B) sodium-potassium
    C) sodium-chloride
    D) phosphorus-calcium
    E) phosphorus-chlorine

16. Antidiuretic hormone and oxytocin are products of
    A) endocrine glands.
    B) blood capillaries.
    C) neurosecretory cells.
    D) the anterior pituitary.
    E) kidney and uterine wall cells, respectively.

17. Which of the following would tend to promote water retention by the kidney?
    A) many nephridia
    B) a short distal tubule
    C) a high filtration rate
    D) a long proximal tubule
    E) a long loop of Henle

18. The decline in the frequency of the sickle-cell anemia allele in the American population is the result of
    A) a lower mutation rate in the United States than in Africa.
    B) the advantage of both homozygous forms over the heterozygous form.
    C) the development of appropriate medical treatment in the United States.
    D) a decline in the occurrence of malaria in the United States.
    E) nonrandom mating.

19. Net primary productivity is the
    A) rate of photosynthesis.
    B) rate of energy flow.
    C) amount of energy stored in an ecosystem.
    D) amount of energy utilized.
    E) amount of energy stored in plant tissue in excess of that used in respiration by autotrophs.

20. Chemosynthetic organisms are
    A) primary consumers.
    B) secondary consumers.
    C) tertiary consumers.
    D) primary producers.
    E) secondary producers.

Chemistry Questions (21 – 40)

21. The following reaction is classified as _____ .
$K_2SO_4 + BaCl_2 \rightarrow BaSO_4 + 2\,KCl$

A) metathesis and redox
B) displacement and redox
C) metathesis
D) displacement only
E) combination only

22. Write the balanced, total ionic equation for the reaction of calcium hydroxide with nitric acid using integers. What is the sum of the stoichiometric coefficients of the ions on the left side of the balanced equation?

A) three
B) four
C) seven
D) six
E) five

23. The number of unpaired electrons in the lowest energy electron configuration of an isolated sulfur atom is _____ .

A) 1
B) 3
C) 4
D) 0
E) 2

24. The quantum mechanical approach to atomic structure permits the calculation of _____ .

A) the most probable radius of an orbit that an electron of specified energy will follow.
B) the most probable spin value that will be associated with an electron of specified energy.
C) the most probable distance between any two specified electrons.
D) a region about the nucleus in which electrons will probably be found.
E) the number of electrons in an atom.

25. The n and l quantum numbers of the highest energy electrons of an element are n = 4 and l = 2 . The element is a(n) ____ .

A) nonmetal
B) noble gas
C) d-transition metal
D) representative element
E) f-transition metal

26. Which of the following structures does NOT represent a potentially strong hydrogen bond?

A) O•••H•••O
B) N•••H•••N
C) O•••H•••N
D) C•••H•••N
E) F•••H•••F

27. The predicted molecular geometry of ICl_3 would be?

A) triangular pyramidal
B) triangular planar
C) triangular bipyrimidal
D) linear
E) T-shaped

28. It required 25.0 mL of 0.333 M sodium hydroxide solution to completely neutralize 15.0 mL of sulfuric acid solution. What was the molarity of the sulfuric acid solution?

A) 0.200 M
B) 0.278 M
C) 0.555 M
D) 1.11 M
E) 0.430 M

29. What volume of 0.10 M potassium dichromate would be required to oxidize 60 mL of 0.10 M sodium sulfite in acidic solution? The products include Cr^{3+} and SO_4^{2-} ions.

A) 30 mL
B) 20 mL
C) 60 mL
D) 40 mL
E) 10 mL

30. Surface tension is _____ .
   A) the inward force that must be overcome in order to expand the surface area of a liquid
   B) the resistance to flow of a liquid
   C) responsible for capillary action
   D) the adhesive force between molecules
   E) a constant for all liquids at the same temperature

31. Colloids consisting of solids or liquids dispersed in a gas medium are called _____ .
   A) emulsions
   B) sols and gels
   C) none of these
   D) foams
   E) aerosols

32. The reaction $N_2O_4(g) \rightarrow 2\ NO_2(g)$ would be spontaneous at one atm and _____ temperature.
   A) high
   B) low
   C) at all temperatures above the liquefaction point
   D) at no temperature above the liquefaction point
   E) It is not possible to answer without access to Thermodynamic tables

33. Bond energies help assess the kinetics of a reaction because they provide a way to estimate _____ .
   A) ΔS
   B) ΔG
   C) the activation energy of the reaction
   D) ΔH
   E) the equilibrium constant

34. Given the reaction
$2\ CO(g) + O_2(g) \rightarrow 2\ CO_2\ (g)$ which is the relationship between K_c and K_p?
   A) $K_p = K_c\ (RT)^{-2}$
   B) $K_p = K_c$
   C) $K_p = K_c\ RT$
   D) $K_p = K_c\ (RT)^{-1}$
   E) $K_p = K_c\ (RT)^2$

35. K_a for HX is 1.31×10^{-3} at 25°C. What are $[\ H_3O^+\ ]$ and $[\ HX\ ]$ for a 0.0200 M solution of HX ?

	$[\ H_3O^+\ ]$	$[\ HX\ ]$
A)	4.5×10^{-3}	1.6×10^{-2}
B)	5.1×10^{-3}	1.5×10^{-2}
C)	5.3×10^{-3}	1.5×10^{-2}
D)	5.7×10^{-3}	1.4×10^{-2}
E)	6.0×10^{-3}	1.4×10^{-2}

36. What is the pH of the solution resulting from mixing 100 ml of a 0.1 M aqueous solution of the weak acid HA with 100 ml of a 0.1 aqueous solution of the weak acid MOH? Assume MA is a soluble salt. For HA, $K_a = 3.1 \times 10^{-4}$.
For MOH, $K_b = 3.1 \times 10^{-4}$
   A) 2
   B) 5
   C) 7
   D) 9
   E) 11

37. If a solution is 1.00×10^{-5} M in manganese nitrate and 1.50×10^{-3} M in aqueous ammonia, will manganese hydroxide precipitate?
K_b(ammonia) $= 1.8 \times 10^{-5}$,
K_{sp}(manganese hydroxide) $= 2.5 \times 10^{-13}$
   A) No, because $Q_{sp} > K_{sp}$.
   B) No, because $K_{sp} > Q_{sp}$.
   C) Yes, because $K_{sp} > Q_{sp}$.
   D) Yes, because $Q_{sp} > K_{sp}$.
   E) Yes, because $Q_{sp} = K_{sp}$.

38. Consider the voltaic cell
$Ga\ /\ Ga^{3+}(1\ M)\ //\ Ni^{2+}(1\ M)\ /\ Ni$
$Ga^{3+} + 3\ e^- \rightarrow Ga$ $\quad E° = -0.560$ V
$Ni^{2+} + 2\ e^- \rightarrow Ni$ $\quad E° = -0.230$ V
What maximum available energy can be obtained from the cell at 25°C?
   A) 191 kJ/mol
   B) 63.7 kJ/mol
   C) 159.2 kJ/mol
   D) 31.8 kJ/mol
   E) 95.5 kJ/mol

39. A 542. mL sample of oxygen was collected by displacement of water at 24°C under a total barometric pressure of 672. torr. What mass of dry oxygen (in grams) was collected? The vapor pressure of water at 24°C is 22 torr.
    A) 0.326 g
    B) 0.412 g
    C) 0.304 g
    D) 0.608 g
    E) 0.650 g

40. We have two liters of an aqueous solution that is 0.10 M in acetic acid and 0.10 M in sodium acetate. How many grams of solid sodium hydroxide must be added to this solution to increase its pH by 5.0 percent? Assume no volume change due to the addition of solid sodium hydroxide. For acetic acid, $K_a = 1.8 \times 10^{-5}$
    A) 0.75 g
    B) 0.99 g
    C) 1.36 g
    D) 1.84 g
    E) 2.16 g

Physics Questions (41 – 60)

41. This UT theoretical physicist holds degrees in both physics and mathematics and has done experimental physics as well. He/she has held positions at CERN and the Cavendish Laboratory in Cambridge, England prior to coming to UT. His/her research interests include S-matrix theory, particle collisions, the Quantum Zeno effect, A.I., air pollution and QCD phenomenology. He/she is interested in teaching Engineering Physics and has received numerous teaching excellence awards.
    A) Charles Chiu
    B) Austin Gleeson
    C) Alan MacDonald
    D) Michael Marder
    E) Jack Swift

42. A baryon can be composed of
    A) any odd number of quarks
    B) three quarks with three different colors
    C) three quarks with the same color
    D) two quarks with the same color
    E) a colorless quark-antiquark pair

43. In an accelerator, two protons with equal kinetic energies collide head-on producing the following reaction: $p + p \rightarrow p + p + p + \bar{p}$. What is the minimum kinetic energy of each of the incident proton beams?
    A) 0.00 MeV
    B) 469 MeV
    C) 938 MeV
    D) 1.88 GeV
    E) 2.81 GeV

44. A car is traveling due north at a speed of 110 km/h, while at the same time a truck is traveling at 35° west of north at a speed of 85 km/h. What is the velocity of the truck relative to the car? You may assume that both the car and the truck are traveling at constant velocities.
    A) 63 km/h at 50° E of N
    B) 63 km/h at 50° W of S
    C) 93 km/h at 47° E of N
    D) 190 km/h at 15° E of S
    E) 190 km/h at 15° W of N

45. A projectile is fired from a cannon and must hit a target on the top of a cliff. The target is located 350 m horizontally away from and 75 m above the cannon. If the cannon is fired at 40° above the horizontal, then what is the required initial speed of the projectile in order to hit the target? You may neglect air resistance for this problem.
    A) 68 m/s
    B) 83 m/s
    C) 2.0×10^3 m/s
    D) 3.5×10^3 m/s
    E) 7.0×10^3 m/s

46. When comparing a bowling ball for an adult with one for a child it is observed that they are made out of the same material and thus have the same mass density even though the child's ball has a radius that is half of that of the adult's ball. What is the ratio of the moment of inertia of the child's ball to that of the adult's ball? You may assume that the bowling balls are uniform spheres.

A) (1/2)
B) $(1/2)^2$
C) $(1/2)^3$
D) $(1/2)^4$
E) $(1/2)^5$

47. A uniform solid sphere of radius R rolls without slipping down a loop-the-loop track. The radius of the loop is r and you may assume that the radius of the sphere R is negligible when compared to the radius of the loop r. What is the minimum height above the bottom of the loop from which the sphere can be released on the track in order for it to successfully complete the loop-the-loop? You may assume that energy is conserved during the motion of the sphere on the track.

A) r
B) 2r
C) (5/2) r
D) (27/10) r
E) 3r

48. A car drives toward a wall at a speed of 35.0 m/s while emitting a 550 Hz tone. What is the beat frequency between the emitted frequency and the echo received off of the wall? You may assume that the speed of sound in air is 343 m/s.

A) 56.1 Hz
B) 62.5 Hz
C) 102 Hz
D) 118 Hz
E) 125 Hz

49. Sublimation is a phase change between which of the following states of matter?

A) solid to liquid
B) solid to gas
C) gas to liquid
D) liquid to gas
E) liquid to solid

50. An ice cube at 0.0°C is slowly melting. After 1.0 g of ice melts, what is the change in the ice cube's entropy?

A) 0.015 J/K
B) 0.29 J/K
C) 1.2 J/K
D) 2.0 J/K
E) 8.3 J/K

51. Given that the average temperature of the Earth's atmosphere is 253 K when it is in radiative equilibrium, i.e., it radiates the same power as it absorbs. If the surface temperature of the Sun were to drop by a factor of 2, then what would be the new average temperature of the Earth's atmosphere? Note: the Earth absorbs 70% of the incident solar radiation and for this problem you may assume that this remains constant as the surface temperature of the Sun drops (as well as the emissivities of the Sun and the Earth).

A) 253 K
B) (1/2) 253 K = 127 K
C) $(1/2)^2$ 253 K = 63 K
D) $(1/2)^3$ 253 K = 32 K
E) $(1/2)^4$ 253 K = 16 K

52. A gold wire with a diameter of 0.50 mm has 5.9×10^{28} conduction electrons/m^3. If the drift speed of the electrons is 6.5 μm/s, then what is the current in the wire?

A) 2.5 μA
B) 5.0 μA
C) 24 μA
D) 12 mA
E) 48 mA

53. If two electrons are held at rest 9.0 μm apart from one another, then what is the speed of each electron once they are very far apart from one another? You may assume that the final electric potential energy is effectively zero.
A) 5.3×10^3 m/s
B) 7.5×10^3 m/s
C) 2.5×10^4 m/s
D) 1.8×10^6 m/s
E) 2.5×10^6 m/s

54. An electromagnet consists of a soft iron core inside a solenoid. The solenoid is a cylindrical coil of wire made up of 1800 turns with a radius of 2.0 cm and a length of 15 cm. If the magnetic field inside the iron core has a magnitude of 0.42 T when 2.0 A of current is run through the solenoid, then what is the relative permeability of the iron core?
A) 1.9
B) 3.7
C) 14
D) 37
E) 93

55. A 300-turn solenoid is wrapped around a hollow 6.0 cm long cylinder that has a radius of 1.2 cm. What is the self-inductance of the solenoid?
A) 0.051 mH
B) 0.85 mH
C) 14 mH
D) 110 mH
E) 8.9 H

56. The cylindrical beam of a 10 mW laser is 0.85 cm in radius. What is the rms value of the electric field?
A) 1.3×10^2 V/m
B) 1.8×10^2 V/m
C) 1.3×10^4 V/m
D) 2.2×10^6 V/m
E) 3.2×10^6 V/m

57. An object is placed 6.0 cm in front of a lens. If a virtual image is formed 9.0 cm from the lens, then what is the focal length of the lens and what type of lens is it?
A) 3.0 cm, diverging
B) 3.6 cm, converging
C) 3.6 cm, diverging
D) 18 cm, converging
E) 18 cm, diverging

58. A camera lens with an index of refraction n = 1.50 is coated with a thin film of magnesium fluoride that is 90.0 nm thick and has an index of refraction of n = 1.38. What is the wavelength of light in the visible spectrum that is most strongly transmitted through the film?
A) 248 nm
B) 270 nm
C) 360 nm
D) 497 nm
E) 540 nm

59. The objective lens of an astronomical telescope forms an image of a distant object at the focal point of the eyepiece. If the eyepiece has a focal length of 5.0 cm and the distance between the two lenses is 45 cm, then what is the absolute value of the angular magnification of the telescope?
A) 0.11
B) 0.13
C) 1.1
D) 8
E) 9

60. Radioactive $^{215}_{83}$Bi decays into $^{215}_{84}$Po. Which of the following particles is released in the decay?
A) an alpha particle
B) an electron
C) a positron
D) a proton
E) a neutron

UIL HIGH SCHOOL SCIENCE CONTEST
ANSWER KEY

STATE • 2009

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

41. (A) Charles Chiu has done research in both experimental and theoretical physics. He has also been a member of both the UT Center for Particle Theory and the UT Center for Particles and Fields. He is a member of the UT Academy of Distinguished Teachers and has been innovative in large classroom interactive physics teaching at UT.

42. (B) Baryon are the family of composite particles made up of three quarks. The come in colorless combinations of red, green and blue (or possibly anti-red, anti-green and anti-blue).

43. (C) By conservation of relativistic energy: $(KE + m_pc^2) + (KE + m_pc^2) = 4(0 + m_pc^2)$, recall: $m_{\bar{p}} = m_p$ and note that minimum initial KE implies zero final KE for the reaction. Thus, $KE = m_pc^2 = 938$ MeV.

44. (B) $\mathbf{v}_{TC} = \mathbf{v}_{TG} + \mathbf{v}_{GC} = \mathbf{v}_{TG} - \mathbf{v}_{CG}$, which by components is x-component: $(-85 \sin 35°) - 0 = -48.75$ & y-component: $85 \cos 35° - 110 = -40.37 \Rightarrow \mathbf{v}_{TC} = 63.3$ km/h at 50.4° W of S.

45. (A) From the launch point to the target in the horizontal direction: $350 = 0 + (v_0 \cos 40°)\, t \Rightarrow t = 350/(v_0 \cos 40°)$ thus in the vertical direction $75 = 0 + v_0 \sin 40° [350/(v_0 \cos 40°)] - \frac{1}{2} g [350/(v_0 \cos 40°)]^2$, which gives $v_0 = [350/\cos 40°]\{4.9/(350 \tan 40° - 75)\}^{1/2} = 68.39$ m/s

46. (E) $I_{child}/I_{adult} = (m_cR_c^2)/(m_aR_a^2) = (\rho V_cR_c^2)/(\rho V_aR_a^2) = (\rho 4/3\pi R_c^3R_c^2)/(\rho 4/3\pi R_a 3R_a^2) = (R_c/R_a)^5 = (1/2)^5$

47. (D) By energy conservation: $E_0 = 0+0+mgh = \frac{1}{2} mv^2 + \frac{1}{2} I\omega^2 + mg(2r) = E$, and with $I_{sphere} = 2/5\ mR^2$ and at the top of the loop-the-loop $v_{minimum} = (gr)^{1/2} = R\omega$ since it rolls without slipping. Thus, $mgh = \frac{1}{2} m(gr) + \frac{1}{2} (2/5\ mR^2)[gr/R^2] + mg(2r) \Rightarrow h = \frac{1}{2} r + 1/5\ r + 2r = (27/10)\ r$

48. (E) With $f' = \left(\frac{v \pm v_o}{v \mp v_s}\right) f$, there are two successive Doppler shifts one from the car to the wall and the other from the wall to the car $f_1 = [v/(v-v_{car})]f$ & $f_2 = [(v+v_{car})]f_1 = [(v+v_{car})/(v-v_{car})]f$ $\Rightarrow \Delta f = f_{beat} = [(343+35)/(343-35)]\ 550 - 550 = 125$ Hz

49. (B) Sublimation is a transition from the solid to gas phase with no intermediate liquid phase.

50. (C) $\Delta S = \Delta Q/T = mL_f/T = (0.001)3.33\times10^5/273 = 1.22$ J/K

51. (B) $P_{absorbed} = P_{emitted} \Rightarrow (0.70)e_S\sigma A_S T_S^4 = e_E\sigma A_E T_E^4 \Rightarrow T_E \propto T_S \Rightarrow T_E = \frac{1}{2} (T_E)_0$

52. (D) $I = neAv_{drift} = (5.9\times10^{28})1.6\times10^{-19}[\pi(2.5\times10^{-4})^2]6.5\times10^{-6} = 12$ mA

53. (A) By conservation of energy: $\Delta KE = -\Delta PE = 2(\frac{1}{2} mv^2) - 0 = -(0 - ke^2/r)$ $\Rightarrow v = [(ke^2)/(mr)]^{1/2} = \{[(9.00\times10^9)(1.60\times10^{-19})2]/[9.11\times10^{-31})(9\times10^{-6})]\}^{1/2} = 5.31\times10^3$ m/s

54. (C) $B = \mu nI = (\mu/\mu_0)\mu_0 nI \Rightarrow \mu_{rel} = \mu/\mu_0 = B/B_0 = B/\mu_0 nI = 0.42/[4\pi\times10^{-7}(1800/0.15)2] = 13.9$

55. (B) $L = \mu_0 n^2 Al = 4\pi\times10^{-7}(300/0.06)^2[\pi(0.012)^2]0.06 = 0.853$ mH

56. (A) $I_{avg} = P_{avg}/A = u_{em}c = \varepsilon_0 E_{rms}^2 c \Rightarrow E_{rms} = [P_{avg}/(\varepsilon_0 cA)]^{1/2} = \{[0.010]/[8.85\times10^{-12}(3.00\times10^8)\pi(0.0085)^2]\}^{1/2}$ $= 128.8$ V/m

57. (D) $f = [1/do + 1/di]^{-1} = [1/6 + 1/(-9)]^{-1} = +18$ cm, which is a converging lens

58. (D) The light that is transmitted is not reflected, thus $2t + 0 = m\lambda_{film}/2$, where m = odd integers for destructive interference and there is no net phase change due to inversion upon reflection off of the surfaces, since both inverted. Therefore, $\lambda_{vac} = n_{film}\lambda_{film} = n_{film}4t/m = [1.38(4)90.0]/1 = 497$ nm

59. (D) $L = f_o + f_e \Rightarrow f_o = 45 - 5 = 40$ cm & $|m| = f_o/f_e = 40/5 = 8$

60. (B) $^{215}_{83}Bi \rightarrow {}^{215}_{84}Po + {}^{A}_{Z}X \Rightarrow Z = -1$ & $A = 0 \Rightarrow$ an electron

1. Which of the following is the primary function of a cell's nucleolus?

A) to secrete hydrolytic enzymes
*B) to assemble ribosomes
C) to transcribe DNA into RNA
D) to synthesize DNA
E) to store DNA

Explanation: The nucleolus is a dense area within the nucleus where ribosomes are assembled. It does not synthesize, transcribe, or store DNA, and it does not secrete hydrolytic enzymes.

2. Which of the following is represented by the general formula CH_2O?

*A) sugars
B) fats
C) amino acids
D) nucleic acids
E) None of the above

Explanation: Carbohydrates, which include sugars, have the general structural formula CH_2O. The structural formula of glucose, for example, is $C_6H_{12}O_6$. The exact numbers of C, H, and O atoms vary, however. The structural formula of sucrose, a disaccharide, is $C_{12}H_{22}O_{11}$. There are not exactly twice as many H atoms as C and O atoms, because the disaccharide is formed by a condensation reaction, which removes 2 H atoms and one O atom. Fats, like sugars, contain C, H, and O. However, the structural formulas for fats are quite different than those for sugars. Fats generally have many fewer O atoms than C atoms. This makes them, or at least parts of them, insoluble in water. Amino acids and nucleic acids both contain N atoms. Nucleic acids also contain P atoms, and amino acids may contain S atoms. The structural formulas of both amino and nucleic acids are very different from those of carbohydrates.

3. If a human spermatocyte were to undergo meiosis without separate nuclear membranes forming around the chromosome sets produced, how many chromosomes would the single resulting cell contain?

A) 23
B) 46
*C) 92
D) 184
E) 368

Explanation: Meiosis is a two-step process in which the number of chromosomes is doubled, and the duplicated chromosomes divide to produce single-stranded chromosomes. The cells that undergo meiosis are diploid (having two copies of each chromosome), and the products are haploid (having one copy of each chromosome.) Thus, each chromosome is copied and divides to produce two chromosomes. Therefore, the 46 chromosomes present in a spermatocyte, which is diploid, are copied and divide to produce 92 chromosomes. Usually, these 92 chromosomes are separate by nuclear membranes, forming 4 haploid cells each containing 23 chromosomes each.

4. How many turns of the Krebs cycle are needed to completely break down one glucose molecule?

A) one
*B) two
C) three
D) four
E) six

Note: Answer key as written incorrectly says E (six) is the correct answer. Explanation: One molecule of glucose is broken down first during glycolysis into two molecules of pyruvate, each of which has 3 carbons. One carbon atom is lost in the form of CO_2 when pyruvate is converted into Acetyl-CoA, which contains 2 carbon atoms. The 2 carbon atoms contained in Acetyl-CoA are lost in the form of CO_2 in one turn of the Krebs cycle. Thus, 2 turns of the Krebs cycle are needed in order to completely break down the 2 pyruvate molecules formed from the breakdown of 1 glucose molecule.

5. The puffs that appear on giant chromosomes are accumulations of

A) DNA.
B) repressor molecules.
*C) mRNA.
D) tRNA.
E) RNA.

Explanation: Giant chromosomes occur in certain cells of some insects, such as the fruit fly (*Drosophila melanogaster*). The chromosomes in these cells become very large because their DNA is copied multiple times, but the copies do not separate. Puffs occur along these chromosomes when DNA is being transcribed into RNA (making mRNA).

6. Herpes viruses that produce latent infections include all but which of the following?

*A) hepatitis
B) infectious mononucleosis
C) genital herpes
D) chicken pox
E) cancer

Explanation: Hepatitis viruses are hepatoviruses, in the family Picornaviridae. Infectious mononucleosis is caused by the Epstein-Barr virus, which is a herpesvirus 4. Genital herpes is caused by herpesvirus 2 (but sometimes also by herpesvirus 1). Chicken pox is caused by herpesvirus 3 (varicella-zoster virus). Certain cancers, including Kaposi's sarcoma and Burkitt lymphoma, have been associated with certain herpesviruses (types 8 and 4, respectively). The family of viruses that includes the herpesviruses is called the Herpesviridae.

7. Which of the following is NOT characteristic of diatoms?
A) overlapping shells
B) silica composition
C) perforations in the shell
D) meiosis
*E) flagella

Explanation: Diatoms are unicellular eukaryotic organisms belonging to the family Bacillariophyta. The single cell of a diatom is surrounded by a 2-part, glasslike shell containing silica that fits around it like a Petri dish (one half of the shell is larger than the other). Holes in the shells of diatoms give them unique patterns that are characteristic of certain species. When a diatom undergoes meiosis, its shell falls off. A new shell forms around a fertilized egg of a new diatom. Diatoms lack flagella. They float on the surface of oceans, and they can also glide slowly due to interactions between different proteins in their cytoplasm.

8. Bryophytes differ from all other plants in that they
A) have swimming sperm.
*B) have independent gametophytes and dependent sporophytes.
C) were the first photosynthetic organisms to live on land.
D) exhibit alternation of generations.
E) have gametangia that produce sperm and eggs.

Explanation: Bryophytes have swimming sperm, but so do other seedless vascular plants. Bryophytes have independent gametophytes and dependent sporophytes, a combination which is not seen in other plants. The first photosynthetic organisms to live on land were algae, which are not true plants. Bryophytes exhibit alternation of generations, but so do all other plants. Bryophytes have gametangia that produce sperm and eggs, but so do all other plants.

9. Which of the following is NOT true?
A) The evolution of the coelom enabled animals to grow large.
B) Segmentation allows increasing specialization of body parts.
C) The evolution of an elongated gut allowed specialization of regions to carry out different digestive functions.
*D) Radial symmetry is associated with the greatest diversity and evolutionary success in animals.
E) Cephalization allows concentration of sensory organs in that area of the body.

Explanation: Answer options A, B, C, and E are correct. The coelom, segmentation, one-way gut with specialized regions, and cephalization are all adaptations that have appeared during the evolution of animals, and all of these characteristics are seen in the most recently evolved animals (the vertebrates). Radial symmetry is an ancient trait, seen in jelly fish and starfish for example, and is not associated with the highest level of diversity or evolutionary success in animals.

10. Which of the following elements has a role in electron transport and chlorophyll synthesis?

*A) iron
B) manganese
C) phosphorus
D) zinc
E) boron

Explanation: Iron is a component of electron carriers in aerobic respiration, and it is involved in the synthesis of chlorophyll. Zinc is active in the formation of chlorophyll, but it is not involved in electron transport. Boron is a cofactor in chlorophyll synthesis, but it is not involved in electron transport. Neither manganese nor phosphorus are involved in either electron transport or chlorophyll synthesis.

11. Which color of light is most effective in producing phototropism?

A) red
*B) blue
C) yellow
D) violet
E) green

Explanation: The tropisms are plant growth responses to certain stimuli in the environment. Phototropism is a plant growth response to the direction of light - that is, plants grow in the direction of a light source. This growth response is moderated by the plant hormones called auxins. The photoreceptors that trigger phototropism are located in the tips of plant shoots and are most sensitive to light in the blue range of the electromagnetic spectrum.

12. The characteristics of an apple are

A) a blend of the characteristics of the parent plants that produced its seeds.
*B) determined by the genes of the plant it was produced on.
C) determined by the genes of the pollinating plant.
D) determined by the environmental conditions when the fruit was growing.
E) 50% due to its genotype and 50% due to environment.

Explanation: An apple is a fruit, which is a ripened ovary. An ovary is tissue belonging to the female parent of the embryo that is contained in a seed within the ovary. Therefore, the genetic characteristics of the apple fruit are those of the female parent. (A seed within an ovary, of course, received half of its genes from its egg-producing parent and the other half from its sperm-producing parent.)

13. Which of the following is NOT a function of the liver?
A) formation of urea
B) formation of bile
C) detoxification of poisons
*D) secretion of bicarbonate ions
E) lipid metabolism

Explanation: The liver is a complex organ that carries out many functions. These functions include the production of urea (from its toxic cousin ammonia) and bile, the breakdown of many poisons that enter the body, and digestion and absorption of fats. The liver is also the site of the use of fatty acids for energy production. The liver does not secrete bicarbonate ions.

14. Normal bacterial inhabitants of the human body
A) are naturally resistant to antibiotics.
*B) are able to outcompete some invading pathogens and thus are one of the body's defense mechanisms.
C) can be transformed into pathogenic forms if a person's resistance to disease is low.
D) are unable to survive the human body's defense mechanisms.
E) neither harm nor help the body.

Explanation: The normal bacterial inhabitants ("flora") of the human body are not generally naturally resistant to antibiotics, they cannot be transformed into pathogenic forms if a person's resistance to disease is low, they may be able to survive the body's defense mechanisms but these are not triggered by such organisms, and they do generally help the body. One of the significant features of the normal bacterial flora is that these organisms are abundant and generally outcompete pathogenic forms of bacteria that enter the body. Thus, they function in the body's defenses against infectious disease.

15. The membrane-bound system that maintains the resting membrane potential is the ___ pump.
A) sodium-phosphorus
*B) sodium-potassium
C) sodium-chloride
D) phosphorus-calcium
E) phosphorus-chlorine

Explanation: The sodium-potassium pump actively transports sodium ions out of cells and actively transports potassium ions into cells, both against concentration gradients of the respective ions. The difference in electrical potential across a nerve cell membrane (the inside of the cell is negatively charged relative to the outside of the cell) is maintained by sodium-potassium pumps.

16. Antidiuretic hormone and oxytocin are products of
A) endocrine glands.
B) blood capillaries.
*C) neurosecretory cells.
D) the anterior pituitary.
E) kidney and uterine wall cells, respectively.

Explanation: Antidiuretic hormone (ADH) and oxytocin are unusual hormones in that they are produced by neurosecretory cells of the hypothalamus, which is part of the brain. The neurosecretory cells that produce these hormones extend from the hypothalamus down into the posterior pituitary, where the hormones are secreted and stored. ADH and oxytocin are released into the blood from the posterior pituitary when it receives the appropriate hormonal signals.

17. Which of the following would tend to promote water retention by the kidney?
A) many nephridia
B) a short distal tubule
C) a high filtration rate
D) a long proximal tubule
*E) a long loop of Henle

Explanation: The function of the kidney is to remove fluids containing waste products and other small materials from the blood and eliminate wastes and harmful materials from the body. The substances moving from the blood into the tubules of the kidney are filtered only for size, with proteins and cells generally not moving into the tubules. Materials that are useful to the body, such as glucose and water, are moved from the tubules back into the blood, so the body can retain them. Glucose is actively transported from the tubules into the blood. Water, however, cannot be actively transported. It moves along concentration gradients set up by high salt levels in the center of the kidney. A region of each kidney tubule called the loop of Henle extends into the very salty center of the kidney, and water in that part of the tubule moves into surrounding blood capillaries. The longer the loop of Henle, the more water is removed and returned to the blood rather than excreted in urine.

18. The decline in the frequency of the sickle-cell anemia allele in the American population is the result of
A) a lower mutation rate in the United States than in Africa.
B) the advantage of both homozygous forms over the heterozygous form.
C) the development of appropriate medical treatment in the United States.
*D) a decline in the occurrence of malaria in the United States.
E) nonrandom mating.

Explanation: Sickle cell anemia is a serious disease that is strongly selected against, as many people who have it do not survive to reproductive age. It is a recessively inherited disease. The frequency of the allele for sickle cell anemia is high in some areas of the world, and it turns out that these areas are places where the parasitic blood disease malaria is endemic. In fact, it has been found

that people who are heterozygous for the sickle cell allele (have one normal allele and one sickle cell allele) are less susceptible to malaria than are people who have two normal alleles. Malaria is a very serious and often fatal disease. This phenomenon is known as "heterozygote advantage," and it maintains an otherwise harmful gene in a population when malaria is present. In places where malaria is not present, such as the United States today, there is no heterozygote advantage, so selection tends to eliminate the sickle cell gene from the population.

19. Net primary productivity is the
A) rate of photosynthesis.
B) rate of energy flow.
C) amount of energy stored in an ecosystem.
D) amount of energy utilized.
*E) amount of energy stored in plant tissue in excess of that used in respiration by autotrophs.

Explanation: Plants and other autotrophs (the "algae," mainly) are primary producers - they capture energy in the form of sunlight and convert it into stored chemical energy (sugars). The net primary productivity in an ecosystem is the amount of energy captured by and stored in plants and other autotrophs, minus the amount these organisms use for their own metabolic activities that are fueled by aerobic respiration (which releases stored energy).

20. Chemosynthetic organisms are
A) primary consumers.
B) secondary consumers.
C) tertiary consumers.
*D) primary producers.
E) secondary producers.

Certain prokaryotes are chemosynthetic, as they can convert a formed of stored chemical energy (such as H_2S or NH_3) into another form of stored chemical energy that other organisms can use. These organisms are primary producers.