DENTAL ADMISSION TESTING PROGRAM

2009 Sample Test

Dental Admission Testing Program
211 East Chicago Avenue, Suite 600
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DENTAL ADMISSION TEST PREPARATION MATERIALS

How does one prepare for the DAT? There are no shortcuts to the process of learning, and these test preparation materials are not designed to provide the applicant with an opportunity to bypass the extensive process of absorbing basic information through class participation and months of study. These test preparation materials contain samples of the four examinations used in the Dental Admission Testing Program. These are available to DAT applicants as a means of discovering possible areas of weakness in their comprehension of subjects covered by the test. They will also enable the candidates to become familiar with the types of material included in the test as well as with the general coverage and format of the various parts of the test battery.

The entire examination takes 4 hours and 30 minutes (including a 15-minute break). The time limit is indicated on the computer screen. The **Survey of the Natural Sciences** and the **Perceptual Ability Test** are administered first. The **Reading Comprehension Test** and the **Quantitative Reasoning Test** are administered after an optional 15-minute rest break.

The **Survey of the Natural Sciences** is a test of achievement. The content is limited to those areas covered by an entire first-year course in biology, general chemistry, and organic chemistry. The examination is comprised of 100 items: 40 biology items, 30 general chemistry items, and 30 organic chemistry items. The candidate is given 90 minutes to complete all 100 items. It is important, therefore, that candidates pace themselves, since separate subscores will be given for each of the three sections.

The **Perceptual Ability Test** includes various types of nonverbal visual acuity items. One section covers two-dimensional perception, while the other sections cover three-dimensional perception. It is important that the candidate study the instructions at the beginning of each section. The examination consists of 90 items and has a 60-minute time limit. Candidates must pace themselves so that they complete all sections of the examination. Examinees are not permitted to use measuring devices (i.e., pencils and fingers) while taking the **Perceptual Ability Test**.

The **Reading Comprehension Test** contains passages typical of the material that might be read in dental school. Although these materials contain only one passage, the actual Reading Comprehension Test contains three passages, each with 16 to 17 items, for a total of 50 items. The time limit of the examination is 60 minutes. Candidates are encouraged to read each passage before attempting to answer the corresponding questions.

The **Quantitative Reasoning Test** measures the candidate's ability to reason with numbers, to manipulate numerical relationships, and deal intelligently with quantitative materials. Candidates are given 45 minutes to complete the 40-item examination. Calculators are not permitted.

The answers for each practice test and a raw score/standard score conversion table are all located at the end of these test preparation materials. By locating the number of correct answers you selected on each test, you will be able to determine your standard score.

There is no penalty for guessing. Your total score is based on the number of correct responses. Therefore, you should attempt to answer all test items.

Improper access to test content by test takers will result in test results being voided.

Each test item is a question or incomplete statement followed by suggested answers or completions. Read the item, decide which choice is best, and circle the corresponding option.

PERIODIC TABLE OF THE ELEMENTS

IA 1	IIA 2	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	VIIIB 8	VIIIB 9	VIIIB 10	IB 11	IIB 12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	Noble gases VIIIA 18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											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											13 A1 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 58.69	29 Cu 63.55	30 Zn 65.37	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 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.40	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.91	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.20	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 T1 204.37	82 Pb 207.19	83 Bi 209.00	84 Po 209.00	85 At ~210	86 Rn (~222)
87 Fr (223)	88 Ra 226.02	89 Ac (227)	104 Ung (261)	105 Unp (262)	106 Sg (263)	107 Uns (262)	108 Uno (265)	109 Une (266)									

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.40	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 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (256)	102 No (254)	103 Lr (257)

Survey of the Natural Sciences   Time limit: 90 minutes

This examination is comprised of 100 items:
Biology (1-40), General Chemistry (41-70), and Organic Chemistry (71-100)

1. Which of the following processes do Fungi carry out that is important in the earth's food webs?

   A. Predation
   B. Autotrophism
   C. Photosynthesis
   D. Chemosynthesis
   E. Decomposition

2. In a mammal, which of the following is the common passage through which air and food are transported?

   A. Trachea
   B. Pharynx
   C. Larynx
   D. Esophagus
   E. Epiglottis

3. If the biological success of a phylum can be measured by its total number of individuals and its greatest number of different species, then which of the following animals are the most successful?

   A. Coelenterates (cnidarians)
   B. Arthropods
   C. Chordates
   D. Mollusks
   E. Annelids

4. Which of the following best describes microfilaments in the cell?

   A. They function in many types of cell movement.
   B. They become chromosomes when the cell divides.
   C. They generate membrane potentials.
   D. They serve as information storage molecules.
   E. They form basal bodies and centrioles.

5. Which of the following is a pollen-producing structure associated with flowering plants?

   A. Pistil
   B. Stigma
   C. Anther
   D. Calyx
   E. Meristem

6. Locomotion can be associated with each of the following EXCEPT one. Which one is the EXCEPTION?

   A. Cilia
   B. Flagella
   C. Pseudopodia
   D. Striated muscle
   E. Contractile vacuoles

7. Which of the following determines the primary structure of a protein?

   A. Environmental factors
   B. Sequence of nucleotides in messenger RNA
   C. Tertiary structures
   D. Specific ribosomes
   E. Hydrogen bonds

8. A woman with type AB blood has children with a man with type O blood. Which of the following are the possible blood types their children could have?

   A. AB; A; B; and O
   B. AB and O
   C. A and B
   D. A; B; and O
   E. O

9. Suppose an animal has a gene for coat color that is sex-linked (X-linkage) and incompletely dominant, and in which females with an AA genotype have a black coat color; aa individuals have a yellow color; and those with Aa have a marble coloration. If a marble female was crossed with a yellow male, then each of the following might result under normal Mendelian conditions EXCEPT one. Which one is the EXCEPTION?

    A.   Black male
    B.   Black female
    C.   Yellow male
    D.   Yellow female
    E.   Marble female

10. Where does cleavage of the egg begin in humans?

    A.   Ovary
    B.   Vagina
    C.   Oviduct/Fallopian tube
    D.   Body of the uterus
    E.   Cervix of the uterus

11. Naked mole rats, which live in underground tunnels in parts of Africa, live in colonies consisting of a dominant female, several breeding males, and a number of nonbreeding males and females with different functions, such as foraging and tunnel maintenance. These mammals most closely approximate the behavioral system of a

    A.   pride of lions.
    B.   herd of elephants.
    C.   flock of birds.
    D.   colony of bees.
    E.   school of fish.

12. The following diagram represents a cell in which of the following stages of meiosis?

    A.   Metaphase I
    B.   Anaphase I
    C.   Telophase I
    D.   Anaphase II
    E.   Prophase II

13. Which of the following proteins is involved in cell motility?

    A.   Dynein
    B.   Lipase
    C.   Trypsin
    D.   Peroxidase
    E.   B-glucosidase

14. Which of the following is the major intracellular buffer?

    A.   TRIS
    B.   Acetate
    C.   Phosphate
    D.   Bicarbonate
    E.   Calcium carbonate

15. If nondisjunction of chromosome 21 occurs during meiosis I of spermatogenesis, which of the following statements would be true about the resulting four sperm?

- A. Two sperm would be normal.
- B. Two sperm would lack chromosome 21.
- C. Three sperm would lack chromosome 21.
- D. All four sperm would lack chromosome 21.
- E. One sperm would have an extra copy of chromosome 21.

16. Which of the following proteins would normally be involved in receptor-mediated endocytosis?

- A. Desmin
- B. Tubulin
- C. Clathrin
- D. Spectrin
- E. Hyaluronidase

17. Which of the following cells creates antibody-producing plasma cells?

- A. B cells
- B. T-helper cells
- C. Cytotoxic T cells
- D. Macrophages
- E. Natural killer cells

18. The fusion of male and female pronuclei characterizes the final step of

- A. ovulation.
- B. sperm meiosis.
- C. gametogenesis.
- D. egg maturation.
- E. fertilization.

19. Although entropy continually increases within the universe as a whole, developing organisms gradually become more organized. Which of the following are these organisms capable of doing to aid this process?

- A. Lowering activation energy with enzymes
- B. Violating the Second Law of Thermodynamics
- C. Using external sources of energy
- D. Concentrating their own molecules so that energy flow is reversed
- E. Creating energy

20. At what stage in mitosis are all the chromosomes of a cell positioned at approximately equal distances between two spindle poles?

- A. Prophase
- B. Anaphase
- C. Metaphase
- D. Telophase
- E. Prometaphase

21. Which type of cell junction allows ion flow between adjacent cells?

- A. Desmosome
- B. Gap junction
- C. Microvilli
- D. Tight junction
- E. Septate junction

22. Which of the following equals cardiac output?

- A. Stroke volume
- B. Stroke volume divided by heart rate
- C. Stroke volume multiplied by heart rate
- D. Heart rate multiplied by blood pressure
- E. Stroke volume multiplied by blood pressure

23. Which of the following would light pass through first?

- A. Pupil
- B. Cornea
- C. Retina
- D. Vitreous body
- E. Crystalline lens

24. Which of the following areas is best described as a major biotic region with short growing seasons, large variation in annual temperatures, and permafrost for a substantial part of the year?

- A. Coniferous forest
- B. Antarctic ice island
- C. Arctic tundra
- D. Grassland
- E. Desert biome

25. The mammalian placenta is actually derived from two sources; it forms partly from the mother's uterine lining and partly from the embryonic

    A. somite.
    B. chorion.
    C. allantois.
    D. neural tube.
    E. inner cell mass.

26. In terms of its function in a bird embryo, which of the following extra-embryonic membranes acts as an early urinary bladder?

    A. Yolk sac
    B. Chorion
    C. Amnion
    D. Allantois
    E. Placenta

27. Which of the following best describes a zygote?

    A. Early cleavage stage before blastula
    B. Embryo younger than eight weeks
    C. Bone in the embryonic skull
    D. Immature egg or sperm cell
    E. Fertilized egg cell

28. Which of the following describes the acrosome reaction?

    A. Response of a sperm to contact with an egg
    B. Activation of a sperm flagellum
    C. The completion of meiosis following ovulation
    D. Interaction between a sperm nucleus and an egg nucleus
    E. The conversion of the sperm head to the male pronucleus

29. A hormone which lowers glucose concentration in the blood by stimulating its uptake in the body's cells is produced in the

    A. liver.
    B. adrenal cortex.
    C. anterior pituitary.
    D. posterior pituitary.
    E. pancreatic islets.

30. Which of the following has both biotic and abiotic components?

    A. Ecosystems
    B. Food webs
    C. Food pyramids
    D. Populations
    E. Communities

31. Growth (increased length) of long bones originate in which of the following regions?

    A. Diaphysis
    B. Metaphysis
    C. Epiphysis
    D. Periosteum
    E. Medullary cavity

32. In what order are the following structures thought to have appeared on the primitive earth?

    1. Proteinoids (precursors of amino acids)
    2. Protocells
    3. Inorganic molecules such as H_2O and CO_2
    4. Small organic molecules such as methane

    A. 1, 2, 3, 4
    B. 1, 3, 2, 4
    C. 2, 3, 4, 1
    D. 3, 4, 2, 1
    E. 3, 4, 1, 2

33. Oxygen began to build up in the primitive atmosphere as a result of which of the following types of structures or organisms?

    A. Enzymes
    B. Autotrophs
    C. Protocells
    D. Heterotrophs
    E. Nucleic acids

34. In skeletal muscle, which of the following represent the two major contractile proteins for force development?

   A. Troponin and tropomyosin
   B. Collagen and keratin
   C. Tubulin and alpha-actinin
   D. Myosin and actin
   E. Actin and tubulin

35. Which of the following characteristics in a newborn would be the best evidence that nondisjunction occurred during meiosis in one of the baby's parents?

   A. The newborn has a heart defect.
   B. The newborn is diagnosed mentally retarded.
   C. Testing of DNA shows a defective gene.
   D. Karyotype shows a malformed chromosome.
   E. Karyotype shows an abnormal number of chromosomes.

36. Which of the following statements best describes the Krebs Cycle?

   A. Glucose is broken down to two molecules of pyruvic acid.
   B. Carbon monoxide is combined with nitrogen waste, generating urea.
   C. Two molecules of acetyl CoA are broken down to carbon dioxide.
   D. Electrons are passed down a series of receptors, generating ATP by chemiosmosis.
   E. Carbon dioxide is added to ribulose biphosphate, generating phosphoglycer-aldehyde.

37. The phrase "zero population growth" describes which of the following conditions within a population?

   A. Population has become extinct.
   B. Population is no longer producing its young.
   C. Birth rate and death rate in the population are equal.
   D. Birth rate in the population is less than the death rate.
   E. Birth rate in the population is greater than the death rate.

38. A form of colorblindness in humans is a sex-linked, recessive trait. If a normal male and a colorblind female have children, which of the following is the probability that their daughter would be born colorblind?

   A. 0.00
   B. 0.25
   C. 0.50
   D. 0.75
   E. 1.00

39. An experiment was conducted to determine the effect of a new antiviral agent on HIV-infected cells in laboratory cultured cells. The following data were obtained

Time (week)	Percent Cells alive
0	100
1	72.6
2	55.9
3	38.8
4	25.1
5	18.6
6	14.3
7	14.1
8	10.2

According to the data, during which one-week period did more cells die than any other week?

   A. Week 1
   B. Week 3
   C. Week 4
   D. Week 5
   E. Week 7

40. Where are linked genes found?

    A.   On the same chromosome
    B.   On different chromosomes
    C.   On sister chromatids
    D.   On non-sister chromatids

41. Exactly 492 g of kerosene are required to fill a certain container. If the density of the kerosene was $0.820 \text{ g} \cdot \text{mL}^{-1}$, and at the same temperature the density of mercury was $13.5 \text{ g} \cdot \text{ml}^{-1}$, then what mass of mercury, in grams, would be necessary to fill the container?

    A. $\dfrac{(492)(0.820)}{13.5}$

    B. $\dfrac{(492)(13.5)}{0.820}$

    C. $\dfrac{0.820}{(492)(13.5)}$

    D. $(492)(13.5)(0.82)$

    E. $\dfrac{13.5}{(492)(0.820)}$

42. Which of the following is the $[OH^-]$, in M, in a 0.010 M $Ca(OH)_2$ solution?

    A. 1×10^{-7}
    B.   0.0050
    C.   0.010
    D.   0.020
    E.   0.040

43. Which of the following sets of coefficients correctly balances the reaction shown below?

$$\_C_3H_8 + \_O_2 \rightarrow \_CO_2 + \_H_2O$$

    A.   1, 7, 3, 4
    B.   1, 7, 3, 8
    C.   1, 5, 3, 4
    D.   2, 12, 6, 8
    E.   2, 7, 3, 8

44. If 50.0 mL of H_2SO_4 required 50.0 mL of 1.0 M NaOH for a complete neutralization reaction, according to the equation shown below, what would be the molarity of an acid?

$$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$$

    A.   0.33
    B.   0.5
    C.   1.0
    D.   2.0
    E.   4.0

45. Which of the following best represents a simple conjugate acid/base pair?

    A. H_2O and H^-
    B. H_2O and O^{2-}
    C. HCO_3^- and CO_3^{2-}
    D. H_3PO_4 and PO_4^{3-}
    E. H_3O^+ and HCO_3^-

46. The reaction shown below is at equilibrium. Which of the following will make it shift to the left?

$$2\ NH_3(g) \rightleftharpoons N_2(g) + 3\ H_2(g)$$

    A.   An increase in pressure
    B.   A decrease in pressure
    C.   A decrease in concentration of N_2
    D.   A decrease in concentration of H_2
    E.   An increase in concentration of NH_3

47. Which of the following describes the molecular geometry of H_2Se?

    A.   Linear
    B.   Bent
    C.   Trigonal
    D.   Tetrahedral
    E.   Triangular pyramid

48. Which of the following represents the electron configuration for the transition metal Ti (atomic number = 22)?

A. $1s^2 2s^2 2p^6 3s^2 3p^{10}$
B. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^2$
C. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^3$
D. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4$
E. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

49. If a first-order reaction A $\rightarrow$ B has a half-life of 10.2 minutes and starts with a concentration of A = 1 mol•L^{-1}, then what concentration of A will be present after 51.0 minutes of reaction?

A. 31/32
B. 15/16
C. 1/5
D. 1/16
E. 1/32

50. A 125 g portion of ethylene glycol (62 g•mol^{-1}) is dissolved in 1000 g of water. The freezing point of water is 0.00°C. Its molal freezing point lowering constant is 1.86°C m^{-1}. Which of the following will be the freezing point (in °C) of the resulting solution?

A. 0.5
B. 0
C. -8
D. -3.75
E. -0.232

51. The addition of 3.31 kJ of heat to a 300 g sample of mercury at 19.0°C caused the temperature to rise to 99.0°C. What is the specific heat of mercury in J•g^{-1} • °C^{-1}?

A. $\dfrac{3,310}{(300)(99)}$

B. $\dfrac{3,310}{(300)(80)}$

C. $\dfrac{3,310}{(300)(19)}$

D. $\dfrac{3.31}{(300)(118)}$

E. $\dfrac{3.31}{380}$

52. Which of the following properties of liquids increases with rising temperature?

A. Density
B. Viscosity
C. Boiling point
D. Vapor pressure
E. Surface tension

53. At some point during an analysis of the reaction shown below, $NH_3(g)$ was consumed at a rate of 1.2 mol L^{-1} s^{-1}. At what rate, in mol L^{-1} s^{-1}, was $H_2O(g)$ being formed?

$$4\,NH_3(g) + 3\,O_2(g) \rightarrow 2\,N_2(g) + 6\,H_2O(g)$$

A. 1.2
B. 1.8
C. 2.4
D. 3.0
E. 3.6

54. HCN is a weak acid. Which of the following equations is the equilibrium constant expression for this acid in aqueous solution?

A. $K_a = \dfrac{[HCN]}{[H_3O^+][CN^-]}$

B. $K_a = \dfrac{[H_3O^+][HCN]^2}{[CN^-]}$

C. $K_a = \dfrac{[H_3O^+][HCN]}{[CN^-]}$

D. $K_a = \dfrac{[H_3O^+][CN^-]}{[HCN]}$

E. $K_a = \dfrac{[HCN]^2}{[H_3O^+][CN^-]}$

55. Which of the following is produced by the electrolysis of 18 g of H_2O?

A. 1 mol of O_2
B. 2 mol of O_2
C. 1 mol of H_2
D. 2 mol of H_2
E. 1/2 mol of H_2

56. What percent of the initial radioactivity will remain after one hour has passed if the half-life of a radioactive isotope is 20 minutes?

A. 50
B. 33.3
C. 25
D. 12.5
E. 6.25

57. Which of the following properties is most characteristic of metals?

A. Produce binary hydrides that are insoluble in water
B. React readily to produce diatomic molecules
C. Oxidize non-metals in acidic solutions
D. Form cations by loss of electrons
E. Have high electron affinities

58. Which of the following bond types is most like to occur between two elements, where one has low ionization energy, and the other has high electron affinity?

A. Ionic
B. Metallic
C. Hydrogen
D. Polar covalent
E. Non-polar covalent

59. Each of the following statements is correct of ionic compounds in the solid state EXCEPT o Which one is the EXCEPTION?

A. They are hard.
B. They are brittle.
C. They break with definite faces.
D. They exist as crystalline solids.
E. They are good conductors of electricity

60. Which of the following liquids is immiscible water?

A. CH_3CO_2H
B. $C_6H_5CH_3$
C. $C_2H_4(OH)_2$
D. $(C_2H_4)_3N$
E. $CH_3CH(OH)CH_3$

61. The volume of a mole of gas is

A. 22.4 liters.
B. directly proportional to pressure and K temperature.
C. directly proportional to pressure, inver proportional to Kelvin temperature.
D. inversely proportional to pressure, dire proportional to Kelvin temperature.
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62. If a chemist needed to measure 12.52 mL of a solution, the best piece of laboratory equipme use would be

A. an Erlenmeyer flask.
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D. a buret.
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E. a weighing bottle.

63. In which of the following does nitrogen have an oxidation number of +4?

    A. HNO_3
    B. N_2O
    C. NO_2
    D. NH_4Cl
    E. $NaNO_2$

64. Which of the following pieces of glassware is NOT designed to measure solution volumes accurately?

    A.   Buret
    B.   Volumetric flask
    C.   Graduated cylinder
    D.   Beaker
    E.   Volumetric pipet

65. Consider the equilibrium reaction

$$2\ NO(g) + O_2(g) \leftrightharpoons 2\ NO_2(g);\ K = 2.0.$$

Which of the following is the correct value of K for the reaction

$$NO_2(g) \leftrightharpoons NO(g) + 1/2\ O_2(g)?$$

    A. $\left(\dfrac{1}{2.0}\right)^{1/2}$

    B. $(-2.0)^{1/2}$

    C. $\left(\dfrac{2.0}{2}\right)$

    D. $\left(\dfrac{1}{2.0}\right)^{2}$

    E. $(-2.0)^{2}$

66. Each of the following is an example of a chemical change EXCEPT one. Which one is the EXCEPTION?

    A.   Hydrogen peroxide decomposing to form molecular oxygen and water
    B.   Methanol burning in air with a colorless flame
    C.   Aluminum foil melting at 660°C
    D.   Hydrochloric acid neutralizing a solution of sodium hydroxide
    E.   Iron metal rusting

67. The heat of formation reaction for solid $CaCO_3$ is

    A. $Ca(OH)_2(aq) + 2\ H_2CO_3(aq) \rightarrow CaCO_3(s) + H_2O(l)$

    B. $CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$

    C. $Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$

    D. $Ca(s) + C(graphite) + 3/2\ O_2(g) \rightarrow CaCO_3(s)$

    E. $2\ CaCO_3(s) \rightarrow 2\ Ca(s) + 2\ C(graphite) + 2\ O_3(g)$

68. The volume of an ideal gas is zero at

    A.   -273 K.
    B.   -273°C.
    C.   0°C.
    D.   0°F.
    E.   212°F.

69. Which of the following is the largest atom?

    A.   Al
    B.   O
    C.   Mg
    D.   Be
    E.   Si

70. Which of the following is the interaction responsible for the observation that pure ionic compounds have relatively high melting points?

    A.   Ion-ion attraction
    B.   Dipole-dipole attraction
    C.   London dispersion force
    D.   Ion-dipole attraction
    E.   Hydrogen bonding

71. What is the major product of the following reaction sequence?

1. Sn, HCl
2. NaNO2, HCl (HONO) 0°C
3. CuCN
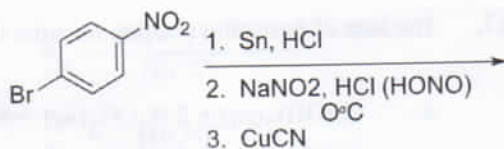
A.

B.

C.

D.

E.

72. Oxymercuration-demercuration of which of the following produces a secondary alcohol?

$$CH_3CH_2Br + NaOH \rightarrow CH_3CH_2OH + NaBr$$
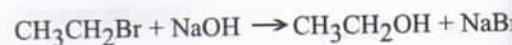
$rate = k[CH3CH2Br]\,[NaOH]$

A.

B.

C.

D.

E.

73. Which of the following is the most stable conformation of trans-1-chloro-4-methylcy-clohexane?

A.

B.

C.

D.

E.
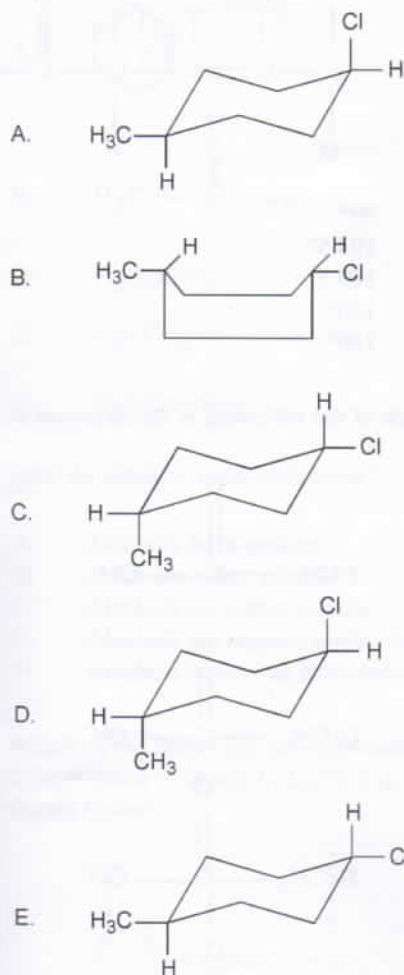
74. Which of the following compounds is the most thermodynamically stable?

B. $CH_2 = C = CHCH_2CH_2CH_3$

C. $CH_3CH_2CH = C = CHCH_3$

D. $CH_3CH = CHCH = CHCH_3$

E. $CH_2 = CHCH_2CH = CHCH_3$
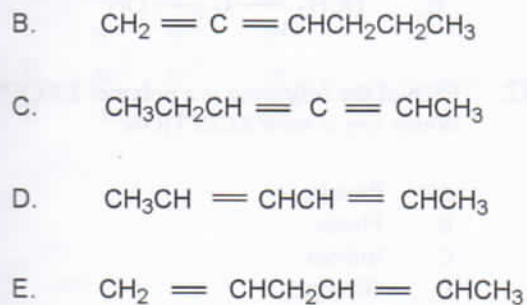
75. Which of the following are the two Brønsted-Lowry acids in the equilibrium shown below?

$$H_3C-\overset{O}{\overset{||}{C}}-OH \ + \ NaOH \ \rightleftharpoons \ H_3C-\overset{O}{\overset{||}{C}}-O^-Na^+ \ + \ H_2O$$

A. $H_3C-\overset{O}{\overset{||}{C}}-OH \ + \ NaOH$

B. $H_3C-\overset{O}{\overset{||}{C}}-O^-Na^+ \ + \ H_2O$

C. $NaOH \ + \ H_2O$

D. $H_3C-\overset{O}{\overset{||}{C}}-OH \ + \ H_2O$

E. $H_3C-\overset{O}{\overset{||}{C}}-O^-Na^+ \ + \ NaOH$
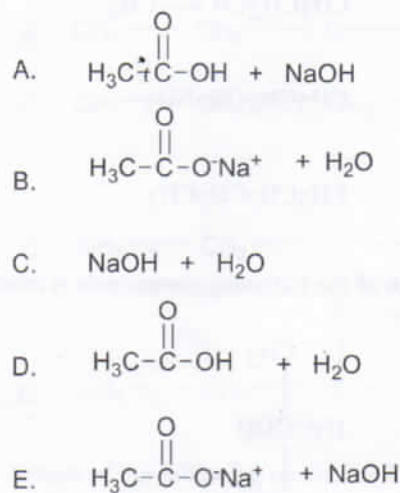
76. Glycine is a water soluble, high-melting solid that has both acidic and basic properties. Which structure best represents glycine at a pH 7.0?

A. $H_3\overset{\oplus}{N}CH_2 - \overset{O}{\overset{||}{C}} - OH$

B. $H_2NCH_2 - \overset{O}{\overset{||}{C}} - O^{\ominus}$

C. $H_2NCH_2 - \overset{O}{\overset{||}{C}} - OH$

D. $H_3\overset{\oplus}{N}CH_2 - \overset{O}{\overset{||}{C}} - O^{\ominus}$

E. $\overset{\ominus}{H}NCH_2 - \overset{O}{\overset{||}{C}} - O^{\ominus}$
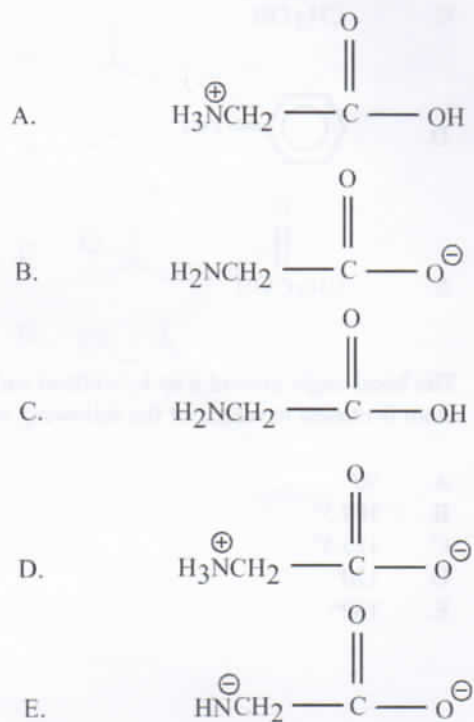
77. Which compound would be expected to show intense IR absorption at 1,710 cm-1?

A. $CH_3CH_2CH_2$ — C(=O) — OH

B. CH_3CH_2CH = CH_2

C. $CH_3CH_2CH_2NH_2$

D. $CH_3CH_2CH_2CH_3$
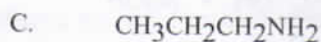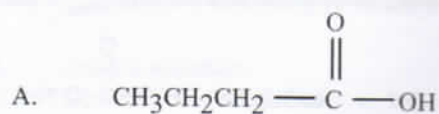
78. Which of the following compounds is most acidic?

A. H_3CCOH with CH_3 above and CH_3 below

B. CH_3CH_2OH

C. CH_3OH

D. benzene ring — OH

E. CH_3COH (with C=O)
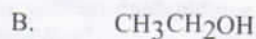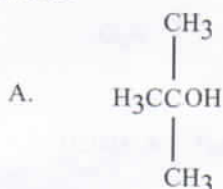
79. The bond angle around a sp hybridized carbon atom is closest to which of the following values?

A. 90°
B. 109.5°
C. 110.5°
D. 120°
E. 180°

80. The bond angle (∠1) shown below is closest to which of the following degrees?

H_3C — C(H)(H) — C = C(∠1) — C(H)(H) — C(=O) — H
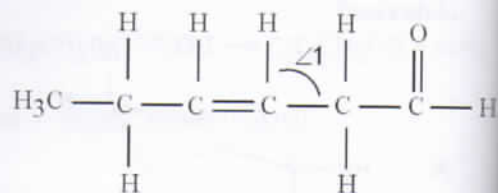
A. 90°
B. 104.5°
C. 109.5°
D. 120°
E. 180°

81. Which of the following is the strongest acid?

A. FCH_2 — C(=O) — OH

B. $ClCH_2$ — C(=O) — OH

C. $BrCH_2$ — C(=O) — OH

D. ICH_2 — C(=O) — OH

E. HCH_2 — C(=O) — OH
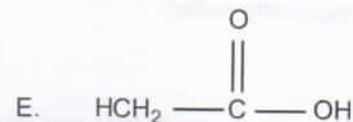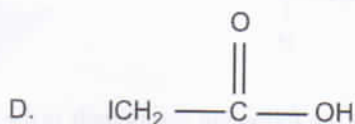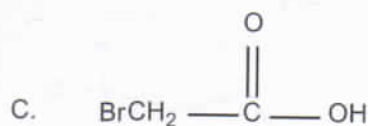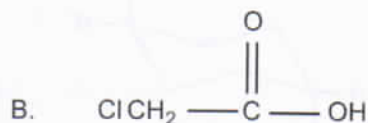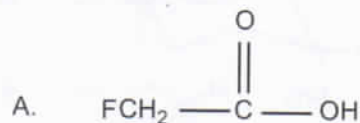
82. Each of the following is a polymer EXCEPT. Which one is the EXCEPTION?

A. Protein
B. Plastic
C. Rubber
D. Glycogen
E. Petroleum

83. Which of the following compounds shows intermolecular hydrogen bonding?

A. [benzene ring with —OCH₃ substituent]

B. $H_3C - \overset{\displaystyle O}{\overset{\displaystyle \|}{C}} - H$

C. H_3COCH_3

D. H_3CCH_2Cl

E. $H_3CCH_2NH_2$
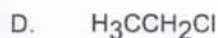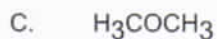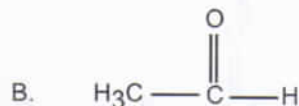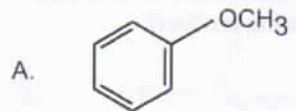
84. Why do alcohols react with acids?

A. Alcohols have protons.
B. Acids are water soluble.
C. Alcohols are water soluble.
D. Alcohols are organic molecules.
E. Alcohols behave as Brønsted-Lowry bases.

85. Which of the following best represents the hybridization of atoms 1, 2, and 3 in the structure shown below?
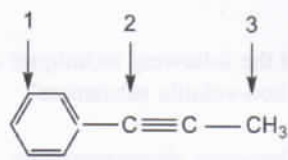
[structure: benzene ring — C≡C — CH₃ with positions labeled 1, 2, 3]

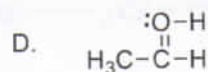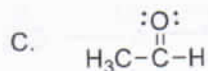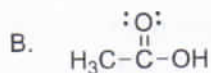|	1	2	3
A.	sp	sp^3	sp^2
B.	sp^3	sp	sp^2
C.	sp^3	sp^2	sp
D.	sp^2	sp^3	sp
E.	sp^2	sp	sp^3

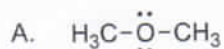**86.** The following compounds have similar molecular weights. Which would be expected to have the lowest boiling point?

A. $CH_3 - \overset{\displaystyle CH_3}{\underset{\displaystyle |}{CH}} - OH$

B. $CH_3 - CH_2 - O - CH_3$

C. $CH_3 - CH_2 - CH_2 - OH$

D. $CH_3 - CH_2 - \overset{\displaystyle CH_3}{\underset{\displaystyle |}{N}} - H$

E. $CH_3 - CH_2 - \overset{\displaystyle O}{\overset{\displaystyle \|}{C}} - NH_2$
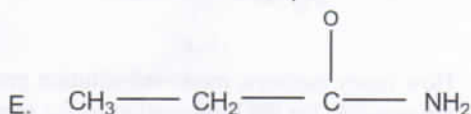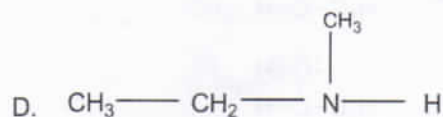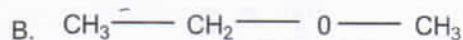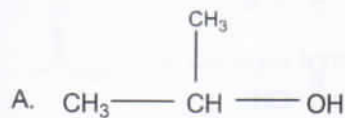
87. Which of the following represents the major product of the reaction shown below?

[alkene structure] + HCl $\longrightarrow$

A. [structure with CCl]

B. [structure with Cl]

C. [structure Cl]
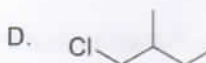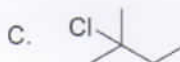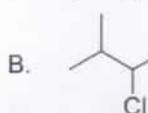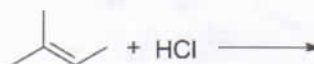
D. [structure Cl]

88. In which of the following Lewis structures does the oxygen have a formal charge of +1?

A. $H_3C-\ddot{O}-CH_3$

B.
$$H_3C-\overset{:O:}{\underset{\|}{C}}-OH$$

C.
$$H_3C-\overset{:O:}{\underset{\|}{C}}-H$$

D.
$$H_3C-\overset{:O-H}{\underset{\|}{C}}-H$$

E.
$$H_3C-\overset{:\ddot{O}-H}{\underset{\underset{:\ddot{O}-H}{|}}{\overset{|}{C}}}-H$$
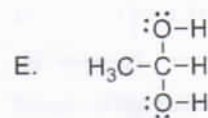
89. How many isomeric mono-substitution products are possible for the bromination of the aromatic hydrocarbon naphthalene?

$$\xrightarrow[\text{Fe}]{\text{Br}_2} \quad C_{14}H_9 + HBr$$
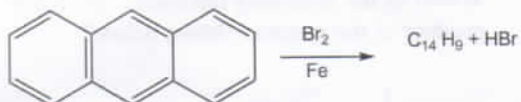
A. 1
B. 2
C. 3
D. 4
E. 5

90. What is the structure of a compound having a molecular formula C_7H_{12}, which upon ozonolys and subsequent treatment with zinc and water, yields the following product?

A.

B.

C.

D.

E.
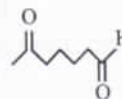
91. Which of the following techniques can be used separate non-volatile substances?

A. Thin-layer chromatography
B. Gas-liquid chromatography
C. Sublimination
D. Distillation
E. Steam distillation

92. Which of the following carbonyl compounds is hydrolyzed the slowest with $OH^{\ominus}$?

A. $CH_3 - \overset{\overset{\displaystyle O}{\|}}{C} - Cl$

B. $CH_3 - \overset{\overset{\displaystyle O}{\|}}{C} - OCH_3$

C. $CH_3 - \overset{\overset{\displaystyle O}{\|}}{C} - NH_2$

D. $CH_3 - \overset{\overset{\displaystyle O}{\|}}{C} - Br$

E. $CH_3 - \overset{\overset{\displaystyle O}{\|}}{C} - O - \overset{\overset{\displaystyle O}{\|}}{C} - CH_3$

93. Which of the following is the intermediate formed upon the addition of methylmagnesium bromide to 2-butanone?

$$\text{(2-butanone)} + CH_3MgBr \longrightarrow$$

A. $H_3C - \overset{\overset{\displaystyle \overset{\oplus}{O} \ \overset{\ominus}{Br}}{|}}{\underset{\displaystyle CH_3}{|}} - CH_2CH_3$

B. $H_3C - \overset{\overset{\displaystyle \overset{\ominus}{O} \ \overset{\oplus}{MgBr}}{|}}{\underset{\displaystyle CH_3}{|}} - CH_2CH_3$

C. $H_3C - \overset{\overset{\displaystyle \overset{\ominus}{O} \ \overset{\oplus}{Mg}}{|}}{\underset{\displaystyle CH_3}{|}} - CH_2CH_3$

D. $H_3C - \overset{\overset{\displaystyle \overset{\oplus}{O} \ \overset{\ominus}{MgBr}}{|}}{\underset{\displaystyle CH_3}{|}} - CH_2CH_3$

E. $H_3C - \overset{\overset{\displaystyle \overset{\ominus}{O} \ \overset{\oplus}{Br}}{|}}{\underset{\displaystyle CH_3}{|}} - CH_2CH_3$
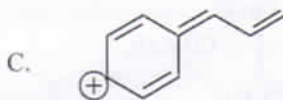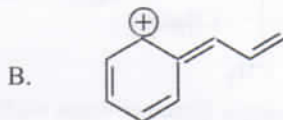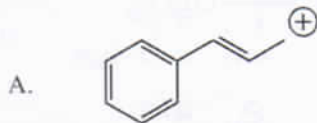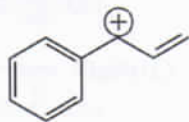
94. Which of the following is the hybridization of the nitrogen atom of acetonitrile?

$$H3C{-}C{\frown}N:$$

acetonitrile

A. s
B. p
C. sp
D. sp^2
E. $sp3$

95. Each of the following structures is a resonance form of the ion shown below EXCEPT one. Which one is the EXCEPTION?

A.

B.

C.

D.

E.
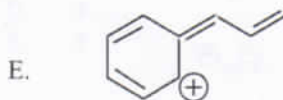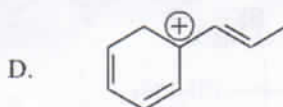
96. A mixture of a carboxylic acid and an amine that have been dissolved in an organic solvent can best be separated by which of the following operations?

A. Extracting the amine into aqueous NaOH
B. Extracting the amine into water
C. Extracting the carboxylic acid into aqueous NaOH
D. Extracting the carboxylic acid into water
E. Extracting the carboxylic acid into aqueous HCl

97. What is the relationship between the two molecules shown?
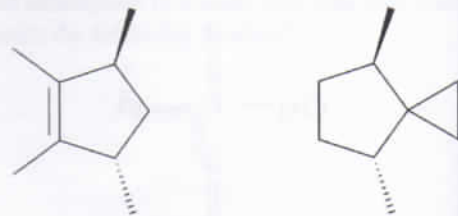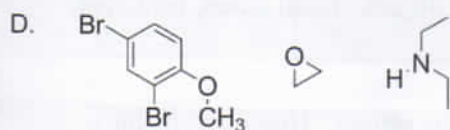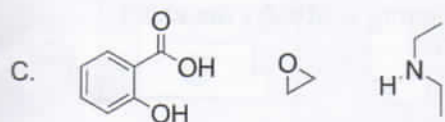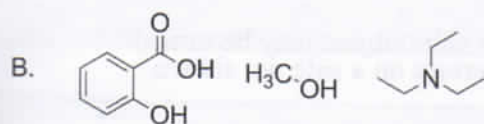

A. Constitutional isomers
B. Enantiomers
C. Geometric isomers
D. Identical

98. What is the relationship between the two molecules shown?
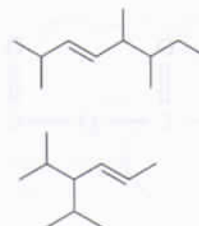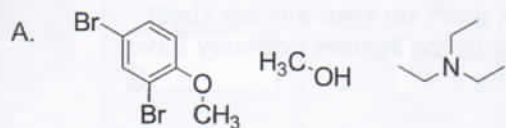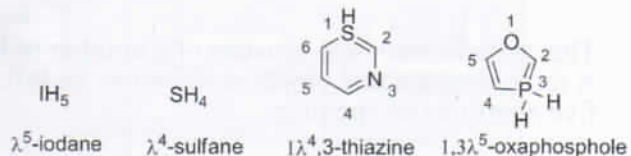

A. Constitutional isomers
B. Geometric isomers
C. Identical
D. None of the above

99. Which of the following sets of starting materials is suited best for the multistep synthesis of the antispasmodic spasmolytol?

Br-[benzene ring]-CH₂-O-CH₂CH₂-N(CH₂CH₃)₂

Br CH₃

spasmolytol

A. Br-[benzene ring]-O, Br CH₃   H₃C-OH   N

B. [benzene ring with C(=O)OH]-OH   H₃C-OH   N

C. [benzene ring with C(=O)OH]-OH   O-cyclopropane   H-N

D. Br-[benzene ring]-O, Br CH₃   O-cyclopropane   H-N

100. Which of the following IUPAC rules for naming of compounds with a neutral skeletal atom that has a nonstandard bonding number is consistent with the pattern in the given examples?

IH_5 SH_4 [thiazine ring]   [oxaphosphole ring]

λ^5-iodane λ^4-sulfane $1\lambda^4,3$-thiazine $1,3\lambda^5$-oxaphosphole

A. A nonstandard bonding number of a neutral skeletal atom in a parent hydride is indicated by the symbol λ^n, where n is the total number of atoms bonded to the skeletal atom.

B. A nonstandard bonding number of a neutral skeletal atom in a parent hydride is indicated by the symbol λ^n, where n is the number of substituents.

C. A nonstandard bonding number of a neutral skeletal atom in a parent hydride is indicated by the symbol λ^n, where n is the position number.

D. A nonstandard bonding number of a neutral skeletal atom in a parent hydride is indicated by the symbol λ^n, where n is the bonding number.

Perceptual Ability Test Time limit: 60 minutes

PART 1

For questions 1 through 15

This visualization test consists of a number of items similar to the sample below. A three-dimensional object is shown at the left. This is followed by outlines of five apertures or openings.

In each item the task is exactly the same. First, you are to imagine how the object looks from all directions (rather than from a single direction as shown). Then pick, from the five apertures outlined, the opening through which the object could pass directly if the proper side were inserted first. Finally, mark on your answer sheet (after the number of the item) the letter corresponding to the answer you may have chosen.
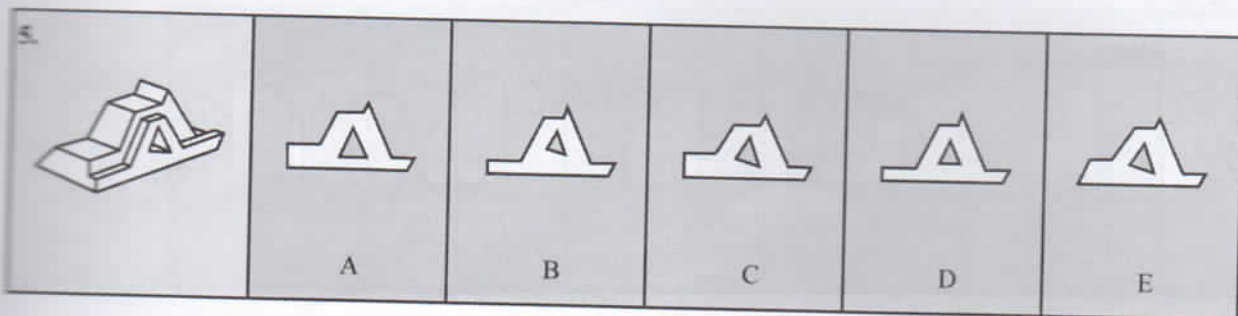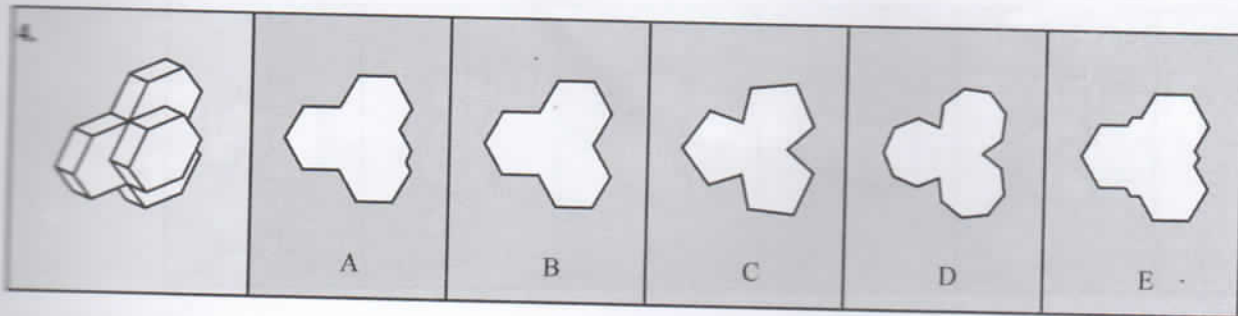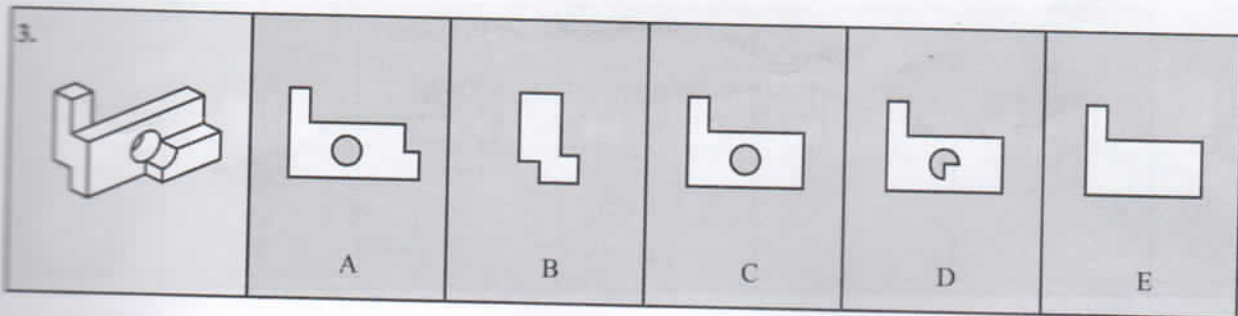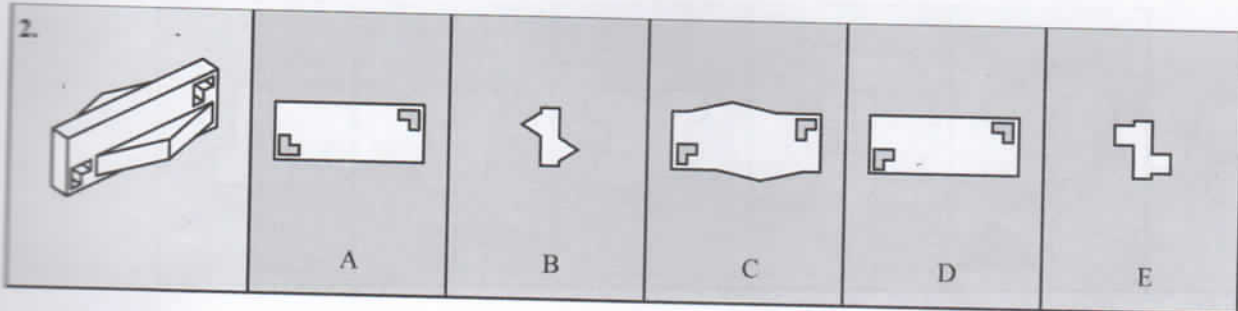
Here are the rules:

1. Prior to passing through the aperture, the irregular solid object may be turned in any direction. It may be started through the aperture on a side not shown.

2. Once the object is started through the aperture, it may not be turned or twisted. It must pass completely through the opening. The opening is always the exact shape of the appropriate external outline of the object.

3. Both objects and apertures are drawn to the same scale. Thus it is possible for an opening to be the correct shape but too small for the object. In all cases, however, differences are large enough to judge by eye.

4. There are no irregularities in any hidden portion of the object. However, if the figure has symmetric indentations, the hidden portion is symmetric with the part shown.

5. For each object there is only one correct aperture.

Example: (Do not mark the answer to this example on the answer sheet.)
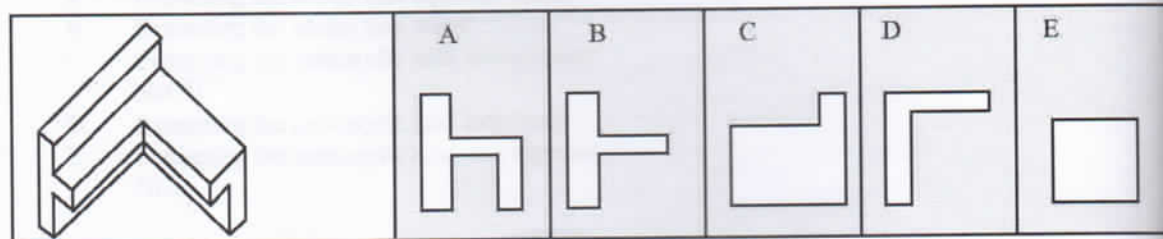
The correct answer is C since the object would pass through this aperture if the side at the left were introduced first.

Proceed to Questions.

1.   A   B   C   D   E

2.   A   B   C   D   E

3.   A   B   C   D   E
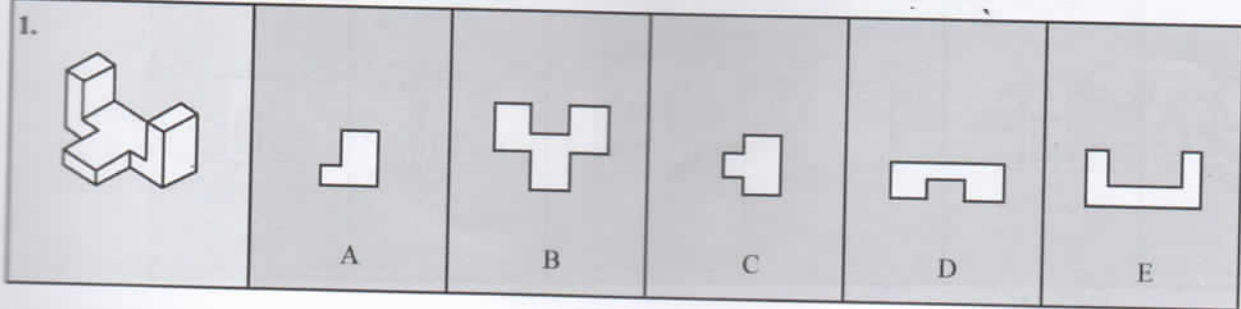
4.   A   B   C   D   E

5.   A   B   C   D   E

6.		A	B	C	D	E

7.		A	B	C	D	E

8.		A	B	C	D	E

9.		A	B	C	D	E

10.		A	B	C	D	E

11.

A B C D E

12.

A B C D E

13.

A B C D E

14.

A B C D E

15.

A B C D E
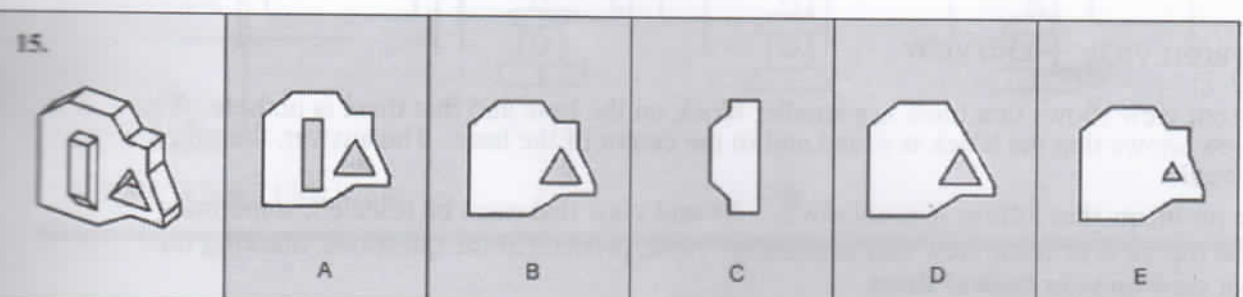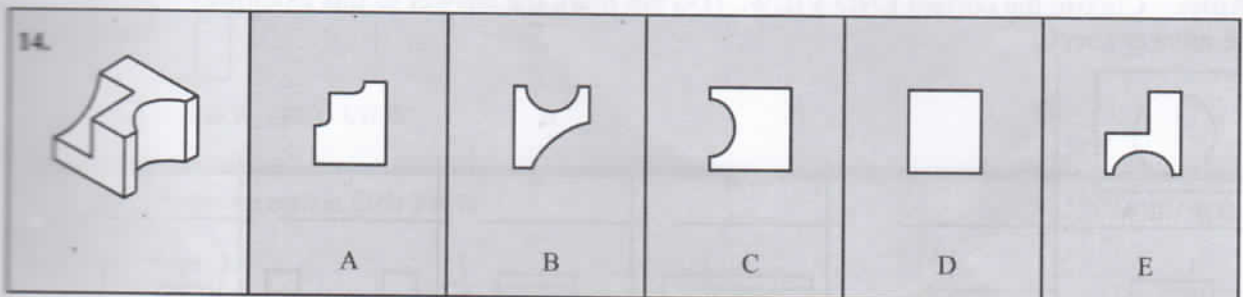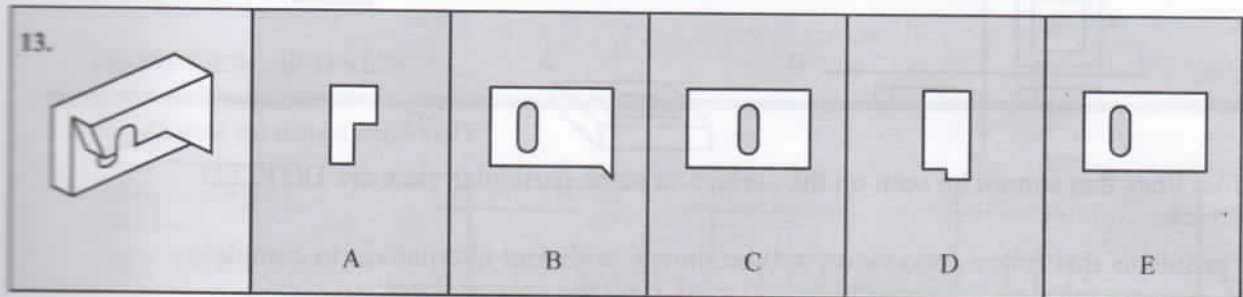
DO NOT STOP - READ DIRECTIONS FOR PART 2 AND CONTINUE

PART 2

For questions 16 through 30

The pictures that follow are top, front, and end views of various solid objects. The views are without perspective. That is, the points in the viewed surface are viewed along parallel lines of vision. The projection looking DOWN on it is shown in the upper left-hand corner (TOP VIEW). The projection looking at the object from the FRONT is shown in the lower left-hand corner (FRONT VIEW). The projection looking at the object from the END is shown in the lower right-hand corner (END VIEW). These views are ALWAYS in the same positions and are labeled accordingly.
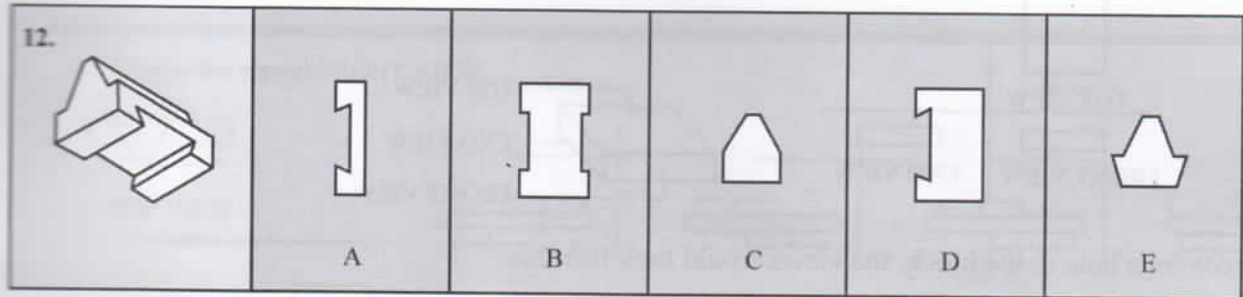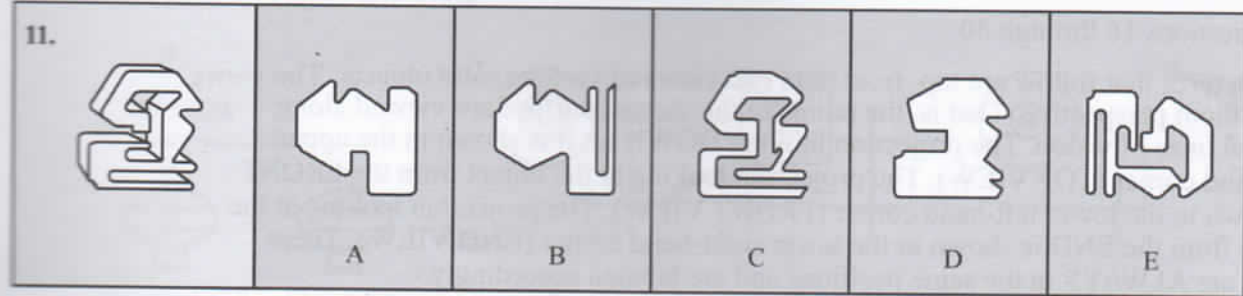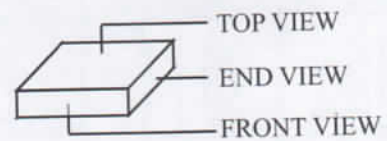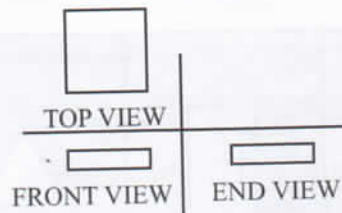
If there were a hole in the block, the views would look like this:
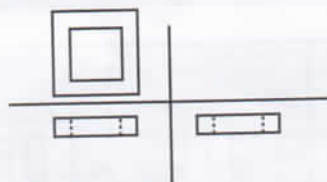
Note that lines that cannot be seen on the surface in some particular view are DOTTED in that view.

In the problems that follow, two views will be shown, with four alternatives to complete the set. You are to select the correct one and mark it on the answer sheet.

Example: Choose the correct END VIEW. (Do not mark the answer to this example on the answer sheet.)
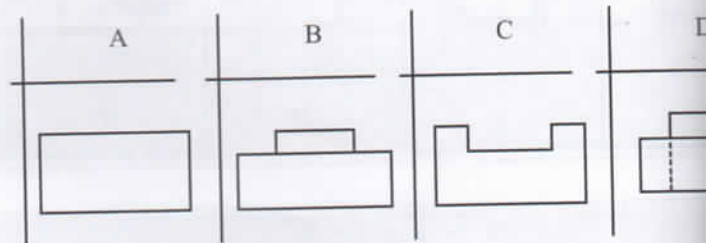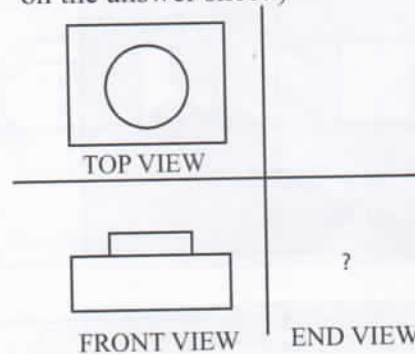
The front view shows that there is a smaller block on the base and that there is no hole. The top view shows that the block is round and in the center of the base. The answer, therefore, must be B.

In the problems that follow, it is not always the end view that must be selected, sometimes it is the top view or front view that is missing. Now, proceed to the questions, marking the correct view on your answer sheet.

Proceed to Questions.

16. Choose the correct TOP VIEW.
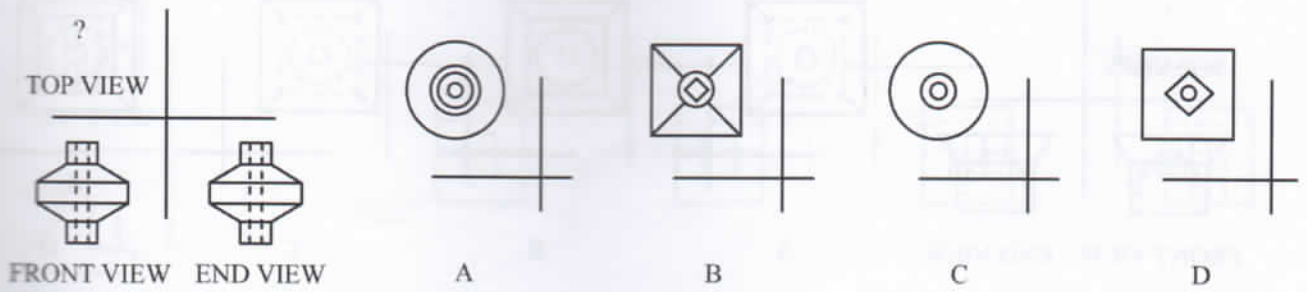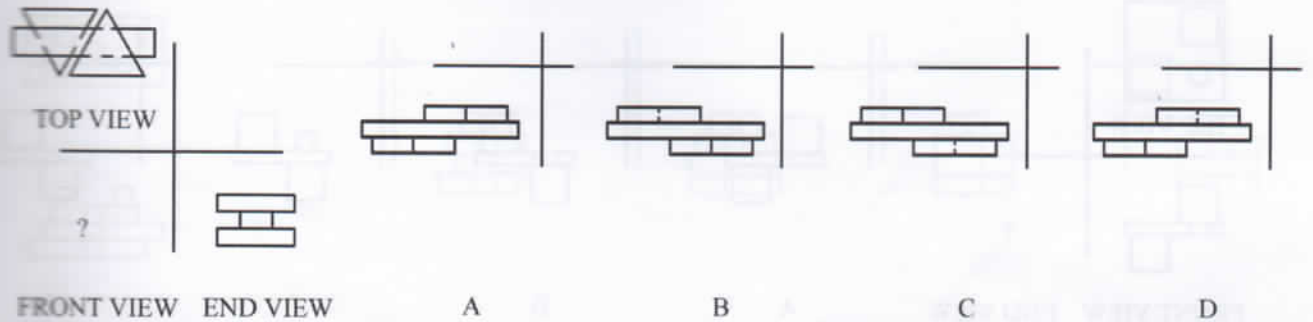
?

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D

17. Choose the correct FRONT VIEW.

TOP VIEW

?

FRONT VIEW   END VIEW   A   B   C   D

18. Choose the correct END VIEW.

TOP VIEW

?

FRONT VIEW   END VIEW   A   B   C   D

19. Choose the correct END VIEW.

TOP VIEW

?

FRONT VIEW   END VIEW   A   B   C   D

20. Choose the correct TOP VIEW.

?

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D

---

21. Choose the correct END VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C

?

---

22. Choose the correct END VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C

?

---

23. Choose the correct TOP VIEW.

?

TOP VIEW

FRONT VIEW   END VIEW   A   B   C

---

24. Choose the correct END VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D

25. Choose the correct END VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D

26. Choose the correct END VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D

27. Choose the correct FRONT VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D

28. Choose the correct END VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D

29. Choose the correct END VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D

30. Choose the correct END VIEW.

TOP VIEW

FRONT VIEW   END VIEW   A   B   C   D
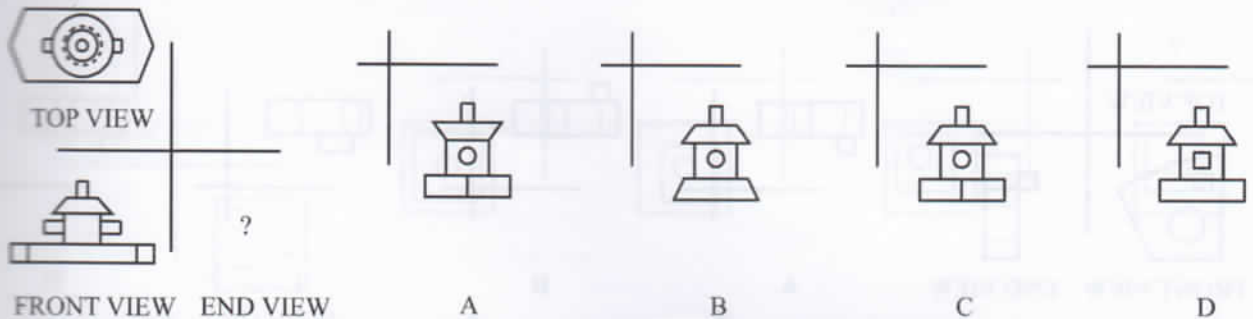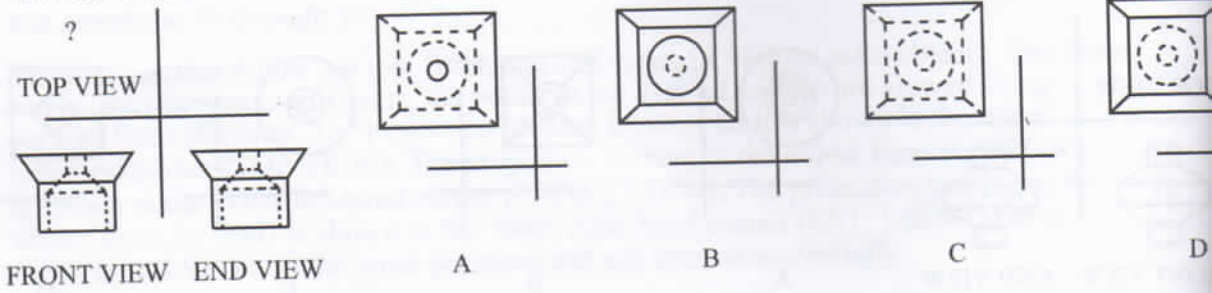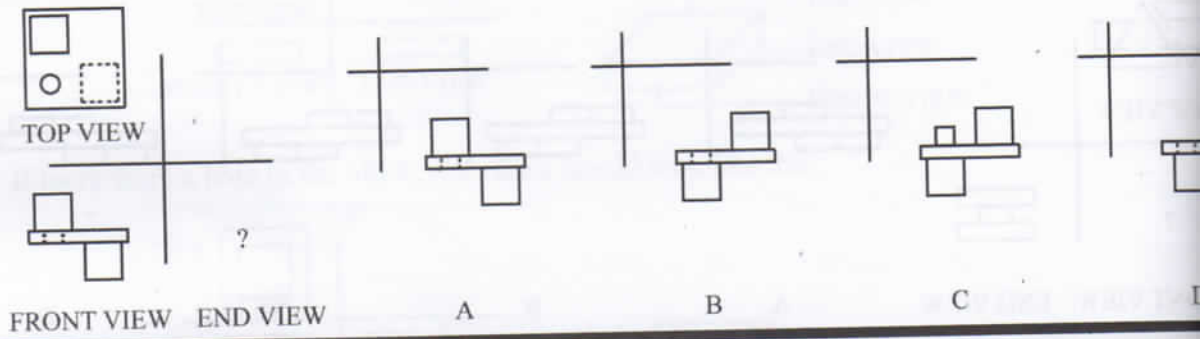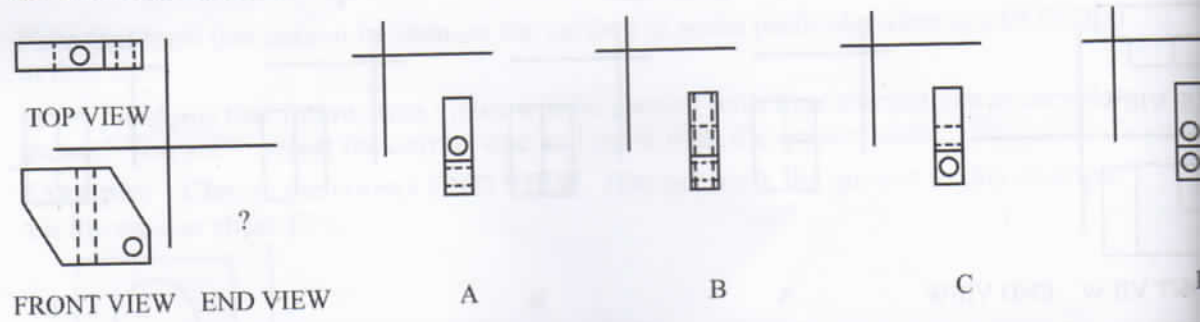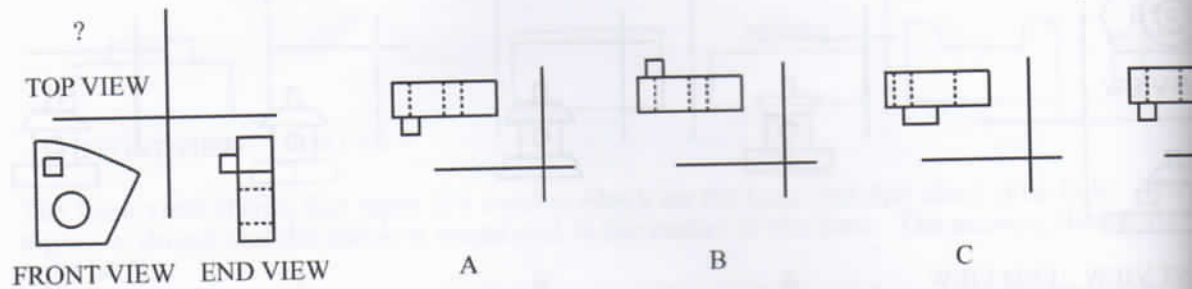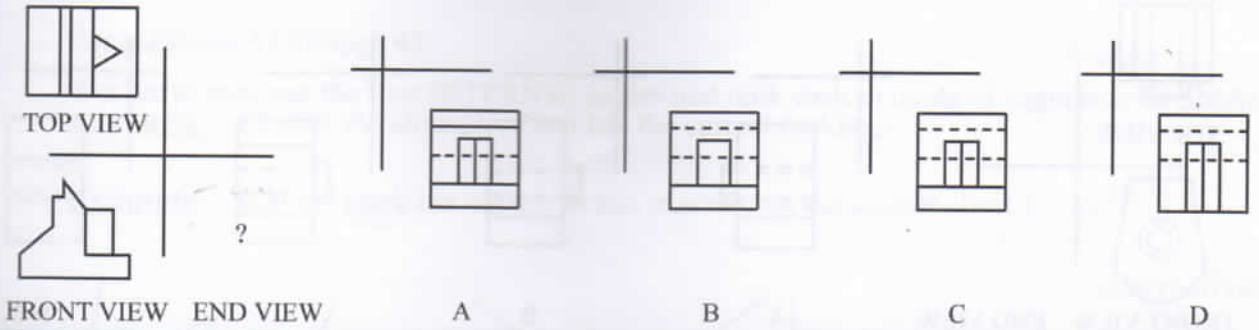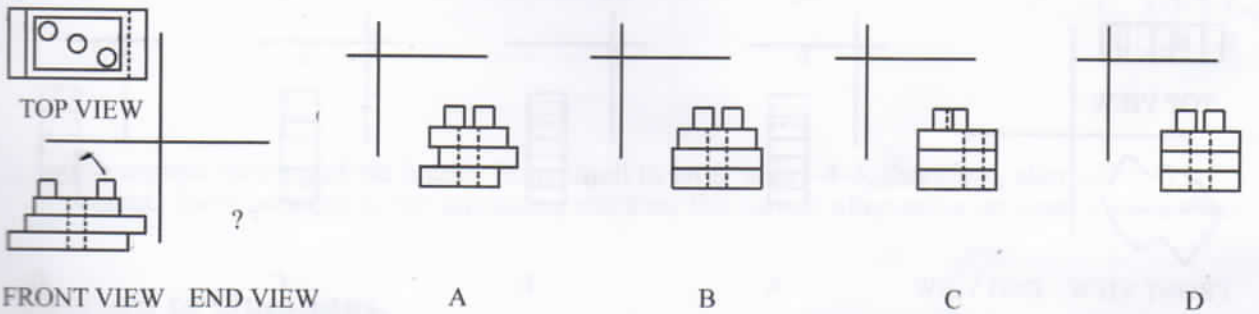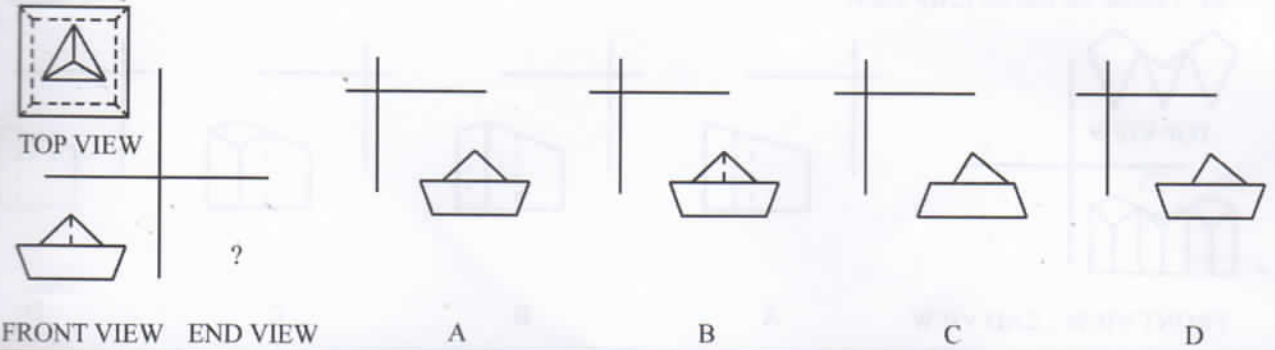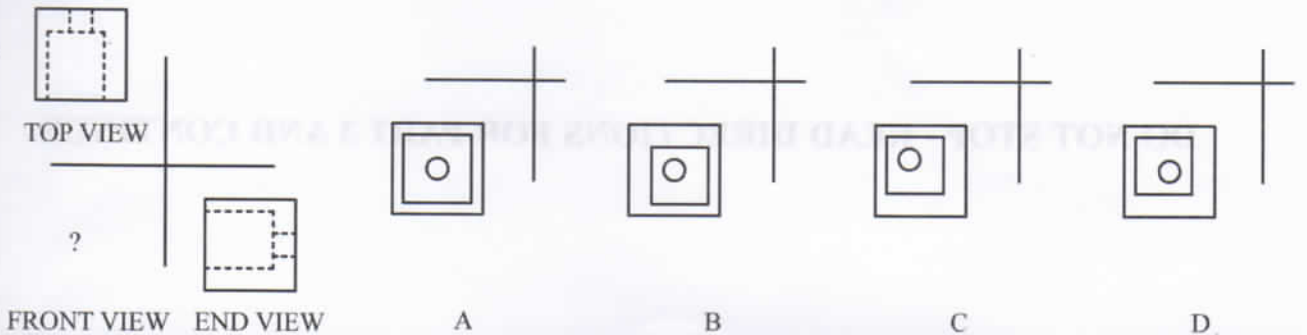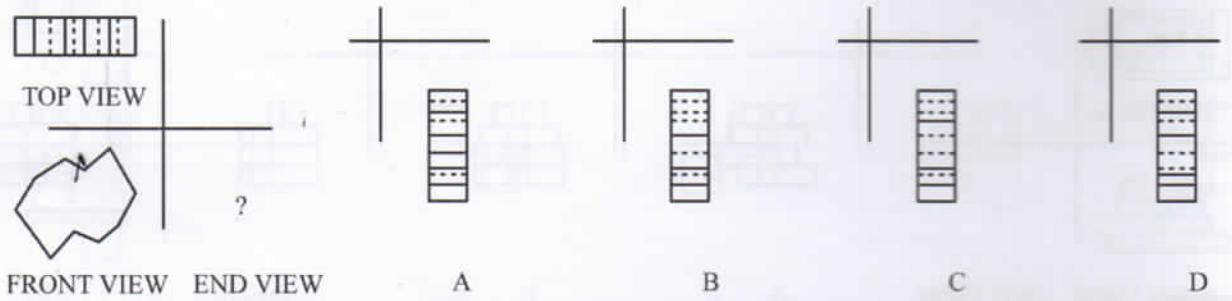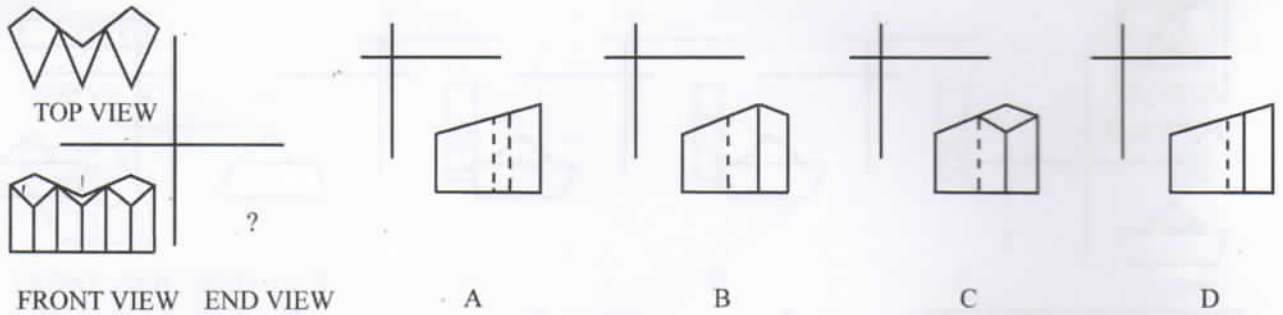
DO NOT STOP - READ DIRECTIONS FOR PART 3 AND CONTINUE

PART 3

For questions 31 through 45

You are to examine the four INTERIOR angles and rank each in terms of degrees from SMALL to LARGE. Choose the alternative that has the correct ranking.

Example: (Do not mark the answer to this example on the answer sheet.)
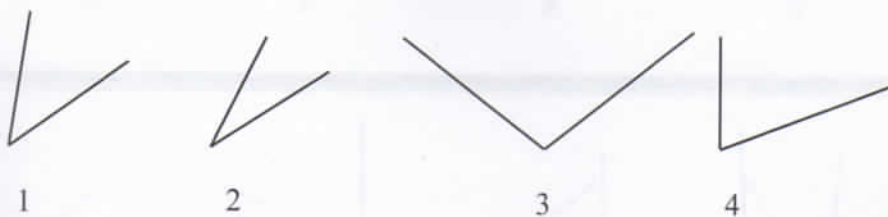
Alternatives:

1   2   3   4

A. 1-2-3-4
B. 2-1-4-3
C. 1-3-2-4
D. 3-4-1-2

The correct ranking of the angles from small to large is 2-1-4-3; therefore, alternative B is correct. Now, proceed to the questions, marking the correct alternative on your answer sheet.

Proceed to Questions.

31.

A.	2-1-3-4
B.	2-1-4-3
C.	1-2-3-4
D.	2-4-3-1

32.

A.	2-4-3-1
B.	4-3-2-1
C.	3-4-2-1
D.	3-4-1-2

33.

A.	2-3-4-1
B.	2-3-1-4
C.	3-2-1-4
D.	3-2-4-1
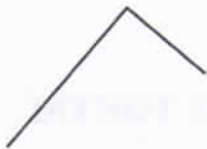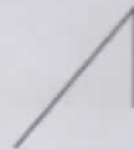
34.

A.	2-4-3-1
B.	4-2-3-1
C.	2-4-1-3
D.	4-2-1-3

35.

A.	3-1-4-2
B.	1-3-4-2
C.	1-3-2-4
D.	3-2-1-4

36.
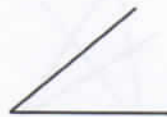
A.	4-1-3-2
B.	1-2-4-3
C.	4-2-1-3
D.	1-4-3-2

37.

A.	4-2-1-3
B.	2-4-1-3
C.	2-4-3-1
D.	4-1-2-3

38.

A.	3-2-4-1
B.	1-4-3-2
C.	2-3-1-4
D.	2-1-3-4

39.
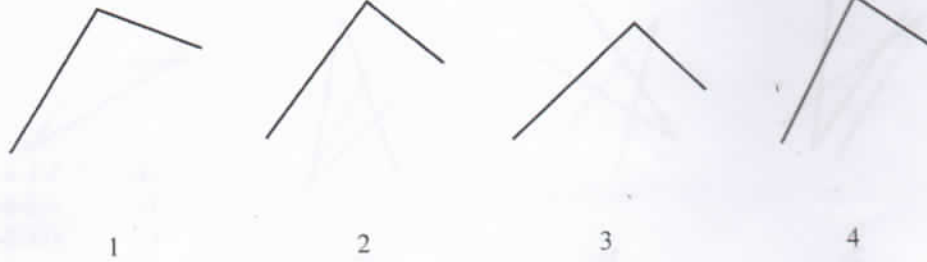
A. 2-4-3-
B. 4-3-2-
C. 2-4-1-
D. 4-2-3-
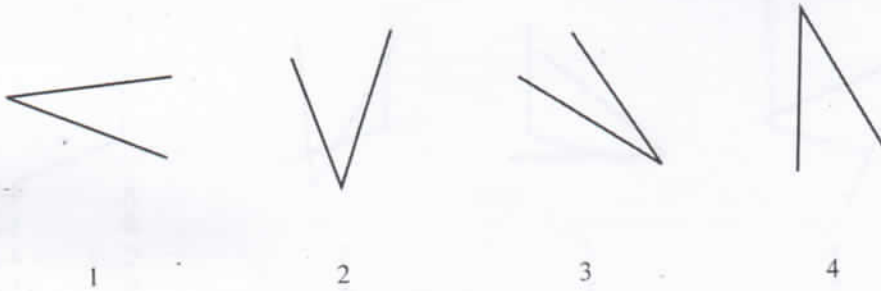
40.

A. 3-1-4-
B. 1-3-4-
C. 1-3-2-
D. 3-2-1-

41.

A. 4-2-1-
B. 2-4-1-
C. 2-4-3-
D. 4-2-3-

42.

A. 3-4-
B. 4-3-
C. 2-4-
D. 3-4-

43.

1   2   3   4
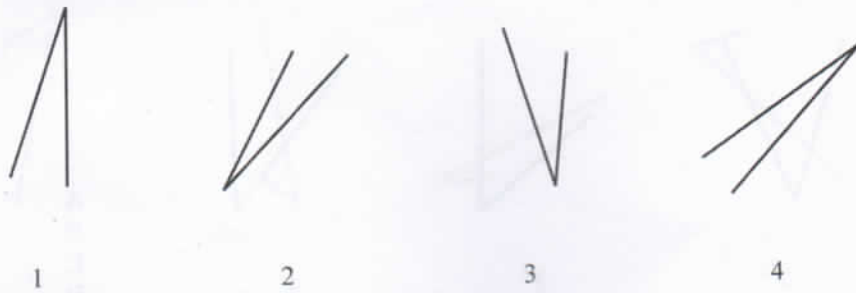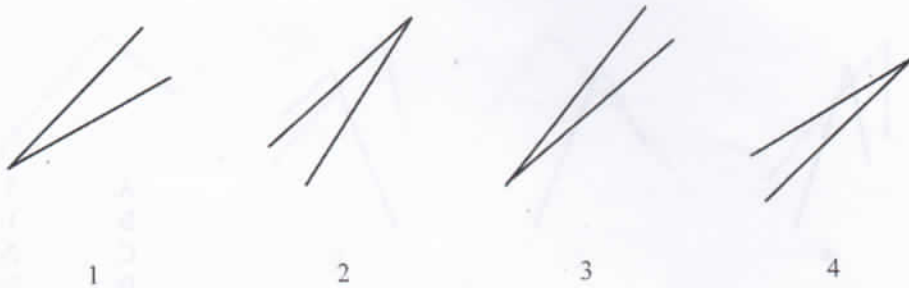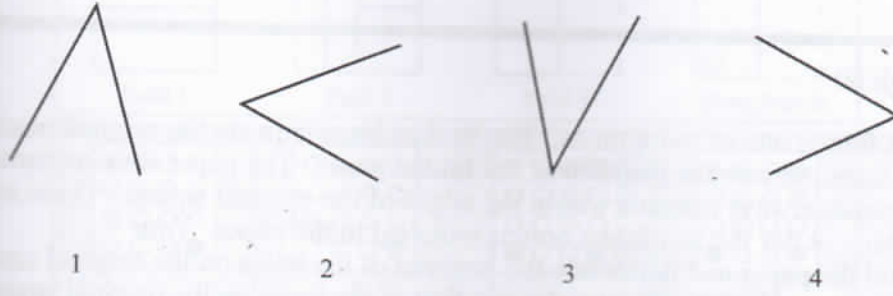
A.   3-2-4-1
B.   1-3-2-4
C.   3-1-2-4
D.   3-2-1-4

44.

1   2   3   4
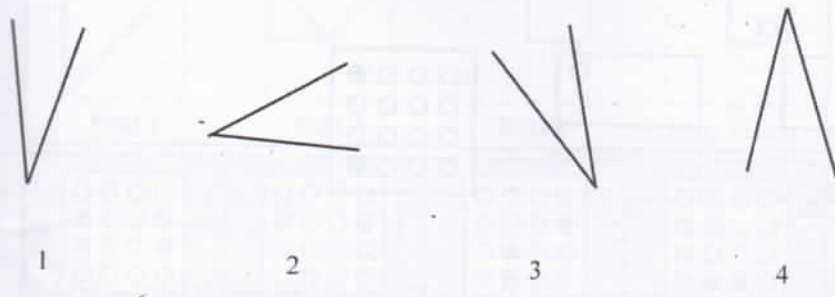
A.   1-3-4-2
B.   3-1-2-4
C.   1-3-2-4
D.   3-1-4-2

45.

1   2   3   4
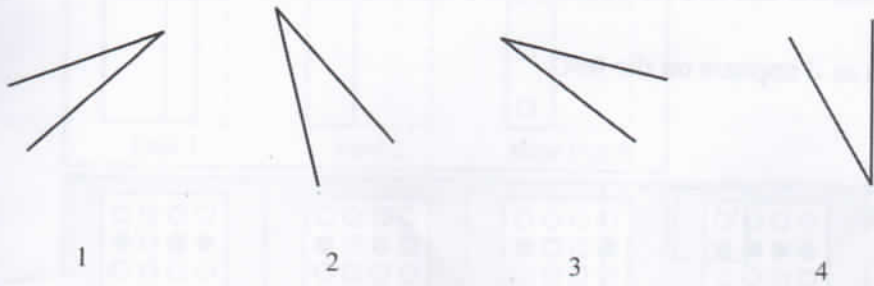
A.   3-1-4-2
B.   1-3-4-2
C.   1-3-2-4
D.   3-2-1-4

DO NOT STOP - READ DIRECTIONS FOR PART 4 AND CONTINUE

50.

Fold 1   Fold 2   Fold 3   Hole Punch

A   B   C   D   E

51.

Fold 1   Fold 2   Hole Punch

A   B   C   D   E

52.

Fold 1   Fold 2   Fold 3   Hole Punch

A   B   C   D   E

53.

Fold 1   Fold 2   Hole Punch

A   B   C   D   E

54.

Fold 1	Fold 2	Fold 3	Hole Punch

A	B	C	D	E

55.

Fold 1	Fold 2	Fold 3	Hole Punch

A	B	C	D	E

56.

Fold 1	Fold 2	Fold 3	Hole Punch

A	B	C	D	E

57.

Fold 1	Fold 2	Fold 3	Hole Punch

A	B	C	D	E

58.

Fold 1	Fold 2	Fold 3	Hole Punch

A	B	C	D	E

59.

Fold 1	Fold 2	Fold 3	Hole Punch

A	B	C	D	E

60.

Fold 1	Fold 2	Fold 3	Hole Punch

A	B	C	D	E
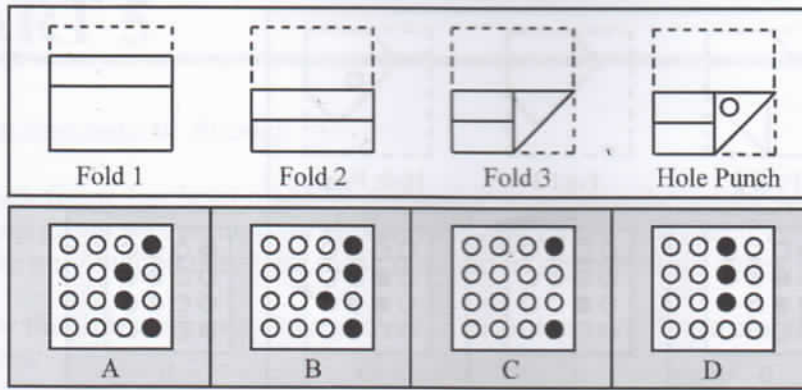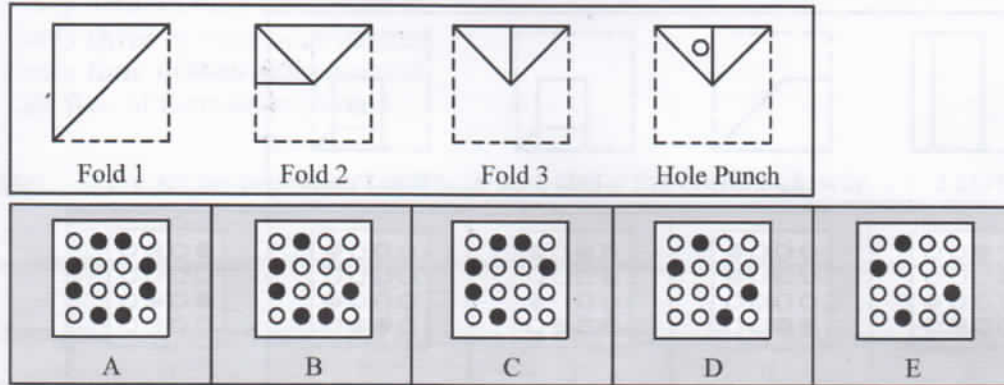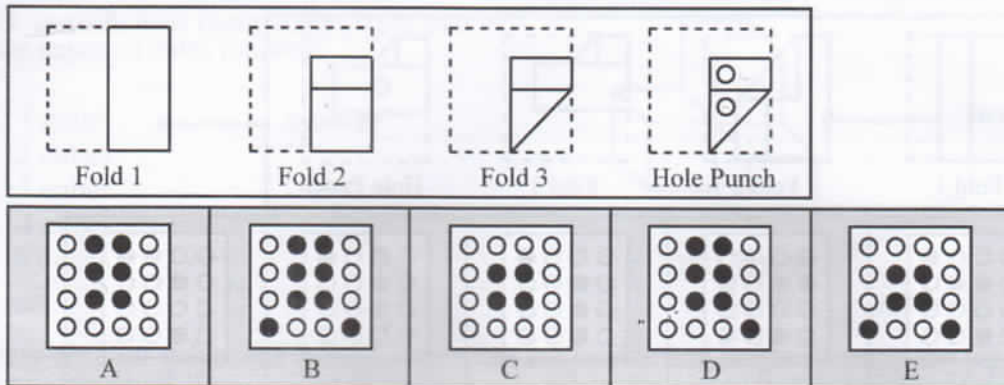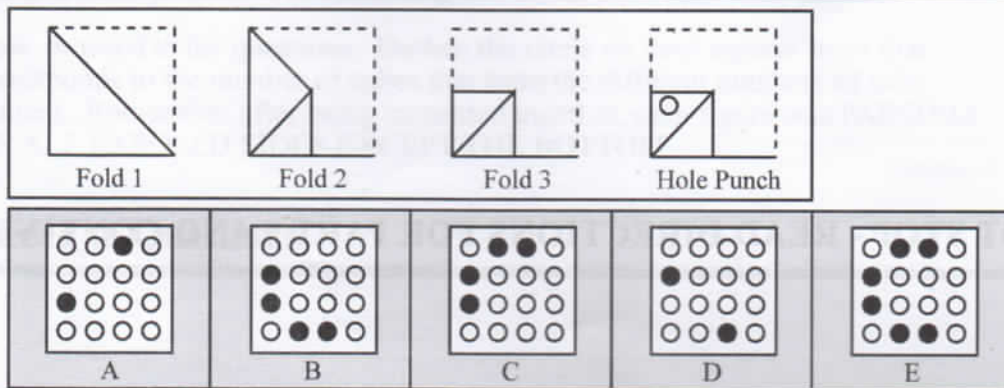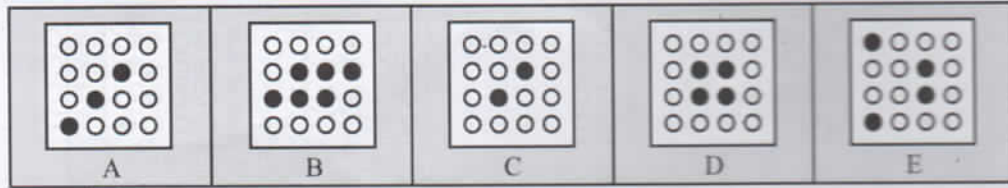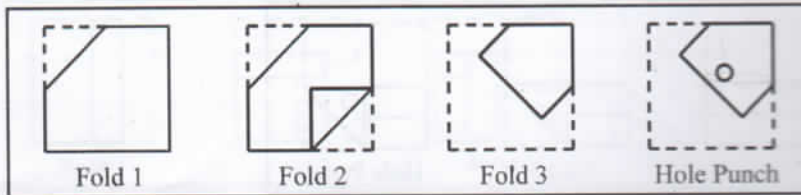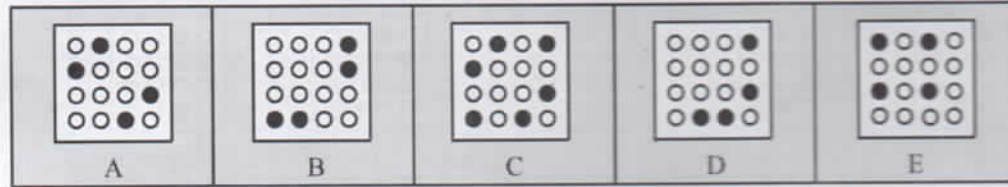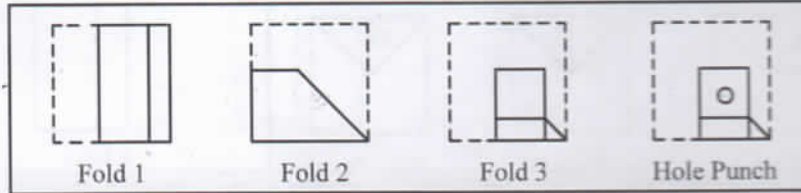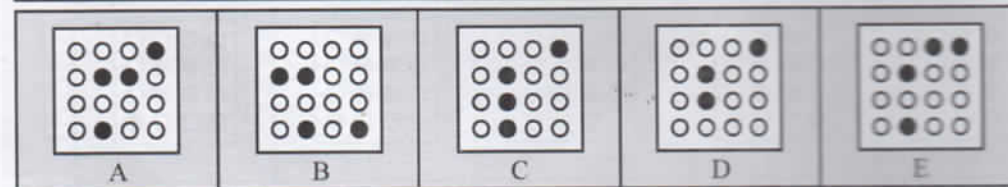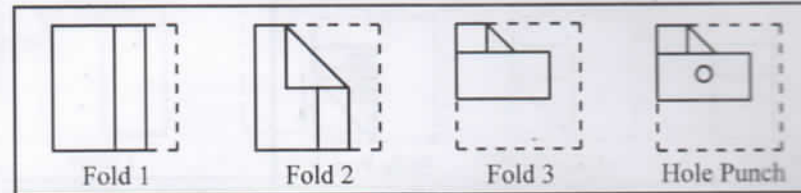
DO NOT STOP - READ DIRECTIONS FOR PART 5 AND CONTINUE

PART 5

Each figure has been made by cementing together cubes of the same size. After being cemented each group was painted on all sides EXCEPT FOR THE BOTTOM ON WHICH IT IS RESTING. The only hidden cubes are those required to support other cubes.

For the following questions you are to examine each figure closely to determine how many cubes have:

only **one** of their sides painted.
only **two** of their sides painted.
only **three** of their sides painted.
only **four** of their sides painted.
all **five** of their sides painted.

Note: There are no problems for which zero (0) is the correct answer.

Example: (Do not mark the answers to this example on your answer sheet.)

PROBLEM Z

In Figure Z, how many cubes have two of their exposed sides painted?

A. 1 cube ←——— **Answer**
B. 2 cubes
C. 3 cubes
D. 4 cubes
E. 5 cubes
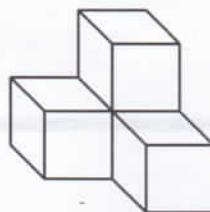
←——— **Invisible cube**

FIGURE Z

There are four cubes in Figure Z, three that are visible and one supporting the top cube that is invisible. The invisible cube has only two sides painted. The top cube has five sides painted. The remaining two cubes have four sides painted.

Now, proceed to the questions. Darken the circle on your answer sheet that corresponds to the number of cubes that have the different numbers of sides painted. Remember, after being cemented together, each figure was PAINTED ON ALL EXPOSED SIDES EXCEPT THE BOTTOM.

Proceed to Questions.

PROBLEM A

61. In Figure A, how many cubes have two of their exposed sides painted?

    A.   1 cube
    B.   2 cubes
    C.   3 cubes
    D.   4 cubes
    E.   5 cubes

62. In Figure A, how many cubes have three of their exposed sides painted?

    A.   1 cube
    B.   2 cubes
    C.   3 cubes
    D.   4 cubes
    E.   5 cubes
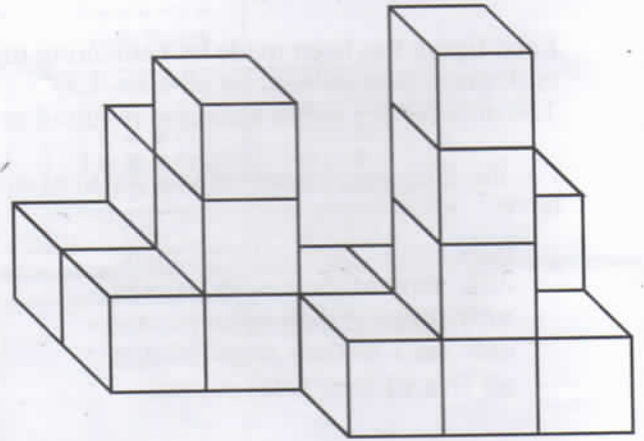
63. In Figure A, how many cubes have four of their exposed sides painted?

    A.   1 cube
    B.   2 cubes
    C.   3 cubes
    D.   4 cubes
    E.   5 cubes

FIGURE A

PROBLEM B

64. In Figure B, how many cubes have two of their exposed sides painted?

    A.   1 cube
    B.   2 cubes
    C.   3 cubes
    D.   4 cubes
    E.   5 cubes

65. In Figure B, how many cubes have four of their exposed sides painted?

    A.   3 cubes
    B.   4 cubes
    C.   5 cubes
    D.   6 cubes
    E.   7 cubes
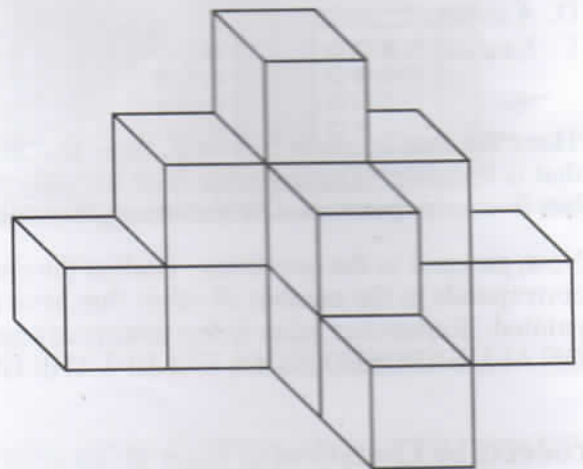
FIGURE B

PROBLEM C

66. In Figure C, how many cubes have two of their exposed sides painted?

   A.   2 cubes
   B.   3 cubes
   C.   4 cubes
   D.   5 cubes
   E.   6 cubes

67. In Figure C, how many cubes have three of their exposed sides painted?

   A.   2 cubes
   B.   3 cubes
   C.   4 cubes
   D.   5 cubes
   E.   7 cubes

68. In Figure C, how many cubes have four of their exposed sides painted?

   A.   1 cube
   B.   2 cubes
   C.   3 cubes
   D.   4 cubes
   E.   5 cubes
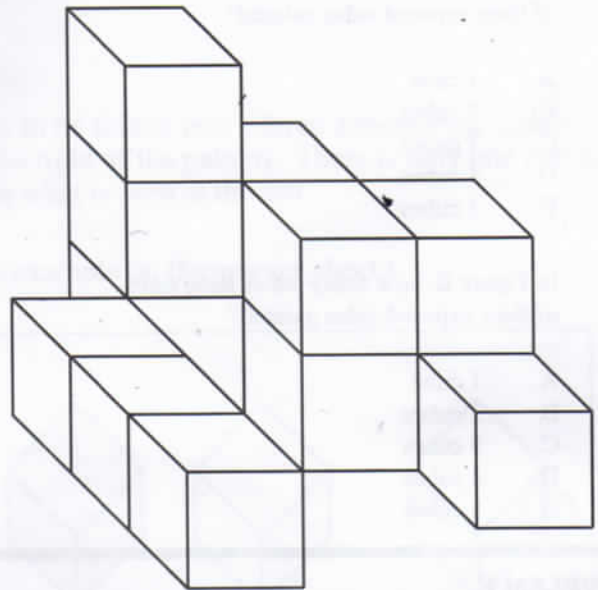
FIGURE C

PROBLEM D

69. In Figure D, how many cubes have two of their exposed sides painted?

   A.   1 cube
   B.   2 cubes
   C.   3 cubes
   D.   4 cubes
   E.   5 cubes

70. In Figure D, how many cubes have four of their exposed sides painted?

   A.   1 cube
   B.   2 cubes
   C.   3 cubes
   D.   4 cubes
   E.   5 cubes
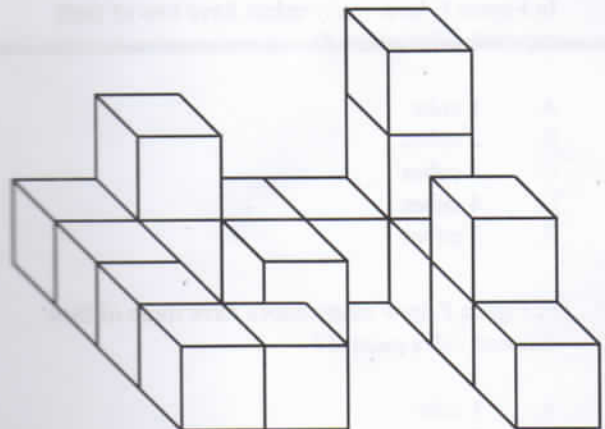
FIGURE D

PROBLEM E

71. In Figure E, how many cubes have two of their exposed sides painted?

   A. 1 cube
   B. 2 cubes
   C. 3 cubes
   D. 4 cubes
   E. 5 cubes

72. In Figure E, how many cubes have three of their exposed sides painted?

   A. 1 cube
   B. 2 cubes
   C. 3 cubes
   D. 4 cubes
   E. 5 cubes
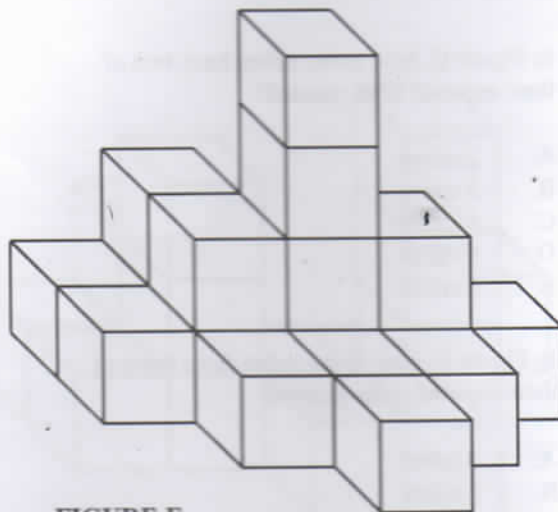
FIGURE E

PROBLEM F

73. In Figure F, how many cubes have one of their exposed sides painted?

   A. 1 cube
   B. 2 cubes
   C. 3 cubes
   D. 4 cubes
   E. 5 cubes

74. In Figure F, how many cubes have two of their exposed sides painted?

   A. 1 cube
   B. 2 cubes
   C. 3 cubes
   D. 4 cubes
   E. 5 cubes

75. In Figure F, how many cubes have three of their exposed sides painted?

   A. 1 cube
   B. 2 cubes
   C. 3 cubes
   D. 4 cubes
   E. 5 cubes
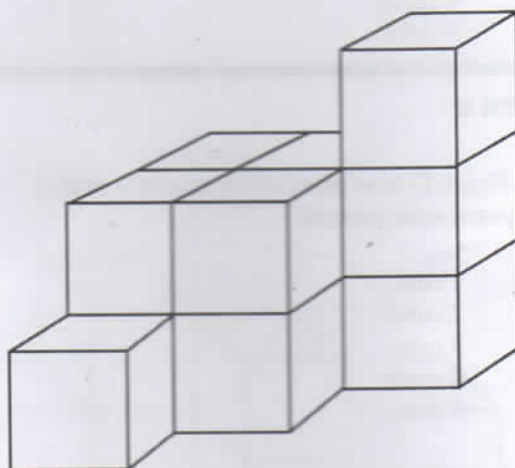
FIGURE F

PART 6

A flat pattern will be presented. This pattern is to be folded into a three dimensional figure. The correct figure is one of the four given at the right of the pattern. There is only one correct figure in each set. The outside of the pattern is what is seen at the left.

Example: (Do not mark the answer to this example on the answer sheet.)

A   B   C   D
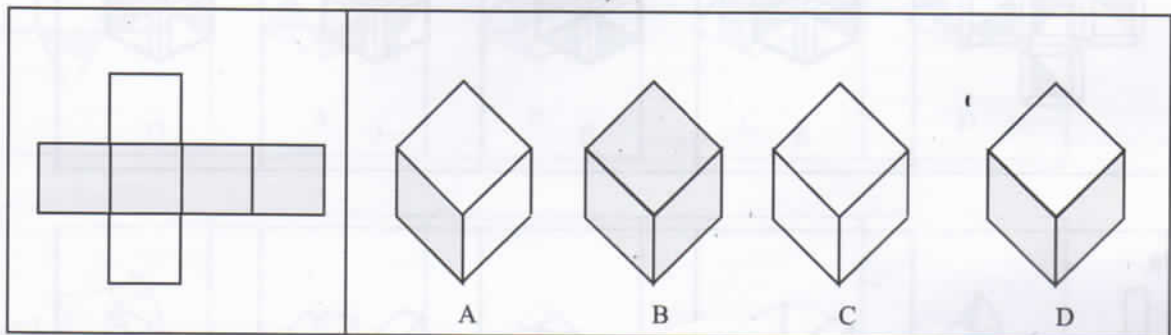
One of the above figures (A, B, C, or D) can be formed from the flat pattern given at the left. The only figure that corresponds to the pattern is D. If the shaded surfaces are looked at as the sides of the box, then all four sides must be shaded, while the top and bottom are white.

Proceed to Questions.

76.	A	B	C	D

77.	A	B	C	D

78.	A	B	C	D

79.	A	B	C	D

80.	A	B	C	D
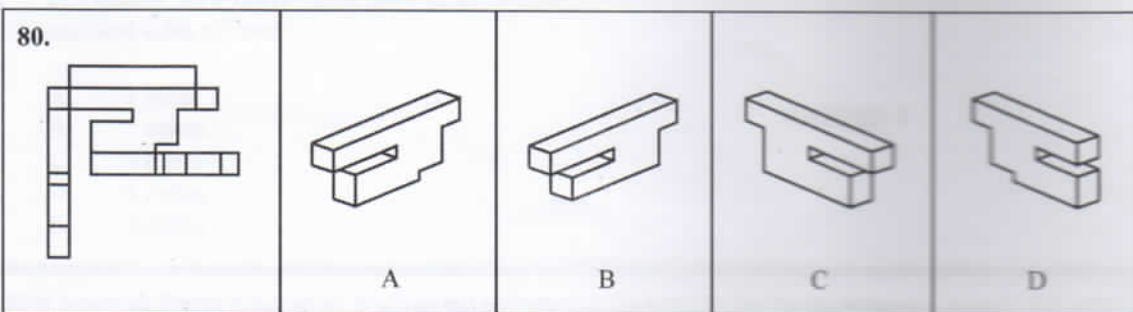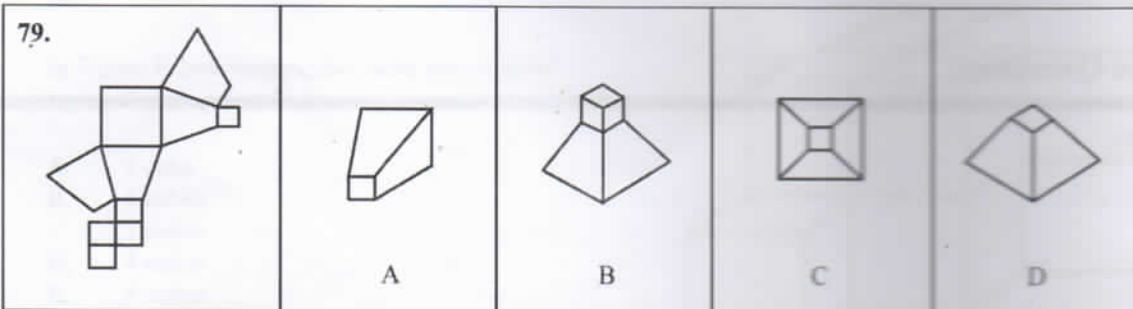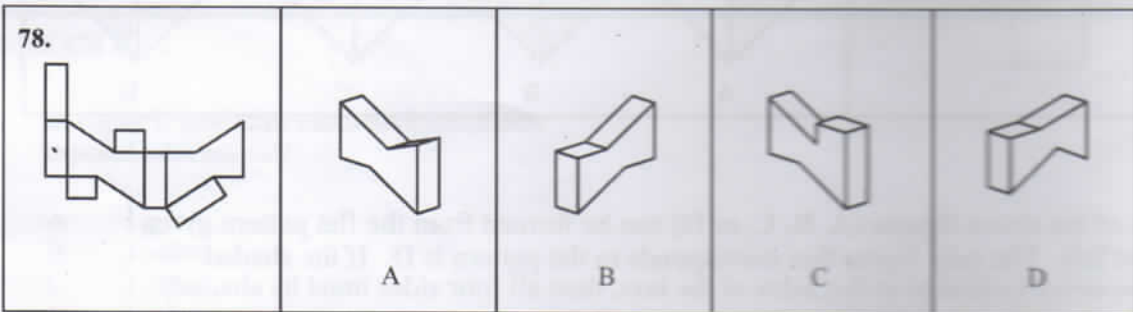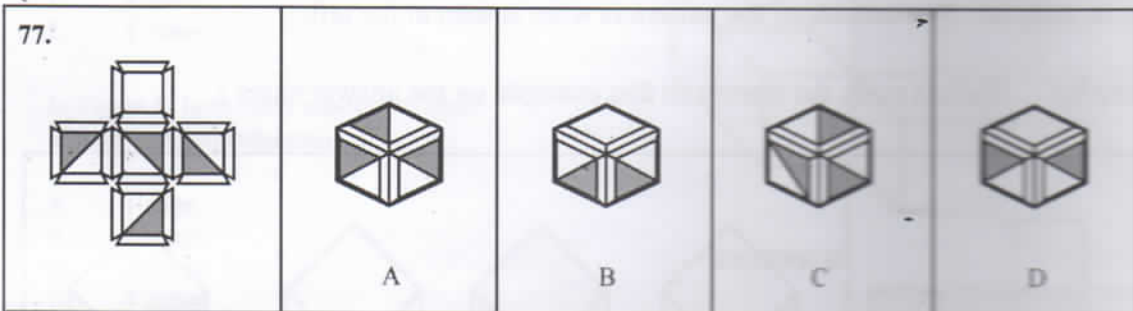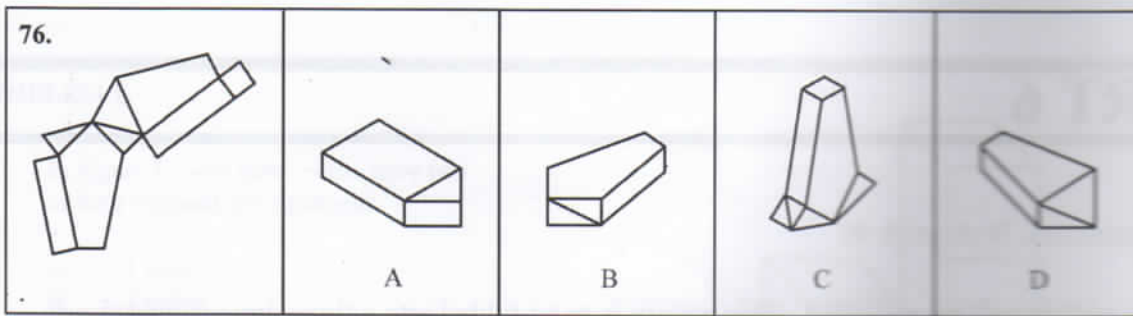
81.

	A	B	C	D

82.

	A	B	C	D

83.

	A	B	C	D

84.

	A	B	C	D

85.

	A	B	C	D

86.

A B C D

87.

A B C D

88.

A B C D

89.

A B C D

90.

A B C D
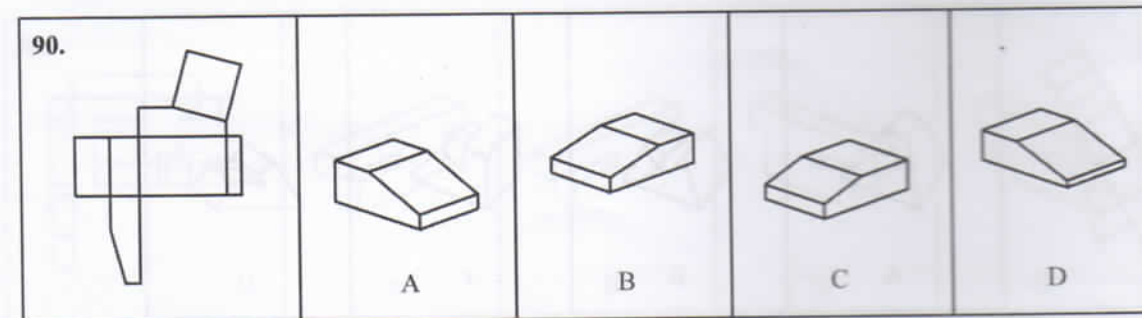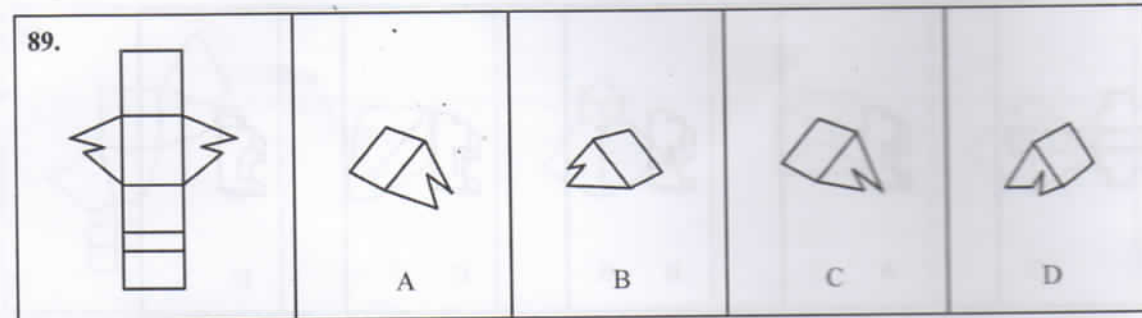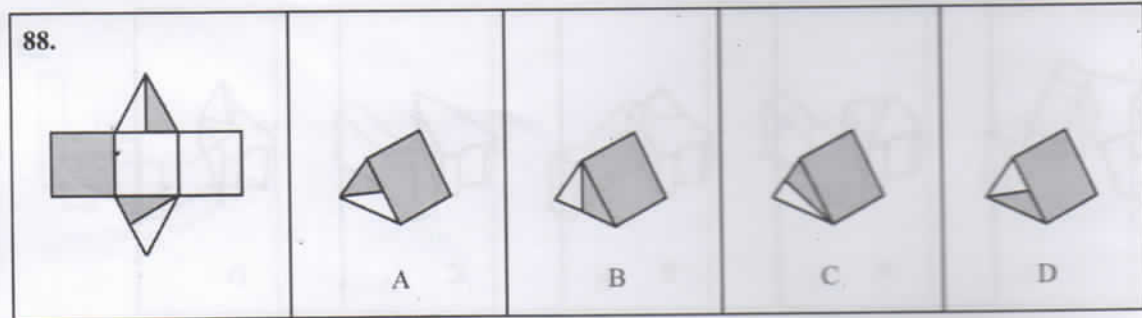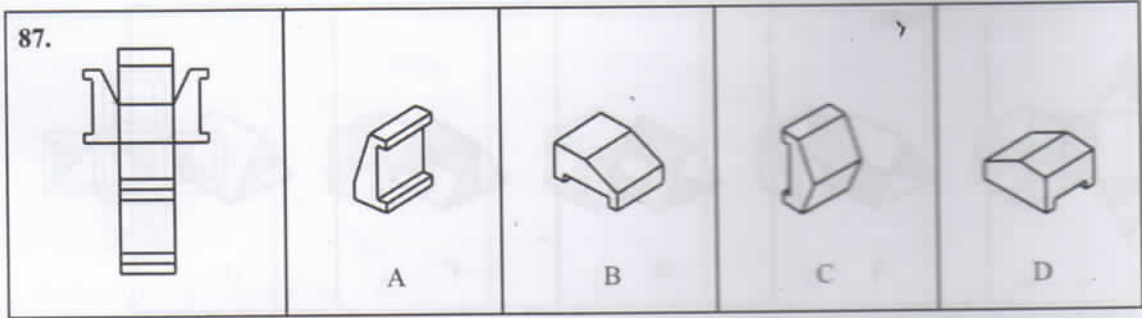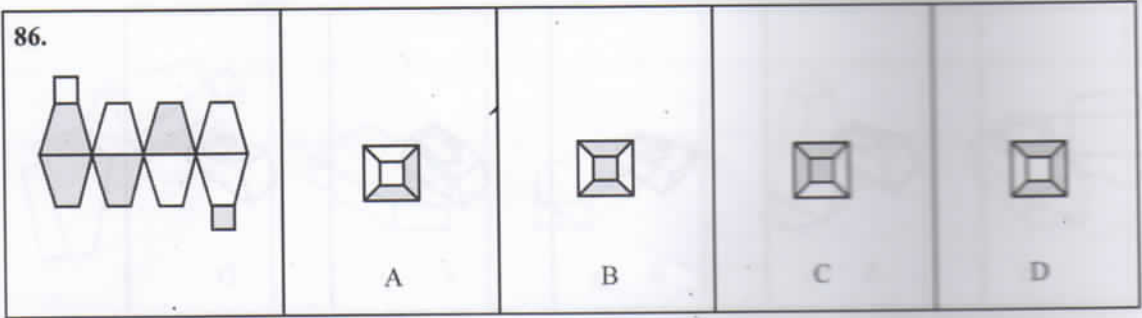
Passage 1

Epidemiology

England suffered a series of cholera epidemics in the 19th century. The first occurred in 1832 and caused the death of approximately 6,000 people. The second epidemic occurred in 1849. It provided the British physician John Snow the opportunity to investigate the outbreak, which laid the foundation for modern epidemiology.

Noting that different diseases seemed to be transmitted from one person to the next by different routes, Snow began to suspect that water might be the vehicle of transmission in this cholera epidemic. The epidemic hit hard in the Golden Square district of London with over 500 cholera deaths in a 10-day period. Snow used a spotting map to record the household location of those who died from cholera. He noticed that the cases seemed to cluster around the water pump on Broad Street. Indeed, most people who died from cholera had either drunk directly from the well or brought well water to their home. When the pump handle was removed, the number of new cases decreased markedly.

Well water contamination suggested to Snow that other sources of water might also pose a risk. Fortunately for Snow, William Farr, superintendent of the General Register Office, had compiled and tabulated the number of cholera deaths per 100,000 persons by London district and water supply company. The worst hit districts had their water supplied by two companies-the Lambeth Company and the Southwark and Vauxhall Company, both of which drew water from a heavily polluted section of the Thames River. Additionally, it happened that in some districts both companies provided water in a random distribution. That is, it was possible for two adjacent houses to receive their water from different companies.

Between 1849 and 1853, the Lambeth Company relocated its source to a much less polluted section of the Thames River. This was fortuitous, for when the 1853-54 cholera epidemic struck London, Snow was able to conduct a "natural experiment." He obtained from the General Register Office the addresses of people who died from cholera. By visiting the victims' houses and nearby households which were not afflicted, and identifying the water supply company, Snow was able to demonstrate that the water supplied by Southwark and Vauxhall was the cause of the epidemic in London. Over a seven-month period there were 315 cholera deaths per 10,000 households among those supplied by Southwark and Vauxhall, but only 37 deaths per 10,000 households among those supplied by Lambeth Company.

As a result of his insight and systematic observation, Snow described the distribution, frequency, and cause of the cholera epidemic. He was, perhaps, the first practitioner of what we now call epidemiology. Epidemiology is the science that deals with the incidence, distribution, causation, and control of disease in a population. While the physician thinks of the individual as the patient, the epidemiologist thinks of the community or the population as the patient. Epidemiology has the same etymology as the word "epidemic" and, early on, dealt primarily with infectious diseases such as cholera, smallpox, tuberculosis, measles, and poliomyelitis.

Infectious disease epidemiology is not limited to these classic killers. In the mid-1970s, six cases of what was thought to be juvenile rheumatoid arthritis (JRA) appeared in a short time in a region of Connecticut. As JRA is rare, this group of cases represented a small epidemic that required investigation. Ultimately, a new disease was identified-Lyme disease-which was eventually shown to be a bacterial infection transmitted by ticks that infest wooded areas and woodland animals such as deer. Legionnaire's disease and AIDS are two other examples of modern diseases that were first identified by the astute observation of a small disease cluster of an anomalous or rare condition.

Infectious diseases are not the only concern of epidemiologists. Occupation and environmental epidemiology deals with hazards of the workplace and environmental hazards that affect the population-at-large. The hazards found in the work place and the general environment are similar, though the intensity and duration of exposure in the work place is often much greater. Miners, stonecutters and sandblasters, for example, are exposed to mineral dusts that can cause respiratory disease. Chemical solvents pose a hazard to workers in chemical manufacturing plants all the way to the dry cleaning proprietor. Office workers are subject to repetitive stress injuries such as carpal tunnel syndrome and to other musculoskeletal ills. Environmental hazards range from asbestos exposure

from insulation used in commercial and residential dwellings, to lead paint that results in lead poisoning among small children who eat the paint chips common in older and poorly maintained buildings, to air pollution that may affect millions of city dwellers on any given day or week.

Another large area of epidemiology is the study of chronic diseases and life style choices or circumstances. This is difficult to investigate because of the complex web of interactions. A particular disease may be multifactorial. That is, there are many contributing factors that may cause the problem, and a particular life style choice may contribute to several or many diseases or conditions. In some instances, however, the link or the association between the hazard and the outcome is quite strong. Smoking, for example, is linked with a 70% increase in mortality (death rate); increased morbidity (disease rate) due to cardiovascular diseases, cancers, and peptic ulcer disease; and low birthrate and increased prenatal morbidity. Other life style choices that affect mortality and morbidity are alcohol consumption, diet, sleeping habits, drug use, sexual behaviors, exercise, and risk-taking proclivity (for example, not wearing seatbelts or engaging in high-risk sports such as downhill skiing).

There are two major approaches that epidemi-ologists may take to study the incidence, distribution, causation and control of disease in a population. The first, descriptive epidemiology, addresses the first two areas-incidence and distribution, especially with regard to person, place, and time. Person refers to age, sex, marital status, race and ethnicity, religion, socioeconomic status, occupation, and life style behaviors that may characterize those who have a particular disease or condition. Characteristics of place include country, state, county, and municipal comparisons, urban versus rural comparisons or localized disease occurrence. Temporal factors include seasonal, weekly or circadian fluctuations, and comparisons over time (days, weeks, years, or decades). An unusual concentration of cases in a local geographic area or in a limited time frame represent spatial and temporal clustering, respectively. Descriptive epidemi-ological studies help to identify health problems and aid in resource allocation decisions. Descriptive studies include the simple case report, a report of a case series or disease cluster, and cross-sectional studies to determine the distribution of hazards and disease in a given population.

The second major type of epidemiological study-an analytical study-addresses the issues of causation and control. Analytical studies themselves are of two types: observational and experimental. In observational studies, the investigator or researcher does not intervene but rather carefully notes who was exposed and who was not, as well as who developed the disease or condition and who did not. The epidemiologist then attempts to link the exposure and the outcome in a meaningful way. Observational studies may be conducted in two ways. In the first, the investigator assembles a group of people who are and are not exposed to the hazard, say a group of smokers and non-smokers. The two groups are followed over time, noting how many of each develop, for example, lung cancer. If all other factors are equal and the rate of lung cancer is greater for the smokers than the non-smokers, we may conclude that smoking increases the chance of developing lung cancer. Observational studies of this type are called cohort studies. In the second approach, the investigator assembles two groups of people-one which has the disease or condition and one which does not, and determines past exposure to the hazard. Using the smoking example, the investigator would find a group of lung cancer patients (cases) and another group of persons who do not have lung cancer (controls) but who are otherwise very much like the cancer patients. Again, if all other factors are equal, and the rate of past smoking among the lung cancer patients is greater than among the healthy persons, we may conclude that lung cancer is more likely to occur among smokers than non-smokers. This type of observational study is called a case-control study.

The second type of analytical study is the experimental or interventional study. In this type of study, the investigator assigns the individual to one of the two groups and manipulates the study factors. The efficacy of new drugs or treatments is often studied this way. To evaluate a new drug for hypertension, for example, the investigator would assemble a large group of patients with hypertension and randomly assign each to either the group that will receive the new drug (the experimental group) or the group that will receive a placebo (the control group). If the blood pressure in the persons in the experimental group is significantly reduced after taking the drug compared to the control group, then we may conclude that the new drug is an effective anti-hypertensive agent. This particular version of an experimental study is called a randomized clinical trial. The results of analytical studies-observational and

experimental-are usually subject to statistical analyses to determine whether the results of the particular study are likely to be real and meaningful or just a chance fluke.

Epidemiological knowledge has many applications. New diseases will be identified and old ones will become better understood. The effectiveness of diagnostic tests, treatment alternatives and public health programs will be evaluated so that the best alternatives may be pursued. Populations at risk will be identified so that as individuals and a society we can take appropriate preventive measures. New questions will be raised that may direct future research.

1. Which of the following represents the number of cholera outbreaks occurring in England during the 1800's?

    A.   1
    B.   2
    C.   3
    D.   4
    E.   5

2. During the 1849 cholera outbreak, which of the following represents the approximate number of deaths occurring in the Golden Square district of London within a 10-day period?

    A.   35
    B.   300
    C.   500
    D.   2000
    E.   6000

3. Which of the following study designs best characterizes John Snow's investigation of the 1849 cholera outbreak?

    A.   Case Series
    B.   Cross-sectional
    C.   Case-control
    D.   Cohort
    E.   Experimental

4. The pump that was the source of contaminated water was at which of the following locations?

    A.   Brobdingnag Way
    B.   Broad Street
    C.   Boardwalk
    D.   Broadbent Avenue
    E.   Broadway

5. Which of the following is the name of the water company that relocated its source of water between 1849 and 1853?

    A.   Southwark and Vauxhall
    B.   Golden and Lambeth
    C.   Southfork
    D.   Lambeth
    E.   Vauxhall

6. During the 1853-54 cholera outbreak, the mortality rate among those who drank contaminated water was approximately how many times higher than those who drank uncontaminated water?

    A.   5
    B.   10
    C.   15
    D.   20
    E.   50

7. Each of the following disease characteristics is generally dealt with by epidemiology EXCEPT one. Which one is the EXCEPTION?

    A.   Causation
    B.   Incidence
    C.   Distribution
    D.   Control
    E.   Cure

8. Which of the following best defines "etymology" based on usage in this narrative?

    A.   Study of insects
    B.   Cause of disease
    C.   Professional conduct
    D.   Word origins
    E.   Memorable event

9. Each of the following infectious diseases was mentioned in this narrative EXCEPT one. Which one is the EXCEPTION?

    A.   Syphilis
    B.   Smallpox
    C.   Tuberculosis
    D.   Measles
    E.   Poliomyelitis

10. Which of the following modes of transmission applies to Lyme disease?

    A.   Food borne
    B.   Airborne
    C.   Sexually transmitted
    D.   Water borne
    E.   Arthropod borne

11. Which of the following populations is particularly susceptible to lead poisoning?

    A.   Office workers
    B.   Dry cleaning proprietors
    C.   Nursing home residents
    D.   Small children
    E.   Downhill skiers

12. The hazards found in the work place are very different from those found in the general environment.

Carpal tunnel syndrome is a musculoskeletal problem.

    A.   Both statements are true.
    B.   Both statements are false.
    C.   The first statement is true, the second is false.
    D.   The first statement is false, the second is true.

13. Which of the following represents the percentage increase in mortality of smokers over non-smokers?

    A.   5
    B.   20
    C.   45
    D.   60
    E.   70

14. Each of the following is a characteristic of "person" in a descriptive epidemiological study EXCEPT one. Which one is the EXCEPTION?

    A.   Residence
    B.   Sex
    C.   Race
    D.   Occupation
    E.   Age

15. Which of the following study designs is generally used to test the effectiveness of a new drug?

    A.   Case series
    B.   Cross-sectional
    C.   Case-control
    D.   Cohort
    E.   Experimental

16. An unusually high concentration of cases in a local geographic area is called a disease cluster.

Lyme disease first appeared as a disease cluster.

    A.   Both statements are true.
    B.   Both statements are false.
    C.   The first statement is true, the second is false.
    D.   The first statement is false, the second is tue.

17. Each of the following is the name or label of the group that receives the drug in a randomized clinical trial EXCEPT one. Which one is the EXCEPTION?

    A.   Cohort
    B.   Controls
    C.   Cases
    D.   Consultants
    E.   Cluster

18. A busy clinician is most likely to conduct and report which of the following types of studies?

    A.   Case series
    B.   Cross-sectional
    C.   Case-control
    D.   Cohort
    E.   Experimental

19. Demonstrating an association between a specific chronic disease and a life style choice might be difficult because of which of the following?

    A.   Life styles of the rich and famous prevent disease.
    B.   Patients are likely to die very quickly.
    C.   Life style choices tend to remain stable.
    D.   The disease may have many contributing factors.
    E.   An association has never been shown, suggesting none is to be found.

20. Which of the following study designs best characterizes John Snow's investigation of the 1853-54 cholera outbreak?

    A.   Case series
    B.   Cross-sectional
    C.   Case-control
    D.   Cohort
    E.   Experimental

Passage 2

Lightning: A Force of Nature

Until Benjamin Franklin's famous kite and key experiment in 1752, little was known about the nature of lightning. Since then, science has come a long way in explaining this fascinating phenomenon.

Lightning is most commonly produced by thunderclouds (cumulonimbus) but can also occur during volcanic eruptions and sandstorms. Thunderclouds, which contain a combination of wind, water, and ice, form when cold, dense air mixes with warm, moist air. This amalgamation of elements and temperature results in the formation of a dipole, where the upper part of the cloud carries a predominantly positive charge and the lower part holds a net negative charge.

Although intracloud discharges are most common, cloud-to-ground lightning is perhaps better understood because of its direct impact on people. Lightning causes about 100 deaths per year in the United States, more than hurricanes and tornadoes combined. Ninety percent of lightning strike victims survive but may suffer severe injury and/or disability such as blindness or neurological damage. Symptoms may not appear until months after a strike and frequently include memory loss, chronic pain, dizziness, sleep disturbance, and chronic fatigue.

While a lightning strike may seem like a rare event, lightning hits the ground 25 million times each year in the United States. As lightning descends from the parent cloud, it travels in 50-yard sections known as stepped leaders. Since air is a poor conductor of electricity, a leader, or ionized path of air, is necessary for current to flow. The earth and objects on the earth's

surface accumulate a positive charge in response to the strong negative charge from the hovering cloud. Charged ground-based objects initiate "streamers" or "upward leaders," which reach up toward the cloud. As several leaders branch downward, the leader closest to earth unites with a streamer, thereby completing the circuit and allowing current flow between cloud and earth. Tall metal objects and trees are likely targets for a lightning current, although lightning does not necessarily strike the tallest object in its vicinity. Lightning can also travel through power lines or plumbing in a building.

Lightning releases massive amounts of energy in the form of light and heat. In fact, a lightning bolt is hotter than the surface of the sun. This sudden release of intense heat creates a high pressure region of air that rapidly expands and collides with surrounding air. This disturbance produces a shockwave, which then decays into an ordinary sound wave, or thunder. Thunder generated from a lightning strike travels one mile every five seconds. To determine lightning's proximity (in miles), simply count the number of seconds between the flash and the thunder and divide by five.

If the time between lightning and thunder is 30 seconds or less, safe shelter should be sought immediately. The safest location during a lightning storm is a large, fully enclosed building that has wiring and plumbing systems, which can conduct lightning safely to the ground. If safe shelter is not available, a person's risk of being struck can be minimized by avoiding tall, isolated objects, metal structures, water, high elevations, wide-open areas, and, especially, trees. A car is a relatively safe place during a thunderstorm, but not because the rubber tires provide insulation; rather, the surrounding metal acts as a Faraday Cage, directing the electrical current along the exterior surface and shielding objects within which keeps the electricity outside of the vehicle.

Because lightning has the capacity to severely damage equipment and other property, several types of lightning protection designs work in tandem to minimize the destruction that can result from a strike. Conventional lightning protection systems for ground-based structures consist of three elements: air terminals, down conductors, and grounding electrodes.

Air terminals such as lightning rods intercept lightning by creating upward streamers that connect with downward leaders. In some cases, air-termination is accomplished by overhead shield wires and masts located next to the structure or building. Air terminal designs that purportedly eliminate, redirect, or perform preferential capture of lightning have been found to be ineffective in a number of reports.

Down conductor systems provide a bridge for current to flow from air terminals to earthbound terminals. Down conductors are placed outside of the structure and are made of flexible cable or rigid strap. A building's structural steel, which in some cases functions as a Faraday Cage, may serve in place of a down conductor system. Adequate bonding joins metallic parts and ensures that all metal conductors entering a structure (e.g., gas and water piping, data transmission lines, metal door frames, railings, etc.) are electrically referenced to the same ground potential. Exothermal bonding (i.e., a weld) is preferred over mechanical bonding, because mechanical bonds may corrode or become damaged.

Grounding electrodes provide optimum electrical continuity between conductors and the earth. A good grounding system reduces AC impedance via buried linear or radial conductors, and reduces DC resistance through soil additives such as carbon, concrete, and natural salts.

Protection from lightning is usually implicit in a building's design, but is it possible to predict where lightning will strike? Although several detection instruments are available, lightning is a stochastic event and therefore impossible to predict 100% of the time. Advanced sensor and radar systems such as those used by NASA and the National Lightning Detection Network can predict lightning strikes with 90% or more accuracy within a range of kilometers (anywhere from ten to several hundred depending on the type of instrument). In addition, more complex detectors may supplement lightning detection with magnetic direction finders, time of arrival techniques, or interferometry to collect data on storm convection and dynamics, and other lightning-related events.

Lightning remains a fascinating phenomenon, a combination of natural beauty and an awesome destructive force that cannot be totally controlled. Viewing lightning is an experience to be appreciated but from afar.

21. What is the most common type of lightning discharge?

   A. Cloud-to-ground
   B. Cloud-to-sky
   C. Intracloud
   D. Intercloud

22. Which of the following is the best description of lightning?

   A. Sustained high-current electrical discharge with path length kilometers long
   B. Transient high-current electrical discharge with a path length kilometers long
   C. Sustained high-current electrical discharge with path length a few meters long
   D. Transient high-current electrical discharge with a path length a few meters long

23. Which of the following conditions is most likely to generate lightning?

   A. Cold moist air colliding with warm dry air
   B. A light fluffy snow combined with high winds
   C. A combination of moist air, wind, water, and ice
   D. Dry air and high winds combined with sandstorms

24. What is the main cause of lightning?

   A. Inability of a cloud to maintain a dipole
   B. Increased electrical charge in the atmosphere
   C. Decrease in the electrical potential of a cloud
   D. Breakdown in the air's ability to block the flow of electrons

25. Negative charges from a cumulonimbus cloud discharging lightning cause which of the following phenomenon?

   A. Stepped leaders reach upward from the ground.
   B. Surrounding clouds accumulate negative charges.
   C. Trees and buildings accumulate a positive charge.
   D. Streamers reach downward from the clouds to the ground.

26. Which of the following conditions is most responsible for the creation of thunder?

   A. Charged moist air colliding with high-pressure air
   B. High-pressure air colliding with surrounding stationary air
   C. The intense light produced by lightning creates a sonic boom.
   D. A sudden drop in air temperature creating a low-pressure area

27. How many seconds does it take to hear thunder from a lightning strike five miles away?

   A. 15
   B. 20
   C. 25
   D. 30

28. Which of the following are components of a lightning protection system?

   A. Air terminals, bonding, and inductors
   B. Faraday Cages, down conductors, and air terminals
   C. Down conductors, lightning rods, and interferometers
   D. Lightning rods, grounding electrodes, and down conductors

29. What is the primary purpose of a down conductor?

   A. Function as a Faraday Cage
   B. Link air terminals and grounding electrodes
   C. Redirect lightning to the air termination system
   D. Provide electrical continuity between two air terminals

30. Lightning is more likely to strike a person in a

   A. rowboat rather than in an airplane.
   B. wired building rather than under a tree.
   C. ditch in an open field rather than on a mountain.
   D. car on an open road rather than hiking in the forest.

31. Lightning detection equipment helps NASA scientists gather information about impending storms.

High-tech instruments use radial spectrometry and magnetic direction finders to predict lightning strikes with 99% accuracy to within a few feet of the strike.

   A. Both statements are true.
   B. Both statements are false.
   C. The first statement is true, the second is false.
   D. The first statement is false, the second is true.

32. How does a Faraday Cage provide protection against a lightning strike?

   A. Serves as a shield against ionized currents of air
   B. Provides a path for current to flow into the earth
   C. Creates a buffer between electrically charged regions of air
   D. Redirects current flow from down conductors to grounding electrodes

33. Which of the following can contribute to the function of a grounding system?

   A. Closed-circuit television
   B. Furniture with metal parts
   C. Glass window panes
   D. Polyvinyl chloride (PVC) pipes

34. What is the main function of grounding electrodes as a component of a lightning protection system?

   A. Maintain all metal conductors at the same potential
   B. Dissipation of electrical current into and below the earth's surface
   C. Provide electrical continuity between down conductors and air terminals
   D. Maintain electrical current flow between structural components of a building

35. Ideally, grounding systems should maximize AC impedance and DC resistance to lightning.

Failure of exothermal bonds can often be attributed to corrosion.

   A. Both statements are true.
   B. Both statements are false.
   C. The first statement is true, the second is false.
   D. The first statement is false, the second is true.

Passage 3

Stirling Engines

As the name implies, heat engines are machines that convert thermal energy into work. Regardless of the type of heat engine, they all operate on the same basic principle: Mechanical work is generated by the changes in pressure and volume that result from the cyclical heating and cooling of a liquid or gas, a process referred to as a gas cycle. A simple demonstration of this principle can be illustrated by putting a balloon over the mouth of a bottle. If the bottle is heated, the

gases within the bottle will take thermal energy from the heat source, also known as a heat reservoir, and expand, causing the balloon to inflate.

When the bottle is subsequently cooled, the gases contract as they release thermal energy to a cold reservoir, and the balloon will deflate. If the balloon were replaced with a piston, then the repeated heating and cooling would cause the piston to move up and down. In both cases thermal energy is being converted into motion, which can be harnessed to do mechanical work. It should be noted, however, that according to the Second Law of Thermodynamics, this or any other energy conversion process is not 100% efficient, and some of the input energy will remain as thermal energy.

The process of heating and cooling a working fluid to generate work is not trivial. It has been estimated that heat engines, which include the internal combustion engines of most automobiles, diesel engines, and gas turbine engines of airplanes, generate 90% of the motive power in the world and account for 60% of the world's energy consumption. While the benefits of heat engines are readily experienced every time we use one, their pervasive nature also has negative effects. For example, most of the heat engines encountered today depend on a limited and essentially nonrenewable resource, fossil fuel. Additionally, many of the heat engines common today contribute to global warming by the expulsion into the atmosphere of the spent fuel exhaust products they generate, in addition to any unconverted heat. Because of the significant impact heat engines have on our world, efforts have been made to improve our understanding and use of these machines. One type of heat engine that has received more attention over the past 30 years is the Stirling engine. It may help reduce some of the negative effects caused by the current use of other types of heat engines.

Stirling engines are not a new invention. These external combustion engines were invented and patented in 1816 by the Scottish inventor Robert Stirling. At the time, the prevailing engine was the steam engine. While steam engines were essentially responsible for the start of the Industrial Revolution, they were also quite dangerous. Suboptimal construction materials and the high pressure needed to operate them resulted in many injuries and deaths. In an effort to overcome the safety concerns, Robert Stirling designed an engine that could work at lower temperatures and pressures.

The Stirling engine operates on the same basic principle as all heat engines; however, there are several key features that distinguish it from other heat engines and make it a potentially desirable alternative. First, the working fluid of Stirling engines is located with a piston in a sealed cylinder, which allows the fluid to be recycled. This is in contrast to the internal combustion engine, in which the working fluid, air, must enter and exit the cylinder at the beginning and end of each cycle of heating and cooling. Second, the thermal energy that enters the Stirling engine is provided from an external heat source, rather than by the compression and ignition of fuel inside the engine, as occurs in an internal combustion engine. The fact that Stirling engines are external combustion engines means that they can use almost any available source of thermal energy, whether it is generated by continuous combustion of organic fuel or by the sun. Additionally, the absence of an explosive combustion event within the engine, along with the lack of an exhaust step, allows Stirling engines to operate quietly, smoothly, and without the release of spent fuel gases that occurs in internal combustion engines. Finally, Stirling engines are quite energy efficient. They are able to convert 36%-50% of the input thermal energy into usable work, compared to the 25%-40% of internal combustion engines.

While Robert Stirling's invention proved to be much safer than the steam engine, it never gained wide acceptance and usage. For about the first 100 years after its invention the Stirling engine was primarily used on farms to pump water or in small communities to generate electricity. At the time, the limited use of the Stirling engine was likely due to its enormous size, as well as the abundant supply of coal and oil needed to run steam and, later, internal combustion engines. In the 1970s, however, the increasing concern over shrinking fossil fuel reserves and the environmental consequences associated with internal combustion engines prompted more interest for wider use of the Stirling engine.

Despite the advantages of Stirling engines compared to internal combustion engines, their use is currently limited to small-scale applications. For example, Stirling engines are being used to liquefy gases in small cooling devices. These cooling devices can be used on satellites, or to power home units. A factor limiting the use of the Stirling engine today is cost. Although they are efficient to use, the production of a Stirling engine requires intricate designs and expensive materials. Additionally, the time it takes for

them to "warm up" and the large temperature differences that must be maintained for them to run efficiently, limit their potential use in such devices as automobiles.

New areas of research and development, however, are supporting the expanded use of Stirling engines. One area of research that holds promise focuses on how Stirling engines can help reduce energy waste and subsequently enhance the health of our global environment. For example, work has been done investigating the potential use of Stirling engines in cogeneration. Cogeneration refers to the process whereby heat engines are used to generate work, and the residual heat from the engine is used for another purpose, such as heating water or a home. Stirling engines are ideal for cogeneration because they are very low-emission engines, unlike other heat engines, and therefore do not add pollution to the environment

Despite any limitations of its use, the benefits associated with the Stirling engine are significant. Further research and development of these benefits will result in Stirling engines becoming more widely used and accepted.

36. A home in a remote part of Arizona has an air conditioning unit driven by a Stirling engine. The unit acquires the necessary thermal energy to run from solar panels mounted on the roof of the house. This unit is designed so that thermal energy not converted into usable work is used to produce the family's supply of hot water. This is an example of

A. the principle behind the gas cycle.
B. the concept of cogeneration.
C. a fire safety hazard.
D. a violation of the Second Law of Thermodynamics.

37. You have a Stirling engine that has a heat reservoir that is at 100° and a cold reservoir that is at 100°. Why will this engine not do work?

A. Heat reservoir is too warm.
B. Cold reservoir is too warm.
C. Temperatures are too high.
D. Temperatures are too low.

38. An external combustion engine burns its fuel source outside the engine.

An automobile engine is an example of an external combustion engine.

A. Both statements are true.
B. Both statements are false.
C. The first statement is true, the second is false.
D. The first statement is false, the second is true.

39. Which of the following statements is a correct interpretation of the Second Law of Thermodynamics?

A. Energy cannot be created or destroyed.
B. Energy conversion processes are very efficient.
C. Energy conversion processes result in some energy being lost as thermal energy.
D. Thermal energy can be converted into mechanical energy.

40. A Stirling engine does not contribute to global warming as much as an internal combustion engine because it does not emit as much waste heat.

A. Both the statement and reason are correct and related.
B. Both the statement and the reason are correct but NOT related.
C. The statement is correct but the reason is NOT.
D. The statement is NOT correct, but the reason is correct.
E. NEITHER the statement NOR the reason is correct.

41. The working fluid of a Stirling engine is

A. air.
B. fossil fuel.
C. reused with each cycle.
D. renewed with each cycle.

42. Which of the following is the best description of a gas cycle?

A. Changes in pressure and volume resulting from the cyclical heating and cooling of a liquid or gas
B. Process by which mechanical energy is converted into thermal energy
C. Release of spent fuel gases that occurs in internal combustion engines
D. External combustion of fuel that allows the release of waste gases into the atmosphere

43. A Stirling engine can be used as a cooling device if the item needing cooling

A. acts as the heat reservoir.
B. acts as the cold reservoir.
C. is a liquid.
D. is a solid.

44. All heat engines contribute to global warming because they generate thermal energy as waste.

A. Both the statement and reason are correct and related.
B. Both the statement and the reason are correct but NOT related.
C. The statement is correct but the reason is NOT.
D. The statement is NOT correct, but the reason is correct.
E. NEITHER the statement NOR the reason is correct.

45. Natural gas is burned to generate the thermal energy used to power a Stirling engine. During a Stirling engine's gas cycle, mechanical work is generated and the engine also radiates heat. This loss of thermal energy to the environment is an example of

A. a design flaw in the engine.
B. the Second Law of Thermodynamics.
C. the incomplete combustion of the gas.
D. poor conversion of thermal energy to mechanical work.

46. The unique feature that makes Stirling engines a good choice to use with solar energy is the fact that they are

A. heat engines.
B. external combustion engines.
C. high-emission engines.
D. internal combustion engines.

47. What is the primary purpose of a heat engine?

A. Generate heat
B. Reduce energy waste
C. Burn fossil fuel
D. Convert thermal energy into work

48. A Stirling engine has a temperature of 25°C inside the cylinder. If the outside of the cylinder is exposed to a temperature of 100°C, what will happen to the gases in the internal cylinder?

  A. Gas pressures will be equalized internally and externally.
  B. Expansion as the temperature increases
  C. Contraction as the temperature increases
  D. Nothing, external changes do not impact internal gases

49. Some Stirling engines have two heat reservoirs: one that is hot and donates heat (unit A), and one that is cold and accepts heat (unit B). You have a Stirling engine for which heat reservoir A is at 100°C and heat reservoir B is at 100°C. What would be the effect if you lowered the temperature of the heat reservoir A to 20°C?

  A. The engine would not do work.
  B. The temperature of reservoir A would decrease further.
  C. The temperature of reservoir B would decrease.
  D. The working fluid would take even more heat away from reservoir A.

50. It is estimated that heat engines account for what percentage of the world's energy consumption?

  A. 25%
  B. 50%
  C. 60%
  D. 90%

1. Which of the following equations best describes the data shown below?

x	y
0	-5
2	-4
-2	-6
-12	-11
12	1

- A. $5x - 2y = 10$
- B. $2x + 2y = 10$
- C. $x - 2y = 10$
- D. $x - 11y = 1$
- E. $x - 2y = 5$

2. Which of the following is the value of x if $(2x-1)3 = 4$?

- A. $-1/3$
- B. $1/3$
- C. 1
- D. $7/6$
- E. 2

3. Which of the following is equivalent to the fraction $\dfrac{\left(1 + \dfrac{3}{7}\right)}{\left(1 - \dfrac{2}{7}\right)}$?

- A. $1/5$
- B. $3/2$
- C. $3/7$
- D. 2
- E. 10

4 In the figure, the horizontal incident ray l strikes the circular mirror, $x^2 + y^2 = 25$, resulting in the reflected ray R. What is the y coordinate of the intersection point of the ray R and the line $x = 12$? You may need to use the identity $\tan 2\theta = 2\tan\theta/1(1-\tan^2\theta)$.
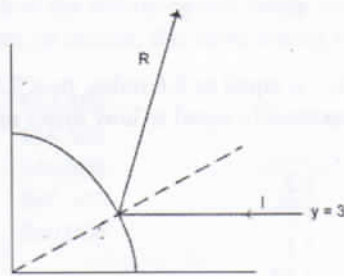
- A. 12 1/3
- B. 13 1/2
- C. 23 4/7
- D. 30 3/7
- E. 37 5/7

5. An elliptical mirror has foci at $(+1,0)$, a major axis length of $\sqrt{20}$, and a minor axis of length 4 units. A beam of light originating from the focus at $(-1,0)$ is reflected of the elliptical mirror once before arriving at the other focus. What is the total length of the path followed by the beam of light?

- A. $\sqrt{3}$
- B. $\sqrt{5}$
- C. $\sqrt{10}$
- D. $\sqrt{12}$
- E. $\sqrt{20}$

6. Pictured is a square 10 units on a side sitting in the corner of the first quadrant. The insides of all four sides are mirrored surfaces that reflect light internally. A beam of light originating on the left wall at $(0,3)$ next strikes the bottom of the box at $(2,0)$ as pictured. What is the x-coordinate of the point where the beam strikes the bottom of the box the next time?
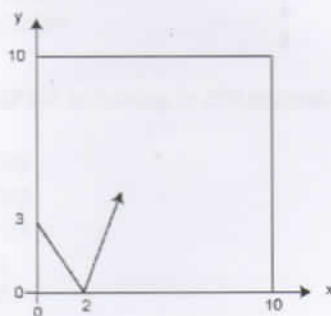
A. 8/3
B. 14/3
C. 18/3
D. 20/3
E. 46/3

7. If 1 km is equal to 0.6 miles, then 2.5 km is approximately equal to how many miles?

A. 1.2
B. 1.5
C. 3.1
D. 4.17
E. 15

8. Determine the sets of points whose distances from (-2, 2) and (3, -3) are in the ratio of 2:3.

A. Circle with center (-3,3) with radius $2\sqrt{6}$
B. Circle with center (-6,6) with radius $6\sqrt{2}$
C. Ellipse with equation $(x^2+9) + (y^2+36) = 1$
D. Ellipse with equation $(x^2+36) + (y^2+9) = 1$
E. Ellipse with semiaxes $x = \sqrt{3}$, $y = \sqrt{6}$

9. Which of the following is equal to cos x if sec x = -5/3 and if $\pi/2 < x < 3\pi/4$?

A. -0.28
B. -0.6
C. 8/5
D. 7/25
E. 16/25

10. Which of the following represents the length of the side of a square that has the same numerical value for square units of area and units of perimeter?

A. 1
B. 2
C. 3
D. 4
E. 5

11. Which of the following represents the distance between the points (8, -2) and (5, 3) in the standard coordinate plane?

A. 4
B. $\sqrt{10}$
C. 8
D. $\sqrt{34}$
E. $2\sqrt{10}$

12. Which of the following is the length of the side labeled S in the right triangle given below?
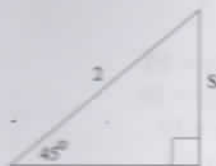
A. 1
B. $\frac{\sqrt{2}}{2}$
C. $\frac{\sqrt{3}}{2}$
D. $\sqrt{2}$
E. 2

13. A velocity of 15 mph is equal to a velocity of how many ft per second?

A. 22
B. 88
C. 352
D. 440
E. 900

14. An angle α in standard position is illustrated in the figure shown below. The coordinates of the point P on the terminal side of the angle are (-8, +15). Which of the following represents cos α?
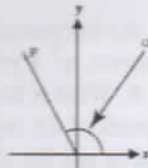
A. 7/17
B. 8/17
C. 15/17
D. -7/17
E. -8/17

15. Which of the following is the value of tan $(-\pi/4)$?

A. -2
B. -1
C. 0
D. 1
E. $\sqrt{\dfrac{3}{2}}$

16. How many miles does 2.5 km equal if 1 km equals 0.6 miles?

A. 0.015
B. 0.15
C. 1.5
D. 15
E. 150

17. Which of the following is equal to x if $(0.36/0.6)(100/72)x = 1$?

A. 12/1000
B. 10/12
C. 12/10
D. 100/12
E. 12/1

18. If an electron has a mass of 9.109×10^{-31} kg, and a proton has a mass of 1.672×10^{-27} kg, approximately how many electrons are required to have the same mass as one proton?

A. 1.8×10^3
B. 1.8×10^5
C. 1.8×10^{-58}
D. 1.8×10^{-3}
E. 1.8×10^{-5}

19. A person is offered a job with a first-year salary of $30,000. Each succeeding year, she receives a 10 percent cost-of-living increase. In addition, each year she is offered up to a $2,000 merit increase. Which of the following will be the maximum amount, in dollars, she earns during the third year?

A. $37,400
B. $38,500
C. $40,000
D. $40,500
E. $60,000

20. Which of the following represents the best approximation for $(3.45 \times 10^7)/(8.29 \times 10^{-2})$?

A. 4.16×10^2
B. 4.16×10^4
C. 4.16×10^6
D. 4.16×10^8
E. 4.16×10^{10}

21. If a machine weighs 3.2 kg, then which of the following will be its weight in g?

A. 3,200
B. 320
C. 32
D. 0.032
E. 0.0032

22. A container holds 8 red and 4 white balls. Two balls are drawn in sequence without replacement from the container. Which of the following represents the probability that exactly one of these balls is red?

A. 16/33
B. 32/132
C. 12/32
D. 56/132
E. 32/144

23. Which of the following is 250 percent of 2/3?

A. 3/5
B. 3/2
C. 5/3
D. 1
E. 2

24. Which of the following is the value of x in the expression shown below if $x \neq 3$ and $x \neq 4$?

$$\frac{5}{2(x+3)} - \frac{1}{(4-x)} = \frac{-2x-1}{-x^2+x+12}$$

A. 16/3
B. 3/16
C. 14/3
D. 3/14
E. 16/11

25. To the nearest multiple of 10, which of the following approximates 29.2 x 9.9?

A. 180
B. 260
C. 270
D. 290
E. 300

26. Which of the following is the number of ounces equivalent to 3 3/8 pounds?

A. 27
B. 34
C. 52
D. 54
E. 62

27. Two days, 10 hours, 18 minutes equals how many minutes?

A. 3018
B. 3218
C. 3498
D. 4858
E. 7818

28. Which of the following is the Celsius equivalent of -13°F?

A. -7.2
B. -23.4
C. -25.0
D. -55.4
E. 24.8

29. Suppose that the speed of light, in cm/sec, is 29,980,000,000. Which of the following represents this in scientific notation?

A. 2998×10^7
B. 2998×10^{12}
C. 2.998×10^{10}
D. 29.98×10^9
E. 2.998×10^{-10}

30. Which of the following best approximates the area, in sq ft, of a circle with a 16-ft radius?

A. 50
B. 100
C. 200
D. 800
E. 1,600

31. Which of the following is the length of each side of a regular hexagon inscribed in a circle with a diameter of 12?

A. 6
B. 12
C. 3
D. $3\sqrt{3}$
E. $4\sqrt{3}$

32. A soup can has a base diameter of 6 cm and a height of 8 cm. If the label on the can covers the sides, what is the area of the label in cm^2, neglecting overlap?

A. 48π
B. 64π
C. 72π
D. 80π
E. 96π

33. How many yards are the equivalent of 18,000 inches?

A. 50
B. 500
C. 648
D. 1500
E. 6000

34. An isosceles triangle has an 8-inch base and a height of 3 inches. Which of the following is the measure of the angle included between the two equivalent sides of the triangle?

A. arctan 3/8
B. 2 (arctan 4/3)
C. tan 3/4
D. 1/2 tan 4/3
E. 2 (tan 3/8)

35. A tennis pro shop tenders a purchase for 4 dozen sweaters at $27 each, 1 1/2 dozen pairs of court shoes at $33 each, 2 dozen racquets at $40 each, and 11 dozen tennis ball packs at $1.20 each. Which of the following best approximates the total cost of the purchase order?

A. $2,000
B. $2,400
C. $2,500
D. $2,850
E. $3,000

36. City workers demarcate a rectangular area that measures 120 feet x 60 feet. If the diagonal of the rectangle is plotted, then which of the following is the smaller of the two angles?
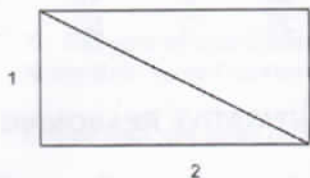
A. tan 2
B. tan 1/2
C. 1/2 tan 2
D. arctan 2
E. arctan 1/2

37. If three coins are flipped, which of the following is the probability that all three faces will be heads?

A. 3/8
B. 1/6
C. 1/4
D. 1/3
E. 1/2

38. A two-disc compact disc set has side times 28:20, 25:45, 25:30, and 21:40. Which of the following is the playing time of the CD set?

	Hours	Minutes
A.	99	25
B.	100	45
C.	101	15
D.	101	25
E.	101	45

39. If f is a function that satisfies $f(x+y) = f(x) f(y)$ for all real numbers x and y. Which of the following must be of $f(0)$?

A. $f(0) = 1$
B. $f(0) = 0$
C. Either $f(0) = 1$ or $f(0) = 0$
D. Insufficient information to draw a conclusion

40. Two sides of an isosceles triangle have length 10 with the third side shorter than these two. If the area is 48, what is the longest possible third side?

A. 10
B. 12
C. 14
D. 16
E. 18

SURVEY OF THE NATURAL SCIENCES

1.	E	26.	D	51.	B	76.	D
2.	B	27.	E	52.	D	77.	A
3.	B	28.	A	53.	B	78.	E
4.	A	29.	E	54.	D	79.	E
5.	C	30.	A	55.	C	80.	D
6.	E	31.	C	56.	D	81.	A
7.	B	32.	E	57.	D	82.	E
8.	C	33.	B	58.	A	83.	E
9.	B	34.	D	59.	E	84.	E
10.	C	35.	E	60.	B	85.	E
11.	D	36.	C	61.	D	86.	B
12.	B	37.	C	62.	D	87.	C
13.	A	38.	A	63.	C	88.	D
14.	D	39.	A	64.	D	89.	B
15.	B	40.	A	65.	A	90.	D
16.	C	41.	B	66.	C	91.	A
17.	C	42.	D	67.	D	92.	C
18.	A	43.	C	68.	B	93.	B
19.	E	44.	B	69.	C	94.	C
20.	C	45.	C	70.	A	95.	D
21.	B	46.	A	71.	C	96.	C
22.	C	47.	B	72.	C	97.	D
23.	B	48.	E	73.	E	98.	D
24.	C	49.	E	74.	D	99.	C
25.	B	50.	D	75.	D	100.	D

READING COMPREHENSION

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

PERCEPTUAL ABILITY TEST

1.	E	21.	B	41.	A	61.	D	81.	A
2	E	22.	B	42.	A	62.	E	82.	A
3.	C	23.	A	43.	C	63.	C	83.	D
4.	B	24.	C	44.	A	64.	C	84.	A
5.	C	25.	B	45.	C	65.	D	85.	C
6.	A	26.	D	46.	B	66.	B	86.	C
7.	B	27.	D	47.	D	67.	D	87.	B
8.	B	28.	B	48.	A	68.	D	88.	D
9.	C	29.	B	49.	E	69.	D	89.	C
10.	D	30.	D	50.	E	70.	D	90.	B
11.	E	31.	B	51.	A	71.	B		
12.	D	32.	C	52.	B	72.	E		
13.	E	33.	C	53.	D	73.	B		
14.	C	34.	B	54.	E	74.	C		
15.	B	35.	C	55.	B	75.	E		
16.	C	36.	A	56.	B	76.	D		
17.	D	37.	A	57.	C	77.	D		
18.	B	38.	D	58.	C	78.	B		
19.	C	39.	D	59.	E	79.	B		
20.	A	40.	A	60.	E	80.	A		

QUANTATATIVE REASONING TEST

1.	C	15.	B	29.	C
2.	D	16.	C	30.	D
3.	D	17.	C	31.	A
4.	D	18.	A	32.	A
5.	E	19.	D	33.	B
6.	B	20.	D	34.	B
7.	B	21.	A	35.	E
8.	B	22.	A	36.	E
9.	B	23.	C	37.	A
10.	D	24.	A	38.	C
11.	C	25.	D	39.	B
12.	D	26.	D	40.	D
13.	A	27.	C		
14.	E	28.	C		

ESTIMATING YOUR STANDARD SCORE

The Raw Score/Standard Score Conversion Table is designed to help you estimate the standard scores that you would have received on the various tests if you had actually taken them. On the DAT, eight standard test scores are reported: Quantitative Reasoning, a separate 40-item test; Reading Comprehension, a 50-item test; Biology, the first 40 items of the Survey of the Natural Sciences; General Chemistry, items 41-70 on the Survey of the Natural Sciences; Organic Chemistry, items 71-100 on the Survey of the Natural Sciences; Total Science, combining the three parts of the Survey of the Natural Sciences (100 items); and Perceptual Ability, a separate 90-item test; Academic Average, the average of the standard scores on the Quantitative Reasoning, Reading Comprehension, Biology, and General and Organic Chemistry tests,

The following procedure will allow you to estimate your standard score.

1.   Take the practice test under timed conditions to approximate the actual test administration.

2.   There is no penalty for attempting an item and getting it wrong. You should attempt every item, eliminating as many incorrect answers as possible when you are not sure of the correct response.

3.   Score the test using the answer key on the following page. Assign 1 point for every item answered correctly and 0 points for every item answered incorrectly.

4.   Add up all the points on a test. This is your raw score.

5.   The next step is to convert your raw score to a standard score. The standard scores on the DAT are reported on a scale ranging from 1 to 30. The mean of the test is approximately 17 but varies from test to test, and test date to test date, depending on the distribution of ability in the persons taking each test.

      To find your standard score, locate the appropriate column for the test you just scored on the Standard Score/Raw Score Conversion Table.

6.   Locate your raw score on that test in this column.

7.   Go across that row to the left-hand column headed "STD Score" to find your standard score.

      For example, if you answered 28 items correctly on the Quantitative Reasoning Test, look to the column labeled QRT and go down that column until you find the score range that includes "28", i.e., 27-28. Then proceed across that row to the column labeled "STD Score" on the left. The row containing 27-28 for the QRT corresponds to a standard score of 19 for that test.

      This procedure can also be used for the Reading Comprehension, Biology, General Chemistry, Organic Chemistry, and Perceptual Ability Tests.

8.   To find your Total Science score, add together your raw scores on Biology, General Chemistry, and Organic Chemistry. The maximum raw score is 100. (Please do not add the standard scores together.)

9.   In the column labeled "SNS" find the row that contains your raw score for the sum of the three science subtests.

10.   Go across the row to the left column to find your Total Science standard score. The Total Science score is not an average of the Biology, General Chemistry and Organic Chemistry standard scores.

For example, if you answered 21 items correctly on Biology, 14 on General Chemistry, and 13 on Organic Chemistry, your Total Science raw score would be 21 + 14 + 13, or 48. Next, find the score range in the "SNS" column that contains "48", i.e., the fifteenth row down when the range is 48-55. Proceed left across that row to the "STD Score" column. In this example, the standard score for a raw score of 48 on the Survey of the Natural Sciences is 15.

11. The Academic Average reported on the DAT is the arithmetic average of five standard scores: Quantitative Reasoning (QRT), Reading Comprehension (RCT), Biology (BIO), General Chemistry (GEN CHEM.), and Organic Chemistry (ORG CHEM). Therefore, if your standard scores on the five tests were

QRT	16
RCT	18
BIO	14
GEN CHEM	15
ORG CHEM	15

$$78 \div 5 = 15.6,$$

the sum of those five scores would be 78. Dividing this total by five yields a score of 15.6. Because the DAT scores are reported only in intervals of 1 point, this would be rounded up to a score of 16. If the average had been 15.4, then the score would have been rounded down to 15.

DENTAL ADMISSION TESTING PROGRAM

STANDARD SCORE-RAW SCORE CONVERSIONS*

TEST PREPARATION MATERIALS

STD SCORE	BIO	GCH	OCH	SNS	PAT	QRT	RCT
1	0	0	0	0-1	0-1	0	0-1
2	-	-	-	-	-	1	-
3	1	-	-	2	2	-	2
4	-	-	-	3	3	2	3
5	-	1	1	4	4	-	-
6	2	-	-	5-6	5	3	4
7	3	2	2	7-8	6-7	4	5-6
8	4	3	3	9-11	8-9	5	7
9	5-6	4	4	12-15	10-13	6-7	8-9
10	7	5	5	16-20	14-16	8-10	10-11
11	8-9	6	6-7	21-25	17-21	11-12	12-13
12	10-11	7-8	8-9	26-31	22-26	13-15	14-16
13	12-14	9-10	10-11	32-39	27-32	16-18	17-19
14	15-17	11-12	12-13	40-46	33-38	19-21	20-21
15	18-19	13-15	14-16	47-54	39-44	22-24	22-24
16	20-22	16-17	17-18	55-61	45-51	25-27	25-27
17	23-25	18-19	19-20	62-68	52-57	28-29	28-30
18	26-27	20-21	21-22	69-74	58-63	30-31	31-33
19	28-30	22-23	23-24	75-80	64-68	32-33	34-36
20	31-32	24	25	81-84	69-73	34-35	37-38
21	33-34	25	26	85-88	74-77	36	39-40
22	35	26	27	89-91	78-80	37	41-42
23	36	27	-	92-93	81-82	38	43
24	37	28	28	94-95	83-84	-	44-45
25	38	-	-	96	85-86	-	46
26	-	29	-	97	87	-	47
27	-	-	29	98	-	39	-
28	39	-	-	-	88	-	48
29	-	-	-	99	-	-	-
30	40	30	30	100	89-90	40	49-50

*The tabled values should be considered only estimates of the examinees' performance on the current test.