The 61st Annual
Merck State Science Day Competition
May 17, 2011

Physics

Directions:
PLEASE DO NOT OPEN THE EXAM BOOKLET UNTIL DIRECTED.

Be sure to fill in your name on the answer sheet both by printing it in the correct space, and by filling in the corresponding letter in the provided spaces.

Use a #2 pencil only.

Carefully erase any errors, and do not make any extraneous marks on the answer sheet. You may write on the test but all answers must be recorded on the Scantron answer sheet.

The test has 60 items that will be scored. You have **90** minutes in which to answer them.

There is only one correct answer per question. Do not spend too much time on any one question. Do the items you find easier first, and then go back to those you find more difficult or time consuming during the time you have remaining. Your individual score will be computed on the basis of the number of correctly answered items. Each question counts the same. No question is weighted. (There is no penalty for guessing)

There are important subject-specific items below that you may find useful in answering certain questions. Be sure to read them before you begin the test.

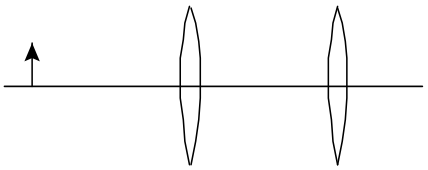
Proton mass	$m_p = 1.67 \times 10^{-27}$ kg
Electron mass	$m_e = 9.11 \times 10^{-31}$ kg
Magnitude of electron charge	$q_e = 1.60 \times 10^{-19}$ C
Speed of light	$c_{\text{in a vacuum}} = 3.00 \times 10^8$ m/s
Coulomb's law constant	$k = 9.0 \times 10^9$ Nm^2/C^2
Universal gravitation constant	$G = 6.67 \times 10^{-11}$ m^3/kg-s^2
Gravitational field near Earth	$g = 9.8$ N/kg
	1 mile = 1.609 km
atmosphere pressure	1 atm= 1.0×10^5 N/m^2 = 1.0×10^5 Pa = 14.7 lb/in^2
Mean radius of the earth	$R = 6.371 \times 10^6$ m
Mass of the earth	$m = 5.98 \times 10^{24}$ kg
Vol of sphere	$Vol_{sphere} = 4/3\ \pi R^3 = 1.33\ \pi R^3$
Surface area of a sphere	Surface $Area_{sphere} = 4\ \pi R^2$

Merck State Science Day 2011 **PHYSICS**

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question and ***place your selection ON THE ANSWER SHEET***

Treat all questions as non-relativistic. Unless otherwise indicated ignore friction with the air. Figures are not drawn to scale.



The following description and figure are for questions 1, 2, and 3.

1-3 Given two thin positive lenses positioned so that their centers of curvature fall on a straight line. The focal length of lens 1, F1,(the left lens) is 0.30 m and the focal length of lens 2, F2, (the right lens) is 0.15 m. The lenses are 0.30 m apart. A small object is located 0.20 m to the left of lens 1. It is located on the principal axis of the lenses and is 0.01 m tall. It is erect.

1.. Compared with the original object the image formed by lens 2 is ___ .

A) real and erect B) real and inverted C) virtual and erect
D) virtual and inverted E) no image is formed

2. The image formed by lens 2 is ___ m tall.

A) no image formed B) 0. 002 C) 0.006 D) 0.02 E) 0.06

3. The focal length of lens 1 is 0.30 m in air. It is a biconvex lens, and the magnitude of the radii are equal. If its radius of curvature were doubled, its focal length would be ___ the original value.

A) 4 times B) double C) the same as D) half E) one-fourth

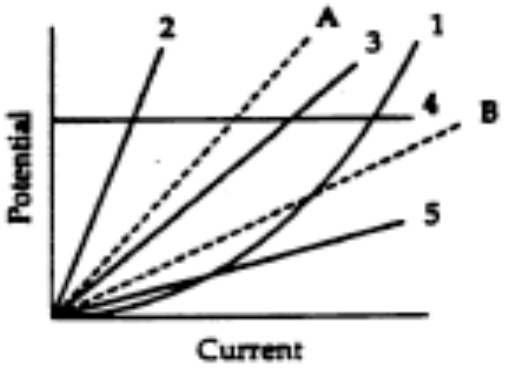
4. Given a moving observer and a stationary sound source. The observer is moving toward the source at a speed of 26.8 m/s (60 miles per hour). The source is emitting a 3,000 Hz sound (as heard on the source). The speed of sound in the air is 343 m/s. The moving observer hears a frequency of approximately ____ Hz .

A) 3800 B) 3700 C) 3500 D) 3200 E) 2800

5. A small object is in space. It is being accelerated by a force of 10 N acting to the right. Then, the object encounters a second force of 10 N to the left. Now, it has two forces acting on it. The object ___ .

A) is brought abruptly to a stop
B) continues with the speed it had when the second force was applied
C) continues to accelerate at a constant rate but to the left
D) slows to rest

The following description and figure are for question 6



6. Given graphs of "Potential Difference as a Function of Current" for two resistors A and B. The dashed lines represent the data for A and B. If resistors A and B were placed in parallel, which of the 5 solid lines would represent the data for the parallel combination? __ .
A) 1 B) 2 C) 3 D) 4 E) 5

The following description is for questions 7, 8, and 9

7-9 Given a string vibrating in its fundamental mode (one loop). Two meters of string are i vibration. The vibration rate is 120 Hz . The amplitude for the motion is 1 cm (0.01 m)

7. The speed of the wave on the string is ____ m/s .
A) 502 B) 480 C) 360 D) 240 E) 120

8. The frequency required to produce a standing wave of two loops is ___ Hz .
A) 502 B) 480 C) 360 D) 240 E) 120

9. If the tension were doubled, the wavelength of the fundamental frequency would ____ time the original. A) 4 B) 2 C) 1.41 D) 1 E) 0.71

10. Given a circular cylindrical water tank. The diameter of the tank is 7.0 m The tank is 15.0 m tall .It is used to store water and is filled to a depth of 12.0 m. The tank is supported. The bottom of the tank is 15.0 m above the ground. The upper end of the tank is open to the atmosphere. There is a round hole in the side of the tank 2.0 m above the bottom. The hole is 0.04 m in diameter. The speed of the water as it exits through the hole is ___ m/s .
A) 9.1 B) 9.9 C) 12.9 D) 14.0 E) 15.3

11. An object is placed to the left of a positive (converging) lens. Regardless of where the object is placed, the image formed by the lens is never__
A) virtual and reduced B) virtual and enlarged C) real and reduced
D) real and enlarged E) real and the same size as the object

The following description is for questions 12, 13, and 14

12, 13, 14 A force of 400 N is exerted on a 200 N block sliding it from rest 12 m downward along an inclined plane. The 400 N force is parallel to the plane. The ending point for the block is 5 m below the elevation of the starting point. In pushing the block down the plane there is a force due to friction of 80.0 N .

12. The coefficient of friction between the block and the plane is __ .
A) 0.20 B) 0.26 C) 0.32 D) 0.44 E) 0.49

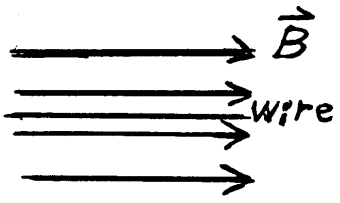
13. The speed of the block at the end of the 12 meters is approximately
___ m/s . A) 70 B) 60 C) 22 D) 16 E) 1.6

14. If the plane were horizontal, the work done by a 400 N push over the 12 m distance would be _____ the value when the plane was inclined.
A) 11/5 times B) more than C) the same as D) 5/11 times E) less than

15. Two people, each of mass 80.0 kg, originally at rest, are having a game of catch on a frictionless horizontal surface. Person I is at the zero mark and throws a 20.0 kg object at 40.0 m/s to a second person II. Person II is at the 10.0 m mark and catches the object. After II catches the object, persons I and II will be separating at __ m/s .
A) 20 B) 18 C) 10 D) 8 E) 2.4

The following description and figure are for question 16

16. A wire is located in the center of a uniform magnetic field as represented to the right. The wire is parallel to the magnetic field lines as shown as to the right. Then the wire is connected to a battery resulting in a traditional current in the wire directed to the right. The force on the wire due to the current in the magnetic field is directed ____ .



A) to the right B) to the left C) toward the top of the page
D) toward the bottom of the page E) none of these

17. A hydraulic jack has a larger piston of diameter 0.18 m in diameter and a smaller piston with a diameter of 0.06 m . If a force of 250.0 Newtons is applied to the smaller piston the force exerted by the larger piston will be ___ Newtons.
A) 2250 B) 750 C) 250 D) 83 E) 28

18. Two lamps, one with a thick filament and one with a thin filament, are connected in serie The current in the thick filament is ____ the current in the thin filament.
A) greater than B) the same as C) less than

19. On the ruler used to obtain the measured value, 0.0350 m , assuming it has the correct number of significant figures, the smallest gap between lines is ____ . A) meters B) decimeters C) cm D) mm E) tenths of mm

20. A 10 kg brick and a 1 kg brick are dropped in a vacuum here on earth. The force of gravity on the 1 kg brick is ____ .
A) equal to the force of gravity on the 10 kg brick
B) one-tenth as large as the force of gravity on the 10 kg brick
C) zero

21. As a basketball player starts to jump for a rebound, the player begins to move faster and faster until the player leaves the floor. During the time that the player is in contact with the floor, the force of the floor on the player is ___ .
A) larger than the player's weight B) less than the players weight
C) equal in magnitude and opposite in direction to the players weight D) zero

22. When sound goes from a medium in which its speed is v into a medium in which i speed is v/2, its frequency _____.
A) doubles B) is the square root of 2 times its original value C) is halved
D) equals its original frequency divided by the square root of 2 E) remains the same

23. If the observed frequency of the light reaching the earth from a star is less than th frequency of light from the same kind of atom "at rest" on earth, the earth is _____ the sta
A) moving away from B) moving toward
C) in resonance with D) stationary with respect to

24 Given a tube open at one end and closed at the other. It resonates with a fundamental frequency f1 . The tube is now open at both end and resonates with a fundamental frequency f2. f1 is ___ f2 .
A) 4 times B) twice C) 1.41 times D) the same as E) half

25. Given a horizontal pipe 0.04 m in radius. The pipe enlarges to a horizontal section 0.08 m in radius. An ideal incompressible liquid flows through the pipe. The flow rate through the first section, the reduced section, is 0.020 m^3/s .
The flow rate in the larger diameter section is __ m^3/s .
A) 0.0025 B) 0.005 C) 0.020 D) 0.040 E) 0.080

The following description is for questions 26, 27, 28 and 29

26, 27, 28, and 29 Given a small object, an arrow, 25 cm to the left of a convex mirror with a focal length of -10 cm. The mirror, object and image are all in air.

26. The magnitude of the radius of curvature of the mirror is ___ cm .
A) 60 B) 40 C) 30 D) 20 E) 10

27. The image formed by the mirror is approximately _____ of the mirror.
A) 7 cm to the right B) 7 cm to the left C) 20 cm to the left
D) 10 cm to the left E) 10 cm to the right

28. If you cover the bottom half of the mirror, the new image ___ .
A) is only the top half of the original
B) is only the bottom half of the orig. image
C) is a full arrow but half the original height
D) is a full arrow but half the original height
E) is a full arrow with the same original height.

29. If the mirror had been in water, then its focal length in water would have been _____ its focal length in air. A) 3/4 B) 4/3
C) equal to D) less than (but not 3/4) E) greater than (but not 4/3)

30. A 1.0 m^3 quantity of an ideal gas has a temperature of 127 degrees Celsius and absolute pressure 2.0 X 10^{+5} Pascal. The temperature is increased to 327 degrees Celsius and the volume increases to 4.0 m^3 .
The absolute pressure will be ____ X 10^{+5} Pascal.
A) 3 B) 1.3 C) 1 D) 0.75 E) 0.5

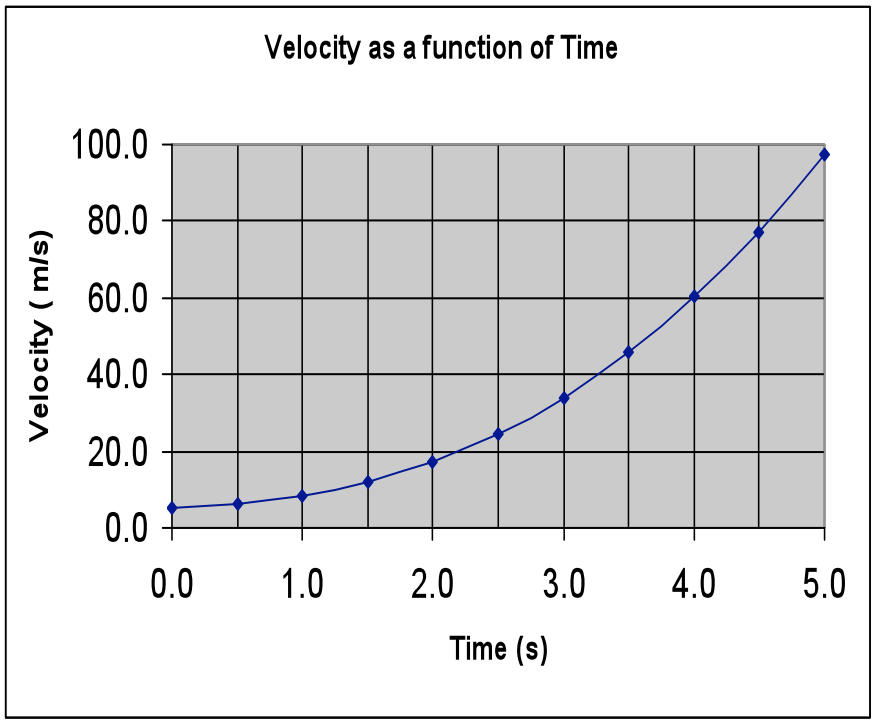
31. Two mechanical waves meeting at a point ___ .
A) combine at the point but bounce off each other like billiard balls
B) always invert each other
C) always reduce the size of each other
D) combine at the point but pass on by unchanged
E) combine at the point but pass on by distorted

32. You hold a 3 Newton apple 2 m off the ground at rest. Upon release the net force on the falling apple is ___ N .

A) 29.4 B) 3 C) 3/9.8 D) 0.2 E) zero

The following description and figure are for questions 33, 34, 35, and 36

Time	Velocity
s	m/s
0.0	5.0
0.5	6.0
1.0	8.3
1.5	12.0
2.0	17.4
2.5	24.7
3.0	34.1
3.5	45.9
4.0	60.2
4.5	77.3
5.0	97.5



33, 34, 35, 36 Given a table and graph to represent the rectilinear horizontal motion of a 2.0 kg mass. When time was zero, the mass was at the zero mark.

33. In the 5.0 s interval represented, the change in momentum of the mass was approximately ___ kg m/s . A) a gain of 185 B) a gain of 92
C) a gain of 86 D) a loss of 90 E) a loss of 275

34. The average velocity of the mass over the 5.0 s was approximately ___ m/s.
A) 46 B) 40 C) 35 D) 30 E) 25

35. When time was 2.0 s, the acceleration of the mass was approximately ___ m/s^2
A) 12 B) 17 C) 22 D) 25 E) 9

36 During the 5 second interval the acceleration was ___ .
A) was positive and constant B) was positive and decreasing
C) was negative and decreasing D) was positive and increasing
E) was negative and getting more negative

The following description is for questions 37 and 38

37-38 Given a 400 N block resting on a flat horizontal table. The coefficient of static friction between the table and the block is 0.30 and the coefficient of kinetic friction is 0.15 .

37. The force from the table on the block while it is setting there is ____ .
A) 418 N directed to the right or left (horizontal) B) directed straight upward
C) 418 N directed upward but leaning to the left or right D) zero E) downward

38. A horizontal force of 100.0 N to the right acts on the block. While the 100 N force is acting, the force from the table on the block is approximately ___ .
A) 412 N directed upward but leaning to the left B) 412 N straight upward
C) 418 N directed upward but leaning to the left D) zero E) 400 N downward

39. The specific heats , expressed in J/ kg C^o , for some materials are:
Aluminum 900, Copper 387, Ice 2090, Iron 448, Water 4186
Given 2 kg of each of these five materials, all at -10 degrees Celsius except the water which is at 10 degrees Celsius. Adding 10 Joules of energy slowly and evenly to each will result in the temperature of ____ increasing the most.
A) ice B) water because you cannot heat ice C) water D) aluminum E) copper

The following description is for questions 40, 41, and 42

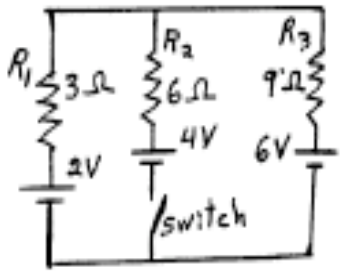
40, 41, 42 Given a monochromatic light source illuminating a double slit and producing an interference pattern on a screen a distance D from the slits. The separation between the zeroth order (point on the screen opposite the midpoint between the slits) and a particular interference maximum is indicated as y.

40. If the wavelength had been 50% larger, the distances to the maximums (the y values) from the center,) , would have ___ .
A) doubled B) been halved C) been 50% larger
D) been 50% smaller E) remained the same

41. If the separation between the slits, d , had been 50% larger, the distances to the maximums (the y values) from the center would have been __ the original.
A) 150% of B) twice C) the same as D) half E) 2/3 as large as

42. If the size of the slits had been increased by 10%, the distances to the maximums (the y values) from the center,) , would have been ___ .
A) 20% larger B) 10% larger C) the same D) 10% smaller E) 20% smaller

The following description and figure are for questions 43 and 44



43-44, Given Resistors R1, R2, and R3 of 3 ohms
6 ohms, and 9 ohms , respectively, and three ideal emf's of 2 V, 4 V, and 6 V , respectively.

43. With the switch closed, the current in R3 is __ A.
A) 2/3 B) 1/2 C) 3/8 D) 14/33 E) 10/33

44. With the switch open the current in R3 is ___ A .
A) 1.5 B) 1.0 C) 0.67 D) 0.33 E) 0.16

The following description is used for questions 45 and 46.
45, 46. A capacitor is charged to 50 V and then discharged through a resistor. The capacitance of the capacitor is 4 microfarads (0.000004 F). The resistance is 2 mega ohm (2,000,000 ohms).

45. The initial charge on the capacitor was ___ Coulomb.
A) 0.0002 B) 0.008 C) 0.08 D) 1.2 E) 1.6

46. After 8 s the current through the resistor was approximately ___ X 10^{-6} A .
A) 5 B) 9 C) 14 D) 18 E) 22

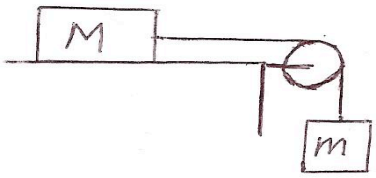
47. Steam enters a turbine at a temperature of 800 degrees Celsius and is exhausted at 200 degrees Celsius. The maximum thermal efficiency for this device is ___ % . A) 67 B) 56 C) 50 D) 46 E) 33

The following description is used for questions 48 and 49
48 – 49. Given an isotropic single frequency sound source radiating equally in all directions. At a point 6.0 m from the source the sound intensity is 10^{-5} W/m^2 , or 70.0 dB .

48. At a point 3.0 m from the source the sound level intensity was ___ W/m^2
A) 0.0004 B) 0.00033 C) 0.00002 D) 0.000033 E) 0.00004

49. The sound level in dB at the 3.0 m distance is approximately__ dB .
A) 6 B) 67 C) 70 D) 73 E) 76

The following description is used for questions 50 and 51



50, 51. Given two masses, M, of 30.0 kg and m of 15.0 kg, attached to the ends of a very light cord which passes over a pulley as shown to the left. M is on a flat horizontal surface. The cord passes from M horizontally over the pulley and then vertically downward to the mass m. The axle of the pulley is frictionless. Neglect the mass of the cord. The pulley is a circular solid disk of uniform density with a radius of 0.10 m and a moment of inertia about its axis of rotation of 0.15 kg-m^2. At time equals zero the pulley and masses are released from rest. Mass m descends and M moves to the right. The pulley rotates with no slippage of the cord. The pulley has an angular acceleration of 2.0 rad/s^2.

50 The tension in the section of cord attached to m is ___ N.
A) 3 B) 82 C) 120 D) 144 E) 147

51. The coefficient of friction between the block M, 30.0 kg, and the plane is ___
A) 0.28 B) 0.33 C) 0.38 D) 0.43 E) 0.48

The following description is used for questions 52 and 53

52, 53. Given a small 0.500 kg mass attached to the right hand end of a "massless spring" on a frictionless horizontal surface. The left end of the spring is attached to a rigid support. The force constant, k, of the spring is 600.0 N/m (force of 600 N is required to stretch the spring horizontally a distance of 1.00 m). The mass is initially in equilibrium and at rest. Then, the mass is displaced from rest a distance of 0.20 m to the right and released with an initial speed of 3.0 m/s back toward the left (toward the support). It oscillates in simple harmonic motion.

52. When the mass is at the 0.15 m mark, its speed will be ___ m/s .
A) 5.5 B) 4.0 C) 3.9 D) 3.5 E) 3.0

53 If this had taken place in "deep space", far away from any large gravitational mass, the period would be ___ that on earth. A) zero (no oscillation) B) many, many times C) the same as D) 8 times E) 32 times

The following description is used for questions 54, and 55.

54-55. Two masses have a "head-on" collision. Mass I has a mass of 4.0 kg and is moving to the right at 3.0 m/s. Mass II has a mass of 3.0 kg and is moving to the left at 2.0 m/s. At time equals zero mass II is 15 m to the right of mass I . The two masses hit and stick together.

54. The masses collide when time is __ s

A) 15 B) 6 C) 5 D) 3 E) never

55. After the collision the velocity of the masses is ___ m/s .

A) 0.86 to the right B) 0.86 to the left C) 1.7 to the right

D) 1.7 to the left E) 3.0 to the right

The following description is for questions 56, and 57

56-57. A parallel plate capacitor is oriented horizontally (plates are horizontal) Plates are 0.02 m apart. The capacitor is in a vacuum. An electron traveling horizontally at 1,000,000 m/s (10^{+6} m/s) enters the gap between the plates at the middle of the gap. The plates are 0.035 m long. The lower plate is positive, and the upper plate is negative. The uniform electric field between the plates is 750 N/C .

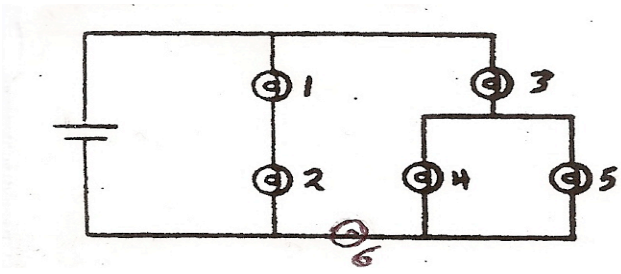
56. While in the field between the plates, the electron descends ___ m

A) 0.01 B) 0.007 C) 0.001 D) 0.0005 E) 0.0007

57. If the particle had been a proton at 1,000,000 m/s, it would have ascended __m

A) 0.01 B) 0.007 C) 0.001 D) 0.0005 E) 0.00004

The following figure and description are for question 58



58. Given six resistors as shown to the left. The resistance of 1 is 1.0 ohm, of 2 is 2.0 ohm, of 3 is 3.0 ohm, etc. The equivalent resistance for the 6 resistors is __ ohms.

A) 2.4

B) 3.2

C) 3.9

D) 4.2

E) 4.8

Use the following information for questions 59 and 60

59-60 Given a one meter long plank weighing 80.0 N. Three forces are applied to the plank. The forces are: 100.0 N at the left end of the plank (the zero mark), and 150.0 N at the 0.90 m mark (0.90 m from the left end), both upward. 100.0 N downward at 0.40 m from the left end, The plank with forces is in equilibrium due to a force at the 0.50 m mark.

59. The center of gravity of the plank is at the __ m on the plank.

A) 0.2 B) 0.25 C) 0.5 D) 0.75 E) 0.85

60. The net force applied at the 0.50 m mark is ___ N .

A) 430 upward B) 80 upward C) zero D) 130 downward E) 70 downward

Merck State Science Day 2011 PHYSICS
Answer Section

MULTIPLE CHOICE

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