1. The diagram below represents magnetic lines of force within a region of space.

The magnetic field is strongest at point
(1) A  (3) C
(2) B  (4) D

2. The diagram below shows the magnetic field that results when a piece of iron is placed between unlike magnetic poles.

At which point is the magnetic field strength greatest?
(1) A  (3) C
(2) B  (4) D

3. A volt is to electric potential as a Tesla is to
(1) electrical energy
(2) electric field intensity
(3) magnetic flux density
(4) charge density

4. In which diagram below is the magnetic flux density at point P greatest?

(1)  
(2)  
(3)  
(4)  

5. As the distance between two opposite magnetic poles increases, the flux density midway between them
(1) decreases  (3) remains the same
(2) increases

6. In the diagram below, a steel paper clip is attached to a string, which is attached to a table. The clip remains suspended beneath a magnet.

As the magnet is lifted, the paper clip begins to fall as a result of
(1) an increase in the potential energy of the clip
(2) an increase in the gravitational field strength near the magnet
(3) a decrease in the magnetic properties of the clip
(4) a decrease in the magnetic field strength near the clip
7. The diagram at the below represents a bar magnet.

The direction of the magnetic field at point $P$ is toward point:

(1) $A$  (2) $B$  (3) $C$  (4) $D$

8. The field around a permanent magnet is caused by the motions of:

(1) nucleons  (2) protons  (3) neutrons  (4) electrons

9. In the diagram above, what is the direction of the magnetic field at point $P$?

(1) toward $A$  (2) toward $B$  (3) toward $C$  (4) toward $D$

10. Conventional current is flowing southward in a power line. The geographic direction of the magnetic field under the power line is:

(1) east  (2) west  (3) north  (4) south

11. Which type of field is present near a moving electric charge?

(1) an electric field, only  (2) a magnetic field, only  (3) both an electric field and a magnetic field  (4) neither an electric field nor a magnetic field
12. Which diagram best represents the magnetic field around a straight wire in which electrons are flowing from left to right?

![Diagram Options]

13. Which diagram best illustrates the magnetic field that exists around a current-carrying wire?

![Diagram Options]

14. The diagram below represents the magnetic field around point $P$, at the center of a current carrying wire.

What is the direction of electron flow in the wire?
(1) from $A$ to $B$
(2) from $B$ to $A$
(3) from $P$ into the page
(4) from $P$ out of the page
15. Electrons are flowing in a conductor as shown in the diagram at the right. What is the direction of the magnetic field at point $P$?

- toward the top of the page
- toward the bottom of the page
- into the page
- out of the page

16. Electrons are moving to the right in the conductor represented in the diagram. What is the direction of the magnetic field above the wire at point $P$?

- into the page
- out of the page
- toward the top of the page
- toward the bottom of the page

17. Each diagram below represents a cross section of a long, straight, current-carrying wire with the electron flow into the page. Which diagram best represents the magnetic field near the wire?

18. Which diagram best represents the magnetic field around a current-bearing conductor?

19. Which diagram best represents the direction of the magnetic field around a wire conductor in which the electrons are moving as indicated? [The X's indicate that the field is directed into the paper and the dots indicate that the field is directed out of the page.]

20. The magnetic lines of force near a long straight current-carrying wire are

- straight lines parallel to the wire
- straight lines perpendicular to the wire
- circles in a plane perpendicular to the wire
- circles in a plane parallel to the wire

21. In order to produce a magnetic field, an electric charge must be

- stationary
- moving
- positive
- negative
22. The diagram below shows an electromagnet made from a nail, a coil of insulated wire, and a battery.

The south pole of the electromagnet is located closest to point
(1) A  (3) C
(2) B  (4) D

23. In which diagram of a current-carrying solenoid is the magnetic field correctly represented?

24. A coil of wire is carrying electric current. As an iron core is inserted into the coil of wire, the field strength of the electromagnet formed
(1) decreases  (3) remains the same
(2) increases
25. Toward which point is the direction of the magnetic field inside the current-carrying coil in the diagram below? (arrows represent direction of electron flow)

![Diagram of a current-carrying coil with arrows indicating electron flow.]

(1) A  (2) B  (3) C  (4) D

26. The diagram below shows a coil of wire (solenoid) connected to a battery.

![Diagram of a solenoid with a battery connected.]

The north pole of a compass placed at point P would be directed toward point
(1) A  (2) B  (3) C  (4) D

27. In the diagram at the right, electron current is passed through a solenoid. The north pole of the solenoid is nearest to point

![Diagram of a solenoid with a north pole marked.]

(1) A  (2) B  (3) C  (4) D

28. The diagram below shows an electron current in a wire loop.

![Diagram of an electron current in a loop.]

What is the direction of the magnetic field at the center of the loop?
(1) out of the page  (2) into the page  (3) clockwise  (4) counterclockwise

29. Two solenoids are wound on soft iron cores and connected to batteries, as shown in the diagram below.

![Diagram of two solenoids with switches S1 and S2.]

When switches S1 and S2 are closed, the solenoids
(1) repel because of adjacent north poles  (2) repel because of adjacent south poles  (3) attract because of adjacent north and south poles  (4) neither attract nor repel
30. The speaker in the diagram below makes use of a current-carrying coil of wire.

The N-pole of the coil would be closest to
(1) A  (3) C
(2) B  (4) D

31. In the diagram below, A, B, C, and D are points near a current-carrying solenoid.

Which point is closest to the north pole of the solenoid?
(1) A  (3) C
(2) B  (4) D

32. If the current through a solenoid increases, the magnetic field strength of the solenoid
(1) decreases  (3) remains the same
(2) increases

33. In the diagram below A, B, C, and D are points in the magnetic field near a current carrying loop. At which points is the direction of the magnetic field into the page?

(1) A and B  (3) C and D
(2) B and C  (4) A and D

34. In the diagram, in which direction is the magnetic field at point X?

(1) toward A  (3) toward C
(2) toward B  (4) toward D
35. The diagram below shows electron $e$ about to enter the region between the poles of two magnets.

Upon entering the region between the poles, the moving electron will experience a magnetic force directed
(1) toward the north pole
(2) toward the south pole
(3) into the page
(4) out of the page

36. In the diagram below, a wire carrying an electron current into the page, as denoted by $X$, is placed in a magnetic field.

The magnetic field exerts a force on the wire toward point
(1) $A$
(2) $B$
(3) $C$
(4) $D$

37. In the diagram at the right, when the negative current is flowing in the direction indicated by the arrow, the direction of the force in the wire will be

(1) toward the north pole
(2) toward the south pole
(3) out of this paper
(4) into this paper

38. In the diagram below, a wire is suspended in the presence of a magnetic field. As electrons begin to flow through the wire as indicated, in which direction will the wire tend to move?

(1) $A$
(2) $B$
(3) $C$
(4) $D$

39. In the diagram at the right, electrons flowing through the wire as shown will cause the wire to move toward the

(1) north pole
(2) south pole
(3) top of the page
(4) bottom of the page
40. In the diagram below, a free electron is traveling upward at speed $V$ parallel to a conductor. An electron current begins to flow upward in the conductor.

Which diagram best represents the resulting magnetic field, $B$, and the direction of the magnetic force, $F$, on the free electron?

41. The diagram below shows particles produced by thermionic emission at the end of a heater element about to enter a magnetic field directed into the page.

Upon entering the magnetic field, the negatively-charged particles will be deflected
(1) toward the top of the page
(2) toward the bottom of the page
(3) into the page
(4) out of the page

42. The diagram below represents a straight conductor between the poles of a permanent magnet.

If electrons flow within the conductor in the direction shown, then the magnetic force on the conductor is directed
(1) toward N
(2) toward S
(3) into the page
(4) out of the page
43. A wire carrying an electron current (e⁻) is placed between the poles of a magnet, as shown in the diagram below.

Which arrow represents the direction of the magnetic force on the current?

(1) A  (3) C
(2) B  (4) D

44. The diagram to the right represents a conductor carrying a current in which the electron flow is from left to right. The conductor is located in a magnetic field which is directed into the page.

The direction of the magnetic force on the conductor will be
(1) into the page
(2) out of the page
(3) toward the top of the page
(4) toward the bottom of the page

45. The diagram at the right represents a conductor carrying an electron current in magnetic field B. The direction of the magnetic force on the conductor is
(1) into the page
(2) out of the page
(3) toward the top of the page
(4) toward the bottom of the page

46. A beam of electrons is moving to the west. In which direction would a magnetic field have to be directed to deflect the beam downward?

(1) north  (3) east
(2) south  (4) west

47. A particle is being accelerated by a magnetic field. This particle must be
(1) neutral and stationary
(2) neutral and in motion
(3) charged and stationary
(4) charged and in motion

48. When electrons flow from point A to point B in the wire shown in the diagram shown to the right, there will be a force produced on the wire

(1) toward N  (3) into the page
(2) toward S  (4) out of the page

49. A charged particle is moving with a constant velocity. On entering a uniform magnetic field, the particle

(1) must decrease in speed
(2) must change the magnitude of its momentum
(3) may change its direction of motion
(4) may increase in kinetic energy

50. An electron moving in a uniform magnetic field experiences the maximum magnetic force when the angle between the direction of the electron's motion and the direction of the magnetic field is

(1) 0°  (3) 90°
(2) 45°  (4) 180°
51. An electron traveling at a speed \( V \) in the plane of this paper enters a uniform magnetic field. Which diagram best represents the condition under which the electron will experience the greatest magnetic force as it enters the magnetic field?

(1)![Diagram](image1)
(2)![Diagram](image2)
(3)![Diagram](image3)
(4)![Diagram](image4)

52. Which device converts electrical energy into mechanical energy?
(1) motor  (3) source of emf
(2) generator  (4) thermocouple

53. The two ends of a wire are connected to a galvanometer, forming a complete electric circuit. The wire is then moved through a magnetic field, as shown in the diagram below.

![Diagram](image5)

The galvanometer is being used to measure
(1) current  (3) temperature change
(2) potential difference  (4) resistance
54. A single loop of wire is placed between the poles of permanent magnets, as shown in the diagram below.

If a potential difference is applied to the ends of loop $AB$, in which direction will the loop move?
(1) up toward $z$  
(2) down toward $z'$  
(3) around the $y$–$y'$-axis  
(4) around the $x$–$x'$-axis

55. As the armature of an operating electric motor turns, a voltage is induced. This voltage is opposite in direction to the applied voltage and referred to as
(1) conduction  
(2) reverse current  
(3) magnetic levitation  
(4) back emf

56. A student uses identical field magnets and coils of wire, as well as additional components, to make the electric motors shown in the diagrams below. Which combination of core and current through the coil of wire will produce the greatest torque on the motor's armature?

57. A direct-current source is used to operate an electric motor. After each half-rotation of the armature, the split-ring commutator
(1) reverses the direction of the field magnet  
(2) increases the direction of the field magnet  
(3) reverses the direction of the current in the armature  
(4) increases the current in the armature

58. An operating electric motor produces a back emf, which opposes the applied potential difference. As a result, the armature current
(1) decreases  
(2) increases  
(3) changes from D.C. to A.C.  
(4) changes from A.C. to D.C.
59. Which statement best describes the torque experienced by a current-carrying loop of wire in an external magnetic field?

(1) It is due to the current in the loop of wire, only.
(2) It is due to the interaction of the external magnetic field and the magnetic field produced by current in the loop.
(3) It is inversely proportional to the length of the conducting loop in the magnetic field.
(4) It is inversely proportional to the strength of the permanent magnetic field.

60. A split-ring commutator is used to

(1) reduce the voltage in a transformer
(2) reduce the resistance of the shunt in an ammeter
(3) make the light waves coherent in a laser
(4) keep the torque acting in the same direction in a motor

61. The loop shown in the diagram below rotates about an axis which is perpendicular to a constant uniform magnetic field.

If only the direction of the field is reversed, the magnitude of the maximum induced potential difference will

(1) decrease
(2) increase
(3) remain the same

62. The diagram below shows a solenoid that is free to rotate around an axis at its center, C, is placed between the poles of a permanent magnet.

As an electron current starts through the solenoid in the direction shown, the solenoid will

(1) remain motionless
(2) vibrate back and forth
(3) start turning clockwise
(4) start turning counterclockwise

63. The torque on the armature of an operating electric motor may be increased by

(1) decreasing the current in the armature
(2) decreasing the magnetic field strength of the field poles
(3) increasing the potential difference applied to the armature
(4) increasing the distance between the armature and the field poles

64. In a practical motor, the coil is wound around a soft iron core. The purpose of the soft iron core is to

(1) strengthen and concentrate the magnetic field through the coil
(2) cause the torque on the coil to remain in the same direction
(3) convert alternating current to direct current
(4) oppose the applied potential difference and reduce the current in the coil

65. The physical structure of an electric motor most closely resembles that of

(1) a mass spectrograph
(2) a cathode ray tube
(3) a transformer
(4) an electric generator
66. The diagram below shows a wire moving to the right at speed \( v \) through a uniform magnetic field that is directed into the page.

As the speed of the wire is increased, the induced potential difference will
(1) decrease  (3) remain the same
(2) increase

67. A potential difference of 12 volts is induced across a 0.20-meter-long straight wire as it is moved at a constant speed of 3.0 meters per second perpendicular to a uniform magnetic field. What is the strength of the magnetic field?
(1) 180 T  (3) 13 T
(2) 20. T  (4) 7.2 T

68. In the diagram below, a segment of wire, \( RS \), which is 0.20 meter in length, is free to slide along a U-shaped wire located in a uniform 0.60-tesla magnetic field directed into the page.

If wire segment \( RS \) is slid to the right at a constant speed of 4.0 meters per second, the potential difference induced across the ends of the wire segment is
(1) 0.12 V  (3) 2.4 V
(2) 0.48 V  (4) 4.8 V

69. The diagram below shows an end view of a metal rod moving upward perpendicular to a uniform magnetic field having a flux density of \( 2.0 \times 10^{-2} \) Tesla. The 2.0-meter-long wire is moving at a constant speed of 3.0 meters per second.

What is the emf induced across the rod?
(1) 0.060 V  (3) 1.2 V
(2) 0.12 V  (4) 6.0 V

70. A potential difference of 10. volts is induced in a wire as it is moved at a constant speed of 5.0 meters per second perpendicular to a magnetic field with a flux density of 4.0 Newtons per ampere-meter. What is the length of the wire in the field?
(1) 0.50 m  (3) 8.0 m
(2) 2.0 m  (4) 200 m

71. In the diagram below, a 0.50 meter long wire is moved at a speed of 2.0 meters per second perpendicularly through a uniform magnetic field with a flux density of 3.0 Teslas directed into the page.

What is the induced electromotive force?
(1) 1.0 V  (3) 3.0 V
(2) 1.5 V  (4) 12 V
72. The magnitude of the electric potential induced across the ends of a conductor moving in a magnetic field may be increased by
(1) increasing the diameter of the conductor
(2) increasing the speed of the conductor
(3) decreasing the resistance of the conductor
(4) decreasing the length of the conductor

73. A conductor is moving perpendicularly through magnetic field $B$ as represented in the diagram above. If the magnetic field strength is doubled, the electric potential across the ends of the conductor will
(1) be quartered
(2) double
(3) be halved
(4) remain the same

74. A conducting loop is rotating in a uniform magnetic field, causing an induced potential difference across the ends of the loop. As the speed of rotation of the loop increases, the induced potential difference
(1) decreases
(2) increases
(3) remains the same

75. A conducting loop is rotating at a constant frequency between opposite poles of a magnet, causing an induced potential difference across the ends of the loop. As the two magnetic poles are moved farther apart, the induced potential difference
(1) decreases
(2) increases
(3) remains the same

76. In the diagram below, a potential difference is induced in a rectangular wire loop as it is rotated at constant speed between two magnetic poles.

If the direction of the field is reversed and the speed of rotation is doubled, the magnitude of the maximum induced potential difference will be
(1) one-half as great
(2) twice as great
(3) the same
(4) four times as great

77. The diagram below shows an electron, $e$, located in a magnetic field.

There is no magnetic force on the electron when it moves
(1) toward the right side of the page
(2) toward the top of the page
(3) into the page
(4) out of the page
78. A wire conductor moves perpendicularly at constant speed through a magnetic field. If the flux density increases, the potential difference induced across the ends of the wire will
(1) decrease    (3) remain the same
(2) increase

79. The diagram below shows conductor C between two opposite magnetic poles.

![Diagram of conductor C between magnetic poles]

Which procedure will produce the greatest induced potential difference in the conductor?
(1) holding the conductor stationary between the poles
(2) moving the conductor out of the page
(3) moving the conductor toward the right side of the page
(4) moving the conductor toward the N-pole

80. The diagram below shows a copper wire located between the poles of a magnet.

![Diagram of wire between magnetic poles]

Maximum electric potential will be induced in the wire when it is moved at a constant speed toward which point?
(1) A    (3) C
(2) B    (4) D

81. A conducting loop is rotated one full turn (360°) in a uniform magnetic field. Which graph best represents the induced potential difference across the ends of the loop as a function of the angular rotation?

![Graphs of induced potential difference]

82. The diagram below shows a current-carrying wire located in a magnetic field which is directed toward the top of the page. The electromagnetic force on the wire is directed out of the page.

![Diagram of current-carrying wire in magnetic field]

In the wire, the electron flow is directed toward the
(1) left    (3) top of the page
(2) right    (4) bottom of the page
83. In the diagram below, a portion of a wire is being moved upward through a magnetic field.

The direction of the induced electron current in the wire is toward point
(1) A    (3) C
(2) B    (4) D

84. The device used to convert mechanical energy into electrical energy is called
(1) a photoelectric cell
(2) an electric generator
(3) an electric motor
(4) an electrochemical cell

85. Moving a magnet through a coil of wire converts
(1) chemical energy to electrical energy
(2) mechanical energy to electrical energy
(3) heat energy to electrical energy
(4) light energy to electrical energy

86. The diagram at the right shows a wire loop rotating between magnetic poles. During 360° of rotation about the axis shown, the induced potential difference changes in

(1) direction, only
(2) magnitude, only
(3) both magnitude and direction
(4) neither magnitude nor direction

87. A wire conductor is moved at constant speed perpendicularly to a uniform magnetic field. If the strength of the magnetic field is increased, the induced potential across the ends of the conductor
(1) decreases    (3) remains the same
(2) increases

88. A wire loop is rotating between the poles of a magnet as represented below.

As the loop rotates 90 degrees about the axis, the magnitude of the induced current in resistor \( R \)
(1) decreases    (3) remains the same
(2) increases
89. The diagram below shows the cross section of a wire which is perpendicular to the page and a uniform magnetic field directed to the right. Toward which point should the wire be moved to induce the maximum electric potential? [Assume the same speed would be used in each direction.]

(1) 1  (3) 3
(2) 2  (4) 4

90. An electric potential difference will be induced between the ends of the conductor shown in the diagram below when the conductor moves in direction

(1) A  (3) C
(2) B  (4) D

91. The 200.-turn primary coil of a transformer is connected to a 120-volt line. How many turns must the secondary coil of the transformer have if it is to provide 240 volts? [Assume 100% efficiency.]

(1) 100  (3) 1,200
(2) 400  (4) 2,400

92. A transformer plugged into a 120-volt household electrical outlet is used to operate a doorbell at a potential difference of 12 volts. What is the ratio of the number of turns in the primary coil to the number of turns in the secondary coil of the transformer?

(1) 10:1  (3) 120:1
(2) 12:1  (4) 1440:1

93. A 100% efficient transformer has an 800.-turn primary coil connected to 120-volt alternating current source. If the secondary coil has 400 turns, what is the voltage induced in the secondary coil?

(1) 30. V  (3) 240 V
(2) 60. V  (4) 480 V

94. The diagram below shows a step-up transformer having a primary coil with two windings and a secondary coil with four windings.

When a potential difference of 12 volts is applied to the primary coil, what is the current in an 8.0-ohm resistor connected to the secondary coil as shown?

(1) 0.33 A  (3) 3.0 A
(2) 0.75 A  (4) 4.5 A

95. The transformer on a power pole steps down the voltage from 10,800 volts to 120 volts. If the secondary coil contains 360 turns, how many turns are on the primary coil?

(1) 30  (3) 3600
(2) 90  (4) 32,400
96. When a 12-volt potential difference is applied to the primary coil of a transformer, an 8.0-volt potential difference is induced in the secondary coil. If the primary coil has 24 turns, how many turns does the secondary coil have? [Assume 100% efficiency.]
   (1) 36  (3) 3
   (2) 16  (4) 4

97. A transformer has 150 turns of wire in the primary coil and 1,200 turns of wire in the secondary coil. The potential difference across the primary coil is 110 volts. What is the potential difference induced across the secondary coil?
   (1) 14 V  (3) 150 V
   (2) 110 V  (4) 880 V

98. A transformer is designed to step 220 volts up to 2,200 volts. There are 200 turns on the primary coil. How many turns are there on the secondary coil?
   (1) 20  (3) 1,000
   (2) 200  (4) 2,000

99. In order for a transformer to function, its primary and secondary coils must
   (1) be made of different elements
   (2) be kept at different temperatures
   (3) have the same weight
   (4) have continually changing magnetic fields

100. An ideal transformer has a current of 2.0 amperes and a potential difference of 120 volts across its primary coil. If the current in the secondary coil is 0.50 ampere, the potential difference across the secondary coil is
   (1) 480 V  (3) 60. V
   (2) 120 V  (4) 30. V

101. In a transformer, two coils of wire are wound around a common iron core. To operate properly, the transformer requires
   (1) an alternating-current source
   (2) a direct-current source
   (3) a battery
   (4) this setup will not work properly

102. The primary coil of an operating transformer has 200 turns and the secondary coil has 40 turns. This transformer is being used to
   (1) decrease voltage and decrease current
   (2) decrease voltage and increase current
   (3) increase voltage and decrease current
   (4) increase voltage and increase current

103. Which device does not operate by means of torque exerted on a current-carrying loop of wire in a magnetic field?
   (1) ammeter  (3) transformer
   (2) electric motor  (4) voltmeter

104. A positively charged particle traveling at $7.5 \times 10^5$ meters per second enter a uniform magnetic field perpendicular to the lines of force. While in the $4.0 \times 10^{-2}$-Tesla magnetic field, a net force of $9.6 \times 10^{-15}$ Newton acts on the particle. What is the magnitude of the charge on the particle?
   (1) $1.6 \times 10^{-19}$ C  (3) $9.6 \times 10^{-19}$ C
   (2) $3.2 \times 10^{-19}$ C  (4) $3.2 \times 10^{19}$ C

105. A proton (charge +1) and an alpha particle (charge +2) each move perpendicularly through a magnetic field at the same speed. Compared to the magnetic force on the proton, the magnetic force on the alpha particle is
   (1) less  (3) the same
   (2) greater

106. An electron moves at $3.0 \times 10^7$ meters per second perpendicularly to a magnetic field that has a flux density of 2.0 Teslas. What is the magnitude of the force on the electron?
   (1) $9.6 \times 10^{-19}$ N  (3) $9.6 \times 10^{-12}$ N
   (2) $3.2 \times 10^{-19}$ N  (4) $4.8 \times 10^{-12}$ N
107. A beam of electrons is moving through a uniform magnetic field perpendicular to the field. Which graph shows how the magnetic force varies as the speed of the electrons is increased?
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104. 2
105. 2
106. 3
107. 1