# Chapter 21: ELECTRIC CHARGE

1. A coulomb is the same as:

   A. an ampere/second
   B. half an ampere·second$^2$
   C. an ampere/meter$^2$
   D. an ampere·second
   E. a newton·meter$^2$

   ans: D

2. A kiloampere·hour is a unit of:

   A. current
   B. charge per time
   C. power
   D. charge
   E. energy

   ans: D

3. The magnitude of the charge on an electron is approximately:

   A. $10^{23}$ C
   B. $10^{-23}$ C
   C. $10^{19}$ C
   D. $10^{-19}$ C
   E. $10^{9}$ C

   ans: D

4. The total negative charge on the electrons in 1 mol of helium (atomic number 2, molar mass 4) is:

   A. $4.8 \times 10^4$ C
   B. $9.6 \times 10^4$ C
   C. $1.9 \times 10^5$ C
   D. $3.8 \times 10^5$ C
   E. $7.7 \times 10^5$ C

   ans: C

5. The total negative charge on the electrons in 1 kg of helium (atomic number 2, molar mass 4) is:

   A. 48 C
   B. $2.4 \times 10^7$ C
   C. $4.8 \times 10^7$ C
   D. $9.6 \times 10^8$ C
   E. $1.9 \times 10^8$ C

   ans: C

6. A wire carries a steady current of 2 A. The charge that passes a cross section in 2 s is:
   A. $3.2 \times 10^{-19}$ C
   B. $6.4 \times 10^{-19}$ C
   C. 1 C
   D. 2 C
   E. 4 C

   ans: E

7. A wire contains a steady current of 2 A. The number of electrons that pass a cross section in 2 s is:
   A. 2
   B. 4
   C. $6.3 \times 10^{18}$
   D. $1.3 \times 10^{19}$
   E. $2.5 \times 10^{19}$

   ans: E

8. The charge on a glass rod that has been rubbed with silk is called positive:
   A. by arbitrary convention
   B. so that the proton charge will be positive
   C. to conform to the conventions adopted for $G$ and $m$ in Newton's law of gravitation
   D. because like charges repel
   E. because glass is an insulator

   ans: A

9. To make an uncharged object have a negative charge we must:
   A. add some atoms
   B. remove some atoms
   C. add some electrons
   D. remove some electrons
   E. write down a negative sign

   ans: C

10. To make an uncharged object have a positive charge:
    A. remove some neutrons
    B. add some neutrons
    C. add some electrons
    D. remove some electrons
    E. heat it to cause a change of phase

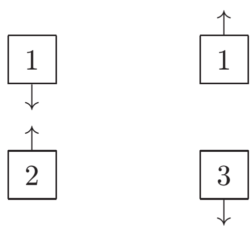
    ans: D

11. When a hard rubber rod is given a negative charge by rubbing it with wool:
    A. positive charges are transferred from rod to wool
    B. negative charges are transferred from rod to wool
    C. positive charges are transferred from wool to rod
    D. negative charges are transferred from wool to rod
    E. negative charges are created and stored on the rod
    ans: D

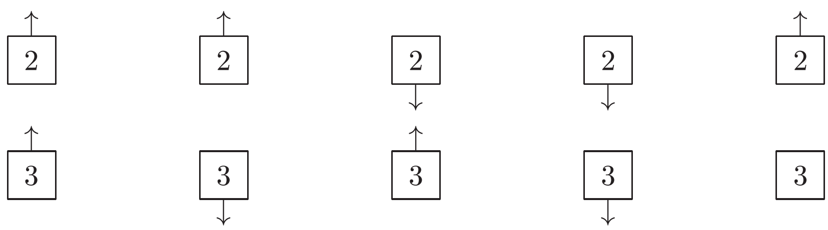
12. An electrical insulator is a material:
    A. containing no electrons
    B. through which electrons do not flow easily
    C. that has more electrons than protons on its surface
    D. cannot be a pure chemical element
    E. must be a crystal
    ans: B

13. A conductor is distinguished from an insulator with the same number of atoms by the number of:
    A. nearly free atoms
    B. electrons
    C. nearly free electrons
    D. protons
    E. molecules
    ans: C

14. The diagram shows two pairs of heavily charged plastic cubes. Cubes 1 and 2 attract each other and cubes 1 and 3 repel each other.



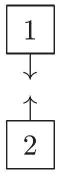

Which of the following illustrates the forces of cube 2 on cube 3 and cube 3 on cube 2?



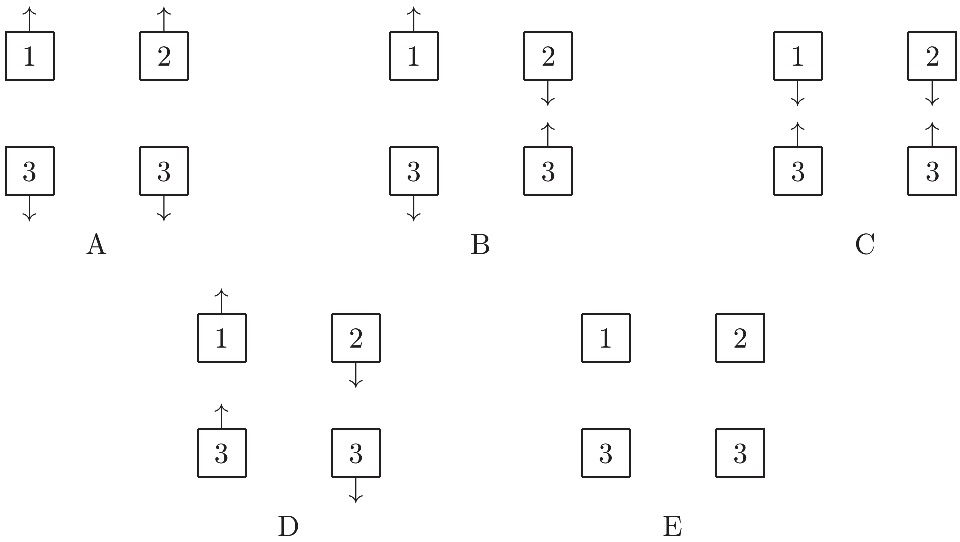

A B C D E

ans: C

15. The diagram shows a pair of heavily charged plastic cubes that attract each other.




Cube 3 is a conductor and is uncharged. Which of the following illustrates the forces between cubes 1 and 3 and between cubes 2 and 3?




ans: C

16. A neutral metal ball is suspended by a string. A positively charged insulating rod is placed near the ball, which is observed to be attracted to the rod. This is because:

A. the ball becomes positively charged by induction
B. the ball becomes negatively charged by induction
C. the number of electrons in the ball is more than the number in the rod
D. the string is not a perfect insulator
E. there is a rearrangement of the electrons in the ball

ans: E

17. A positively charged insulating rod is brought close to an object that is suspended by a string. If the object is attracted toward the rod we can conclude:

A. the object is positively charged
B. the object is negatively charged
C. the object is an insulator
D. the object is a conductor
E. none of the above

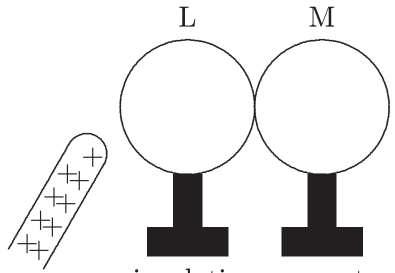
ans: E

18. A positively charged insulating rod is brought close to an object that is suspended by a string. If the object is repelled away from the rod we can conclude:

A. the object is positively charged
B. the object is negatively charged
C. the object is an insulator
D. the object is a conductor
E. none of the above

ans: A

19. Two uncharged metal spheres, L and M, are in contact. A negatively charged rod is brought close to L, but not touching it, as shown. The two spheres are slightly separated and the rod is then withdrawn. As a result:




A. both spheres are neutral
B. both spheres are positive
C. both spheres are negative
D. L is negative and M is positive
E. L is positive and M is negative

ans: D

20. A positively charged metal sphere A is brought into contact with an uncharged metal sphere B. As a result:

A. both spheres are positively charged
B. A is positively charged and B is neutral
C. A is positively charged and B is negatively charged
D. A is neutral and B is positively charged
E. A is neutral and B is negatively charged

ans: A

21. The leaves of a positively charged electroscope diverge more when an object is brought near the knob of the electroscope. The object must be:

A. a conductor
B. an insulator
C. positively charged
D. negatively charged
E. uncharged

ans: C

22. A negatively charged rubber rod is brought near the knob of a positively charged electroscope. The result is that:

A. the electroscope leaves will move farther apart
B. the rod will lose its charge
C. the electroscope leaves will tend to collapse
D. the electroscope will become discharged
E. nothing noticeable will happen

ans: C

23. An electroscope is charged by induction using a glass rod that has been made positive by rubbing it with silk. The electroscope leaves:

A. gain electrons
B. gain protons
C. lose electrons
D. lose protons
E. gain an equal number of protons and electrons

ans: A

24. Consider the following procedural steps:

1. ground an electroscope
2. remove the ground from the electroscope
3. touch a charged rod to the electroscope
4. bring a charged rod near, but not touching, the electroscope
5. remove the charged rod

To charge an electroscope by induction, use the sequence:

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

ans: B

25. A charged insulator can be discharged by passing it just above a flame. This is because the flame:

A. warms it
B. dries it
C. contains carbon dioxide
D. contains ions
E. contains more rapidly moving atoms

ans: D

26. A small object has charge $Q$. Charge $q$ is removed from it and placed on a second small object. The two objects are placed 1 m apart. For the force that each object exerts on the other to be a maximum. $q$ should be:

A. $2Q$
B. $Q$
C. $Q/2$
D. $Q/4$
E. 0

ans: C

27. Two small charged objects attract each other with a force $F$ when separated by a distance $d$. If the charge on each object is reduced to one-fourth of its original value and the distance between them is reduced to $d/2$ the force becomes:

A. $F/16$
B. $F/8$
C. $F/4$
D. $F/2$
E. $F$

ans: C

28. Two identical conducting spheres A and B carry equal charge. They are separated by a distance much larger than their diameters. A third identical conducting sphere C is uncharged. Sphere C is first touched to A, then to B, and finally removed. As a result, the electrostatic force between A and B, which was originally $F$, becomes:

A. $F/2$
B. $F/4$
C. $3F/8$
D. $F/16$
E. 0

ans: C

29. Two particles, X and Y, are 4 m apart. X has a charge of $2Q$ and Y has a charge of $Q$. The force of X on Y:

A. has twice the magnitude of the force of Y on X
B. has half the magnitude of the force of Y on X
C. has four times the magnitude of the force of Y on X
D. has one-fourth the magnitude of the force of Y on X
E. has the same magnitude as the force of Y on X

ans: E

30. The units of $1/4\pi\epsilon_0$ are:

A. $N^2C^2$
B. $N \cdot m/C$
C. $N^2 \cdot m^2/C^2$
D. $N \cdot m^2/C^2$
E. $m^2/C^2$

ans: D

31. A 5.0-C charge is 10 m from a −2.0-C charge. The electrostatic force on the positive charge is:

A. $9.0 \times 10^8$ N toward the negative charge
B. $9.0 \times 10^8$ N away from the negative charge
C. $9.0 \times 10^9$ N toward the negative charge
D. $9.0 \times 10^9$ N away from the negative charge
E. none of these

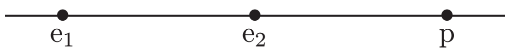
ans: A

32. Two identical charges, 2.0 m apart, exert forces of magnitude 4.0 N on each other. The value of either charge is:

A. $1.8 \times 10^{-9}$ C
B. $2.1 \times 10^{-5}$ C
C. $4.2 \times 10^{-5}$ C
D. $1.9 \times 10^{5}$ C
E. $3.8 \times 10^{5}$ C

ans: C

33. Two electrons ($e_1$ and $e_2$) and a proton (p) lie on a straight line, as shown. The directions of the force of $e_2$ on $e_1$, the force of p on $e_1$, and the total force on $e_1$, respectively, are:




A. $\longrightarrow, \longleftarrow, \longrightarrow$
B. $\longleftarrow, \longrightarrow, \longrightarrow$
C. $\longrightarrow, \longleftarrow, \longleftarrow$
D. $\longleftarrow, \longrightarrow, \longleftarrow$
E. $\longleftarrow, \longleftarrow, \longleftarrow$

ans: D

34. Two protons ($p_1$ and $p_2$) and an electron (e) lie on a straight line, as shown. The directions of the force of $p_1$ on e, the force of $p_2$ on e, and the total force on e, respectively, are:


A. $\longrightarrow, \longleftarrow, \longrightarrow$
B. $\longleftarrow, \longrightarrow, \longrightarrow$
C. $\longrightarrow, \longleftarrow, \longleftarrow$
D. $\longleftarrow, \longrightarrow, \longleftarrow$
E. $\longleftarrow, \longleftarrow, \longleftarrow$

ans: D

35. Two particles have charges $Q$ and $-Q$ (equal magnitude and opposite sign). For a net force of zero to be exerted on a third charge it must be placed:

A. midway between $Q$ and $-Q$
B. on the perpendicular bisector of the line joining $Q$ and $-Q$, but not on that line itself
C. on the line joining $Q$ and $-Q$, to the side of $Q$ opposite $-Q$
D. on the line joining $Q$ and $-Q$, to the side of $-Q$ opposite Q
E. at none of these places (there is no place)

ans: E

36. Particles 1, with charge $q_1$, and 2, with charge $q_2$, are on the x axis, with particle 1 at $x = a$ and particle 2 at $x = -2a$. For the net force on a third charged particle, at the origin, to be zero, $q_1$ and $q_2$ must be related by $q_2 =$:

A. $2q_1$
B. $4q_1$
C. $-2q_1$
D. $-4q_1$
E. $-q_1/4$

ans: B

37. Two particles A and B have identical charge $Q$. For a net force of zero to be exerted on a third charged particle it must be placed:

A. midway between A and B
B. on the perpendicular bisector of the line joining A and B but away from the line
C. on the line joining A and B, not between the particles
D. on the line joining A and B, closer to one of them than the other
E. at none of these places (there is no place)

ans: A

38. A particle with charge 2-$\mu$C is placed at the origin, an identical particle, with the same charge, is placed 2 m from the origin on the $x$ axis, and a third identical particle, with the same charge, is placed 2 m from the origin on the $y$ axis. The magnitude of the force on the particle at the origin is:

A. $9.0 \times 10^{-3}$ N
B. $6.4 \times 10^{-3}$ N
C. $1.3 \times 10^{-2}$ N
D. $1.8 \times 10^{-2}$ N
E. $3.6 \times 10^{-2}$ N

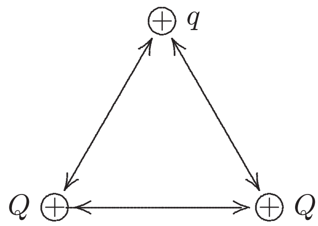
ans: C

39. Charge $Q$ is spread uniformly along the circumference of a circle of radius $R$. A point particle with charge $q$ is placed at the center of this circle. The total force exerted on the particle can be calculated by Coulomb's law:

A. just use $R$ for the distance
B. just use $2R$ for the distance
C. just use $2\pi R$ for the distance
D. the result of the calculation is zero
E. none of the above

ans: D

40. Two particles, each with charge $Q$, and a third particle, with charge $q$, are placed at the vertices of an equilateral triangle as shown. The total force on the particle with charge $q$ is:




A. parallel to the left side of the triangle
B. parallel to the right side of the triangle
C. parallel to the bottom side of the triangle
D. perpendicular to the bottom side of the triangle
E. perpendicular to the left side of the triangle

ans: D

41. A particle with charge $Q$ is on the $y$ axis a distance $a$ from the origin and a particle with charge $q$ is on the $x$ axis a distance $d$ from the origin. The value of $d$ for which the $x$ component of the force on the second particle is the greatest is:

A. 0
B. $a$
C. $\sqrt{2}a$
D. $a/2$
E. $a/\sqrt{2}$

ans: E

42. In the Rutherford model of the hydrogen atom, a proton (mass $M$, charge $Q$) is the nucleus and an electron (mass $m$, charge $q$) moves around the proton in a circle of radius $r$. Let $k$ denote the Coulomb force constant ($1/4\pi\epsilon_0$) and $G$ the universal gravitational constant. The ratio of the electrostatic force to the gravitational force between electron and proton is:

A. $kQq/GMmr^2$
B. $GQq/kMm$
C. $kMm/GQq$
D. $GMm/kQq$
E. $kQq/GMm$

ans: E

43. A particle with a charge of $5 \times 10^{-6}$ C and a mass of 20 g moves uniformly with a speed of 7 m/s in a circular orbit around a stationary particle with a charge of $-5 \times 10^{-6}$ C. The radius of the orbit is:

A. 0
B. 0.23 m
C. 0.62 m
D. 1.6
E. 4.4 m

ans: B

44. Charge is distributed uniformly on the surface of a spherical balloon (an insulator). A point particle with charge $q$ is inside. The electrical force on the particle is greatest when:

A. it is near the inside surface of the balloon
B. it is at the center of the balloon
C. it is halfway between the balloon center and the inside surface
D. it is anywhere inside (the force is same everywhere and is not zero)
E. it is anywhere inside (the force is zero everywhere)

ans: E

45. Charge is distributed on the surface of a spherical conducting shell. A point particle with charge $q$ is inside. If polarization effects are negligible the electrical force on the particle is greatest when:

A. it is near the inside surface of the balloon
B. it is at the center of the balloon
C. it is halfway between the balloon center and the inside surface
D. it is anywhere inside (the force is same everywhere and is not zero)
E. it is anywhere inside (the force is zero everywhere)

ans: A

# Chapter 22: ELECTRIC FIELDS

1. An electric field is most directly related to:
   A. the momentum of a test charge
   B. the kinetic energy of a test charge
   C. the potential energy of a test charge
   D. the force acting on a test charge
   E. the charge carried by a test charge

   ans: D

2. As used in the definition of electric field, a "test charge":
   A. has zero charge
   B. has charge of magnitude 1 C
   C. has charge of magnitude $1.6 \times 10^{-19}$ C
   D. must be an electron
   E. none of the above

   ans: E

3. Experimenter A uses a test charge $q_0$ and experimenter B uses a test charge $-2q_0$ to measure an electric field produced by stationary charges. A finds a field that is:
   A. the same in both magnitude and direction as the field found by B
   B. greater in magnitude than the field found by B
   C. less in magnitude than the field found by B
   D. opposite in direction to the field found by B
   E. either greater or less than the field found by B, depending on the accelerations of the test charges

   ans: A

4. The units of the electric field are:
   A. $\mathrm{N \cdot C^2}$
   B. C/N
   C. N
   D. N/C
   E. $\mathrm{C/m^2}$

   ans: D

5. The units of the electric field are:
   A. J/(C·m)
   B. J/C
   C. J·C
   D. J/m
   E. none of these

   ans: A

6. Electric field lines:
   A. are trajectories of a test charge
   B. are vectors in the direction of the electric field
   C. form closed loops
   D. cross each other in the region between two point charges
   E. are none of the above

   ans: E

7. Two thin spherical shells, one with radius $R$ and the other with radius $2R$, surround an isolated charged point particle. The ratio of the number of field lines through the larger sphere to the number through the smaller is:
   A. 1
   B. 2
   C. 4
   D. 1/2
   E. 1/4

   ans: A

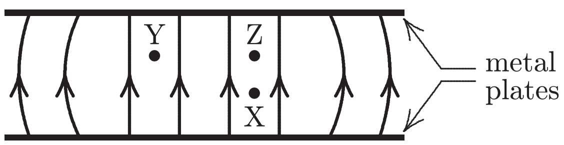
8. A certain physics textbook shows a region of space in which two electric field lines cross each other. We conclude that:
   A. at least two point charges are present
   B. an electrical conductor is present
   C. an insulator is present
   D. the field points in two directions at the same place
   E. the author made a mistake

   ans: E

9. Choose the correct statement concerning electric field lines:
   A. field lines may cross
   B. field lines are close together where the field is large
   C. field lines point away from a negatively charged particle
   D. a charged point particle released from rest moves along a field line
   E. none of these are correct

   ans: B

10. The diagram shows the electric field lines due to two charged parallel metal plates. We conclude that:




   A. the upper plate is positive and the lower plate is negative
   B. a proton at X would experience the same force if it were placed at Y
   C. a proton at X experiences a greater force than if it were placed at Z
   D. a proton at X experiences less force than if it were placed at Z
   E. an electron at X could have its weight balanced by the electrical force

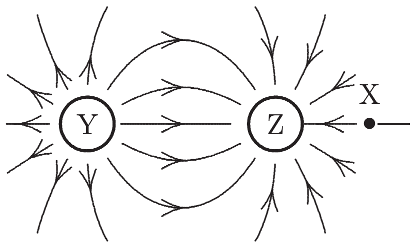
   ans: B

11. Let $k$ denote $1/4\pi\epsilon_0$. The magnitude of the electric field at a distance $r$ from an isolated point particle with charge $q$ is:

A. $kq/r$
B. $kr/q$
C. $kq/r^3$
D. $kq/r^2$
E. $kq^2/r^2$

ans: D

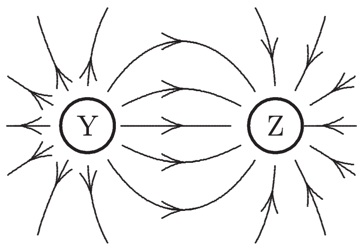
12. The diagram shows the electric field lines in a region of space containing two small charged spheres (Y and Z). Then:




A. Y is negative and Z is positive
B. the magnitude of the electric field is the same everywhere
C. the electric field is strongest midway between Y and Z
D. the electric field is not zero anywhere (except infinitely far from the spheres)
E. Y and Z must have the same sign

ans: D

13. The diagram shows the electric field lines in a region of space containing two small charged spheres (Y and Z). Then:




A. Y is negative and Z is positive
B. the magnitude of the electric field is the same everywhere
C. the electric field is strongest midway between Y and Z
D. Y is positive and Z is negative
E. Y and Z must have the same sign

ans: D

14. The electric field at a distance of 10 cm from an isolated point particle with a charge of $2\times10^{-9}$ C is:

A. 1.8 N/C
B. 180 N/C
C. 18 N/C
D. 1800 N/C
E. none of these

ans: D

15. An isolated charged point particle produces an electric field with magnitude $E$ at a point 2 m away from the charge. A point at which the field magnitude is $E/4$ is:

A. 1 m away from the particle
B. 0.5 m away from the particle
C. 2 m away from the particle
D. 4 m away from the particle
E. 8 m away from the particle

ans: D

16. An isolated charged point particle produces an electric field with magnitude $E$ at a point 2 m away. At a point 1 m from the particle the magnitude of the field is:

A. $E$
B. $2E$
C. $4E$
D. $E/2$
E. $E/4$

ans: C

17. Two protons ($p_1$ and $p_2$) are on the $x$ axis, as shown below. The directions of the electric field at points 1, 2, and 3, respectively, are:


A. $\longrightarrow, \longleftarrow, \longrightarrow$
B. $\longleftarrow, \longrightarrow, \longleftarrow$
C. $\longleftarrow, \longrightarrow, \longrightarrow$
D. $\longleftarrow, \longleftarrow, \longleftarrow$
E. $\longleftarrow, \longleftarrow, \longrightarrow$

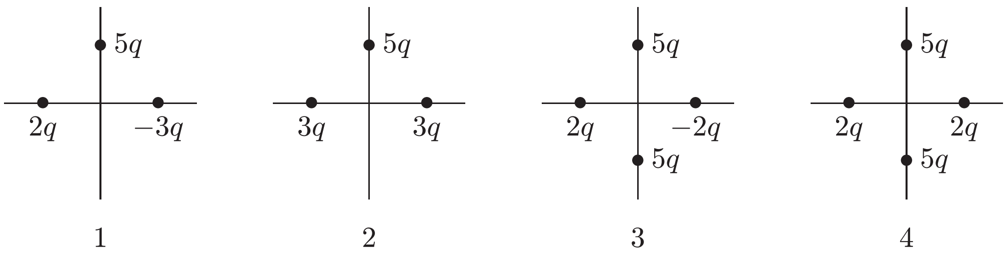
ans: E

18. Two point particles, with a charges of $q_1$ and $q_2$, are placed a distance $r$ apart. The electric field is zero at a point P between the particles on the line segment connecting them. We conclude that:

A. $q_1$ and $q_2$ must have the same magnitude and sign
B. P must be midway between the particles
C. $q_1$ and $q_2$ must have the same sign but may have different magnitudes
D. $q_1$ and $q_2$ must have equal magnitudes and opposite signs
E. $q_1$ and $q_2$ must have opposite signs and may have different magnitudes

ans: C

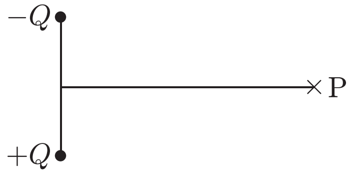
19. The diagrams below depict four different charge distributions. The charge particles are all the same distance from the origin. The electric field at the origin:




A. is greatest for situation 1
B. is greatest for situation 3
C. is zero for situation 4
D. is downward for situation 1
E. is downward for situation 3

ans: C

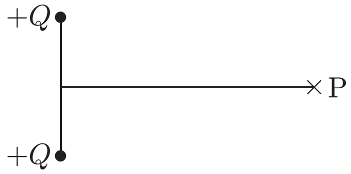
20. The diagram shows a particle with positive charge $Q$ and a particle with negative charge $-Q$. The electric field at point P on the perpendicular bisector of the line joining them is:




A. ↑
B. ↓
C. →
D. ←
E. zero

ans: A

21. The diagram shows two identical particles, each with positive charge $Q$. The electric field at point P on the perpendicular bisector of the line joining them is:




A. $\uparrow$
B. $\downarrow$
C. $\rightarrow$
D. $\leftarrow$
E. zero

ans: C

22. Two point particles, one with charge $+8 \times 10^{-9}$ C and the other with charge $-2 \times 10^{-9}$ C, are separated by 4 m. The electric field in N/C midway between them is:

A. $9 \times 10^{9}$
B. $13,500$
C. $135,000$
D. $36 \times 10^{-9}$
E. 22.5

ans: E

23. Two charged point particles are located at two vertices of an equilateral triangle and the electric field is zero at the third vertex. We conclude:

A. the two particles have charges with opposite signs and the same magnitude
B. the two particles have charges with opposite signs and different magnitudes
C. the two particles have identical charges
D. the two particles have charges with the same sign but different magnitudes
E. at least one other charged particle is present

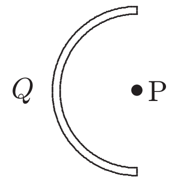
ans: E

24. Two point particles, with the same charge, are located at two vertices of an equilateral triangle. A third charged particle is placed so the electric field at the third vertex is zero. The third particle must:

A. be on the perpendicular bisector of the line joining the first two charges
B. be on the line joining the first two charges
C. have the same charge as the first two particles
D. have charge of the same magnitude as the first two charges but its charge may have a different sign
E. be at the center of the triangle

ans: A

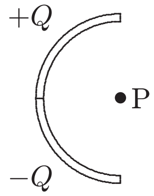
25. Positive charge $Q$ is uniformly distributed on a semicircular rod. What is the direction of the electric field at point P, the center of the semicircle?




A. $\uparrow$
B. $\downarrow$
C. $\leftarrow$
D. $\rightarrow$
E. $\nearrow$

ans: D

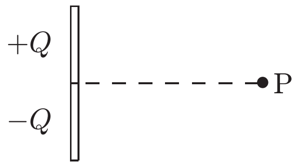
26. Positive charge $+Q$ is uniformly distributed on the upper half a semicircular rod and negative charge $-Q$ is uniformly distributed on the lower half. What is the direction of the electric field at point P, the center of the semicircle?




A. $\uparrow$
B. $\downarrow$
C. $\leftarrow$
D. $\rightarrow$
E. $\nearrow$

ans: B

27. Positive charge $+Q$ is uniformly distributed on the upper half a rod and negative charge $-Q$ is uniformly distributed on the lower half. What is the direction of the electric field at point P, on the perpendicular bisector of the rod?




A. $\uparrow$
B. $\downarrow$
C. $\leftarrow$
D. $\rightarrow$
E. $\nearrow$

ans: B

28. The electric field due to a uniform distribution of charge on a spherical shell is zero:
   A. everywhere
   B. nowhere
   C. only at the center of the shell
   D. only inside the shell
   E. only outside the shell

   ans: D

29. A charged particle is placed in an electric field that varies with location. No force is exerted on this charge:
   A. at locations where the electric field is zero
   B. at locations where the electric field strength is $1/(1.6 \times 10^{-19})$ N/C
   C. if the particle is moving along a field line
   D. if the particle is moving perpendicularly to a field line
   E. if the field is caused by an equal amount of positive and negative charge

   ans: A

30. The magnitude of the force of a 400-N/C electric field on a 0.02-C point charge is:
   A. 8.0 N
   B. $8 \times 10^{-5}$ N
   C. $8 \times 10^{-3}$ N
   D. 0.08 N
   E. $2 \times 10^{11}$ N

   ans: A

31. A 200-N/C electric field is in the positive $x$ direction. The force on an electron in this field is:
   A. 200 N in the positive $x$ direction
   B. 200 N in the negative $x$ direction
   C. $3.2 \times 10^{-17}$ N in the positive $x$ direction
   D. $3.2 \times 10^{-17}$ N in the negative $x$ direction
   E. 0

   ans: D

32. An electron traveling north enters a region where the electric field is uniform and points north. The electron:
   A. speeds up
   B. slows down
   C. veers east
   D. veers west
   E. continues with the same speed in the same direction

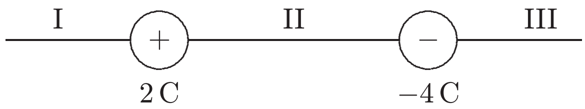
   ans: B

33. An electron traveling north enters a region where the electric field is uniform and points west. The electron:

A. speeds up
B. slows down
C. veers east
D. veers west
E. continues with the same speed in the same direction

ans: C

34. Two charged particles are arranged as shown. In which region could a third particle, with charge $+1\,\mathrm{C}$, be placed so that the net electrostatic force on it is zero?




A. I only
B. I and II only
C. lII only
D. I and III only
E. II only

ans: A

35. An electric dipole consists of a particle with a charge of $+6\times10^{-6}\,\mathrm{C}$ at the origin and a particle with a charge of $-6\times10^{-6}\,\mathrm{C}$ on the $x$ axis at $x = 3\times10^{-3}\,\mathrm{m}$. Its dipole moment is:

A. $1.8\times10^{-8}\,\mathrm{C\cdot m}$, in the positive $x$ direction
B. $1.8\times10^{-8}\,\mathrm{C\cdot m}$, in the negative $x$ direction
C. 0 because the net charge is 0
D. $1.8\times10^{-8}\,\mathrm{C\cdot m}$, in the positive $y$ direction
E. $1.8\times10^{-8}\,\mathrm{C\cdot m}$, in the negative $y$ direction

ans: B

36. The force exerted by a uniform electric field on a dipole is:

A. parallel to the dipole moment
B. perpendicular to the dipole moment
C. parallel to the electric field
D. perpendicular to the electric field
E. none of the above

ans: E

37. An electric field exerts a torque on a dipole only if:

A. the field is parallel to the dipole moment
B. the field is not parallel to the dipole moment
C. the field is perpendicular to the dipole moment
D. the field is not perpendicular to the dipole moment
E. the field is uniform

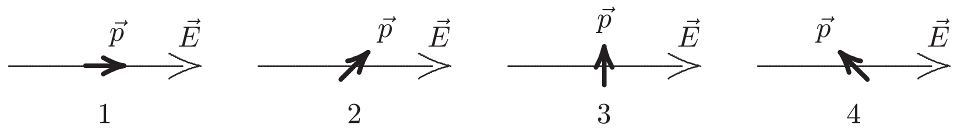
ans: B

38. The torque exerted by an electric field on a dipole is:

A. parallel to the field and perpendicular to the dipole moment
B. parallel to both the field and dipole moment
C. perpendicular to both the field and dipole moment
D. parallel to the dipole moment and perpendicular to the field
E. not related to the directions of the field and dipole moment

ans: C

39. The diagrams show four possible orientations of an electric dipole in a uniform electric field $\vec{E}$. Rank them according to the magnitude of the torque exerted on the dipole by the field, least to greatest.




A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 1, 2, 4, 3
D. 3, 2 and 4 tie, then 1
E. 1, 2 and 4 tie, then 3

ans: E

40. A uniform electric field of 300 N/C makes an angle of 25° with the dipole moment of an electric dipole. If the torque exerted by the field has a magnitude of $2.5 \times 10^{-7}$ N·m, the dipole moment must be:

A. $8.3 \times 10^{-10}$ C · m
B. $9.2 \times 10^{-10}$ C · m
C. $2.0 \times 10^{-9}$ C · m
D. $8.3 \times 10^{-5}$ C · m
E. $1.8 \times 10^{-4}$ C · m

ans: C

41. When the dipole moment of a dipole in a uniform electric field rotates to become more nearly aligned with the field:

A. the field does positive work and the potential energy increases
B. the field does positive work and the potential energy decreases
C. the field does negative work and the potential energy increases
D. the field does negative work and the potential energy decreases
E. the field does no work

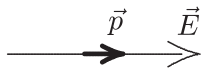
ans: B

42. The dipole moment of a dipole in a 300-N/C electric field is initially perpendicular to the field, but it rotates so it is in the same direction as the field. If the moment has a magnitude of $2 \times 10^{-9}\,\mathrm{C \cdot m}$, the work done by the field is:

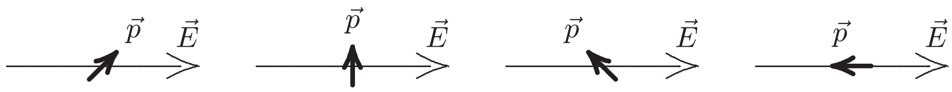
A. $-12 \times 10^{-7}\,\mathrm{J}$
B. $-6 \times 10^{-7}\,\mathrm{J}$
C. 0
D. $6 \times 10^{-7}\,\mathrm{J}$
E. $12 \times 10^{-7}\,\mathrm{J}$

ans: D

43. An electric dipole is oriented parallel to a uniform electric field, as shown.




It is rotated to one of the five orientations shown below. Rank the final orientations according to the change in the potential energy of the dipole-field system, most negative to most positive.




1 2 3 4

A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 1, 2, 4, 3
D. 3, 2 and 4 tie, then 1
E. 1, 2 and 4 tie, then 3

ans: A

44. The purpose of Milliken's oil drop experiment was to determine:

A. the mass of an electron
B. the charge of an electron
C. the ratio of charge to mass for an electron
D. the sign of the charge on an electron
E. viscosity

ans: B

45. A charged oil drop with a mass of $2 \times 10^{-4}\,\mathrm{kg}$ is held suspended by a downward electric field of $300\,\mathrm{N/C}$. The charge on the drop is:

A. $+1.5 \times 10^{-6}\,\mathrm{C}$
B. $-1.5 \times 10^{-6}\,\mathrm{C}$
C. $+6.5 \times 10^{-6}\,\mathrm{C}$
D. $-6.5 \times 10^{-6}\,\mathrm{C}$
E. 0

ans: D

## Chapter 23: GAUSS' LAW

1. A total charge of $6.3 \times 10^{-8}$ C is distributed uniformly throughout a 2.7-cm radius sphere. The volume charge density is:
   A. $3.7 \times 10^{-7}\,\mathrm{C/m^3}$
   B. $6.9 \times 10^{-6}\,\mathrm{C/m^3}$
   C. $6.9 \times 10^{-6}\,\mathrm{C/m^2}$
   D. $2.5 \times 10^{-4}\,\mathrm{C/m^3}$
   E. $7.6 \times 10^{-4}\,\mathrm{C/m^3}$
   ans: E

2. Charge is placed on the surface of a 2.7-cm radius isolated conducting sphere. The surface charge density is uniform and has the value $6.9 \times 10^{-6}\,\mathrm{C/m^2}$. The total charge on the sphere is:
   A. $5.6 \times 10^{-10}$ C
   B. $2.1 \times 10^{-8}$ C
   C. $4.7 \times 10^{-8}$ C
   D. $6.3 \times 10^{-8}$ C
   E. $9.5 \times 10^{-3}$ C
   ans: D

3. A spherical shell has an inner radius of 3.7 cm and an outer radius of 4.5 cm. If charge is distributed uniformly throughout the shell with a volume density of $6.1 \times 10^{-4}\,\mathrm{C/m^3}$ the total charge is:
   A. $1.0 \times 10^{-7}$ C
   B. $1.3 \times 10^{-7}$ C
   C. $2.0 \times 10^{-7}$ C
   D. $2.3 \times 10^{-7}$ C
   E. $4.0 \times 10^{-7}$ C
   ans: A

4. A cylinder has a radius of 2.1 cm and a length of 8.8 cm. Total charge $6.1 \times 10^{-7}$ C is distributed uniformly throughout. The volume charge density is:
   A. $5.3 \times 10^{-5}\,\mathrm{C/m^3}$
   B. $5.3 \times 10^{-5}\,\mathrm{C/m^2}$
   C. $8.5 \times 10^{-4}\,\mathrm{C/m^3}$
   D. $5.0 \times 10^{-3}\,\mathrm{C/m^3}$
   E. $6.3 \times 10^{-2}\,\mathrm{C/m^3}$
   ans: D

5. When a piece of paper is held with one face perpendicular to a uniform electric field the flux through it is $25\,\mathrm{N\cdot m^2/C}$. When the paper is turned 25° with respect to the field the flux through it is:

A. 0
B. $12\,\mathrm{N\cdot m^2/C}$
C. $21\,\mathrm{N\cdot m^2/C}$
D. $23\,\mathrm{N\cdot m^2/C}$
E. $25\,\mathrm{N\cdot m^2/C}$

ans: D

6. The flux of the electric field $(24\,\mathrm{N/C})\,\hat{\imath} + (30\,\mathrm{N/C})\,\hat{\jmath} + (16\,\mathrm{N/C})\,\hat{k}$ through a $2.0\,\mathrm{m^2}$ portion of the $yz$ plane is:

A. $32\,\mathrm{N\cdot m^2/C}$
B. $34\,\mathrm{N\cdot m^2/C}$
C. $42\,\mathrm{N\cdot m^2/C}$
D. $48\,\mathrm{N\cdot m^2/C}$
E. $60\,\mathrm{N\cdot m^2/C}$

ans: D

7. Consider Gauss's law: $\oint \vec{E}\cdot d\vec{A} = q/\epsilon_0$. Which of the following is true?

A. $\vec{E}$ must be the electric field due to the enclosed charge
B. If $q = 0$, then $\vec{E} = 0$ everywhere on the Gaussian surface
C. If the three particles inside have charges of $+q$, $+q$, and $-2q$, then the integral is zero
D. on the surface $\vec{E}$ is everywhere parallel to $d\vec{A}$
E. If a charge is placed outside the surface, then it cannot affect $\vec{E}$ at any point on the surface

ans: C

8. A charged point particle is placed at the center of a spherical Gaussian surface. The electric flux $\Phi_E$ is changed if:

A. the sphere is replaced by a cube of the same volume
B. the sphere is replaced by a cube of one-tenth the volume
C. the point charge is moved off center (but still inside the original sphere)
D. the point charge is moved to just outside the sphere
E. a second point charge is placed just outside the sphere

ans: D

9. Choose the INCORRECT statement:

A. Gauss' law can be derived from Coulomb's law
B. Gauss' law states that the net number of lines crossing any closed surface in an outward direction is proportional to the net charge enclosed within the surface
C. Coulomb's law can be derived from Gauss' law and symmetry
D. Gauss' law applies to a closed surface of any shape
E. According to Gauss' law, if a closed surface encloses no charge, then the electric field must vanish everywhere on the surface

ans: E

10. The outer surface of the cardboard center of a paper towel roll:
    A. is a possible Gaussian surface
    B. cannot be a Gaussian surface because it encloses no charge
    C. cannot be a Gaussian surface since it is an insulator
    D. cannot be a Gaussian surface because it is not a closed surface
    E. none of the above

    ans: D

11. A physics instructor in an anteroom charges an electrostatic generator to $25\,\mu$C, then carries it into the lecture hall. The net electric flux in $\text{N}\cdot\text{m}^2/\text{C}$ through the lecture hall walls is:
    A. 0
    B. $25 \times 10^{-6}$
    C. $2.2 \times 10^{5}$
    D. $2.8 \times 10^{6}$
    E. can not tell unless the lecture hall dimensions are given

    ans: D

12. A point particle with charge $q$ is placed inside the cube but not at its center. The electric flux through any one side of the cube:
    A. is zero
    B. is $q/\epsilon_0$
    C. is $q/4\epsilon_0$
    D. is $q/6\epsilon_0$
    E. cannot be computed using Gauss' law

    ans: E

13. A particle with charge 5.0-$\mu$C is placed at the corner of a cube. The total electric flux in $\text{N}\cdot\text{m}^2\,/\text{C}$ through all sides of the cube is:
    A. 0
    B. $7.1 \times 10^{4}$
    C. $9.4 \times 10^{4}$
    D. $1.4 \times 10^{5}$
    E. $5.6 \times 10^{5}$

    ans: E

14. A point particle with charge $q$ is at the center of a Gaussian surface in the form of a cube. The electric flux through any one face of the cube is:
    A. $q/\epsilon_0$
    B. $q/4\pi\epsilon_0$
    C. $q/3\epsilon_0$
    D. $q/6\epsilon_0$
    E. $q/12\epsilon_0$

    ans: D

15. The table below gives the electric flux in $N \cdot m^2/C$ through the ends and round surfaces of four Gaussian surfaces in the form of cylinders. Rank the cylinders according to the charge inside, from the most negative to the most positive.

| | left end | right end | rounded surface |
|---|---|---|---|
| cylinder 1: | $+2 \times 10^{-9}$ | $+4 \times 10^{-9}$ | $-6 \times 10^{-9}$ |
| cylinder 2: | $+3 \times 10^{-9}$ | $-2 \times 10^{-9}$ | $+6 \times 10^{-9}$ |
| cylinder 3: | $-2 \times 10^{-9}$ | $-5 \times 10^{-9}$ | $+3 \times 10^{-9}$ |
| cylinder 4: | $+2 \times 10^{-9}$ | $-5 \times 10^{-9}$ | $-3 \times 10^{-9}$ |

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

ans: E

16. A conducting sphere of radius 0.01 m has a charge of $1.0 \times 10^{-9}$ C deposited on it. The magnitude of the electric field in N/C just outside the surface of the sphere is:

A. 0
B. 450
C. 900
D. 4500
E. 90, 000

ans: C

17. A round wastepaper basket with a 0.15-m radius opening is in a uniform electric field of 300 N/C, perpendicular to the opening. The total flux through the sides and bottom, in $N \cdot m^2$ C, is:

A. 0
B. 4.2
C. 21
D. 280
E. can not tell without knowing the areas of the sides and bottom

ans: C

18. 10 C of charge are placed on a spherical conducting shell. A particle with a charge of −3 C is placed at the center of the cavity. The net charge on the inner surface of the shell is:

A. −7 C
B. −3 C
C. 0 C
D. +3 C
E. +7 C

ans: D

19. 10 C of charge are placed on a spherical conducting shell. A particle with a charge of −3 C is placed at the center of the cavity. The net charge on the outer surface of the shell is:

A. −7 C
B. −3 C
C. 0 C
D. +3 C
E. +7 C

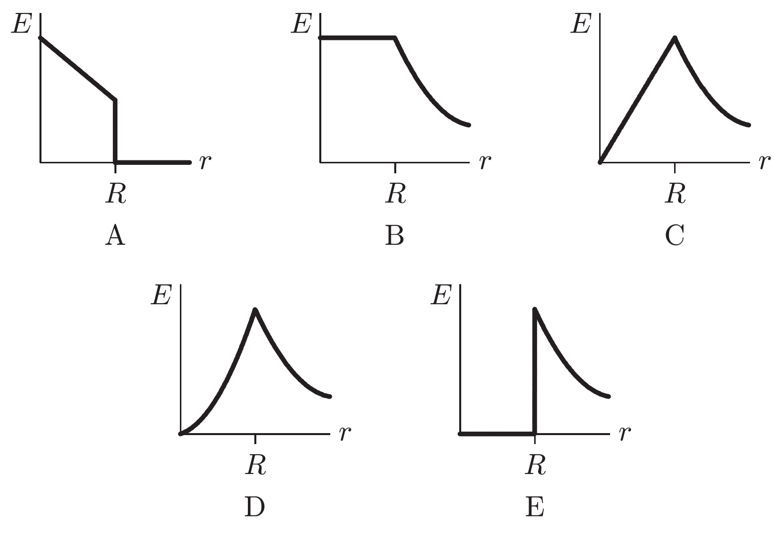
ans: E

20. A 30-N/C uniform electric field points perpendicularly toward the left face of a large neutral conducting sheet. The surface charge density in $\mathrm{C/m^2}$ on the left and right faces, respectively, are:

A. $-2.7 \times 10^{-9}\,\mathrm{C/m^2}$; $+2.7 \times 10^{-9}\,\mathrm{C/m^2}$
B. $+2.7 \times 10^{-9}\,\mathrm{C/m^2}$; $-2.7 \times 10^{-9}\,\mathrm{C/m^2}$
C. $-5.3 \times 10^{-9}\,\mathrm{C/m^2}$; $+5.3 \times 10^{-9}\,\mathrm{C/m^2}$
D. $+5.3 \times 10^{-9}\,\mathrm{C/m^2}$; $-5.3 \times 10^{-9}\,\mathrm{C/m^2}$
E. 0; 0

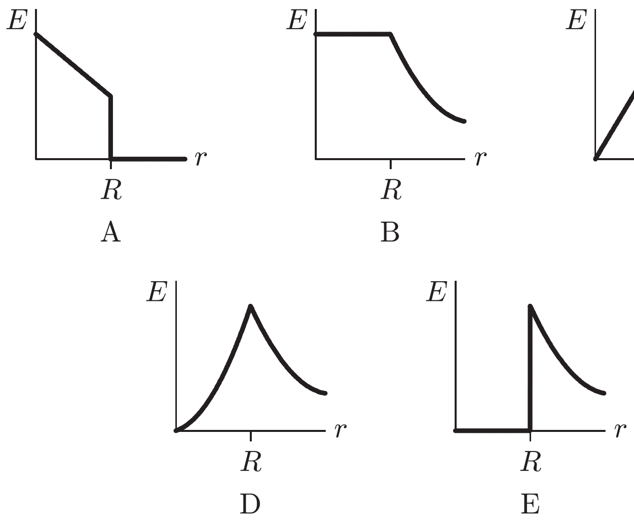
ans: A

21. A solid insulating sphere of radius $R$ contains positive charge that is distributed with a volume charge density that does not depend on angle but does increase with distance from the sphere center. Which of the graphs below might give the magnitude $E$ of the electric field as a function of the distance $r$ from the center of the sphere?




ans: D

22. Which of the following graphs represents the magnitude of the electric field as a function of the distance from the center of a solid charged conducting sphere of radius $R$?




ans: E

23. Charge $Q$ is distributed uniformly throughout an insulating sphere of radius $R$. The magnitude of the electric field at a point $R/2$ from the center is:
A. $Q/4\pi\epsilon_0 R^2$
B. $Q/\pi\epsilon_0 R^2$
C. $3Q/4\pi\epsilon_0 R^2$
D. $Q/8\pi\epsilon_0 R^2$
E. none of these

ans: D

24. Positive charge $Q$ is distributed uniformly throughout an insulating sphere of radius $R$, centered at the origin. A particle with positive charge $Q$ is placed at $x = 2R$ on the $x$ axis. The magnitude of the electric field at $x = R/2$ on the $x$ axis is:
A. $Q/4\pi\epsilon_0 R^2$
B. $Q/8\pi\epsilon_0 R^2$
C. $Q/72\pi\epsilon_0 R^2$
D. $17Q/72\pi\epsilon_0 R^2$
E. none of these

ans: C

25. Charge $Q$ is distributed uniformly throughout a spherical insulating shell. The net electric flux in $\mathrm{N \cdot m^2/C}$ through the inner surface of the shell is:
A. 0
B. $Q/\epsilon_0$
C. $2Q/\epsilon_0$
D. $Q/4\pi\epsilon_0$
E. $Q/2\pi\epsilon_0$

ans: A

26. Charge $Q$ is distributed uniformly throughout a spherical insulating shell. The net electric flux in $\mathrm{N \cdot m^2/C}$ through the outer surface of the shell is:

A. 0
B. $Q/\epsilon_0$
C. $2Q/\epsilon_0$
D. $Q/4\epsilon_0$
E. $Q/2\pi\epsilon_0$

ans: B

27. A 3.5-cm radius hemisphere contains a total charge of $6.6 \times 10^{-7}\,\mathrm{C}$. The flux through the rounded portion of the surface is $9.8 \times 10^4\,\mathrm{N \cdot m^2/C}$. The flux through the flat base is:

A. 0
B. $+2.3 \times 10^4\,\mathrm{N \cdot m^2/C}$
C. $-2.3 \times 10^4\,\mathrm{N \cdot m^2/C}$
D. $-9.8 \times 10^4\,\mathrm{N \cdot m^2/C}$
E. $+9.8 \times 10^4\,\mathrm{N \cdot m^2/C}$

ans: C

28. Charge is distributed uniformly along a long straight wire. The electric field 2 cm from the wire is 20 N/C. The electric field 4 cm from the wire is:

A. 120 N/C
B. 80 N/C
C. 40 N/C
D. 10 N/C
E. 5 N/C

ans: D

29. Positive charge $Q$ is placed on a conducting spherical shell with inner radius $R_1$ and outer radius $R_2$. A particle with charge $q$ is placed at the center of the cavity. The magnitude of the electric field at a point in the cavity, a distance $r$ from the center, is:

A. zero
B. $Q/4\pi\epsilon_0 R_1^2$
C. $q/4\pi\epsilon_0 r^2$
D. $(q+Q)/4\pi\epsilon_0 r^2$
E. $(q+Q)/4\pi\epsilon_0(R_1^2 - r^2)$

ans: C

30. Positive charge $Q$ is placed on a conducting spherical shell with inner radius $R_1$ and outer radius $R_2$. A point charge $q$ is placed at the center of the cavity. The magnitude of the electric field at a point outside the shell, a distance $r$ from the center, is:

A. zero
B. $Q/4\pi\epsilon_0 r^2$
C. $q/4\pi\epsilon_0 r^2$
D. $(q+Q)/4\pi\epsilon_0 r^2$
E. $(q+Q)/4\pi\epsilon_0(R_1^2 - r^2)$

ans: D

31. Positive charge $Q$ is placed on a conducting spherical shell with inner radius $R_1$ and outer radius $R_2$. A point charge $q$ is placed at the center of the cavity. The magnitude of the electric field produced by the charge on the inner surface at a point in the interior of the conductor, a distance $r$ from the center, is:

A. 0
B. $Q/4v\pi\epsilon_0 R_1^2$
C. $Q/4\pi\epsilon_0 R_2^2$
D. $q/4\pi\epsilon_0 r^2$
E. $Q/4\pi\epsilon_0 r^2$

ans: D

32. A long line of charge with $\lambda_\ell$ charge per unit length runs along the cylindrical axis of a cylindrical shell which carries a charge per unit length of $\lambda_c$. The charge per unit length on the inner and outer surfaces of the shell, respectively are:

A. $\lambda_\ell$ and $\lambda_c$
B. $-\lambda_\ell$ and $\lambda_c + \lambda_\ell$
C. $-\lambda_\ell$ and $\lambda_c - \lambda_c$
D. $\lambda_\ell + \lambda_c$ and $\lambda_c - \lambda_\ell$
E. $\lambda_\ell - \lambda_c$ and $\lambda_c + \lambda_\ell$

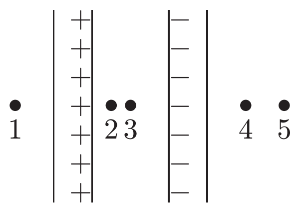
ans: B

33. Charge is distributed uniformly on the surface of a large flat plate. The electric field 2 cm from the plate is 30 N/C. The electric field 4 cm from the plate is:

A. 120 N/C
B. 80 N/C
C. 30 N/C
D. 15 N/C
E. 7.5 N/C

ans: C

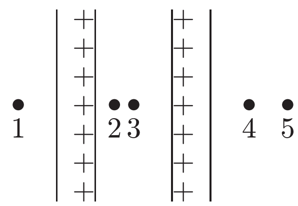
34. Two large insulating parallel plates carry charge of equal magnitude, one positive and the other negative, that is distributed uniformly over their inner surfaces. Rank the points 1 through 5 according to the magnitude of the electric field at the points, least to greatest.




A. 1, 2, 3, 4, 5
B. 2, then 1, 3, and 4 tied, then 5
C. 1, 4, and 5 tie, then 2 and 3 tie
D. 2 and 3 tie, then 1 and 4 tie, then 5
E. 2 and 3 tie, then 1, 4, and 5 tie

ans: C

35. Two large parallel plates carry positive charge of equal magnitude that is distributed uniformly over their inner surfaces. Rank the points 1 through 5 according to the magnitude of the electric field at the points, least to greatest.




A. 1, 2, 3, 4, 5
B. 5, 4, 3, 2, 1
C. 1, 4, and 5 tie, then 2 and 3 tie
D. 2 and 3 tie, then 1 and 4 tie, then 5
E. 2 and 3 tie, then 1, 4, and 5 tie

ans: E

36. A particle with charge $Q$ is placed outside a large neutral conducting sheet. At any point in the interior of the sheet the electric field produced by charges on the surface is directed:

A. toward the surface
B. away from the surface
C. toward $Q$
D. away from $Q$
E. none of the above

ans: C

37. A hollow conductor is positively charged. A small uncharged metal ball is lowered by a silk thread through a small opening in the top of the conductor and allowed to touch its inner surface. After the ball is removed, it will have:

A. a positive charge
B. a negative charge
C. no appreciable charge
D. a charge whose sign depends on what part of the inner surface it touched
E. a charge whose sign depends on where the small hole is located in the conductor

ans: C

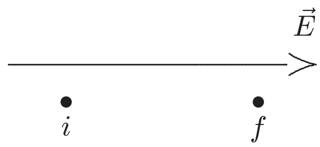
38. A spherical conducting shell has charge $Q$. A particle with charge $q$ is placed at the center of the cavity. The charge on the inner surface of the shell and the charge on the outer surface of the shell, respectively, are:

A. 0, $Q$
B. $q$, $Q - q$
C. $Q$, 0
D. $-q$, $Q + q$
E. $-q$, 0

ans: D

## Chapter 24: ELECTRIC POTENTIAL

1. An electron moves from point $i$ to point $f$, in the direction of a uniform electric field. During this displacement:




A. the work done by the field is positive and the potential energy of the electron-field system increases
B. the work done by the field is negative and the potential energy of the electron-field system increases
C. the work done by the field is positive and the potential energy of the electron-field system decreases
D. the work done by the field is negative and the potential energy of the electron-field system decreases
E. the work done by the field is positive and the potential energy of the electron-field system does not change

ans: B

2. A particle with a charge of $5.5 \times 10^{-8\,\mathrm{C}}$ is 3.5 cm from a particle with a charge of $-2.3 \times 10^{-8}$ C. The potential energy of this two-particle system, relative to the potential energy at infinite separation, is:

A. $3.2 \times 10^{-4}$ J
B. $-3.2 \times 10^{-4}$ J
C. $9.3 \times 10^{-3}$ J
D. $-9.3 \times 10^{-3}$ J
E. zero

ans: B

3. A particle with a charge of $5.5 \times 10^{-8}$ C is fixed at the origin. A particle with a charge of $-2.3 \times 10^{-8}$ C is moved from $x = 3.5$ cm on the $x$ axis to $y = 4.3$ cm on the $y$ axis. The change in potential energy of the two-particle system is:

A. $3.1 \times 10^{-3}$ J
B. $-3.1 \times 10^{-3}$ J
C. $6.0 \times 10^{-5}$ J
D. $-6.0 \times 10^{-5}$ J
E. 0

ans: C

4. A particle with a charge of $5.5 \times 10^{-8}$ C charge is fixed at the origin. A particle with a charge of $-2.3 \times 10^{-8}$ C charge is moved from $x = 3.5$ cm on the $x$ axis to $y = 3.5$ cm on the $y$ axis. The change in the potential energy of the two-particle system is:
   A. $3.2 \times 10^{-4}$ J
   B. $-3.2 \times 10^{-4}$ J
   C. $9.3 \times 10^{-3}$ J
   D. $-9.3 \times 10^{-3}$ J
   E. 0

   ans: E

5. Three particles lie on the $x$ axis: particle 1, with a charge of $1 \times 10^{-8}$ C is at $x = 1$ cm, particle 2, with a charge of $2 \times 10^{-8}$ C, is at $x = 2$ cm, and particle 3, with a charge of $-3 \times 10^{-8}$ C, is at $x = 3$ cm. The potential energy of this arrangement, relative to the potential energy for infinite separation, is:
   A. $+4.9 \times 10^{-4}$ J
   B. $-4.9 \times 10^{-4}$ J
   C. $+8.5 \times 10^{-4}$ J
   D. $-8.5 \times 10^{-4}$ J
   E. zero

   ans: B

6. Two identical particles, each with charge $q$, are placed on the $x$ axis, one at the origin and the other at $x = 5$ cm. A third particle, with charge $-q$, is placed on the $x$ axis so the potential energy of the three-particle system is the same as the potential energy at infinite separation. Its $x$ coordinate is:
   A. 13 cm
   B. 2.5 cm
   C. 7.5 cm
   D. 10 cm
   E. $-5$ cm

   ans: A

7. Choose the correct statement:
   A. A proton tends to go from a region of low potential to a region of high potential
   B. The potential of a negatively charged conductor must be negative
   C. If $\vec{E} = 0$ at a point P then $V$ must be zero at P
   D. If $V = 0$ at a point P then $\vec{E}$ must be zero at P
   E. None of the above are correct

   ans: E

8. If 500 J of work are required to carry a charged particle between two points with a potential difference of 20 V, the magnitude of the charge on the particle is:
   A. 0.040 C
   B. 12.5 C
   C. 20 C
   D. cannot be computed unless the path is given
   E. none of these

   ans: B

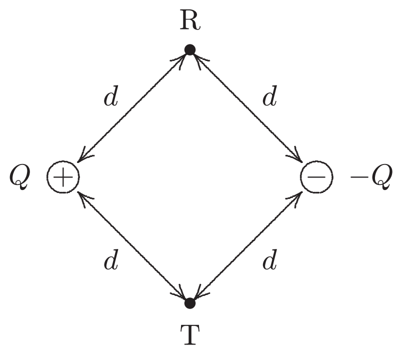
9. The potential difference between two points is 100 V. If a particle with a charge of 2 C is transported from one of these points to the other, the magnitude of the work done is:
   A. 200 J
   B. 100 J
   C. 50 J
   D. 100 J
   E. 2 J

   ans: A

10. During a lightning discharge, 30 C of charge move through a potential difference of $1.0 \times 10^8$ V in $2.0 \times 10^{-2}$ s. The energy released by this lightning bolt is:
   A. $1.5 \times 10^{11}$ J
   B. $3.0 \times 10^9$ J
   C. $6.0 \times 10^7$ J
   D. $3.3 \times 10^6$ J
   E. 1500 J

   ans: B

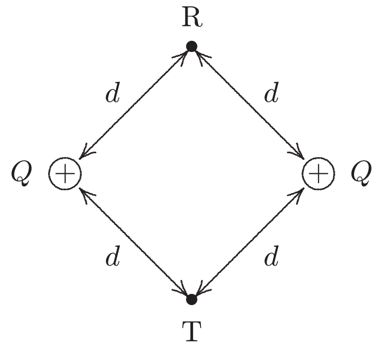
11. Points R and T are each a distance $d$ from each of two particles with charges of equal magnitudes and opposite signs as shown. If $k = 1/4\pi\epsilon_0$, the work required to move a particle with a negative charge $q$ from R to T is:




   A. 0
   B. $kqQ/d^2$
   C. $kqQ/d$
   D. $kqQ/(\sqrt{2}d)$
   E. $kQq/(2d)$

   ans: A

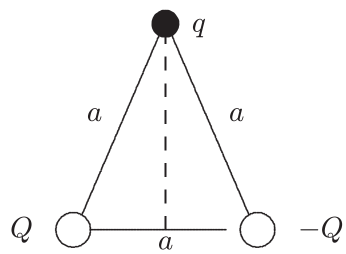
12. Points R and T are each a distance $d$ from each of two particles with equal positive charges as shown. If $k = 1/4\pi\epsilon_0$, the work required to move a particle with charge $q$ from R to T is:




A. 0
B. $kQq/d^2$
C. $kQq/d$
D. $kQq/(\sqrt{2}d)$
E. $kQq/(2d)$

ans: A

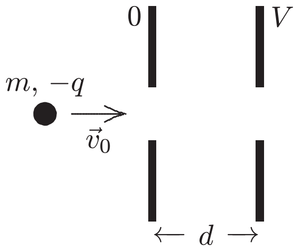
13. Two particle with charges $Q$ and $-Q$ are fixed at the vertices of an equilateral triangle with sides of length $a$. If $k = 1/4\pi\epsilon_0$, the work required to move a particle with charge $q$ from the other vertex to the center of the line joining the fixed particles is:




A. 0
B. $kQq/a$
C. $kQq/a^2$
D. $2kQq/a$
E. $\sqrt{2}kQq/a$

ans: A

14. A particle with mass $m$ and charge $-q$ is projected with speed $v_0$ into the region between two parallel plates as shown. The potential difference between the two plates is $V$ and their separation is $d$. The change in kinetic energy of the particle as it traverses this region is:




A. $-qV/d$
B. $2qV/mv_0^2$
C. $qV$
D. $mv_0^2/2$
E. none of these

ans: C

15. An electron is accelerated from rest through a potential difference $V$. Its final speed is proportional to:

A. $V$
B. $V^2$
C. $\sqrt{V}$
D. $1/V$
E. $1/\sqrt{V}$

ans: C

16. In separate experiments, four different particles each start from far away with the same speed and impinge directly on a gold nucleus. The masses and charges of the particles are

particle 1: mass $m_0$, charge $q_0$
particle 2: mass $2m_0$, charge $2q_0$
particle 3: mass $2m_0$, charge $q_0/2$
particle 4: mass $m_0/2$, charge $2q_0$

Rank the particles according to the distance of closest approach to the gold nucleus, from smallest to largest.

A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 3, 1 and 2 tie, then 4
D. 4, 1 and 2 tie, then 1
E. 1 and 2 tie, then 3, 4

ans: C

17. Two large parallel conducting plates are separated by a distance $d$, placed in a vacuum, and connected to a source of potential difference $V$. An oxygen ion, with charge $2e$, starts from rest on the surface of one plate and accelerates to the other. If $e$ denotes the magnitude of the electron charge, the final kinetic energy of this ion is:

A. $eV/2$
B. $eV/d$
C. $eVd$
D. $Vd/e$
E. $2eV$

ans: E

18. An electron volt is :

A. the force acting on an electron in a field of 1 N/C
B. the force required to move an electron 1 meter
C. the energy gained by an electron in moving through a potential difference of 1 volt
D. the energy needed to move an electron through 1 meter in any electric field
E. the work done when 1 coulomb of charge is moved through a potential difference of 1 volt.

ans: C

19. An electron has charge $-e$ and mass $m_e$. A proton has charge $e$ and mass $1840m_e$. A "proton volt" is equal to:

A. 1 eV
B. 1840 eV
C. (1/1840) eV
D. $\sqrt{1840}$ eV
E. $(1/\sqrt{1840})$ eV

ans: A

20. Two conducting spheres, one having twice the diameter of the other, are separated by a distance large compared to their diameters. The smaller sphere (1) has charge $q$ and the larger sphere (2) is uncharged. If the spheres are then connected by a long thin wire:


A. 1 and 2 have the same potential
B. 2 has twice the potential of 1
C. 2 has half the potential of 1
D. 1 and 2 have the same charge
E. all of the charge is dissipated

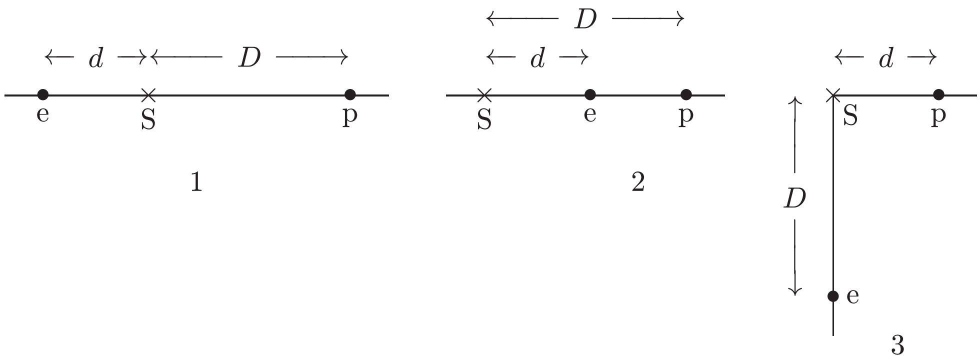
ans: A

21. Two conducting spheres are far apart. The smaller sphere carries a total charge $Q$. The larger sphere has a radius that is twice that of the smaller and is neutral. After the two spheres are connected by a conducting wire, the charges on the smaller and larger spheres, respectively, are:

A. $Q/2$ and $Q/2$
B. $Q/3$ and $2Q/3$
C. $2Q/3$ and $Q/3$
D. zero and $Q$
E. $2Q$ and $-Q$

ans: B

22. Three possible configurations for an electron e and a proton p are shown below. Take the zero of potential to be at infinity and rank the three configurations according to the potential at S, from most negative to most positive.




A. 1, 2, 3
B. 3, 2, 1
C. 2, 3, 1
D. 1 and 2 tie, then 3
E. 1 and 3 tie, then 2

ans: D

23. A conducting sphere with radius $R$ is charged until the magnitude of the electric field just outside its surface is $E$. The electric potential of the sphere, relative to the potential far away, is:

A. zero
B. $E/R$
C. $E/R^2$
D. $ER$
E. $ER^2$

ans: D

24. A 5-cm radius conducting sphere has a surface charge density of $2 \times 10^{-6}\,\mathrm{C/m^2}$ on its surface. Its electric potential, relative to the potential far away, is:

A. $1.1 \times 10^4$ V
B. $2.2 \times 10^4$ V
C. $2.3 \times 10^5$ V
D. $3.6 \times 10^5$ V
E. $7.2 \times 10^6$ V

ans: A

25. A hollow metal sphere is charged to a potential $V$. The potential at its center is:

A. $V$
B. 0
C. $-V$
D. $2V$
E. $\pi V$

ans: A

26. Positive charge is distributed uniformly throughout a non-conducting sphere. The highest electric potential occurs:

A. at the center
B. at the surface
C. halfway between the center and surface
D. just outside the surface
E. far from the sphere

ans: A

27. A total charge of $7 \times 10^{-8}$ C is uniformly distributed throughout a non-conducting sphere with a radius of 5 cm. The electric potential at the surface, relative to the potential far away, is about:

A. $-1.3 \times 10^4$ V
B. $1.3 \times 10^4$ V
C. $7.0 \times 10^5$ V
D. $-6.3 \times 10^4$ V
E. 0

ans: B

28. Eight identical spherical raindrops are each at a potential $V$, relative to the potential far away. They coalesce to make one spherical raindrop whose potential is:

A. $V/8$
B. $V/2$
C. $2V$
D. $4V$
E. $8V$

ans: D

29. A metal sphere carries a charge of $5 \times 10^{-9}$ C and is at a potential of 400 V, relative to the potential far away. The potential at the center of the sphere is:
A. 400 V
B. −400 V
C. $2 \times 10^{-6}$ V
D. 0
E. none of these
ans: A

30. A 5-cm radius isolated conducting sphere is charged so its potential is +100 V, relative to the potential far away. The charge density on its surface is:
A. $+2.2 \times 10^{-7}\ \mathrm{C/m^2}$
B. $-2.2 \times 10^{-7}\ \mathrm{C/m^2}$
C. $+3.5 \times 10^{-7}\ \mathrm{C/m^2}$
D. $-3.5 \times 10^{-7}\ \mathrm{C/m^2}$
E. $+1.8 \times 10^{-8}\ \mathrm{C/m^2}$
ans: E

31. A conducting sphere has charge $Q$ and its electric potential is $V$, relative to the potential far away. If the charge is doubled to $2Q$, the potential is:
A. $V$
B. $2V$
C. $4V$
D. $V/2$
E. $V/4$
ans: B

32. The potential difference between the ends of a 2-meter stick that is parallel to a uniform electric field is 400 V. The magnitude of the electric field is:
A. zero
B. 100 V/m
C. 200 V/m
D. 400 V/m
E. 800 V/m
ans: E

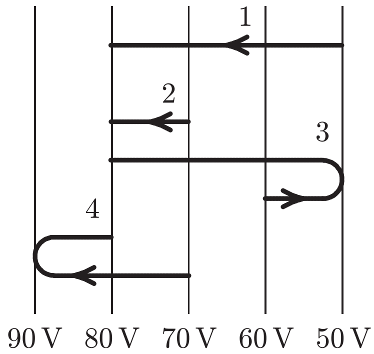
33. In a certain region of space the electric potential increases uniformly from east to west and does not vary in any other direction. The electric field:
A. points east and varies with position
B. points east and does not vary with position
C. points west and varies with position
D. points west and does not vary with position
E. points north and does not vary with position
ans: B

34. If the electric field is in the positive $x$ direction and has a magnitude given by $E = Cx^2$, where $C$ is a constant, then the electric potential is given by $V =$:

A. $2Cx$
B. $-2Cx$
C. $Cx^3/3$
D. $-Cx^3/3$
E. $-3Cx^3$

ans: D

35. An electron goes from one equipotential surface to another along one of the four paths shown below. Rank the paths according to the work done by the electric field, from least to greatest.




A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 1, 3, 4 and 2 tie
D. 4 and 2 tie, then 3, then 1
E. 4, 3, 1, 2

ans: D

36. The work required to carry a particle with a charge of 6.0 C from a 5.0-V equipotential surface to a 6.0-V equipotential surface and back again to the 5.0-V surface is:

A. 0
B. $1.2 \times 10^{-5}$ J
C. $3.0 \times 10^{-5}$ J
D. $6.0 \times 10^{-5}$ J
E. $6.0 \times 10^{-6}$ J

ans: A

37. The equipotential surfaces associated with a charged point particles are:

A. radially outward from the particle
B. vertical planes
C. horizontal planes
D. concentric spheres centered at the particle
E. concentric cylinders with the particle on the axis.

ans: D

38. The electric field in a region around the origin is given by $\vec{E} = C(x\,\hat{\imath} + y\,\hat{\jmath})$, where $C$ is a constant. The equipotential surfaces in that region are:

A. concentric cylinders with axes along the $z$ axis
B. concentric cylinders with axes along the $x$ axis
C. concentric spheres centered at the origin
D. planes parallel to the $xy$ plane
E. planes parallel to the $yz$ plane

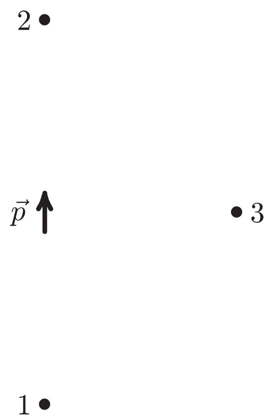
ans: A

39. The electric potential in a certain region of space is given by $V = -7.5x^2 + 3x$, where $V$ is in volts and $x$ is in meters. In this region the equipotential surfaces are:

A. planes parallel to the $x$ axis
B. planes parallel to the $yz$ plane
C. concentric spheres centered at the origin
D. concentric cylinders with the $x$ axis as the cylinder axis
E. unknown unless the charge is given

ans: B

40. In the diagram, the points 1, 2, and 3 are all the same very large distance from a dipole. Rank the points according to the values of the electric potential at them, from the most negative to the most positive.




A. 1, 2, 3
B. 3, 2, 1
C. 2, 3, 1
D. 1, 3, 2
E. 1 and 2 tie, then 3

ans: D

41. A particle with charge $q$ is to be brought from far away to a point near an electric dipole. No work is done if the final position of the particle is on:

A. the line through the charges of the dipole
B. a line that is perpendicular to the dipole moment
C. a line that makes an angle of 45° with the dipole moment
D. a line that makes an angle of 30° with the dipole moment
E. none of the above

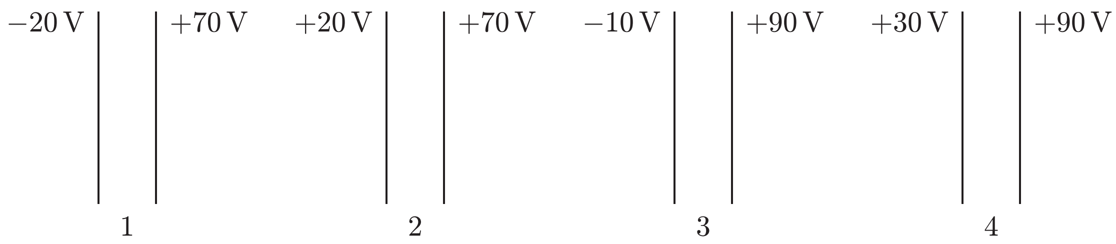
ans: B

42. Equipotential surfaces associated with an electric dipole are:

A. spheres centered on the dipole
B. cylinders with axes along the dipole moment
C. planes perpendicular to the dipole moment
D. planes parallel to the dipole moment
E. none of the above

ans: E

43. The diagram shows four pairs of large parallel conducting plates. The value of the electric potential is given for each plate. Rank the pairs according to the magnitude of the electric field between the plates, least to greatest.




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

ans: D

# Chapter 25: CAPACITANCE

1. The units of capacitance are equivalent to:
   A. J/C
   B. V/C
   C. $J^2/C$
   D. C/J
   E. $C^2/J$
   ans: E

2. A farad is the same as a:
   A. J/V
   B. V/J
   C. C/V
   D. V/C
   E. N/C
   ans: C

3. A capacitor C "has a charge Q". The actual charges on its plates are:
   A. $Q$, $Q$
   B. $Q/2$, $Q/2$
   C. $Q$, $-Q$
   D. $Q/2$, $-Q/2$
   E. $Q$, 0
   ans: C

4. Each plate of a capacitor stores a charge of magnitude 1 mC when a 100-V potential difference is applied. The capacitance is:
   A. $5\,\mu$F
   B. $10\,\mu$F
   C. $50\,\mu$F
   D. $100\,\mu$F
   E. none of these
   ans: B

5. To charge a 1-F capacitor with 2 C requires a potential difference of:
   A. 2 V
   B. 0.2 V
   C. 5 V
   D. 0.5 V
   E. none of these
   ans: A

6. The capacitance of a parallel-plate capacitor with plate area $A$ and plate separation $d$ is given by:
   A. $\epsilon_0 d/A$
   B. $\epsilon_0 d/2A$
   C. $\epsilon_0 A/d$
   D. $\epsilon_0 A/2d$
   E. $Ad/\epsilon_0$
   ans: C

7. The capacitance of a parallel-plate capacitor is:
   A. proportional to the plate area
   B. proportional to the charge stored
   C. independent of any material inserted between the plates
   D. proportional to the potential difference of the plates
   E. proportional to the plate separation
   ans: A

8. The plate areas and plate separations of five parallel plate capacitors are
   capacitor 1: area $A_0$, separation $d_0$
   capacitor 2: area $2A_0$, separation $2d_0$
   capacitor 3: area $2A_0$, separation $d_0/2$
   capacitor 4: area $A_0/2$, separation $2d_0$
   capacitor 5: area $A_0$, separation $d_0/2$
   Rank these according to their capacitances, least to greatest.
   A. 1, 2, 3, 4, 5
   B. 5, 4, 3, 2, 1
   C. 5, 3 and 4 tie, then 1, 2
   D. 4, 1 and 2 tie, then 5, 3
   E. 3, 5, 1 and 2 tie, 1, 4
   ans: D

9. The capacitance of a parallel-plate capacitor can be increased by:
   A. increasing the charge
   B. decreasing the charge
   C. increasing the plate separation
   D. decreasing the plate separation
   E. decreasing the plate area
   ans: D

10. If both the plate area and the plate separation of a parallel-plate capacitor are doubled, the capacitance is:
    A. doubled
    B. halved
    C. unchanged
    D. tripled
    E. quadrupled
    ans: C

11. If the plate area of an isolated charged parallel-plate capacitor is doubled:
   A. the electric field is doubled
   B. the potential difference is halved
   C. the charge on each plate is halved
   D. the surface charge density on each plate is doubled
   E. none of the above

   ans: B

12. If the plate separation of an isolated charged parallel-plate capacitor is doubled:
   A. the electric field is doubled
   B. the potential difference is halved
   C. the charge on each plate is halved
   D. the surface charge density on each plate is doubled
   E. none of the above

   ans: E

13. Pulling the plates of an isolated charged capacitor apart:
   A. increases the capacitance
   B. increases the potential difference
   C. does not affect the potential difference
   D. decreases the potential difference
   E. does not affect the capacitance

   ans: B

14. If the charge on a parallel-plate capacitor is doubled:
   A. the capacitance is halved
   B. the capacitance is doubled
   C. the electric field is halved
   D. the electric field is doubled
   E. the surface charge density is not changed on either plate

   ans: D

15. A parallel-plate capacitor has a plate area of $0.2\,\mathrm{m}^2$ and a plate separation of $0.1\,\mathrm{mm}$. To obtain an electric field of $2.0 \times 10^6\,\mathrm{V/m}$ between the plates, the magnitude of the charge on each plate should be:
   A. $8.9 \times 10^{-7}\,\mathrm{C}$
   B. $1.8 \times 10^{-6}\,\mathrm{C}$
   C. $3.5 \times 10^{-6}\,\mathrm{C}$
   D. $7.1 \times 10^{-6}\,\mathrm{C}$
   E. $1.4 \times 10^{-5}\,\mathrm{C}$

   ans: D

16. A parallel-plate capacitor has a plate area of $0.2\,\mathrm{m}^2$ and a plate separation of $0.1\,\mathrm{mm}$. If the charge on each plate has a magnitude of $4 \times 10^{-6}\,\mathrm{C}$ the potential difference across the plates is approximately:

A. 0
B. $4 \times 10^{-2}\,\mathrm{V}$
C. $1 \times 10^{2}\,\mathrm{V}$
D. $2 \times 10^{2}\,\mathrm{V}$
E. $4 \times 10^{8}\,\mathrm{V}$

ans: D

17. The capacitance of a spherical capacitor with inner radius $a$ and outer radius $b$ is proportional to:

A. $a/b$
B. $b - a$
C. $b^2 - a^2$
D. $ab/(b - a)$
E. $ab/(b^2 - a^2)$

ans: D

18. The capacitance of a single isolated spherical conductor with radius $R$ is proportional to:

A. $R$
B. $R^2$
C. $1/R$
D. $1/R^2$
E. none of these

ans: A

19. Two conducting spheres have radii of $R_1$ and $R_2$, with $R_1$ greater than $R_2$. If they are far apart the capacitance is proportional to:

A. $R_1R_2/(R_1 - R_2)$
B. $R_1^2 - R_2^2$
C. $(R_1 - R_2)/R_1R_2$
D. $R_1^2 + R_2^2$
E. none of these

ans: A

20. The capacitance of a cylindrical capacitor can be increased by:

A. decreasing both the radius of the inner cylinder and the length
B. increasing both the radius of the inner cylinder and the length
C. increasing the radius of the outer cylindrical shell and decreasing the length
D. decreasing the radius of the inner cylinder and increasing the radius of the outer cylindrical shell
E. only by decreasing the length

ans: B

21. A battery is used to charge a series combination of two identical capacitors. If the potential difference across the battery terminals is $V$ and total charge $Q$ flows through the battery during the charging process then the charge on the positive plate of each capacitor and the potential difference across each capacitor are:
A. $Q/2$ and $V/2$, respectively
B. $Q$ and $V$, respectively
C. $Q/2$ and $V$, respectively
D. $Q$ and $V/2$, respectively
E. $Q$ and $2V$, respectively
ans: D

22. A battery is used to charge a parallel combination of two identical capacitors. If the potential difference across the battery terminals is $V$ and total charge $Q$ flows through the battery during the charging process then the charge on the positive plate of each capacitor and the potential difference across each capacitor are:
A. $Q/2$ and $V/2$, respectively
B. $Q$ and $V$, respectively
C. $Q/2$ and $V$, respectively
D. $Q$ and $V/2$, respectively
E. $Q$ and $2V$, respectively
ans: C

23. A 2-$\mu$F and a 1-$\mu$F capacitor are connected in series and a potential difference is applied across the combination. The 2-$\mu$F capacitor has:
A. twice the charge of the 1-$\mu$F capacitor
B. half the charge of the 1-$\mu$F capacitor
C. twice the potential difference of the 1-$\mu$F capacitor
D. half the potential difference of the 1-$\mu$F capacitor
E. none of the above
ans: D

24. A 2-$\mu$F and a 1-$\mu$F capacitor are connected in parallel and a potential difference is applied across the combination. The 2-$\mu$F capacitor has:
A. twice the charge of the 1-$\mu$F capacitor
B. half the charge of the 1-$\mu$F capacitor
C. twice the potential difference of the 1-$\mu$F capacitor
D. half the potential difference of the 1-$\mu$F capacitor
E. none of the above
ans: A

25. Let $Q$ denote charge, $V$ denote potential difference, and $U$ denote stored energy. Of these quantities, capacitors in series must have the same:
A. $Q$ only
B. $V$ only
C. $U$ only
D. $Q$ and $U$ only
E. $V$ and $U$ only
ans: A

26. Let $Q$ denote charge, $V$ denote potential difference, and $U$ denote stored energy. Of these quantities, capacitors in parallel must have the same:

A. $Q$ only
B. $V$ only
C. $U$ only
D. $Q$ and $U$ only
E. $V$ and $U$ only

ans: B

27. Capacitors $C_1$ and $C_2$ are connected in parallel. The equivalent capacitance is given by:

A. $C_1C_2/(C_1 + C_2)$
B. $(C_1 + C_2)/C_1C_2$
C. $1/(C_1 + C_2)$
D. $C_1/C_2$
E. $C_1 + C_2$

ans: E

28. Capacitors $C_1$ and $C_2$ are connected in series. The equivalent capacitance is given by:

A. $C_1C_2/(C_1 + C_2)$
B. $(C_1 + C_2)/C_1C_2$
C. $1/(C_1 + C_2)$
D. $C_1/C_2$
E. $C_1 + C_2$

ans: A

29. Capacitors $C_1$ and $C_2$ are connected in series and a potential difference is applied to the combination. If the capacitor that is equivalent to the combination has the same potential difference, then the charge on the equivalent capacitor is the same as:

A. the charge on $C_1$
B. the sum of the charges on $C_1$ and $C_2$
C. the difference of the charges on $C_1$ and $C_2$
D. the product of the charges on $C_1$ and $C_2$
E. none of the above

ans: A

30. Capacitors $C_1$ and $C_2$ are connected in parallel and a potential difference is applied to the combination. If the capacitor that is equivalent to the combination has the same potential difference, then the charge on the equivalent capacitor is the same as:

A. the charge on $C_1$
B. the sum of the charges on $C_1$ and $C_2$
C. the difference of the charges on $C_1$ and $C_2$
D. the product of the charges on $C_1$ and $C_2$
E. none of the above

ans: B

31. Two identical capacitors are connected in series and two, each identical to the first, are connected in parallel. The equivalent capacitance of the series connection is ____ the equivalent capacitance of parallel connection.

A. twice
B. four times
C. half
D. one-fourth
E. the same as

ans: D

32. Two identical capacitors, each with capacitance $C$, are connected in parallel and the combination is connected in series to a third identical capacitor. The equivalent capacitance of this arrangement is:

A. $2C/3$
B. $C$
C. $3C/2$
D. $2C$
E. $3C$

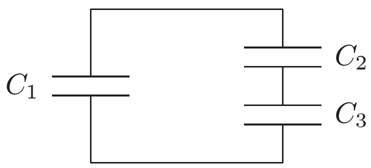
ans: A

33. A 2-$\mu$F and a 1-$\mu$F capacitor are connected in series and charged from a battery. They store charges $P$ and $Q$, respectively. When disconnected and charged separately using the same battery, they have charges $R$ and $S$, respectively. Then:

A. $R > S > Q = P$
B. $P > Q > R = S$
C. $R > P = Q > S$
D. $R = P > S = Q$
E. $R > P > S = Q$

ans: A

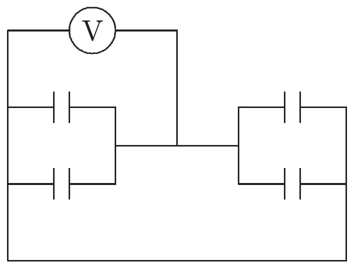
34. Capacitor $C_1$ is connected alone to a battery and charged until the magnitude of the charge on each plate is $4.0 \times 10^{-8}$ C. Then it is removed from the battery and connected to two other capacitors $C_2$ and $C_3$, as shown. The charge on the positive plate of $C_1$ is then $1.0 \times 10^{-8}$ C. The charges on the positive plates of $C_2$ and $C_3$ are:




A. $q_2 = 3.0 \times 10^{-8}$ C and $q_3 = 3.0 \times 10^{-8}$ C
B. $q_2 = 2.0 \times 10^{-8}$ C and $q_3 = 2.0 \times 10^{-8}$ C
C. $q_2 = 5.0 \times 10^{-8}$ C and $q_3 = 1.0 \times 10^{-8}$ C
D. $q_2 = 3.0 \times 10^{-8}$ C and $q_3 = 1.0 \times 10^{-8}$ C
E. $q_2 = 1.0 \times 10^{-8}$ C and $q_3 = 3.0 \times 10^{-8}$ C

ans: A

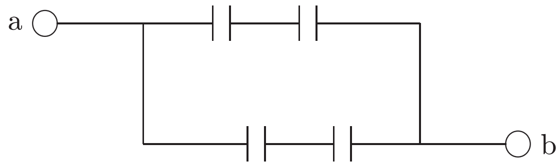
35. Each of the four capacitors shown is 500 $\mu$F. The voltmeter reads 1000 V. The magnitude of the charge, in coulombs, on each capacitor plate is:




A. 0.2
B. 0.5
C. 20
D. 50
E. none of these

ans: B

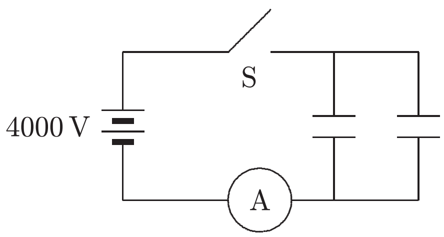
36. The diagram shows four 6-$\mu$F capacitors. The capacitance between points a and b is:




A. 3 $\mu$F
B. 4 $\mu$F
C. 6 $\mu$F
D. 9 $\mu$F
E. 1 $\mu$F

ans: C

37. Each of the two 25-$\mu$F capacitors shown is initially uncharged. How many coulombs of charge pass through the ammeter A after the switch S is closed?




A. 0.10
B. 0.20
C. 10
D. 0.05
E. none of these

ans: B

38. A 20-F capacitor is charged to 200 V. Its stored energy is:

A. 4000 J
B. 4 J
C. 0.4 J
D. 2000 J
E. 0.1 J

ans: C

39. A charged capacitor stores 10 C at 40 V. Its stored energy is:

A. 400 J
B. 4 J
C. 0.2 J
D. 2.5 J
E. 200 J

ans: E

40. A 2-$\mu$F and a 1-$\mu$F capacitor are connected in series and charged by a battery. They store energies $P$ and $Q$, respectively. When disconnected and charged separately using the same battery, they store energies $R$ and $S$, respectively. Then:

A. $R > P > S > Q$
B. $P > Q > R > S$
C. $R > P > Q > S$
D. $P > R > S > Q$
E. $R > S > Q > P$

ans: E

41. The quantity $(1/2)\epsilon_0 E^2$ has the significance of:

A. energy/farad
B. energy/coulomb
C. energy
D. energy/volume
E. energy/volt

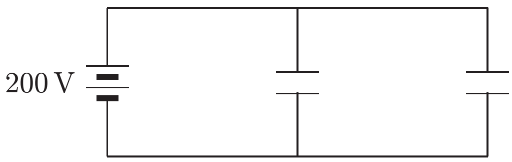
ans: D

42. Capacitors A and B are identical. Capacitor A is charged so it stores 4 J of energy and capacitor B is uncharged. The capacitors are then connected in parallel. The total stored energy in the capacitors is now:

A. 16 J
B. 8 J
C. 4 J
D. 2 J
E. 1 J

ans: D

43. To store a total of 0.040 J of energy in the two identical capacitors shown, each should have a capacitance of:




A. $0.10\,\mu$F
B. $0.50\,\mu$F$0.10\,\mu$F
C. $1.0\,\mu$J
D. $1.5\,\mu$F
E. $2.0\,\mu$F
ans: C

44. A battery is used to charge a parallel-plate capacitor, after which it is disconnected. Then the plates are pulled apart to twice their original separation. This process will double the:
A. capacitance
B. surface charge density on each plate
C. stored energy
D. electric field between the two places
E. charge on each plate
ans: C

45. A parallel-plate capacitor has a plate area of $0.3\,\text{m}^2$ and a plate separation of 0.1 mm. If the charge on each plate has a magnitude of $5 \times 10^{-6}$ C then the force exerted by one plate on the other has a magnitude of about:
A. 0
B. 5 N
C. 9 N
D. $1 \times 10^4$ N
E. $9 \times 10^5$ N
ans: B

46. A certain capacitor has a capacitance of $5.0\,\mu$F. After it is charged to $5.0\,\mu$C and isolated, the plates are brought closer together so its capacitance becomes $10\,\mu$F. The work done by the agent is about:
A. zero
B. $1.25 \times 10^{-6}$ J
C. $-1.25 \times 10^{-6}$ J
D. $8.3 \times 10^{-7}$ J
E. $-8.3 \times 10^{-7}$ J
ans: C

47. A dielectric slab is slowly inserted between the plates of a parallel plate capacitor, while the potential difference between the plates is held constant by a battery. As it is being inserted:

A. the capacitance, the potential difference between the plates, and the charge on the positive plate all increase
B. the capacitance, the potential difference between the plates, and the charge on the positive plate all decrease
C. the potential difference between the plates increases, the charge on the positive plate decreases, and the capacitance remains the same
D. the capacitance and the charge on the positive plate decrease but the potential difference between the plates remains the same
E. the capacitance and the charge on the positive plate increase but the potential difference between the plates remains the same

ans: E

48. An air-filled parallel-plate capacitor has a capacitance of 1 pF. The plate separation is then doubled and a wax dielectric is inserted, completely filling the space between the plates. As a result, the capacitance becomes 2 pF. The dielectric constant of the wax is:

A. 0.25
B. 0.5
C. 2.0
D. 4.0
E. 8.0

ans: D

49. One of materials listed below is to be placed between two identical metal sheets, with no, air gap, to form a parallel-plate capacitor. Which produces the greatest capacitance?

A. material of thickness 0.1 mm and dielectric constant 2
B. material of thickness 0.2 mm and dielectric constant 3
C. material of thickness 0.3 mm and dielectric constant 2
D. material of thickness 0.4 mm and dielectric constant 8
E. material of thickness 0.5 mm and dielectric constant 11

ans: E

50. Two capacitors are identical except that one is filled with air and the other with oil. Both capacitors carry the same charge. The ratio of the electric fields $E_{\rm air}/E_{\rm oil}$ is:

A. between 0 and 1
B. 0
C. 1
D. between 1 and infinity
E. infinite

ans: D

51. A parallel-plate capacitor, with air dielectric, is charged by a battery, after which the battery is disconnected. A slab of glass dielectric is then slowly inserted between the plates. As it is being inserted:

A. a force repels the glass out of the capacitor
B. a force attracts the glass into the capacitor
C. no force acts on the glass
D. a net charge appears on the glass
E. the glass makes the plates repel each other

ans: B

52. Two parallel-plate capacitors with the same plate separation but different capacitance are connected in parallel to a battery. Both capacitors are filled with air. The quantity that is NOT the same for both capacitors when they are fully charged is:

A. potential difference
B. energy density
C. electric field between the plates
D. charge on the positive plate
E. dielectric constant

ans: D

53. Two parallel-plate capacitors with the same plate area but different capacitance are connected in parallel to a battery. Both capacitors are filled with air. The quantity that is the same for both capacitors when they are fully charged is:

A. potential difference
B. energy density
C. electric field between the plates
D. charge on the positive plate
E. plate separation

ans: A

54. Two parallel-plate capacitors with different plate separation but the same capacitance are connected in series to a battery. Both capacitors are filled with air. The quantity that is NOT the same for both capacitors when they are fully charged is:

A. potential difference
B. stored energy
C. electric field between the plates
D. charge on the positive plate
E. dielectric constant

ans: C

55. Two parallel-plate capacitors with different capacitance but the same plate separation are connected in series to a battery. Both capacitors are filled with air. The quantity that is the same for both capacitors when they are fully charged is:

A. potential difference
B. stored energy
C. energy density
D. electric field between the plates
E. charge on the positive plate

ans: E

## Chapter 26: CURRENT AND RESISTANCE

1. A car battery is rated at $80\,\mathrm{A}\cdot\mathrm{h}$. An ampere-hour is a unit of:
   A. power
   B. energy
   C. current
   D. charge
   E. force
   ans: D

2. Current has units:
   A. kilowatt·hour
   B. coulomb/second
   C. coulomb
   D. volt
   E. ohm
   ans: B

3. Current has units:
   A. kilowatt·hour
   B. ampere
   C. coulomb
   D. volt
   E. ohm
   ans: B

4. The units of resistivity are:
   A. ohm
   B. ohm·meter
   C. ohm/meter
   D. ohm/meter$^2$
   E. none of these
   ans: B

5. The rate at which electrical energy is used may be measured in:
   A. watt/second
   B. watt·second
   C. watt
   D. joule·second
   E. kilowatt·hour
   ans: C

6. Energy may be measured in:
   A. kilowatt
   B. joule·second
   C. watt
   D. watt·second
   E. volt/ohm

   ans: D

7. Which one of the following quantities is correctly matched to its unit?
   A. Power — kW·h
   B. Energy — kW
   C. Potential difference — J/C
   D. Current — A/s
   E. Resistance — V/C

   ans: C

8. Current is a measure of:
   A. force that moves a charge past a point
   B. resistance to the movement of a charge past a point
   C. energy used to move a charge past a point
   D. amount of charge that moves past a point per unit time
   E. speed with which a charge moves past a point

   ans: D

9. A 60-watt light bulb carries a current of 0.5 A. The total charge passing through it in one hour is:
   A. 120 C
   B. 3600 C
   C. 3000 C
   D. 2400 C
   E. 1800 C

   ans: E

10. A 10-ohm resistor has a constant current. If 1200 C of charge flow through it in 4 minutes what is the value of the current?
    A. 3.0 A
    B. 5.0 A
    C. 11 A
    D. 15 A
    E. 20 A

    ans: D

11. Conduction electrons move to the right in a certain wire. This indicates that:
   A. the current density and electric field both point right
   B. the current density and electric field both point left
   C. the current density points right and the electric field points left
   D. the current density points left and the electric field points right
   E. the current density points left but the direction of the electric field is unknown

   ans: B

12. Two wires made of different materials have the same uniform current density. They carry the same current only if:
   A. their lengths are the same
   B. their cross-sectional areas are the same
   C. both their lengths and cross-sectional areas are the same
   D. the potential differences across them are the same
   E. the electric fields in them are the same

   ans: B

13. A wire with a length of 150 m and a radius of 0.15 mm carries a current with a uniform current density of $2.8 \times 10^7$ A/m$^2$. The current is:
   A. $0.63\,A^2$
   B. $2.0\,A$
   C. $5.9\,A^2$
   D. $296\,A$
   E. $400\,A^2$

   ans: B

14. In a conductor carrying a current we expect the electron drift speed to be:
   A. much greater than the average electron speed
   B. much less than the average electron speed
   C. about the same as the average electron speed
   D. less than the average electron speed at low temperature and greater than the average electron speed at high temperature
   E. less than the average electron speed at high temperature and greater than the average electron speed at low temperature

   ans: B

15. Two substances are identical except that the electron mean free time for substance A is twice the electron mean free time for substance B. If the same electric field exists in both substances the electron drift speed in A is:
   A. the same as in B
   B. twice that in B
   C. half that in B
   D. four times that in B
   E. one-fourth that in B

   ans: B

16. The current is zero in a conductor when no potential difference is applied because:
    A. the electrons are not moving
    B. the electrons are not moving fast enough
    C. for every electron with a given velocity there is another with a velocity of equal magnitude and opposite direction.
    D. equal numbers of electrons and protons are moving together
    E. otherwise Ohm's law would not be valid

    ans: C

17. The current density is the same in two wires. Wire A has twice the free-electron concentration of wire B. The drift speed of electrons in A is:
    A. twice that of electrons in B
    B. four times that of electrons in B
    C. half that of electrons in B
    D. one-fourth that of electrons in B
    E. the same as that of electrons in B

    ans: C

18. Copper contains $8.4 \times 10^{28}$ free electrons/$\mathrm{m}^3$. A copper wire of cross-sectional area $7.4 \times 10^{-7}\,\mathrm{m}^2$ carries a current of $1\,\mathrm{A}$. The electron drift speed is approximately:
    A. $3 \times 10^8\,\mathrm{m/s}$
    B. $10^3\,\mathrm{m/s}$
    C. $1\,\mathrm{m/s}$
    D. $10^{-4}\,\mathrm{m/s}$
    E. $10^{-23}\,\mathrm{m/s}$

    ans: D

19. If $\vec{J}$ is the current density and $d\vec{A}$ is a vector element of area then the integral $\int \vec{J} \cdot d\vec{A}$ over an area represents:
    A. the electric flux through the area
    B. the average current density at the position of the area
    C. the resistance of the area
    D. the resistivity of the area
    E. the current through the area

    ans: E

20. If the potential difference across a resistor is doubled:
    A. only the current is doubled
    B. only the current is halved
    C. only the resistance is doubled
    D. only the resistance is halved
    E. both the current and resistance are doubled

    ans: A

21. Five cylindrical wires are made of the same material. Their lengths and radii are

wire 1: length $\ell$, radius $r$
wire 2: length $\ell/4$, radius $r/2$
wire 3: length $\ell/2$, radius $r/2$
wire 4: length $\ell$, radius $r/2$
wire 5: length $5\ell$, radius $2r$

Rank the wires according to their resistances, least to greatest.

A. 1, 2, 3, 4, 5
B. 5, 4, 3, 2, 1
C. 1 and 2 tie, then 5, 3, 4
D. 1, 3, 4, 2, 5
E. 1, 2, 4, 3, 5

ans: C

22. Of the following, the copper conductor that has the least resistance is:

A. thin, long and hot
B. thick, short and cool
C. thick, long and hot
D. thin, short and cool
E. thin, short and hot

ans: B

23. A cylindrical copper rod has resistance $R$. It is reformed to twice its original length with no change of volume. Its new resistance is:

A. $R$
B. $2R$
C. $4R$
D. $8R$
E. $R/2$

ans: C

24. The resistance of a rod does NOT depend on:

A. its temperature
B. its material
C. its length
D. its conductivity
E. the shape of its (fixed) cross-sectional area

ans: E

25. A certain wire has resistance $R$. Another wire, of the same material, has half the length and half the diameter of the first wire. The resistance of the second wire is:

A. $R/4$
B. $R/2$
C. $R$
D. $2R$
E. $4R$

ans: D

26. A nichrome wire is 1 m long and $1 \times 10^{-6}\,\mathrm{m}^2$ in cross-sectional area. When connected to a potential difference of 2 V, a current of 4 A exists in the wire. The resistivity of this nichrome is:

A. $10^{-7}\,\Omega \cdot \mathrm{m}$
B. $2 \times 10^{-7}\,\Omega \cdot \mathrm{m}$
C. $4 \times 10^{-7}\,\Omega \cdot \mathrm{m}$
D. $5 \times 10^{-7}\,\Omega \cdot \mathrm{m}$
E. $8 \times 10^{-7}\,\Omega \cdot \mathrm{m}$

ans: D

27. Two conductors are made of the same material and have the same length. Conductor A is a solid wire of diameter 1 m. Conductor B is a hollow tube of inside diameter 1 m and outside diameter 2 m. The ratio of their resistance, $R_A/R_B$, is:

A. 1
B. $\sqrt{2}$
C. 2
D. 3
E. 4

ans: D

28. Conductivity is:

A. the same as resistivity, it is just more convenient to use for good conductors
B. expressed in $\Omega^{-1}$
C. equal to 1/resistance
D. expressed in $(\Omega \cdot \mathrm{m})^{-1}$
E. not a meaningful quantity for an insulator

ans: D

29. A certain sample carries a current of 4 A when the potential difference is 2 V and a current of 10 A when the potential difference is 4 V. This sample:

A. obeys Ohm's law
B. has a resistance of $0.5\,\Omega$ at 1 V
C. has a resistance of $2.5\,\Omega$ at 1 V
D. has a resistance of $2.5\,\Omega$ at 2 V
E. does not have a resistance

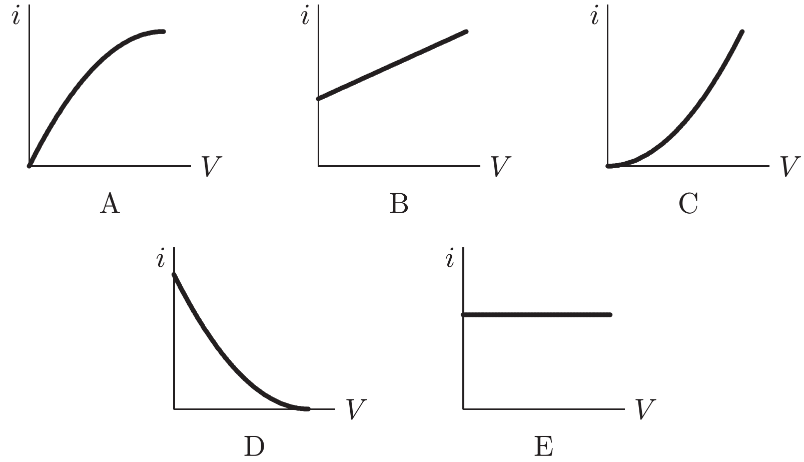
ans: B

30. A current of 0.5 A exists in a 60-ohm lamp. The applied potential difference is:

A. 15 V
B. 30 V
C. 60 V
D. 120 V
E. none of these

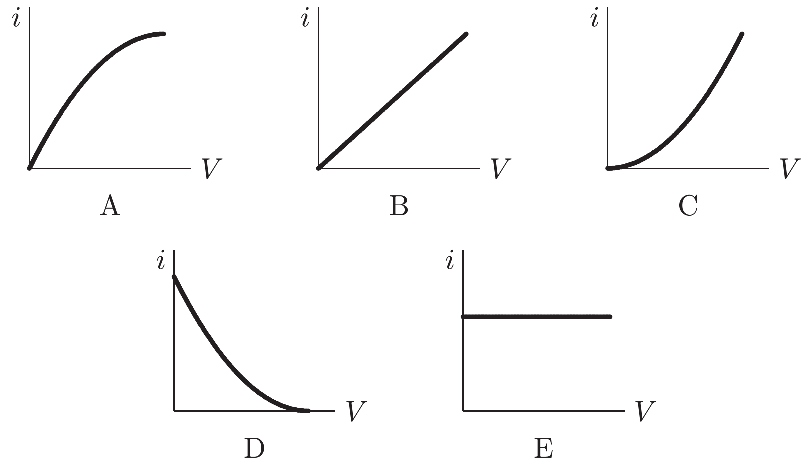
ans: B

31. Which of the following graphs best represents the current-voltage relationship of an incandescent light bulb?




ans: A

32. Which of the following graphs best represents the current-voltage relationship for a device that obeys Ohm's law?




ans: B

33. Two wires are made of the same material and have the same length but different radii. They are joined end-to-end and a potential difference is maintained across the combination. Of the following the quantity that is the same for both wires is:

A. potential difference
B. current
C. current density
D. electric field
E. conduction electron drift speed

ans: B

34. For an ohmic substance the resistivity is the proportionality constant for:
   A. current and potential difference
   B. current and electric field
   C. current density and potential difference
   D. current density and electric field
   E. potential difference and electric field

   ans: D

35. For an ohmic resistor, resistance is the proportionality constant for:
   A. potential difference and electric field
   B. current and electric field
   C. current and length
   D. current and cross-sectional area
   E. current and potential difference

   ans: E

36. For an ohmic substance, the resistivity depends on:
   A. the electric field
   B. the potential difference
   C. the current density
   D. the electron mean free time
   E. the cross-sectional area of the sample

   ans: D

37. For a cylindrical resistor made of ohmic material, the resistance does NOT depend on:
   A. the current
   B. the length
   C. the cross-sectional area
   D. the resistivity
   E. the electron drift velocity

   ans: A

38. For an ohmic substance, the electron drift velocity is proportional to:
   A. the cross-sectional area of the sample
   B. the length of the sample
   C. the mass of an electron
   D. the electric field in the sample
   E. none of the above

   ans: D

39. You wish to triple the rate of energy dissipation in a heating device. To do this you could triple:

A. the potential difference keeping the resistance the same
B. the current keeping the resistance the same
C. the resistance keeping the potential difference the same
D. the resistance keeping the current the same
E. both the potential difference and current

ans: D

40. A student kept her 60-watt, 120-volt study lamp turned on from 2:00 PM until 2:00 AM. How many coulombs of charge went through it?

A. 150
B. $3,600$
C. $7,200$
D. $18,000$
E. $21,600$

ans: E

41. A flat iron is marked "120 V, 600 W". In normal use, the current in it is:

A. 2 A
B. 4 A
C. 5 A
D. 7.2 A
E. 0.2 A

ans: C

42. An certain resistor dissipates 0.5 W when connected to a 3 V potential difference. When connected to a 1 V potential difference, this resistor will dissipate:

A. 0.5 W
B. 0.167 W
C. 1.5 W
D. 0.056 W
E. none of these

ans: D

43. An ordinary light bulb is marked "60 W, 120 V". Its resistance is:

A. $60\,\Omega$
B. $120\,\Omega$
C. $180\,\Omega$
D. $240\,\Omega$
E. $15\,\Omega$

ans: D

44. The mechanical equivalent of heat is $1\,\text{cal} = 4.18\,\text{J}$. The specific heat of water is $1\,\text{cal/g}\cdot\text{K}$. An electric immersion water heater, rated at 400 W, should heat a kilogram of water from $10^\circ$ C to $30^\circ$ C in about:

A. 3.5 min
B. 1 min
C. 15 min
D. 45 min
E. 15 s

ans: A

45. It is better to send 10,000 kW of electric power long distances at 10,000 V rather than at 220 V because:

A. there is less heating in the transmission wires
B. the resistance of the wires is less at high voltages
C. more current is transmitted at high voltages
D. the insulation is more effective at high voltages
E. the $iR$ drop along the wires is greater at high voltage

ans: A

46. Suppose the electric company charges 10 cents per kW·h. How much does it cost to use a 125 W lamp 4 hours a day for 30 days?

A. $1.20
B. $1.50
C. $1.80
D. $7.20
E. none of these

ans: B

47. A certain x-ray tube requires a current of 7 mA at a voltage of 80 kV. The rate of energy dissipation (in watts) is:

A. 560
B. 5600
C. 26
D. 11.4
E. 87.5

ans: A

48. The mechanical equivalent of heat is $1\,\text{cal} = 4.18\,\text{J}$. A heating coil, connected to a 120-V source, provides 60,000 calories in 10 minutes. The current in the coil is:

A. 0.83 A
B. 2 A
C. 3.5 A
D. 20 A
E. 50 A

ans: C

49. You buy a “75 W” light bulb. The label means that:

A. no matter how you use the bulb, the power will be 75 W
B. the bulb was filled with 75 W at the factory
C. the actual power dissipated will be much higher than 75 W since most of the power appears as heat
D. the bulb is expected to burn out after you use up its 75 W
E. none of the above

ans: E

50. A current of 0.3 A is passed through a lamp for 2 minutes using a 6-V power supply. The energy dissipated by this lamp during the 2 minutes is:

A. 1.8 J
B. 12 J
C. 20 J
D. 36 J
E. 216 J

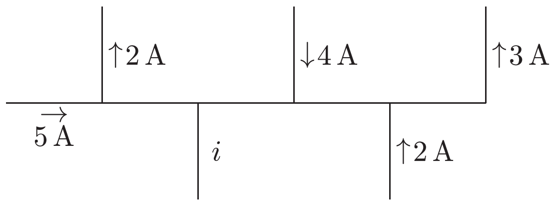
ans: E

## Chapter 27: CIRCUITS

1. "The sum of the currents into a junction equals the sum of the currents out of the junction" is a consequence of:
   A. Newton's third law
   B. Ohm's law
   C. Newton's second law
   D. conservation of energy
   E. conservation of charge
   ans: E

2. "The sum of the emf's and potential differences around a closed loop equals zero" is a consequence of:
   A. Newton's third law
   B. Ohm's law
   C. Newton's second law
   D. conservation of energy
   E. conservation of charge
   ans: D

3. A portion of a circuit is shown, with the values of the currents given for some branches. What is the direction and value of the current $i$?




   A. ↓, 6 A
   B. ↑, 6 A
   C. ↓, 4 A
   D. ↑, 4 A
   E. ↓, 2 A
   ans: A

4. Four wires meet at a junction. The first carries 4 A into the junction, the second carries 5 A out of the junction, and the third carries 2 A out of the junction. The fourth carries:
   A. 7 A out of the junction
   B. 7 A into the junction
   C. 3 A out of the junction
   D. 3 A into the junction
   E. 1 A into the junction
   ans: D

5. In the context of the loop and junctions rules for electrical circuits a junction is:
   A. where a wire is connected to a resistor
   B. where a wire is connected to a battery
   C. where only two wires are joined
   D. where three or more wires are joined
   E. where a wire is bent

   ans: D

6. For any circuit the number of independent equations containing emf's, resistances, and currents equals:
   A. the number of junctions
   B. the number of junctions minus 1
   C. the number of branches
   D. the number of branches minus 1
   E. the number of closed loops

   ans: C

7. If a circuit has $L$ closed loops, $B$ branches, and $J$ junctions the number of independent loop equations is:
   A. $B - J + 1$
   B. $B - J$
   C. $B$
   D. $L$
   E. $L - J$

   ans: A

8. A battery is connected across a series combination of two identical resistors. If the potential difference across the terminals is $V$ and the current in the battery is $i$, then:
   A. the potential difference across each resistor is $V$ and the current in each resistor is $i$
   B. the potential difference across each resistor is $V/2$ and the current in each resistor is $i/2$
   C. the potential difference across each resistor is $V$ and the current in each resistor is $i/2$
   D. the potential difference across each resistor is $V/2$ and the current in each resistor is $i$
   E. none of the above are true

   ans: D

9. A battery is connected across a parallel combination of two identical resistors. If the potential difference across the terminals is $V$ and the current in the battery is $i$, then:
   A. the potential difference across each resistor is $V$ and the current in each resistor is $i$
   B. the potential difference across each resistor is $V/2$ and the current in each resistor is $i/2$
   C. the potential difference across each resistor is $V$ and the current in each resistor is $i/2$
   D. the potential difference across each resistor is $V/2$ and the current in each resistor is $i$
   E. none of the above are true

   ans: C

10. A total resistance of $3.0\,\Omega$ is to be produced by combining an unknown resistor $R$ with a $12\,\Omega$ resistor. What is the value of $R$ and how is it to be connected to the $12\,\Omega$ resistor?

A. $4.0\,\Omega$, parallel
B. $4.0\,\Omega$, series
C. $2.4\,\Omega$, parallel
D. $2.4\,\Omega$, series
E. $9.0\,\Omega$, series

ans: A

11. By using only two resistors, $R_1$ and $R_2$, a student is able to obtain resistances of $3\,\Omega$, $4\,\Omega$, $12\,\Omega$, and $16\,\Omega$. The values of $R_1$ and $R_2$ (in ohms) are:

A. 3, 4
B. 2, 12
C. 3, 16
D. 4, 12
E. 4, 16

ans: D

12. Four 20-$\Omega$ resistors are connected in parallel and the combination is connected to a 20-V emf device. The current in the device is:

A. 0.25 A
B. 1.0 A
C. 4.0 A
D. 5.0 A
E. 100 A

ans: C

13. Four 20-$\Omega$ resistors are connected in parallel and the combination is connected to a 20-V emf device. The current in any one of the resistors is:

A. 0.25 A
B. 1.0 A
C. 4.0 A
D. 5.0 A
E. 100 A

ans: B

14. Four 20-$\Omega$ resistors are connected in series and the combination is connected to a 20-V emf device. The current in any one of the resistors is:

A. 0.25 A
B. 1.0 A
C. 4.0 A
D. 5.0 A
E. 100 A

ans: A

15. Four 20-Ω resistors are connected in series and the combination is connected to a 20-V emf device. The potential difference across any one of the resistors is:
    A. 1 V
    B. 4 V
    C. 5 V
    D. 20 V
    E. 80 V
    ans: C

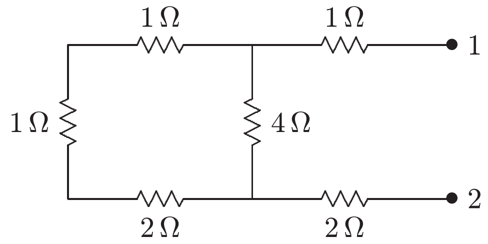
16. Nine identical wires, each of diameter $d$ and length $L$, are connected in parallel. The combination has the same resistance as a single similar wire of length $L$ but whose diameter is:
    A. $3d$
    B. $9d$
    C. $d/3$
    D. $d/9$
    E. $d/81$
    ans: A

17. Nine identical wires, each of diameter $d$ and length $L$, are connected in series. The combination has the same resistance as a single similar wire of length $L$ but whose diameter is:
    A. $3d$
    B. $9d$
    C. $d/3$
    D. $d/9$
    E. $d/81$
    ans: C

18. Two wires made of the same material have the same lengths but different diameters. They are connected in parallel to a battery. The quantity that is NOT the same for the wires is:
    A. the end-to-end potential difference
    B. the current
    C. the current density
    D. the electric field
    E. the electron drift velocity
    ans: B

19. Two wires made of the same material have the same lengths but different diameters. They are connected in series to a battery. The quantity that is the same for the wires is:
    A. the end-to-end potential difference
    B. the current
    C. the current density
    D. the electric field
    E. the electron drift velocity
    ans: B

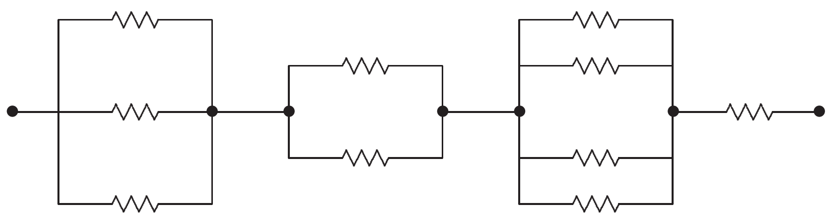
20. The equivalent resistance between points 1 and 2 of the circuit shown is:




A. $3\,\Omega$
B. $4\,\Omega$
C. $5\,\Omega$
D. $6\,\Omega$
E. $7\,\Omega$

ans: C

21. Each of the resistors in the diagram has a resistance of $12\,\Omega$. The resistance of the entire circuit is:



A. $5.76\,\Omega$
B. $25\,\Omega$
C. $48\,\Omega$
D. $120\,\Omega$
E. none of these

ans: B

22. The resistance of resistor 1 is twice the resistance of resistor 2. The two are connected in parallel and a potential difference is maintained across the combination. Then:

A. the current in 1 is twice that in 2
B. the current in 1 is half that in 2
C. the potential difference across 1 is twice that across 2
D. the potential difference across 1 is half that across 2
E. none of the above are true

ans: B

23. The resistance of resistor 1 is twice the resistance of resistor 2. The two are connected in series and a potential difference is maintained across the combination. Then:

A. the current in 1 is twice that in 2
B. the current in 1 is half that in 2
C. the potential difference across 1 is twice that across 2
D. the potential difference across 1 is half that across 2
E. none of the above are true

ans: C

24. Resistor 1 has twice the resistance of resistor 2. The two are connected in series and a potential difference is maintained across the combination. The rate of thermal energy generation in 1 is:

A. the same as that in 2
B. twice that in 2
C. half that in 2
D. four times that in 2
E. one-fourth that in 2

ans: B

25. Resistor 1 has twice the resistance of resistor 2. The two are connected in parallel and a potential difference is maintained across the combination. The rate of thermal energy generation in 1 is:

A. the same as that in 2
B. twice that in 2
C. half that in 2
D. four times that in 2
E. one-fourth that in 2

ans: C

26. The emf of a battery is equal to its terminal potential difference:

A. under all conditions
B. only when the battery is being charged
C. only when a large current is in the battery
D. only when there is no current in the battery
E. under no conditions

ans: D

27. The terminal potential difference of a battery is less than its emf:

A. under all conditions
B. only when the battery is being charged
C. only when the battery is being discharged
D. only when there is no current in the battery
E. under no conditions

ans: C

28. A battery has an emf of 9 V and an internal resistance of 2 Ω. If the potential difference across its terminals is greater than 9 V:

A. it must be connected across a large external resistance
B. it must be connected across a small external resistance
C. the current must be out of the positive terminal
D. the current must be out of the negative terminal
E. the current must be zero

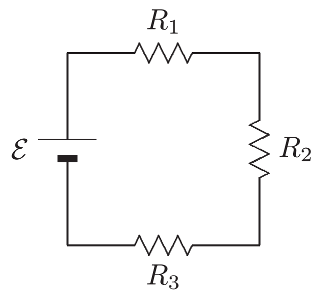
ans: D

29. A battery with an emf of 24 V is connected to a 6-Ω resistor. As a result, current of 3 A exists in the resistor. The terminal potential difference of the battery is:

A. 0
B. 6 V
C. 12 V
D. 18 V
E. 24 V

ans: D

30. In the diagram $R_1 > R_2 > R_3$. Rank the three resistors according to the current in them, least to greatest.




A. 1, 2, 3
B. 3, 2, 1
C. 1, 3, 2
D. 3, 1, 3
E. All are the same

ans: E

31. Resistances of 2.0 Ω, 4.0 Ω, and 6.0 Ω and a 24-V emf device are all in parallel. The current in the 2.0-Ω resistor is:

A. 12 A
B. 4.0 A
C. 2.4 A
D. 2.0 A
E. 0.50 A

ans: A

32. Resistances of $2.0\,\Omega$, $4.0\,\Omega$, and $6.0\,\Omega$ and a 24-V emf device are all in series. The potential difference across the 2.0-$\Omega$ resistor is:

A. 4 V
B. 8 V
C. 12 V
D. 24 V
E. 48 V

ans: A

33. A battery with an emf of 12 V and an internal resistance of $1\,\Omega$ is used to charge a battery with an emf of 10 V and an internal resistance of $1\,\Omega$. The current in the circuit is:

A. 1 A
B. 2 A
C. 4 A
D. 11 A
E. 22 A

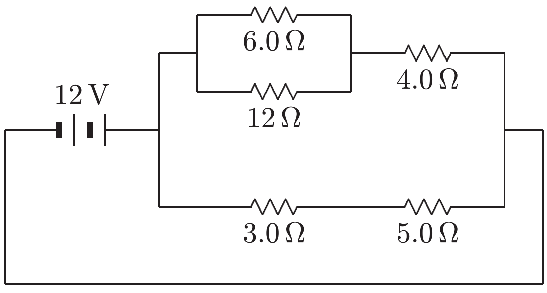
ans: A

34. In the diagram, the current in the 3-$\Omega$ resistor is 4 A. The potential difference between points 1 and 2 is:


A. 0.75 V
B. 0.8 V
C. 1.25 V
D. 12 V
E. 20 V

ans: E

35. The current in the 5.0-$\Omega$ resistor in the circuit shown is:




A. 0.42 A
B. 0.67 A
C. 1.5 A
D. 2.4 A
E. 3.0 A

ans: C

36. A 3-Ω and a 1.5-Ω resistor are wired in parallel and the combination is wired in series to a 4-Ω resistor and a 10-V emf device. The current in the 3-Ω resistor is:

A. 0.33 A
B. 0.67 A
C. 2.0 A
D. 3.3 A
E. 6.7 A

ans: B

37. A 3-Ω and a 1.5-Ω resistor are wired in parallel and the combination is wired in series to a 4-Ω resistor and a 10-V emf device. The potential difference across the 3-Ω resistor is:

A. 2.0 V
B. 6.0 V
C. 8.0 V
D. 10 V
E. 12 V

ans: A

38. Two identical batteries, each with an emf of 18 V and an internal resistance of 1 Ω, are wired in parallel by connecting their positive terminals together and connecting their negative terminals together. The combination is then wired across a 4-Ω resistor. The current in the 4-Ω resistor is:

A. 1.0 A
B. 2.0 A
C. 4.0 A
D. 3.6 A
E. 7.2 A

ans: C

39. Two identical batteries, each with an emf of 18 V and an internal resistance of 1 Ω, are wired in parallel by connecting their positive terminals together and connecting their negative terminals together. The combination is then wired across a 4-Ω resistor. The current in each battery is:

A. 1.0 A
B. 2.0 A
C. 4.0 A
D. 3.6 A
E. 7.2 A

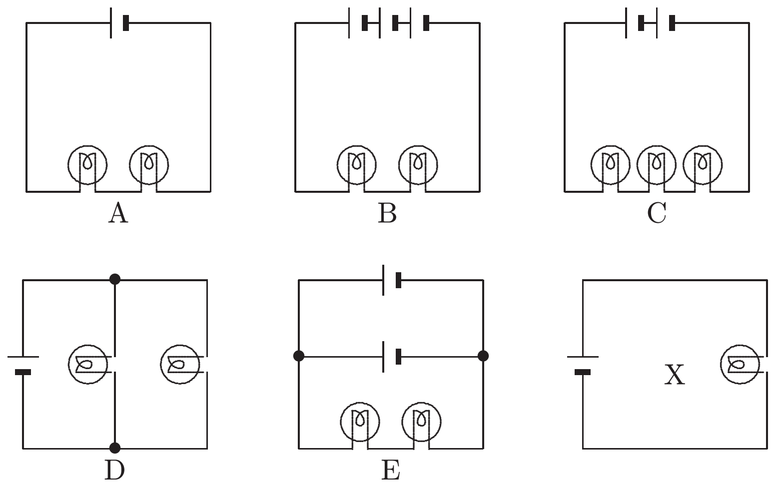
ans: B

40. Two identical batteries, each with an emf of 18 V and an internal resistance of 1 $\Omega$, are wired in parallel by connecting their positive terminals together and connecting their negative terminals together. The combination is then wired across a 4-$\Omega$ resistor. The potential difference across the 4-$\Omega$ resistor is:

A. 4.0 V
B. 8.0 V
C. 14 V
D. 16 V
E. 29 V

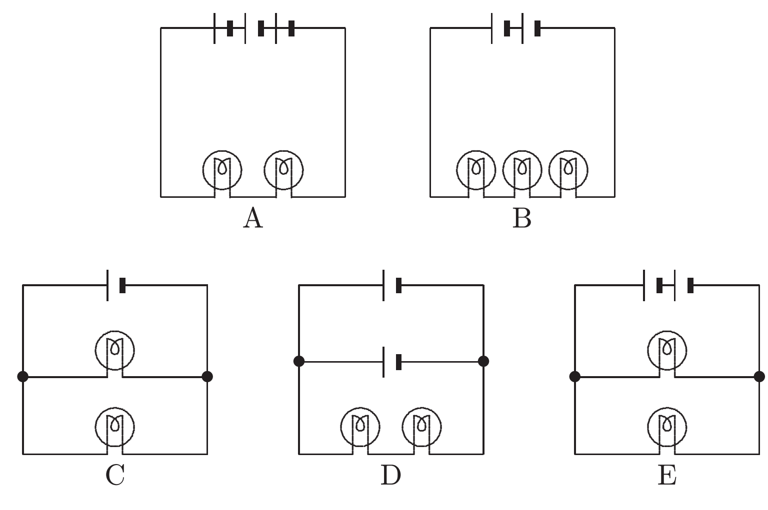
ans: D

41. In the diagrams, all light bulbs are identical and all emf devices are identical. In which circuit (A, B, C, D, E) will the bulbs glow with the same brightness as in circuit X?




ans: D

42. In the diagrams, all light bulbs are identical and all emf devices are identical. In which circuit (A, B, C, D, E) will the bulbs be dimmest?




ans: D

43. A 120-V power line is protected by a 15-A fuse. What is the maximum number of "120 V, 500 W" light bulbs that can be operated at full brightness from this line?

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

ans: C

44. Two 110-V light bulbs, one "25 W" and the other "100 W", are connected in series to a 110 V source. Then:

A. the current in the 100-W bulb is greater than that in the 25-W bulb
B. the current in the 100-W bulb is less than that in the 25-W bulb
C. both bulbs will light with equal brightness
D. each bulb will have a potential difference of 55 V
E. none of the above

ans: E

45. A resistor with resistance $R_1$ and a resistor with resistance $R_2$ are connected in parallel to an ideal battery with emf $\mathcal{E}$. The rate of thermal energy generation in the resistor with resistance $R_1$ is:

A. $\mathcal{E}^2/R_1$
B. $\mathcal{E}^2 R_1/(R_1+R_2)^2$
C. $\mathcal{E}^2/(R_1+R_2)$
D. $\mathcal{E}^2/R_2$
E. $\mathcal{E}^2 R_1/R_2^2$

ans: A

46. In an antique automobile, a 6-V battery supplies a total of 48 W to two identical headlights in parallel. The resistance (in ohms) of each bulb is:

A. 0.67
B. 1.5
C. 3
D. 4
E. 8

ans: B

47. Resistor 1 has twice the resistance of resistor 2. They are connected in parallel to a battery. The ratio of the thermal energy generation rate in 1 to that in 2 is:

A. 1 : 4
B. 1 : 2
C. 1 : 1
D. 2 : 1
E. 4 : 1

ans: B

48. A series circuit consists of a battery with internal resistance $r$ and an external resistor $R$. If these two resistances are equal ($r = R$) then the thermal energy generated per unit time by the internal resistance $r$ is:

A. the same as by $R$
B. half that by $R$
C. twice that by $R$
D. one-third that by $R$
E. unknown unless the emf is given

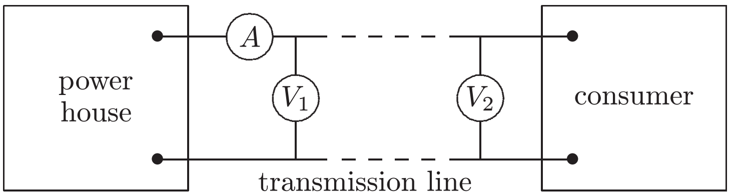
ans: A

49. The positive terminals of two batteries with emf's of $\mathcal{E}_1$ and $\mathcal{E}_2$, respectively, are connected together. Here $\mathcal{E}_2 > \mathcal{E}_1$. The circuit is completed by connecting the negative terminals. If each battery has an internal resistance $r$, the rate with which electrical energy is converted to chemical energy in the smaller battery is:

A. $\mathcal{E}_1^2/r$
B. $\mathcal{E}_1^2/2r$
C. $(\mathcal{E}_2 - \mathcal{E}_1)\mathcal{E}_1/r$
D. $(\mathcal{E}_2 - \mathcal{E}_1)\mathcal{E}_1/2r$
E. $\mathcal{E}_2^2/2r$

ans: D

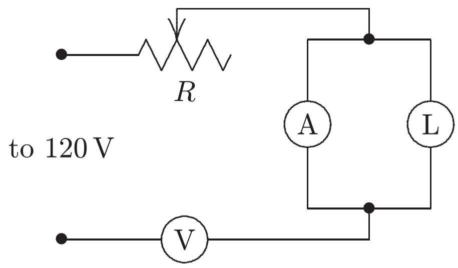
50. In the figure, voltmeter $V_1$ reads 600 V, voltmeter $V_2$ reads 580 V, and ammeter A reads 100 A. The power wasted in the transmission line connecting the power house to the consumer is:




A. 1 kW
B. 2 kW
C. 58 kW
D. 59 kW
E. 60 kW

ans: B

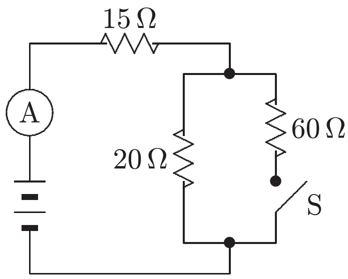
51. The circuit shown was wired for the purpose of measuring the resistance of the lamp L. Inspection shows that:




A. voltmeter V and rheostat R should be interchanged
B. the circuit is satisfactory
C. the ammeter A should be in parallel with R, not L
D. the meters, V and A, should be interchanged
E. L and V should be interchanged

ans: D

52. When switch S is open, the ammeter in the circuit shown reads 2.0 A. When S is closed, the ammeter reading:




A. increases slightly
B. remains the same
C. decreases slightly
D. doubles
E. halves

ans: A

53. A certain galvanometer has a resistance of 100 Ω and requires 1 mA for full scale deflection. To make this into a voltmeter reading 1 V full scale, connect a resistance of:

A. 1000 Ω in parallel
B. 900 Ω in series
C. 1000 Ω in series
D. 10 Ω in parallel
E. 0.1 Ω in series

ans: B

54. To make a galvanometer into an ammeter, connect:
   A. a high resistance in parallel
   B. a high resistance in series
   C. a low resistance in series
   D. a low resistance in parallel
   E. a source of emf in series
   ans: D

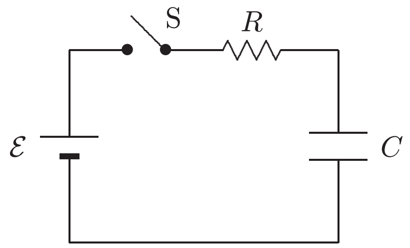
55. A certain voltmeter has an internal resistance of $10,000\,\Omega$ and a range from 0 to 100 V. To give it a range from 0 to 1000 V, one should connect:
   A. $100,000\,\Omega$ in series
   B. $100,000\,\Omega$ in parallel
   C. $1000\,\Omega$ in series
   D. $1000\,\Omega$ in parallel
   E. $90,000\,\Omega$ in series
   ans: E

56. A certain ammeter has an internal resistance of $1\,\Omega$ and a range from 0 to 50 mA. To make its range from 0 to 5 A, use:
   A. a series resistance of $99\,\Omega$
   B. an extremely large (say $10^6\ \Omega$ ) series resistance
   C. a resistance of $99\,\Omega$ in parallel
   D. a resistance of $1/99\,\Omega$ in parallel
   E. a resistance of $1/1000\,\Omega$ in parallel
   ans: D

57. A galvanometer has an internal resistance of $12\,\Omega$ and requires 0.01 A for full scale deflection. To convert it to a voltmeter reading 3 V full scale, one must use a series resistance of:
   A. $102\,\Omega$
   B. $288\,\Omega$
   C. $300\,\Omega$
   D. $360\,\Omega$
   E. $412\,\Omega$
   ans: B

58. A certain voltmeter has an internal resistance of $10,000\,\Omega$ and a range from 0 to 12 V. To extend its range to 120 V, use a series resistance of:
   A. $1,111\,\Omega$
   B. $90,000\,\Omega$
   C. $100,000\,\Omega$
   D. $108,000\,\Omega$
   E. $120,000\,\Omega$
   ans: B

59. Four circuits have the form shown in the diagram. The capacitor is initially uncharged and the switch S is open.



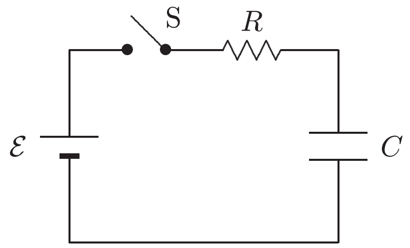

The values of the emf $\mathcal{E}$, resistance $R$, and capacitance $C$ for each of the circuits are

circuit 1: $\mathcal{E} = 18\,\mathrm{V}$, $R = 3\,\Omega$, $C = 1\,\mu\mathrm{F}$
circuit 2: $\mathcal{E} = 18\,\mathrm{V}$, $R = 6\,\Omega$, $C = 9\,\mu\mathrm{F}$
circuit 3: $\mathcal{E} = 12\,\mathrm{V}$, $R = 1\,\Omega$, $C = 7\,\mu\mathrm{F}$
circuit 4: $\mathcal{E} = 10\,\mathrm{V}$, $R = 5\,\Omega$, $C = 7\,\mu\mathrm{F}$

Rank the circuits according to the current just after switch S is closed least to greatest.
A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 4, 2, 3, 1
D. 4, 2, 1, 3
E. 3, 1, 2, 4

ans: D

60. Four circuits have the form shown in the diagram. The capacitor is initially uncharged and the switch S is open.




The values of the emf $\mathcal{E}$, resistance $R$, and capacitance $C$ for each of the circuits are

circuit 1: $\mathcal{E} = 18\,\mathrm{V}$, $R = 3\,\Omega$, $C = 1\,\mu\mathrm{F}$
circuit 2: $\mathcal{E} = 18\,\mathrm{V}$, $R = 6\,\Omega$, $C = 9\,\mu\mathrm{F}$
circuit 3: $\mathcal{E} = 12\,\mathrm{V}$, $R = 1\,\Omega$, $C = 7\,\mu\mathrm{F}$
circuit 4: $\mathcal{E} = 10\,\mathrm{V}$, $R = 5\,\Omega$, $C = 7\,\mu\mathrm{F}$

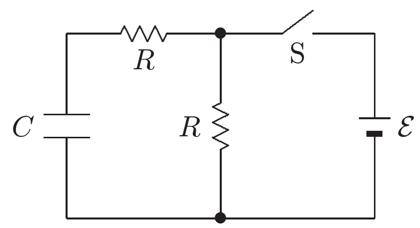
Rank the circuits according to the time after switch S is closed for the capacitors to reach half their final charges, least to greatest.
A. 1, 2, 3, 4
B. 4, 3, 2, 1
C. 1, 3, 4, 2
D. 1 and 2 tied, then 4, 3
E. 4, 3, then 1 and 2 tied

ans: C

61. The time constant $RC$ has units of:
A. second/farad
B. second/ohm
C. 1/second
D. second/watt
E. none of these

ans: E

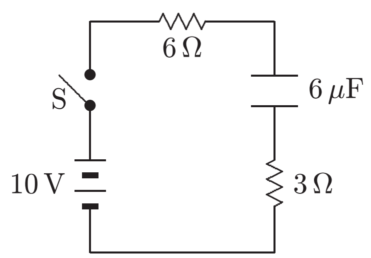
62. In the circuit shown, both resistors have the same value $R$. Suppose switch S is initially closed. When it is then opened, the circuit has a time constant $\tau_a$. Conversely, suppose S is initially open. When it is then closed, the circuit has a time constant $\tau_b$. The ratio $\tau_a/\tau_b$ is:




A. 1
B. 2
C. 0.5
D. 0.667
E. 1.5

ans: B

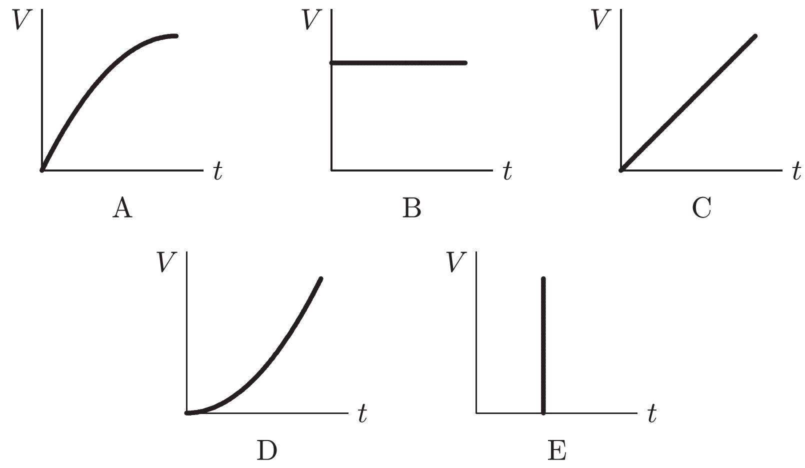
63. In the circuit shown, the capacitor is initially uncharged. At time $t = 0$, switch S is closed. If $\tau$ denotes the time constant, the approximate current through the $3\,\Omega$ resistor when $t = \tau/10$ is:




A. 0.38 A
B. 0.50 A
C. 0.75 A
D. 1.0 A
E. 1.5 A

ans: D

64. Suppose the current charging a capacitor is kept constant. Which graph below correctly gives the potential difference $V$ across the capacitor as a function of time?




ans: C

65. A charged capacitor is being discharged through a resistor. At the end of one time constant the charge has been reduced by $(1 - 1/e) = 63\%$ of its initial value. At the end of two time constants the charge has been reduced by what percent of its initial value?

A. 82%
B. 86%
C. 100%
D. Between 90% and 100%
E. Need to know more data to answer the question

ans: B

66. An initially uncharged capacitor C is connected in series with resistor R. This combination is then connected to a battery of emf $V_0$. Sufficient time elapses so that a steady state is reached. Which of the following statements is NOT true?

A. The time constant is independent of $V_0$
B. The final charge on C is independent of $R$
C. The total thermal energy generated by R is independent of $R$
D. The total thermal energy generated by R is independent of $V_0$
E. The initial current (just after the battery was connected) is independent of $C$

ans: C

67. A certain capacitor, in series with a resistor, is being charged. At the end of 10 ms its charge is half the final value. The time constant for the process is about:

A. 0.43 ms
B. 2.3 ms
C. 6.9 ms
D. 10 ms
E. 14 ms

ans: E

68. A certain capacitor, in series with a 720-$\Omega$ resistor, is being charged. At the end of 10 ms its charge is half the final value. The capacitance is about:

A. 9.6 $\mu$F
B. 14 $\mu$F
C. 20 $\mu$F
D. 7.2 F
E. 10 F

ans: C

69. In the capacitor discharge formula $q = q_0 e^{-t/RC}$ the symbol $t$ represents:

A. the time constant
B. the time it takes for C to lose the fraction $1/e$ of its initial charge
C. the time it takes for C to lose the fraction $(1 - 1/e)$ of its initial charge
D. the time it takes for C to lose essentially all of its initial charge
E. none of the above

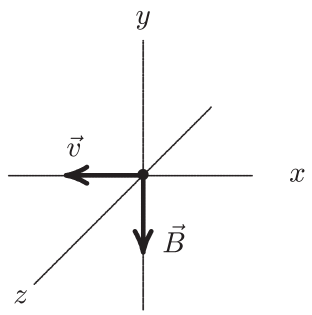
ans: E

## Chapter 28: MAGNETIC FIELDS

1. Units of a magnetic field might be:
   A. C·m/s
   B. C·s/m
   C. C/kg
   D. kg/C·s
   E. N/C·m
   ans: D

2. In the formula $\vec{F} = q\vec{v} \times \vec{B}$:
   A. $\vec{F}$ must be perpendicular to $\vec{v}$ but not necessarily to $\vec{B}$
   B. $\vec{F}$ must be perpendicular to $\vec{B}$ but not necessarily to $\vec{v}$
   C. $\vec{v}$ must be perpendicular to $\vec{B}$ but not necessarily to $\vec{F}$
   D. all three vectors must be mutually perpendicular
   E. $\vec{F}$ must be perpendicular to both $\vec{v}$ and $\vec{B}$
   ans: E

3. An electron moves in the negative $x$ direction, through a uniform magnetic field in the negative $y$ direction. The magnetic force on the electron is:




   A. in the negative $x$ direction
   B. in the positive $y$ direction
   C. in the negative $y$ direction
   D. in the positive $z$ direction
   E. in the negative $z$ direction
   ans: E

4. At any point the magnetic field lines are in the direction of:
   A. the magnetic force on a moving positive charge
   B. the magnetic force on a moving negative charge
   C. the velocity of a moving positive charge
   D. the velocity of a moving negative charge
   E. none of the above
   ans: E

5. The magnetic force on a charged particle is in the direction of its velocity if:
   A. it is moving in the direction of the field
   B. it is moving opposite to the direction of the field
   C. it is moving perpendicular to the field
   D. it is moving in some other direction
   E. never

   ans: E

6. A magnetic field exerts a force on a charged particle:
   A. always
   B. never
   C. if the particle is moving across the field lines
   D. if the particle is moving along the field lines
   E. if the particle is at rest

   ans: C

7. The direction of the magnetic field in a certain region of space is determined by firing a test charge into the region with its velocity in various directions in different trials. The field direction is:
   A. one of the directions of the velocity when the magnetic force is zero
   B. the direction of the velocity when the magnetic force is a maximum
   C. the direction of the magnetic force
   D. perpendicular to the velocity when the magnetic force is zero
   E. none of the above

   ans: A

8. An electron is moving north in a region where the magnetic field is south. The magnetic force exerted on the electron is:
   A. zero
   B. up
   C. down
   D. east
   E. west

   ans: A

9. A magnetic field CANNOT:
   A. exert a force on a charged particle
   B. change the velocity of a charged particle
   C. change the momentum of a charged particle
   D. change the kinetic energy of a charged particle
   E. change the trajectory of a charged particle

   ans: D

10. A proton (charge $e$), traveling perpendicular to a magnetic field, experiences the same force as an alpha particle (charge $2e$) which is also traveling perpendicular to the same field. The ratio of their speeds, $v_{\text{proton}}/v_{\text{alpha}}$, is:

A. 0.5
B. 1
C. 2
D. 4
E. 8

ans: C

11. A hydrogen atom that has lost its electron is moving east in a region where the magnetic field is directed from south to north. It will be deflected:

A. up
B. down
C. north
D. south
E. not at all

ans: A

12. A beam of electrons is sent horizontally down the axis of a tube to strike a fluorescent screen at the end of the tube. On the way, the electrons encounter a magnetic field directed vertically downward. The spot on the screen will therefore be deflected:

A. upward
B. downward
C. to the right as seen from the electron source
D. to the left as seen from the electron source
E. not at all

ans: C

13. An electron (charge $= -1.6 \times 10^{-19}$ C) is moving at $3 \times 10^5$ m/s in the positive $x$ direction. A magnetic field of 0.8 T is in the positive $z$ direction. The magnetic force on the electron is:

A. 0
B. $4 \times 10^{-14}$ N, in the positive $z$ direction
C. $4 \times 10^{-14}$ N, in the negative $z$ direction
D. $4 \times 10^{-14}$ N, in the positive $y$ direction
E. $4 \times 10^{-14}$ N, in the negative $y$ direction

ans: D

14. At one instant an electron (charge $= -1.6 \times 10^{-19}$ C) is moving in the $xy$ plane, the components of its velocity being $v_x = 5 \times 10^5$ m/s and $v_y = 3 \times 10^5$ m/s. A magnetic field of 0.8 T is in the positive $x$ direction. At that instant the magnitude of the magnetic force on the electron is:

A. 0
B. $2.6 \times 10^{-14}$ N
C. $3.8 \times 10^{-14}$ N
D. $6.4 \times 10^{-14}$ N
E. $1.0 \times 10^{-13}$ N

ans: C

15. At one instant an electron (charge $= -1.6 \times 10^{-19}$ C) is moving in the $xy$ plane, the components of its velocity being $v_x = 5 \times 10^5$ m/s and $v_y = 3 \times 10^5$ m/s. A magnetic field of 0.8 T is in the positive $x$ direction. At that instant the magnitude of the magnetic force on the electron is:

A. 0
B. $3.8 \times 10^{-14}$ N
C. $5.1 \times 10^{-14}$ N
D. $6.4 \times 10^{-14}$ N
E. $7.5 \times 10^{-14}$ N

ans: B

16. An electron travels due north through a vacuum in a region of uniform magnetic field $\vec{B}$ that is also directed due north. It will:

A. be unaffected by the field
B. speed up
C. slow down
D. follow a right-handed corkscrew path
E. follow a left-handed corkscrew path

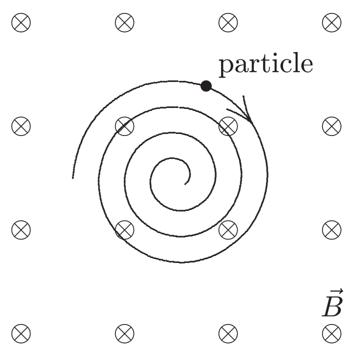
ans: A

17. At one instant an electron is moving in the positive $x$ direction along the $x$ axis in a region where there is a uniform magnetic field in the positive $z$ direction. When viewed from a point on the positive $z$ axis, it subsequent motion is:

A. straight ahead
B. counterclockwise around a circle in the $xy$ plane
C. clockwise around a circle in the $xy$ plane
D. in the positive $z$ direction
E. in the negative $z$ direction

ans: B

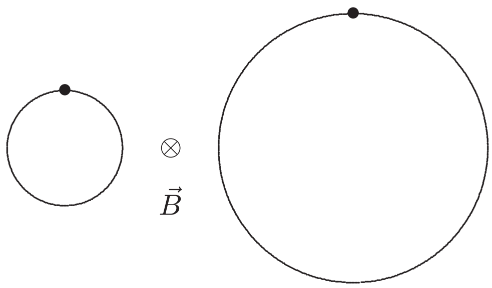
18. A uniform magnetic field is directed into the page. A charged particle, moving in the plane of the page, follows a clockwise spiral of decreasing radius as shown. A reasonable explanation is:




A. the charge is positive and slowing down
B. the charge is negative and slowing down
C. the charge is positive and speeding up
D. the charge is negative and speeding up
E. none of the above

ans: B

19. An electron and a proton each travel with equal speeds around circular orbits in the same uniform magnetic field, as shown in the diagram (not to scale). The field is into the page on the diagram. Because the electron is less massive than the proton and because the electron is negatively charged and the proton is positively charged:




A. the electron travels clockwise around the smaller circle and the proton travels counterclockwise around the larger circle
B. the electron travels counterclockwise around the smaller circle and the proton travels clockwise around the larger circle
C. the electron travels clockwise around the larger circle and the proton travels counterclockwise around the smaller circle
D. the electron travels counterclockwise around the larger circle and the proton travels clockwise around the smaller circle
E. the electron travels counterclockwise around the smaller circle and the proton travels counterclockwise around the larger circle

ans: A

20. An electron is launched with velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$. The angle $\theta$ between $\vec{v}$ and $\vec{B}$ is between 0 and 90°. As a result, the electron follows a helix, its velocity vector $\vec{v}$ returning to its initial value in a time interval of:

A. $2\pi m/eB$
B. $2\pi mv/e\mathrm{B}$
C. $2\pi mv\sin\theta/eB$
D. $2\pi mv\cos\theta/eB$
E. none of these

ans: A

21. An electron and a proton are both initially moving with the same speed and in the same direction at 90° to the same uniform magnetic field. They experience magnetic forces, which are initially:

A. identical
B. equal in magnitude but opposite in direction
C. in the same direction and differing in magnitude by a factor of 1840
D. in opposite directions and differing in magnitude by a factor of 1840
E. equal in magnitude but perpendicular to each other.

ans: B

22. An electron enters a region of uniform perpendicular $\vec{E}$ and $\vec{B}$ fields. It is observed that the velocity $\vec{v}$ of the electron is unaffected. A possible explanation is:

A. $\vec{v}$ is parallel to $\vec{E}$ and has magnitude $E/B$
B. $\vec{v}$ is parallel to $\vec{B}$
C. $\vec{v}$ is perpendicular to both $\vec{E}$ and $\vec{B}$ and has magnitude $B/E$
D. $\vec{v}$ is perpendicular to both $\vec{E}$ and $\vec{B}$ and has magnitude $E/B$
E. the given situation is impossible

ans: D

23. A charged particle is projected into a region of uniform, parallel, $\vec{E}$ and $\vec{B}$ fields. The force on the particle is:

A. zero
B. at some angle $< 90^\circ$ with the field lines
C. along the field lines
D. perpendicular to the field lines
E. unknown (need to know the sign of the charge)

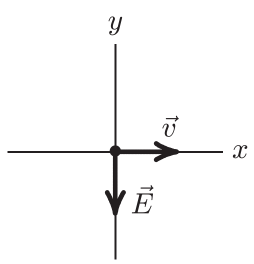
ans: B

24. A uniform magnetic field is in the positive $z$ direction. A positively charged particle is moving in the positive $x$ direction through the field. The net force on the particle can be made zero by applying an electric field in what direction?

A. Positive $y$
B. Negative $y$
C. Positive $x$
D. Negative $x$
E. Positive $z$

ans: B

25. An electron is traveling in the positive $x$ direction. A uniform electric field $\vec{E}$ is in the negative $y$ direction. If a uniform magnetic field with the appropriate magnitude and direction also exists in the region, the total force on the electron will be zero. The appropriate direction for the magnetic field is:




A. the positive $y$ direction
B. the negative $y$ direction
C. into the page
D. out of the page
E. the negative $x$ direction

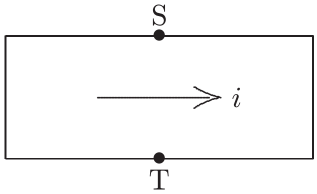
ans: C

26. An ion with a charge of $+3.2\times10^{-19}$ C is in a region where a uniform electric field of $5\times10^4$ V/m is perpendicular to a uniform magnetic field of 0.8 T. If its acceleration is zero then its speed must be:

A. 0
B. $1.6 \times 10^4$ m/s
C. $4.0 \times 10^4$ m/s
D. $6.3 \times 10^4$ m/s
E. any value but 0

ans: D

27. The current is from left to right in the conductor shown. The magnetic field is into the page and point S is at a higher potential than point T. The charge carriers are:




A. positive
B. negative
C. neutral
D. absent
E. moving near the speed of light

ans: A

28. Electrons (mass $m$, charge $-e$) are accelerated from rest through a potential difference $V$ and are then deflected by a magnetic field $\vec{B}$ that is perpendicular to their velocity. The radius of the resulting electron trajectory is:

A. $(\sqrt{2eV/m})/B$
B. $B\sqrt{2eV}/m$
C. $(\sqrt{2mV/e})/B$
D. $B\sqrt{2mV}/e$
E. none of these

ans: C

29. In a certain mass spectrometer, an ion beam passes through a velocity filter consisting of mutually perpendicular fields $\vec{E}$ and $\vec{B}$. The beam then enters a region of another magnetic field $\vec{B}'$ perpendicular to the beam. The radius of curvature of the resulting ion beam is proportional to:

A. $EB'/B$
B. $EB/B'$
C. $BB'/E$
D. $B/EB'$
E. $E/BB'$

ans: E

30. A cyclotron operates with a given magnetic field and at a given frequency. If $R$ denotes the radius of the final orbit, the final particle energy is proportional to:

A. $1/R$
B. $R$
C. $R^2$
D. $R^3$
E. $R^4$

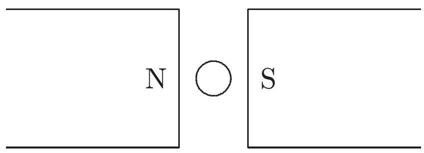
ans: C

31. J. J. Thomson's experiment, involving the motion of an electron beam in mutually perpendicular $\vec{E}$ and $\vec{B}$ fields, gave the value of:

A. mass of an electron
B. charge of an electron
C. Earth's magnetic field
D. charge/mass ratio for electrons
E. Avogadro's number

ans: D

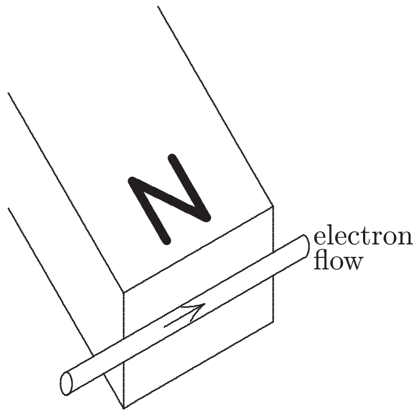
32. The diagram shows a straight wire carrying a flow of electrons into the page. The wire is between the poles of a permanent magnet. The direction of the magnetic force exerted on the wire is:




A. $\uparrow$
B. $\downarrow$
C. $\leftarrow$
D. $\rightarrow$
E. into the page

ans: A

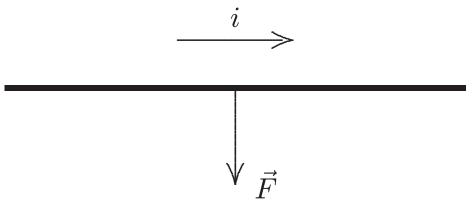
33. The figure shows the motion of electrons in a wire that is near the N pole of a magnet. The wire will be pushed:




A. toward the magnet
B. away from the magnet
C. downwards
D. upwards
E. along its length

ans: D

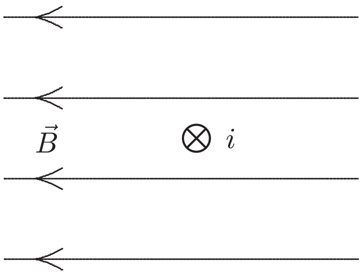
34. The diagram shows a straight wire carrying current $i$ in a uniform magnetic field. The magnetic force on the wire is indicated by an arrow but the magnetic field is not shown. Of the following possibilities, the direction of the magnetic field is:




A. opposite the direction of the current
B. opposite the direction of $\vec{F}$
C. in the direction of $\vec{F}$
D. into the page
E. out of the page

ans: E

35. The figure shows a uniform magnetic field $\vec{B}$ directed to the left and a wire carrying a current into the page. The magnetic force acting on the wire is:




A. toward the top of the page
B. toward the bottom of the page
C. toward the left
D. toward the right
E. zero

ans: A

36. A loop of wire carrying a current of 2.0 A is in the shape of a right triangle with two equal sides, each 15 cm long. A 0.7 T uniform magnetic field is parallel to the hypotenuse. The resultant magnetic force on the two equal sides has a magnitude of:

A. 0
B. 0.21 N
C. 0.30 N
D. 0.41 N
E. 0.51 N

ans: A

37. A loop of wire carrying a current of 2.0 A is in the shape of a right triangle with two equal sides, each 15 cm long. A 0.7 T uniform magnetic field is in the plane of the triangle and is perpendicular to the hypotenuse. The magnetic force on either of the two equal sides has a magnitude of:

A. zero
B. 0.105 N
C. 0.15 N
D. 0.21 N
E. 0.25 N

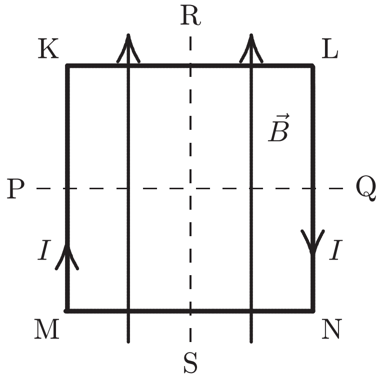
ans: C

38. A current is clockwise around the outside edge of this page and a uniform magnetic field is directed parallel to the page, from left to right. If the magnetic force is the only force acting on the page, the page will turn so the right edge:

A. moves toward you
B. moves away from you
C. moves to your right
D. moves to your left
E. does not move

ans: A

39. A square loop of wire lies in the plane of the page and carries a current I as shown. There is a uniform magnetic field $\vec{B}$ parallel to the side MK as indicated. The loop will tend to rotate:




A. about PQ with KL coming out of the page
B. about PQ with KL going into the page
C. about RS with MK coming out of the page
D. about RS with MK going into the page
E. about an axis perpendicular to the page.

ans: A

40. The units of magnetic dipole moment are:

A. ampere
B. ampere·meter
C. ampere·meter$^2$
D. ampere/meter
E. ampere/meter$^2$

ans: C

41. You are facing a loop of wire which carries a clockwise current of 3.0 A and which surrounds an area of $5.8 \times 10^{-2}\,\mathrm{m}^2$. The magnetic dipole moment of the loop is:

A. $3.0\,\mathrm{A \cdot m^2}$, away from you
B. $3.0\,\mathrm{A \cdot m^2}$, toward you
C. $0.17\,\mathrm{A \cdot m^2}$, away from you
D. $0.17\,\mathrm{A \cdot m^2}$, toward you
E. $0.17\,\mathrm{A \cdot m^2}$, left to right

ans: C

42. The magnetic torque exerted on a flat current-carrying loop of wire by a uniform magnetic field $\vec{B}$ is:

A. maximum when the plane of the loop is perpendicular to $\vec{B}$
B. maximum when the plane of the loop is parallel to $\vec{B}$
C. dependent on the shape of the loop for a fixed loop area
D. independent of the orientation of the loop
E. such as to rotate the loop around the magnetic field lines

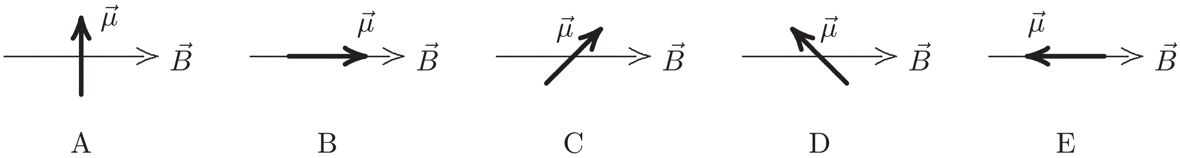
ans: B

43. A circular loop of wire with a radius of 20 cm lies in the $xy$ plane and carries a current of 2 A, counterclockwise when viewed from a point on the positive $z$ axis. Its magnetic dipole moment is:

A. $0.25\,\mathrm{A\cdot m^2}$, in the positive $z$ direction
B. $0.25\,\mathrm{A\cdot m^2}$, in the negative $z$ direction
C. $2.5\,\mathrm{A\cdot m^2}$, in the positive $z$ direction
D. $2.5\,\mathrm{A\cdot m^2}$, in the negative $z$ direction
E. $0.25\,\mathrm{A\cdot m^2}$, in the $xy$ plane

ans: A

44. The diagrams show five possible orientations of a magnetic dipole $\vec{\mu}$ in a uniform magnetic field $\vec{B}$. For which of these does the magnetic torque on the dipole have the greatest magnitude?




ans: A

45. The magnetic dipole moment of a current-carrying loop of wire is in the positive $z$ direction. If a uniform magnetic field is in the positive $x$ direction the magnetic torque on the loop is:

A. 0
B. in the positive $y$ direction
C. in the negative $y$ direction
D. in the positive $z$ direction
E. in the negative $z$ direction

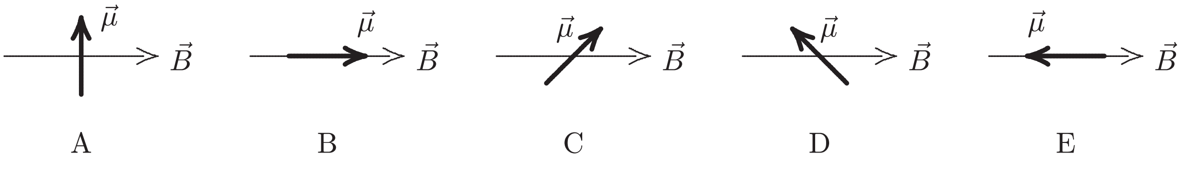
ans: B

46. For a loop of current-carrying wire in a uniform magnetic field the potential energy is a minimum if the magnetic dipole moment of the loop is:

A. in the same direction as the field
B. in the direction opposite to that of the field
C. perpendicular to the field
D. at an angle of 45° to the field
E. none of the above

ans: A

47. The diagrams show five possible orientations of a magnetic dipole $\vec{\mu}$ in a uniform magnetic field $\vec{B}$. For which of these is the potential energy the greatest?




ans: E

48. A loop of current-carrying wire has a magnetic dipole moment of $5 \times 10^{-4}\,\mathrm{A \cdot m^2}$. The moment initially is aligned with a 0.5-T magnetic field. To rotate the loop so its dipole moment is perpendicular to the field and hold it in that orientation, you must do work of:

A. 0
B. $2.5 \times 10^{-4}\,\mathrm{J}$
C. $-2.5 \times 10^{-4}\,\mathrm{J}$
D. $1.0 \times 10^{-3}\,\mathrm{J}$
E. $-1.0 \times 10^{-3}\,\mathrm{J}$

ans: B

## Chapter 29: MAGNETIC FIELDS DUE TO CURRENTS

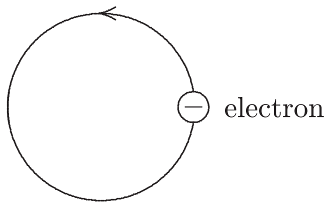
1. Suitable units for $\mu_0$ are:
   A. tesla
   B. newton/ampere$^2$
   C. weber/meter
   D. kilogram·ampere/meter
   E. tesla·meter/ampere

   ans: E

2. A "coulomb" is:
   A. one ampere per second
   B. the quantity of charge that will exert a force of 1 N on a similar charge at a distance of 1 m
   C. the amount of current in each of two long parallel wires, separated by 1 m, that produces a force of $2 \times 10^{-7}$ N/m
   D. the amount of charge that flows past a point in one second when the current is 1 A
   E. an abbreviation for a certain combination of kilogram, meter and second

   ans: D

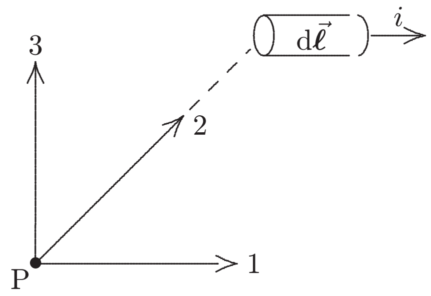
3. Electrons are going around a circle in a counterclockwise direction as shown. At the center of the circle they produce a magnetic field that is:




   A. into the page
   B. out of the page
   C. to the left
   D. to the right
   E. zero

   ans: A

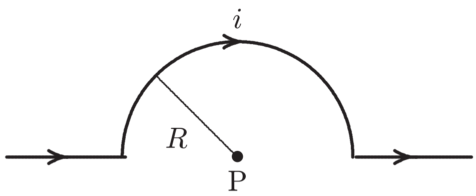
4. In the figure, the current element $i\,\mathrm{d}\vec{\ell}$, the point P, and the three vectors (1, 2, 3) are all in the plane of the page. The direction of $\mathrm{d}\vec{B}$, due to this current element, at the point P is:




A. in the direction marked “1”
B. in the direction marked “2”
C. in the direction marked “3”
D. out of the page
E. into the page

ans: E

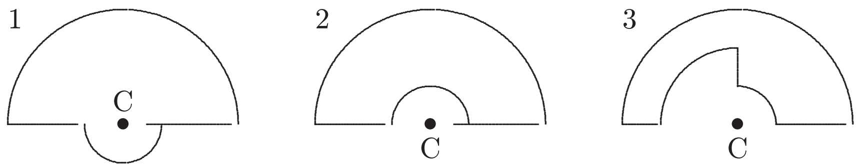
5. The magnitude of the magnetic field at point P, at the center of the semicircle shown, is given by:




A. $2\mu_0 i/R$
B. $\mu_0 i/R$
C. $\mu_0 i/4\pi R$
D. $\mu_0 i/2R$
E. $\mu_0 i/4R$

ans: E

6. The diagrams show three circuits consisting of concentric circular arcs (either half or quarter circles of radii $r$, $2r$, and $3r$) and radial lengths. The circuits carry the same current. Rank them according to the magnitudes of the magnetic fields they produce at C, least to greatest.




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

ans: B

7. Lines of the magnetic field produced by a long straight wire carrying a current are:

A. in the direction of the current
B. opposite to the direction of the current
C. radially outward from the wire
D. radially inward toward the wire
E. circles that are concentric with the wire

ans: E

8. In an overhead straight wire, the current is north. The magnetic field due to this current, at our point of observation, is:

A. east
B. up
C. north
D. down
E. west

ans: E

9. A wire carrying a large current $i$ from east to west is placed over an ordinary magnetic compass. The end of the compass needle marked "N" will point:

A. north
B. south
C. east
D. west
E. the compass will act as an electric motor, hence the needle will keep rotating

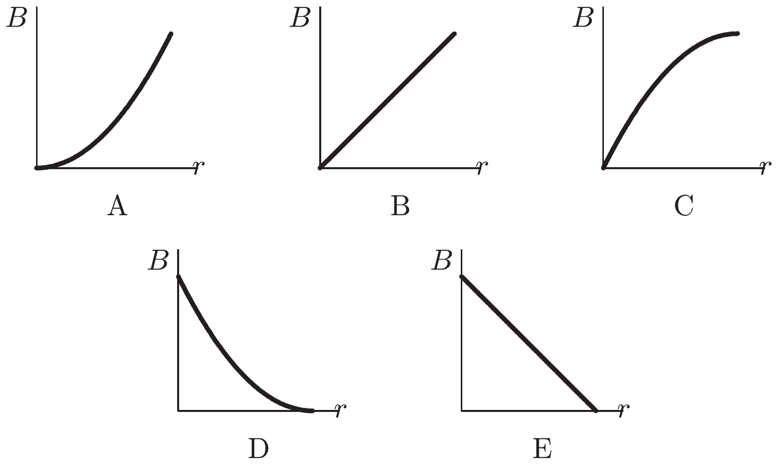
ans: B

10. The magnetic field outside a long straight current-carrying wire depends on the distance $R$ from the wire axis according to:

A. $R$
B. $1/R$
C. $1/R^2$
D. $1/R^3$
E. $1/R^{3/2}$

ans: B

11. Which graph correctly gives the magnitude of the magnetic field outside an infinitely long straight current-carrying wire as a function of the distance $r$ from the wire?




ans: D

12. The magnetic field a distance 2 cm from a long straight current-carrying wire is $2.0 \times 10^{-5}$ T. The current in the wire is:

A. 0.16 A
B. 1.0 A
C. 2.0 A
D. 4.0 A
E. 25 A

ans: C

13. Two long parallel straight wires carry equal currents in opposite directions. At a point midway between the wires, the magnetic field they produce is:

A. zero
B. non-zero and along a line connecting the wires
C. non-zero and parallel to the wires
D. non-zero and perpendicular to the plane of the two wires
E. none of the above

ans: D

14. Two long straight wires are parallel and carry current in the same direction. The currents are 8.0 and 12 A and the wires are separated by 0.40 cm. The magnetic field in tesla at a point midway between the wires is:

A. 0
B. $4.0 \times 10^{-4}$
C. $8.0 \times 10^{-4}$
D. $12 \times 10^{-4}$
E. $20 \times 10^{-4}$

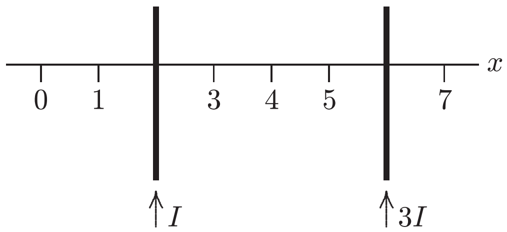
ans: B

15. Two long straight wires are parallel and carry current in opposite directions. The currents are 8.0 and 12 A and the wires are separated by 0.40 cm. The magnetic field in tesla at a point midway between the wires is:

A. 0
B. $4.0 \times 10^{-4}$
C. $8.0 \times 10^{-4}$
D. $12 \times 10^{-4}$
E. $20 \times 10^{-4}$

ans: E

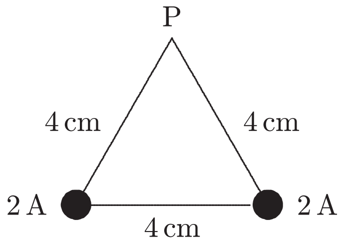
16. Two long straight current-carrying parallel wires cross the $x$ axis and carry currents $I$ and $3I$ in the same direction, as shown. At what value of $x$ is the net magnetic field zero?




A. 0
B. 1
C. 3
D. 5
E. 7

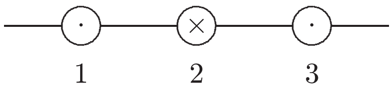
ans: C

17. Two long straight wires pierce the plane of the paper at vertices of an equilateral triangle as shown below. They each carry 2 A, out of the paper. The magnetic field at the third vertex (P) has magnitude (in T):




A. $1.0 \times 10^{-5}$
B. $1.7 \times 10^{-5}$
C. $2.0 \times 10^{-5}$
D. $5.0 \times 10^{-6}$
E. $8.7 \times 10^{-6}$
ans: B

18. The diagram shows three equally spaced wires that are perpendicular to the page. The currents are all equal, two being out of the page and one being into the page. Rank the wires according to the magnitudes of the magnetic forces on them, from least to greatest.




A. 1, 2, 3
B. 2, 1 and 3 tie
C. 2 and 3 tie, then 1
D. 1 and 3 tie, then 2
E. 3, 2, 1
ans: B

19. Two parallel wires carrying equal currents of 10 A attract each other with a force of 1 mN. If both currents are doubled, the force of attraction will be:
A. 1 mN
B. 4 mN
C. 0.5 mN
D. 0.25 mN
E. 2 mN
ans: B

20. Two parallel long wires carry the same current and repel each other with a force $F$ per unit length. If both these currents are doubled and the wire separation tripled, the force per unit length becomes:

A. $2F/9$
B. $4F/9$
C. $2F/3$
D. $4F/3$
E. $6F$

ans: D

21. Two parallel wires, 4 cm apart, carry currents of 2 A and 4 A respectively, in the same direction. The force per unit length in N/m of one wire on the other is:

A. $1 \times 10^{-3}$, repulsive
B. $1 \times 10^{-3}$, attractive
C. $4 \times 10^{-5}$, repulsive
D. $4 \times 10^{-5}$, attractive
E. none of these

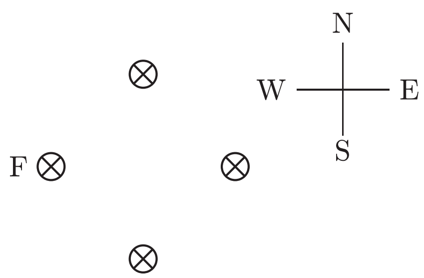
ans: D

22. Two parallel wires, 4 cm apart, carry currents of 2 A and 4 A respectively, in opposite directions. The force per unit length in N/m of one wire on the other is:

A. $1 \times 10^{-3}$, repulsive
B. $1 \times 10^{-3}$, attractive
C. $4 \times 10^{-5}$, repulsive
D. $4 \times 10^{-5}$, attractive
E. none of these

ans: C

23. Four long straight wires carry equal currents into the page as shown. The magnetic force exerted on wire F is:

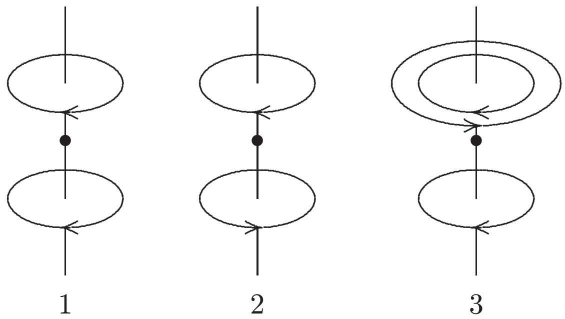



A. north
B. east
C. south
D. west
E. zero

ans: B

24. A constant current is sent through a helical coil. The coil:
    A. tends to get shorter
    B. tends to get longer
    C. tends to rotate about its axis
    D. produces zero magnetic field at its center
    E. none of the above
    ans: A

25. The diagram shows three arrangements of circular loops, centered on vertical axes and carrying identical currents in the directions indicated. Rank the arrangements according to the magnitudes of the magnetic fields at the midpoints between the loops on the central axes.




    A. 1, 2, 3
    B. 2, 1, 3
    C. 2, 3, 1
    D. 3, 2, 1
    E. 3, 1, 2
    ans: C

26. Helmholtz coils are commonly used in the laboratory because the magnetic field between them:
    A. can be varied more easily than the fields of other current arrangements
    B. is especially strong
    C. nearly cancels Earth's magnetic field
    D. is parallel to the plane of the coils
    E. is nearly uniform
    ans: E

27. If the radius of a pair of Helmholtz coils is $R$ then the distance between the coils is:
    A. $R/4$
    B. $R/2$
    C. $R$
    D. $2R$
    E. $4R$
    ans: C

28. If $R$ is the distance from a magnetic dipole, then the magnetic field it produces is proportional to:

A. $R$
B. $1/R$
C. $R^2$
D. $1/R^2$
E. $1/R^3$

ans: E

29. A square loop of current-carrying wire with edge length $a$ is in the $xy$ plane, the origin being at its center. Along which of the following lines can a charge move without experiencing a magnetic force?

A. $x = 0$, $y = a/2$
B. $x = a/2$, $y = a/2$
C. $x = a/2$, $y = 0$
D. $x = 0$, $y = 0$
E. $x = 0$, $z = 0$

ans: D

30. In Ampere's law, $\oint \vec{B} \cdot d\vec{s} = \mu_0 i$, the integration must be over any:

A. surface
B. closed surface
C. path
D. closed path
E. closed path that surrounds all the current producing $\vec{B}$

ans: D

31. In Ampere's law, $\oint \vec{B} \cdot d\vec{s} = \mu_0 i$, the symbol $d\vec{s}$ is:

A. an infinitesimal piece of the wire that carries current $i$
B. in the direction of $\vec{B}$
C. perpendicular to $\vec{B}$
D. a vector whose magnitude is the length of the wire that carries current $i$
E. none of the above

ans: E

32. In Ampere's law, $\oint \vec{B} \cdot d\vec{s} = \mu_0 i$, the direction of the integration around the path:

A. must be clockwise
B. must be counterclockwise
C. must be such as to follow the magnetic field lines
D. must be along the wire in the direction of the current
E. none of the above

ans: E

33. A long straight wire carrying a 3.0 A current enters a room through a window 1.5 m high and 1.0 m wide. The path integral $\oint \vec{B} \cdot d\vec{s}$ around the window frame has the value (in T·m):

A. 0.20
B. $2.5 \times 10^{-7}$
C. $3.0 \times 10^{-7}$
D. $3.8 \times 10^{-6}$
E. none of these

ans: D

34. Two long straight wires enter a room through a door. One carries a current of 3.0 A into the room while the other carries a current of 5.0 A out. The magnitude of the path integral $\oint \vec{B} \cdot d\vec{s}$ around the door frame is:

A. $2.5 \times 10^{-6}\,\mathrm{T \cdot m}$
B. $3.8 \times 10^{-6}\,\mathrm{T \cdot m}$
C. $6.3 \times 10^{-6}\,\mathrm{T \cdot m}$
D. $1.0 \times 10^{-5}\,\mathrm{T \cdot m}$
E. none of these

ans: A

35. If the magnetic field $\vec{B}$ is uniform over the area bounded by a circle with radius $R$, the net current through the circle is:

A. 0
B. $2\pi RB/\mu_0$
C. $\pi R^2 B/\mu_0$
D. $RB/2\mu_0$
E. $2RB/\mu_0$

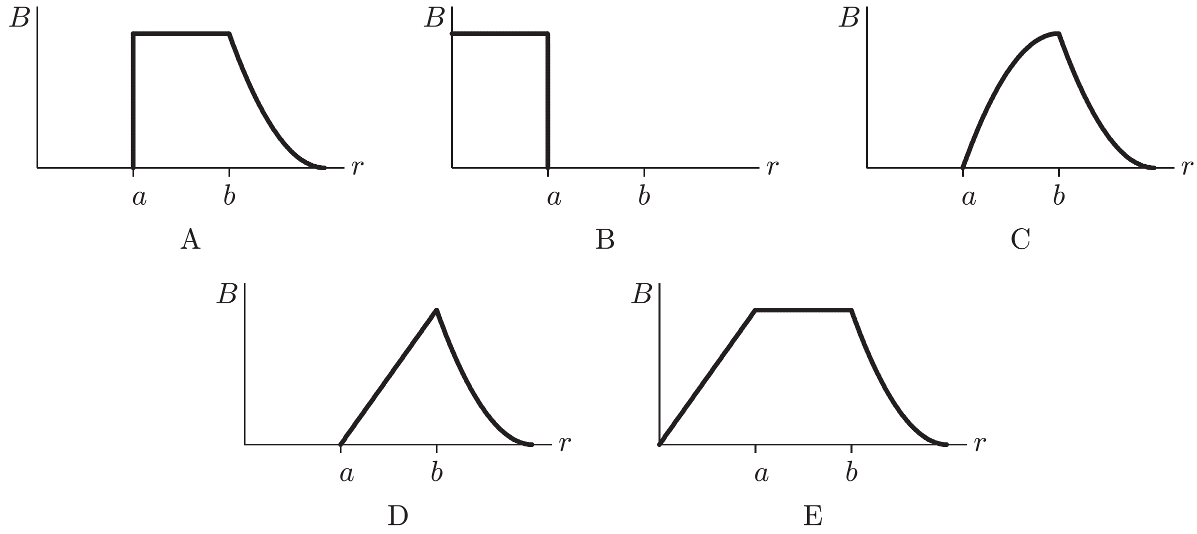
ans: A

36. The magnetic field at any point is given by $\vec{B} = A\vec{r} \times \hat{\mathrm{k}}$, where $\vec{r}$ is the position vector of the point and $A$ is a constant. The net current through a circle of radius $R$, in the $xy$ plane and centered at the origin is given by:

A. $\pi AR^2/\mu_0$
B. $2\pi AR/\mu_0$
C. $4\pi AR^3/3\mu_0$
D. $2\pi AR^2/\mu_0$
E. $\pi AR^2/2\mu_0$

ans: D

37. A hollow cylindrical conductor (inner radius $= a$, outer radius $= b$) carries a current $i$ uniformly spread over its cross section. Which graph below correctly gives $B$ as a function of the distance $r$ from the center of the cylinder?




ans: C

38. A long straight cylindrical shell carries current $i$ parallel to its axis and uniformly distributed over its cross section. The magnitude of the magnetic field is greatest:

A. at the inner surface of the shell
B. at the outer surface of the shell
C. inside the shell near the middle
D. in hollow region near the inner surface of the shell
E. near the center of the hollow region

ans: B

39. A long straight cylindrical shell has inner radius $R_i$ and outer radius $R_o$. It carries current $i$, uniformly distributed over its cross section. A wire is parallel to the cylinder axis, in the hollow region ($r < R_i$). The magnetic field is zero everywhere outside the shell ($r > R_o$). We conclude that the wire:

A. is on the cylinder axis and carries current $i$ in the same direction as the current in the shell
B. may be anywhere in the hollow region but must be carrying current $i$ in the direction opposite to that of the current in the shell
C. may be anywhere in the hollow region but must be carrying current $i$ in the same direction as the current in the shell
D. is on the cylinder axis and carries current $i$ in the direction opposite to that of the current in the shell
E. does not carry any current

ans: D

40. A long straight cylindrical shell has inner radius $R_i$ and outer radius $R_o$. It carries a current $i$, uniformly distributed over its cross section. A wire is parallel to the cylinder axis, in the hollow region ($r < R_i$). The magnetic field is zero everywhere in the hollow region. We conclude that the wire:

A. is on the cylinder axis and carries current $i$ in the same direction as the current in the shell
B. may be anywhere in the hollow region but must be carrying current $i$ in the direction opposite to that of the current in the shell
C. may be anywhere in the hollow region but must be carrying current $i$ in the same direction as the current in the shell
D. is on the cylinder axis and carries current $i$ in the direction opposite to that of the current in the shell
E. does not carry any current

ans: E

41. The magnetic field $B$ inside a long ideal solenoid is independent of:

A. the current
B. the core material
C. the spacing of the windings
D. the cross-sectional area of the solenoid
E. the direction of the current

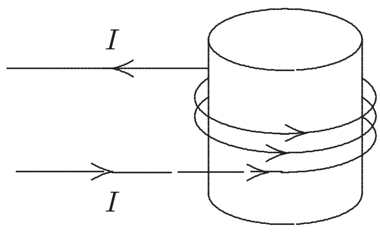
ans: D

42. Two long ideal solenoids (with radii 20 mm and 30 mm, respectively) have the same number of turns of wire per unit length. The smaller solenoid is mounted inside the larger, along a common axis. The magnetic field within the inner solenoid is zero. The current in the inner solenoid must be:

A. two-thirds the current in the outer solenoid
B. one-third the current in the outer solenoid
C. twice the current in the outer solenoid
D. half the current in the outer solenoid
E. the same as the current in the outer solenoid

ans: E

43. Magnetic field lines inside the solenoid shown are:




A. clockwise circles as one looks down the axis from the top of the page
B. counterclockwise circles as one looks down the axis from the top of the page
C. toward the top of the page
D. toward the bottom of the page
E. in no direction since $B = 0$

ans: C

44. Solenoid 2 has twice the radius and six times the number of turns per unit length as solenoid 1. The ratio of the magnetic field in the interior of 2 to that in the interior of 1 is:

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

ans: C

45. A solenoid is 3.0 cm long and has a radius of 0.50 cm. It is wrapped with 500 turns of wire carrying a current of 2.0 A. The magnetic field at the center of the solenoid is:

A. $9.9 \times 10^{-8}$ T
B. $1.3 \times 10^{-3}$ T
C. $4.2 \times 10^{-2}$ T
D. 16 T
E. 20 T

ans: C

46. A toroid with a square cross section carries current $i$. The magnetic field has its largest magnitude:

A. at the center of the hole
B. just inside the toroid at its inner surface
C. just inside the toroid at its outer surface
D. at any point inside (the field is uniform)
E. none of the above

ans: B

47. A toroid has a square cross section with the length of an edge equal to the radius of the inner surface. The ratio of the magnitude of the magnetic field at the inner surface to the magnitude of the field at the outer surface is:

A. 1/4
B. 1/2
C. 1
D. 2
E. 4

ans: D

## Chapter 41: CONDUCTION OF ELECTRICITY IN SOLIDS

1. In a pure metal the collisions that are characterized by the mean free time $\tau$ in the expression for the resistivity are chiefly between:
   A. electrons and other electrons
   B. electrons with energy about equal to the Fermi energy and atoms
   C. all electrons and atoms
   D. electrons with energy much less than the Fermi energy and atoms
   E. atoms and other atoms

   ans: B

2. A certain metal has $5.3 \times 10^{29}$ conduction electrons/m$^3$ and an electrical resistivity of $1.9 \times 10^{-9}\,\Omega \cdot \mathrm{m}$. The average time between collisions of electrons with atoms in the metal is:
   A. $5.6 \times 10^{-33}\,\mathrm{s}$
   B. $1.3 \times 10^{-31}\,\mathrm{s}$
   C. $9.9 \times 10^{-22}\,\mathrm{s}$
   D. $4.6 \times 10^{-15}\,\mathrm{s}$
   E. $3.5 \times 10^{-14}\,\mathrm{s}$

   ans: C

3. Which one of the following statements concerning electron energy bands in solids is true?
   A. The bands occur as a direct consequence of the Fermi-Dirac occupancy probability function
   B. Electrical conduction arises from the motion of electrons in completely filled bands
   C. Within a given band, all electron energy levels are equal to each other
   D. An insulator has a large energy separation between the highest filled band and the lowest empty band
   E. Only insulators have energy bands

   ans: D

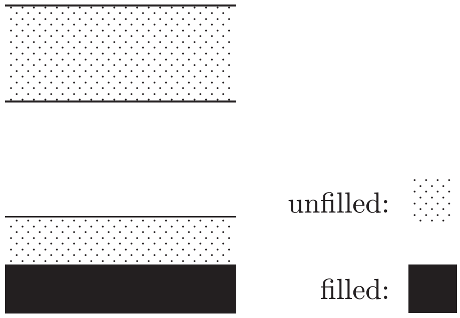
4. If $E_0$ and $E_T$ are the average energies of the "free" electrons in a metal at $0\,\mathrm{K}$ and room temperature, respectively, then the ratio $E_T/E_0$ is approximately:
   A. 0
   B. 1
   C. 100
   D. $10^6$
   E. infinity

   ans: B

5. The energy gap (in eV) between the valence and conduction bands of an insulator is of the order of:
   A. $10^{-19}$
   B. 0.001
   C. 0.1
   D. 10
   E. 1000

   ans: D

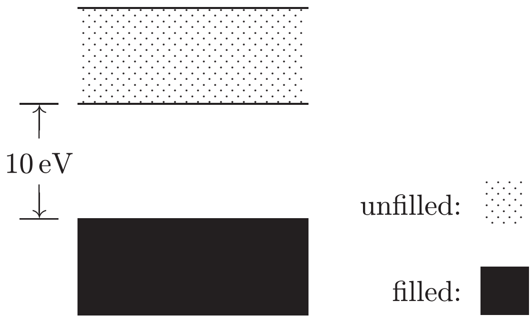
6. The energy level diagram shown applies to:




A. a conductor
B. an insulator
C. a semiconductor
D. an isolated molecule
E. an isolated atom

ans: A

7. The energy level diagram shown applies to:




A. a conductor
B. an insulator
C. a semiconductor
D. an isolated atom
E. a free-electron gas

ans: B

8. The energy level diagram shown applies to:


A. a conductor
B. an insulator
C. a semiconductor
D. an isolated molecule
E. an isolated atom

ans: C

9. Possible units for the density of states function $N(E)$ are:

A. $J/m^3$
B. $1/J$
C. $m^{-3}$
D. $J^{-1}\cdot m^{-3}$
E. $kg/m^3$

ans: D

10. The density of states for a metal depends primarily on:

A. the temperature
B. the energy
C. the density of the metal
D. the volume of the sample
E. none of these

ans: B

11. The Fermi-Dirac occupancy probability $P(E)$ varies between:

A. 0 and 1
B. 0 and infinity
C. 1 and infinity
D. $-1$ and 1
E. 0 and $E_F$

ans: A

12. For a metal at absolute temperature $T$, with Fermi energy $E_F$, the occupancy probability is given by:
A. $e^{(E-E_F)/kT}$
B. $e^{-(E-E_F)/kT}$
C. $\dfrac{1}{e^{(E-E_F)/kT}+1}$
D. $\dfrac{1}{e^{-(E-E_F)/kT}+1}$
E. $\dfrac{1}{e^{(E-E_F)/kT}-1}$
ans: C

13. In a metal at 0 K, the Fermi energy is:
A. the highest energy of any electron
B. the lowest energy of any electron
C. the mean thermal energy of the electrons
D. the energy of the top of the valence band
E. the energy at the bottom of the conduction band
ans: A

14. The occupancy probability for a state with energy equal to the Fermi energy is:
A. 0
B. 0.5
C. 1
D. 1.5
E. 2
ans: B

15. The Fermi energy of a metal depends primarily on:
A. the temperature
B. the volume of the sample
C. the mass density of the metal
D. the size of the sample
E. the number density of conduction electrons
ans: E

16. The speed of an electron with energy equal to the Fermi energy for copper is on the order of:
A. $10^6$ m/s
B. $10^{-6}$ m/s
C. 10 m/s
D. $10^{-1}$ m/s
E. $10^9$ m/s
ans: A

17. At $T = 0\,\mathrm{K}$ the probability that a state $0.50\,\mathrm{eV}$ below the Fermi level is occupied is about:
A. 0
B. $5.0 \times 10^{-9}$
C. $5.0 \times 10^{-6}$
D. $5.0 \times 10^{-3}$
E. 1
ans: E

18. At $T = 0\,\mathrm{K}$ the probability that a state $0.50\,\mathrm{eV}$ above the Fermi level is occupied is about:
A. 0
B. $5.0 \times 10^{-9}$
C. $5.0 \times 10^{-6}$
D. $5.0 \times 10^{-3}$
E. 1
ans: A

19. At room temperature $kT$ is about $0.0259\,\mathrm{eV}$. The probability that a state $0.50\,\mathrm{eV}$ above the Fermi level is occupied at room temperature is:
A. 1
B. 0.05
C. 0.025
D. $5.0 \times 10^{-6}$
E. $4.1 \times 10^{-9}$
ans: E

20. At room temperature $kT$ is about $0.0259\,\mathrm{eV}$. The probability that a state $0.50\,\mathrm{eV}$ below the Fermi level is unoccupied at room temperature is:
A. 1
B. 0.05
C. 0.025
D. $5.0 \times 10^{-6}$
E. $4.1 \times 10^{-9}$
ans: E

21. If the density of states is $N(E)$ and the occupancy probability is $P(E)$, then the density of occupied states is:
A. $N(E) + P(E)$
B. $N(E)/P(E)$
C. $N(E) - P(E)$
D. $N(E)P(E)$
E. $P(E)/N(E)$
ans: D

22. A hole refers to:
   A. a proton
   B. a positively charged electron
   C. an electron that has somehow lost its charge
   D. a microscopic defect in a solid
   E. the absence of an electron in an otherwise filled band

   ans: E

23. Electrons in a full band do not contribute to the current when an electric field exists in a solid because:
   A. the field cannot exert a force on them
   B. the individual contributions cancel each other
   C. they are not moving
   D. they make transitions to other bands
   E. they leave the solid

   ans: B

24. For a pure semiconductor the Fermi level is:
   A. in the conduction band
   B. well above the conduction band
   C. in the valence band
   D. well below the valence band
   E. near the center of the gap between the valence and conduction bands

   ans: E

25. The number density $n$ of conduction electrons, the resistivity $\rho$, and the temperature coefficient of resistivity $\alpha$ are given below for five materials. Which is a semiconductor?
   A. $n = 10^{29}\,\mathrm{m}^{-3}$, $\rho = 10^{-8}\,\Omega\cdot\mathrm{m}$, $\alpha = +10^{-3}\,\mathrm{K}^{-1}$
   B. $n = 10^{28}\,\mathrm{m}^{-3}$, $\rho = 10^{-9}\,\Omega\cdot\mathrm{m}$, $\alpha = -10^{-3}\,\mathrm{K}^{-1}$
   C. $n = 10^{28}\,\mathrm{m}^{-3}$, $\rho = 10^{-9}\,\Omega\cdot\mathrm{m}$, $\alpha = +10^{-3}\,\mathrm{K}^{-1}$
   D. $n = 10^{15}\,\mathrm{m}^{-3}$, $\rho = 10^{3}\,\Omega\cdot\mathrm{m}$, $\alpha = -10^{-2}\,\mathrm{K}^{-1}$
   E. $n = 10^{15}\,\mathrm{m}^{-3}$, $\rho = 10^{-7}\,\Omega\cdot\mathrm{m}$, $\alpha = +10^{-3}\,\mathrm{K}^{-1}$

   ans: D

26. A pure semiconductor at room temperature has:
   A. more electrons/m$^3$ in its conduction band than holes/m$^3$ in its valence band
   B. more electrons/m$^3$ in its conduction band than a typical metal
   C. more electrons/m$^3$ in its valence band than at $T = 0\,\mathrm{K}$
   D. more holes/m$^3$ in its valence band than electrons/m$^3$ in its valence band
   E. none of the above

   ans: E

27. For a metal at room temperature the temperature coefficient of resistivity is determined primarily by:
   A. the number of electrons in the conduction band
   B. the number of impurity atoms
   C. the binding energy of outer shell electrons
   D. collisions between conduction electrons and atoms
   E. none of the above

   ans: D

28. For a pure semiconductor at room temperature the temperature coefficient of resistivity is determined primarily by:
   A. the number of electrons in the conduction band
   B. the number of replacement atoms
   C. the binding energy of outer shell electrons
   D. collisions between conduction electrons and atoms
   E. none of the above

   ans: A

29. A certain material has a resistivity of $7.8 \times 10^3\,\Omega\cdot\mathrm{m}$ at room temperature and it increases as the temperature is raised by $100^\circ$ C. The material is most likely:
   A. a metal
   B. a pure semiconductor
   C. a heavily doped semiconductor
   D. an insulator
   E. none of the above

   ans: C

30. A certain material has a resistivity of $7.8 \times 10^3\,\Omega\cdot\mathrm{m}$ at room temperature and it decreases as the temperature is raised by $100^\circ$ C. The material is most likely:
   A. a metal
   B. a pure semiconductor
   C. a heavily doped semiconductor
   D. an insulator
   E. none of the above

   ans: B

31. A certain material has a resistivity of $7.8 \times 10^{-8}\,\Omega\cdot\mathrm{m}$ at room temperature and it increases as the temperature is raised by $100^\circ$ C. The material is most likely:
   A. a metal
   B. a pure semiconductor
   C. a heavily doped semiconductor
   D. an insulator
   E. none of the above

   ans: A

32. Donor atoms introduced into a pure semiconductor at room temperature:
A. increase the number of electrons in the conduction band
B. increase the number of holes in the valence band
C. lower the Fermi level
D. increase the electrical resistivity
E. none of the above
ans: A

33. Acceptor atoms introduced into a pure semiconductor at room temperature:
A. increase the number of electrons in the conduction band
B. increase the number of holes in the valence band
C. raise the Fermi level
D. increase the electrical resistivity
E. none of the above
ans: B

34. An acceptor replacement atom in silicon might have ______ electrons in its outer shell.
A. 3
B. 4
C. 5
D. 6
E. 7
ans: A

35. A donor replacement atom in silicon might have ______ electrons in its outer shell.
A. 1
B. 2
C. 3
D. 4
E. 5
ans: E

36. A given doped semiconductor can be identified as $p$ or $n$ type by:
A. measuring its electrical conductivity
B. measuring its magnetic susceptibility
C. measuring its coefficient of resistivity
D. measuring its heat capacity
E. performing a Hall effect experiment
ans: E

37. The contact electric field in the depletion region of a $p$-$n$ junction is produced by:
A. electrons in the conduction band alone
B. holes in the valence band alone
C. electrons and holes together
D. charged replacement atoms
E. an applied bias potential difference
ans: D

38. For an unbiased $p$-$n$ junction, the energy at the bottom of the conduction band on the $n$ side is:

A. higher than the energy at the bottom of the conduction band on the $p$ side
B. lower than the energy at the bottom of the conduction band on the $p$ side
C. lower than the energy at the top of the valence band on the $n$ side
D. lower than the energy at the top of the valence band on the $p$ side
E. the same as the energy at the bottom of the conduction band on the $p$ side

ans: B

39. In an unbiased $p$-$n$ junction:

A. the electric potential vanishes everywhere
B. the electric field vanishes everywhere
C. the drift current vanishes everywhere
D. the diffusion current vanishes everywhere
E. the diffusion and drift currents cancel each other

ans: E

40. Application of a forward bias to a $p$-$n$ junction:

A. narrows the depletion zone
B. increases the electric field in the depletion zone
C. increases the potential difference across the depletion zone
D. increases the number of donors on the $n$ side
E. decreases the number of donors on the $n$ side

ans: A

41. Application of a forward bias to a $p$-$n$ junction:

A. increases the drift current in the depletion zone
B. increases the diffusion current in the depletion zone
C. decreases the drift current on the $p$ side outside the depletion zone
D. decreases the drift current on the $n$ side outside the depletion zone
E. does not change the current anywhere

ans: B

42. When a forward bias is applied to a $p$-$n$ junction the concentration of electrons on the $p$ side:

A. increases slightly
B. increases dramatically
C. decreases slightly
D. decreases dramatically
E. does not change

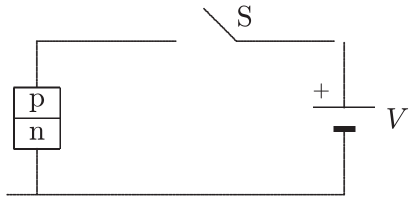
ans: B

43. Which of the following is NOT true when a back bias is applied to a $p$-$n$ junction?

A. Electrons flow from the $p$ to the $n$ side
B. Holes flow from the $p$ to the $n$ side
C. The electric field in the depletion zone increases
D. The potential difference across the depletion zone increases
E. The depletion zone narrows

ans: B

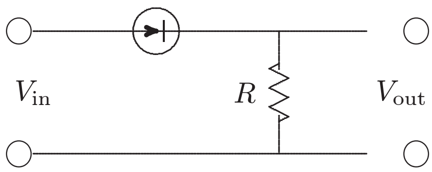
44. Switch S is closed to apply a potential difference $V$ across a $p$-$n$ junction as shown. Relative to the energy levels of the $n$-type material, with the switch open, the electron levels of the $p$-type material are:

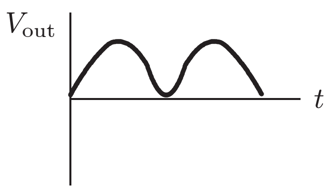



A. unchanged
B. lowered by the amount $e^{-Ve/kT}$
C. lowered by the amount $Ve$
D. raised by the amount $e^{-Ve/kT}$
E. raised by the amount $Ve$

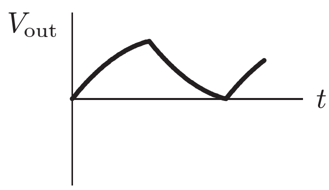
ans: C

45. A sinusoidal potential difference $V_{\text{in}} = V_m \sin(\omega t)$ is applied to the $p$-$n$ junction as shown. Which graph correctly shows $V_{\text{out}}$ as a function of time?

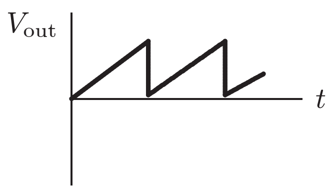


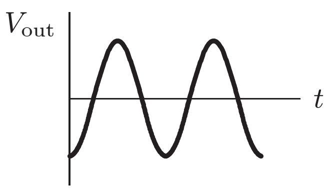

A



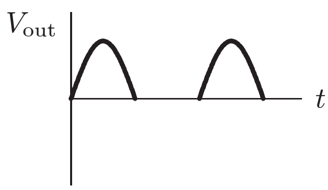

B




C




D




E

ans: E

46. In normal operation the current in a MOSFIT device is controlled by changing:
   A. the number of donors and acceptors
   B. the width of the depletion zone
   C. the size of the sample
   D. the density of electron states
   E. the temperature

   ans: B

47. "LED" stands for:
   A. Less Energy Donated
   B. Light Energy Degrader
   C. Luminescent Energy Developer
   D. Laser Energy Detonator
   E. none of the above

   ans: E

48. A light emitting diode emits light when:
   A. electrons are excited from the valence to the conduction band
   B. electrons from the conduction band recombine with holes from the valence band
   C. electrons collide with atoms
   D. electrons are accelerated by the electric field in the depletion region
   E. the junction gets hot

   ans: B

49. The gap between the valence and conduction bands of a certain semiconductor is $0.85\,\mathrm{eV}$. When this semiconductor is used to form a light emitting diode, the wavelength of the light emitted:
   A. is in a range above $1.5 \times 10^{-6}\,\mathrm{m}$
   B. is in a range below $1.5 \times 10^{-6}\,\mathrm{m}$
   C. is always $1.5 \times 10^{-6}\,\mathrm{m}$
   D. is in a range centered on $1.5 \times 10^{-6}\,\mathrm{m}$
   E. has nothing to do with the gap

   ans: B