The original magnitude of the force on the $+Q$ charge was $F$. What is the magnitude of the force on the $+Q$ charge now?

1. $4F$
2. $5F/2$
3. $3F$
4. $2F$
5. $F$
6. $F/4$
Two small objects each with a net charge of \( +Q \) exert a force of magnitude \( F \) on each other:

We replace one of the objects with another whose net charge is \( +4Q \):

What is the magnitude of the force on the \( +4Q \) charge?

1. 4F
2. 5F/2
3. 3F
4. 2F
5. F
6. F/4
Now what is the magnitude of the force on the +4Q charge?

1. $\frac{4F}{3}$
2. $\frac{4F}{9}$
3. $\frac{F}{3}$
4. $\frac{5F}{18}$
5. $\frac{2F}{9}$
6. $\frac{F}{9}$
7. $\frac{F}{36}$
8. $4F$
Here are two charges of equal magnitude but opposite sign, separated by a distance s.

What is the direction (a-j) of the electric field at location 1?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
8. h
9. i
10. j
Here are two charges of equal magnitude but opposite sign, separated by a distance \( s \).

What is the direction (a-j) of the electric field at location 2?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
8. h
9. i
10. j
A moving electron with charge \(-e\) travels along the path shown, and passes through a region of electric field. There are no other charges present. The electric field is zero everywhere except in the gray region.

What is a possible direction (a-g) of the electric field in the region where the field is non-zero?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
A non-conducting wall is given a net negative charge. Next, a sheet of very flexible rubber with zero net charge is suspended from the ceiling near the charged wall as shown. The rubber sheet will …

1. not be affected by the charges on the wall since rubber is an insulator.
2. not be affected by the charged wall because the rubber sheet has zero net charge.
3. bend away from the wall due to the electrical repulsion between the electrons in the rubber and the charges on the wall
4. bend away from the wall due to the polarization of the rubber molecules by the charged wall
5. bend toward the wall due to the polarization of the rubber molecules by the charged wall
Salt water contains $n$ sodium ions ($\text{Na}^+$) per cubic meter and $n$ chloride ions ($\text{Cl}^-$) per cubic meter. A battery is connected to metal rods that dip into a narrow pipe full of salt water. The cross sectional area of the pipe is $A$. What is the direction of conventional current flow in the salt water?

1. to the right
2. to the left
3. There is no conventional current, because the motion of the positive and negative ions cancel each other out.
Salt water contains $n$ sodium ions ($\text{Na}^+$) per cubic meter and $n$ chloride ions ($\text{Cl}^-$) per cubic meter. A battery is connected to metal rods that dip into a narrow pipe full of salt water. The cross-sectional area of the pipe is $A$. The magnitude of the drift velocity of the sodium ions is $v_{Na}$ and the magnitude of the drift velocity of the chloride ions is $v_{Cl}$. Assume that $v_{Na} > v_{Cl}$.

What is the magnitude of the ammeter reading?

1. $enAv(\text{Na}) - enAv(\text{Cl})$
2. $enAv(\text{Na}) + enAv(\text{Cl})$
3. $enAv(\text{Na})$
4. $enAv(\text{Cl})$
5. zero
The light bulbs and batteries are identical in the three circuits shown. Rank the currents read by the three ammeters from largest to smallest.

1. \( I_1 = I_2 = I_3 \)
2. \( I_1 = I_2 > I_3 \)
3. \( I_1 = I_3 > I_2 \)
4. \( I_2 = I_1 > I_3 \)
5. \( I_2 = I_3 > I_1 \)
6. \( I_3 > I_1 = I_2 \)
7. \( I_3 > I_1 > I_2 \)
8. \( I_3 > I_2 > I_1 \)
The light bulbs and batteries are identical in the three circuits shown. The batteries have negligible internal resistance. Rank all 5 light bulbs in order of brightness from brightest to dimmest.

1. \( A = B = C > D = E \)
2. \( A > B = C = D = E \)
3. \( A > B = C > D = E \)
4. \( A > B > C > D = E \)
5. \( A = D = E > B = C \)
6. \( A = D = E > B > C \)
7. \( A > D = E > B = C \)
8. \( D = E > A > B = C \)
Which of the following statements is true about the electric field inside the bulb filament?

1. The field must be zero because the filament is made of metal.
2. The field must be zero because a current is flowing.
3. The field must be zero because any excess charges are on the surface of the filament.
4. The field must be non-zero because the flowing current produces an electric field.
5. The field must be non-zero because no current will flow without an applied field.
The capacitor is originally charged. How does the current $I$ in the ammeter behave as a function of time after the switch is closed?

1. $I = 0$ always
2. $I = \text{constant, not equal to } 0$
3. $I \text{ increases, then is constant.}$
4. $I \text{ instantly jumps up, then slowly decreases.}$
5. None of the above.
In a certain region of space there is a uniform electric field of magnitude $E$. The potential difference $V_2 - V_1 = $?

1. $+Ew$
2. $-Ew$
3. $+Eh$
4. $-Eh$
5. $+E \sqrt{h^2 + w^2}$
6. $-E \sqrt{h^2 + w^2}$
7. zero
In a certain region of space there is a uniform electric field of magnitude $E$. The potential difference $V_3 - V_1 = ?$

1. $+Ew$
2. $-Ew$
3. $+Eh$
4. $-Eh$
5. $+E \sqrt{h^2 + w^2}$
6. $-E \sqrt{h^2 + w^2}$
7. zero
In a certain region of space there is a uniform electric field of magnitude $E$. The potential difference $V_4 - V_1 =$?

1. $+Ew$
2. $-Ew$
3. $+Eh$
4. $-Eh$
5. $+E \sqrt{h^2 + w^2}$
6. $-E \sqrt{h^2 + w^2}$
7. zero
What is the magnitude of the potential difference between points $A$ and $B$ on the circuit while the switch is open?

1. 0 volts
2. 3 volts
3. 6 volts
4. 12 volts
5. none of the above
Here is a cylinder on whose surfaces there is an electric field whose direction is vertically upward, but whose magnitude varies as shown.

The cylinder encloses …

1. no net charge
2. net positive charge
3. net negative charge
4. There is not enough information available to determine whether there is charge net charge inside the cylinder.
In static equilibrium, the potential difference between two points inside a solid piece of metal is …

1. zero because metals block electric interactions
2. zero because the electric field is zero inside the metal
3. non-zero if the piece of metal is not spherical
4. non-zero if there are charges on the surface of the metal
A proton is initially at rest in a region of uniform magnetic field as shown. There are no other charges present.

What is the direction of the initial magnetic force on the proton?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
8. h

e: out of page
f: into page
g: zero magnitude
h: None of the above
Here is a bar magnet. The magnetic field made by the bar magnet at one location is shown on the diagram.

What is the direction of the magnetic field at location 1?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
8. h
9. i
10. j
Here is a bar magnet. The magnetic field made by the bar magnet at one location is shown on the diagram.

What is the direction of the magnetic field at location 2?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
8. h
9. i
10. j
A moving electron travels along the path shown, and passes through a region of magnetic field. There are no other charges present. The magnetic field is zero everywhere except in the gray region.

What is a possible direction of the magnetic field in the region where the field is non-zero?

1. a
2. b
3. c
4. d
5. e
6. f
7. g

e: out of page
f: into page
g: none of the above
Two identical circular loops of wire, perpendicular to the page, carry the same conventional current $I$.

In the Front View what is the direction of the magnetic field due to the loops at the location $P$, which is midway between the loops?

1. a
2. b
3. c
4. d
5. e
6. f
7. g

e: out of page 

f: into page 

g: none of the above
Two wire lie in the plane of the page. Wire 1 carries conventional current to the left, and wire 2 carries conventional current to the right.

What is the direction of the magnetic force that wire 1 exerts on wire 2?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
A proton moves with constant velocity $\vec{v}$ to the right through a region where there is a uniform magnetic field of magnitude $B$ that points into the page. There is also an electric field in this region. The magnetic field and the electric field are produced by devices not shown on the diagram.

What is the direction of the electric field in the region?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
A proton moves with constant velocity \( \vec{v} \) to the right through a region where there is a uniform magnetic field of magnitude \( B \) that points into the page. There is also an electric field in this region. The magnetic field and the electric field are produced by devices not shown on the diagram.

What is the magnitude of the electric field?

1. 1 \( e v B \)
2. 2 \( \vec{v} \times \vec{B} \)
3. 3 \( vB \)
4. d \( B \)
5. e \( e \vec{v} \times \vec{B} \)
6. f \( vB / e \)
7. g \( ev \)
Here is a long solenoid and an end view of the solenoid. Conventional current runs counter-clockwise in the solenoid and is increasing with time.

What is the direction in the end view of the electric field at location 1?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
Here is a long solenoid and an end view of the solenoid. Conventional current runs counter-clockwise in the solenoid and is increasing with time.

What is the direction in the end view of the electric field at location 2?

1. a
2. b
3. c
4. d
5. e
6. f
7. g
A neutral metal bar is moving at constant velocity \( \vec{v} \) to the right through a region where there is a uniform magnetic field pointing out of the page. The magnetic field is produced by some large coils which are not shown.

Which of the following diagrams best describes the state of the metal bar?
A variable power supply is connected to a coil and an ammeter, and the time dependence of the ammeter reading is shown. A nearby coil is connected to a voltmeter.

Which of the following graphs correctly shows the time dependence of the voltmeter reading?

1. a  
2. b  
3. c  
4. d  
5. e  
6. f
Answers

1. 1 16. 2
2. 1 17. 4
3. 2 18. 2
4. 5 19. 2
5. 1 20. 7
6. 4 21. 1
7. 5 22. 5
8. 2 23. 5
9. 2 24. 1
10. 6 25. 4
11. 5 26. 4
12. 5 27. 1
13. 4 28. 2
14. 2 29. 3
15. 7 30. 6
31. 4