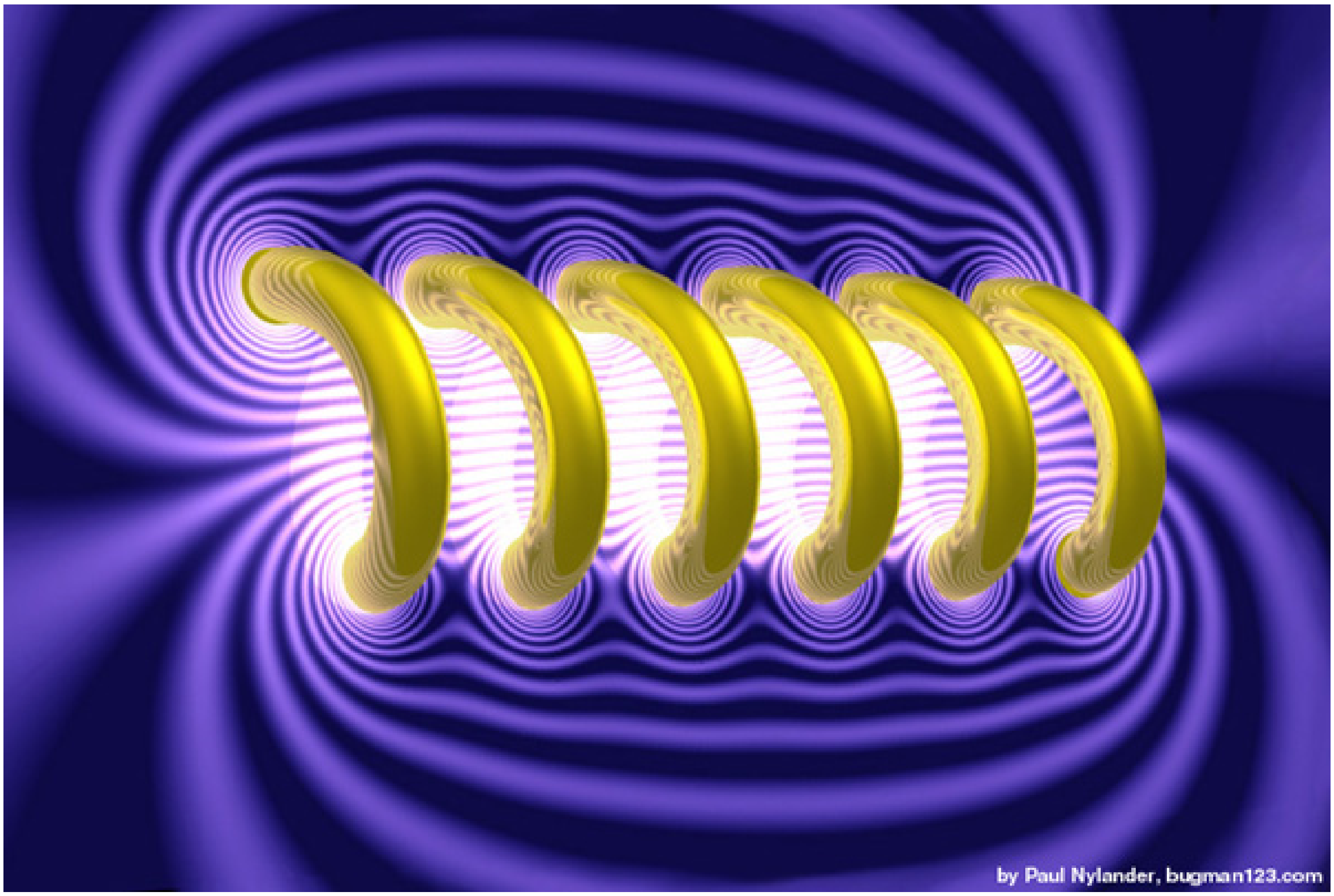
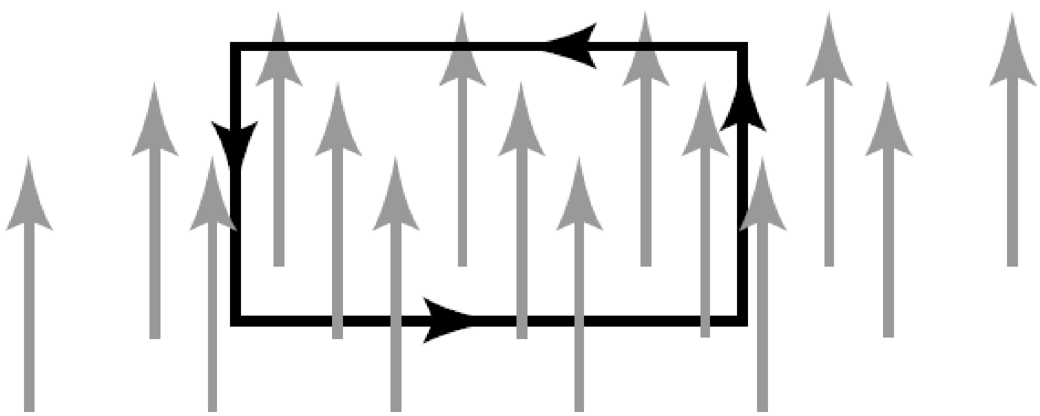
Magnetic Sources



A rectangular loop is placed in a uniform magnetic field with the plane of the loop parallel to the direction of the field. If a current is made to flow through the loop in the sense shown by the arrows, the field exerts on the loop:



A. a net force.

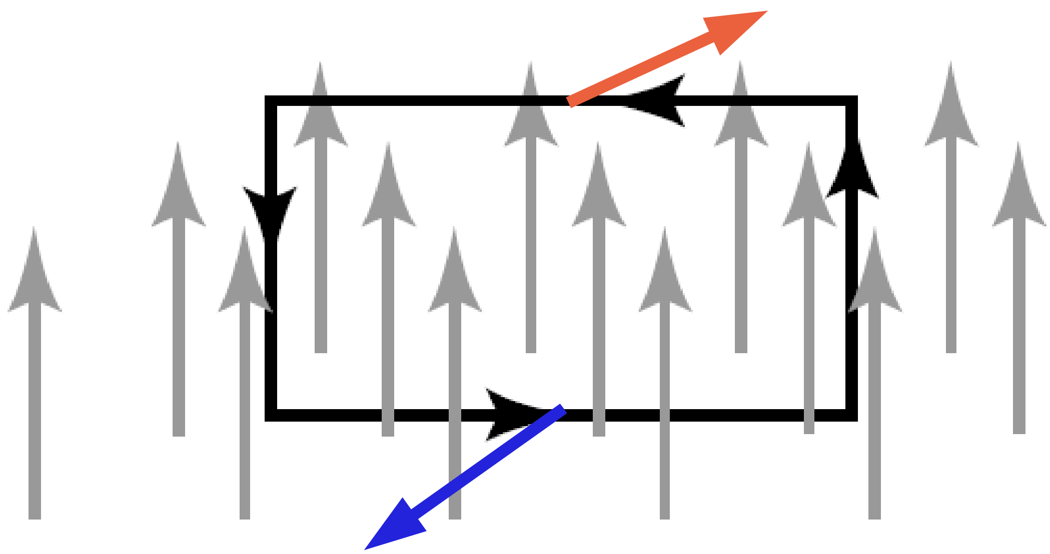
B. a net torque.

C. a net force and a net torque.

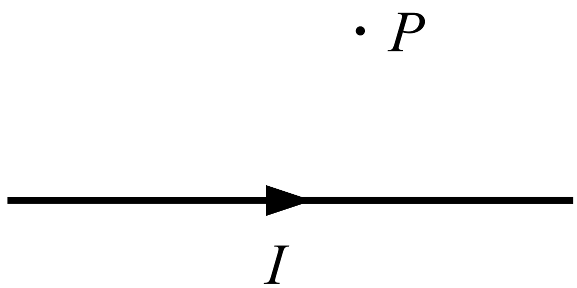
D. neither a net force nor a net torque.

ANS: B—The field exerts a net torque on the loop.

The diagram below shows the forces on each segment of the wire. There is not a force on either of the side segments because those currents are co-linear with the field. The force on the top segment (red) points into the page. The force on the bottom segment (blue) points out of the page. Because these segments are the same length, carry the same current, and are both perpendicular to the same field, they will have the same magnitude. Therefore, the net force on the loop is zero. However, there certainly is a torque around an axis that runs horizontally through the picture. This torque will seek to turn the loop so that the face currently pointing out of the page will be turned upward.



A compass is placed at point P above a wire carrying a current that is directed toward the right. In which direction does the needle of the compass point?

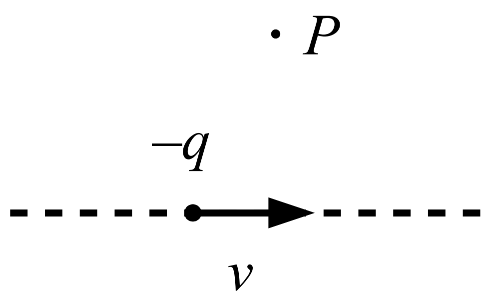


A. up.
B. down.
C. into the plane of the drawing.
D. out of the plane of the drawing.
E. left.
F. right.
G. cannot be determined without knowing if positive or negative charge carriers cause the current.

ANS: D—The needle points out of the plane of the drawing.

A long straight current-carrying wire will create a magnetic field that circles around the wire. The direction of the field is easily determined by a right-hand rule: put the thumb of your right hand in the direction of the current; the magnetic field lines will curl around the wire in the same direction as the fingers of your right hand around your extended thumb. Lay your right hand over this picture, with the back of your hand resting against the page. Your fingers will point up to point *P*, and the tips of your curled fingers will point out of the page. This is the direction of the magnetic field at point *P*. (If *P* were below the wire, the field would point into the page. You can see this by laying your right hand palm-down on the page with your thumb pointing to the right. Your fingers will point down to *P*, and the tips of your fingers will point into the page.)

A negative particle moves rightward along the trajectory shown. As the particle moves by, in which direction does a compass needle placed at point *P* point?



A. up.

B. down.

C. into the plane of the drawing.

D. out of the plane of the drawing.

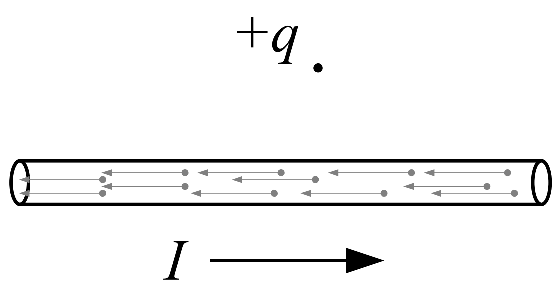
E. left.

F. right.

ANS: C—The compass needle points into the plane of the drawing.

The magnetic field created by a moving charge will be similar to that produced by a current. The field lines will circle around the path that the particle is moving. We can use the right-hand rule above. However, in this case we have a negative charge moving, so you must point the thumb of your right hand opposite to the direction of the charge's velocity. (Remember, current always points in the direction of flow of positive charge, or opposite the direction of flow of negative charge.) According to the right hand rule, the field will point into the page.

A positively charged particle is placed at rest near a wire carrying a steady rightward current. The rightward current is due to leftward motion of negatively charged electrons in the wire. The wire exerts on the particle



A. an electric force.

B. a magnetic force.

C. both of the above.

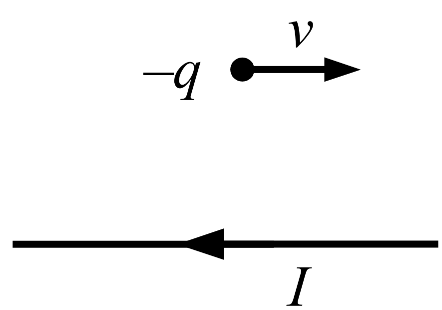
D. neither of the above.

ANS: D—There is neither an electric nor a magnetic force between the wire and particle.

There is no electric force on the positive charge at *P*, even though negative charges are moving through the wire. This is because the wire remains electrically neutral. Electrons move through the wire, but there is always a collection of fixed positive charges in the wire.

There is also no magnetic force on the particle at *P*, even though the current creates a magnetic field at *P* (which points into the page, if you're keeping score). This is because magnetic fields only exert forces on moving charges. The charge at *P* is fixed.

A negatively charged particle moves to the right parallel to a wire carrying a leftward electric current. In which direction is the magnetic force on the particle?



A. up.

B. down.

C. into the plane of the drawing.

D. out of the plane of the drawing.

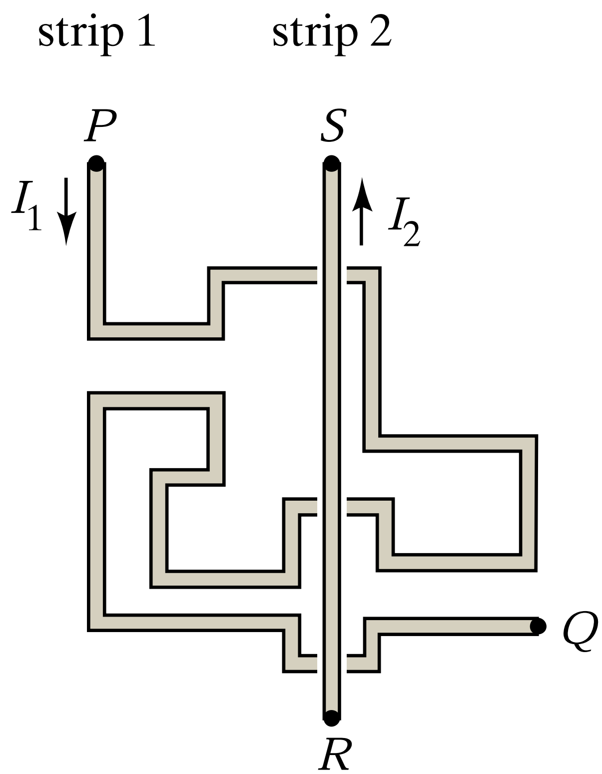
E. left.

F. right.

ANS: B—The magnetic force on the particle points downward.

The leftward current creates a magnetic field that points into the page at the charge's location (one of our right hand rules). The negative charge is moving perpendicular to this field, so there will be a magnetic force on the charge. According to the right-hand rule for cross products, if $\vec{\mathbf{v}}$ points to the right and $\vec{\mathbf{B}}$ points into the page, then $\vec{\mathbf{v}} \times \vec{\mathbf{B}}$ points up. The charge is negative, so the magnetic force ($\vec{\mathbf{F}}_B = q\vec{\mathbf{v}} \times \vec{\mathbf{B}}$) points to the downward.

On a computer chip, two conducting strips carry charge from *P* to *Q* and from *R* to *S*. If the current direction is reversed in both wires, the net magnetic force of strip 1 on strip 2



A. remains the same.

B. reverses.

C. changes in magnitude, but not in direction.

D. changes to some other direction.

E. other

ANS: A—The magnetic force remains the same when both currents are reversed.

The magnetic force that strip 1 exerts on strip 2 reverses when the current in strip 1 is reversed. The shape of strip 1 does not matter, because the relative positions of all points on the strips will not change, only the direction of the current at each point in strip 1. If we also reverse the current in strip 2, the magnetic force on strip 2 is again reversed, returning the net force to what it was before the two currents were reversed.

Warmup Question

As discussed in the reading assignment, the magnetic field lines for a long, straight current are circles around the wire. What about the magnetic field vectors themselves? If you draw them as little straight arrows with beginning and ends, what would the figure look like? Describe the picture as best as you can.

ANS: The field vectors would be arrows tangent to the circular field lines. The lengths of these arrows will decrease as we move farther from the wire.

Warmup Question

Okay, time to sort out the confusion. So far in the section on magnetism (including the reading for today) we have encountered two different right-hand rules. Not in the sense of “you could flap your hand or you can use three fingers” different, but rather right-hand rules applied in very different situations: one from last week, and one from today’s reading. Explain the two different rules and the cases in which they apply.

ANS: The first rule applied to forces on moving charges and currents. Finding the direction of a force requires finding the direction of a cross product ($\vec{\mathbf{v}} \times \vec{\mathbf{B}}$, or $\vec{\ell} \times \vec{\mathbf{B}}$). This, of course, requires a right-hand rule in which the index finger of your right hand points in the direction of the first vector, your middle finger points in the direction of the second vector, and your thumb points in the direction of the cross product. (Alternatively, the fingers of your hand point in the direction of the first vector, your palm points in the direction of the second vector, and your thumb points in the direction of the cross product.)

The second rule applies to magnetic fields created by electric currents. Point the thumb of your right hand in the direction of the current, and your fingers will curl in the direction of the circular magnetic field that surrounds the current.

Warmup Question

A positively charged particle is moving near a long straight current. The particle's velocity is parallel to the current and in the same direction. What is the direction of the magnetic force on it?

A. Toward the current
B. Away from the current
C. Parallel to the current, i.e., in the direction of motion
D. Anti-parallel to the current, i.e., opposite the direction of motion
E. Around the current (either way!)
F. The force is zero

ANS: A—The magnetic force points toward the current.

You must apply the right hand rule for creating magnetic fields to determine the direction of the field produced by the current. Then apply the right hand rule for forces on moving charges to see that the positive charge will be attracted to the current. Of course, you can also just remember that two currents in the same direction will exert an attractive force on each other, then recognize a moving positive charge as analogous to an electric current.