New Jersey Center for Teaching and Learning

Progressive Science Initiative

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Magnetism

www.njctl.org

How to Use this File

- Each topic is composed of brief direct instruction

- There are formative assessment questions after every topic denoted by black text and a number in the upper left.

- Students work in groups to solve these problems but use student responders to enter their own answers.

- Designed for SMART Response PE student response systems.

- Use only as many questions as necessary for a sufficient number of students to learn a topic.

- Full information on how to teach with NJCTL courses can be found at njctl.org/courses/teaching methods

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The Nature of Magnetism

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History

Magnets were first discovered over 2000 years ago by the Chinese and the Greeks and were used for various non scientific purposes.

The name was coined by the Greeks, as certain magnetic rocks (magnetite) were found in the province of Magnesia.

Unlike electrical effects due to the rubbing of various substances, like amber, to separate the electrical charges so there would be attractive and repulsive forces, these magnets came out of the ground already attracting and repelling certain materials.

History

It wasn't until after the 1000 A.D. that Chinese, European and Persian mariners separately used magnets for navigation.

When a magnetic material, shaped in the form of a needle and floated on the surface of water, it always pointed in the same direction - towards the north.

Always being able to tell which direction was north was a critical factor in ushering in the age of exploration.

It wasn't until 1600 when this phenomenon was explained by William Gilbert.

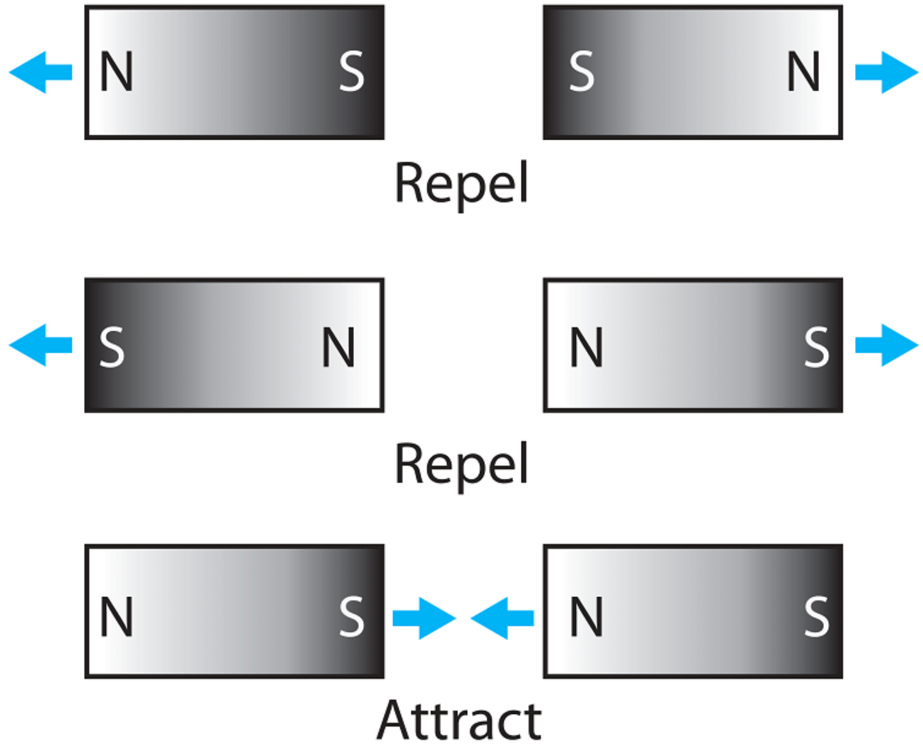
irst, the nature of magnetism will be discussed.

Magnet Properties

Magnets have two ends (poles) called north and south.

Like poles repel; unlike poles attract.

This attraction or repulsion is the magnetic force.



These are examples of bar magnets.

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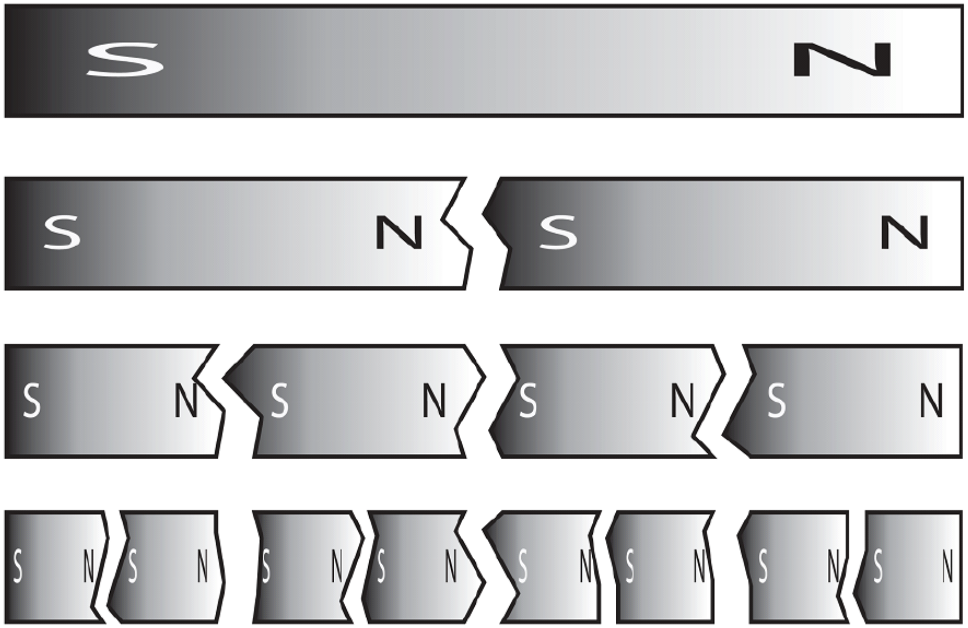
Magnetic Poles

When a magnet is cut in half, each piece still has a north and a south pole. No matter how many times the magnet is cut, the pieces still have a north and south pole.

This works all the way down to the atomic level!



Magnetic Poles and Electric charges

The behavior of magnetic poles (north and south) are similar to electric charges (positive and negative) where opposite poles/charges attract and like poles/charges repel.

There are two significant differences between these effects.

One, certain materials are naturally magnetic, where electrical properties result from physical rubbing.

And secondly - there are independent positive and negative charges, but magnetic materials always contain a north and a south pole.

1 What are the two kinds of magnetic poles?

A North and Negative.

B South and Positive.

C Postive and Negative.

D North and South.

Answer

1 What are the two kinds of magnetic poles?

A North and Negativ

B South and Positi

C Postive and Neg

D North and Sou

Answer

D

2 Which of the following combination of magnetic poles will exert an attractive force on each other?

- A North and North.
- B North and South.
- C South and South.

Answer

http://njc.tl/lx

2 Which of the following combination of magnetic poles will exert an attractive force on each other?

- A North and North.
- B North and South
- C South and South

Answer

B

3 It is possible to find a magnet that only has a north pole.

- True
- False

Answer

http://njc.tl/ly

3 It is possible to find a magnet that only has a north pole.

- True
- False

Answer

False

http://njc.tl/ly

Magnetic Fields

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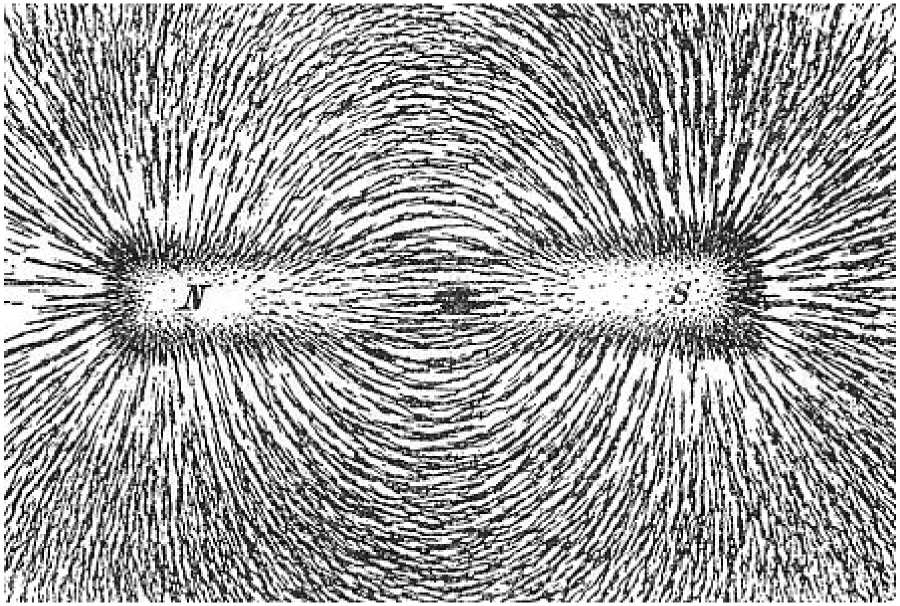
Magnetic Fields

Electric field lines were used to show how electric charges would exert forces on other charges. A similar concept will be used in Magnetism.



What's nice about Magnetic field lines is that they are more easily "seen." The above is a picture of iron filings sprinkled on a paper ... of a bar magnet.

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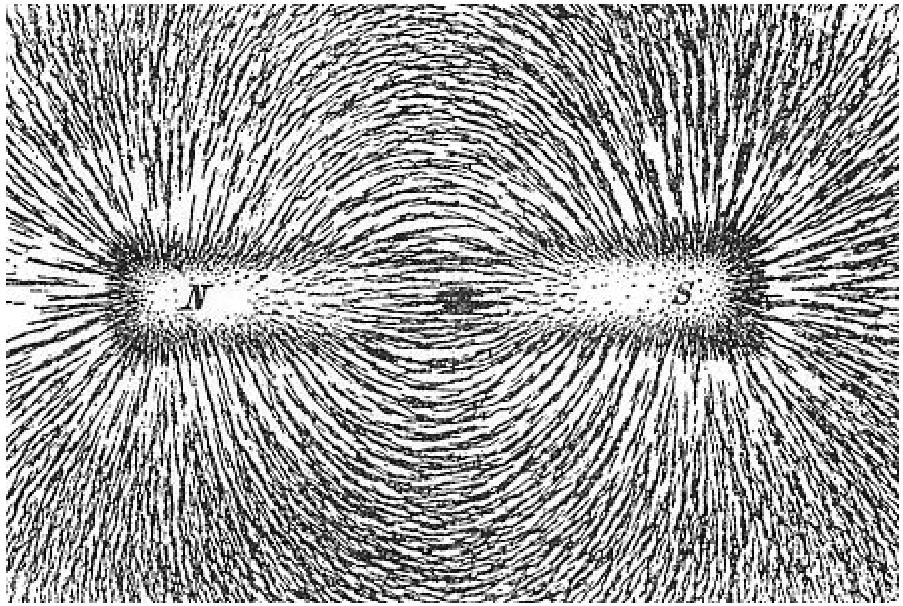
Magnetic Fields

The iron filings act like little bar magnets, and align with the magnetic field of the large magnet.



The field exits one end of the magnet and returns to the other end. Note also, that the field lines extend through the magnet, g a complete loop (unlike Electric Field Lines).

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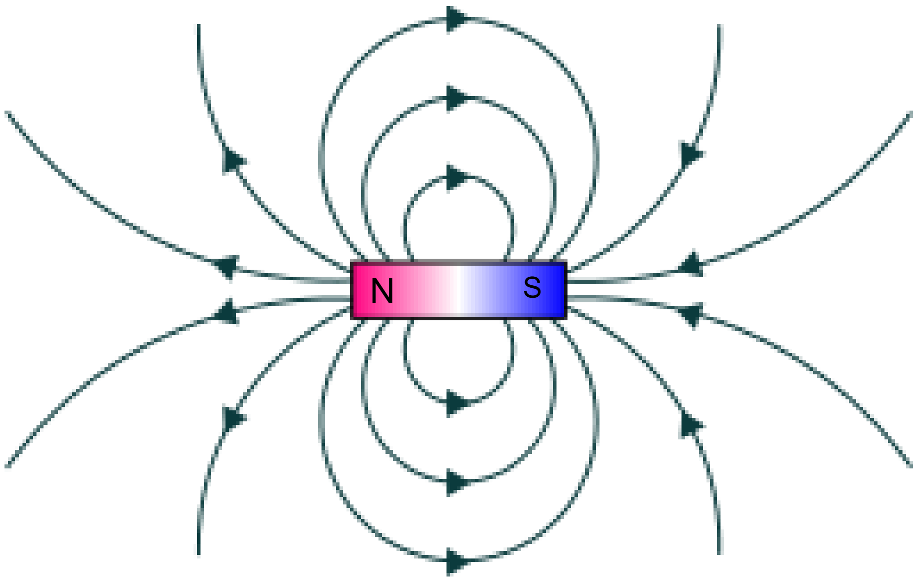
Magnetic Fields

Arbitrarily, magnetic field lines are defined as leaving the north pole of the magnet and reentering at the south pole as seen below. The lines specify the direction that the north pole of a magnet will point to.



The more lines per unit area, the stronger the field.

The lines that seem not to be in loops are - we just ran out of room on the slide. All magnetic field lines form complete loops.

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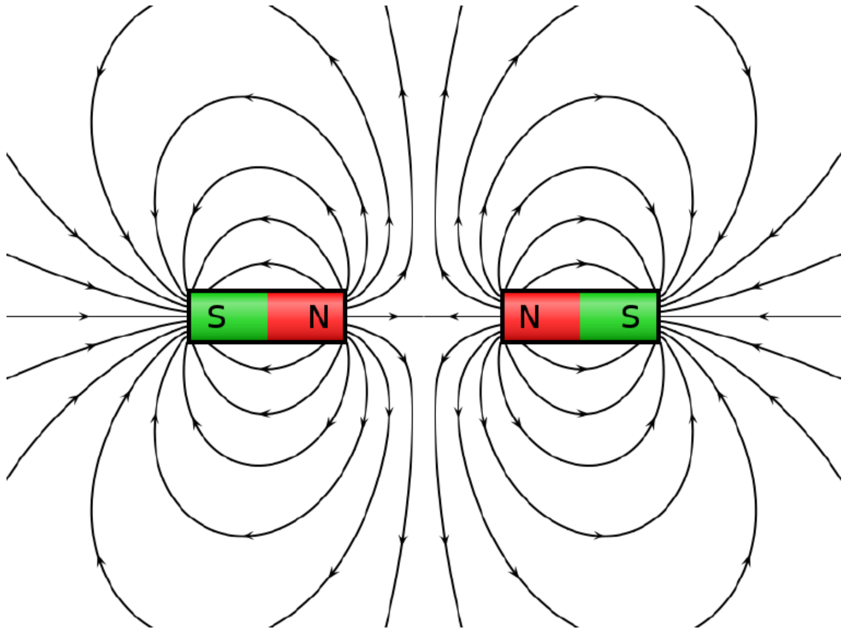
Magnetic Fields

Like Electric Fields, different configurations of magnets will produce interesting Magnetic Fields.



Here are two magnets with their north poles next to each other - these magnets are repelling each other.

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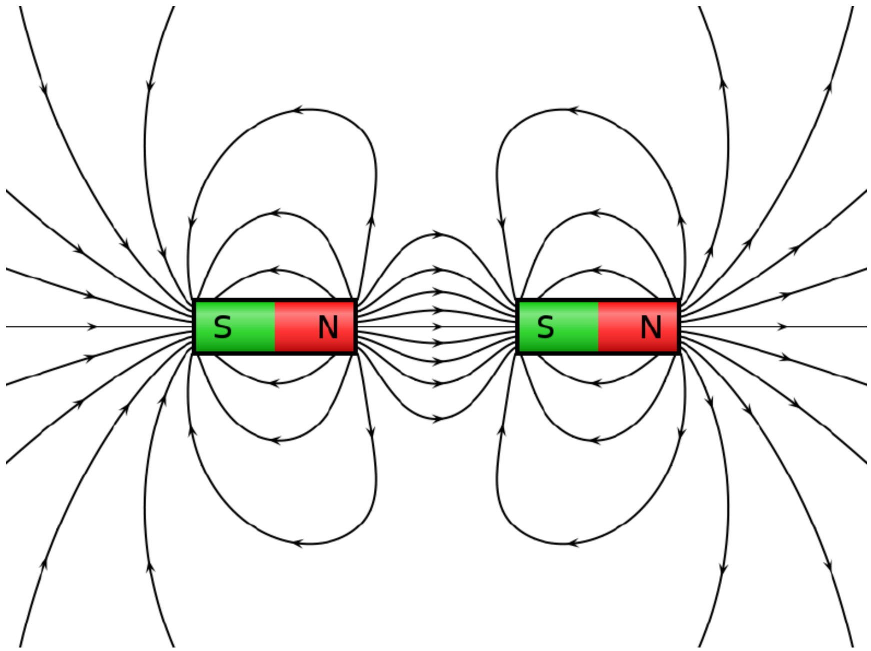
Magnetic Fields

Like Electric Fields, different configurations of magnets will produce interesting Magnetic Fields.



Here are two magnets with their opposite poles next to each other
e magnets are attracting each other.

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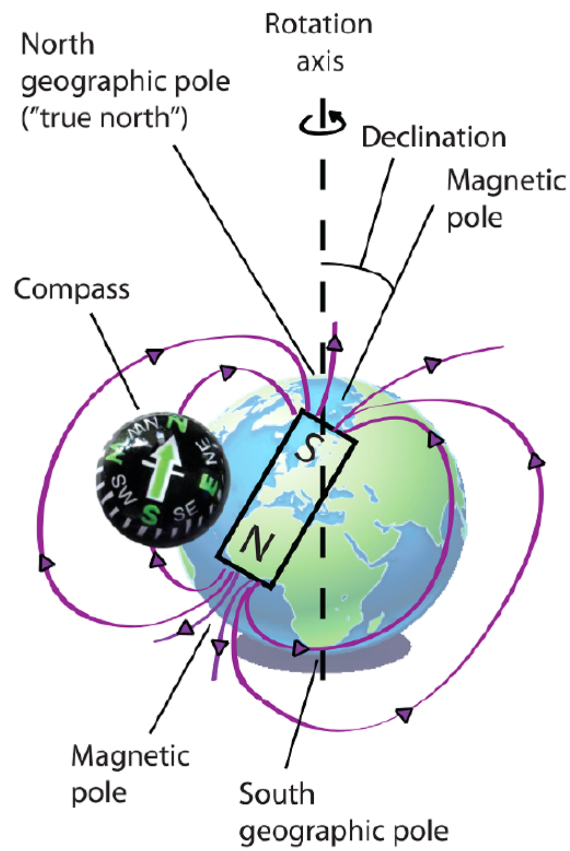
The Earth's Magnetic Field

The Earth’s magnetic field is similar to that of a bar magnet.

It is caused by the circulation of molten iron alloys in the earth's outer core.

The Earth’s “North Pole” is really a south magnetic pole as the north ends of magnets are attracted to it.

The magnetic poles are not along the earth's rotation.



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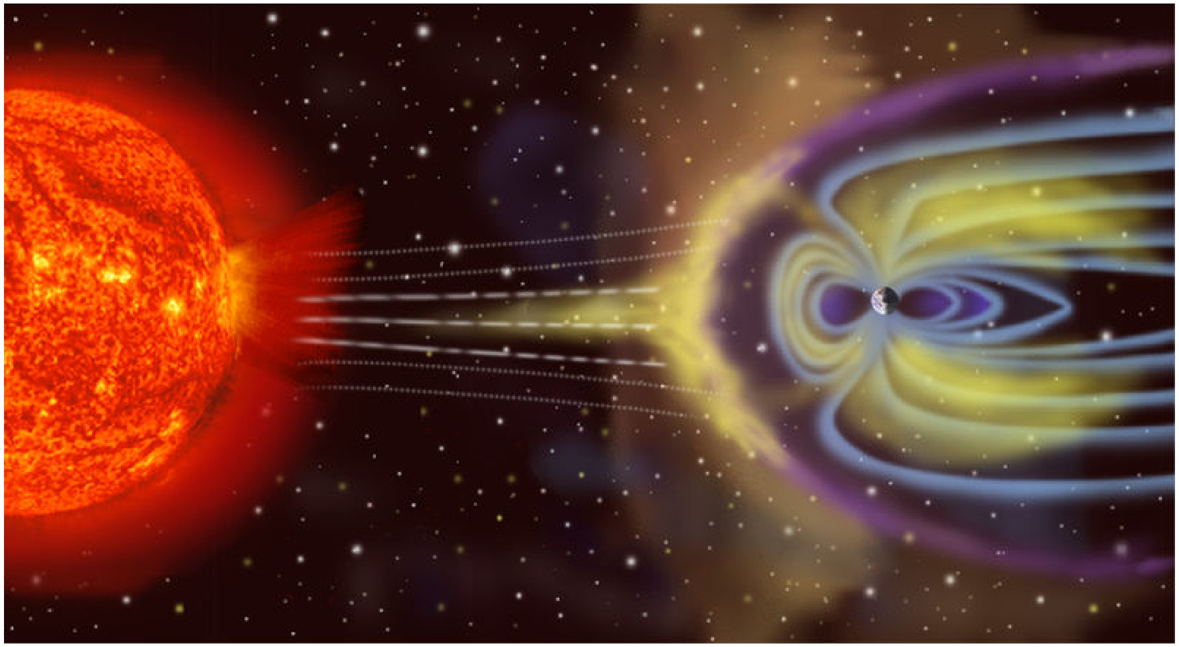
The Earth's Magnetic Field

The Magnetic Field extends from the core to the outer limits of the atmosphere (magnetosphere).

This picture shows the interaction of the solar wind (ions and electrons) with the magnetosphere.



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The Earth's Magnetic Field

This interaction also produces the Aurora Borealis and Aurora Australis.

Magnetic Field Units

The symbol for the Magnetic Field is B. The field is a vector and has both magnitude and direction.

The unit of B is the Tesla, T, where $1T = 1\frac{N}{Amp - m}$

Because the Tesla is such a large magnitude, another unit is frequently used, the Gauss, G, where $1G = 10^{-4}T$

To gain perspective, the magnetic field of the Earth at its surface is around 0.5 x 10^{-4} T or simply 0.5 G.

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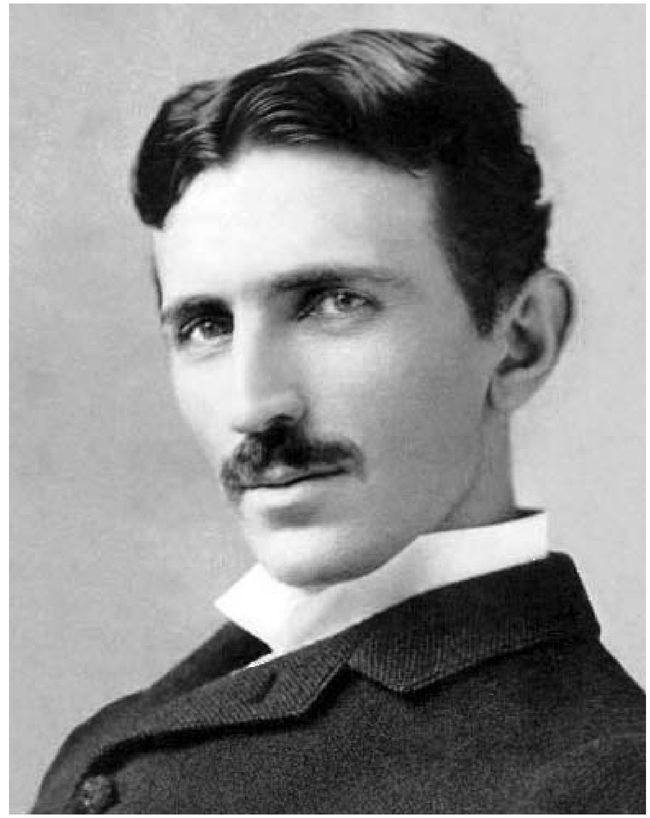
Magnetic Field Units

Carl Friedrich Gauss
1777-1855 - Mathematician and
st.



Nikola Tesla
1856-1943, Inventor, Engineer, Physicist.

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Origin and direction of Magnetic Fields

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Electric Currents Produce Magnetic Fields

In 1820, while searching for a relationship between electricity and magnetism, Hans Christian Oersted noticed that a compass needle would be deflected away from pointing towards the north pole when he connected a wire to a battery, and would return to pointing north when the circuit was disconnected.

Oersted deduced that an electric current produced a magnetic field that affected the compass needle more strongly than the earth's magnetic field.

In addition to this first experimental evidence that electric and magnetic fields are related, Oersted produced Aluminum for the first time (which was later used to carry current).

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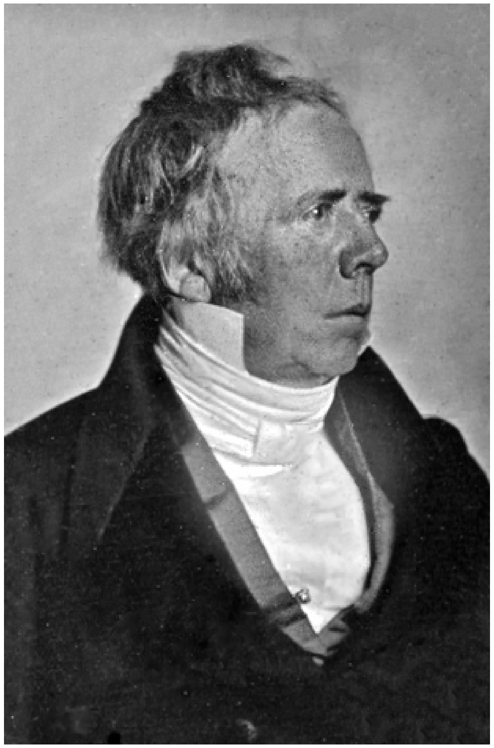
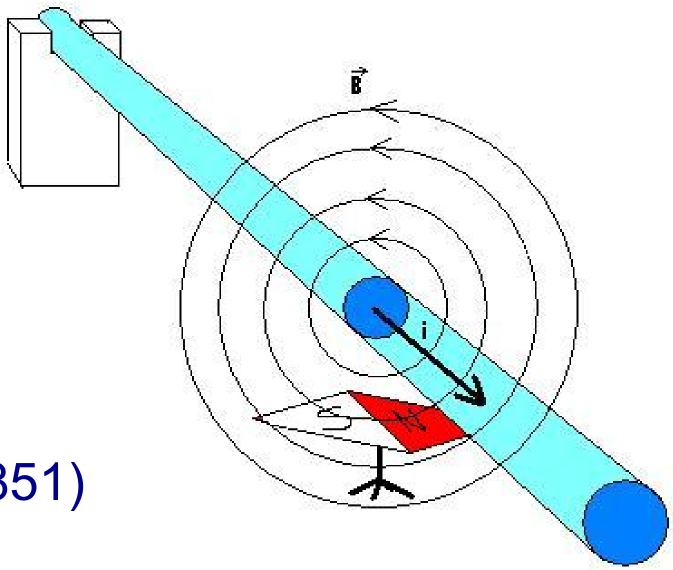
Electric Currents Produce Magnetic Fields



Current carrying wire generating a magnetic field that deflects a compass needle.

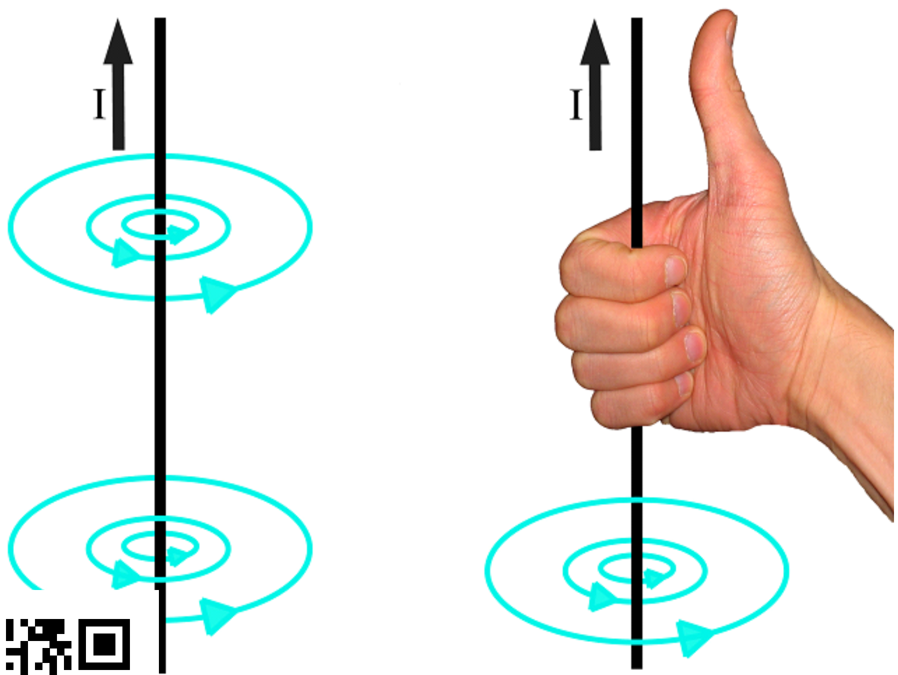


Hans Christian Oersted (1777-1851)
Physicist and Chemist

http://njc.tl/m0

Electric Currents Produce Magnetic Fields

It has been experimentally observed that the direction of the magnetic field depends on the direction of the electric current.



The direction of the field is given by the right-hand rule (actually through the use of vector calculus, but the right-hand rule gives the correct result).

Orient your right hand thumb in the direction of the current.

The B field follows the path followed by your curled fingers.

http://njc.tl/m0

Electric Currents Produce Magnetic Fields

When you have a current circulating around an iron core, a magnetic field is created and the device is called an electromagnet.

This is an industrial electromagnet that when the current is turned on, it picks up metallic objects.

Metal scrap is being attracted from the ground to the electromagnet.


Quelle: Deutsche Fotothek

http://njc.tl/m0

Electric Currents Produce Magnetic Fields

Earlier, it was stated that when a magnet is cut in half, and those pieces are cut in half and this is continued all the way down to the atomic level, then each piece would still have a north and south pole.

This is because the movement of the electrons in the nucleus can be viewed as tiny electric currents. And as shown by Oersted, changing electric currents generate magnetic fields.

So each atom is acting as a magnet with a north and south pole.

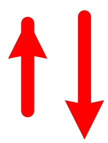
http://njc.tl/m0

Direction of Magnetic Fields

Another difference between electric fields and magnetic fields, is that we can normally understand an electric field very easily on two dimensional paper (the electric field is, of course, three dimensional, but is easily represented in two dimensions).

But, as you just saw with Oersted's experiment, the magnetic field is looping around the wire so magnetic fields need to be shown as three dimensional to be understood. Somehow, we need to show this third dimension on our paper.

We have left / right: 

Up / down: 

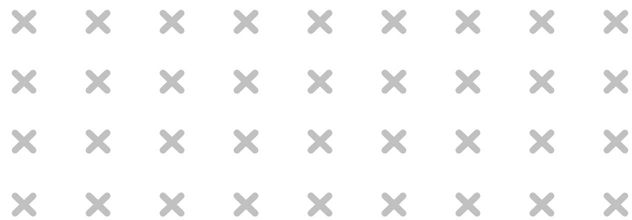
How do we represent the third dimension on a page of paper?

http://njc.tl/m0

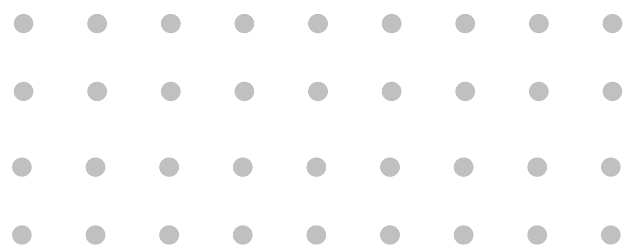
Magnetic Fields

Picture the field line (which is a vector with magnitude and direction) like an arrow. The head of the arrow is the direction of the field.

If the magnetic field is into the page, you will see the tail of the arrow:



If the magnetic field is out of the page, you will see the front of the arrow:



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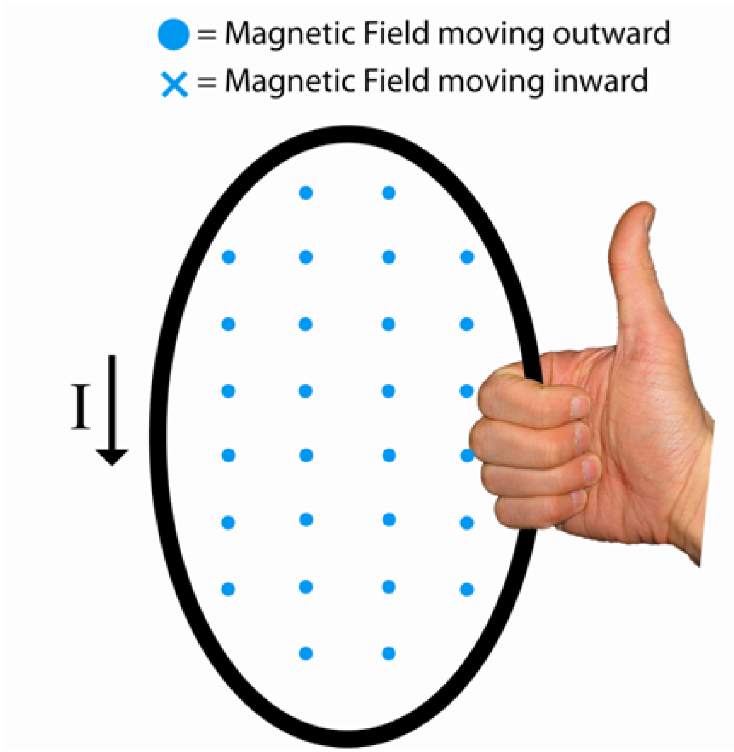
Electric Currents Produce Magnetic Fields

Here's how the magnetic field would look inside a current carrying loop.

Your thumb points in the direction of the current, and your fingers curl around and show the magnetic field coming out of the board within the loop.

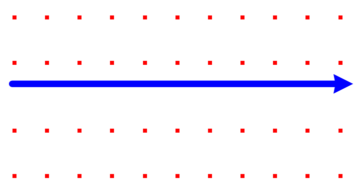
What direction is the magnetic field outside the loop? That's right - into the board, as your fingers continue curling.



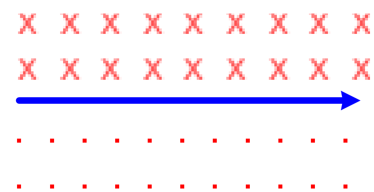
http://njc.tl/m0

4 Which diagram shows the magnetic field (red) around a current carrying wire (blue?)

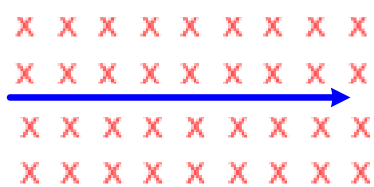
A



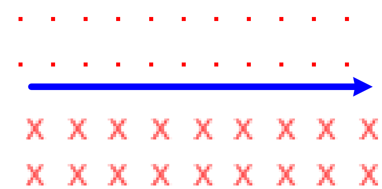
B



C



D

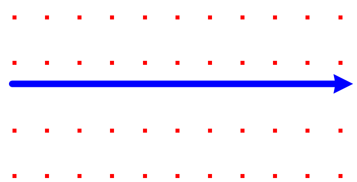


Answer

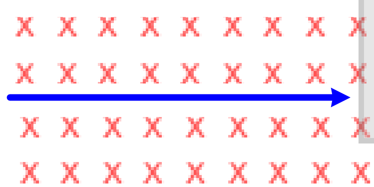
http://njc.tl/m1

4 Which diagram shows the magnetic field (red) around a current carrying wire (blue?)

A



C

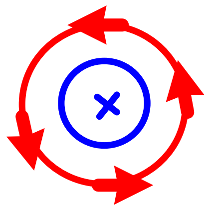


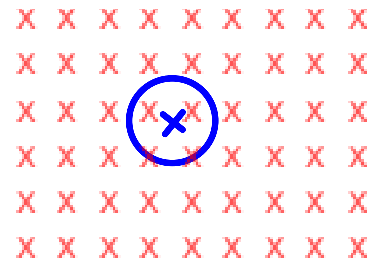
Answer

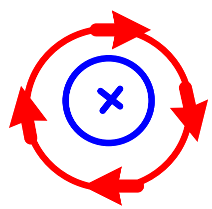
D

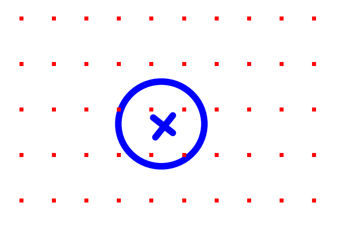
http://njc.tl/m1

5 Which diagram shows the magnetic field (red) around a current carrying wire (blue)?

A 

B 

C 

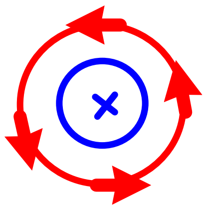
D 

Answer

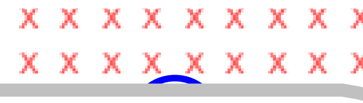
http://njc.tl/m2

5 Which diagram shows the magnetic field (red) around a current carrying wire (blue)?

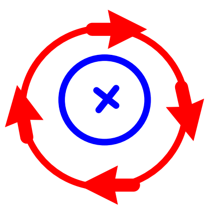
A



B



C



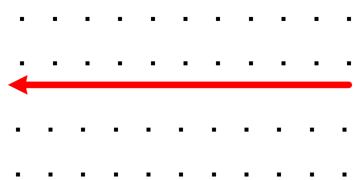
Answer

C

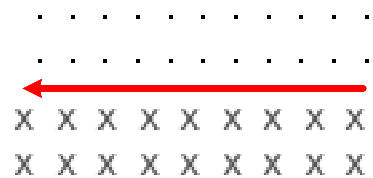

http://njc.tl/m2

6 Which diagram shows the magnetic field (black) around a current carrying wire (red)?

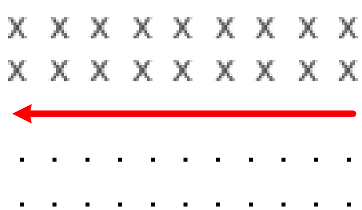
A



B



C

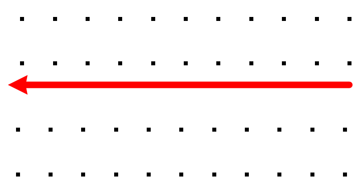


D

Answer

6 Which diagram shows the magnetic field (black) around a current carrying wire (red)?

A



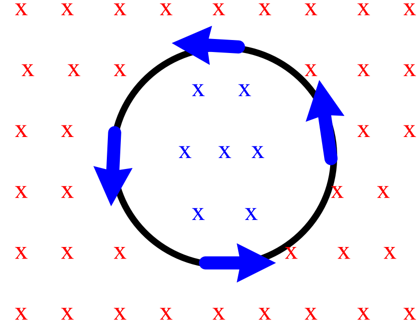
C

Answer

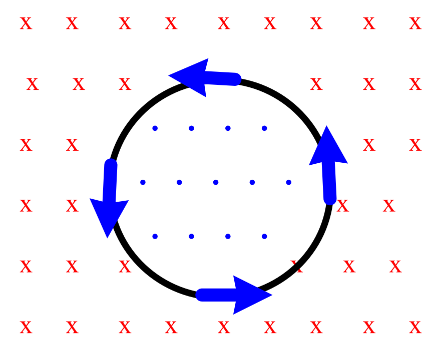
C

7 Which diagram shows the magnetic field inside and outside a current carrying loop of wire?

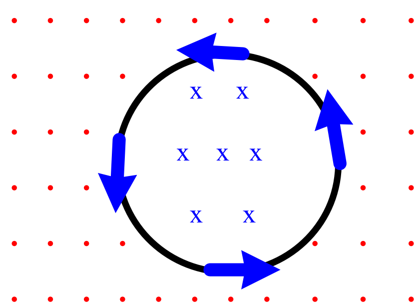
A



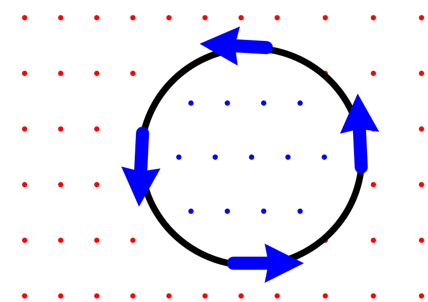
B



C



D

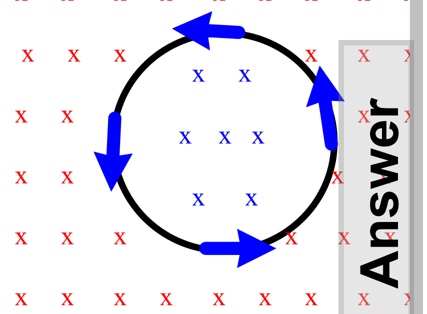


Answer

http://njc.tl/m3

7 Which diagram shows the magnetic field inside and outside a current carrying loop of wire?

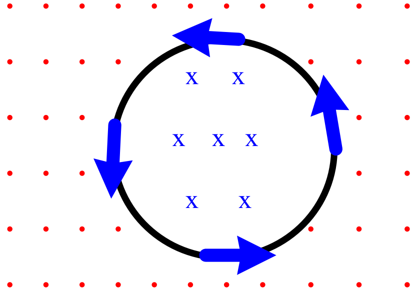
A

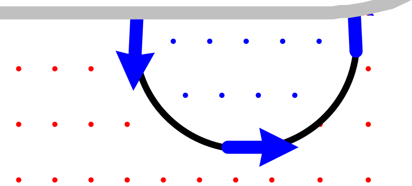


Answer

B

C

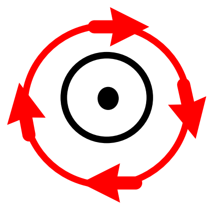




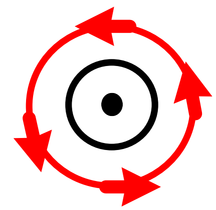
http://njc.tl/m3

8 Which diagram shows the magnetic field around a current carrying wire?

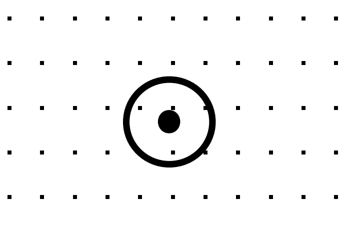
A



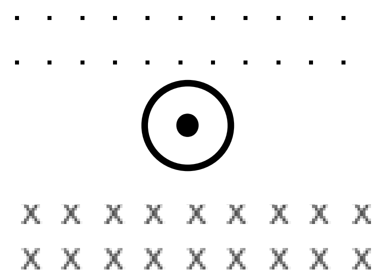
B



C



D

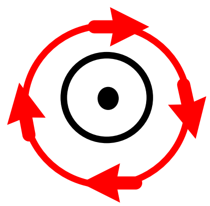


Answer

http://njc.tl/m4

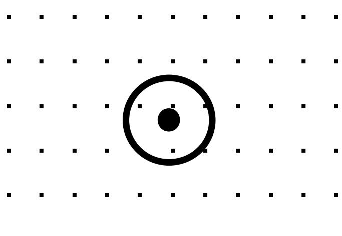
8 Which diagram shows the magnetic field around a current carrying wire?

A



B

C



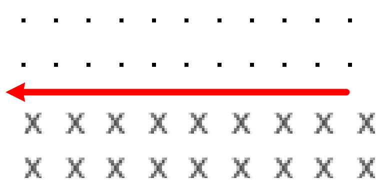
Answer

B

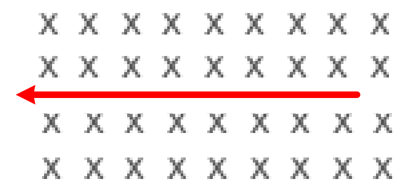
http://njc.tl/m4

9 Which diagram shows the magnetic field around a current carrying wire?

A

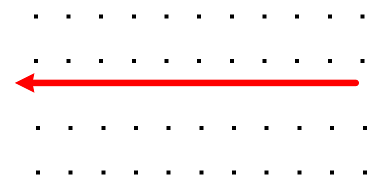


B



C

D

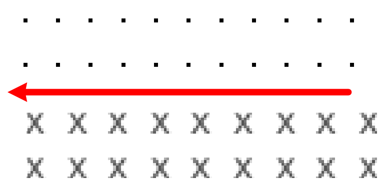


Answer

http://njc.tl/m5

9 Which diagram shows the magnetic field around a current carrying wire?

A



C

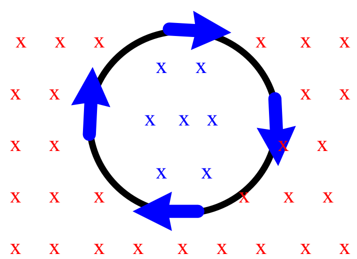
Answer

C

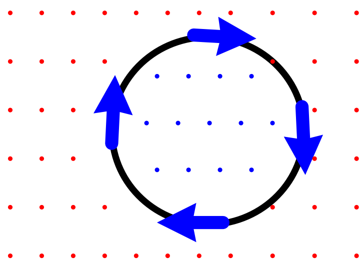
http://njc.tl/m5

10 Which diagram shows the magnetic field inside and outside a current carrying loop of wire?

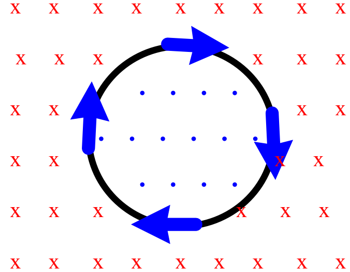
A



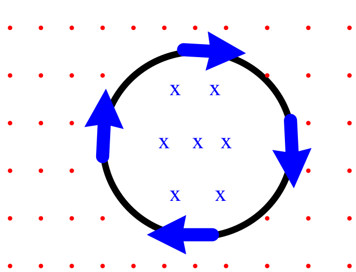
B



C



D

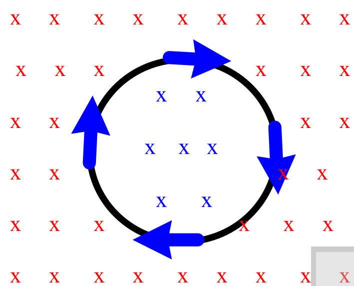


Answer

http://njc.tl/m6

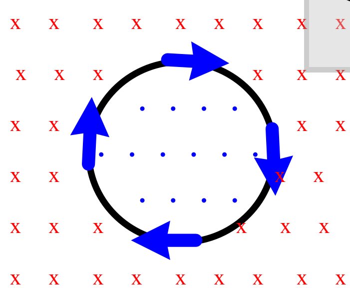
10 Which diagram shows the magnetic field inside and outside a current carrying loop of wire?

A



B

C



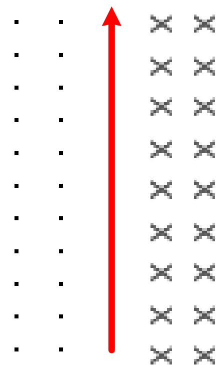
Answer

D

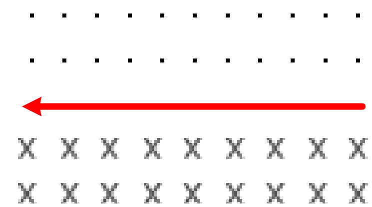
http://njc.tl/m6

11 Which diagram shows the magnetic field around a current carrying wire?

A

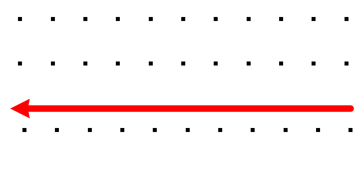


B



C

D

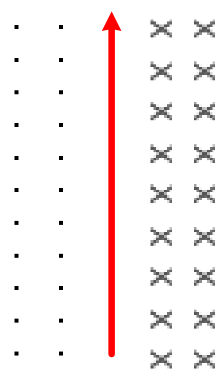


Answer

http://njc.tl/m7

11 Which diagram shows the magnetic field around a current carrying wire?

A



Answer

A

C

http://njc.tl/m7

Magnetic Field force on a moving Electric Charge

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http://njc.tl/m8

Magnetic Field force on a moving Electric Charge

Not only do magnetic poles exert a force on each other, but a magnetic field will exert a force on a moving charge. If the charge is not moving - it does not feel the force. This is a very unique concept and phenomenon in the universe.

The force on a moving charge is related to the magnitude of its charge, velocity and strength of the magnetic field - but only the portion of the magnetic field that is perpendicular to the charge's motion. This will become clearer in AP Physics, but for now, here's the equation:

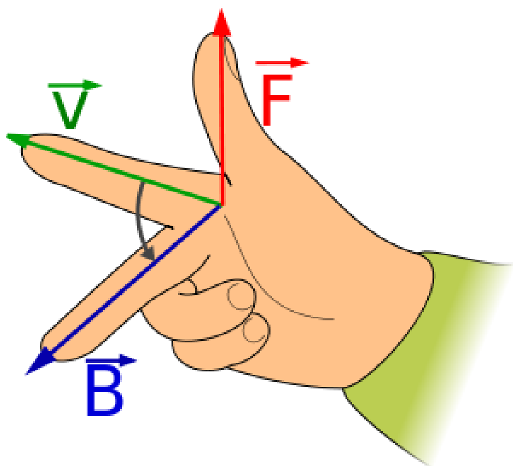
$F = qvB_{perpendicular}$

http://njc.tl/m8

Magnetic Field force on a moving Electric Charge

The direction of the force on a positive charge is perpendicular to both the direction of the charge's velocity and the magnetic field.

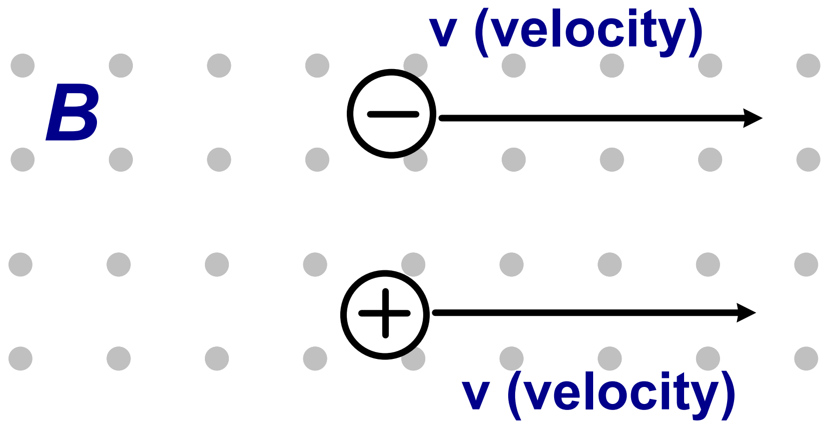
It is found by putting your forefinger (or all four fingers) in the direction of the charge's motion, then curling your fingers in the direction of the magnetic field. The thumb will point in the direction of the magnetic force.



http://njc.tl/m8

NOTE: if the velocity of the charge is in the same direction as the magnetic field - there is no force on the charge.

Force on a Moving Charge

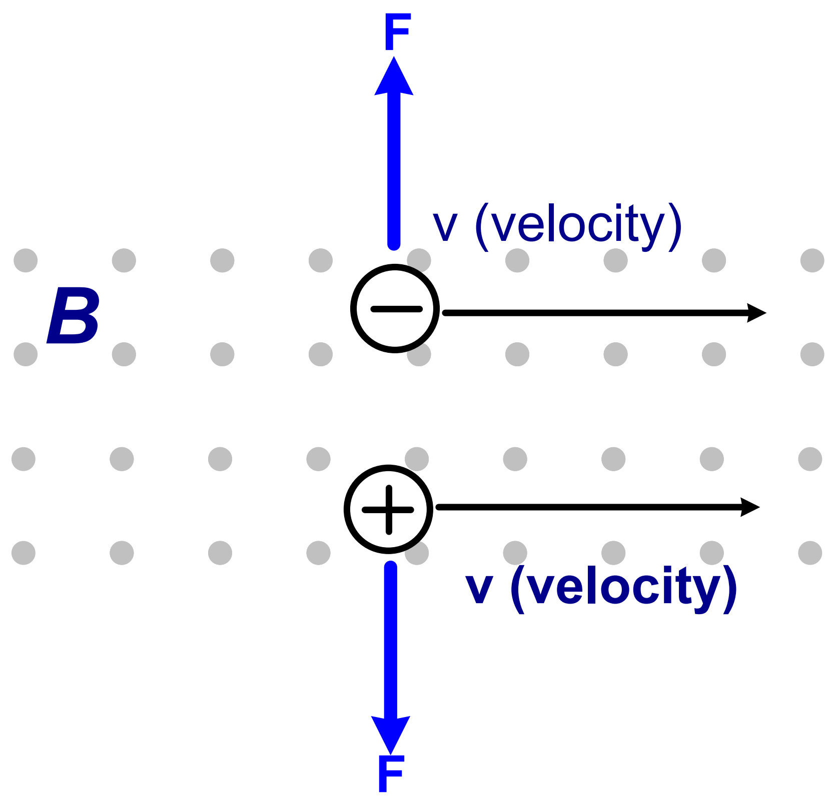


Here, we have the case of a negative charge and a positive charge moving to the right in a uniform magnetic field that is pointed out of the page.

Use the right hand rule to find the force on the positive charge. Use the same method for the negative charge, but then flip the direction of the resultant force.

http://njc.tl/m8

Force on a Moving Charge



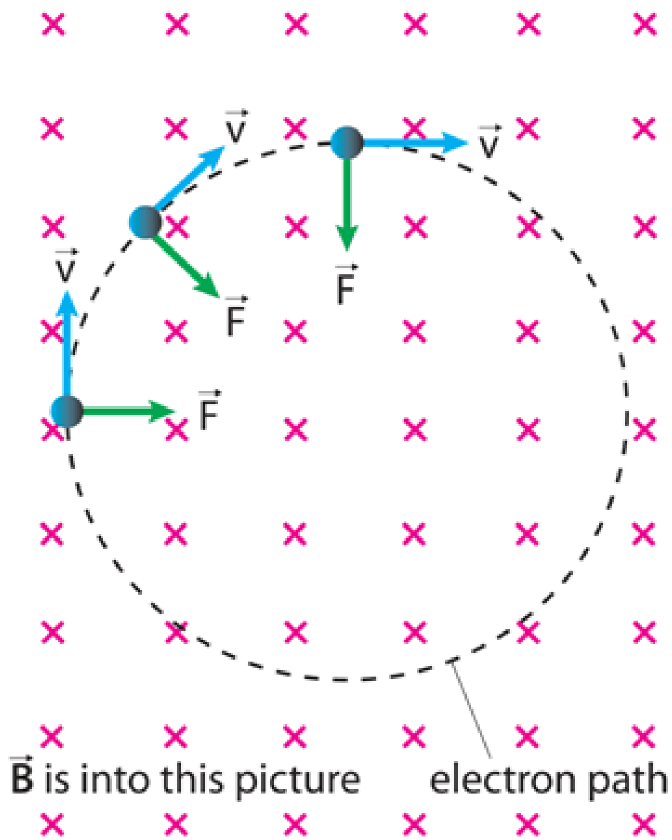
The direction of the magnetic force is opposite for negative and positive charges. Also, the magnetic force is perpendicular to both the charge's velocity and the direction of the magnetic field.

Force on Electric Charge Moving in a Magnetic Field

Since the magnetic force is perpendicular to the charge's velocity, we have a "center seeking" force, which results in centripetal motion - the charge moves in a circle.

An electron injected with velocity, v, into the magnetic field on the right will have a magnetic force directed to the right at all times (towards the middle of a circle). A positive particle will move in a counter

se path.

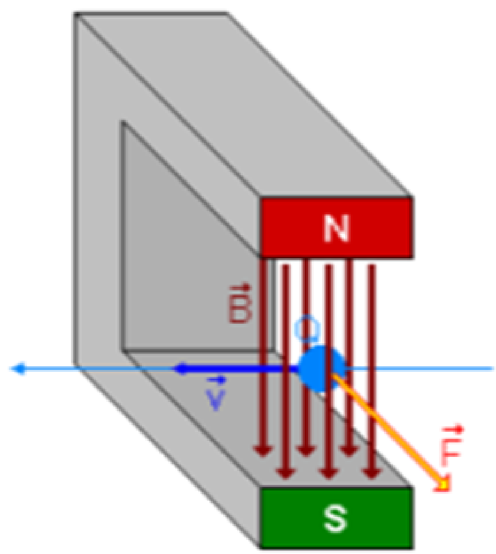


http://njc.tl/m8

Magnetic Field force on a moving Electric Charge

The horseshoe magnet to the right has a uniform magnetic field pointing from the top to the bottom.

Note that the charge is moving to the left in the first picture. Using the right hand rule, the force on the charge is out of the page.



http://njc.tl/m8

12 A proton moving at a speed of 75,000 m/s horizontally to the right enters a uniform magnetic field of 0.050 T which is directed vertically downward. Find the direction and magnitude of the magnetic force on the proton.

Answer

http://njc.tl/m9

12 A proton moving at a speed of 75,000 m/s horizontally to the right enters a uniform magnetic field of 0.050 T which is directed vertically downward. Find the direction and magnitude of th

Answer

$$F_B = qvB_{perpendicular}$$

$$= (1.6x10^{-19}C)(75,000\frac{m}{s})(0.05T)$$

$$= 6.0x10^{-6}N$$

directed into the page

http://njc.tl/m9

13 An electron experiences an upward force of 2.8×10^{-12} N when it is moving at a speed of 5.1×10^{6} m/s towards the north. What is the direction and magnitude of the magnetic field?

Answer

13 An electron experiences an upward force of 2.8x10^{-12} N when it is moving at a speed of 5.1x10^{6} m/s towards the north. What is the direction and magnitude of the magnetic field?

Answer

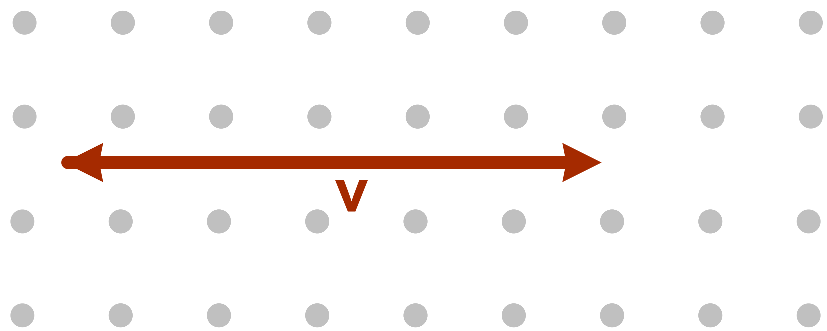
$$F_B = qvB_{perpendicular}$$

$$B_{perpendicular} = \frac{F_B}{qv}$$

$$B_{perpendicular} = \frac{2.8 \times 10^{-12} N}{(1.6 \times 10^{-19} C)(5.1 \times 10^{6}\ m/s)}$$

$$B = 3.43\ T\ directed\ toward\ the\ east$$

14 What is the direction of the force on a proton moving to the right, with speed v, as shown below?

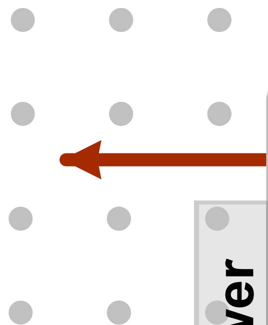


- A $\rightarrow$
- B $\uparrow$
- C $\odot$
- D $\downarrow$
- E zero

Answer

http://njc.tl/mb

14 What is the direction of the force on a proton moving to the right, with speed v, as shown below?

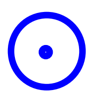


Answer

D

A 

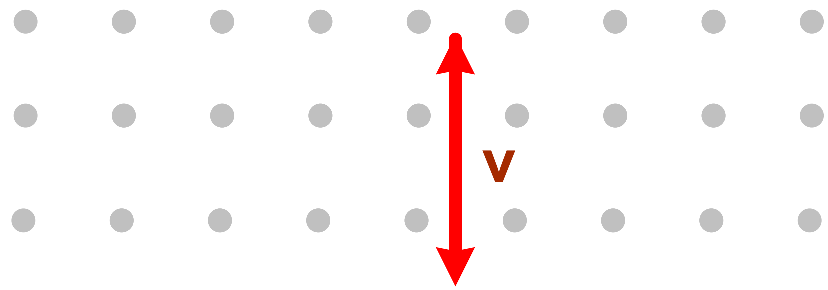
B 

C 

http://njc.tl/mb

15 What is the direction of the magnetic force on the proton below?

- A →
- B ↑
- C ↓
- D ←
- E ⊙
- F Zero

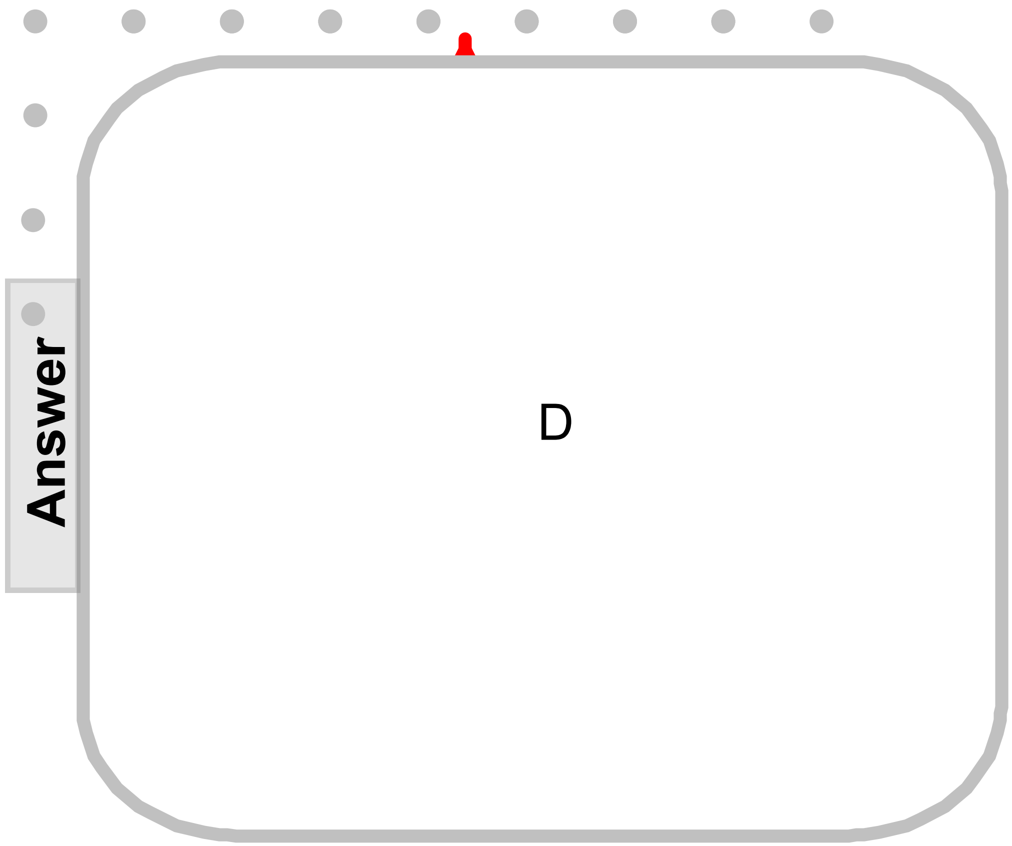


Answer

http://njc.tl/mc

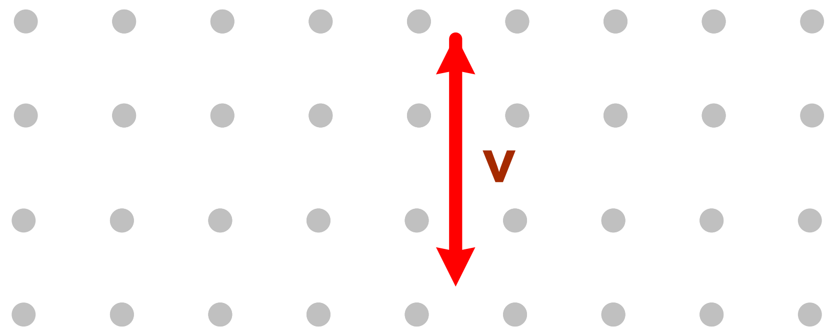
15 What is the direction of the magnetic force on the proton below?

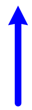
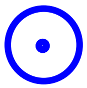
- A
- B
- C
- D
- E
- F Zero



http://njc.tl/mc

16 What is the direction of the magnetic force on the electron below?



- A 
- B 
- C 
- D 
- E 
- F Zero

Answer

16 What is the direction of the magnetic force on the electron below?

- A $\rightarrow$
- B $\uparrow$
- C $\downarrow$
- D $\leftarrow$
- E $\odot$
- F Zero

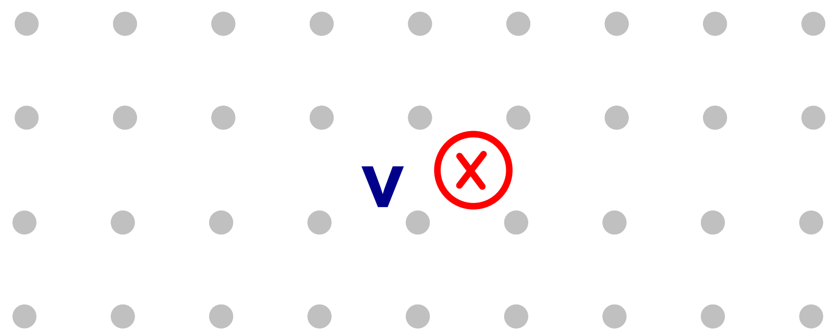
http://njc.tl/md

Answer

A

17 What is the direction of the magnetic force on the electron below?

- A →
- B ↑
- C ↓
- D ←
- E ⊙
- F ⊗
- G Zero



Answer

http://njc.tl/me

17 What is the direction of the magnetic force on the electron below?

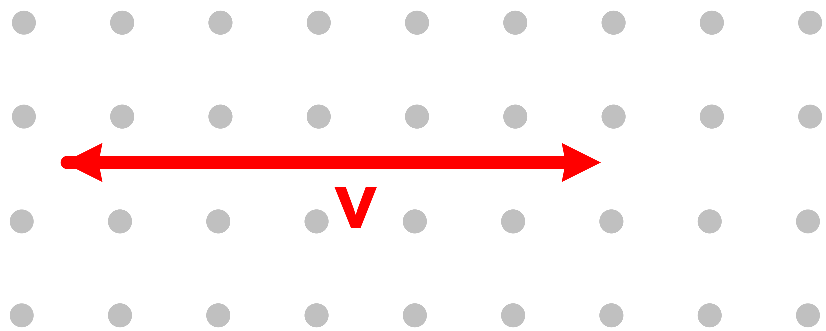
- A →
- B ↑
- C ↓
- D ←
- E ⊙
- F ⊗
- G Zero

Answer

G

18 What is the direction of the magnetic force on the electron below?

- A →
- B ↑
- C ↓
- D ←
- E ⊙
- F ⊗
- G Zero



Answer

http://njc.tl/mf

18 What is the direction of the magnetic force on the electron below?

- A →
- B ↑
- C ↓
- D ←
- E ⊙
- F ⊗
- G Zero

Answer

B

http://njc.tl/mf

19 What is the direction of the magnetic force on the proton below?

A

B

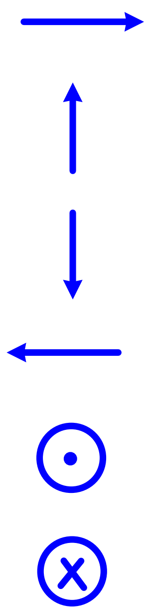
C

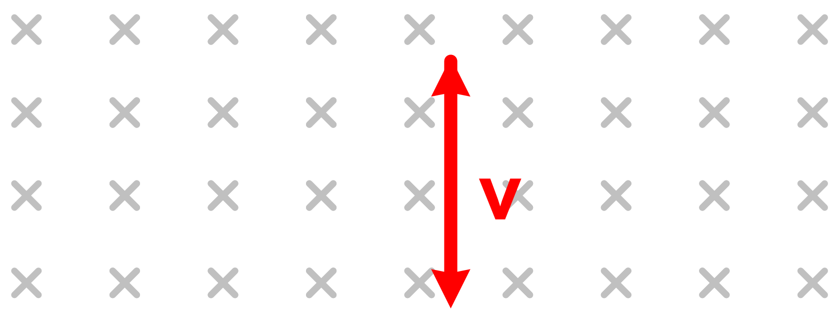
D

E

F

G Zero





Answer

http://njc.tl/mg

19 What is the direction of the magnetic force on the proton below?

- A $\rightarrow$
- B $\uparrow$
- C $\downarrow$
- D $\leftarrow$
- E $\odot$
- F $\otimes$
- G Zero

Answer

A

Magnetic Field force on a current carrying wire

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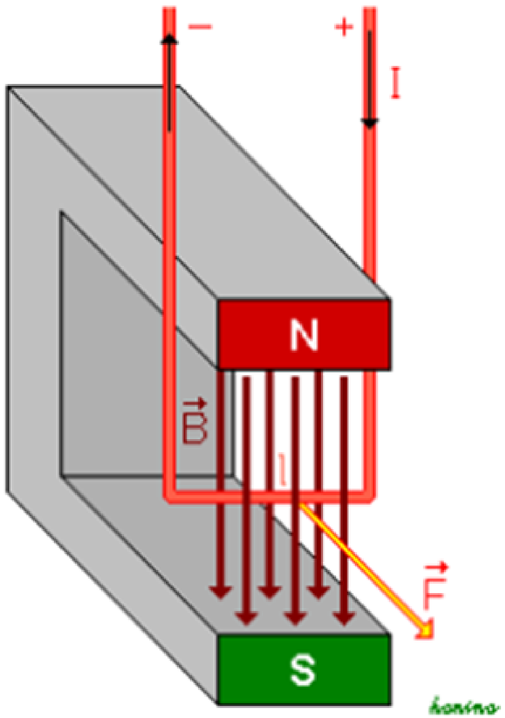
Magnetic Field Force on a current carrying wire

A magnet exerts a force on a current-carrying wire (this was shown earlier when we were considering the force on a charge - a current is just the movement of charges), so you might expect this force.



Magnetic Field Force on a current carrying wire

The direction is given by the right hand rule again - but, this time, place your fingers in the direction of the conventional current, then curl them into the magnetic field. Your thumb will point in the direction of the force.

This is a little different from when we found the magnetic field around a current carrying wire - in that case, your thumb was in the direction of the current, and your curling fingers described the magnetic field direction.

Magnetic Field Force on a current carrying wire

The force on the wire depends on the current,the length of the wire, the magnetic field, and its orientation.

$$F = ILB_{perpendicular}$$

I is the current
L is the length of wire
B is the magnetic field (perpendicular to both the force and current)

20 A 0.5 m long wire carries a current of 2.0 A in a direction perpendicular to a 0.3 T magnetic field. What is the magnitude of the magnetic force acting on the wire?

Answer

20 A 0.5 m long wire carries a current of 2.0 A in a direction perpendicular to a 0.3 T magnetic field. What is the magnitude of the magnetic force acting on the wire?

Answer

$$F_B = ILB_{perpendicular}$$
$$= (2A)(0.5m)(0.3T)$$
$$= 0.3N$$

http://njc.tl/mi

21 A uniform magnetic field exerts a maximum force of 20 mN on a 0.25 m long wire carrying a current of 2.0 A. What is the strength of the magnetic field?

Students type their answers here
Students type their answers here
Students type their answers here
Students type their answers here

Answer

http://njc.tl/mj

21 A uniform magnetic field exerts a maximum force of 20 mN on a 0.25 m long wire carrying a current of 2.0 A. What is the strength of the magnetic field?

Students type their answers here

Answer

$$F_B = ILB_{perpendicular}$$

$$B_{\max} = B_{perpendicular} = \frac{F_B}{IL}$$

$$= \frac{(20x10^{-3}N)}{(2.0A)(0.25m)}$$

$$= 0.04T$$

22 A 0.050N force acts on a 10.0 cm wire that is perpendicular to a 0.30 T magnetic field. What is the magnitude of the electric current through the wire?

Answer

:om/ecf/ids_a/video_i

22 A 0.050N force acts on a 10.0 cm wire that is perpendicular to a 0.30 T magnetic field. What is the magnitude of the electric current through the wire?

Answer

$$F_B = ILB_{perpendicular}$$

$$I = \frac{F_B}{LB_{perp}}$$

$$= \frac{(0.050N)}{(0.100m)(0.30T)}$$

$$= 1.7A$$

com/edit?ls...o_i

23 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A
- B
- C
- D
- E
- F
- G zero

Answer

http://njc.tl/mk

23 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

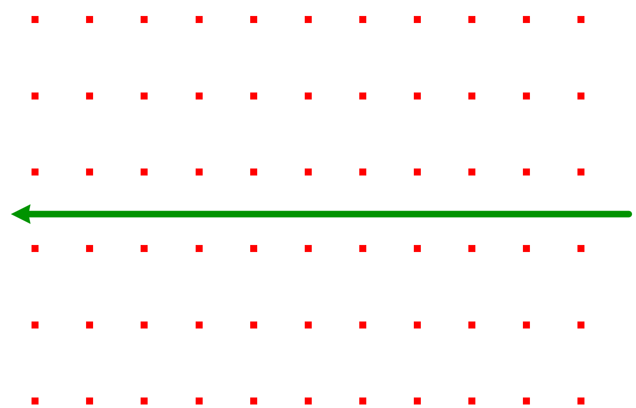
Answer

B

http://njc.tl/mk

24 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A
- B
- C
- D
- E
- F
- G zero



Answer

http://njc.tl/ml

24 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

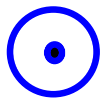
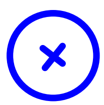
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

B

http://njc.tl/ml

25 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero

Answer

http://njc.tl/mm

25 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

A

B

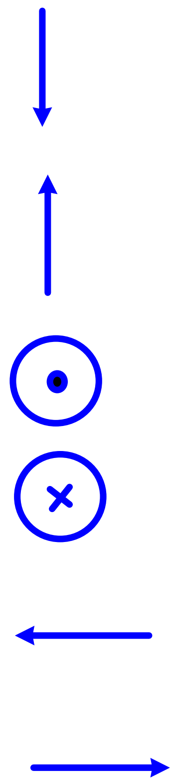
C

D

E

F

G



zero

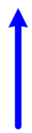
Answer

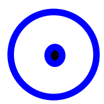
A

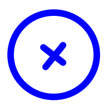
http://njc.tl/mm

26 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

A 

B 

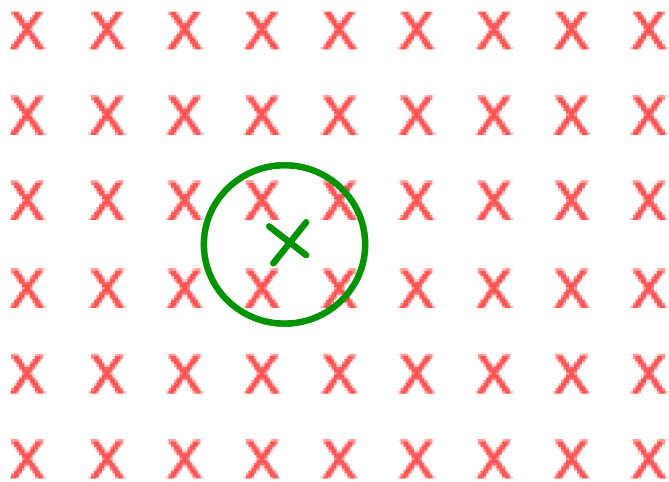
C 

D 

E 

F 

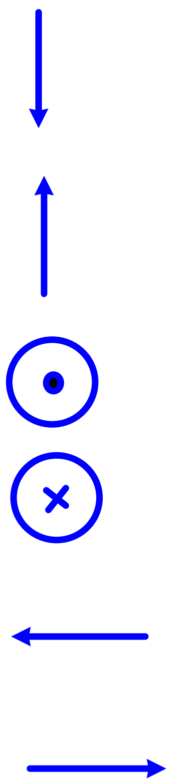
G zero



Answer

http://njc.tl/mn

26 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?



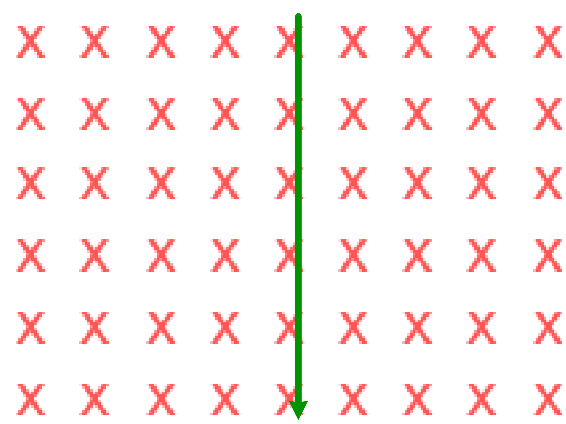
- A
- B
- C
- D
- E
- F
- G zero

Answer

G

27 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero



Answer

http://njc.tl/mo

27 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

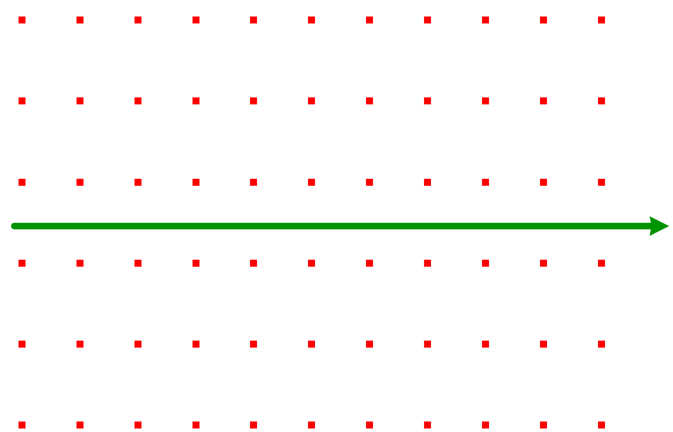
Answer

F

http://njc.tl/mo

28 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero



Answer

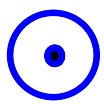
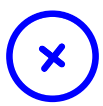
28 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

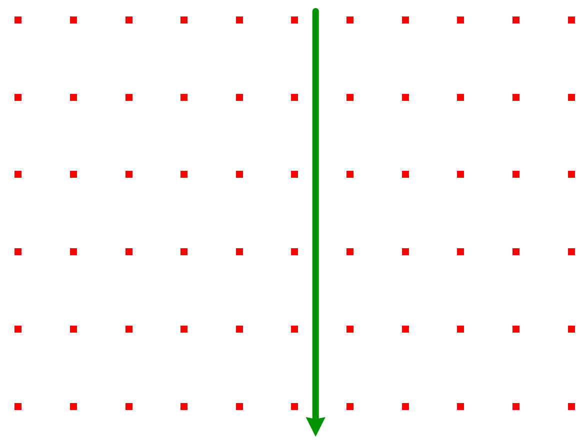
- A
- B
- C
- D
- E
- F
- G zero

Answer

A

29 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

29 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

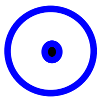
Answer

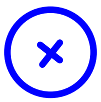
E

30 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

A 

B 

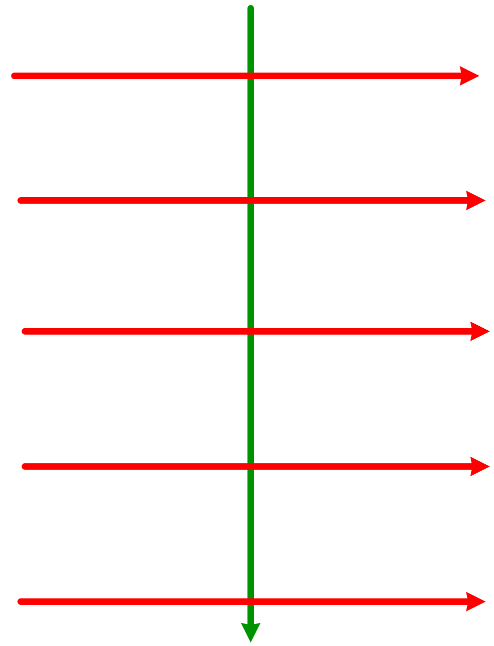
C 

D 

E 

F 

G zero



Answer

30 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

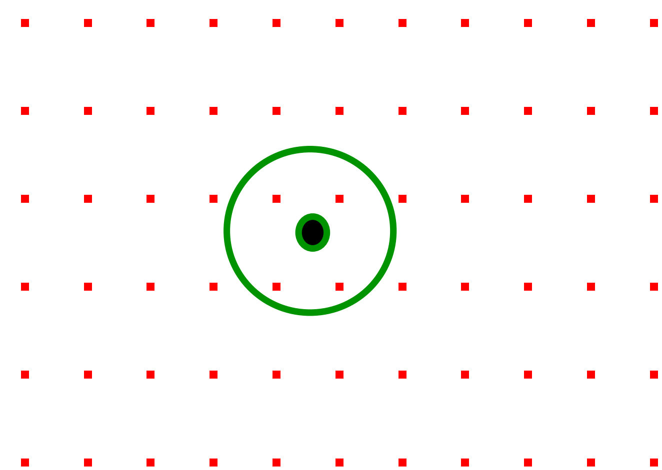
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

C

31 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero



Answer

31 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

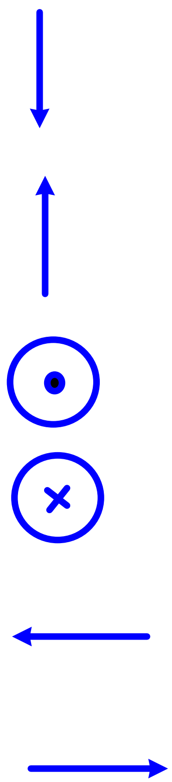
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

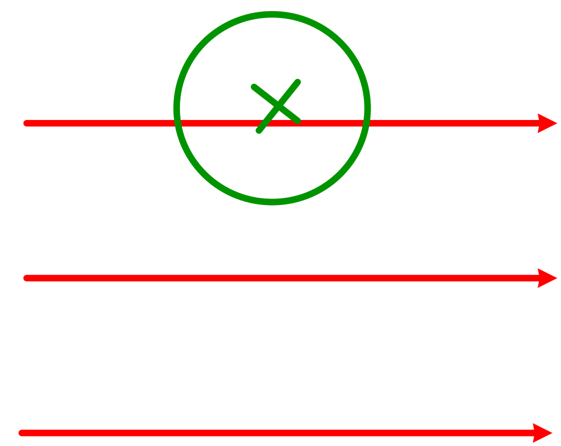
Answer

G

32 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A
- B
- C
- D
- E
- F
- G zero





Answer

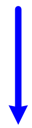
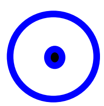
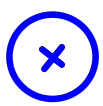
32 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

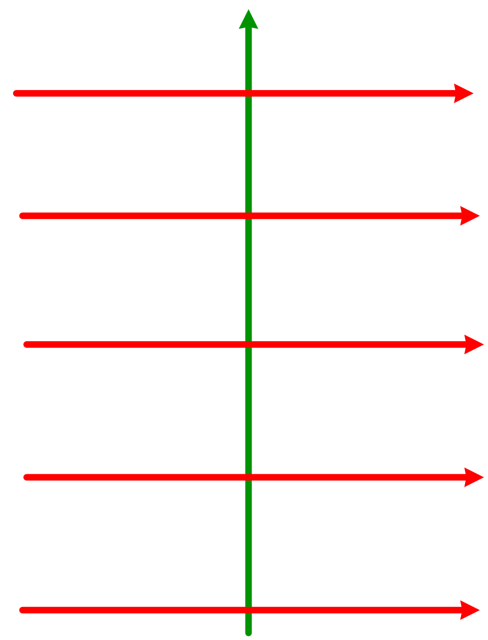
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

A

33 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

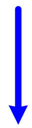
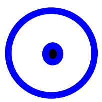
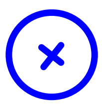
33 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

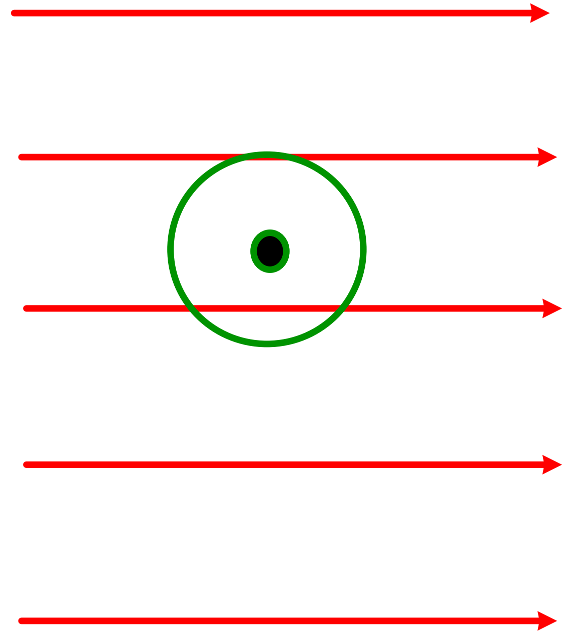
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

D

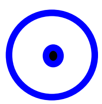
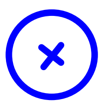
34 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

34 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

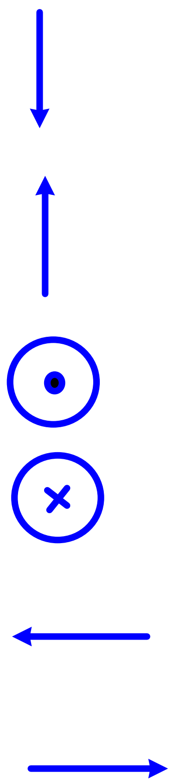
- A 
- B 
- C 
- D 
- E 
- F 
- G zero

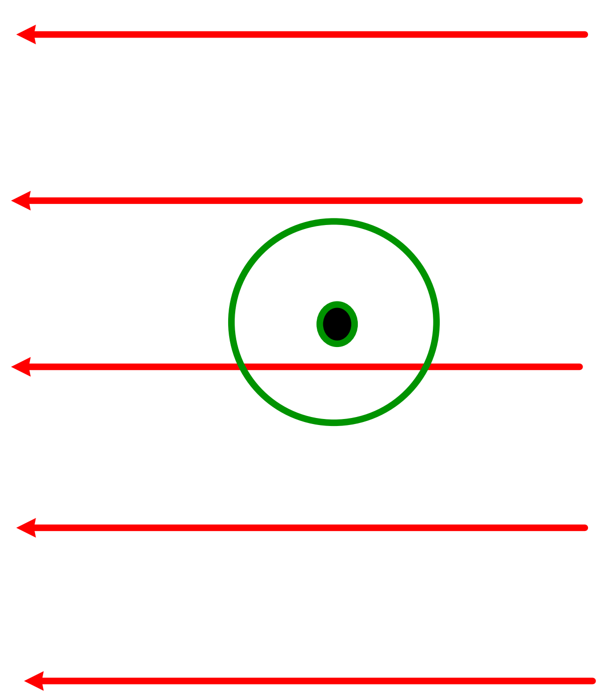
Answer

B

35 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A
- B
- C
- D
- E
- F
- G zero





Answer

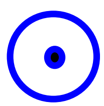
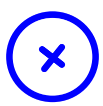
35 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

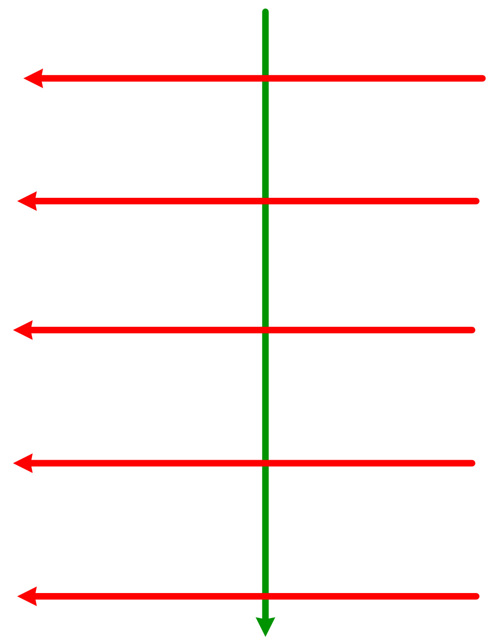
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

E

36 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

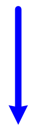
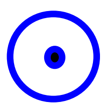
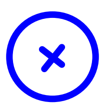
36 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

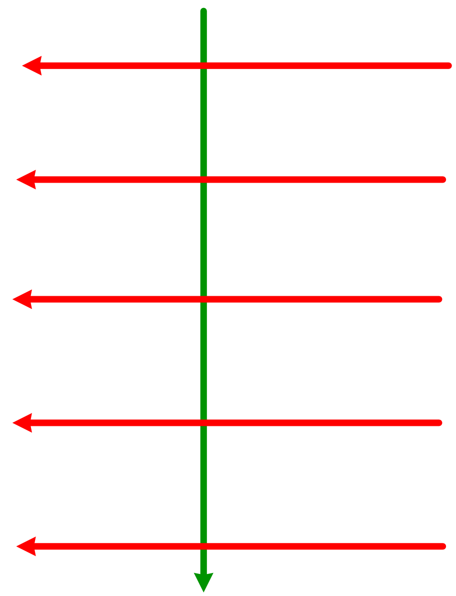
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

D

37 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

37 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

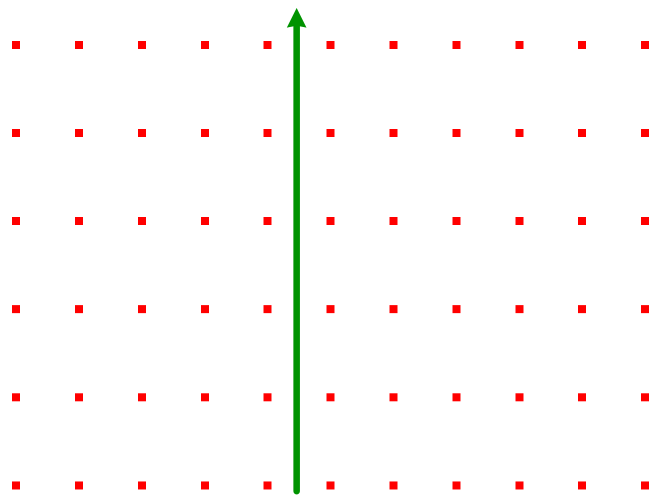
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

G

38 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero



Answer

38 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

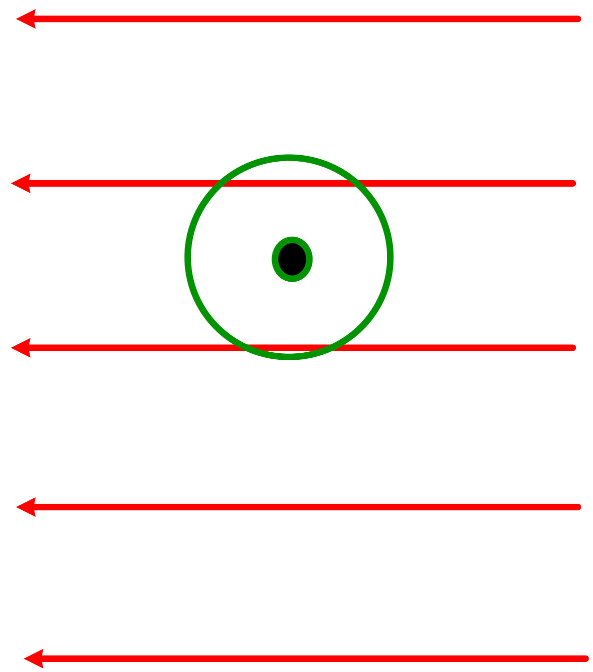
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

F

39 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero



Answer

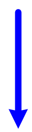
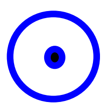
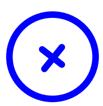
39 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

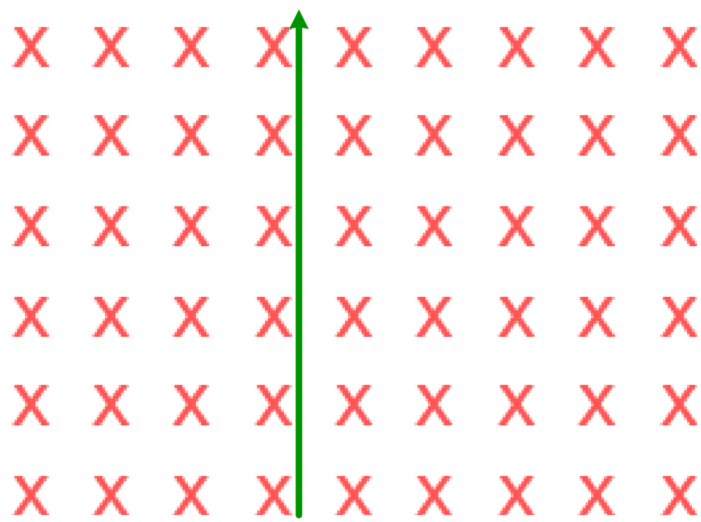
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

F

40 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

40 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

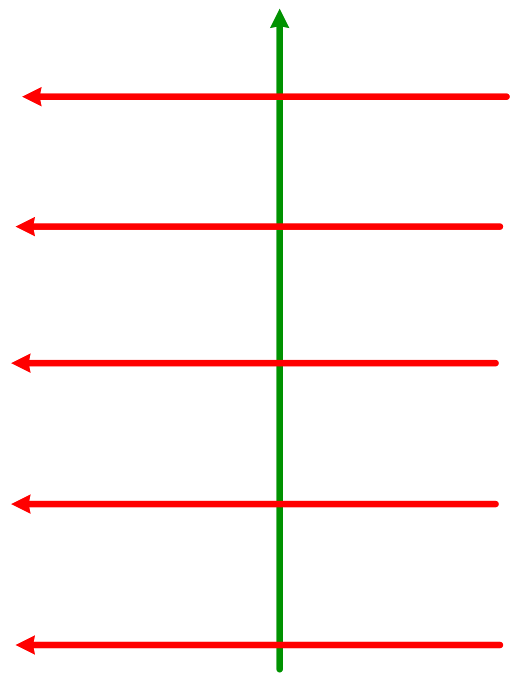
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

E

41 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero



Answer

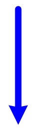
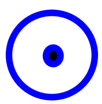
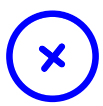
41 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

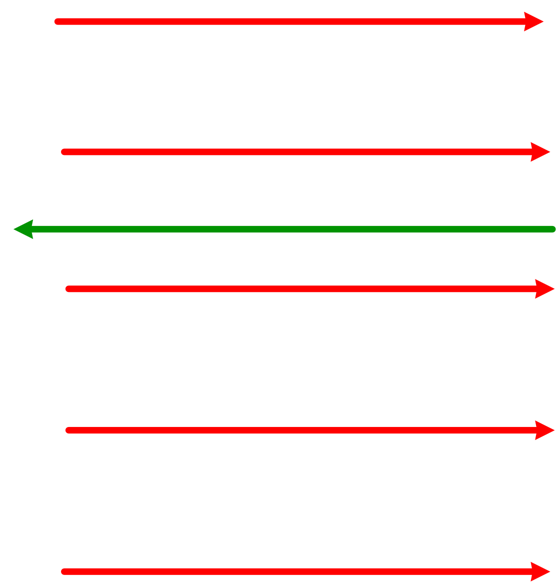
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

C

42 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

42 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

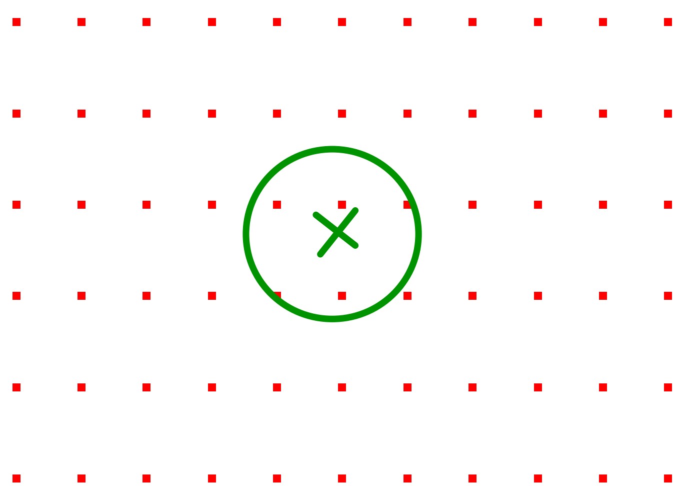
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

G

43 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero



Answer

43 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

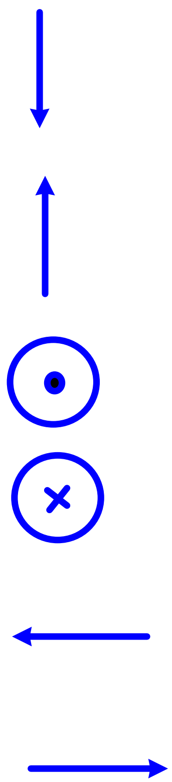
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

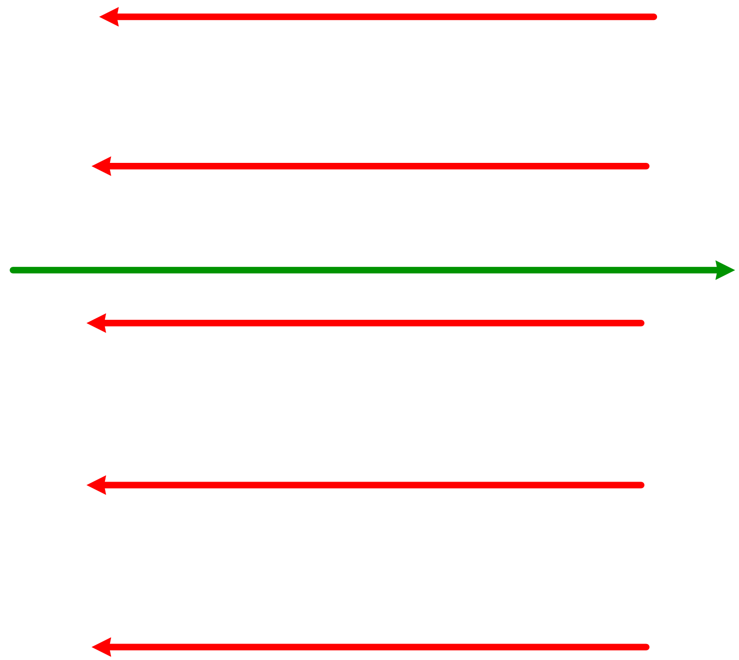
Answer

G

44 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A
- B
- C
- D
- E
- F
- G zero

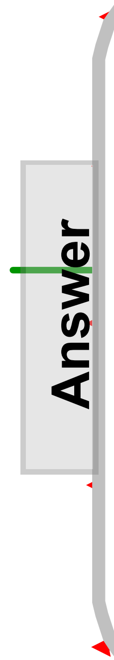




Answer

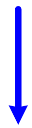
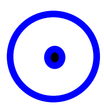
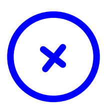
44 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

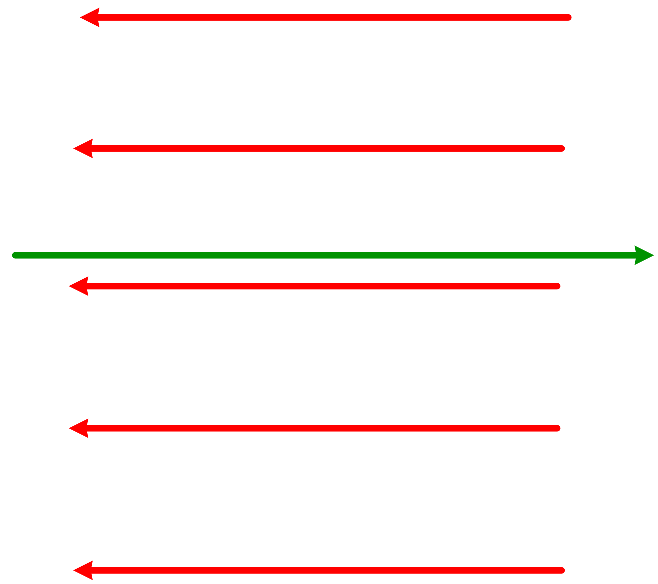
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero



C

45 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

45 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

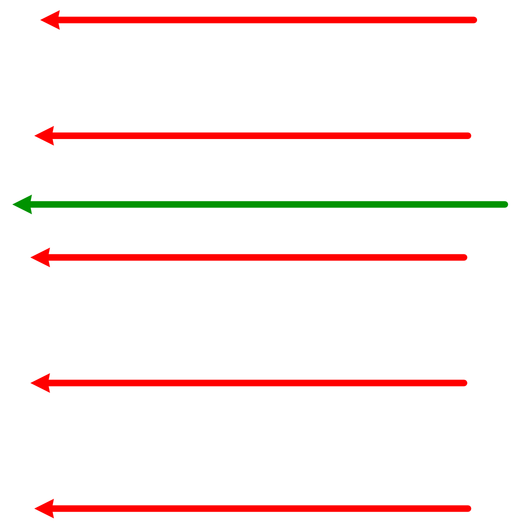
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

D

46 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero



Answer

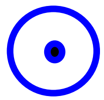
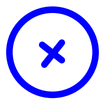
46 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

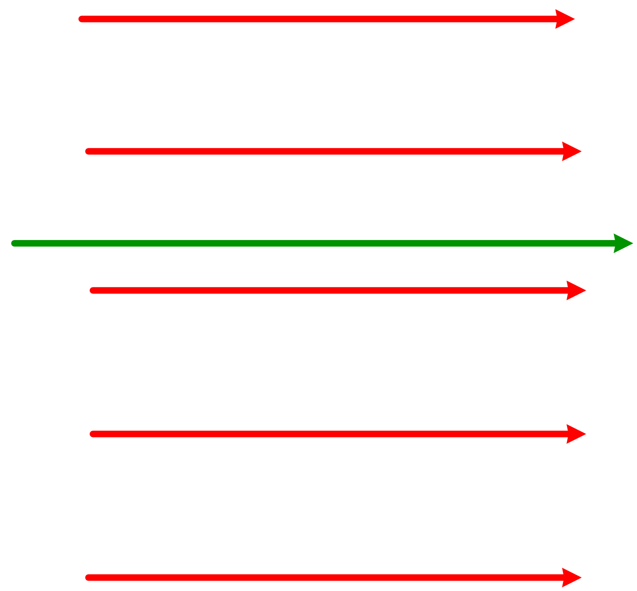
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

G

47 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

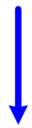
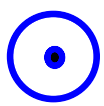
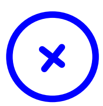
47 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

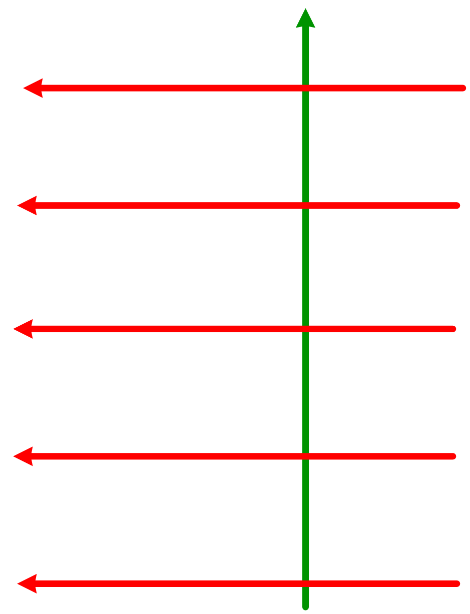
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

G

48 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

48 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

G

49 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

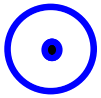
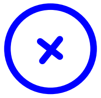
49 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

D

50 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero

Answer

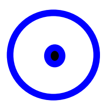
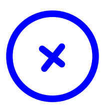
50 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

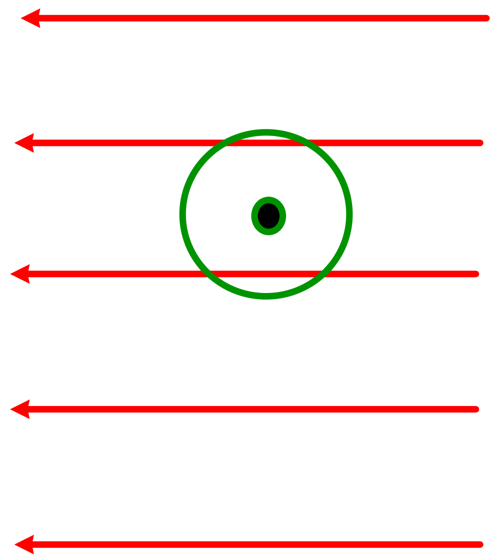
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

C

51 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

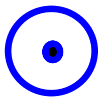
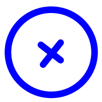
51 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

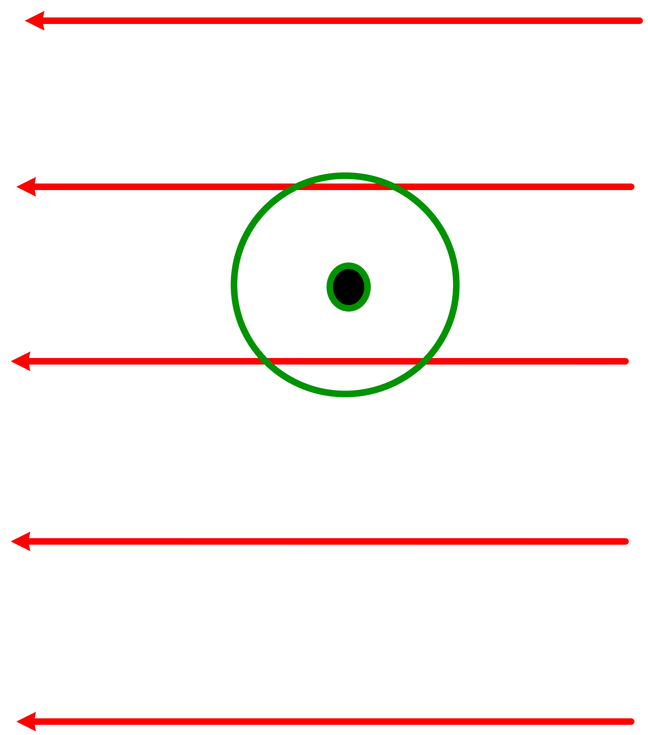
- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero

Answer

A

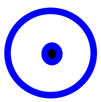
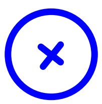
52 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

52 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

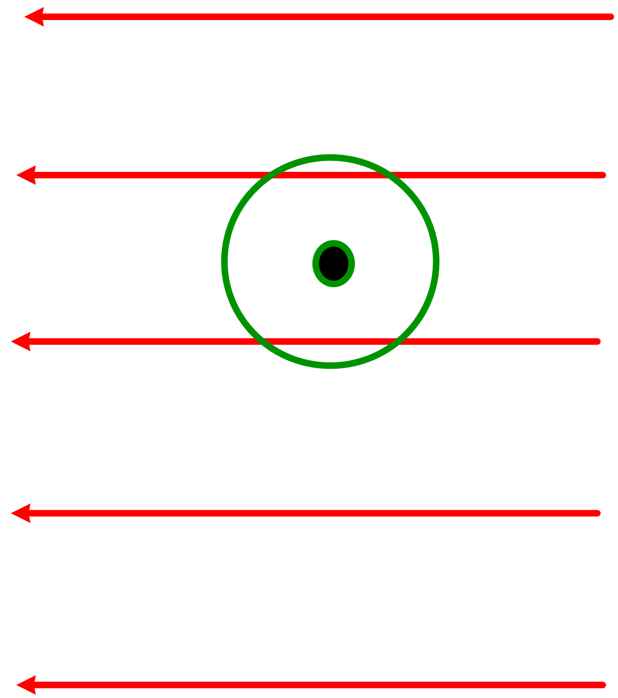
- A 
- B 
- C 
- D 
- E 
- F 
- G zero

Answer

E

53 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A
- B
- C
- D
- E
- F
- G zero



Answer

53 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

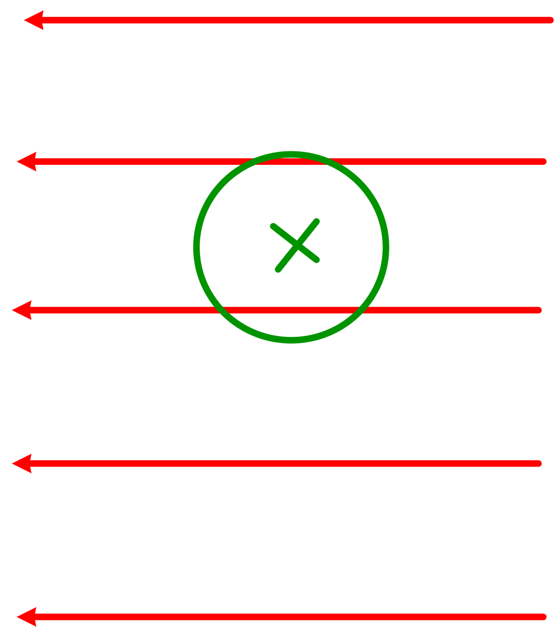
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

F

54 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A $\downarrow$
- B $\uparrow$
- C $\odot$
- D $\otimes$
- E $\leftarrow$
- F $\rightarrow$
- G zero



Answer

54 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

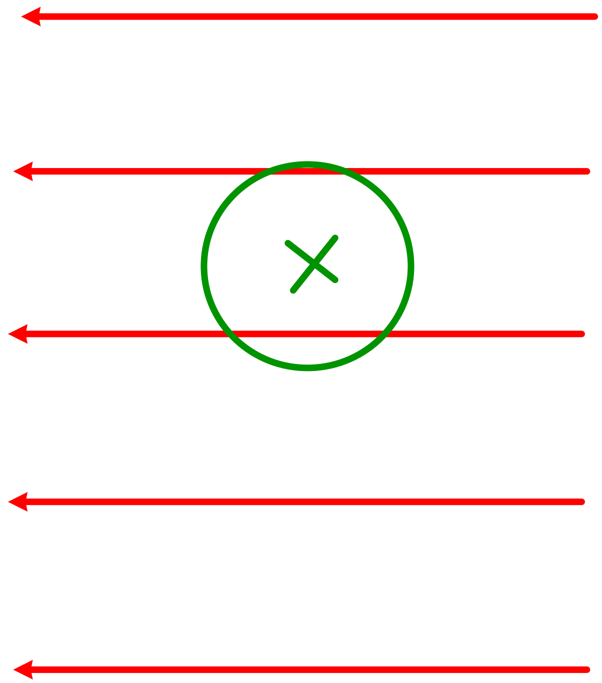
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

B

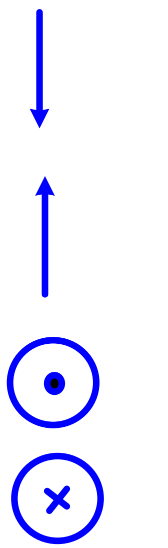
55 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

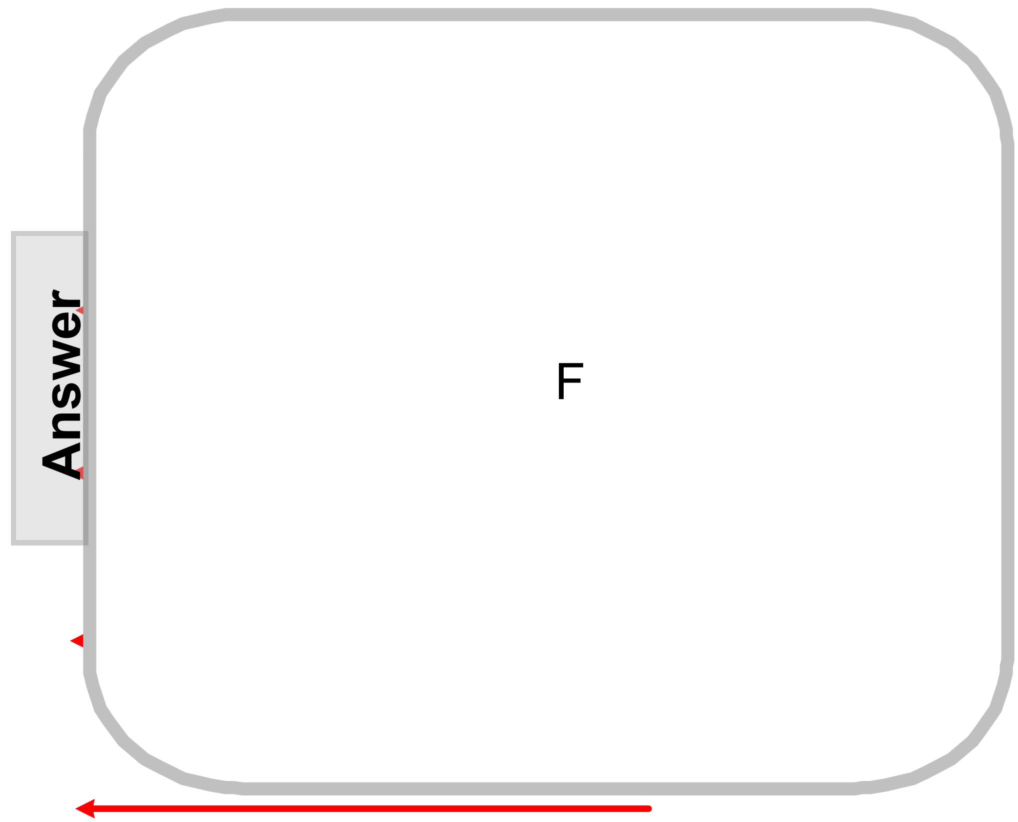


Answer

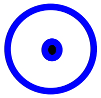
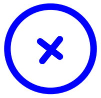
55 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

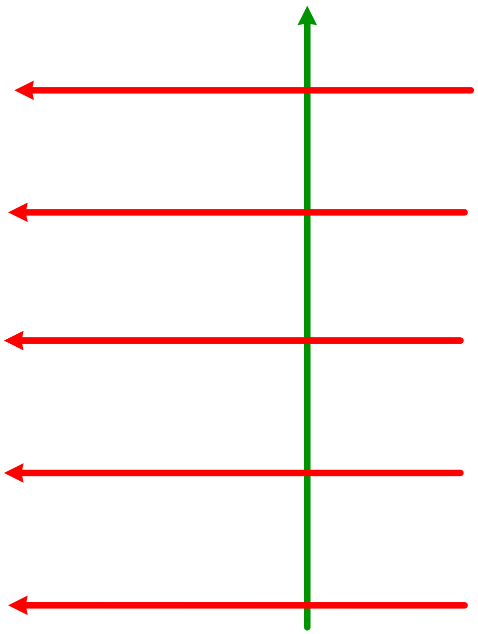


- A
- B
- C
- D
- E
- F
- G zero



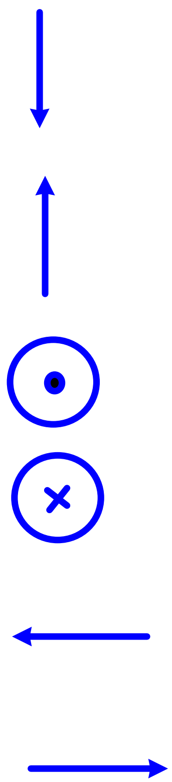
56 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A 
- B 
- C 
- D 
- E 
- F 
- G zero



Answer

56 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?



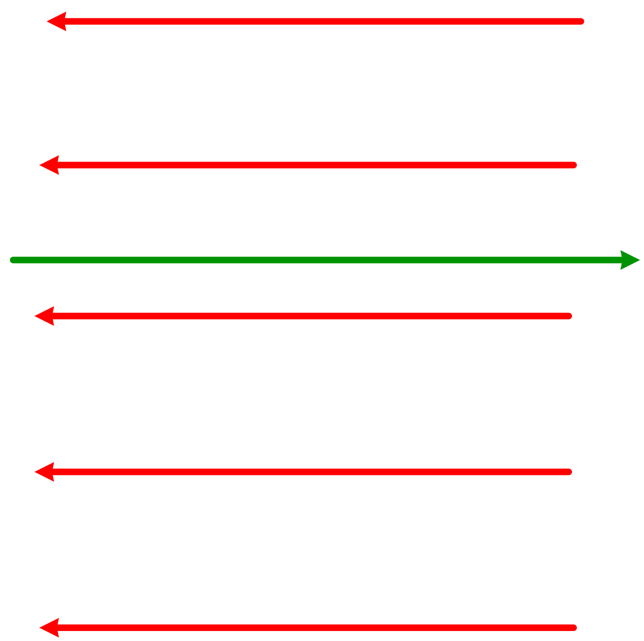
- A
- B
- C
- D
- E
- F
- G zero

Answer

G

57 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A
- B
- C
- D
- E
- F
- G zero



Answer

57 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

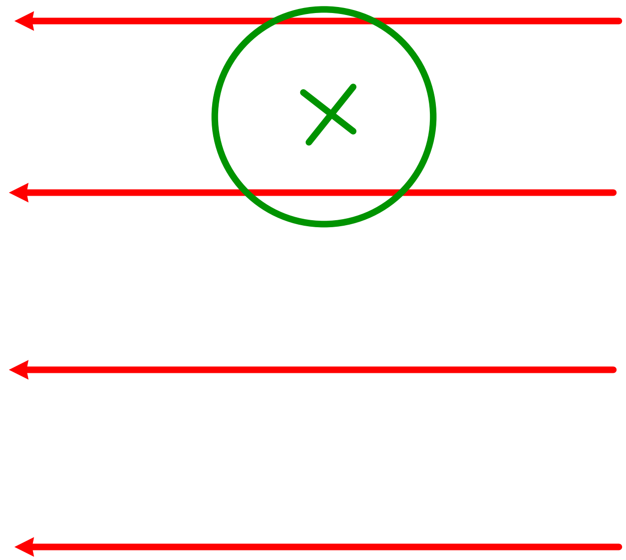
- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

G

58 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A
- B
- C
- D
- E
- F
- G zero



Answer

58 What is the direction of the magnetic force on the current carrying wire (green) in the magnetic field (red)?

- A ↓
- B ↑
- C ⊙
- D ⊗
- E ←
- F →
- G zero

Answer

E

Magnetic Field due to a long straight current carrying wire

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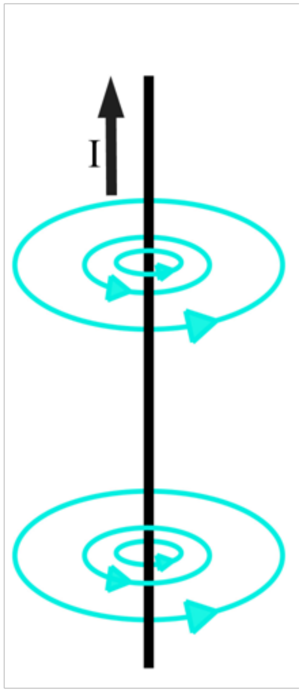
Magnetic Field Due to a Long Straight Wire

It was determined experimentally by Oersted, Ampere and others that the magnetic field decreases as the distance, r, away from the wire. The Biot-Savart Law and Ampere's Law (which will be done in AP Physics) both calculate this value:



$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

The constant μ_0 is called the permeability of free space, and has the value:

$$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T\cdot m/A}$$

The constant μ_0 is the magnetic equivalent of the electrical constant , ε_0 , which is the permittivity of free space.

http://njc.tl/mp

59 What is the magnetic field at a point 0.50 m away from a wire carrying 40.0 A of current?

Answer

http://njc.tl/mq

59 What is the magnetic field at a point 0.50 m away from a wire carrying 40.0 A of current?

Answer

$$B = \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{(4\pi x10^{-7} NA^{-2})(40.0A)}{2\pi(0.5m)}$$

$$= 1.6x10^{-5} T$$

60 A long straight wire carries a current of 12 A towards the west (left). What is the direction and magnitude of the magnetic field 10.0 cm to the south (below) the wire?

Answer

http://njc.tl/mr

60 A long straight wire carries a current of 12 A towards the west (left). What is the direction and magnitude of the magnetic field 10.0 cm to the south (below) the wire?

Answer

$$B = \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{(4\pi x10^{-7} NA^{-2})(12.0A)}{2\pi(0.1m)}$$

$$= 2.4x10^{-5} T$$

directed out of the page

61 A straight wire with a current of 50 A is oriented vertically. What is the magnitude of the magnetic field at a point 2 m away from the wire?

Answer

61 A straight wire with a current of 50 A is oriented vertically. What is the magnitude of the magnetic field at a point 2 m away from the wire?

Answer

$$B = \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{(4\pi x10^{-7} NA^{-2})(50.0A)}{2\pi(2m)}$$

$$= 5x10^{-6} T$$

http://njc.tl/ms

62 A long straight wire carries a current of 30.0 A towards the west (left). What is the direction and magnitude of the magnetic field 5.0 m to the north (above) the wire?

Answer

http://njc.tl/mt

62 A long straight wire carries a current of 30.0 A towards the west (left). What is the direction and magnitude of the magnetic field 5.0 … ire?

Answer

$$B = \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{(4\pi x10^{-7}\,NA^{-2})(30.0A)}{2\pi(5.0m)}$$

$$= 1.2x10^{-6}T$$

into the page

http://njc.tl/mt

Magnetic Field force between two current carrying wires

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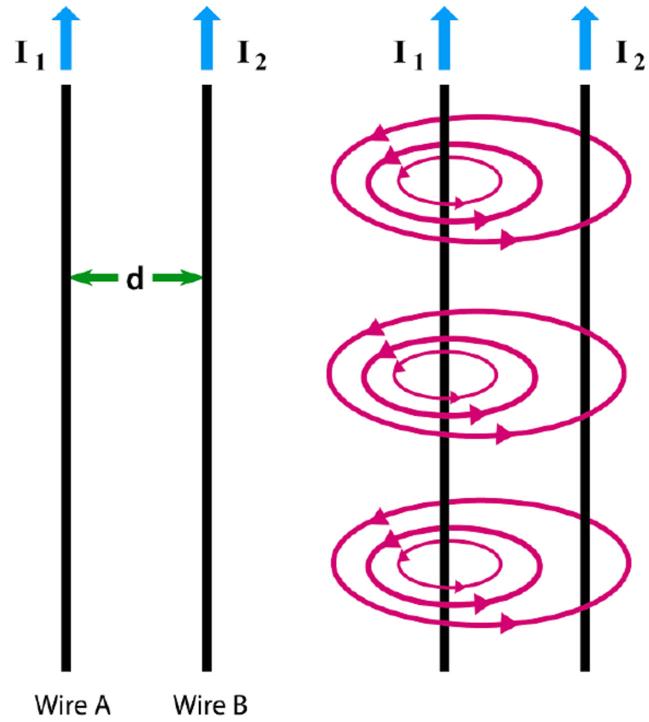
Force between Two Parallel Wires

Set up two current carrying wires, each of length L, next to each other. Each wire will create a magnetic field that will exert a force on the other wire. Let's look at the force on Wire B due to Wire A.

Since the wires are separated by a distance d, the magnetic field generated by Wire A at Wire B's position is:

$$B_1 = \frac{\mu_0}{2\pi}\frac{I_1}{d}$$



Force between Two Parallel Wires

The magnetic field due to Wire A is everywhere perpendicular to the current in Wire B, so the force on Wire B due to Wire A is:

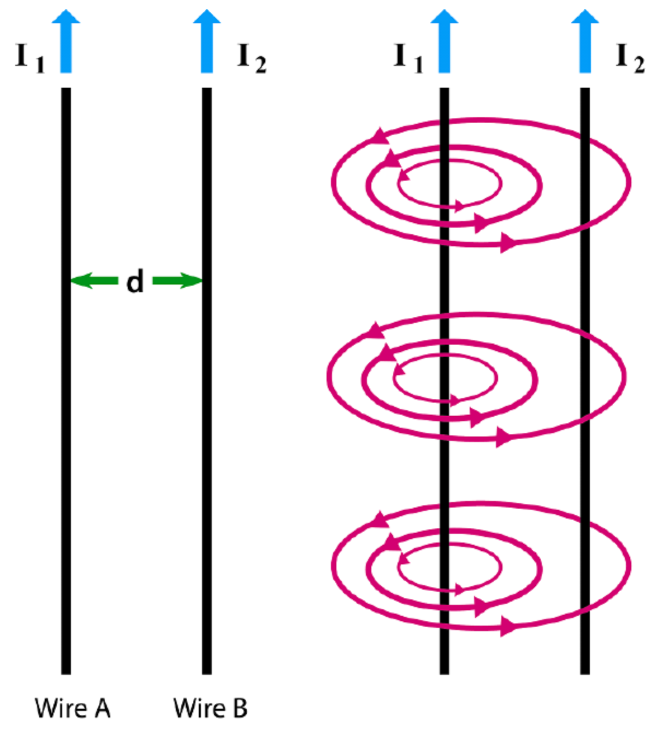
$$F_{AB} = I_2 L B_1$$

Substitue the value of B_1 found on the previous slide:

$$F_{AB} = I_2 L \frac{\mu_0 I_1}{2\pi d}$$

And rearranging:

$$F_{AB} = \frac{\mu_0 I_1 I_2}{2\pi d} L$$

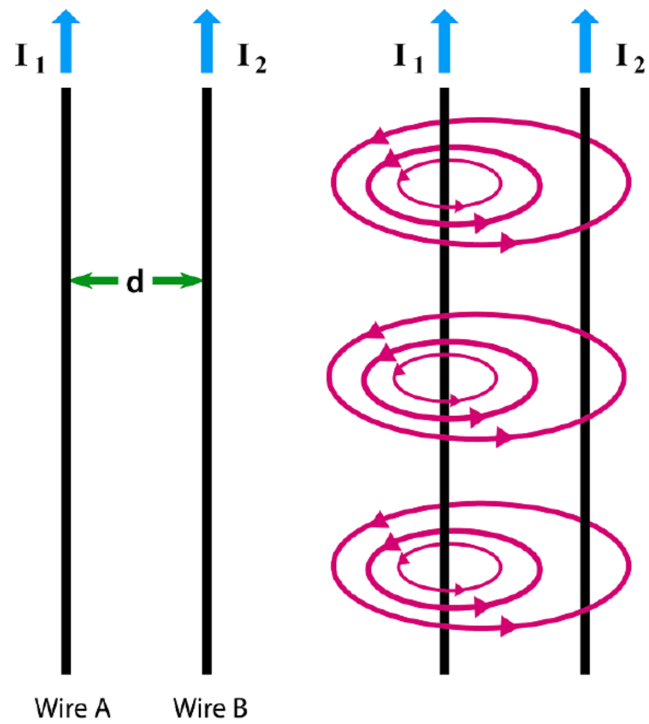


http://njc.tl/mu

Force between Two Parallel Wires

We can carry out a similar analysis for the force that wire B exerts on wire A or, we could just use Newton's Third Law (it also works on magnetic and electrical forces) to state that the magnitudes of the two forces are equal.

$$\left|F_{BA}\right| = \left|F_{AB}\right| = \frac{\mu_0 I_1 I_2}{2\pi d} L$$

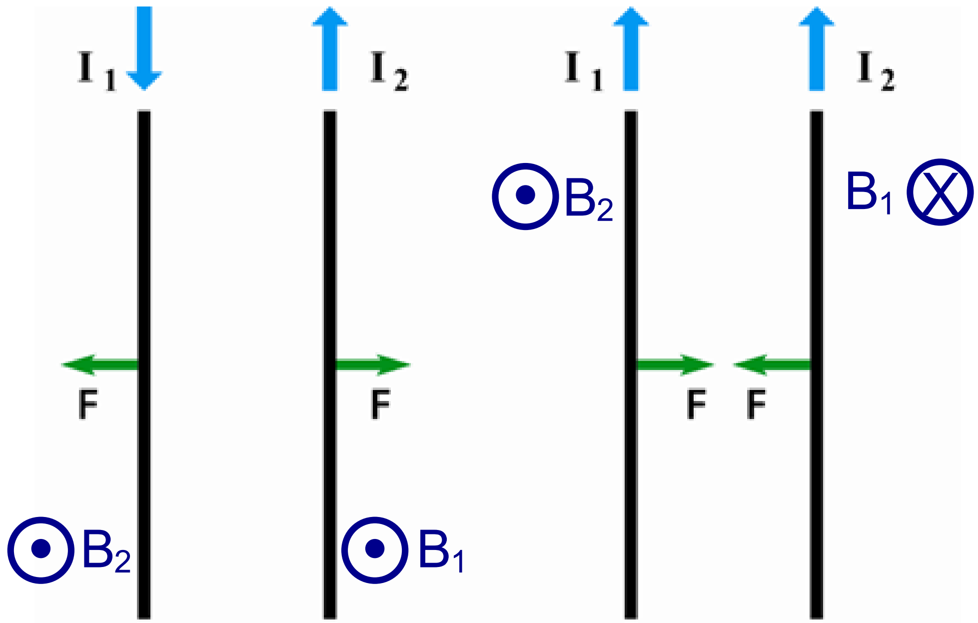


http://njc.tl/mu

Force between Two Parallel Wires

Using the right hand rule, the directions of B_1 and B_2 for both of the situations to the right are shown.

Then, the directions of the force on both wires are found by the right hand rule.



Parallel currents in the same direction attract.
Parallel currents in opposite directions (antiparallel) repel.

http://njc.tl/mu

63 What is the magnitude and direction of the magnetic ? force between two parallel wires, 5.0 m long, 2.0 cm apart, if each carries a current of 15 A in opposite directions?

Answer

http:/ / njc.tl/ mv

63 What is the magnitude and direction of the magnetic ? force between two parallel wires, 5.0 m long, 2.0 cm apart, if each carries a current of 15 A in opposite directions?

Answer

$$F = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

$$= \frac{(4\pi x 10^{-7} NA^{-2})(15A)(15A)(5m)}{2\pi(.02m)}$$

$$= 1.1N$$

the wires repel each other

64 Two parallel wires with currents flowing in opposite directions at 5.8 A and 3.2 A are separated by a distance of 12 cm. The length of the wires is 9.6m. What is the magnitude and direction of the magnetic force beween the wires?

Answer

http://njc.tl/mw

64 Two parallel wires with currents flowing in opposite directions at 5.8 A and 3.2 A are separated by a distance of 12 cm. The length of the wires is 9.6m. What is the magnitude and direction of the magnetic force beween the wires?

Answer

$$F = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

$$= \frac{(4\pi x 10^{-7} NA^{-2})(5.8A)(3.2A)(9.6m)}{2\pi(.12m)}$$

$$= 2.7x10^{-4} N$$

the wires repel each other

http://njc.tl/mw

65 What is the magnitude and direction of the magnetic field force between two parallel wires 0.50 m long and 1.0 cm apart if each carries a current of 0.25 A in the same direction?

Answer

http://njc.tl/mx

65 What is the magnitude and direction of the magnetic field force between two parallel wires 0.50 m long and 1.0 cm apart if each carries a current of 0.25 A in the same direction?

Answer

$$F = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

$$= \frac{(4\pi x10^{-7} NA^{-2})(.25A)(.25A)(0.5m)}{2\pi(.01m)}$$

$$= 6.3x10^{-7} N$$

the wires attract each other

http://njc.tl/mx

*Mass Spectrometer

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of Contents

*Mass Spectrometer

Now that electric and magnetic fields have both been presented, it is time to show an application that uses both types of fields.

A Mass Spectrometer is used to separate out atoms and molecules based on their mass - and is used to analyze the physical makeup of substances in terms of their relative concentrations of their constituent parts.

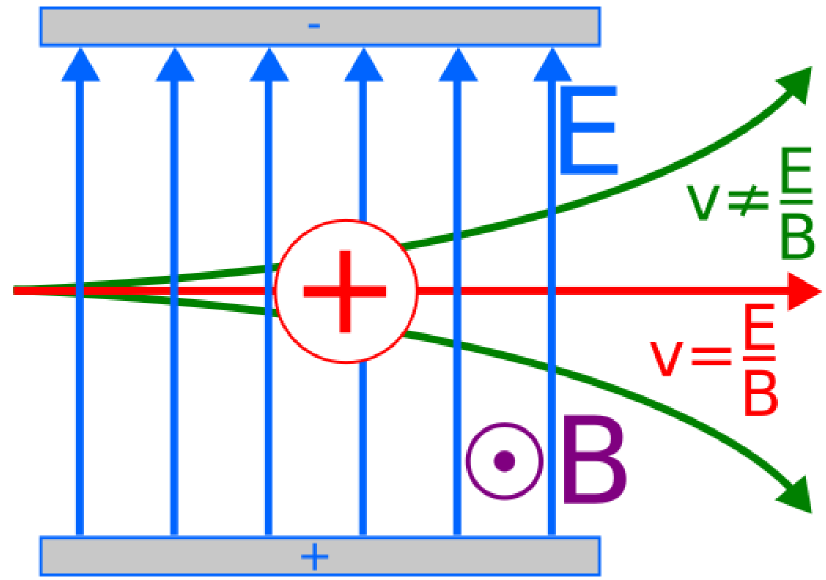
*Mass Spectrometer

This is the first part of a Mass Spectrometer - the Velocity Selector.

The substance to be analyzed is charged and injected into the left side of the Velocity Selector.

An Electric field is directed vertically up, and a Magnetic Field is perpendicular to it and directed out of the page.

Velocity Selector



There is a slit at the right side which only allows particles that are undeflected by the two fields to pass through.

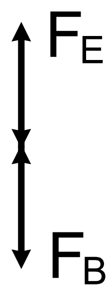
*Mass Spectrometer

Here is the free body diagram and the balanced force equation for a particle to go straight through the selector (Zero acceleration in the up/down direction).

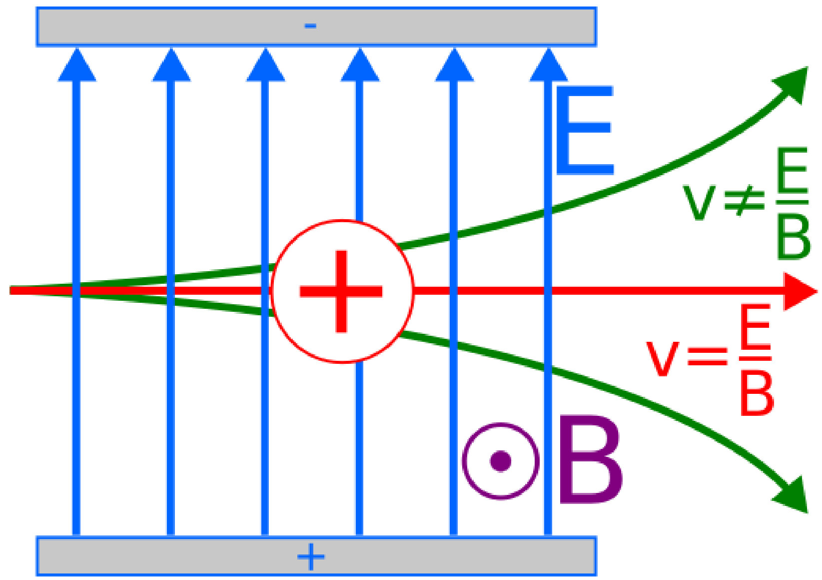
$$F_E - F_B = 0$$

$$qE - qvB = 0$$

$$v = \frac{E}{B}$$



Velocity Selector

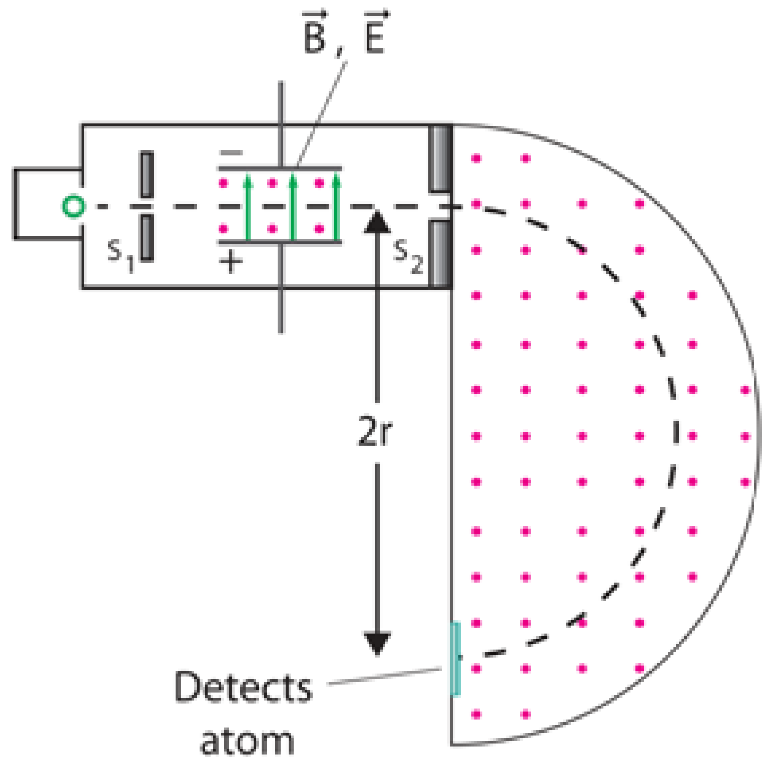


Only particles with a velocity v=E/B will pass straight through - hence the name "Velocity Selector."

http://njc.tl/my

*Mass Spectrometer

The second part of the Mass Spectrometer is a semicircle, with a magnetic field again pointing out of the page, and of the same magnitude as the magnetic field in the velocity selector. Atoms reaching the second magnetic field will have the same speed because of the velocity selector.




http://njc.tl/my

*Mass Spectrometer

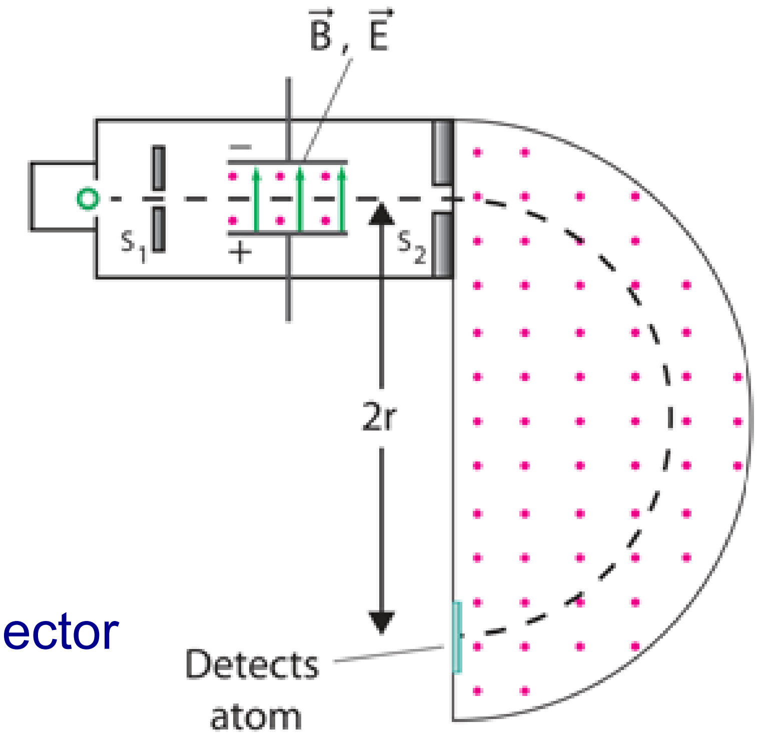
The magnetic field in stage 2 will exert a centripetal force on the charges entering it.

$$F_B = \frac{mv^2}{r}$$ Newton's Second Law

$$qvB = \frac{mv^2}{r}$$ Magnetic Field Force

$$m = \frac{qBr}{v}$$ Solving for m

$$m = \frac{qrB^2}{E}$$ v=E/B from velocity selector



The various masses will separate out along the diameter of the semicircle and are calculated by the above equation.

Summary

- Magnets have North and South poles.
- Like poles repel, unlike poles attract each other.
- Unit of magnetic field: Tesla=10^4 Gauss.
- Electric currents produce Magnetic fields
- A magnetic field exerts a force on a moving charge:

$$F = qvB_{perpendicular}$$

- A magnetic field exerts a force on an electric current:

$$F = ILB_{perpendicular}$$

- Magnitude of the field of a long, straight current-carrying wire:

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

- Parallel currents attract; antiparallel currents repel

http://njc.tl/mz