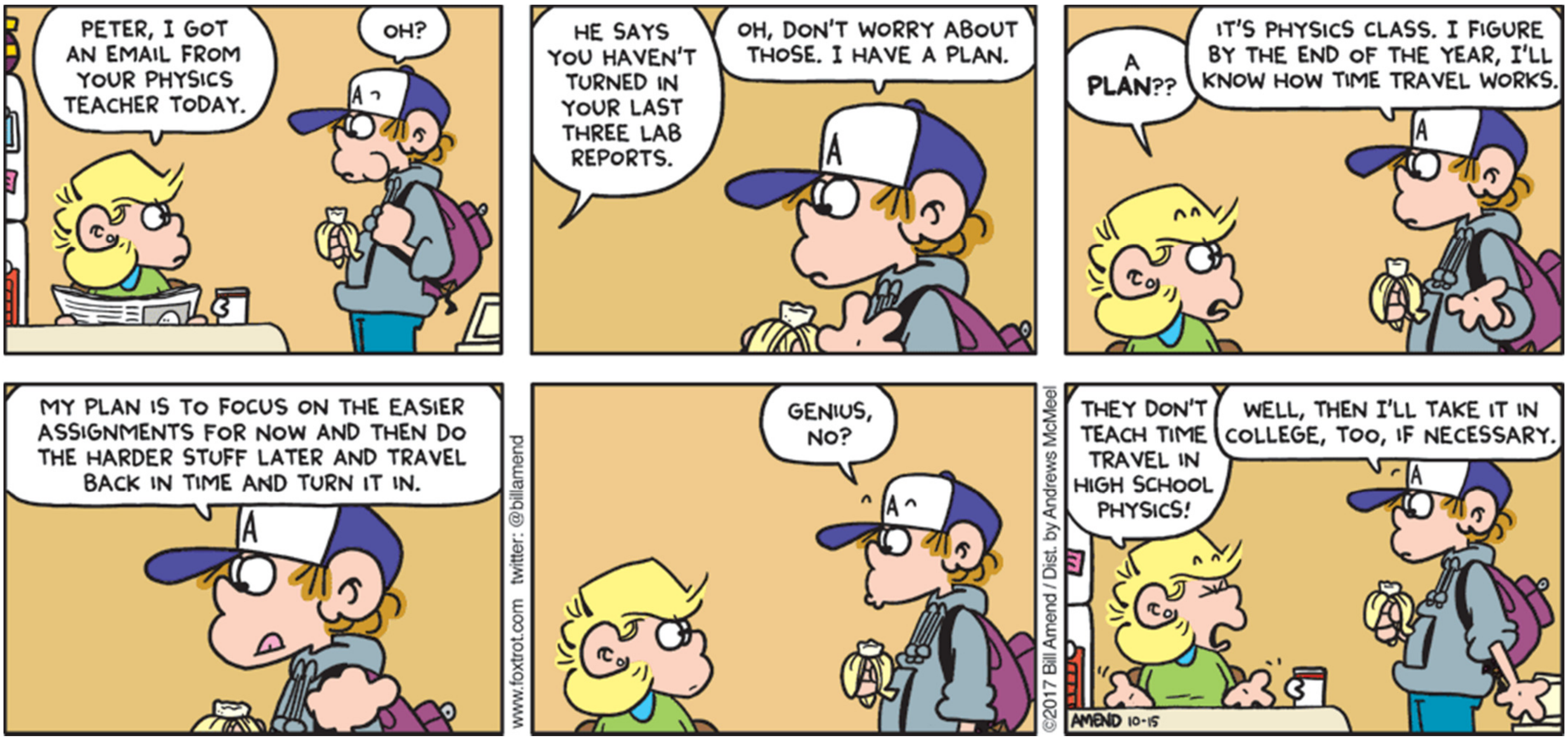
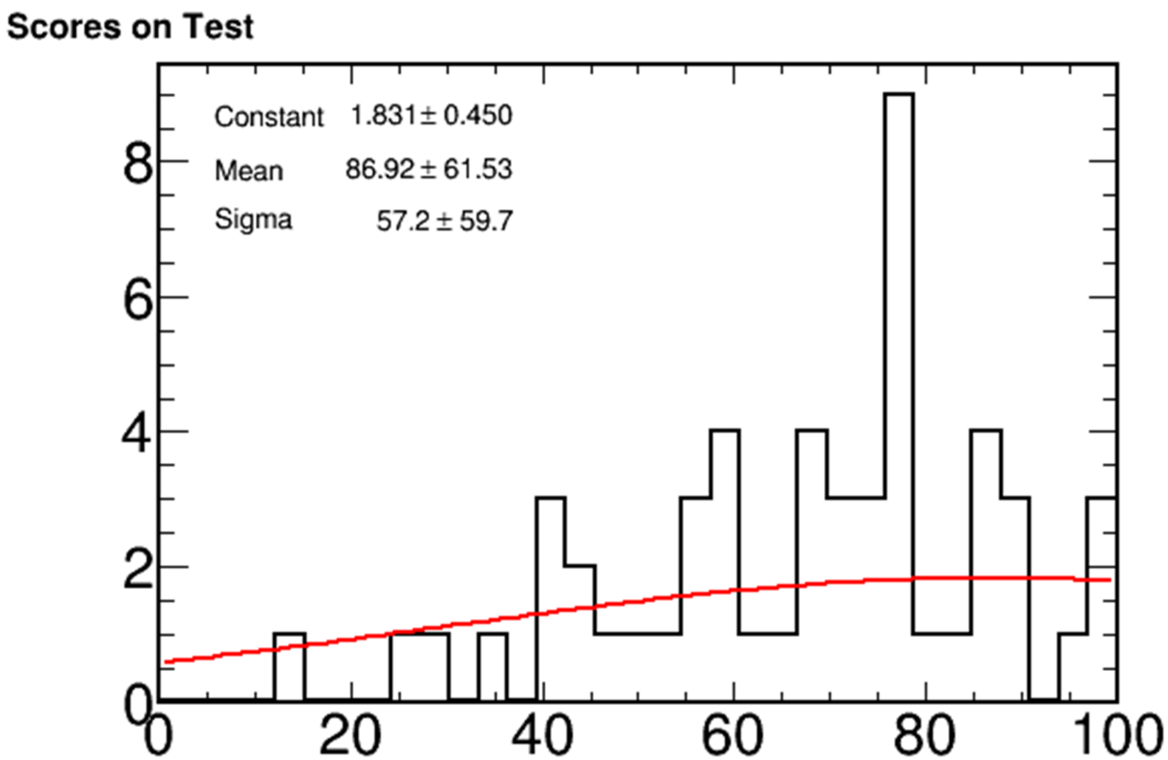
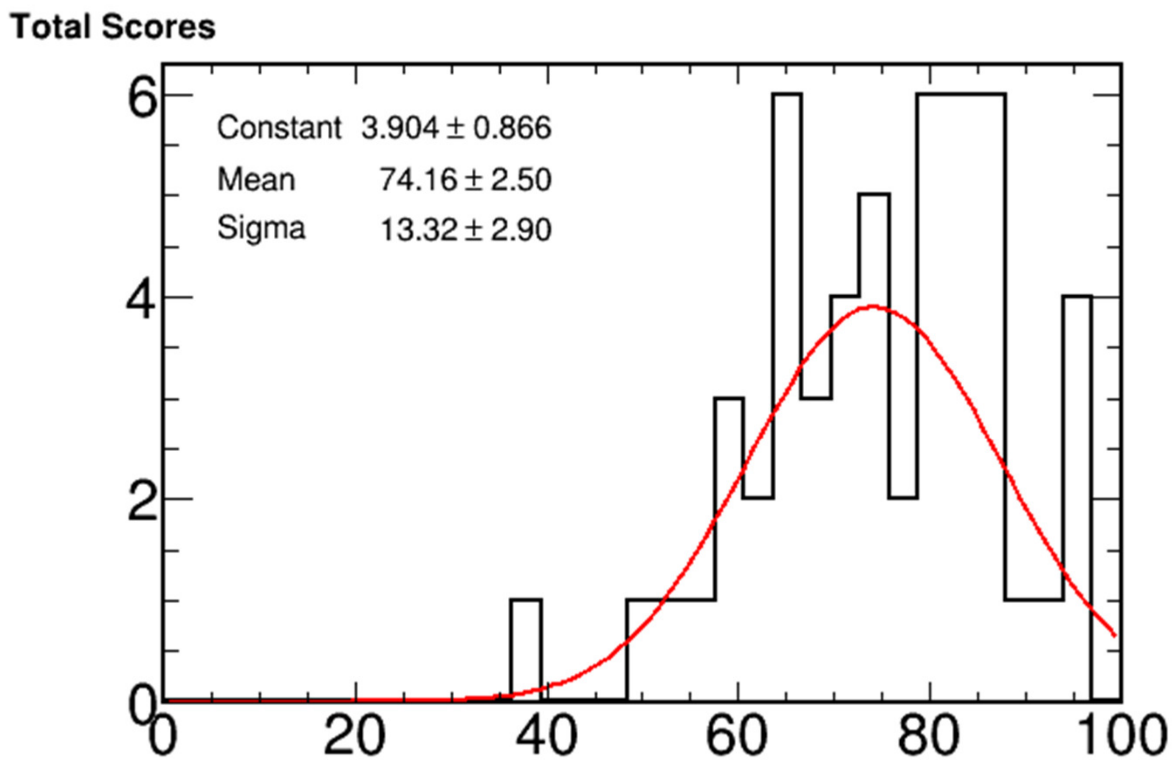

PETER, I GOT AN EMAIL FROM YOUR PHYSICS TEACHER TODAY.
OH?
HE SAYS YOU HAVEN'T TURNED IN YOUR LAST THREE LAB REPORTS.
OH, DON'T WORRY ABOUT THOSE. I HAVE A PLAN.
A **PLAN**??
IT'S PHYSICS CLASS. I FIGURE BY THE END OF THE YEAR, I'LL KNOW HOW TIME TRAVEL WORKS.
MY PLAN IS TO FOCUS ON THE EASIER ASSIGNMENTS FOR NOW AND THEN DO THE HARDER STUFF LATER AND TRAVEL BACK IN TIME AND TURN IT IN.
www.foxtrot.com twitter: @billamend
GENIUS, NO?
©2017 Bill Amend / Dist. by Andrews McMeel
THEY DON'T TEACH TIME TRAVEL IN HIGH SCHOOL PHYSICS!
WELL, THEN I'LL TAKE IT IN COLLEGE, TOO, IF NECESSARY.
AMEND 10-15



Much better average than first test –
But a really wide spread in grades!


Total Scores
Constant 3.904 ± 0.866
Mean 74.16 ± 2.50
Sigma 13.32 ± 2.90
0
2
4
6
0
20
40
60
80
100

$\vec{E}$: a "force field" made by charge

a map of the force some other charge would feel $\vec{F}_E = q\vec{E}$

$\vec{B}$: another force field made by moving charges

(we have never found a stationary "magnetic charge")

charges moving through $\vec{B}$ feel a force

$$\vec{F}_B = q\vec{v} \times \vec{B}$$

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

Let’s set aside this force for now, and figure out how you get a “**B**”

$\vec{B}$ = Magnetic Field

units T Tesla

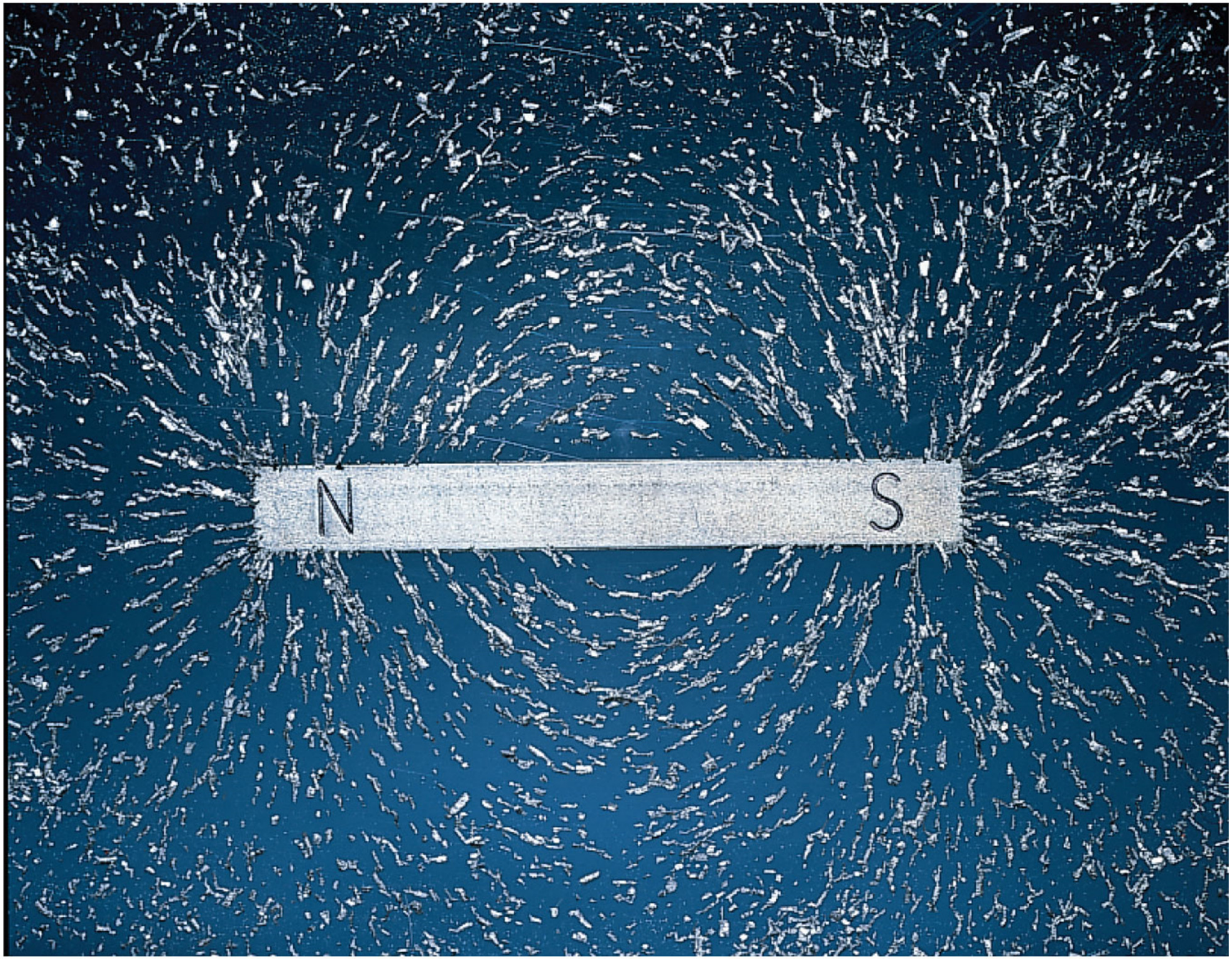
$$T = \frac{N}{C(m/s)} = \frac{N}{\frac{C}{s}m} = \frac{N}{A \cdot m}$$

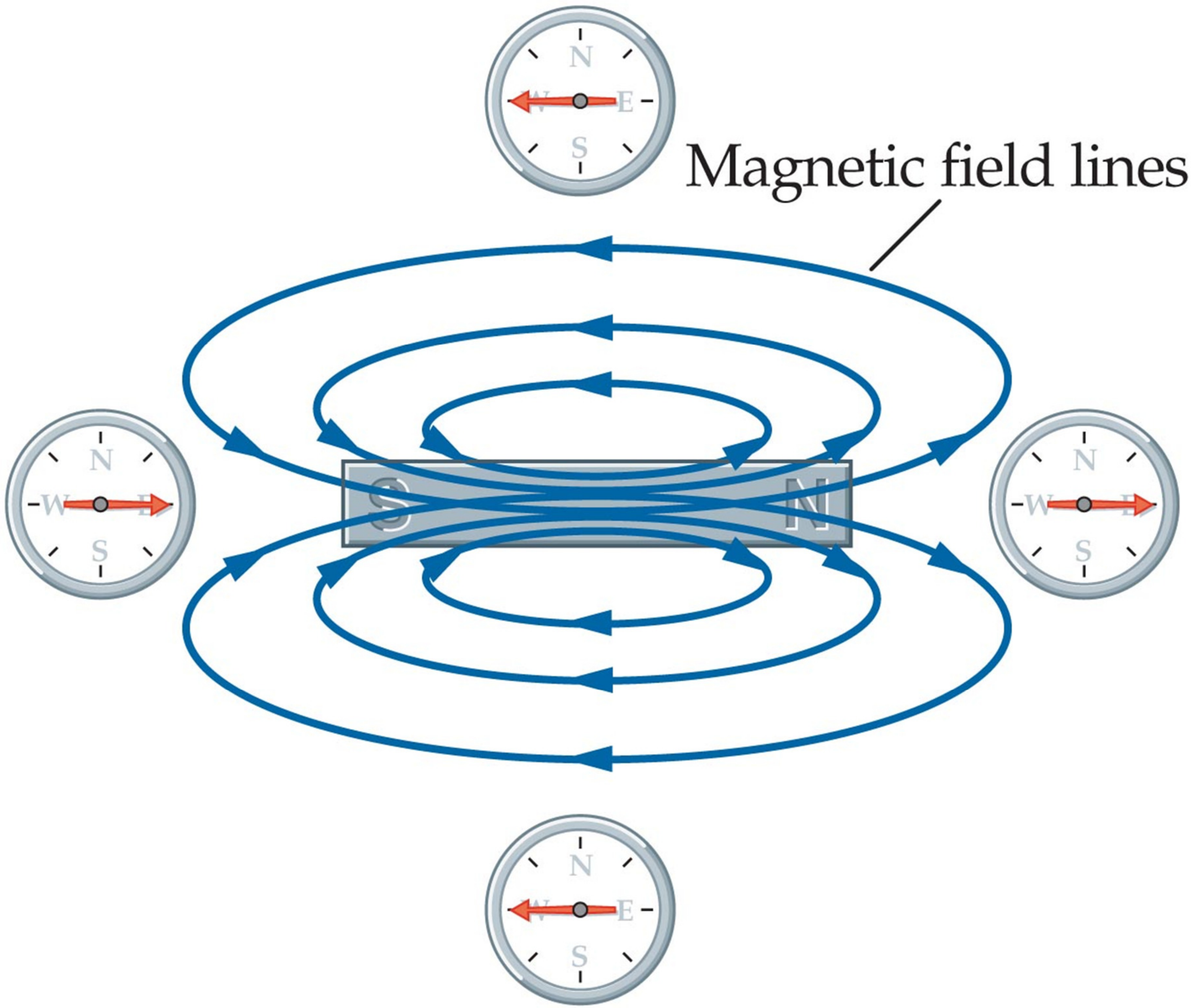
non-SI common unit

Gauss G = 10^{-4} T

Because Earth's $|\vec{B}| \sim 1$ G

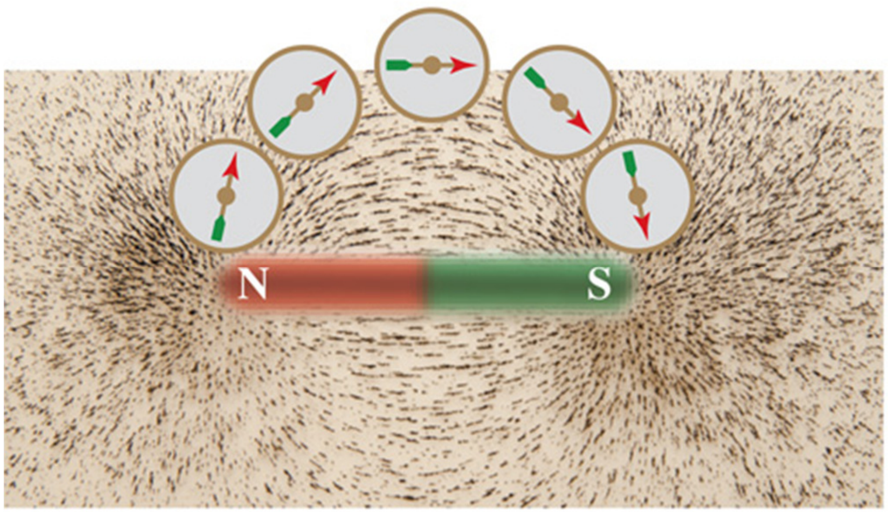
Big Electromagnet $\sim$ T


N
S

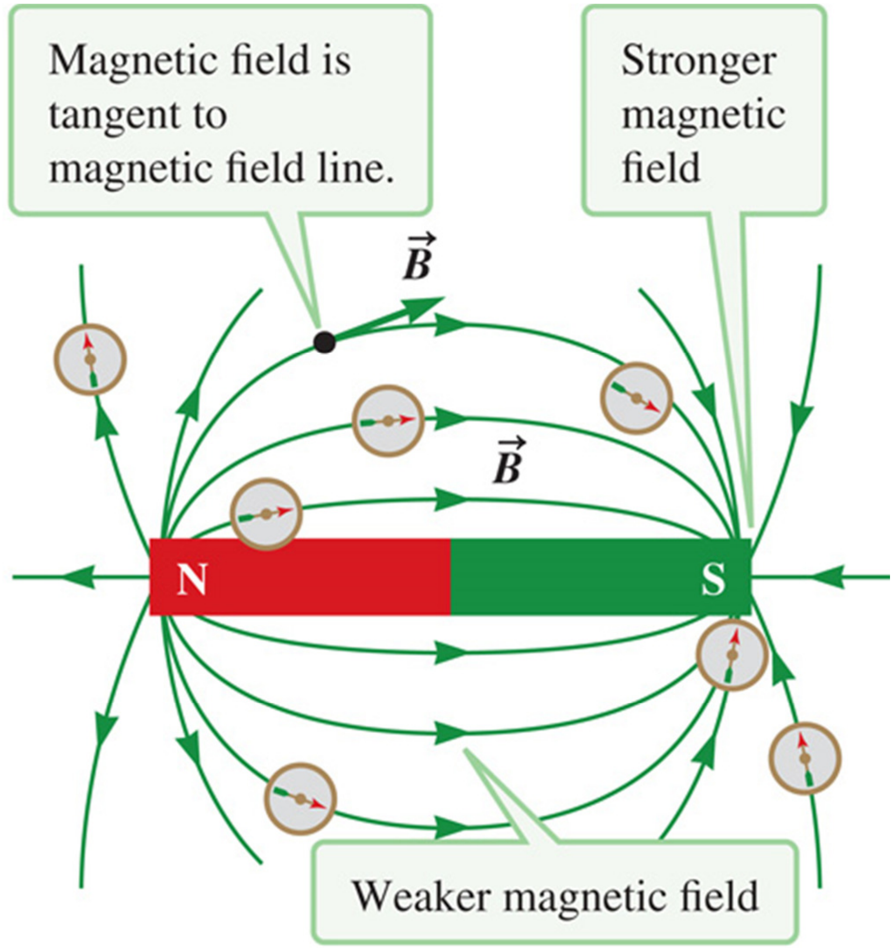


N
W
E
S
Magnetic field lines
S
N

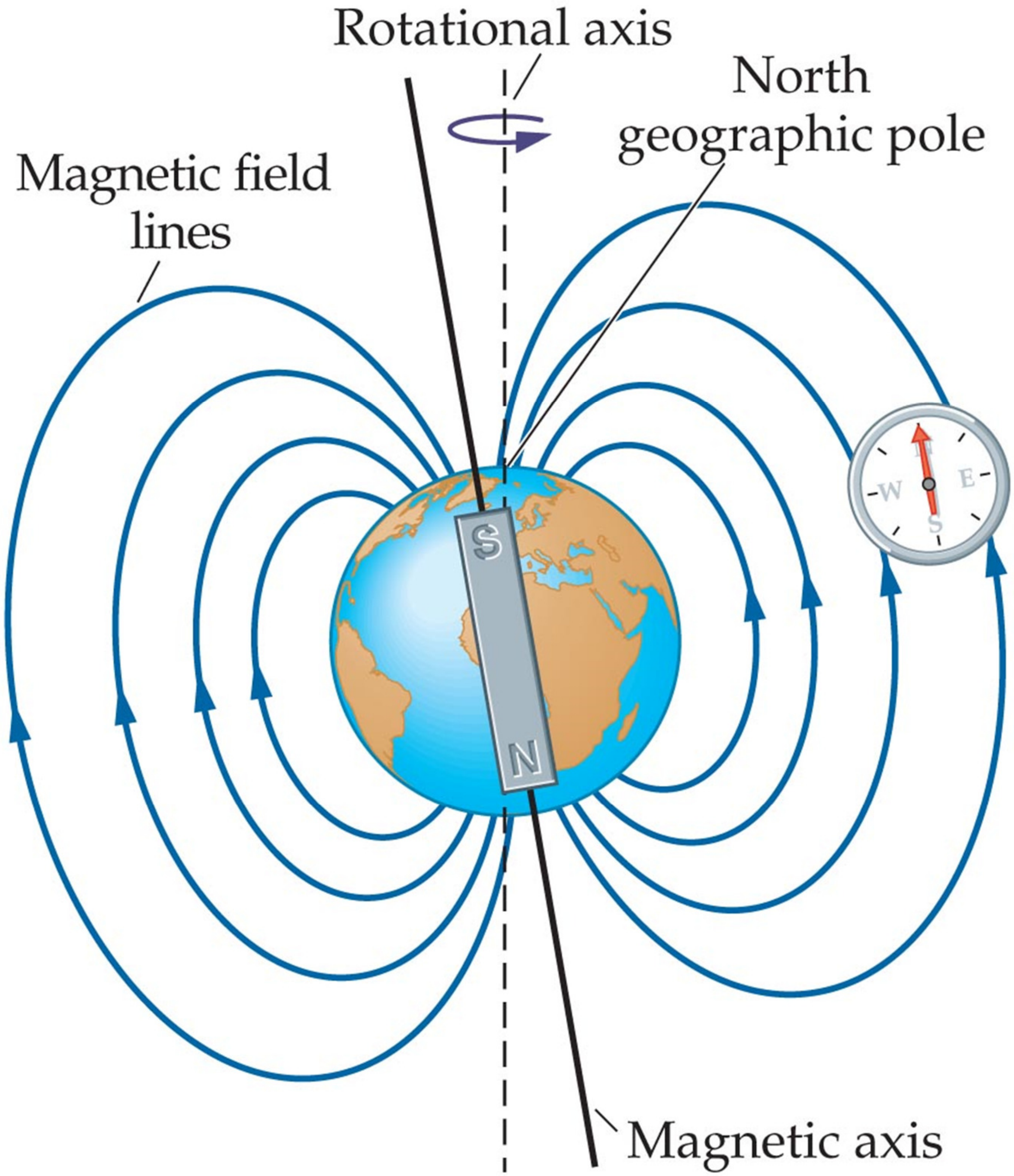
Fig.30.5

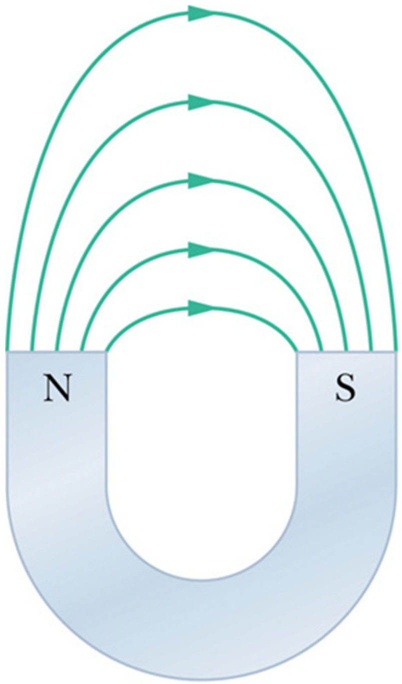

N
S

A.

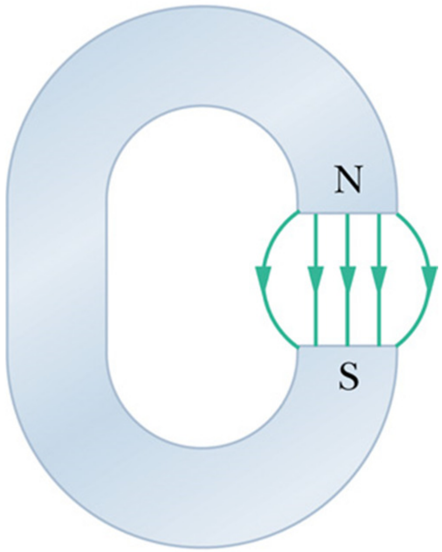

Magnetic field is tangent to magnetic field line.
Stronger magnetic field
$\vec{B}$
$\vec{B}$
N
S
Weaker magnetic field

B.


Rotational axis
North geographic pole
Magnetic field lines
S
N
W
E
S
Magnetic axis

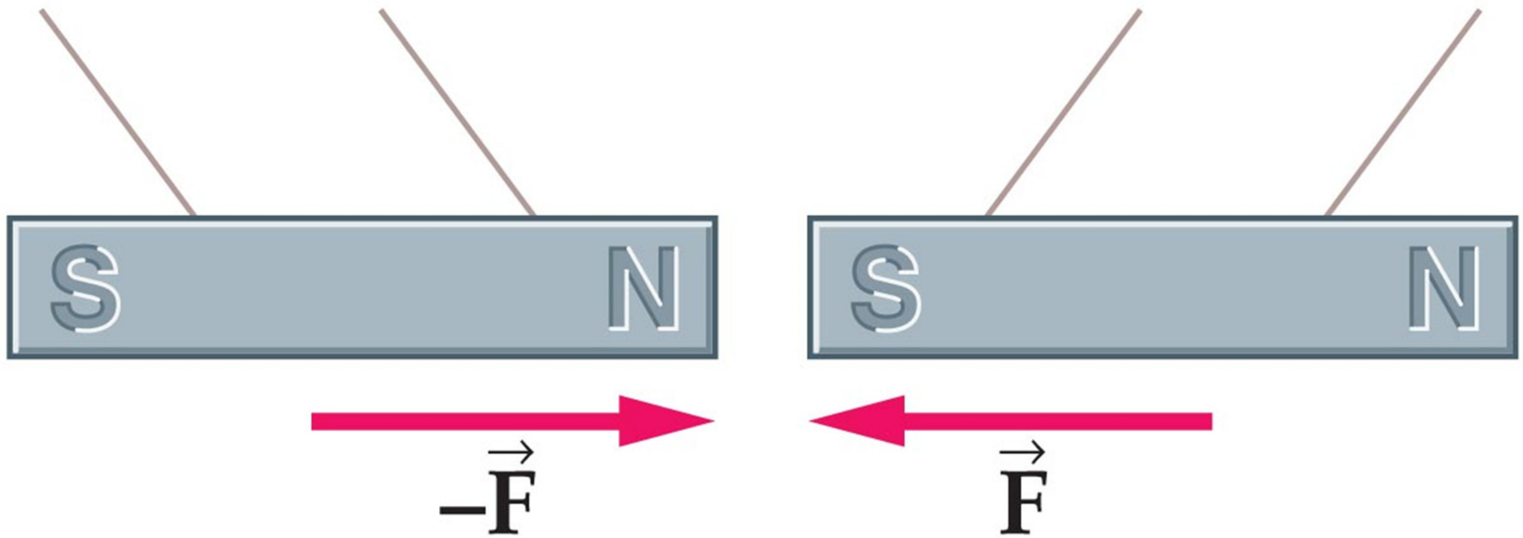


(*a*)

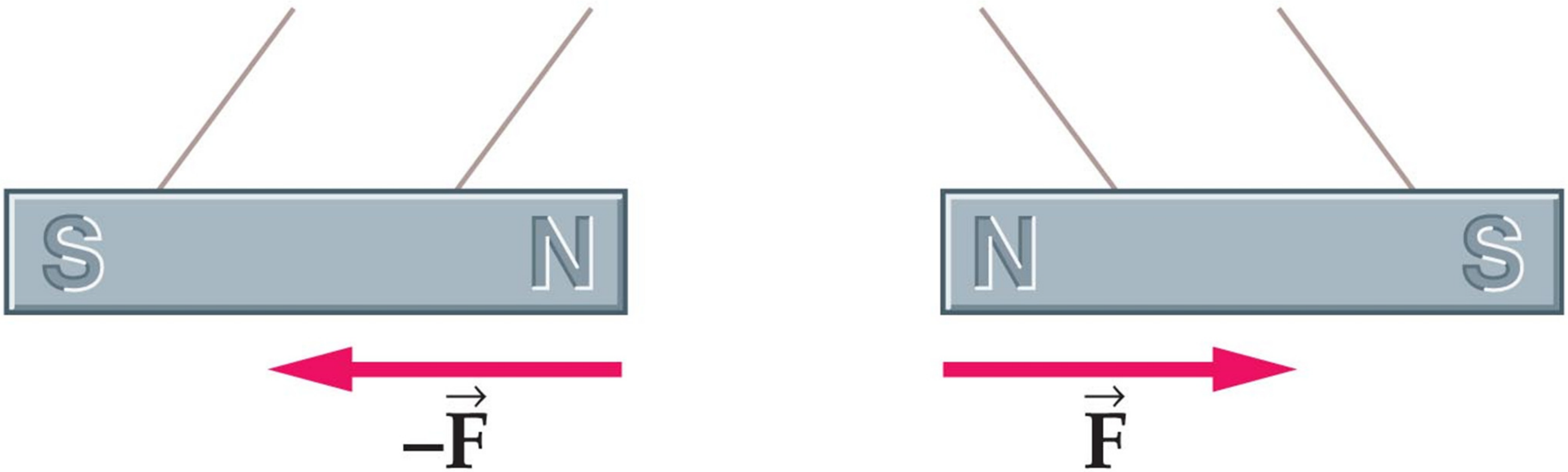


(*b*)

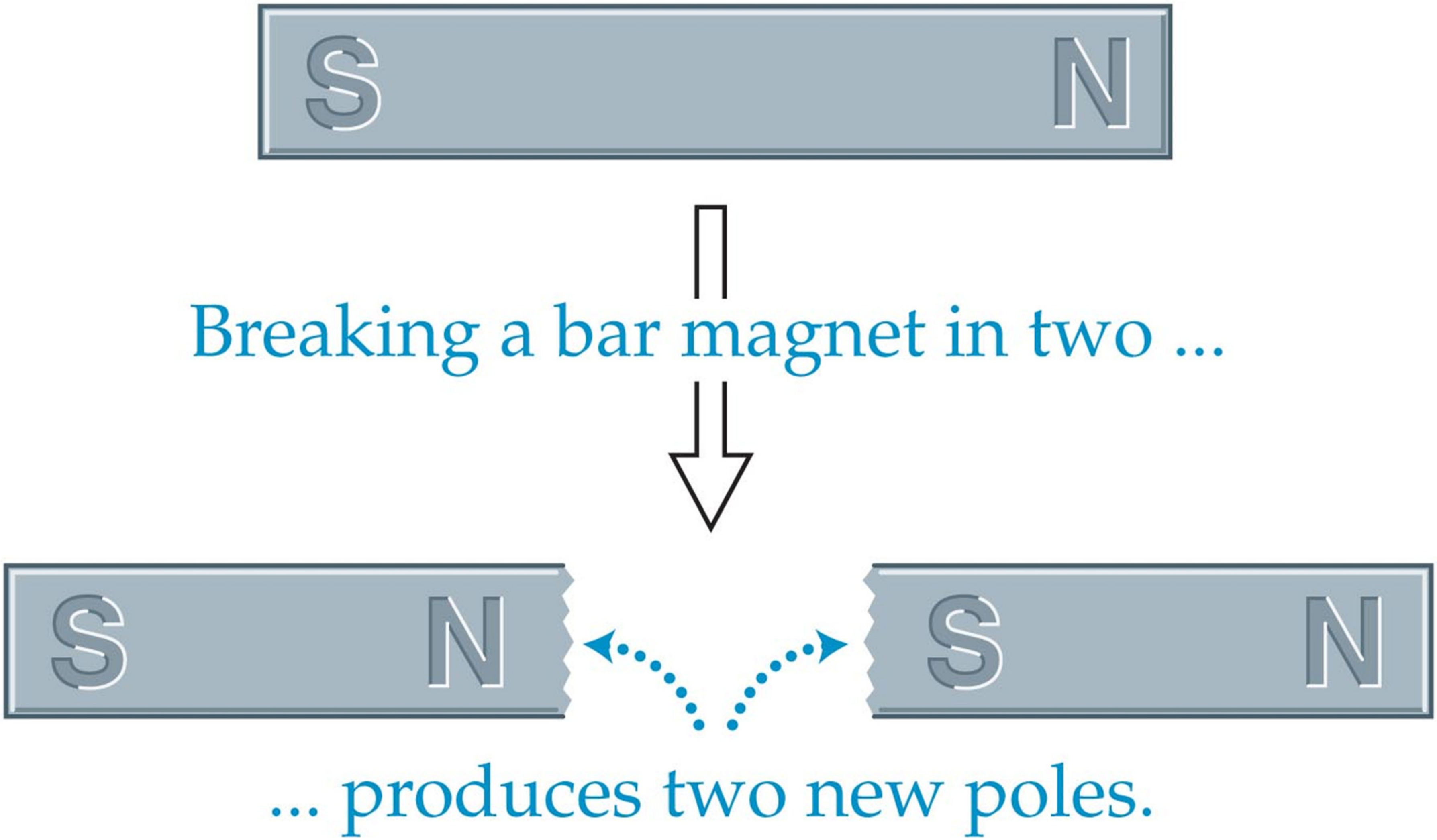
(b)



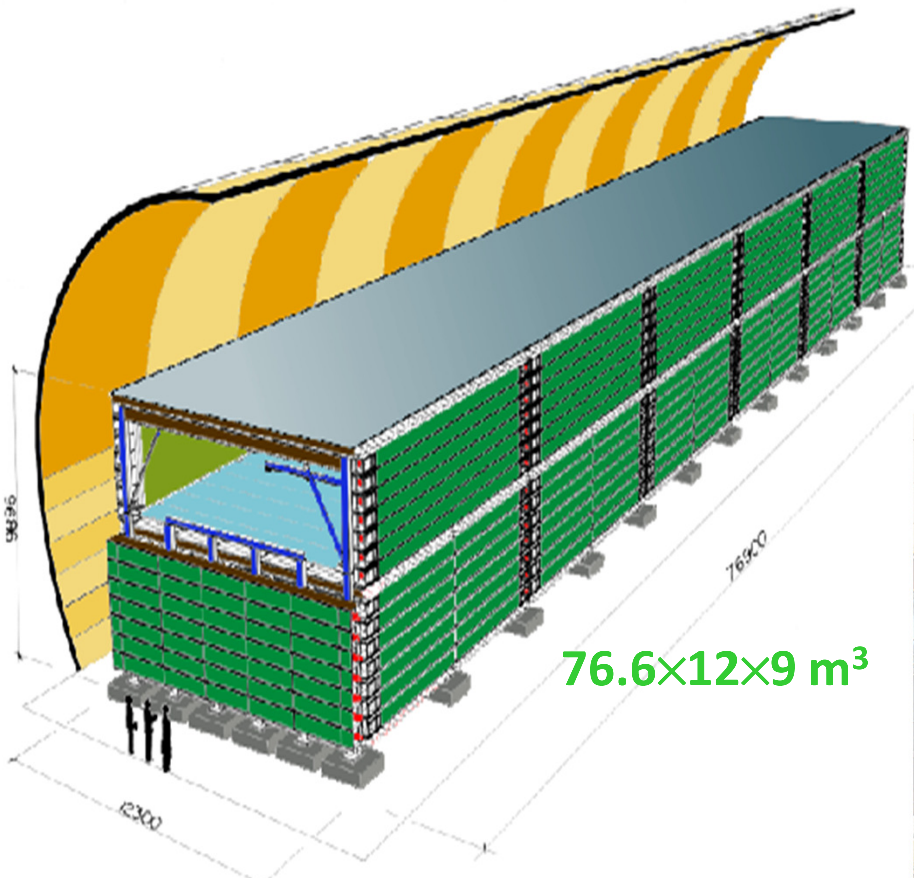
(a) Opposite poles attract

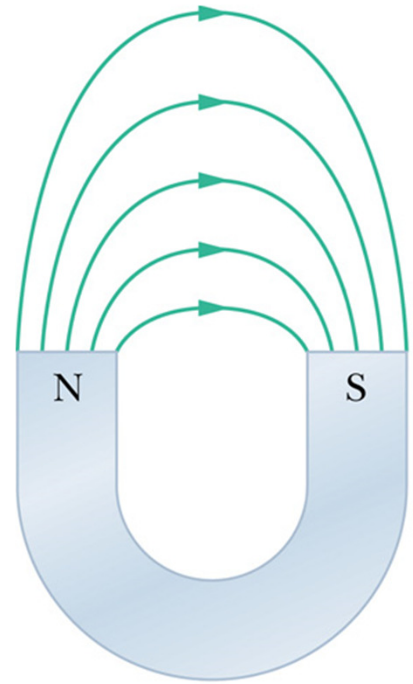


(b) Like poles repel

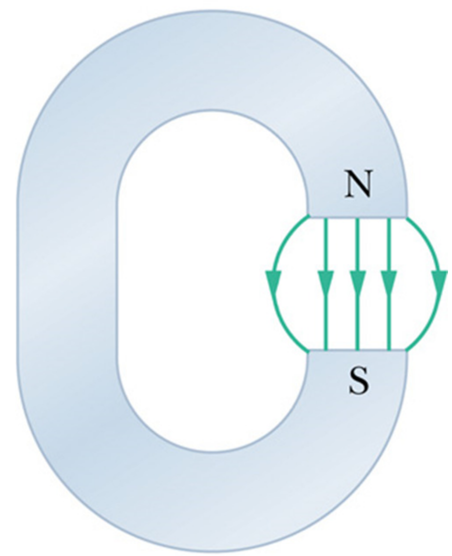

S
N
Breaking a bar magnet in two ...
S
N
S
N
... produces two new poles.

MACRO, a mile deep under the Apennines
Looked for more than a decade,
saw no monopoles





(*a*)



(*b*)

Fig.30.10

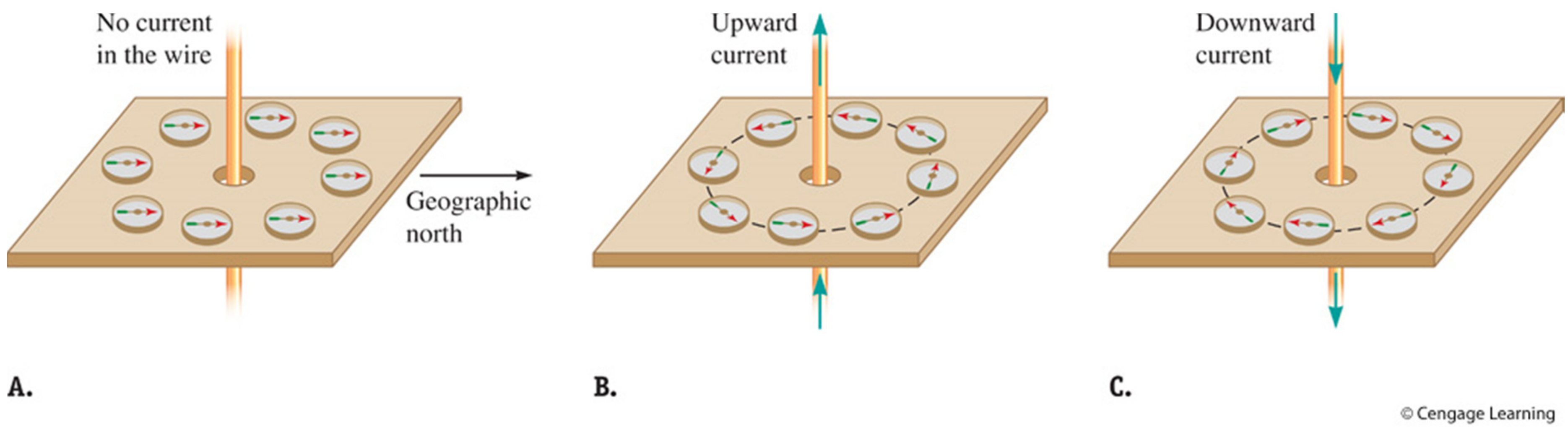

No current
in the wire
Geographic
north
A.
Upward
current
B.
Downward
current
C.
© Cengage Learning

Fig.30.11

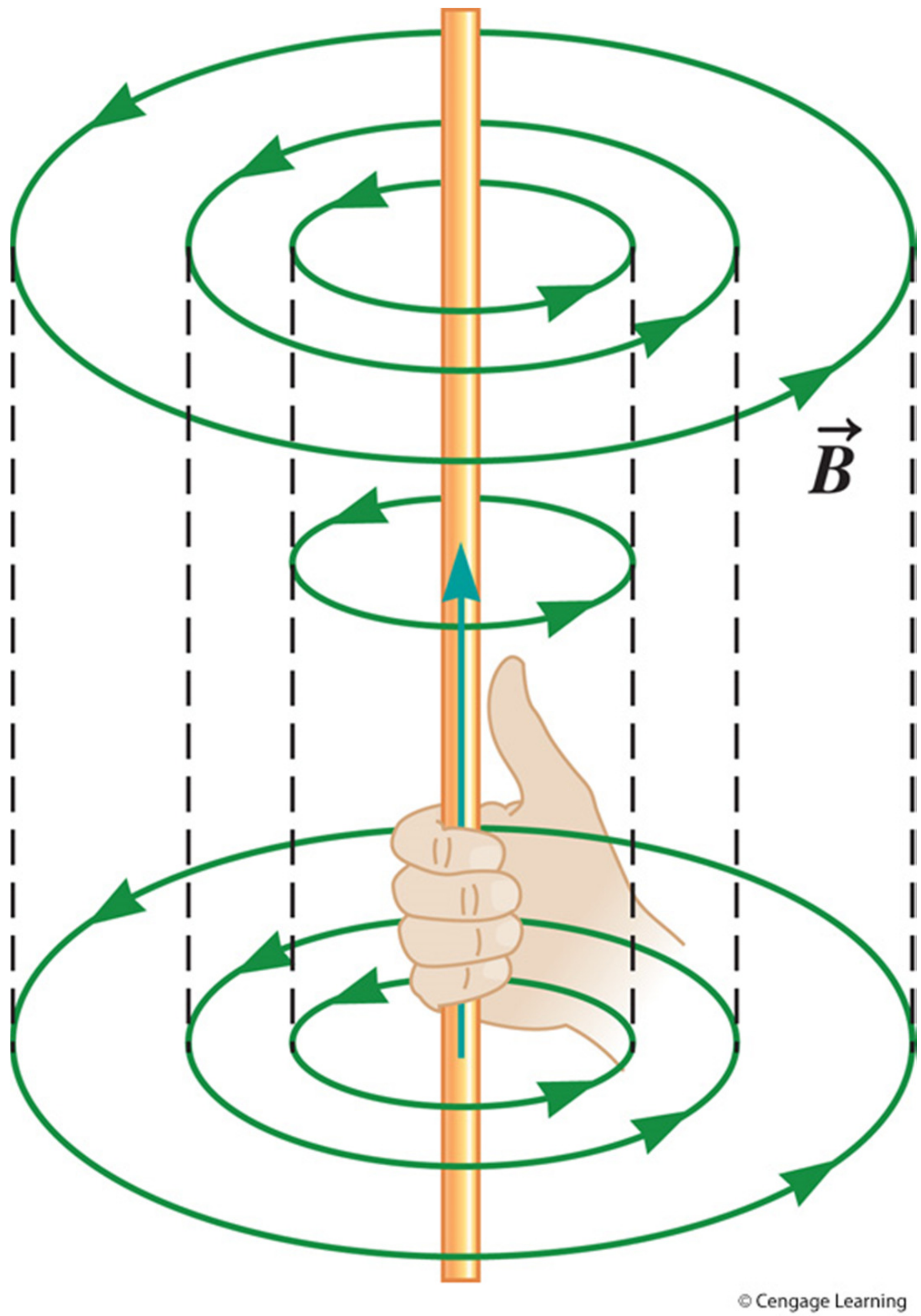
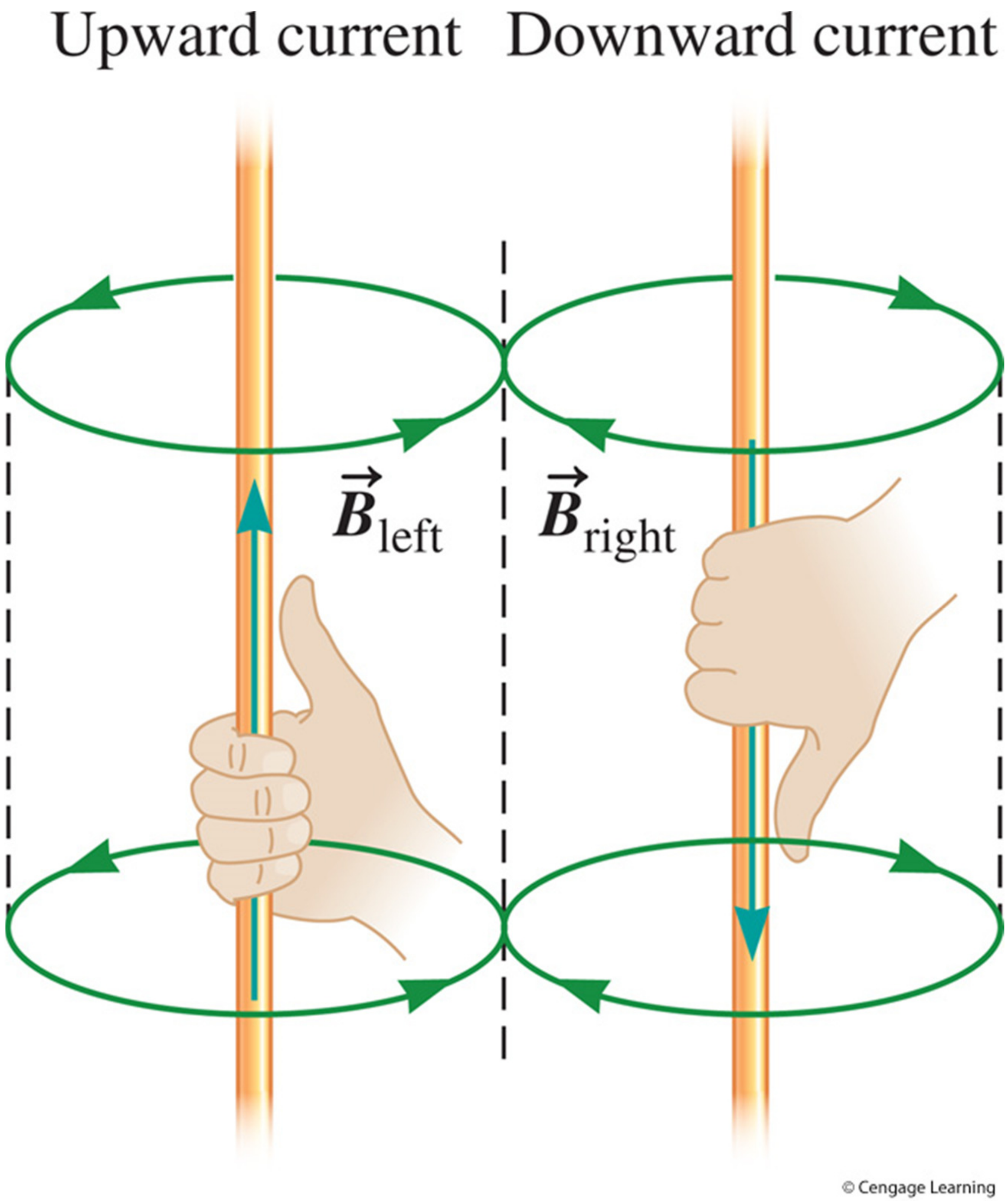
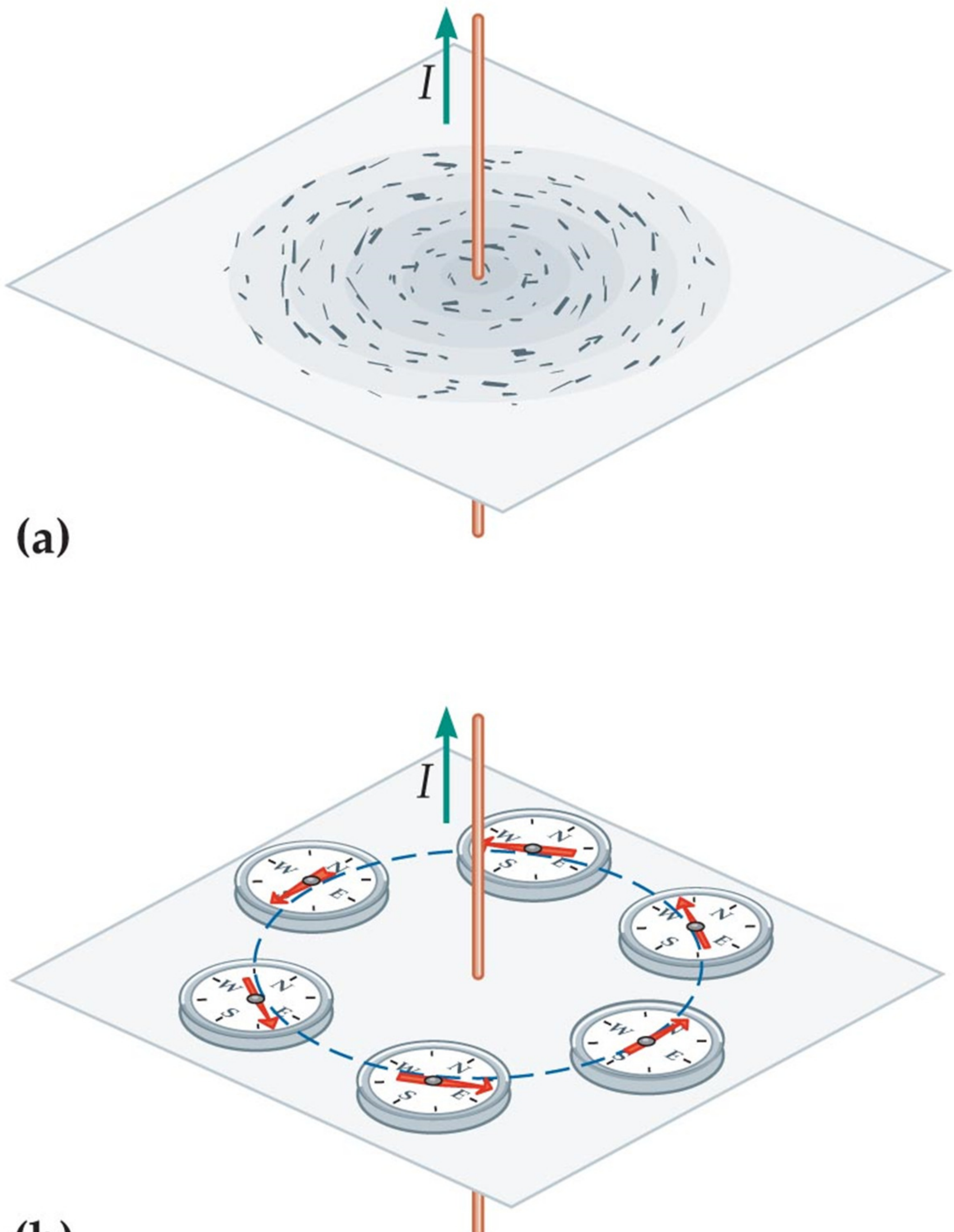


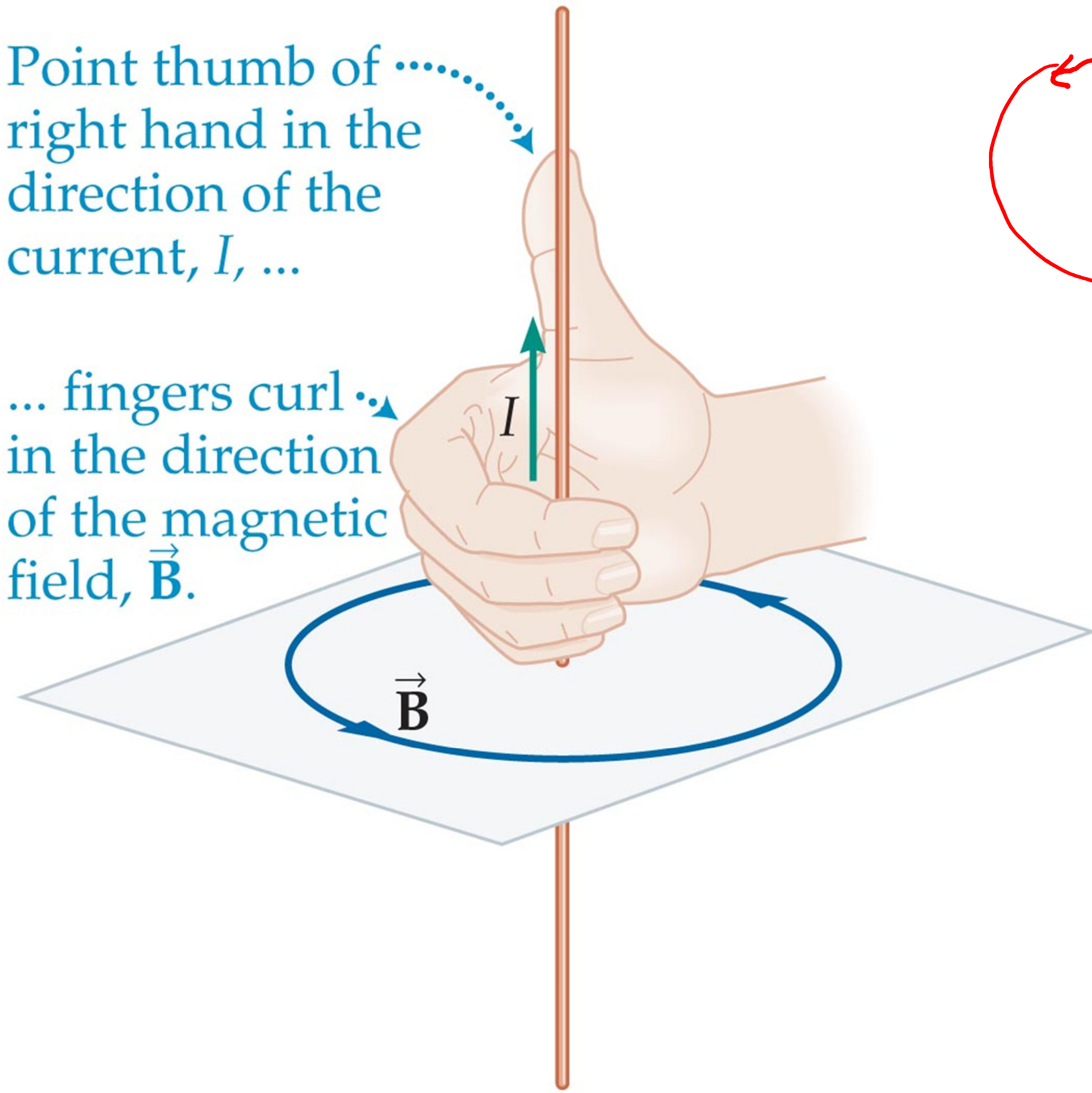
Fig.30.12


Upward current
Downward current
$\vec{B}_{\text{left}}$
$\vec{B}_{\text{right}}$
© Cengage Learning



(a)

(b)


Point thumb of right hand in the direction of the current, I, ...
... fingers curl in the direction of the magnetic field, B⃗.
I
B⃗

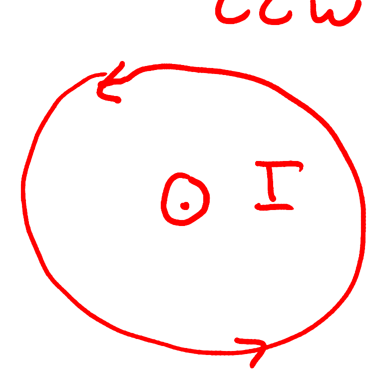
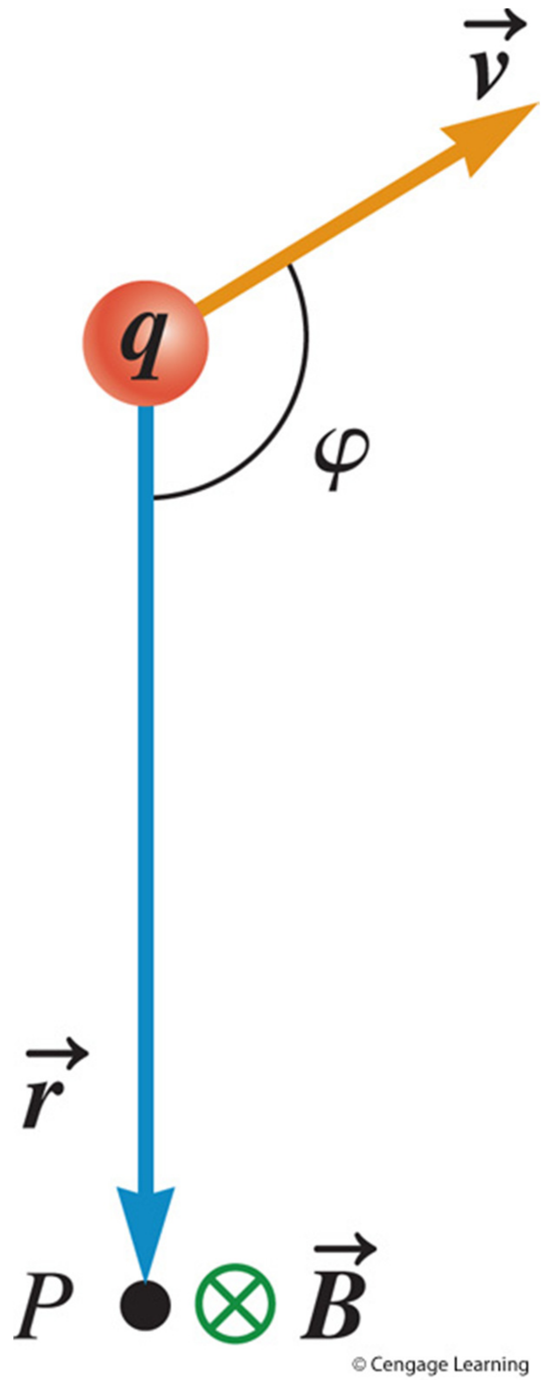
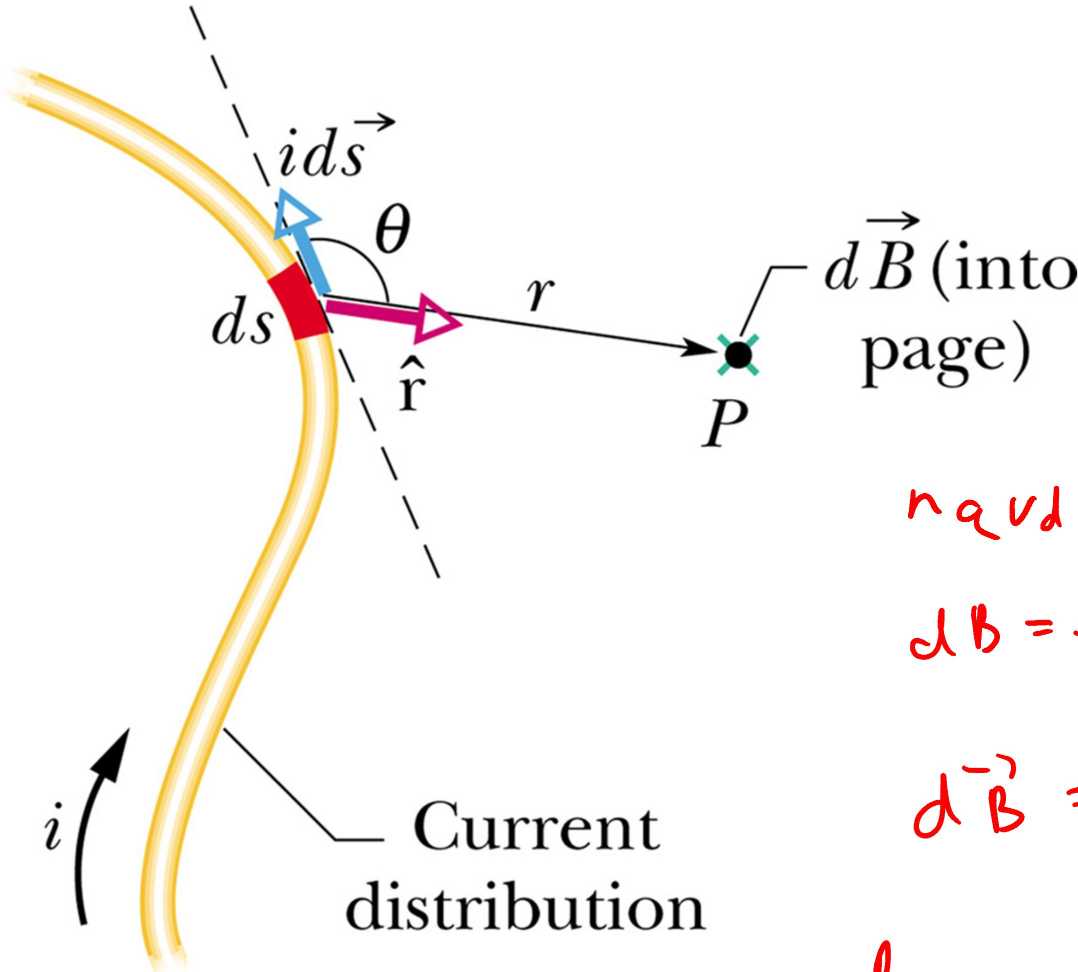

ccw
I

Fig.30.13



$$\vec{\boldsymbol{B}} = \left(\frac{\mu_0}{4\pi}\right) q \frac{\vec{\boldsymbol{v}} \times \vec{\boldsymbol{r}}}{r^3}$$



$$dQ = nqA\,ds$$

moving @ v_d

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{(dQ)\,v_d \sin\theta}{r^2}$$

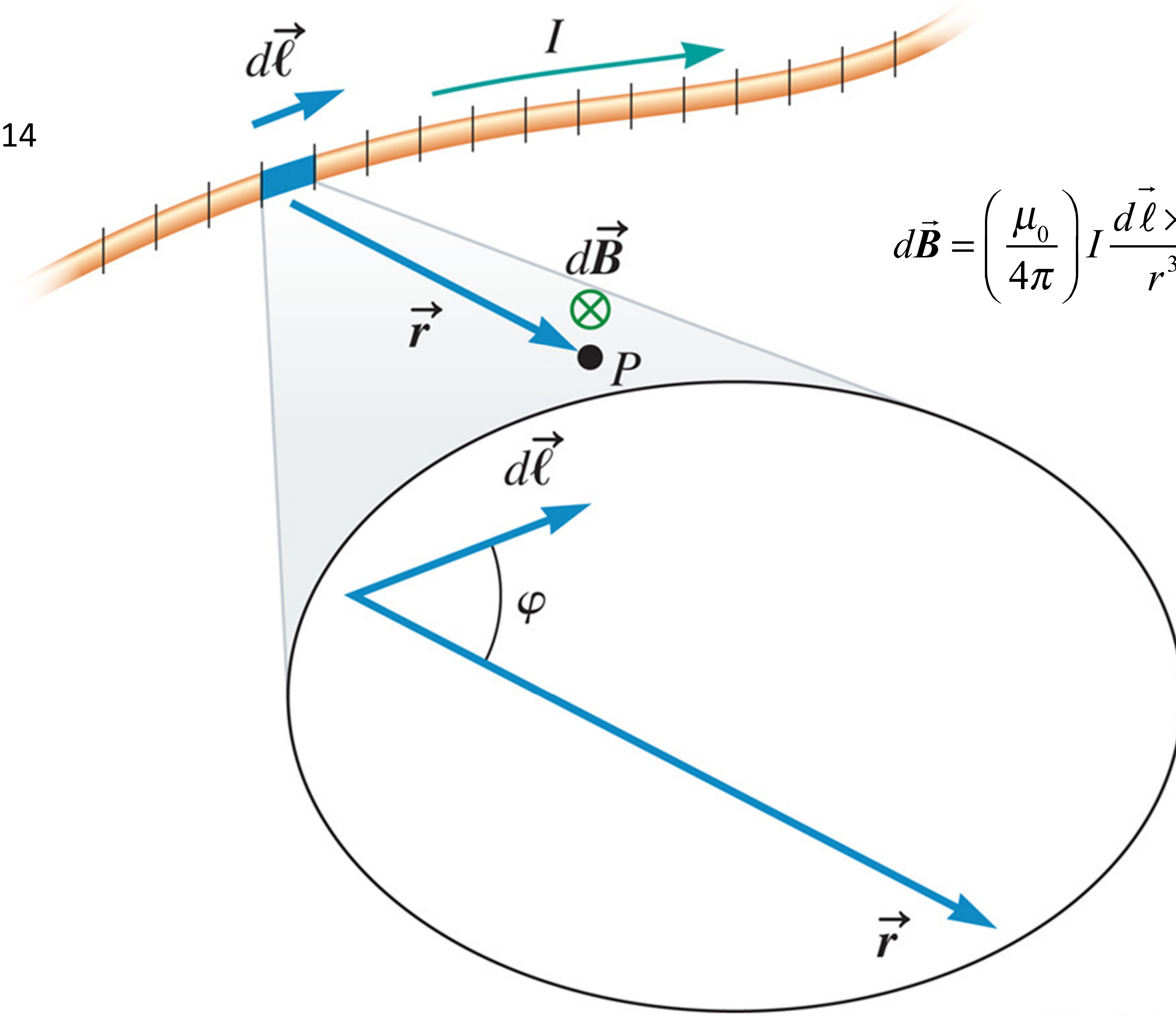
$$nqv_dA = I$$

$$dB = \frac{\mu_0}{4\pi}\frac{I\,ds\,\sin\theta}{r^2}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{s}\times\hat{r}}{r^2}$$

Biot - Savart Law

Fig.30.14

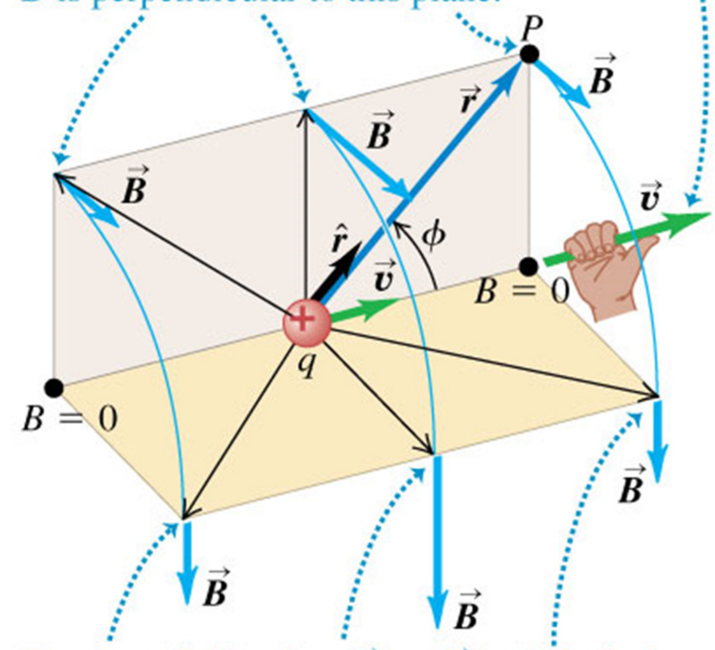


$$d\vec{B} = \left(\frac{\mu_0}{4\pi}\right) I \frac{d\vec{\ell} \times \vec{r}}{r^3}$$

(a) Perspective view

Right-hand rule for the magnetic field due to a positive charge moving at constant velocity: Point the thumb of your right hand in the direction of the velocity. Your fingers now curl around the charge in the direction of the magnetic field lines. (If the charge is negative, the field lines are in the opposite direction.)

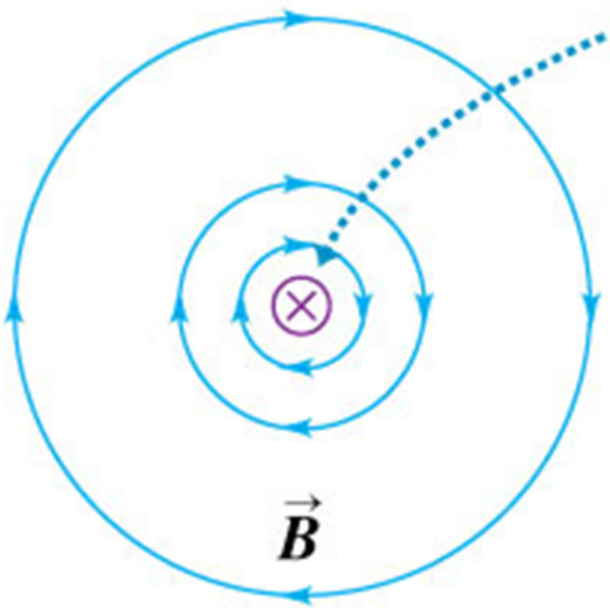
For these field points, $\vec{r}$ and $\vec{v}$ both lie in the beige plane, and $\vec{B}$ is perpendicular to this plane.



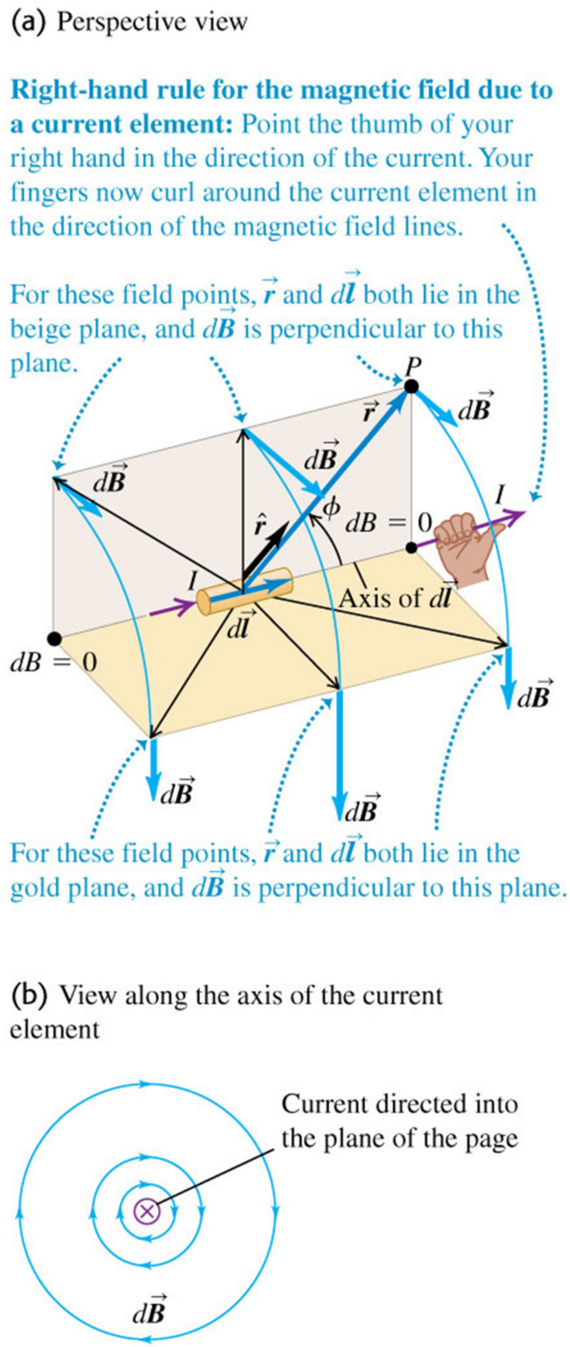
For these field points, $\vec{r}$ and $\vec{v}$ both lie in the gold plane, and $\vec{B}$ is perpendicular to this plane.

$$\vec{B} = \left(\frac{\mu_0}{4\pi}\right) q \frac{\vec{v} \times \vec{r}}{r^3}$$

(b) View from behind the charge



The × symbol indicates that the charge is moving into the plane of the page (away from you).



$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

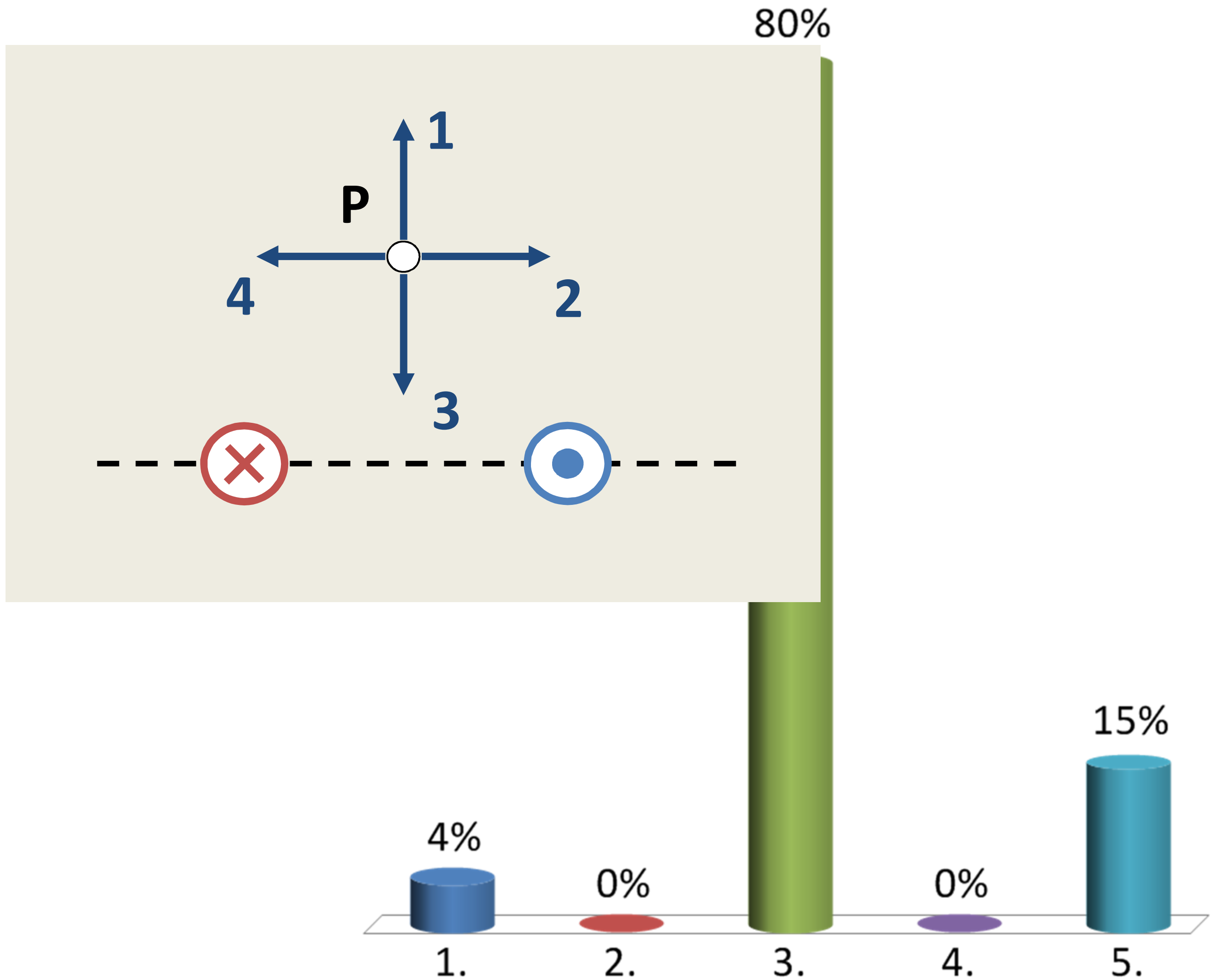
$$|\vec{B}| = \frac{\mu_0}{4\pi} \frac{q|v| \sin\theta}{r^2}$$

$$\mu_0 = 4\pi \times 10^{-7} \ \frac{Tm}{A}$$

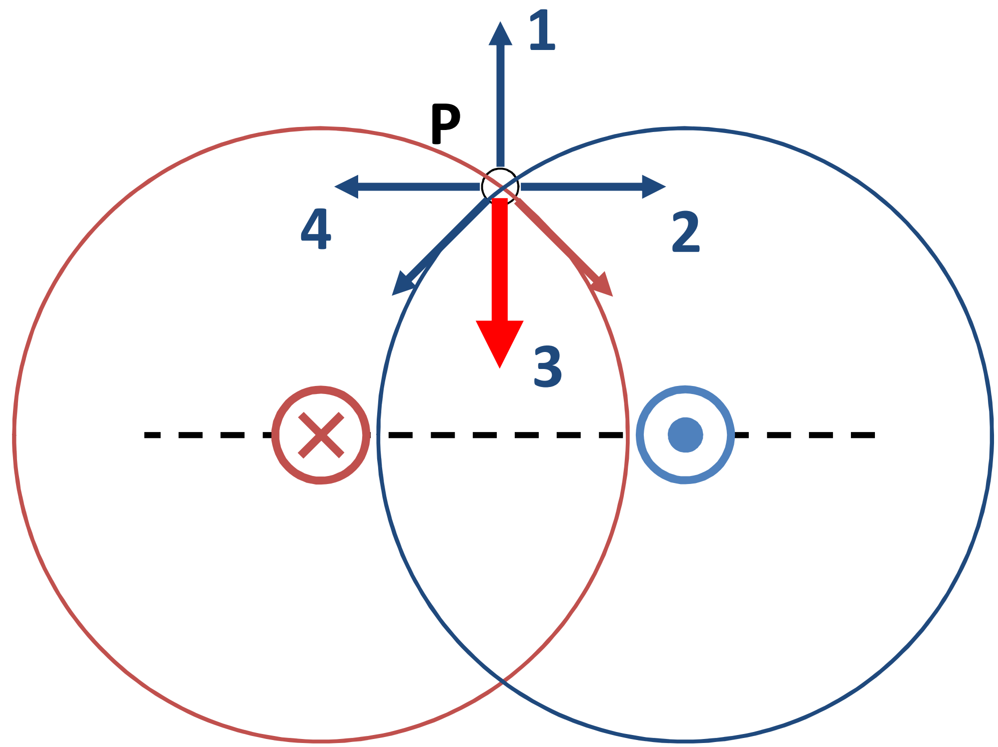
$$d\vec{B} = \left(\frac{\mu_0}{4\pi}\right) I \frac{d\vec{\ell} \times \vec{r}}{r^3}$$

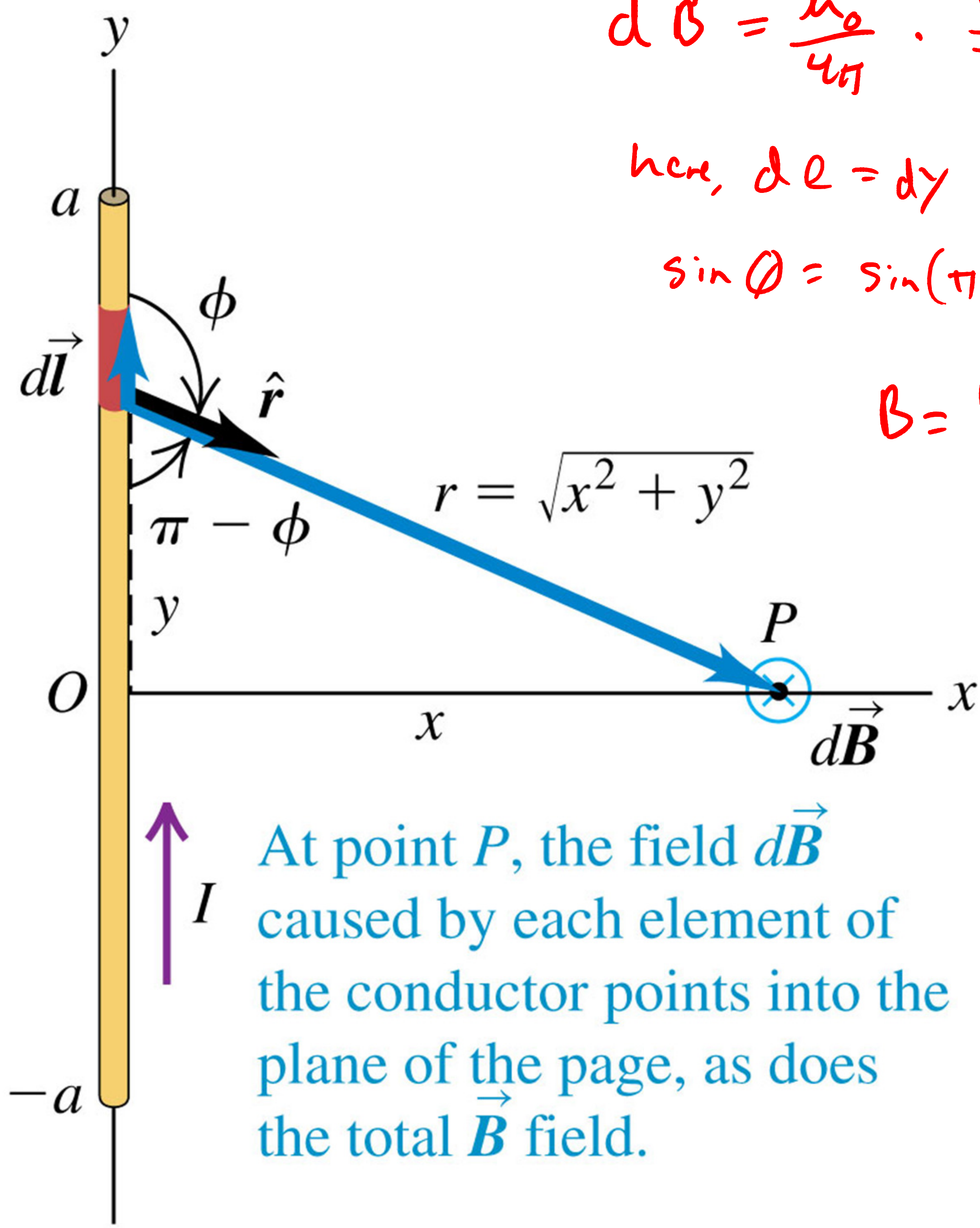
If the currents in these wires have the same magnitude but opposite directions, what is the direction of the magnetic field at point P?

1. Direction 1
2. Direction 2
3. ✓ Direction 3
4. Direction 4
5. Bfield is zero



46 of 52


1
P
4
2
3



At point P, the field $d\vec{B}$ caused by each element of the conductor points into the plane of the page, as does the total $\vec{B}$ field.

$$d\vec{B} = \frac{\mu_0}{4\pi} \cdot \frac{I\, d\vec{l} \times \hat{r}}{r^2}$$

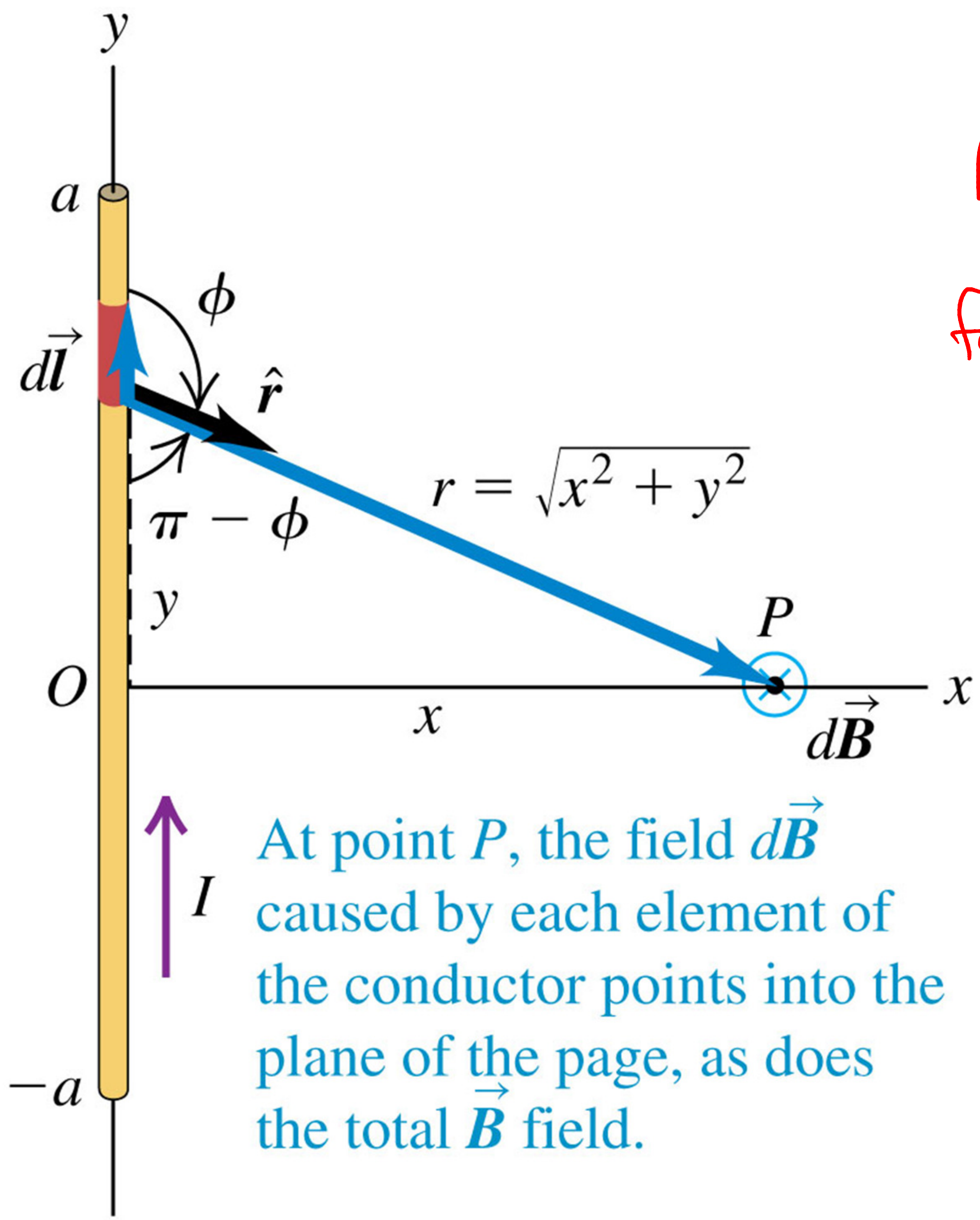
here, $dl = dy$ $\quad r = \sqrt{x^2 + y^2}$

$$\sin\phi = \sin(\pi - \phi) = \frac{x}{r}$$

$$B = \int dB = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{x\, dy}{r^3}$$

$$= \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{x\, dy}{\left(\sqrt{x^2+y^2}\right)^3}$$

$$B = \frac{\mu_0 I}{4\pi} \frac{2a}{x\sqrt{x^2+a^2}}$$



$$B = \frac{\mu_0 I}{4\pi} \frac{2a}{x\sqrt{x^2+a^2}}$$

for looong wire $(a \gg x)$

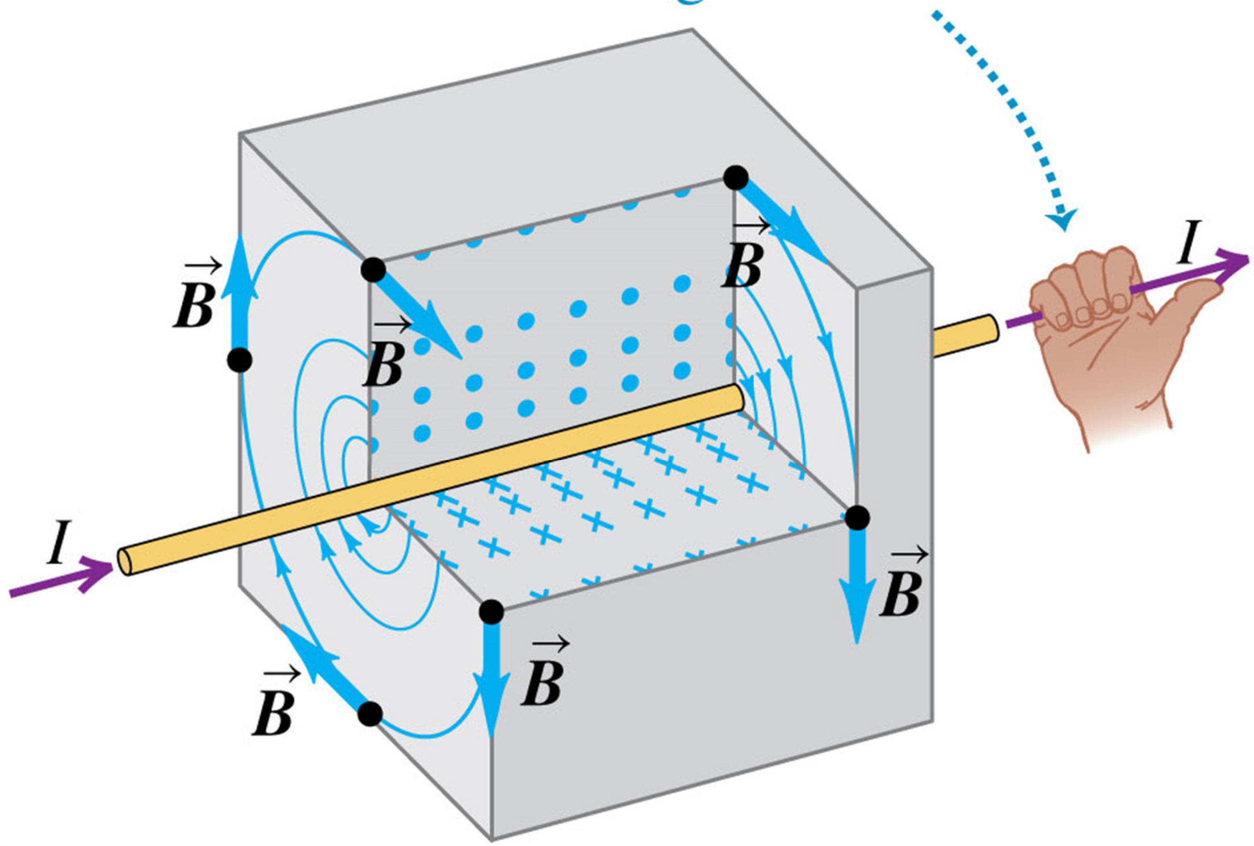
$$\sqrt{x^2+a^2} \simeq a$$

$$B = \frac{\mu_0 I}{4\pi} \frac{2\cancel{a}}{x\,\cancel{a}}$$

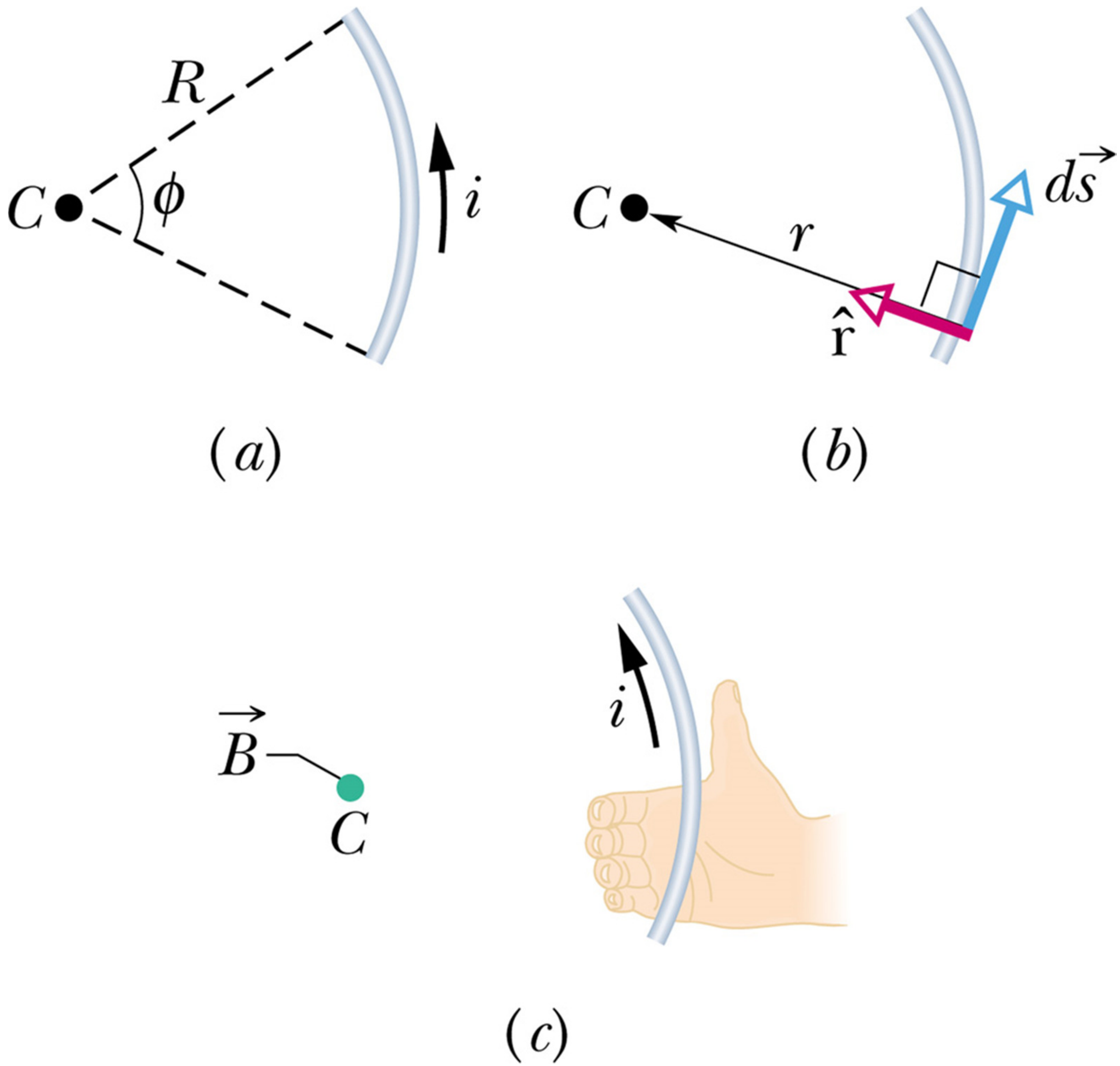
$$B = \frac{\mu_0 I}{2\pi x}$$

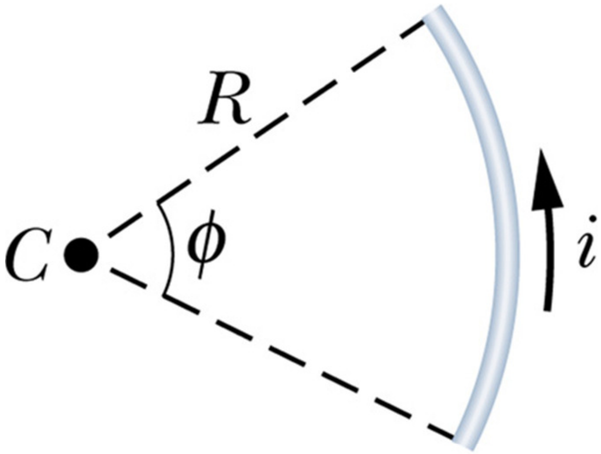
$$|B| = \frac{\mu_0 I}{2\pi r}$$

Right-hand rule for the magnetic field around a current-carrying wire: Point the thumb of your right hand in the direction of the current. Your fingers now curl around the wire in the direction of the magnetic field lines.

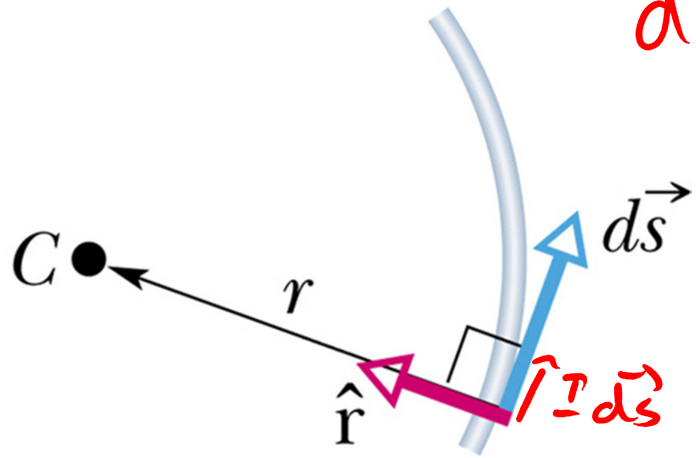


$$|B| = \frac{\mu_0 I}{2\pi r}$$


R
C
φ
i
(a)
C
r
r̂
ds
(b)
B
C
i
(c)



(a)



(b)

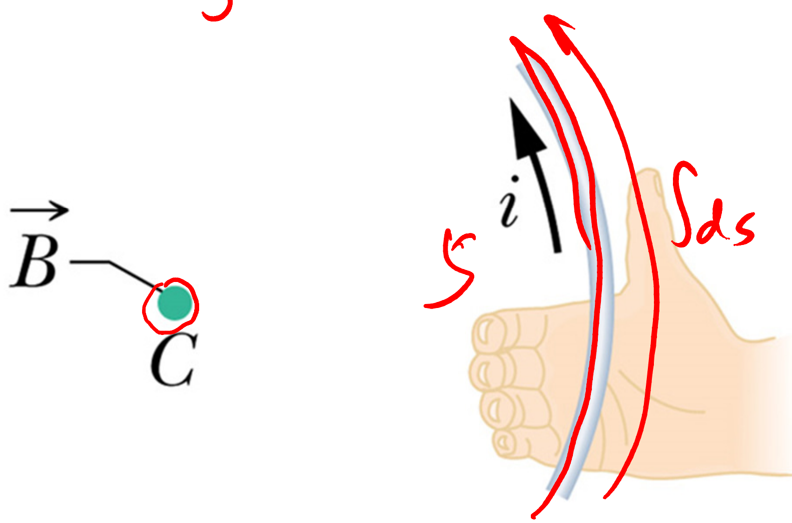
$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{l}\times\hat{r}}{r^2}$$

$d\vec{s}\times\hat{r}$

$|d\vec{s}|\sin 90°$

$$dB = \frac{\mu_0}{4\pi}\frac{I}{r^2}|ds|$$

$S = \phi R$



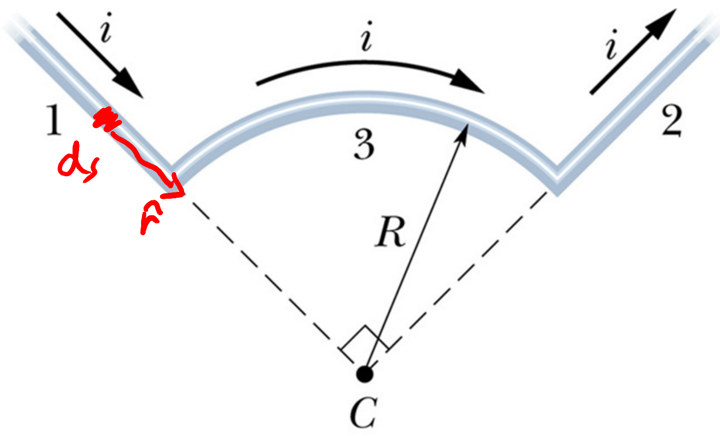
(c)

$$B = \int dB = \int \frac{\mu_0}{4\pi}\frac{I}{r^2}\,ds$$

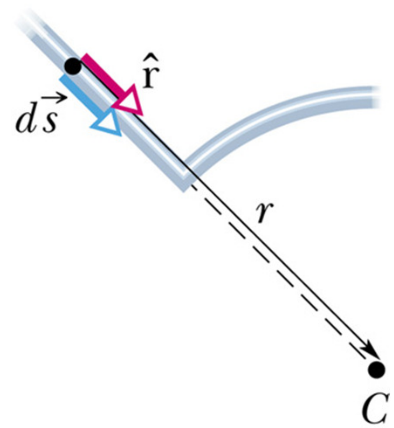
$$= \frac{\mu_0}{4\pi}\frac{I}{r^2}\int ds$$

$$= \frac{\mu_0}{4\pi}\frac{I}{r^2}S$$

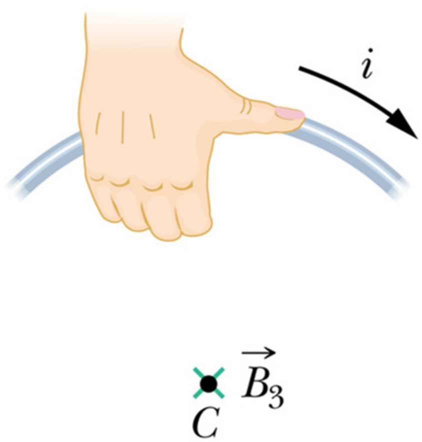
length of arc



(a)



(b)



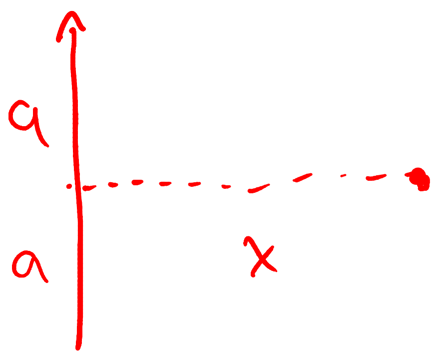
(c)

$I\, d\vec{s} \times \hat{r}$

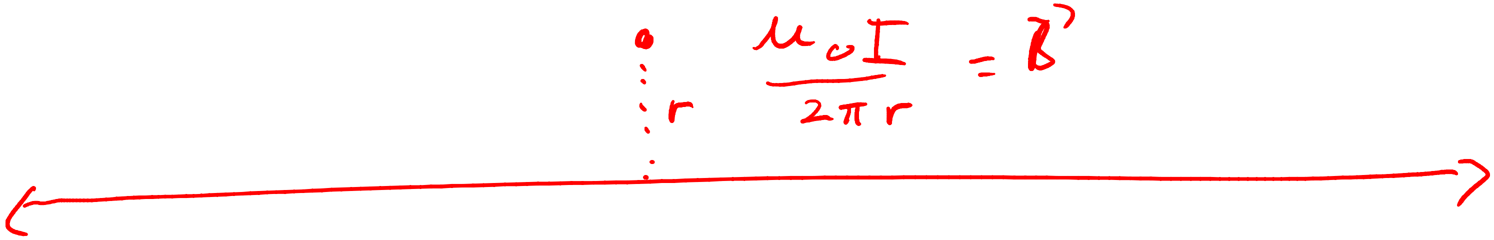
$B = \frac{\mu_0}{4\pi} \frac{I}{r^2} \cdot S$

Biot-Savart worksheet

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{I}{r^2} S \quad \text{where } S = \theta r$$



$$\vec{B} = \frac{\mu_0 I}{4\pi}\frac{2a}{x\sqrt{x^2+a^2}}$$



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