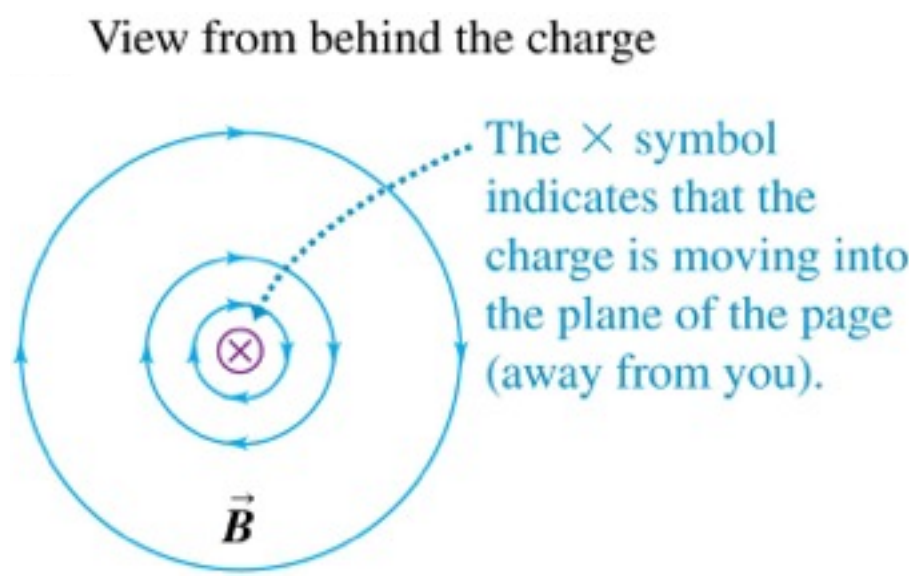
Lecture 30

PHYC 161 Fall 2016

The magnetic field of a moving charge

- A moving charge generates a magnetic field that depends on the velocity of the charge, and the distance from the charge.

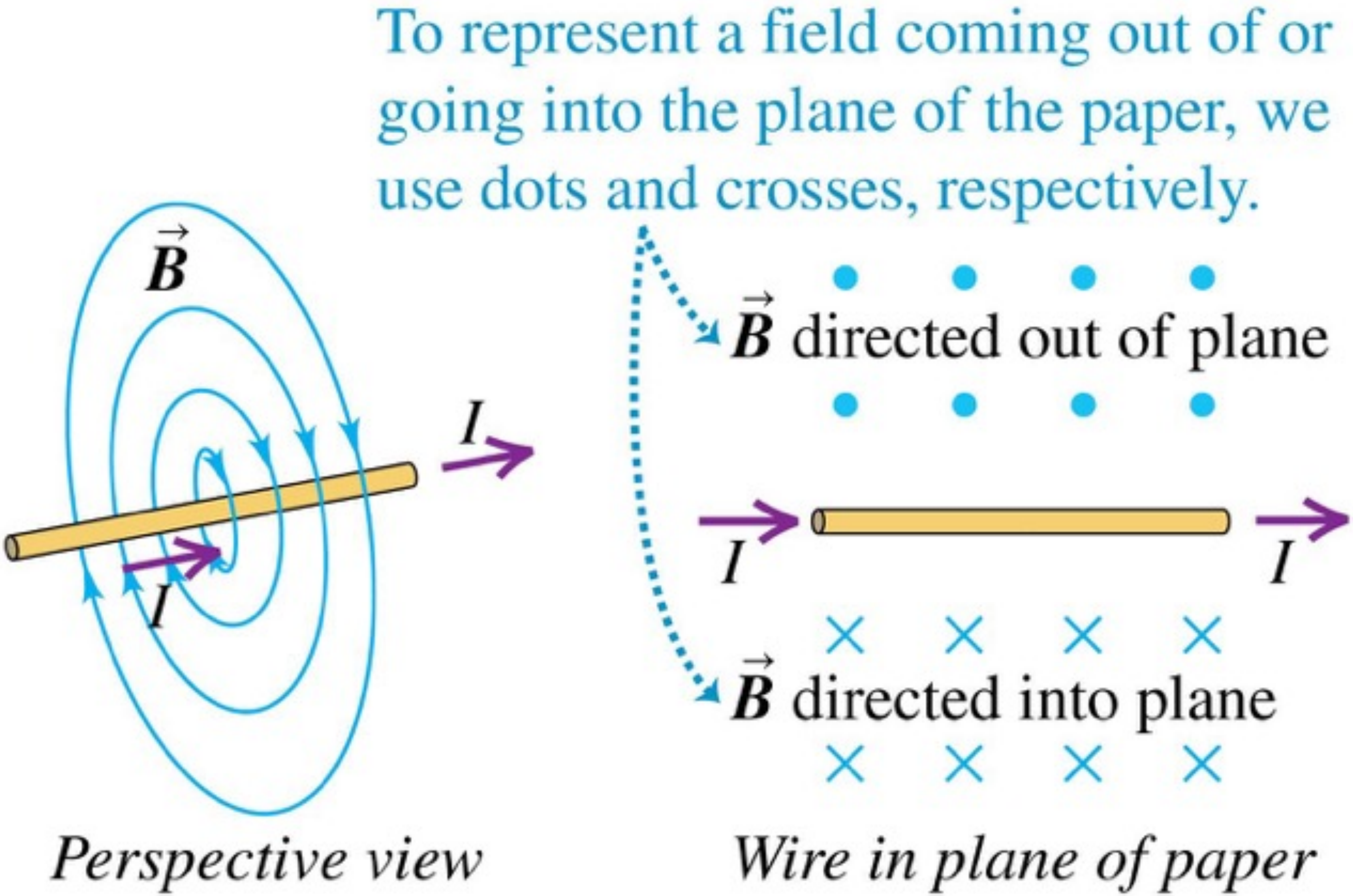


Magnetic field due to a point charge with constant velocity:

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

- μ_0: Magnetic constant
- q: Charge
- $\vec{v}$: Velocity
- $\hat{r}$: Unit vector from point charge toward where field is measured
- r: Distance from point charge to where field is measured

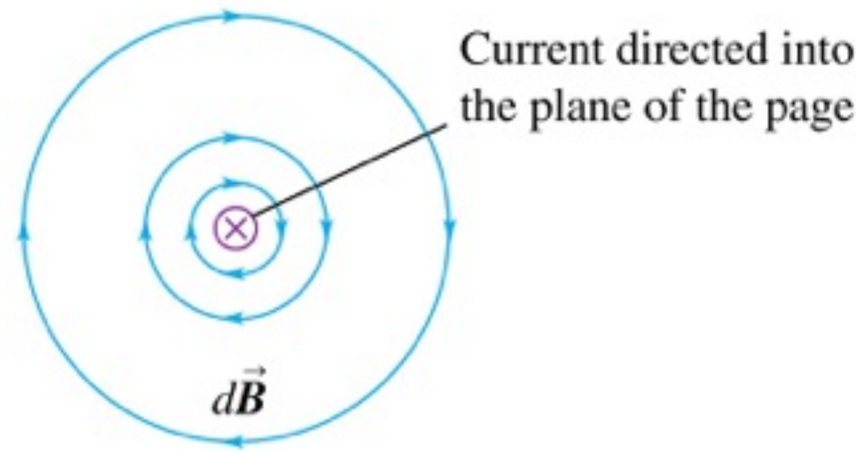
Magnetic field of a straight current-carrying wire

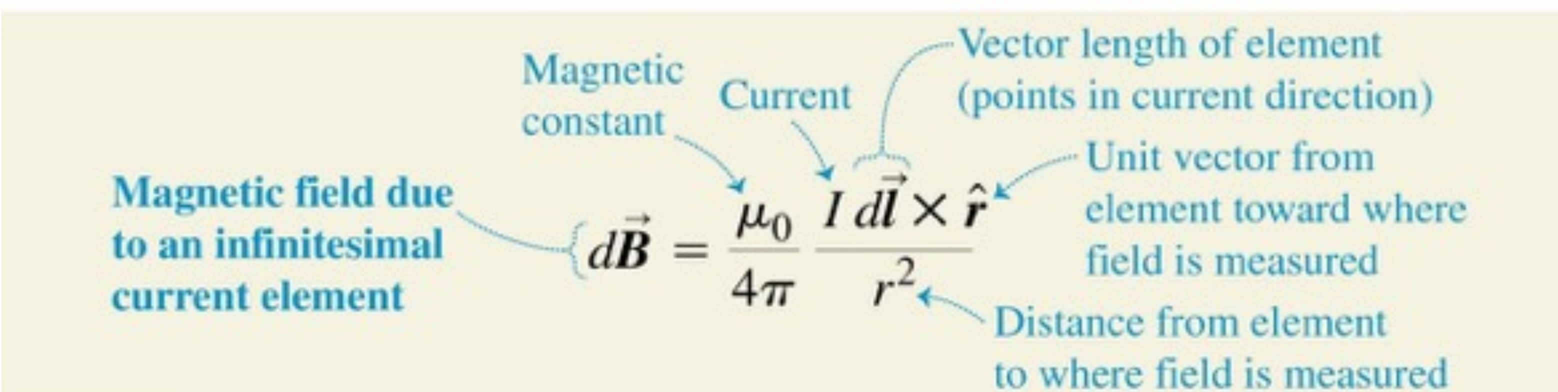


Magnetic field of a current element

- The total magnetic field of several moving charges is the vector sum of each field.
- The magnetic field caused by a short segment of a current-carrying conductor is found using the **law of Biot and Savart**:

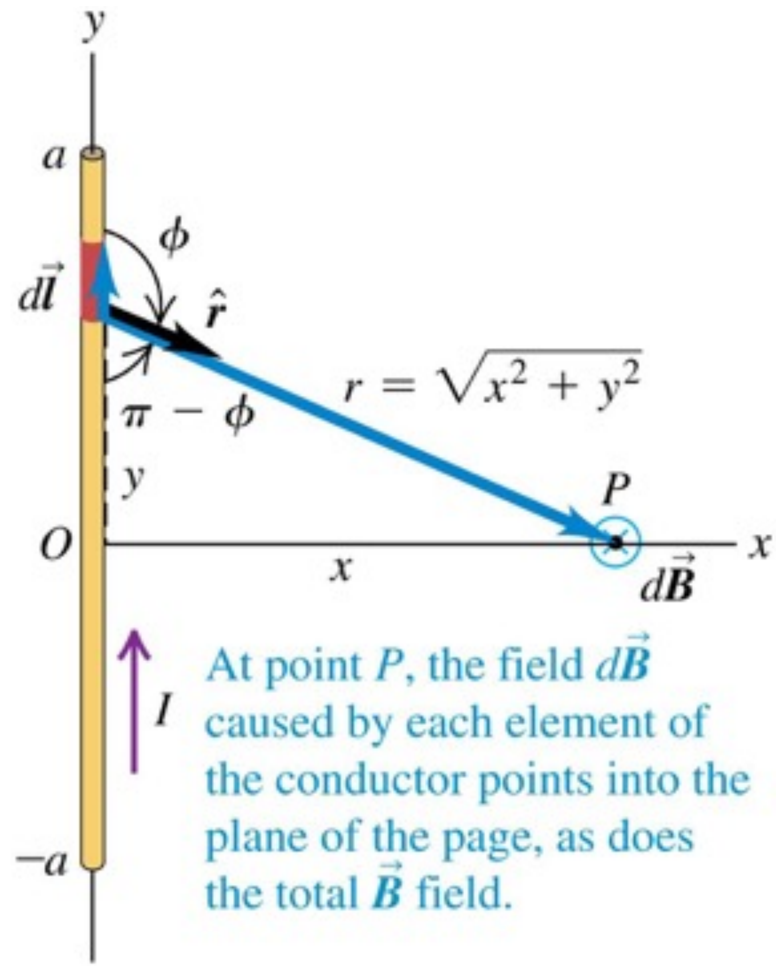
View along the axis of the current element





Magnetic field of a straight current-carrying conductor

- Let's use the law of Biot and Savart to find the magnetic field produced by a straight current-carrying conductor.
- The figure shows such a conductor with length $2a$ carrying a current I.
- We will find $\vec{B}$ at a point a distance x from the conductor on its perpendicular bisector.



Magnetic field of a straight current-carrying conductor

- Since the direction of the magnetic field from all parts of the wire is the same, we can integrate the magnitude of the magnetic field and obtain:

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

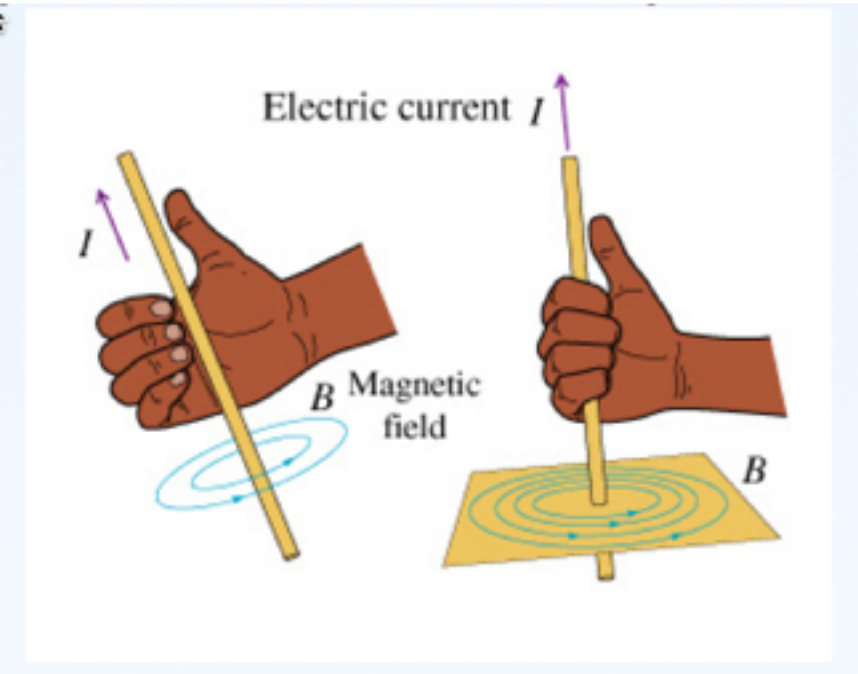
- As the length of the wire approaches infinity, $x >> a$, and the distance x may be replaced with r to indicate this is a radius of a circle centered on the conductor:

Magnetic field near a long, straight, current-carrying conductor → $B = \frac{\mu_0 I}{2\pi r}$

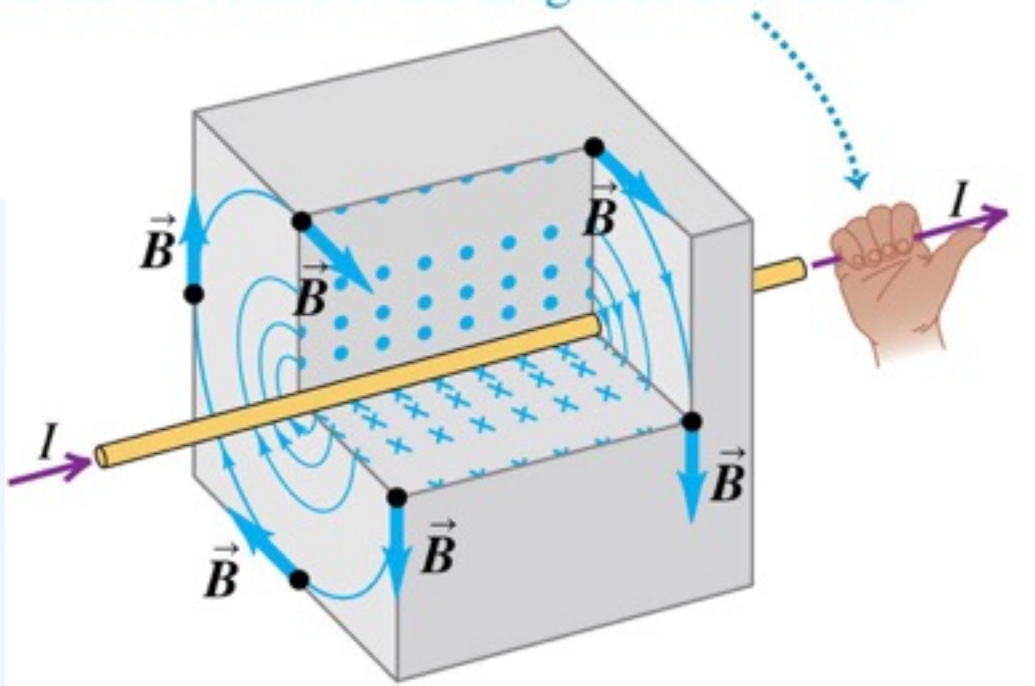
Magnetic constant (μ_0); Current (I); Distance from conductor (r)

Magnetic field of a straight current-carrying conductor

- The field lines around a long, straight, current-carrying conductor are circles, with directions determined by the right-hand rule.



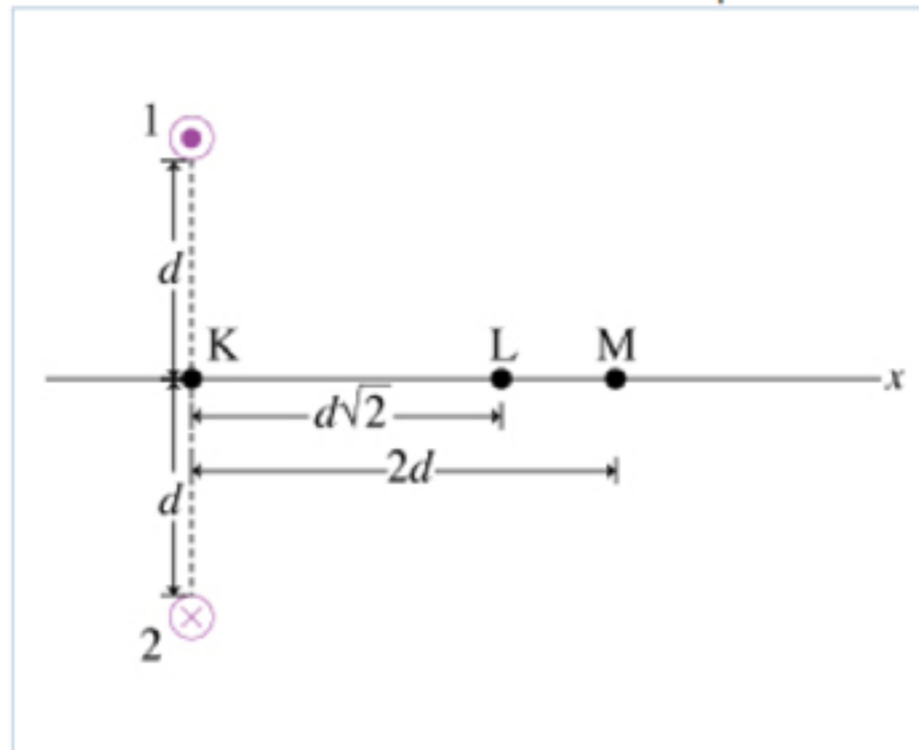
Right-hand rule for the magnetic field around a current-carrying wire: Point the thumb of your right hand in the direction of the current. Your fingers now curl around the wire in the direction of the magnetic field lines.



HW problem

In this problem, you will be asked to calculate the magnetic field due to a set of two wires with antiparallel currents as shown in the diagram . Each of the wires carries a current of magnitude I. The current in wire 1 is directed out of the page and that in wire 2 is directed into the page. The distance between the wires is $2d$. The *x* axis is perpendicular to the line connecting the wires and is equidistant from the wires.

As you answer the questions posed here, try to look for a pattern in your answers.



B-field at K, L, M:

(a) zero, ↑ , ↑

(b) ← , →, →

(c) → ,→ , →

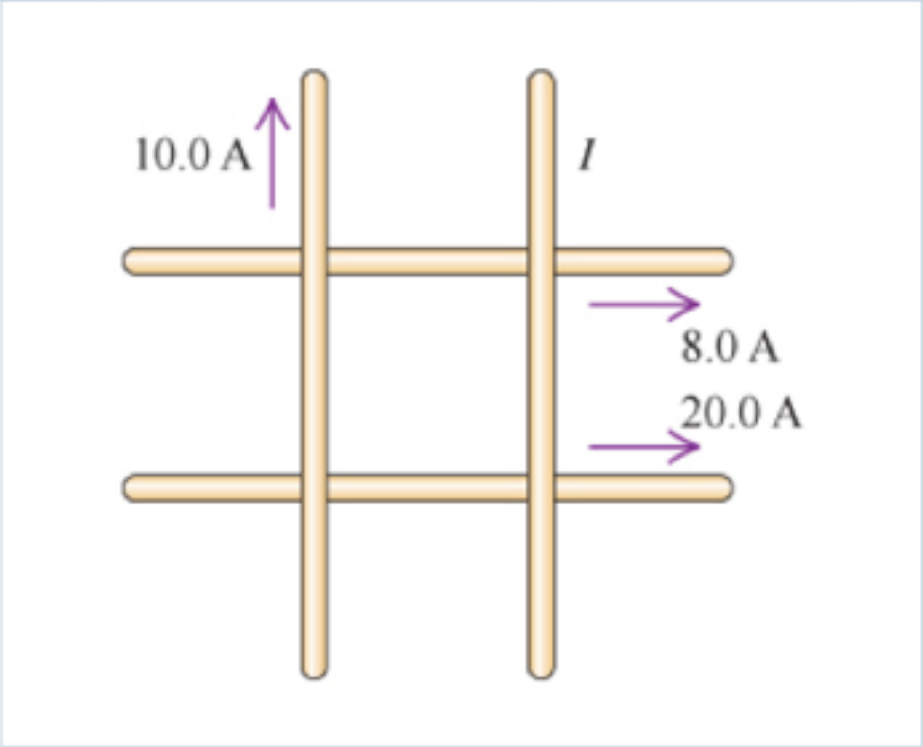
(d) zero , ↓ , ↓

(e) not enough info

± Canceling a Magnetic Field

Description: ± Includes Math Remediation. The student must find the current needed in a wire to cancel the magnetic field from three other wires at the center of a square. Each wire lies along one edge of the square.

Four very long, current-carrying wires in the same plane intersect to form a square with side lengths of 46.0 cm , as shown in the figure . The currents running through the wires are 8.0 A, 20.0 A, 10.0 A, and I.

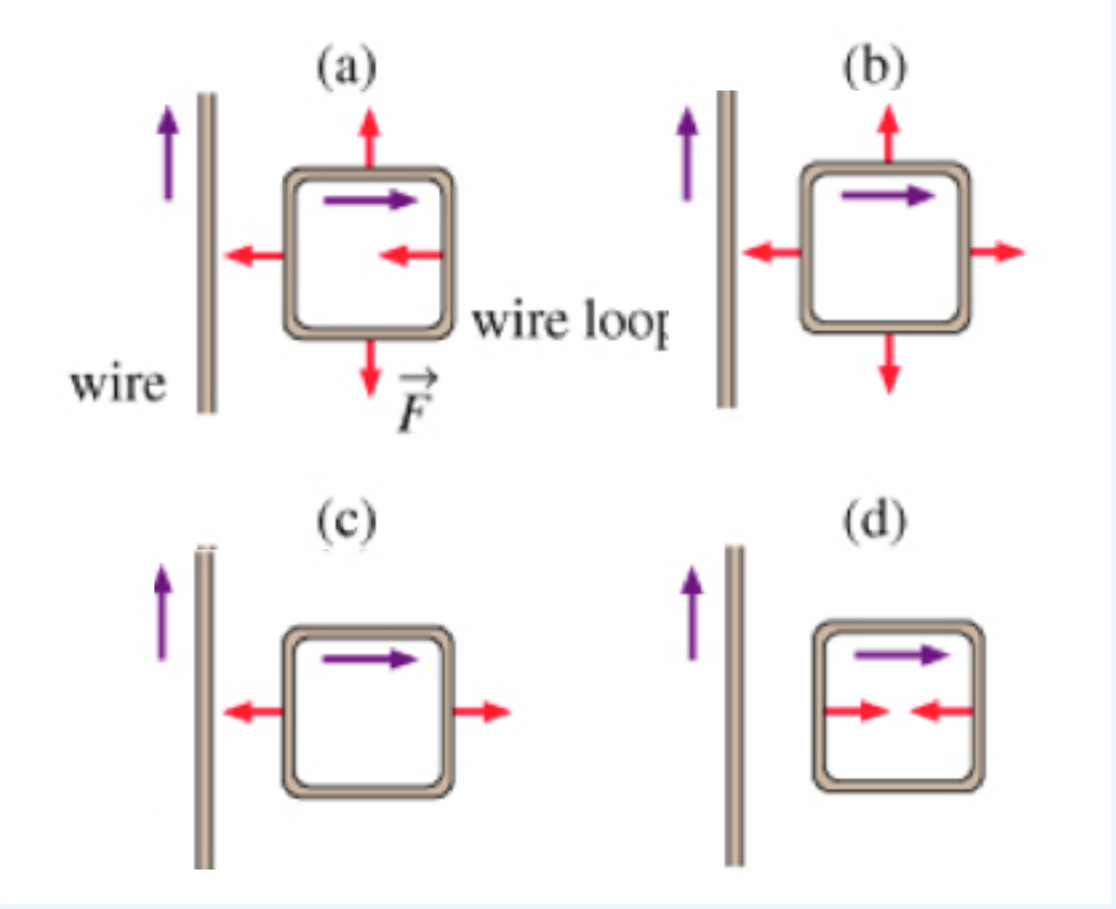


What current, I, will make field at center zero?

(a) I = 12 A, upward
(b) I = 2 A, upward
(c) I = 2 A, downward
(d) I = 22 A downward
(e) I = 12 A, downward

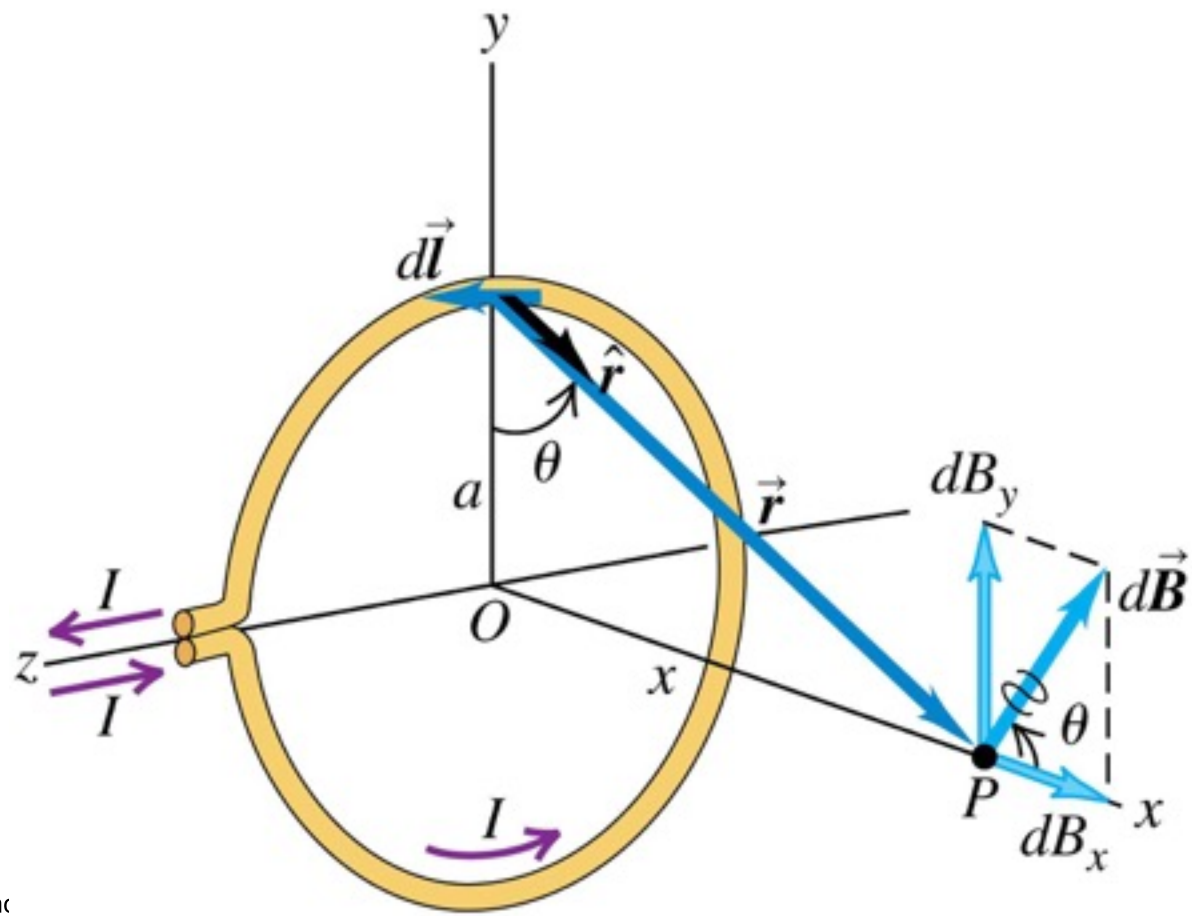
HW32

Which of the following diagrams correctly indicates the direction of the force on each individual line segment?



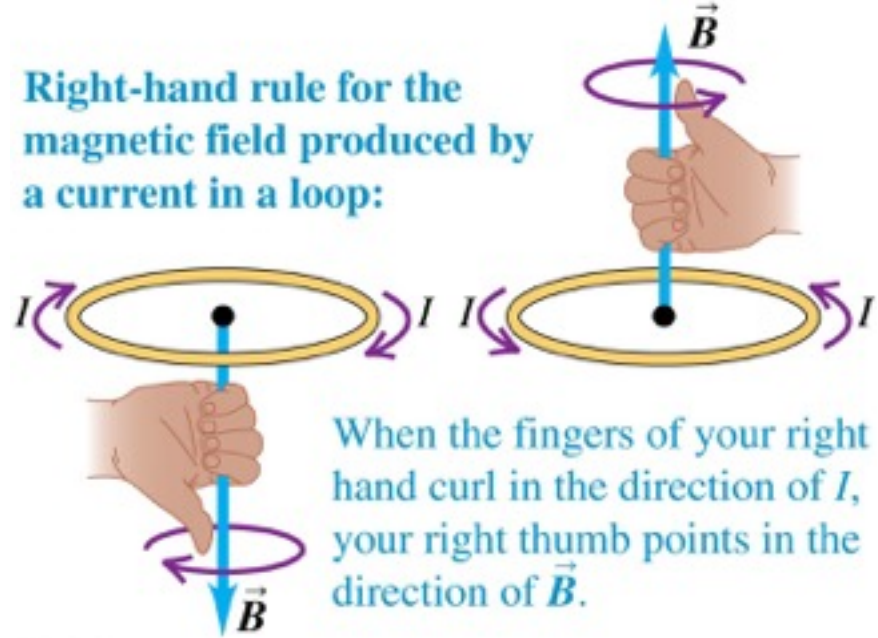
Magnetic field of a circular current loop

- Shown is a circular conductor with radius *a* carrying a counterclockwise current *I*.
- We wish to calculate the magnetic field on the axis of the loop.



Magnetic field of a circular current loop

- The magnetic field along the axis of a loop of radius *a* carrying a current *I* is given by the equation below.
- The direction is given by the right-hand rule shown.



Magnetic field on axis of a circular current-carrying loop

$$B_x = \frac{\mu_0 I a^2}{2(x^2 + a^2)^{3/2}}$$

Magnetic constant

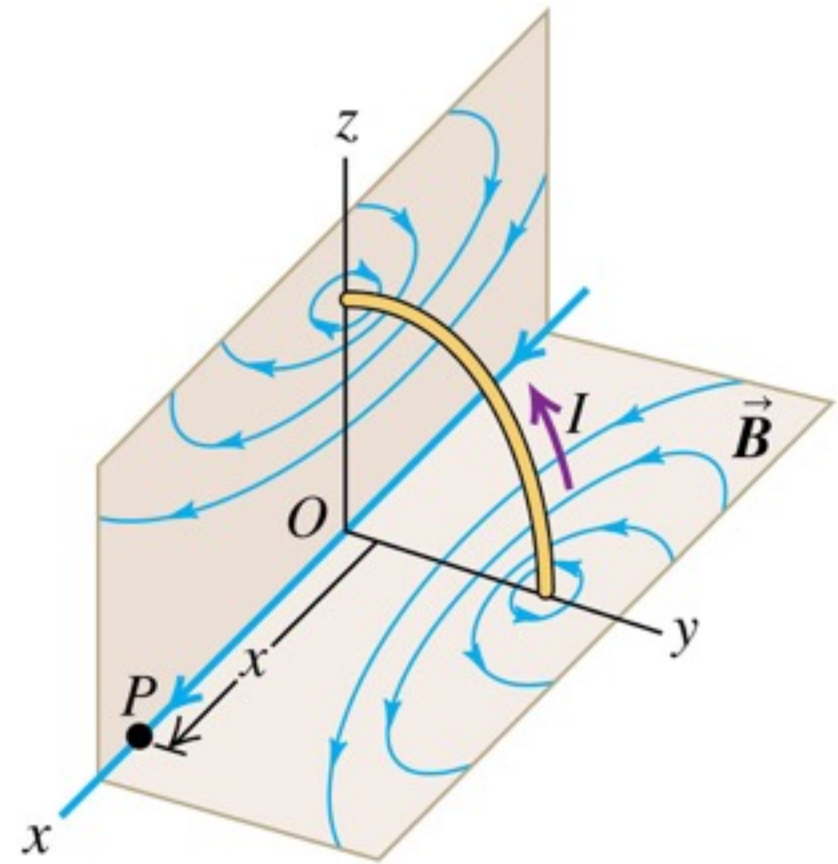
Current

Radius of loop

Distance along axis from center of loop to field point

Magnetic field lines of a circular current loop

- The figure shows some of the magnetic field lines surrounding a circular current loop (magnetic dipole) in planes through the axis.
- The field lines for the circular current loop are closed curves that encircle the conductor; they are not circles, however.

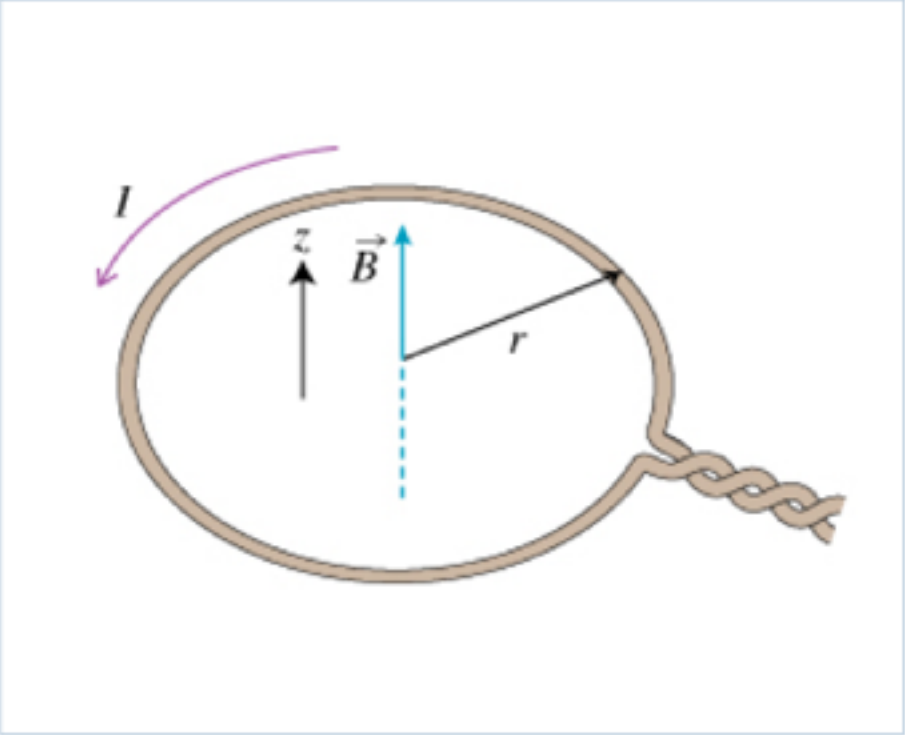


HW

Magnetic Field at the Center of a Wire Loop

Description: Use Biot-Savart law to find field at x = y = z = 0 of a one turn loop.

A piece of wire is bent to form a circle with radius r. It has a steady current I flowing through it in a counterclockwise direction as seen from the top (looking in the negative z direction).



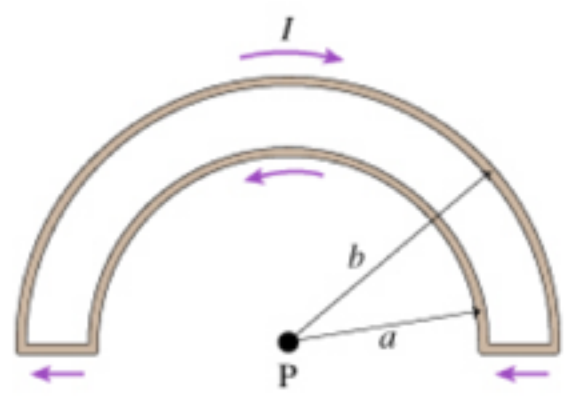
HW

Magnetic Field due to Semicircular Wires

Description: This problem establishes the magnetic field resulting from the current flowing in two, concentric, semicircular wires.

A loop of wire is in the shape of two concentric semicircles as shown.

The inner circle has radius a; the outer circle has radius b. A current I flows clockwise through the outer wire and counterclockwise through the inner wire.



Part A

What is the magnitude, B, of the magnetic field at the center of the semicircles?

Currents and planetary magnetism

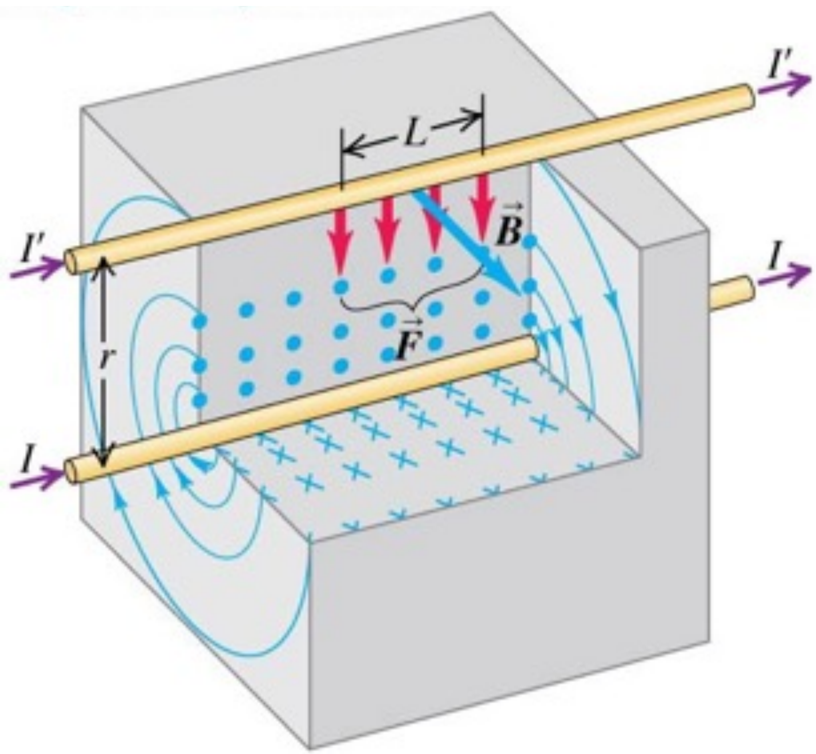
- The earth's magnetic field is caused by currents circulating within its molten, conducting interior.
- These currents are stirred by our planet's relatively rapid spin (one rotation per 24 hours).
- The moon's internal currents are much weaker; it is much smaller than the earth, has a predominantly solid interior, and spins slowly (one rotation per 27.3 days).
- Hence the moon's magnetic field is only about 10^{-4} as strong as that of the earth.

Magnetic fields of current-carrying wires

- Computer cables, or cables for audio-video equipment, create little or no magnetic field.
- This is because within each cable, closely spaced wires carry current in both directions along the length of the cable.
- The magnetic fields from these opposing currents cancel each other.

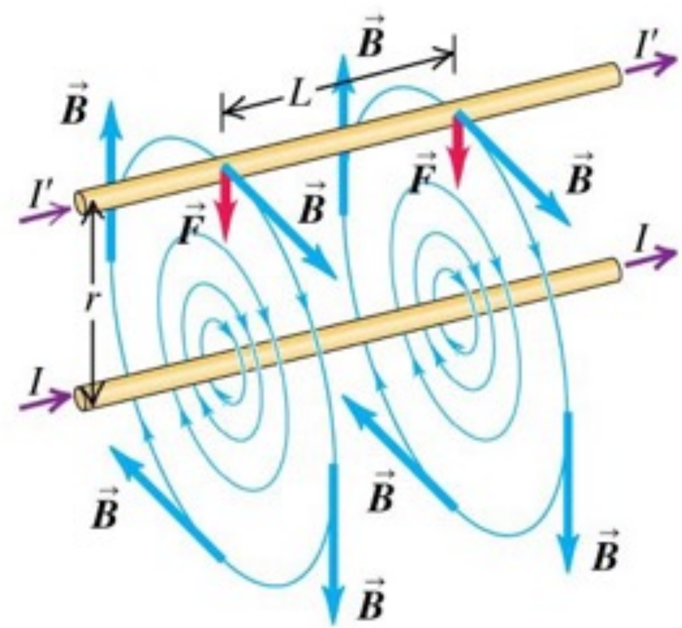
Force between parallel conductors

- The magnetic field of the lower wire exerts an *attractive* force on the upper wire.
- If the wires had currents in *opposite* directions, they would *repel* each other.



Force between parallel conductors

- The figure shows segments of two long, straight, parallel conductors separated by a distance r and carrying currents I and I' in the same direction.
- Each conductor lies in the magnetic field set up by the other, so each experiences a force.



Magnetic force per unit length between two long, parallel, current-carrying conductors

$$\frac{F}{L} = \frac{\mu_0 I I'}{2\pi r}$$

Magnetic constant (μ_0)
Current in first conductor (I)
Current in second conductor (I')
Distance between conductors (r)