MAGNETIC FORCES

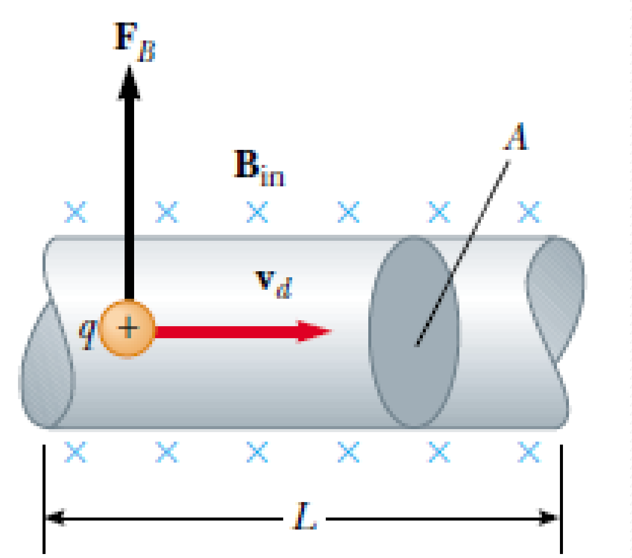
Magnetic Force Acting on a Current-Carrying Conductor

- A segment of a current-carrying wire in a magnetic field **B.**
- **The magnetic force** exerted on each charge making up the current is

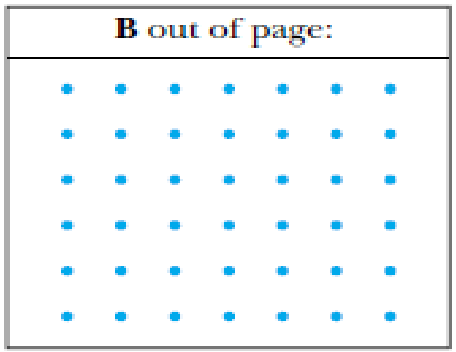
$$q\vec{v}_d \times \vec{B}$$

and the net force on the segment of length *L is*

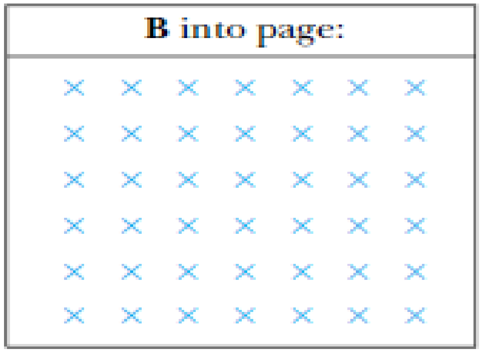
$$I\vec{L} \times \vec{B}$$



Magnetic Force Acting on a Current-Carrying Conductor



(a)



(b)

(a) Magnetic field lines coming out of the paper are indicated by dots, representing the tips of arrows coming outward.

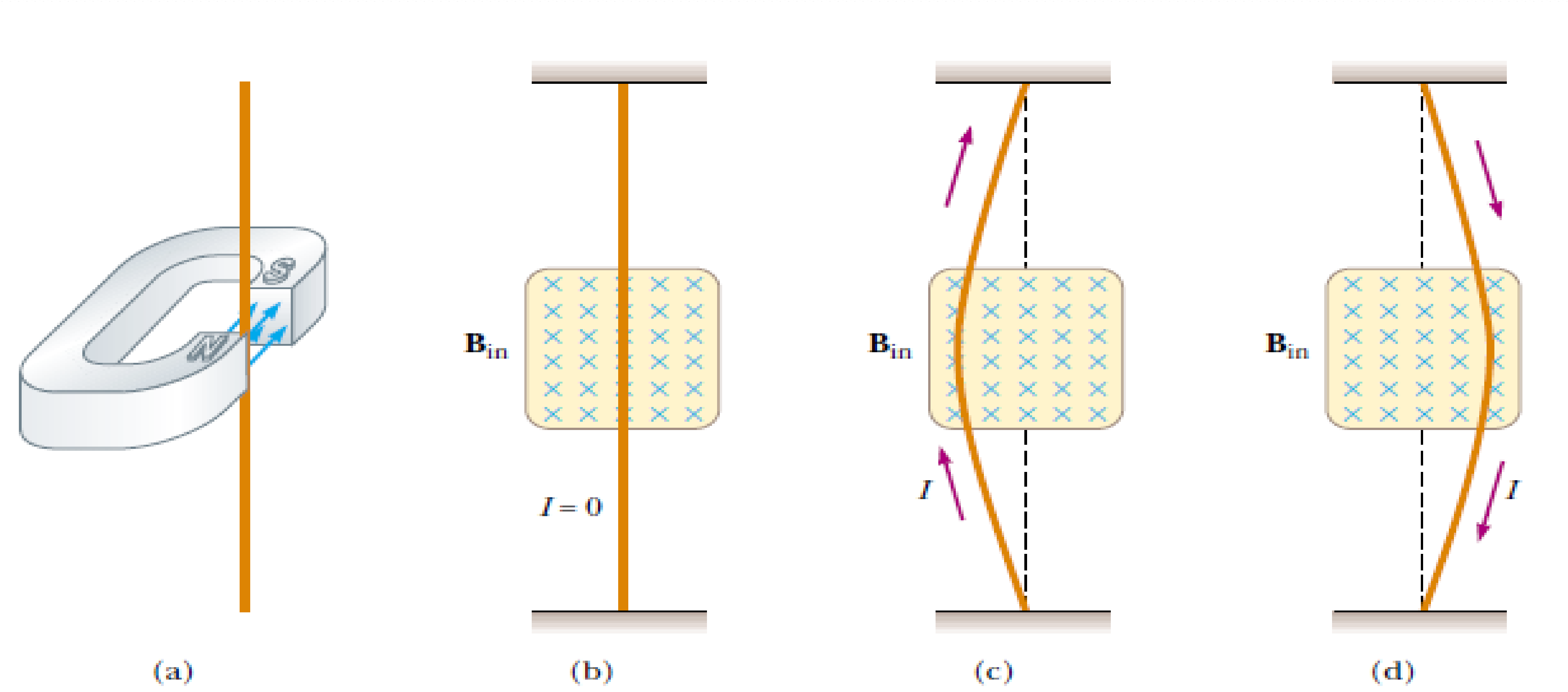
(b) Magnetic field lines going into the paper are indicated by crosses, representing the feathers of arrows going inward.

$$\vec{F}_B = (q\vec{V}_d \times \vec{B})nAL$$

where L is a vector that points in the direction of the current *I and has a magnitude* equal to the length *L of the segment*.

$$\vec{F}_B = I\vec{L} \times \vec{B}$$

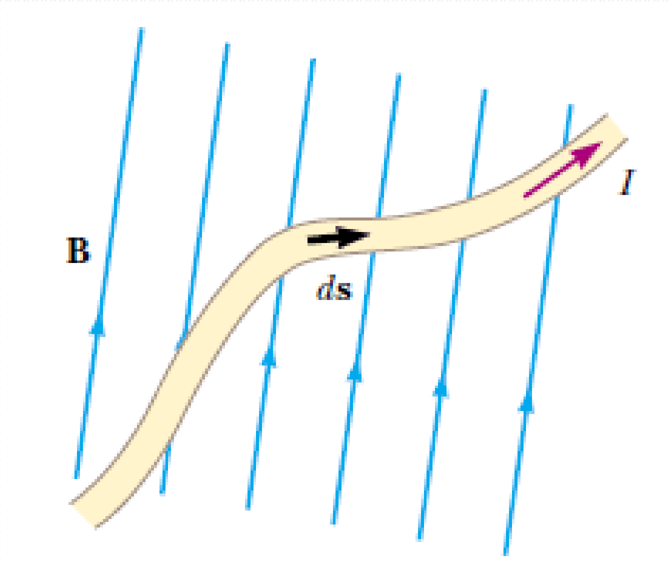
Magnetic For.ce Acting on a Current-Carrying Conductor,cont.



(a) A wire suspended vertically between the poles of a magnet.
the magnetic field (**blue crosses**) is directed into the page.
When(B) there is no current in the wire, it remains vertical.
(c) the current is upward, the wire deflects to the left.
(d) the current is downward, the wire deflects to the right.

Magnetic Force

A wire segment of arbitrary shape carrying a current *I*
in a magnetic field **B** experiences a magnetic force.
The magnetic force on any segment *ds* ***is***

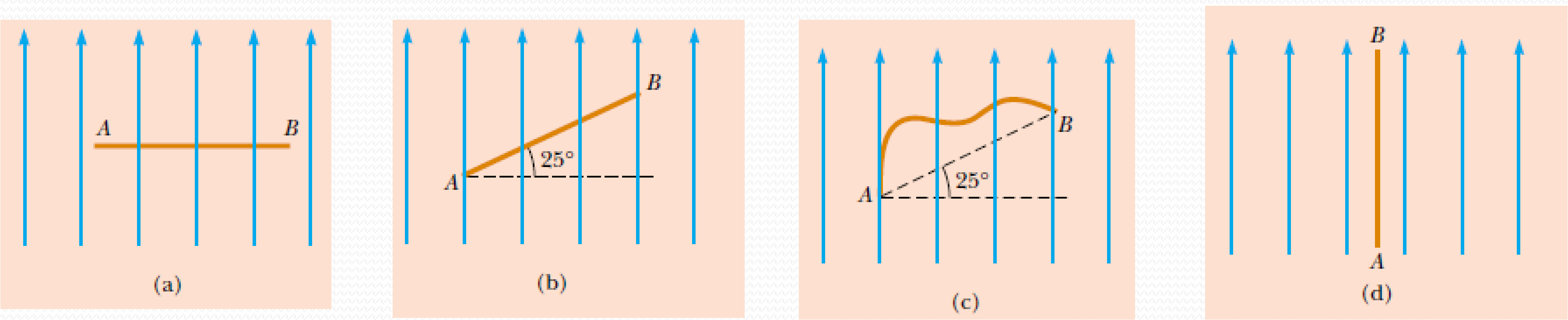


$$\vec{F}_B = I\vec{ds} \times \vec{B}$$

and is directed out of the page.
You should use the right-hand rule to confirm this force direction.

$$\vec{F}_B = I\int_a^b \vec{ds} \times \vec{B}$$

Which wire experiences the greatest magnetic force?



The four wires shown in the Figure . all carry the same current from point *A to point B through the same magnetic field*. *In all four parts of* the figure, the points *A and B are 10 cm apart.* *Rank the wires according to the magnitude* of the magnetic force exerted on them, from greatest to least.

Quick Quiz

A wire carries current in the plane of this paper toward the top of the page. The wire experiences a magnetic force toward the right edge of the page.

The direction of the magnetic field causing this force is

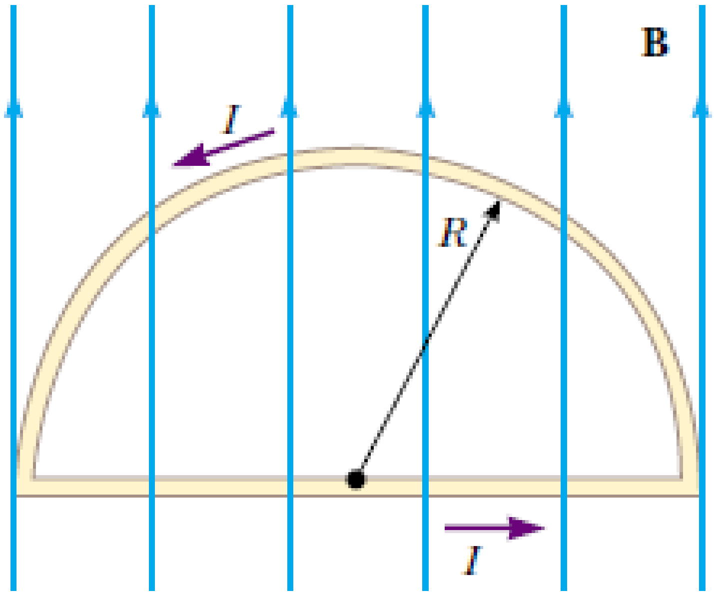
(a) in the plane of the page and toward the left edge,

(b) in the plane of the page and toward the bottom edge,

(c) upward out of the page,

(d) downward into the page.

Force on a Semicircular Conductor



A wire bent into a semicircle of radius *R* *forms a closed* circuit and carries a current *I. The wire lies in the xy* plane, and a uniform magnetic field is directed along the positive *y axis, as shown in the Figure.*

Find the magnitude and direction of the magnetic force acting on the straight portion of the wire and on the curved portion.

Solution

- The magnetic force on the straight portion of the loop is 2*IRB and directed out of the page, and* the magnetic force on the curved portion is 2*IRB directed into* the page.

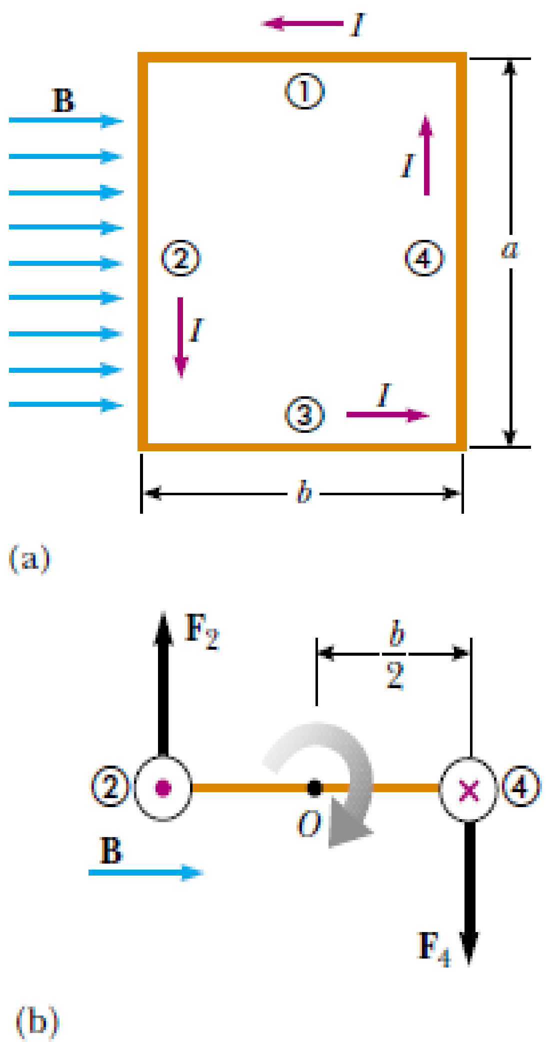
$$\vec{F}_1 = 2IRB\hat{k}$$

$$\vec{F}_2 = -2IRB\hat{k}$$

- The net magnetic force acting on a closed current loop in a uniform magnetic field is zero.

$$\sum \vec{F} = \vec{F}_1 + \vec{F}_2 = 2IRB\hat{k} - 2IRB\hat{k} = 0$$

Torque on a Current Loop in a Uniform Magnetic Field



Consider a rectangular loop carrying a current *I in the presence of a uniform magnetic* field directed parallel to the plane of the loop, as shown in Figure.

No magnetic forces act on sides 1 and 3 because these wires are parallel to the field;

L x B = 0 for these sides.

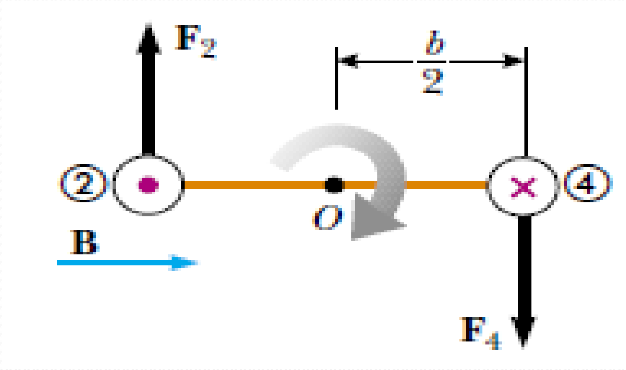
However, magnetic forces do act on sides 2 and 4 because these sides are oriented perpendicular to the field.

The magnitude of these forces is, from Equation :

I ***L*** x ***B*** = ***F*:** $F_2 = F_4 = IaB$

Torque on a Current Loop in a Uniform Magnetic Field,cont

If the loop is pivoted so that it can rotate about point *O, these two forces produce about O a torque that rotates the loop clockwise. The* magnitude of this torque max is



$$\tau_{\max} = F_2 \frac{b}{2} + F_4 \frac{b}{2} = (IaB)\frac{b}{2} + (IaB)\frac{b}{2} = IabB$$

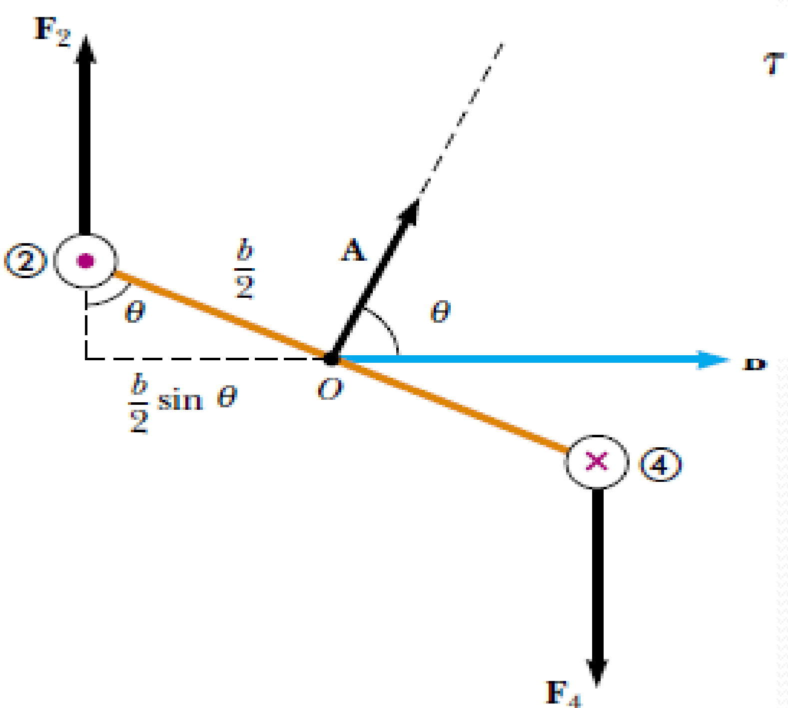
where the moment arm about *O is b/2 for each force. Because the area enclosed by the* loop is *A = ab, we can express the maximum torque as*

$$\tau_{\max} = IAB$$

Loop rotated through an angle with respect to the magnetic field.

An end view of the If **B is at an angle θ** with respect to vector **A, which is perpendicular to** the plane of the loop,

the torque τ is *I A B sin θ where* the magnitude of **A is *A, the area of the loop.***



$$\tau = F_2 \frac{b}{2} \sin\theta + F_4 \frac{b}{2} \sin\theta$$

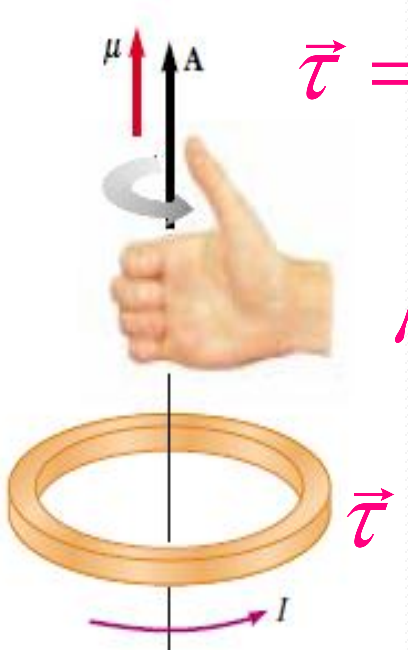
$$= IaB\left(\frac{b}{2}\sin\theta\right) + IaB\left(\frac{b}{2}\sin\theta\right) = IabB\sin\theta$$

$$= IAB\sin\theta$$

The direction of the magnetic moment

Right-hand rule for determining the direction of the vector **A.**

The direction of the magnetic moment " is the same as the direction of **A.**



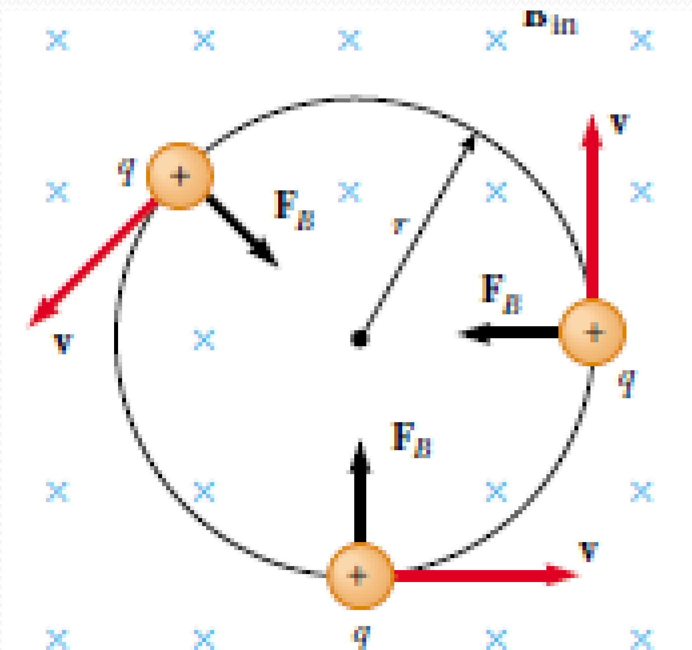
$$\vec{\tau} = I\vec{A}\times\vec{B}$$ τ :Torque on a current loop in a magnetic field

$$\vec{\mu} = I\vec{A}$$ μ :Magnetic dipole moment of a current loop

$$\vec{\tau} = \vec{\mu}\times\vec{B}$$ Torque on a magnetic moment in a magnetic field:

Motion of a Charged Particle in a Uniform Magnetic Field

When the velocity of a charged particle is perpendicular to a uniform magnetic field, the particle moves in a circular path in a plane perpendicular to **B. The magnetic** force **F*B acting on the charge is*** always directed toward the center of the circle.



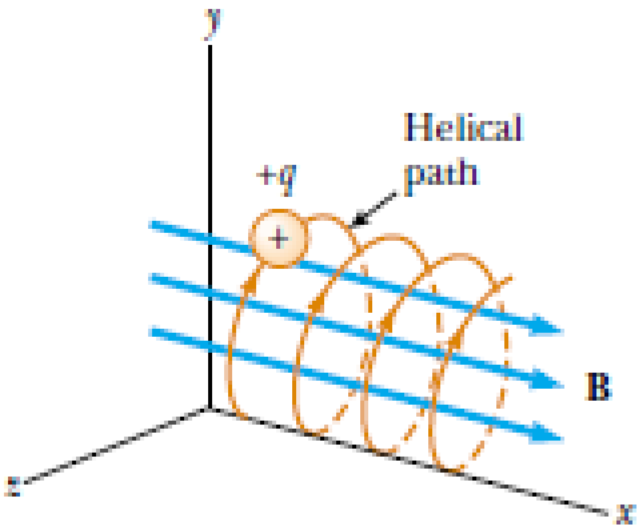
$$\sum \vec{F} = m\vec{a}_c$$

$$\vec{F}_B = qv\vec{B} = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB}$$

Motion of a Charged Particle in a Uniform Magnetic Field

A charged particle **having a velocity vector** that has a component parallel to a uniform magnetic field moves in a helical path



$$\omega = \frac{v}{r} = \frac{qB}{m}$$

$$T = \frac{2\pi r}{v} = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$$