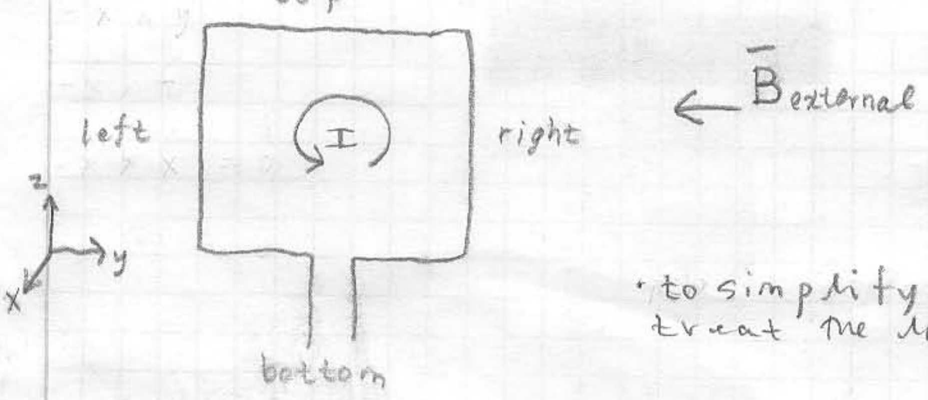
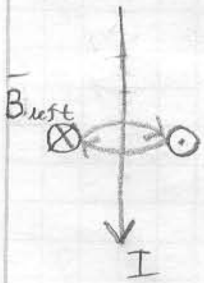
Right hand Rule

A square loop with an anticlockwise current is exposed to an external magnetic field. Determine the forces acting on each side of the loop & if there is a net force or net Torque.



• to simplify the problem we treat the loop as a closed square.

left:



curl fingers RH Rule (1)

Thumb
I along wire

Fingers curl in direction of:
magnetic field $\bar{B}$ induced by moving charges.

• This is the same for each side. The magnetic field close to the current carrying wire will be in the $-\hat{x}$ direction

When a current carrying wire is placed in an external magnetic field it will experience a force equal to the sum of the magnetic forces acting on it.

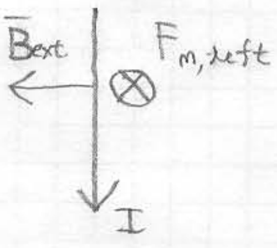
use 3-finger RH Rule (2) to determine the net magnetic force acting on the wire.

Thumb
magnetic force on wire

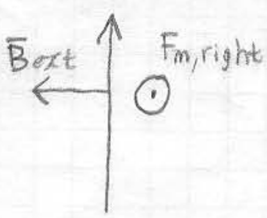
Forefinger
current I

Middle finger
External magnetic Field
(palm facing)

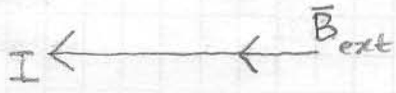
left:



right:



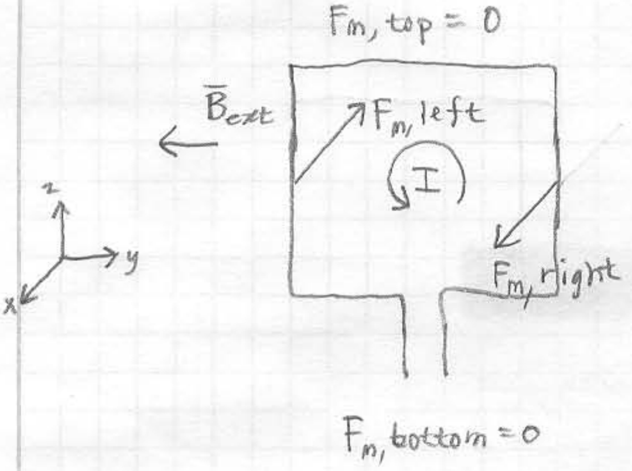
top:



Note: current is perpendicular to external $\bar{B}$ ∴ RH rule does not apply.

$F_{m,top} = F_{m,bottom} = 0$

Right Hand Rule



current thru the loop and $\bar{H}$ are constant $\therefore$

$$|F_{m,left}| = |F_{m,right}|$$

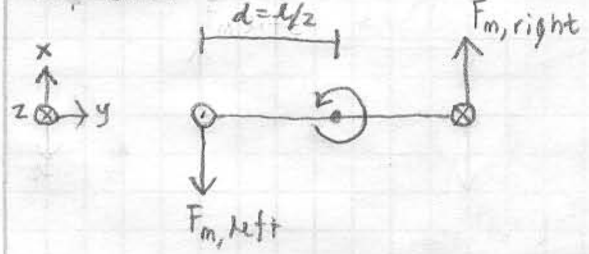
$$-F_{m,left} = F_{m,right}$$

$$F_{m,total} = F_{m,left} + F_{m,top} + F_{m,right} + F_{m,bottom}$$

$$= F_{m,left} + 0 - F_{m,left} + F_{m,bottom}$$

$$\underline{\underline{= 0}} \quad \text{(no net magnetic force)}$$

From the diagram above we can see that there will be a net torque on this loop that causes it to rotate in the anticlockwise direction when viewed from the bottom.



lets verify our answers by answers with some calculations

$$F_m = I \oint_c d\bar{l} \times \bar{B} \ (N) \ (5.10) \qquad l = \text{length of one side}$$

$$F_{m,left} = I \int_0^l \hat{x}\, dx + \hat{y}(0)\, dy - \hat{z}\, dz \times (-\hat{y} B_y)$$

$$= I(-\hat{z}\, l) \times (-\hat{y} B_y) = -\hat{x}\, I l B_y$$

$$F_{m,right} = I \int_0^l \hat{z}\, dz \times (-\hat{y} B_y) = \hat{x}\, I l B_y$$

Note: the direction of these unit vectors agrees with our RH rule.

$F_{m,top} = I(-\hat{y}l) \times (-\hat{y}B_y) = 0$

Note: Here we can see why the RH rule doesn't apply to the top and bottom sides.

$F_{m,bottom} = I(\hat{y}l) \times (-\hat{y}B_y) = 0$

$F_{m,total} = \sum |F_{m,side}| = -IlB_y + IlB_y + 0 + 0 = \underline{\underline{0}}$

$\bar{T} = \bar{d} \times \bar{F}_m \; (N\cdot m) \; (5.13)$ where $\bar{d} = l/2$ · called lever or moment arm

$\bar{T} = (\bar{d} \times \bar{F}_m)_{left} + (\bar{d} \times \bar{F}_m)_{right}$

$= (\bar{d}_{left} \times F_{m,left}) + (\bar{d}_{right} \times F_{m,right})$

$= ((-\hat{y}\, l/2) \times (-\hat{x}\, IlB_y)) + ((\hat{y}\, l/2) \times (\hat{x}\, IlB_y))$

$= (\hat{z}\frac{l}{2} IlB_y) + (\hat{z}\frac{l}{2} IlB_y)$

$= \hat{z}\, l^2 I B_y$ $\qquad l^2 = A$ (area of square loop)

$= \hat{z}\, A I B_y \quad (N\cdot m)$

Torque points in positive direction which corresponds to anticlockwise rotation (Ulaby pg. 211).

RH rule for torque

Thumb	Curl four fingers
Direction of torque	Indicates direction torque is trying to rotate.