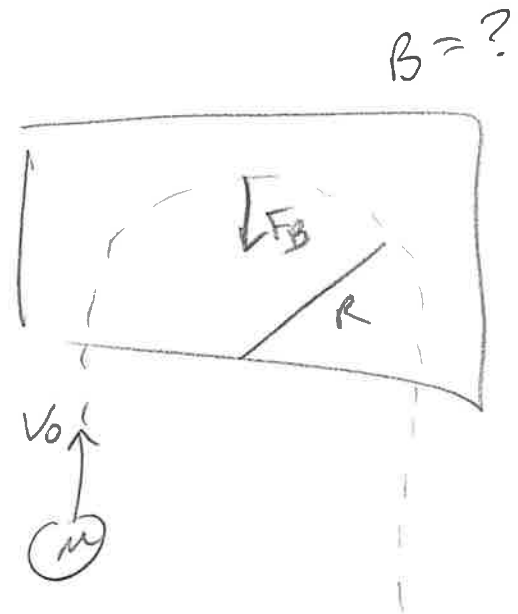
Warm Up



$q = -8.5 \mu C$

$m = 3.1 \times 10^{-12}$ kg

$v = 2.5$ km/s

$R = 0.05$ m

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

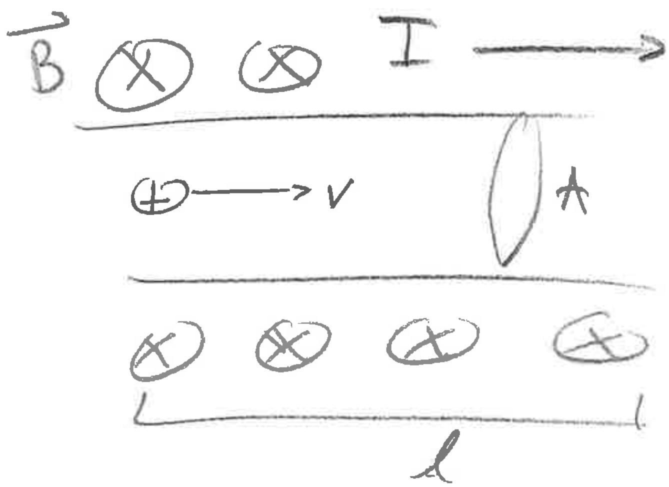
$$B = \frac{mv}{qR}$$

$$|\vec{B}| = 0.0182 T$$

Right hand rule gives into page

$$\boxed{\vec{B} = 18.2 \text{ mT into the page}}$$

Magnetic Force on a Current-Carrying Conductor



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

$|\vec{F}_B| = q v_d |\vec{B}|$ on one particle

For N particles:

$$|\vec{F}_B| = Nq v_d |\vec{B}|$$

$N = nV$ n - number density (particles/m^3)

V - volume of wire

$N = nAl$

$$|\vec{F}_B| = (nA\ell)\, q\, v_d\, |\vec{B}|$$

$$|\vec{F}_B| = \underbrace{nqAv_d}_{I}\, \ell\, |\vec{B}|$$

$$I = nqAv_d$$

$$|\vec{F}_B| = I\ell B$$

$$\boxed{\vec{F}_B = I\,\vec{\ell} \times \vec{B}}$$

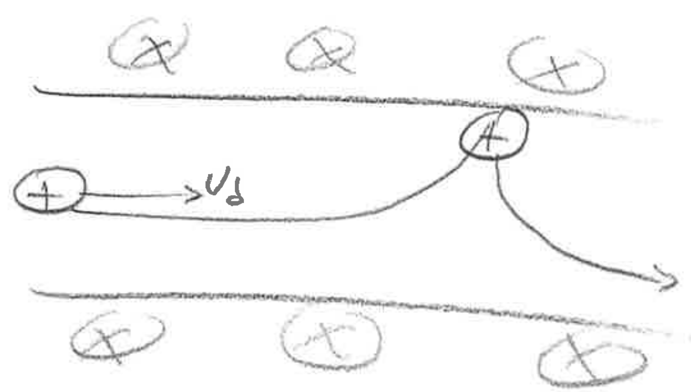
Magnetic force on a current carrying conductor

$\vec{\ell}$ points in the direction of current

$$\boxed{|\vec{F}_B| = I\ell B \sin\theta}$$

θ — angle between current and $\vec{B}$ field.

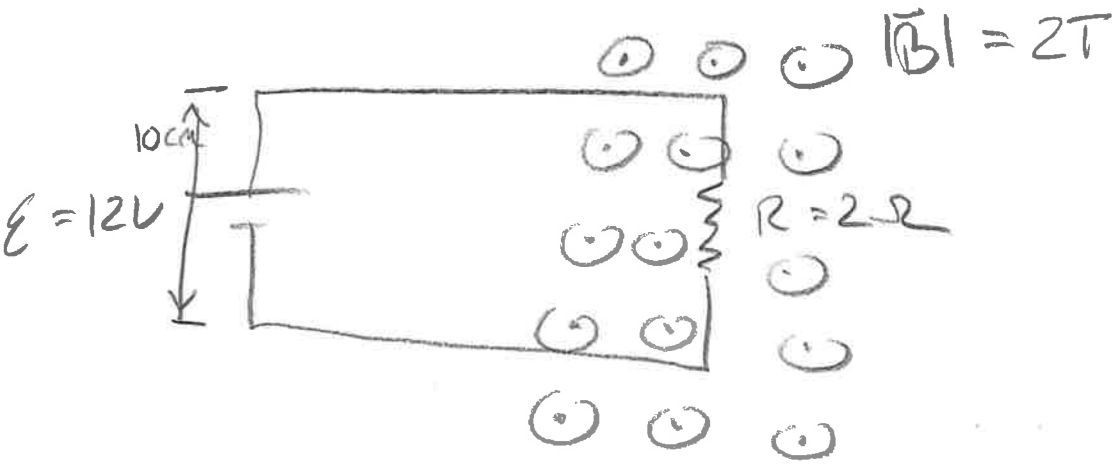
But can't $\vec{B}$ do no work?



- collides with wire boundary
- charge carriers do work!

Magnetic Force on a Current-Carrying Conductor problem!

Calculate the magnetic force on the right segment of the circuit below.



$V = IR$

$I = \frac{V}{R}$

$\vec{F} = I\vec{l} \times \vec{B}$

$F = IlB\sin\theta \qquad \sin\theta = 1$

$F = IlB \qquad F = \frac{V}{R} lB$

$l = 0.1m$

$V = 12V$

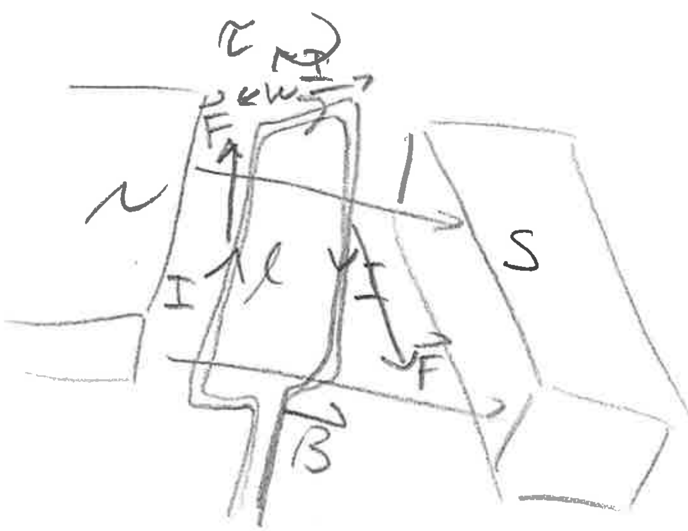
$R = 2\,\Omega$

$B = 2T$

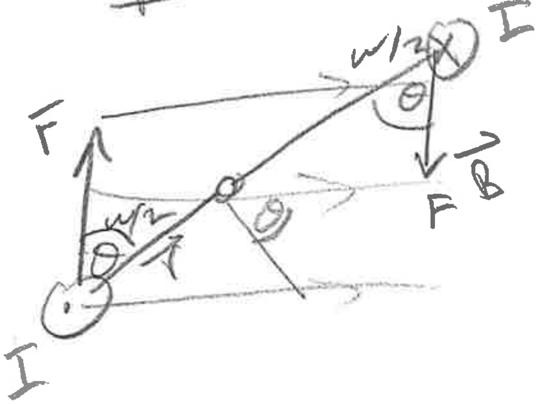
$$\boxed{\vec{F} = 1.2N \text{ left}}$$

Torque on a Current Loop

- Motors

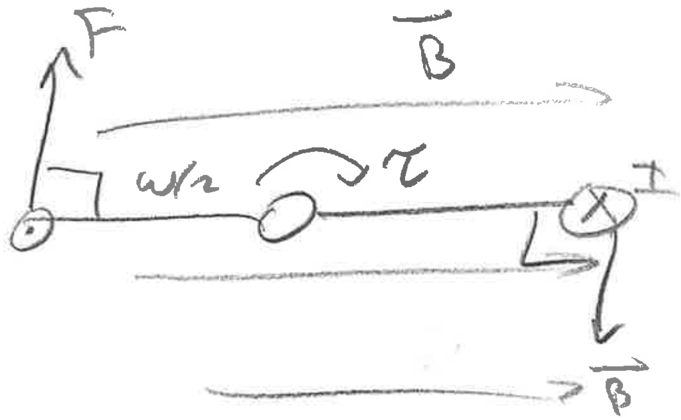


Top-down



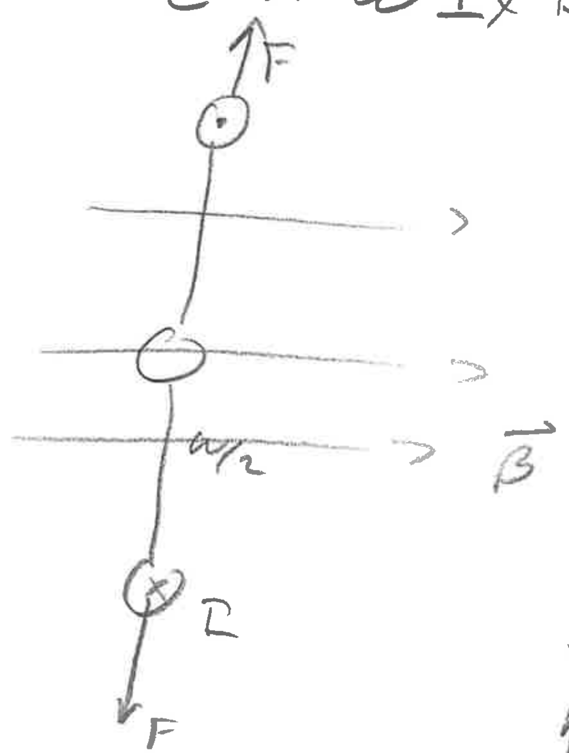
$$\tau = \frac{w}{2} F \sin\theta + \frac{w}{2} F \sin\theta$$

$$\tau = w F \sin\theta$$



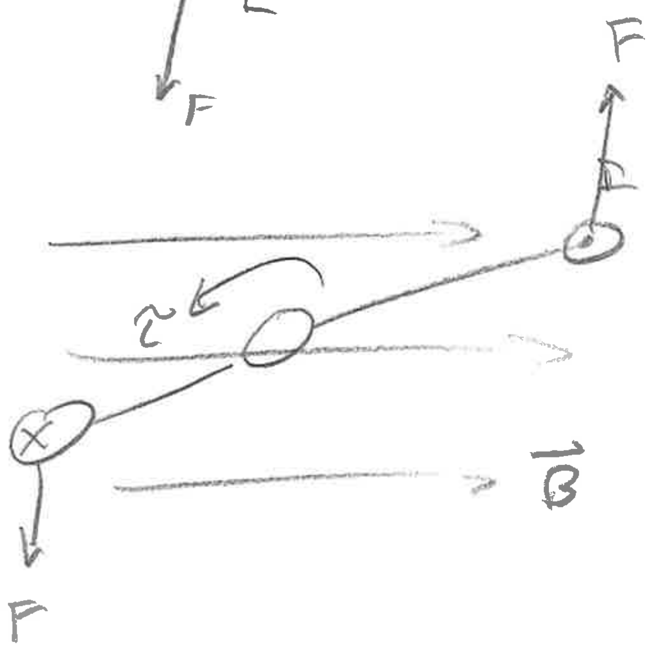
$\tau = w F \sin\theta$

$\tau = w I \ell B$ — Max Torque



$\tau = 0$

$(\sin\theta = 0)$.



τ now opposite direction

$\tau = -w I \ell B \sin\theta$

For N loops!

$$\tau = N I w l B \sin\theta$$

$$w \cdot l = \text{Area of loop}$$

$$\boxed{\tau = N I A B \sin\theta}$$

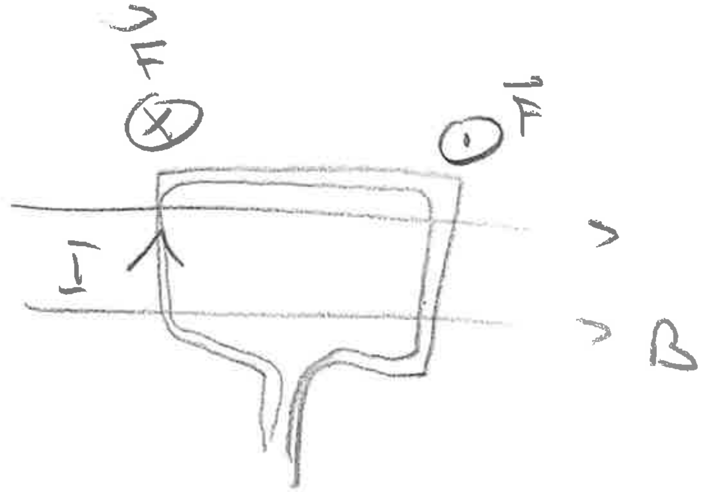
- With constant current, loop will rotate with positive but decreasing torque up until $\theta = 0$, then reverse signs.

- loop will oscillate about $\theta = 0°$.

- Motors use alternating current to keep the loop rotating.

Torque on Current Loop Example

Find the maximum torque on a 100-turn square loop of wire of 10 cm on a side that carries 15 A of current in a 2 T field.



$\tau = NIAB\sin\theta$

$\tau_{max} = NIAB$

$\tau_{max} = NI\ell^2 B$

$\boxed{\tau_{max} = 30\ m\cdot N}$

$N = 100$

$I = 15A$

$A = \ell^2$

$\ell = 0.1$

$B = 2T$