Lecture 23

22 OCT 2014

Magnetic fields

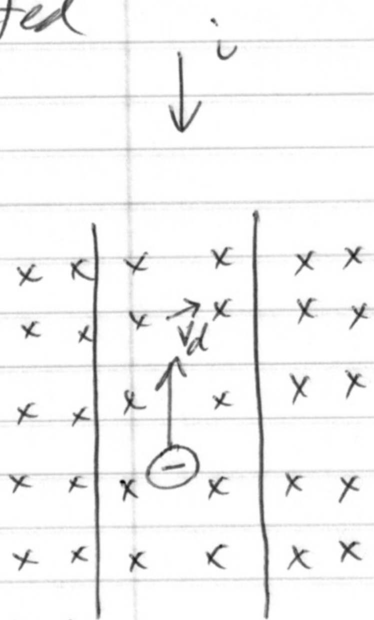
Lorentz force law:

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

force charge E-field velocity magnetic field

Hall effect – (named after Edwin Hall)

drifting conduction electrons in a copper wire are deflected by a magnetic field



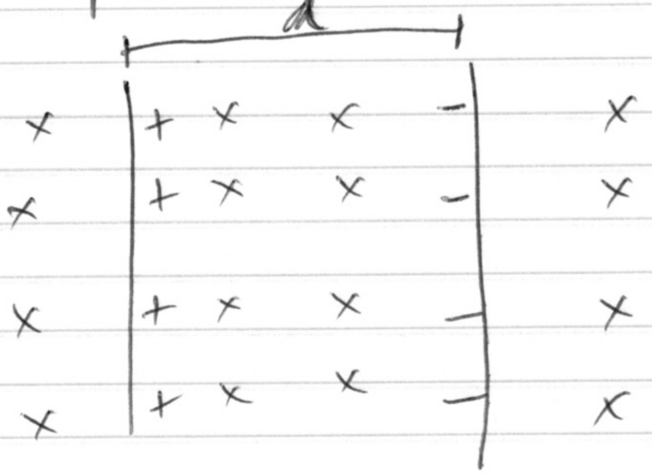
Imagine a copper wire:

- electrons moving at some
- drift velocity $\vec{v}_d$
- x's indicate magnetic field going into paper.

QUESTION: In which direction will the force on the electrons be?

to the right →

So as time goes on, electrons will move to the right & the picture becomes ↓

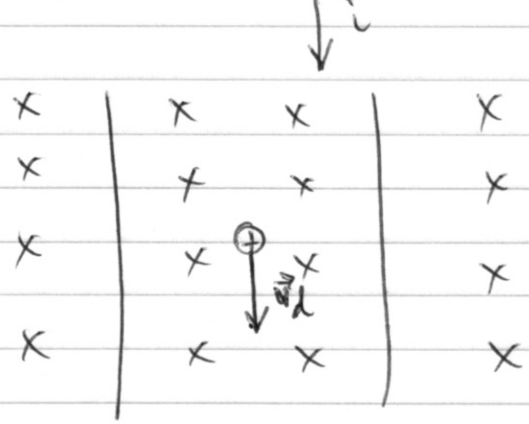


this then induces an E-field

which direction? $\xrightarrow{\vec{E}}$

What is the potential difference between the two ends of the wire? $V=Ed$

Now what if the charge carriers were in fact positive?
(but current in same direction)



Magnetic force will be to the right...

so positive charge carriers will drift to the right.

When electric & magnetic forces are equal, we get

$$eE = e v_d B$$

where v_d is drift speed

But can show that the drift speed is

$v_d = \frac{J}{ne}$ where J current density
& n is number density

(number density is # of charge carriers per unit volume)

using $J = \frac{i}{A}$, we get

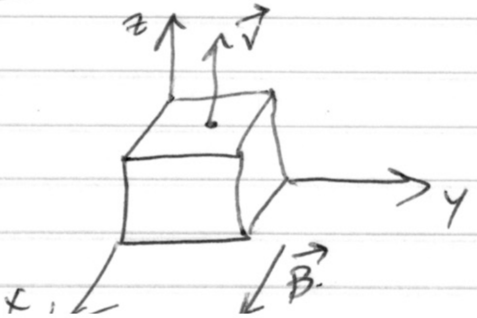
$$V_d = \frac{i}{neA}$$

$$\Rightarrow \quad E = \frac{i}{neA} B$$

$$\Rightarrow \quad \frac{V}{d} = \frac{i}{neA} B$$

$$\Rightarrow \quad n = \frac{iB}{Ve\left(\frac{A}{d}\right)}$$

QUESTION : Moving conductor

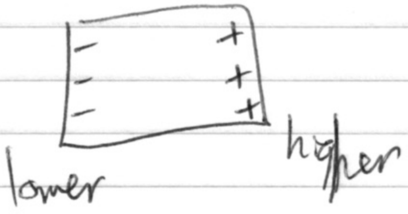


Which cube face is @ a higher potential & which one @ a lower potential?

positive changes move to the right

negative " " " " left

so we get



What is the potential difference between the faces?

$\vec{F}_B$ is $\longrightarrow$ $+$

$\vec{F}_E$ is $\longleftarrow$

After some time, equilibrium is reached & $F_B = F_E$

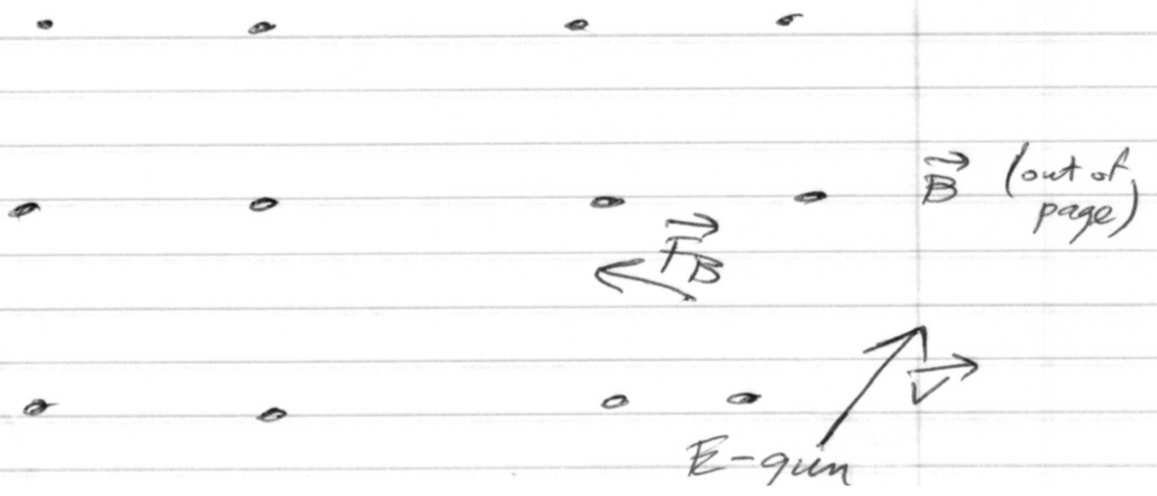
$$\Rightarrow \quad |q| B v \sin(90^\circ) = |q| E$$

$$= |q| \frac{V}{d}$$

$$\Rightarrow \quad dBv = V$$

Circulating charged particles

Given uniform magnetic field coming out of the page + electron gun which fires out an electron @ velocity $\vec{v}$



⑦

magnetic force $\vec{F}_B$ is perpendicular to the velocity $\vec{v}$, causing uniform circular motion

magnitude of magnetic force is

$$|q|vB$$

From Newton's 2nd law applied to uniform circular motion, we have

$$F = \frac{mv^2}{r}$$

giving $$|q|vB = \frac{mv^2}{r}$$

$$\Rightarrow \quad r = \frac{mv}{|q|B}$$

The period T of the motion is circumference divided by speed

$$T = \frac{2\pi r}{v} = \frac{2\pi}{v}\,\frac{mv}{|q|B} = \frac{2\pi m}{|q|B}$$

frequency is $f = \frac{1}{T} = \frac{|q|B}{2\pi m}$

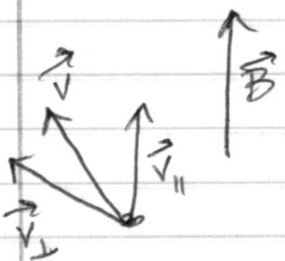
+ angular frequency $\omega =$

$2\pi f = \frac{|q|B}{m}$

period, frequency, + ω do not depend upon speed of particle.

Helical Paths

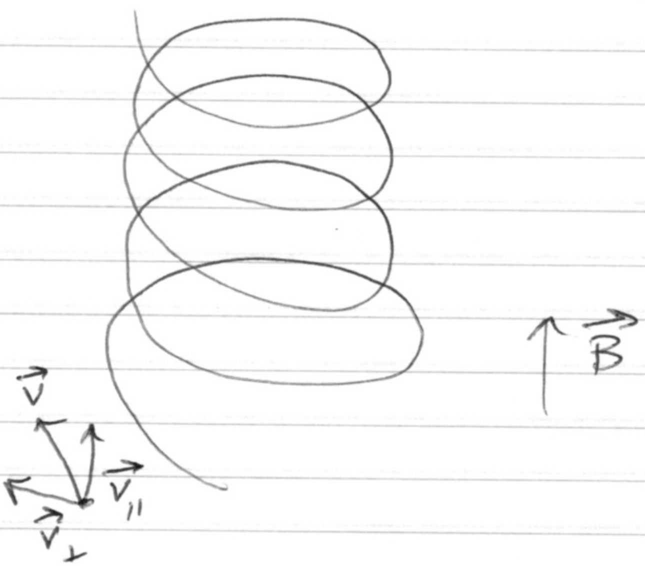
If velocity has a component parallel to B-field, then path will be helical.



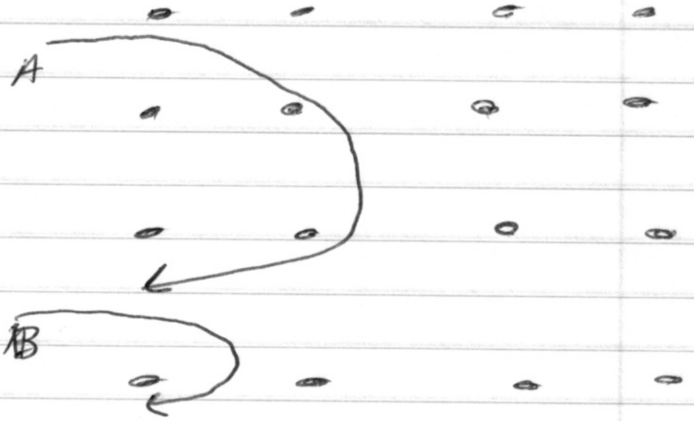
$\vec{v}_{\parallel}$ + $\vec{B}$ are aligned so no force from $\bar{B}$-field, but $\vec{v}_{\parallel}$ still causes it to move up

↖ $\vec{v}_{\perp} \perp \vec{B}$ cause uniform circular motion.

net effect is



QUESTION:



Two charged ions w/ constant velocity v enter a box in which B-field goes out of page. Paths are drawn.

What can you conclude?

a) Both ions are negatively charged

b) mass of A > mass of B

c) charge of A > charge of B

[✓ d)] None of the above

only know m/q