Phys 112 2019

Lecture 19

Mon: Warm Up 8

Tues: Discussion / quiz

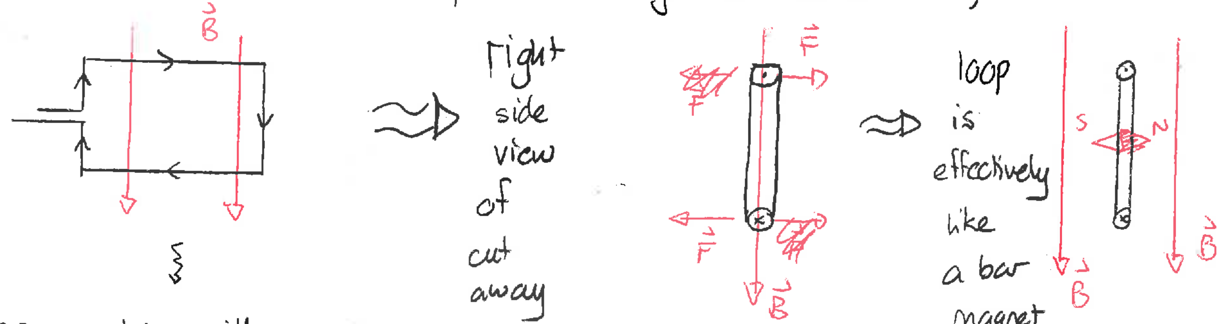
Supp Ex 71, 73, 74, 75

Ch 25 Q 5

Ch 25 Prob 2, 9, 10

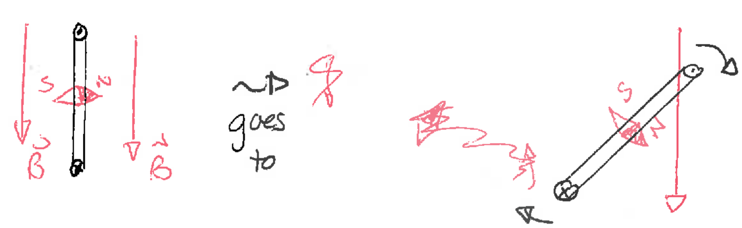
## Magnetic forces on dipoles

Magnetic fields exert forces on currents. When the basic laws for the force exerted by a field on a current are applied to a current loop one finds that the loop will sometimes rotate. We can describe this in terms of the effective field produced by the current loop




loop rotates with top coming out

The fact that the loop is like a bar magnet and has a north and south pole leads to the nomeclature that it is a dipole. We see that the forces cause the dipole to align with the field



Microscopic versions of such dipoles are ubiquitous in nature. Many atomic nuclei have such dipole properties. These include: H, $^{13}C$, .... When placed in an external magnetic field such dipoles can realign themselves. They can also be manipulated by time-varying magnetic fields. This is the idea behind nuclear magnetic resonance and magnetic resonance imaging

Demo: PhET NMR, MRI

1) Simplified ~~MRI~~ NMR

* adjust B to 1.4 T
* turn up power $f = 60Hz$ ⇝ H signal
  $^{13}C$ no signal

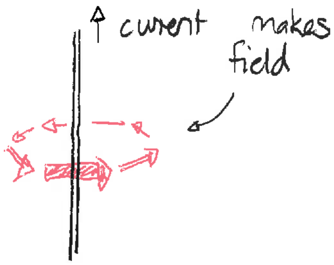
  $f = 15Hz$ ⇝ $^{13}C$ signal / H no signal

2) Simplified MRI

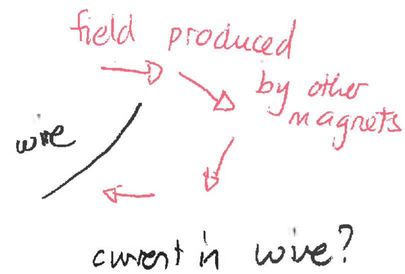
* Set B to 1.4 T, $f = 60Hz$
* No gradients ⇒ signals from everywhere
* Set " to max ⇒ adjust freq ⇒ signals come from different areas.
  ⇒ do s.t. signals come from tumor

# Currents produced by magnetic fields.

Every current produces a magnetic field. Does every magnetic field produce a current




so

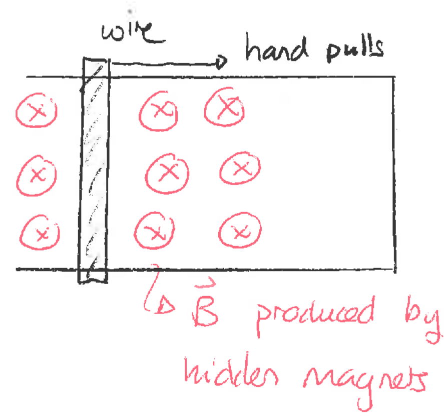



To answer this we will consider two distinct situations:

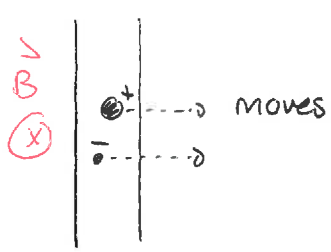
1) a wire moving through a magnetic field
2) a section of wire / loop in a magnetic field that changes with time

## Motional EMF

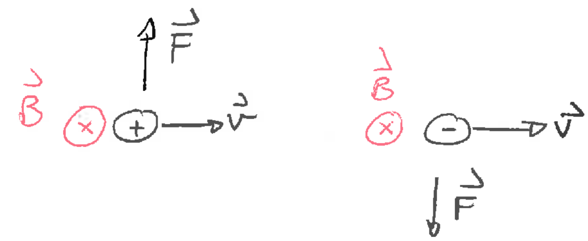
Consider a situation where a wire is in the presence of a magnetic field produced by hidden sources.




Then suppose that the wire is dragged by an external agent (e.g a hand). Then this will drag the positive and negative charges inside the wire through the field. The field can exert forces on such charges



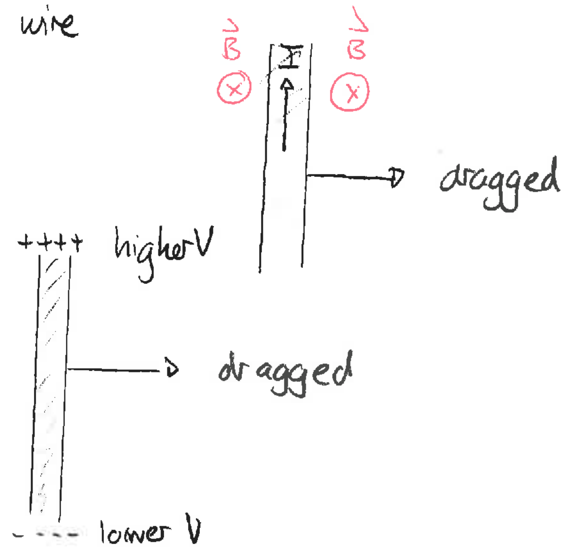
Quiz 1 30% - 70%




On either we can use the right hand rule and we observe that there will be a charge separation. This process produces

1) a current flowing through the wire

2) a charge separation that produces a potential. In this regard, a wire dragged through a magnetic field can function like a battery.




Demo: U Iowa Jump rope

Demo: Galvanometer + magnet → move ~~magne~~ coil near magnet.

These are examples of:

> When a wire is dragged through a magnetic field (not produced by the wire) then the magnetic field can produce
>
> * a current through the wire
> * a potential difference across the wire.

The potential difference that is produced in such situations is called an electromotive force EMF and is denoted $\mathcal{E}$. It has units of volts.

Quiz 2  50% — 70%

Quiz 3  10% – 80%

Demo: PhET generator – show coil in field

A relatively simple analysis shows (pg 881) that:

> If a wire with length L is dragged perpendicular to a uniform magnetic field $\vec{B}$ with speed v then the EMF induced by this is:
>
> $$\mathcal{E} \equiv \Delta V = vLB$$

Example: In some location Earth's magnetic field has magnitude $5.2 \times 10^{-5}$ T. A 2.5m long wire is dragged perpendicular to the field. At what speed must it be dragged to produce a 1.5V EMF.

Answer:

$$\mathcal{E} = vLB$$

$$1.5V = v \, 2.5m \times 5.2 \times 10^{-5} T$$

$$\Rightarrow v = \frac{1.5V}{2.5m \times 5.2 \times 10^{-5} T} = 11.5 \times 10^{3} m/s$$

(7.2 mi per second)