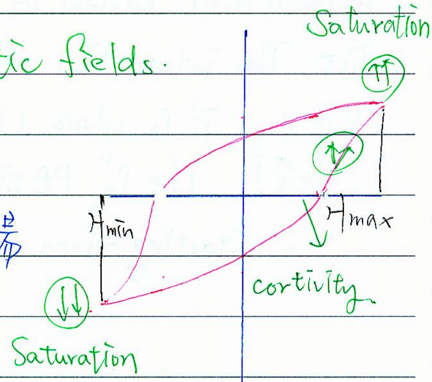
§ 6.4.2 Ferromagnetism 鐵磁

The magnetic domains under applied magnetic fields.



$B = \mu_0 (H + M)$

* Induced magnetization M 磁矩

& Saturated applied fields H 外加磁場

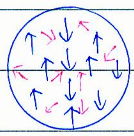
$U = -m_1 \cdot B_2 \leftrightarrow$ calculate the stability

$U = -m \cdot B$

Problem 6.21

max — H_{up} min — H_{down}

* Paramagnetism (順磁) 統計力學



For statistical analysis, it may be shown that the probability of finding any one atom having energy U due to orientation in the field is proportinal to the maxwell distribution at $k_B T$.

Domain of paramagnetic material in nature.

① $U = -\vec{m} \cdot \vec{B}$ potential energy

② probability $\sim e^{-\frac{U}{k_B T}}$

③ Where θ is the angle between $\vec{m}$ and $\vec{B}$, then $U = -mB\cos\theta$.

$\therefore$ The probability is $\boxed{e^{\frac{mB\cos\theta}{k_B T}}}$

From this, curie can calculate the average value of $m\cos\theta$.

$\langle m\cos\theta \rangle = \frac{4}{3}\frac{mB}{k_B T} \cdot m$, where $\frac{mB}{k_B T} \ll 1$.

The magnetization of a paramagnetic with N atoms per unit volume is $\boxed{\vec{M} = 4N\frac{m^2 B}{3k_B T}} \Leftrightarrow \boxed{\vec{M} = \chi_m \vec{H}} \sim \chi_m = \frac{4\mu_0 N m^2}{3k_B T}$ Curie Law

χ_m ↓ Suscoptibility

$\chi \sim \frac{1}{T}$ paramagnetism

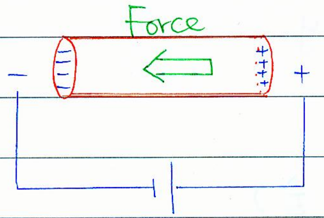
$\chi \sim \frac{1}{T-\theta}$ Antiferromagnetism

$\chi \sim \frac{1}{T+\theta}$ ferromagnetism

$\chi \sim \frac{1}{T \pm \theta}$ Curie Weiss Law

6/17 期末考

§ Electrodynamics [Microscopic View] date . . No. 18



When electric current in material is proportional to the voltage.

$I \sim V$ called as Ohm's Law

$f \equiv$ Force per unit charge $IR = V$ "macroscopic View"

* Into microscopic view

The current density defined as electric current per unit area $J = \frac{I}{A}$ can be expressed in terms of the electron density.

$$J \sim I \sim V \sim f \equiv \sigma f$$

static, steady, dynamics.

* Microscopic view

* The number of atoms per unit volume $n \equiv \frac{N_A \left(\frac{atoms}{mole}\right) \cdot \rho' \left(\frac{kg}{m^3}\right)}{A \left(\frac{kg}{mole}\right)}$, $\rho' \equiv$ 密度 $= D$

* Ohm's law, $I = \frac{V}{R} = \frac{\text{Voltage}}{\text{resistance}}$, $R = \frac{\rho L}{A}$,

電阻 $\rho \equiv$ resistivity 電阻率

Then the current density is $J = \frac{V}{R}/A = \frac{V}{\frac{\rho L}{A} \cdot A} = \frac{EL}{\rho L} = \frac{E}{\rho}$.

$\Longleftrightarrow JA = I = \sigma EA$

* The current density is proportional to the E & $\frac{1}{\rho}$.

Then define a conductivity $\sigma \equiv \frac{1}{\rho}$ 電導率

$\rho \rightsquigarrow 0$, $\sigma \to \infty \Rightarrow$ Superconductivity

5/27 小考: 6.2 ~ Ch6 End.

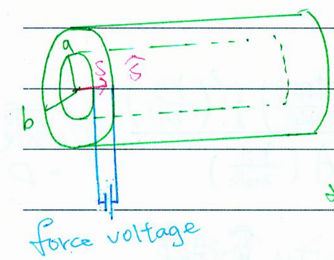
§ 7.1.1 Ohm's Law

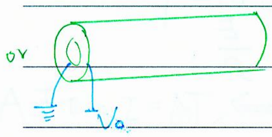
* If force on change will fast/slow velocity.
  So the current density J is $\sim \sigma E$.
* From the Lorentz force $F = q(v \times B + E)$
  Force per unit charge $f = \frac{F}{q} = (\vec{v} \times \vec{B} + \vec{E})$
* Then the current density $J = \sigma \vec{E} = \sigma f$. (7.1) $\boxed{R+C}$
* If we consider the electrodynamic of electron/magnetic force,
  then $J = \sigma(\boxed{\vec{v} \times \vec{B}} + \vec{E})$. (7.2) $\boxed{R+C} + L$

steady $= \frac{\Delta Q}{\Delta T} = I$ ⇘ Static State $I = \frac{Q}{T}$

$\boxed{\text{Ex 7.2}}$ Two long cylinders (radius a & b) are separated by material of conductivity σ. If they are maintained at a potential difference V, what current flows from one to the other in a Length L.

電位差





* The Electric field between a and b cylinder is $E = \frac{\lambda}{2\pi\varepsilon_0 s}\hat{s}$ [See P2.35]

where λ = charge per unit length on the linear cylinder

$I = \int J\,da$

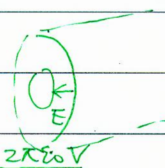
The total current $I = \int J\,da = \int \sigma E\,da$, $\boxed{da = 2\pi s L}$

$= \int_0^L \frac{\lambda}{2\pi\varepsilon_0 s} 2\pi s\,dl = \frac{\sigma\lambda}{\varepsilon_0} L$.

The potential between the cylinder is

$V = -\int \vec{E} \cdot d\vec{s} = -\int \frac{\lambda}{2\pi\varepsilon_0 s} ds$

$V = \frac{\lambda}{2\pi\varepsilon_0} \ln\frac{b}{a} \Rightarrow \lambda = \frac{2\pi\varepsilon_0 V}{\ln\frac{b}{a}}$



* If the current is $I = \frac{\sigma\lambda}{\varepsilon_0} L$ & $\lambda = \frac{2\pi\varepsilon_0 V}{\ln\frac{b}{a}}$
* So the current $I = \frac{2\pi\sigma L}{\ln\frac{b}{a}} V$, Then the resistance is $\boxed{\frac{\ln\frac{b}{a}}{2\pi\sigma L} = R}$

If a free charge moved toward the end of the conductor and establish an electric field $\vec{E}$ given by $\vec{E} = \vec{v} \times \vec{B}$.

The end of the conductor is $V_{ba} = \int_a^b \vec{E} \cdot d\vec{l} = \int_a^b (\vec{v} \times \vec{B}) \cdot d\vec{l}$

Then the difference of voltage is dependent on $\vec{v} \times \vec{B}$

The Vab can be changed as. $V_{ab} = \frac{1}{q}\int q(\vec{v} \times \vec{B}) \cdot d\ell$, averge method

$\boxed{\mathcal{E} = \frac{1}{q}\int q(\vec{v}\times\vec{B})\cdot d\ell}$ $\boxed{\langle B \rangle = \frac{1}{V}\int B \cdot d^3r}$

if $v, B, d\ell$ are constants, then $\mathcal{E} = vBL$, called emf.

5/21 (四)

§ 7.1.2.

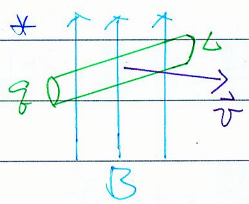
V * Voltage ≡ Applied force F on charges / per charge $\Rightarrow f$

J * Current density $\Rightarrow J = \sigma f$, σ = conductivity = $\frac{1}{\rho}$

Emf * Electromotive Force $\mathcal{E} = V = \int \vec{E} \cdot d\ell \Rightarrow$ Electricstatics 靜電

* $F = q\vec{E} + q\vec{v}\times\vec{B} \rightarrow$ introduce a steady state $\rightarrow$ Electrodynamic 電動

*



Now we consider a conductor of length L moving w/ velocity $\vec{v}$ perpendicular to a uniform field

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

The free charge estabilih an electric field. $q\vec{E}$. Static $\rightarrow$ Steady State then $qE \Rightarrow q\vec{v}\times\vec{B}$ the potential difference between the ends of the conductor is 電压 $V = \int \vec{v}\times\vec{B}\cdot d\ell$ [Electrodynamic 電動]

We obtain $\mathcal{E} = \frac{1}{q}[\int qv\times B \cdot d\ell]$ (平均法) $\Rightarrow$ Average Voltage / per charge.

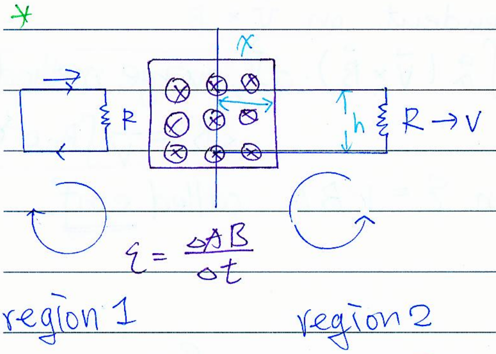
§ 7.1.3 Motional Emf $\Rightarrow \mathcal{E} = \vec{v}BL$ 剛好!!

We consider the processes Static $\rightarrow$ Steady $\rightarrow$ dynamics (motional)

$\mathcal{E} = \frac{x}{t}BL$

$= \frac{\Delta x}{t}BL \Rightarrow \frac{\Delta A}{\Delta t}B$?

*



If the B is point into the page, connecting a resistance R, moving with velocity $\vec{v}_x$

Let us define the flux of area through B field.

1. Then we know $\mathcal{E} = V_x B h = \boxed{\int f_{mag} \cdot dx}$
2. Due to the changing of area, we introduce a ideal of magnetic flux $\boxed{\Phi = BA.}$

* Considering the moving $\vec{v}$.

1. In region 2 the loop is moving out.
   Then the flux is decreasing 通量減少. $\Rightarrow \frac{d\Phi}{dt} = Bh\frac{dx}{dt} = \boxed{-}Bh\vec{v}$ flux decrease.
2. In region 1. the loop is moving in.
   Then the flux is increasing. 通量增加 $\Rightarrow \frac{d\Phi}{dt} = +Bh\vec{v}$
3. So the Emf generate in loop is minus the rate of charge of flux through the loop in region 2. $\mathcal{E} = -\frac{d\Phi}{dt}$.

$\boxed{\text{Conclusion } \mathcal{E} = -\frac{d\Phi}{dt}}$

Problem 7.12 A long solenoid of radius a is driven by an alternating current. So that the field inside is $B(t) = B_0 \cos(\omega t)\hat{z}$. A circuit loop of wire of radius $a/2$ is place inside connecting a resistance R.

$\Phi = BA$ → changing area, → changing B-field → dynamic.

1. $\Phi = \frac{\pi a^2}{4} B$,

So the $\mathcal{E} = \frac{-d\Phi}{dt} = -\frac{d}{dt}\left[\frac{\pi}{4}a^2 B_0 \cos \omega t\right]$

$= \frac{-\pi a^2}{4} B_0 (-\omega) \sin \omega t =$

$= \frac{\pi \omega a^2}{4} B_0 \sin \omega t$,

then $I = \frac{\mathcal{E}}{R} = \frac{\pi \omega a^2}{4R} B_0 \sin \omega t$ #

2. loop area $\pi a^2/4$.