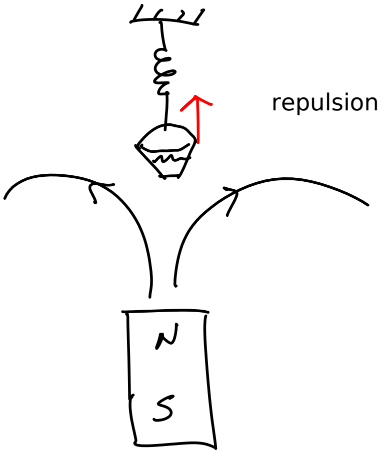
Lecture 36

Homework due Monday April 21
Exam Wednesday April 23

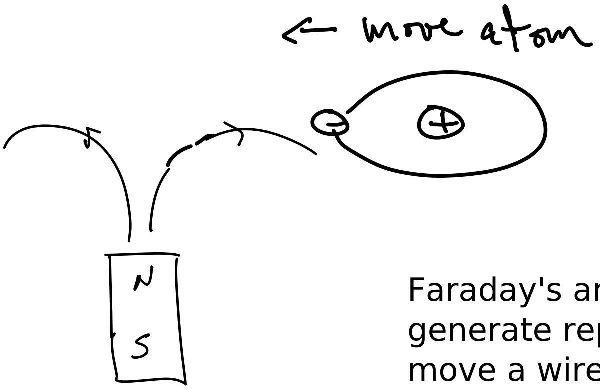
Shadowitz chapter 7

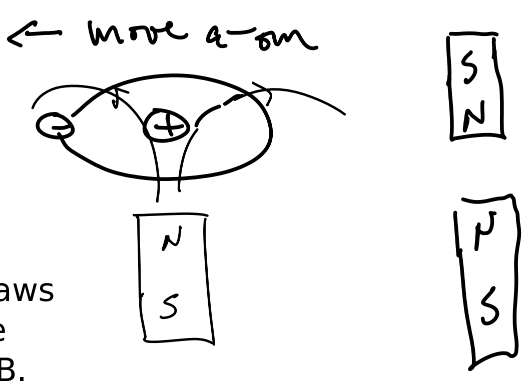
Review



creative/causal: How do I simplify this to understand the repulsion?

planetary motion model





Faraday's and Lenz's laws generate repulsion like move a wire loop into B.

Or you can argue that for circular motion:

$$\frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2} = ma = m\frac{v^2}{r}$$

The magnetic field adds to the centripital force.

$$\frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2} + ev'B = m\frac{v'^2}{r}$$

The new speed is greater than the v.

$$ev'B = \frac{m}{r}\left(v'^2 - v^2\right) = \frac{m}{r}\underbrace{(v'+v)}_{\simeq 2v'}\underbrace{(v'-v)}_{\Delta v}$$

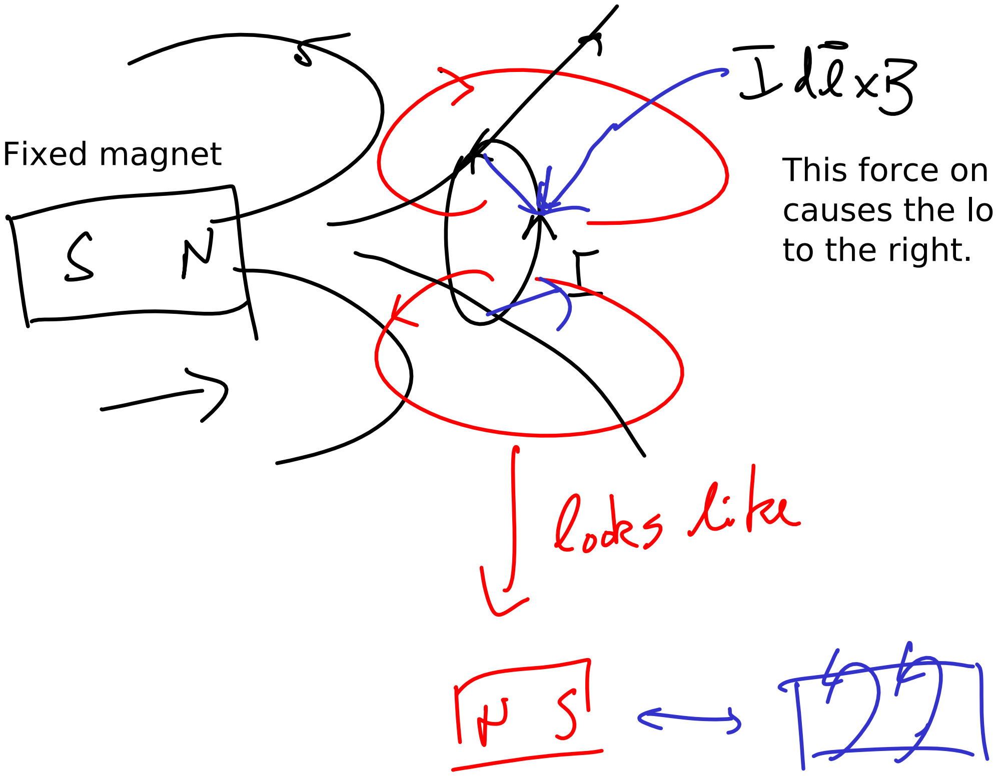
$$\Delta v \simeq \frac{erB}{2m}$$

When B is turned on v increases creating an opposing dipole.

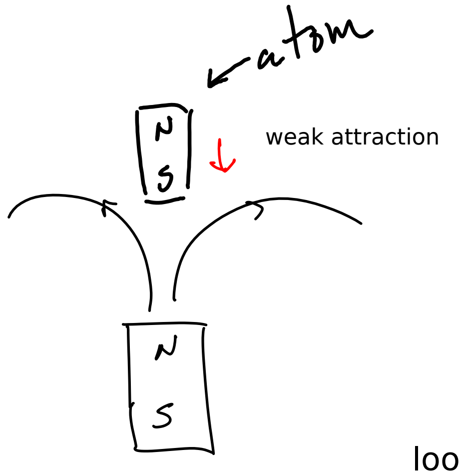
see youtube video on "anti" magnetic water and the levatating frog

Question in class:
causal/creative: What causes one magnet to be repelled by another?

Model one magnet as fixed in space and the other as a loop of current. This current is the bound current. Somehow the magnet has to be brought near the fixed magnet. As it is brought in Faraday's law induces a current and Lenz's law specifies the direction as shown.



This force on the current causes the loop to move to the right.



creative/causal: How do I simplify this to understand the attraction?

electrons have spin angular momentum and a magnetic dipole moment.

look up Bohr magnaton on wikipedia

magnetic dipole moment of the electron = $\frac{e\hbar}{2m} = \overset{\mu}{\overset{\shortparallel}{p}} = I\ \text{area}$

$\simeq 10^{-23}$ J/Tesla

Energy in a magnetic field

$$U = -\underset{\mu = Ia}{\underset{\uparrow}{\vec{p}}}\cdot\vec{B} \qquad \underset{\text{electric dipole}}{\left(-p\cdot\vec{E}\right)}$$

see youtube video on liquid nitrogen vs liquid oxygen: magnetism

Questions on atomic model of paramagentism:

incongruous: oxygen is a diatomic molecule with paired electrons so how can it be paramagnetic?

Look up Mark Bishop's chemistry site MO theory

congruous: How does the temperature effect M for oxygen? How do I calculate that?

$$p(\theta) = e^{-U/kT}/Z \qquad \frac{N(\theta)}{N(0)} = e^{-\Delta U/kT}$$

$$p(\theta=0) = \frac{e^{-U_0/kT}}{Z}$$

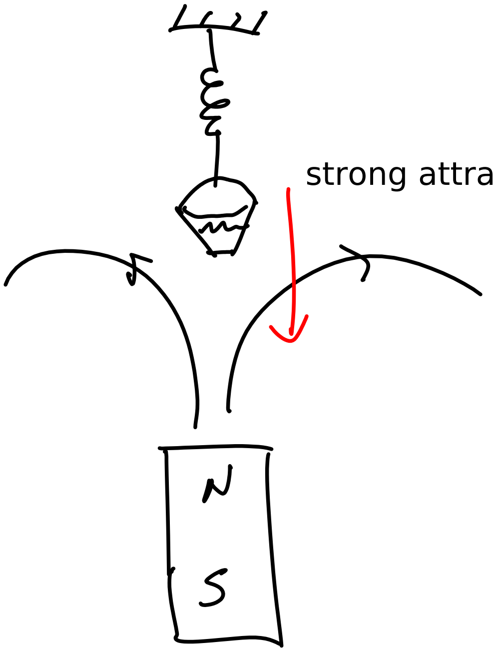
$$\Delta U_{max} \doteq \mu B = 10^{-23} \underset{\underset{1T}{22}}{B} = 10^{-23} J$$

$$kT \simeq 4 \times 10^{-21} J$$

The Boltzman factor indicates that the thermal energy is not enough to misalign the paramagnetic dipoles at room temperature.

informational: Are there any applications of this paramagnetic effect?

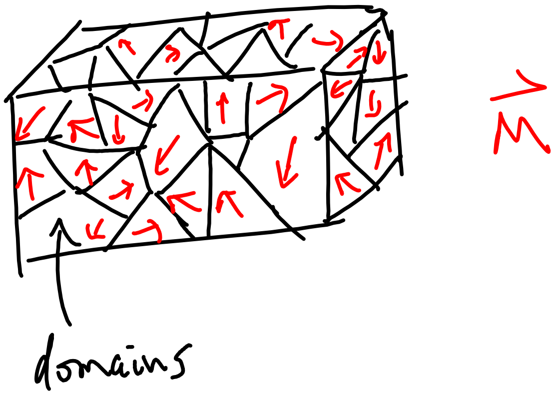
see figure on oxygen sensor for auto exhaust as an example of the application of paramagnetism.



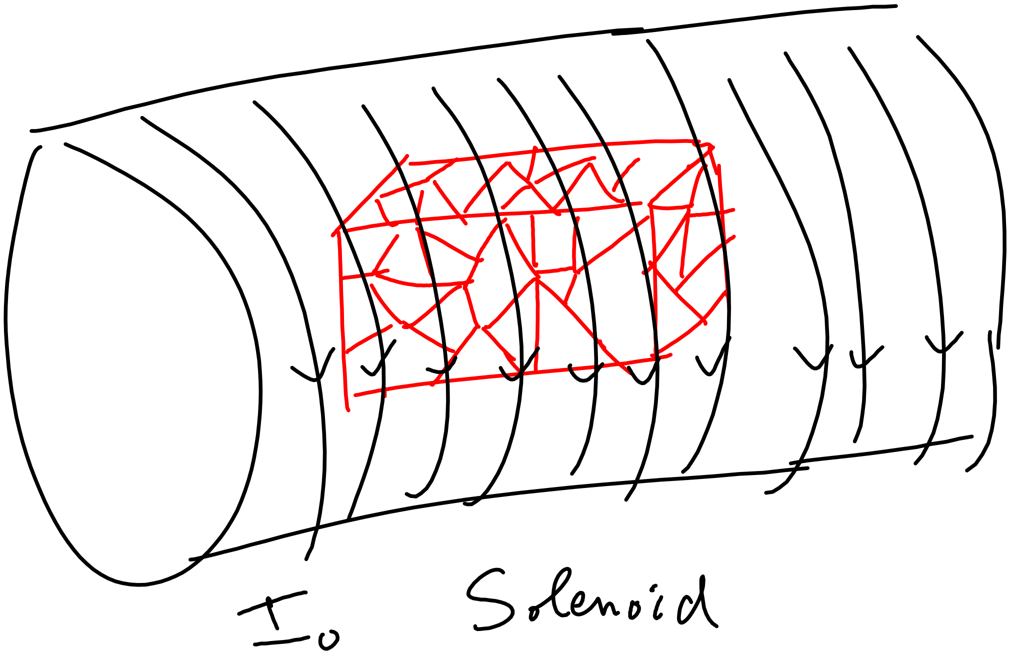
strong attraction

Ferromagnet

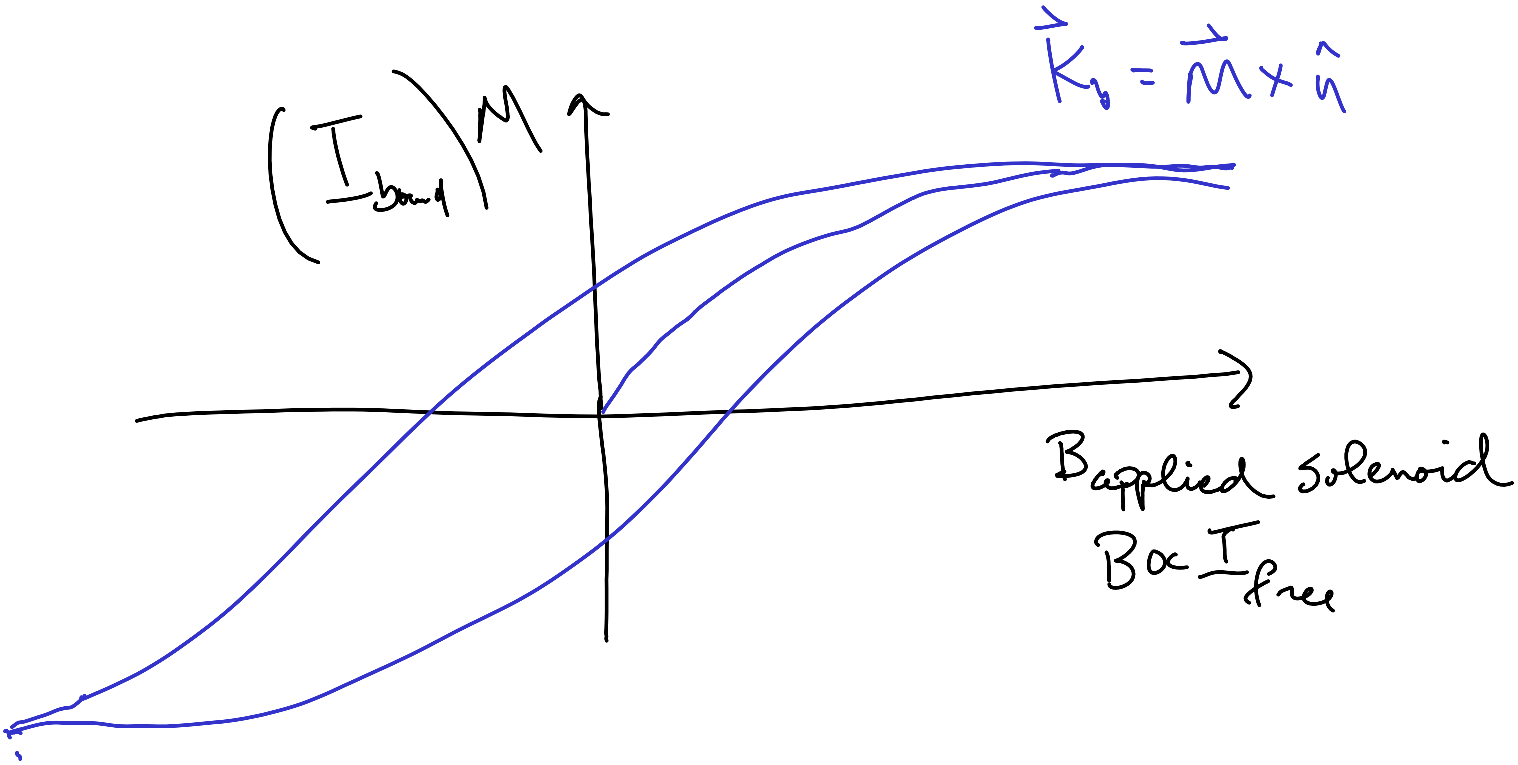
Domain model



All the iron atoms are aligned in a domain but the direction of M for each domain is different.

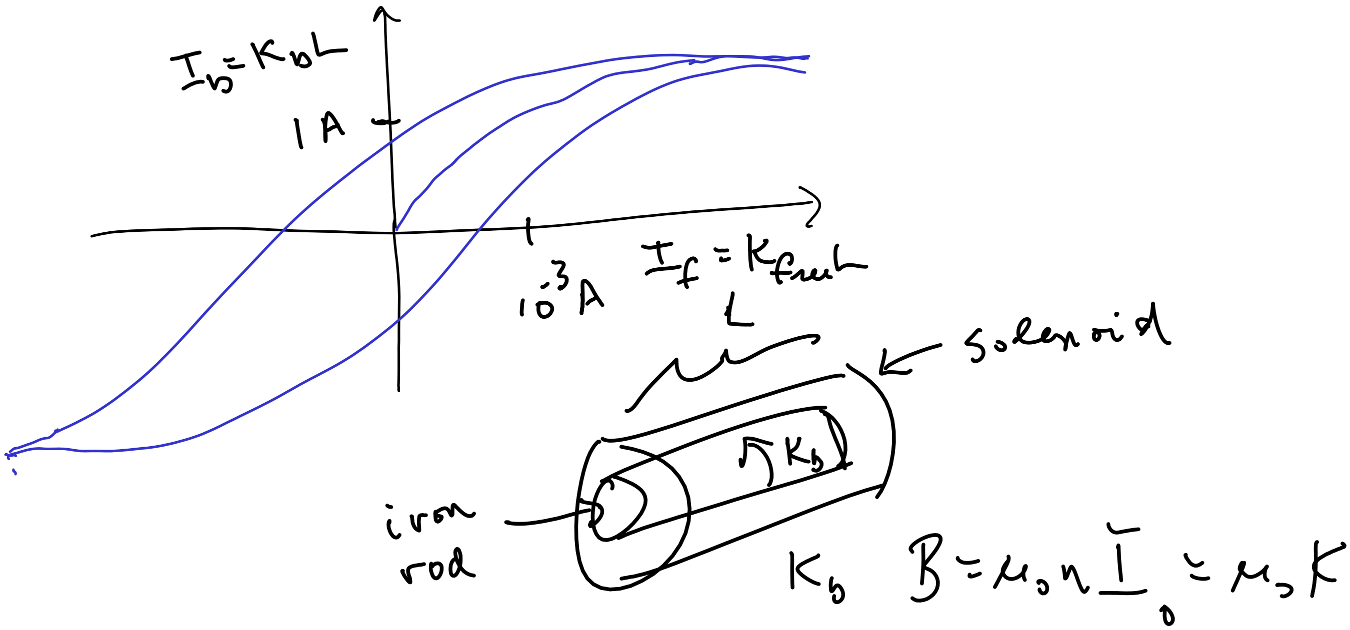


youtube   magnetic domains in an iron core



The magnitization is related to the bound current by $\vec{K}_b = \vec{M} \times \hat{n}$

Therefore we can plot bound surface current vs free surface current from the solenoid into which the rod of iron is place. That is we can compare the free current in the solenoid with the bound current generated by the solenoid's B field.



$B = \mu_0 n \bar{I}_0 = \mu_0 K$

Questions on the domain model:

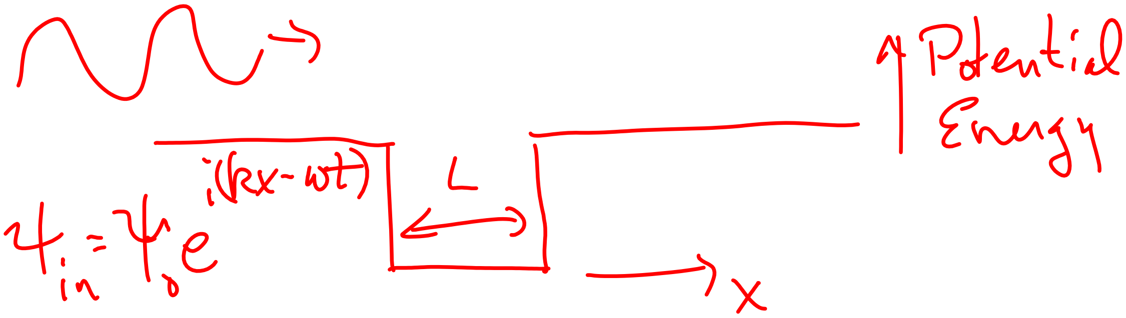
-modifying: how does the temperature effect M in this model?

See curie temperature experiment with a swing on youtube.

youtube curie point heat engine

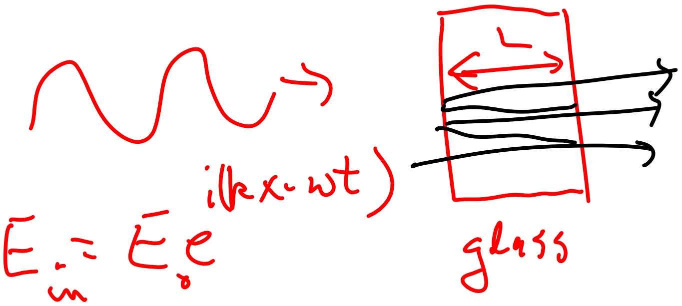
-informational: What other ways can these domains be altered?

Homework problem 4.) "Perturbation" treatment of quantum well or light reflecting from the two boundaries.



$\psi_{in} = \psi_0 e^{i(kx-\omega t)}$

or



$E_{in} = E_0 e^{i(kx-\omega t)}$

$\lambda_n = \frac{c}{n}$

$\omega = \frac{k_0}{n} c$

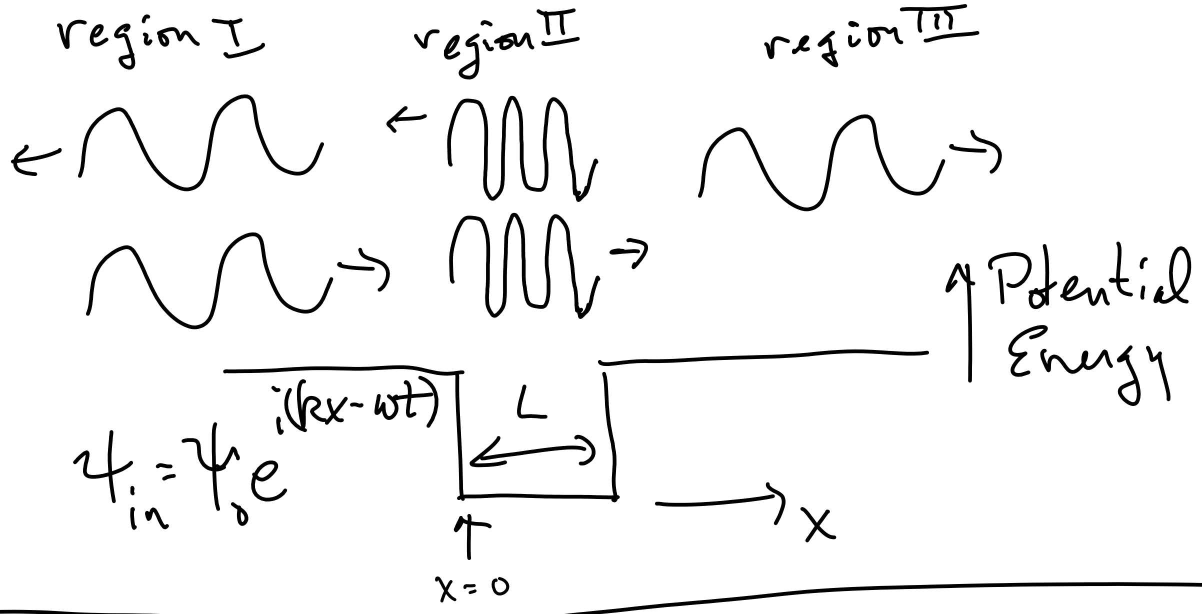
$k_0 = \frac{2\pi}{\lambda_{vacuum}}$

r is the amplitude reflection coefficient and t is the amplitude transmission coefficient for each interface.

Find a series expansion for the electric field transmitted on the right interface (set x=0 at this interface). (b) sum this series to determine the transmitted electric field in terms of r and t.

The 1st term is $E_0 t t$

Rather than doing this expansion in the quantum well problem the exact eqns are solved via the Schrodinger eqn.



$$\psi_{I}^{tot}(x=0,t) = \psi_{II}^{right}(x=0,t) + \psi_{II}^{left}(x=0,t)$$

Bndry condition of wavefunction at the interface

$$\psi_{II}^{right}(x=L,t) + \psi_{II}^{left}(x=L,t) = \psi_{III}^{right}(x=L,t)$$

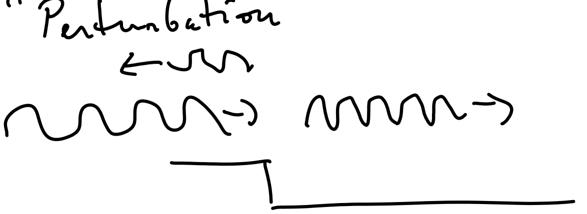
$$\frac{d}{dx}\left(\psi_{I}^{tot}(x,t) = \psi_{II}^{right}(x,t) + \psi_{II}^{left}(x,t)\right)\Big|_{x=0}$$

Bndry condition on the derivative of the wavefunction at the interface

$$\frac{d}{dx}\left(\psi_{II}^{right}(x,t) + \psi_{II}^{left}(x,t) = \psi_{III}^{right}(x,t)\right)\Big|_{x=L}$$

all ψ's $\propto e^{i(kx-\omega t)}$

but k in well > k outside since λ is smaller



find r & t

Use these r and t's the same way as in the EM example above to find how much of the wave gets through the barrier.

find r & t