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EE214000 Electromagnetics, Fall 2020

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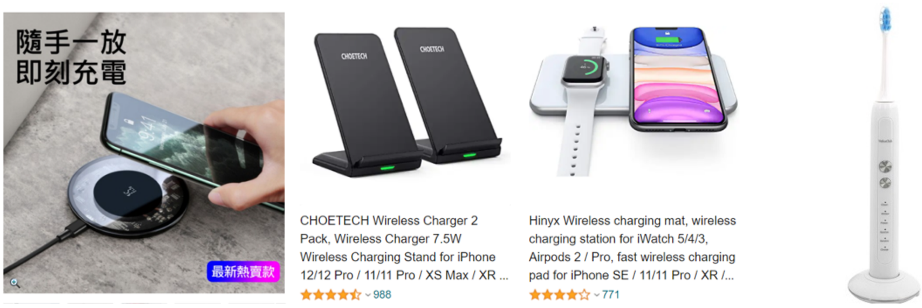
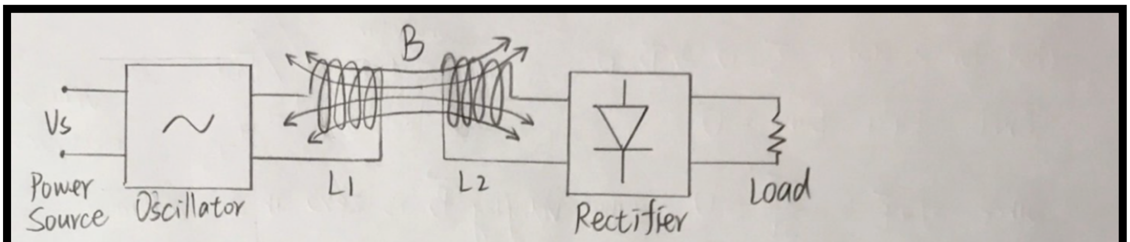
Quiz #17-1, Open books, notes (20 points), due 11 pm, Wednesday, Jan. 6th, 2021
(submission through iLMS)

Late submission won't be accepted!

1. Describe how a cordless charger charges a cell phone, Apple watch, toothbrush etc.? To explain, draw a circuit including two parts, the charger and the appliance. (3+3 points)



*Images extracted from MOMO and Amazon websites.



Wireless battary charging use an inductive or magnetic field between two objects which are typically coils to transfer the energy from one to another. The energy is transferred from the energy source to the receiver where it is typically used to charge the battery in the device.

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2. Write down the 4 Maxwell's Equations, in both differential and integral forms. Also, list the Lorentz Equation and Equation of continuity. Define all the symbols in the expressions. (6 points)

	Differential form	Integral form
Faraday's induction law	$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$	$\oint_C \vec{E} \cdot d\vec{\ell} = -\frac{d}{dt}\int_S \vec{B} \cdot d\vec{s} = -\frac{d\Phi}{dt}$
Gauss law	$\nabla \cdot \vec{D} = \rho$	$\oint_S \vec{D} \cdot d\vec{s} = Q$
Ampere's circuital law	$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{J}$	$\oint_C \vec{H} \cdot d\vec{\ell} = I + \int_S \frac{\partial \vec{D}}{\partial t} \cdot d\vec{s}$
Magnetic Gauss law	$\nabla \cdot \vec{B} = 0$	$\oint_S \vec{B} \cdot d\vec{s} = 0$

Lorentz force equation : $\vec{F} = q\vec{E} + q\vec{u} \times \vec{B}$

Equation of continuity : $\nabla \cdot \vec{J} + \frac{\partial \rho}{\partial t} = 0$

$\vec{E}$: electric field intensity

$\vec{B}$: magnetic flux intensity

Φ : magnetic flux

$\vec{D}$: electric flux density (electric displacement)

ρ : charge density

Q : total charge

$\vec{H}$: magnetic field intensity

$\vec{J}$: current density

I : current

$\vec{F}$: force

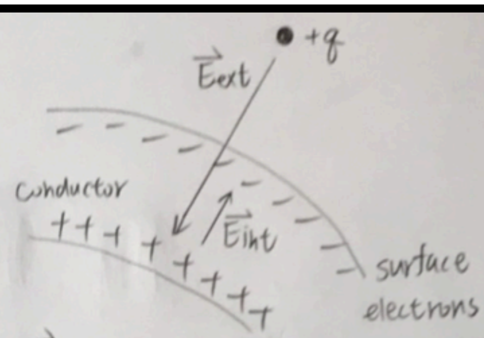
q : charge

$\vec{u}$: velocity

3. Explain why a time-varying magnetic field can't exist in a perfect conductor? (3 points)

A time-varying $\vec{E}=0$ in a perfect conductor for the same reason as that for a static $\vec{E}=0 \Rightarrow \vec{D}=0$

$\vec{E}_{net} = \vec{E}_{ext} - \vec{E}_{int} = 0$



Since $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} = 0$, time-varying $\vec{B}$ is zero in a conductor.
Besides, the relaxation time for a perfect conductor is extremely small.
$\Rightarrow$ time-varying $\vec{E} \longrightarrow 0$ $\Rightarrow$ time-varying $\vec{B} \longrightarrow 0$

4. Explain why $\vec{A}(R,t) = \frac{\mu}{4\pi}\int_{V'} \frac{\vec{J}(t-\sqrt{\mu\varepsilon}R)}{R}dv'$, and $V(R,t) = \frac{1}{4\pi\varepsilon}\int_{V'} \frac{\rho(t-\sqrt{\mu\varepsilon}R)}{R}dv'$ describe the ***retarded*** electromagnetic potentials. In other words, if at time t' your power supply induces time-varying charge $\rho(t')$ and $\vec{J}(t')$ in an antenna, when do you expect that someone would measure $\vec{A}$ and V at a distance R from the antenna? (5 points)

Observe the equation

$t' = t - R\sqrt{\mu\varepsilon}$

t': source time
t: field time

R: resistance
μ: permeability
ε: permittivity

When the wave propagates in medium, there must be the time difference between the source point and the observation point, which means that the electromagnetic potentials will be retarded.