Physics II: 1702
Gravity, Electricity, & Magnetism

Professor Jasper Halekas
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Power Dissipation in Circuits

- Power = VI (always)

- Power dissipation depends on the impedance of the load

- Even for a simple R-circuit, power dissipation is not constant for a given EMF – R matters
  - $P = VI = V*(V/R) = V^2/R$

Power Dissipation in AC Circuits

- In AC circuits, not only do the voltage and impedance matter, but so does the phase

- $P_{inst} = vi = \varepsilon_m \sin(w_d t) * I * \sin(w_d t - \phi)$

  $= \varepsilon_m^2/Z * \sin(w_d t)\sin(w_d t - \phi)$

- $\langle P \rangle = \varepsilon_m^2/(2Z) * \cos(\phi)$

- $\cos(\phi)$ is known as the "power factor"

Concept Check

- What percentage of the power dissipated in an RLC circuit is dissipated in the capacitor?

1. All of it
2. None of it
3. Depends on the phase constant
4. Depends on the impedance

Power Dissipated in Resistor

- $<P_R> = <i^2R> = <(\varepsilon_m/Z*\sin(w_dt-\phi))^2R>$

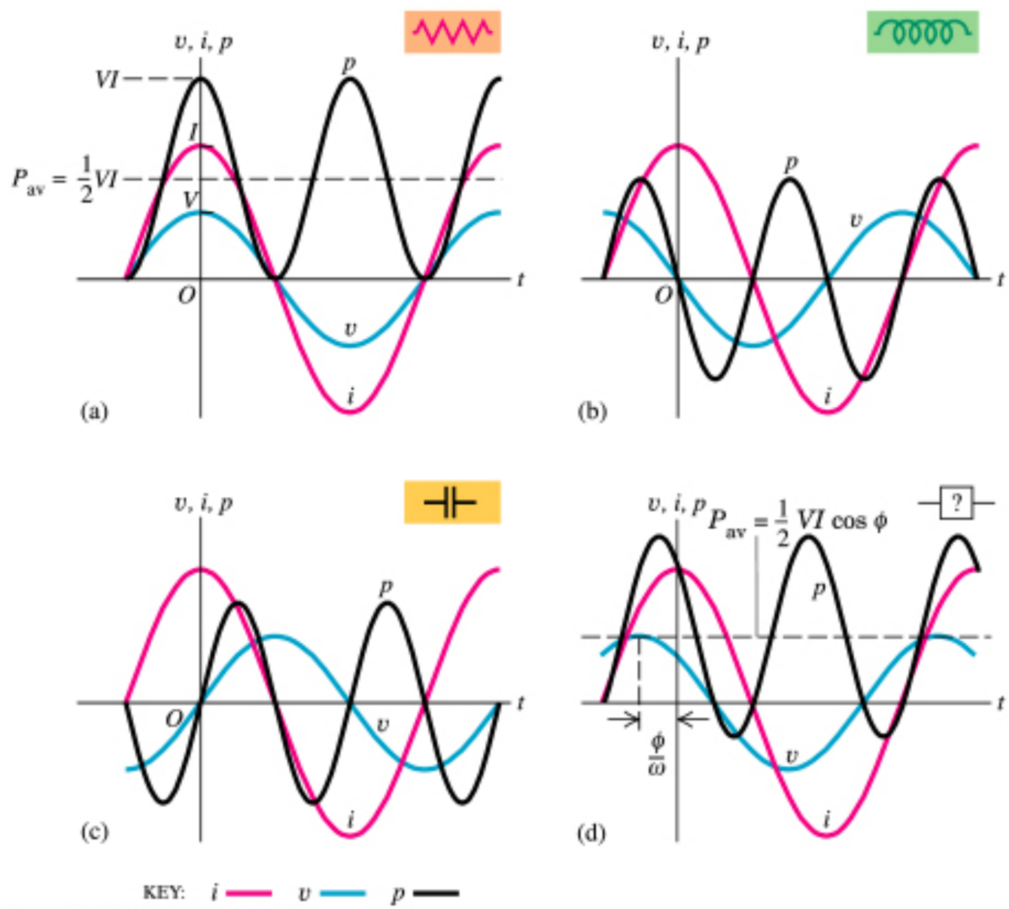
  $= (\varepsilon_m/Z)^2*R/2$

- But, $R/Z = \cos(\phi)$
- So $<P_R> = <P>$
- All power dissipated in resistor

Power in Inductor

- P_{inst} = vi =i*Ldi/dt = L*sin(w_dt-ϕ)*cos(w_dt-ϕ)
  - Instantaneous power oscillates around 0
  - <P> = 0
- Energy is stored, then released, in inductor
- Same argument holds for capacitor

Power Dissipation in RLC Circuits



Concept Check

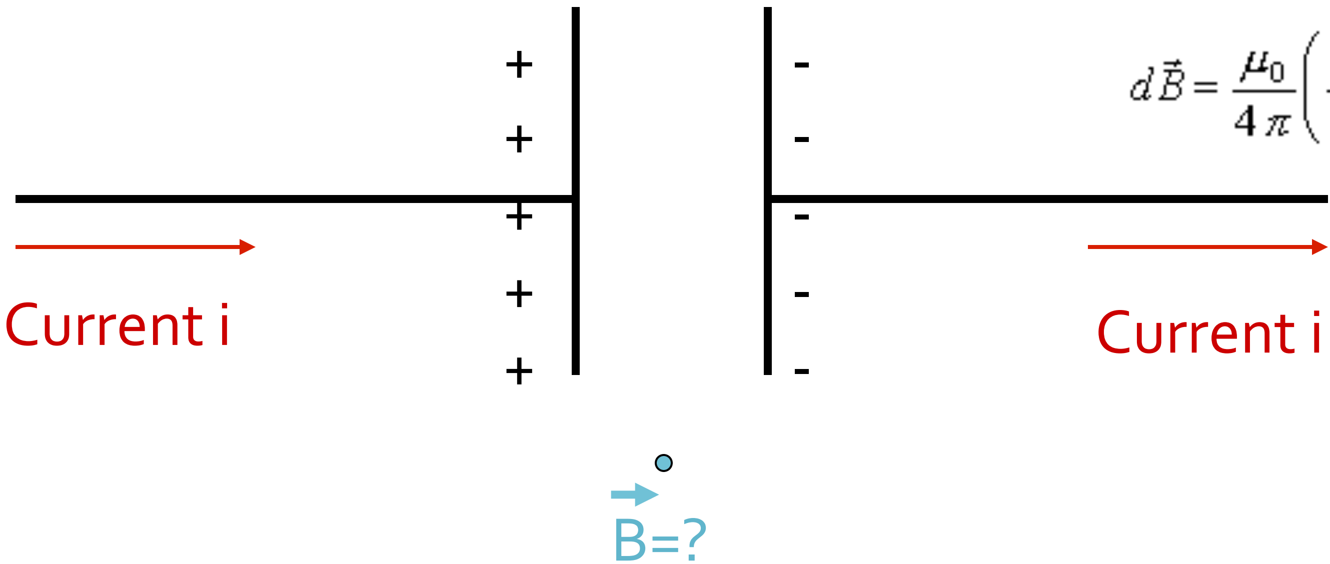
- In a sinusoidally driven series RLC circuit the current leads the applied emf. The rate at which energy is dissipated in the resistor can be increased by:

A. Increasing the capacitance and making no other charges
B. Decreasing the capacitance and making no other charges
C. Decreasing the inductance and making no other charges
D. Decreasing the driving frequency and making no other charges
E. Two of the above

Concept Check

Biot-Savart Law

$$d\vec{B} = \frac{\mu_0}{4\pi}\left(\frac{I\,d\vec{s} \times \hat{r}}{r^2}\right)$$

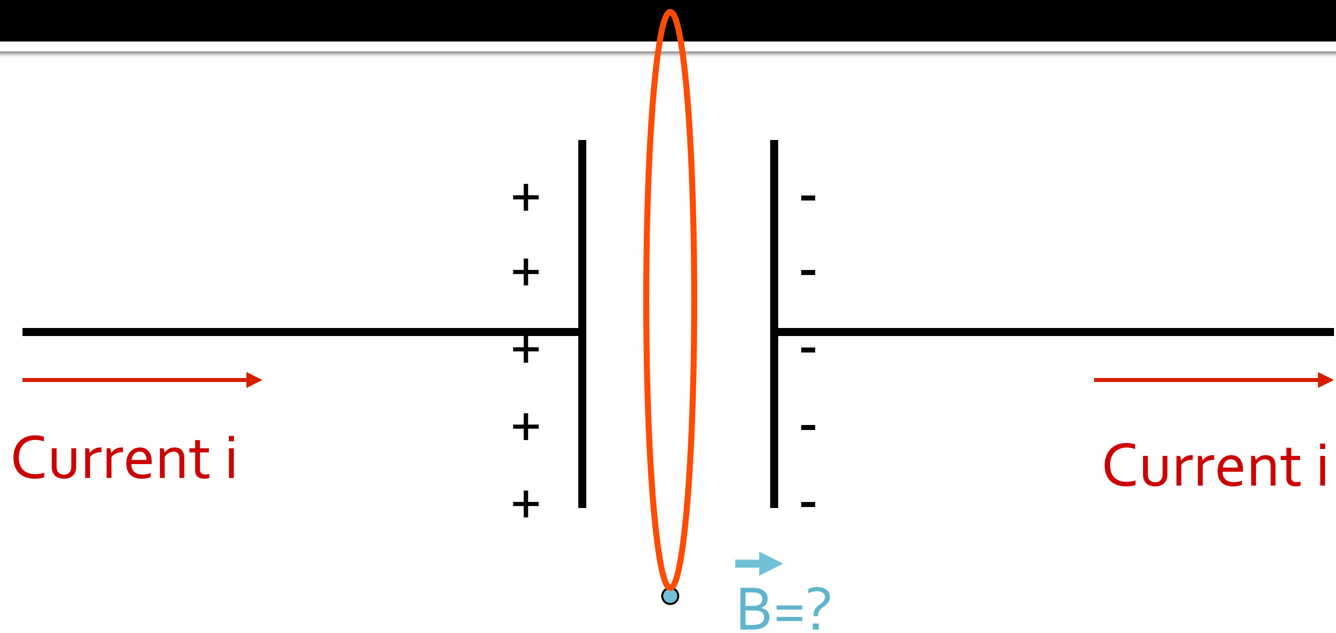


Consider the Biot-Savart Law for Magnetic Fields.
Is there a Magnetic Field at the point labeled between the plates?

A) Yes, there is a B-Field

B) No, there is zero B-field

Concept Check Part II



Now consider an **Amperian Loop** as drawn. According to Ampere's Law is there a Magnetic Field at the point labeled between the plates?

A)Yes, there is a B-Field

B)No, there is zero B-field

Oh No!

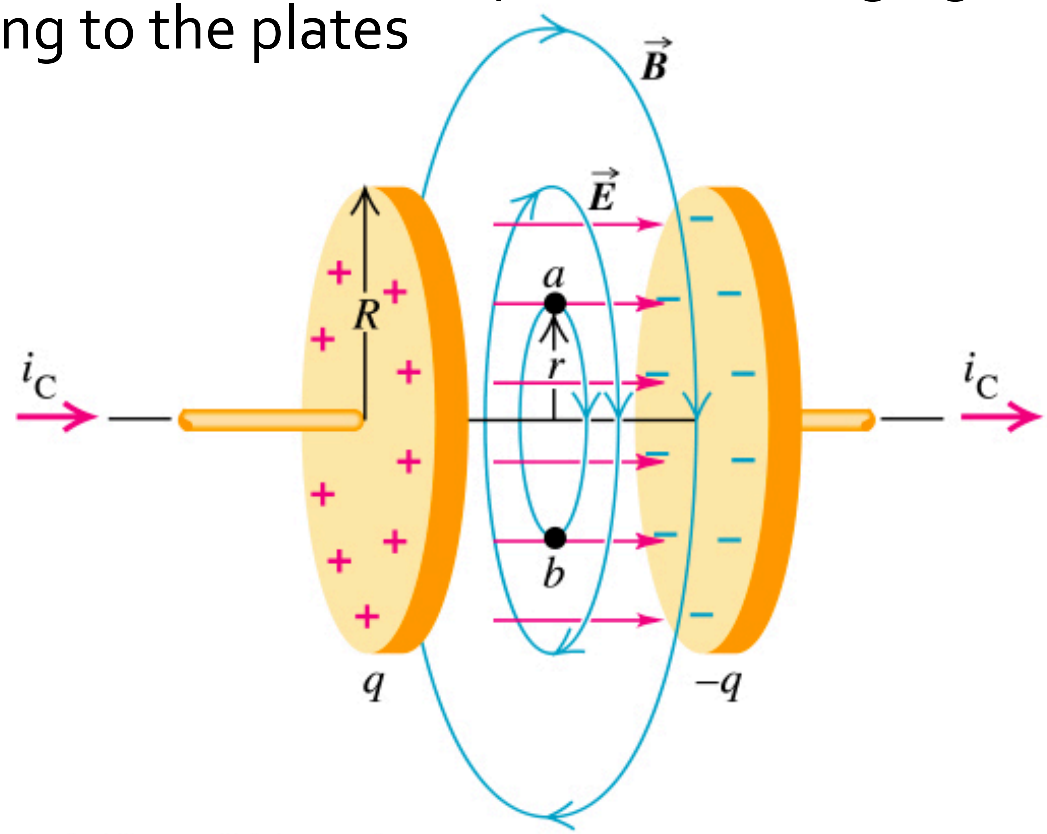
- Ampere's Law is missing a piece!

Modified Ampere's Law
(Ampere-Maxwell Law)

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{enc} + \mu_0 I_{d,enc}$$

Displacement Current: Capacitor

- Can be thought of as “completing” the current through the capacitor
  - Only exists when the capacitor is charging and current is flowing to the plates

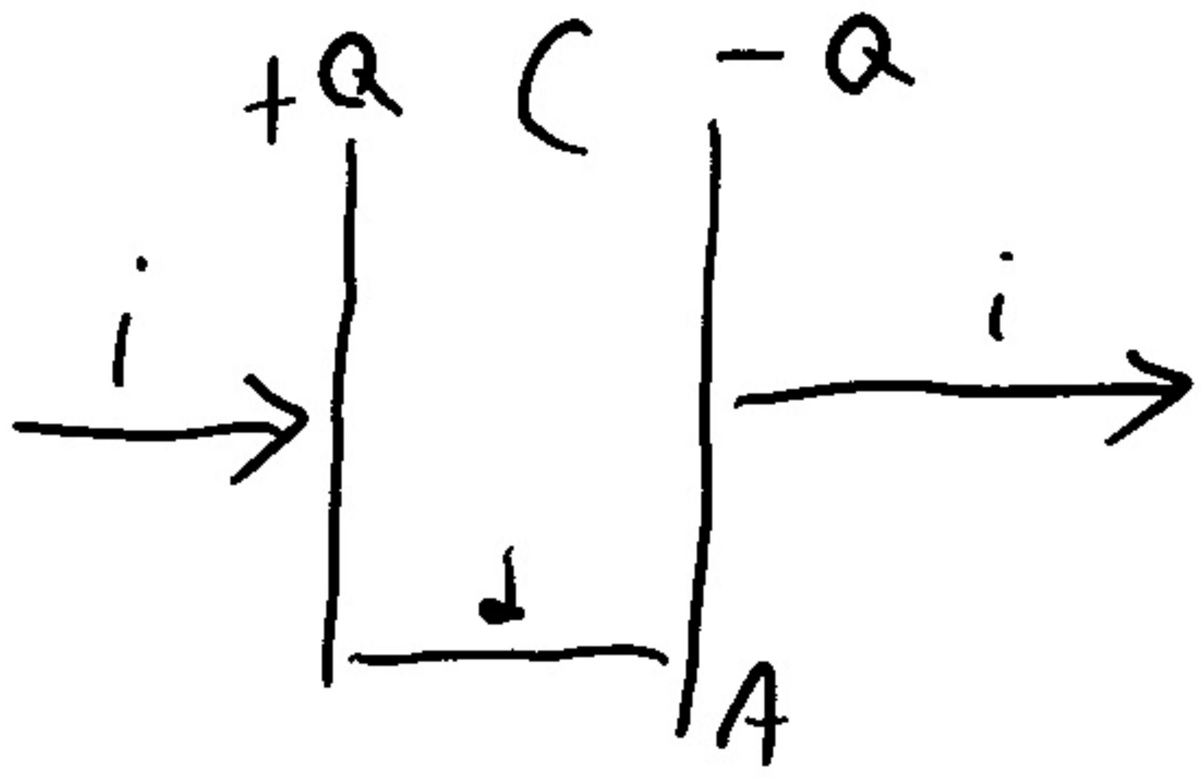


Displacement Current: General

- Is not really a current!
- Related to the change in electric flux through a surface

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{enc} + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$

Displacement current



$C = \varepsilon_0 A/d$

$V = Q/C$ ("infinite plate")

$E = V/d$

$= Q/Cd = Q/\varepsilon_0 A = \sigma/\varepsilon_0$

$\varphi_E = \int \vec{E} \cdot d\vec{A} = EA = Q/\varepsilon_0$

$d\varphi_E/dt = 1/\varepsilon_0 \, dQ/dt = i/\varepsilon_0$

so $i_d = \varepsilon_0 \, d\varphi_E/dt = i$

- True for DC or AC current

- only present when capacitor is charging/discharging

Maxwell's Equations Are Complete!

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{q_{enc}}{\varepsilon_0}$$ ✔

$$\oint \mathbf{B} \cdot d\mathbf{A} = 0$$ ✔

$$\oint \mathbf{E} \cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}$$ ✔

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i_{enc}$$ ✔