ANNOUNCEMENT

***Exam 2**: Monday, November 5, 2012, 8 PM - 10 PM

***Location:** Elliot Hall of Music

*Covers all readings, lectures, homework from Chapters 25 through 28.

*The exam will be multiple choice (15-18 questions).

Be sure to bring your student ID card and your own two-page (two-side) crib sheet, one from exam 1 and a new one.

NOTE THAT FEW EQUATIONS WILL BE GIVEN – YOU ARE REMINDED THAT IT IS YOUR RESPONSIBILITY TO CREATE WHATEVER TWO-SIDED CRIB SHEET YOU WANT TO BRING TO THIS EXAM.

The equation sheet that will be given with the exam is posted on the course homepage. Click on the link on the left labeled “EquationSheet”

ANNOUNCEMENT

No lecture on Tuesday, November 20
(Week of Thanksgiving)

PURDUE UNIVERSITY DEPARTMENT OF PHYSICS

Physics 24100

Electricity & Optics

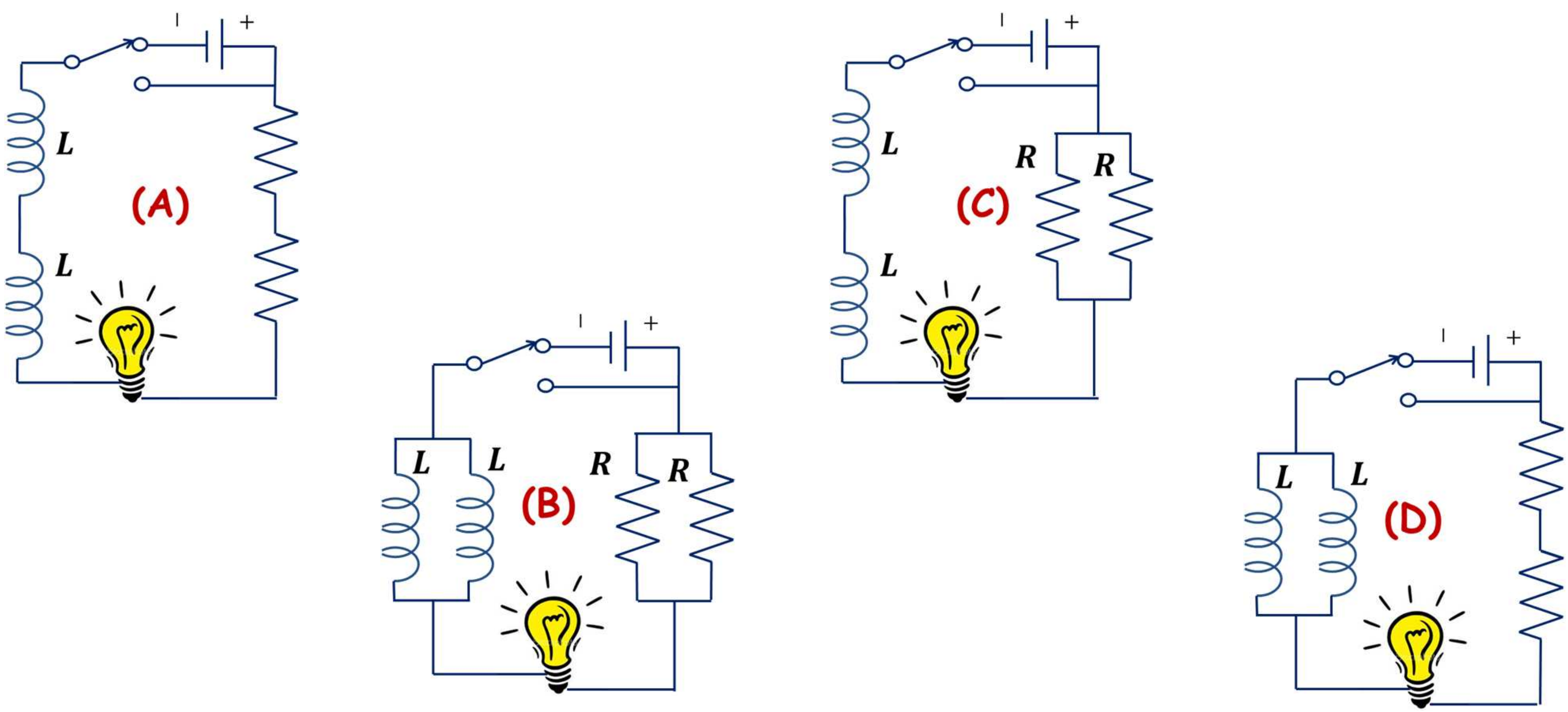
Lecture 19 – Chapter 29 sec. 1,2,5

Fall 2012 Semester

Matthew Jones

Question

- In which circuit will the light stay lit the longest when the circuit is switched at $t = 0$?



Series and Parallel R and L

- Resistors and inductors in series:

$$R_{series} = R_1 + R_2$$
$$L_{series} = L_2 + L_2$$

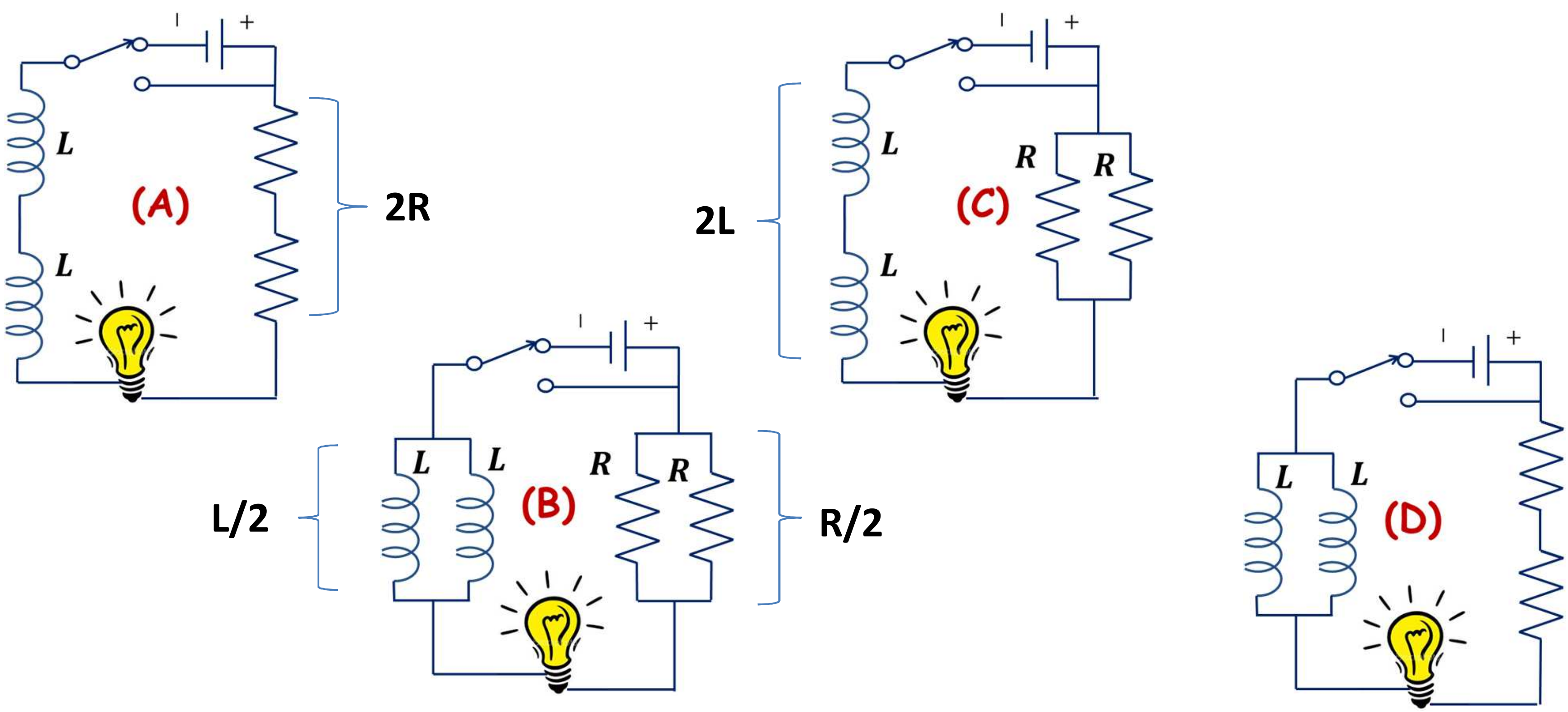
- Resistors and inductors in parallel:

$$R_{parallel} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$$

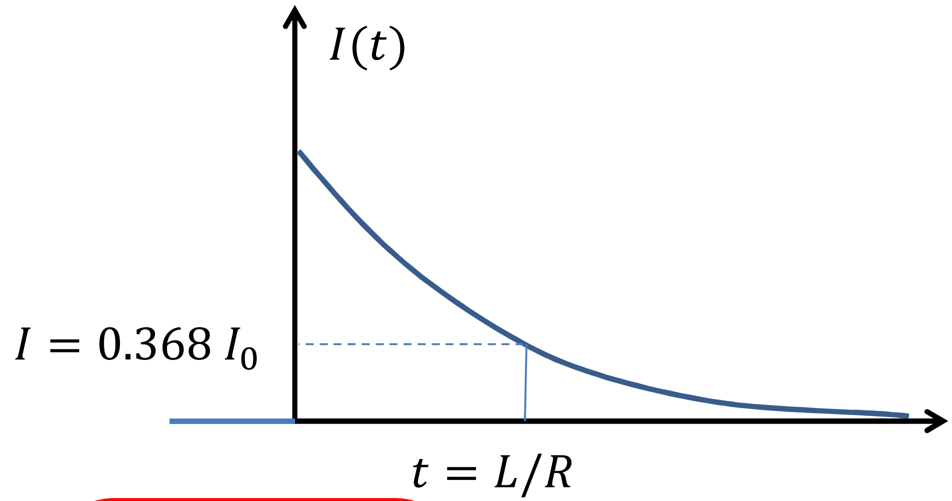
$$L_{parallel} = \left(\frac{1}{L_1} + \frac{1}{L_2}\right)^{-1}$$

Question

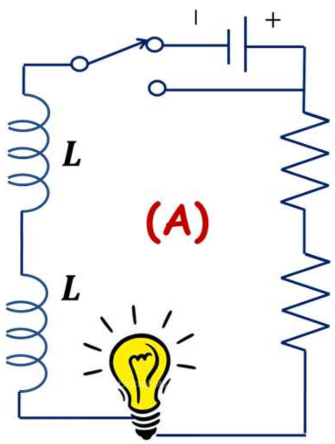
- In which circuit will the light stay lit the longest when the circuit is switched at $t = 0$?



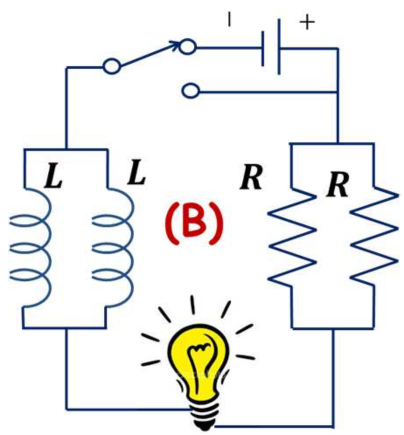
Question

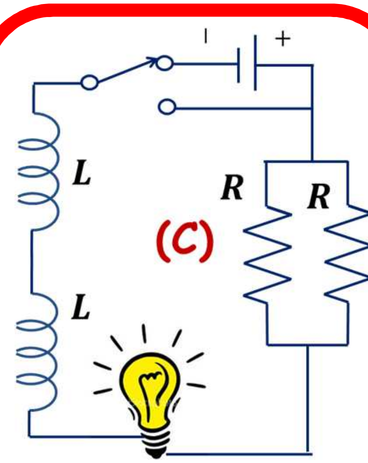


$$\tau = \frac{2L}{2R} = \frac{L}{R}$$



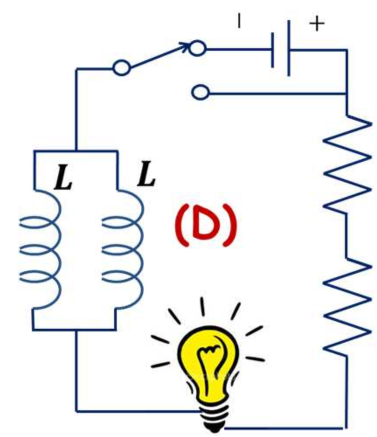
$$\tau = \frac{L/2}{R/2} = \frac{L}{R}$$



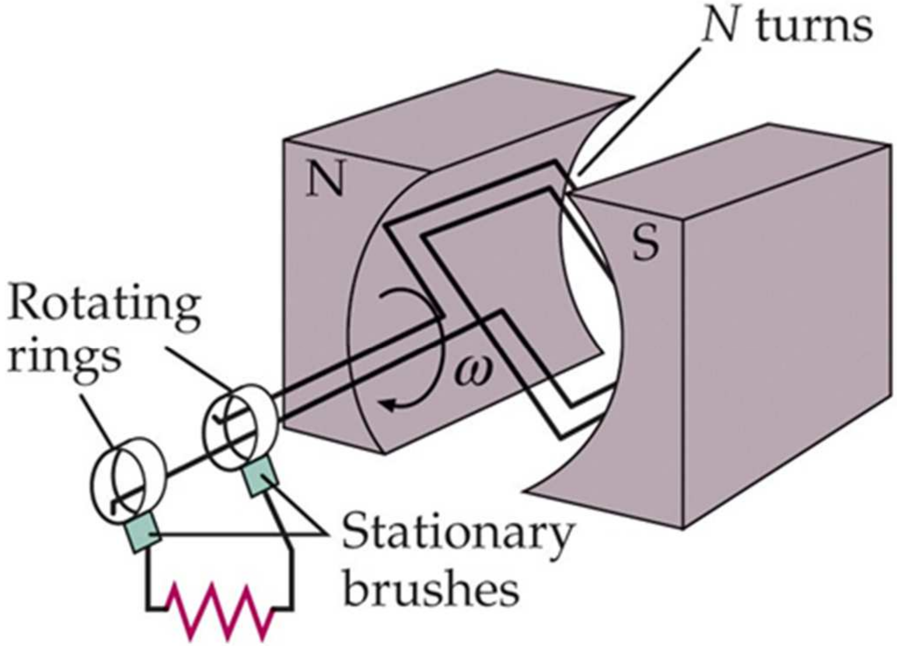


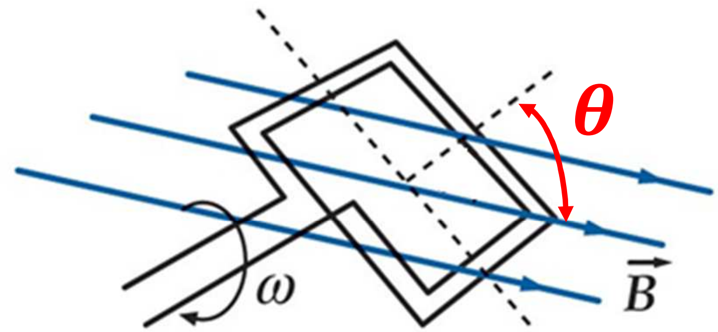
$$\tau = \frac{2L}{R/2} = \frac{4L}{R}$$

$$\tau = \frac{L/2}{2R} = \frac{L}{4R}$$



Alternating Current





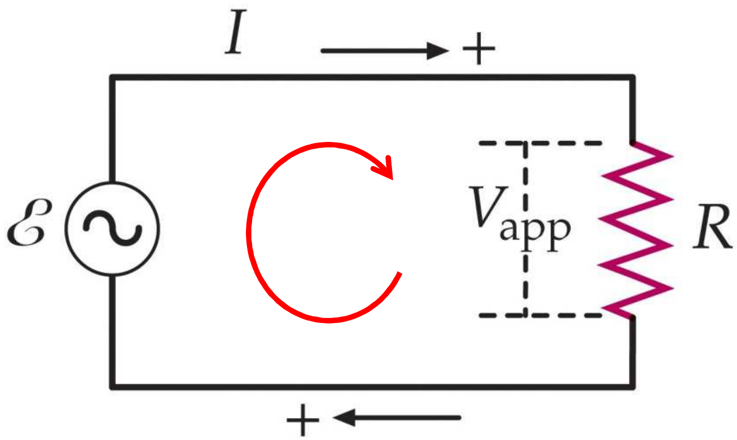
$$\phi_m = NBA\cos\theta$$

$$\mathcal{E} = -\frac{d\phi_m}{dt} = NBA\sin\theta$$

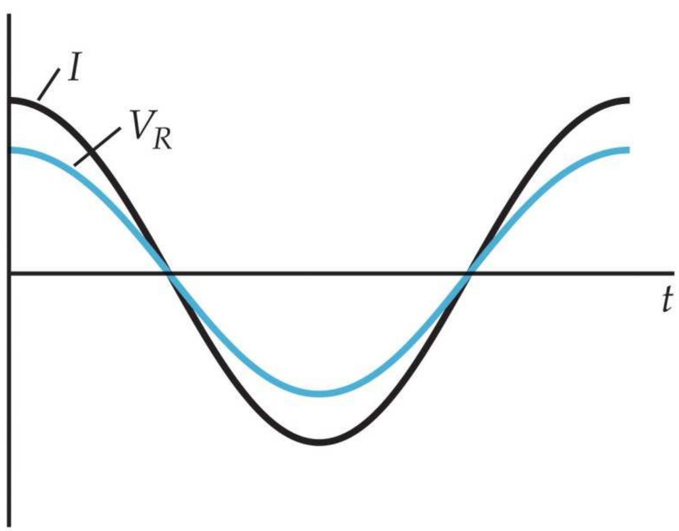
But we can arbitrarily re-define when $t = 0$ and then write this as…

$$\mathcal{E} = NBA\cos\omega t$$

Alternating Current in a Resistor



$$\mathcal{E} = NBA\cos\omega t$$
$$= \mathcal{E}_{peak}\cos\omega t$$
$$V_R = IR$$

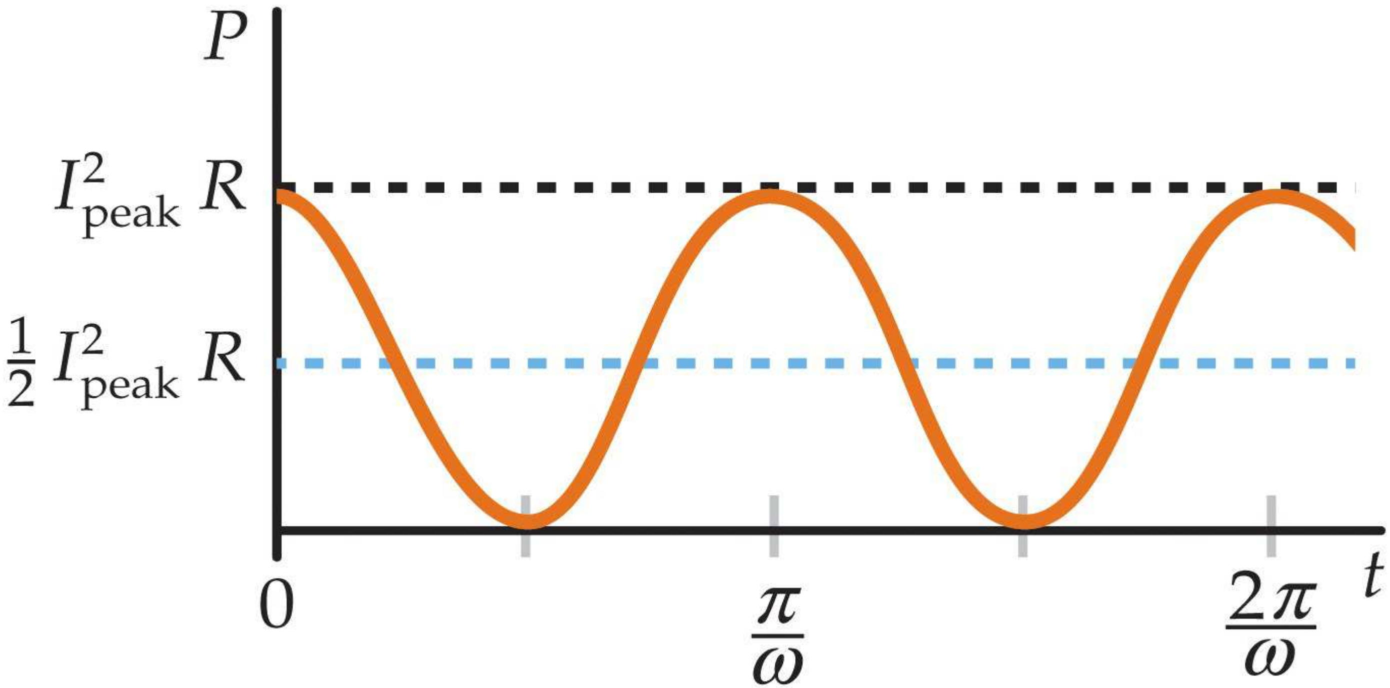


$$I_{peak} = \frac{V_{R\,peak}}{R}$$

Power Dissipated by the Resistor

- Instantaneous power:

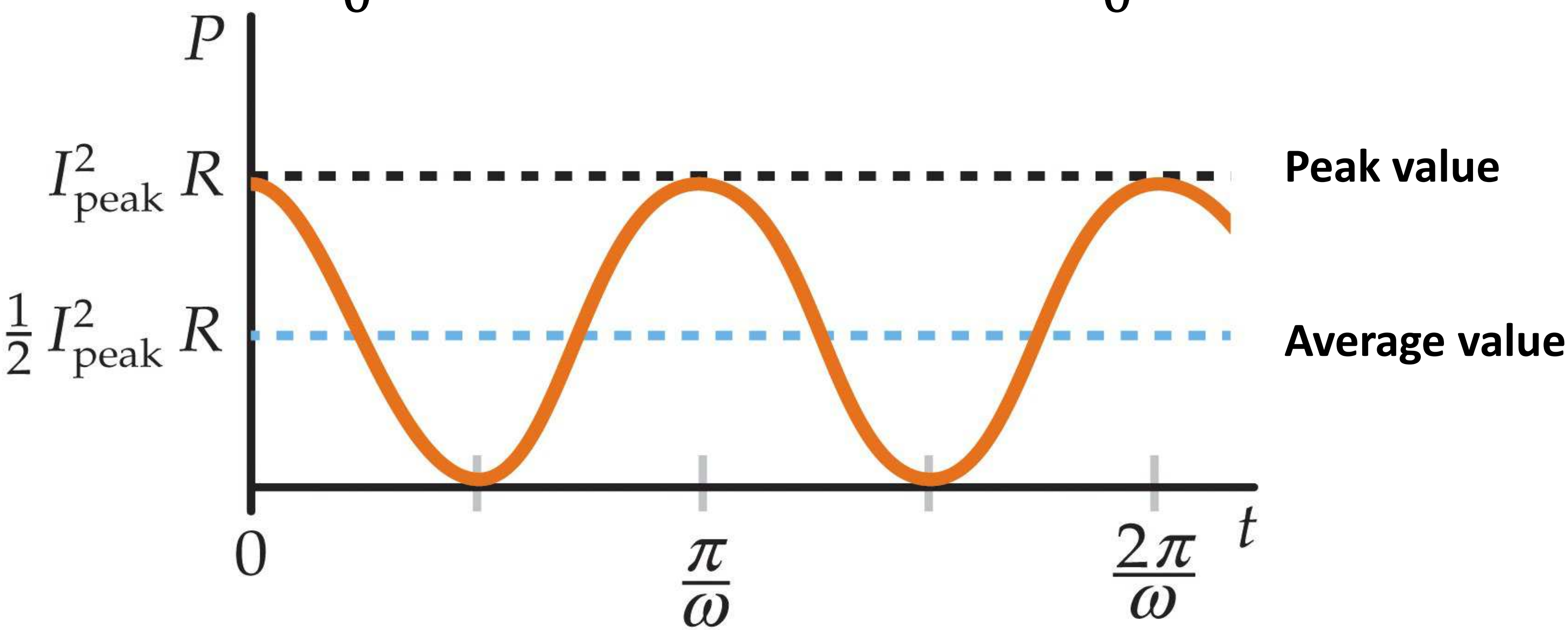
$$P = I^2R = \left(I_{peak}\right)^2 R \cos^2 \omega t$$



Power Dissipated by the Resistor

- Average power

$$P_{av} = \frac{1}{T}\int_0^T P(t)dt = \frac{\left(I_{peak}\right)^2 R}{T}\int_0^T \cos^2 \omega t \, dt$$



Root-Mean-Squared Current

- We can define

$$I_{RMS} = \sqrt{\frac{1}{2}\left(I_{peak}\right)^2} = \frac{I_{peak}}{\sqrt{2}}$$

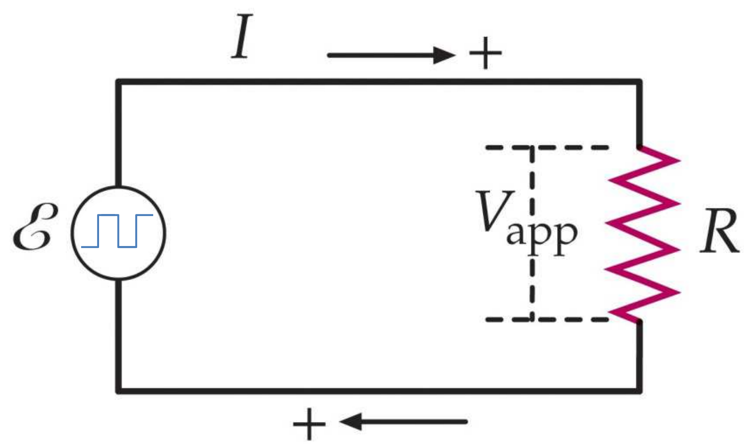
- Now we can write

$$P_{av} = (I_{RMS})^2 R$$

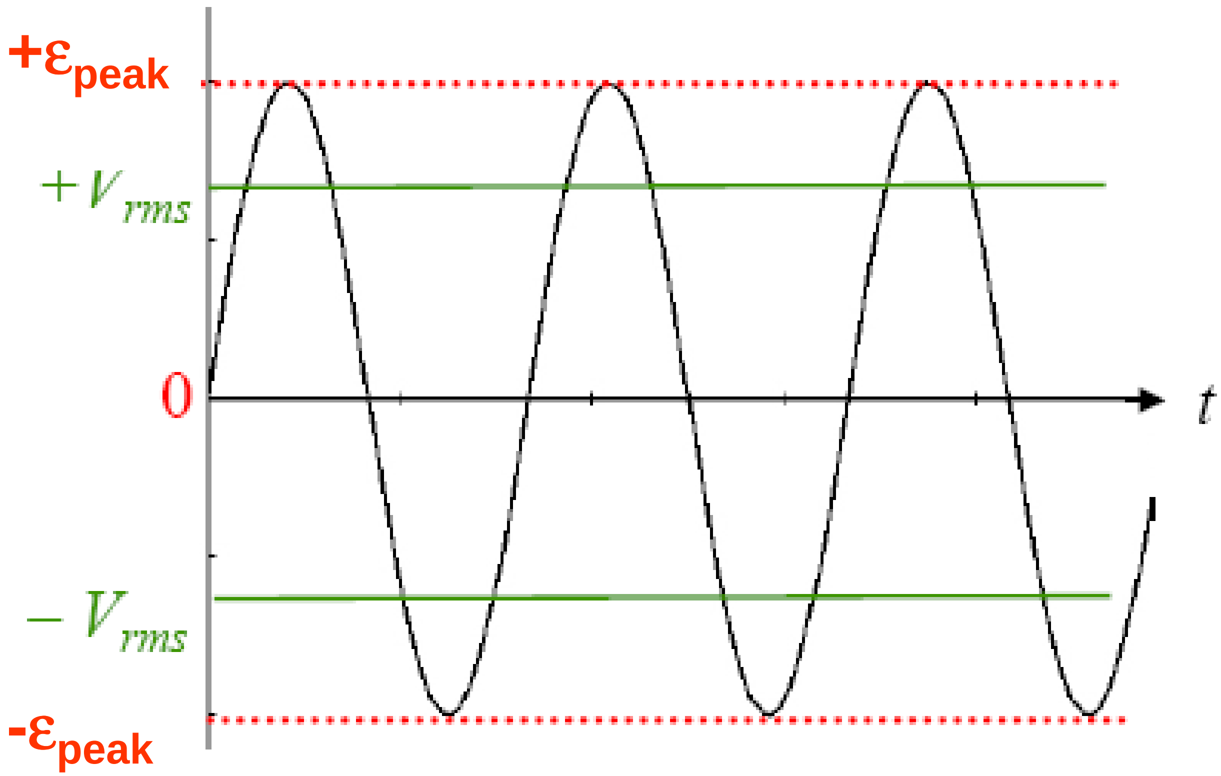
- For AC circuits, we can use the usual DC formulas, provided we use RMS currents and voltages.

Example

- How much power is dissipated through the resistor if the voltage source is a square wave?



Standard AC Voltage in North America

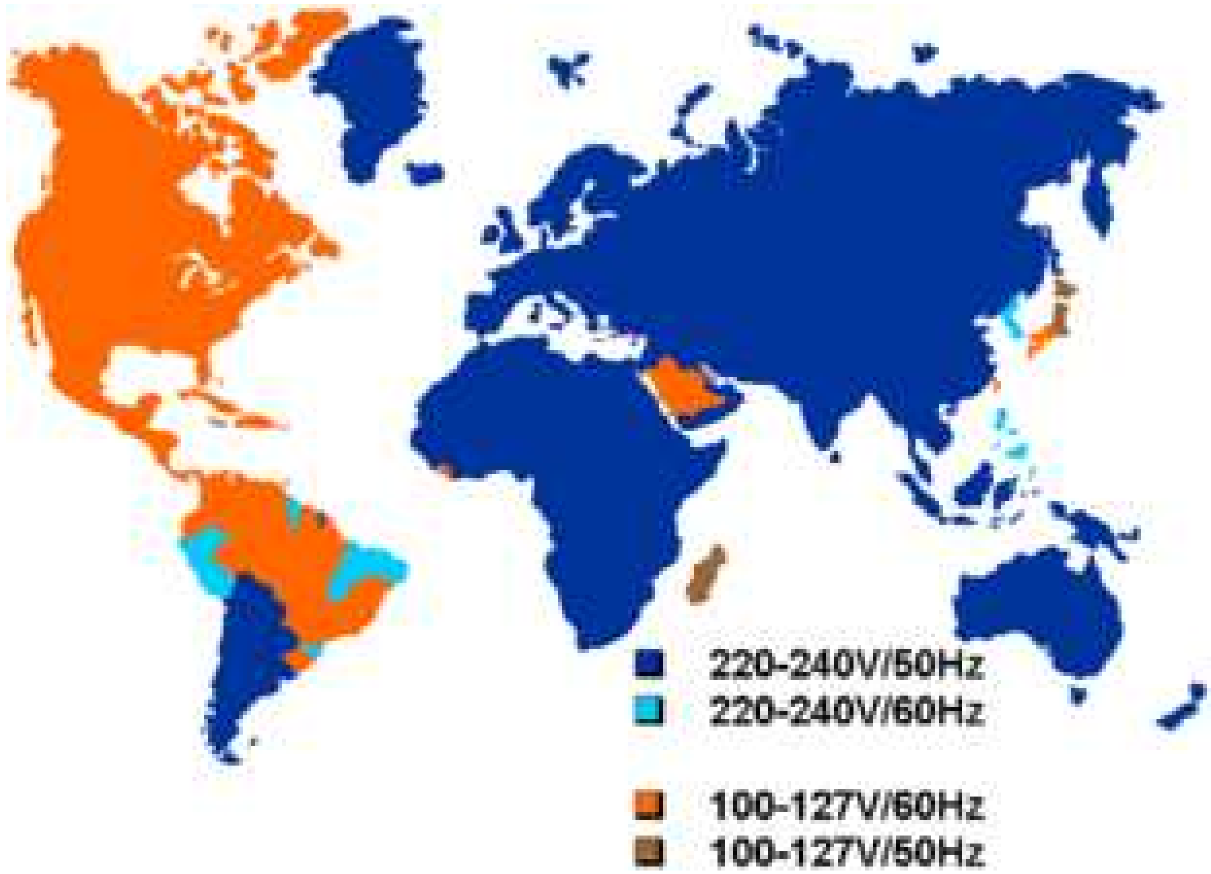


$\sim 180\ V$

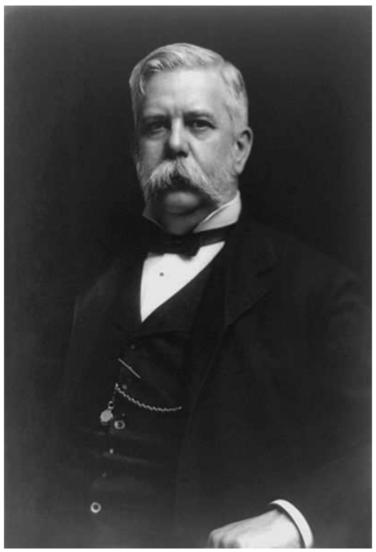
$\sim 110\ V$

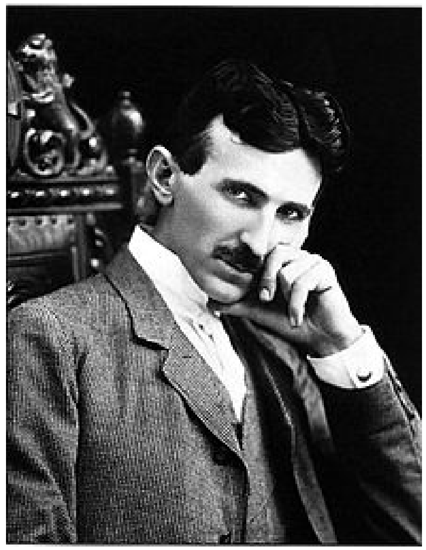
$$\frac{1}{\sqrt{2}} \approx 0.707$$

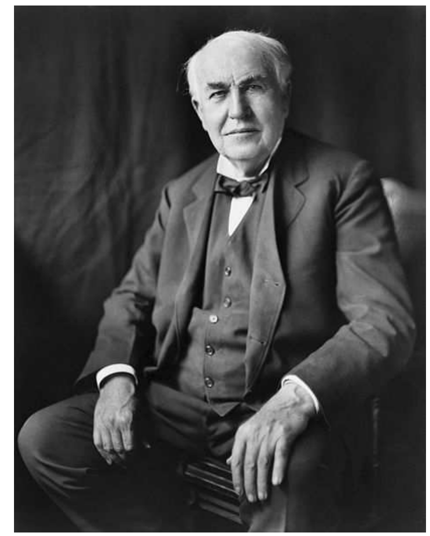
Not a world standard…



AC vs DC Power Distribution



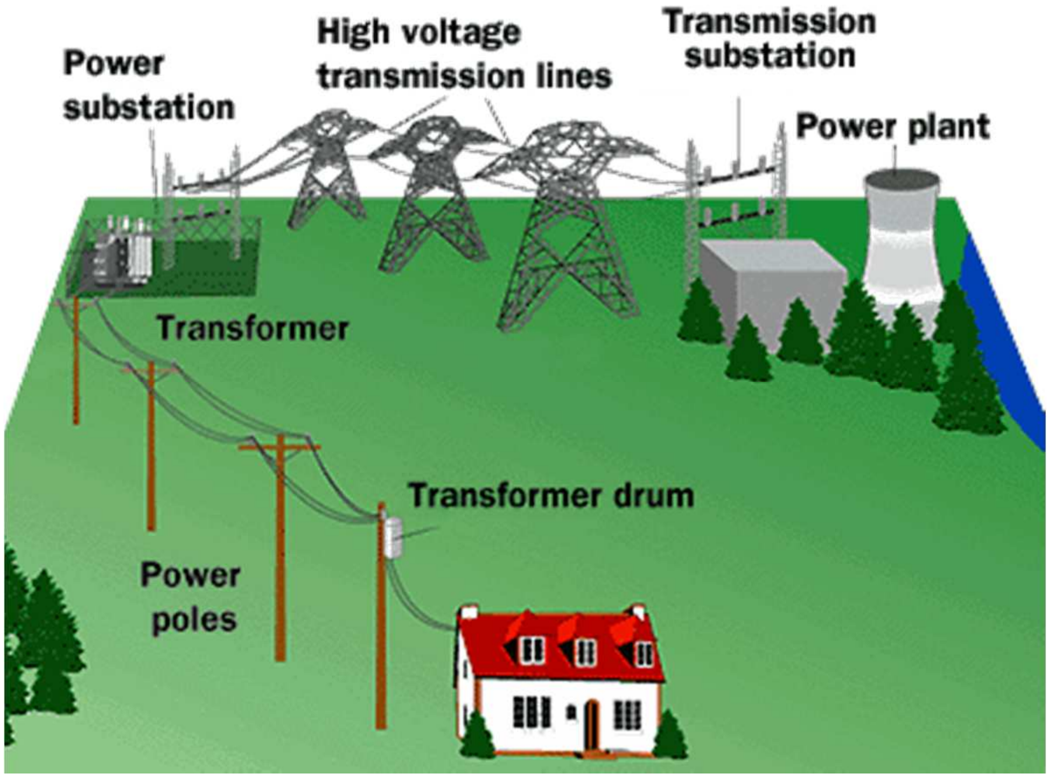




Westinghouse and Tesla promoted AC power distribution.

Edison promoted DC power distribution.

AC Power Distribution Grid



Power loss:

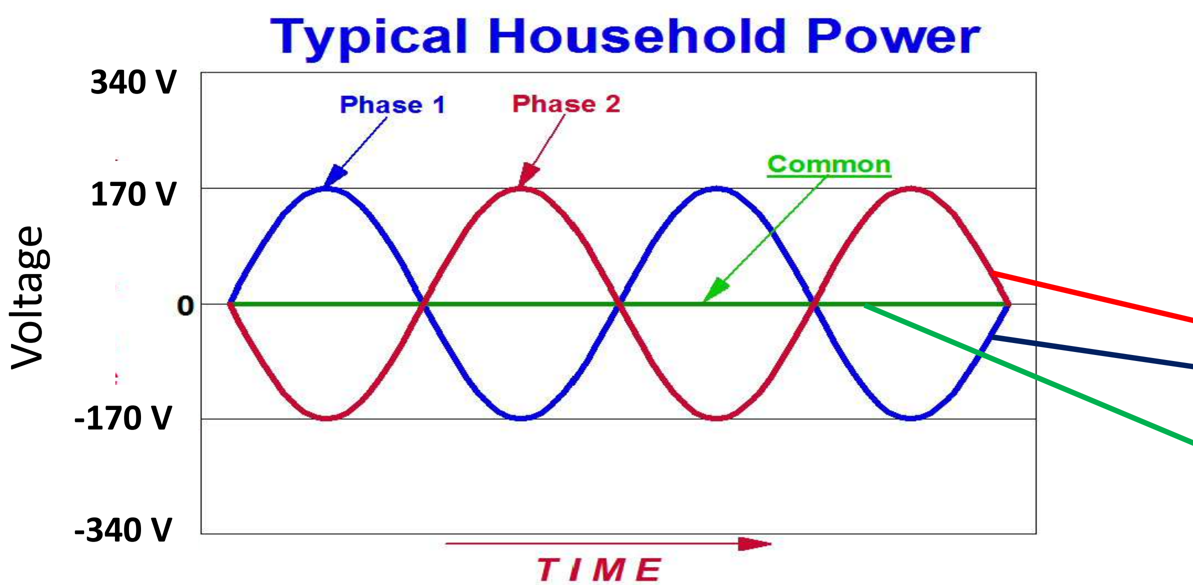
$$P = I^2 R$$

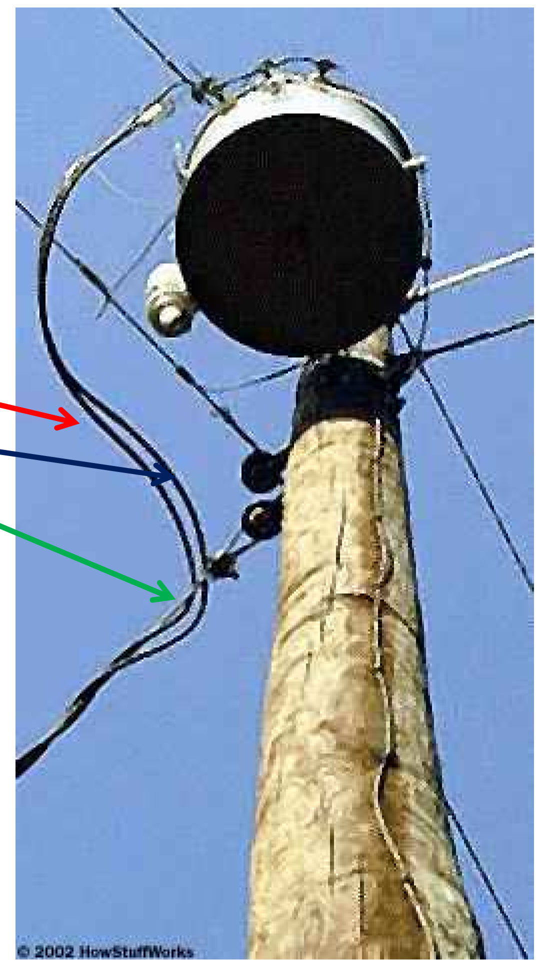
More efficient to distribute power with high voltage, low current.

Transformers convert high voltage AC to low voltage AC.

Two-Phase AC Power

- Usually, two voltage sources are provided that are 180° out of phase:





- Voltage measured between either phase 1 or phase 2 and common is **120 V** (RMS).
- Voltage measured between phase 1 and phase 2 is **240 V** (RMS).

Clicker Question

- Suppose we have two beautifully hand-crafted space heaters both of which use 1500 Watts of power.
  - One is operated from 120 VAC (single phase)
  - The other is operated from 240 VAC (two-phase)
- Which requires less current?

(a) The 120 VAC model
(b) The 240 VAC model
(c) Both are the same

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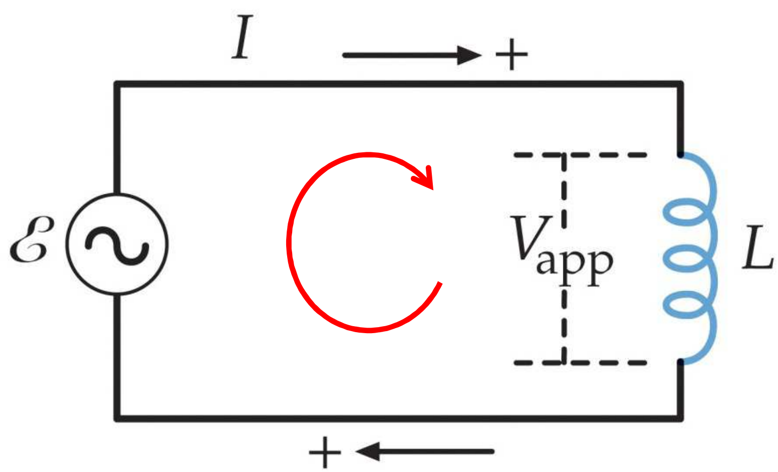
$$P = I\,V$$

Inductors in AC Circuits



- Potential difference across the inductor:

$$V_L = L\frac{dI}{dt}$$

$$\mathcal{E} = \mathcal{E}_{peak}\cos\omega t$$

$$dI = \frac{\mathcal{E}_{peak}}{L}\cos\omega t\, dt$$

$$I(t) = \frac{\mathcal{E}_{peak}}{\omega L}\sin\omega t$$

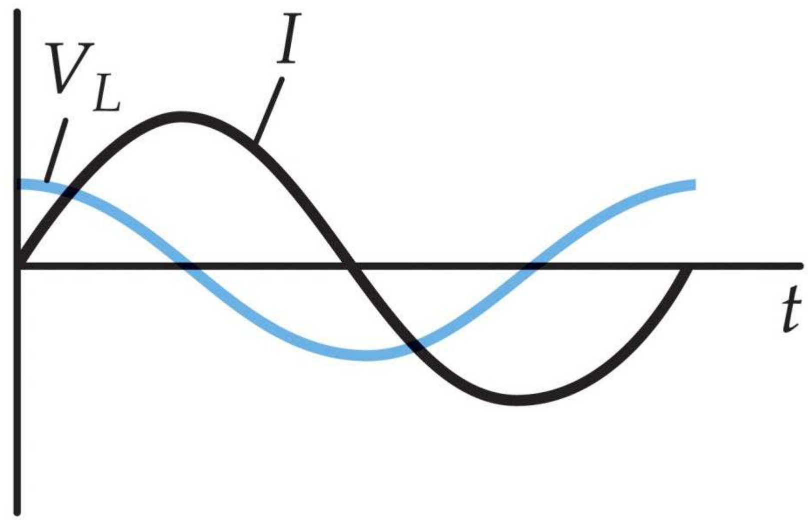
$$I_{peak} = \frac{\mathcal{E}_{peak}}{\omega L}$$

$$I_{rms} = \frac{\mathcal{E}_{rms}}{\omega L}$$

Inductive Reactance

- For a resistor, $I_{rms} = \frac{\varepsilon_{rms}}{R}$
- For an inductor, $I_{rms} = \frac{\varepsilon_{rms}}{\omega L}$
- The quantity $X_L = \omega L$ is sort of like a resistance that *depends on the frequency*.
  - It's called the "inductive reactance"
  - It has units of ohms
- Inductors store (and release) energy – they don't dissipate energy.
  - Average power delivered to an inductor is zero

Inductive Reactance



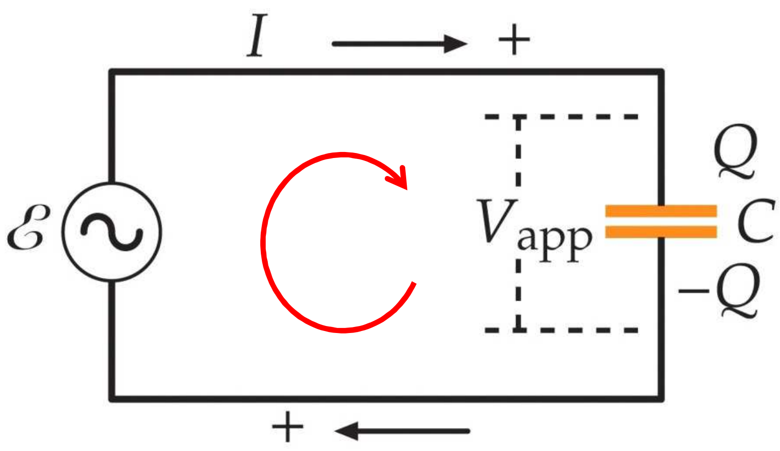
$$V_L = L\frac{dI}{dt}$$

- Potential difference across an inductor is largest when the current is increasing rapidly.
- Potential difference "leads the current" by 90°

Inductive Reactance

- Inductive reactance depends on both ω and L
  - Smaller inductance and higher frequency gives the same reactance
  - Smaller inductors are physically smaller, cost less, and are more efficient (lose less energy due to heating)
- Industrial applications use motor-generators to produce higher frequency (400 Hz) AC power:

Capacitors in AC Circuits



- Potential difference across the capacitor:

$$V_C = \frac{1}{C}\int_0^t I(t)dt$$

$$\mathcal{E} = \mathcal{E}_{peak}\cos\omega t$$

$$I(t) = C\,\frac{d\mathcal{E}}{dt}$$

$$= -\mathcal{E}_{peak}\omega C\sin\omega t$$

$$I_{peak} = \mathcal{E}_{peak}\omega C$$

$$I_{rms} = \mathcal{E}_{rms}\omega C$$

Capacitive Reactance

- We want to be able to write

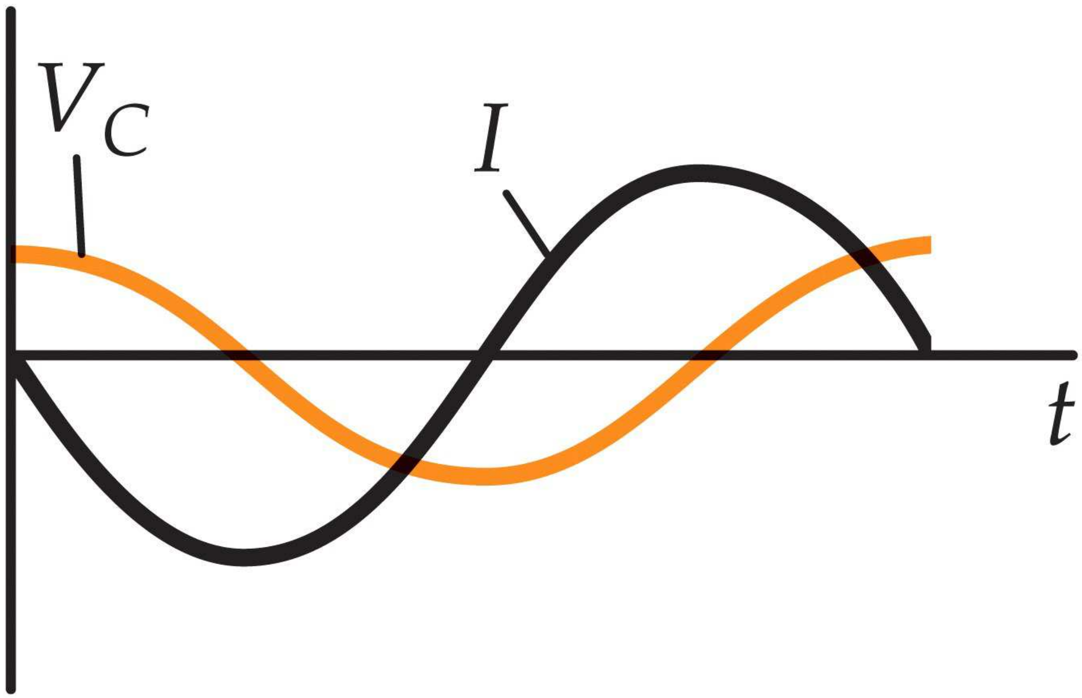
$$I_{rms} = \frac{\mathcal{E}_{rms}}{X_C}$$

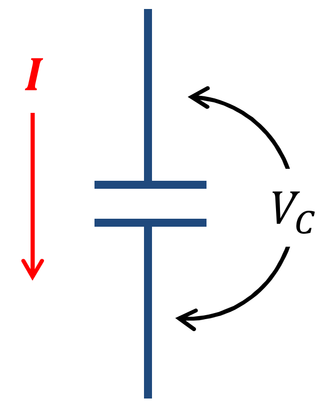
- But we already had $I_{rms} = \mathcal{E}_{rms}\omega C$
- The capacitive reactance is defined

$$X_C = \frac{1}{\omega C}$$

  – Units: ohms, just like R and X_L
- Capacitors store and release energy – they don't dissipate energy
  – Average power delivered to a capacitor is zero

Capacitive Reactance

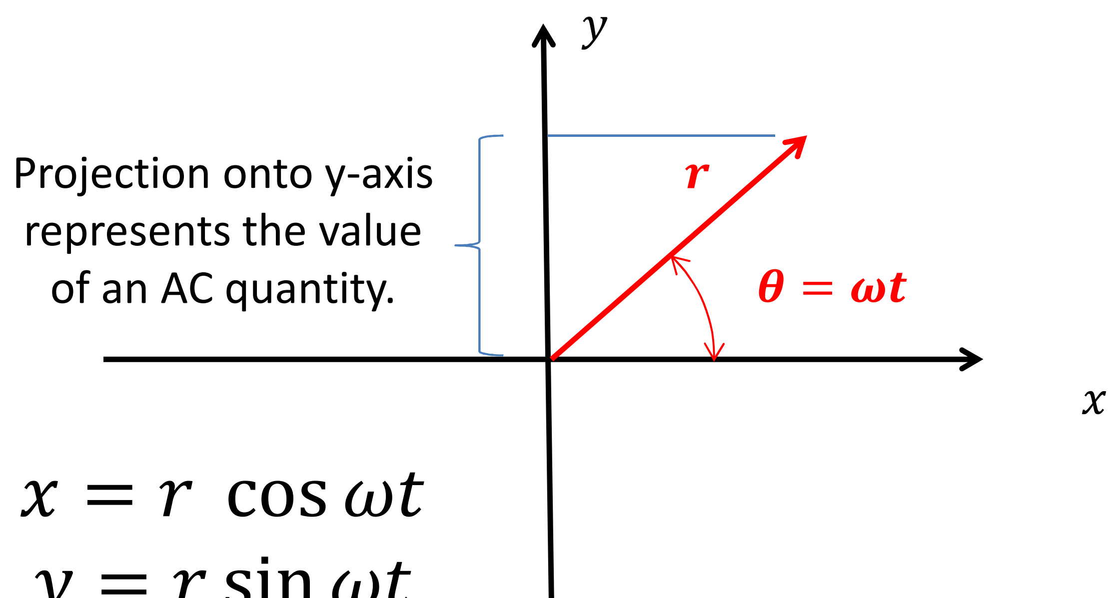




- Potential difference across an inductor is largest when the current is decreasing rapidly.
- Potential difference “lags the current” by 90°

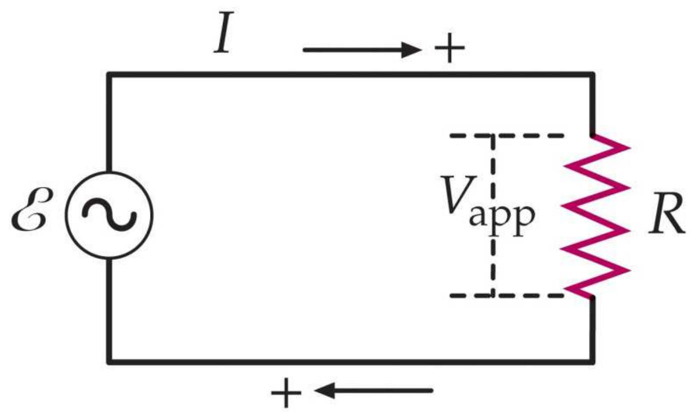
Phasors

- We can keep track of the magnitude and phase of currents and voltages using "phasor" diagrams:



$$x = r\ \cos\omega t$$
$$y = r \sin\omega t$$

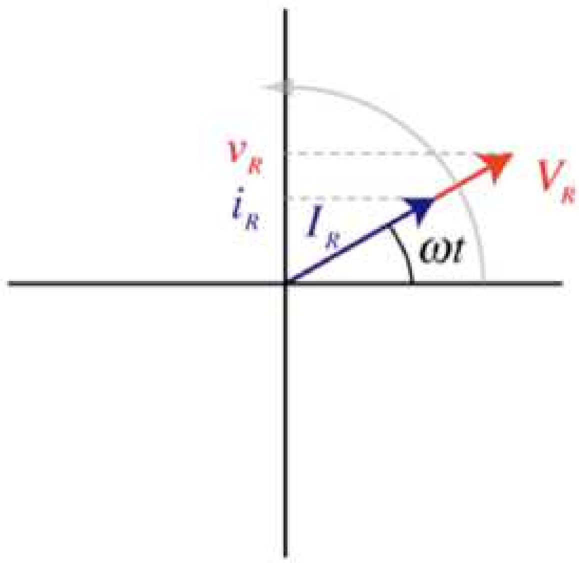
Phasors in a Resistor Circuit

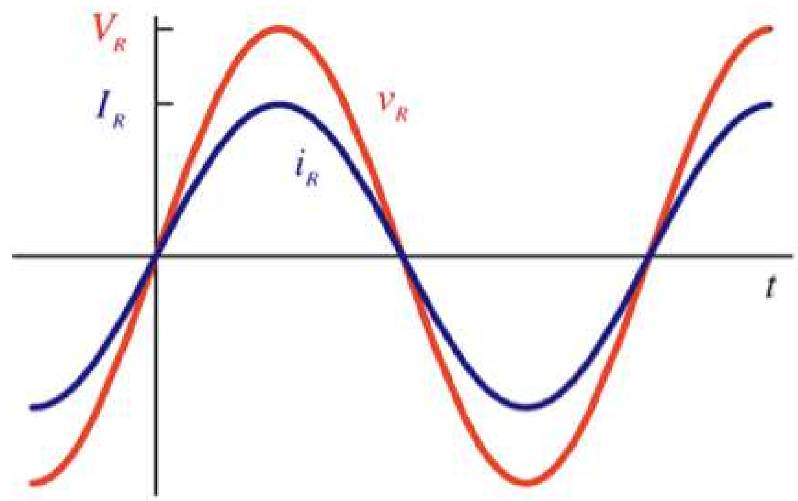


I_R and V_R are in phase:

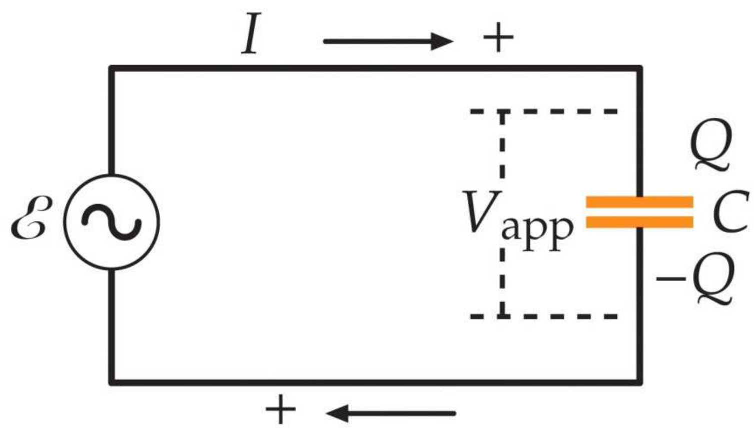
$$V_R = \mathcal{E}_{peak} \sin \omega t$$

$$I_R = \frac{\mathcal{E}_{peak}}{R} \sin \omega t$$





Phasors in a Capacitive Circuit

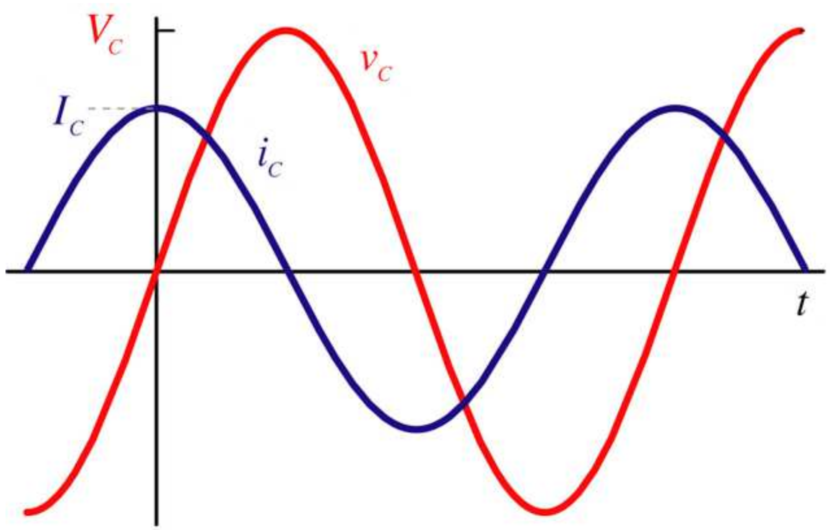


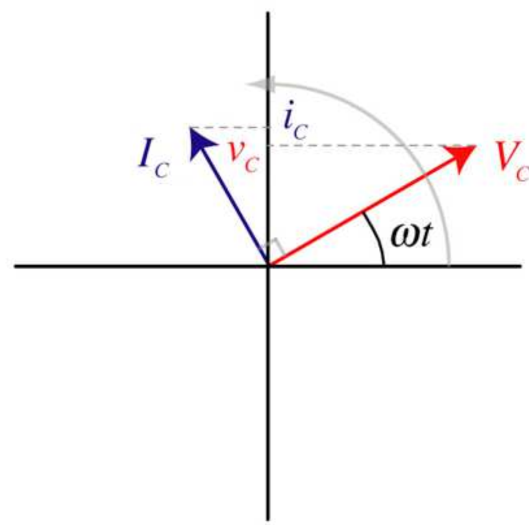
Voltage lags the current by 90°

$$V_C = \mathcal{E}_{peak} \sin \omega t$$

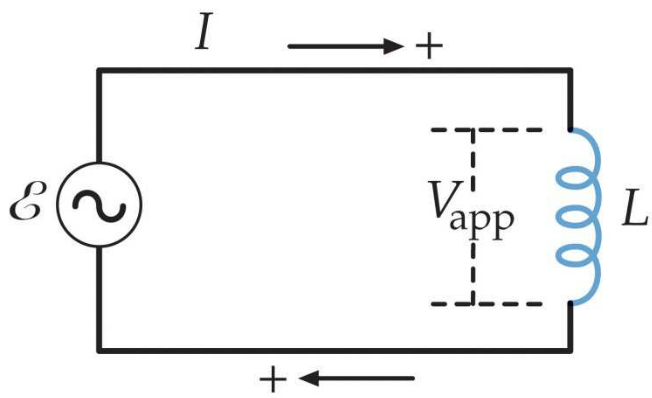
$$I_C = \omega C \mathcal{E}_{peak} \sin(\omega t + 90^\circ)$$

$$= \omega C \mathcal{E}_{peak} \cos \omega t$$





Phasors in an Inductive Circuit

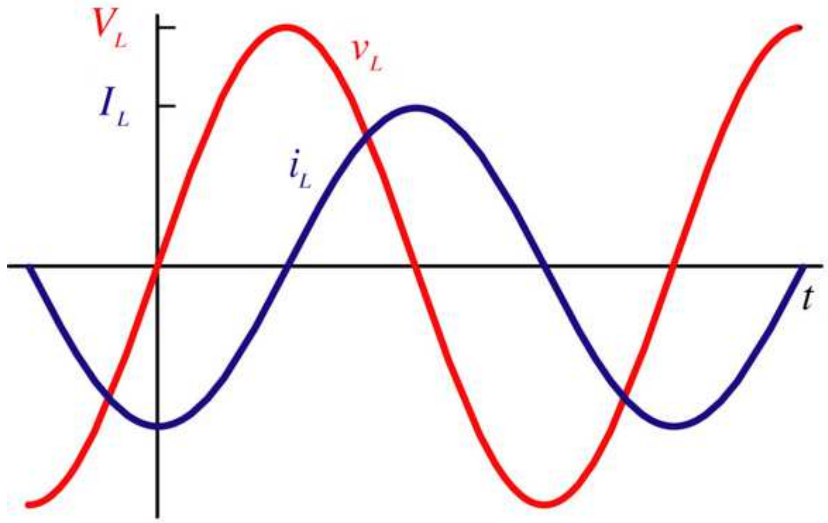


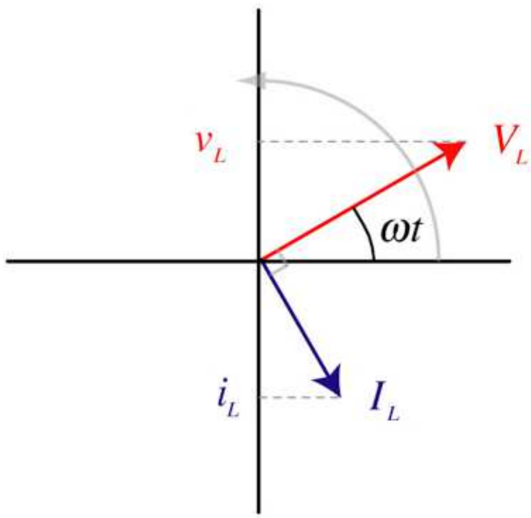
Voltage leads the current by 90°

$$V_C = \mathcal{E}_{peak} \sin \omega t$$

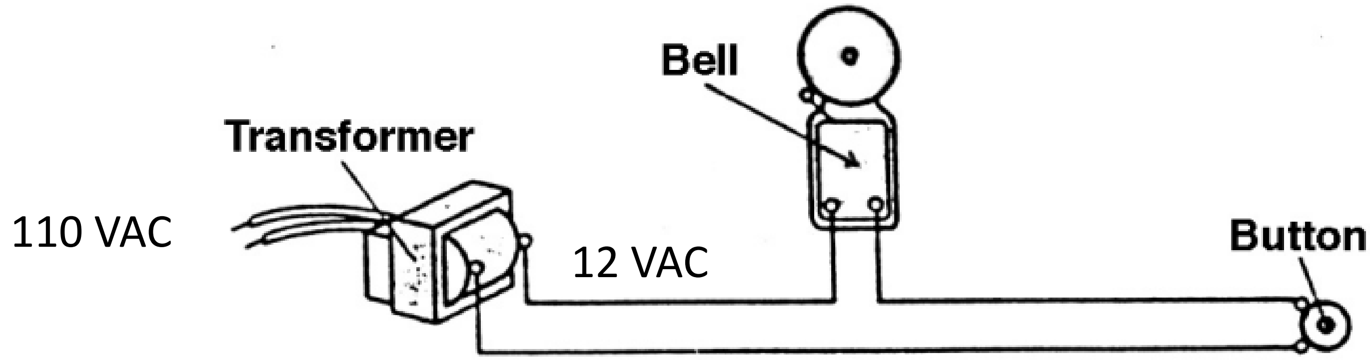
$$I_C = \frac{\mathcal{E}_{peak}}{\omega L} \sin(\omega t - 90^\circ)$$

$$= -\frac{\mathcal{E}_{peak}}{\omega L} \cos \omega t$$





Clicker Question



- A door-bell uses a transformer to produce an AC voltage of 12 volts (RMS).
- What is the peak voltage?

(a) 12 Volts
(b) 24 Volts
(c) 17 Volts
(d) 8.5 Volts