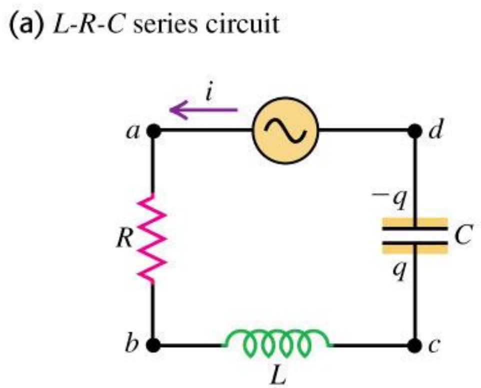
Lecture 40 (Transformers)

Physics 161-01 Spring 2012

Douglas Fields

CPS 40-1

In an *L*-*R*-*C* series circuit as shown, the current has a very small amplitude if the ac source oscillates at a very high frequency. Which circuit element causes this behavior?



A. the resistor *R*

B. the inductor *L*

C. the capacitor *C*

D. Misleading question—the current actually has a very *large* amplitude if the frequency is very high

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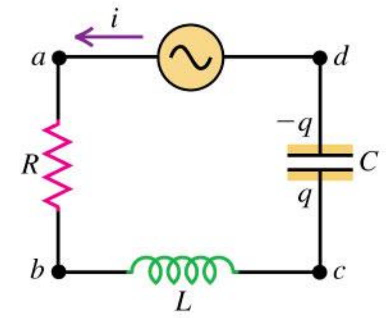
(a) *L*-*R*-*C* series circuit



A. the resistor *R*

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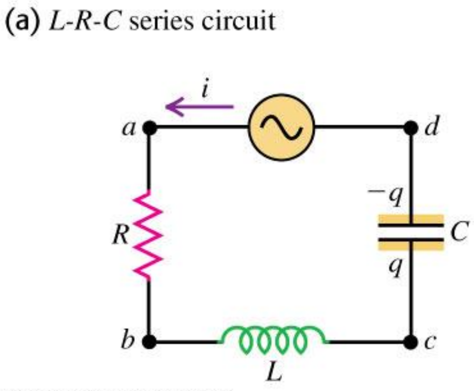
CPS 40-2

In an *L*-*R*-*C* series circuit as shown, there is a phase angle between the instantaneous current through the circuit and the instantaneous voltage v_{ad} across the entire circuit. For what value of the phase angle is the *greatest power* delivered to the resistor?



A. zero

B. 90°

C. 180°

D. 270°

E. none of the above

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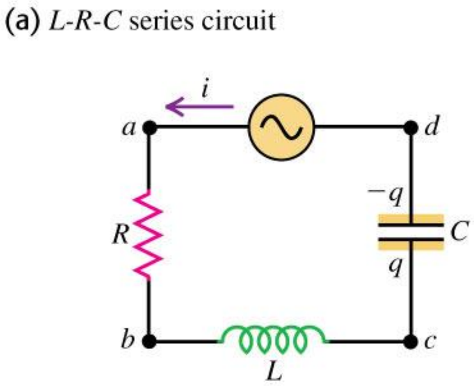

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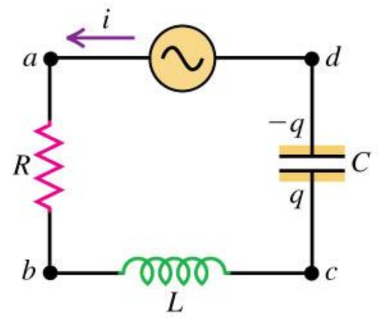
CPS 40-3

In an *L*-*R*-*C* series circuit as shown, suppose that the angular frequency of the ac source equals the resonance angular frequency. In this case, the circuit impedance

(a) *L*-*R*-*C* series circuit



A. is maximum.

B. is minimum, but not zero.

C. is zero.

D. is neither a maximum nor a minimum.

E. not enough information give to decide

CPS 40-3

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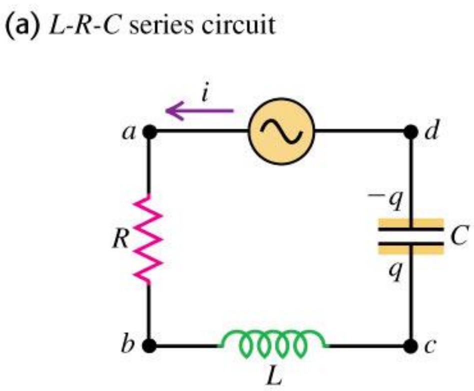

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Transformers

- For long-distance transmission, it is important to have high voltages and low currents to reduce i^2R losses in the lines.
- But, you don't want 500,000V in your household appliances, right?
- Because we use alternating EMFs, it is relatively simple to transform a high potential to a lower one (or vice versa).

Transformers

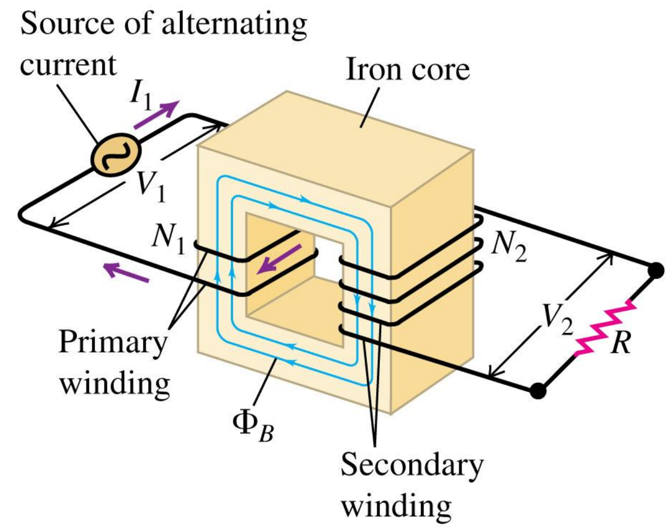
- A typical transformer is just two coils wrapped around a common core.
- If one assumes that all of the magnetic field stays inside the core, then the same magnetic flux passes through each coil.
- Then, using Faraday's law:

$$\mathcal{E}_1 = -N_1 \frac{d\Phi_B}{dt}$$

$$\mathcal{E}_2 = -N_2 \frac{d\Phi_B}{dt}$$

The induced emf *per turn* is the same in both coils, so we adjust the ratio of terminal voltages by adjusting the ratio of turns:

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$



Transformers

- Since the flux (and how it changes) is the same through both coils, then you can divide these two equations to get:

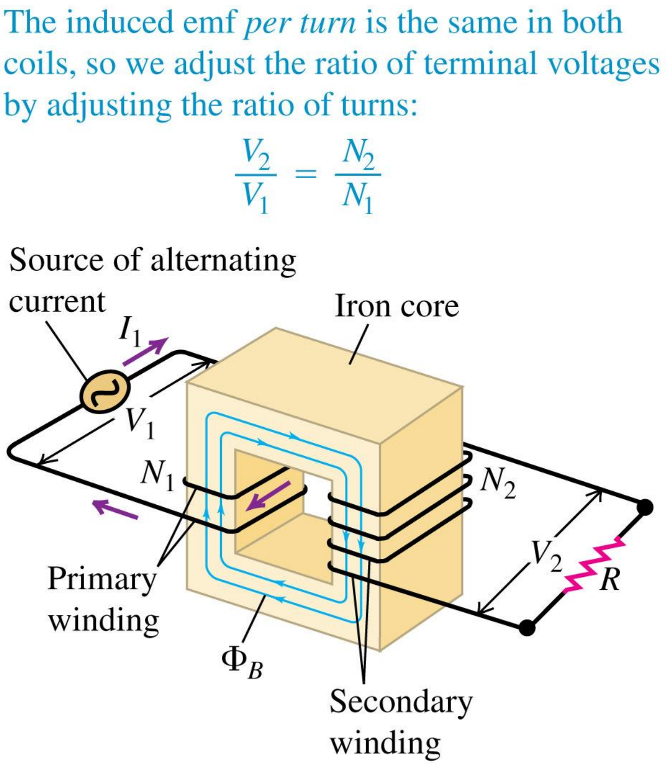
$$\mathcal{E}_1 = -N_1 \frac{d\Phi_B}{dt}$$

$$\div$$

$$\mathcal{E}_2 = -N_2 \frac{d\Phi_B}{dt}$$

$$\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{N_1}{N_2} \Rightarrow$$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

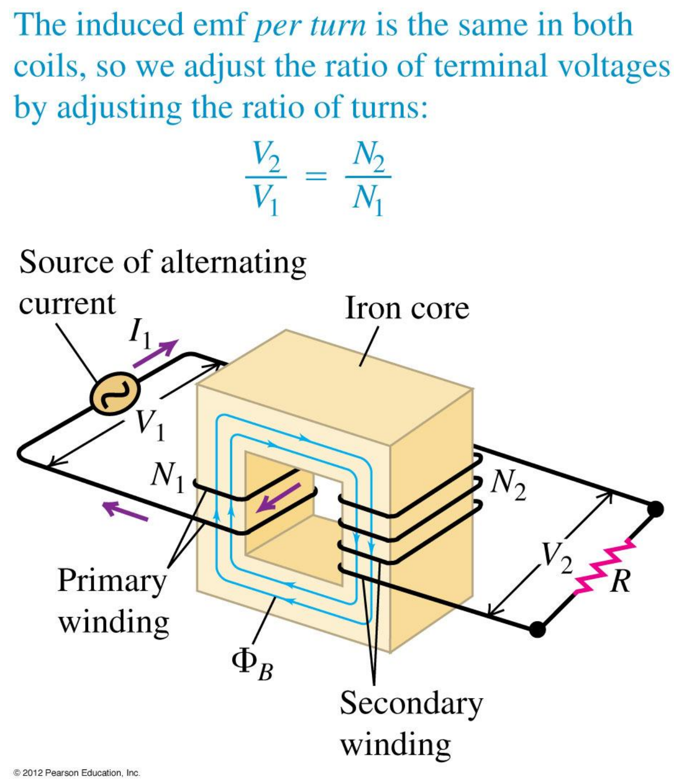


Transformers

- So, the potential at the secondary coil can be stepped down, or up, depending an the ratio of the number of coils:

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow$$

$$V_2 = \frac{N_2}{N_1} V_1$$



Power (Energy) Conservation

- Assuming for a moment that there is no energy lost in the transformer, then the power input to the transformer must be equal to the power output of the transformer:

$$V_1 I_1 = V_2 I_2$$

Transformers

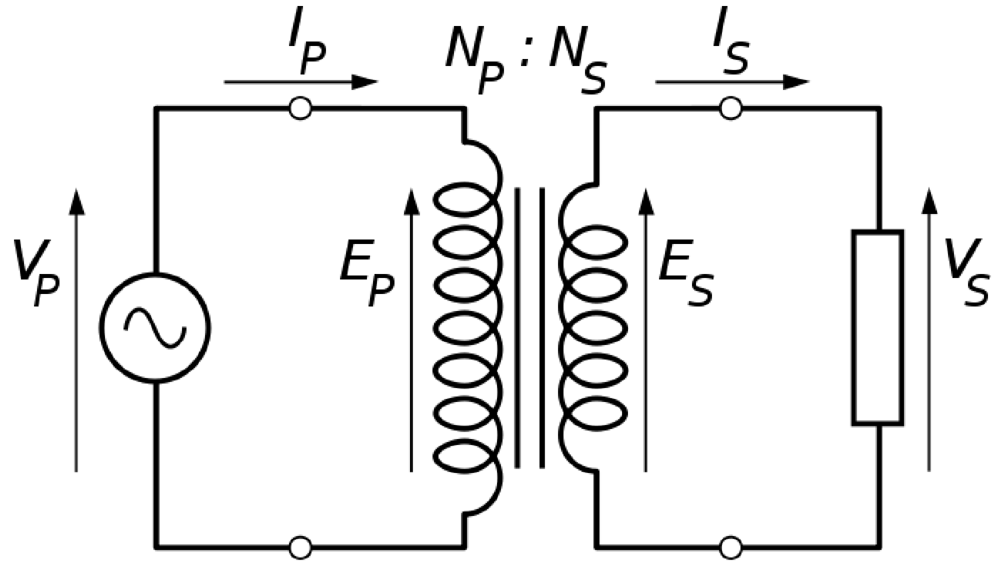
- When the voltage is stepped up, the current is stepped down, and vice versa.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow$$

$$V_2 = \frac{N_2}{N_1} V_1$$

$$V_1 I_1 = V_2 I_2 \Rightarrow$$

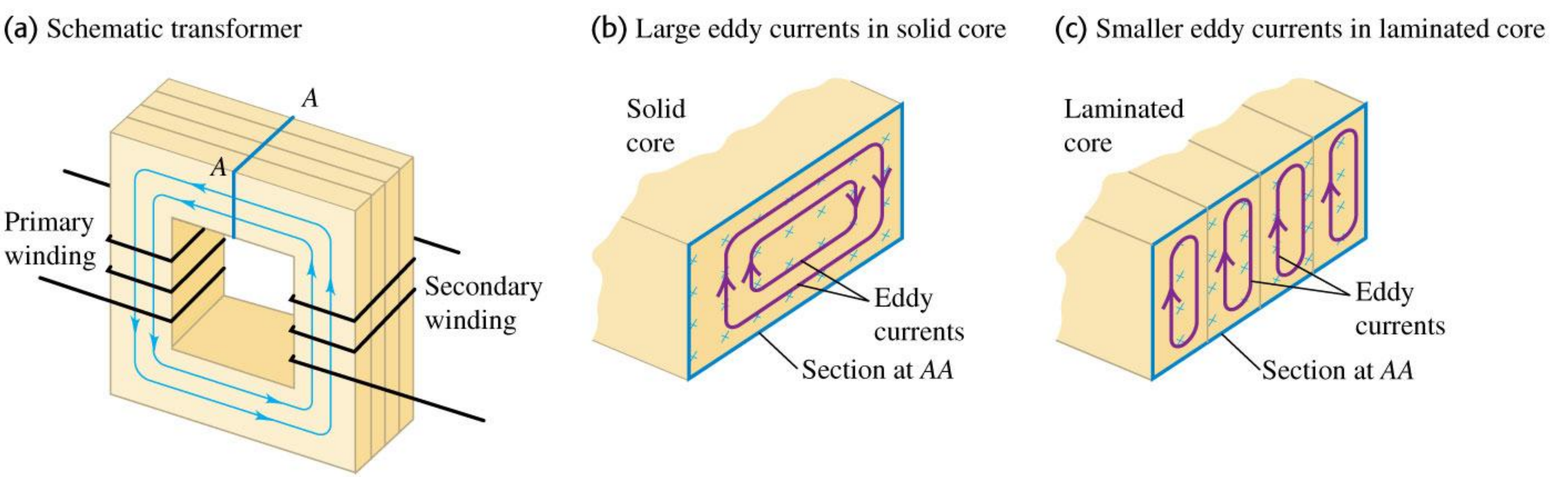
$$\frac{V_1}{V_2} = \frac{I_2}{I_1}$$



$$\frac{V_P}{V_S} = \frac{I_S}{I_P} = \frac{N_P}{N_S}$$

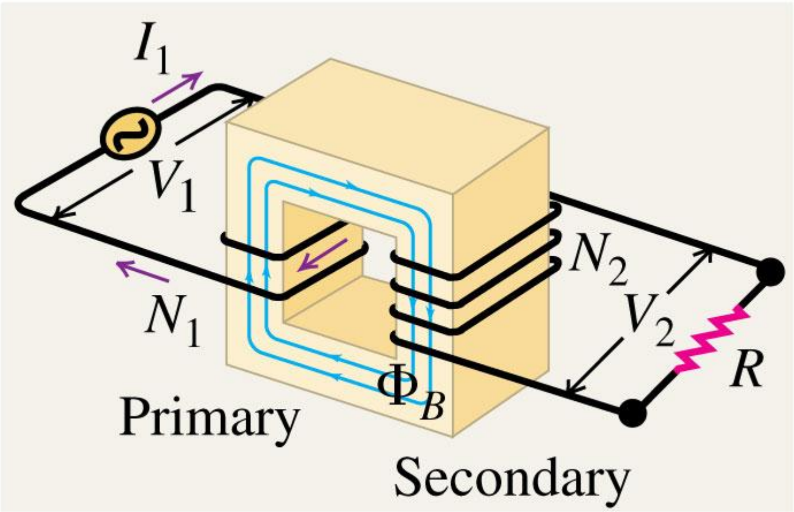
Reducing Eddy Currents

- In the real transformer, energy can be lost through heating the core, from eddy currents.
- In order to lose less energy in the transformer, we can segment the core to reduce the eddy currents, and hence the i^2R losses.



CPS 40-4

In the transformer shown in the drawing, there are more turns in the secondary than in the primary. In this situation, the *voltage amplitude* is



A. greater in the primary than in the secondary.

B. smaller in the primary than in the secondary.

C. the same in the primary and in the secondary.

D. not enough information given to decide

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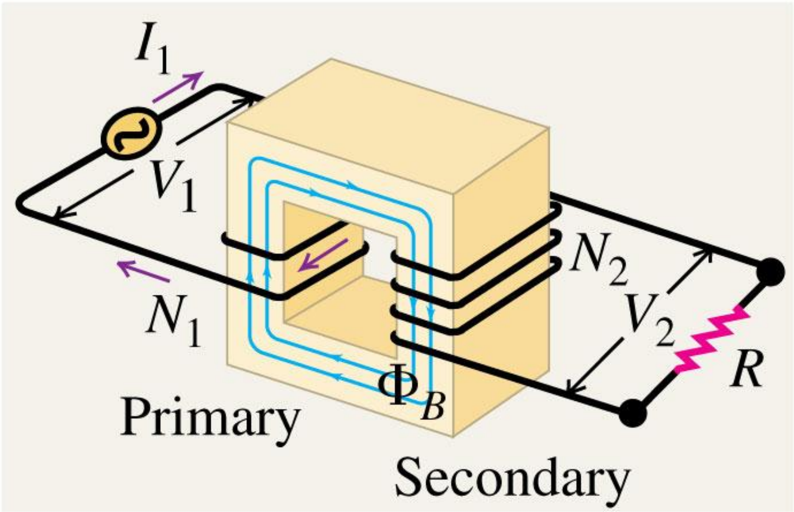

A. greater in the primary than in the secondary.

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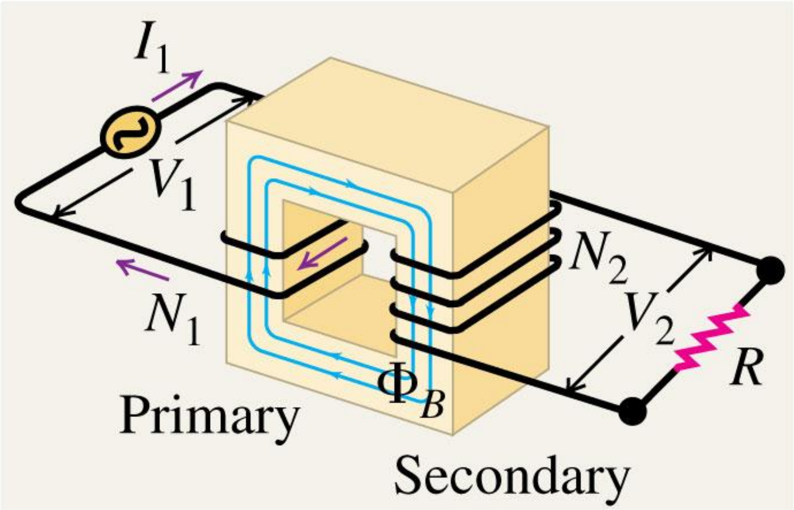
CPS 40-5

In the transformer shown in the drawing, there are more turns in the secondary than in the primary. In this situation, the *current amplitude* is



A. greater in the primary than in the secondary.

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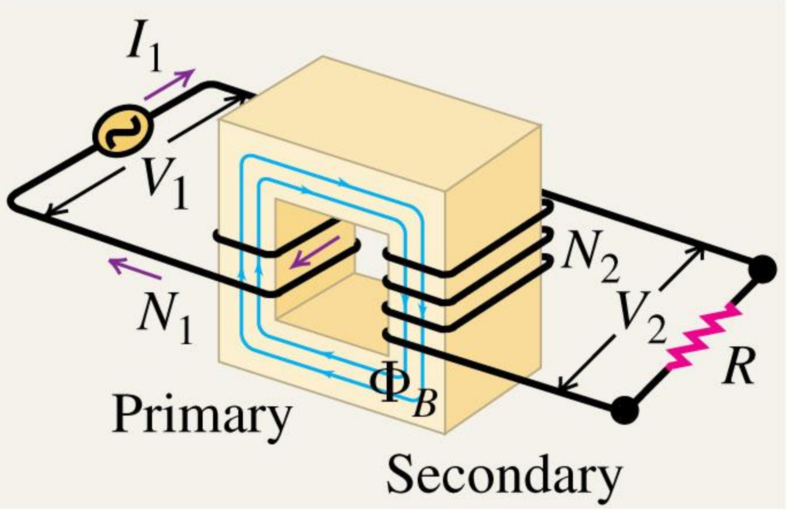

A. greater in the primary than in the secondary.

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