

## Week 7

### Physics 1409/1430 – Physics 2

Hello and Welcome to the weekly resources for PHY 1409/1430 – Physics 2!

This week is Week 7 of classes, and typically in this week of the semester, your professors are covering these topics below. If you do not see the topics your particular section of class is learning this week, please take a look at other weekly resources listed on our website for additional topics throughout the semester.

We also invite you to take a look at the group tutoring chart on our website to see if this course has a group tutoring session offered this semester.

If you have any questions about these study guides, group tutoring sessions, private 30-minute tutoring appointments, the Baylor Tutoring YouTube channel or any tutoring services we offer, please visit our website [www.baylor.edu/tutoring](http://www.baylor.edu/tutoring) or call our drop in center during open business hours, M-Th 9am-8pm on class days, at 254-710-4135.

**Keywords:** Transformers, Inductance, AC Circuits

Important Notes

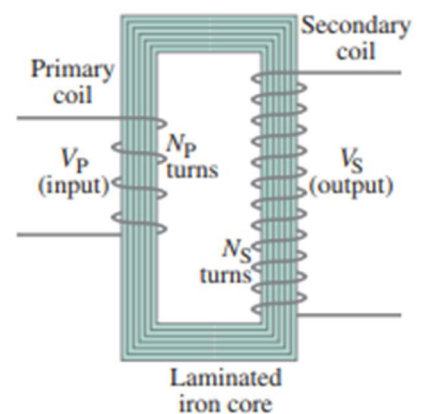
Important Conventions

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### Transformers

A transformer is used to increase or decrease an AC voltage. They are pretty much everywhere.

If you look at the electric pole on your street, you will see silver boxes with two coils coming out, that is a transformer. It essentially consists of two coils, a primary coil and secondary coil. These two coils are located such that the magnetic field produced by the primary coil all passes through the secondary coil. Since the voltage used is alternating, there is a change in flux through the second coil, which induces an AC voltage of the same frequency as the primary coil. These devices are meant to increase or decrease the voltage. This change in voltage is determined by the number of coils in the secondary coil.



The voltage induced in the second coil can be calculated using:

$$V_S = N_S \frac{\Delta\Phi_B}{\Delta t}$$

The number of turns is for the second coil in this equation. The input voltage from the primary coil can be calculated using:

$$V_P = N_P \frac{\Delta\Phi_B}{\Delta t}$$

The number of turns for this equation is for the primary coil. From these equations, we can see that **the ratio of the voltage in the primary and secondary coils is proportional to the number of turns in the coils for both.** Voltage is also directly proportional to the current. Hence, from these relations, we can derive the two transformer equations:

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

**What is essential here is to remember how the number of turns in the coils affect the voltage and currents for the two coils.**

The number of coils for the secondary and primary transformer also tells us the type of transformer. **If the number of coils in the primary coil is greater than the secondary coil, it is a step down transformer. If the number of coils in the secondary coil is greater than the primary coil, it is a step-up transformer.**

### Example

The charger for a cell phone contains a transformer that reduces 120 V to 5 V in AC. If the number of turns in the secondary coil is 30 and the current produced is 700 mA, what is the number of turns in the primary coil, and what is the current in the primary coil?

### Solution

$$N_P / N_S = V_P / V_S$$

$$N_P = N_S (V_P / V_S) = 30(120)/(5) = 720 \text{ turns}$$

**What is essential in these problems is to keep track of the coil you are looking at.**

$$I_p = I_s (N_s)/N_p = (0.7)(30)/(720) = 0.29 \text{ A}$$

## Inductance

Inductance is a principle demonstrated by transformers. When two coils are placed close together and a changing current is passing through one coil, this induces an emf in the second coil. This induction of current is proportional to the rate of change in the current because that rate of change is proportional to the flux. The factor of proportionality for the emf induced is called mutual inductance (M). The induced emf in the second coil and first coil can be calculated using:

$$\mathcal{E}_2 = -M \frac{\Delta I_1}{\Delta t} \qquad \mathcal{E}_1 = -M \frac{\Delta I_2}{\Delta t}$$

The value of mutual inductance is dependent upon physical properties only. It is determined by the size, shape, and number of turns in the coil, and the distance between the two coils. Hence, for a given system, the value of M is constant.

This also occurs in single coils, where there is an induced emf due to AC electricity in the coil itself. The change in current causes a changing magnetic flux in the coil itself, which leads to self-inductance(L). This value is also determined by the physical properties of the coil. The induced emf by self-inductance can be calculated using:

$$\mathcal{E} = -L \frac{\Delta I}{\Delta t}$$

In circuits, these coils are called inductors. They have certain properties in circuits much like capacitors and resistors. What is more important is to understand the behavior in an AC circuit.

## AC Circuits:

In ac circuits, the power source produces an alternating voltage. This power source is represented as



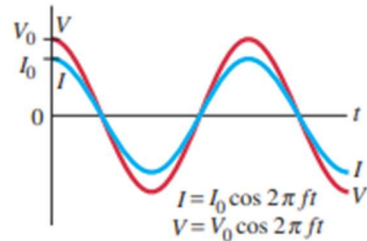
Which produces a sinusoidal voltage. The current and voltage produced follows the behavior of a sinusoidal function.

$$I = I_0 \cos 2\pi ft$$

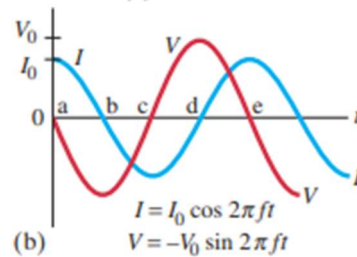
$$V = V_0 \cos 2\pi ft$$

What is essential to understand is how the behavior is in the resistors and inductors of the circuit.

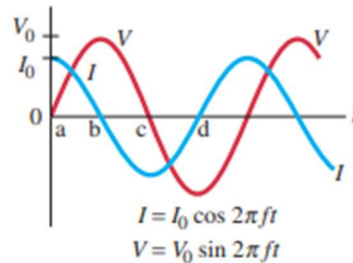
In a resistor, the voltage and current functions are in phase with each other.



But in an inductor, the current lags the voltage by 90 degrees



Finally, in a capacitor, the current leads the voltage by 90 degrees.



### CHECK YOUR LEARNING

1. Which of the following is true about all series ac circuits?
  - a. The voltage across any circuit element is a maximum when the current is a maximum in that circuit element.
  - b. The current at any point in the circuit is always the same as the current at any other point in the circuit.
  - c. The current in the circuit is a maximum when the source ac voltage is a maximum.

- d. Resistors, capacitors, and inductors can all change the phase of the current.
2. A transformer has 200 turns in the primary coil and 400 turns in the secondary coil. What kind of transformers is this? By what factor will the voltage change?
  3. Determine the inductance of a 0.2 m long air-filled Solenoid, 1 cm in diameter with 2000 loops. What kind of inductance is this?
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### **THINGS YOU MAY STRUGGLE WITH**

1. The transformer equation and realizing which voltage should be bigger and which coil should have more loops. Remember the two types of transformers, when you are trying to increase the voltage, you are using a step-up transformer. More loops will correspond to more induced emf. So, the second coil should have more loops than the first. When you want to decrease the voltage, you are using a step-down transformer. Less loops will correspond to less induced emf. So, the first coil should have more loops than the second coil.
2. Remember that when there are two coils (like transformers), if there is an alternating current, they are inducing a current in one another. This property of is called mutual inductance. How much emf is induced is dependent on the coils used and their mutual inductance. Mutual inductance is a PHYSICAL property. But even when there is a coil with ac current, it also induced current, which is referred to a self-inductance, also a PHYSICAL property.
3. AC electricity and oscillations of the voltage and current. The sinusoidal nature tends to create lots of difficulty trying to understand how the behavior affects a circuit and its elements. As far as the wave nature is concerned, remember how the phases for the voltage and current relate in the components. Use the examples shown in the textbook to reinforce how to analyze the numerical values for the circuit.

**Thanks for checking out these weekly resources! Don't forget to check out our website for group tutoring times, video tutorials and lots of other resource: [www.baylor.edu/tutoring](http://www.baylor.edu/tutoring) !**  
**Answers to check you learning questions are below!**

Answers: 1. (b) , 2. Step-up, 2 times primary, 3. Self inductance, 0.002 H