Slide 2: What is an Inductor? How is it Made?

What is an Inductor?

- A passive electronic component that stores energy in a magnetic field when electric current flows through it.
- Opposes changes in current (properly called inductance).
- Symbol: Coil (looks like a series of loops).
- Unit of inductance: Henry (H).

How is it Made?

- Basic construction: Conducting wire (usually copper) wound into a coil around a core.
- Core materials:
  - Air core (no magnetic material)
  - Iron / ferrite / powdered iron core (increases inductance)
- Number of turns, core material, and coil geometry determine the inductance value.
- Formula for inductance of a simple solenoid:

$$L = \frac{\mu N^2 A}{l}$$

where μ = permeability, (N) = number of turns, (A) = cross-sectional area, (l) = length

Slide 3: Basic Purpose of Inductor & Types

Basic Purpose

- Store energy in magnetic field.
- Oppose sudden changes in current.
- Used for filtering, tuning circuits, energy storage (switch mode power supplies), transformers, chokes, etc.

Types of Inductors

- **Air-core inductors** → Low inductance, high frequency applications.
- **Iron-core inductors** → Higher inductance, power applications.
- **Ferrite-core inductors** → High frequency + good magnetic properties.

5. **Toroidal inductors** → Closed magnetic path, low EMI.
6. **Variable inductors** → Adjustable (with movable core).
7. **Chip / SMD inductors** → Surface-mount for modern PCBs.

Slide 4: DC Response & AC Response of Inductor

DC Response

- At the moment of switching on: Inductor acts as open circuit (current cannot change instantly).
- After steady state: Acts as short circuit (resistance of wire only, ideally $R = 0$).
- Energy stored: $E = \frac{1}{2}Li^2$

AC Response

- Offers inductive resistance:

$$X_L = 2\pi f L = \omega L$$

- Impedance: $Z = jX_L$ (purely imaginary for ideal inductor).
- Current lags voltage by 90°.

Slide 5: Waveforms – Voltage & Current for Inductor

Key Relation

$$v = L\frac{di}{dt}$$

Waveforms (Ideal Inductor)

- When voltage is sinusoidal: $v = V_m \sin(\omega t)$
- Current is: $i = -\cos(\omega t)$
  (current lags voltage by 90°).

Visual suggestion for slide:

- Draw two sine curves. Voltage (blue) peaking first, Current (red) delayed by 90°.
- Mark: Voltage leads, Current lags.
- Also show square-wave voltage → triangular current (or vice versa).

Slide 6: Comparison with Resistance

Parameter	Resistor	Inductor
Energy	Dissipates as heat	Stores in magnetic field
Phase	V and I in phase	I lags V by 90°
DC behavior	Constant resistance	Short circuit (ideally, state)
AC opposition	R (frequency independent)	$X_L = \omega L$ (increases with f)
Power	Average power > 0	Average power = 0 (ideal)
Formula	$V = IR$	$v = L\frac{di}{dt}$

Slide 7: Why Current Lags in an Inductor

Explanation

- When voltage is applied, current tries to increase.
- Changing current produces changing magnetic flux.
- Changing flux induces a back-EMF (Lenz's law) that opposes the change in current.
- Therefore, current cannot rise immediately → it lags behind the voltage.
- Mathematically: $v = L\frac{di}{dt}$ → current is the integral of voltage → 90° phase lag for sine waves.

Key point: The inductor "resists" change in current, causing the lag.

Slide 8: Numericals – Inductor & Resistor with AC Source

Example 1

An inductor of 0.9 H is connected to a 230 V, 50 Hz AC supply. Find: (a) Inductive reactance (b) Current

Solution:

$X_L = 2\pi f L = 2 \times 3.14 \times 50 \times 0.9 = 282.6\ \Omega$

$I = \frac{V}{X_L} = \frac{230}{282.6} = 0.81\ A$

Example 2 (Series RL circuit)

R = 30 Ω, L = 0.1 H, V = 200 V, f = 60 Hz

Find impedance, current, and phase angle.

$X_L = 2\pi \times 50 \times 0.1 = 31.4\Omega$

$Z = \sqrt{R^2 + X^2} = \sqrt{30^2 + 31.4^2} = 43.4\Omega$

$I = 230/43.4 = 5.41\ A$

$\phi = \tan^{-1}(X_L/R) = \tan^{-1}(31.4/30) = 46.3^\circ$ (current lags)

(Add 1–2 more numericals if needed on the next slide.)

Slide 9: Inductor Relation with Magnetic Material

- Inductance depends strongly on the core material.
- Magnetic materials concentrate magnetic flux → higher inductance for same number of turns.
- Relative permeability μ_r of the core multiplies the inductance.
- Soft magnetic materials (ferrite, silicon steel) are preferred because they have low hysteresis loss and can be easily magnetized/demagnetized.
- Air has $\mu_r = 1$; ferrites can have μ_r from hundreds to thousands.

Slide 10: Permeability & B-H Curve

Permeability (μ)

- Measure of how easily a material can be magnetized.
- $P = \chi_m$
- $\mu = 4\pi \times 10^{-7}$ H/m (free space)
- Higher μ → higher inductance.

B-H Curve (Magnetization Curve)

- B = Magnetic flux density
- H = Magnetic field strength
- $B = \mu H$
- Non-linear for ferromagnetic materials.
- Shows hysteresis loop (energy loss per cycle).
- Saturation region: further increase in H produces little increase in B.

Slide tip: Insert a standard B-H curve diagram showing linear region, knee, and saturation.

Slide 11: Self Inductance & Mutual Inductance

Self Inductance (L)

- Property of a single coil.
- EMF induced in the coil due to change in its own current:

$$\varepsilon = -L\frac{di}{dt}$$

- $L = N\Phi/I$ (where Φ is flux linkage).

Mutual Inductance (M)

- Property between two coils.
- Change in current in one coil induces EMF in the other.
- $\varepsilon_2 = -M\frac{di_1}{dt}$
- $M = k\sqrt{L_1 L_2}$
  where k is coefficient of coupling ($0 \le k \le 1$)

Applications: Transformers (mutual inductance is the working principle).

Slide 12: Summary / Key Takeaways

- Inductor stores energy in magnetic field and opposes change in current.
- Current lags voltage by 90° in pure inductor.
- Resistance increases with frequency.
- Core material and permeability greatly affect inductance.
- Self inductance vs Mutual inductance form the basis of transformers and coupled circuits.

Tips for making the actual PPT:

- Use consistent color theme (blue/grey for technical look).
- Add circuit diagrams and waveform images on relevant slides.
- Keep text minimal → use bullet points.
- Animate the waveforms (appear step-by-step).
- Add a final "Thank You / Questions" slide.

Would you like me to expand any specific slide with more numericals, diagrams description, or add speaker-notes?

Detailed Document: Inductor under AC Supply – Proof of Current Lag, Waveforms & Numerical Problems

Introduction

An ideal inductor is a pure energy-storage element with zero resistance. When connected to an alternating voltage source, the current through the inductor does **not** remain in phase with the voltage. Instead, the current **lags** the voltage by exactly 90° (or π/2 radians).

This document provides:

- Rigorous mathematical proof
- Physical explanation (why the lag occurs)
- Waveform analysis
- Phasor representation
- Extended numerical problems involving pure inductors and series RL circuits

Mathematical Derivation (Proof of 90° Lag)

Consider a pure inductor of inductance (L) henry connected across an AC voltage source:

$$v = V_m \sin(\omega t)$$

where

- V_m = peak voltage
- $\omega = 2\pi f$ = angular frequency

Fundamental equation of an inductor:

$$v = L\frac{di}{dt}$$

Rearranging:

$$\frac{di}{dt} = \frac{V_m}{L}\sin(\omega t)$$

Integrating both sides with respect to time:

$$i = \int \frac{V_m}{L}\sin(\omega t)\,dt = -\frac{V_m}{\omega L}\cos(\omega t) + C$$

For a pure sinusoidal steady-state AC circuit, the constant of integration $C = 0$ (no DC component).

Thus

$$i = -\frac{V_m}{\omega L}\cos(\omega t)$$

Using the trigonometric identity $-\cos(\theta) = \sin(\theta - 90^\circ)$:

$$i = \frac{V_m}{\omega L}\sin(\omega t - 90^\circ)$$

or

$$i = I_m \sin(\omega t - 90^\circ)$$

where the peak current is

$$I_m = \frac{V_m}{\omega L} = \frac{V_m}{X_L}$$

and $X_L = \omega L = 2\pi f L$ is the inductive reactance.

Conclusion from above steps:
The current expression contains a phase shift of −90°. Therefore, **current lags voltage by 90°**.

Physical Explanation – Why Does Current Lag?

- When an alternating voltage is applied, the current tries to change.
- A changing current produces a changing magnetic flux ($\phi = Li$).
- According to Faraday's law, a changing flux induces an emf:

$$e = -\frac{d\phi}{dt}$$

A. By Lenz's law, this induced emf (back-emf) **opposes** the change in current.

B. Therefore, the current cannot rise or fall at the same instant as the voltage. It is delayed.

C. In the sinusoidal steady state, this continuous opposition results in a precise 90° phase lag.

Key Insight:
The inductor does not dissipate energy; it stores and returns energy. The phase difference of 90° ensures that the average power over a cycle is zero.

Waveform Analysis

Voltage waveform:

$$v = V_m \sin(\omega t)$$

Current waveform:

$$i = I_m \sin(\omega t - 90^\circ)$$

Important observations from the waveforms:

Instant			Explanation
$\omega t = 0^\circ$	0 (rising)	Maximum negative	Current is increasing most rapidly
$\omega t = 90^\circ$	Maximum positive	Zero	Voltage max, current crossing zero
$\omega t = 180^\circ$	0 (falling)	Maximum positive	Current decreasing most rapidly
$\omega t = 270^\circ$	Maximum negative	Zero	Zero

- Voltage reaches its positive peak **first**.
- Current reaches its positive peak **90° later**.
- When voltage is maximum, rate of change of current is zero (current is at peak).
- When voltage is zero, rate of change of current is maximum.

Power waveform:
Instantaneous power $p = vi$ is a double-frequency sine wave that is positive in one half and negative in the other half of the cycle → average power = 0.

Phasor Representation

In phasor form (using R.M.S values):

- Voltage phasor: $\mathbf{V} = V\angle 0^\circ$
- Current phasor: $\mathbf{I} = I\angle -90^\circ$

The impedance of a pure inductor is

$$\mathbf{Z}_L = jX_L = j\omega L$$

Numerical Problems

Pure Inductor Problems

Problem 1
A pure inductor of 0.2 H is connected to a 230 V, 50 Hz AC supply. Calculate:

- Inductive reactance
- R.M.S current
- Peak current
- Equation of instantaneous current (taking voltage as reference)

Solution:

(a) $X_L = 2\pi f L = 2 \times 3.14 \times 50 \times 0.2 = 62.8\Omega$

(b) $I = \frac{V}{X_L} = \frac{230}{62.8} = 3.66\ A$

(c) $I_m = \sqrt{2} \times 3.66 = 5.18\ A$

(d) $\omega = 2\pi f = 2\pi \times 50 = 314\ rad/s$

$i = 5.18\sin(314t - 90^\circ)\ A$

Problem 2
The current through a pure inductor is $i = 8\sin(314t - 60^\circ)$ A.

If $L = 0.1$ H, find the voltage across the inductor and write its instantaneous equation.

Solution:

$X_L = 314 \times 0.1 = 31.4\Omega$

$V_m = I_m X_L = 8 \times 31.4 = 251.2\ V$

Voltage leads current by 90°, so

$v = 251.2\sin(314t - 60^\circ + 90^\circ) = 251.2\sin(314t + 30^\circ)\ V$

Series RL Circuit Problems

Problem 3
A coil has resistance 20 Ω and inductance 0.1 H. It is connected to a 200 V, 50 Hz supply. Calculate:

- Inductive reactance
- Impedance
- Current
- Phase angle
- Power factor
- Power consumed

Solution:

(a) $X_L = 2\pi \times 50 \times 0.1 = 31.4\Omega$

(b) $Z = \sqrt{R^2 + X^2} = \sqrt{20^2 + 31.4^2} = 37.2\Omega$

(c) $I = \frac{V}{Z} = 5.38\ A$

(d) $\phi = \tan^{-1}\left(\frac{X}{R}\right) = \tan^{-1}(1.57) = 57.5^\circ$ (lagging)

(e) Power factor $= \cos\phi = \frac{R}{Z} = 0.538$ lagging

(f) Power $= I^2 R = (5.38)^2 \times 20 = 579\ W$

(or $VI\cos\phi = 200 \times 5.38 \times 0.538 = 579\ W$)

Problem 4
An RL series circuit takes 5 A current when connected to a 100 V, 50 Hz supply. The power consumed is 300 W. Calculate:

- Resistance
- Impedance
- Inductive reactance
- Inductance
- Phase angle

Solution:

(a) $I = I^2 R \Rightarrow 300 = 25 \times R \Rightarrow R = 12\Omega$

(b) $Z = \frac{V}{I} = \frac{100}{5} = 20\Omega$

(c) $X_L = \sqrt{Z^2 - R^2} = \sqrt{400 - 144} = 16\Omega$

(d) $L = \frac{X_L}{2\pi f} = \frac{16}{314} = 0.051\ H$

(e) $\phi = \tan^{-1}\left(\frac{X}{R}\right) = 53.1^\circ$ lagging

Problem 5
A 50 Ω resistor is connected in series with a 0.25 H inductor across a 230 V, 50 Hz supply. Find:

- Current
- Voltage across resistor and inductor
- Power factor
- Draw the phasor diagram description

Solution:

$X_L = 2\pi \times 50 \times 0.25 = 78.5\Omega$

$Z = \sqrt{50^2 + 78.5^2} = 93.1\Omega$

(a) $I = \frac{230}{93.1} = 2.47\ A$

(b) $V_R = IR = 2.47 \times 50 = 123.5\ V$

$V_L = IX_L = 2.47 \times 78.5 = 194\ V$ (Note: $\sqrt{V_R^2 + V_L^2} = 230\ V$)

(c) $\cos\phi = \frac{R}{Z} = 0.537$ lagging

(d) Phasor: Current as reference. V_L in phase with current, V_L leading current by 90°. Resultant voltage leads current by ϕ.

Problem 6
When a pure resistor of 60 Ω is connected to a 200 V AC supply, it draws 5 A. When an inductor is connected in series with the same resistor, the current falls to 2 A. Find the inductance if frequency is 50 Hz.

Solution:

With R only: $I = \frac{V}{R} = 5\ A$ (checks out).

With RL: $Z = \frac{V}{I} = 100\Omega$

$X_L = \sqrt{Z^2 - R^2} = \sqrt{10000 - 3600} = 80\Omega$

$L = \frac{X_L}{2\pi f} = 0.255\ H$