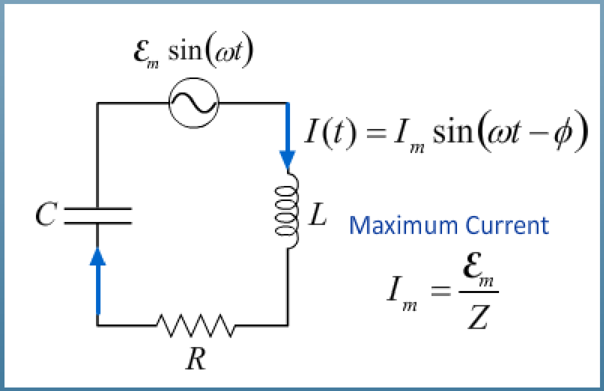
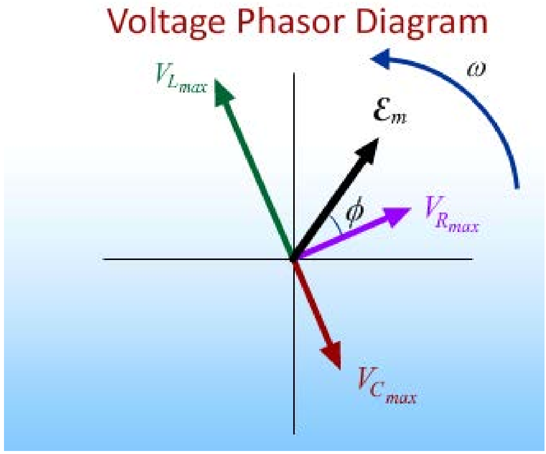


Physics 212
Lecture 20

Today's Concept:

AC Circuits

Maximum currents & voltages
Phasors: A Simple Tool



Your Comments

I think this might be the first checkpoint/prelecture where I just didn't really wrap my head around it at all. I'm hoping that you can over the inphase stuff during lecture

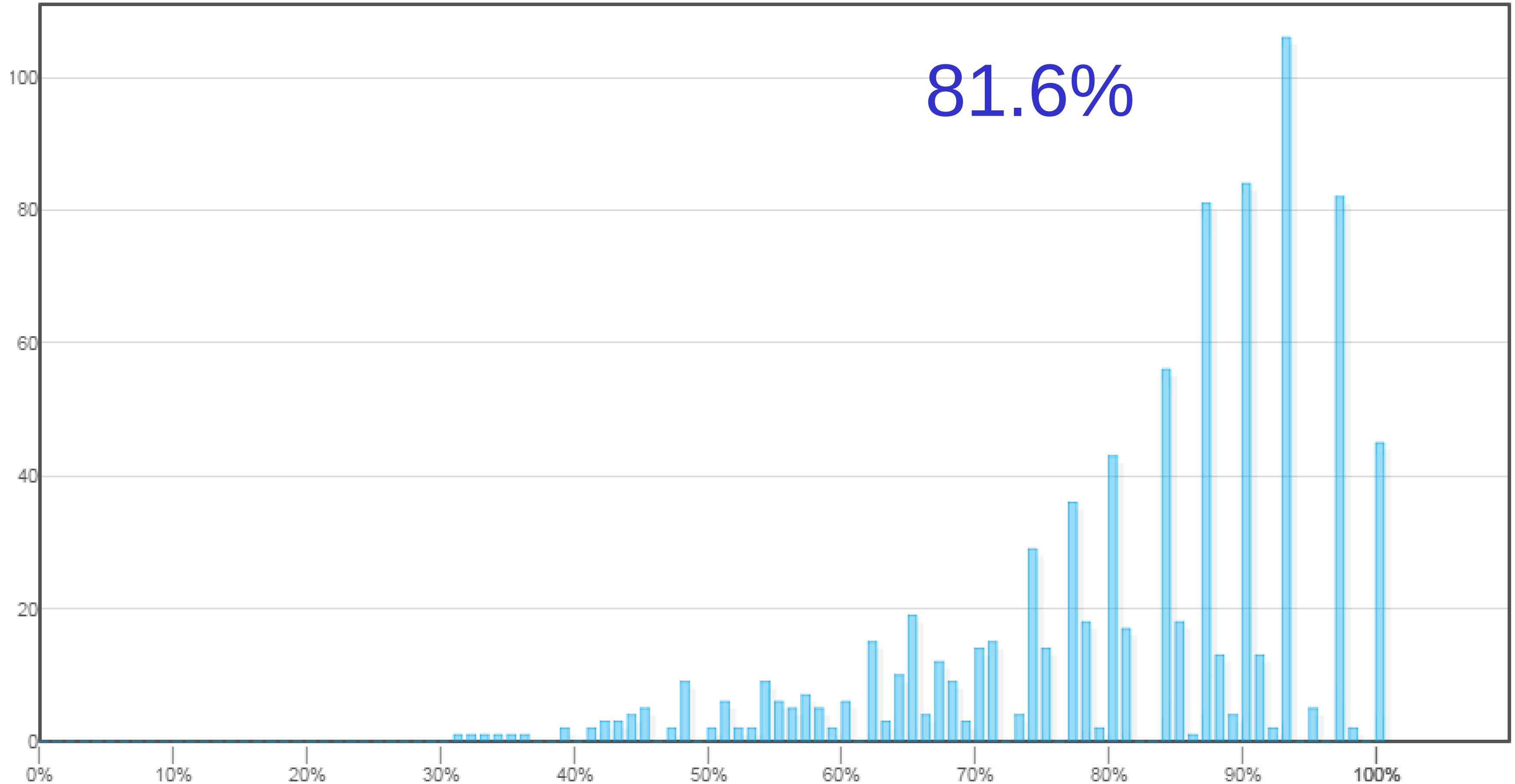
1. Where did the emf(t)=emfm sin(omega t) equation come from? Does it have anything to do with the generator we learned when discussing motional emf and Faraday's law? What angle is omega t measuring? Does it matter? How were we supposed to know what emfm means? 2. The prelecture kept making some point about Ohm's law whenever it reached an equation of the form I = emfm/(constant) (trig function)(omega t). These new equations don't look much like the V=IR Ohm's law I know. What's going on? 3. Relating to phasors: is the value of the phasor equal to its magnitude sin(omega t)? If so, why does the prelecture talk about projecting onto the vertical but sometimes draw projections onto the vertical? 4. The wikipedia article on phasors mentions complex numbers. What's up with that? 5. When we got back to the driven LCR circuit, we used KVR to find a 2nd order differential equation. How did you jump to Asin(omega t)+Bcos(omega t) =0? 6. It looks like you pulled the vector form of KVR out of thin air. What's the rationale behind it? How would a student know to do whatever you did?

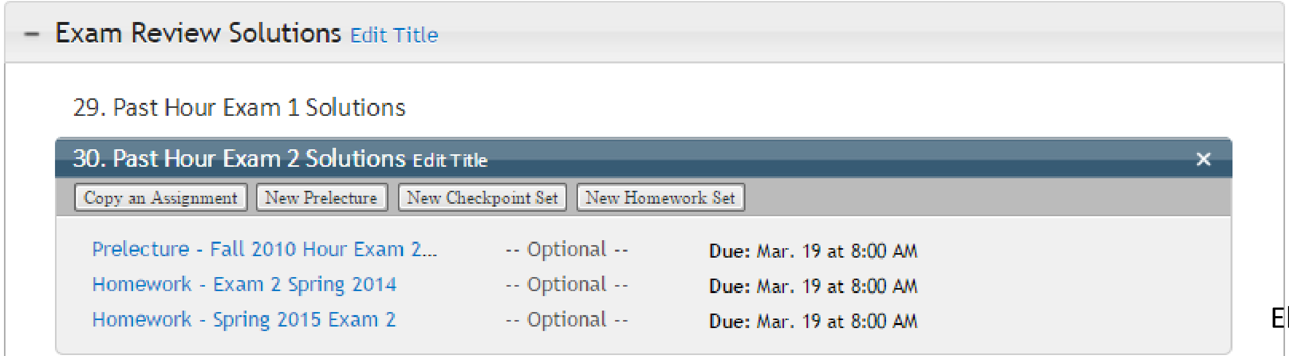
What would be the significance of choosing a capacitor and inductor with a nonzero capacitance and an inductance such that XL - XC = 0 creating an impedance equal to the resistance, R?

I'm kinda lost with this one. I thought I understood the prelecture but when I did AC Circuit 2 I just confused myself more. I don't get it, why does this always happen to me?

我真是x了狗了！Please!!!!!!!Help me out!!!! For this prelecture, it is like talking about the universe.NO CLUE!. I start to realize life is so hard.....Maybe it's time to say good bye to the world. 世界，爱过。

Hour Exam 2 Results

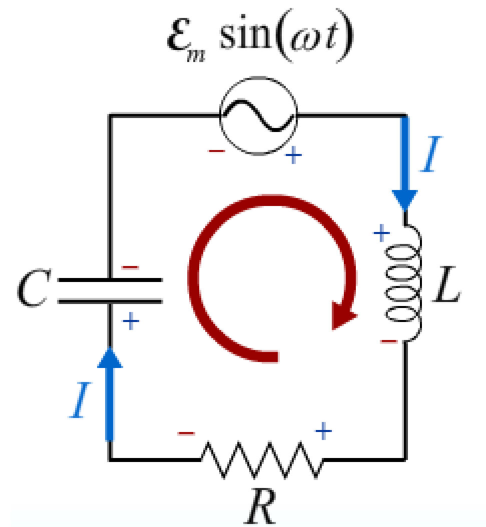




Big Idea

KVR

$$L\frac{d^2Q}{dt^2}+R\frac{dQ}{dt}+\frac{Q}{C}-\varepsilon_m\sin(\omega t)=0$$



Maximum Values (easy V=IR)

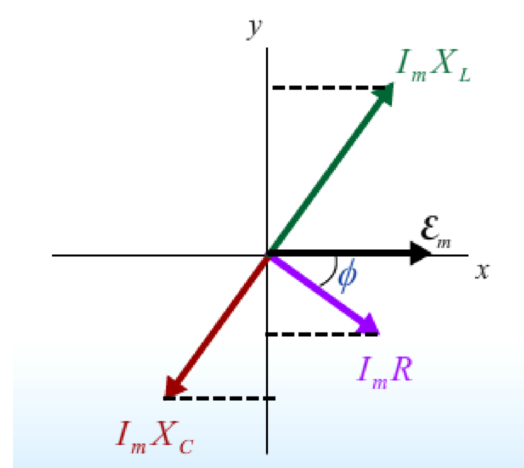
$$V_{Rmax}=I_{max}R$$

$$I_{max}=\varepsilon_{max}/Z \qquad V_{Lmax}=I_{max}X_L$$

$$V_{Cmax}=I_{max}X_C$$

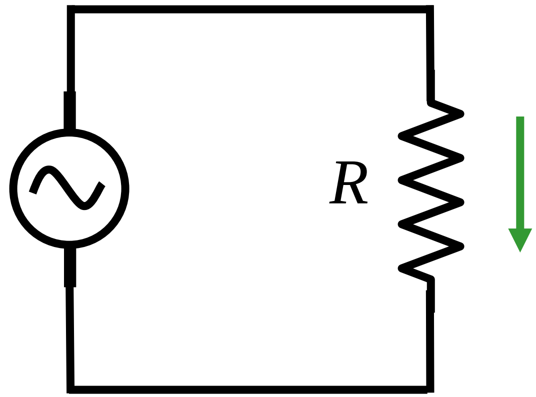
Value at specific time (phasors)

y component gives voltage
V-$_{\text{Inductor}}$ Leads current
V-$_{\text{Capacitor}}$ Lags current



Resistors

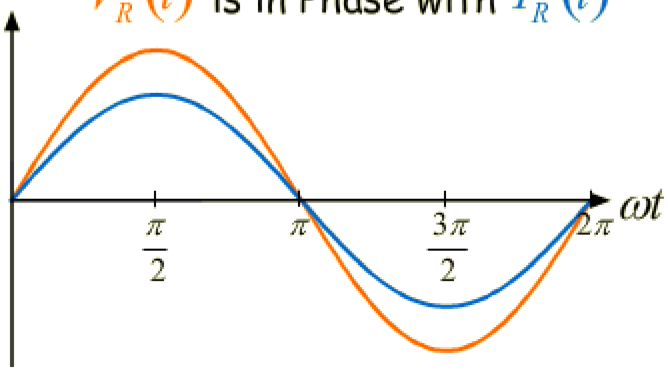
$\mathcal{E} = V_{max}\sin(\omega t)$



$I = V_R/R = \boxed{V_{max}/R}\sin(\omega t)$

Amplitude = V_{max}/R

$V_R(t)$ is in Phase with $I_R(t)$

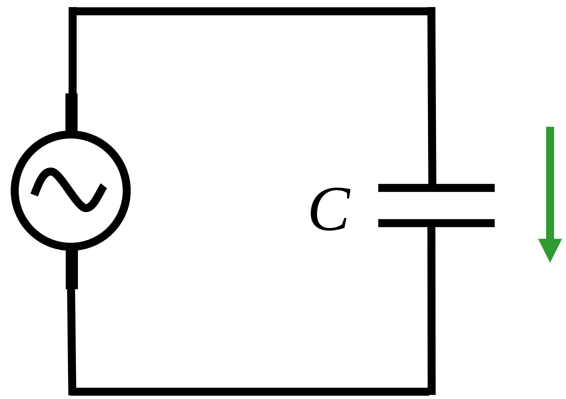


Capacitors

$$Q = CV = CV_{max}\sin(\omega t)$$

$$I = dQ/dt$$

$$\mathcal{E} = V_{max}\sin(\omega t)$$



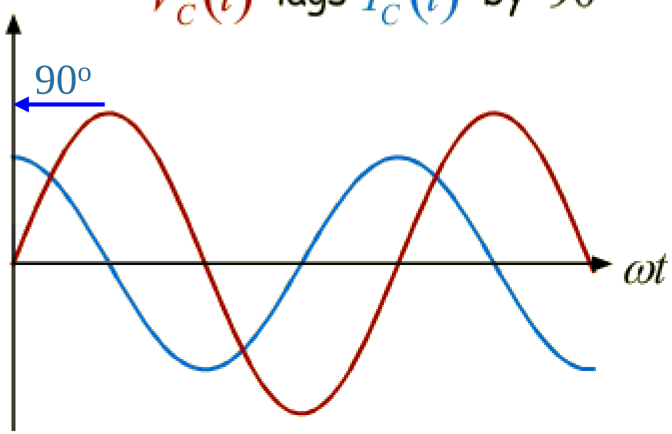
$$I = \boxed{V_{max}\omega C}\cos(\omega t)$$

$$\boxed{\text{Amplitude} = V_{max}/X_C}$$

where $X_C = 1/\omega C$
is like the "resistance"
of the capacitor

X_C depends on ω

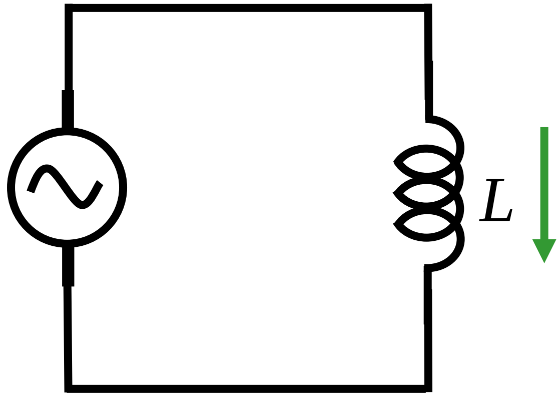
$V_C(t)$ lags $I_C(t)$ by 90°



Inductors

$$L\, dI/dt = V_L = V_{max}\sin(\omega t)$$

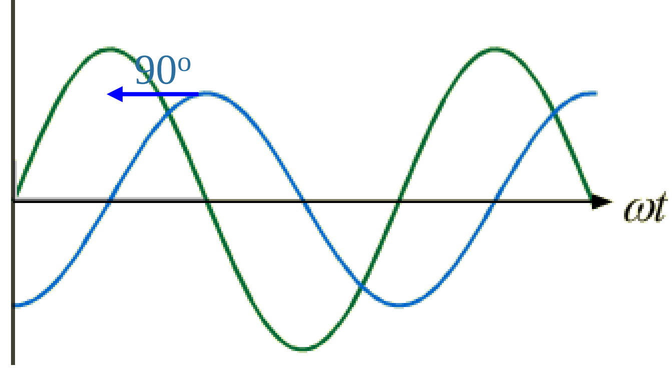
$\mathcal{E} = V_{max}\sin(\omega t)$



$$I = \boxed{-V_{max}/\omega L}\cos(\omega t)$$

$$\boxed{\text{Amplitude} = V_{max}/X_L}$$

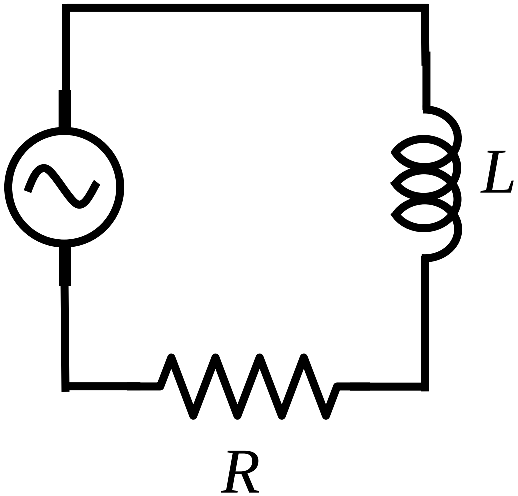
$V_L(t)$ leads $I_L(t)$ by 90°



where $X_L = \omega L$
is like the "resistance"
of the inductor
X_L depends on ω

RL Clicker Question

An RL circuit is driven by an *AC* generator as shown in the figure.



$X_L = \omega L$

As ω -> 0, so does X_L

As ω -> 0,
current gets bigger

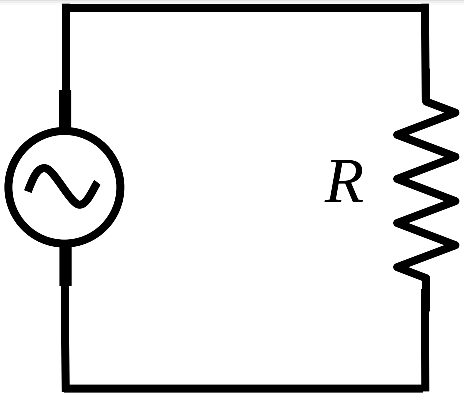
For what driving frequency ω of the generator will the current through the resistor be largest

A) ω large

B) Current through R doesn't depend on ω

C) ω small

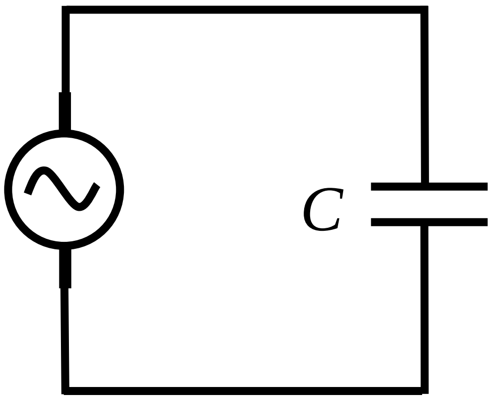
Summary



$$I_{max} = V_{max}/R$$

V_R in phase with I

Because resistors are simple



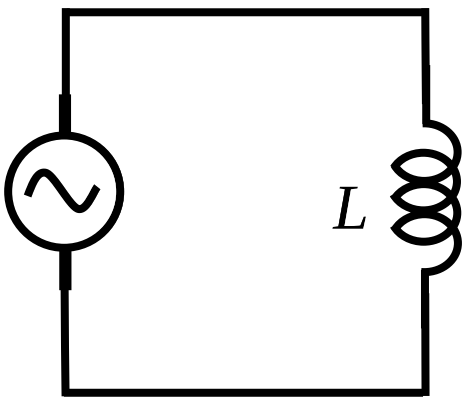
$$I_{max} = V_{max}/X_C$$

$$X_C = 1/\omega C$$

V_C 90° behind I

Current comes first since it charges capacitor

Like a wire at high ω



$$I_{max} = V_{max}/X_L$$

$$X_L = \omega L$$

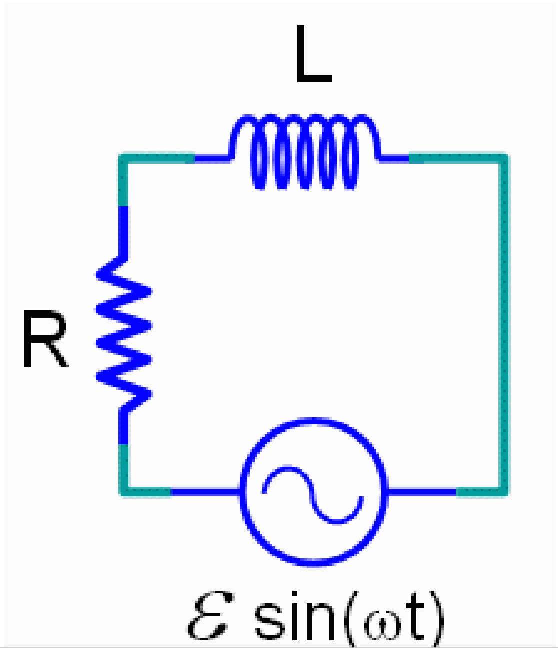
V_L 90° ahead of I

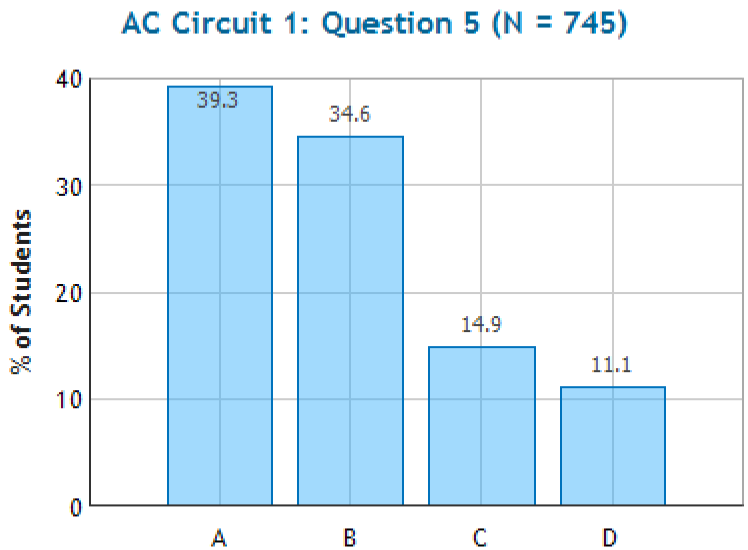
Opposite of capacitor

Like a wire at low ω

CheckPoint 1c

A RL circuit is driven by an AC generator as shown in the figure.





The phase difference between the CURRENT through the resistor and the CURRENT through the inductor is

$\boxed{\textit{A)}\ \text{Is always zero}}$ *B)* Is always 90°
C) Depends on the value of L and R
D) Depends on L, R and the generator voltage

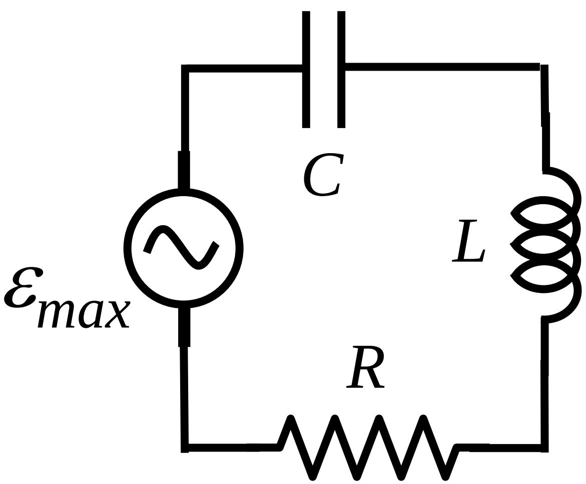
The CURRENT is THE CURRENT
There is only 1 current in this circuit
Same everywhere in circuit

Driven RLC Circuit

Makes sense to write everything in terms of I since this is the same everywhere in a one-loop circuit:

$$V_{max} = I_{max} X_C$$

V 90° behind I



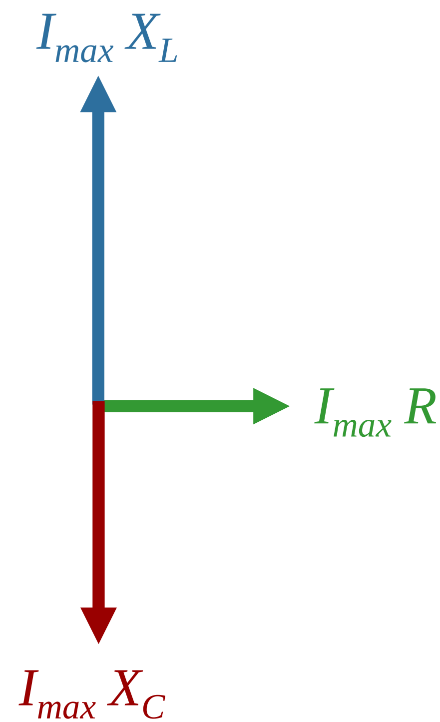
$$V_{max} = I_{max} X_L$$

V 90° ahead of I

$$V_{max} = I_{max} R$$

V in phase with I

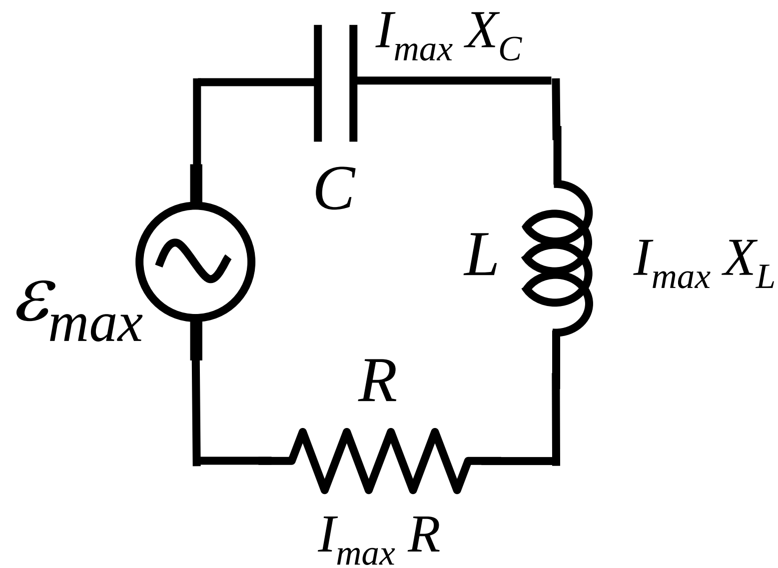
Phasors make this simple to see

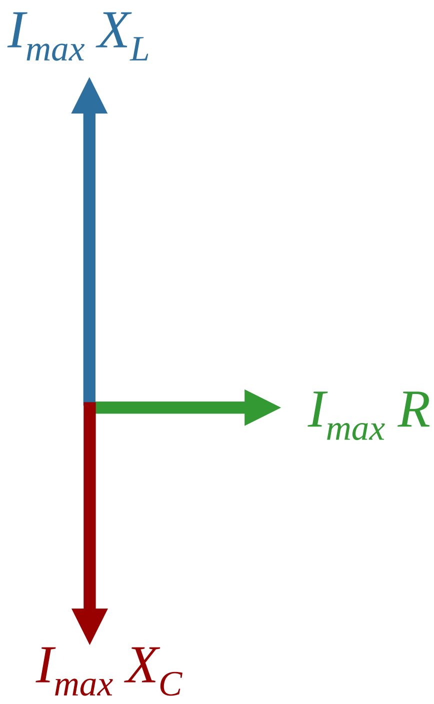


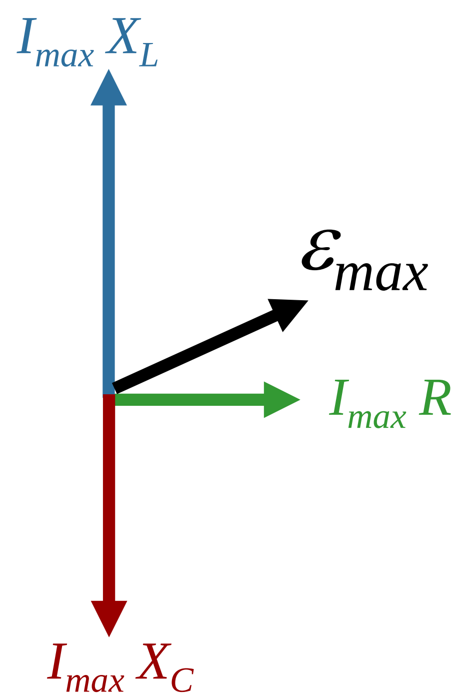
Always looks the same.
Only the lengths will change

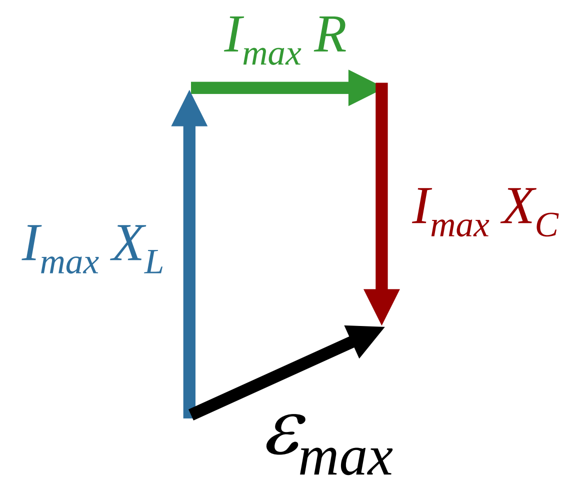
The Voltages still Add Up

But now we are adding vectors:

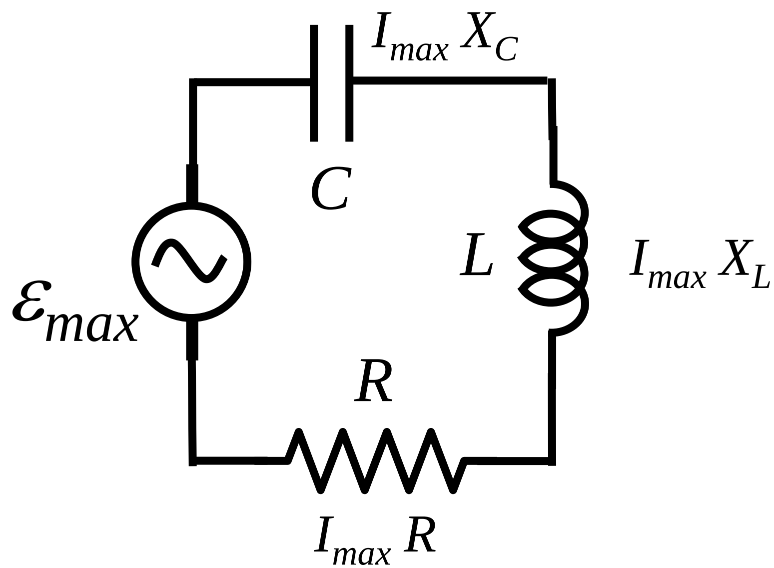


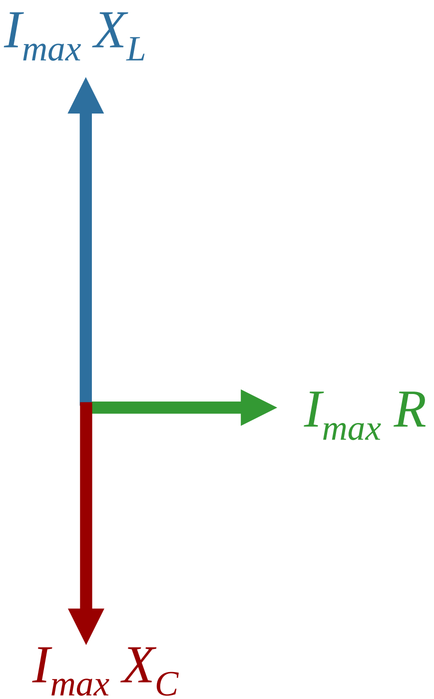


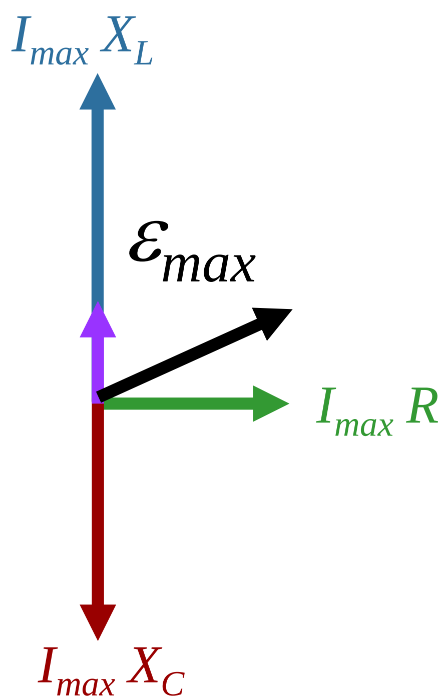




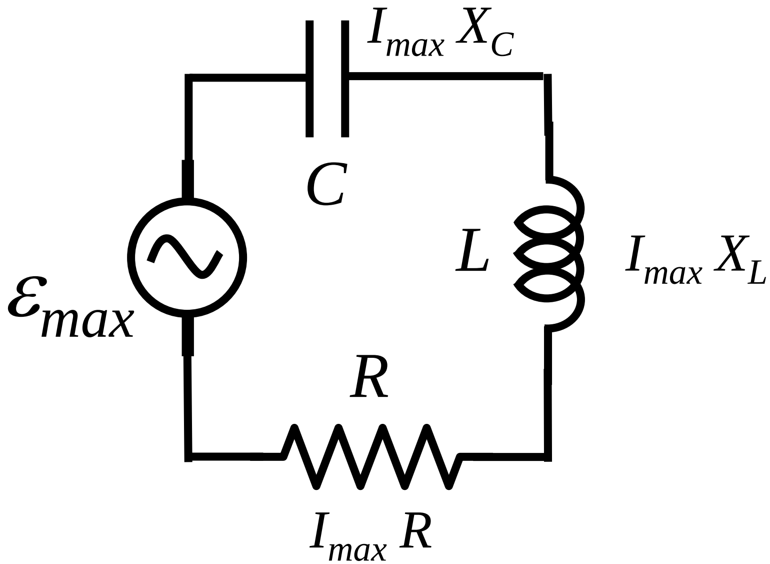
Make this Simpler

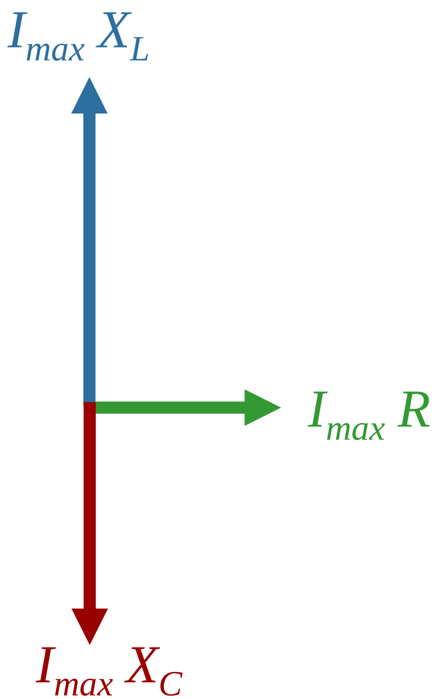




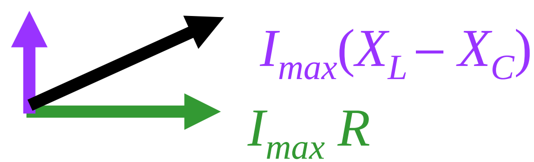


Make this Simpler

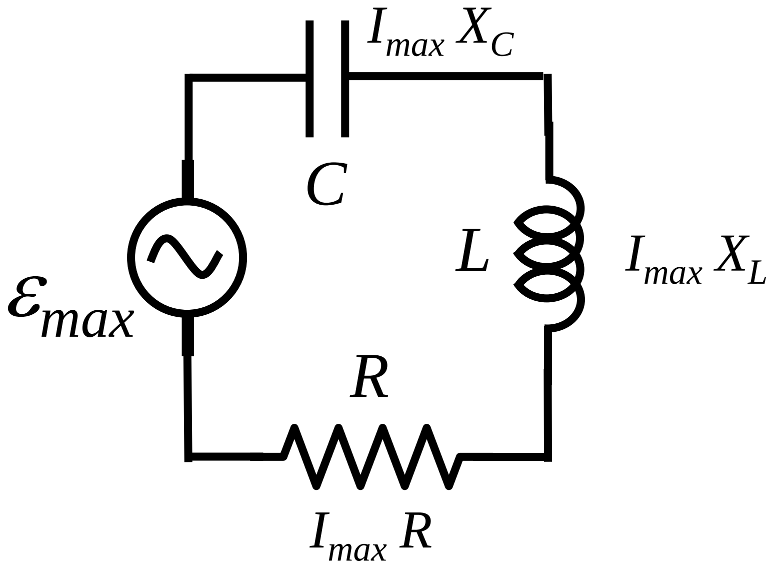




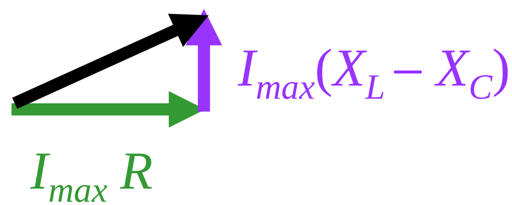
$$\mathcal{E}_{max} = I_{max}Z$$



Make this Simpler

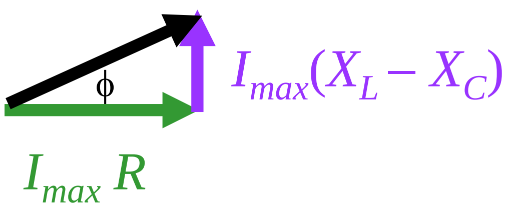


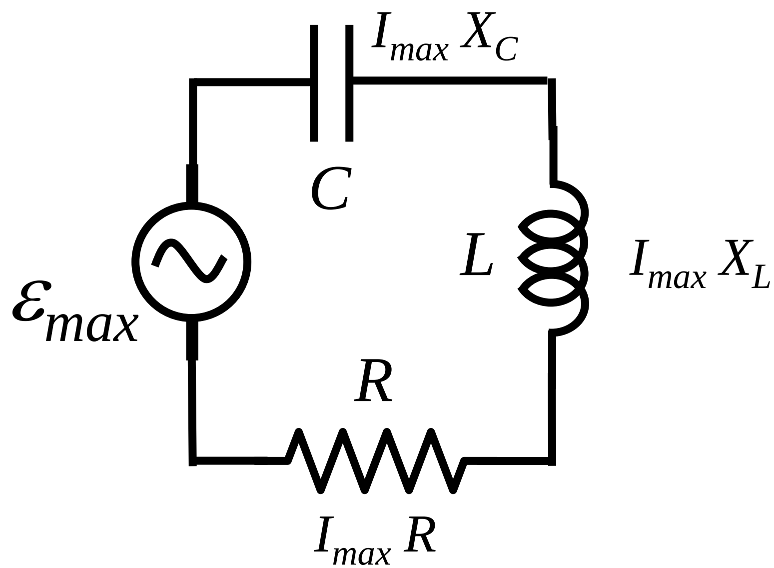
$$\mathcal{E}_{max} = I_{max}\,Z$$

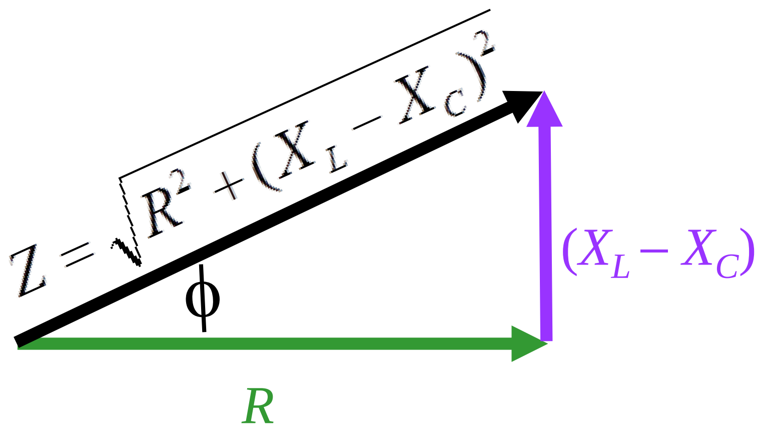


Make this Simpler

$$\mathcal{E}_{max} = I_{max} Z$$







Impedance Triangle

$$\tan(\phi) = \frac{X_L - X_C}{R}$$

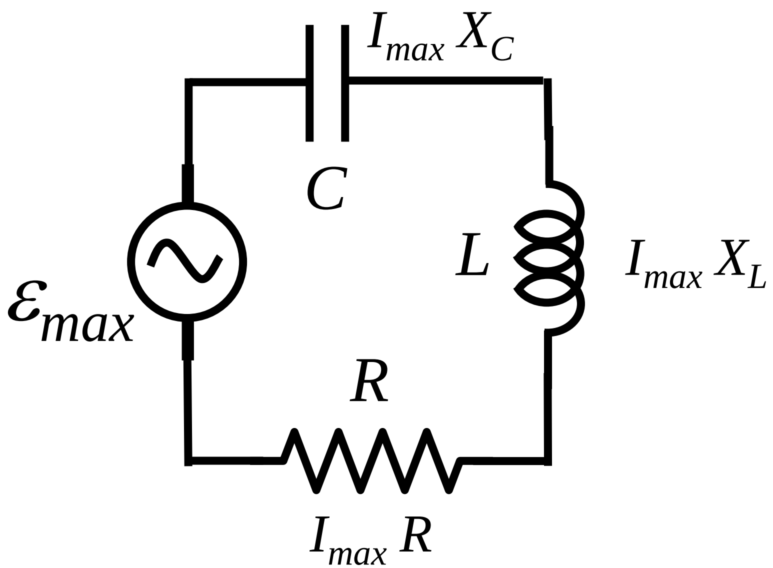
Summary

$$V_{Cmax} = I_{max} X_C$$

$$V_{Lmax} = I_{max} X_L$$

$$V_{Rmax} = I_{max} R$$

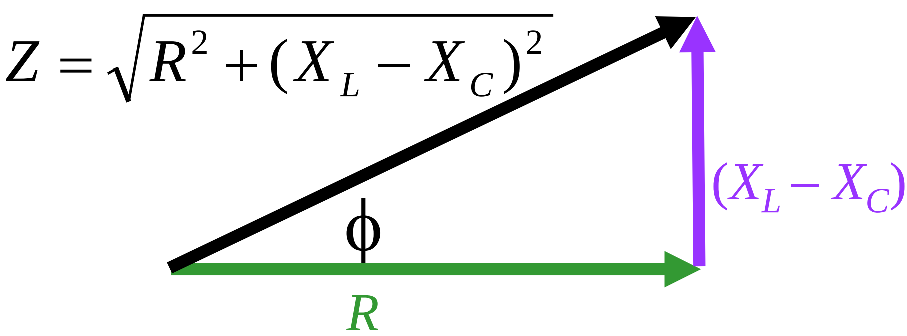
$$\mathcal{E}_{max} = I_{max} Z$$



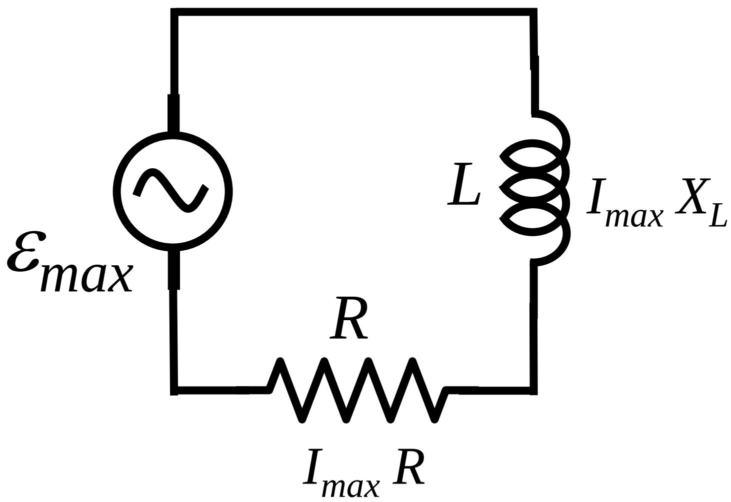
$$I_{max} = \mathcal{E}_{max} / Z$$

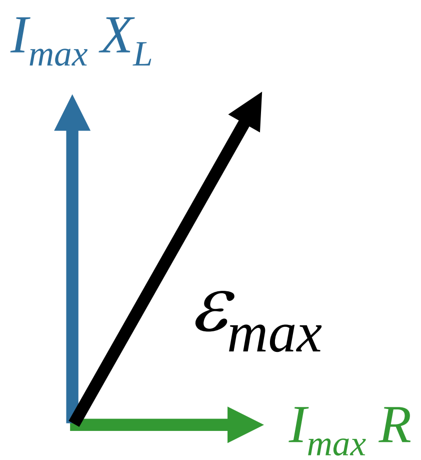
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\tan(\phi) = \frac{X_L - X_C}{R}$$



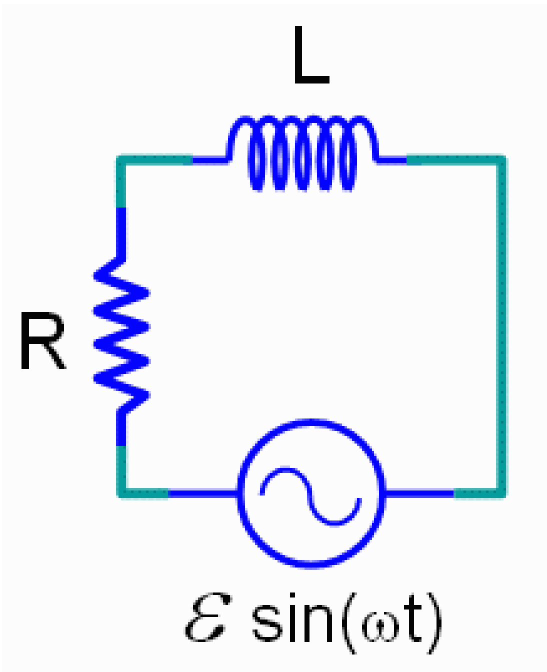
Example: RL Circuit $X_c = 0$





CheckPoint 1a

2) A RL circuit is driven by an AC generator as shown in the figure.

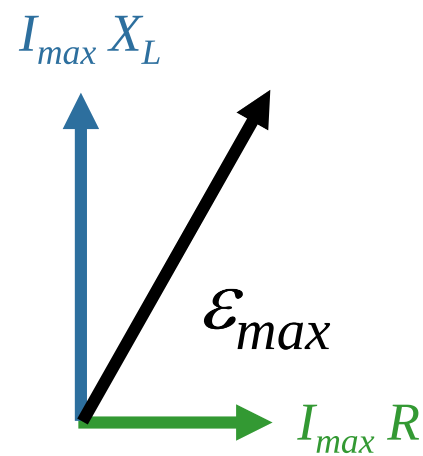


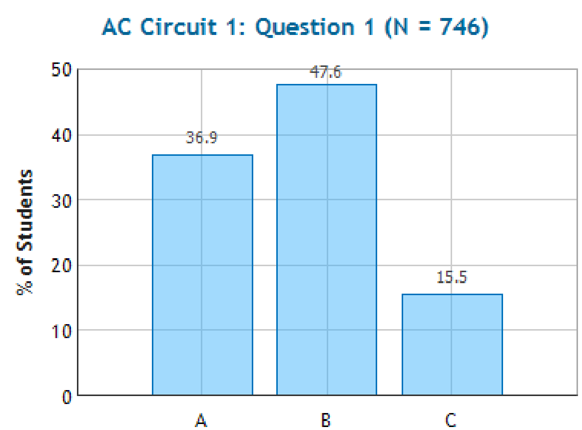
The voltages across the resistor and generator are

A) Always out of phase **B)** Always in phase

C) Sometimes in and sometimes out of phase

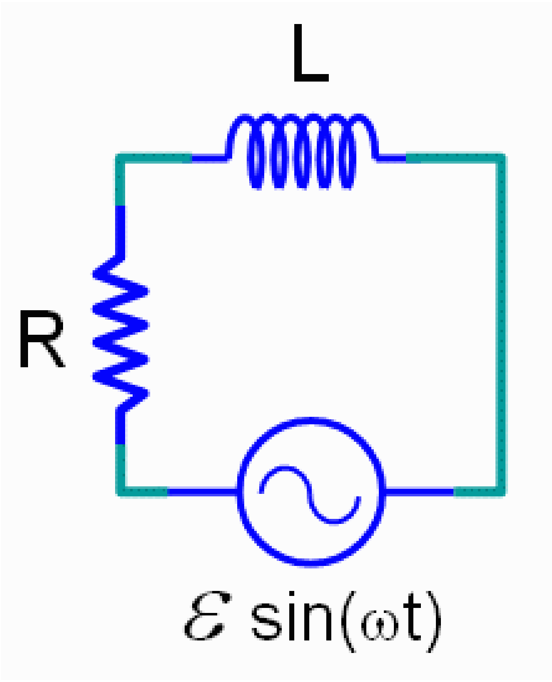
Draw Voltage Phasors



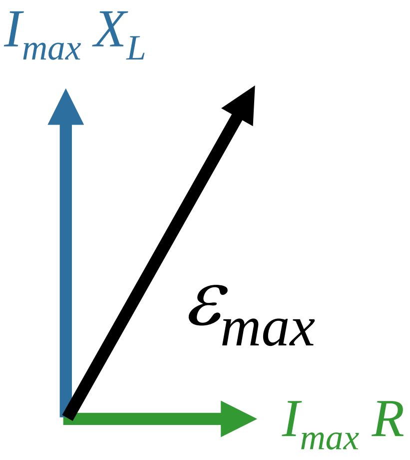


CheckPoint 1b

A RL circuit is driven by an AC generator as shown in the figure.



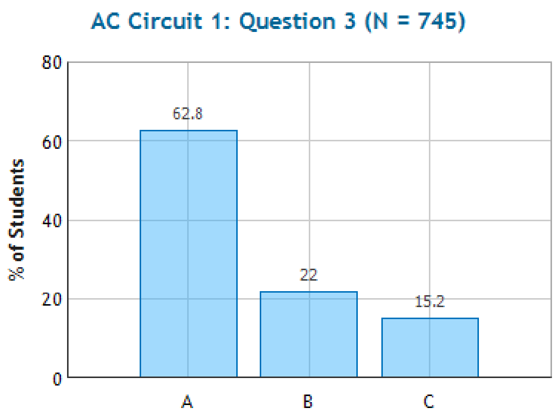
Draw Voltage Phasors



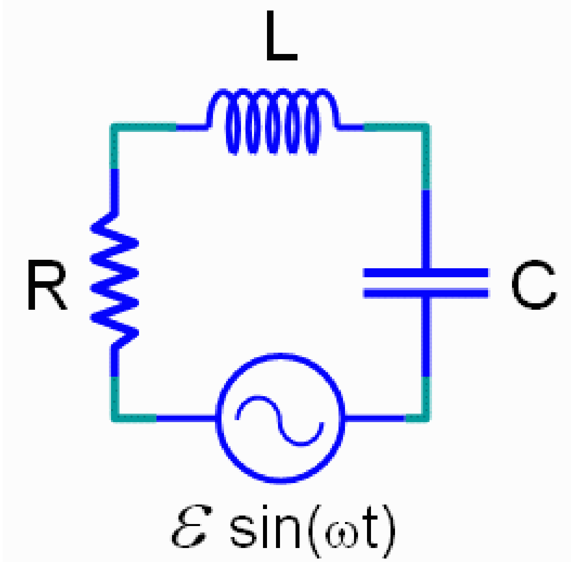
The voltages across the resistor and inductor are

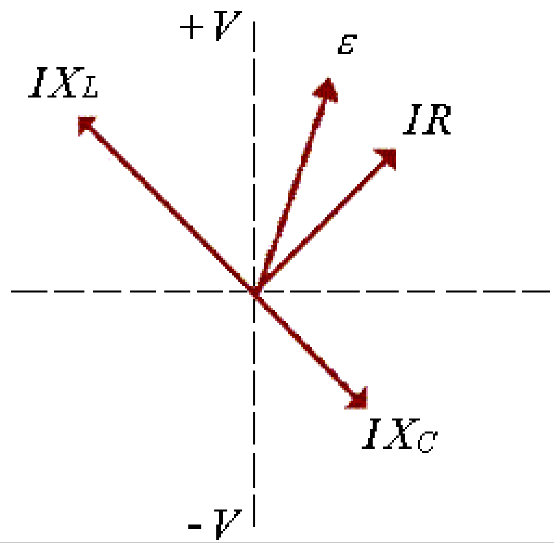
A) Always out of phase **B)** Always in phase

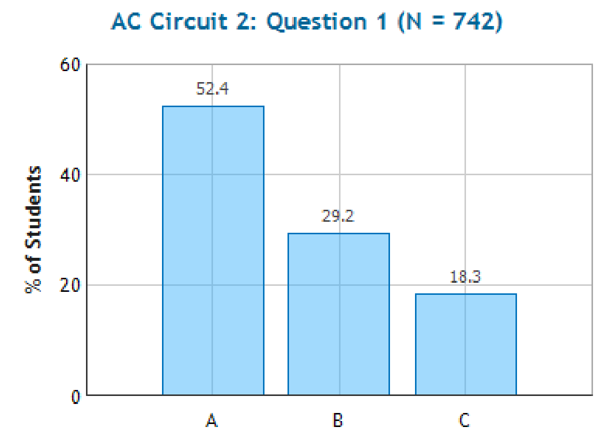
C) Sometimes in and sometimes out of phase



A driven RLC circuit is represented by the phasor diagram below.



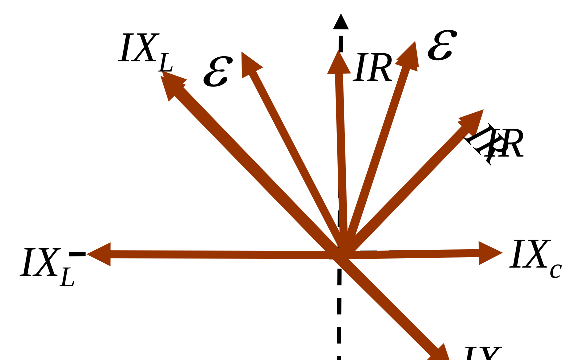




The vertical axis of the phasor diagram represents voltage. When the current through the circuit is maximum, what is the potential difference across the inductor?

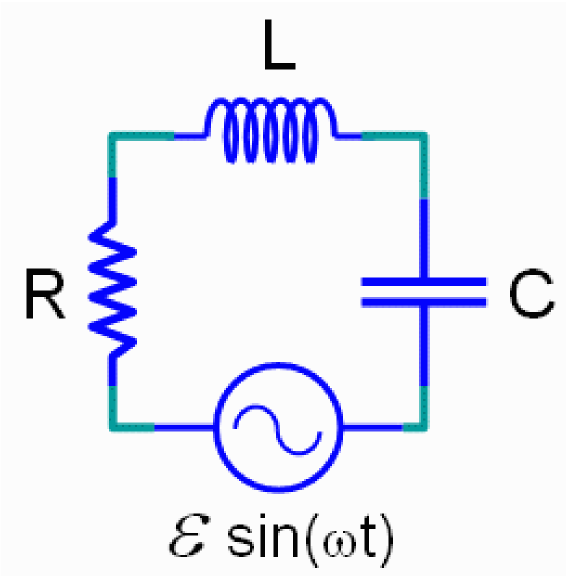
$\boxed{\textbf{A)}\ V_L = 0}$ **B)** $V_L = V_{L,max}/2$ **C)** $V_L = V_{L,max}$

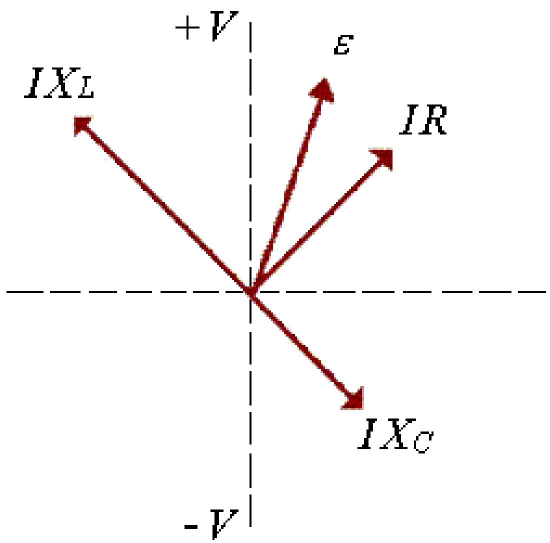
What does the voltage phasor diagram look like when the current is a maximum?

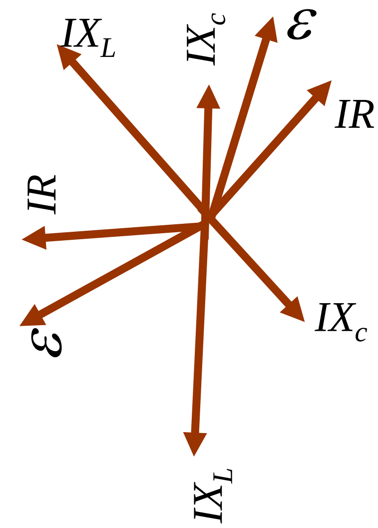


CheckPoint 2b

A driven RLC circuit is represented by the phasor diagram below.







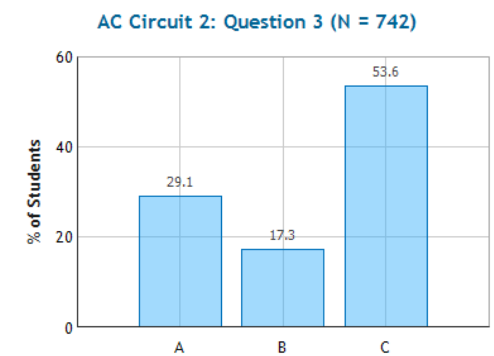
When the capacitor is fully charged, what is the magnitude of the voltage across the inductor?

A) $V_L = 0$

B) $V_L = V_{L,max}/2$

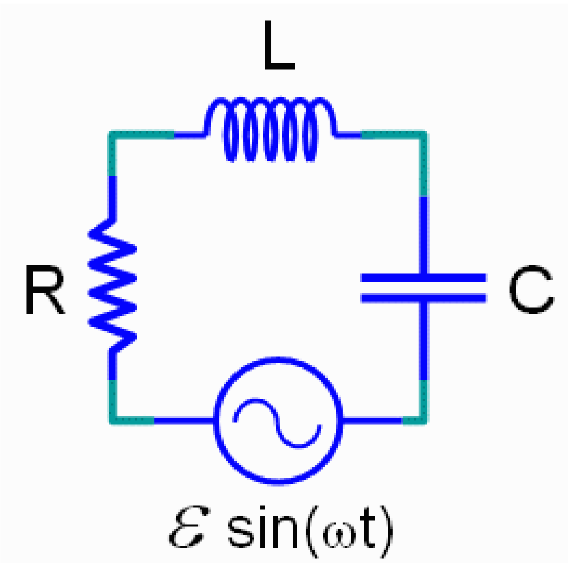
$\boxed{\textbf{C)}\ V_L = V_{L,max}}$

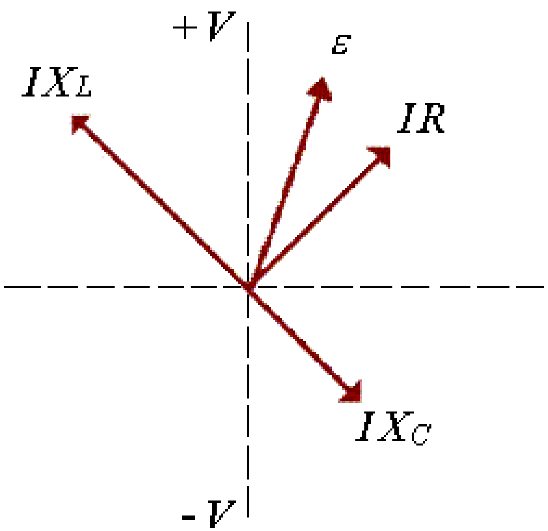
What does the voltage phasor diagram look like when the capacitor is fully charged?

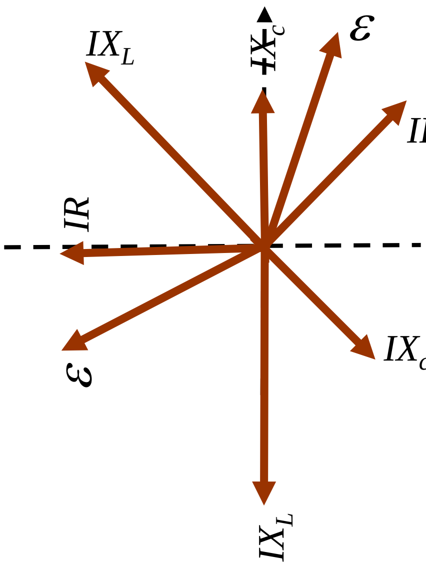


CheckPoint 2C

A driven RLC circuit is represented by the phasor diagram below.







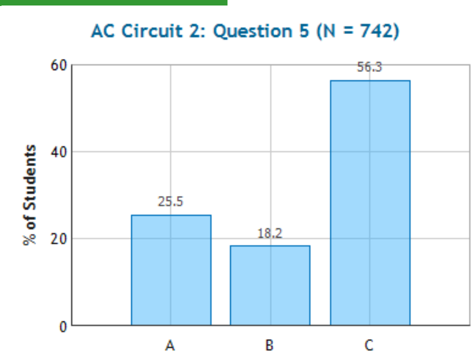
When the voltage across the capacitor is at its positive maximum, $V_C = +V_{C,max}$, what is the voltage across the inductor ?

A) $V_L = 0$

B) $V_L = V_{L,max}$

$\boxed{\textbf{C)}\ V_L = -V_{L,max}}$

What does the voltage phasor diagram look like when the voltage across capacitor is at its positive maximum?



Calculation

Consider the harmonically driven series LCR circuit shown.

$V_{max} = 100\ V$

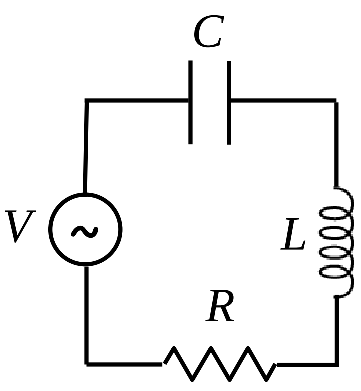
$I_{max} = 2\ mA$

$V_{Cmax} = 113\ V$

The current leads generator voltage by 45^o

L and R are unknown.

What is X_L, the reactance of the inductor, at this frequency?



Conceptual Analysis

The maximum voltage for each component is related to its reactance and to the maximum current.

The impedance triangle determines the relationship between the maximum voltages for the components

Strategic Analysis

Use V_{max} and I_{max} to determine Z

Use impedance triangle to determine R

Use V_{Cmax} and impedance triangle to determine X_L

Calculation

Consider the harmonically driven series LCR circuit shown.

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$I_{max} = 2\ mA$

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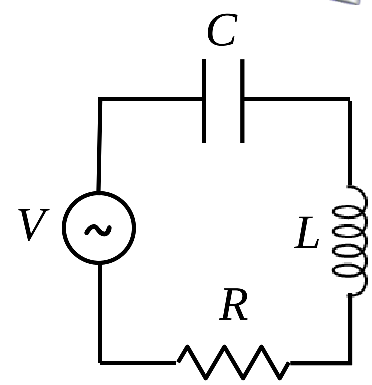


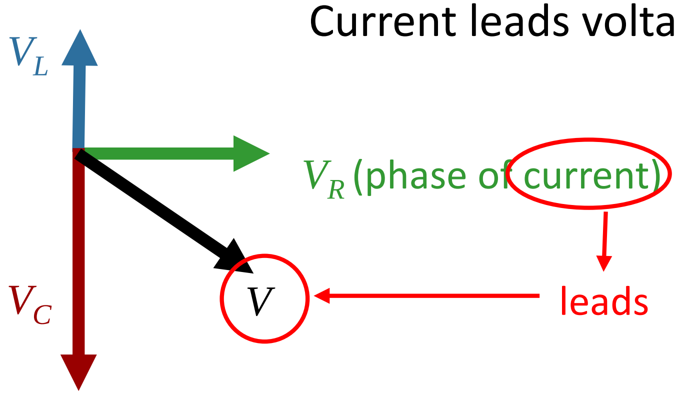
Compare X_L and X_C at this frequency:

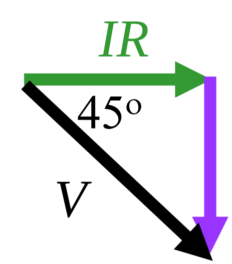
A) $X_L < X_C$ B) $X_L = X_C$ C) $X_L > X_C$ D) Not enough information

This information is determined from the phase

Current leads voltage

$$V_L = I_{\max} X_L$$
$$V_C = I_{\max} X_C$$





Calculation

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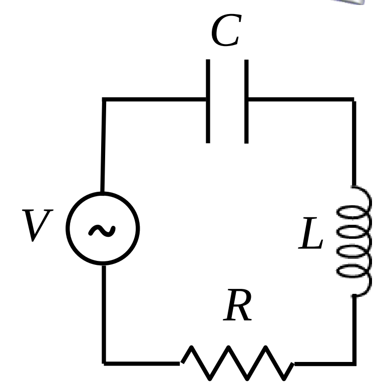
The current leads generator voltage by 45^{o}

L and R are unknown.

What is X_L, the reactance of the inductor, at this frequency?



What is Z, the total impedance of the circuit?

A) $70.7\ k\Omega$ B) $\boxed{50\ k\Omega}$ C) $35.4\ k\Omega$ D) $21.1\ k\Omega$

$$Z = \frac{V_{\max}}{I_{\max}} = \frac{100V}{2mA} = 50k\Omega$$

Calculation

Consider the harmonically driven series LCR circuit shown.

$V_{max} = 100\ V$

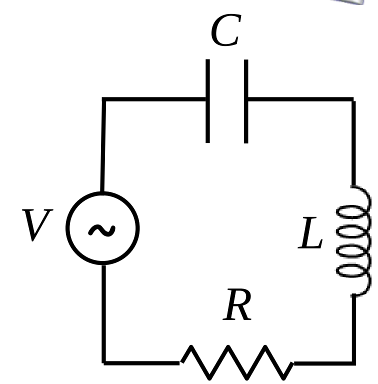
$I_{max} = 2\ mA$

$V_{Cmax} = 113\ V$

The current leads generator voltage by 45^{o}

L and R are unknown.

What is X_L, the reactance of the inductor, at this frequency?



$Z = 50k\Omega$

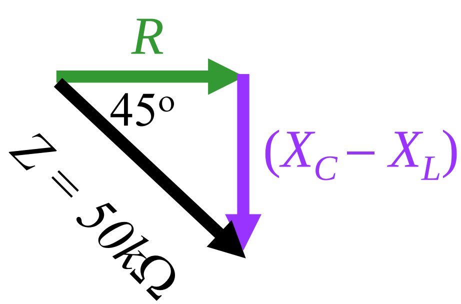
$\sin(45) = .707$

$\cos(45) = .707$

What is R?

A) $70.7\ k\Omega$ B) $50\ k\Omega$ C) $\boxed{35.4\ k\Omega}$ D) $21.1\ k\Omega$

Determined from impedance triangle



$$\cos(45) = \frac{R}{Z} \rightarrow R = Z\cos(45^{o})$$

$$= 50\ k\Omega \times 0.707$$

$$= 35.4\ k\Omega$$

Calculation

Consider the harmonically driven series LCR circuit shown.

$V_{max} = 100\ V$

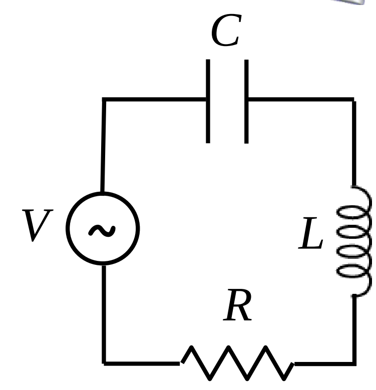
$I_{max} = 2\ mA$

$V_{Cmax} = 113\ V$

The current leads generator voltage by 45^o

L and R are unknown.

What is X_L, the reactance of the inductor, at this frequency?



$Z = 50 k\Omega$

$R = 35.4 k\Omega$

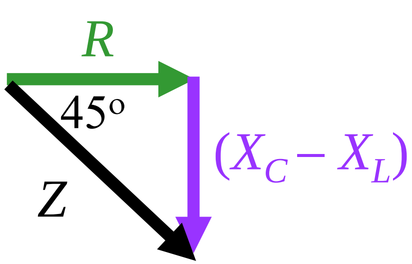
A) $70.7\ k\Omega$

B) $50\ k\Omega$

C) $35.4\ k\Omega$

D) $\boxed{21.1\ k\Omega}$

We start with the impedance triangle:



$$\frac{X_C - X_L}{R} = \tan 45^\circ = 1 \quad \longrightarrow \quad X_L = X_C - R$$

What is X_C?

$$V_{Cmax} = I_{\max} X_C$$

$$X_C = \frac{113}{2} = 56.5 k\Omega$$

$$X_L = 56.5\ k\Omega - 35.4\ k\Omega$$