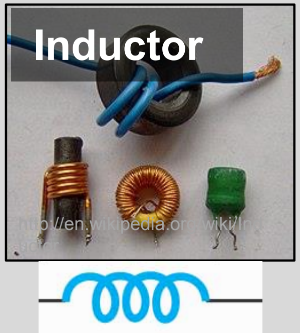
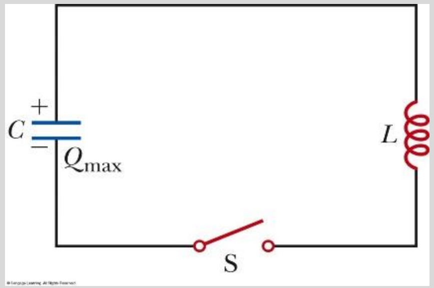
Lecture 10 – chapter 33
Alternating Current Circuit

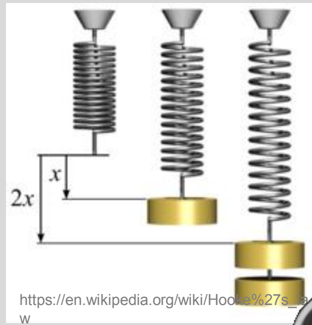
蔡尚岳
政治大學應用物理所

Previous Lecture

- Inductance
  - Self-Inductance
- *RL* Circuit
  - Energy in a Magnetic Field
- Energy Storage Summary
  - Charged capacitor
  - Inductor
  - Resistor
- Mutual Inductance
- *LC* Circuits
- *RLC* Circuit

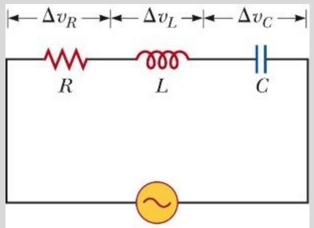






This Lecture

- Alternating-Current Circuits
  - Sinusoids
- ✓ Resistors in an AC Circuit
- ∘ Phasor Diagram
- ✓ Inductors in an AC Circuit
- ✓ Capacitors in an AC Circuit
- The RLC Series Circuit
  - Impedance, Z (阻抗)
- Power in an AC Circuit
- Resonance in a Series RLC Circuit



Electric Circuit

- Signal sources
  - DC: constant **V** and **I**
  - AC: time varying **v(t)** and **i(t)**
- DC model
  - R= V/I, C= open circuit, L= short circuit
- AC model
  - $\mathrm{R} = \frac{v(t)}{i(t)}$ (for a resistor)
  - $\mathrm{i(t)} = C\frac{dv(t)}{dt}$ (for a capacitor)
  - $\mathrm{v(t)} = L\frac{di(t)}{dt}$ (for an inductor)

有沒有遇過在室內燈光下拍照時，發現LCD畫面出現了規律的橫條紋？

https://www.youtube.com/watch?v=fjyQNfn4G-w

為什麼手機拍照或錄影時，
螢幕畫面會有橫條紋及光線閃爍呢？

- 為什麼手機拍照或錄影時，螢幕畫面會有橫條紋及光線閃爍呢？

台灣大哥大

https://www.taiwanmobile.com/blackbean/article_20240114_241463.html

AC Circuit analysis -1

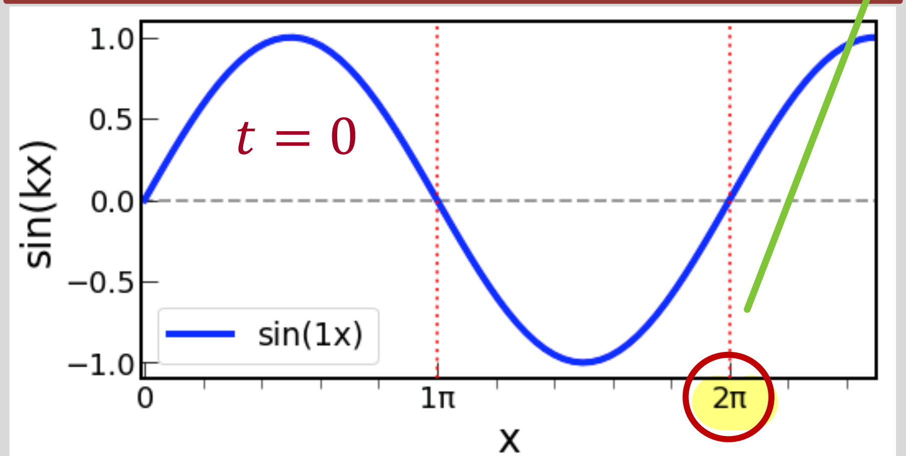
- Time varying signal represented as sum of sinusoids
- Sinusoids : $v(t) = V_{max} \sin(kx+\omega t+\varphi)$ *in general*
  - V_{max} : amplitude (振幅)
  - ω : angular frequency (角頻率)
    - $\omega = 2\pi f$ and $f=1/T$
  - φ: phase (相角)

$T \cdot f = 1$

$T \cdot \omega = 2\pi$

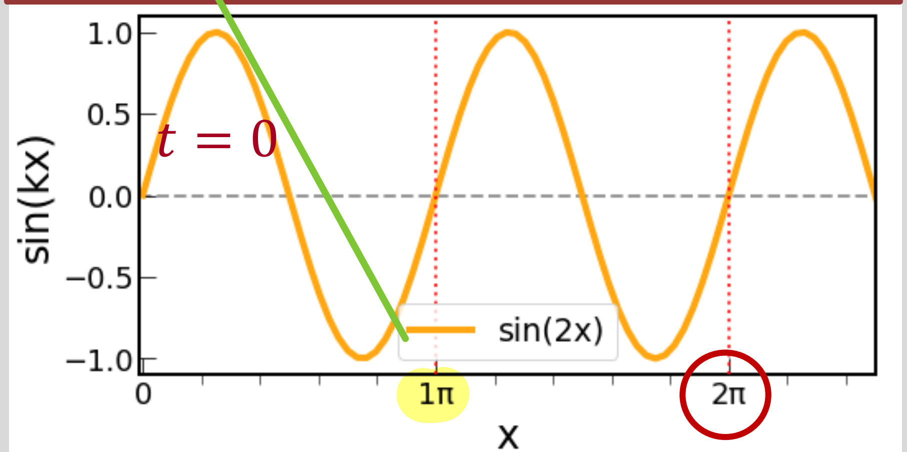
At a particular time,
the shape of a single wave

$\sin(kx) \Rightarrow \sin(1x)$



波數$k = 2\pi/\lambda = 1$ 代表2π有 1 個波長

$\sin(kx) \Rightarrow \sin(2x)$



波數$k = 2\pi/\lambda = 2$ 代表2π有 2 個波長

AC Circuit analysis -1

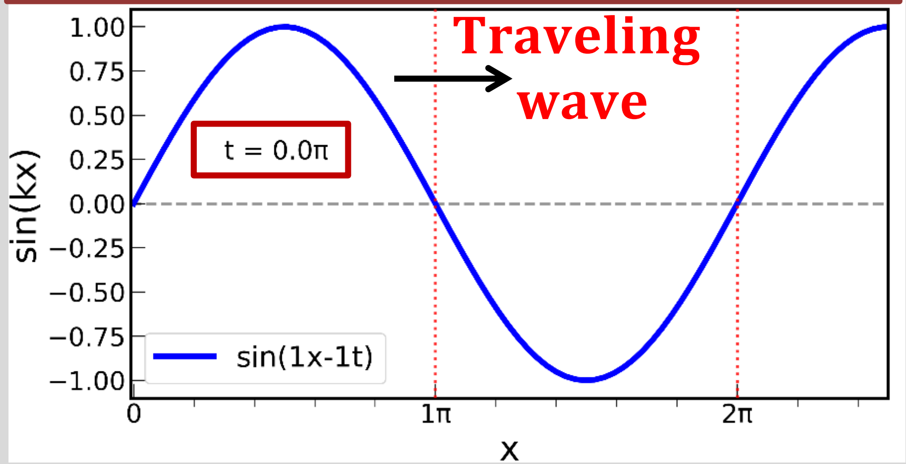
- Time varying signal represented as sum of sinusoids
- Sinusoids : $v(t) = V_{max}\sin(kx+\omega t+\varphi)$ in general
  - V_{max} : amplitude (振幅)
  - ω : angular frequency (角頻率)
    - $\omega = 2\pi f$ and $f = 1/T$
  - φ: phase (相角)

Hz = cycles/sec

Angular Frequency $\boxed{\omega = 2\pi f = \frac{2\pi}{T}}$

rad/sec

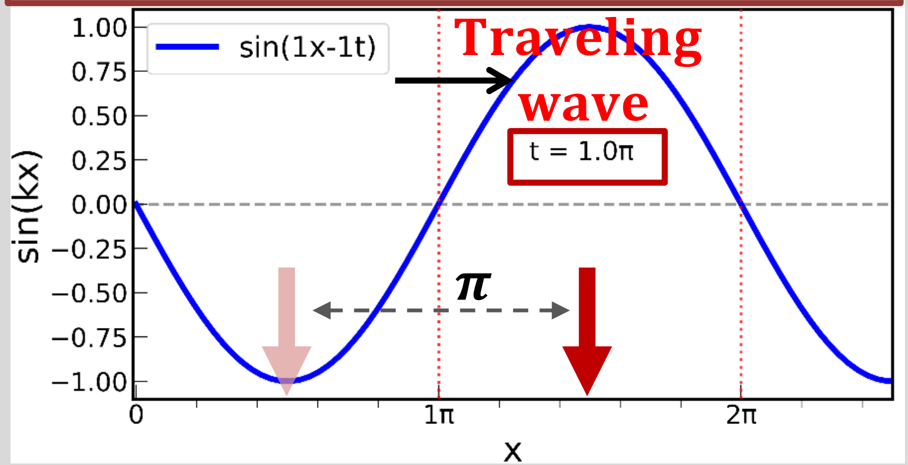
$\sin(kx - \omega t) \Rightarrow \sin(1x - 1t)$



角速度$\omega = 2\pi/T = 1$ 代表走2π要 1個2π時間

$\Rightarrow T = 2\pi$

$\sin(kx - \omega t) \Rightarrow \sin(1x - 1t)$

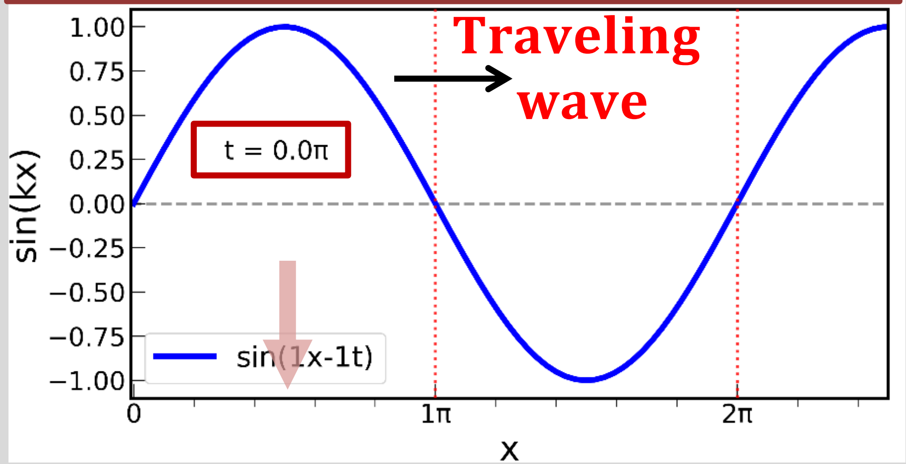


角速度$\omega = 2\pi/T = 1$ 代表走2π要 1個2π時間

AC Circuit analysis -1

- Time varying signal represented as sum of sinusoids
- Sinusoids : $v(t) = V_{max} \sin(kx+\omega t+\varphi)$ *in general*
  - V_{max} : amplitude (振幅)
  - ω : angular frequency (角頻率)
    - $\omega = 2\pi f$ and $f = 1/T$
  - φ: phase (相角)

$$\sin(kx - \omega t) \Rightarrow \sin(1x - 1t)$$



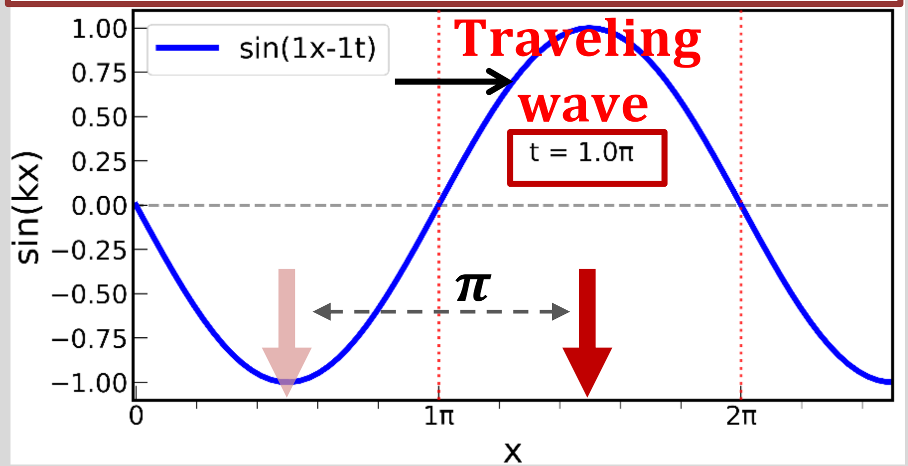
角速度$\omega = 2\pi/T = 1$ 代表走2π要 1個2π時間

- $kx - \omega t$ is right traveling:
  (think of it this way)
  As t increases, you want to get the same phase.
  $\Rightarrow kx - \omega t$ is constant
  $\Rightarrow$ x must increase

AC Circuit analysis -1

- Time varying signal represented as sum of sinusoids
- Sinusoids : $v(t) = V_{max} \sin(kx+\omega t+\varphi)$ *in general*
  - V_{max} : amplitude (振幅)
  - ω : angular frequency (角頻率)
    - $\omega = 2\pi f$ and $f=1/T$
  - φ: phase (相角)

$$\sin(kx - \omega t) \Rightarrow \sin(1x - 1t)$$

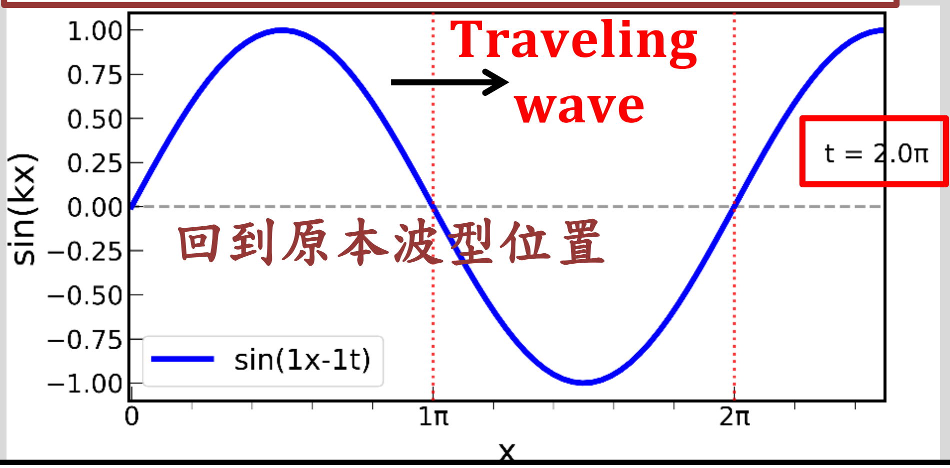


角速度$\omega = 2\pi/T = 1$ 代表走2π要 1個2π時間

AC Circuit analysis -1

- Time varying signal represented as sum of sinusoids
- Sinusoids : $v(t) = V_{max} \sin(kx+\omega t+\varphi)$ *in general*
  - V_{max} : amplitude (振幅)
  - ω : angular frequency (角頻率)
    - $\omega = 2\pi f$ and $f=1/T$
  - φ: phase (相角)

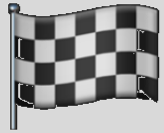
$$\sin(kx-\omega t) \Rightarrow \sin(1x-1t)$$



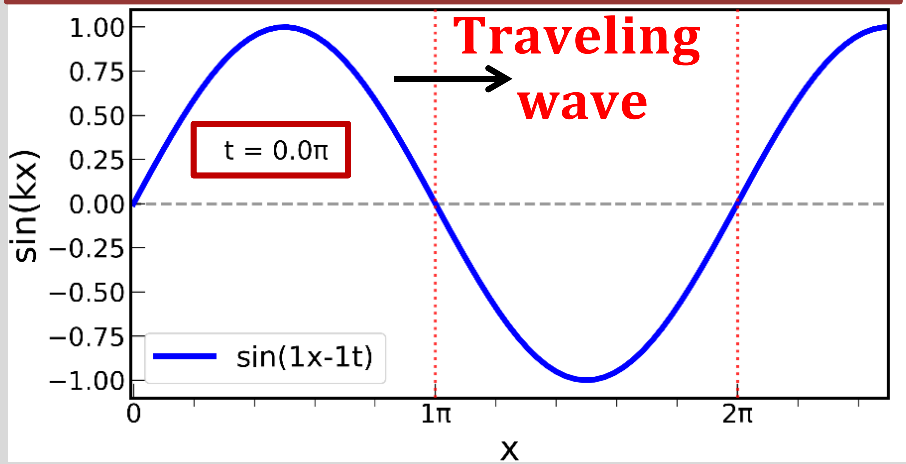
$$\text{角速度}\,\omega = 2\pi/T = 1 \text{ 代表走}2\pi\text{要 }1\text{個}2\pi\text{時間}$$

AC Circuit analysis -1

- Time varying signal represented as sum of sinusoids
- Sinusoids : $v(t) = V_{max} \sin(kx+\omega t+\varphi)$ *in general*
  - V_{max} : amplitude (振幅)
  - ω : angular frequency (角頻率)
    - $\omega = 2\pi f$ and $f=1/T$
  - φ: phase (相角)

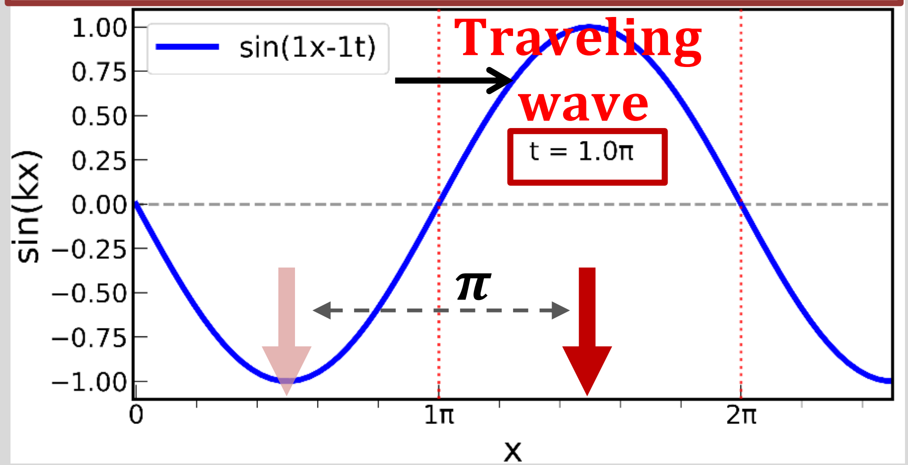


$\sin(kx-\omega t) \Rightarrow \sin(1x-1t)$



角速度$\omega = 2\pi/T = 1$ 代表走2π要 1個2π時間

$\sin(kx-\omega t) \Rightarrow \sin(1x-1t)$

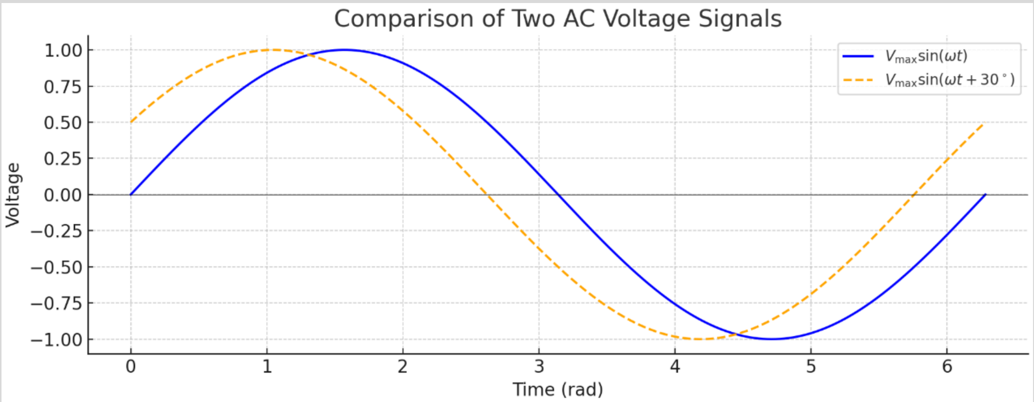


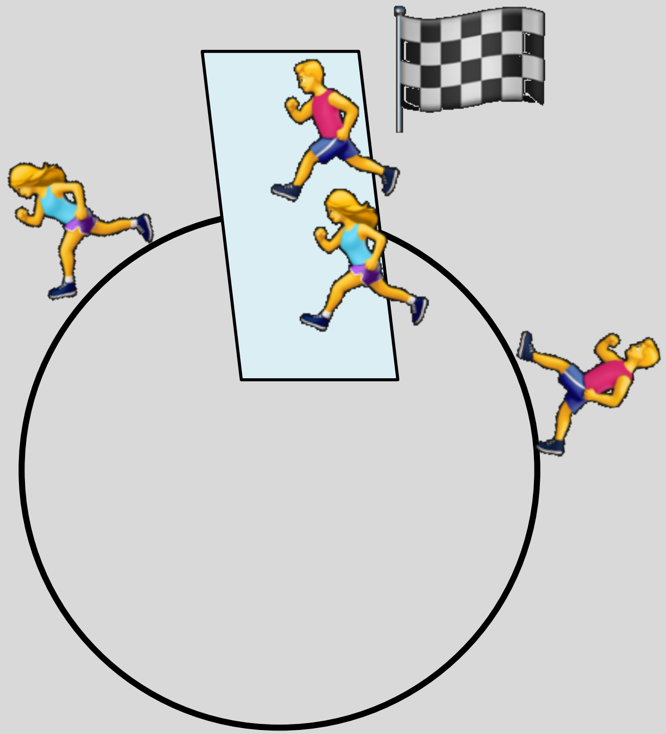
角速度$\omega = 2\pi/T = 1$ 代表走2π要 1個2π時間

AC Circuit analysis -1

- Time varying signal represented as sum of sinusoids
- Sinusoids : $v(t) = V_{max} \sin (kx+\omega t+\varphi)$ *in general*
  - V_{max} : amplitude (振幅)
  - ω : angular frequency (角頻率)
    - $\omega = 2\pi f$ and $f=1/T$
  - φ: phase (相角)

If x=0 and t=0:

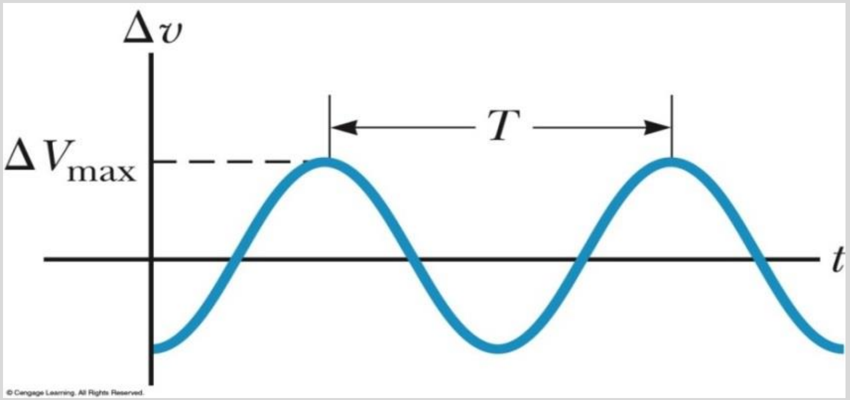




$\sin 30^\circ = 0.5$

AC Circuit analysis -1

- Time varying signal represented as sum of sinusoids
  - Periodic function: $f(t) = \sum_{n=0}^{\infty} A_n \sin(nw_0 t + \varphi_n)$
  - Any function: $f(t) = \int_0^{\infty} A(w) \sin(wt + \varphi(w))$
  - Fourier analysis
- Sinusoids : $v(t) = V_{max} \sin(\omega t + \varphi)$
  - V_{max} : amplitude (振幅)
  - ω : angular frequency (角頻率)
    - $\omega = 2\pi f$ and $f = 1/T$
  - φ: phase (相角)



- Notation note
  - Lower case symbols → instantaneous values
  - Capital letters → fixed values

照明光線也會唱歌 實測燈具閃爍頻率 TVBS NEWS

https://www.youtube.com/watch?v=KBGosSeW_SQ

AC Circuit analysis -2

- For sinusoids signal source, v(t) and i(t) for all circuit elements are also sinusoids
  - Same frequency
  - Vary in amplitude and phase

- Solve A(w) and φ(w) for all circuit elements
  - A(w) : amplitude change as function of w
  - φ(w) : phase change as function of w

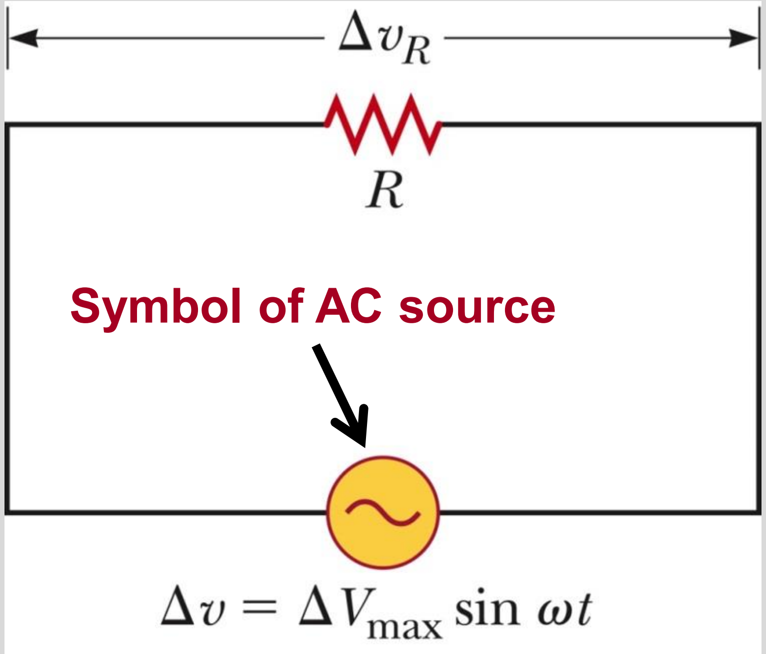
Resistors in an AC Circuit

- $v_R(t) = V_{max} \sin(\omega t + \varphi)$

Kirchhoff's loop rule $\Delta v - i_R R = 0$

$$i_R = \frac{\Delta v}{R} = \frac{\Delta V_{max}}{R} \sin \omega t = I_{max} \sin \omega t$$

- $i_R(t) = (V_{max}/R) \sin(\omega t + \varphi)$



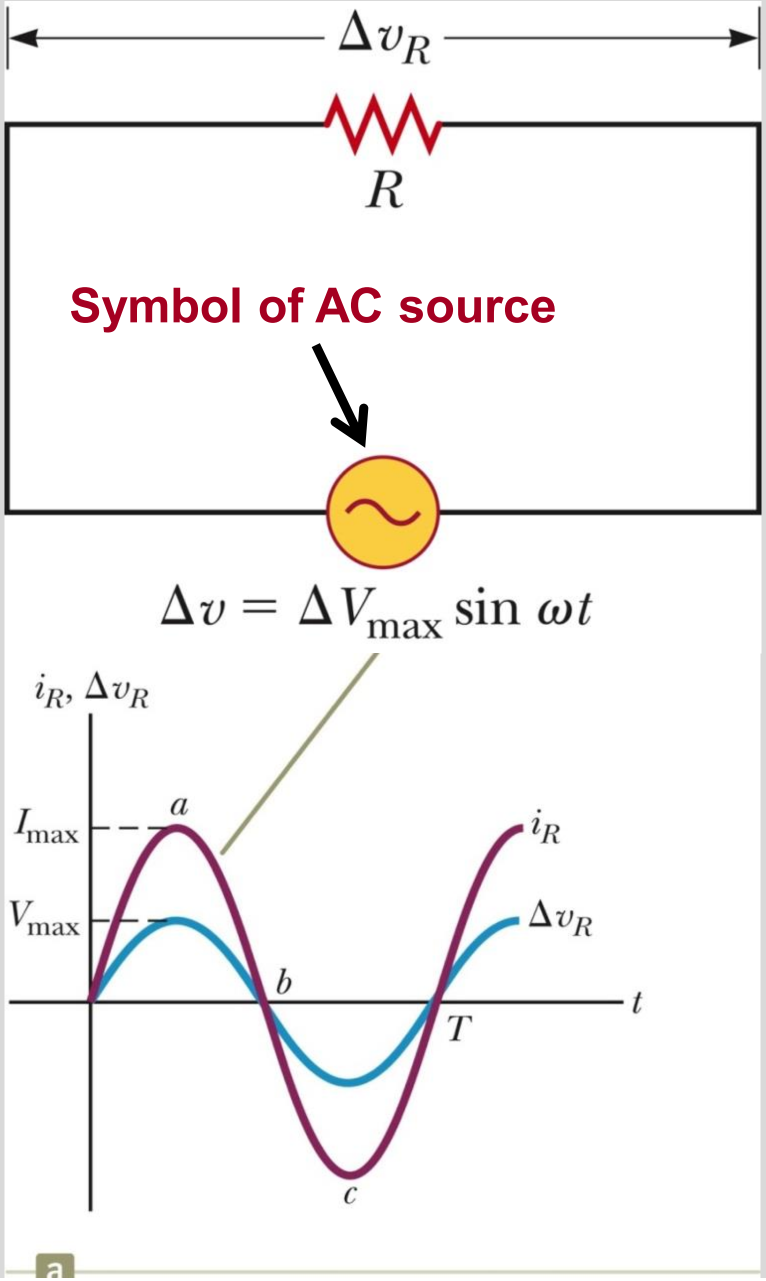
The instantaneous voltage across the resistor

$v_R(t) = i_R(t)R = V_{max} \sin(\omega t + \varphi)$

Resistors in an AC Circuit

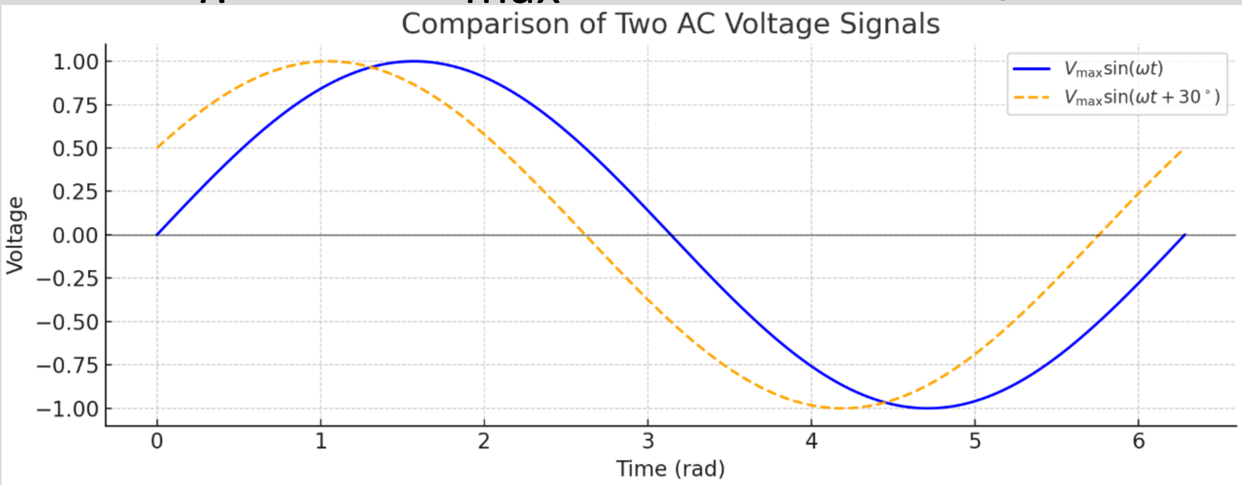
- $v_R(t) = V_{max} \sin(\omega t + \varphi)$
- $i_R(t) = (V_{max}/R) \sin(\omega t + \varphi)$

- For a resistor
  - $\varphi_R(w) = 0$ and $A_R(w) = R$
  - They are constant for any w
  - φ is the same for v(t) and i(t)
    - **in phase**

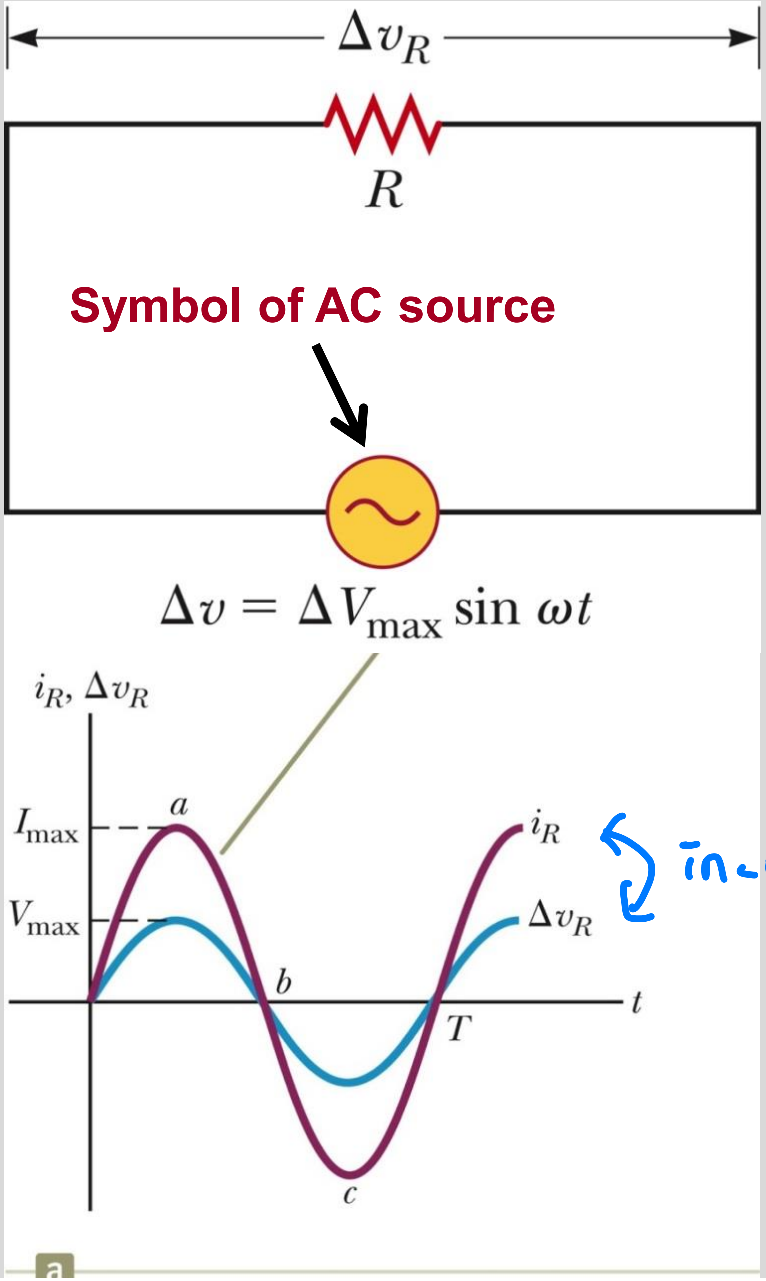


Resistors in an AC Circuit

- $v_R(t) = V_{max} \sin(\omega t + \varphi)$
- $i_R(t) = (V_{max}/R) \sin(\omega t + \varphi)$



  - They are constant for any w
  - φ is the same for v(t) and i(t)
    - **in phase**



in-phase

Section 33.2

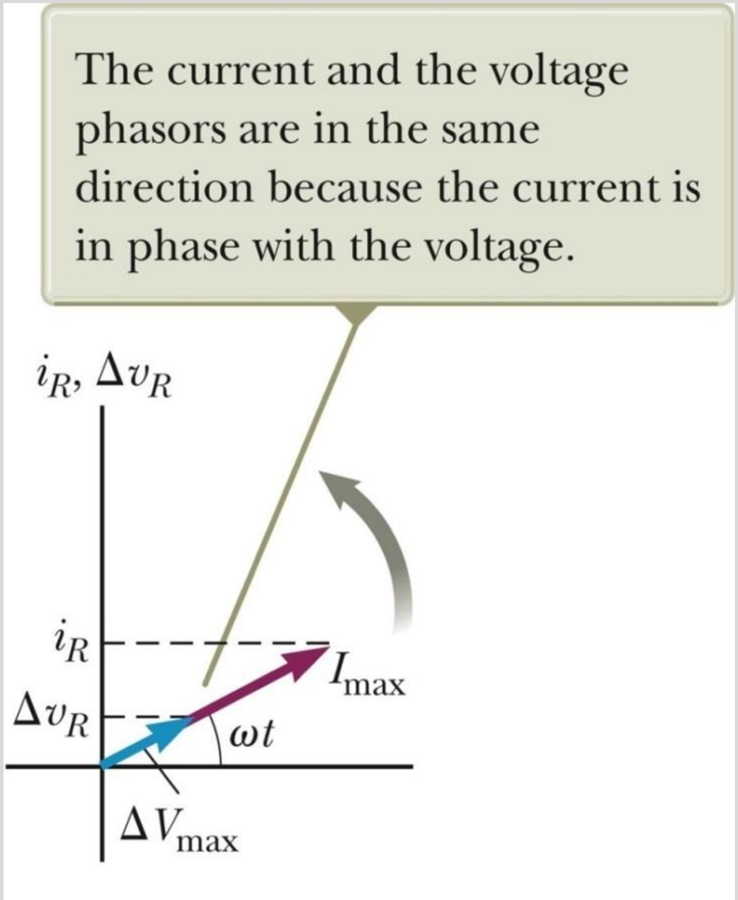
Phasor Diagram

- Simplified sinusoids to a vector (**A phasor**) phase vector
  - Length → maximum value (V_{max} or I_{max})
  - Angle → phase (φ)
  - Rotates counterclockwise at an angular speed (w)
- Notation:
  - Time domain : $v_R(t) = V_{max}\sin(wt + \varphi)$
  - frequency domain Phasor : $V_R = V_{max}\angle\varphi$
  - Phasor to a complex number:

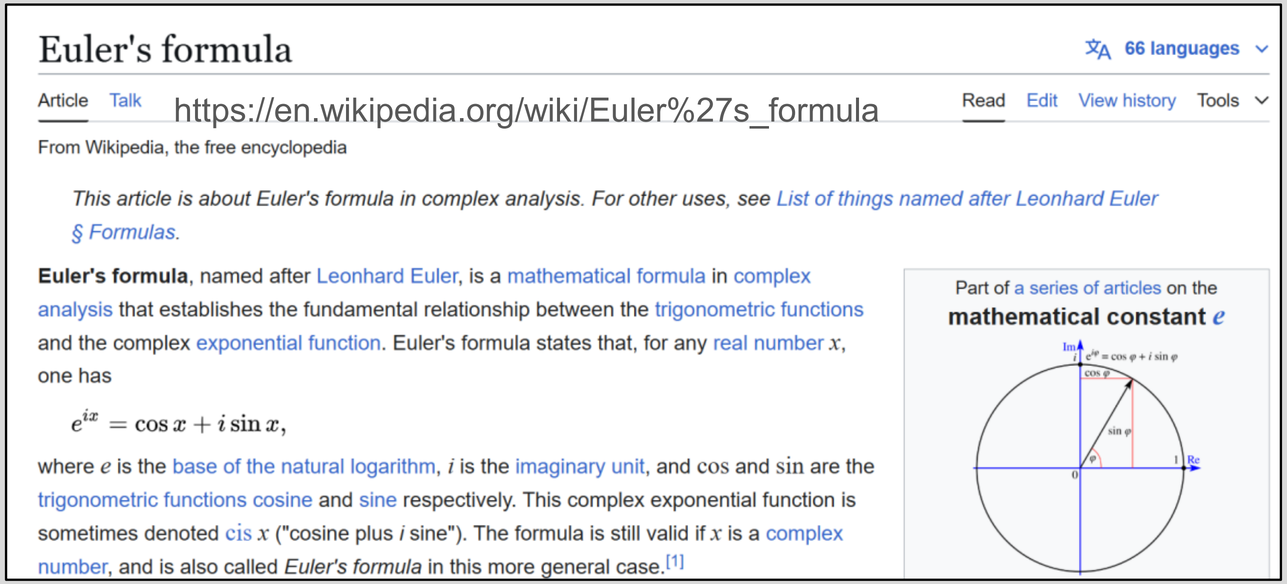
$$\boldsymbol{V_{max}e^{i\varphi} = (V_{max}\cos\varphi) + i(V_{max}\sin\varphi)}$$

  - $i = \sqrt{-1}$ (imaginary number)
  - A vector in the form of complex number

The phase space is similar to polar coordinate



Phasor Diagram



Euler's formula

66 languages

Article Talk https://en.wikipedia.org/wiki/Euler%27s_formula Read Edit View history Tools

From Wikipedia, the free encyclopedia

This article is about Euler's formula in complex analysis. For other uses, see List of things named after Leonhard Euler § Formulas.

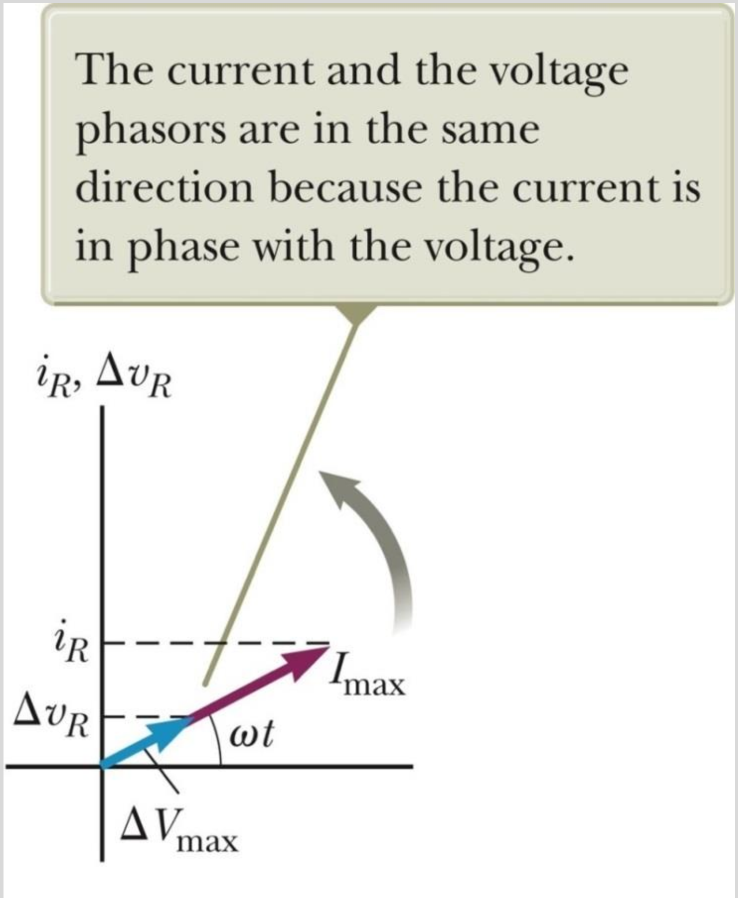
Euler's formula, named after Leonhard Euler, is a mathematical formula in complex analysis that establishes the fundamental relationship between the trigonometric functions and the complex exponential function. Euler's formula states that, for any real number x, one has

$$e^{ix} = \cos x + i \sin x,$$

where e is the base of the natural logarithm, i is the imaginary unit, and cos and sin are the trigonometric functions cosine and sine respectively. This complex exponential function is sometimes denoted $\operatorname{cis} x$ ("cosine plus i sine"). The formula is still valid if x is a complex number, and is also called *Euler's formula* in this more general case.[1]

Part of a series of articles on the
mathematical constant e

The phase space is similar to polar coordinate



- Notation:
  - Time domain : $v_R(t) = V_{max}\sin(wt + \varphi)$
  - Phasor : $V_R = V_{max}\angle\varphi$
  - Phasor to a complex number:

$$\boldsymbol{V_{max}e^{i\varphi} = (V_{max}\cos\varphi) + i(V_{max}\sin\varphi)}$$

    - i = $\sqrt{-1}$
    - A vector in the form of complex number

Section 33.2

Example

- Time signal: 100 sin (20t+30°)
  - W=20 (rad/s)
  - A=100 (V or A)
  - Φ = 30° or $\pi/6$
- Phasor : $100\angle 30°$
- Phasor in complex domain :$100e^{i(30°)}$
  - $100e^{i(30°)} = 100\cos 30° + i\ 100\sin 30° = \cancel{50 + i50\sqrt{3}}$

    $50\sqrt{3} + 50i$

Inductors in an AC Circuit

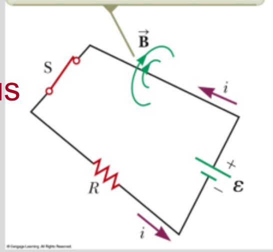
Week 11 Self-Inductance

- When the switch is closed
  - Before reaching maximum, the increasing flux creates an induced emf opposite the direction of the emf of the battery by Lenz's law
- L is called the **inductance** (電感) of the coil

$$L = \frac{\Phi_B}{i} \Rightarrow \boxed{\varepsilon_L = -\frac{d\Phi_B}{dt} = -L\frac{di}{dt}} \quad (32.1)$$

  - SI unit of inductance is the **henry (H)**

After the switch is closed, the current produces a magnetic flux through the area enclosed by the loop. As the current increases toward its equilibrium value, this magnetic flux changes in time and induces an emf in the loop.



The self-induced instantaneous voltage across the inductor

CJLI Section 32.1

correct result, but for the wrong reason

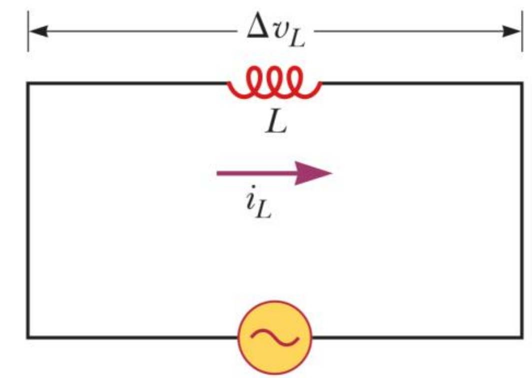


Figure 32.6 A circuit consisting of an inductor of inductance L connected to an AC source.

Kirchhoff's loop rule

$$\Delta v + \Delta v_L = 0$$

$$\Rightarrow \Delta v - L\frac{di_L}{dt} = 0$$

$\Delta v(t) = \Delta V_{max} \sin(\omega t + \varphi)$

$$\boxed{\Delta v = L\frac{di_L}{dt} = \Delta V_{\max} \sin \omega t}$$

$$\Rightarrow di_L = \frac{\Delta V_{\max}}{L} \sin \omega t \, dt$$

$$\Rightarrow i_L = \frac{\Delta V_{\max}}{L}\int \sin \omega t \, dt = -\frac{\Delta V_{\max}}{\omega L} \cos \omega t$$

$\cos \omega t = -\sin(\omega t - \pi/2)$

$$\boxed{i_L = \frac{\Delta V_{\max}}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right)}$$

out of phase by $\pi/2$

$\Rightarrow$ when $\cos \omega t = \pm 1$

$$I_{\max} = \frac{\Delta V_{\max}}{\omega L}$$

Similar to the resistance in a DC circuit, $I = \Delta V / R$

Amperes Volts

ωL must have units of Ohms

Inductive reactance (感抗, 電抗) $X_L \equiv \omega L$ $\quad I_{max} = \Delta V_{max}/X_L$

The instantaneous voltage across the inductor

$$\Delta v_L = -L\frac{di_L}{dt} = -\Delta V_{\max} \sin(\omega t) = -I_{max} X_L \sin(\omega t)$$

$$\Delta V + \Delta V_L = 0 \quad (\text{KVL ???})$$

$$\Rightarrow \Delta V - L\frac{di}{dt} = 0$$

$$\mathcal{E}_L = -L\frac{di_L}{dt}$$

$$\Rightarrow \Delta V = L\frac{di_L}{dt}$$

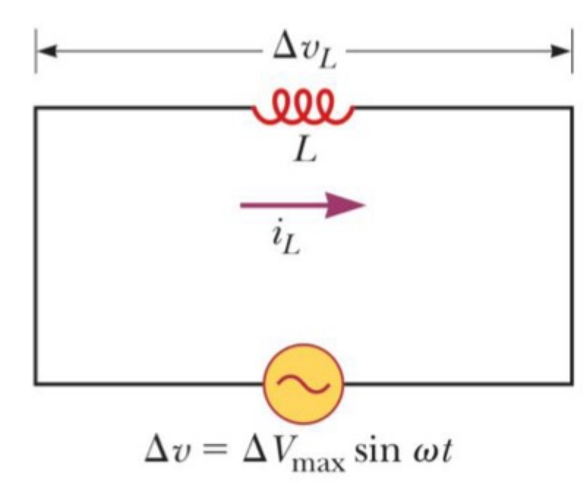


Figure 32.6 A circuit consisting of an inductor of inductance L connected to an AC source.

$$\Rightarrow di_L = \frac{\Delta V}{L} dt$$

$$\Delta V = V_{max} \sin \omega t$$

$$\Rightarrow di_L = \frac{V_{max}}{L} \sin \omega t \, dt$$

$$\Rightarrow i_L = \frac{V_{max}}{L} \int \sin \omega t \, dt$$

Let $a = \omega t$

$$\Rightarrow da = \omega dt$$

$$\Rightarrow dt = \frac{da}{\omega}$$

$$\Rightarrow i_L = \frac{V_{max}}{\omega L} \int \sin a \, da$$

$$\Rightarrow \quad i_L = \frac{V_{max}}{\omega L}\left[-\cos(\omega t)\right]$$

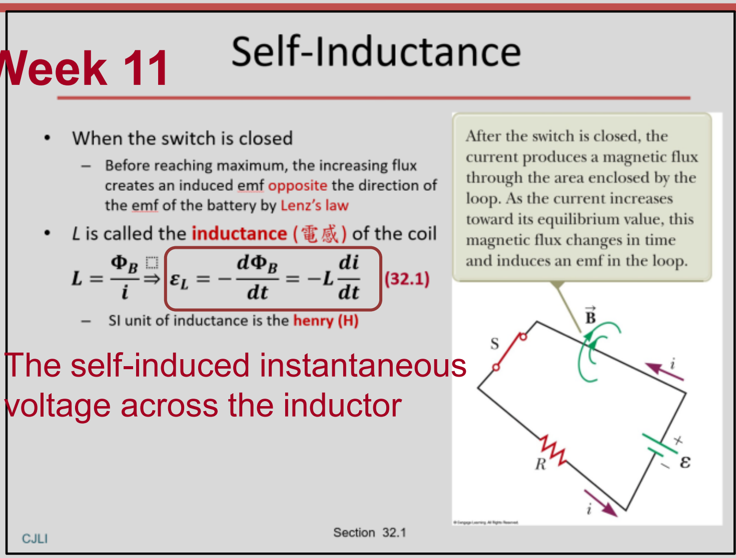
current lags voltage by $\frac{\pi}{2}$

$$\Rightarrow \quad \boxed{i_L = \frac{V_{max}}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)}$$

inductive reactance X_L

Inductors in an AC Circuit

Week 11



The self-induced instantaneous voltage across the inductor

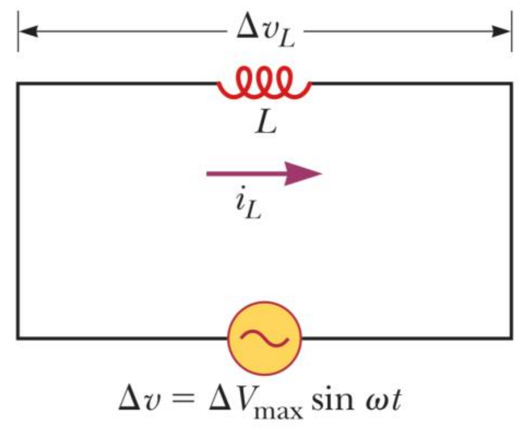


Figure 32.6 A circuit consisting of an inductor of inductance L connected to an AC source.

Kirchhoff's loop rule

$$\Delta v + \Delta v_L = 0$$

$$di_L = \frac{\Delta V_{max}}{L} \sin \omega t \, dt$$

$$\Delta v - L\frac{di_L}{dt} = 0$$

$\Delta v(t) = \Delta V_{max} \sin (\omega t$

$$\boxed{\Delta v = L\frac{di_L}{dt} = \Delta V_{max} \sin}$$

For a given applied Δv, X_L increases as the frequency increases.

This is consistent with Faraday's law: the greater the rate of change of current in the inductor, the larger the back emf.

A larger back emf implies a greater reactance, which in turn results in a smaller current.

± 1

max

L

$/R$

s

ωL must have units of Ohms

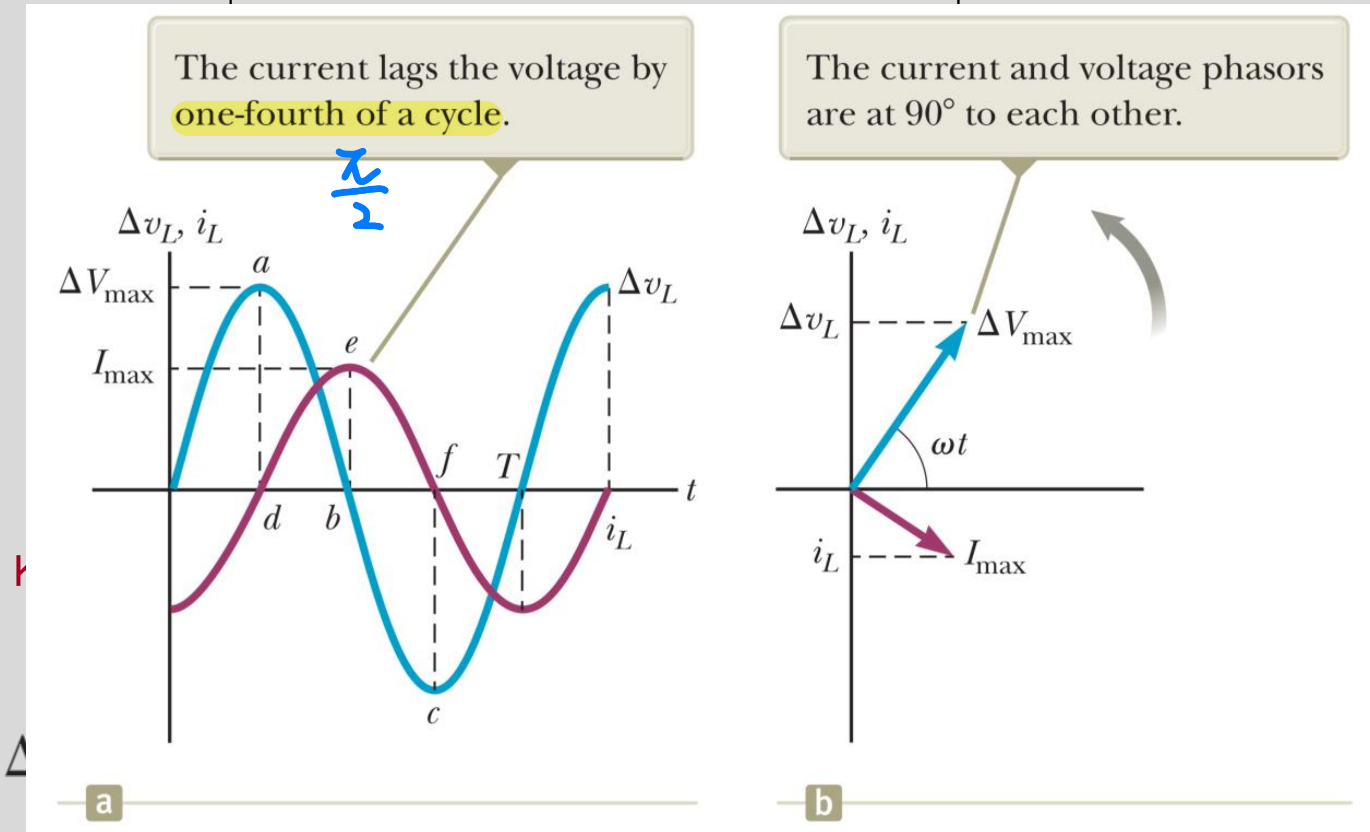
out of phase by $\pi/2$

The instantaneous voltage across the inductor

Inductive reactance 感抗 電抗 $X_L \equiv \omega L$ $\quad I_{max} = \Delta V_{max}/X_L$

$$\Delta v_L = -L\frac{di_L}{dt} = -\Delta V_{max} \sin (\omega t) = -I_{max} X_L \sin (\omega t)$$

Inductors in an AC Circuit



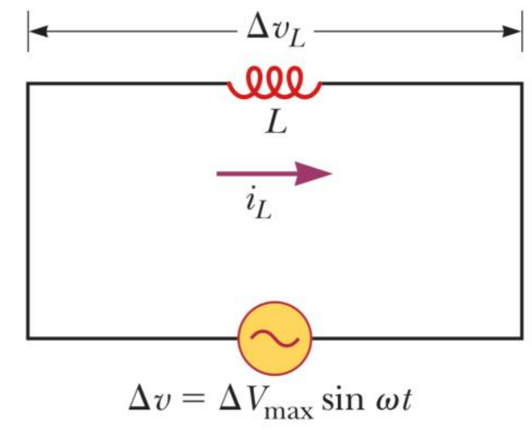


Figure 32.6 A circuit consisting of an inductor of inductance L connected to an AC source.

$\cos \omega t$ $\Rightarrow$ when $\cos \omega t = \pm 1$

$$I_{max} = \frac{\Delta V_{max}}{\omega L}$$

$\Delta v(t) = \Delta V_{max} \sin (\omega t + \varphi)$

$\cos \omega t = \sin(\omega t - \pi/2)$

$$\boxed{\Delta v = L\frac{di_L}{dt} = \Delta V_{max} \sin \omega t}$$

$$\boxed{i_L = \frac{\Delta V_{max}}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right)}$$

out of phase by $\pi/2$

Similar to the resistance in a DC circuit, $I = \Delta V/R$

Amperes Volts

ωL must have units of Ohms

Inductive reactance 電抗 $X_L \equiv \omega L$ 感抗 $\quad I_{max} = \Delta V_{max}/X_L$

The instantaneous voltage across the inductor

$$\Delta v_L = -L\frac{di_L}{dt} = -\Delta V_{max} \sin(\omega t) = -I_{max} X_L \sin(\omega t)$$

Capacitors in an AC Circuit

Week 4

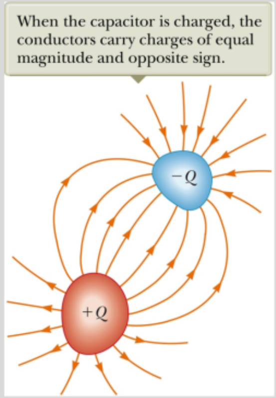
Makeup of a Capacitor

- Consists of two conductors (plates)
  - Charges of equal magnitude and opposite directions
  - Potential difference
- Definition of Capacitance

$$C \equiv \frac{Q}{\Delta V} \qquad \textbf{(26.1)}$$

  - Ability to store charge
  - The SI unit is the **farad (F)**

When the capacitor is charged, the conductors carry charges of equal magnitude and opposite sign.



Section 26.1 8

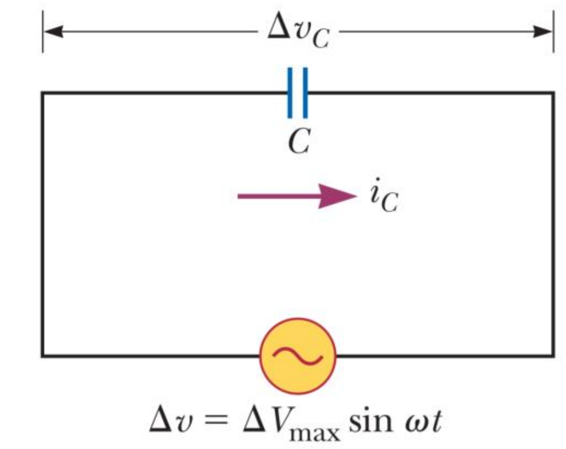


Figure 32.9 A circuit consisting of a capacitor of capacitance C connected to an AC source.

Kirchhoff's loop rule

$$\Delta v + \Delta v_C = 0$$

$$\Rightarrow \Delta v - \frac{q}{C} = 0$$

$$\boxed{\Delta v(t) = \Delta V_{max} \sin(\omega t + \varphi)}$$

$$\Rightarrow i_C = \frac{dq}{dt} = \omega C \Delta V_{\max} \cos \omega t$$

$$\cos \omega t = \sin(\omega t + \pi/2)$$

$$\boxed{i_C = \omega C \Delta V_{\max} \sin\left(\omega t + \frac{\pi}{2}\right)}$$

$\Rightarrow$ when $\cos \omega t = \pm 1$

$$I_{\max} = \omega C \Delta V_{\max} = \frac{\Delta V_{\max}}{(1/\omega C)}$$

out of phase by $\pi/2$

$$q = C \Delta V_{\max} \sin \omega t$$

容抗

Capacitive reactance $X_C \equiv 1/\omega C$ $\qquad I_{max} = \Delta V_{max}/X_C$

The instantaneous voltage across the capacitor $\quad \Delta v_c = \Delta V_{max} \sin(\omega t) = I_{max} X_C \sin(\omega t)$

$\Delta V + \Delta V_c = 0$ (KVL ???)

$C = \frac{Q}{\Delta V}$

$\Rightarrow \Delta V - \frac{q}{C} = 0$

voltage drops across C

$\Rightarrow q = C(\Delta V_{max} \sin \omega t)$

$\Delta V = \Delta V_{max} \sin \omega t$

$\Rightarrow i = \frac{dq}{dt} = \omega C \Delta V_{max} \cos \omega t$

$$\Rightarrow \boxed{i = \frac{\Delta V_{max}}{\frac{1}{\omega C}} \sin\left(\omega t + \frac{\pi}{2}\right)}$$

current leads voltage by $\frac{\pi}{2}$

capacitive reactance

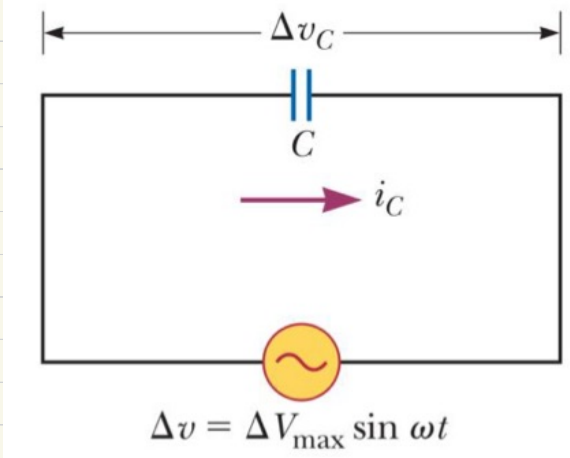
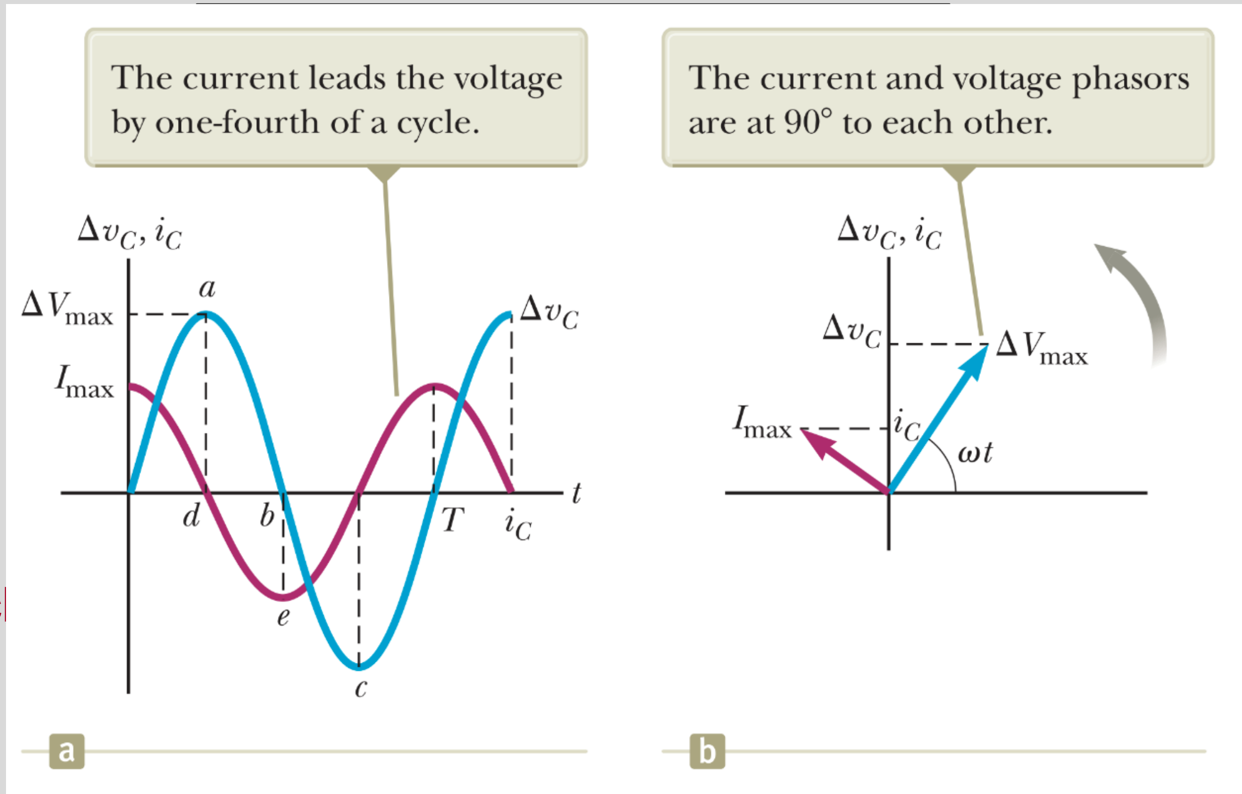


Figure 32.9 A circuit consisting of a capacitor of capacitance C connected to an AC source.

Capacitors in an AC Circuit



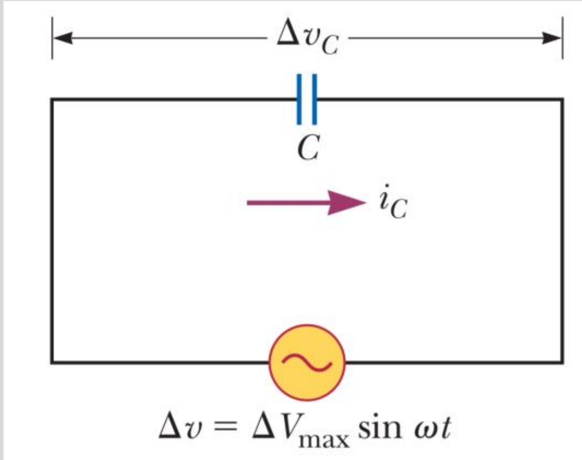


Figure 32.9 A circuit consisting of a capacitor of capacitance C connected to an AC source.

Kirc

C

$\Delta v(t) = \Delta V_{max} \sin (\omega t + \varphi)$

$$i_C = \omega C \Delta V_{max} \sin\left(\omega t + \frac{\pi}{2}\right)$$

2)

$\Rightarrow$ when $\cos \omega t = \pm 1$

$$I_{max} = \omega C \Delta V_{max} = \frac{\Delta V_{max}}{(1/\omega C)}$$

out of phase by $\pi/2$

$$q = C \Delta V_{max} \sin \omega t$$

Capacitive reactance $X_C \equiv 1/\omega C$ $\quad I_{max} = \Delta V_{max}/X_C$

The instantaneous voltage across the capacitor $\quad \Delta v_c = \Delta V_{max} \sin(\omega t) = I_{max} X_C \sin(\omega t)$

Quick Quiz 33.4

b

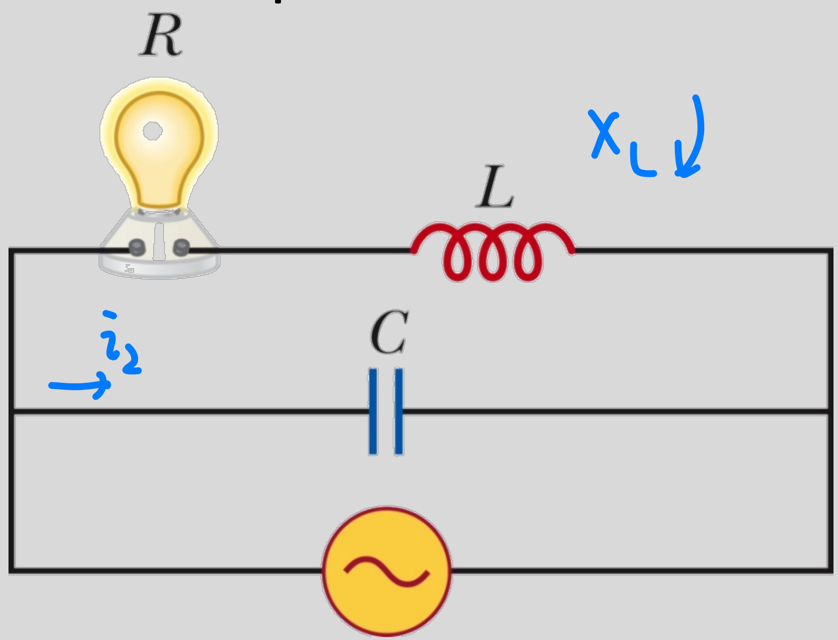
- Consider the AC circuit in Figure 33.12. The frequency of the AC source is adjusted while its voltage amplitude is held Constant. When does the lightbulb glow the brightest?
- **(a)** It glows brightest at high frequencies.
- **(b)** It glows brightest at low frequencies.
- **(c)** The brightness is the same at all frequencies.

$i_1 \uparrow$

- **Answer:** (b)

$X_L \downarrow \Rightarrow \omega L \downarrow \Rightarrow \omega \downarrow$

$i_1 \uparrow$



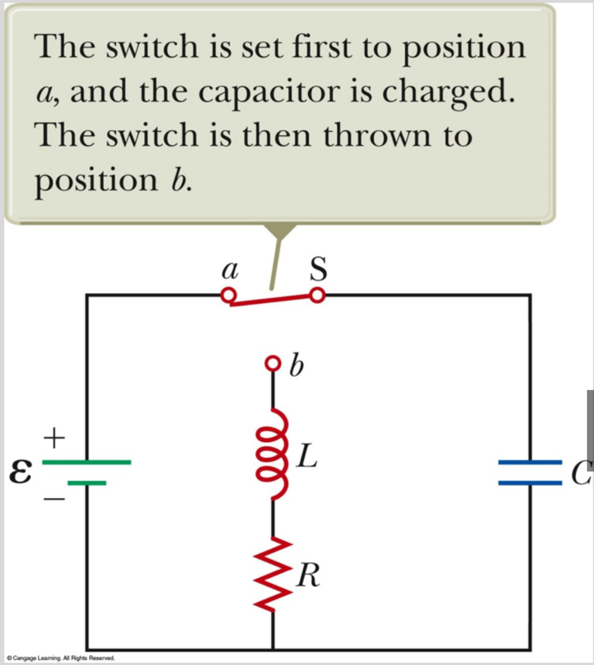
The *RLC* Series Circuit

Week 11 The *RLC* Circuit

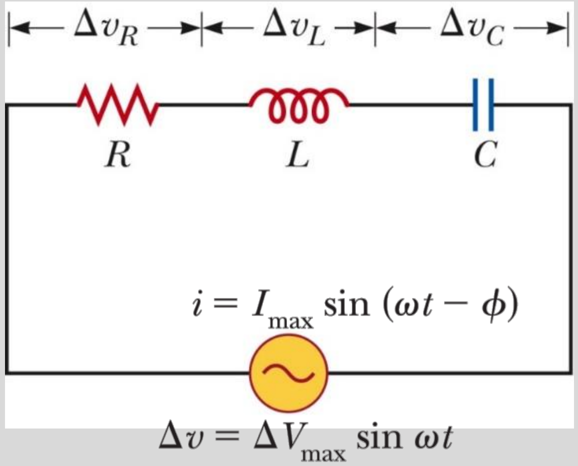
- The total energy is not constant
  - Transformation to internal energy in the resistor at the rate of $dU/dt = -I^2R$
- Kirchhoff's loop laws

$$L\frac{d^2q}{dt^2}+R\frac{dq}{dt}+\frac{q}{C}=0$$

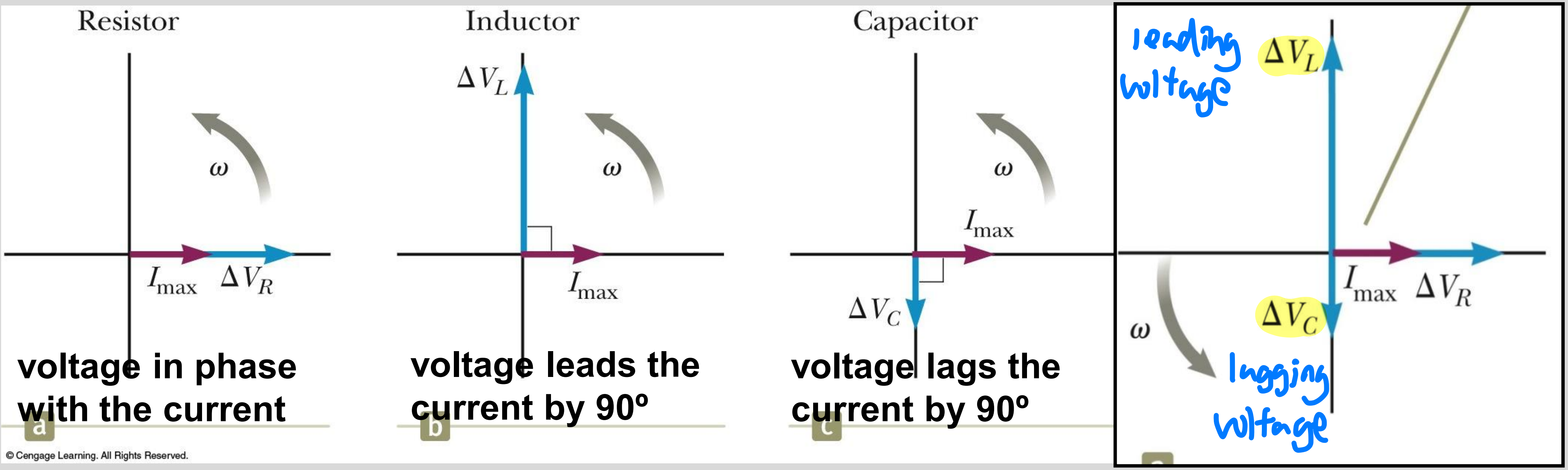
- The *RLC* circuit is analogous to a damped harmonic oscillator
  - Small R
  - Large R
  - R=Rc



Section 32.6



The *RLC* Series Circuit



Using the phase relationships in previous slides, we can express the instantaneous voltages across R, L, C:

$$\boxed{v_R(t) = (I_{max}R)\sin(\omega t)} = iR$$

$$\boxed{v_L(t) = (I_{max}\omega L)\sin(\omega t + 90^\circ)} = L\frac{di}{dt}$$

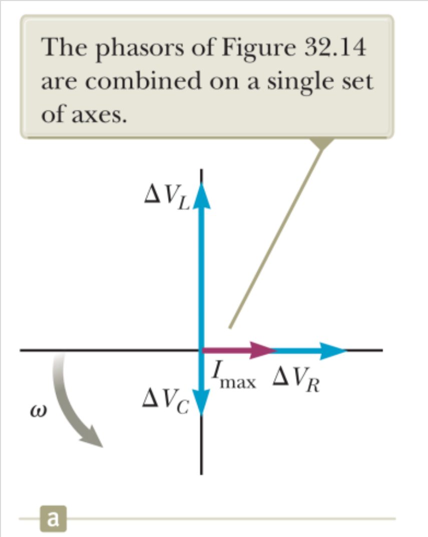
inductive reactance $X_L \equiv \omega L$

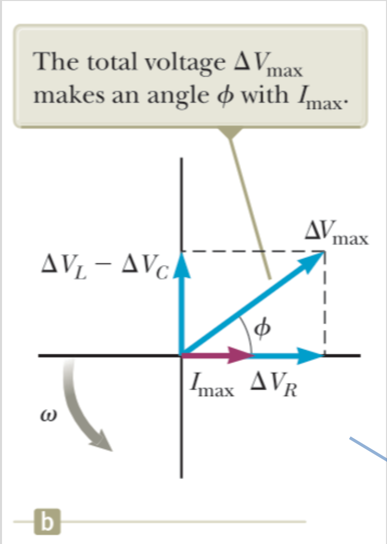
$$\boxed{v_C(t) = (I_{max}\frac{1}{\omega C})\sin(\omega t - 90^\circ)} = \frac{\int i\,d(t)}{C}$$

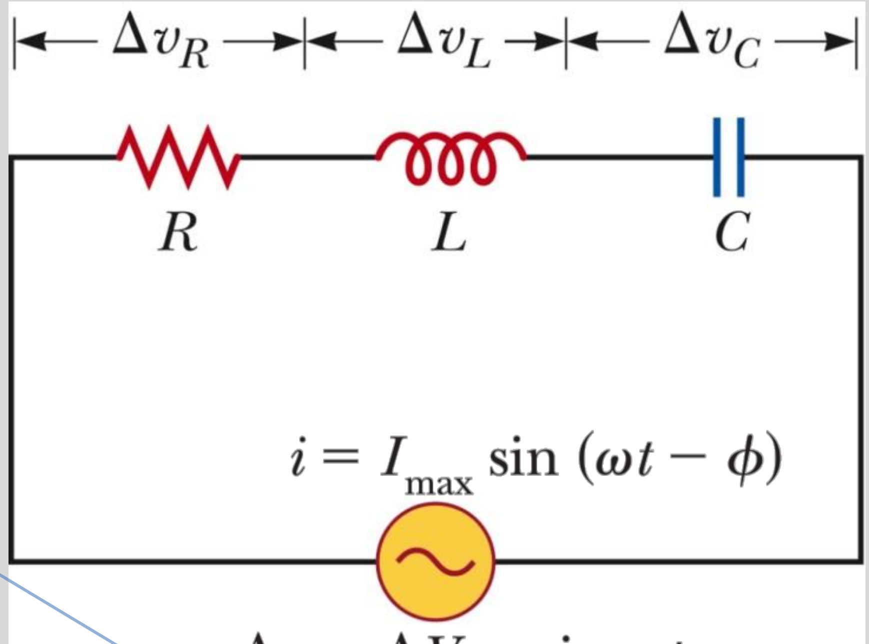
capacitive reactance $X_C \equiv 1/\omega C$

Section 33.5

The *RLC* Series Circuit







$\Delta v = \Delta V_{max} \sin \omega t$

$\Delta v_R + \Delta v_L + \Delta v_C$ =the instantaneous voltage Δv, but Δv_R, Δv_L, Δv_C have different phase relationships with the current, and cannot be added directly.

$$\Delta V_{max} = \sqrt{\Delta V_R^2 + (\Delta V_L - \Delta V_C)^2} = \sqrt{(I_{max}R)^2 + (I_{max}X_L - I_{max}X_C)^2}$$

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

$$\phi = \tan^{-1}\left(\frac{\Delta V_L - \Delta V_C}{\Delta V_R}\right)$$

$$= \tan^{-1}\left(\frac{I_{max}X_L - I_{max}X_C}{I_{max}R}\right)$$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

$X_L = X_C$: pure resistive

$$I_{max} = \frac{\Delta V_{max}}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{\Delta V_{max}}{Z}$$

The impedance Z of the circuit 阻抗

$$Z \equiv \sqrt{R^2 + (X_L - X_C)^2} \quad \text{(ohms)}$$

The *RLC* Series Circuit

- In series, they have same current
  - $i(t) = I_{max} \sin(\omega t+\theta) \rightarrow I_{max}\angle\theta$
- Impedance $Z = Z_R + Z_L + Z_C$

$i = \sqrt{-1}$, we usually use j as per convention

$= R + iwL - i(1/wc)$

$= R + i[wL-(1/wc)]$

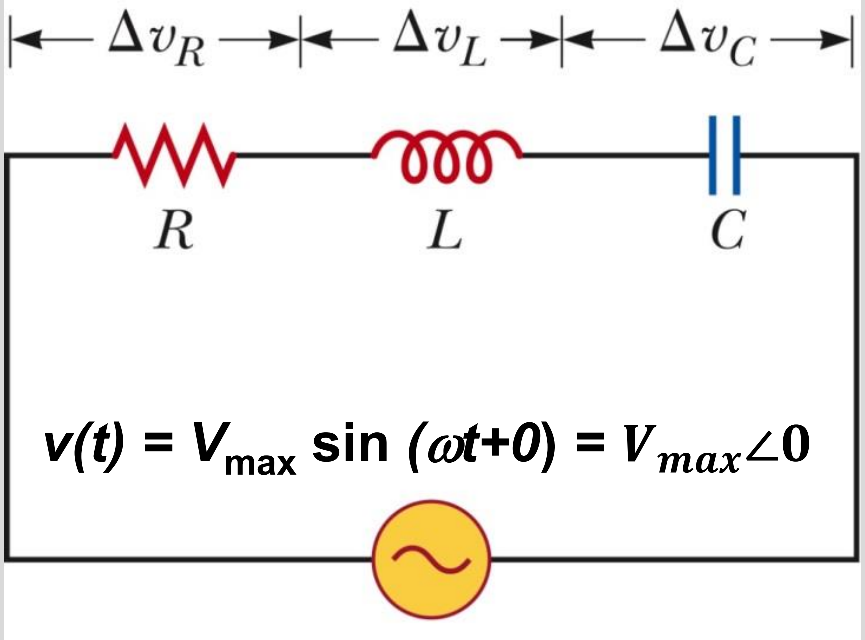
$= A\angle\varphi$

$$A(w) = \sqrt{R^2 + (wL - 1/wC)^2} \qquad \textbf{(33.25)}$$

$$\varphi(w) = \tan^{-1}\frac{wL - 1/wC}{R} \qquad \textbf{(33.27)}$$

$$\mathrm{I} = \frac{V}{Z} = \frac{V_{max}\angle(0)}{A\angle(\varphi)} = \frac{V_{max}}{A}\angle(-\varphi)$$

$$i(t) = \frac{V_{max}}{A(w)}\sin(wt - \varphi(w))$$



(33.24)

(33.26)

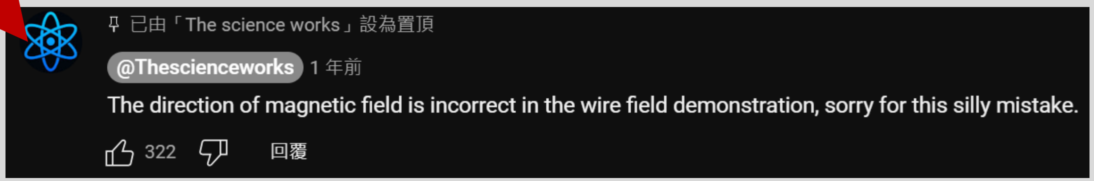
$X_L = \omega L$

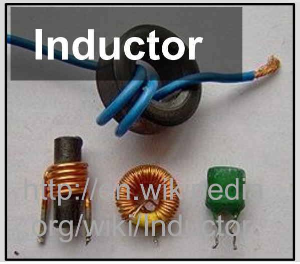
$X_c = \frac{1}{wC}$

Inductor

網路資訊，同學要記得獨立思考，自主查證

https://www.youtube.com/watch?v=pbwr73R6Ay8





Impedance, Z (阻抗)

- For circuit element in phasor space
  - Z=V/I
  - Z is a complex number (a+bi, where i = $\sqrt{-1}$)

We usually use j by convention

- Resistor : Z_R = R = $R\angle 0^\circ$
- Inductor: $X_L \equiv \omega L$ → high impedance at high w
  - In phasor: $Z_L = \omega L \angle 90^\circ$
  - In complex: $Z_L = \omega L(0+i) = \omega L(i)$

$$\boxed{e^{ix} = \cos x + i \sin x}$$

- Capacitor : $X_C \equiv 1/\omega C$ → low impedance at high w
  - In phasor : $Z_C = (1/\omega C)\angle -90^\circ$
  - In complex : $Z_C = (1/\omega C)(0\text{-}i) = (1/\omega C)(\text{-}i)$

theoretically perfect inductor & capacitor : $R_L = R_C = 0$

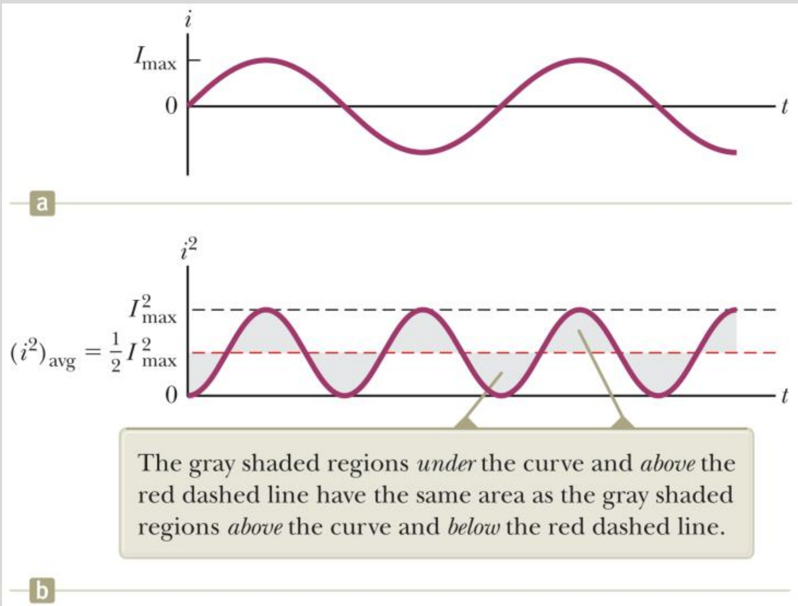
Power in an AC Circuit

- For sinusoid, the average current in one cycle is zero
- The rms (root mean square) current or voltage are used in an AC circuit

$$I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}} = 0.707\, I_{\text{max}} \qquad \Delta V_{\text{rms}} = \frac{\Delta V_{\text{max}}}{\sqrt{2}} = 0.707\, \Delta V_{\text{max}}$$

(33.4)
(33.5)

  - AC ammeters and voltmeters are designed to read rms values



The average power delivered to a R that carries an AC

$$P_{\text{avg}} = I^2_{\text{rms}} R$$

The *P* an AC with Imax 2.00 A delivers to a R
= The *P* a DC with (0.707)(2.00 A) =1.41 A delivers to a R

Power in an AC Circuit

- For sinusoid, the average current in one cycle is zero
- The rms (root mean square) current or voltage are used in an AC circuit

$$I_{\text{rms}} = \frac{I_{\max}}{\sqrt{2}} = 0.707\, I_{\max} \qquad \Delta V_{\text{rms}} = \frac{\Delta V_{\max}}{\sqrt{2}} = 0.707\, \Delta V_{\max}$$

(33.4)
(33.5)

  - AC ammeters and voltmeters are designed to read rms values

- For all circuit element p = *iv* and $P_{avg} = \int_0^T (iv)\, dt \,/\, T$

Power in an AC Circuit

想知道細節的看書本

- $p = iv = I_{max} \sin(\omega t + \phi)\, \Delta V_{max} \sin(\omega t)$
- $P_{avg} = \frac{1}{2} I_{max} V_{max} \cos\phi = I_{rms} V_{rms} \cos\phi$ **(33.30) (33.31)**
  - 功率因數
  - **cos ϕ** is called the **power factor** of the circuit
  - The power delivered by an AC circuit depends on the phase
  - No power losses are associated with pure capacitors and pure inductors in an AC circuit

$\cos\frac{\pi}{2} = 1$, $\cos\frac{3\pi}{2} = -1$

- For RLC circuit,

$f_0 = \frac{1}{2\pi\sqrt{LC}}$

→ resonant angular frequency

$$\omega_0 = \frac{1}{\sqrt{LC}} \quad \textbf{(33.35)}$$

$$\omega_0 L = 1/\omega_0 C$$

  - 共振
  - Resonance frequency when $X_L = X_C$
  - The impedance have a minimum value
  - The current has its maximum value
  - The average power has is a maximum.

$$I_{rms} = \frac{\Delta V_{rms}}{Z} = \frac{\Delta V_{rms}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

🔌 What it Tells You:

It represents the **fraction of power** that is **actually used** to do useful work (real power), compared to the **total power** supplied (apparent power).

🧠 In Terms of Power:

$$P_{\text{avg}} = I_{\text{rms}} V_{\text{rms}} \cos\phi$$

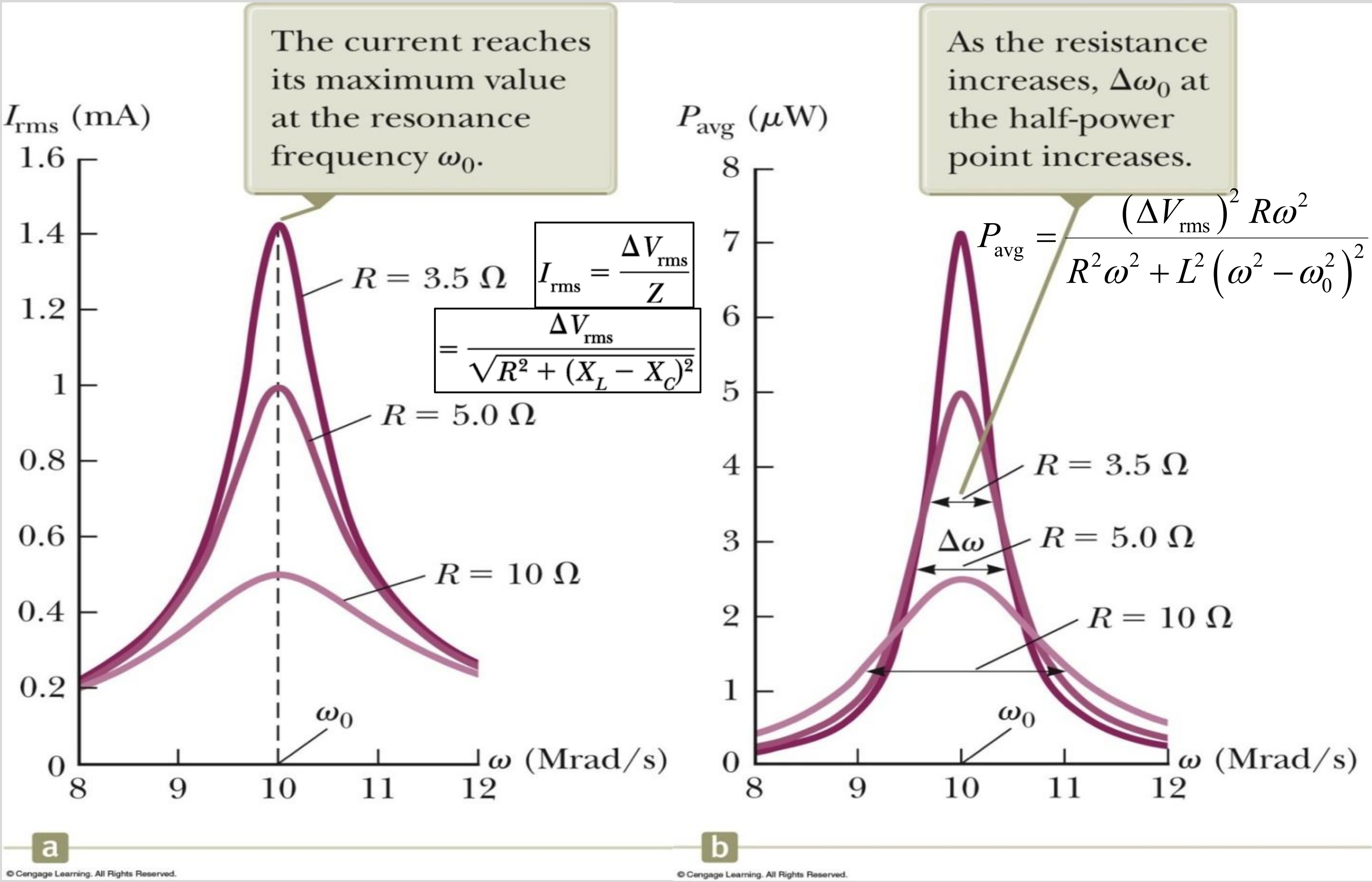
- $I_{\text{rms}} V_{\text{rms}}$ = **apparent power** (VA)
- $\cos\phi$ = **power factor**
- P_{avg} = **real (useful) power** (watts)

⚡ Interpretations:

Power Factor $\cos\phi$	Meaning
1 (ideal)	All power is used usefully (pure resistor)
0	All power is reactive (pure L or C)
between 0 and 1	Some power is wasted as reactive energy

Resonance in RLC Circuit

- As R decreases, the curve becomes narrower and taller
- at resonance, the average power is a maximum.



$$P_{avg} = I_{rms}^2 R = \left(\frac{\Delta V_{rms}}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}} \right)^2 R$$

$$\left(\omega L - \frac{1}{\omega C} = \frac{L(\omega^2 - \frac{1}{LC})}{\omega} = \frac{L(\omega^2 - \omega_0^2)}{\omega} \quad \text{resonance frequency} \quad \omega_0 = \frac{1}{\sqrt{LC}} \right)$$

$$= \frac{\Delta V_{rms}^2 R}{R^2 + \frac{L^2(\omega^2 - \omega_0^2)^2}{\omega^2}}$$

$$= \frac{\Delta V_{rms}^2 R \omega^2}{R^2\omega^2 + L^2(\omega^2 - \omega_0^2)^2}$$

Quality Factor (Q)

Q Factor

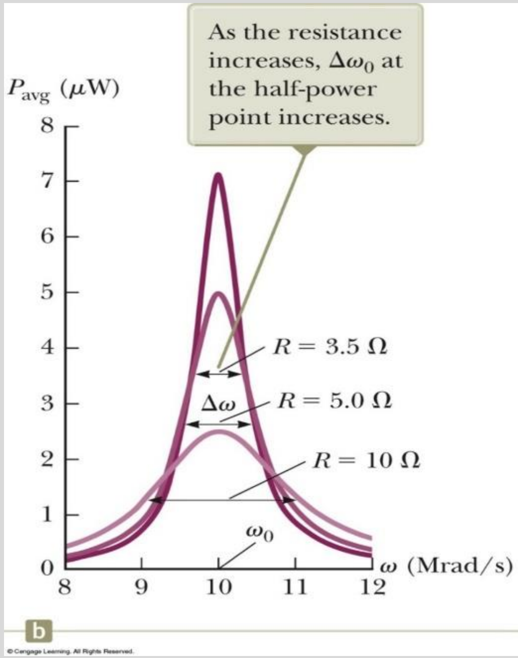
- The sharpness of the resonance curve

$\boxed{\Delta\omega = \frac{R}{L}}$

品質因子 $Q = \omega_0 / \Delta\omega = (\omega_0 L) / R$ **(33.38)**

  - $\Delta\omega$ is the width of the curve, measured between the two values of ω for which P_{avg} has half its maximum value (*half-power points)*

- Example: A radio's receiving circuit
  - A high-Q circuit (Narrow peak)
    - responds only to a narrow range of frequencies
  - A low-Q circuit (Broad peak)
    - Detect a much broader range of frequencies



⑥ Angular Half-Power Bandwidth $\Delta\omega$ in RLC

1° $i_{max} = \dfrac{V}{Z}$

$= \dfrac{V}{R}$

At resonance frequency $(X_L = X_C)$,

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

2° At half power frequencies,

$P = \dfrac{P_{max}}{2} = \dfrac{i_{max}^2 R}{2} = \left(\dfrac{i_{max}}{\sqrt{2}}\right)^2 R$

$\hookrightarrow$ i in the circuit at half-power frequencies

3° $V = \dfrac{i_{max}}{\sqrt{2}} Z$

$= \left(\dfrac{V}{\sqrt{2}R}\right)^2 Z$

From 1°,

$i_{max} = \dfrac{V}{R}$

$\Rightarrow \sqrt{2}R = Z \quad \Rightarrow \quad 2R^2 = Z^2$

4° We use the formula

$$Z^2 = R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2$$

From 3°,
$2R^2 = Z^2$

$$\Rightarrow 2R^2 = R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2$$

$$\Rightarrow R = \pm\left(\omega L - \frac{1}{\omega C}\right)$$

$\Rightarrow$ There are 2 values of half power angular frequencies

$$R = \omega_1 L - \frac{1}{\omega_1 C} \quad \text{or} \quad \frac{1}{\omega_2 C} - \omega_2 L$$

$$\Rightarrow R = \frac{\omega_1^2 LC - 1}{\omega_1 C} \quad \text{or} \quad \frac{1 - \omega_2^2 LC}{\omega_2 C}$$

$$\Rightarrow \quad \omega_1 CR = \omega_1^2 LC - 1 \quad \ldots \text{ equation } A$$

or

$$\omega_2 CR = 1 - \omega_2^2 LC \quad \ldots \text{ equation } B$$

5° Add equation A and equation B

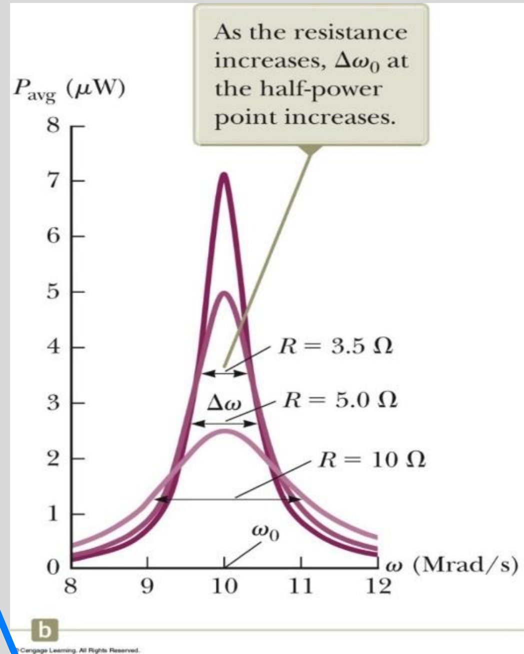
$$(\omega_1 + \omega_2) CR = \omega_1^2 LC - \omega_2^2 LC$$

$$\Rightarrow \cancel{(\omega_1 + \omega_2)} \cancel{C}R = \cancel{(\omega_1 + \omega_2)} (\omega_1 - \omega_2) L\cancel{C}$$

$$\Rightarrow \quad \Delta\omega = \omega_1 - \omega_2 = \frac{R}{L}$$

Quality Factor (Q)

- Example: A radio's receiving circuit
  - A high-*Q* circuit (Narrow peak)
    - responds only to a narrow range of frequencies
  - A low-*Q* circuit (Broad peak)
    - Detect a much broader range of frequencies



轉動調諧旋鈕(Tuning Knob)=>改變電容=>調整共振頻率=>因為只有相匹配的頻率電路才會有反應=>需要高品質因子消去其他訊號=>我們要的訊號傳至揚聲器

high Q, narrow peak

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Q factor

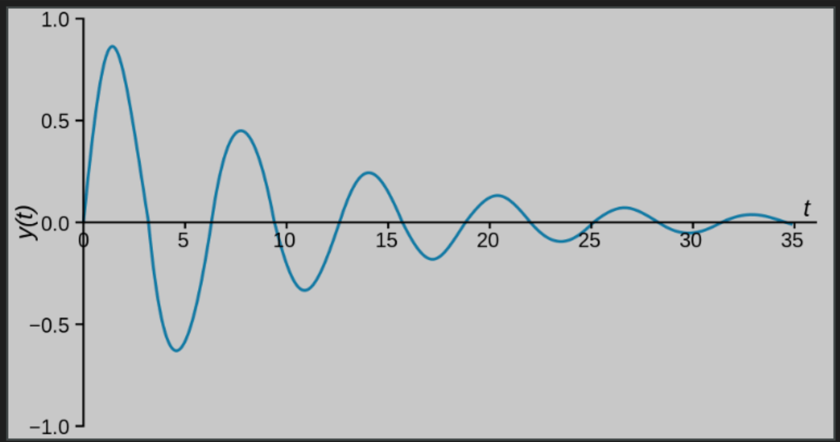
24 languages

Article Talk

Read Edit View history

From Wikipedia, the free encyclopedia

*For other uses of the terms **Q**, **Q factor**, and **Quality factor**, see Q value (disambiguation).*



A damped oscillation. A low Q factor – about 5 here – means the oscillation dies out rapidly.

In physics and engineering, the **quality factor** or **Q factor** is a dimensionless parameter that describes how underdamped an oscillator or resonator is. It is defined as the ratio of the initial energy stored in the resonator to the energy lost in one radian of the cycle of oscillation.[1] Q factor is alternatively defined as the ratio of a resonator's centre frequency to its bandwidth when subject to an oscillating driving force. These two definitions give numerically similar, but not identical, results.[2] Higher Q indicates a lower rate of energy loss and the oscillations die out more slowly. A pendulum suspended from a high-quality bearing, oscillating in air, has a high Q, while a pendulum immersed in oil has a low one. Resonators with high quality factors have low damping, so that they ring or vibrate longer.

A high-Q circuit is **more underdamped**, meaning it loses energy slowly. As a result:

- It **resonates strongly** at its natural frequency ω_0,
- But it **doesn’t respond much to nearby frequencies**,
- So its **response curve is sharp and narrow**—the system stores energy well and only lets through a tight band of frequencies.

In contrast, a low-Q circuit is **more damped**, meaning:

- It loses energy quickly,
- It doesn’t build up energy at one frequency very well,
- So it **responds over a broader range** of frequencies, giving a **wide, flat peak**.

AC Transformers (變壓器)

https://www.apple.com/tw/shop/product/G11C2TA/A/133-%E5%90%8B-macbook-pro-apple-m1-%E6%99%B6%E7%89%87%E9%85%8D%E5%82%99-8-%E6%A0%B8%E5%BF%83-cpu-%E8%88%87-8-%E6%A0%B8%E5%BF%83-gpu-%E5%A4%AA%E7%A9%BA%E7%81%B0%E8%89%B2-%E6%95%B4%E4%BF%AE%E5%93%81

https://www.apple.com/uk/shop/product/MD565B/B/apple-60w-magsafe-2-power-adapter-macbook-pro-with-13-inch-retina-display

電源供應器裡面有不同元件，包含…等:

AC Transformers (變壓器):
升高或降低交流電壓

INPUT（輸入）：適用於100~240V交流電，頻率為50~60Hz，電流為2A之電源輸入。

OUTPUT（輸出）：適用於19V直流電，電流6.32A之電源輸出。瓦特數: 19V * 6.32A = 120W（最大值）

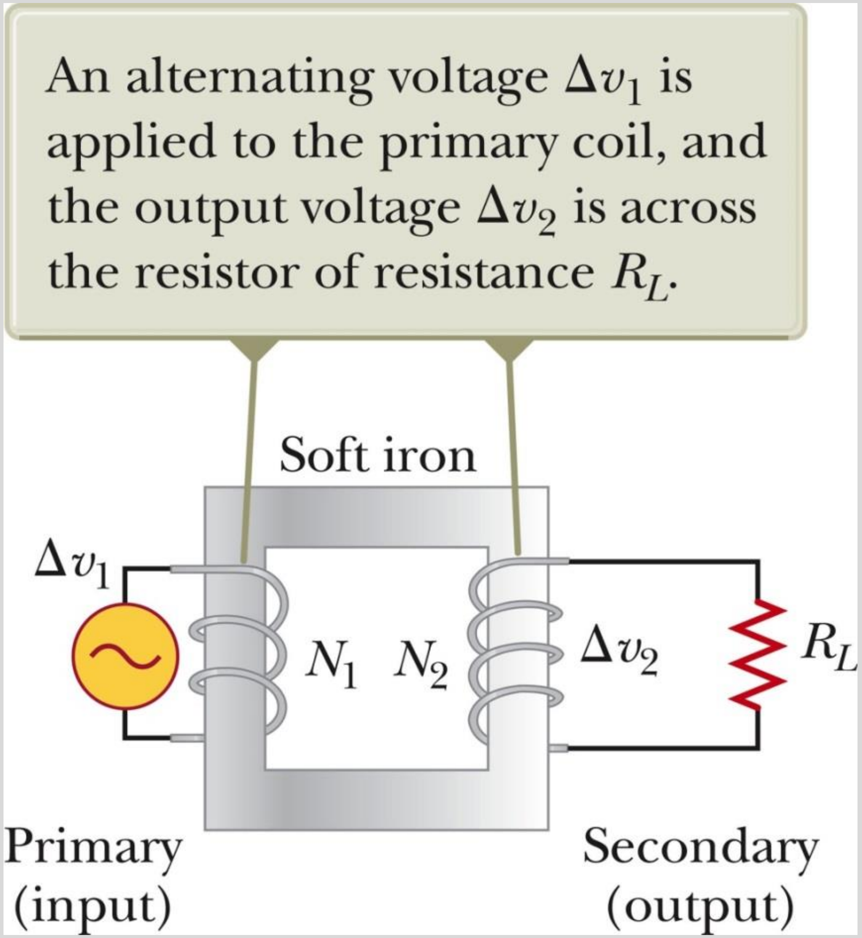
https://www.asus.com/tw/support/faq/1015066/

Rectifier Circuit (整流電路):
交流->直流

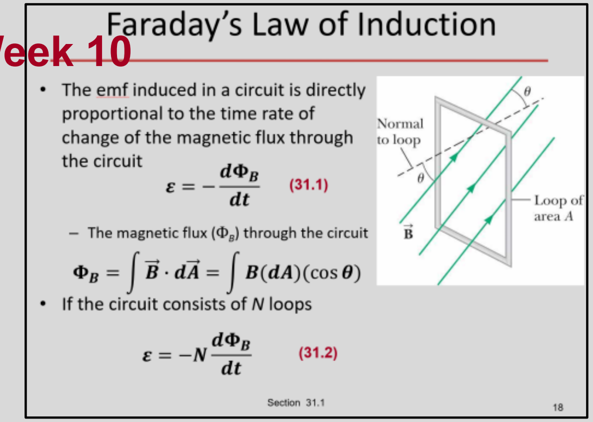
AC Transformers (變壓器)

- Two coils of wire wound around a core
  - *Primary* (N_1 turns): input AC voltage source
  - *Secondary* (N_2 turns): connected to a resistor (R_L)
- The core of iron
  - increase the magnetic flux
  - provide a medium for the flux to pass from one coil to the other

$$\Delta v_1 = -N_1 \frac{d\Phi_B}{dt} \qquad \Delta v_2 = -N_2 \frac{d\Phi_B}{dt}$$



Week 10



Faraday's Law of Induction

- The emf induced in a circuit is directly proportional to the time rate of change of the magnetic flux through the circuit

$$\varepsilon = -\frac{d\Phi_B}{dt} \quad \text{(31.1)}$$

  - The magnetic flux (Φ_B) through the circuit

$$\Phi_B = \int \vec{B} \cdot d\vec{A} = \int B(dA)(\cos\theta)$$

- If the circuit consists of N loops

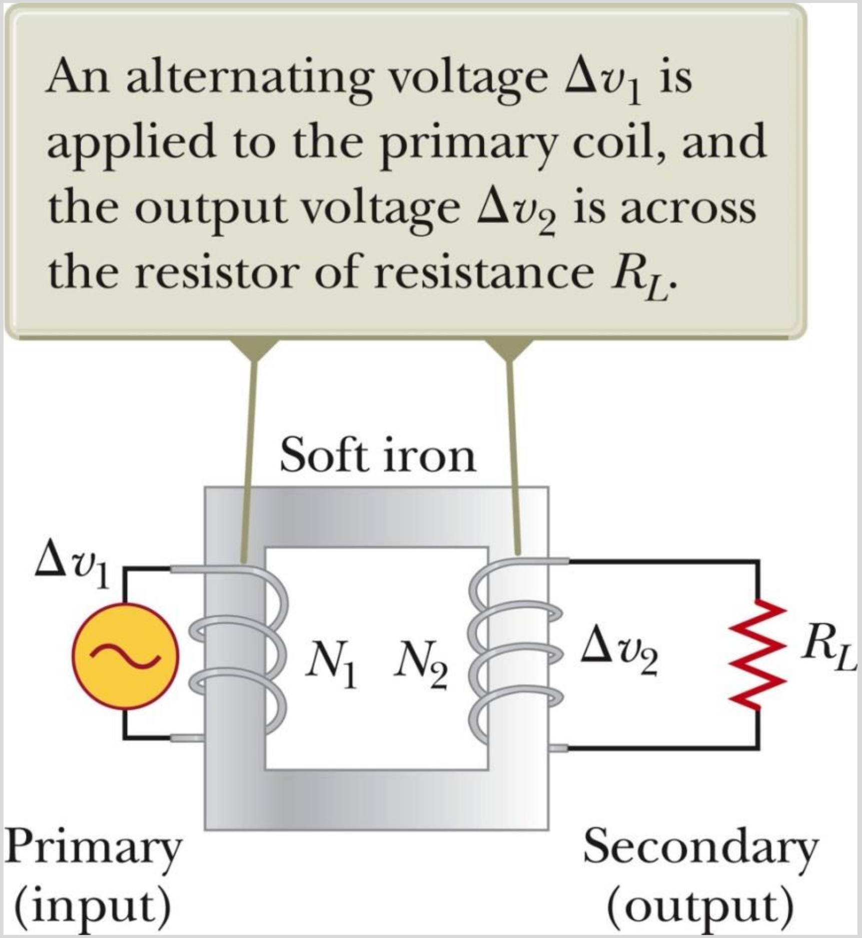
$$\varepsilon = -N\frac{d\Phi_B}{dt} \quad \text{(31.2)}$$

Normal to loop
Loop of area A
$\vec{B}$
θ

Section 31.1 18

AC Transformers (變壓器)

- Two coils of wire wound around a core
  - *Primary* (N_1 turns): input AC voltage source
  - *Secondary* (N_2 turns): connected to a resistor (R_L)
- The core of iron
  - increase the magnetic flux
  - provide a medium for the flux to pass from one coil to the other



$$\Delta v_1 = -N_1 \frac{d\Phi_B}{dt} \qquad \Delta v_2 = -N_2 \frac{d\Phi_B}{dt}$$

$$\Delta v_2 = \frac{N_2}{N_1}\Delta v_1 \qquad \textbf{(33.41)} \qquad \frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1}$$

no losses, the power 1 = power 2

$$P = I_1\Delta V_1 = I_2\Delta V_2$$

$$R_{eq} = \frac{\Delta V_1}{I_1} = \left(\frac{N_1}{N_2}\right)^2\frac{\Delta V_2}{I_2} = \left(\frac{N_1}{N_2}\right)^2 R_L \qquad \textbf{(33.43)}$$

$$\frac{1}{I_1} = \frac{\Delta V_1}{I_2\Delta V_2}$$

$$\frac{\Delta V_1}{I_1} = \frac{\Delta V_1 * \Delta V_1}{I_2\Delta V_2} = \left(\frac{N_1}{N_2}\right)^2(\Delta V_2)^2\frac{1}{I_2\Delta V_2}$$

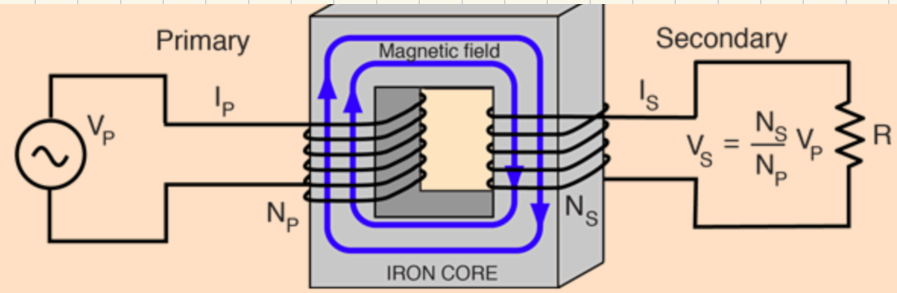
$$\boxed{\frac{N_2}{N_1} = \frac{\Delta V_2}{\Delta V_1} \; \frac{\text{ideal}}{\text{transformer}} \; \frac{I_1}{I_2}}$$

Lenz's Law

no power loss

$$\begin{cases} \Delta V_1 = -N_1 \dfrac{d\Phi_B}{dt} \\ \Delta V_2 = -N_2 \dfrac{d\Phi_B}{dt} \end{cases}$$

$$P = I_1 \Delta V_1 = I_2 \Delta V_2$$

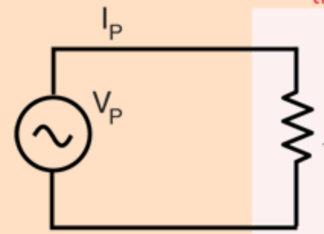


Treating the circuit as if the primary were a simple series resistor R_P, the effective value of that resistor can be calculated from Ohm's law and the transformer relationship.

Ohm's law	Transformer relationship	Power in = power out
$R_P = \dfrac{V_P}{I_P}$	$V_P = V_S \dfrac{N_P}{N_S}$	$I_P = \dfrac{I_S V_S}{V_P}$

$$R_P = \frac{V_S \dfrac{N_P}{N_S}}{\dfrac{I_S V_S}{V_P}} = R\left(\frac{N_P}{N_S}\right)\left(\frac{V_P}{V_S}\right) = R\left(\frac{N_P}{N_S}\right)^2$$

Reflected load for transformer circuit

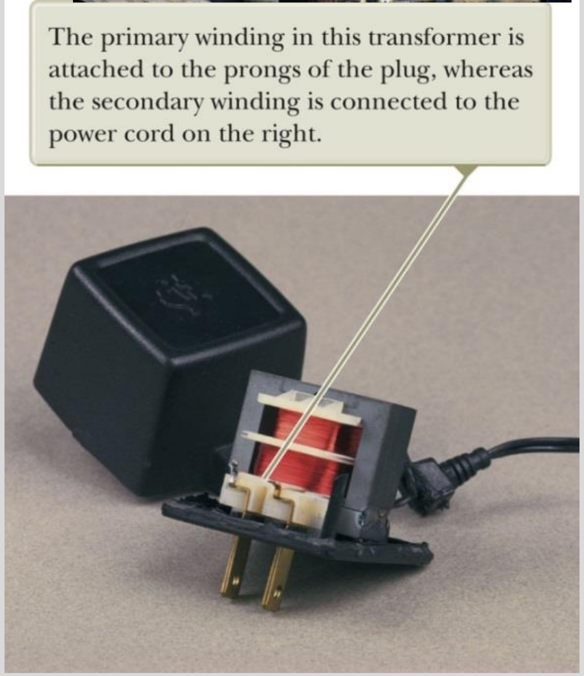


$$R_P = R\left(\frac{N_P}{N_S}\right)^2$$

This "reflected load" approach provides the advantage of treating the circuit as a simple resistor circuit for the calculation of different load conditions.

AC Transformers

- An ideal transformer has zero energy losses
  - Typical transformers have power efficiencies of 90% to 99%
- Applications
  - lower AC voltage for household electronic devices
  - Match resistances between the primary circuit and the load
    - Maximum power transfer can be achieved between a given power source and the load resistance
    - In stereo terminology, this technique is called ***impedance matching***

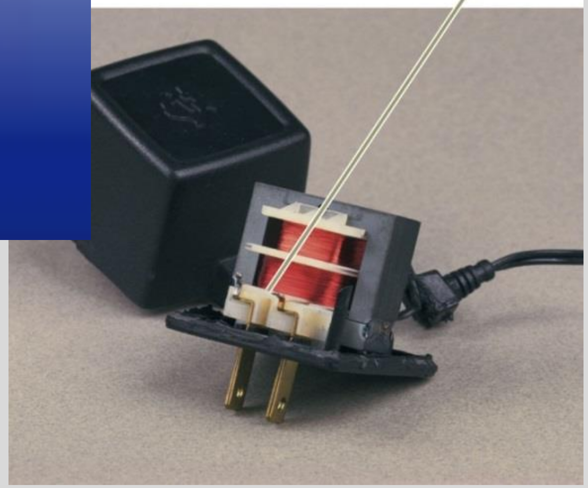


AC Transformers

- An ideal transformer has zero energy losses

impedance matching

e primary winding in this transformer is
ched to the prongs of the plug, whereas
secondary winding is connected to the
ver cord on the right.



https://www.youtube.com/watch?v=8zrobYGsdp4

Section 33.8

AC Transformers

首頁 / BLOG文章

讓光亮到達每個角落── 讀《牽電點燈：逐布踏實的配電大業》

發布日期：2023-12-15

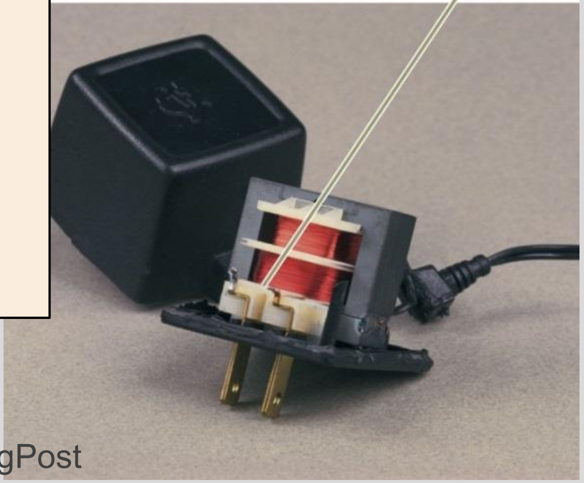
你曾經看過電線桿上的廣告標語嗎？在20世紀後期的臺灣，遍布於電線桿上的廣告，是大街小巷裡的尋常風景。如果追溯到更早的時代，我們會發現日治時期的電線桿廣告，其實需要繳錢才能張貼！及至近代，當電線桿遍布於城市與鄉村之後，電線桿上的廣告已變得不甚稀奇，也難於逐一管理。大概因為這些原因，就形成了電線桿上隨意張貼廣告的亂像吧。

電線桿、變電箱等等設備，對於民生用電的供輸扮演著不可或缺的角色。不過，人們對於這些設備卻經常帶著嫌惡的目光。特別在早年的臺灣，當架空線路仍舊佔據大街小巷的時候，電線桿上的變壓器與民宅的距離通常十分靠近。而由於這些變壓器經常因為跳電故障而發出轟然巨響，經常引起民眾恐慌。久而久之，變成了所謂的「鄰避設施」。

實際上，變壓器的爆響只是保險絲燒掉的安全機制，如果深入了解其中原理，便會發現配電設備其實相當安全。不過，隨著時間演進，台電也有許多創新作為，解決了上述問題。譬如線路的地下化、變點所改採屋內型等等。時至今日，臺灣的主要城市裡已很難看到電線漫天交錯、雜亂無章的景象，變電箱的爆響也不在那麼頻繁聽見。所有這些現象，其實代表了我們對於配電設備的感知越來越少，甚至遺忘它們的存在。

被暱稱為「菜瓜棚」的開閉場，也是早期常見的配電設備之一。（圖像來源：台灣電力公司）

The primary winding in this transformer is attached to the prongs of the plug, whereas the secondary winding is connected to the power cord on the right.



https://service.taipower.com.tw/Collection/2009/2025/7733/blogPost

Section 33.8

AC Transformers

變電箱又爆炸了？其實是保險絲燒掉啦！

「砰！台電的變壓器又爆炸了！」我們總是在媒體報導上看到這種聳動的標題。事實上，「變壓器」不會爆炸。變壓器裡面主要架構其實只有鐵心、銅線及絕緣油。

關於「砰」的「爆炸」聲為什麼會出現呢？我們可以用家中電箱裡的保險絲來理解。如果我們一時疏忽，讓家裡用電量較大的電器同時啟動—譬如烤箱、微波爐及冷氣等，結果會發生什麼事呢？就是跳電，保險絲燒掉了。保險絲燒掉的時候，會發出很大的聲響，或許還會伴隨火花。

同樣的，當一個區域用電負載大於變壓器時，變壓器為了防止損壞，它的保險絲也會燒掉；因為它的保險絲絕對比家裡的大支，如果是位於電線桿上，又在空曠的地方，它發出「砰」的聲音會顯得更為巨大，伴隨的火花也非常閃亮，大家才會說「爆炸」。其實這表示保護機制發揮作用，對大家來說不全然是壞事，因為更提醒台電公司必須重新檢視區域用電負載，加強宣導節約用電的重要性。

台電公司為了確保變壓器正常運作，變壓器內灌滿了絕緣油。絕緣油具有高功率電阻、高閃火點、蒸發耗損率低等特性，能夠保護變壓器內的線路，也具有降溫散熱的功能。

由於變壓器位於戶外，無法完全隔離動植物的生長與活動，往往「燒掉」是因為火花波及纏繞的藤蔓，或周遭樹木繁茂的枝葉，植物一旦燒起來，變壓器外殼的油漆也會燒起來，但是內部並不會受到影響。

針對春風吹又生，生長速度奇快的藤蔓，台電公司每3 個月就得派員除一次變壓器上的藤蔓，但由於全臺的電桿數量非常龐大，往往這裡的還沒有除完，那裡的已經又長得很茂盛了。而周遭的大樹自然也不可以隨便砍除，只能儘量剪除會造成安全疑慮的枝葉。

再加上，臺灣四面環海，在西南沿海等海風侵襲鹽塵害嚴重的地區，桿上設備為了要避免絕緣間距不足，都會把設備間距加長，但即使加長後，時間一久，也容易出現設備損壞，或設備之間距離因鹽害縮小，產生嘶嘶嘶的聲音，因此，桿上設備清洗也成為重要的維護工作之一。

此外，由於民眾常將窗戶加設鐵窗，或商店裝設廣告招牌，為避免在吊裝施工時，不慎碰觸到供電線路而感電，或外物碰觸導致停電，甚至衍生更嚴重的事故，台電公司從1993 年起，實施高壓架空裸線改善計畫，將鄰近房屋的高壓架空裸線架高，或進行絕緣被覆—就是使用絕緣材質把裸露線路包覆起來，以降低感電事件發生的可能。慢慢的，裸露設備愈來愈少，民眾感電事故由1992 年時的108 件，到2016 年已大幅降低為11 件，2018 年降低為4 件，有效將民眾感電傷亡事故降到最低。近年來雖偶有碰觸到線路而遭到感電的實例發生，但大多都是偷電纜的或是偷鳥集團不慎碰觸所造成，民眾感電案已大幅降低。

電業文物典藏

'n ... his technique is called

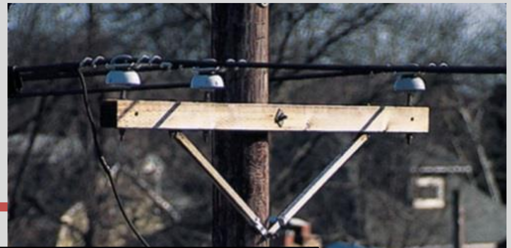
m

在電線桿上辛勤工作的台電人員。（圖像來源：行政院經濟部網站）

https://service.taipower.com.tw/Collection/2009/2025/7733/blogPost

Section 33.8

AC Transformers



Texas Instruments

Search

Login / Register English Ship to USD

產品 應用領域 設計與開發 品質與可靠性 訂購資源 關於 TI

首頁 / 產品 / 音訊 / 音訊放大器

https://www.ti.com/zh-tw/audio-ic/amplifiers/overview.html

音訊放大器

放大您的音訊系統

檢視所有產品

從毫瓦到千瓦、類比到數位，還有中間所有產品，我們的音訊放大器產品組合都可幫助您強化音訊解決方案。我們提供使用簡單的高性能音訊放大器機體電路，包括數位和類比輸入 D 類揚聲器放大器、智慧型放大器、整合式耳機放大器、音頻訊算放大器和線路驅動器/接收器，提供各種輸出功率與性能以滿足您的設計需求。

張忠謀

https://zh.wikipedia.org/zh-tw/%E5%BC%B5%E5%BF%A0%E8%AC%80

- es
- f
-

 – Match resistances between the primary circuit and the load
    - Maximum power transfer can be achieved between given power source and the load resistance
    - In stereo terminology, this technique is called ***impedance matching***

職業經歷 [編輯]

1955年，張忠謀因兩次未能通過麻省理工學院的博士學位資格考試，決定嘗試進入職場。其在自傳中將落選博士的經歷「視為一生的最大幸運」。初期曾考慮到福特汽車的底特律研發中心工作，因福特汽車給的薪資待遇比希凡尼亞公司（Sylvania Electric Products）的半導體部門少了一美元的月薪，所以選擇進入希凡尼亞公司工作，從此踏入半導體產業。1958年到德州儀器事業部工作，三年後成為工程部經理。1962年入籍美國，1964年獲得美國史丹佛大學電機工程學系博士學位。

1968年，張忠謀與德州儀器執行長雪普德赴台商討德州儀器在台灣設廠案，與李國鼎首次見面。[8][9]

1972年，升任德州儀器集團副總經理。[9]1981年，張忠謀受邀來台建言，與孫運璿見 … 剛成立的新竹科學園區參訪，孫運璿邀請張忠謀出任工研院院長一 … [10][9]1983年，離開德州儀器，改入通用儀器公司擔任營運長。

阻抗匹配 [編輯]

文A 22 種語言

條目 討論 汉 漢 臺灣正體 閱讀 編輯 檢視歷史 工具

https://zh.wikipedia.org/zh-tw/%E9%98%BB%E6%8A%97%E5%8C%B9%E9%85%8D

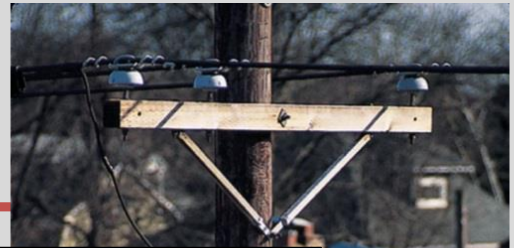
維基百科，自由的百科全書

阻抗匹配（Impedance matching）是微波電子學裡的一部分，主要用於傳輸線上，來達至所有高頻的微波信號皆能傳至負載點的目的，幾乎不會有信號反射回來源點，從而起到保證設備正常工作、提升能源效益、避免訊號失真、增強信噪比等作用。

大體上，阻抗匹配有兩種，一種是通過改變阻抗（用於集總參數電路），另一種則是調整傳輸線的波長（用於傳輸線）。

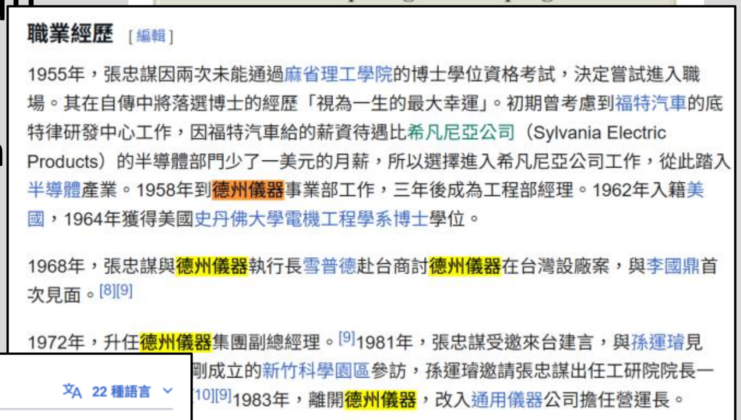
要匹配一組線路，首先把負載點的阻抗值，除以傳輸線的特性阻抗值來歸一化，然後把數值劃在史密斯圖上。

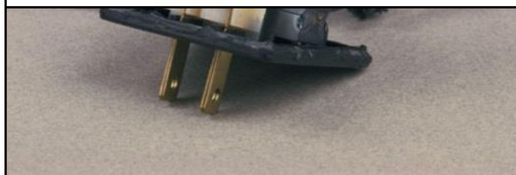
AC Transformers



- ...es
  ...f
-

  – Match resistances between the primary circuit and the load
    - Maximum power transfer can be achieved between given power source and the load resistance
    - In stereo terminology, this technique is called ***impedance matching***





Example 33.7

- An electricity-generating station needs to deliver energy at a rate of 20 MW to a city 1.0 km away. A common voltage for commercial power generators is 22 kV, but a step up transformer is used to boost the voltage to 230 kV before transmission. P_{avg}
- **(A)** If the resistance of the wires is 2.0 Ω and the energy costs are about 0.11 \$/kWh, estimate the cost of the energy converted to internal energy in the wires during one day.

ΔV_{rms} R

energy cost

Δt

- **Solution:**

$$I_{\text{rms}} = \frac{P_{\text{avg}}}{\Delta V_{\text{rms}}} = \frac{20\times10^{6}\ \text{W}}{230\times10^{3}\ \text{V}} = 87\text{A}$$

$$P_{\text{wires}} = I_{\text{rms}}^{2} R = (87\text{A})^{2}(2.0\Omega) = 15\ \text{kW}$$

total energy transferred

$$T_{\text{ET}} = P_{\text{wires}}\Delta t = (15\text{kW})(24\text{h}) = 363\ \text{kWh}$$

$$\text{Cost} = (363\ \text{kWh})(\$0.11/\text{kWh}) = \$40$$

Cont. 33.7

- **(B)** Repeat the calculation for the situation in which the Power plant delivers the energy at its original voltage of 22 kV.
- **Solution:**

$$I_{\text{rms}} = \frac{P_{\text{avg}}}{\Delta V_{\text{rms}}} = \frac{20\times10^6\,\text{W}}{22\times10^3\,\text{V}} = 909\ \text{A}$$

$$P_{\text{wires}} = I_{\text{rms}}^2 R = (909\text{A})^2(2.0\Omega) = 1.7\times10^3\ \text{kW}$$

$$T_{\text{ET}} = P_{\text{wires}}\Delta t = (1.7\times10^3\ \text{kW})(24\,\text{h}) = 4.0\times10^4\ \text{kWh}$$

$$\text{Cost} = (4.0\times10^4\ \text{kWh})(\$0.11\,/\text{kWh}) = \$4.4\times10^3$$

(110 times the cost)

台灣電力公司兒童網

電怎麼到我家

電從哪裡來　輸電線路　變電所

為什麼家裡會有電呢？

小朋友們會不會好奇家裡面的電是怎麼來的呢?

馬路上常常出現畫了很多圖案的大箱子是什麼?遠遠的地方有一座又一座的高塔又是什麼呢?這些都是為了要將電能夠送到每一個人的家中所建置的設備！

發電廠都設在比較偏遠的地區，遠離用電多的地方，為了提高輸電能力並減少損失，發電廠所產生的電力須先提高電壓，然後藉助輸變電系統轉變電壓、傳輸電力，供給用戶使用。

發電廠的發電機產生的電壓僅有11,000到22,000伏特，必須先把電壓升高，然後經由超高電壓輸送電線送至都市、工業區等附近的變電所，使電壓降至11,000或22,000伏特，最後傳送到市內的亭置式、地面式變壓器或電線桿上的變壓器，再將電壓降至110或220伏特後，接至家庭內使用。

為何發電廠電力輸送必須使用高電壓傳送？

發電廠產生的電如何經由電線輸送到各地呢？由於電線有電阻，電流的熱效應會使電線本身發熱，造成部分電能的損失。通過的電流愈大，損失的能量就愈多。

為了減少在線路上電能的損失，在電力輸送過程中盡可能降低流經導線的電流。如果電功率維持定值，則提升電壓可使傳送的電流減小，故電力輸送一般都使用高電壓來傳送。

https://www.taipower.com.tw/1136/1146/2268/3101/normalPost

台灣電力公司兒童網

電怎麼到我家

電從哪裡來 輸電線路 變電所

輸電線路

從工廠生產的產品，必須透過物流的方式將產品送到各個經銷據點販售，輸電線路就扮演著運送跟傳輸角色，把電從發電廠送到家裡。

輸送電力的電線依照電壓的不同可以分為34萬5千伏特輸電線、16萬1千伏特輸電線、6萬9千伏特輸電線、2萬2千伏特配電線以及1萬1千伏特配電線。

任何導線，有電流通過，都會產生磁場，包括我們家裏的電線、電器或輸電線路都一樣有磁場，只是電流小或距離遠，磁場強度會相對減低。 高壓輸電線均以三相方式輸送，產生的磁場會相互抵消，在地面所能感受的磁場強度甚低，不但在安全值以內，對人體健康而言，依各方專家的報告，絕大部份認為沒有影響。

小朋友，快來認識「變電所」吧！

變電所是電力轉換站，用以提高或降低電壓，並分配用電量。從發電廠送電到用戶家中的過程中，變電所扮演的角色，可比喻為高速公路的交流道。車輛在上高速公路前須在交流道先行加速；同理，電廠發出的電要先經過變電所昇高電壓才可大量快速的輸送。車輛要進入市區，必須下交流道減速慢行，再駛向大街小巷，同樣的，高壓電須經過變電所降低電壓才可依序分送各地，並逐段降低到用戶可使用的電壓。

像交流道或車站若離市區太遠，就失去設站的意義一般。為維持供電品質，避免用戶有電壓下降問題，變電所應儘量設在負載中心，也就是說，變電所要儘可能靠近用電多的地方，變電所若遠離負載中心，不僅送電損失大，而且用戶電壓降低，頻率不穩定，會影響用電品質。

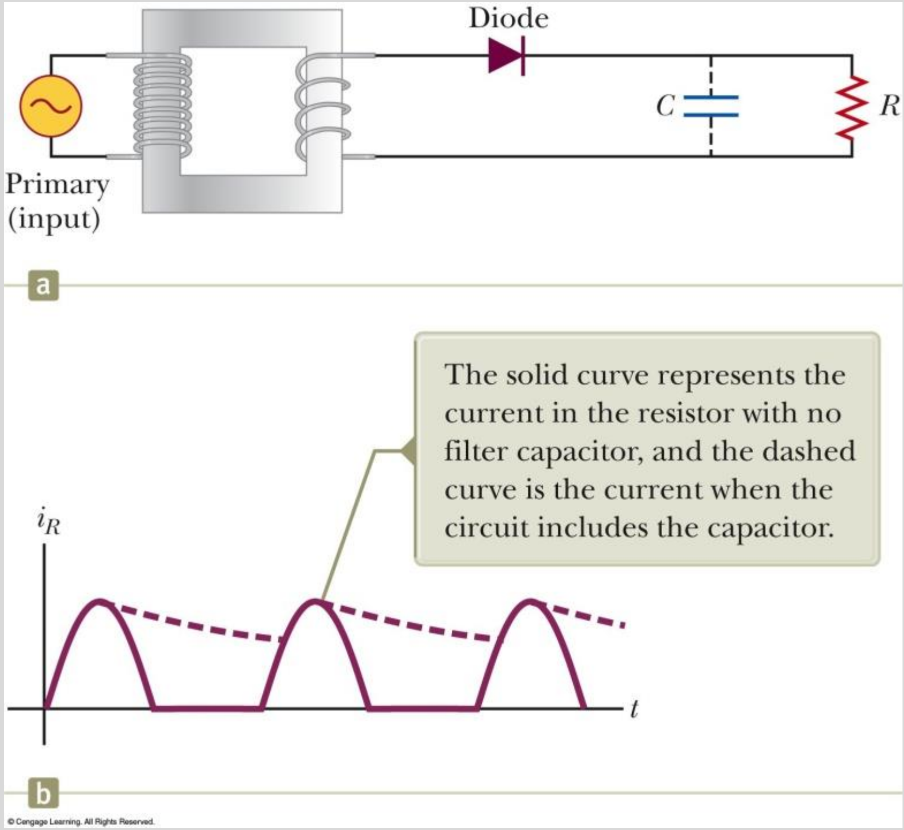
變電所可分為屋外式變電所或屋內式變電所，變電所產生的磁場強度遠低於一般家庭常用的電器設備或用品使用時所產生的磁力線，對人體健康而言，依各方專家的報告，絕大部份認為沒有影響的喔！

小朋友，現在對變電所有更了解一點了嗎？

https://www.taipower.com.tw/1136/1146/2268/3101/normalPost

Rectifier Circuit (整流電路)

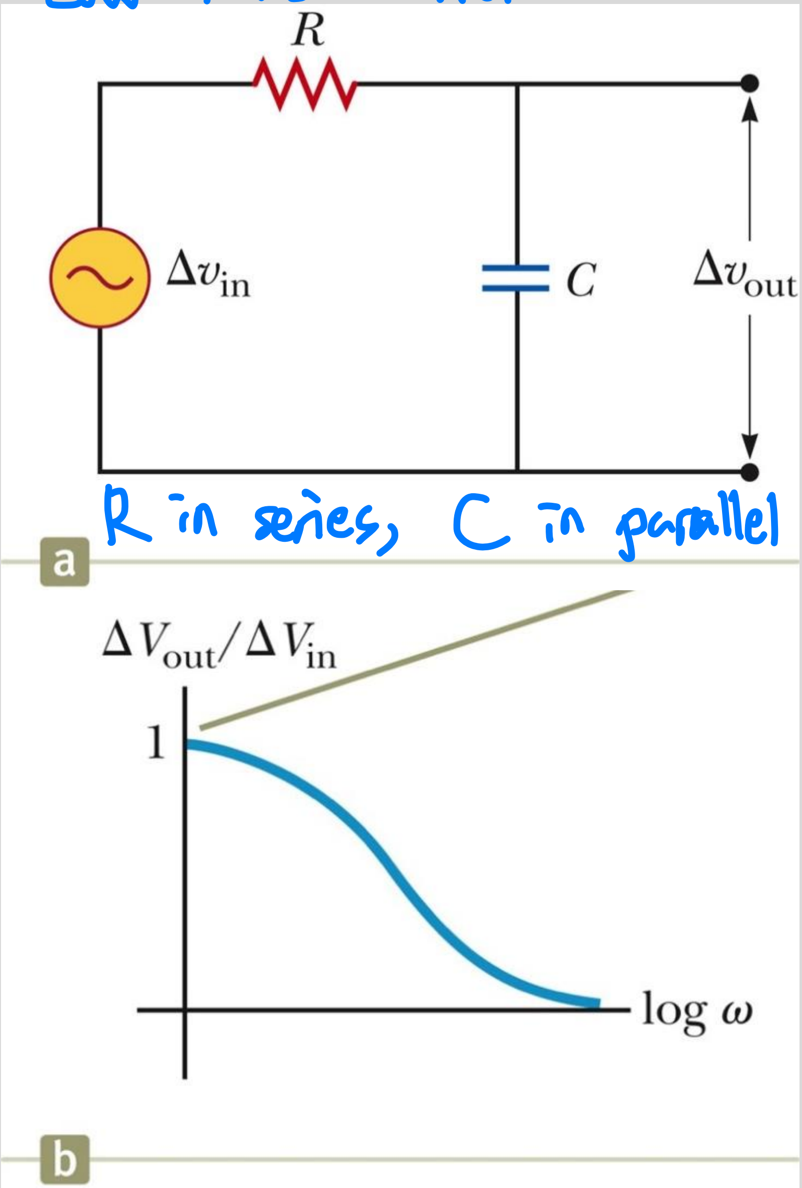
- Converting AC to DC
  - **Diode (二極體) :** A circuit element that conducts current in one direction but not the other
  - The diode makes the alternating current to the positive portion of the cycle (solid line)
  - The capacitor causes a simple DC power supply (Dash line)
- The transformer reduces the 120 V power line to typically 6 V or 9 V (for device)



Filter Circuit

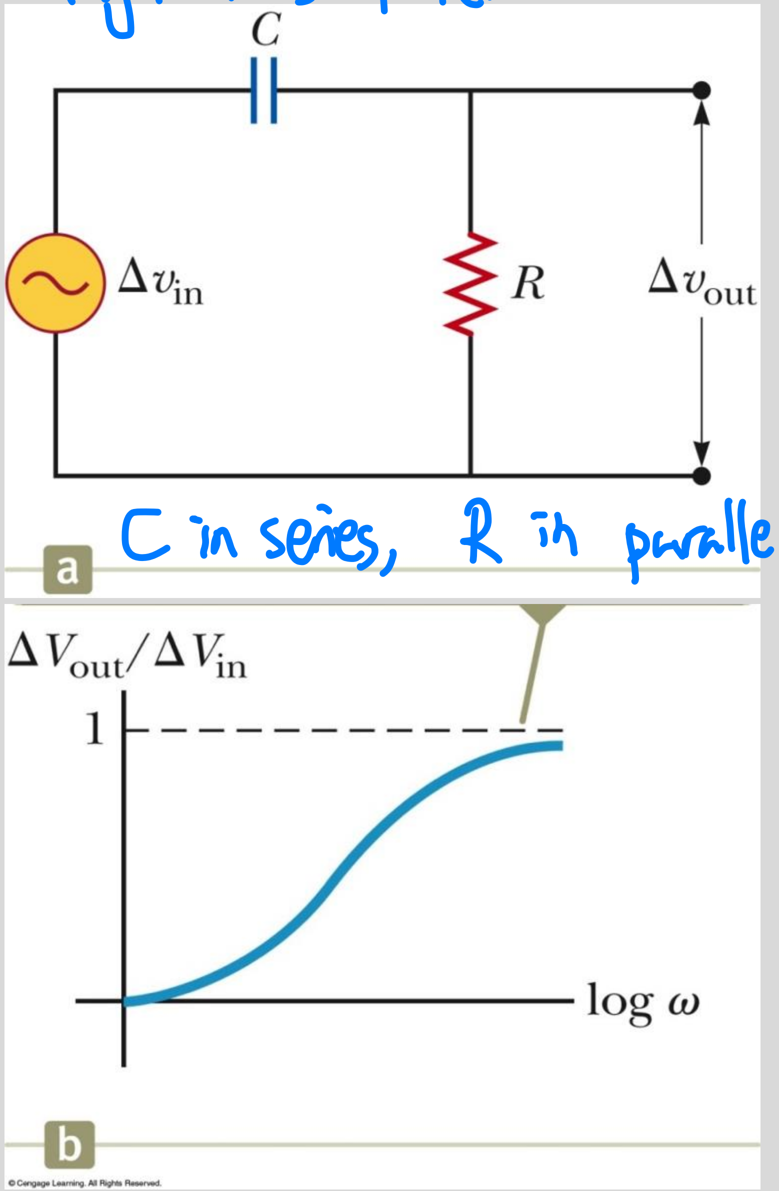
$x_c = \frac{1}{\omega C}$

Low-Pass Filter



R in series, C in parallel

High-Pass Filter



C in series, R in parallel

🔷 LOW-PASS FILTER (left side)

⚙️ Circuit:

Input → Resistor R → Output across Capacitor C

📊 Behavior:

At low frequency:

- Capacitor reactance $X_C = \frac{1}{\omega C}$ is **very large**.
- So, **capacitor acts like an open circuit** → voltage **drops across the capacitor**.
- $\Rightarrow V_{\text{out}} \approx V_{\text{in}}$

At high frequency:

- X_C becomes **very small** → capacitor behaves like a **short circuit**.
- Most voltage drops across R, **not** across the capacitor.
- $\Rightarrow V_{\text{out}} \approx 0$

✅ **Conclusion**: Low frequencies pass; high frequencies get blocked at the output.

🔷 HIGH-PASS FILTER (right side)

⚙️ Circuit:

Input → Capacitor C → Output across Resistor R

📊 Behavior:

At low frequency:

- X_C is large → capacitor resists current.
- Almost **no current flows** through the resistor → $V_{\text{out}} \approx 0$

At high frequency:

- X_C is small → capacitor lets current pass easily.
- Voltage drops across the resistor → $V_{\text{out}} \approx V_{\text{in}}$

✅ **Conclusion**: High frequencies pass; low frequencies get blocked.

Summary

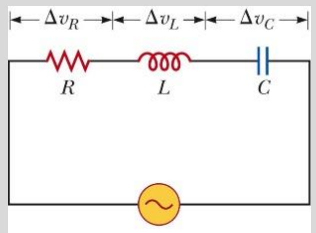
- AC circuit analysis
  - Signal as sum of sinusoids
  - Signal (a sinusoid function): $v(t) = V_{max}\sin(wt + \varphi)$
  - Phasor (a vector): $V = V_{max}\angle\varphi$
  - Phasor in complex exponential (a complex number):

$$\boldsymbol{V_{max}e^{i\varphi} = (V_{max}\cos\varphi) + i(\,V_{max}\sin\varphi)}$$

- Impedance, **Z=V/I** (a complex number)
  - Resistor : $Z_R = R$
  - Inductor: $Z_L = iX_L = = X_L\angle 90^\circ = wL\angle 90^\circ$
  - Capacitor : $Z_C = -\,iX_C = X_C(0-i) = \frac{1}{wC}\angle -90^\circ$
- Power : $\boldsymbol{P_{avg}} = \frac{1}{2} I_{max} V_{max} \cos\phi = \boldsymbol{I_{rms}V_{rms}\cos\phi}$

This Lecture

- Alternating-Current Circuits
  - Sinusoids
- ✓ Resistors in an AC Circuit
- ∘ Phasor Diagram
- ✓ Inductors in an AC Circuit
- ✓ Capacitors in an AC Circuit
- The RLC Series Circuit
  - Impedance, Z (阻抗)
- Power in an AC Circuit
- Resonance in a Series RLC Circuit



Announcement

- Homework W12 has been assigned on Moodle.
  - One-week submission: 100% credit.
  - Afterwards: 70% credit.