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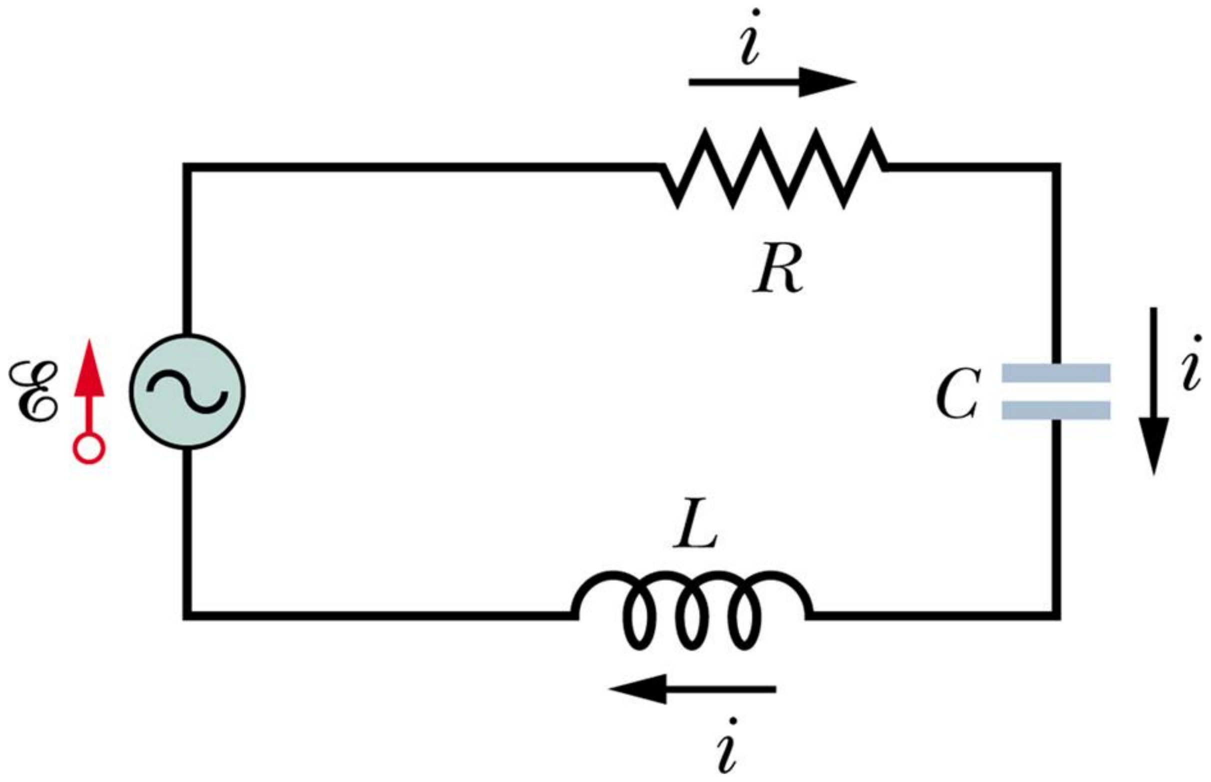
  1. University Physics, Bauer and Westfall, McGraw-Hill, 2011.
  2. Principles of Physics, Halliday, Resnick, and Walker, Wiley, 8th and 9th Ed.
- The rest is made by me.

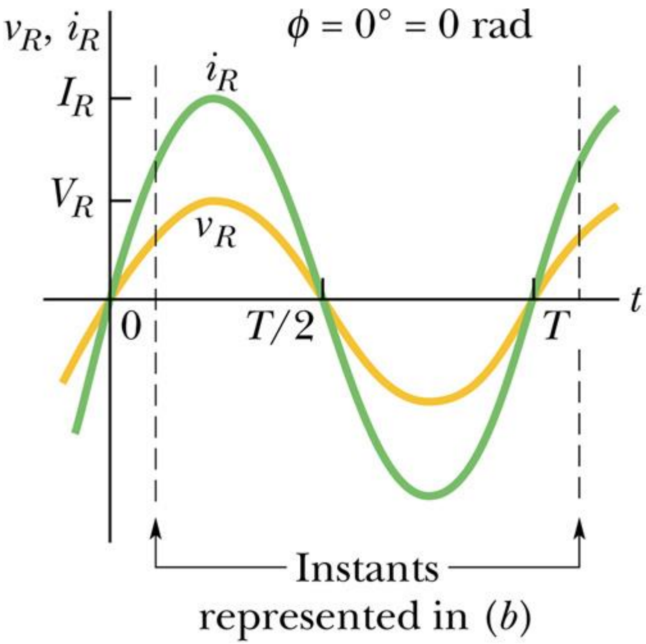
RLC circuits



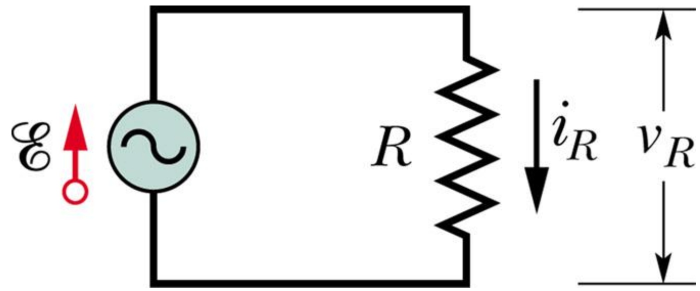
$$\mathcal{E} = \mathcal{E}_m \sin \omega_d t \qquad i = I \sin(\omega_d t - \phi)$$

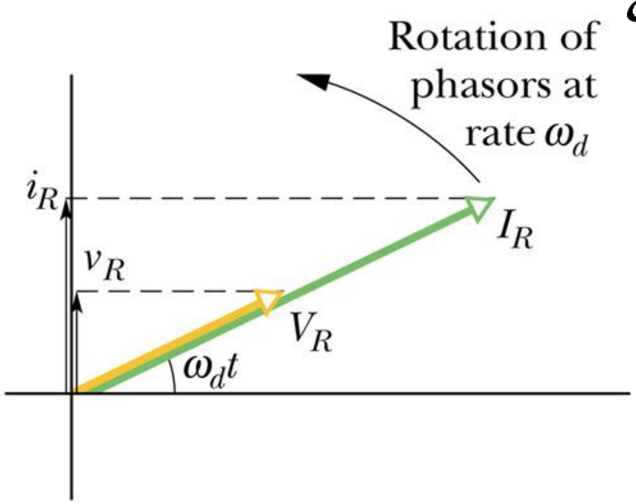
I와 ϕ구하기

Circuit with R



(a)





(b)

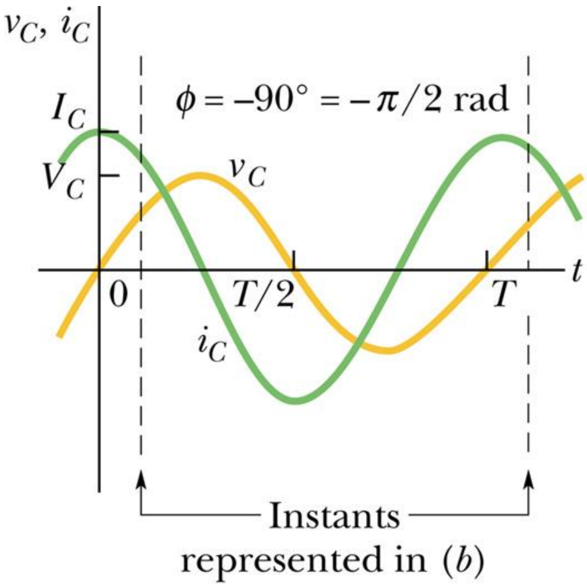
$$\mathcal{E} - v_R = 0 \longrightarrow v_R = \mathcal{E}_m \sin \omega_d t = V_R \sin \omega_d t$$

$$i_R = \frac{v_R}{R} = \frac{V_R}{R} \sin \omega_d t \to \phi = 0$$

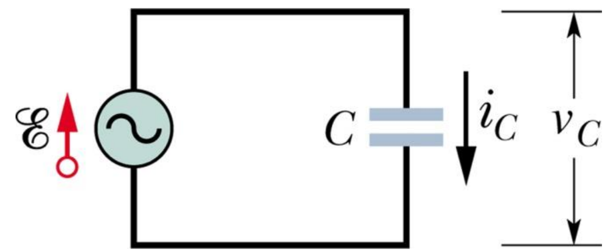
$$i_R = I_R \sin(\omega_d t - \phi)$$

$$V_R = I_R R$$

Circuit with C



(a)



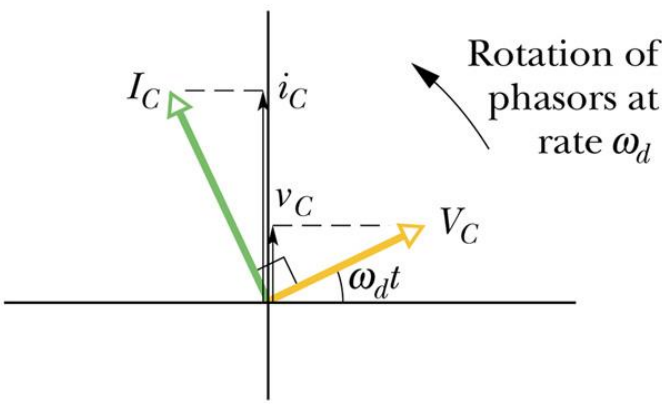
$$v_C = V_C \sin\omega_d t$$

$$q_C = C v_C = C V_C \sin\omega_d t$$

$$i_C = \frac{dq_C}{dt} = \omega_d \cos\omega_d t$$

축전기형 저항 (capacitive resistance)

$$X_C = \frac{1}{\omega_d C}$$

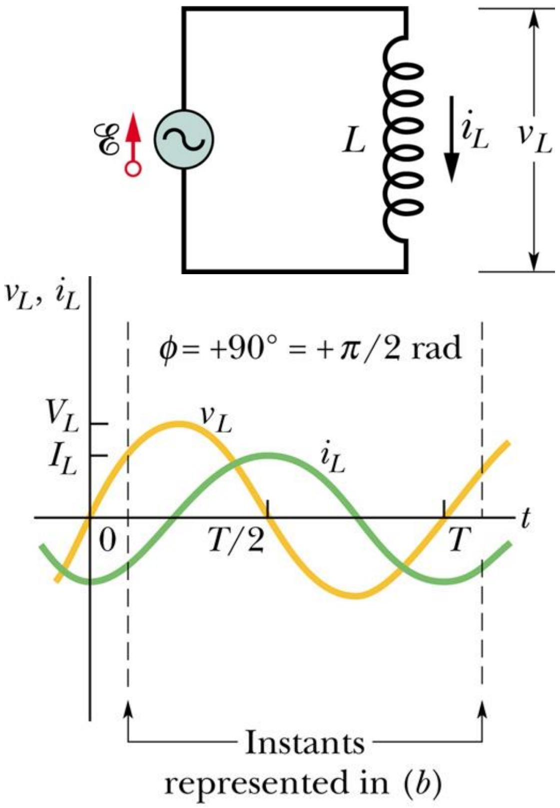


(b)

$$\cos\omega_d t = \sin(\omega_d t + 90°)$$

$$i_C = \frac{V_C}{X_C}\sin(\omega_d t + 90°) = I_C \sin(\omega_d t - \phi) \longrightarrow \phi = -\frac{\pi}{2}$$

$$V_C = I_C X_C$$



(a)

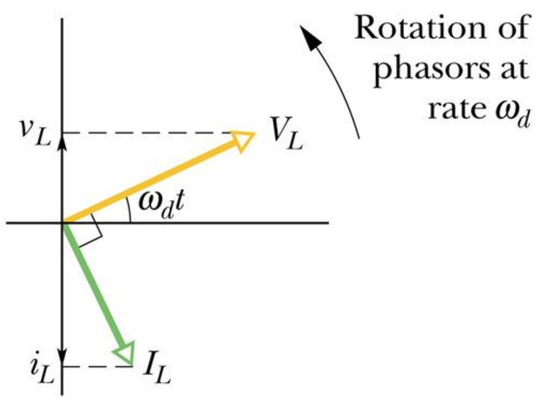
Circuit with L

$$v_L = V_L \sin\omega_d t = L\frac{di_L}{dt}$$

$$i_L = \int di_L = \frac{V_L}{L}\int \sin\omega_d t\,dt = -\frac{V_L}{\omega_d L}\cos\omega_d t$$

유도형 저항 (inductive resistance)

$$X_L = \omega_d L$$



(b)

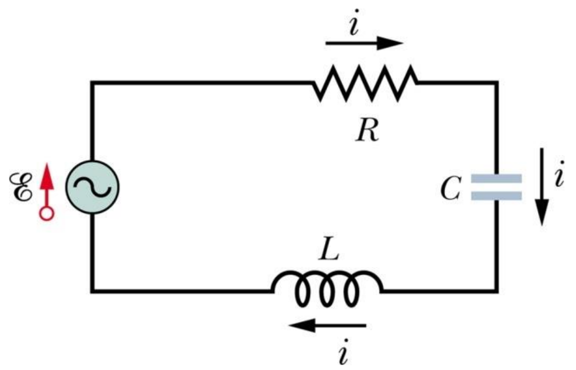
$$-\cos\omega_d t = \sin(\omega_d t - 90°)$$

$$i_L = \frac{V_L}{X_L}\sin(\omega_d t - 90°) = I_L \sin(\omega_d t - \phi) \longrightarrow \phi = \frac{\pi}{2}$$

$$V_L = I_L X_L$$

RLC 회로

$$\mathcal{E} = \mathcal{E}_m \sin \omega_d t,$$
$$i = I \sin(\omega_d t - \phi).$$

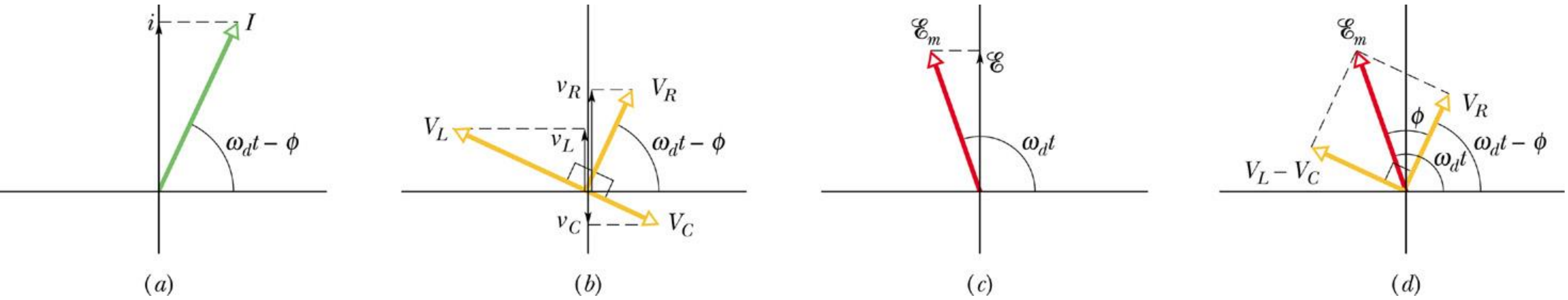


- 저항: 전류는 퍼텐셜과 같은 위상.
- 축전기: 전류가 90도 빠름.
- 인덕터: 전류가 90도 느림.

$$\mathcal{E}_m^2 = V_R^2 + (V_L - V_C)^2 = (IR)^2 + (IX_L - IX_C)^2$$

$$I = \frac{\mathcal{E}_m}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{\mathcal{E}_m}{Z}$$
$$= \frac{\mathcal{E}_m}{\sqrt{R^2 + \left(\omega_d L - 1/(\omega_d C)\right)^2}}$$

Series RLC circuit



$$\mathcal{E} = \mathcal{E}_m \sin \omega_d t, \;\; i = I \sin(\omega_d t - \phi)$$

$$\mathcal{E} = v_R + v_C + v_L$$

$$\mathcal{E}_m^2 = V_R^2 + (V_L - V_C)^2 = (IR)^2 + (IX_L - IX_C)^2$$

$$I = \frac{\mathcal{E}_m}{\sqrt{R^2 + (X_L - X_C)^2}}$$

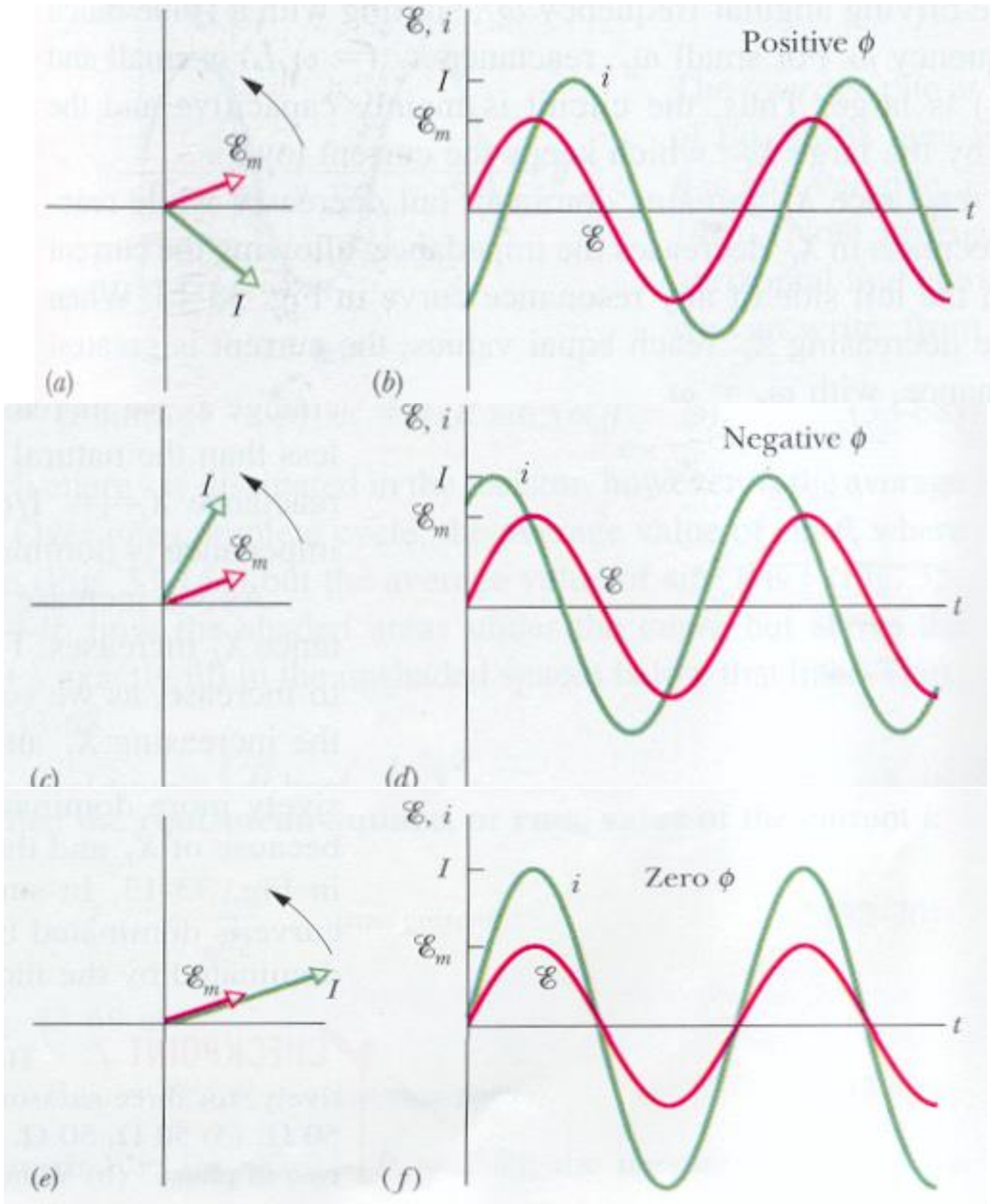
impedance

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

$$I = \frac{\mathcal{E}_m}{Z} = \frac{\mathcal{E}_m}{\sqrt{R^2 + (\omega_d L - 1/\omega_d C)^2}}$$

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

Phase constants and resonance



$$X_L > X_C$$

$$X_L < X_C$$

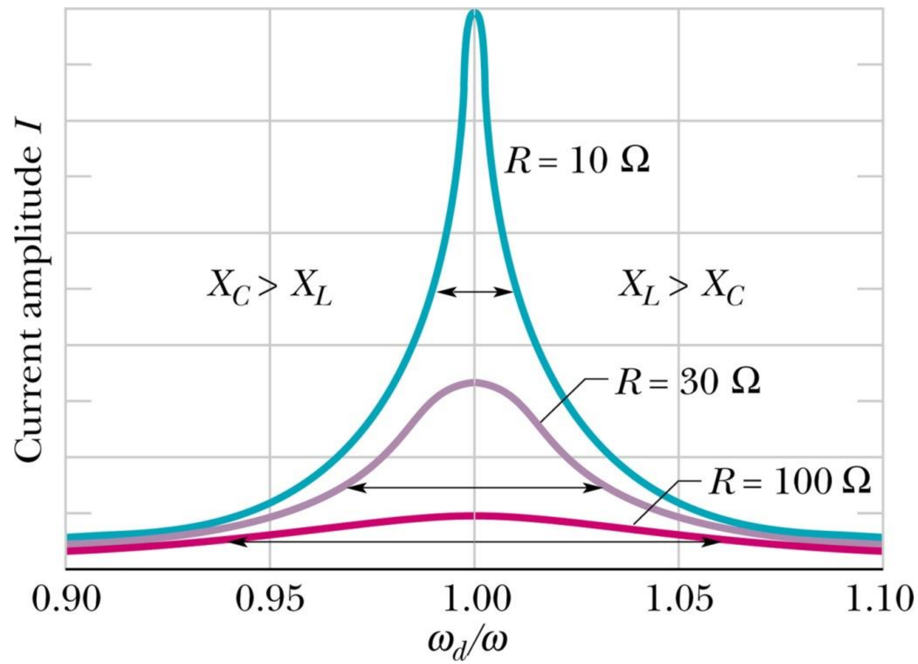
$$X_L = X_C$$

phase

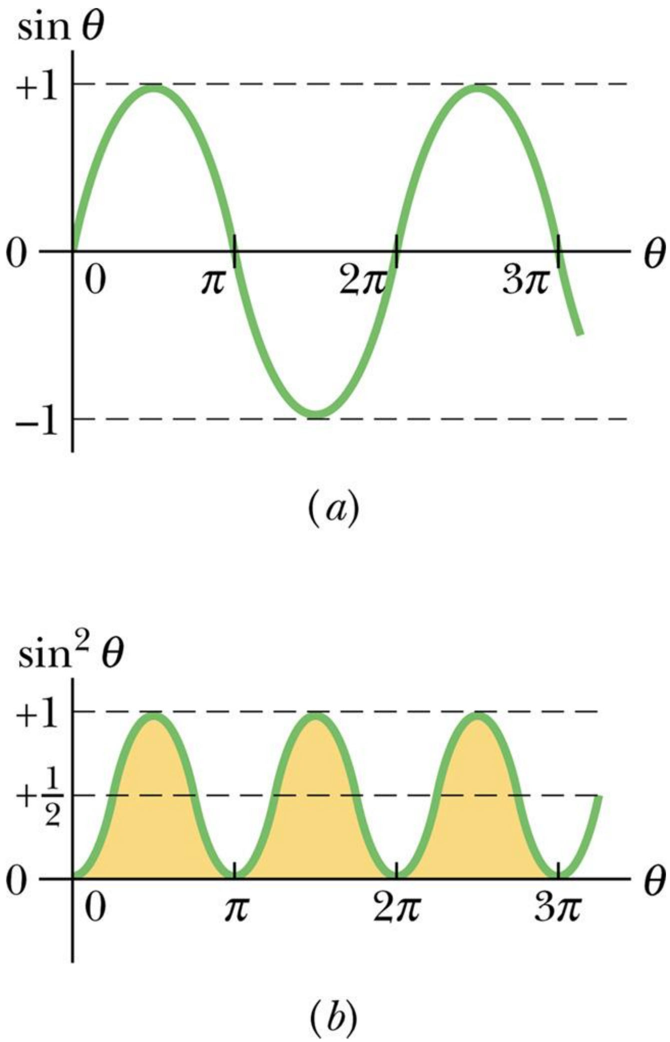
$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{IX_C - IX_L}{IR} = \frac{X_L - X_C}{R}.$$

공명현상 (resonance)
흐르는 전류가 최대일 조건

$$\omega_d = \omega = \frac{1}{\sqrt{LC}}$$



Power in AC circuits



$$P = i^2 R = I^2 R \sin^2(\omega_d t - \phi)$$

$$P_{\text{av}} = \frac{I^2 R}{2} = \left(\frac{I}{\sqrt{2}}\right)^2 R = I_{\text{rms}}^2 R$$

$$I_{\text{rms}} = \frac{I}{\sqrt{2}}, \quad V_{\text{rms}} = \frac{V}{\sqrt{2}}, \quad \mathcal{E}_{\text{rms}} = \frac{\mathcal{E}_m}{\sqrt{2}}$$

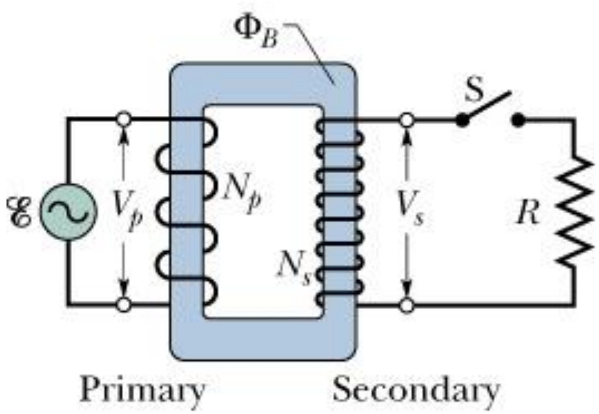
$$I_{\text{rms}} = \frac{\mathcal{E}_{\text{rms}}}{\sqrt{2}} = \frac{\mathcal{E}_{\text{rms}}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$P_{\text{av}} = \frac{\mathcal{E}_{\text{rms}}}{Z} I_{\text{rms}} \frac{R}{Z}$$

$$\cos\phi = \frac{V_R}{\mathcal{E}_m} = \frac{IR}{IZ} = \frac{R}{Z}$$

$$P_{\text{av}} = \mathcal{E}_{\text{rms}} I_{\text{rms}} \cos\phi$$

Transformer



$$\mathcal{E} = \mathcal{E}_m \sin \omega t$$

$$\mathcal{E}_{\text{turn}} = \frac{d\phi_B}{dt}$$

$$V_p = N_P \mathcal{E}_{\text{turn}}$$

$$V_s = N_s \mathcal{E}_{\text{turn}}$$

$$\mathcal{E}_{\text{turn}} = \frac{V_p}{N_p} = \frac{V_s}{N_s}$$

$$V_s = V_p \frac{N_s}{N_p}$$

회로에 연결된 경우

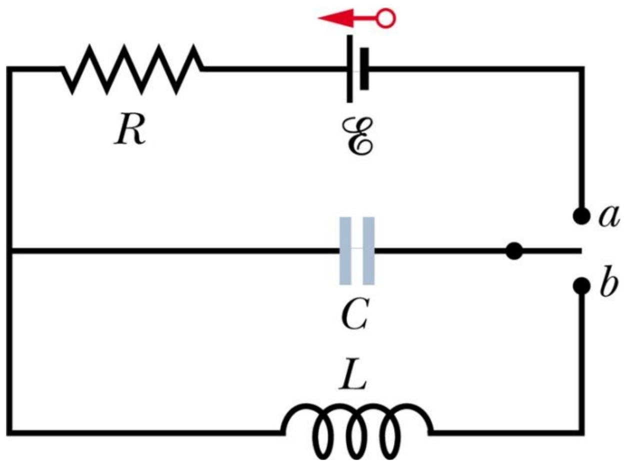
$$I_p V_p = I_s V_s$$

$$I_s = I_p \frac{N_p}{N_s} = \frac{V_s}{R} = V_p \frac{N_s}{N_p} \frac{1}{R}$$

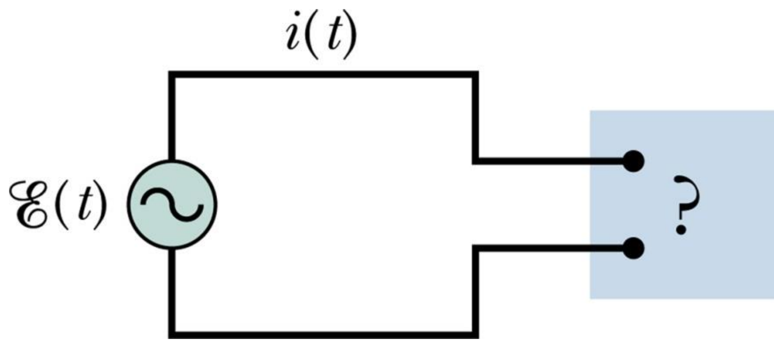
$$I_p = \frac{1}{R} \left(\frac{N_s}{N_p} \right)^2 V_p$$

$$R_{\text{eq}} = \left(\frac{N_p}{N_s} \right)^2 R$$

Problem



Problem



$$\mathcal{E}(t) = (75.0\text{V}) \sin \omega_d t$$

$$i(t) = (1.20\text{A}) \sin(\omega_d t + 42.0°)$$

(a) Power factor?
(b) Cureent leading or lagging the emf?
(c) Inductive or capacitive?
(d) In resonance?
(e) Capacitor? Or an inductor? Or a resistor?
(f) Average energy transfer

Chap. 31 Electromagnetic waves

Laws on E&M so far

Electric field

$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$$

Gauss' law on static charges
(equivalent to Coulomb's law)

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

Faraday's law
Induced electric field due to time-varying magnetic field

Magnetic field

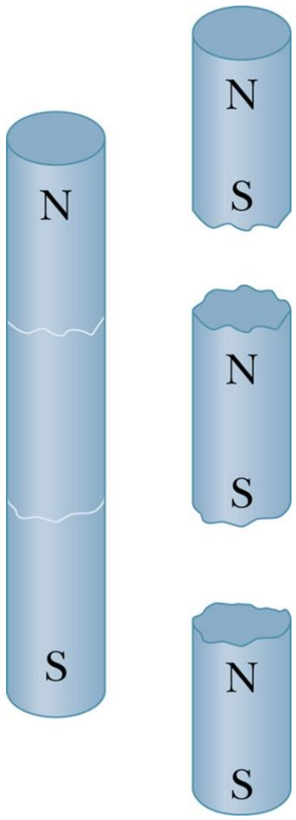
$$\oint \vec{B} \cdot d\vec{A} = 0$$

Gauss' law on magnetic field
No magnetic charges

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i$$

Ampere's law
Magnetic field produced by a current

Gauss' law on magnetic field



Magnetic fields are always produced by magnetic dipoles.

Magnetic flux $$\Phi_B = \oint \vec{B} \cdot d\vec{A} = 0$$

n.b.: $$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

Induced magnetic field

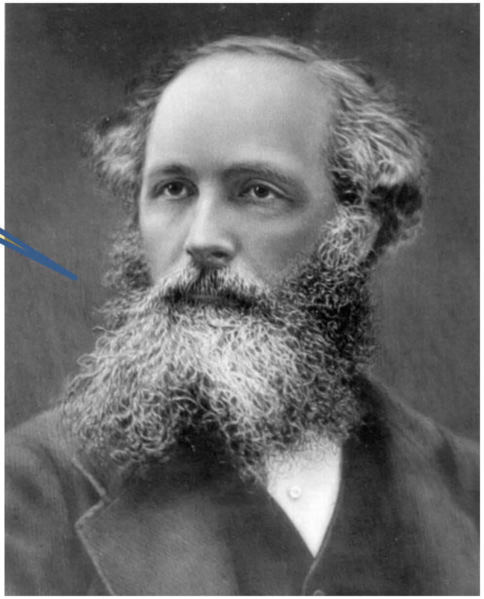
Faraday's law: $$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

On the other hand, can a time-varying electric field induce a magnetic field?

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

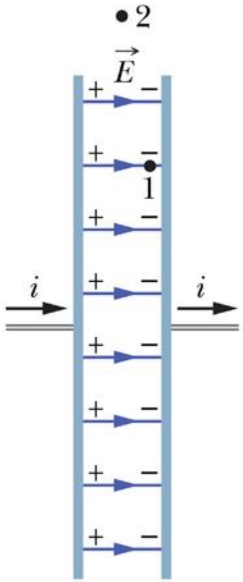
Maxwell's induction law

Yes!

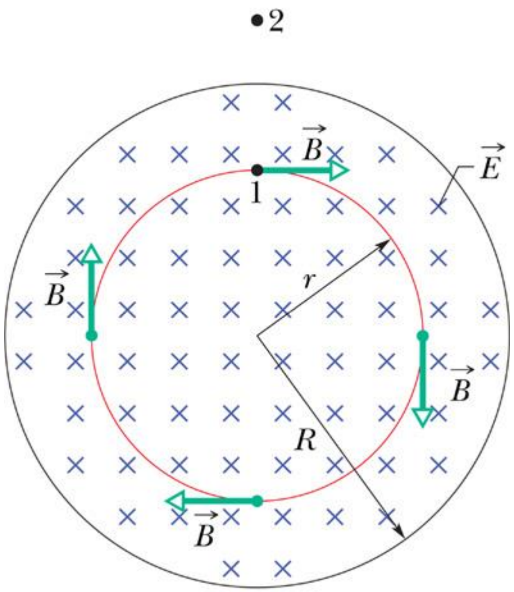


Ampere-Maxwell's law

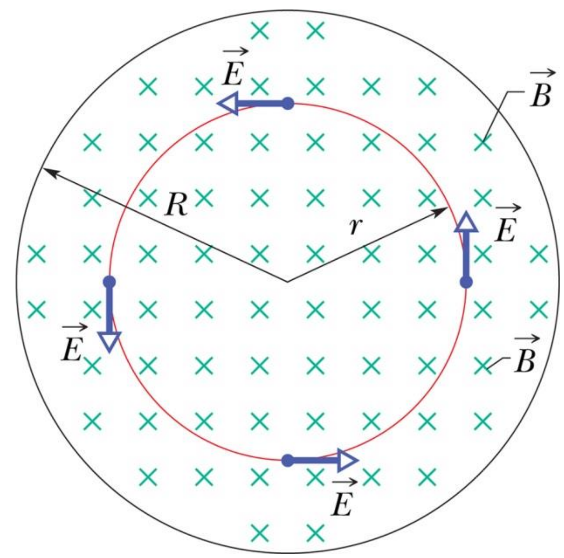
$$\oint \vec{B} \cdot d\vec{s} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i_{\text{enc}}$$



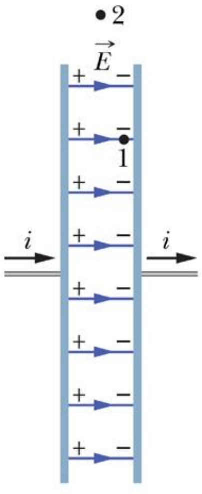
(a)



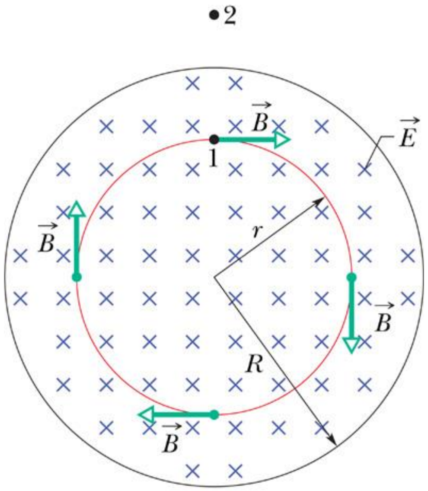
(b)



Example



(a)



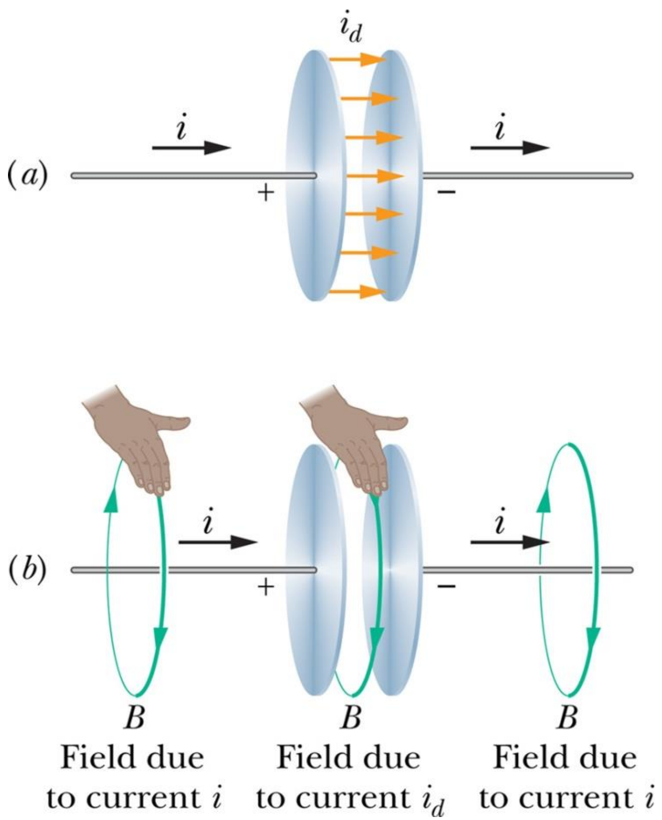
(b)

displacement current

$$i_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i_{d,\text{enc}} + \mu_0 i_{\text{enc}}$$

Ampere-Maxwell's law



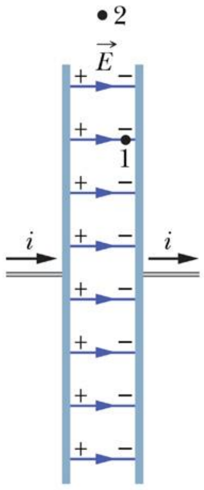
$$q = \epsilon_0 A E \qquad \frac{dq}{dt} = i = \epsilon_0 A \frac{dE}{dt}$$

$$i_d = \epsilon_0 \frac{d\Phi_E}{dt} = \epsilon_0 \frac{d(EA)}{dt} = \epsilon_0 A \frac{dE}{dt}$$

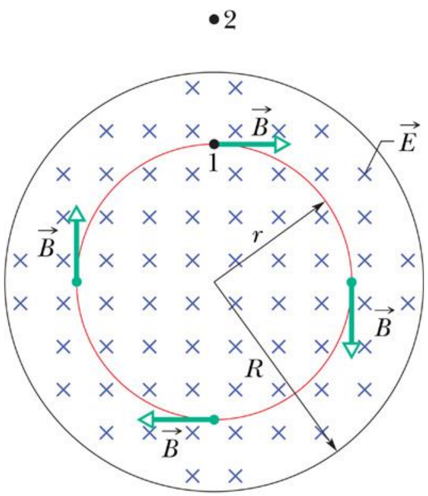
$$i_d = i$$

$$B = \begin{cases} \left(\frac{\mu_0 i_d}{2\pi R^2}\right) r, & \text{Inside C} \\ \frac{\mu_0 i_d}{2\pi r} & \text{Outside C} \end{cases}$$

Sample



(a)



(b)

Maxwell's equations

Maxwell's Equations[a]

Name	Equation	
Gauss' law for electricity	$\oint \vec{E} \cdot d\vec{A} = q_{enc}/\varepsilon_0$	Relates net electric flux to net enclosed electric charge
Gauss' law for magnetism	$\oint \vec{B} \cdot d\vec{A} = 0$	Relates net magnetic flux to net enclosed magnetic charge
Faraday's law	$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$	Relates induced electric field to changing magnetic flux
Ampere–Maxwell law	$\oint \vec{B} \cdot d\vec{s} = \mu_0\varepsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i_{enc}$	Relates induced magnetic field to changing electric flux and to current

[a]Written on the assumption that no dielectric or magnetic materials are present.