PHYS 212 Review 3

Exam 3

Queue

Exam 3 Overview

18) RL Circuits

19) LC Circuits

20) AC Circuits

21) AC Power and Resonance

22) Maxwell’s Displacement Current

23) EM Waves

24) Polarization

25) Refraction

RL Circuits

Inductors behave “oppositely” to capacitors (i.e. at t=0 and t=∞ when charging up)

Inductors in circuits add in series and in parallel like resistors

$$L \equiv \frac{\Phi_B}{I}$$

Inductance: L = magnetic flux / current

Time constant: τ = **L / R**

$$\tau = \frac{L}{R} \qquad V = L\frac{dI}{dt}$$

Charging and Discharging Equations

$$I(t) = I(\infty)\left(1 - e^{-t/\tau}\right) \qquad I(t) = I(0)e^{-t/\tau}$$

RL Circuits cont.

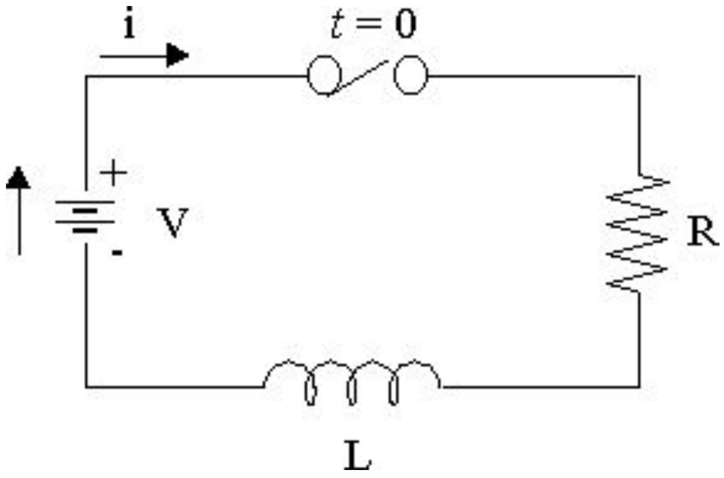
Charging

t = 0 → inductor acts like an open circuit

- I = 0 A, but there is a voltage

t = ∞ → inductor acts like a wire (short circuit)

- V = 0 V, but there is a current



Discharging

t = 0 → inductor acts like a current source (I at t = 0 is the same as I at t = ∞ found when charging up)

t = ∞ → inductor acts like a wire (no more current in the circuit)

LC Circuits

Inductors and capacitors are storage devices so their energies are constantly oscillating between one another (given an initial voltage/current)

Total Potential Energy: $U_{total} = U_{inductor} + U_{capacitor} = 0.5LI^2 + 0.5CV^2$

Resonance only occurs at the natural frequency: ω_0

Natural Frequency

$$\omega_o = \frac{1}{\sqrt{LC}}$$

$$U = \frac{1}{2}LI^2 \qquad U = \frac{1}{2}CV^2$$

AC Circuits (RLC)

Resistor is in phase with the current

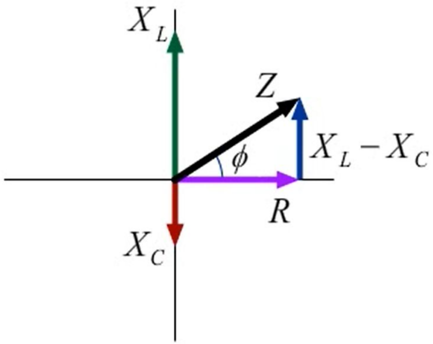
Inductor leads current by 90 degrees

Capacitor lags current by 90 degrees

Steps for AC Circuit Problems:

1) Find the reactances first (X_L and X_c)
2) Then find impedance (Z)
3) Now you can solve for I_m
4) Solve for phase of the generator
    a) **If phase is positive → generator voltage leads current**
    b) **If phase is negative → generator voltage lags current**

Impedance Phasor Diagram



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

$$I_m = \frac{\mathcal{E}_m}{Z}$$ Maximum Current

Inductor Reactance $X_L = \omega L$

Capacitor Reactance $X_C = \frac{1}{\omega C}$

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

Average Power and Resonance

Resonance occurs when $\boldsymbol{\omega = \omega_o}$

This makes $X_L = X_C$ thus $Z = R$ => this is when $\mathbf{I_m}$ **is at its maximum value**

$$\langle P_{Generator} \rangle = \mathcal{E}_{rms} I_{rms} \cos\phi$$

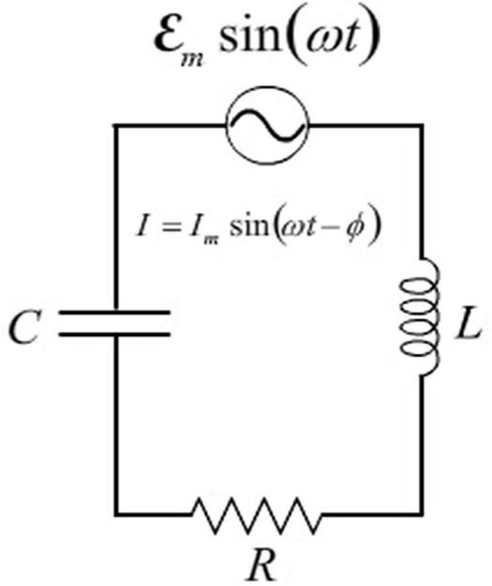
Root Mean Square (rms)

$$\mathcal{E}_{rms} = \frac{\mathcal{E}_m}{\sqrt{2}}$$ Voltage

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$ Current

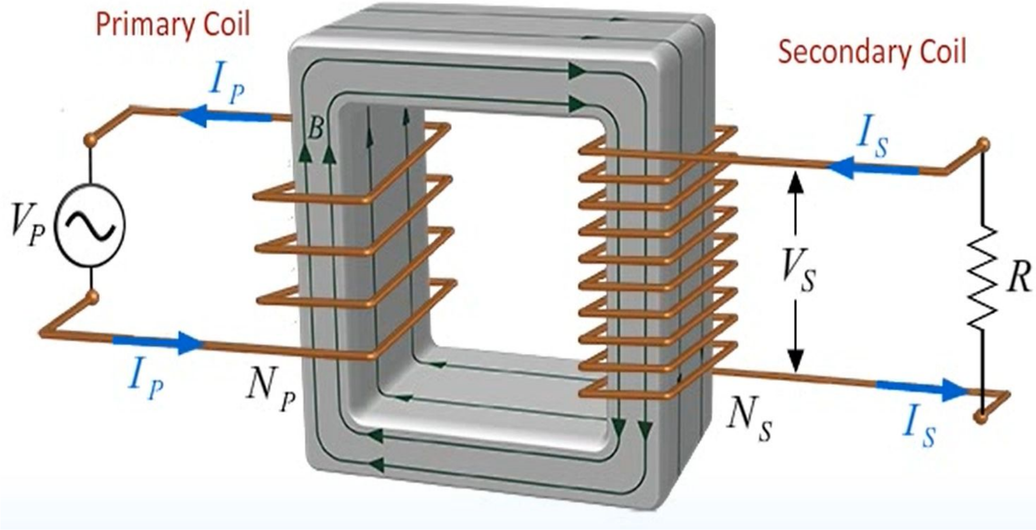
Natural Frequency

$$\omega_o = \frac{1}{\sqrt{LC}}$$



Transformers

Transformers are used to convert from high voltages to low voltages and vice versa



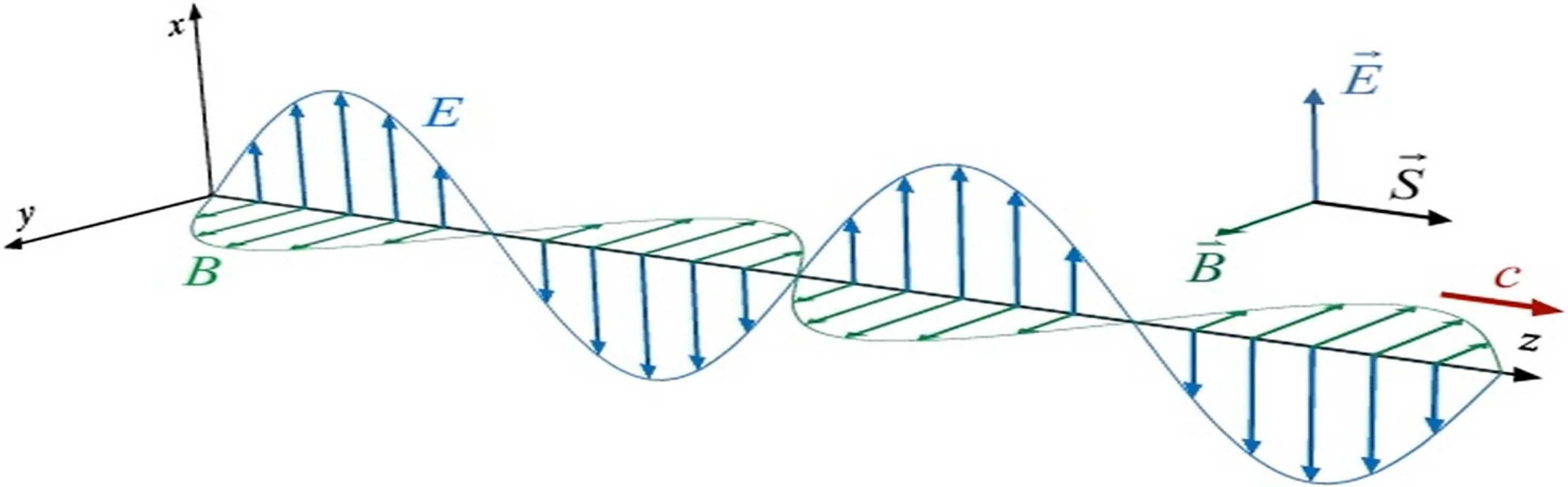
Voltage Relation

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

Current Relation

$$\frac{I_P}{I_S} = \frac{N_S}{N_P}$$

EM Wave Image (Remember this image!)



EM Wave Properties

$$E_x = E_o \cos(kz - \omega t)$$

E and B have the same waveform: If E is sin(kz-ωt) then B is also sin(kz-ωt)

Magnitude of B is smaller: $B_o = E_o$ / c where c is the speed of light (3 x 10^8 m/s)

The “x, y, or z” variable inside the argument tells you the direction of propagation
cos(kz - ωt) travels in +z-direction, cos(kz + ωt) travels in -z-direction

Wave parameters: $\omega = 2\pi f$, $v = \lambda f = \omega / k$ (v = c for EM waves in free-space)

Poynting vector (S) points in the same direction the wave is traveling

$S = (E \times B) / \mu_o$

Power = S x A (units: W) , **Intensity = Power / Area = S** (units: W/m^2)

Doppler Shift

$$f' = f\sqrt{\frac{1 \pm \beta}{1 \mp \beta}} \xrightarrow{\beta \ll 1} f' \approx f(1 \pm \beta)$$

where $\beta \equiv \frac{v}{c}$

Decreasing Separation

$$f' = f\sqrt{\frac{1+\beta}{1-\beta}}$$

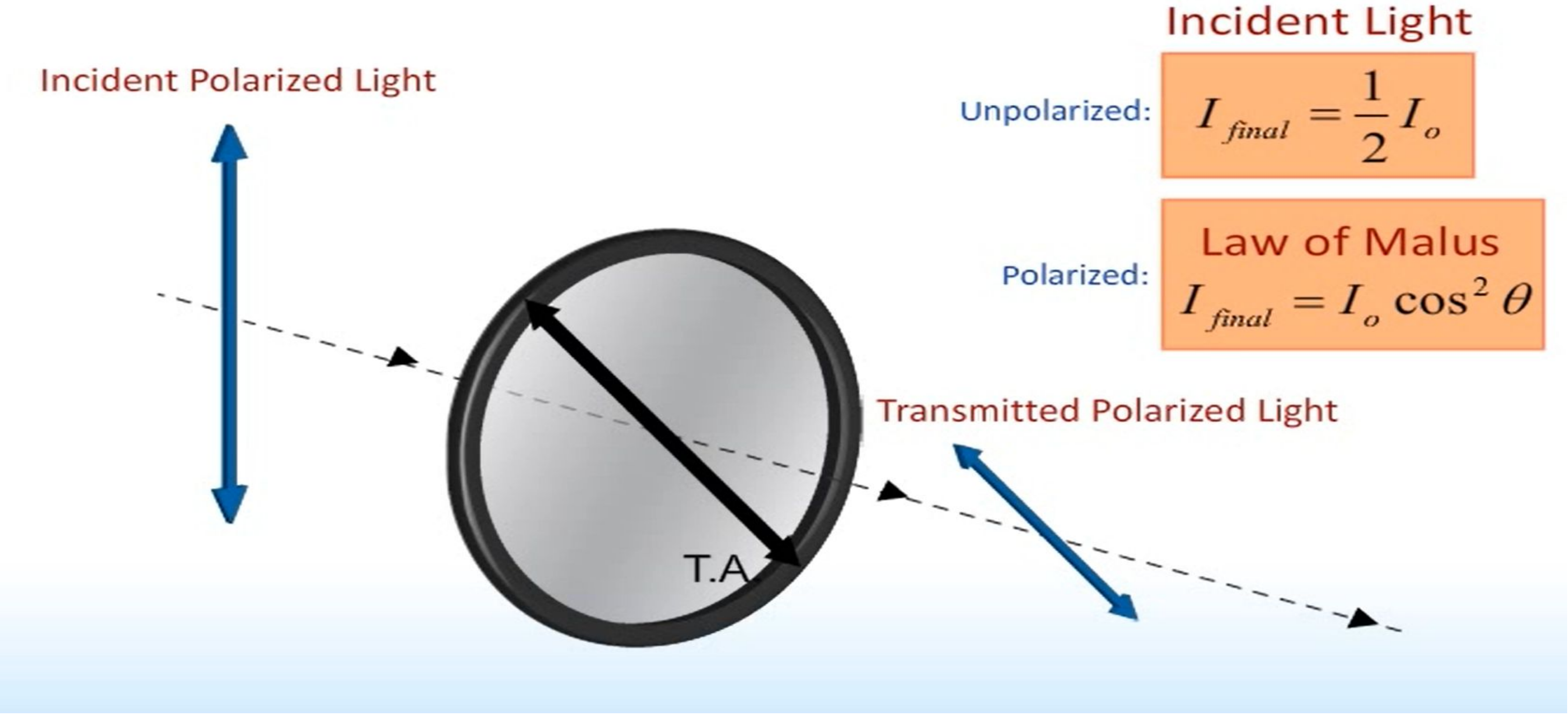
$(f' > f)$

Increasing Separation

$$f' = f\sqrt{\frac{1-\beta}{1+\beta}}$$

$(f' < f)$

Linear Polarization

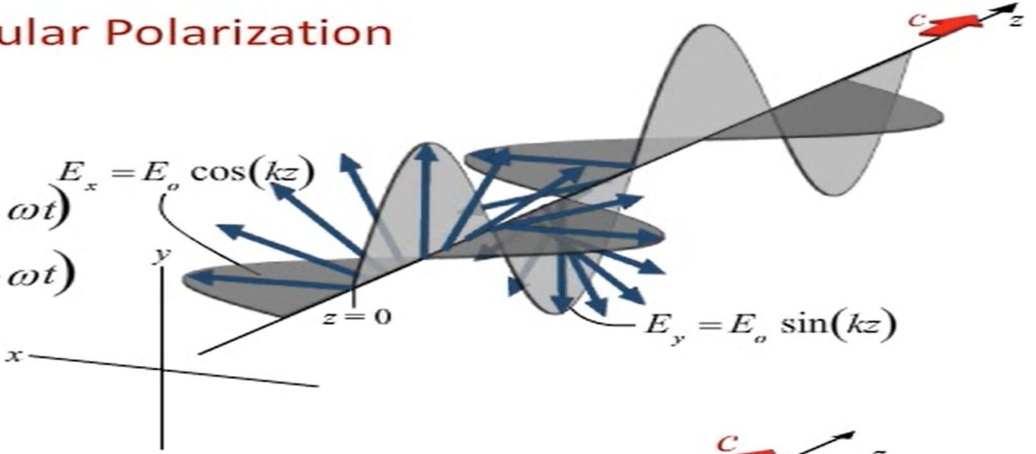


Circular Polarization

Circular Polarization

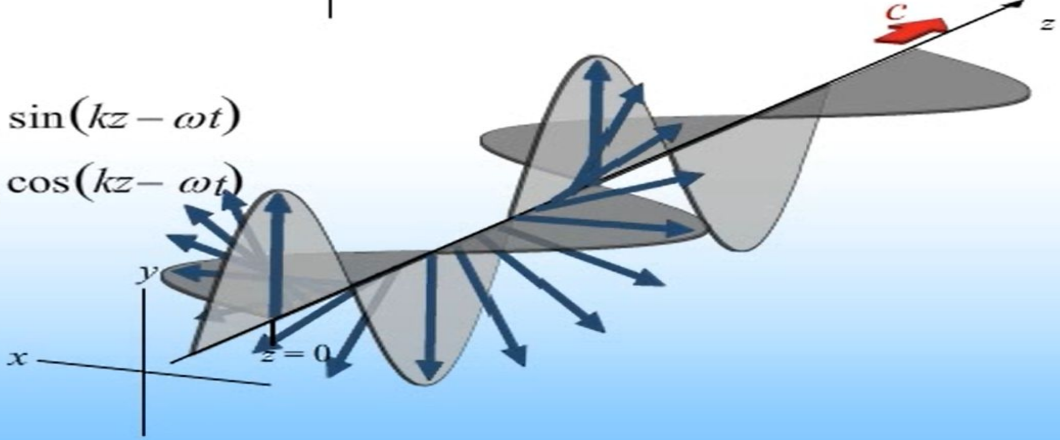
Right-handed (RCP):

$$\phi_x - \phi_y = \frac{\pi}{2} \xrightarrow{\text{Examples}} \begin{cases} E_x = E_o \cos(kz - \omega t) \\ E_y = E_o \sin(kz - \omega t) \end{cases}$$



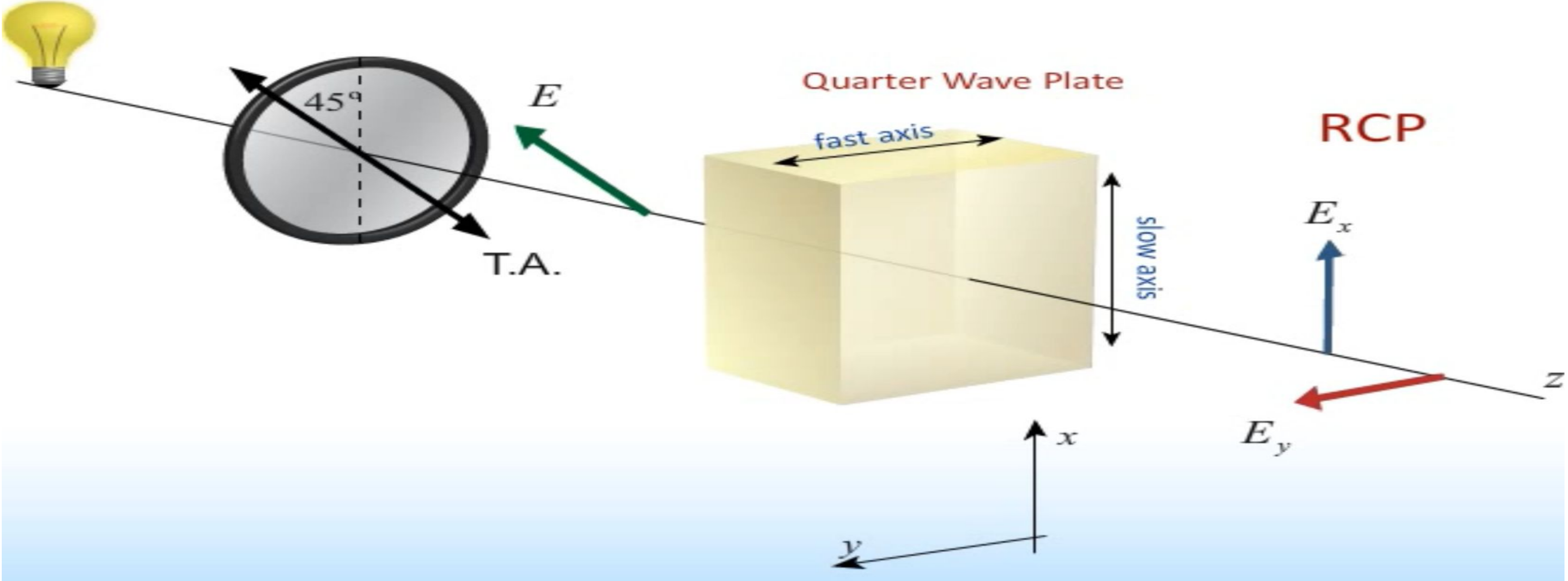
Left-handed (LCP):

$$\phi_x - \phi_y = -\frac{\pi}{2} \xrightarrow{\text{Examples}} \begin{cases} E_x = E_o \sin(kz - \omega t) \\ E_y = E_o \cos(kz - \omega t) \end{cases}$$



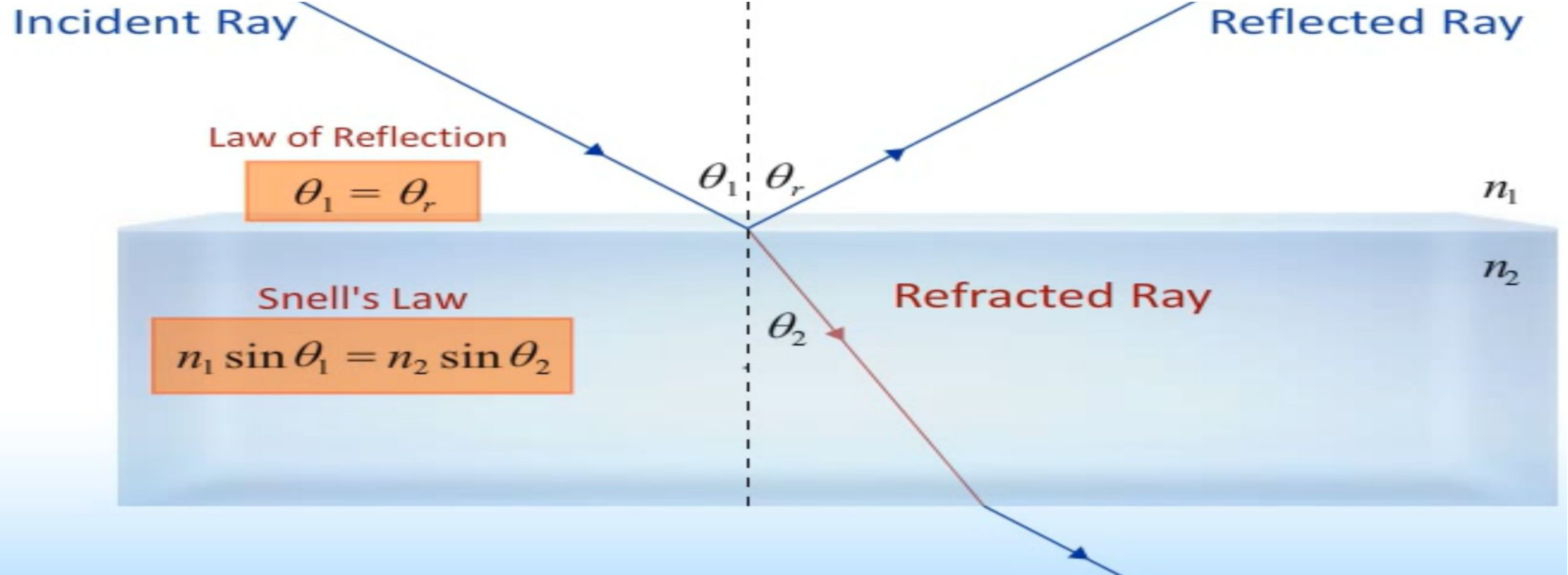
Circular Polarization cont.

- Produced by passing linear polarized light through a quarter wave plate **(only if the light isn't 100% vertically or horizontally linearly polarized beforehand)**
- If **Slow-Axis X Fast-Axis** = **Direction of Wave → RCP , otherwise LCP**



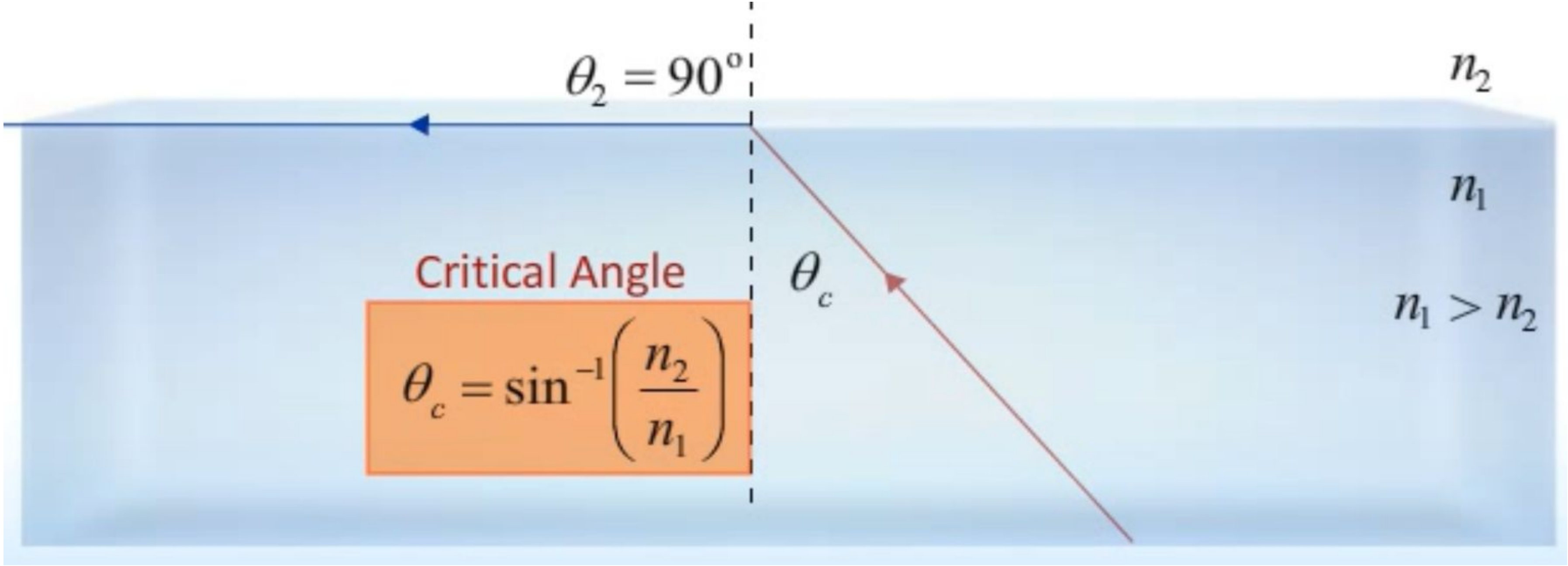
Reflection and Refraction

- **Law of Reflection** - the incident angle is equal to the reflected angle wrt the normal
- **Index of Refraction** - n = c/v is material specific: for vacuum/air n = 1
- **Snell's Law** - used to find the angle of the refracted ray wrt the normal



Reflection and Refraction cont.

Total Internal Reflection - only happens when rays are at the critical angle or at angles larger than the critical angle



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