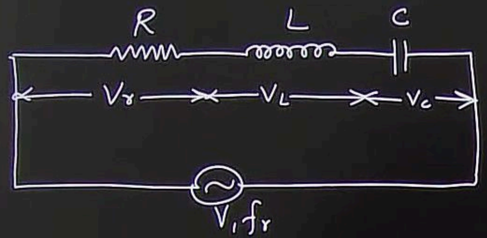
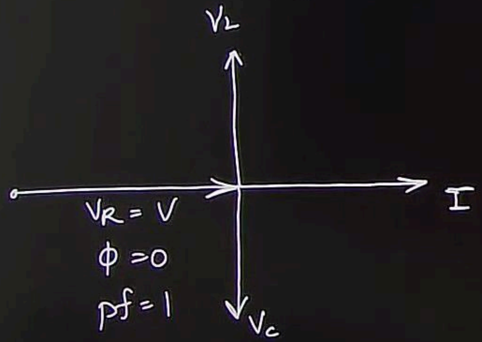
Series Resonance



Circuit diagram



Imp points

$X = (X_L - X_C)\ \Omega$

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

$X_C = \dfrac{1}{2\pi f C}\ \Omega$

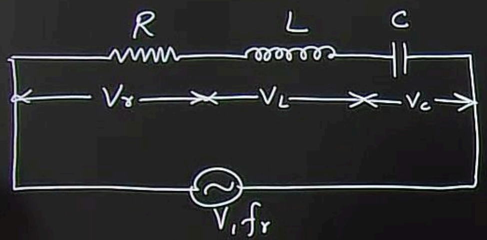
$pf = 1,\ \phi = 0$

$X_L - X_C = 0$

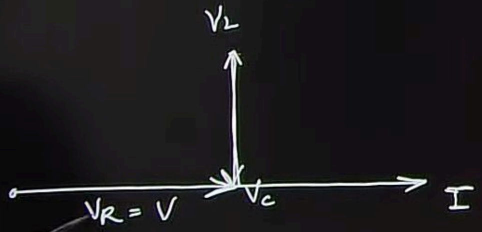
$X_L = X_C$

Here the frequency is termed as resonance frequency

Series Resonance



Circuit diagram



$V_R = V$

$\phi = 0$

$pf = 1$

Imp points.

$$X = (X_L - X_C)\ \Omega$$

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

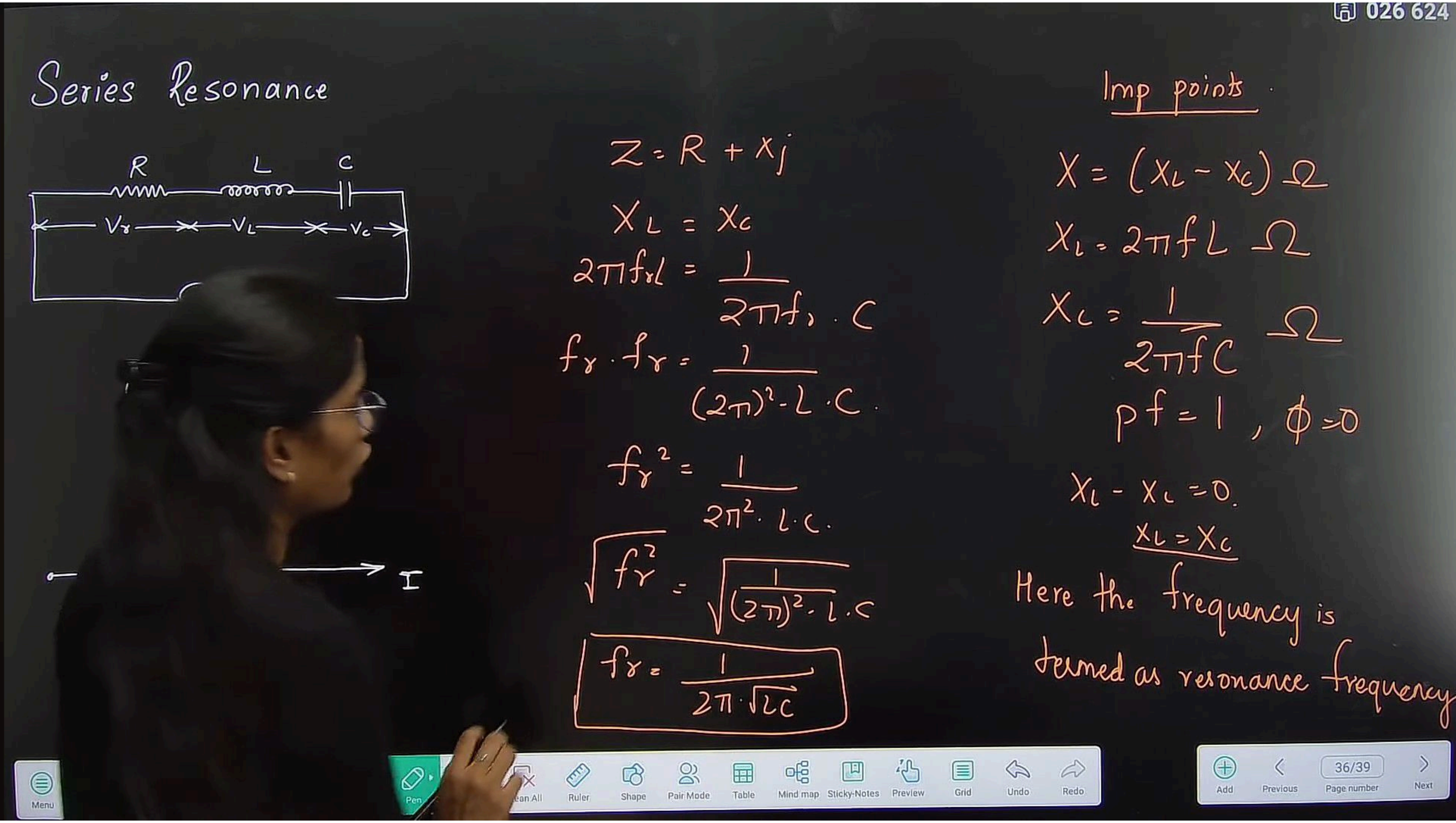
$$X_C = \frac{1}{2\pi f C}\ \Omega$$

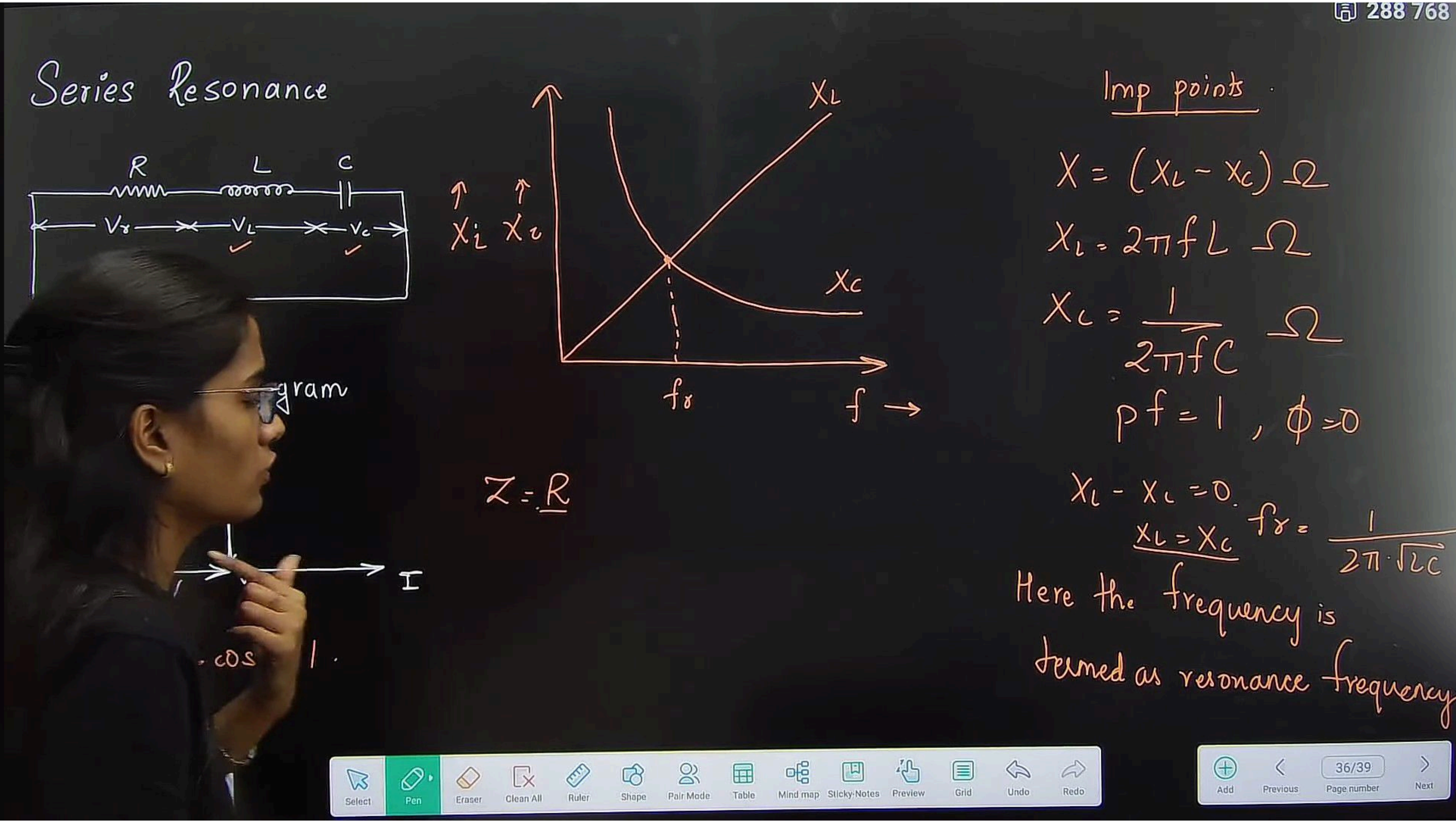
$$pf = 1,\ \phi = 0$$

$$X_L - X_C = 0$$

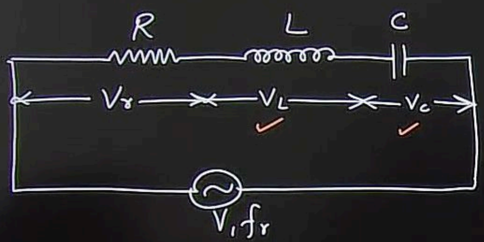
$$X_L = X_C$$

Here the frequency is termed as resonance frequency

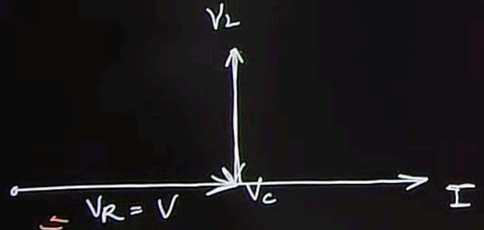

026 624
Series Resonance
R L C
V_r V_L V_c
I
$Z = R + Xj$
$X_L = X_c$
$2\pi f_r L = \frac{1}{2\pi f_r \cdot C}$
$f_r \cdot f_r = \frac{1}{(2\pi)^2 \cdot L \cdot C}$
$f_r^2 = \frac{1}{2\pi^2 \cdot L \cdot C}$
$\sqrt{f_r^2} = \sqrt{\frac{1}{(2\pi)^2 \cdot L \cdot C}}$
$\boxed{f_r = \frac{1}{2\pi \cdot \sqrt{LC}}}$
Imp points.
$X = (X_L - X_c)\ \Omega$
$X_L = 2\pi f L\ \Omega$
$X_c = \frac{1}{2\pi f C}\ \Omega$
$pf = 1,\ \phi = 0$
$X_L - X_c = 0.$
$X_L = X_c$
Here the frequency is termed as resonance frequency
Menu
Pen
ean All
Ruler
Shape
Pair Mode
Table
Mind map
Sticky-Notes
Preview
Grid
Undo
Redo
Add
Previous
36/39
Page number
Next


288 768
Series Resonance
R
L
C
Vr
VL
Vc
gram
I
cos
1.
XL
XC
Xl
Xc
fr
f
Z = R
Imp points
X = (XL − XC) Ω
XL = 2πfL Ω
XC = 1 / 2πfC Ω
pf = 1 , ϕ = 0
XL − XC = 0.
XL = XC
fr = 1 / 2π·√LC
Here the frequency is
termed as resonance frequency
Select
Pen
Eraser
Clean All
Ruler
Shape
Pair Mode
Table
Mind map
Sticky-Notes
Preview
Grid
Undo
Redo
Add
Previous
36/39
Page number
Next

Series Resonance



Circuit diagram



$\phi = 0$

$pf = 1 = \cos 0 = 1.$

Q-factor

$$Q = \frac{V_L \text{ or } V_C}{V}$$

$$= \frac{\cancel{I} \cdot X_L}{\cancel{I} R}$$

$$Q = \frac{\omega L}{R}$$

$$Q = \frac{2\pi f_r \cdot L}{R}$$

$$Q = \frac{\cancel{2\pi} L}{R} \cdot \frac{1}{\cancel{2\pi}\sqrt{LC}}$$

$$Q = \frac{L}{R} \cdot \frac{1}{\sqrt{LC}}$$

$$= \frac{\cancel{\sqrt{L}} \times \sqrt{L}}{R \cdot \cancel{\sqrt{L}}\sqrt{C}}$$

$$\boxed{Q = \frac{1}{R} \cdot \frac{\sqrt{L}}{\sqrt{C}}}$$

Imp points

$X = (X_L - X_c)\ \Omega$

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

$X_c = \frac{1}{2\pi f C}\ \Omega$

$pf = 1,\ \phi = 0$

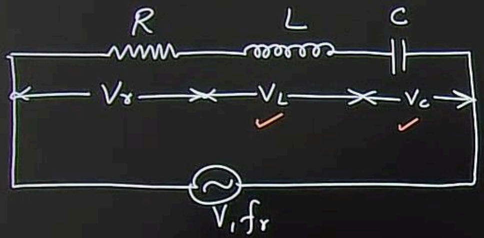
$X_L - X_c = 0.$

$X_L = X_c$

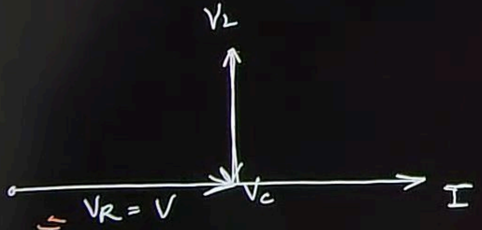
$$\boxed{f_r = \frac{1}{2\pi \cdot \sqrt{LC}}}$$

Here the frequency is termed as resonance frequency

Series Resonance



Circuit diagram



$= V_R = V$

$\phi = 0$

$pf = 1 = \cos 0 = 1$.

To find Voltage drop.

$$V_L = I_r \cdot X_L \rightarrow \omega L \rightarrow 2\pi f_r L$$

$$= \frac{V}{R} \cdot 2\pi \cdot \frac{1}{2\pi\sqrt{LC}} \cdot L$$

$$V_L = \frac{V}{R} \cdot \frac{\sqrt{L}}{\sqrt{C}}$$

$$V_L = \frac{V}{R} \sqrt{\frac{L}{C}}$$

$$\frac{\cancel{\sqrt{L}} \cdot \sqrt{L}}{\cancel{\sqrt{L}}\sqrt{C}} = \frac{\sqrt{L}}{\sqrt{C}}$$

Imp points.

$X = (X_L - X_C)\ \Omega$

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

$X_C = \frac{1}{2\pi f C}\ \Omega$

$pf = 1,\ \phi = 0$

$X_L - X_C = 0$.

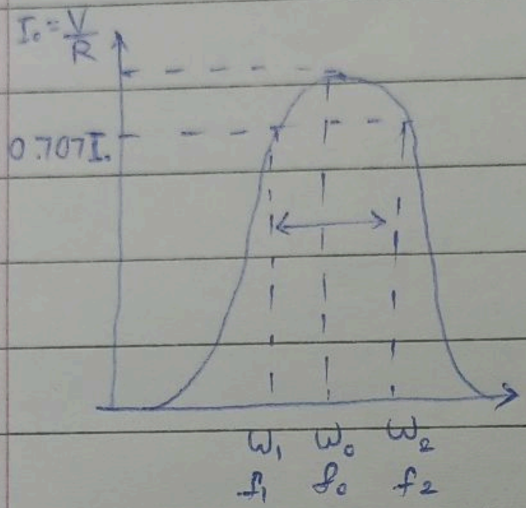
$X_L = X_C$

$\boxed{f_r = \frac{1}{2\pi \cdot \sqrt{LC}}}$

Here the frequency is termed as resonance frequency

f_r = Q factor x Bandwidth.

* Bandwidth



Bandwidth $= \omega_2 - \omega_1$

$I_0 \rightarrow$ Max current at Resonance

$I = I_0 / \sqrt{2}$ or $0.707 I_0$

$P = VI \cos \phi$

At Resonance

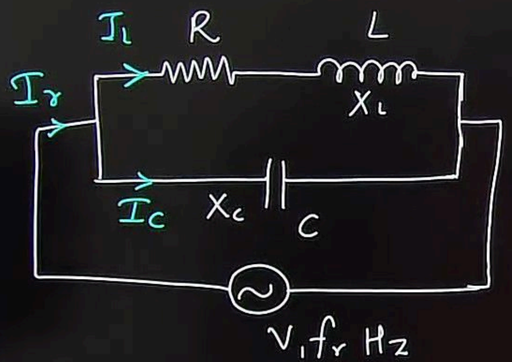
$P_0 = I_0^2 R$

for $I_0 / \sqrt{2} = I$,

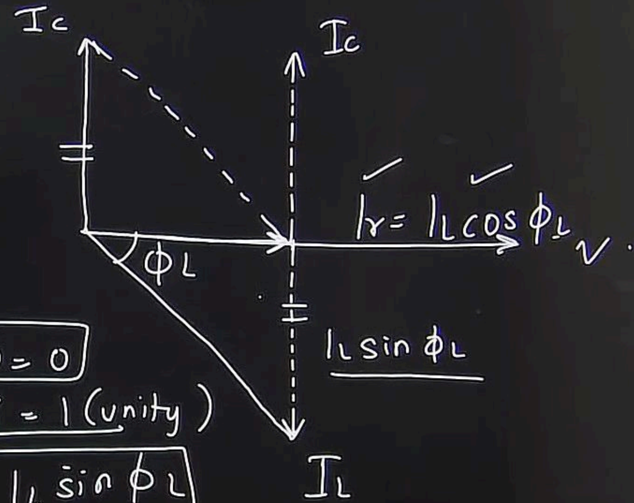
$$P_0 = \frac{I_0^2 R}{2} = \frac{P_0}{2}$$

f_1 & $f_2 \rightarrow$ also called Half Power points.

Parallel Resonance



a) Circuit diagram



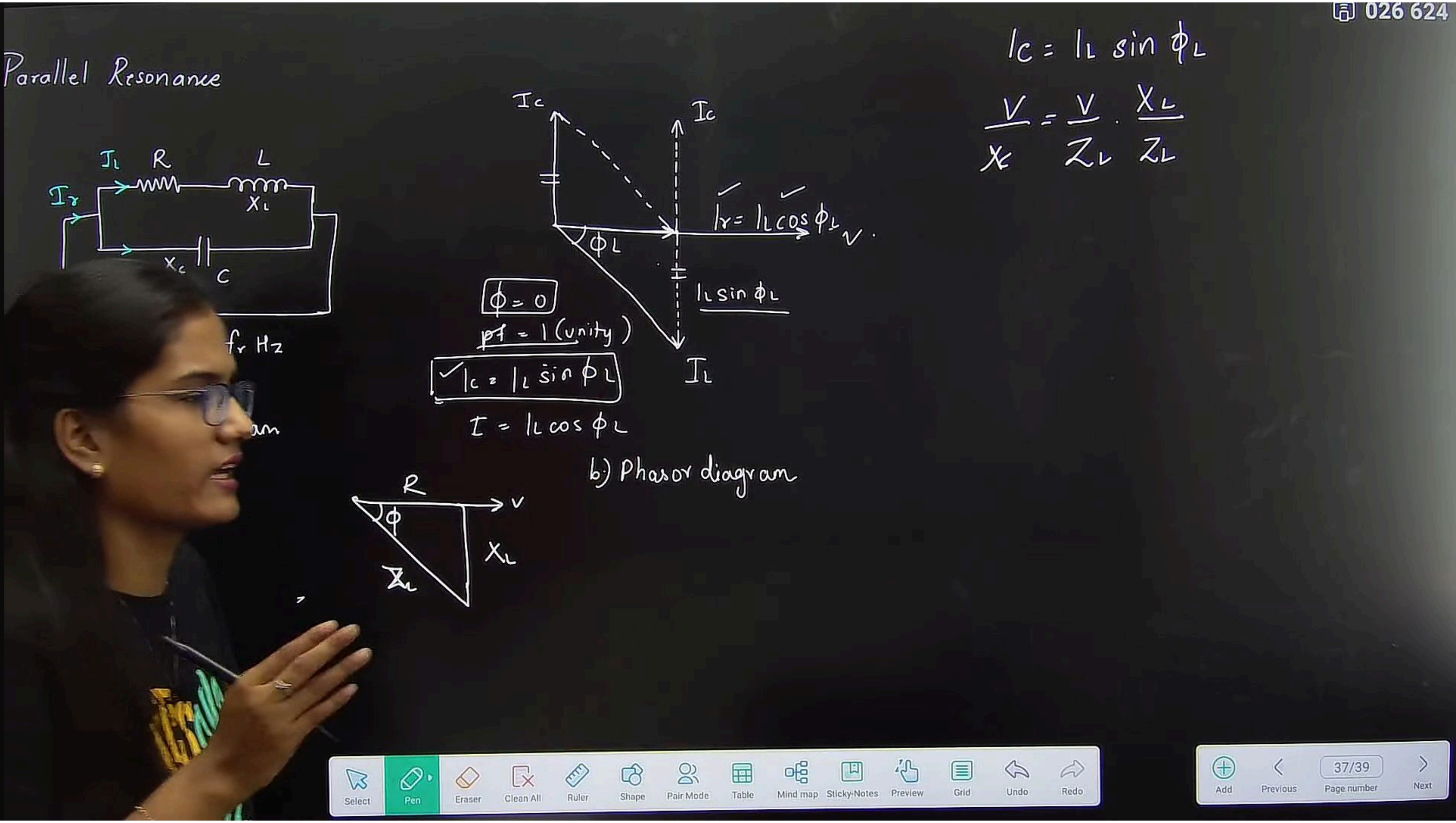
$\boxed{\phi = 0}$

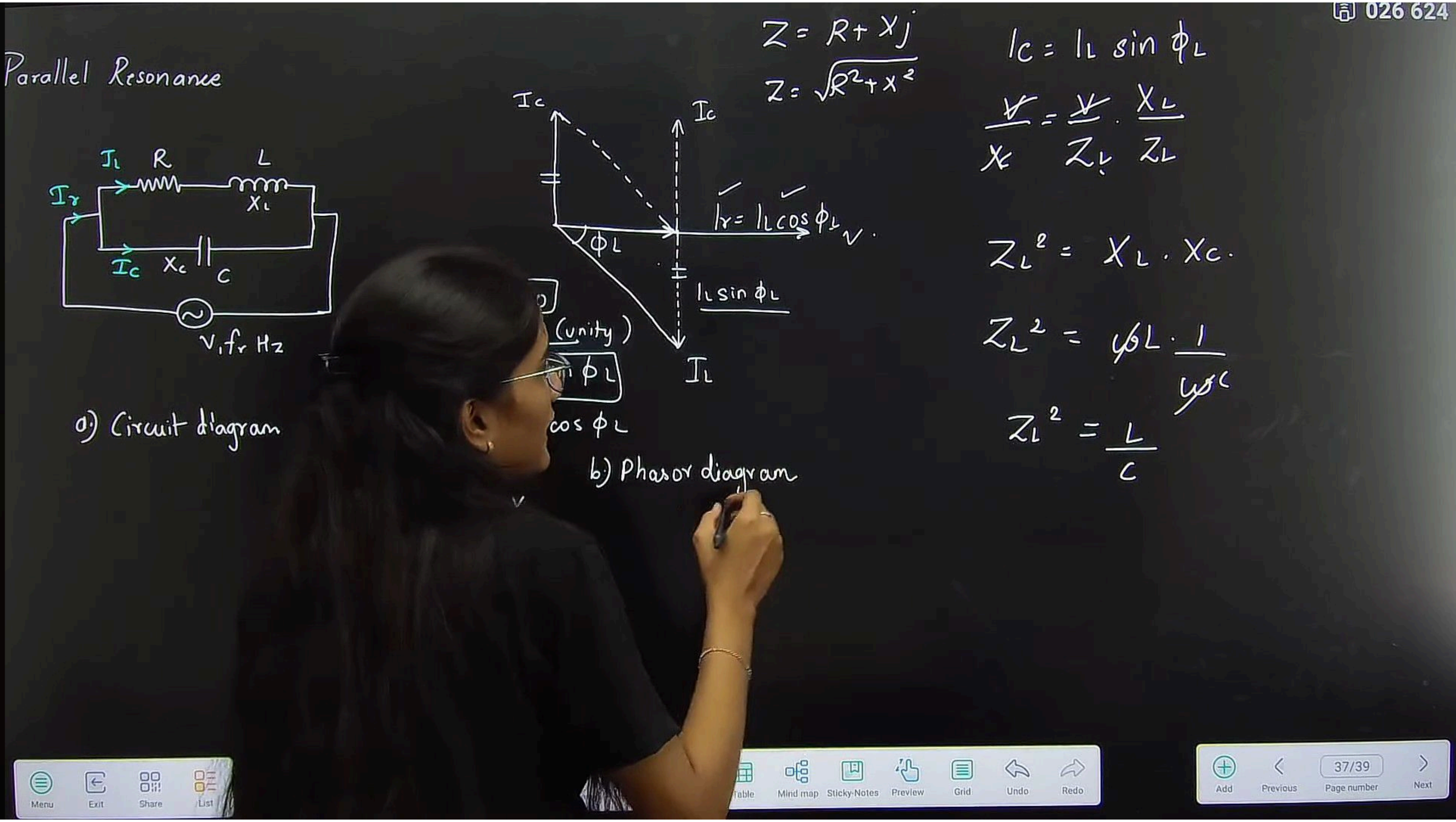
pf = 1 (unity)

$\boxed{I_C = I_L \sin \phi_L}$

$I = I_L \cos \phi_L$

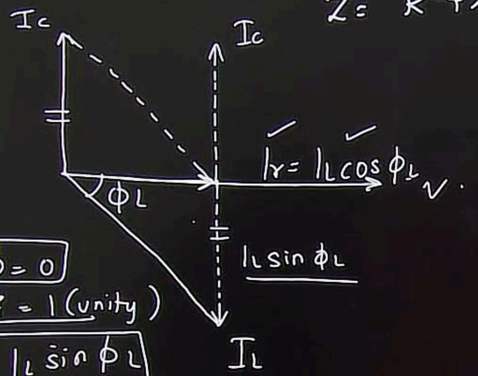
b) Phasor diagram


026 624
Parallel Resonance
I_r
I_L R L
X_L
X_C C
f_r Hz
I_C
I_C
$I_r = I_L \cos\phi_L$
V
ϕ_L
$I_L \sin\phi_L$
I_L
$\boxed{\phi = 0}$
$\cancel{pf} = 1$ (unity)
$\boxed{I_C = I_L \sin\phi_L}$
$I = I_L \cos\phi_L$
b) Phasor diagram
R
V
ϕ
X_L
Z_L
$I_C = I_L \sin\phi_L$
$\frac{V}{X_C} = \frac{V}{Z_L} \cdot \frac{X_L}{Z_L}$
Select
Pen
Eraser
Clean All
Ruler
Shape
Pair Mode
Table
Mind map
Sticky-Notes
Preview
Grid
Undo
Redo
Add
Previous
37/39
Page number
Next



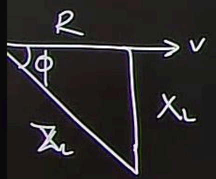
Parallel Resonance
026 624
Z = R + Xj
Z = √(R² + X²)
Ic = IL sin φL
V/Xc = V/ZL · XL/ZL
ZL² = XL · Xc
ZL² = ωL · 1/ωC
ZL² = L/C
Ir
IL
R
L
XL
Ic
Xc
C
V, fr Hz
a) Circuit diagram
Ic
Ir = IL cos φL
V
φL
IL sin φL
IL
(unity)
b) Phasor diagram
Menu
Exit
Share
List
Table
Mind map
Sticky-Notes
Preview
Grid
Undo
Redo
Add
Previous
37/39
Page number
Next

$$Z = R + Xj$$
$$Z^2 = R^2 + X^2$$



$$\boxed{\phi = 0}$$
$$\cancel{pf} = 1 \text{ (unity)}$$
$$\boxed{I_c = I_L \sin\phi_L}$$
$$I = I_L \cos\phi_L$$

b) Phasor diagram

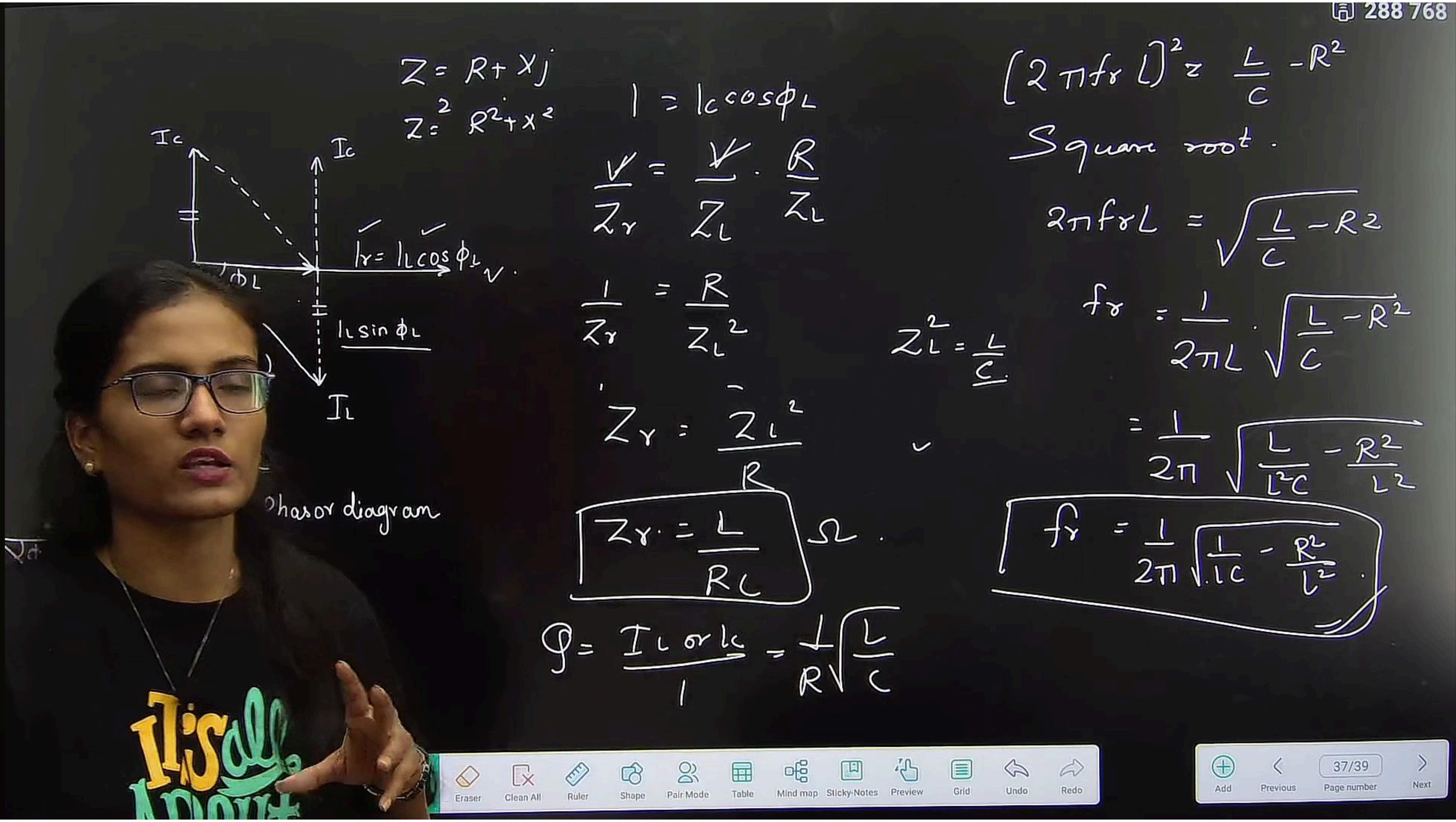


$$I_C = I_L \sin\phi_L$$
$$\frac{V}{X_C} = \frac{V}{Z_L} \cdot \frac{X_L}{Z_L}$$
$$Z_L^2 = X_L \cdot X_C$$
$$Z_L^2 = \cancel{\omega} L \cdot \frac{1}{\cancel{\omega} C}$$
$$Z_L^2 = \frac{L}{C}$$
$$R^2 + X_L^2 = \frac{L}{C}$$
$$R^2 + [2\pi f_r L]^2 = \frac{L}{C}.$$

$$(2\pi f_r L)^2 = \frac{L}{C} - R^2$$

Square root.

$$2\pi f_r L = \sqrt{\frac{L}{C} - R^2}$$
$$f_r = \frac{1}{2\pi L} \cdot \sqrt{\frac{L}{C} - R^2}$$
$$= \frac{1}{2\pi} \sqrt{\frac{L}{L^2 C} - \frac{R^2}{L^2}}$$
$$\boxed{f_r = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}}.$$


288 768
Z = R + Xj
Z² = R² + X²
Ic
Ic
Ir = IL cos φL
V
IL sin φL
IL
Phasor diagram
1 = Ic cos φL
V/Zr = V/ZL · R/ZL
1/Zr = R/ZL²
Zr = ZL²/R
Zr = L/RC Ω
Q = IL or Ic / I = 1/R √(L/C)
ZL² = L/C
(2π fr L)² = L/C − R²
Square root.
2π fr L = √(L/C − R²)
fr = 1/(2πL) √(L/C − R²)
= 1/2π √(L/(L²C) − R²/L²)
fr = 1/2π √(1/LC − R²/L²)
Eraser
Clean All
Ruler
Shape
Pair Mode
Table
Mind map
Sticky-Notes
Preview
Grid
Undo
Redo
Add
Previous
37/39
Page number
Next

550 912

Comparison between series and parallel resonance

Particular	Series circuit	Parallel Circuit
1. Impedance at resonance	Minimum ($Z_r = R$) $X = 0$	Maximum $Z_r = \frac{L}{CR}$
2. Current at resonance	Maximum ($I_r = \frac{V}{R}$) Voltage drop $\frac{V}{R}\sqrt{\frac{L}{C}}$	Minimum $I_r = \frac{V}{Z_r}$
3. Resonant frequency	$f_r = \frac{1}{2\pi\sqrt{LC}}$ Hz	$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$
4. Q-Factor	$Q = \frac{V_L \text{ or } V_C}{V} = \frac{1}{R}\sqrt{\frac{L}{C}}$	$Q = \frac{I_L \text{ or } I_C}{I}$
5. It magnifies	Voltage	Current
6. When $f < f_r$	Circuit is capacitive	Circuit is inductive
7. When $f > f_r$	Circuit is Inductive	Circuit is capacitive

Q. A parallel circuit consists of a 2.5 μF capacitor and a coil whose resistance and inductance are 15 Ω & 260 mH. Determine the resonant frequency, Q factor of the circuit at resonance & dynamic impedance.

Given data: $C = 2.5 \times 10^{-6}\,F$

$R = 15\,\Omega$

$L = 260 \times 10^{-3}\,H$

Resonant frequency $= \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC} - \dfrac{R^2}{L^2}} = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{260\times10^{-3}\times 2.5\times10^{-6}} - \dfrac{(15)^2}{(260\times10^{-3})^2}}$

$= 197.19\,Hz$

Q factor $= \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$

$= \dfrac{1}{15}\sqrt{\dfrac{260\times10^{-3}}{2.5\times10^{-6}}} = 21.49$

Dynamic Impedance $Z = \dfrac{L}{CR} = \dfrac{260\times10^{-3}}{2.5\times10^{-6}\times 15}$

$Z = 6933.33\,\Omega$

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Add Previous 39/40 Page number Next