

Ch # 16

Alternating Current

The current whose polarity continuously changes after a specific interval of time is called alternating current. It is produced by an alternating source.
mathematically,

$$I = I_0 \sin \theta$$

$$= I_0 \sin \omega t$$

$$I = I_0 \sin (2\pi f t)$$

$$I = I_0 \sin \left(\frac{2\pi}{T} t \right)$$

For $\theta = 0^\circ$

$$I = I_0 \sin 0^\circ$$

$$= I_0 (0)$$

$$I = 0$$

For $\theta = 90^\circ$

$$I = I_0 \sin 90^\circ$$

$$= I_0 (1)$$

$$I = I_0$$

For $\theta = 180^\circ$

$$I = I_0 \sin 180^\circ$$

$$= I_0 (0)$$

$$I = 0$$

for $\theta = 270^\circ$

$$I = I_0 \sin 270^\circ$$

$$= I_0 (-1)$$

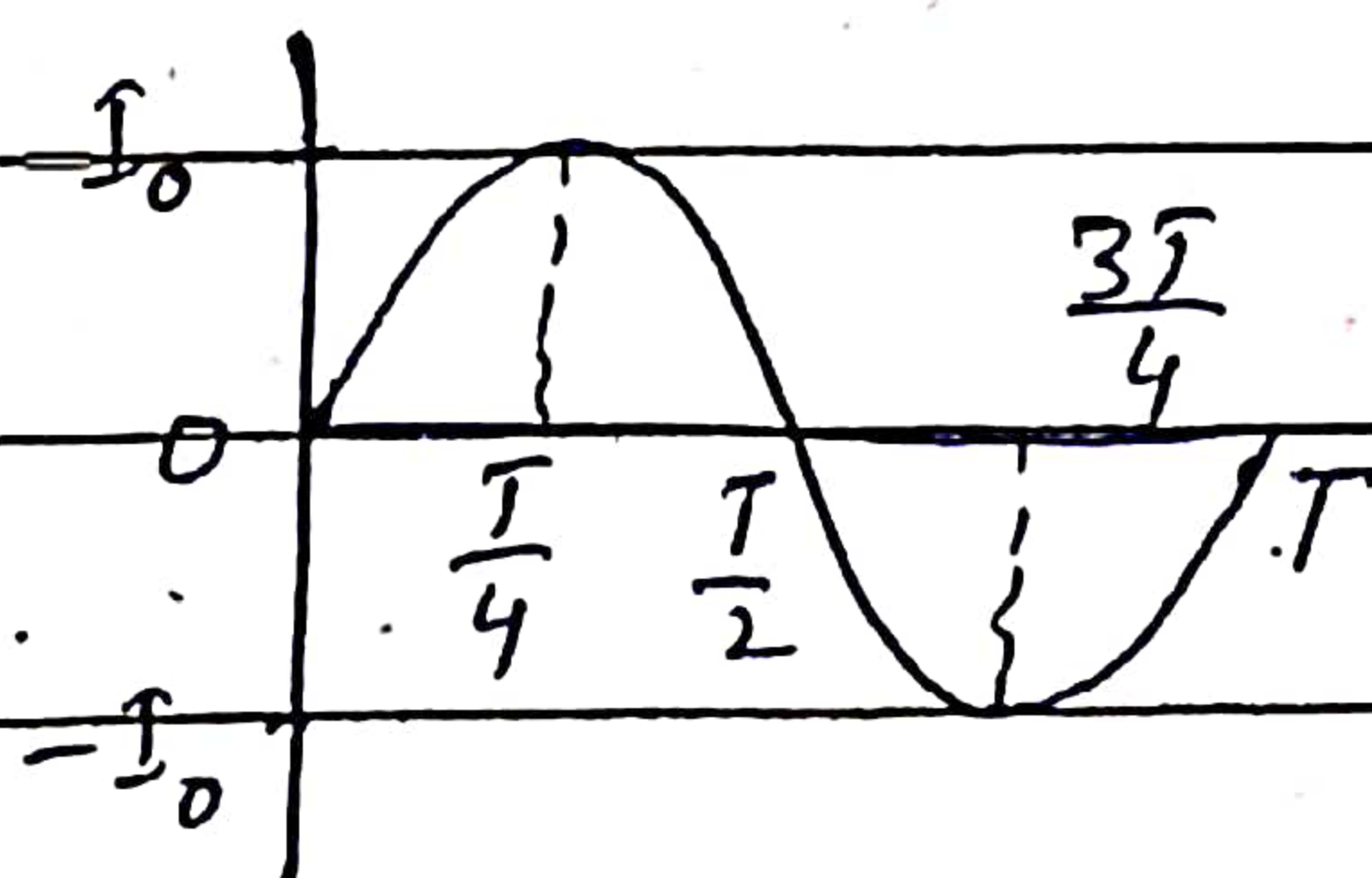
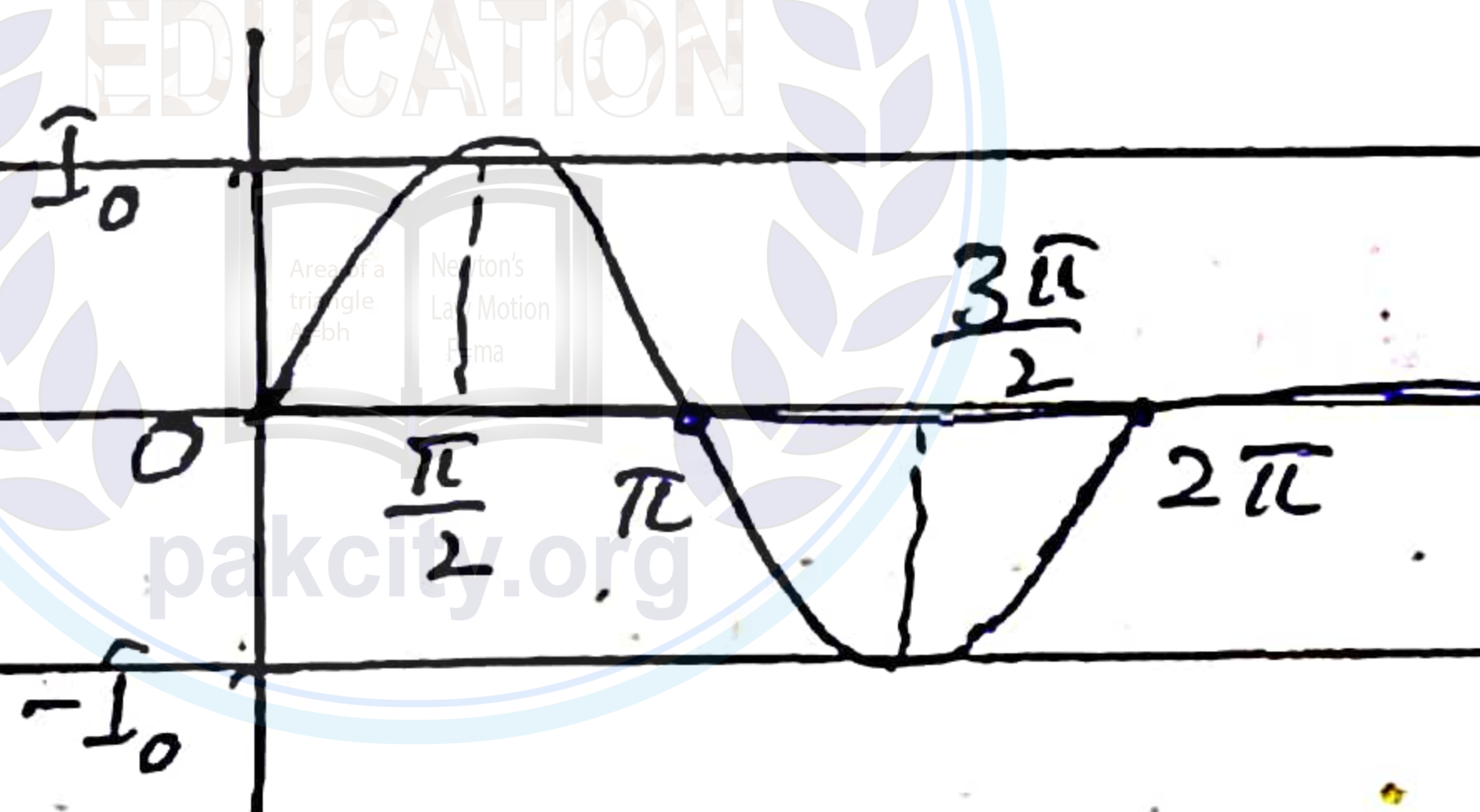
$$I = -I_0$$

for $\theta = 360^\circ$

$$I = I_0 \sin 360^\circ$$

$$= I_0 (0)$$

$$I = 0$$



The alternating current changes during angle

$0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}, 2\pi$ with time

period $0, \frac{T}{4}, \frac{T}{2}, \frac{3T}{4}, T$.

Instantaneous Value:

The Value of the Voltage and Current that exists in a Circuit at any instant of time 't' measured for some reference point is called as instantaneous value.

It can have any value between ^{plus maximum value} $+V_0$ and negative maximum value $-V_0$ and is denoted by V .

Mathematically it is given by..

$$V = V_0 \sin \theta \Rightarrow V = V_0 \sin \omega t.$$

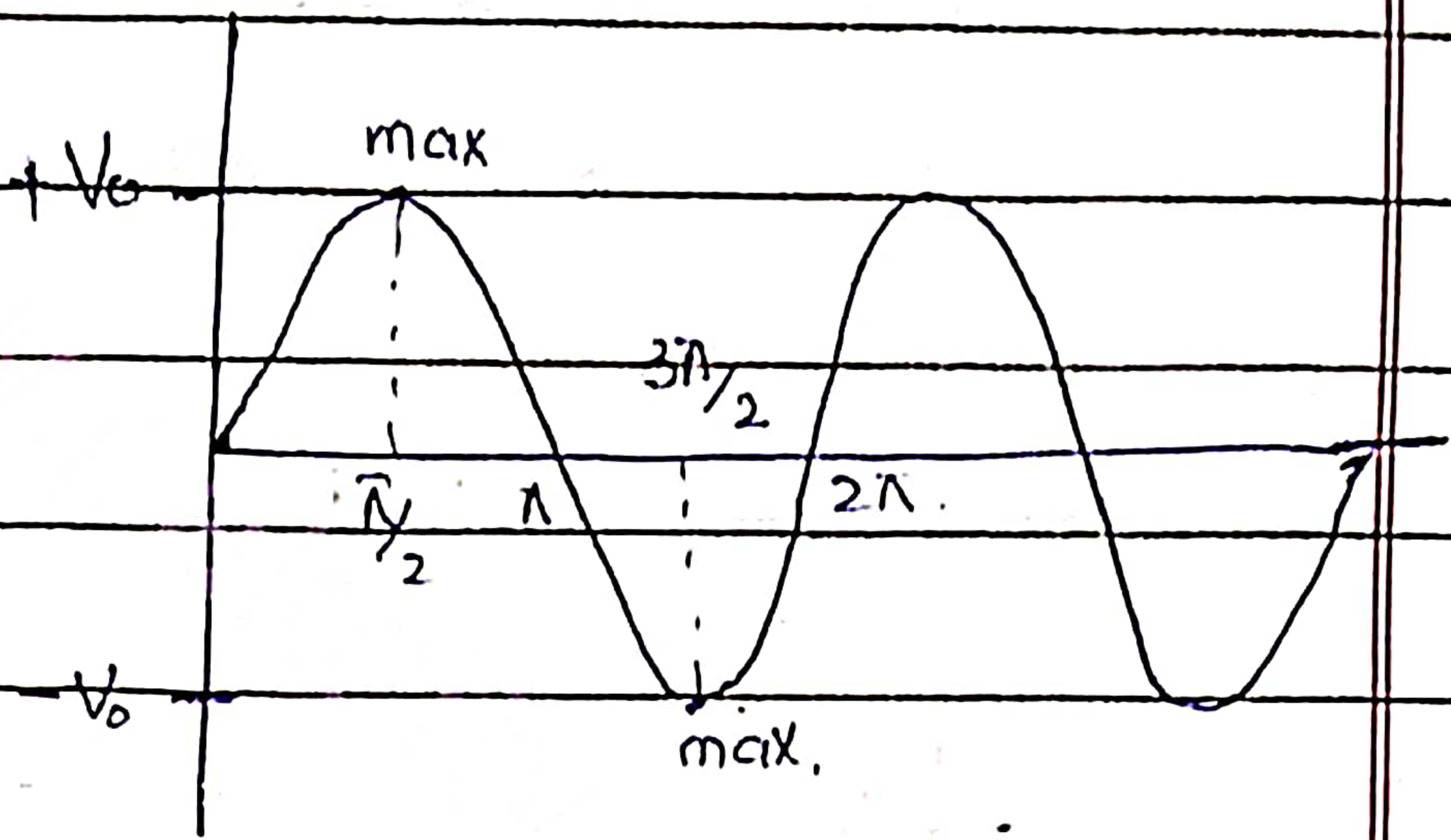
$$V = V_0 \sin \frac{2\pi}{T} \times V_0 \sin 2\pi f t.$$

Peak Value: It is the maximum value reached by the Voltage or current in one cycle. For example voltage shown in figure has a peak value of V_0 .

Peak to Peak value:

The sum of the positive and negative peak values usually written as P-P.

value. The R-P value of the voltage waveform shown in figure is $2V_0$.



Root mean square (rms) value:

The square root of mean square values of current or voltage is called root mean square (rms) value. Many electrical instrument measure rms values.

$$I_{rms} = \sqrt{\frac{0 + I_0^2}{2}} = \sqrt{\frac{I_0^2}{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$I_{rms} = 0.7 I_0$$

Similarly,

$$V_{rms} = 0.7 V_0$$

rms value is less than peak value.



Phase of A.C:

The angle θ which specifies the phase of instantaneous value of alternating voltage or current is known as its phase.

The instantaneous value of Alternating Voltage is given by

$$V = V_0 \sin \omega t$$

$$V = V_0 \sin \theta$$

The phase at the

positive peak is $\pi/2 = 90^\circ$

and it is $3\pi/2 = 270^\circ$

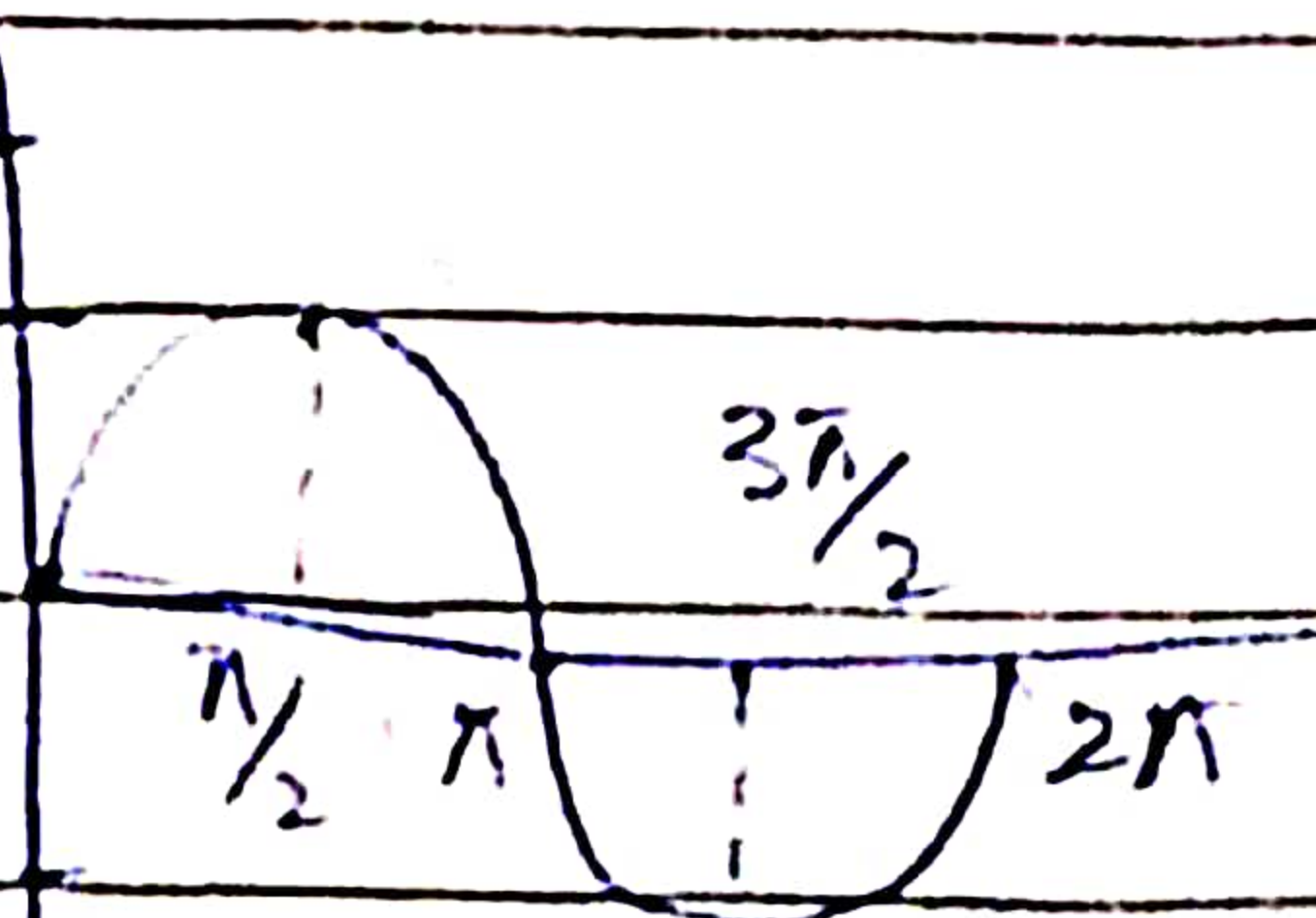
at the negative

peak. The point

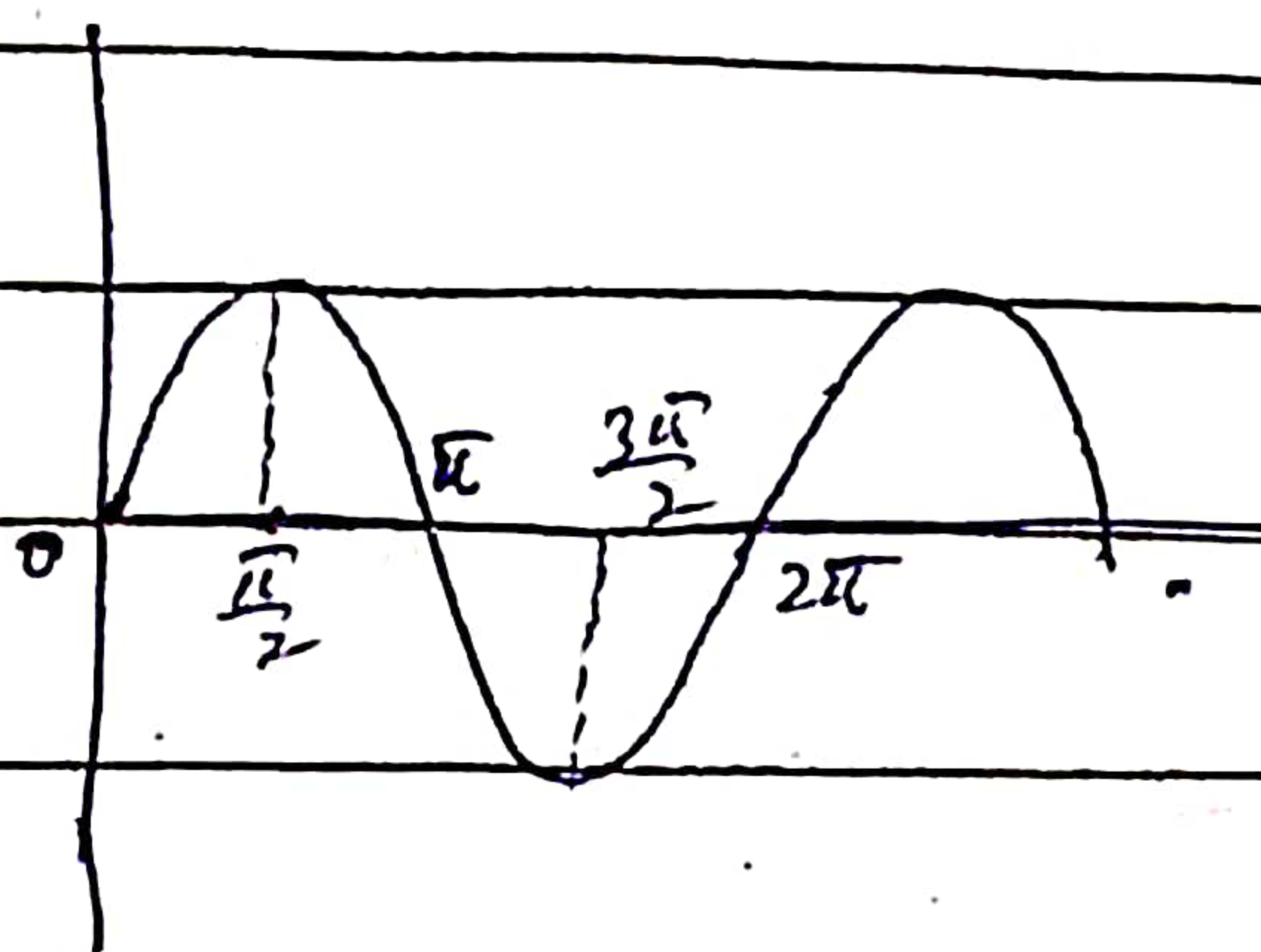
where the waveform crosses

the time axis correspond to

the phase 0 and π .

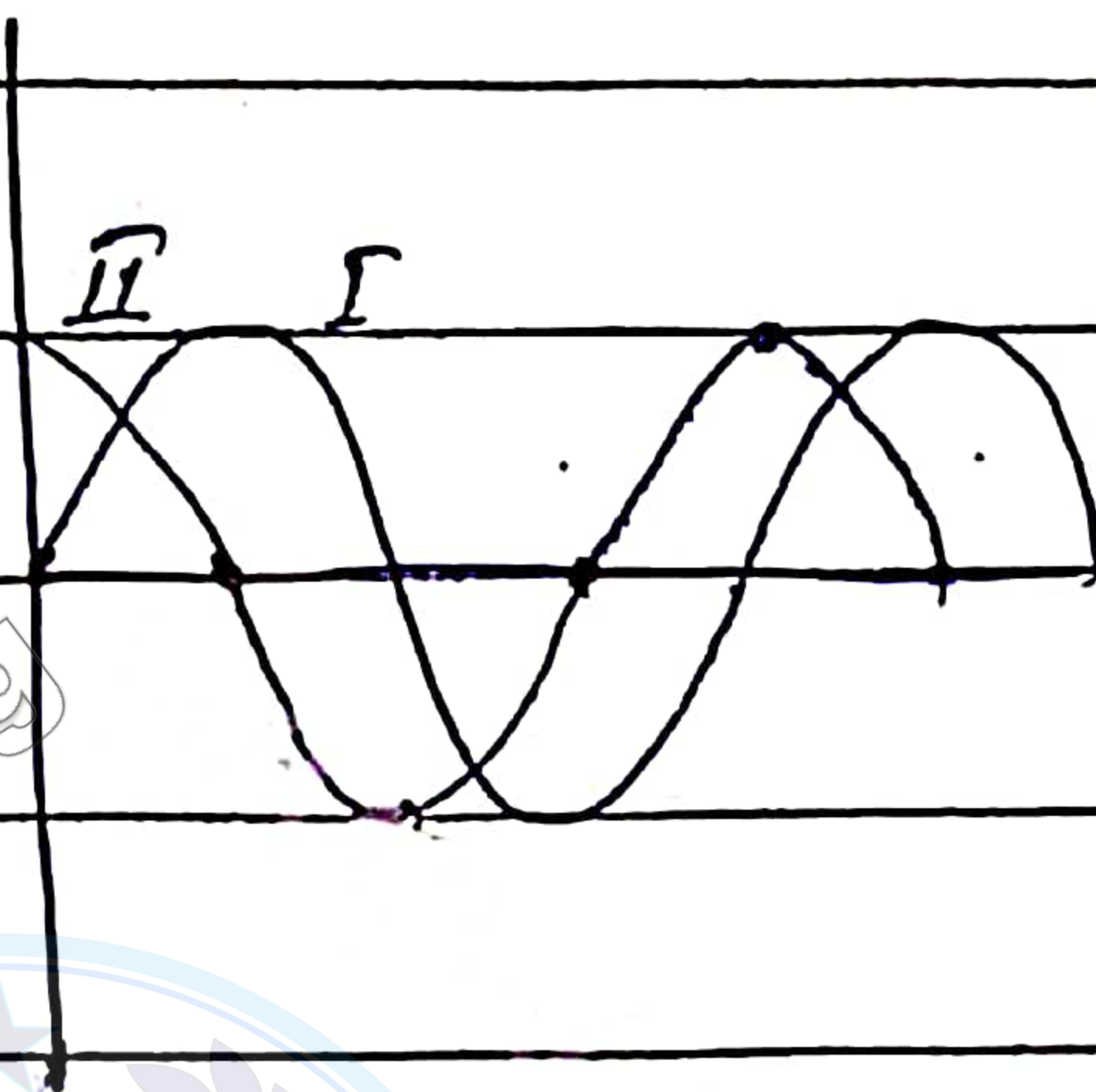


Phase lead and phase lag:

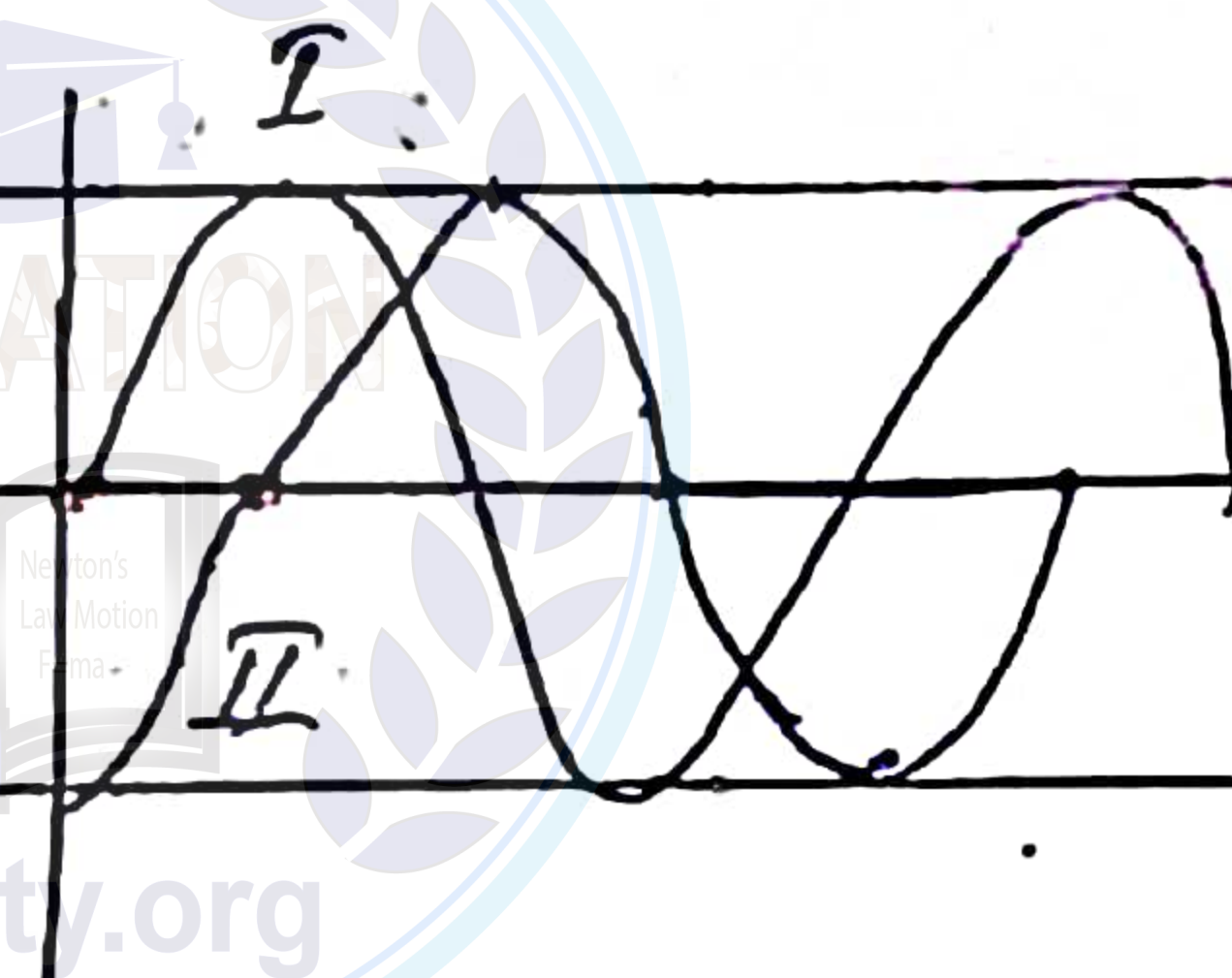


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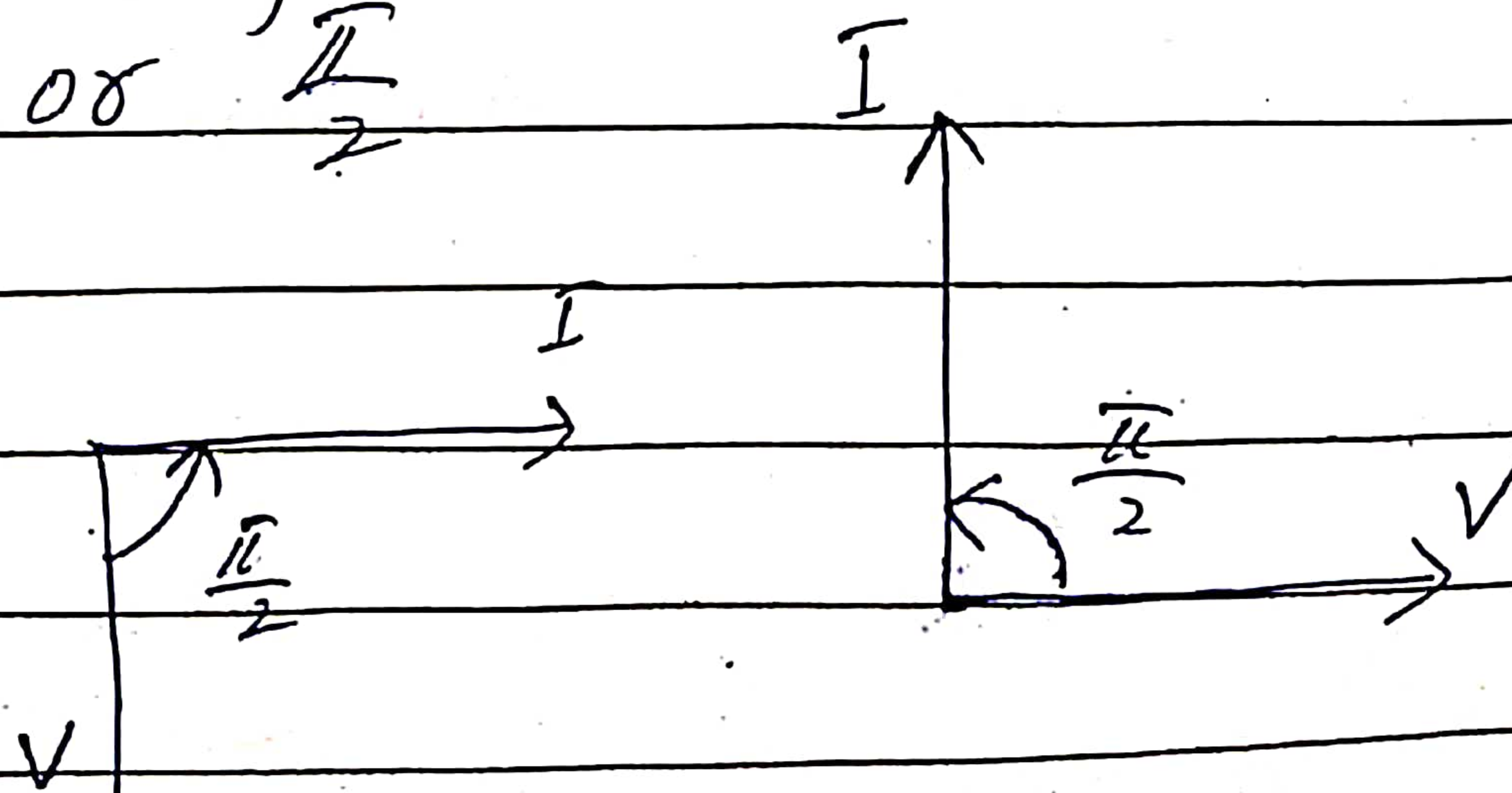
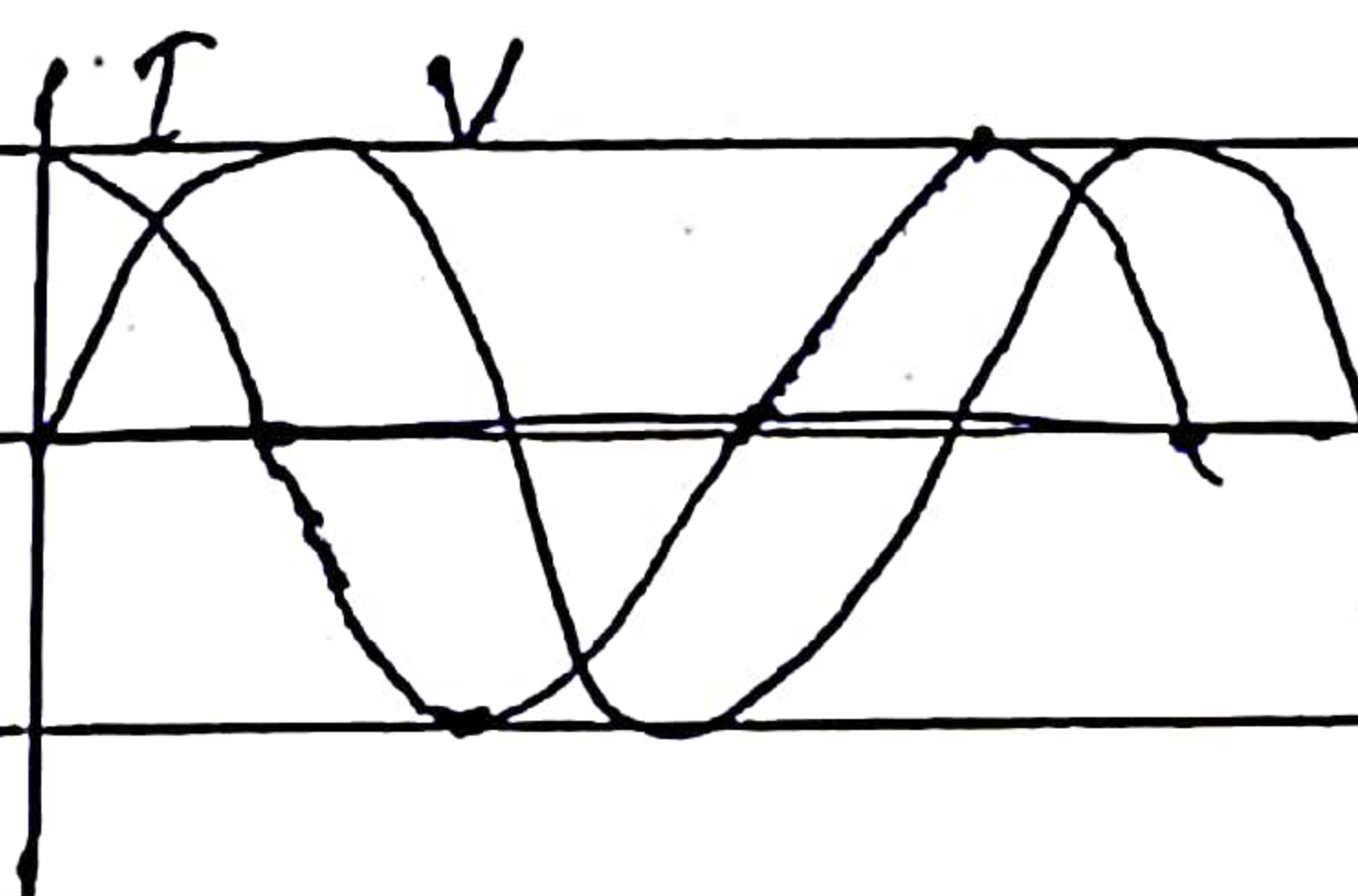
Here wave II leads and wave I lags.



Here wave I leads and wave II lags.



Here Current I leads and voltage lags by phase of 90° or $\frac{\pi}{2}$



A.C. Circuits.

D.C. Circuit:

The basic circuit element in D.C. circuit is a resistor (R) which controls the current or voltage and the relationship between them is given by Ohm's law

$$V = IR.$$

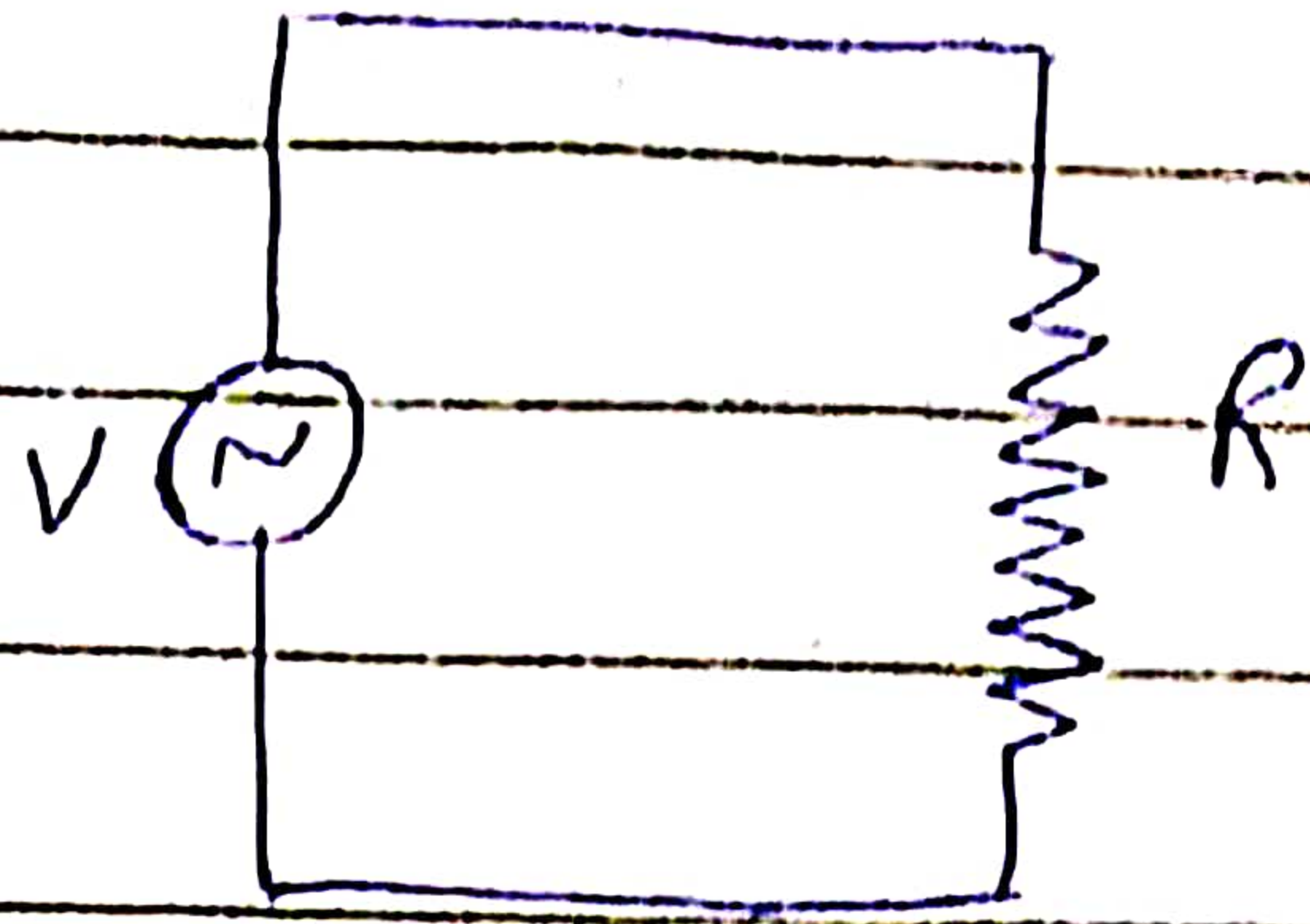


A.C. Circuit:

In A.C. circuit, in addition to Resistor (R) two new circuit elements namely inductor (L) and capacitor (C) become relevant. The current and voltages in A.C. circuit are controlled by three elements R , L and C .

AC Through A Resistor

Consider
a resistor R
connected
to AC source
in series



as shown in the figure.
The alternating voltage applied
through the source is:

$$V = V_0 \sin \omega t$$

while the current I
flowing through the circuit
is:

$$I = \frac{V}{R} = \frac{V_0 \sin \omega t}{R}$$

$$I = I_0 \sin \omega t$$

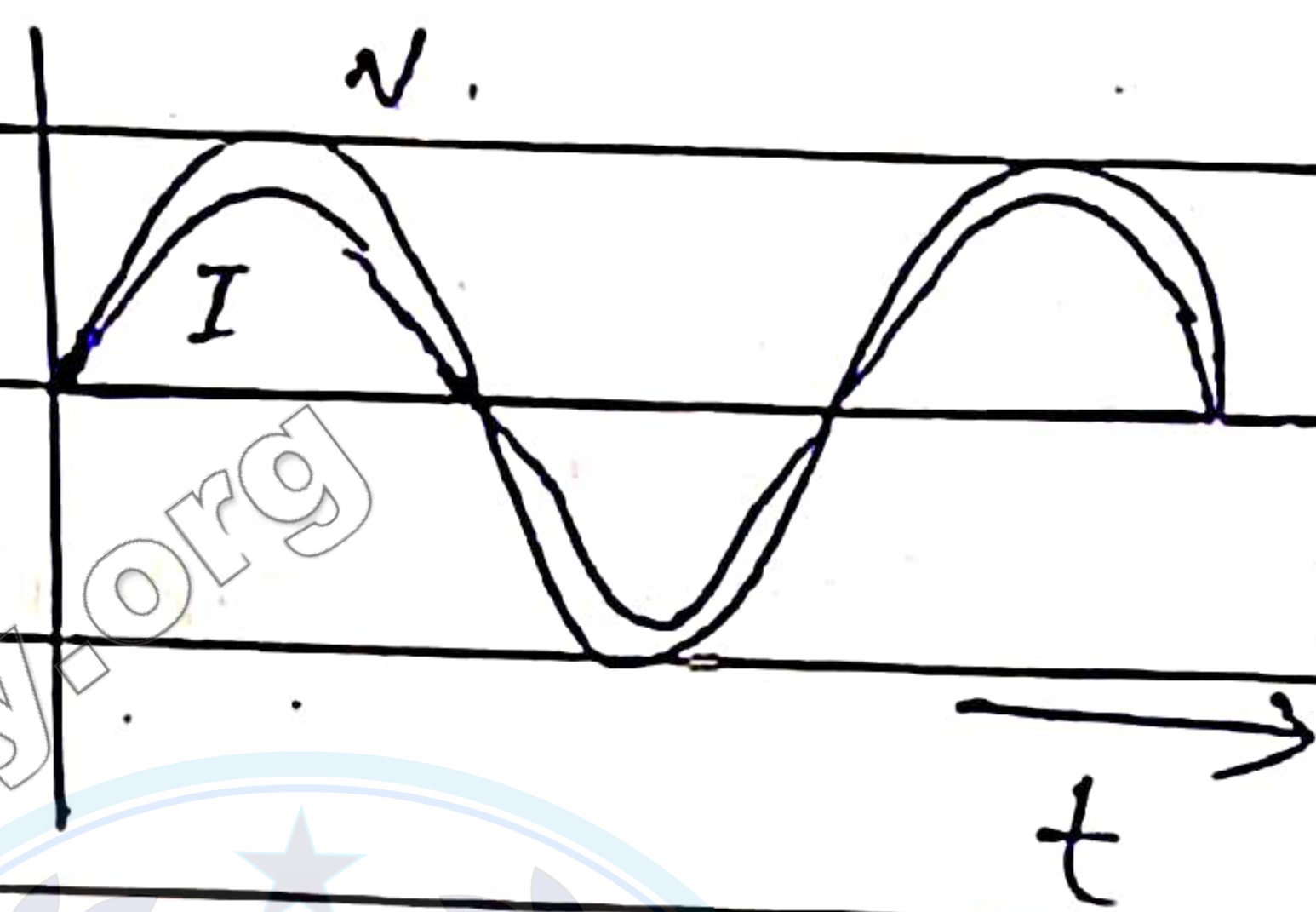
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Phase difference:

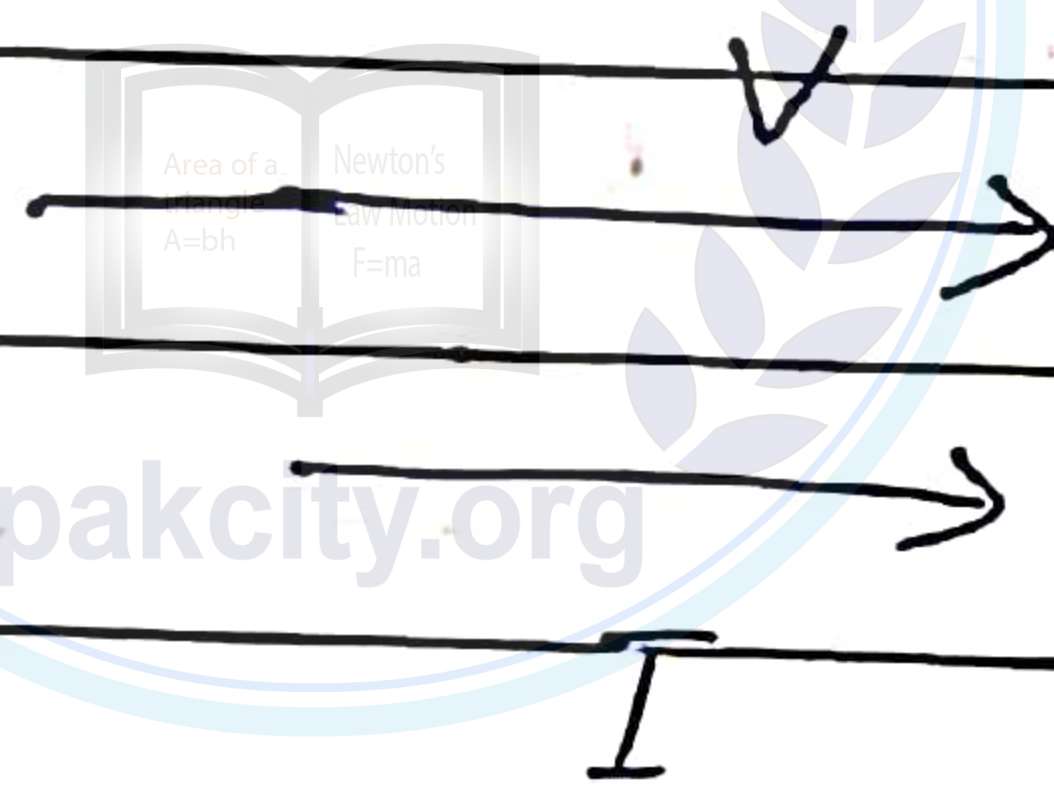
We can see that
both the voltage and
current are changing with
the same phase. Both
current and voltage are
maximum and minimum for

same phase. Therefore, for a resistive circuit voltage and current are in phase. The phase difference is zero.

Graphical representation:



Vector representation:



Power dissipation:

The opposition to the flow of electrons through the conductor is called resistance, it is due to the atoms of the conductor. Due to resistance power is dissipated across it, given by

$$P = VI$$

According to Ohm's law

$$V = IR$$

$$P = IRI$$

$$P = I^2 R$$

As

$$I = \frac{V}{R}$$

So,

$$P = V \frac{V}{R}$$

$$P = \frac{V^2}{R}$$

The power is measured in watt, voltage in volt, current in ampere and resistance in ohm.

AC Through A Capacitor

A capacitor is an electrical device used to store charge.

Consider a capacitor having capacitance C connected with AC source, switch and a bulb in

Series as shown in the figure. When the switch

is closed the current starts

flowing

in the

circuit by AC source. For the first half cycle the

capacitor is charged and for next half cycle it

discharges. In this way, the capacitor charges and discharges continuously.

The AC

voltage applied by the

source is:

$$V = V_0 \sin \omega t$$

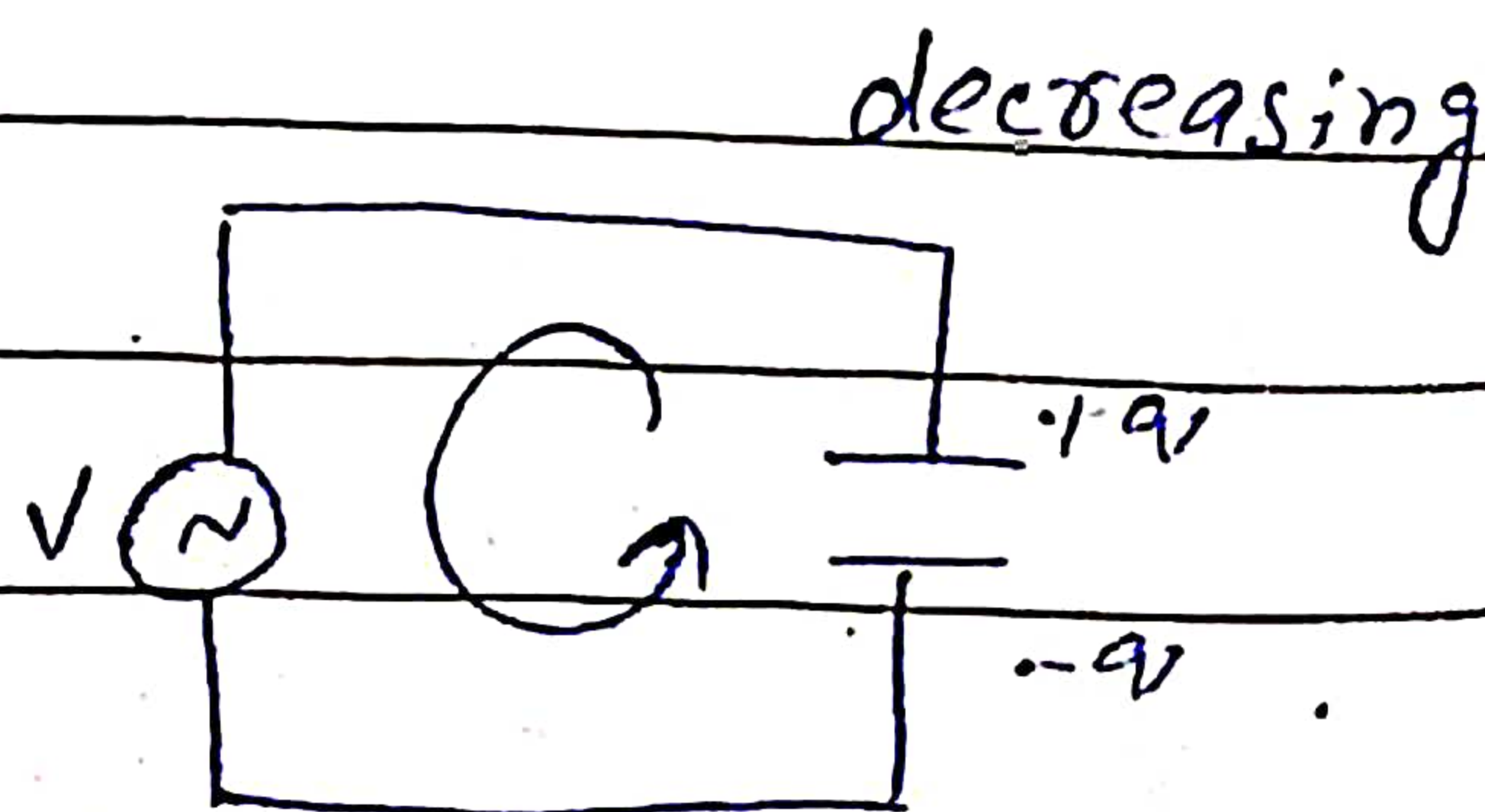
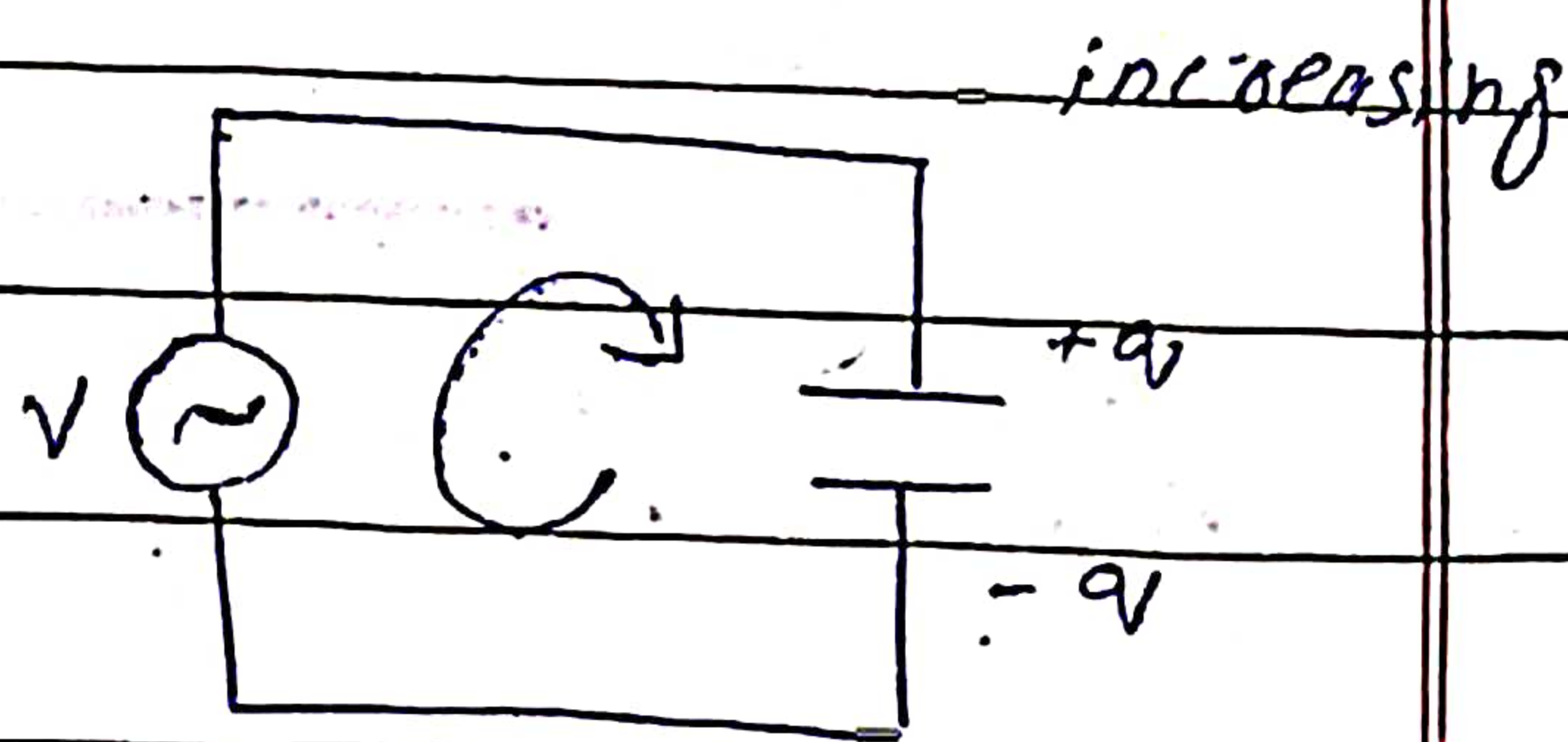
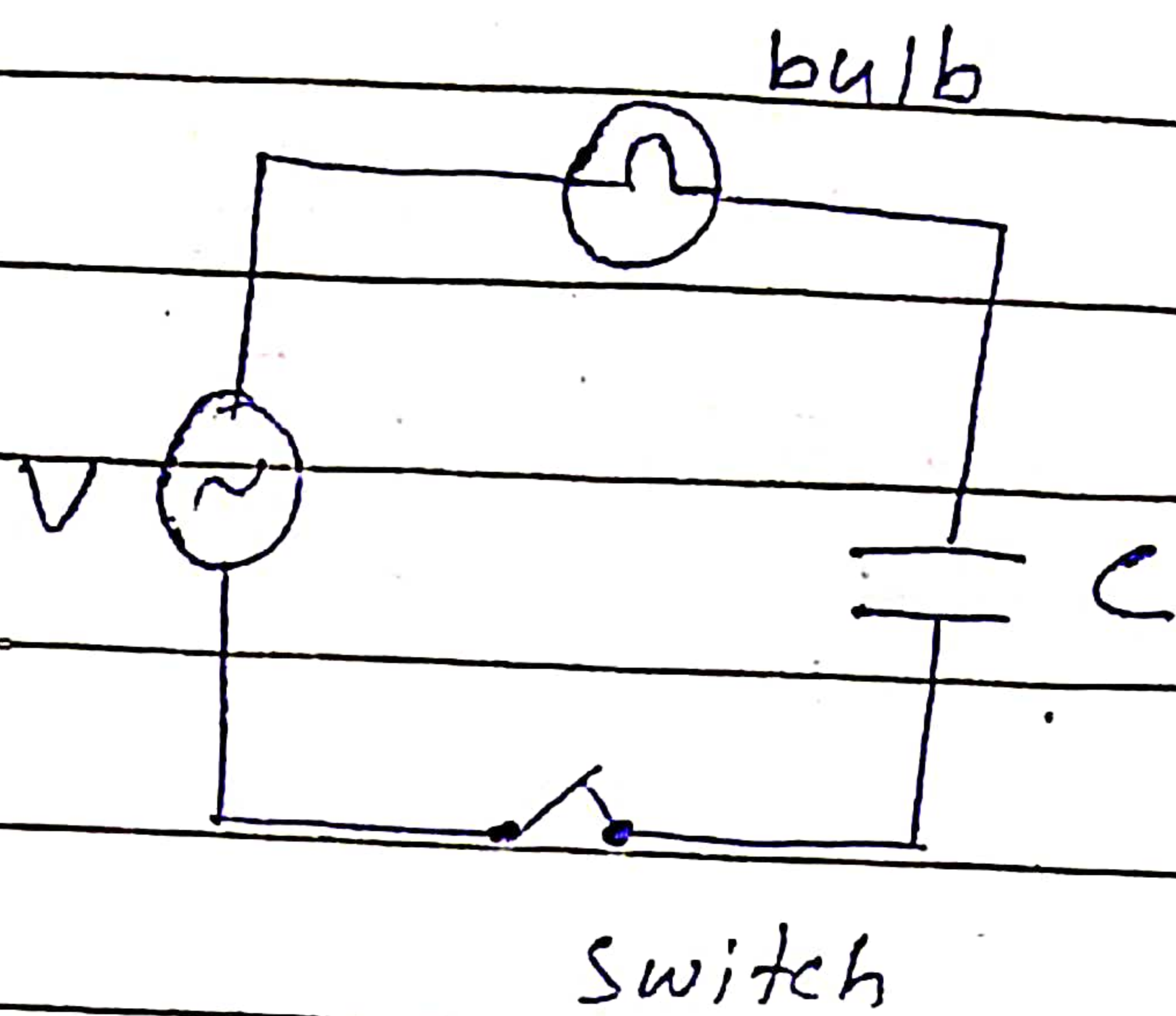
For the

charge q

stored on

the plates

of capacitor.



$$q = CV$$

$$q = CV_0 \sin \omega t$$

From the above relations we can say that voltage and charge are in phase. Now we know that current is the rate of flow of charge

$$I = \frac{\Delta q}{\Delta t}$$



The above relation shows that when $q=0$ maximum change in charge will occur. So, current is maximum. At this point voltage will also be zero.

Phase difference:

For a pure capacitive circuit, current leads the voltage by a phase of 90° or $\frac{\pi}{2}$.

Graphical representation:

The drawn

graph

shows that

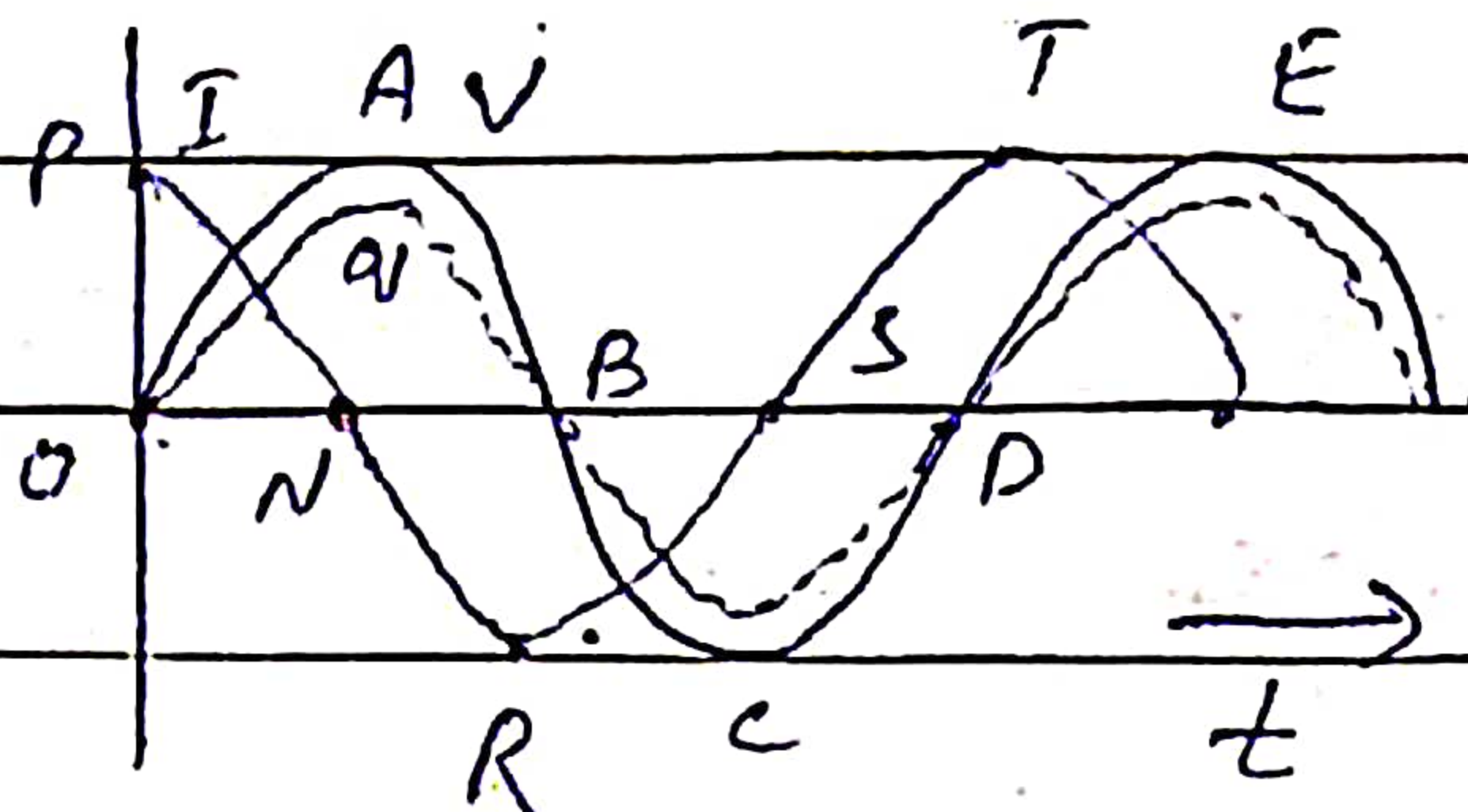
voltage (V)

and charge (q)

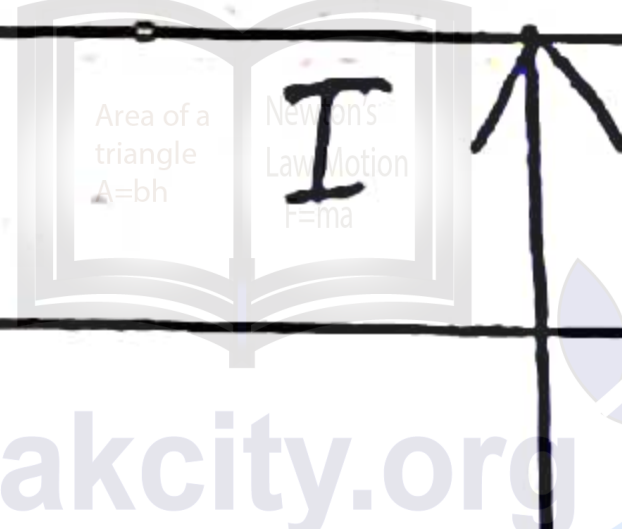
are in phase

while current (I) leads the

voltage at every point with
phase difference of $\frac{\pi}{2}$ or 90° .



Vector representation:



Capacitive reactance:

The resistance of the capacitor is called capacitive reactance. It is denoted by X_c . Mathematically,

$$X_c = \frac{V_{rms}}{I_{rms}}$$

The SI unit of x_c is ohm (Ω)

Also

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

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

→ For low frequency x_c will be large and current will be small.

→ For high frequency x_c will be small and current will be large.

Power dissipation:



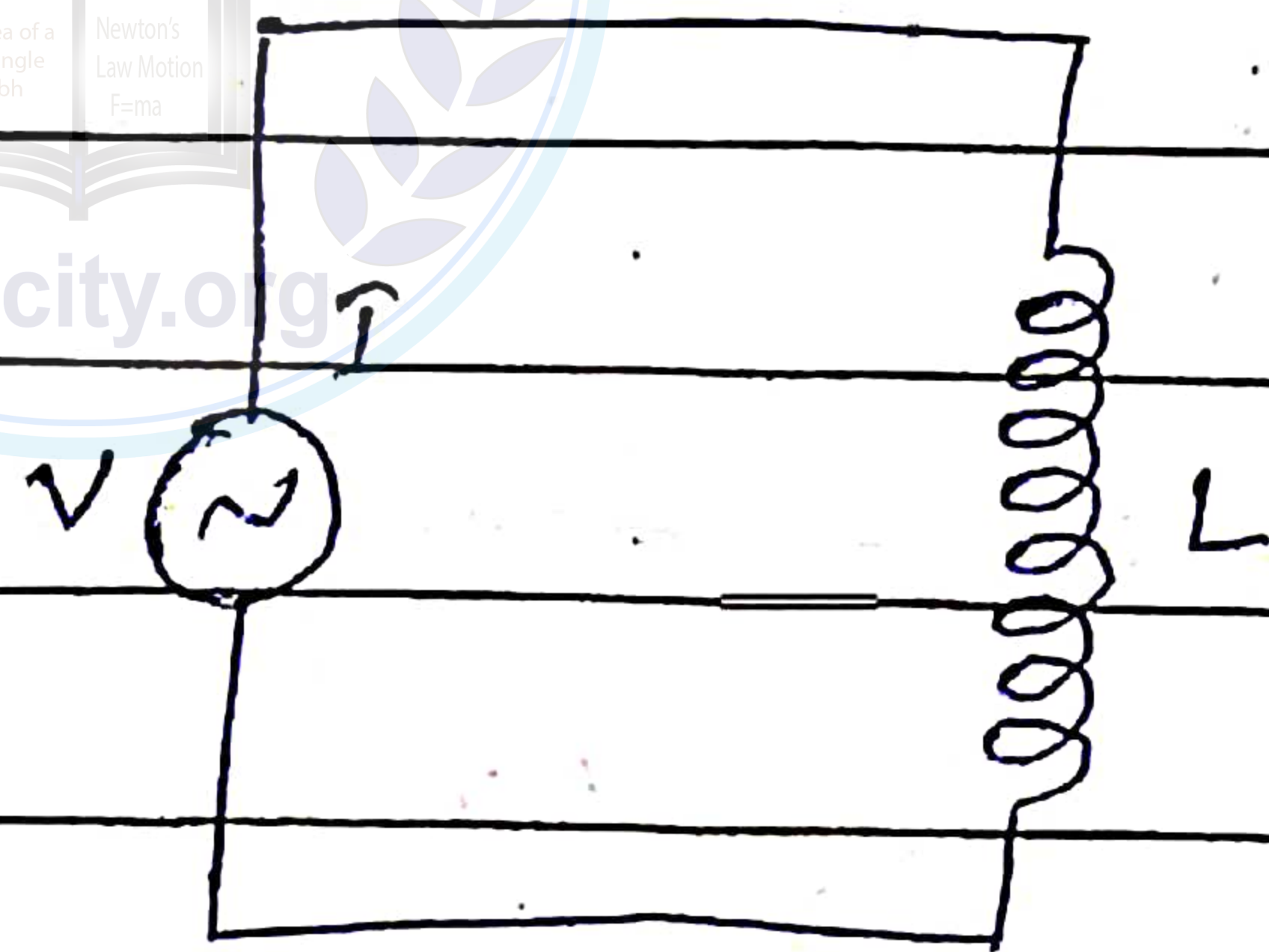
For a pure capacitive circuit, the power dissipation will be zero.

Because capacitor gets charge for positive half cycle and discharges for next negative half cycle.

AC Through An Inductor

An inductor is usually in the form of a coil or a solenoid wound on a thick wire so that it has a large value of self inductance and negligible resistance.

Consider an inductor of self inductance L connected with an AC source in series as shown in the figure. The alternating current provided by the source is:



$$I = I_0 \sin \omega t$$

$$I = I_0 \sin (2\pi f t)$$

When the current flows through the inductor it induces back emf in it given by

$$\mathcal{E} = L \frac{\Delta I}{\Delta t}$$

This back emf opposes the applied voltage. Therefore, the voltage must be equal to the back emf:

$$V = L \frac{\Delta I}{\Delta t}$$

The above relation shows that when the current is zero, maximum change in current can occur. So, voltage will be maximum. So, for a pure inductive circuit voltage leads the current by a phase of 90° or $\frac{\pi}{2}$.

Phase difference:

The phase difference between voltage and current is 90° or $\frac{\pi}{2}$. Here voltage leads the current for pure inductive circuit.

Graphical representation:

in

drawn

graph

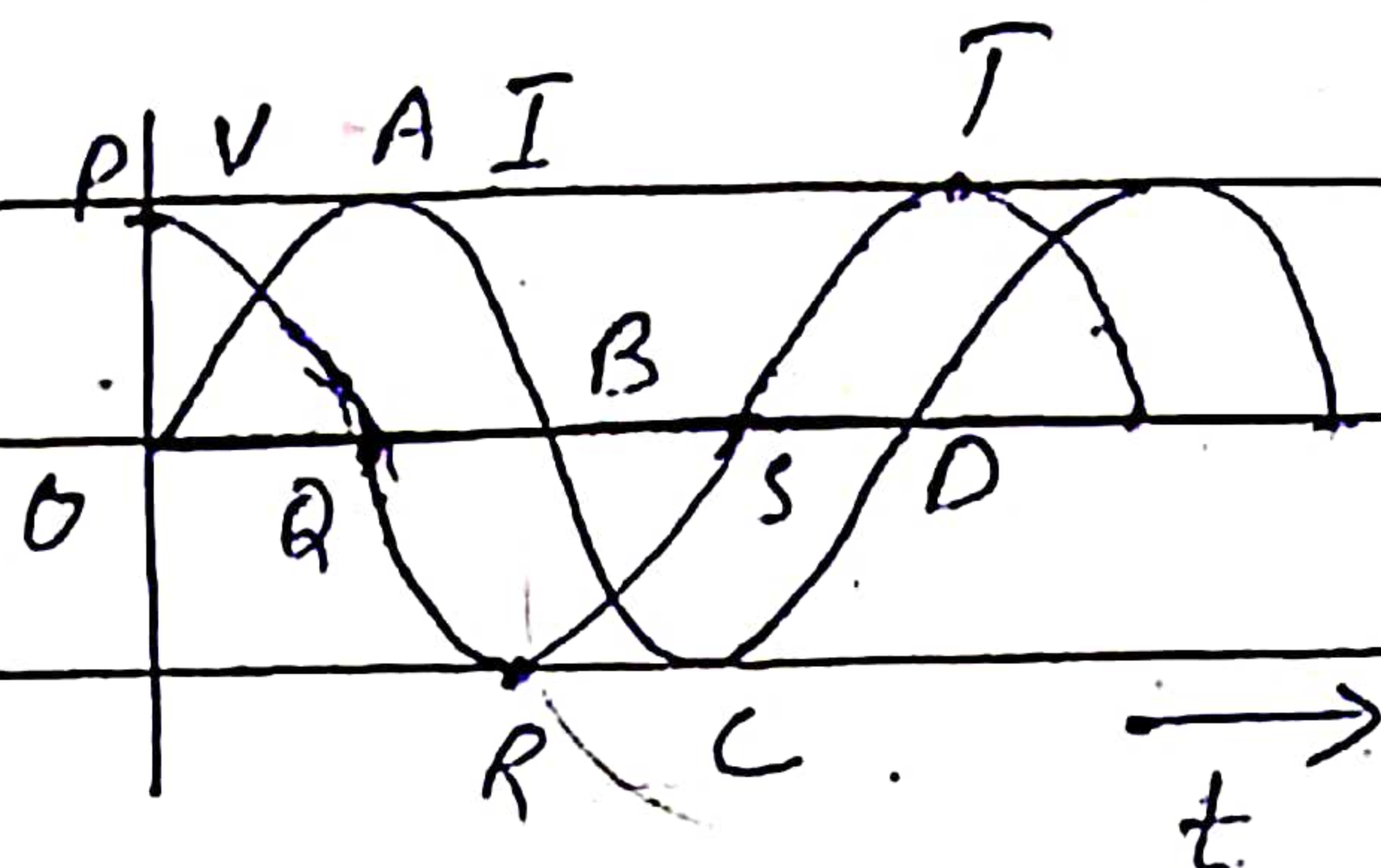
shows that

voltage

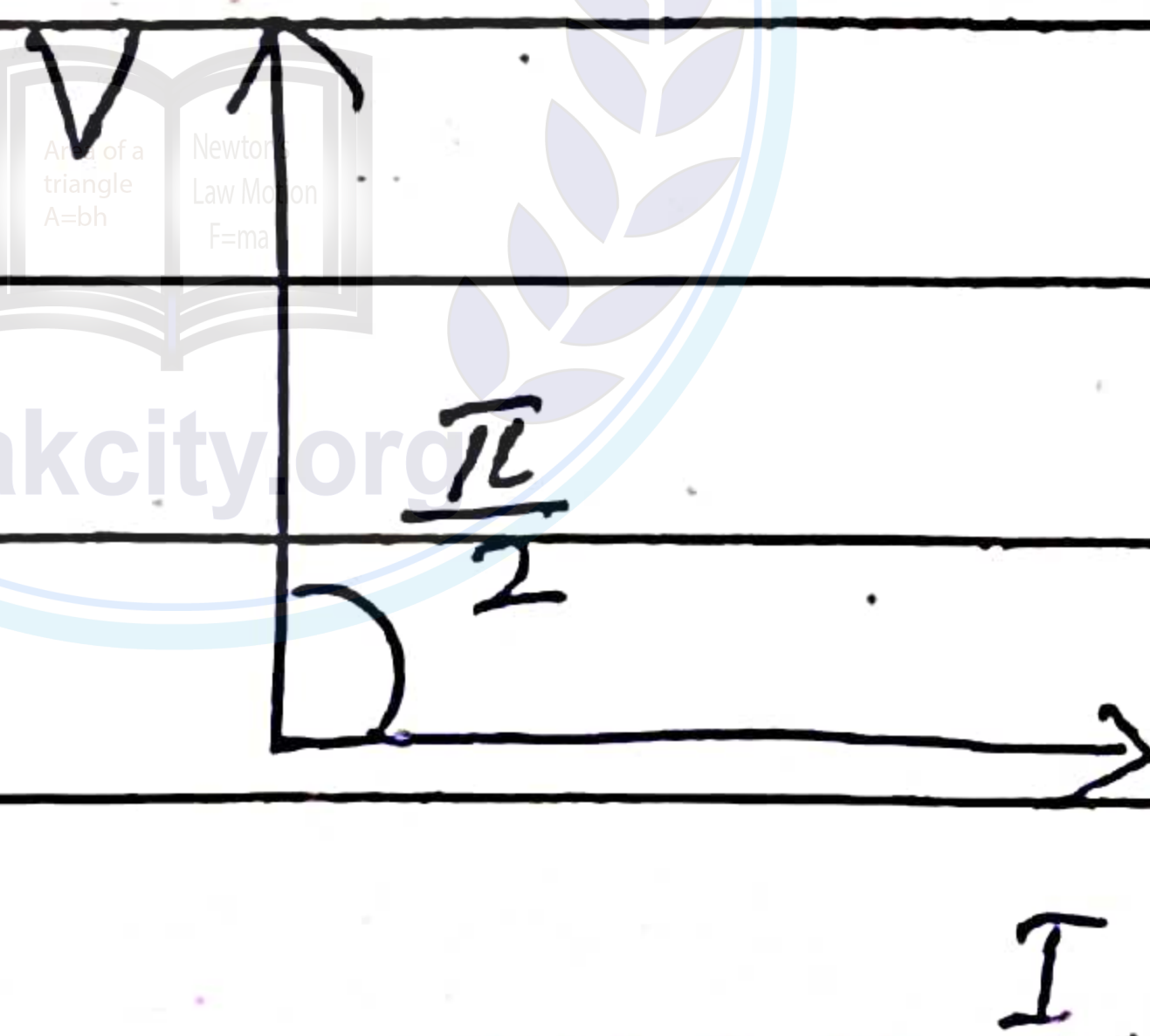
leads the

current with phase of 90°

or $\frac{\pi}{2}$ at any point in the graph.



Vector representation:



Inductive reactance:

The resistance of the inductor is known as inductive reactance. It is denoted by X_L . Mathematically,

$$X_L = \frac{V_{rms}}{I_{rms}}$$

Its SI unit is ohm.

And

$$X_L = \omega L$$

$$X_L = 2\pi f L$$

→ For low frequency,
 X_L will be small and
current will be large.

→ For high frequency,
 X_L will be large and
current will be small.

Power dissipation:

for a pure
inductive circuit, the power
dissipation will be zero.

Because for half cycle of
AC energy is stored and
for next half cycle energy
is used.

→ Impedance:

An A.C circuit may consist of a Resistance (R) an Inductance (L) and a capacitance (C) and the combination of these elements. The combine effect of Resistance and reactances in such a circuit is known as impedance.

It is denoted by (Z)

Mathematical:

$$Z = \frac{V_{rms}}{I_{rms}}$$

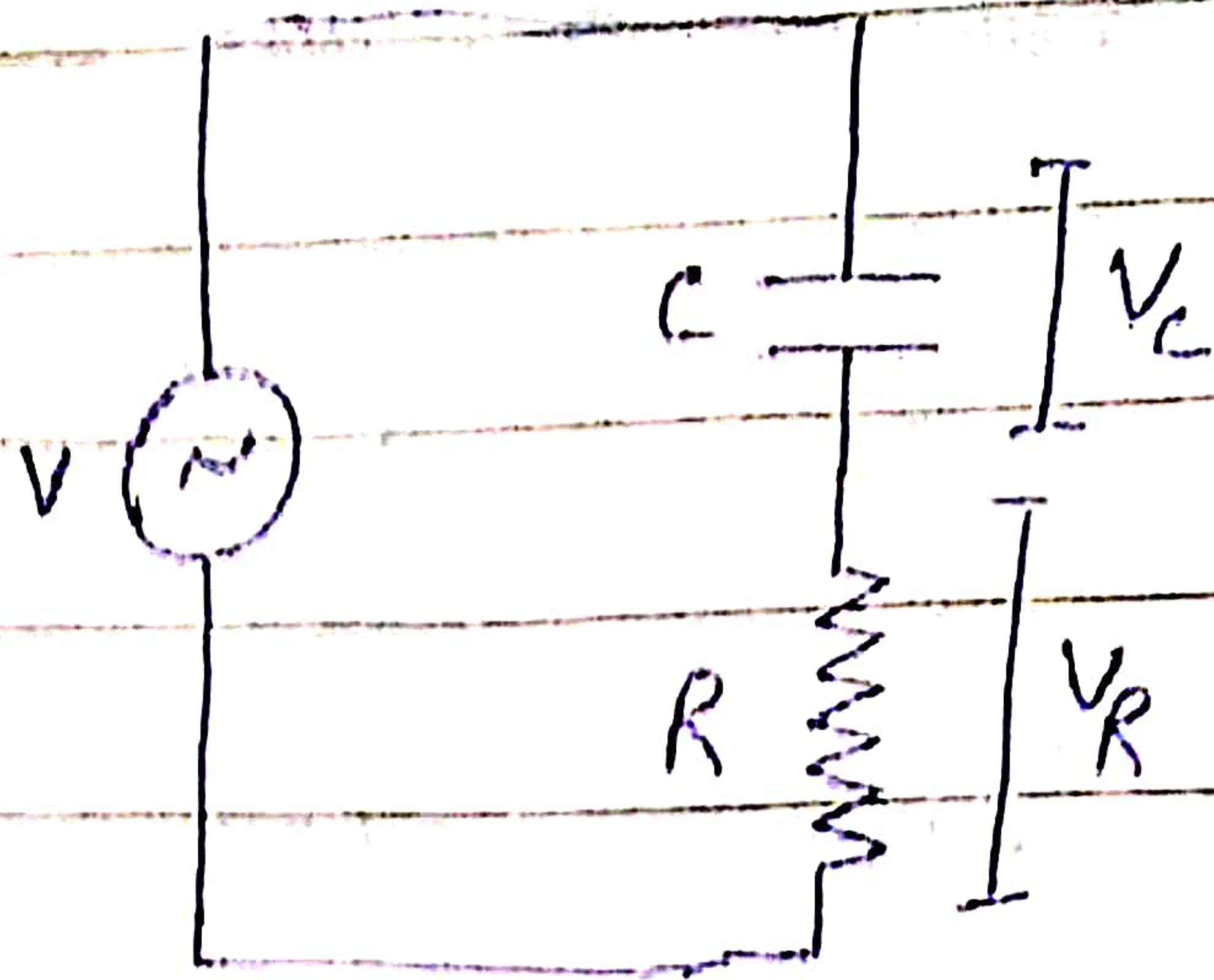
Unit:

Its unit is ohm (Ω).

R-C series Circuit

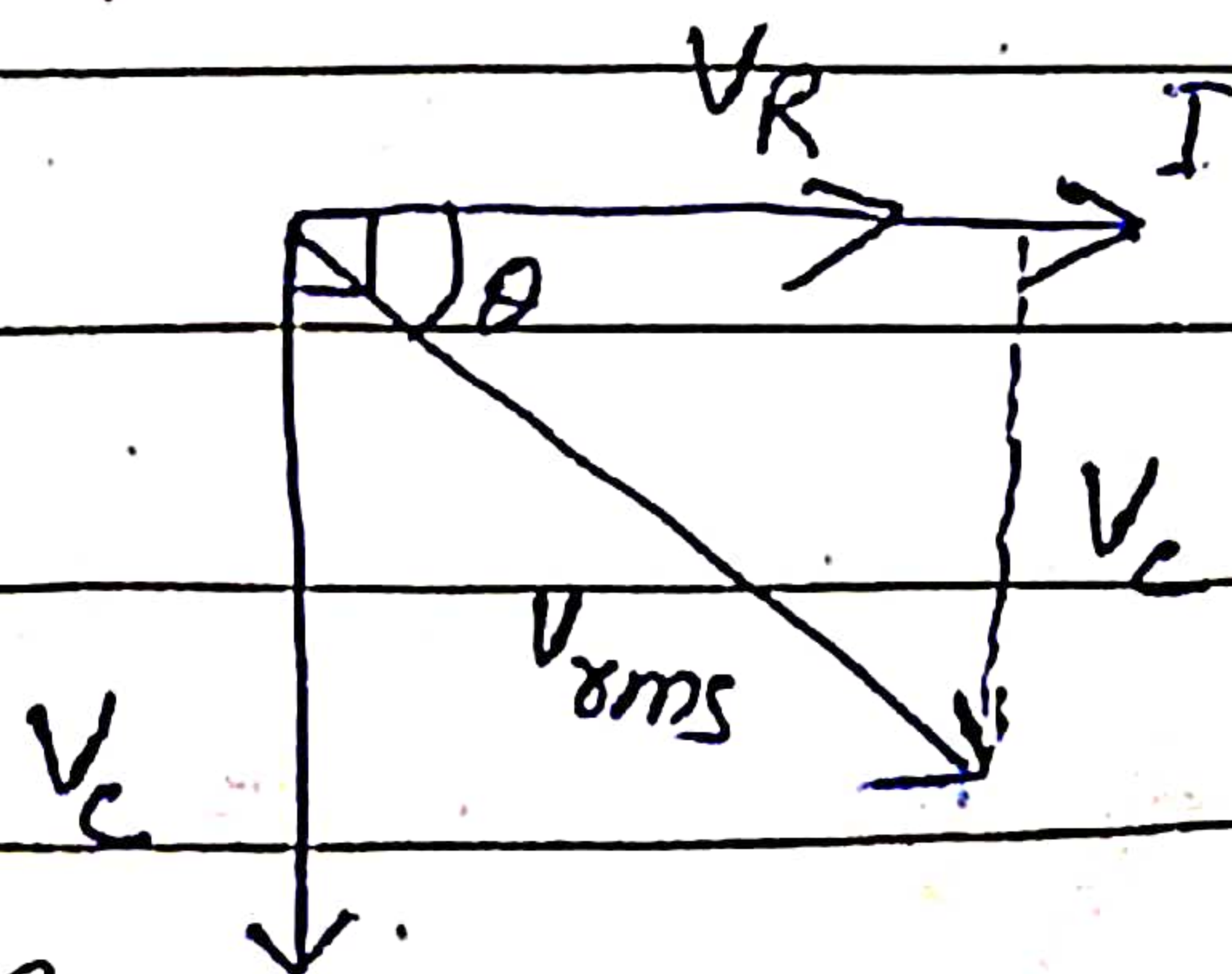
The electrical circuit in which resistor R and capacitor C are connected in series with an AC source, it is called RC series circuit.

Consider
a capacitor
of capacitance
 C and
resistor R
are connected
in series
with an



AC source having potential
difference V . For the series
combination voltage of the
source divides along capacitor
 V_C and resistor V_R . If the
current flowing in the
circuit is I_{rms} . For
resistor, voltage and current
will be in phase. For
capacitor, current leads the
voltage with a phase of
 90° or $\frac{\pi}{2}$.

By applying
Pythagorean theorem



$$(\text{hyp})^2 = (\text{base})^2 + (\text{perp})^2$$

$$V_{rms}^2 = V_R^2 + V_C^2$$

$$= (I_{rms} R)^2 + (I_{rms} X_C)^2$$

$$V_{rms}^2 = I_{rms}^2 (R^2 + X_C^2)$$

$$\sqrt{V_{rms}^2} = \sqrt{I_{rms}^2 (R^2 + X_C^2)}$$

$$V_{rms} = I_{rms} \sqrt{R^2 + X_C^2}$$

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

So, impedance of the circuit will be:

$$\boxed{\text{impedance} = Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}}$$

For the shown graph:

$$\tan \theta = \frac{\text{Perp}}{\text{base}}$$

$$= \frac{V_C}{V_R}$$

$$= \frac{I_{rms} X_C}{I_{rms} R}$$

$$\tan \theta = \frac{X_C}{R}$$

$$\theta = \tan^{-1} \frac{X_c}{R}$$

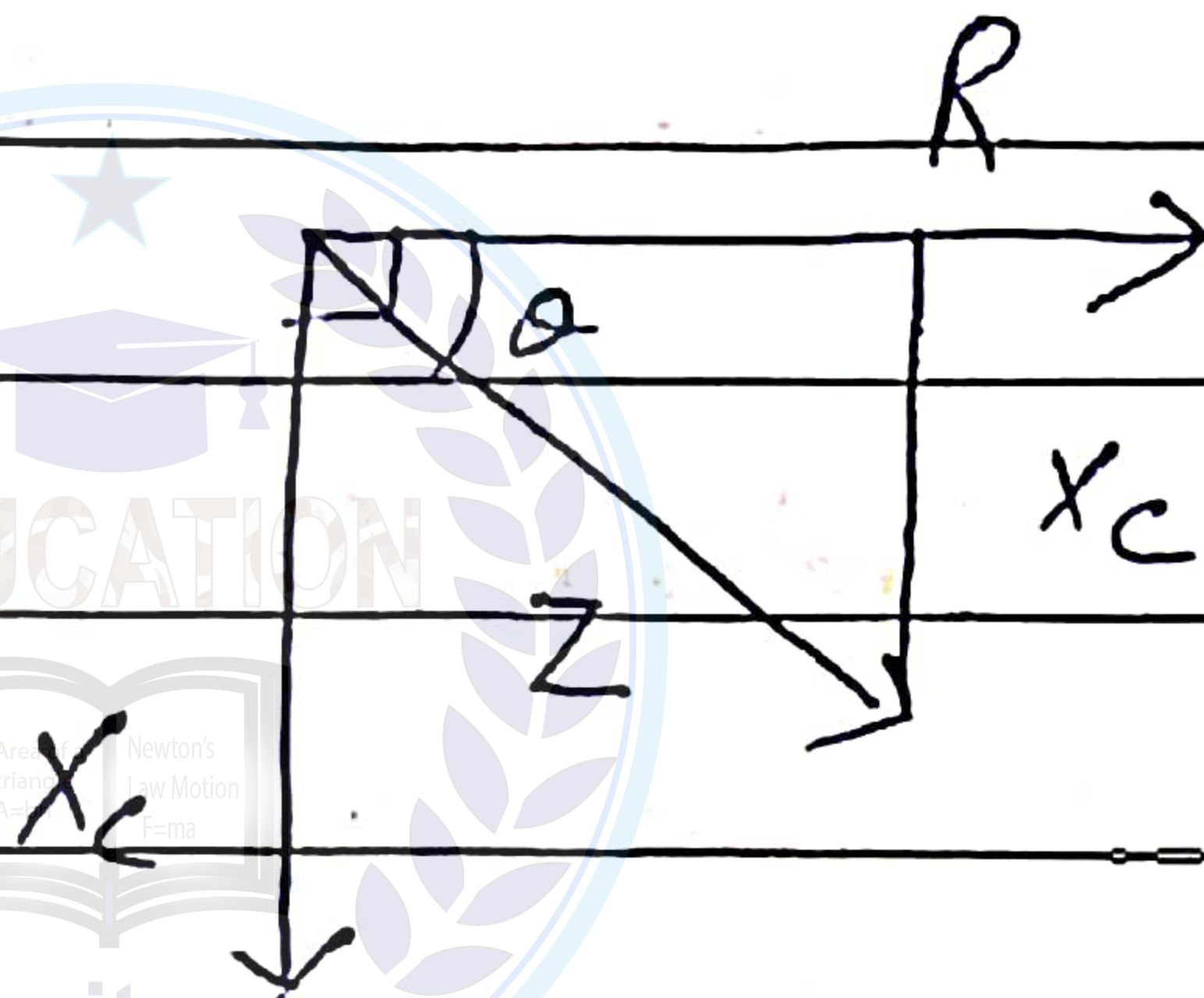
$$= \tan^{-1} \left(\frac{\frac{1}{\omega C}}{R} \right)$$

$$\theta = \tan^{-1} \left(\frac{1}{\omega CR} \right)$$

If ~~the~~^{we} draw the graph that shows the relation between impedance, resistance and capacitive reactance.

Applying

Pythagorean theorem:



$$(\text{hyp})^2 = (\text{base})^2 + (\text{perp})^2$$

$$Z^2 = R^2 + X_c^2$$

$$\sqrt{Z^2} = \sqrt{R^2 + X_c^2}$$

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

And

$$\tan \theta = \frac{\text{perp}}{\text{base}}$$

$$\tan \theta = \frac{X_L}{R}$$

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

$$\theta = \tan^{-1} \left(\frac{1}{\omega CR} \right)$$

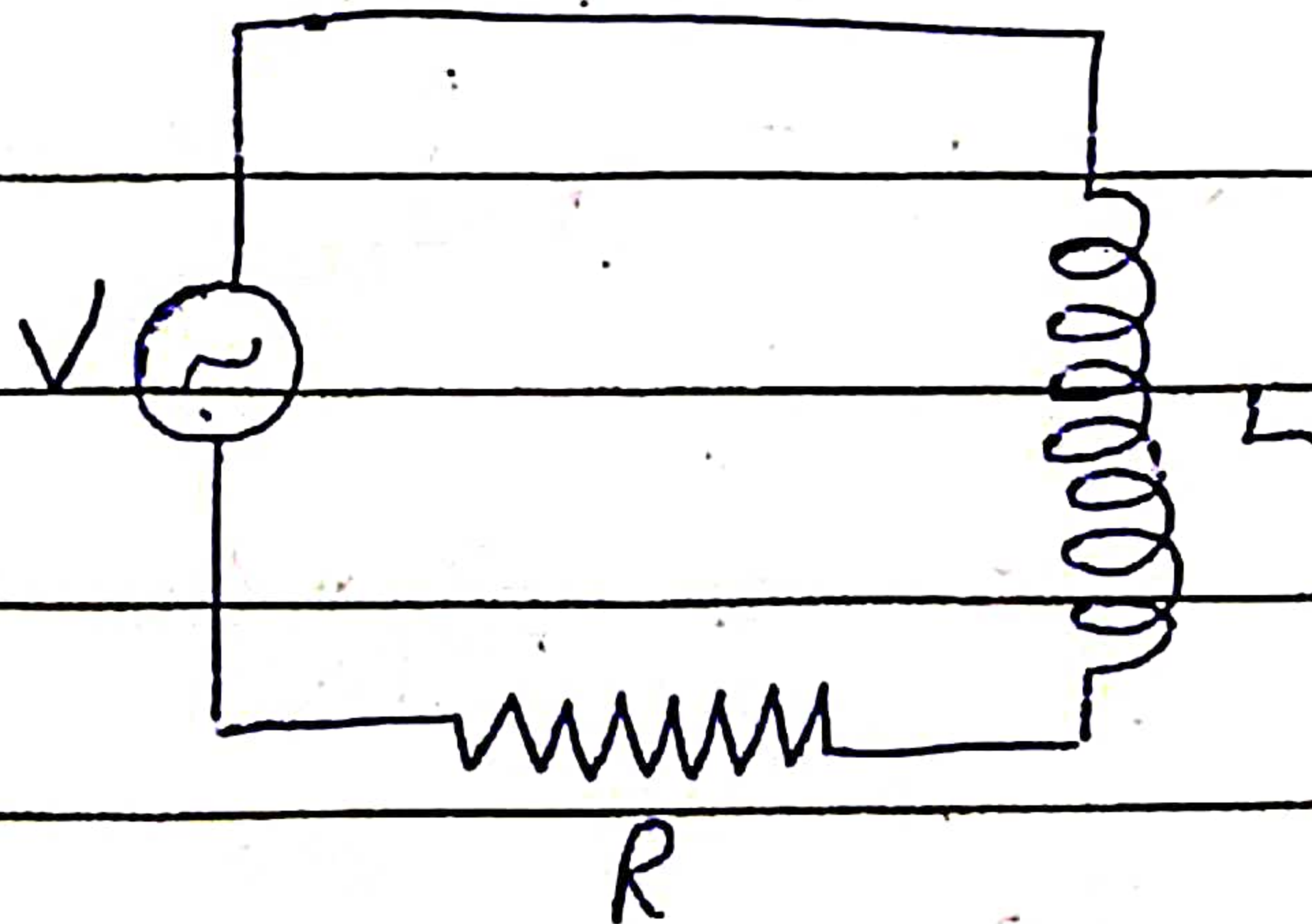
This is the angle made between impedance Z and resistance R . This is the phase difference between voltage V and current I .

R-L Series Circuit

The electrical circuit in which resistor R and inductor L are connected in series with an AC source is called RL series circuit.

Consider

an inductor having inductance L and resistor R connected in

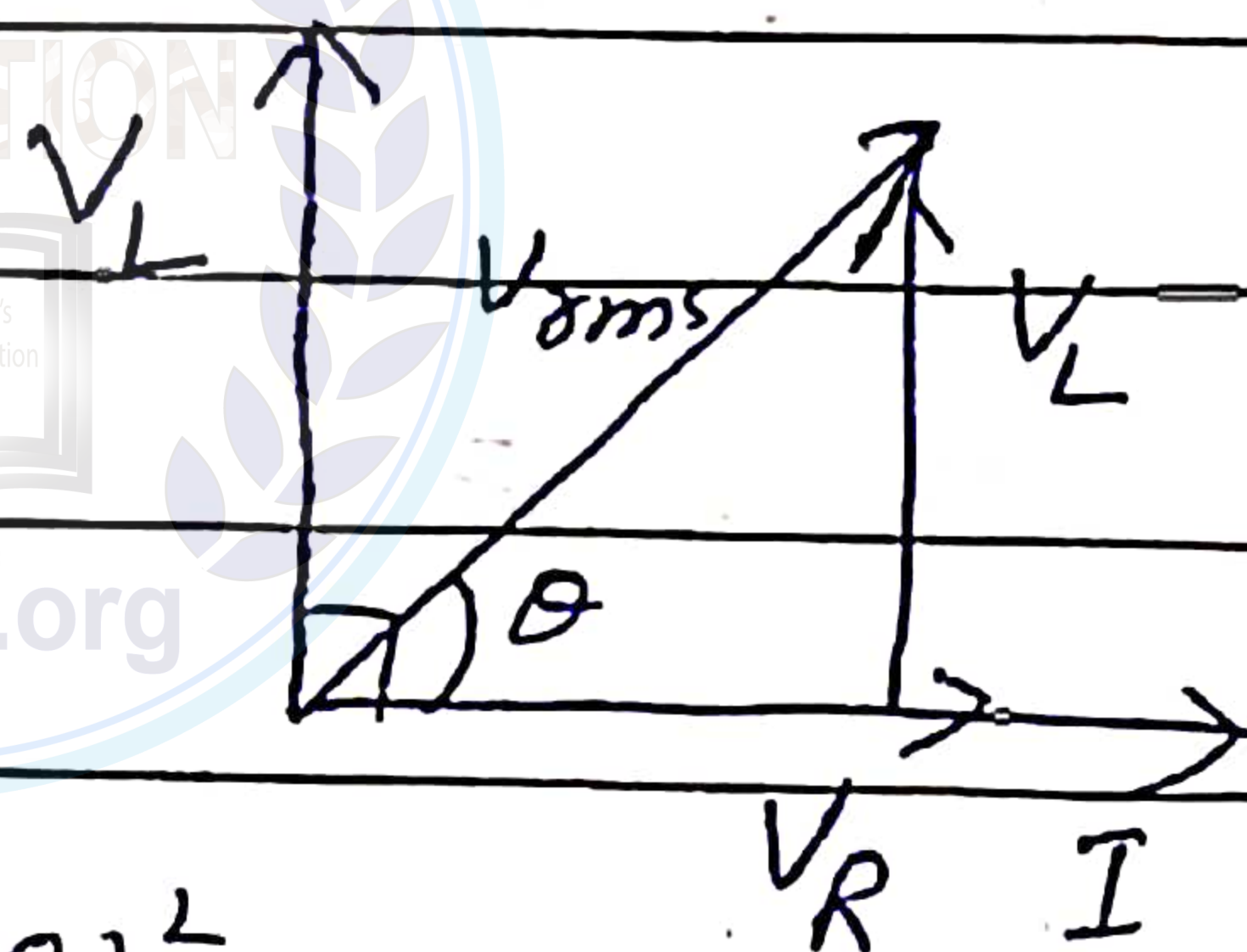


series with an AC source

having potential difference V as shown in the figure.

For the series combination voltage divides across the inductor and resistor. If the current I is flowing in the circuit. For resistor, current and voltage are in phase while for inductor voltage leads the current with phase of 90° or $\frac{\pi}{2}$.

Applying
Pythagorean
theorem:



$$(\text{hyp})^2 = (\text{base})^2 + (\text{perp})^2$$

$$V_{rms}^2 = V_R^2 + V_L^2$$

$$= (\hat{I}_{rms} R)^2 + (\hat{I}_{rms} X_L)^2$$

$$V_{rms}^2 = \hat{I}_{rms}^2 (R^2 + X_L^2)$$

$$\sqrt{V_{rms}^2} = \sqrt{\hat{I}_{rms}^2 (R^2 + X_L^2)}$$

$$\frac{V_{rms}}{I_{rms}} = \sqrt{R^2 + X_L^2}$$

$$Z = \sqrt{R^2 + (\omega L)^2}$$

This is the expression for impedance of RL series circuit.

For the shown graph

$$\tan \theta = \frac{\text{opp}}{\text{base}}$$

$$= \frac{V_L}{V_R}$$

$$= \frac{I_{rms} X_L}{I_{rms} R}$$

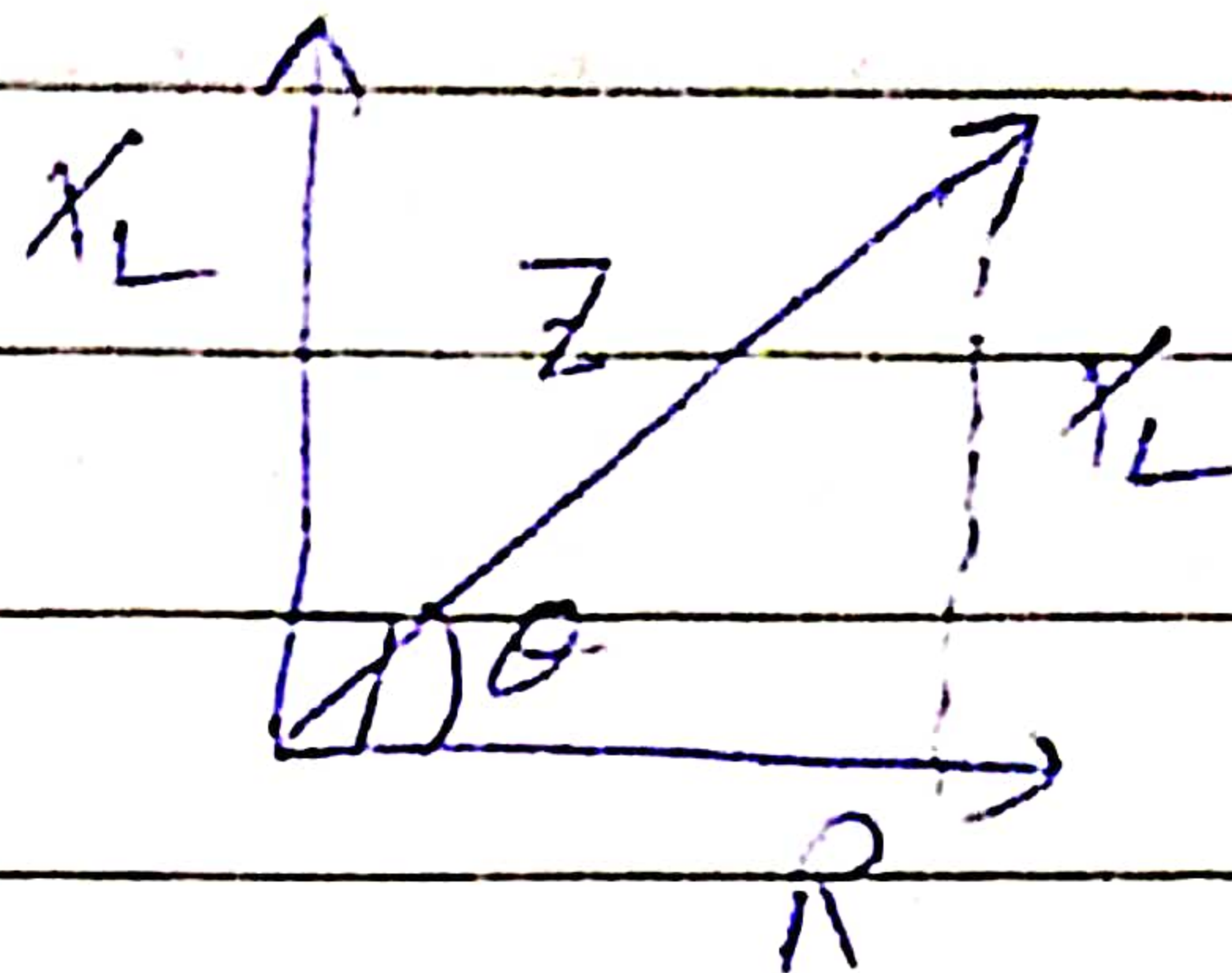
$$\tan \theta = \frac{X_L}{R}$$

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

$$\theta = \tan^{-1} \frac{\omega L}{R}$$

If we draw the graph that shows the relation between impedance, resistance and inductive reactance.

Applying
Pythagorean
theorem:



$$(\text{hyp})^2 = (\text{base})^2 + (\text{perp})^2$$

$$Z^2 = R^2 + X_L^2$$

$$Z = \sqrt{R^2 + X_L^2}$$

$$Z = \sqrt{R^2 + (\omega L)^2}$$

and $\tan \theta = \frac{\text{perp}}{\text{base}}$

$$\tan \theta = \frac{X_L}{R}$$

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

$$\theta = \tan^{-1} \left(\frac{\omega L}{R} \right)$$

This is the angle between impedance and resistance R which is also phase difference between voltage V and current I .

Power in A.C circuit:

The power in A.C circuit is

The phase difference between applied voltage (V) and current (I) is $V_{rms} \cos \theta$

Actually it is this component of voltage vector which is in phase with current. So, the power dissipated in A.C circuit.

$$P = I_{rms} \times V_{rms} \cos \theta$$

The factor $\cos \theta$ is known as (power factor)

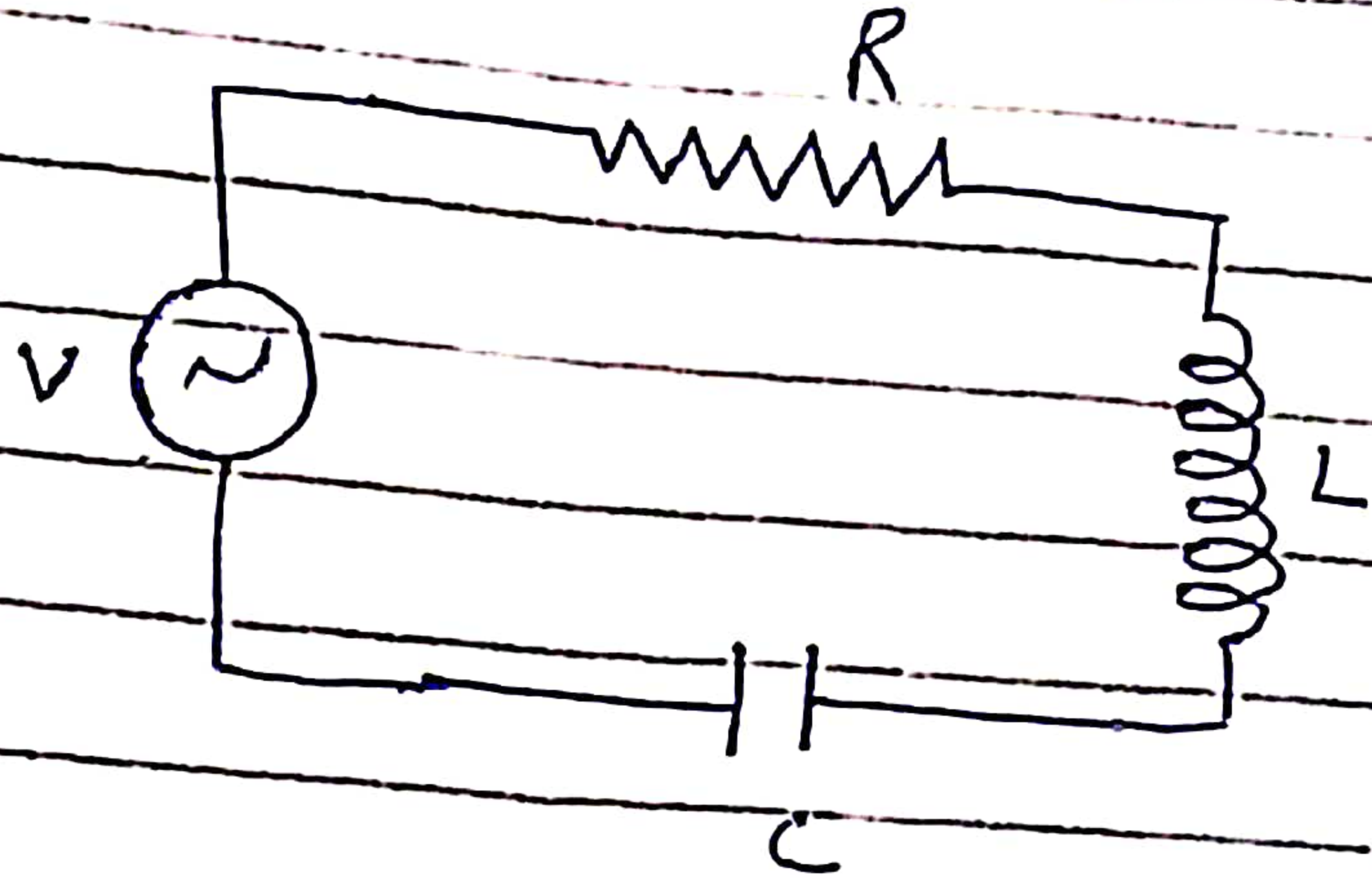
Series Resonance Circuit

The electrical circuit in which resistor R , capacitor C and inductor L are connected in series with an AC source having potential difference V as shown in the figure. The capacitive reactance

is

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

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



while inductive reactance is given by

$$X_L = \omega L$$

$$X_L = 2\pi f L$$

For the low frequency, the capacitive reactance X_c will be greater than inductive reactance X_L . So, capacitance dominates at low frequency and circuit will behave as RC circuit.

For the high frequency the inductive reactance X_L will be greater than capacitive reactance X_c . So, inductance dominates at high frequency and circuit will behave as RL circuit.

Resonance frequency:

The specific frequency at which inductive and capacitive reactances becomes equal ($X_C = X_L$) is called resonance frequency. This condition is called resonance. Now

$$X_C = X_L$$

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

$$\frac{1}{LC} = \omega^2$$

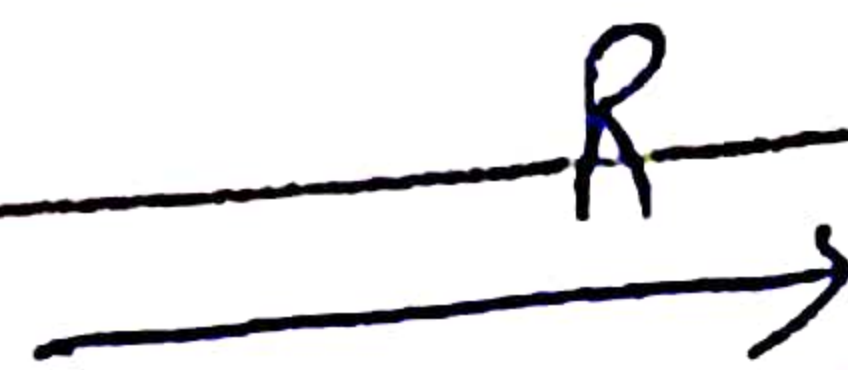
$$\sqrt{\omega^2} = \sqrt{\frac{1}{LC}}$$

$$2\omega = \frac{1}{\sqrt{LC}}$$

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

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

At resonance:



Properties:

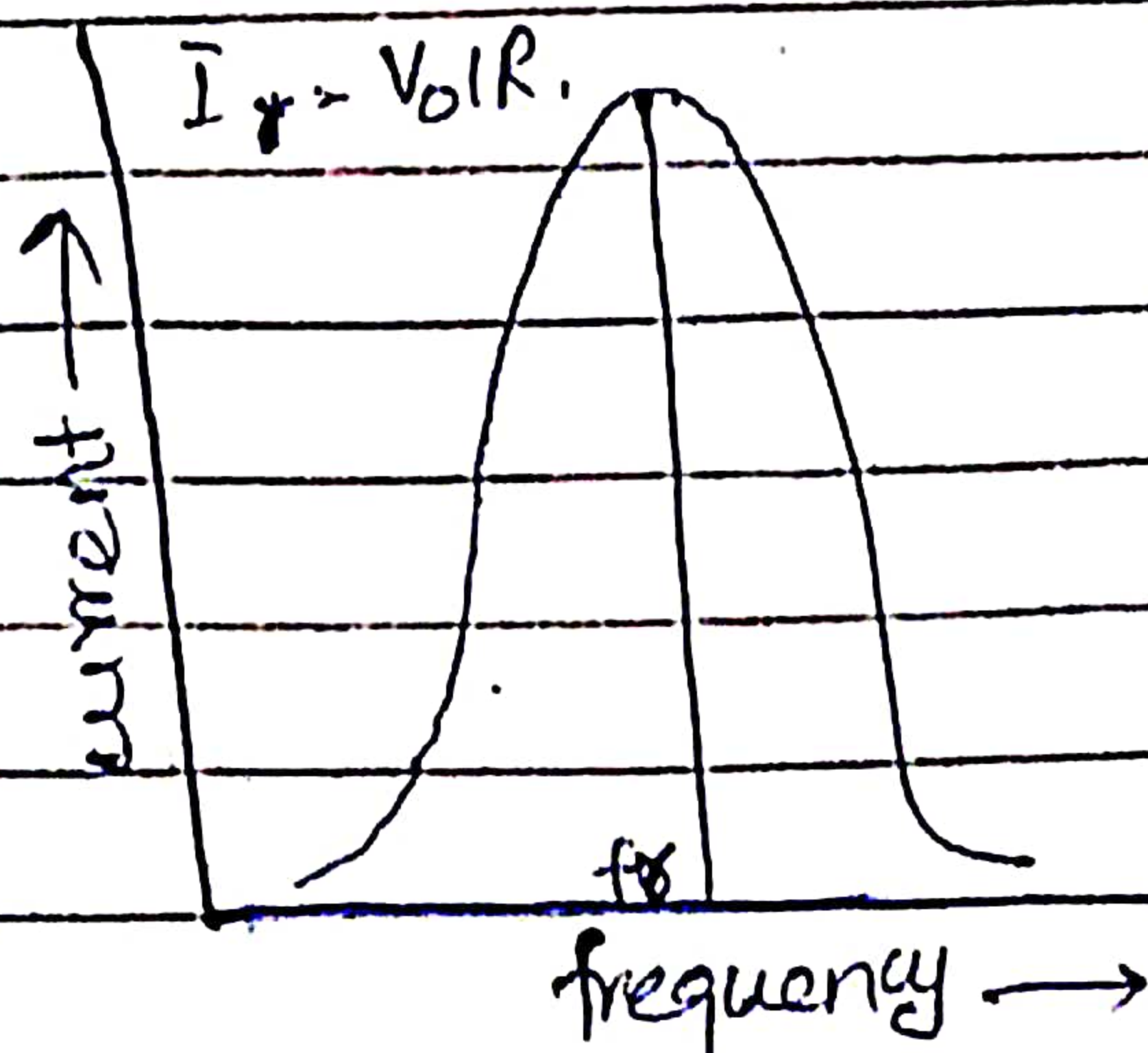
- 1- The resonance frequency is given by

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

- 2- The impedance of the circuit at resonance is only resistive so the current and voltage are in phase. The power factor is 1.

- 3- The impedance of the circuit is minimum at this frequency and it is equal to R .

- 4- If the amplitude of the source voltage V_0 is constant the current is a maximum at the resonance frequency and its value is V_0/R . The variation of current with the frequency is shown.



5- At resonance V_L , the voltage drop across inductance and V_C the voltage drop across capacitance may be much larger than the source voltage.

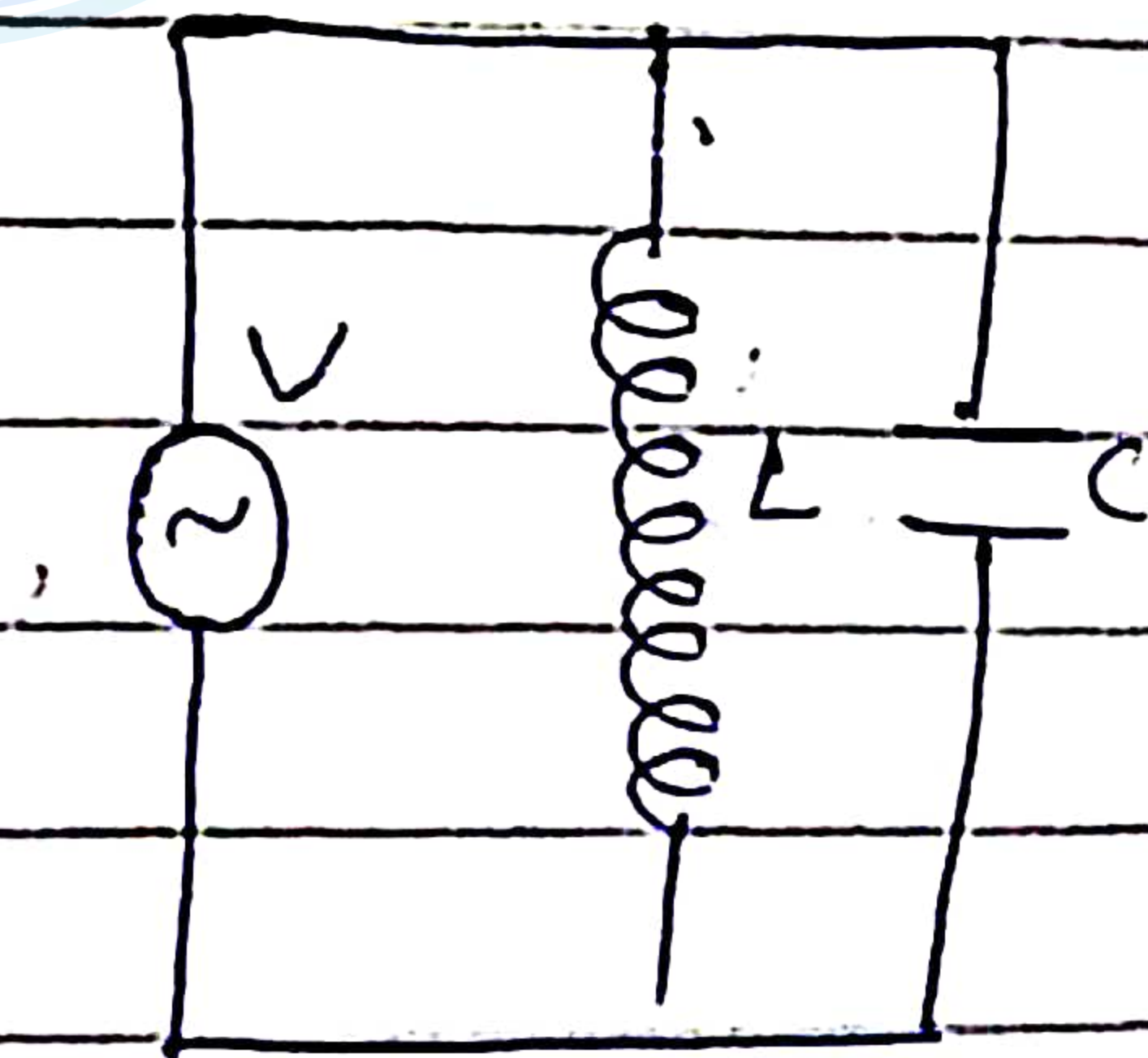
Parallel Resonance Circuit:

The electrical circuit in which the Resistor (R), Capacitor (C) and inductor (L) are connected in parallel with an AC source having a potential difference (V) as shown in the figure.

The Capacitive Reactance is

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

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



while inductive Reactance is given by

$$X_L = \omega L$$

$$X_L = 2\pi f L$$

For the low frequency the capacitive reactance X_C will be greater than inductive reactance X_L so, capacitance dominates at low frequency and circuit will behave as RC circuit.

For high frequency the inductive reactance X_L will be greater than capacitive reactance X_C so inductance dominates with high frequency and circuit will behave as RL circuit.

Resonance Frequency:

The specific frequency at which inductive and capacitive reactances becomes equal ($X_C = X_L$) is called Resonance frequency.

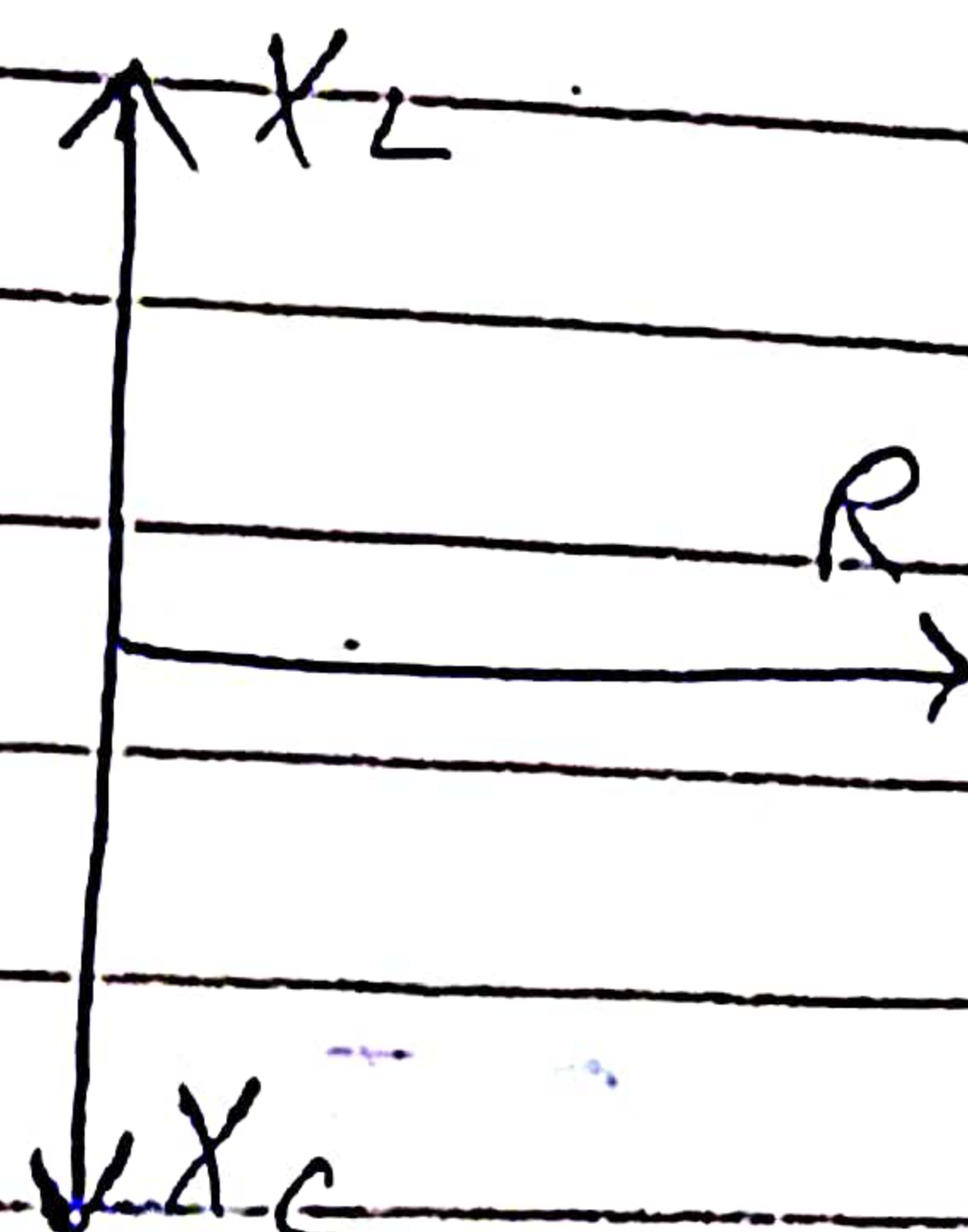
$$X_C = X_L$$

$$\frac{1}{\omega_r C} = \omega_r L$$

$$\frac{1}{LC} = \omega_r^2$$

$$\sqrt{\omega_r^2} = \sqrt{\frac{1}{LC}}$$

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



for resonance



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

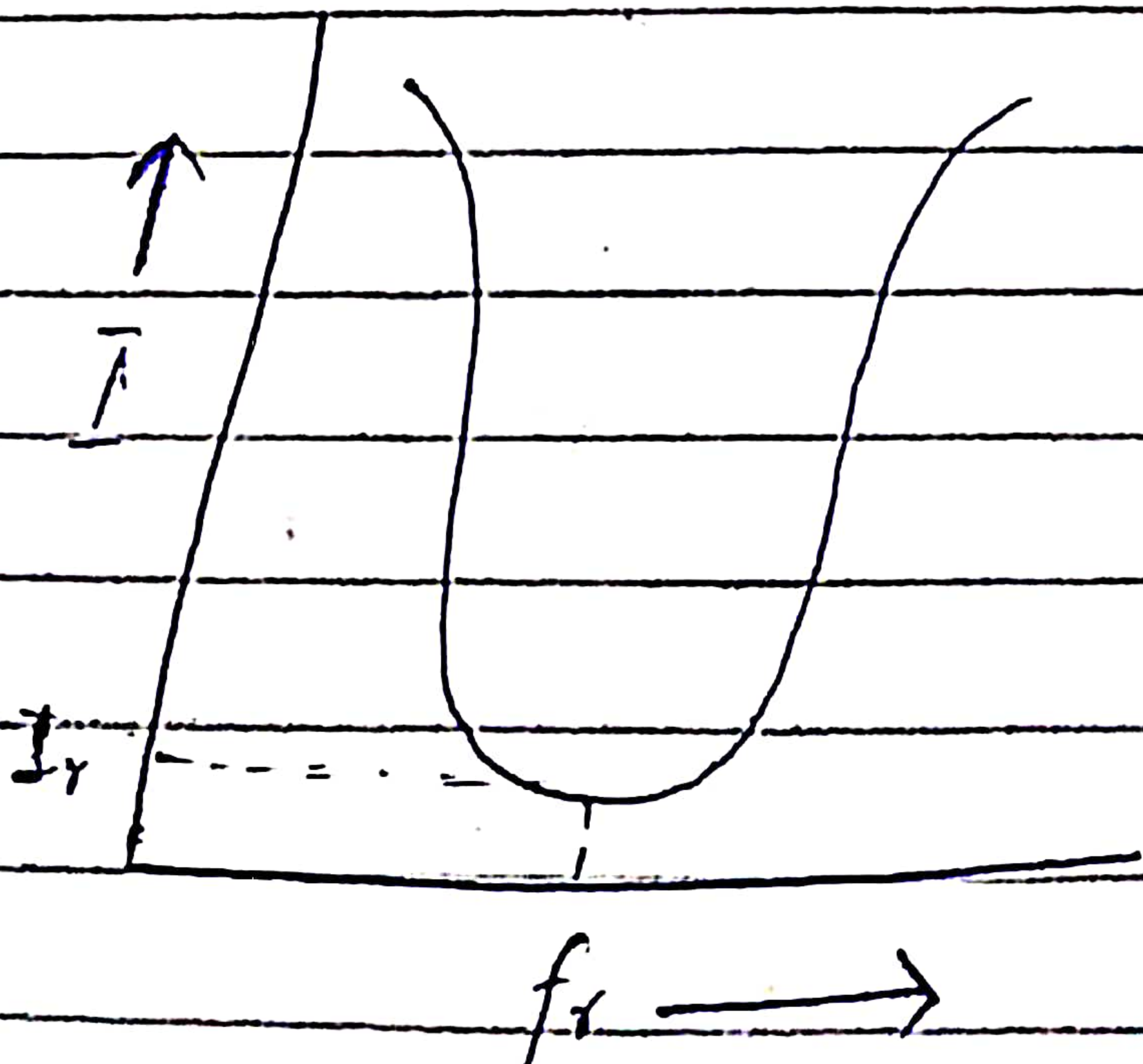
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Properties:

1- Resonance frequency is $f_r = \frac{1}{2\pi\sqrt{LC}}$

2- At the resonance frequency, the circuit impedance is maximum. It is resistive.

3- At the resonance the current is minimum and it is in phase with the applied voltage. So, the power factor is one. The variation of the current with the frequency of the source is shown.



4- At resonance the branch currents I_L and I_C may each be larger than the source current I_s .

Choke :

It is a coil which consist of thick copper wire wound closely in a large number of turns over a soft iron laminated cores. This makes an inductance of the coil quite large where the resistor R is very small. Thus it consume extremely small power.

It is used in AC circuit to limit current with extremely small wastage of energy as compared to the small resistance or a rheostat.

Electromagnetic waves:

The waves which do not require any material medium for their propagation are called electromagnetic waves. For example, radio waves, microwaves, infra-red radiation, x-rays, gamma rays etc. Changing magnetic flux create electric field and changing electric flux creates magnetic field, while both these fields create electromagnetic waves. For electromagnetic waves both electric and magnetic fields are perpendicular.

Maxwell's equations:

In 1864 British physicist James Clerk Maxwell formulated a set of equations known as Maxwell's equations which explained the various electromagnetic phenomena.

According to these equations, a changing electric magnetic flux create an electric field and changing electric flux creates a magnetic field.

Speed of electromagnetic waves:

The electromagnetic waves are periodic, hence they have a wavelength given by the relation $c = f\lambda$ where f is the frequency, c is the speed of light. In free space the speed of electromagnetic wave is same as speed of light.

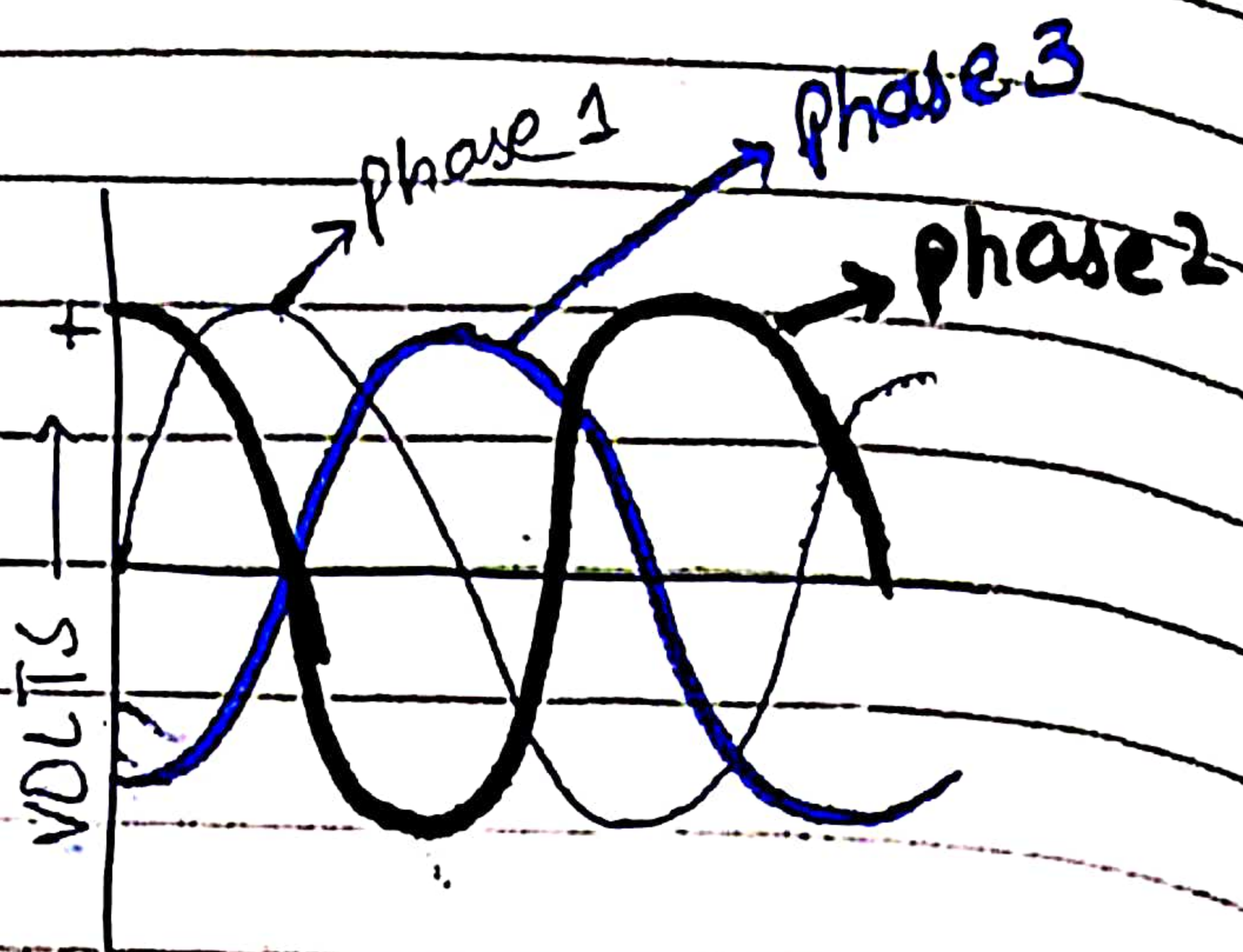
THREE PHASE A.C SUPPLY.

→ three phase A.C generator:

In three phase A.C generator instead of one coil there are three coils inclined at 120° to each other. Each connected to its own part of slip rings. When this combination of three coils rotates in the magnetic field. Each coil generates an alternating voltage across its own pair of slip rings. Thus three alternating voltages are generated.

Phase Difference:

The phase difference between these voltages is 120° . It



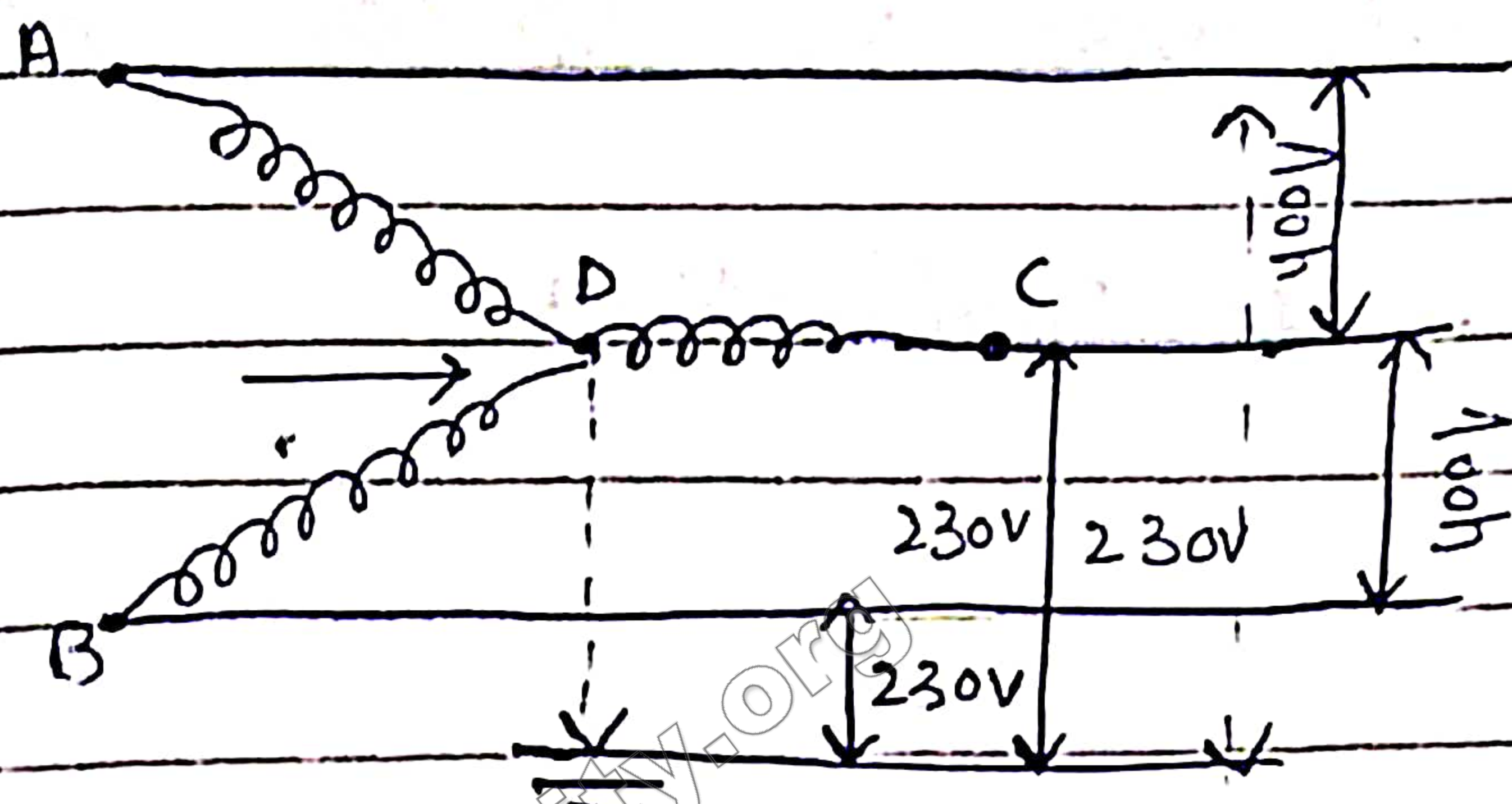
means that

when voltage across the first pair of slip rings is zero, having the phase of zero. The voltage across the second pair of slip rings would not be zero but it will have a phase of 120° . Similarly at this instant the voltage generated across the third pair will have a phase of 240° .

Terminals:

The machine instead of having six terminals, two for each pair of slip rings has only four terminals because the starting point of all the three coils has a common junction which is often earthed to the shaft of the generator and the

other three ends of the coil are connected to three separate terminals on the machine. These four terminals along with the lines and coils connected to them are shown.



voltage:

The voltage across each of the lines are connected to terminals A, B, C and the neutral line is 230 V. Because of 120° phase shift, the voltage across any two lines is about 400V.

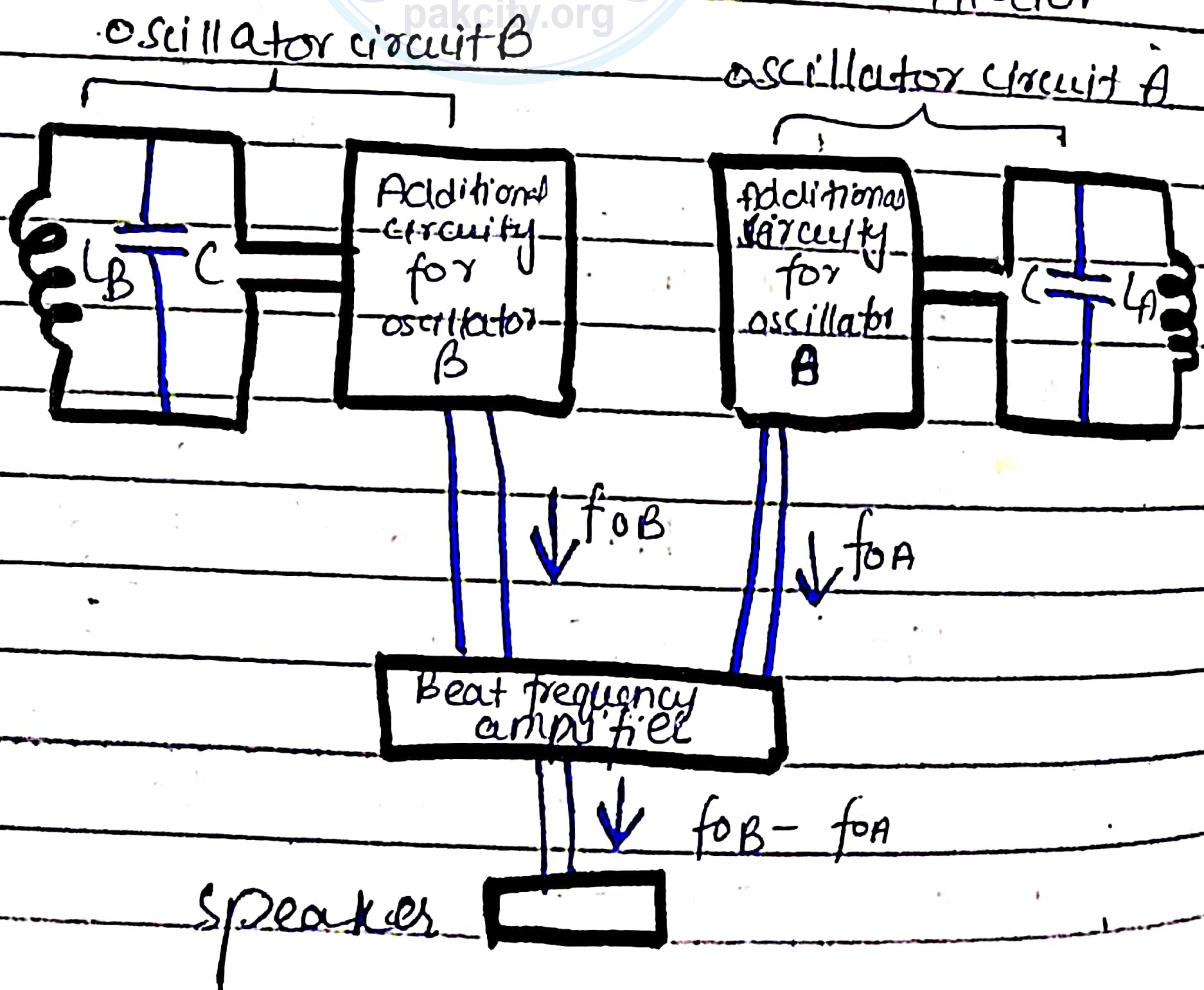
Advantages:

- 1) The main advantage of having the three phase supply is that the total load of the house or a factory is divided in three parts so, that none of the line is overloaded.

- 2) The three phase supply also provides 400 Volts which can be used to operate some special applications requiring 400V for their operation.

Principle of Metal Detectors. electrical oscillator:

A coil and a capacitor are electrical components which together can produce oscillating man-spring system. In this case energy oscillates between a capacitor and an inductor. The circuit is called an electrical oscillator.



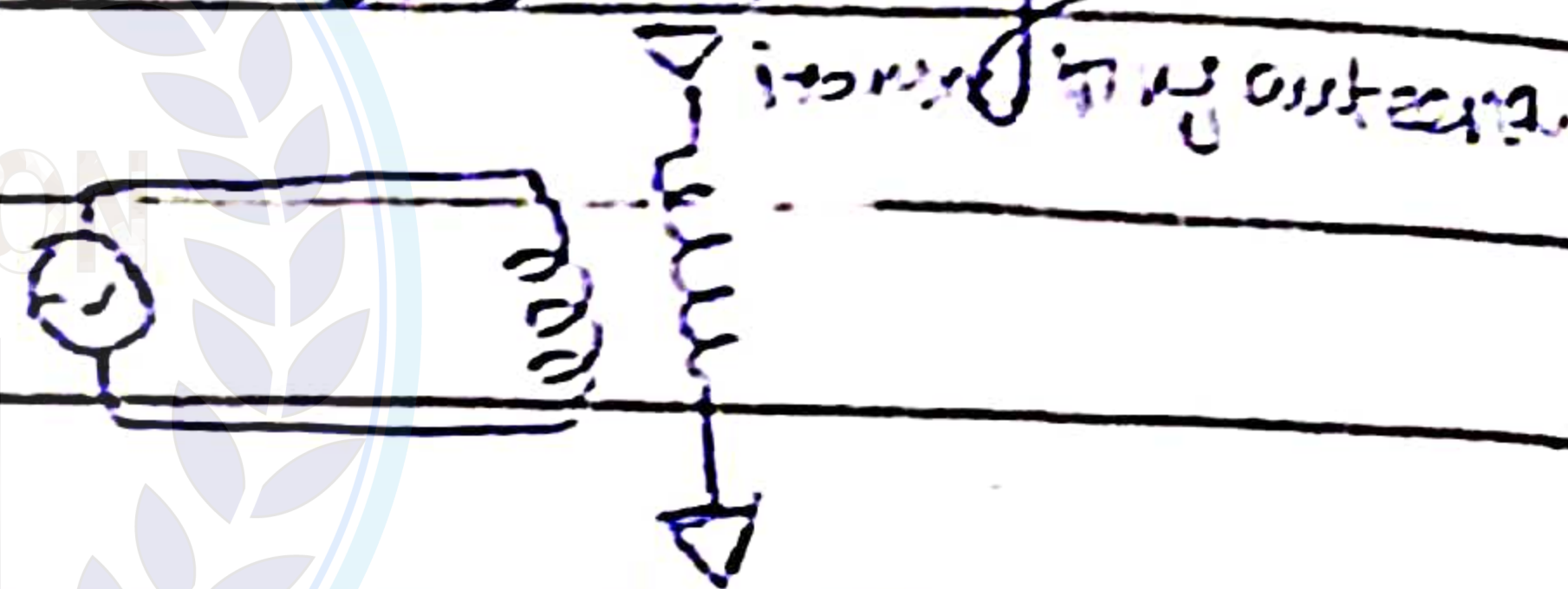
Working:

Two such oscillators A and B are used in the operation of a common type of metal detector. In the absence of any nearby metal object, the inductances L_A and L_B are the same and hence the resonance frequency of the two circuits is also same. When the inductor B, called the search coil comes near a metal object, its inductance L_B decreases and corresponding oscillator frequency increases and thus a beat note is heard in the attached speaker. Such detectors are extensively used not only for various security checks but also to locate buried metal objects.

Principle of Generation, Transmission and Reception of Electromagnetic waves.

→ Transmitting Antenna:

The piece of the wire along which charges are made to accelerate is known as transmitting antenna. It is charged by an alternating source of potential of frequency (f) and time period (T). As the charging potential alternates, the charge on the antenna also constantly reverses.



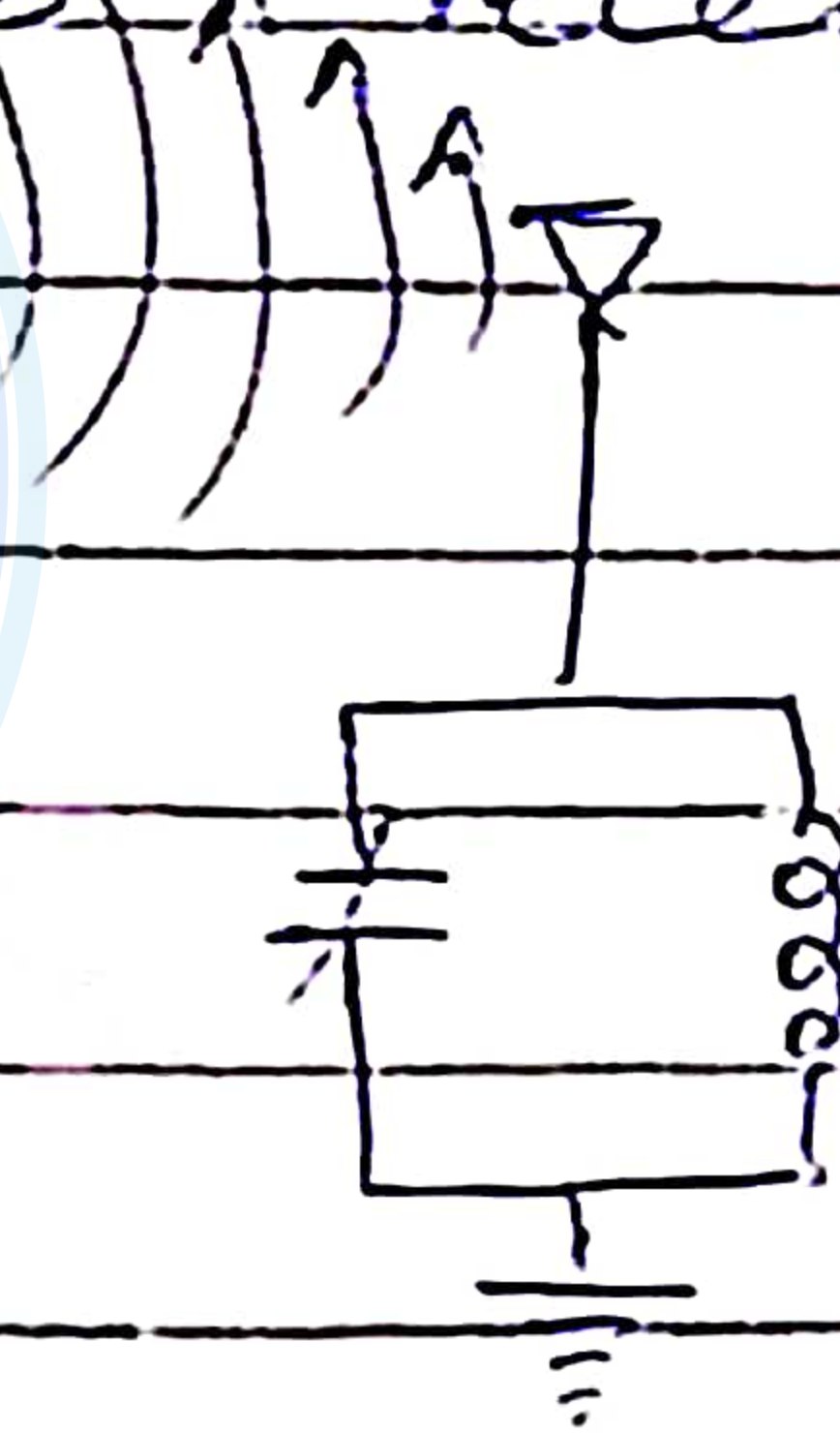
Radio waves:-

The charging electrical flux sets up an electromagnetic waves which propagated out in space away from the antenna. The frequency with which the field alternates is equal to the frequency of the source generating them. The electromagnetic waves which are propagated out in space from antenna of a transmitter are known as

radiowaves. In free space these rays travel with the speed of light.

Receiving antenna:

The electrons in the wire move under the action of the oscillating electric field which give rise to an alternating voltage across the wire. The frequency of this voltage is the same as that of the wave intercepting the wire. This wire receiving the wave is known as receiving antenna.



Modulation:

Defination:

Modulation is the process of combining the low frequency signal with the high frequency radio wave called carrier wave. The resultant wave is called modulated carrier wave. The low frequency signal is known as modulation signals.

Types:

There are two types of modulation which are:

- 1- Amplitude Modulation (A-M)
- 2- Frequency Modulation (F.M).

Amplitude Modulation:

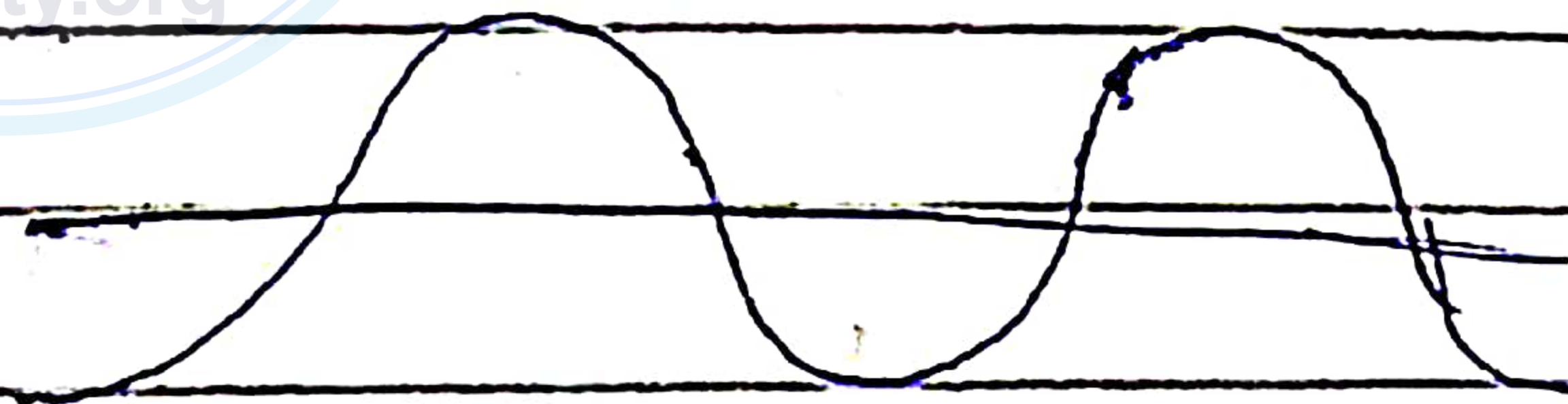
In this type of modulation the amplitude of the carrier wave is increased or decreased as the amplitude of superposing modulating signal increases or decreases.

Figure (a)

represents the high frequency carrier wave of constant amplitude and frequency.



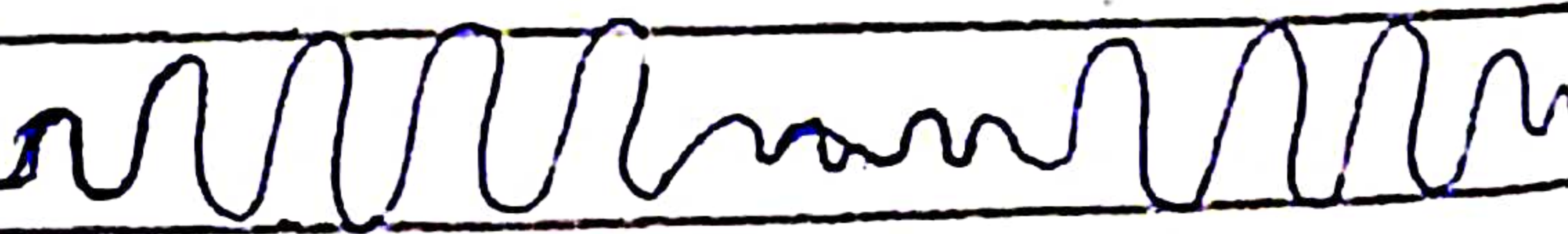
a) carrier wave.



b) audio signal

Figure (b)

represents the low or audio frequency signals of a sine wave form.



c) amplitude modulated wave

Figure (c) shows the result obtained by modulating the carrier waves with the modulating wave.

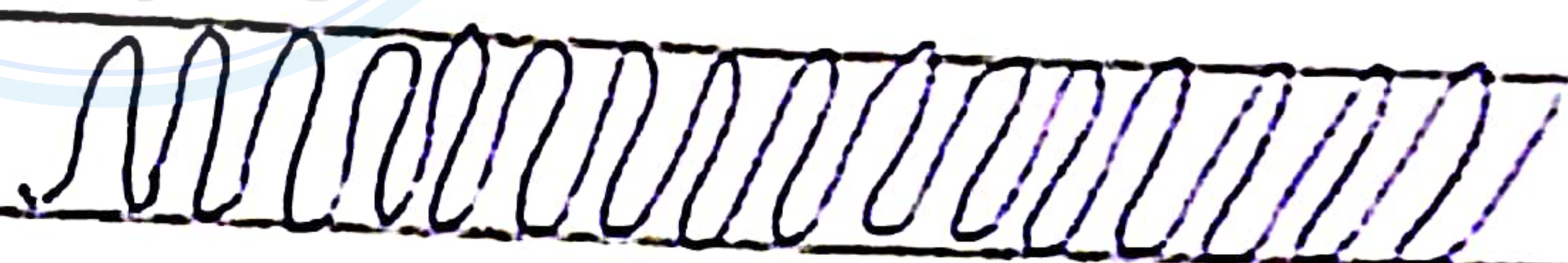
Range:- 540 kHz to 1600 kHz

Frequency Modulation:

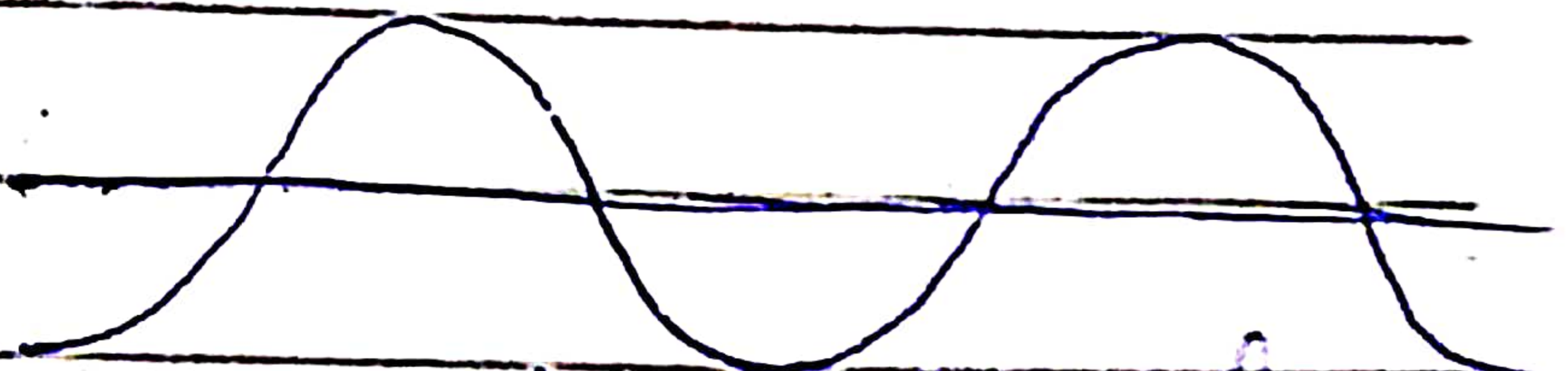
In this type of modulation the frequency of the carrier wave is increased or decreased as the modulating signals amplitude increased or decreased but the carrier waves amplitude remains constant.

Range:

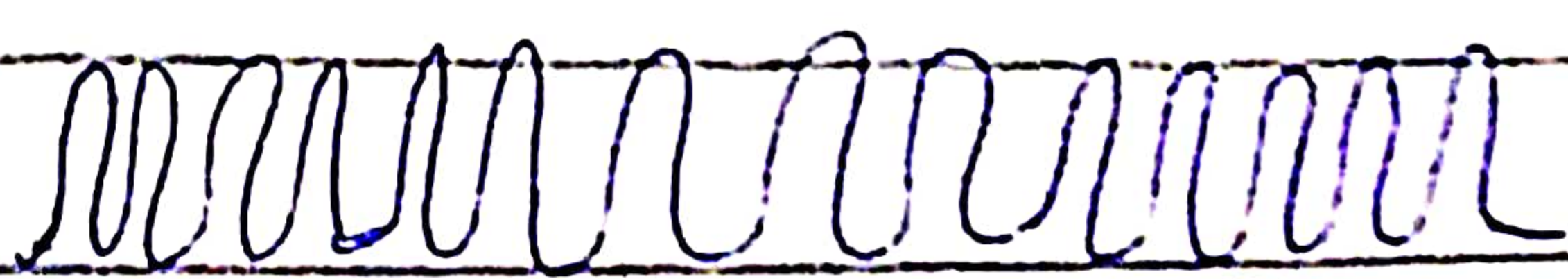
88 MHz to 108 MHz.



a) Carrier wave



b) audio signal



c) frequency modulated wave

Properties:

- F.M radiowaves are affected less by electrical interference than A.M radio waves.
- It provide high quality transmission of sound. however they have a shorter wavelength than A.M waves are less able to travel around obstacles such as hills and large buildings.

Short Questions

16.1

$$I_{rms} = 10A, \text{ peak value} = I_0 = ?$$

we know that

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$10 = \frac{I_0}{\sqrt{2}}$$

$$I_0 = (10)(\sqrt{2})$$

$$I_0 = (1.41)(10)$$

$$I_0 = 14.1 A$$

10.2 (a) Inductance is the device that permits flow of direct current but opposes the flow of alternating current.
As

$$X_L = \omega L$$

$$X_L = 2\pi f L$$

For direct current $f = 0$

$$X_L = 2\pi (0) L$$

$$X_L = 0$$

So, inductive reactance is zero for direct current and it will pass through it.

(b) Capacitor is the device that permits flow of alternating current but not the direct current.

As
$$X_C = \frac{1}{\omega C}$$

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

For direct current $f = 0$

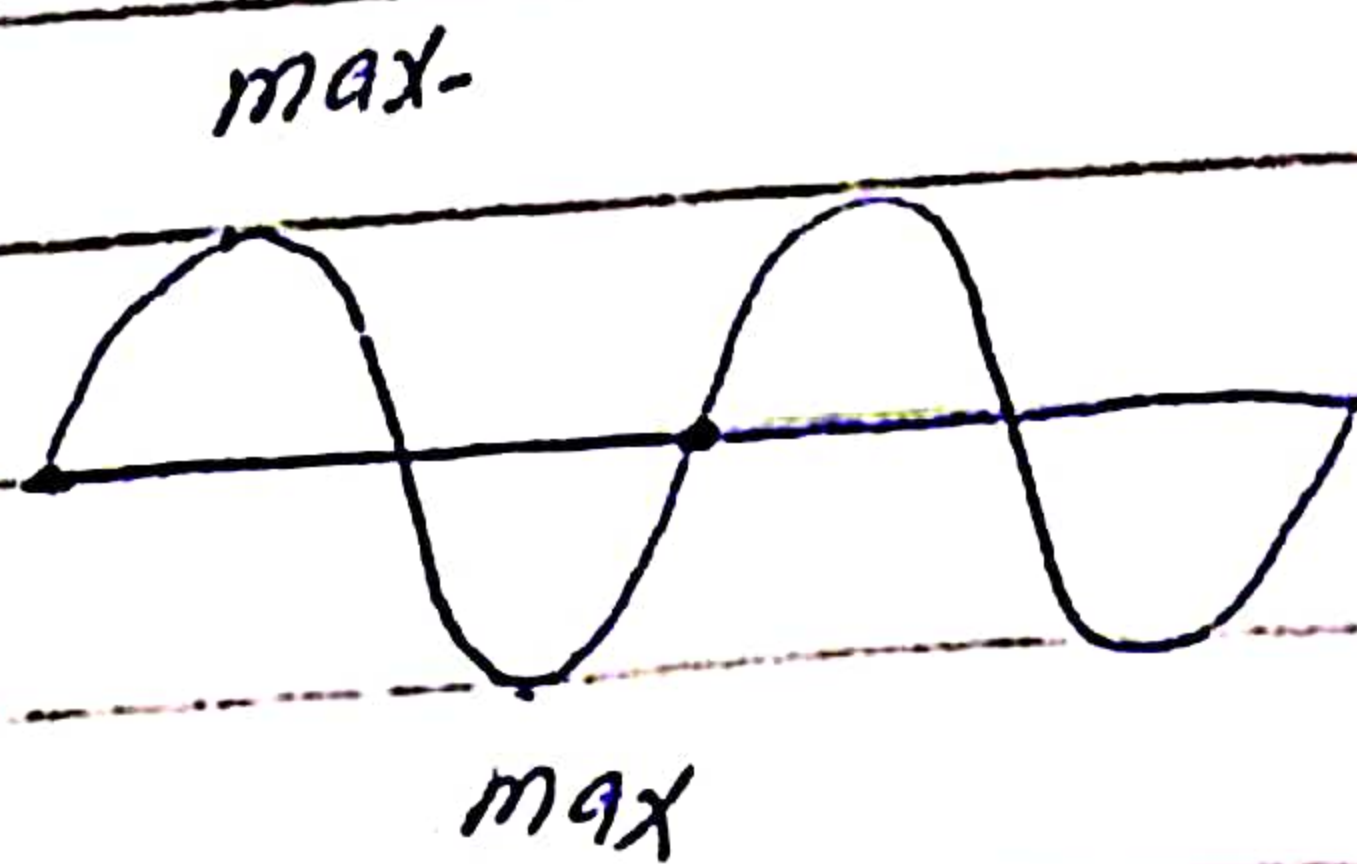
$$X_C = \frac{1}{0}$$

$$X_C = \infty$$

So, capacitive reactance is

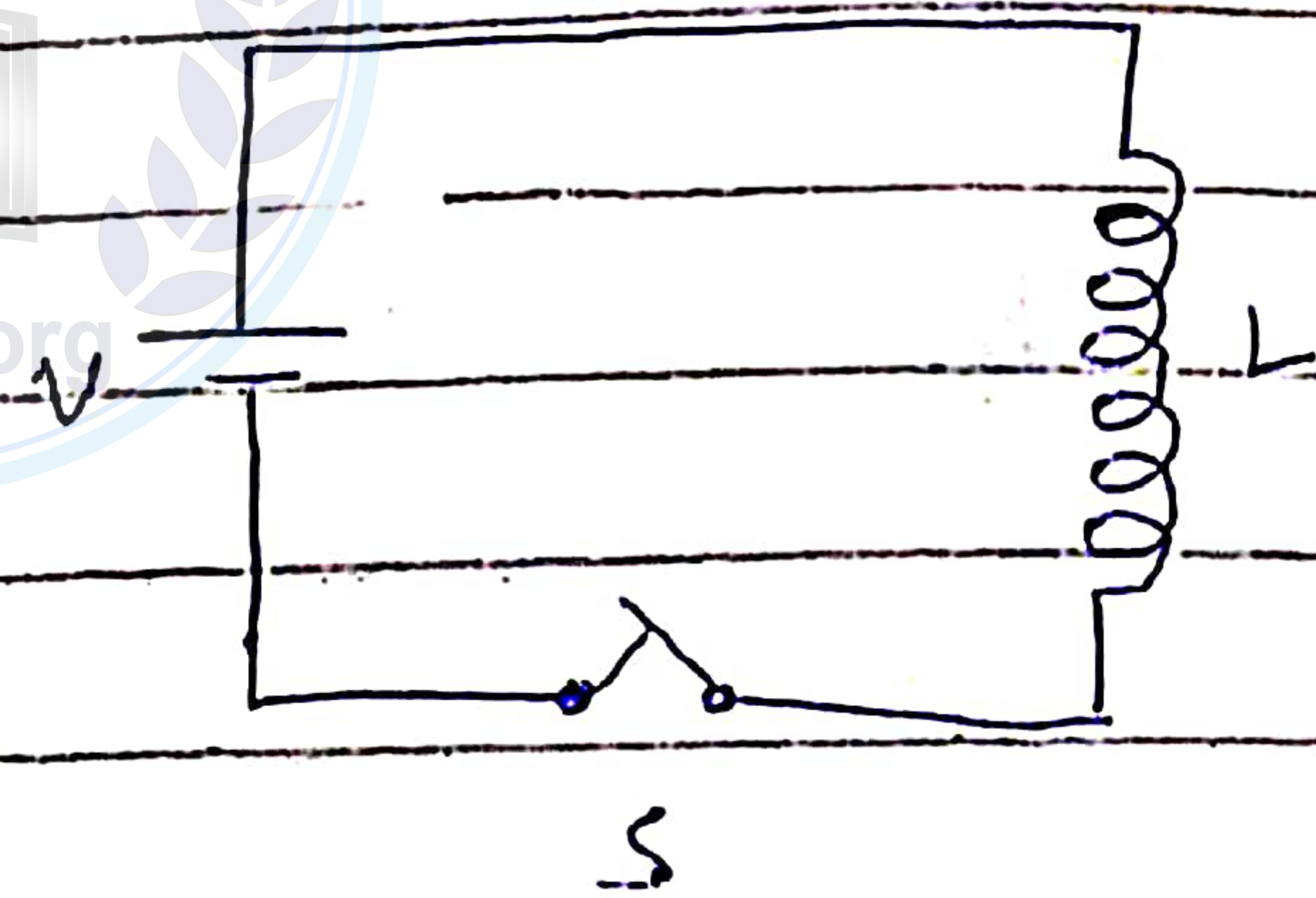
infinity for direct current
and direct current will not
pass through capacitor.

16.3: An
incandescent
lamp will
reach maximum
brilliance two



times in one
wave. So, for a 50 Hz
source, the lamp will reach
 $50 \times 2 = 100$ times to
maximum brilliance.

16.4: A circuit
contains an
iron-cored
inductor, a
switch and
a DC source



arranged in series.

When the switch is closed energy
gets stored in the inductor.

If we now open the switch
the stored energy will jump/move
across the contacts of switch
and in this way a spark
is produced.

B.S: (a)

inductor

The

is:

reactance of

$$X_L = \omega L$$

$$X_L = 2\pi f L$$

If the frequency is doubled.

$$X_L' = 2\pi (2f) L$$

$$= 2 (2\pi f L)$$

$$X_L' = 2 X_L$$

So, reactance of inductor will also become double.

(b)

The

reactance of

capacitor

is:

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

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

If frequency is doubled.

$$X_C' = \frac{1}{2\pi (2f) C}$$

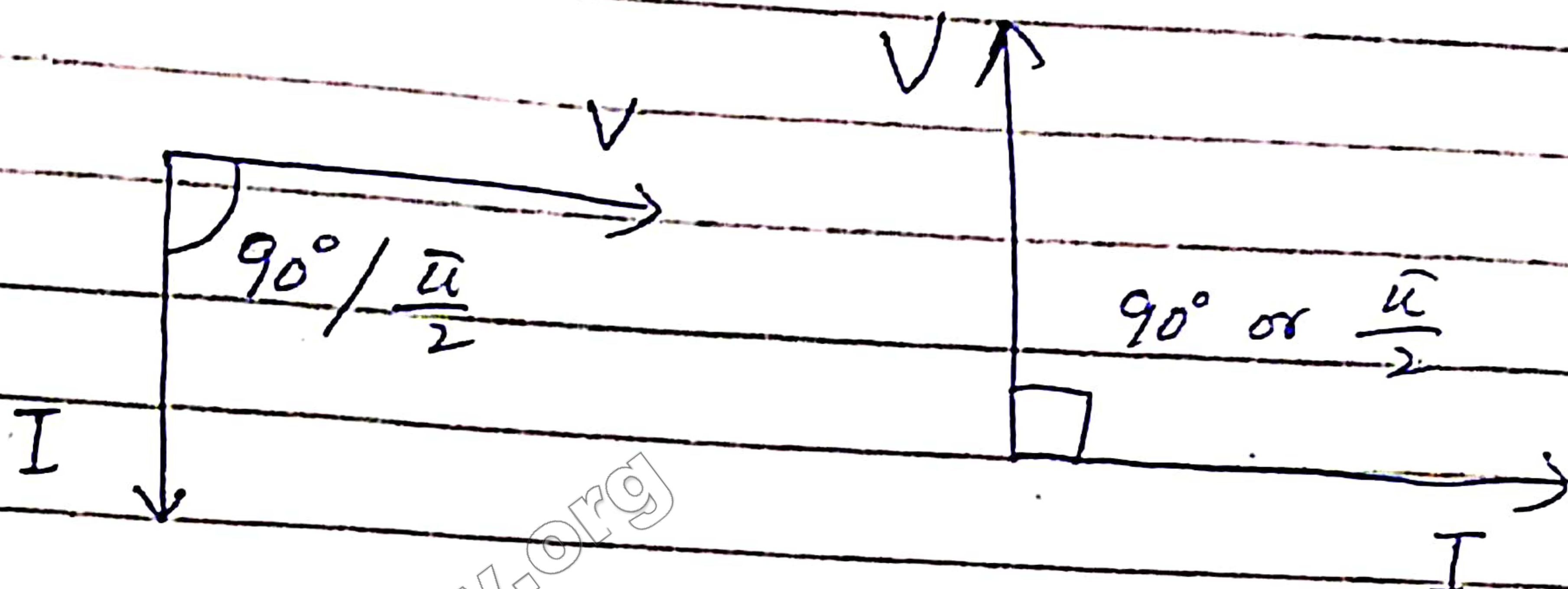
$$= \frac{1}{2} \left(\frac{1}{2\pi f C} \right)$$

$$X_C' = \frac{1}{2} X_C$$

So, reactance of capacitor

will become half.

16.6: In a R-L circuit, current will lag from the voltage through a phase of 90° or $\frac{\pi}{2}$.



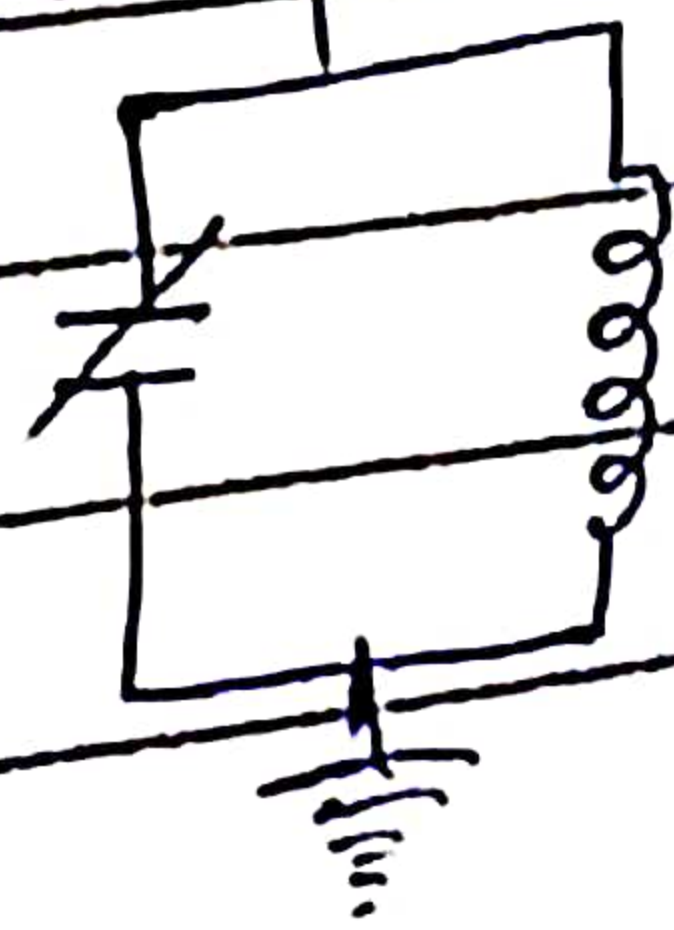
16.7: A choke coil placed in series with an electric lamp in AC circuit causes the lamp to become dim. Because most of the energy is stored across the choke.

A variable capacitor added in series in this circuit may be adjusted until the lamp glows with normal brilliance. Because capacitor will be continuously charged and discharged so that the current in the circuit will remain same.

16.8: The wave which does not require any material medium for their propagation are called electromagnetic waves. For example, radio waves, microwaves, infrared radiation, X-rays, gamma rays etc. Changing magnetic field creates electric field while changing electric flux creates magnetic field. Both these fields create electromagnetic waves. For both electric and magnetic fields are perpendicular.

16.9:

If one adjust the value of the capacitor so, that the natural frequency of L-C circuit is the same as that of the transmitting station to be picked up. The circuit will resonate under the driving action of the antenna consequently the L-C circuit will build up a large response to the action of only that radio wave to which it is tuned.



16-10: Amplitude Modulation:

In this type of modulation the amplitude of the carrier wave is increased or decreased as the amplitude of the superposing modulating signal increased and decreased.

Range:

540 kHz - 1600 kHz

carrier wave

audio signals

amplitude modulating wave

Frequency Modulation:

In this type of modulation the frequency of the carrier wave increases or decreases as the modulating signal amplitude increases or decreases but the carrier wave amplitude remains constant.

Range:

88 MHz - 108 MHz

carrier wave

audio signal

frequency modulating wave

16.1 Data

$$I = 20 \sin 100\pi t$$

frequency = $f = ?$

maximum current = $I_0 = ?$

rms current = $I_{rms} = ?$

Solution: we know that

$$I = I_0 \sin 2\pi f t$$

comparing with

$$I = 20 \sin 100\pi t$$

$$\Rightarrow \boxed{I_0 = 20 \text{ A}}$$

$$2\pi f t = 100\pi t$$

$$2f = 100$$

$$f = \frac{100}{2}$$

$$\Rightarrow \boxed{f = 50 \text{ Hz}}$$

$$\text{And } I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$= \frac{20}{\sqrt{2}}$$

$$\boxed{I_{rms} = 14 \text{ A}}$$

16.2 Data

$$\text{maximum current} = I_0 = 15 \text{ A}$$

$$\text{rms current} = I_{\text{rms}} = ?$$

$$\text{instantaneous current} = I = ?$$

$$\text{time} = t = \frac{1}{300} \text{ s}$$

$$\text{frequency} = f = 50 \text{ Hz}$$

Solution:

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

$$= \frac{15}{\sqrt{2}}$$

$$I_{\text{rms}} = 10.6 \text{ A}$$

$$I = I_0 \sin(2\pi ft)$$

$$= 15 \sin 2\pi (50) \left(\frac{1}{300} \right)$$

$$= 15 \sin \frac{\pi}{3}$$

$$I = 13 \text{ A}$$

$$\therefore \pi = 180^\circ$$

16.3 Data

$$\text{current} = I_{\text{rms}} = ?$$

$$\text{inductive reactance} = X_L = ?$$

$$\text{voltage} = V = 220 \text{ V}$$

$$\text{frequency} = f = 50 \text{ Hz}$$

$$\text{inductance} = L = 10 \text{ H}$$

Solution:

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

$$= 2\pi (50)(10)$$

$$X_L = 3141 \Omega$$

NBW

$$I_{rms} = \frac{V_{rms}}{X_L}$$

$$= \frac{220}{3141}$$

$$I_{rms} = 0.07 A$$

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16.4 Data

$$\text{inductance} = L = \frac{1}{\pi} H$$

$$\text{resistance} = R = 2000 \Omega$$

$$\text{frequency} = f = 50 \text{ Hz}$$

$$\text{inductive reactance} = X_L = ?$$

$$\text{impedance} = Z = ?$$

Solution:

$$X_L = \omega L$$

$$X_L = 2\pi f L$$

$$= 2\pi (50) \left(\frac{1}{\pi} \right)$$

$$X_L = 100 \Omega$$

now

$$Z = \sqrt{R^2 + X_L^2}$$

$$Z = \sqrt{(2000)^2 + (100)^2}$$

$$Z = 2002.5 \Omega$$

16.5 Data

$$\text{inductance} = L = \frac{3}{\pi} \text{ H}$$

$$\text{resistance} = R = 40 \Omega$$

$$\text{peak current} = I_0 = ?$$

$$\text{rms current} = I_{\text{rms}} = ?$$

$$\text{phase difference} = \phi = ?$$

$$V = 350 \sin(100\pi t)$$

Solution:

$$V = 350 \sin(100\pi t)$$

comparing with:

$$V = V_0 \sin(2\pi f t)$$

$$V_0 = 350 \text{ V}, \quad 2\pi f = 100\pi$$

$$f = \frac{100}{2}$$

$$f = 50 \text{ Hz}$$

now

$$X_L = \omega L$$

$$= 2\pi f L$$

$$= 2\pi (50) \left(\frac{3}{\pi}\right)$$

$$X_L = 300 \Omega$$

$$Z = \sqrt{R^2 + X_L^2}$$

$$= \sqrt{(40)^2 + (300)^2}$$

$$Z = 303 \Omega$$

Now

$$I_0 = \frac{V_0}{Z}$$

$$= \frac{350}{303}$$

$$I_0 = 1.16 \text{ A}$$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{1.16}{\sqrt{2}}$$

$$I_{\text{rms}} = 0.82 \text{ A}$$

and

$$\theta = \tan^{-1} \frac{X_L}{R}$$

$$= \tan^{-1} \left(\frac{300}{40} \right)$$

$$\theta = 82.4^\circ$$

16.6 Data

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$$\text{inductance} = L = 10 \text{ mH} = 10 \times 10^{-3} \text{ H}$$

$$L = 10^{-2} \text{ H}$$

$$\text{resistance} = R = 20 \Omega$$

$$\text{voltage} = V = 240 \text{ V}$$

$$\text{frequency} = f = \frac{180}{\pi} \text{ Hz}$$

$$\text{power dissipated} = P = ?$$

Solution:

$$P = V_{rms} I_{rms} \cos \theta$$

and

$$I_{rms} = \frac{V_{rms}}{Z}$$

but

$$Z = \sqrt{R^2 + X_L^2}$$

where

$$X_L = \omega L$$

$$= 2\pi f L$$

$$= 2\pi \left(\frac{180}{\pi} \right) (10^{-2})$$

$$X_L = 3.6 \Omega$$

now

$$Z = \sqrt{(20)^2 + (3.6)^2}$$

$$Z = 20.3 \Omega$$

now

$$I_{rms} = \frac{240}{20.3}$$

$$I_{rms} = 11.8 \text{ A}$$

now

$$\theta = \tan^{-1} \frac{X_L}{R}$$

$$= \tan^{-1} \left(\frac{3.6}{20} \right)$$

$$\theta = 10.2^\circ$$

Now

$$P = (240)(11.8) \cos 10.2^\circ$$

$$P = 2787 \text{ W}$$

Also

$$P = V_{\text{rms}} I_{\text{rms}}$$

$$= (240)(11.8)$$

$$P = 2832 \text{ W}$$

16.7 Data

$$\text{current} = I_{\text{rms}} = ?$$

$$\text{capacitance} = C = 0.5 \mu\text{F}$$

$$C = 0.5 \times 10^{-6} \text{ F}$$

$$\text{voltage} = V_{\text{rms}} = 150 \text{ V}$$

$$\text{frequency} = f = 50 \text{ Hz}$$

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Solution:

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

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

$$= \frac{1}{2\pi(50)(0.5 \times 10^{-6})}$$

$$6366 \Omega$$

$$X_C =$$

Now
$$I_{rms} = \frac{V_{rms}}{X_c}$$

$$I_{rms} = \frac{150}{6366}$$

$$I_{rms} = 0.02A$$



16.8 Data

voltage = $V = 12V$

frequency = $f = 50 \text{ Hz}$

capacitance = $C = 3 \mu F$

$$C = 3 \times 10^{-6} F$$

resistance = $R = 1 \text{ K} \Omega = 10^3 \Omega$

phase angle = $\theta = ?$

Solution:

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

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

$$= \frac{1}{2\pi (50)(3 \times 10^{-6})}$$

$$X_c = 1061 \Omega$$

Now

$$\theta = \tan^{-1} \frac{X_c}{R}$$

$$= \tan^{-1} \left(\frac{1061}{1000} \right)$$

$$\theta = 46.7^\circ$$

16.9 Data

resonant frequency = $f_r = ?$
inductance = $L = 2.5 \text{ H}$
capacitance = $C = 40 \mu\text{F}$
 $C = 40 \times 10^{-6} \text{ F}$

Solution:

$$f_r = \frac{1}{2\pi \sqrt{LC}}$$
$$= \frac{1}{2\pi \sqrt{(2.5)(40 \times 10^{-6})}}$$

$$f_r = 15.9 \text{ Hz}$$

16.10 Data



inductance = $L = 150 \mu\text{H}$
 $L = 150 \times 10^{-6} \text{ H}$

maximum capacitance = $C_{\text{max}} = 500 \text{ pF}$

$$C_{\text{max}} = 500 \times 10^{-12} \text{ F}$$

minimum capacitance = $C_{\text{min}} = 20 \text{ pF}$
 $C_{\text{min}} = 20 \times 10^{-12} \text{ F}$

$f_{\text{max}} = ?$, $f_{\text{min}} = ?$

Solution:

$$f_{\text{max}} = \frac{1}{2\pi \sqrt{LC_{\text{min}}}}$$

$$= \frac{1}{2\pi \sqrt{(150 \times 10^{-6})(20 \times 10^{-12})}}$$

$$f_{max} = 2905758 \text{ Hz}$$

$$= 2.905758 \times 10^6 \text{ Hz}$$

$$f_{max} = 2.91 \text{ MHz}$$

$$f_{min} = \frac{1}{2\pi \sqrt{LC_{max}}}$$

$$= \frac{1}{2\pi \sqrt{(150 \times 10^{-6}) (500 \times 10^{-12})}}$$

$$f_{min} = 581152 \text{ Hz}$$

$$= 0.581152 \times 10^6 \text{ Hz}$$

$$f_{min} = 0.58 \text{ MHz}$$

2nd Year Physics
Chapter # 16
Alternating Current



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