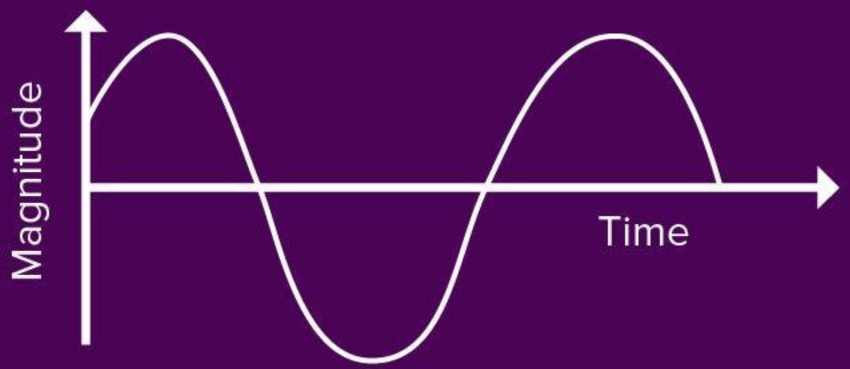
ALTERNATING CURRENT - L1



PHYSICS

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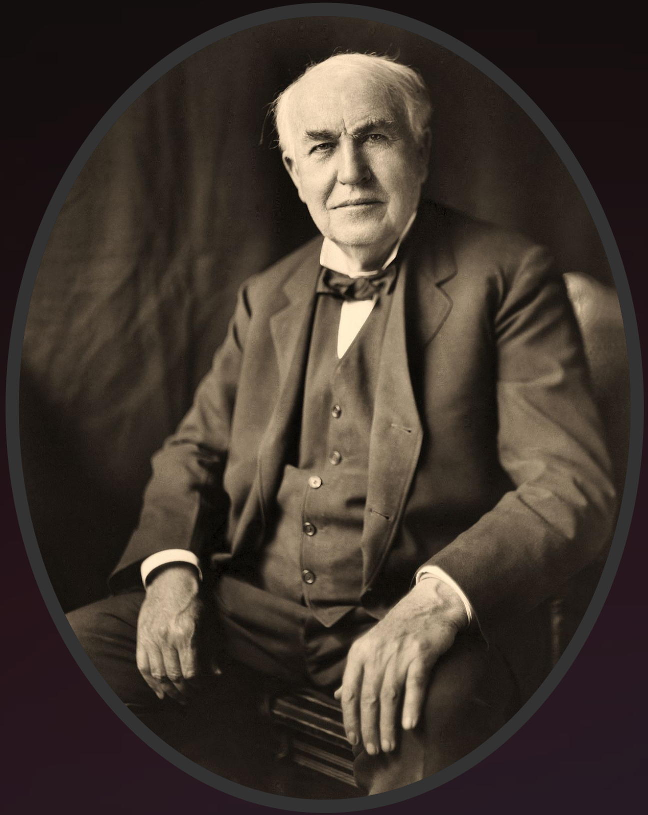
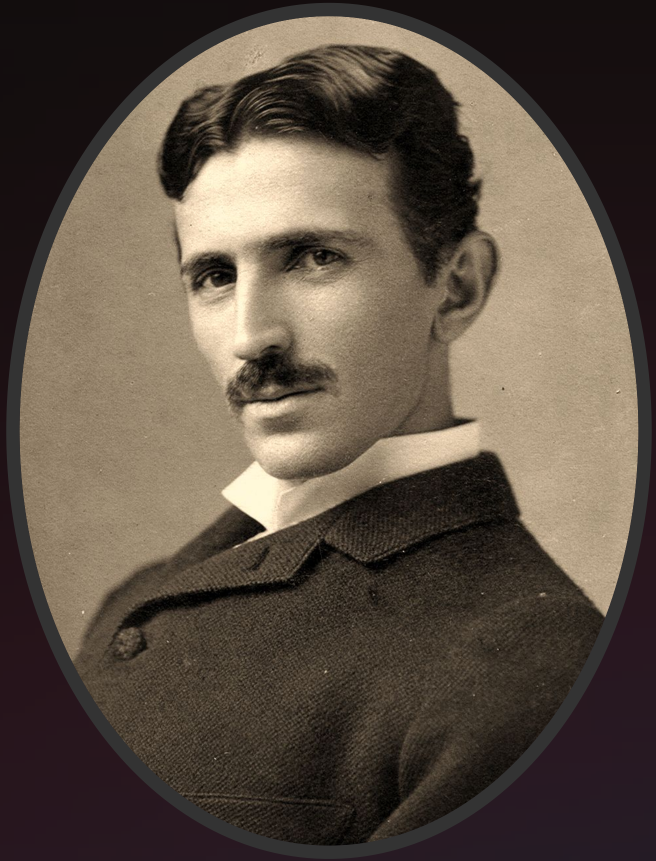
THE CURRENT WAR



THOMAS ALVA EDISON

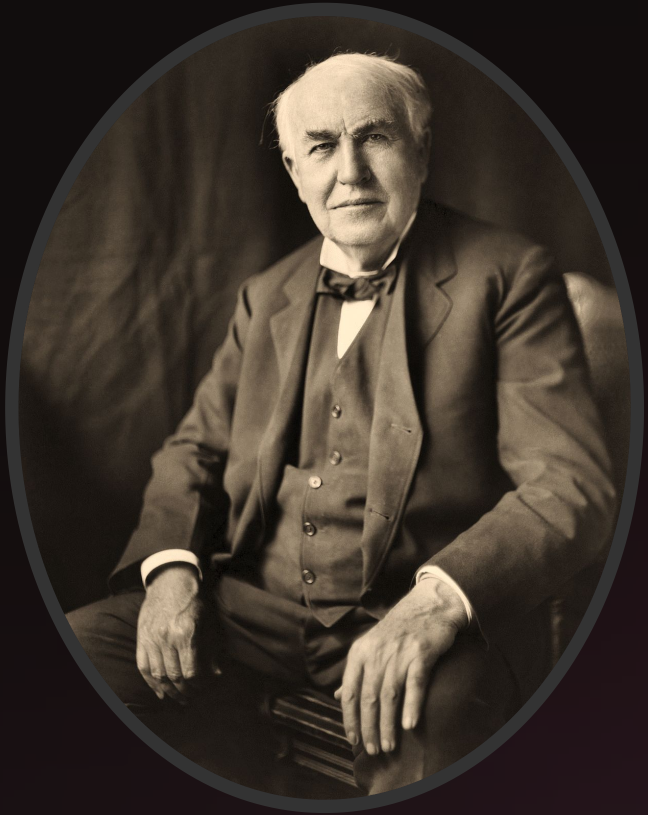
DIRECT CURRENT, 1880s

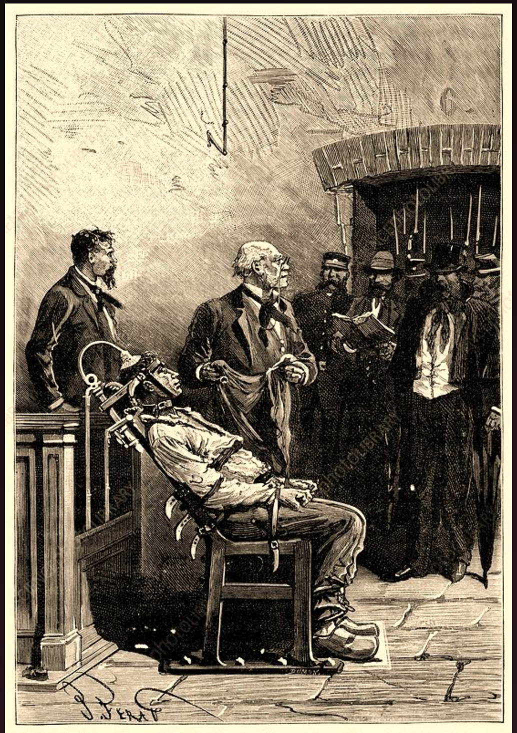
THE CURRENT WAR



THE ALTERNATING CURRENT SYSTEM,1888

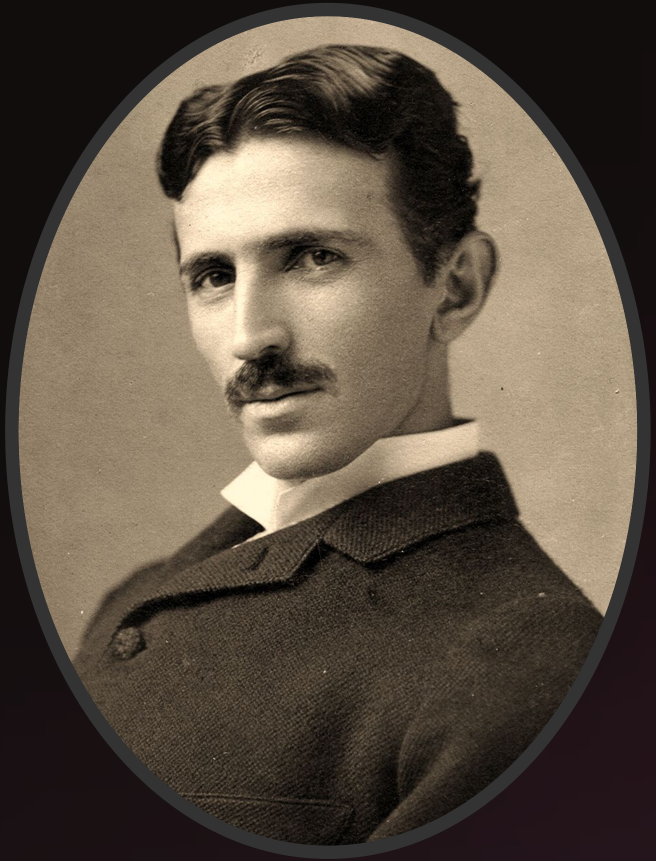
THE CURRENT WAR

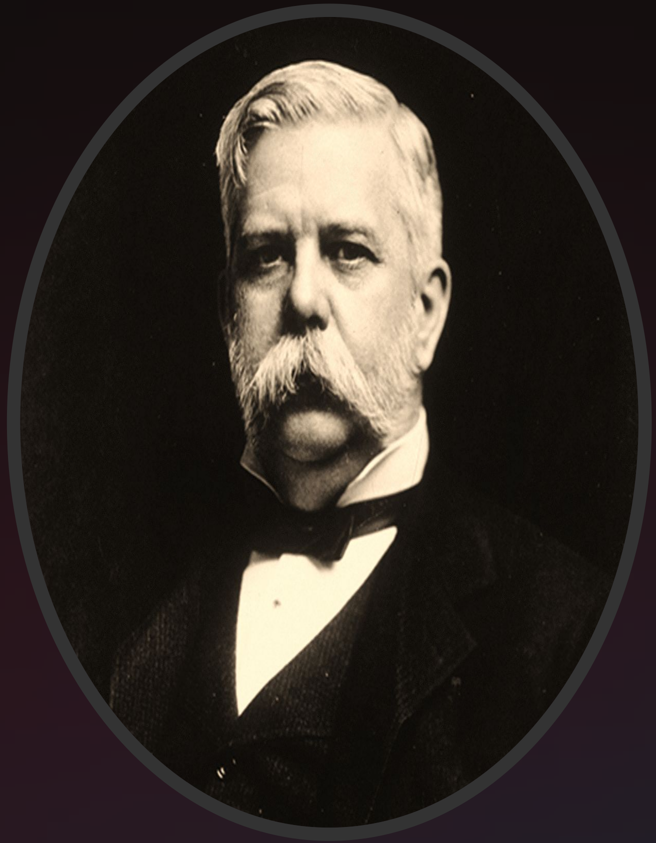




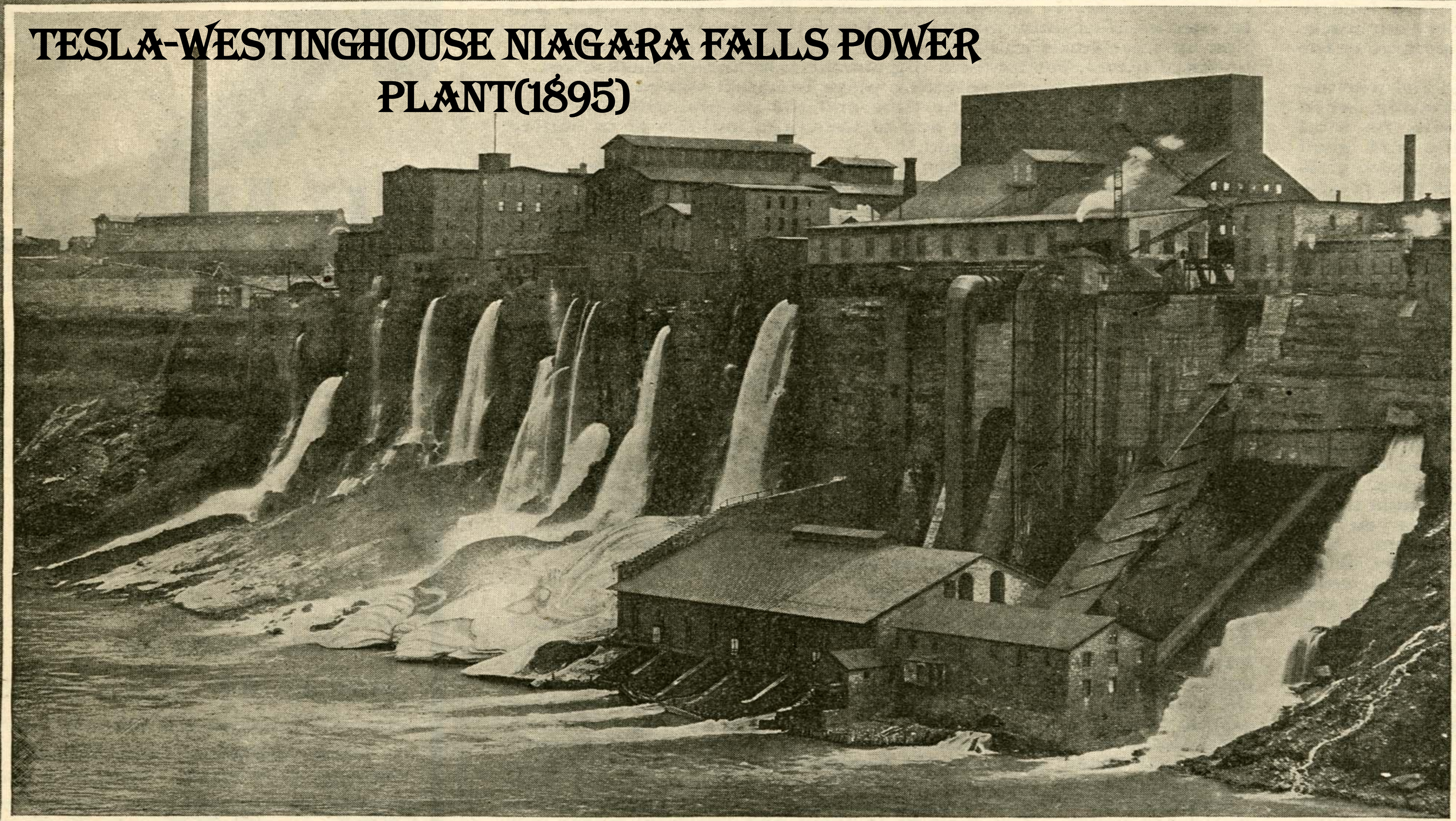
EDISON electrocuted animals and human to show that AC was **too dangerous** to use.

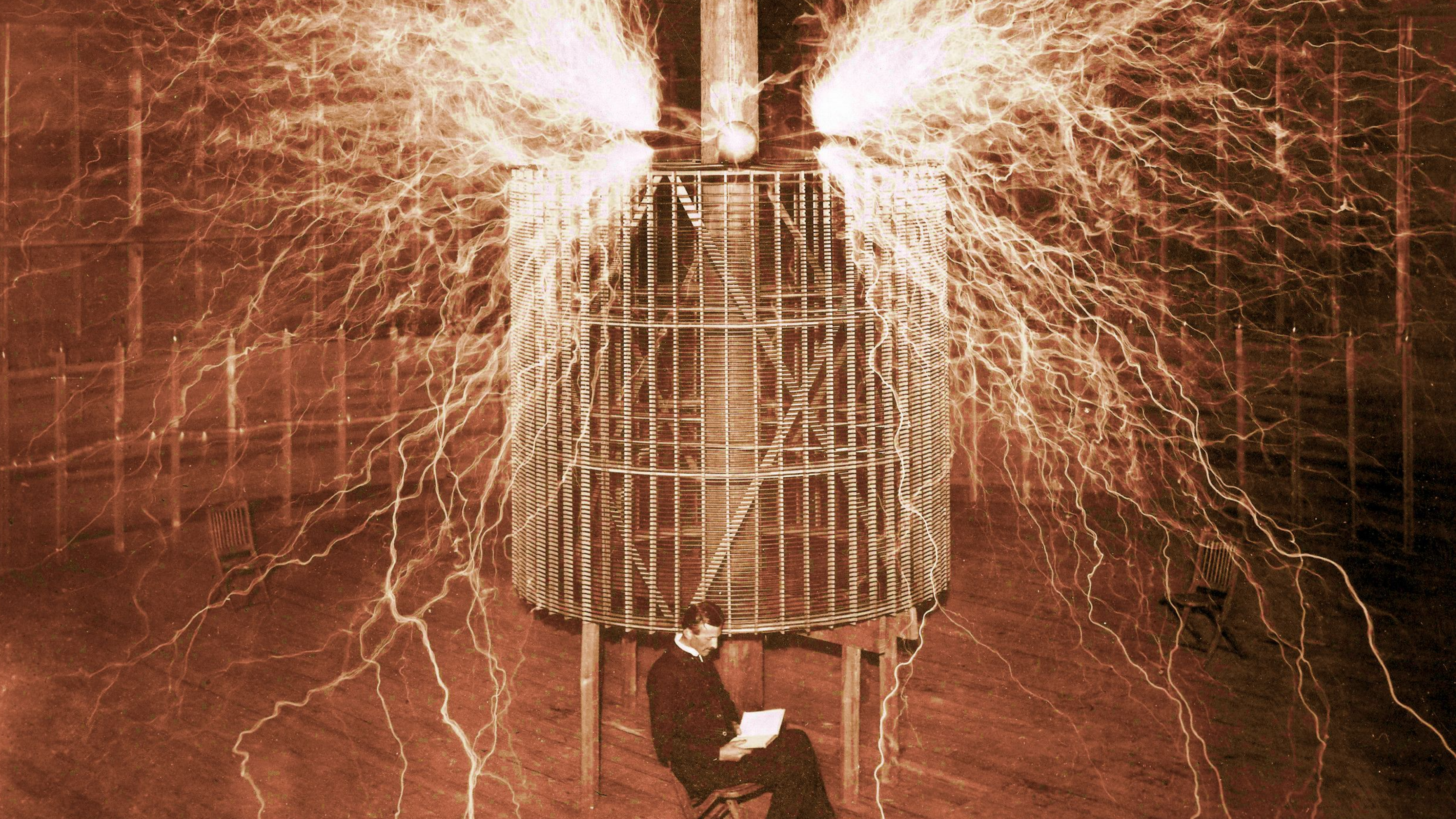
THE CURRENT WAR



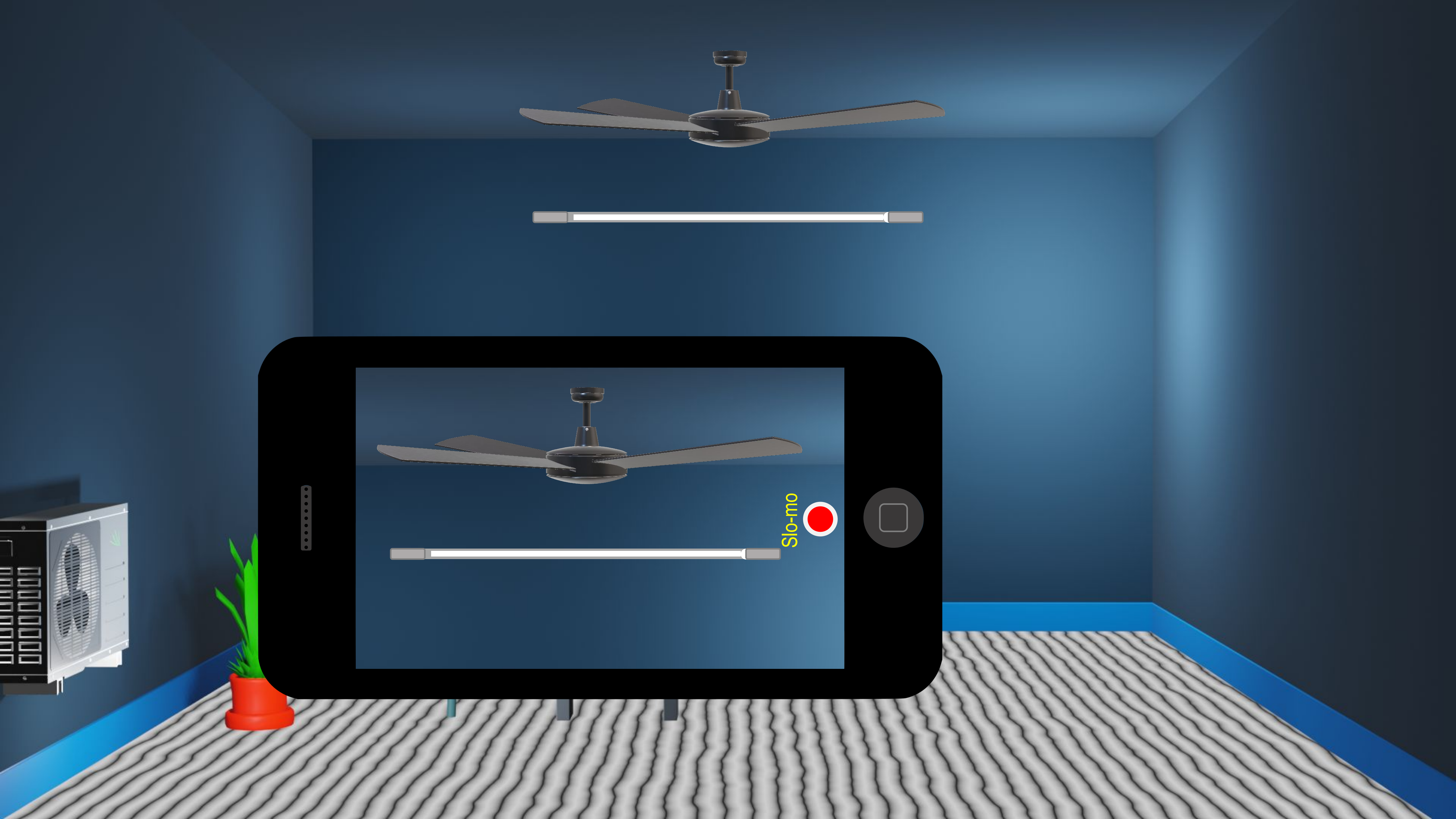


In July
1888


TESLA-WESTINGHOUSE NIAGARA FALLS POWER PLANT(1895)



POWER TRANSMISSION

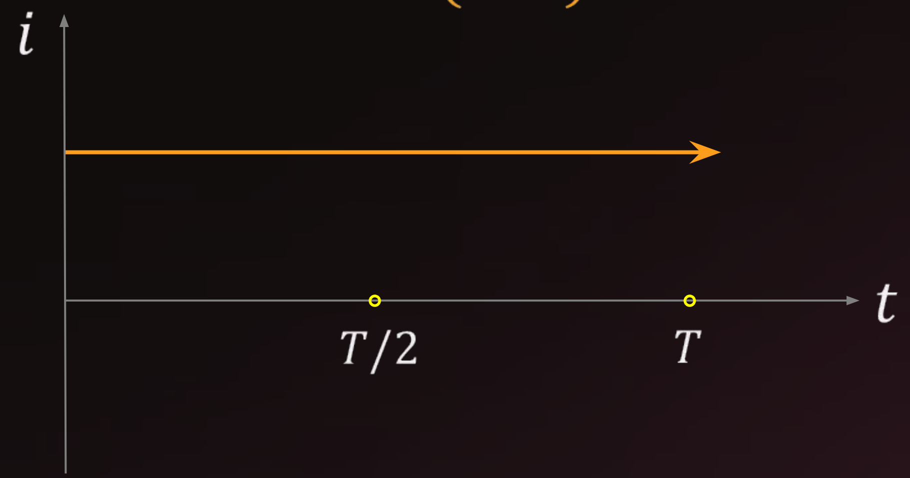

Slo-mo

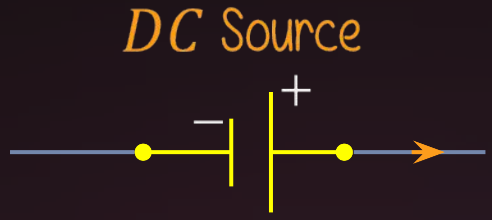
CONTENTS

Alternating current

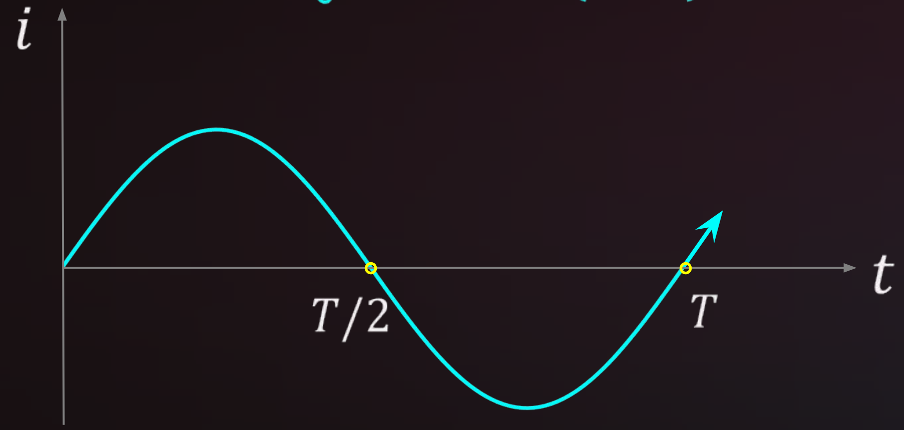
An electric current which periodically reverses its direction in contrast to direct current which flows only in one direction.

Direct Current (DC)



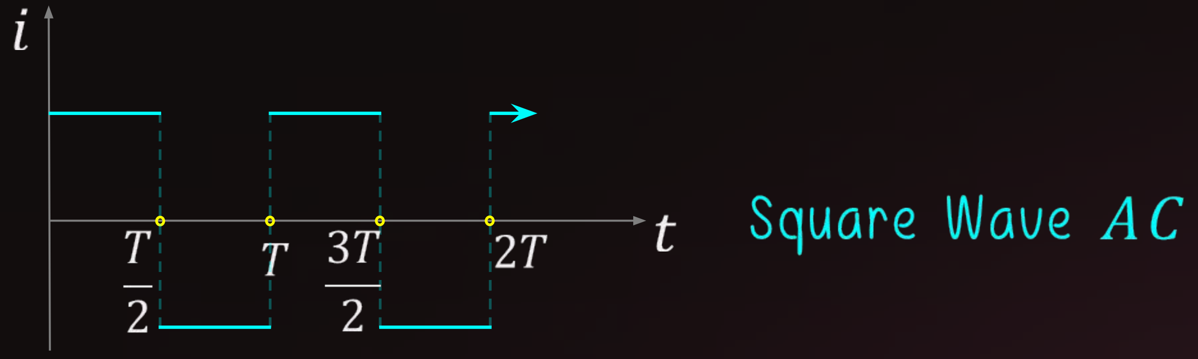


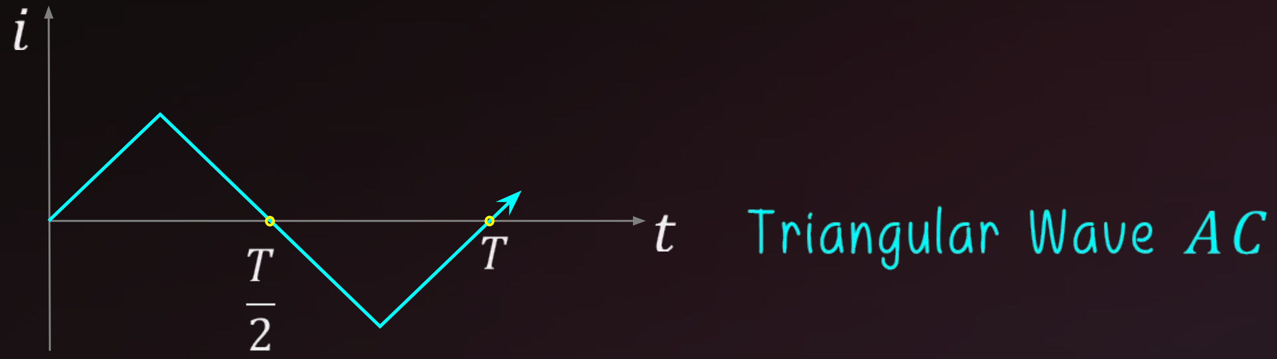
Alternating Current (AC)

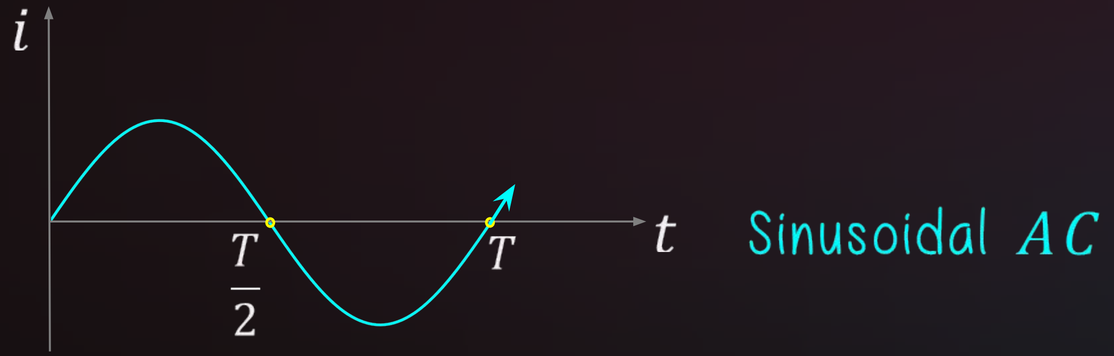


Alternating current

An electric current which periodically reverses its direction in contrast to direct current which flows only in one direction.

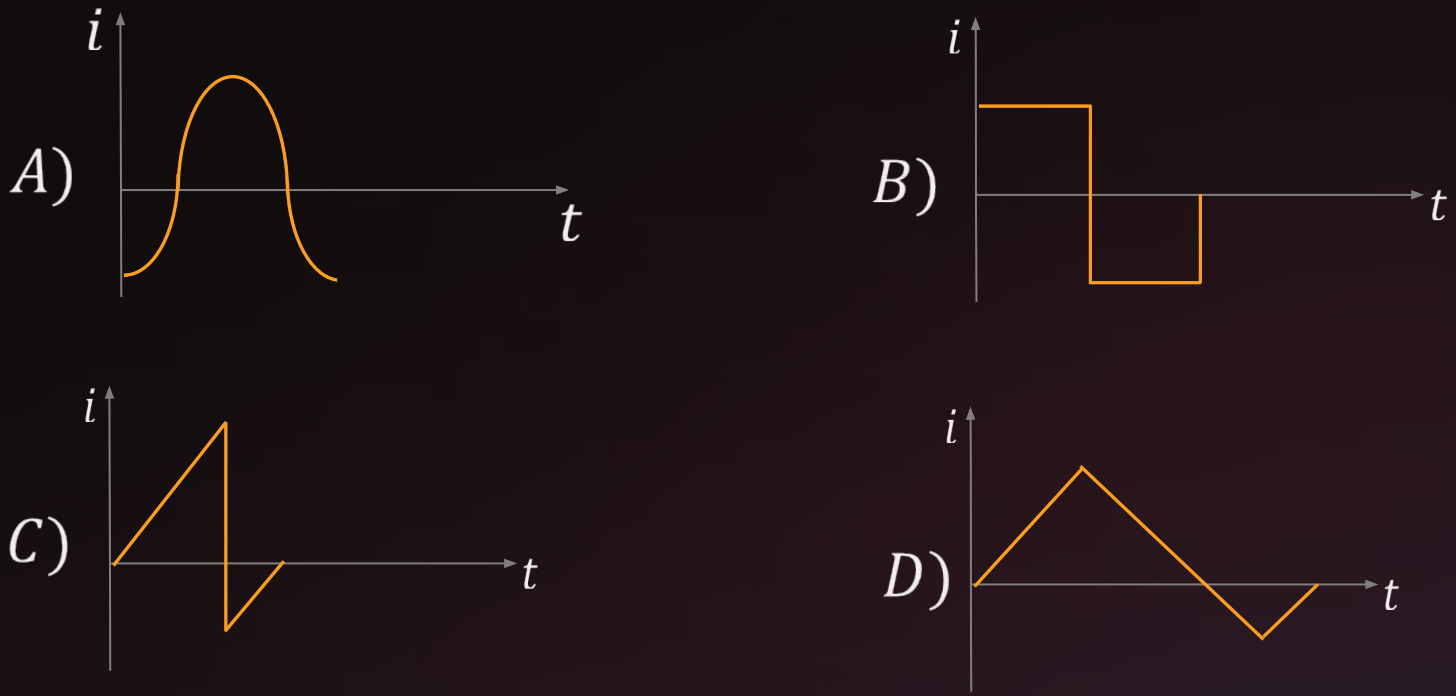






Question

Variation of emf with time for four types of generators are shown in the figures. Which amongst them can be called AC.



a) only A

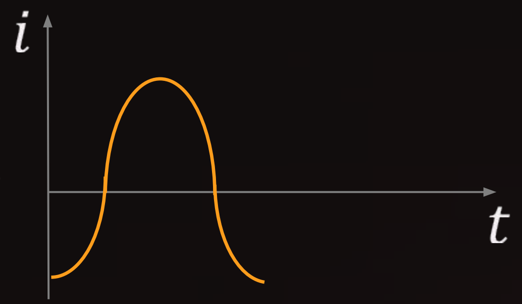
b) A & D

c) A, B, C, D

d) A & B

DISCUSSION

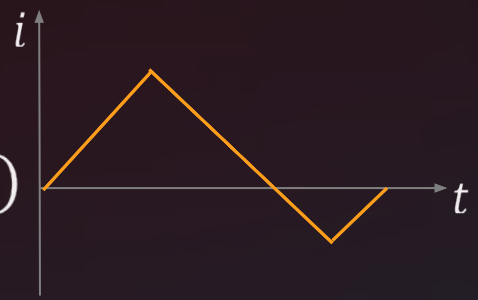
A)



B)

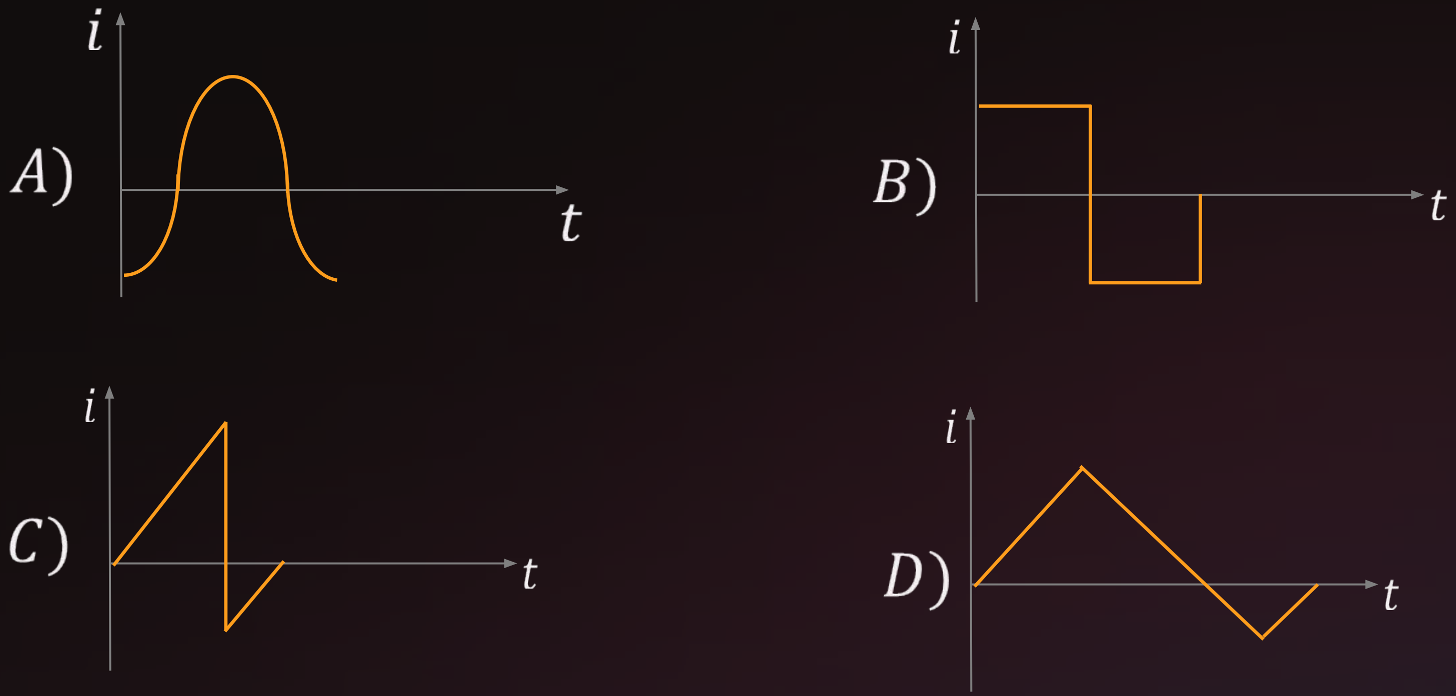
C)

D)



ANSWER

Which of the following are not alternating currents.



a) only A

b) A & D

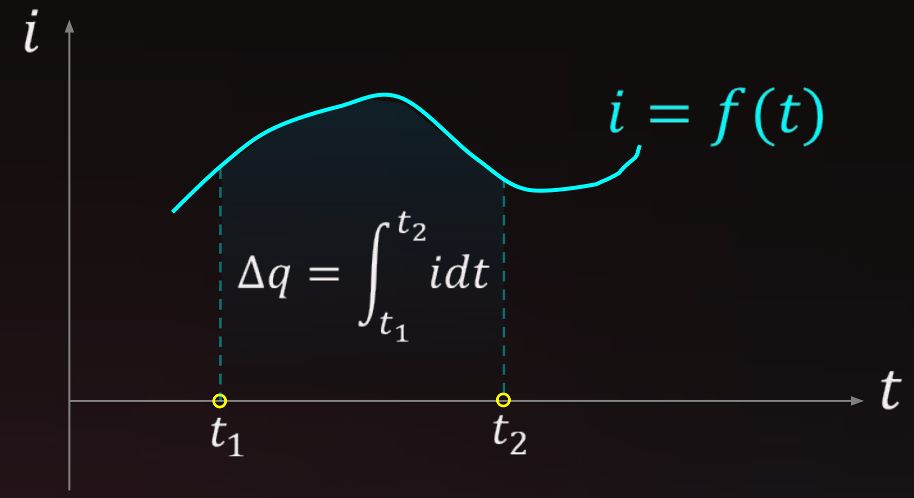
c) A, B, C, D

d) A & B

Current

Average current $(i_{av}) = \dfrac{\Delta q}{\Delta t}$

Average current representations $\quad i_{av} = \langle i \rangle = \overline{(i)}$



Average current (i_{av}) for time varying current is

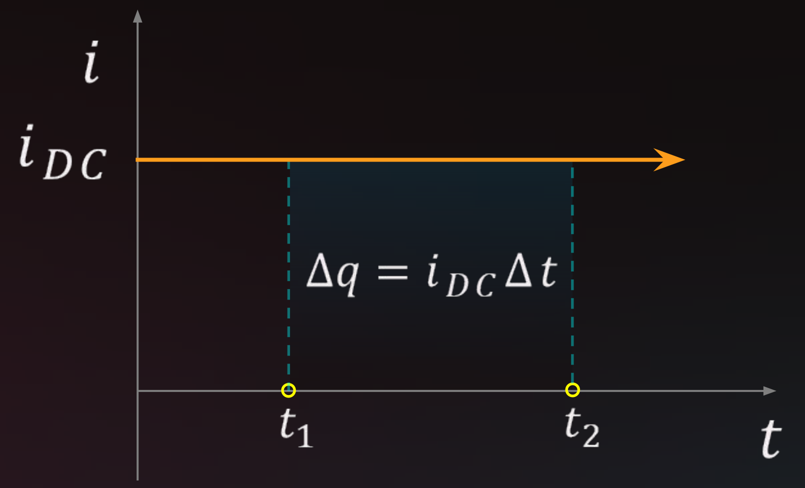
$$i_{av} = \frac{\Delta q}{\Delta t} = \frac{\int_{t_1}^{t_2} idt}{t_2 - t_1}$$

$$i_{av} = \frac{1}{\Delta t}\int_{t_1}^{t_2} idt$$

Current

$$t_1$$

Average value of an AC is equal to that DC for which the amount of charge that flows in a given amount of time is the same as that of AC .



$$\Delta q_{DC} = i_{DC}\Delta t \qquad \Delta q_{AC} = \int_{t_1}^{t_2} i\,dt$$

$$i_{DC}\Delta t = \int_{t_1}^{t_2} i\,dt$$

$$i_{DC} = \frac{1}{\Delta t}\int_{t_1}^{t_2} i\,dt$$

If $\Delta q_{DC} = \Delta q_{AC} \Rightarrow$ $i_{av} = i_{DC}$

Question

If $i = 3t^2$, find average current in $2\ s$.

a) $12\ A$

b) $3\ A$

c) $4\ A$

d) $0\ A$

SUMMARY

If $i = 3t^2$, find average current in 2 s.

$i = 3t^2$

$$i_{av} = \frac{1}{\Delta t}\int_{t_1}^{t_2} i\,dt$$

$t_1 = 0\ s$
$t_2 = 2\ s$

$$i_{av} = \frac{1}{2}\int_{0}^{2} 3t^2\,dt$$

$$i_{av} = \frac{1}{2}\left(\frac{3t^3}{3}\right)_0^2 = \frac{8}{2}\ A$$

$$i_{av} = 4\ A$$

ANSWER

If $i = 3t^2$, find average current in $2\ s$.

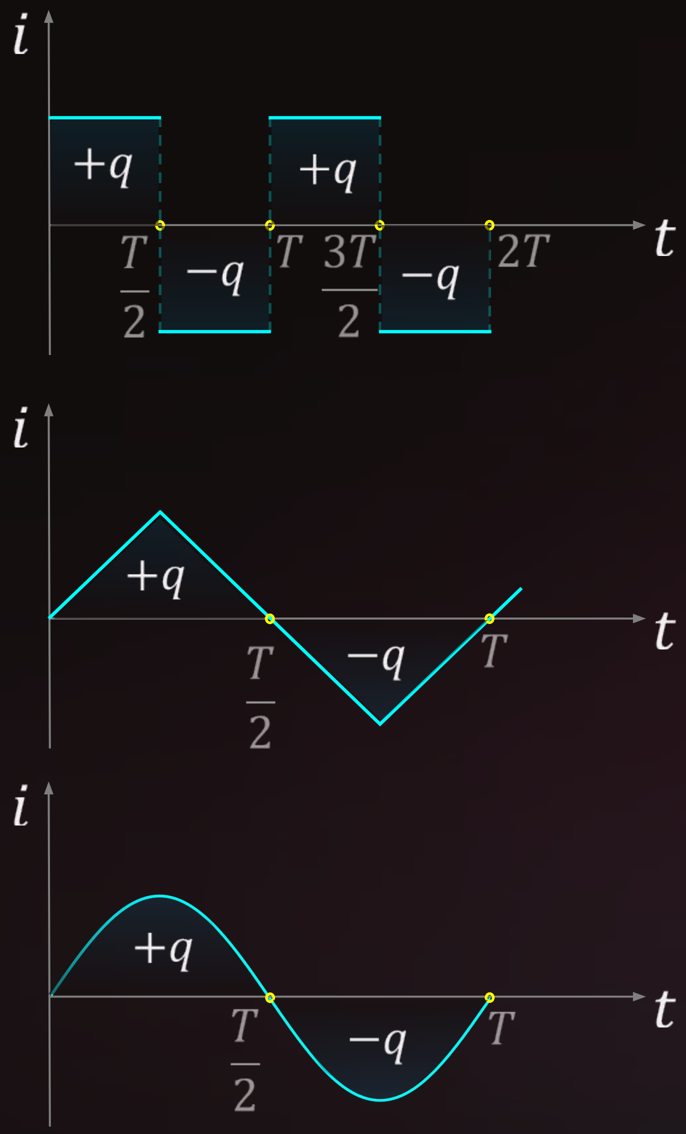
a) $12\ A$

b) $3\ A$

c) $4\ A$

d) $0\ A$

AC

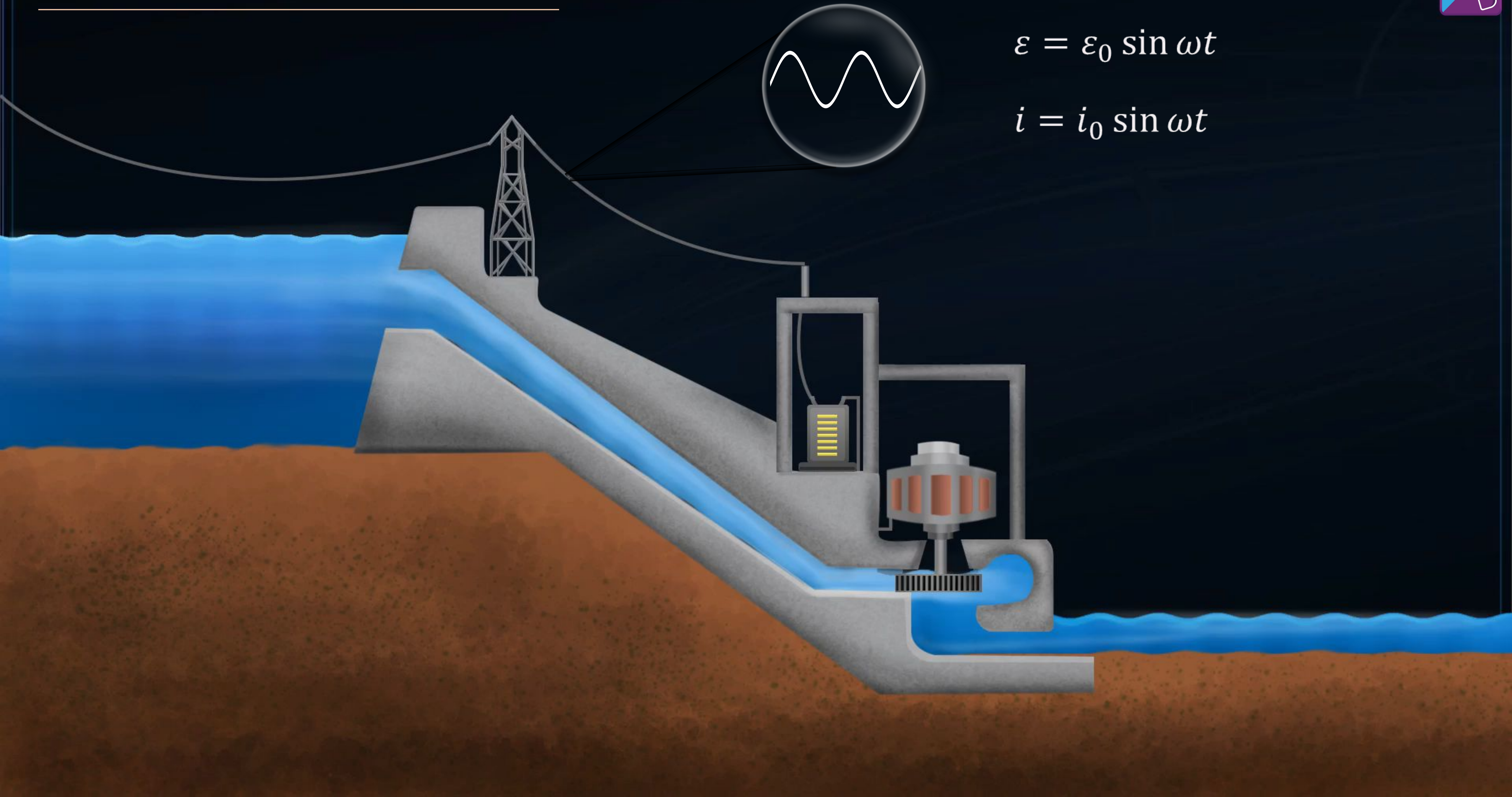


$$\therefore \int_0^T i\,dt = q - q = 0$$

$$i_{av} = \frac{1}{\Delta t}\int_0^T i\,dt = 0$$

i_{av} for full cycle of AC is zero

current



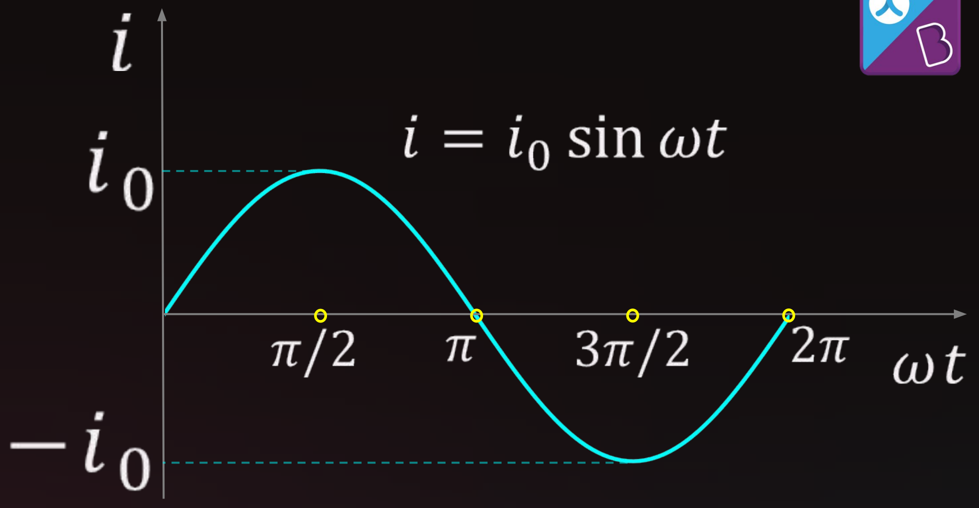
$$\varepsilon = \varepsilon_0 \sin \omega t$$

$$i = i_0 \sin \omega t$$

SINUSOIDAL AC

For full cycle

$$i_{av} = \frac{1}{(T-0)} \int_0^T i_0 \sin \omega t \, dt \qquad \left(i_{av} = \frac{1}{\Delta t} \int_{t_1}^{t_2} i dt \right)$$



$$i_{av} = \frac{1}{T} i_0 \left(-\frac{\cos \omega t}{\omega} \right)_0^T = \frac{i_0}{T\omega} (\cos 0 - \cos \omega T)$$

$$i_{av} = \frac{i_0}{T\omega} (\cos 0 - \cos 2\pi) = 0 \qquad \left(\omega = \frac{2\pi}{T} \right)$$

$$(i_{av})_{full\ cycle} = 0$$

SINUSOIDAL AC

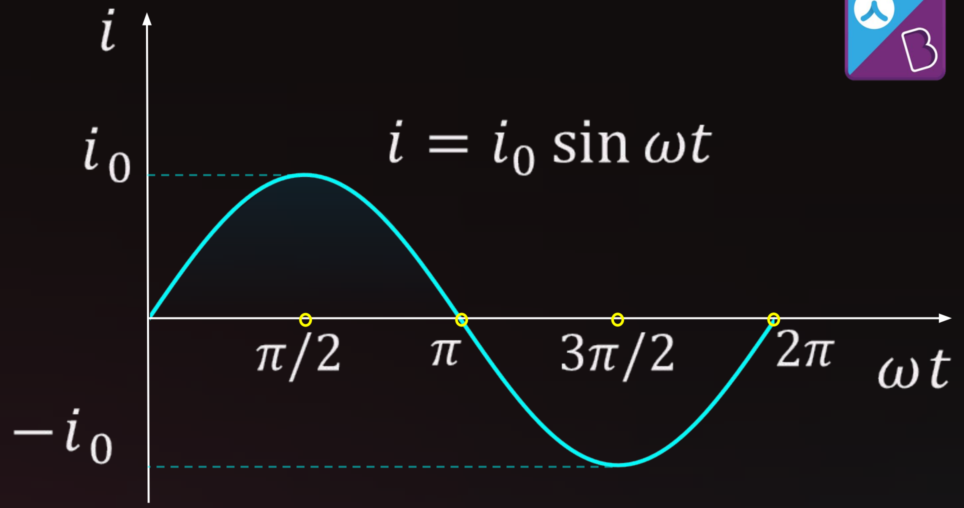
For half cycle

$$i_{av} = \frac{1}{\left(\frac{T}{2} - 0\right)} \int_0^{T/2} i_0 \sin \omega t \, dt$$

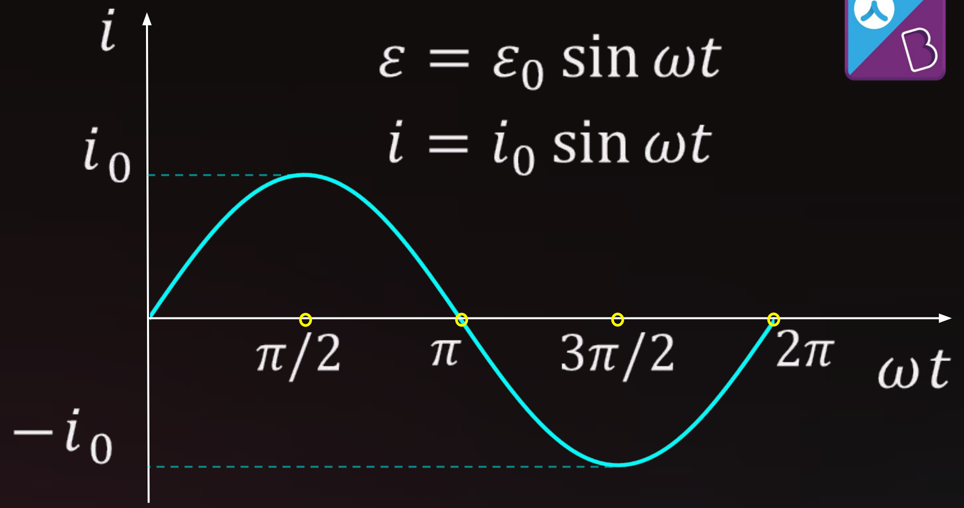
$$i_{av} = \frac{2}{T} i_0 \left(-\frac{\cos \omega t}{\omega}\right)_0^{T/2} = \frac{2i_0}{T\omega}\left(\cos 0 - \cos \frac{\omega T}{2}\right)$$

$$i_{av} = \frac{2i_0}{T\omega}(\cos 0 - \cos \pi) = \frac{4i_0}{T \times \frac{2\pi}{T}}$$

$$(i_{av})_{half\ cycle} = \frac{2i_0}{\pi}$$



SINUSOIDAL AC



- For full cycle $$(i_{av})_{full\ cycle} = 0$$
- For half cycle $$(i_{av})_{half\ cycle} = \frac{2i_0}{\pi}$$
- For half cycle $$(\varepsilon_{av})_{half\ cycle} = \frac{2\varepsilon_0}{\pi}$$

Root mean square(rms) value

Root mean square (rms)

$$\sqrt{< x^2 >} = x_{rms}$$

$$i_{rms} = \sqrt{< i^2 >}$$

$$i_{rms} = \sqrt{\frac{1}{\Delta t}\int_{t_1}^{t_2} i^2 dt}$$

$$\varepsilon_{rms} = \sqrt{< \varepsilon^2 >}$$

$$\varepsilon_{rms} = \sqrt{\frac{1}{\Delta t}\int_{t_1}^{t_2} \varepsilon^2 dt}$$

AC

$$i_{rms} = \sqrt{< i^2 >}$$

$$i_{rms} = \sqrt{< i_0^2 \sin^2 \omega t >}$$

$$i_{rms}^2 = \frac{1}{T}\int_0^T i_0^2 \sin^2 \omega t \; dt = \frac{i_0^2}{T}\int_0^T \sin^2 \omega t \; dt$$

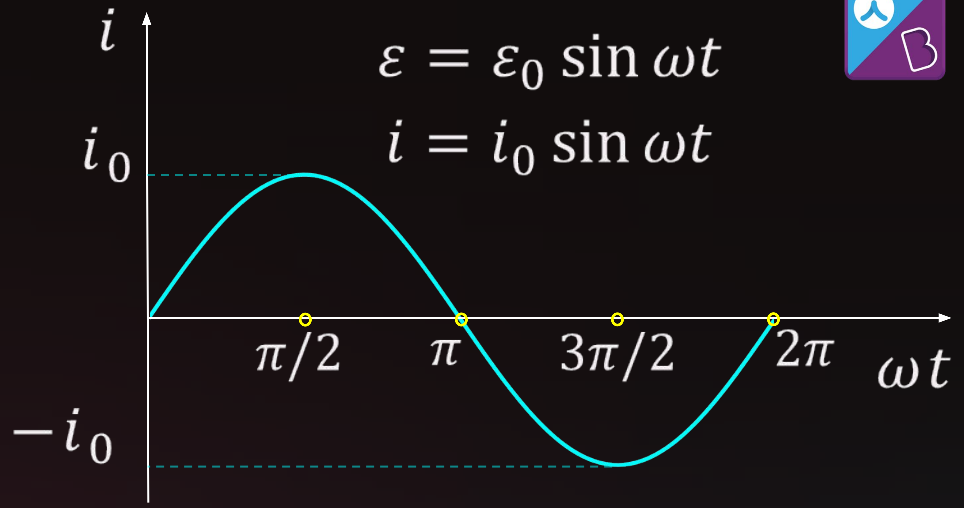
$$i_{rms}^2 = \frac{i_0^2}{T}\int_0^T \frac{1 - \cos 2\omega t}{2} \, dt$$

$$\left(\sin^2 \theta = \frac{1 - \cos 2\theta}{2}\right)$$

$$i_{rms}^2 = \frac{i_0^2}{2T}\left(t - \frac{\sin 2\omega t}{2\omega}\right)_0^T$$

$$\varepsilon = \varepsilon_0 \sin \omega t$$

$$i = i_0 \sin \omega t$$



AC

$$i_{rms} = \sqrt{< i^2 >}$$

$$i_{rms}^2 = \frac{i_0^2}{2T}\left(t - \frac{\sin 2\omega t}{2\omega}\right)_0^T \qquad \left(T = \frac{2\pi}{\omega}\right)$$

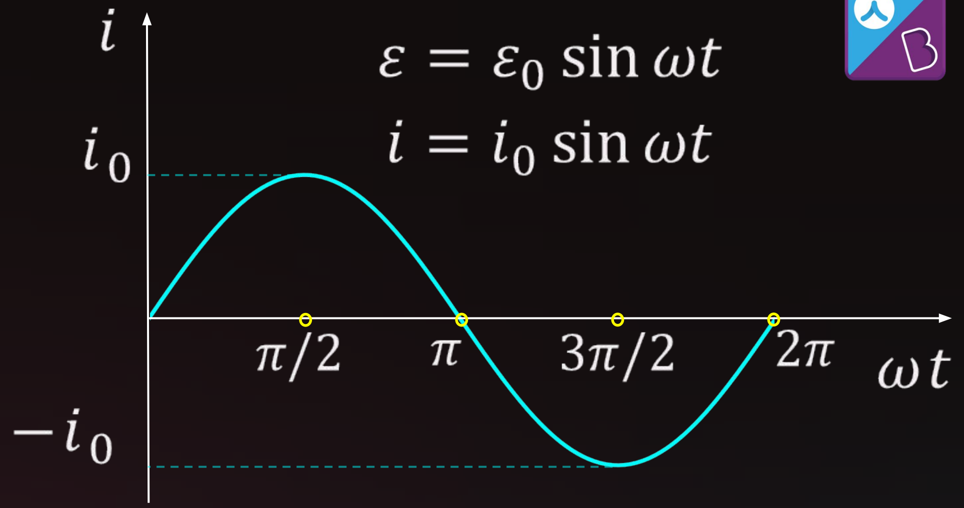
$$i_{rms}^2 = \frac{i_0^2}{2T}\left(\left(T - \frac{\sin 2\omega\left(\frac{2\pi}{\omega}\right)}{2\omega}\right) - (0 - \sin 0)\right) = \frac{i_0^2}{2T}\mathrm{T}$$

$$i_{rms}^2 = \frac{i_0^2}{2}$$

$$i_{rms} = \frac{i_0}{\sqrt{2}}$$

$$\varepsilon = \varepsilon_0 \sin \omega t$$

$$i = i_0 \sin \omega t$$



AC

$$i_{rms} = \frac{i_0}{\sqrt{2}}$$

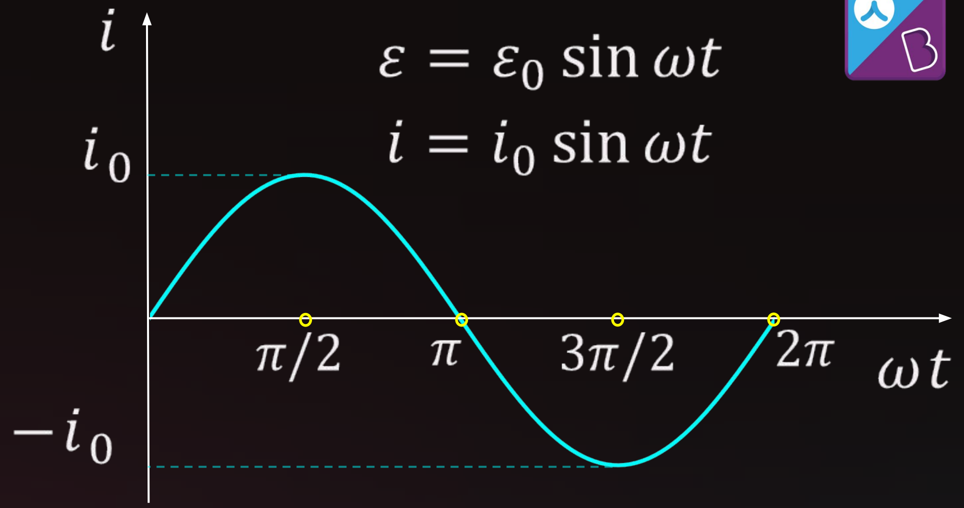
$$(i_{av})_{half\ cycle} = \frac{2i_0}{\pi}$$

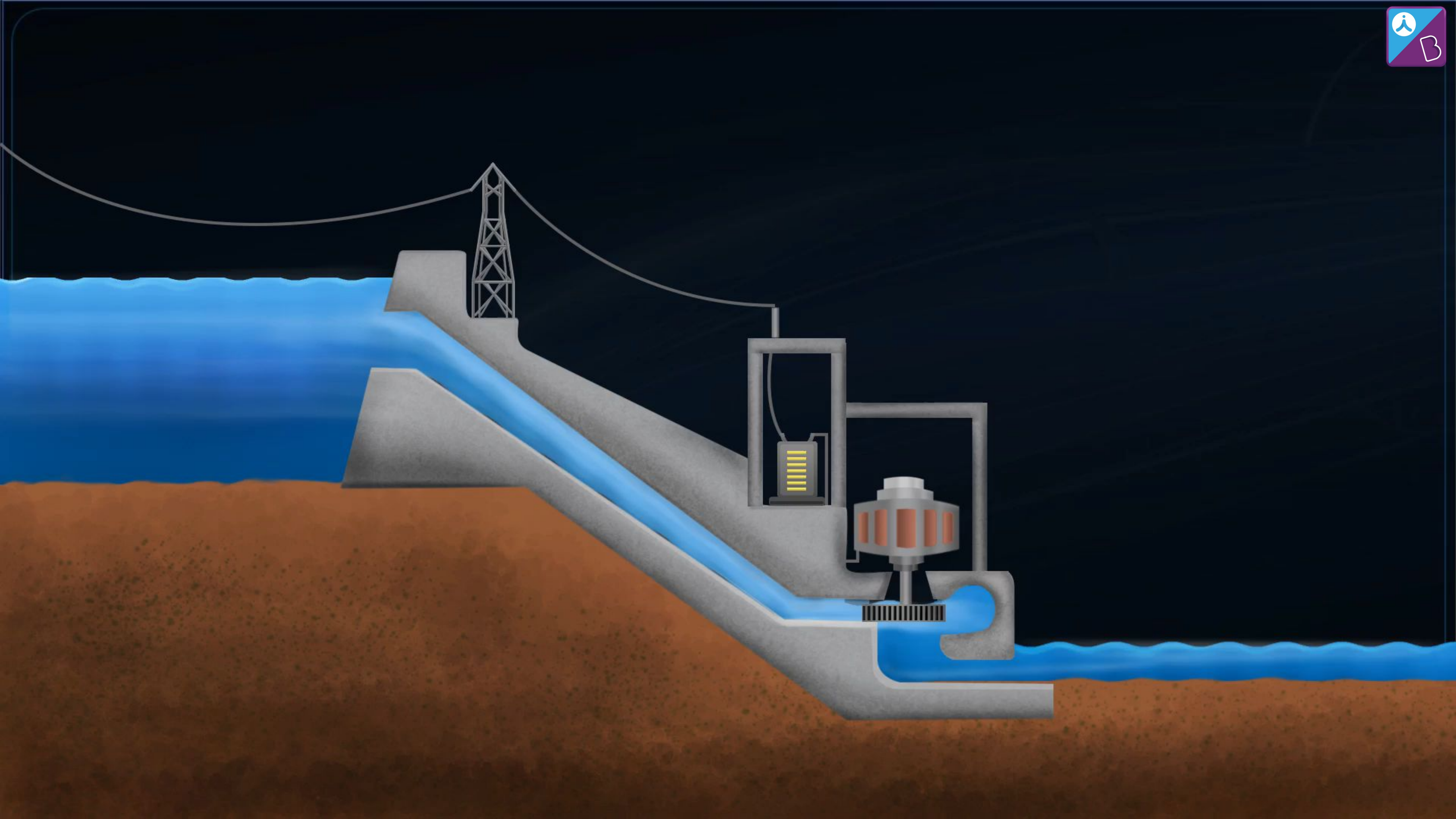
$$\varepsilon_{rms} = \frac{\varepsilon_0}{\sqrt{2}}$$

$$(\varepsilon_{av})_{half\ cycle} = \frac{2\varepsilon_0}{\pi}$$

$$\varepsilon = \varepsilon_0 \sin \omega t$$

$$i = i_0 \sin \omega t$$





Household current $\rightarrow$ sinusoidal AC ($\varepsilon = \varepsilon_0 \sin \omega t$)

$220\ V, 50\ Hz$

Significance OF Rms value

Household current $\rightarrow$ sinusoidal AC ($\varepsilon = \varepsilon_0 \sin \omega t$)

$220\ V, 50\ Hz$

- $\varepsilon_{rms} = 220\ V$
- $\varepsilon_{av} = 0\ V$
- $\varepsilon_0 = \sqrt{2}\varepsilon_{rms}$

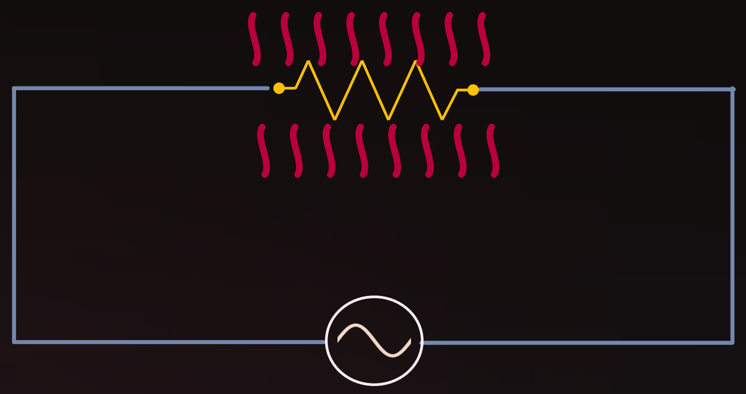
$\varepsilon_0 = \sqrt{2} \times 220 = 311.12\ V \approx 311\ V$

If problem states only ε (not $\varepsilon_0, \varepsilon_{rms}, \varepsilon_{av}$) then, consider it as ε_{rms}

Significance OF Rms value

Heat produced in AC circuit through resistor R in time t_1 to t_2

$$H_{AC} = \int_{t_1}^{t_2} i_{AC}^2 R dt \qquad i_{rms} = \sqrt{\frac{1}{\Delta t}\int_{t_1}^{t_2} i_{AC}^2 dt}$$



$$i_{AC} = i_0 \sin \omega t$$

Heat produced in DC circuit through resistor R in time t_1 to t_2

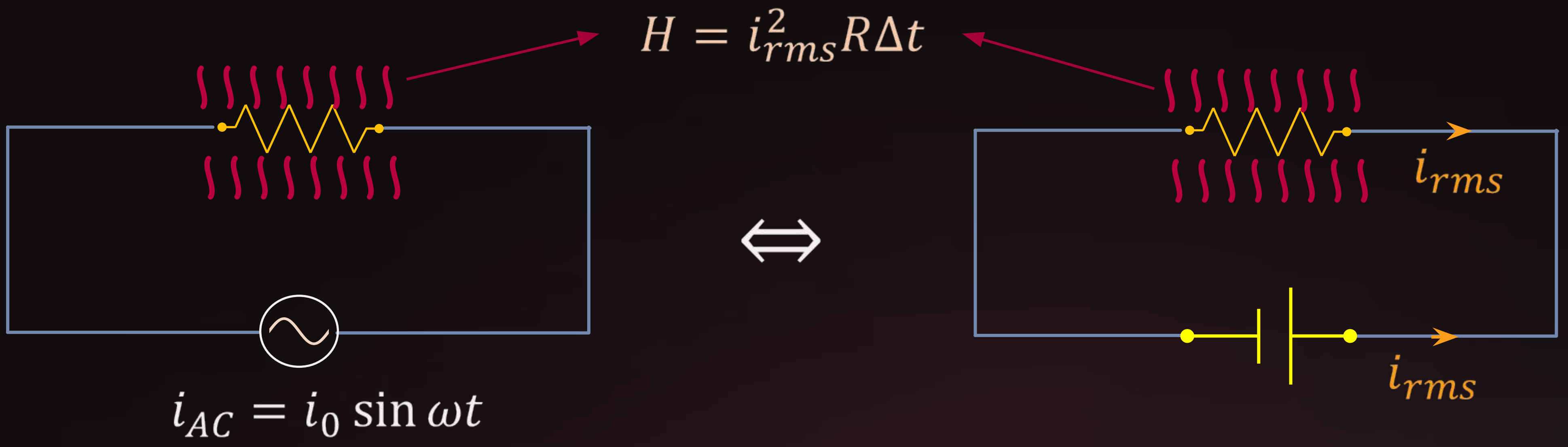
$$H_{DC} = i_{DC}^2 R \Delta t$$

$$i_{DC}^2 R \Delta t = \int_{t_1}^{t_2} i_{AC}^2 R dt$$

$$i_{DC} = \sqrt{\frac{1}{\Delta t}\int_{t_1}^{t_2} i_{AC}^2 dt}$$

$\therefore$ If $\Delta H_{DC} = \Delta H_{AC} \Rightarrow$ $i_{rms} = i_{DC}$

Significance OF Rms value

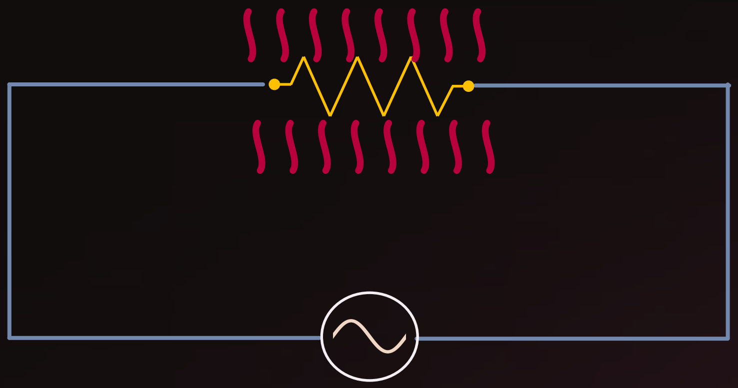


RMS value of a given AC can be defined as that DC value which produces same heat in a resistance which the AC produces in that resistance in same duration.

i_{rms} is the effective DC value of a given AC

Significance OF Rms value

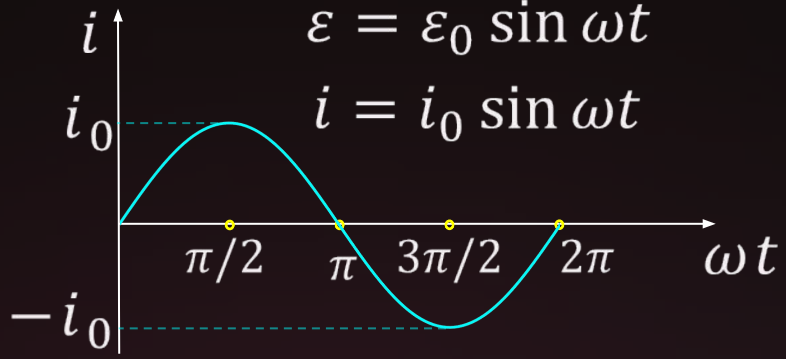
$$H = i_{rms}^2 R \Delta t$$



$$i_{AC} = i_0 \sin \omega t$$

$$\varepsilon = \varepsilon_0 \sin \omega t$$

$$i = i_0 \sin \omega t$$



- DC devices cannot measure alternating current or emf. Normal Ammeter, Voltmeter will show only zero for AC

- Hot Wire Ammeter & Hot Wire Voltmeter are used to measure AC. They measure RMS value of i & ε.

Question

If the voltage of a source in an AC circuit is represented by the equation, $E = 220\sqrt{2}\sin(314t)$. Calculate the peak value of the current if the net resistance of the circuit is $220\ \Omega$. Take $\sqrt{2} = 1.4$

a) $1.8\ A$

b) $1.6\ A$

c) $1.4\ A$

d) $1.2\ A$

DISCUSSION

Given,

Voltage, $\varepsilon = 220\sqrt{2}\sin(314t)$

Comparing with $\varepsilon = \varepsilon_o \sin \omega t$, we get,

$$\varepsilon_o = 220\sqrt{2}\ V$$

So, peak value of current

$$i_o = \frac{\varepsilon_o}{R} = \frac{220\sqrt{2}}{220}$$

$$i_o = 1.4\ A$$

ANSWER

If the voltage of a source in an AC circuit is represented by the equation, $E = 220\sqrt{2}\sin(314t)$. Calculate the peak value of the current if the net resistance of the circuit is $220\ \Omega$. Take $\sqrt{2} = 1.4$

a) $1.8\ A$

b) $1.6\ A$

c) $1.4\ A$

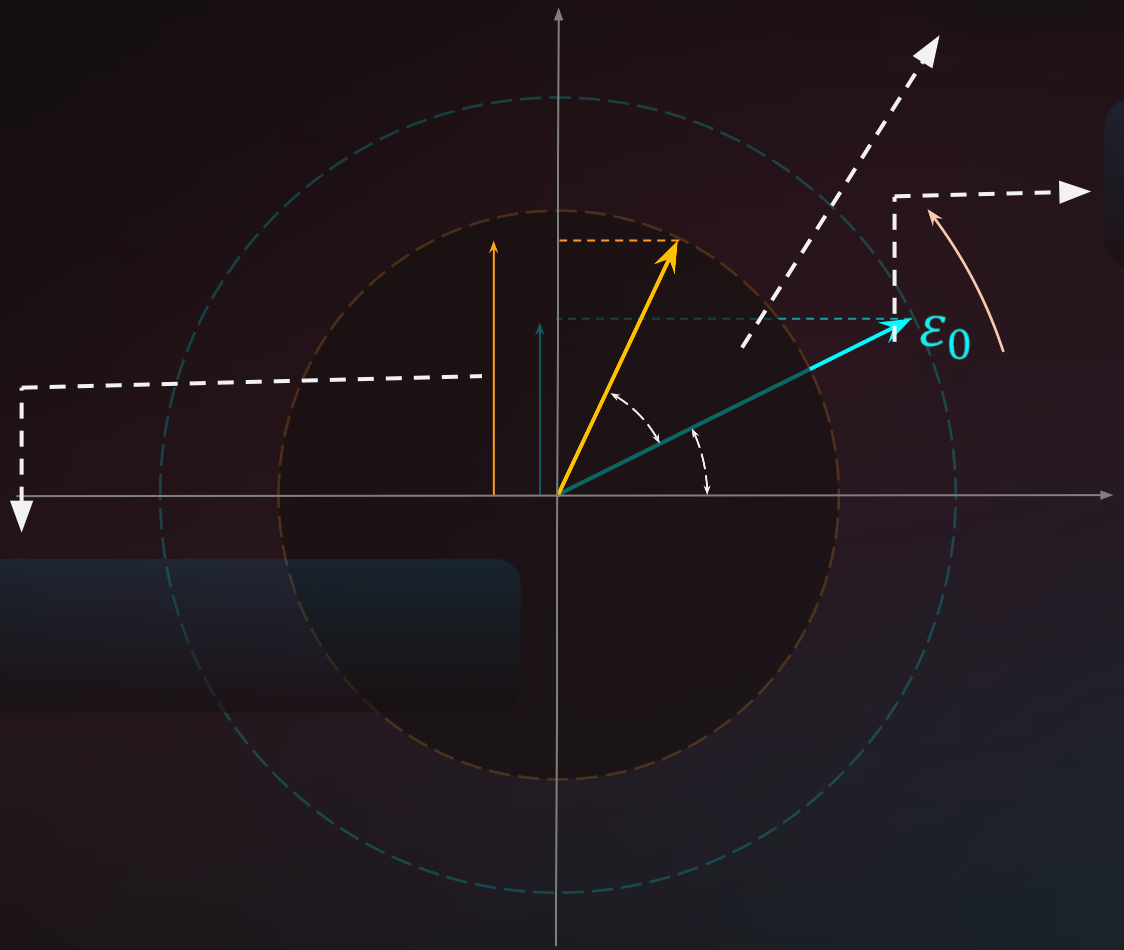
d) $1.2\ A$

diagram

A diagram that represents AC and voltage of same frequency as rotating vectors (phasors)

along with proper phase angle between them.

Phase difference



CIRCUITS

I. An AC source connected only to:

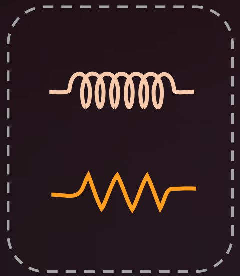

A Resistor

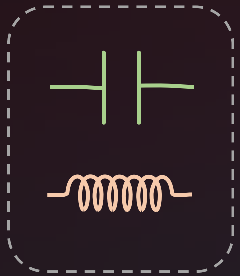

An Inductor


A Capacitor

II. An AC source connected to more than one element.


RC Circuit

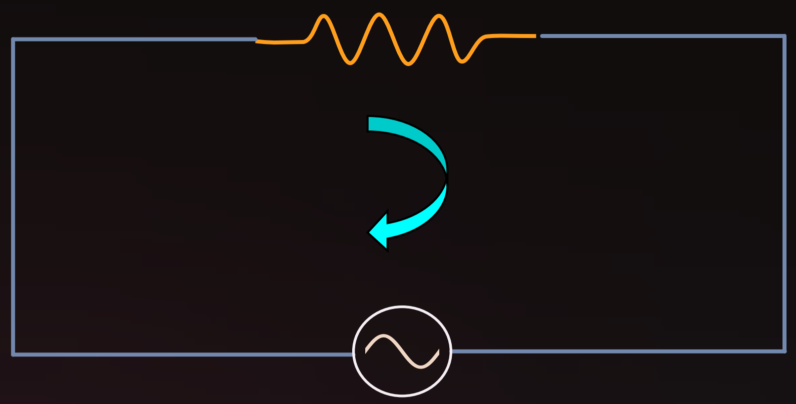

LR Circuit


LC Circuit


LCR Circuit

Circuit

Apply KVL ;



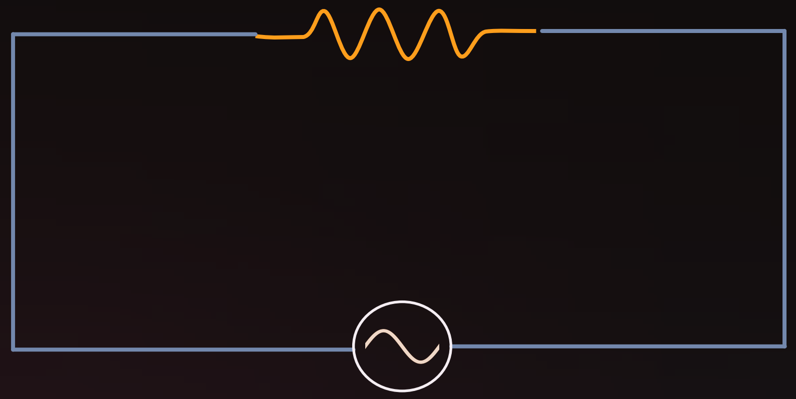
Peak voltage

Peak current

Current is in phase with potential

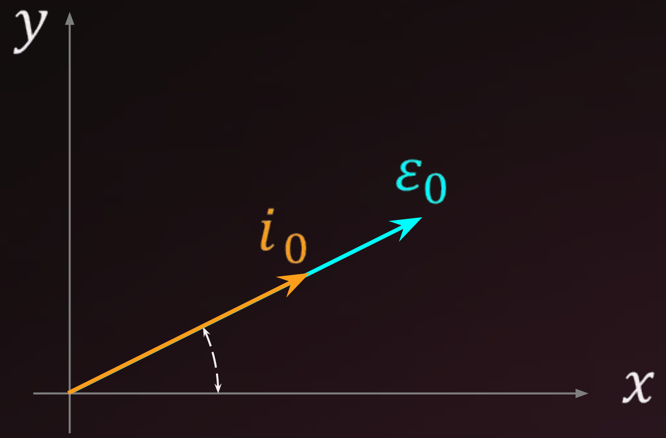
Circuit

Current is in phase with potential

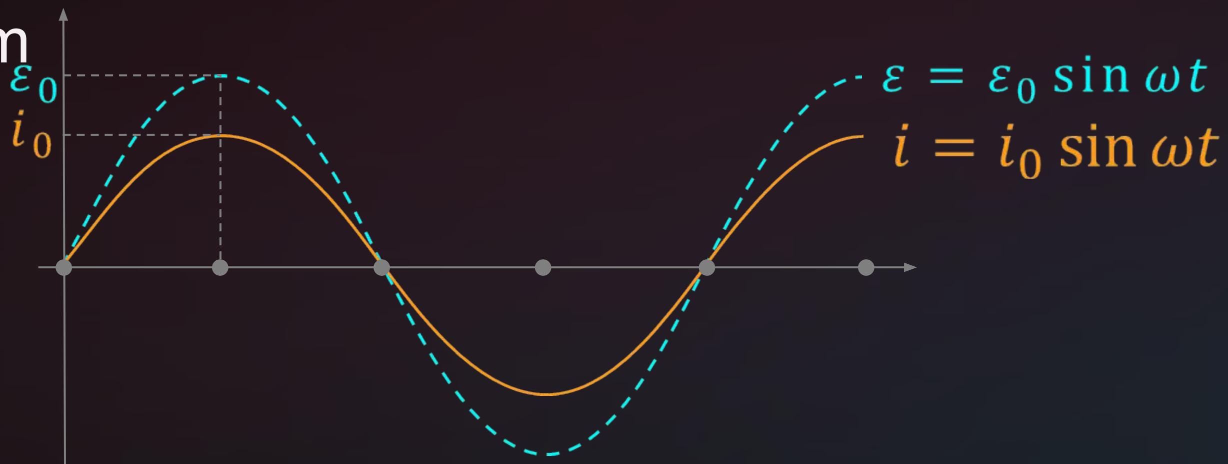


$$i = i_0 \sin \omega t$$

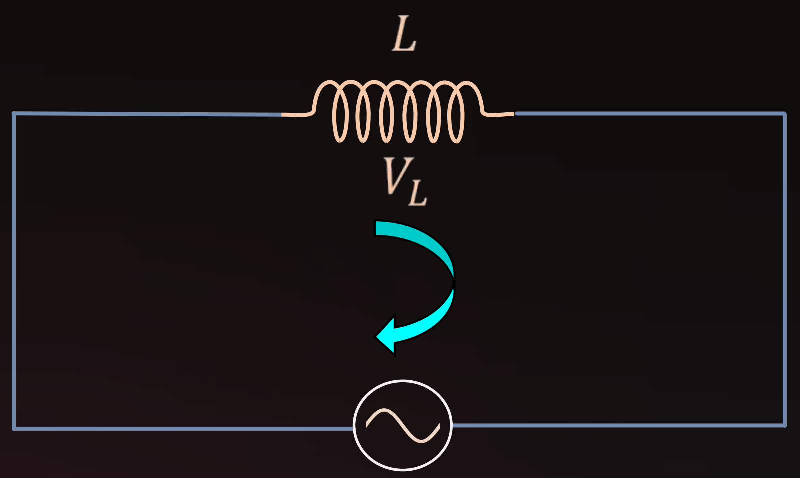
Phasor diagram



Wave diagram



Circuit



$\varepsilon = \varepsilon_0 \sin \omega t$

Potential drop across inductance,

$$V_L = L\frac{di}{dt}$$

Apply KVL ;

$$\varepsilon - V_L = 0$$

$$L\frac{di}{dt} = \varepsilon \quad \Rightarrow \quad di = \frac{\varepsilon}{L}dt$$

$$i = \int di = \int \frac{\varepsilon_0 \sin \omega t}{L} dt$$

$$i = \frac{\varepsilon_0}{L}\frac{(-\cos \omega t)}{\omega} = -\frac{\varepsilon_0}{L\omega} \cos \omega t$$

Circuit

$$i = \frac{\varepsilon_0}{L}\frac{(-\cos \omega t)}{\omega} = -\frac{\varepsilon_0}{L\omega}\cos \omega t$$

$$i = -\frac{\varepsilon_0}{L\omega}\sin\left(\frac{\pi}{2} - \omega t\right) = \frac{\varepsilon_0}{L\omega}\sin\left(\omega t - \frac{\pi}{2}\right)$$

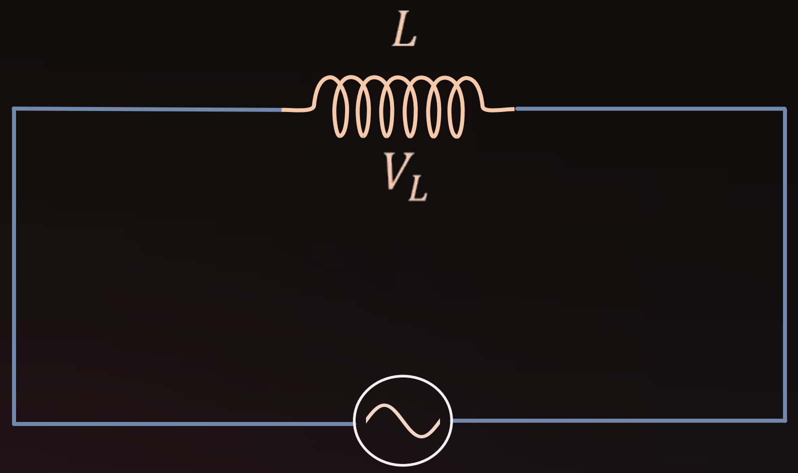
i_0

$$i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$i_0 = \frac{\varepsilon_0}{L\omega} = \frac{\varepsilon_0}{X_L}$$

$$X_L = L\omega$$ Inductive reactance

SI Unit : Ohm (Ω)

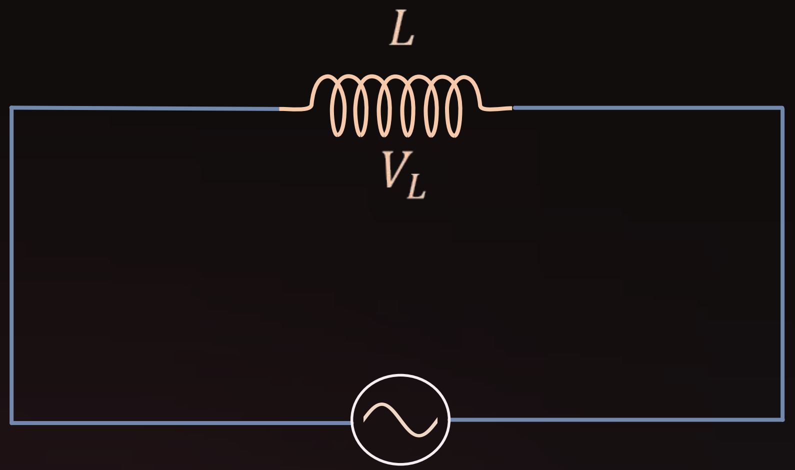


$$\varepsilon = \varepsilon_0 \sin \omega t$$

Circuit

Phase difference $(\phi) = \left(\omega t - \frac{\pi}{2}\right) - \omega t = -\frac{\pi}{2}$

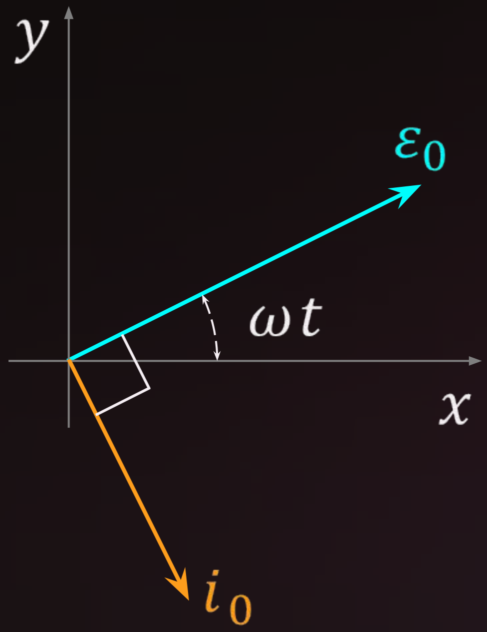
Current lags potential by $90°$



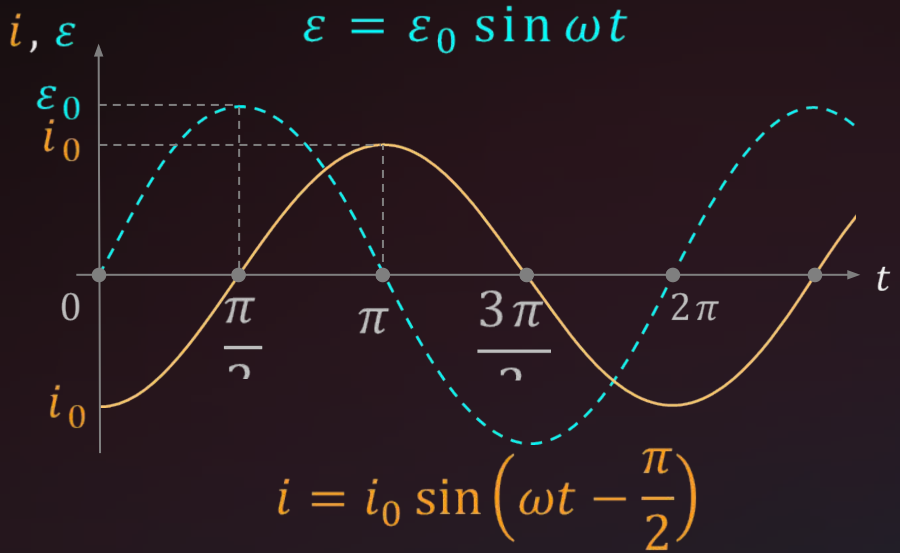
$$\varepsilon = \varepsilon_0 \sin \omega t$$

$$i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$$

Phasor diagram



Wave diagram

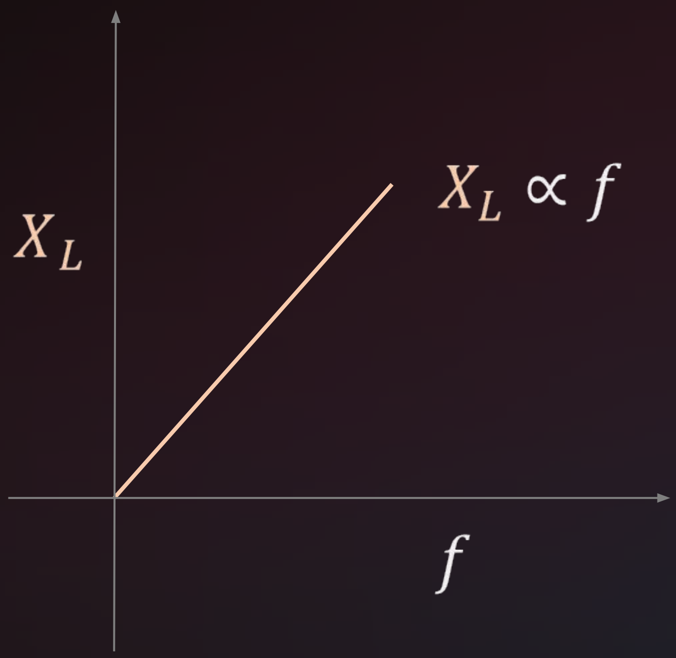


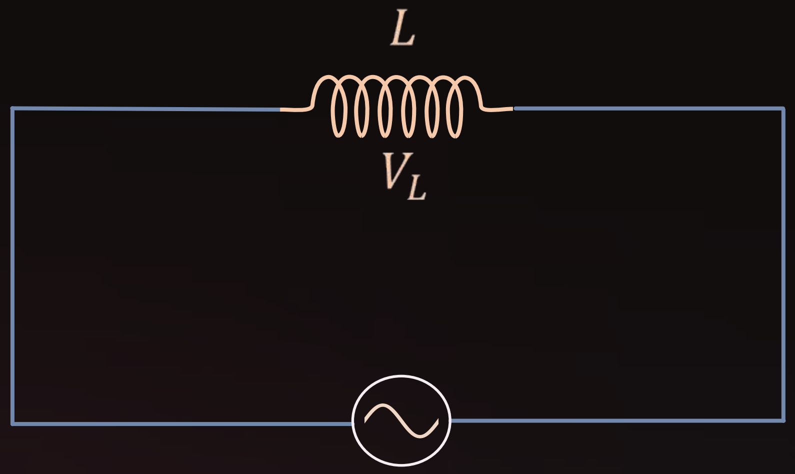
Circuit

X_L v/s frequency (f)

$$X_L = L\omega$$

$$X_L = L \times 2\pi f \quad (\because \omega = 2\pi f)$$





$$\varepsilon = \varepsilon_0 \sin \omega t$$

$$i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$$

Question

Find i_{avg} and i_{rms} of given circuit.

a

$i_{avg} = 0$

$i_{rms} = 0$

b

$i_{avg} = \frac{1}{\pi} A$

$i_{rms} = \frac{0.5}{\sqrt{2}} A$

c

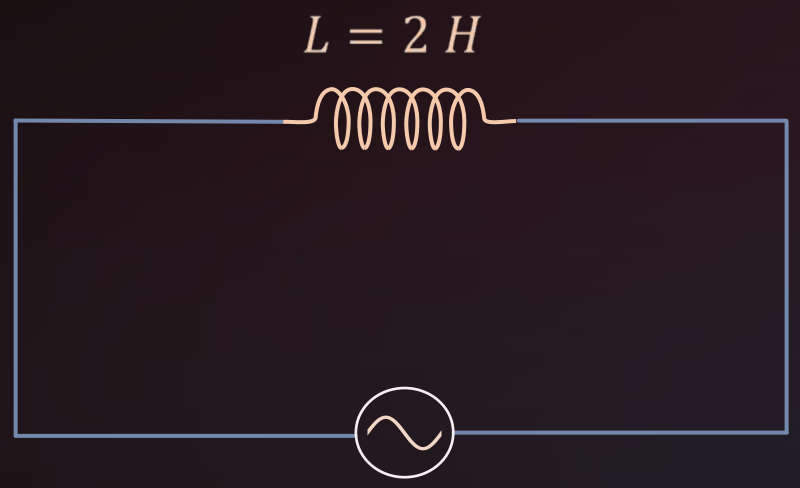
$i_{avg} = 0$

$i_{rms} = \frac{0.5}{\sqrt{2}} A$

d

$i_{avg} = \frac{2}{\pi} A$

$i_{rms} = 0$



$\varepsilon = 10 \sin(10t + 30°)$

Y

$$\varepsilon = \varepsilon_0 \sin(\omega t + \phi)$$

$$\varepsilon_0 = 10\ V$$

$$\omega = 10\ s^{-1}$$

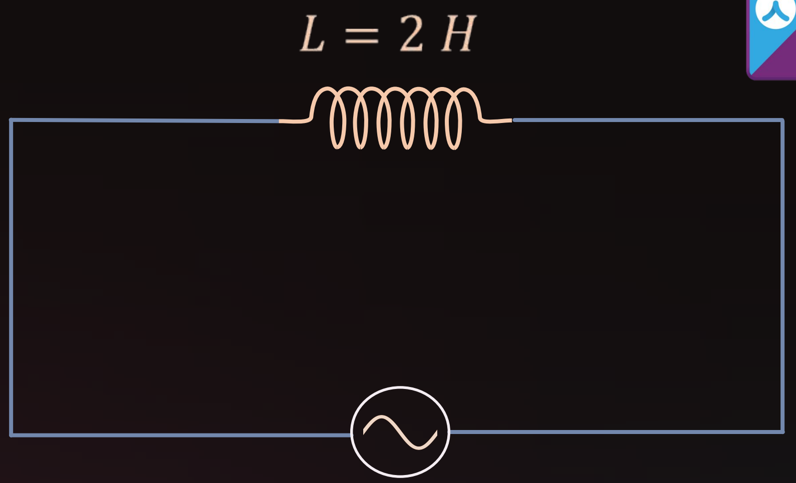
$$i_0 = \frac{\varepsilon_0}{X_L}$$

$$i_0 = \frac{\varepsilon_0}{L\omega}$$

$$i_0 = \frac{10}{2 \times 10} = 0.5\ A$$

$i_{avg} = 0$ (For full cycle of AC $i_{av} = 0$)

$$i_{rms} = \frac{i_0}{\sqrt{2}} = \frac{0.5}{\sqrt{2}}\ A$$



$$\varepsilon = 10 \sin(10t + 30°)$$

ANSWER

Find i_{avg} and i_{rms} of given circuit.

a

$i_{avg} = 0$

$i_{rms} = 0$

b

$i_{avg} = \frac{1}{\pi} A$

$i_{rms} = \frac{0.5}{\sqrt{2}} A$

c

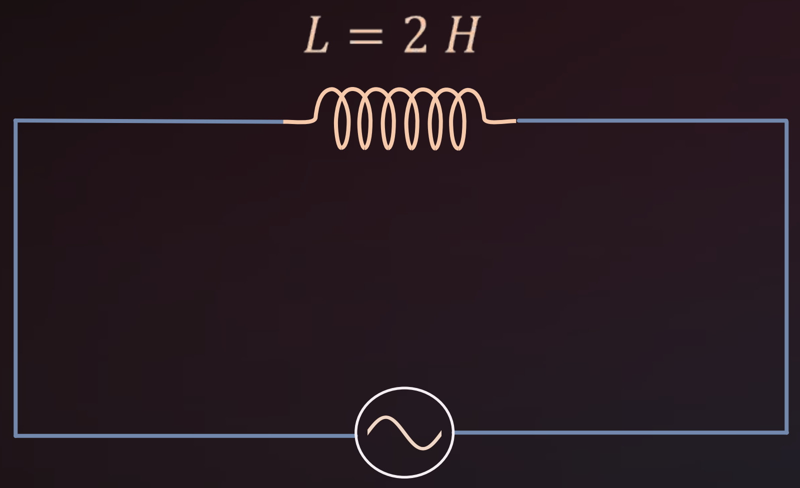
$i_{avg} = 0$

$i_{rms} = \frac{0.5}{\sqrt{2}} A$

d

$i_{avg} = \frac{2}{\pi} A$

$i_{rms} = 0$



$\varepsilon = 10 \sin(10t + 30°)$