# ملزمة الوحدة العاشرة دارات التيار المتناوب مع تدريبات




إعداد: عبد الرحمن عصام

| المزيد من الملفات بحسب الصف الثاني عشر المتقدم والمادة فيزياء في الفصل الثالث | |
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اسم الطالب: ..........................................................................................

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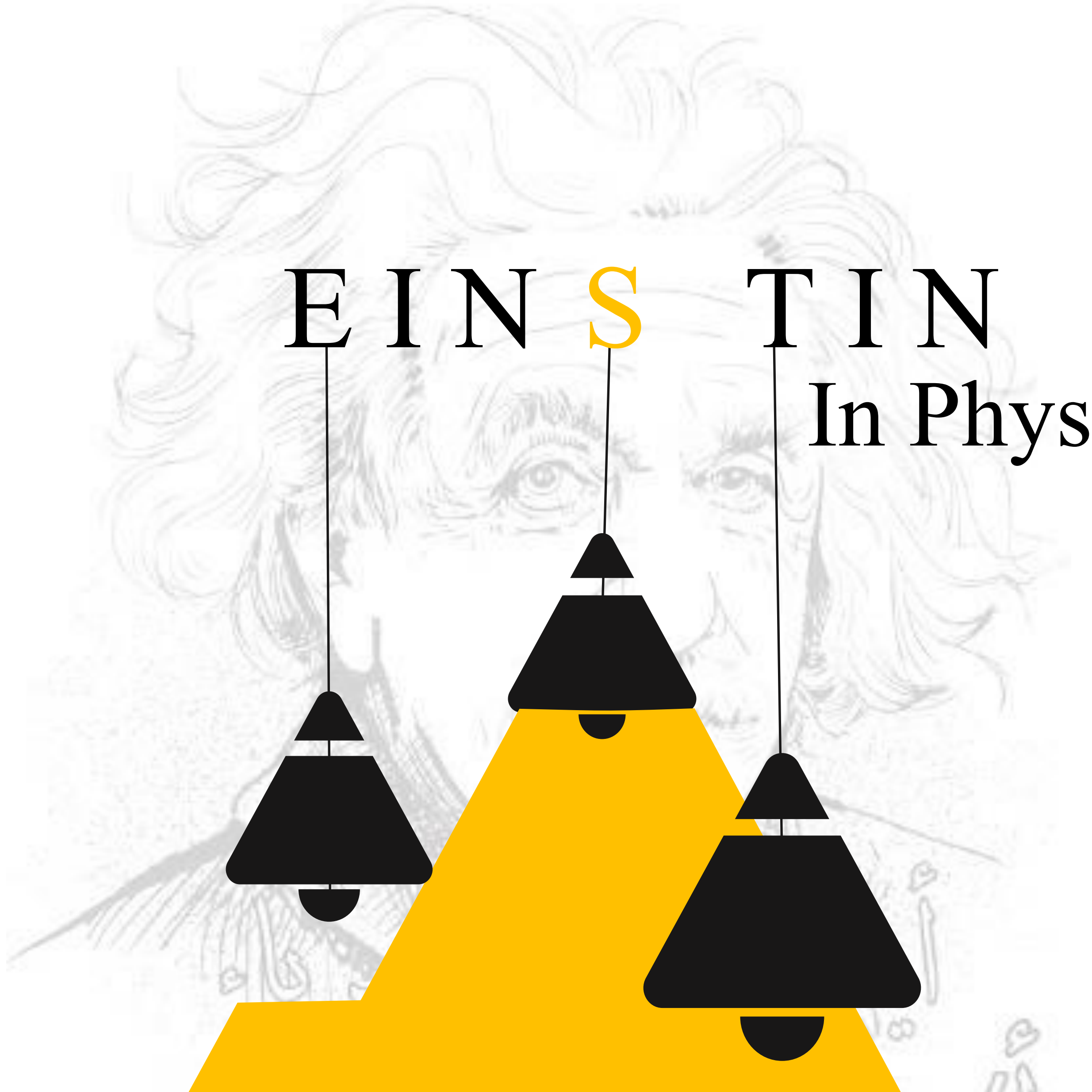
## In Physics



قديما كانت تمثل الفيزياء رعبا للطالب أما الآن

اسلوب جديد لعرض الفيزياء بعيدا عن التعقيد

# TERM 3

# UNIT 10

## Alternating Current Circuits

1- LC Circuits

4- Driven AC Circuits

7- Transformers

Chapter 10
Alternating Current Circuits

اينشتاين في الفيزياء

2024

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# 1 LC Circuits

*Alternating current:*
*A current whose intensity and direction change as a sinusoidal function*
*LC circuits have currents and voltages that vary sinusoidally with time, rather than increasing or decreasing exponentially with time, these variations of voltage and current in LC circuits are called electromagnetic oscillations .*

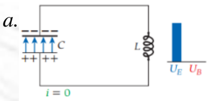
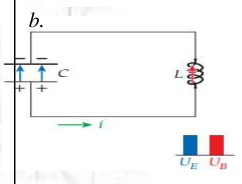
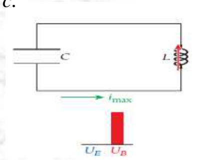
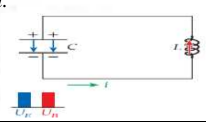
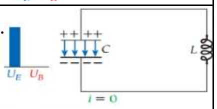
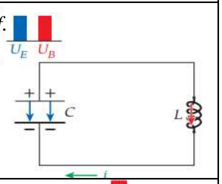
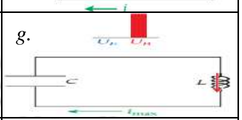
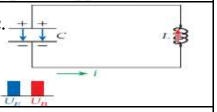
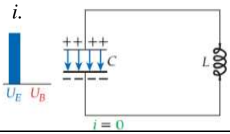
- *The energy stored in the magnetic field of an inductor with inductance L is given by:* $U_B = \frac{1}{2} L i^2$

  *Where:*
  *i is the current flowing (A)*
  *L is the inductance of the inductor (H)*

- *The energy stored in the electric field of a capacitor with capacitance C is given by:* $U_E = \frac{1}{2}\frac{q^2}{c} = \frac{1}{2} C\Delta V^2 = \frac{1}{2} q\Delta V$

  *Where*
  *q is the magnitude of the charge(C)*
  *C is the capacitance of the capacitor(F)*

***How does the (LC Circuits) work ?***

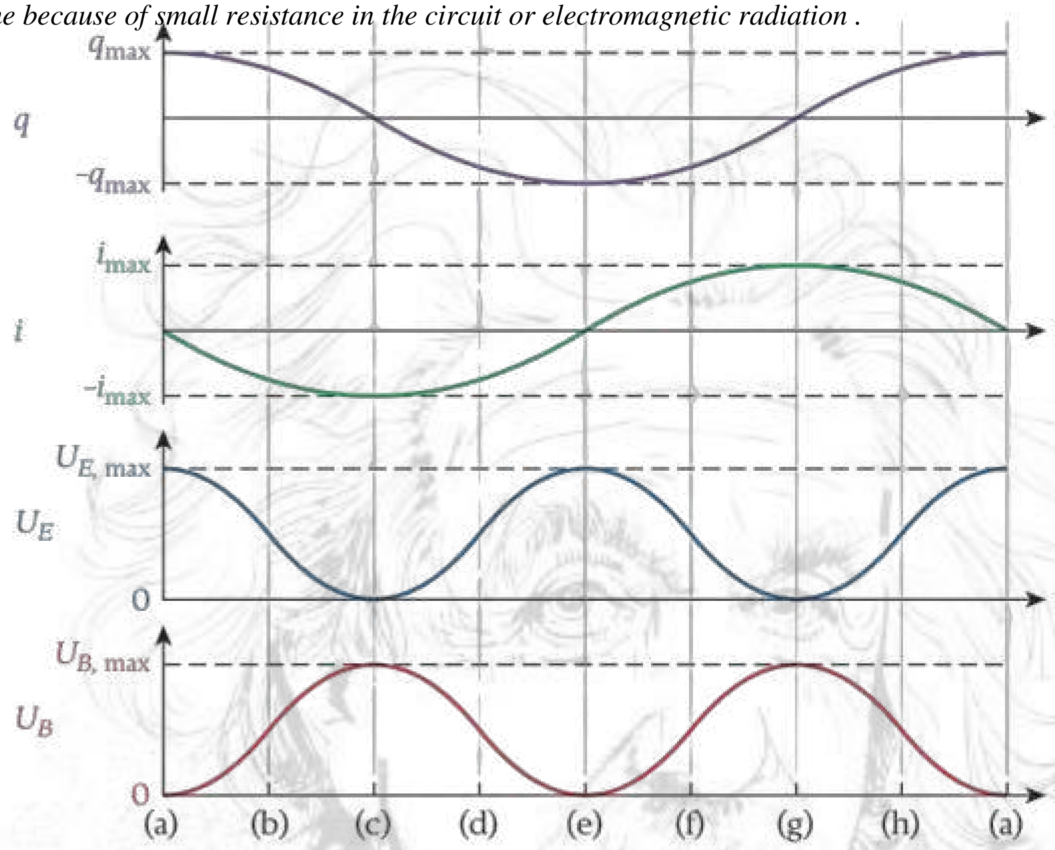
| | |
|---|---|
| *the capacitor is initially fully charged (with the positive charge on the bottom plate) and then connected to the circuit. At that time, the energy in the circuit is contained entirely in the electric field of the capacitor .* | a.  |
| *The capacitor begins to discharge through the inductor in Figure b. At this point, current is flowing through the inductor, which generates a magnetic field. (A green arrow or label below each circuit diagram indicates the direction and the magnitude of the instantaneous current, i.) Now part of the energy of the circuit is stored in the electric field of the capacitor and part in the magnetic field of the inductor* | b.  |
| *The current begins to level off as the inductor's increasing magnetic field induces an emf that opposes the current. In Figure c, the capacitor is completely discharged, and maximum current is flowing through the inductor. (When the magnitude of i has its maximum value, it is designated as imax in the figure.) All the energy of the circuit is now stored in the magnetic field of the inductor* | c.  |
| *the current continues to flow, decreasing from its maximum value, which causes the magnetic field in the inductor to decrease. In Figure d, the capacitor begins to charge with the opposite polarity (positive charge on the top plate). Energy is again stored in the electric field of the capacitor, as well as in the magnetic field of the inductor* | d.  |
| *In Figure e, the energy in the circuit is again entirely contained in the electric field of the capacitor. Note that the electric field now points in the opposite direction from the original field in Figure a. The current is zero, as is the magnetic field in the inductor* | e.  |
| *In Figure f, the capacitor begins to discharge again, producing a current flowing in the direction opposite to that in parts (b) through (d) of the figure; this current in turn creates a magnetic field in the opposite direction in the inductor. Again, part of the energy is stored in the electric field and part in the magnetic field. In Figure g* | f.  |
| *the energy is all stored in the magnetic field of the inductor, but with the magnetic field in the opposite direction from that in Figure c and with the maximum current in the opposite direction from that in Figure c* | g.  |
| *the capacitor begins to charge again, meaning there is energy in both the electric and magnetic fields.* | h.  |
| *The state of the circuit then returns to that shown in Figure a. The circuit continues to oscillate indefinitely because there is no resistor in it, and the electric and magnetic fields together conserve energy.* | i.  |

*The total energy stored in the (LC) circuit is :*

$$U_T = U_{E\,max} = U_{B\,max}$$

*By neglecting the resistance of the circuit , the total energy stored in the circuit remains constant and the circuit continues to oscillate indefinitely .*

*The real (LC) circuits does not oscillate indefinitely , instead the oscillations die away with time because of small resistance in the circuit or electromagnetic radiation .*




*Notes :*

- ❖ *Current (i) and Charge (q) invers proportional*
- ❖ *electric energy ($U_E$) and the magnetic energy ($U_B$)*

*Check your understanding:*

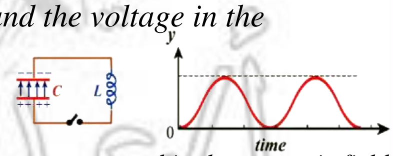
1. *In an oscillating LCcircuit, the total stores energy is U and the maximum charge on the capacitor is Q . When the charge on the capacitor is Q/2,*

*the energy stored in the inductor is :*

ⓐ $\frac{1}{4}U$ ⓑ $\frac{4}{3}U$ ⓒ $2U$ ⓓ $\frac{1}{2}U$

2. *When the switch of the circuit in the figure is closed , the current and the voltage in the circuit oscillate over time .*

*What is the physical quantity represented by the y-axis in the graph ?*



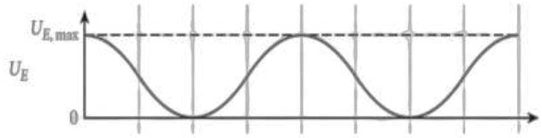

ⓐ *the current* ⓑ *the energy stored in the electric field* ⓒ *the charge* ⓓ *the energy stored in the magnetic field*

3. *In the previous circuit which of the following are true with respect to the capacitor voltage ?*

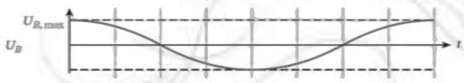
ⓐ *Maximum when the current is maximum .* ⓒ *Maximum when the magnetic energy is maximum*

ⓑ *Maximum when the current is zero .* ⓓ *All of above*

4. *The graph below represents the variation of electric energy for a simple, single-loop LC circuit.*




*Which of the graphs below will represent the corresponding magnetic energy graph for the same circuit?*

ⓐ


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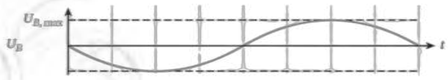

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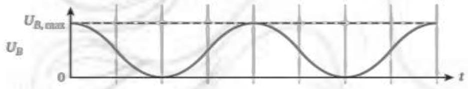

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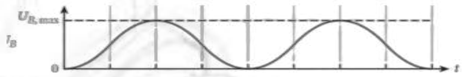
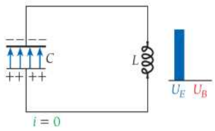


5. *The figure shows that the charge on the capacitor in an LC circuit is largest when the current is zero. What about the potential difference across the capacitor?*



*a) The potential difference across the capacitor is largest when the current is the largest.*
*b) The potential difference across the capacitor is largest when the charge is the largest.*
*c) The potential difference across the capacitor does not change.*

6. *A circuit contains a capacitor with C=1.5) μ F and an inductor with L=3.5 mH as shown in the figure . the capacitor is fully charged using a (12 V) battery and then connected to the circuit . What is the total energy stored in the circuit ?*

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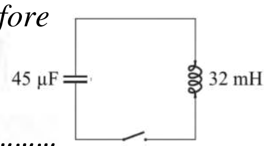
7. *The figure below shows an LC circuit. The capacitor is fully charged to* $q = 10\mu C$ *before the switch is closed.*




a. *What is the maximum energy stored in the capacitor?*

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b. *Determine the maximum current in the inductor ?*

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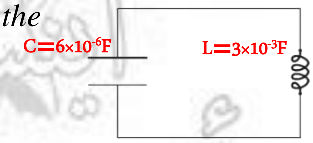
8. *The figure shows an oscillating LC circuit. The maximum charge on the capacitor is (9.0μC).*




a. *find the energy stored in the magnetic field of the inductor when the charge of the capacitor is maximum.*

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b. *Calculate the energy stored in the electric field of the capacitor when ther charge of the capacitor is maximum.*

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9. *The LC circuit shown in the figure*

*has a 4.0μF capacitance a ,7.0mH inductance and a 3.0A maximum current*

a. *What is the maximum charge on the capacitor ?*

b. *What is the total energy stored in the circuit ?*

c. *What is the energy stored in the electric field of the capacitor when the current in the circuit equals 1.0A ?*

d. *What is the current in the circuit when the charge on the capacitor is $3\times10^{-3}$ F ?*

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10. *A 2.00-μF capacitor is fully charged by being connected to a 12.0 V battery. The fully charged capacitoris then connected to a 0.250-H inductor.*

*Calculate the maximum current in the inductor.*

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*many interesting effects occur in a circuit in which the current oscillates continuously. This section investigates some of these effects, starting with a time-varying source of emf and then considering in turn a resistor, a capacitor, and an inductor connected to this source the driving emf,given by*

$$V_{emf} = V_{max} \sin \omega t$$

*Where :*

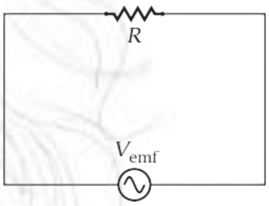
- ❖ *ω is the angular frequency of the emf*
- ❖ *Vmax is the maximum amplitude or value of the emf*

*Alternating current (AC), The current, i, as a function of time is given by*

$$i = I \sin(\omega t - \emptyset)$$

*where :*

*I is the amplitude of the current and the angular frequency of the time-varying current is the same as that of the driving emf, but the phase constant ϕ is not zero. Note that, as is the convention, the phase constant is preceded by a negative sign*




***Circuit with a resistor***

*Applying Kirchhoff's Loop Rule to this circuit, we obtain*

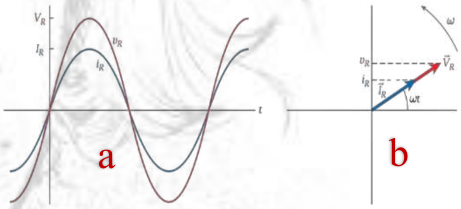
$$V_{emf} - V_R = 0$$

*Where VR is the voltage drop across the resistor*

$$V_{emf} = V_R$$

$$v_R = V_{max} \sin(\omega t) = V_R \sin(\omega t)$$

*Alternating voltage and current for a single-loop circuit containing a source of time-varying emf and a resistor:*
*(a)voltage and current as functions of time;*
*(b)phasors representing voltage and current, showing that they are in phase.*




*According to Ohm's Law, V = iR, so we can write*

$$i_R = \frac{v_R}{R} = \frac{V_R}{R} \sin(\omega t) = I_R \sin(\omega t)$$

*The current flowing through the resistor and the voltage across the resistor are in phase, which means that* <u>*the phase difference between the current and the voltage is zero*</u>.

*Check your understanding:*

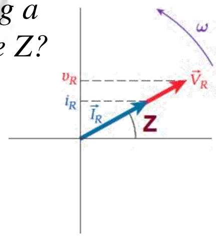
*1.* What does ϕ in the equation bellow represent for $i = I \sin(\omega t - \phi)$ Single-loop alternating current circuit?

ⓐ *Phase constant* ⓑ *Time constant* ⓒ *Frequency* ⓓ *Velocity*

2. *What does the angle ϕ equal in single-loop circuit with a resistor and a source of time-varying emf*

ⓐ 0 ⓑ 90 ⓒ 180 ⓓ 30

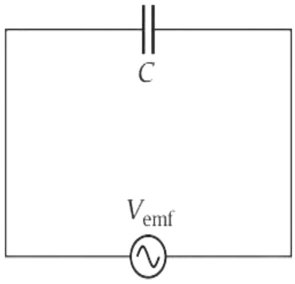
3. *The figure shows voltage and current phasors for a single-loop circuit containing a source of time-varying emf and a resistor.Which of the following expresses angle Z?*




ⓐ $T$ ⓑ $\omega^2$ ⓒ $\omega t$ ⓓ $\omega$

***Circuit with a Capacitor***

*The voltage across the capacitor is given by Kirchhoff's Loop Rule*




$$V_{emf} - V_c = 0$$

$$V_{emf} = V_c$$

*where $v_C$ is the voltage drop across the capacitor*

$$v_c = V_{max}\sin(\omega t) = V_c \sin(\omega t)$$

*where $V_C$ is the maximum voltage across the capacitor.*

*Since $q = CV$ for a capacitor, we can write* $q = CV_c \sin(\omega t)$

$$i_c = \frac{dq}{dt} = \frac{d(CV_c \sin(\omega t))}{dt} = \omega C V_c \cos(\omega t)$$

*by defining a quantity that is similar to resistance, called the capacitive reactance* $X_C$:

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

*This definition allows us to express the current, $i_C$, as*

$$i_C = \frac{V_c}{X_C}\cos(\omega t)$$

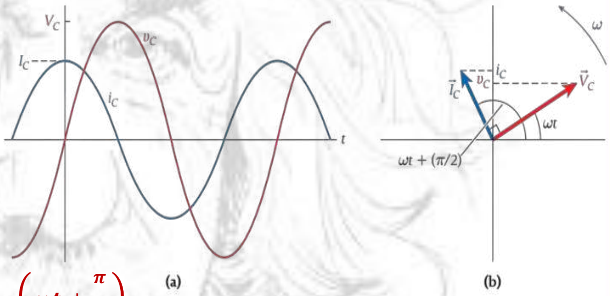
*Alternating voltage and current for a single-loop circuit containing a source of emf and a capacitor:*

*voltage and current as functions of time:*

*phasors representing voltage and current,*

*showing that they are out of phase by $\frac{\pi}{2}$ rad (90°).*

**We can use** $\cos\theta = \sin(\theta + \frac{\pi}{2})$




$$i_C = \frac{V_c}{X_C}$$

$$i_C = i_C \cos(\omega t) = i_C \sin\left(\omega t + \frac{\pi}{2}\right)$$

*The amplitude of the voltage across the capacitor and the amplitude of the current through the capacitor are related by* $V_c = i_C \times X_C$

*Check your understanding:*

*Consider a circuit with a source of time-varying emf given by* $V_{emf} = (120\sin(377\ rad/s)t)V$. *and a capacitor with capacitance* $C = 5.00\ \mu F$.

4. *What is the current in the circuit at* $t = 1.00\ s$?

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5. *what angular frequency* $\omega$ *will a* $10.0\mu F$ *capacitor have reactance* $X_C = 200\Omega$?

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6. *A capacitor with capacitance ($C = 5.00 \times 10^{-6}$ F) is connected to an AC power source having a peak value of ($V = 10.0$ V) and ($f = 100.$ Hz).*
a. *Find the reactance of the capacitor*
b. *Find the maximum current in the circuit.*

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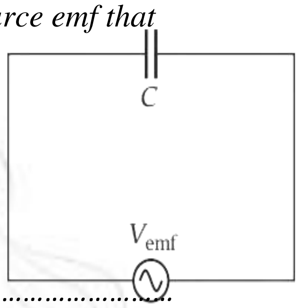
7. *An electrical circuit contains capacitor ($C = 16.0\ \mu F$) is connected to a source emf that the current source changes with time* $i_C = i_C \sin\left(100\pi t + \frac{\pi}{2}\right)$




   a. *Calculate the frequency of the electrical source ($f$)*
   b. *Find the capacitive reactance ( XC)*
   c. *Calculate the maximum value of the current ( I)*
   d. *Calculate the maximum value of the voltage(V)*
   e. *Write the equation for the voltage as function of time*

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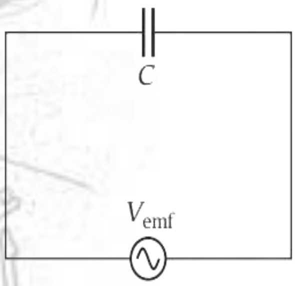
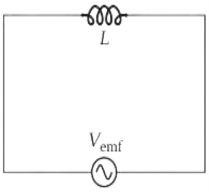
8. *A circuit containing a capacitor, has a source of time varying emf that provides a voltage given by $v_C = V_C \sin(\omega t)$ . What is the current, $i_C$, through the capacitor when the potential difference across it is largest ($v_C = V_{max}$)?*




a. $i_C = 0$
b. $i_C = +I_{max}$
c. $i_C = -I_{max}$

***Circuit with an inductor***




*apply Kirchhoff's Loop Rule to this circuit to obtain the voltage across the inductor*

$$v_L = V_{max}\sin(\omega t) = V_L\sin(\omega t)$$

*where VL is the maximum voltage across the inductor. A changing current in an inductor induces an emf given by*

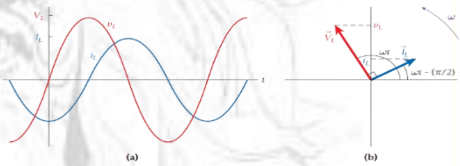
$$V_L = L\frac{di}{dt}$$

*Note that for positive* $\frac{di}{dt}$ *the voltage drop across the inductor is positive because the direction of current is the direction of decreasing potential. Thus, we can write*

$$V_L = L\frac{di}{dt} = V_L\sin(\omega t) \longleftrightarrow \frac{di}{dt} = \frac{V_L}{L}\sin(\omega t)$$

$$i_L = \int \frac{V_L}{L}\sin(\omega t)\,dt = \frac{V_L}{\omega L}\cos(\omega t)$$

*Alternating voltage and current for a single-loop circuit containing a source of emf and an inductor:*
*(a)voltage and current as functions of time;*
*(b)phasors representing voltage and current, showing that they are out of phase by* $-\frac{\pi}{2}rad$ *(–90°).*




*The inductive reactance, which, like the capacitive reactance, is similar to resistance, is defined as* $X_L = \omega L$

*Using the inductive reactance, we can express iL as*

$$i_L = \frac{V_L}{\omega L}\cos(\omega t) = -\,i_L\cos(\omega t)$$

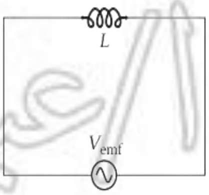
*where IL is the maximum current.*

*Because* $-\cos\theta = \sin(\theta - \frac{\pi}{2})$ *we can rewrite* $iL = -IL\cos\omega t$ *as follows:*

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

*Check your understanding:*

9. *An inductor with inductance* $L = 47.0\ mH$ *is connected to an AC power source having a peak value of* $V = 12.0\ V$ *and* $f = 1000.\ Hz$
a. *Find the reactance of the inductor(L)*
b. *Find the maximum current in the circuit*

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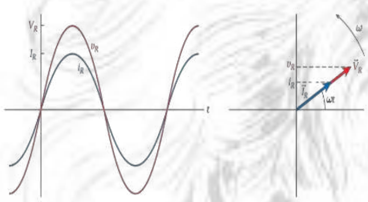
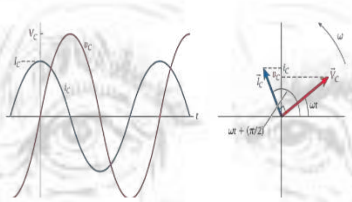
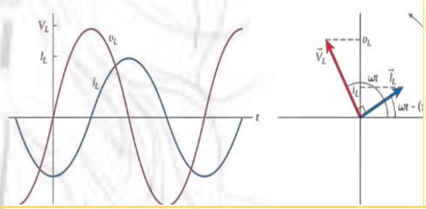
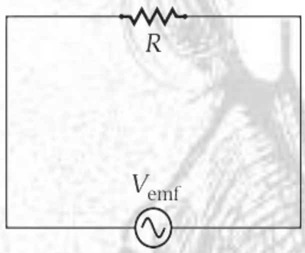
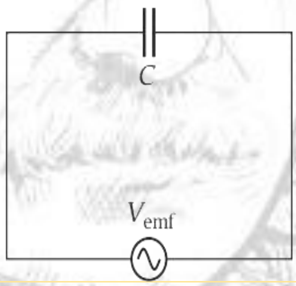
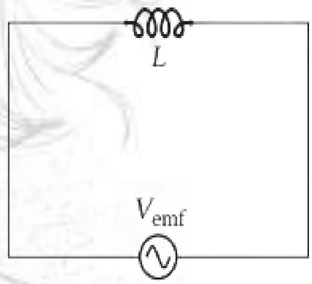
*Summary for (R C,L )*

| | a resistor R | Capacitor C | inductor L |
|---|---|---|---|
| Voltage ΔV | $V\,emf = V max\,sin(\omega t)$ | $v_c = V_{max}\sin(\omega t) = V_c \sin(\omega t)$ | $v_L = V_{max}\sin(\omega t) = V_L \sin(\omega t)$ |
| Current I | $i_R = \frac{v_R}{R} = \frac{V_R}{R}\sin(\omega t) = I_R \sin(\omega t)$ | $ic = ic\cos(\omega t) = ic\sin\left(\omega t + \frac{\pi}{2}\right)$ | $i_L = \frac{V_L}{\omega L}\cos(\omega t) = -i_L\cos(\omega t)$ |
| Ohms law | $V_R = I \times R$ | $V_C = I \times X_C$ | $V_L = I \times X_L$ |
| Formala | $R = \frac{V_R}{I}$ | $X_C = \frac{1}{\omega C}$ | $X_L = \omega L$ |
| Phase ϕ | 0 | $+\frac{\pi}{2}$ | $-\frac{\pi}{2}$ |
| Angular frequency ω | Not depend on | $\omega = 2\pi f$ | $\omega = 2\pi f$ |
| |  |  |  |
| |  |  |  |

# 7 Transformers

*Transformers are devices that increase or decrease potential difference with relatively little waste of energy*

*Note:*

*Only alternating current can be sent through a transformer. Direct current cannot pass through a transformer*

*What is the principle of transformer work?*

*The transformer depends on mutual inductance where an EMF and current in one coil due to changing current in another coil.*

***What are the components of the transformers?***

*Primary coil : Which is connecting to the alternating current source*

*Secondary coil : Which is connecting to the devices (resistance)*

*Iron core : Which is carrying the changes in magnetic field from the primary coil to the secondary coil.*

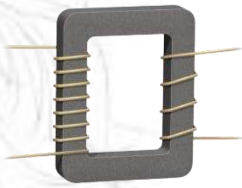
*The ideal transformer equation*

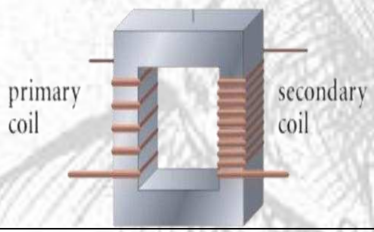
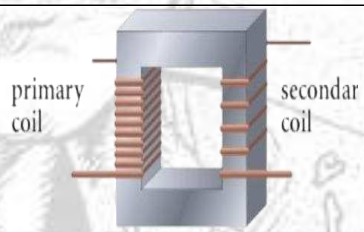
$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$$

*Type of transformers*

*1-A transformer that takes voltages from lower to higher values is called a step-up transformer.*

*2-a transformer that takes voltages from higher to lower values is called a step-down transformer.*



| *step-up transformer* | *step-down transformer* |
|---|---|
| $N_S > N_P$ | $N_S < N_P$ |
| $V_S > V_P$ | $V_S < V_P$ |
| $I_P > I_S$ | $I_P < I_S$ |
|   |   |

***How does transformer work ?***

*The secondary coil of a transformer has NS turns. The time-varying emf in the primary coil induces a time-varying magnetic field in the iron core. This core passes through the secondary coil. Thus, a time-varying voltage is induced in the secondary coil, as described by Faraday's Law of Induction:*

$$V_{emf} = -N\frac{d\phi_B}{dt}$$

- *If a resistor, R, is connected across the secondary windings, a current, IS, will begin to flow through the secondary coil.*
- *The power in the secondary circuit is then $P_S = I_S V_S$.*
- *Energy conservation requires that the power delivered to the primary coil be transferred to the secondary coil, so we can write* $P_S = P_p \longleftrightarrow I_S V_S = I_p V_p$

*Note*

- *Real transformers do have some losses. Part of these losses result from the fact that the alternating magnetic fields from the coils induce eddy currents in the iron core of the transformer. To counter this effect, transformer cores are constructed by laminating layers of metal to inhibit the formation of eddy currents. Modern transformers can transform voltages with very little loss.*
- *The continuous current is constant in intensity and direction, and is generated in the primary winding. It does not travel to the secondary winding through the iron core. A magnetic field constant, and since the field is constant, then there is no inductive current in the secondary winding (inductive electric force)*
- *At the power electrical station there is a voltage transformer a step-up transformer. (to reduce current) in order to reduce the energy loss when it is sent to Consumption area.*
- *In the consumption area, there are voltage converters a step-down transformer.*

*Check your understanding:*

1. *A step-up transformer has a primary coil consisting of 200 turns and a secondary coil consisting of 3000 turns. The primary coil is supplied with an effective AC voltage of 90.0 V*
   a. *What is the voltage in the secondary circuit*
   b. *The current in the secondary circuit is 2.0 A. What is the current in the primary circuit*

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2. *A step-up transformer has a primary coil consisting of 200 turns and a secondary coil consisting of 30 turns. The primary coil is supplied with an effective DC voltage of 10.0 V. what is the voltage in the secondary circuit*

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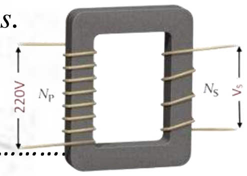
3. *The figure shows a transformer with NP primary windings and NS secondary windings. What is VS?*

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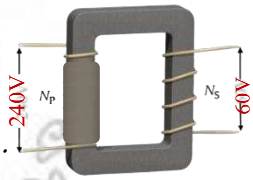
4. *According to the figure below, the number of the primary coil turns Np in the transformer is hidden:*
   *Find the number of turns Np.*

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**Einstein Abdelrahman Esam**

**THE END**

**Senior 2024**