Chapter 1 (Part 1)

Alternating current circuit

دوائر التيار المتردد

DC

AC

Dr. Asmae Mimouni

$\sqrt{-1}$ عدد تخيلي

$j = \sqrt{-1}$

$$\underbrace{x}_{Re} + \underbrace{jy}_{Im}$$ عدد مركب

Complex Numbers for AC Circuits

ارقام مركبة

$$\sqrt{9} = 3$$

$$\sqrt{-9} = \sqrt{-1}\,\sqrt{9} = 3j$$

الرياضيات المستخدمة في هندسة الإلكترونيات لجمع المقاومات والتيارات أو الفولتية المستمرة تستخدم ما يسمى "الأرقام الحقيقية" إما كأعداد صحيحة أو كسور.

●لكن الأعداد الحقيقية ليست هي النوع الوحيد من الأعداد الذي نحتاج إلى استخدامه خاصة عند التعامل مع المصادر والمتجهات الجيبية المعتمدة على التردد.

●بالإضافة إلى استخدام الأعداد العادية أو الحقيقية، تم تقديم الأعداد المركبة للسماح بحل المعادلات المعقدة باستخدام الأعداد التي تمثل الجذور التربيعية للأعداد السالبة، √-1.

●في هندسة الإلكترونيات يسمى هذا النوع من الأرقام "رقم وهمي" ولتمييز الرقم التخيلي عن الرقم الحقيقي، يتم استخدام الحرف "j" المعروف عادة في هندسة الإلكترونيات باسم العامل.j

●يتم وضع حرف j أمام الرقم الحقيقي للدلالة على عملية الرقم التخيلي الخاص به. ومن أمثلة الأرقام التخيليةj3 :، j12، j100إلخ.

ثم يتكون العدد المركب من جزأين مختلفين ولكنهما مترابطان إلى حد كبير، "الرقم الحقيقي" بالإضافة إلى "الرقم التخيلي

تمثل الأرقام المركبة نقاطًا في مركب أو مستوى ثنائي الأبعاد يتم الرجوع إليها إلى محورين مختلفين. ويسمى المحور الأفقي "المحور الحقيقي" بينما يسمى المحور الرأسي "المحور التخيلي". يتم اختصار الأجزاء الحقيقية والتخيلية للعدد المركب بـ Re(z) و Im(z)على التوالي.

●يمكن جمع الأعداد المركبة التي تتكون من أرقام حقيقية (المكون النشط) وأرقام خيالية (المكون التفاعلي) وطرحها واستخدامها بنفس الطريقة التي يتم بها استخدام الجبر الأولي لتحليل دوائر التيار المستمر

●القواعد والقوانين المستخدمة في الرياضيات لجمع أو طرح الأعداد التخيلية هي نفسها المستخدمة في الأعداد الحقيقية، j2 + j4 = j6 وما إلى ذلك.

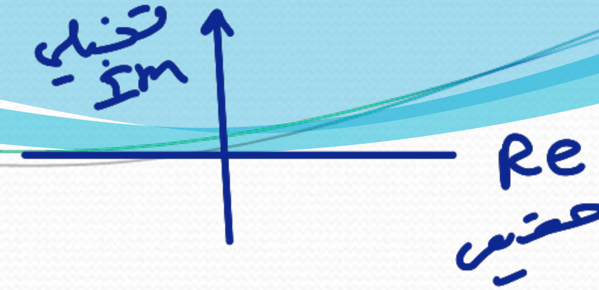
الفرق الوحيد هو في الضرب لأن ضرب رقمين وهميين معًا يصبح رقمًا حقيقيًا سالبًا. يمكن أيضًا اعتبار الأعداد الحقيقية عددًا مركبًا ولكن بجزء وهمي صفري يسمى." j0

Complex Numbers and Phasors

- The mathematics used in Electronics Engineering to add together resistances, currents or DC voltages use what are called "real numbers" either as integers or as fractions.
- But real numbers are not the only kind of numbers we need to use especially when dealing with frequency dependent sinusoidal sources and vectors.
- As well as using normal or real numbers, Complex Numbers were introduced to allow complex equations to be solved with numbers that are the square roots of negative numbers, √-1.
- In Electronics Engineering this type of number is called an "imaginary number" and to distinguish an imaginary number from a real number the letter " j " known commonly in Electronics Engineering as the j-operator, is used.

3j 4j

- The letter **j** is placed in front of a real number to signify its imaginary number operation. Examples of imaginary numbers are: j3, j12, j100 etc. Then a complex number consists of two distinct but very much related parts, a " Real Number " plus an " Imaginary Number ". 5 + 6j



Complex Numbers and Phasors

- Complex Numbers represent points in a two dimensional complex or s-plane that are referenced to two distinct axes. The horizontal axis is called the "real axis" while the vertical axis is called the "imaginary axis". The real and imaginary parts of a complex number are abbreviated as Re(z) and Im(z), respectively.
- Complex numbers that are made up of real (the active component) and imaginary (the reactive component) numbers can be added, subtracted and used in exactly the same way as elementary algebra is used to analyse DC Circuits

  مكون نشط

  مكون تفاعلي
- The rules and laws used in mathematics for the addition or subtraction of imaginary numbers are the same as for real numbers, j2 + j4 = j6 etc. The only difference is in multiplication because two imaginary numbers multiplied together becomes a negative real number. Real numbers can also be thought of as a complex number but with a zero imaginary part labeled j0.

$$\underbrace{(2+3j)}_{z_1} + \underbrace{(5+2j)}_{z_2} = 7+5j$$

The basic complex (imaginary) number is "i."

To avoid confusion we replace "i" with "j"

$$j = \sqrt{-1}$$

$$j^2 = jj = \sqrt{-1}\sqrt{-1} = -1$$

$$j^3 = jj^2 = j(-1) = -j$$

$$j^4 = j^2 j^2 = (-1)(-1) = +1$$

$$j^5 = jj^4 = j(+1) = j$$

$\sqrt{-1}^{2} = -1$

$\sqrt{-1}\sqrt{-1}\sqrt{-1}$

$-1j = -j$

كل مره نضرب بـ j بيدي دوران عكس عقارب الساعة بزاوية 90

The j-operator has a value exactly equal to √-1, so successive multiplication of " j ", (j x j) will result in j having the following values of, -1, -j and +1. As the j-operator is commonly used to indicate the anticlockwise rotation of a vector, each successive multiplication or power of " j, j^2, j^3 etc, will force the vector to rotate through an angle of 90° anticlockwise as shown below. Likewise, if the multiplication of the vector results in a -j operator then the phase shift will be -90°, i.e. a clockwise rotation.

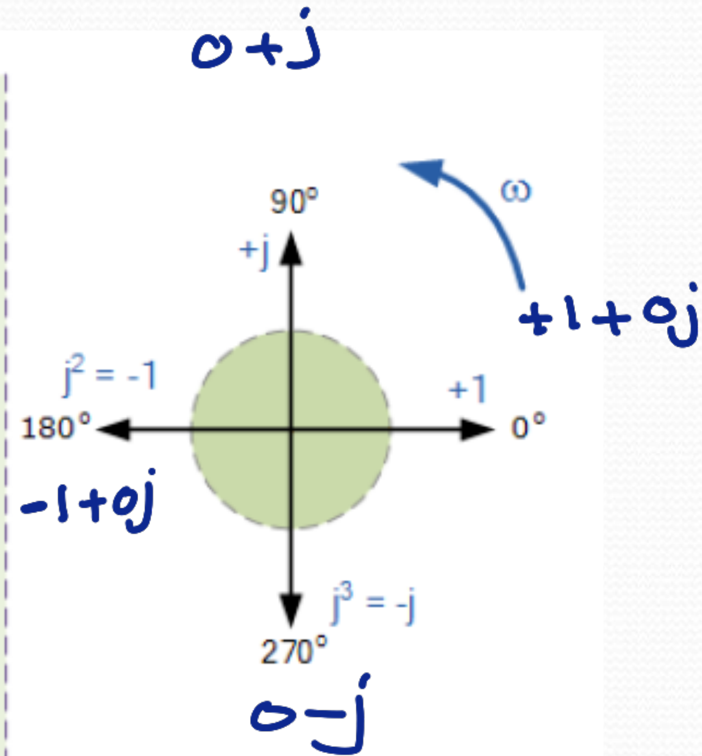
$j\,j = -1$

90° rotation: $j^{1} = \sqrt{-1} = +j$

180° rotation: $j^{2} = \left(\sqrt{-1}\right)^{2} = -1$

270° rotation: $j^{3} = \left(\sqrt{-1}\right)^{3} = -j$

360° rotation: $j^{4} = \left(\sqrt{-1}\right)^{4} = +1$



Complex Numbers using the Rectangular Form

We saw that a complex number is represented by a real part and an imaginary part that takes the generalized form of:

حقيقي

Where:

مركب

$$Z = X + jY$$

التخيلي

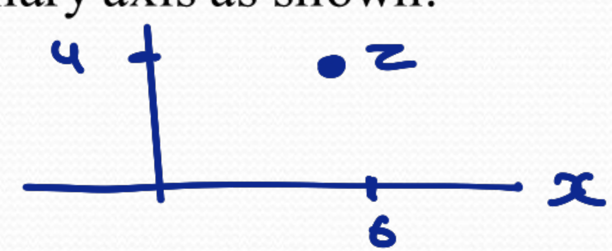
Z - is the Complex Number representing the Vector

X - is the Real part or the Active component

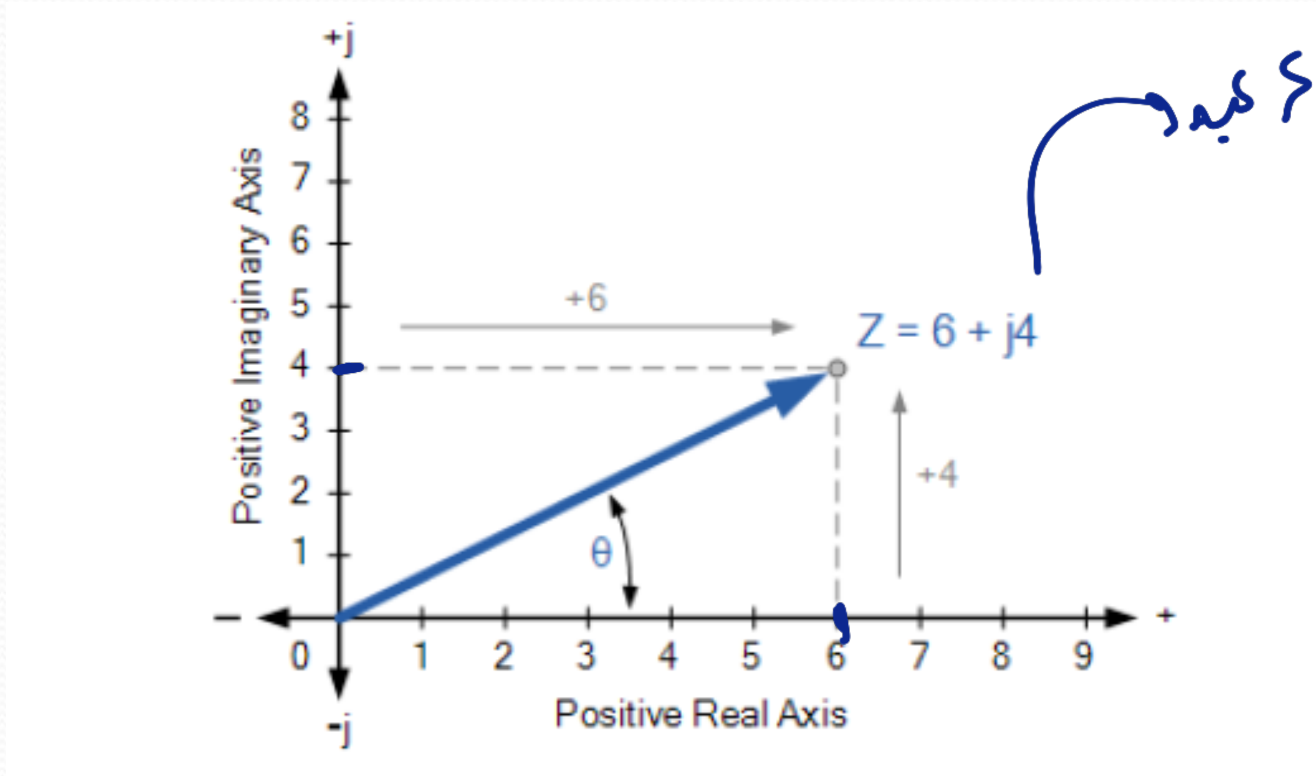
Y - is the Imaginary part or the Reactive component j - is defined by $\sqrt{-1}$

In the rectangular form, a complex number can be represented as a point on a two-dimensional plane called the **complex** or **s-plane**.

So for example, $Z = 6 + j4$ represents a single point whose coordinates represent 6 on the horizontal real axis and 4 on the vertical imaginary axis as shown.



Complex Numbers using the Complex or s-plane



بالصيغة الكيدو

both the real and imaginary parts of a complex number in the rectangular form can be either a positive number or a negative number, then both the real and imaginary axis must also extend in both the positive and negative directions. This then produces a complex plane with four quadrants called an $\boxed{\text{Argand Diagram}}$ as shown below.

1.5 Four Quadrant Argand Diagram

$z = 6 + 4j \rightarrow (r, \theta)$

هون العدد المركب الى الصوره القطبية (polar)

$\theta = \tan^{-1}\left(\frac{4}{6}\right)$

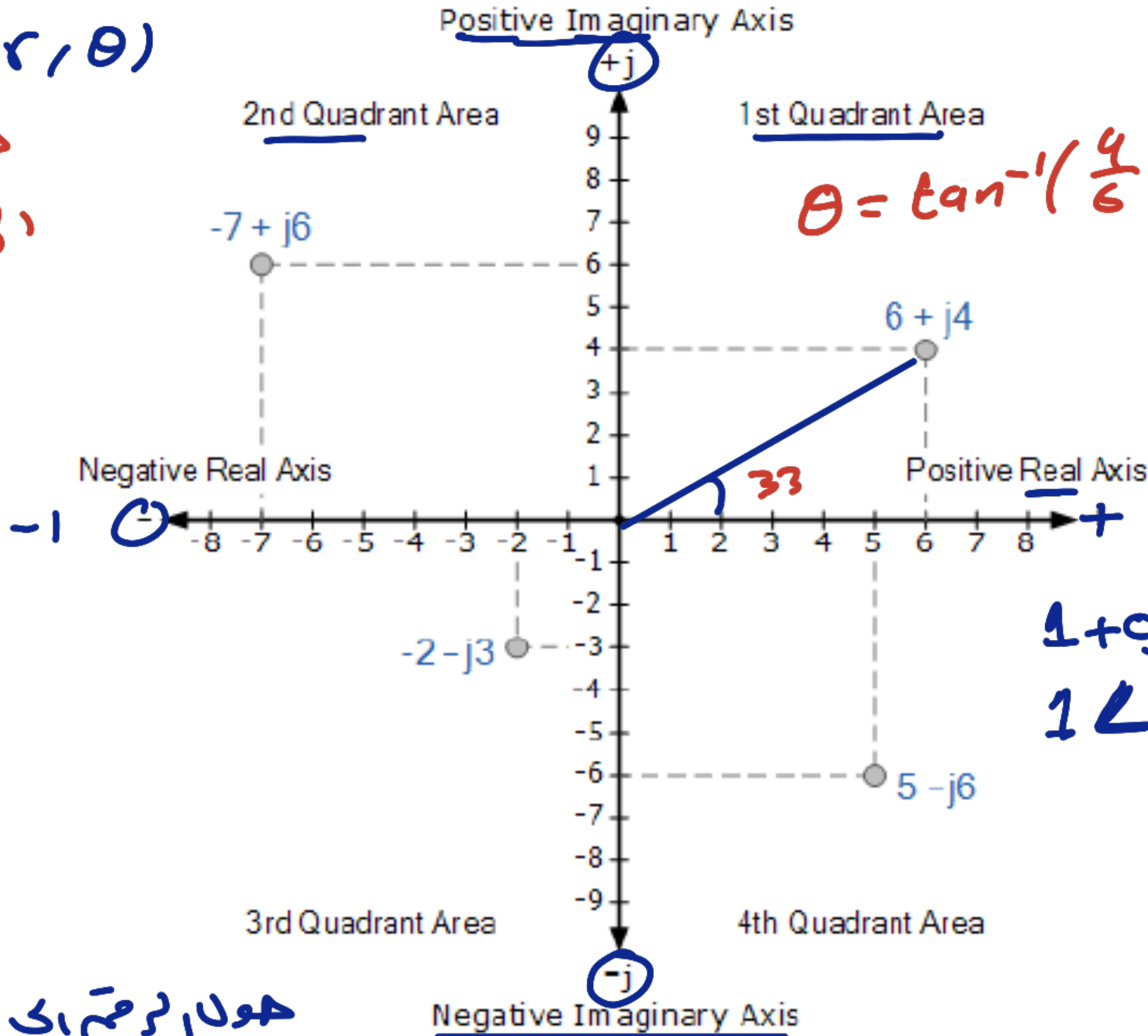
$\theta = 33.7$

$r = \sqrt{4^2 + 6^2}$

$r = 7.2$

$(\overset{r}{7.2}, \overset{\theta}{33.7})$

هون رجعتها الى الصوره المربعية



$\theta = \tan^{-1}\left(\frac{4}{6}\right) = 33.7$

$1 + 0j$

$1 \angle 0$

$x = r\cos\theta = 7.2\cos 33.7 = 6$

$y = r\sin\theta = 7.2\sin 33.7 = 4$

On the Argand diagram, the horizontal axis represents all positive real numbers to the right of the vertical imaginary axis and all negative real numbers to the left of the vertical imaginary axis. All positive imaginary numbers are represented above the horizontal axis while all the negative imaginary numbers are below the horizontal real axis. This then produces a two dimensional complex plane with four distinct quadrants labeled, QI, QII, QIII, and QIV. The Argand diagram above can also be used to represent a rotating phasor as a point in the complex plane whose radius is given by the magnitude of the phasor will draw a full circle around it for every 2π/ω seconds.

Then we can extend this idea further to show the definition of a complex number in both the polar and rectangular form for rotations of 90o.

يستخدم مخطط ارگاند للتعبير عن المتغير الدوري

$$0^{\circ} = \pm 360^{\circ} = +1 = 1\angle 0^{\circ} = 1 + j0$$

$$+90^{\circ} = +\sqrt{-1} = +j = 1\angle +90^{\circ} = 0 + j1$$

$$-90^{\circ} = -\sqrt{-1} = -j = 1\angle -90^{\circ} = 0 - j1$$

$$\pm 180^{\circ} = \left(\sqrt{-1}\right)^{2} = -1 = 1\angle \pm 180^{\circ} = -1 + j0$$

Complex Numbers can also have “zero” real or imaginary parts such as: Z = 6 + j0 or Z = 0 + j4. In this case the points are plotted directly onto the real or imaginary axis. Also, the angle of a complex number can be calculated using simple trigonometry to calculate the angles of right-angled triangles, or measured anti-clockwise around the Argand diagram starting from the positive real axis.

- Angles between 0 and 90o will be in the first quadrant (I).
- Angles (θ) between 90 and 180o in the second quadrant (II).
- The third quadrant (III) includes angles between 180 and 270o and
- The fourth and final quadrant (IV) which completes the full circle, includes the angles between 270 and 360o and so on.

In all the four quadrants the relevant angles can be found from:

tan-1(imaginary component ÷ real component)

Complex Numbers using Polar Form

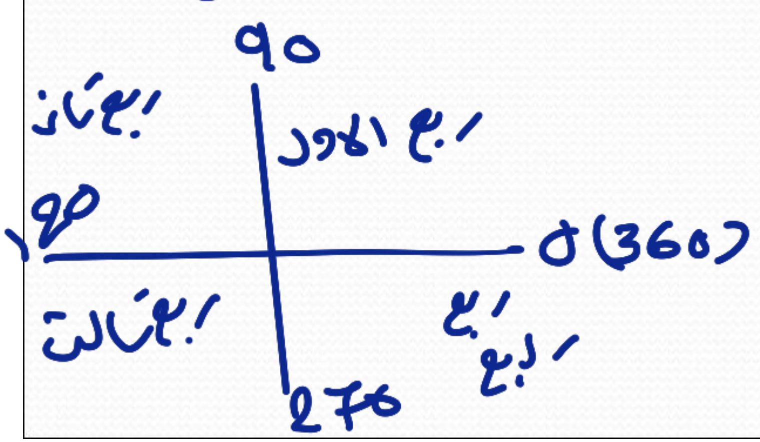
Unlike rectangular form which plots points in the complex plane, the Polar Form of a complex number is written in terms of its magnitude and angle. Thus, a polar form vector is presented as: $Z = A \angle \pm\theta$, where: Z is the complex number in polar form, A is the magnitude or modulo of the vector and θ is its angle or argument of A which can be either positive or negative. The magnitude and angle of the point still remains the same as for the rectangular form above, this time in polar form the location of the point is represented in a “triangular form” as shown below.

جميع الاعداد الحقيقيه $Z = X + 0j$ تقع على محور X

$\angle 0$ $\angle 180$

جميع الاعداد التخيليه فقط $Z = 0 + j$ تقع على محور y

$\angle 90$ $\angle -90$



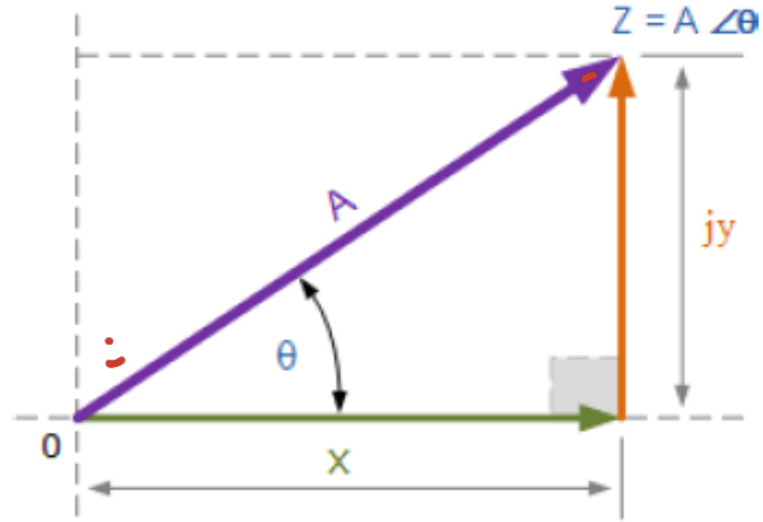
حساب الزاويه

$$\theta = \tan^{-1}\left(\frac{Im}{Re}\right)$$

صيغه القطبيه عدد مركب

$z = x + iy \rightsquigarrow (r, \theta)$

Polar Form Representation of a Complex Number



$\theta = \tan^{-1}\left(\frac{Im}{Re}\right)$

$r = \sqrt{Im^2 + Re^2}$

y^2 x^2

As the polar representation of a point is based around the triangular form, we can use simple geometry of the triangle and especially trigonometry and Pythagoras's Theorem on triangles to find both the magnitude and the angle of the complex number. As we remember from school, trigonometry deals with the relationship between the sides and the angles of triangles so we can describe the relationships between the sides as:

$$A^2 = x^2 + y^2$$

$$A = \sqrt{x^2 + y^2}$$

Also, $x = A.\cos\theta$, $y = A.\sin\theta$

Using trigonometry again, the angle θ of A is given as follows.

$\theta = \tan^{-1} y$

$z \leftarrow$ Polar $\rightsquigarrow$ تحويل

$(r, \theta) \rightsquigarrow x + iy$

$x = r\cos\theta$

$y = r\sin\theta$

Types of current

- There are two main types of current flow in a circuit in our world. One is Direct Current (DC), which is a constant stream of electrons in one direction in other words the electric charge (current) only flows in one direction . The other is Alternating Current, which is a stream of charges that reverses direction in other words an electric current that reverses its direction many times a second at regular intervals, typically used in power supplies.
- Most of the digital electronics that you build will use DC. However, it is important to understand some AC concepts. Most homes are wired for AC.
- AC also has some useful properties, such as being able to convert voltage levels with a single component (a transformer), which is why AC was chosen as the primary means to transmit electricity over long distances.

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تيار مباشر

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تيار متناوب (AC)

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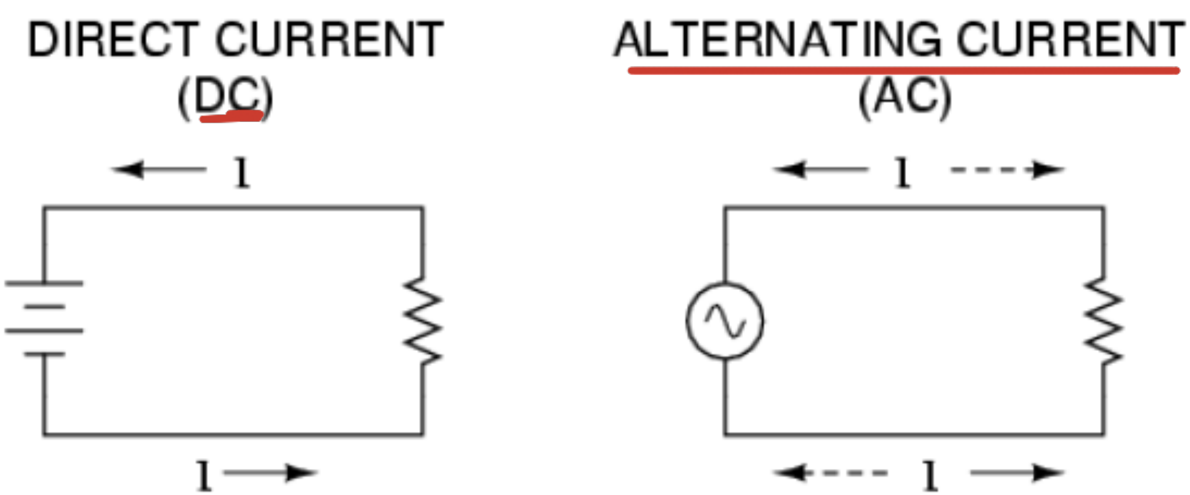
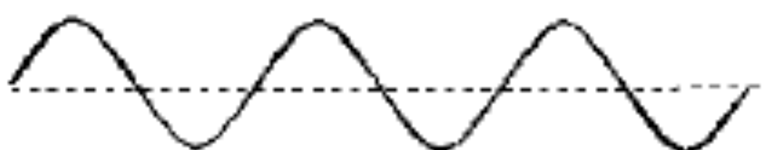


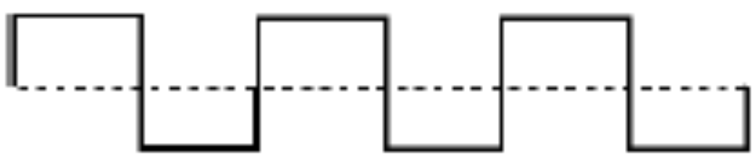
الموجات الدوريه

<u>Types of Periodic Waveform</u>

A waveform is a representation of how alternating current (AC) varies with time. The most familiar AC waveform is the **sine wave**, which derives its name from the fact that the current or voltage varies with the sine of the elapsed time. Other common AC waveforms are: the square wave, the ramp, the saw tooth wave, and the triangular wave. Their general shapes are shown below

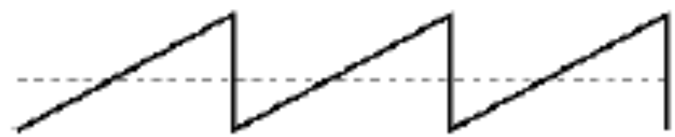


sine

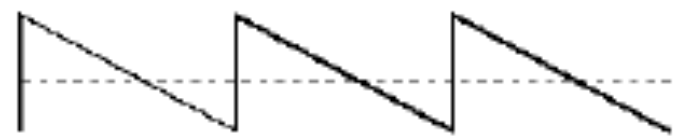


square

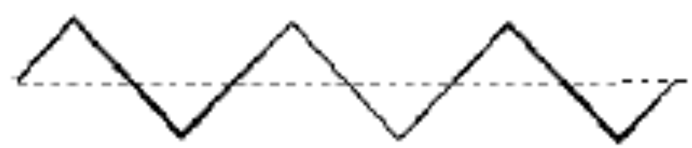
مربعة



ramp

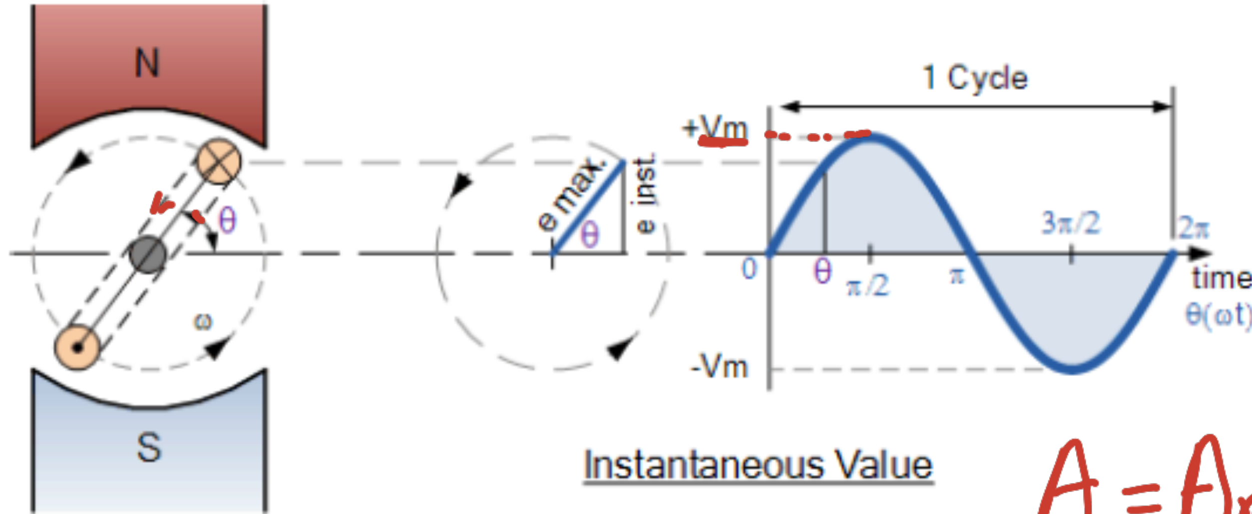


اسنان منشار sawtooth



مثلثة triangular

Sinusoidal Waveform

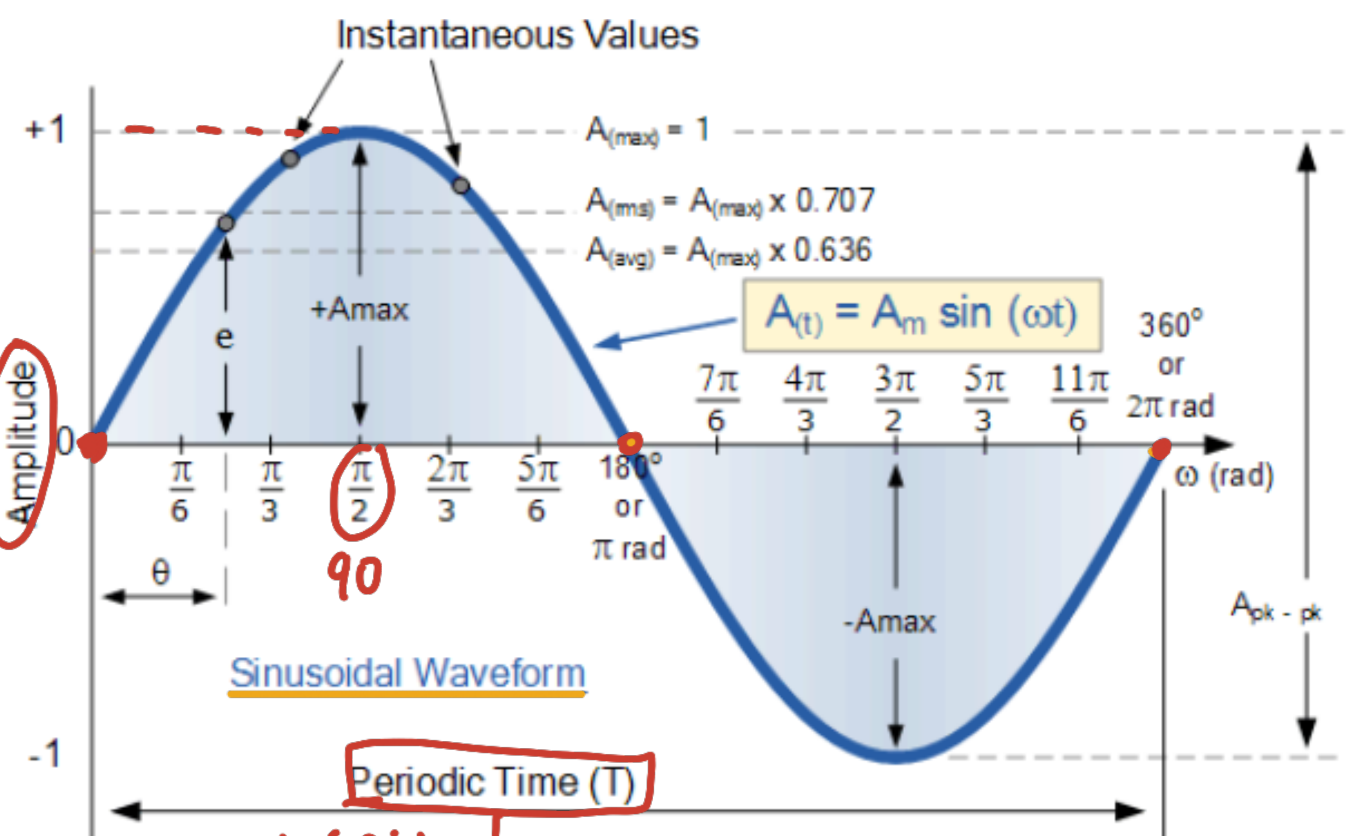


الزاوية

$A = A_m \sin(\omega t)$

سرعة

زمن



الاتساع

الزمن الدوري

Frequency f (التردد)

التردد : عدد الدورات في الثانيه

- The frequency of a supply is the number of times a cycle appears in one second and that frequency is measured in Hertz.
- As one cycle of induced emf is produced each full revolution of the coil through a magnetic field comprising of a north and south pole as shown above, if the coil rotates at a constant speed a constant number of cycles will be produced per second giving a constant frequency.
- By increasing the speed of rotation of the coil the frequency will also be increased.
- the frequency output from an AC generator is:

اذا كانت سرعه دوران الملف ثابته اذآ التردد تكون ثابتة

$$f \propto N, \quad \text{and} \quad f \propto P$$

$$\therefore f = N \times P \quad \text{in cycles/min}$$

$$\boxed{f = \frac{NP}{60}\ (Hz)}$$

As frequency is measured in Hertz

$$\text{Frequency}, (f) = \frac{NP}{60}\ \text{Hz}$$

سرعه الدوران   عدد ازواج الاقطاب

Where: N is the speed of rotation in r.p.m. P is the number of "pairs of poles" and 60 converts it into seconds. Scientists describe the cycle of switching directions as the Frequency. Frequency is measured in Hertz (Hz).

الزمن الدوري

الزمن اللازم لانهاء دورة

- The Period, (T) is the length of time in seconds that the waveform takes to repeat itself from start to finish in other words the time taken for an AC Waveform to complete one full pattern from its positive half to its negative half and back to its zero baseline again. This can also be called the Periodic Time of the waveform for sine waves, or the Pulse Width for square waves.
- The Frequency, (f) is the number of times the waveform repeats itself within a one second time period (the number of complete cycles that are produced within one second (cycles/second)). Frequency is the reciprocal of the time period, ($f = 1/T$) with the unit of frequency being the Hertz, (Hz).

$$f = \frac{1}{T}$$

الزمن الدوري = مقلوب التردد

$$T = \frac{1}{f}$$

Instantaneous Voltage

$I_i = I_{max} \sin \theta$

$V_i = V_{max} \sin \theta$

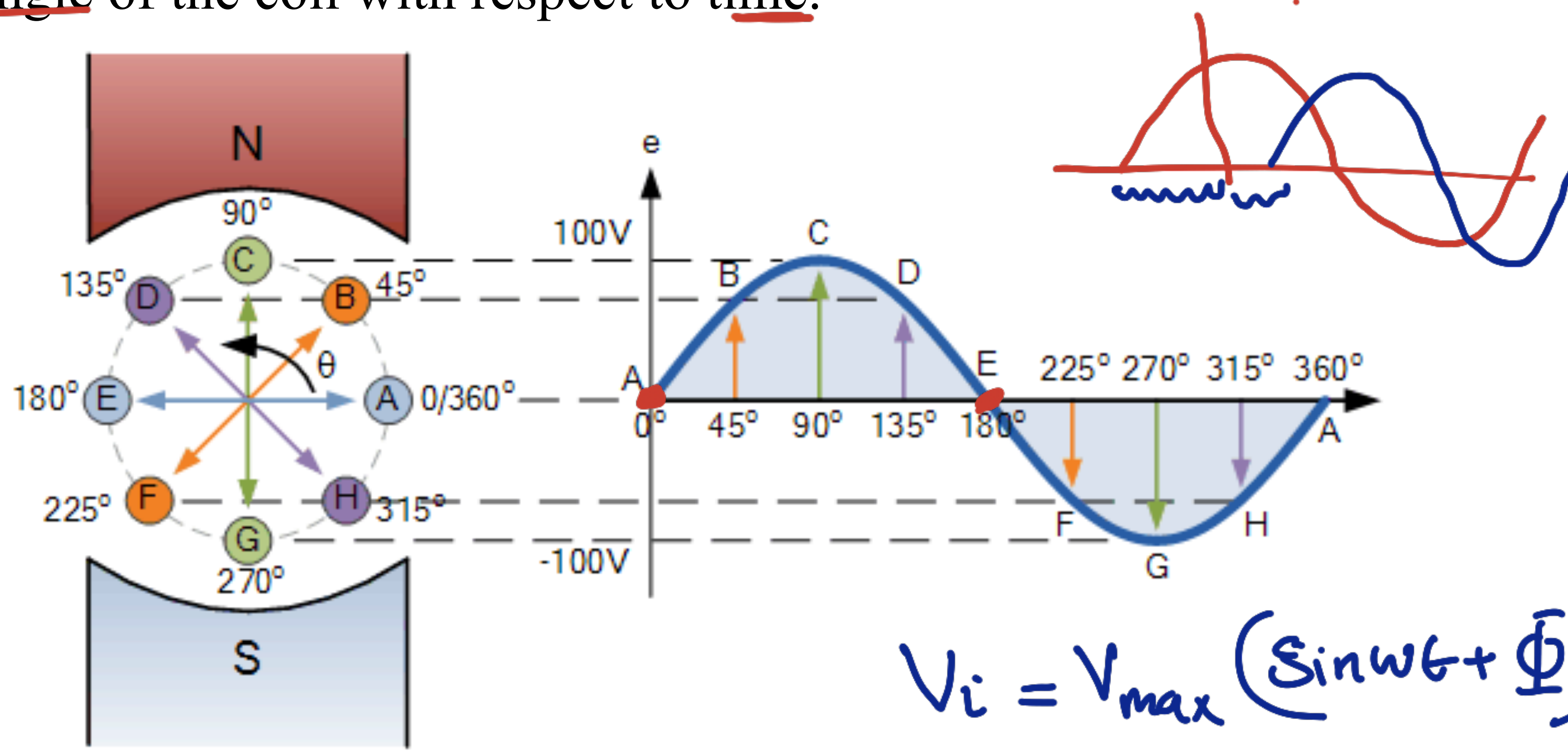
The instantaneous values of a sinusoidal waveform is given as:

the Instantaneous value = Maximum value x sin θ

$$V_i = V_{max} \times \sin\theta = 100 \times \sin 45 = 71$$

Where, Vmax is the maximum voltage induced in the coil and $\boxed{\theta = \omega t,}$ is the rotational angle of the coil with respect to time.

زاوية الدوران



$V_i = V_{max}(\sin \omega t + \Phi)$

$f = \frac{\omega}{2\pi}$ $\omega = 2\pi f$

Definition of a Radian

- The Radian, (rad) is defined mathematically as a quadrant of a circle where the distance subtended on the circumference equals the radius (r) of the circle.
- Since the circumference of a circle is equal to 2π x radius, there must be $\boxed{2\pi}$ radians around a 360ocircle, so 1 radian = 360o/2π = 57.3o.

Relationship between Degrees and Radians

$$\text{Rad} \xrightarrow{\times 180/\pi} \text{degree} \qquad \text{degree} \xrightarrow{\times \pi/180} \text{Rad}$$

$$\text{Radians} = \left(\frac{\pi}{180^0}\right) \times \text{degrees}$$

$$\text{Degrees} = \left(\frac{180^0}{\pi}\right) \times \text{radians}$$

$1 \times \frac{180}{\pi}$

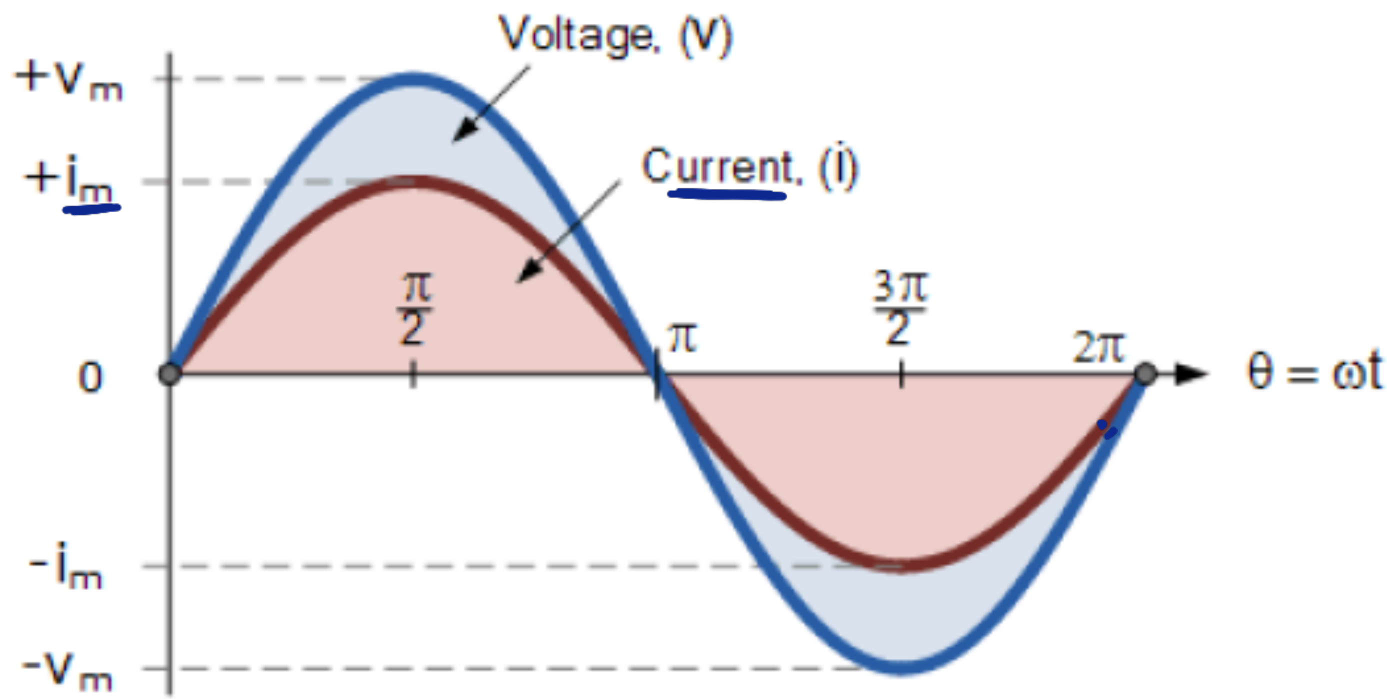
degree	rad
0	0
45	π/4
90	π/2
180	π
270	3π/2
360	2π
30	π/6
60	π/3

Angular Velocity

$$\boxed{\omega = 2\pi f} \text{ (rad/sec)}$$

Two Sinusoidal Waveforms "in-phase"

متوافقة في الطور



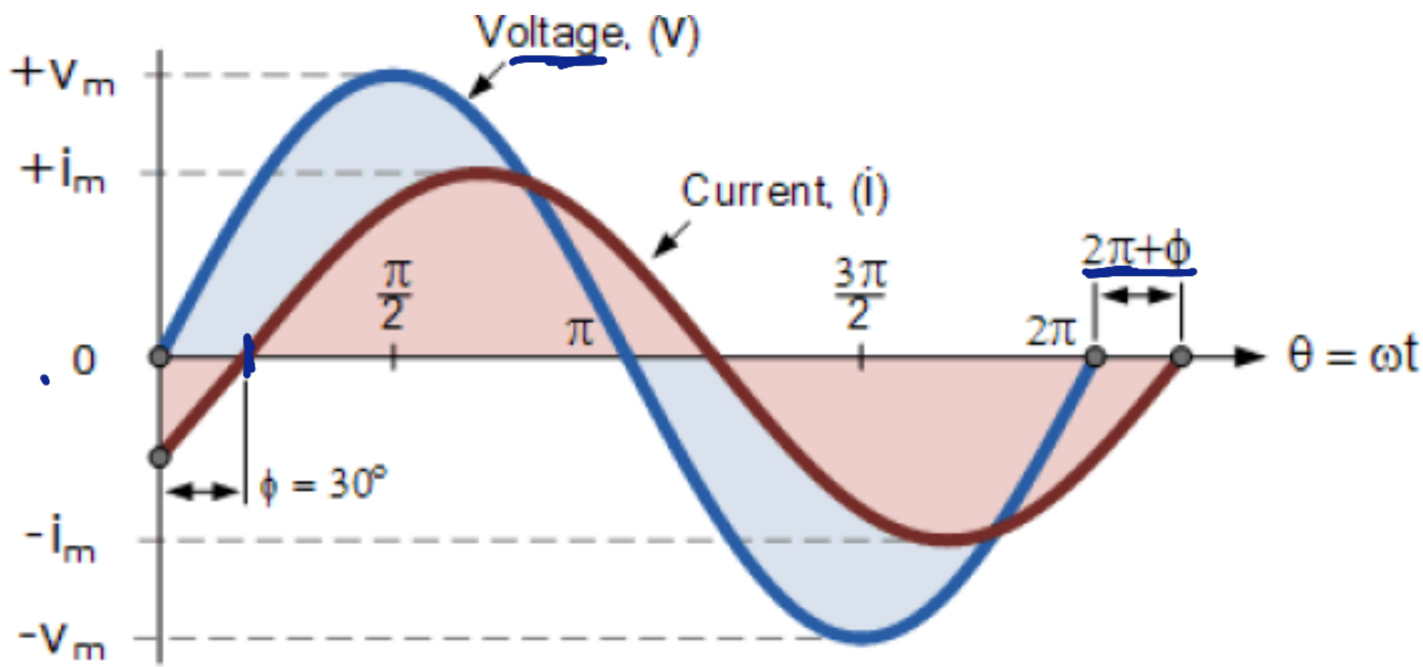
$I_i = I_m \sin(\omega t)$

$V_i = V_m \sin(\omega t)$

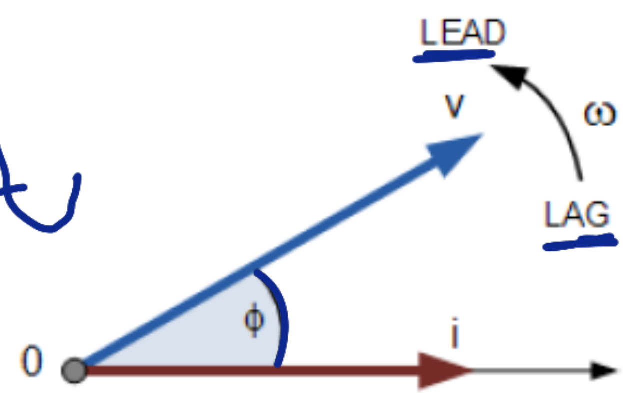
Phase Difference of a Sinusoidal Waveform

The voltage waveform above starts at zero along the horizontal reference axis, but at that same instant of time the current waveform is still negative in value and does not cross this reference axis until 30° later. Then there exists a **Phase difference** between the two waveforms.

فرق في الطور

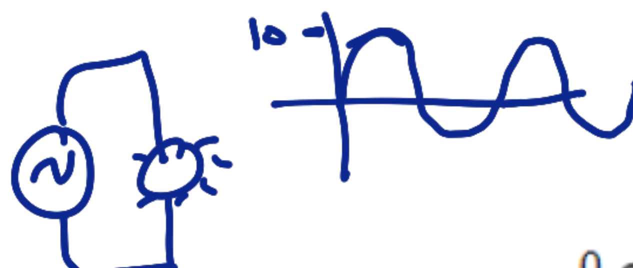


$(\theta \pm \phi)$



DC

V=10V



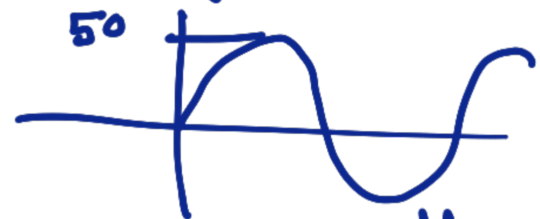
متوسط الجذر التربيعي

Rms(root mean square) Current and Voltage

- The *rms current* is the direct current that would dissipate the same amount of energy in a resistor as is actually dissipated by the AC current

قيمة التيار الفعالة

$$I_{rms} = \frac{I_{max}}{\sqrt{2}} = 0.707\ I_{max}$$



- Alternating voltages can also be discussed in terms of rms values

$$V_{rms} = \frac{50}{\sqrt{2}}$$

$$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}} = 0.707\ \Delta V_{max}$$

تمثل الجهد المتناوب لدورة كاملة (القيمة الفعالة)

- The rms value is the sum of values throughout one complete time period. Rms is also called the effective value.

- It is the value given by a voltmeter to ac voltages.
- The average power delivered to a resistance is given by the formula

القدرة ، المتوسطة

- Pavg= Irms^2 R
- This formula is for a sine wave only

$$P = I_{rms}^2 R$$

القدرة المستهلكة في المقاومة

العامل الشكلي معامل القمة

Form Factor and Crest Factor

معاملات تعطي معلومات عن الشكل الاصلي للموجة

Both **Form Factor** and **Crest Factor** can be used to give information about the actual shape of the AC waveform.

Form Factor is the ratio between the average value and the RMS value and is given as:

1.109

For a pure sinusoida

Crest Factor is the ra

$$\boxed{\text{Form Factor}} = \frac{\text{R.M.S value}}{\text{Average value}} = \frac{0.707 \times V_{max}}{0.637 \times V_{max}}$$

eform and is given as:

$$\frac{V_m/\sqrt{2}}{0.637 \times V_{max}} = \frac{rms}{\text{المتوسط}} = \text{العامل الشكلي}$$

For a pure sinusoidal waveform the Crest Factor will always be equal to 1.414.

$$\boxed{\text{Crest Factor}} = \frac{\text{Peak value}}{\text{R.M.S. value}} = \frac{V_{max}}{0.707 \times V_{max}}$$

$= 1.414$

قيمة ثابتة للموجة الجيبية

قوانين كيرتشوف

Kirchhoff's circuit laws

حفظ الطاقة   حفظ الشحنه

Kirchhoff's circuit laws are two equalities that deal with the conservation of charge and energy in electrical circuits, and were first described in 1845 by Gustav Kirchhoff. These "laws" are widely used in the analysis and design of electronic circuits.

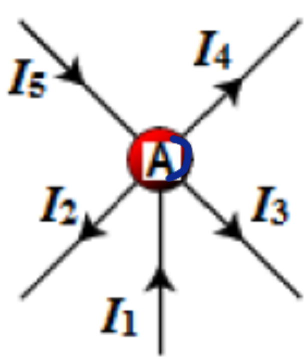
● **Kirchhoff's current law (KCL) :**

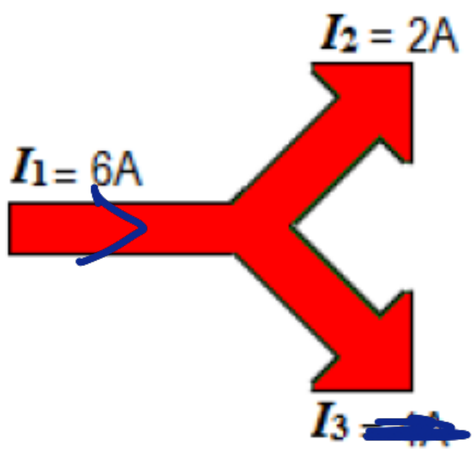
القانون الاول (حفظ الشحنة)

The current entering any junction in a circuit network is equal to the current leaving that junction.

قانون كيرشتوف الاول :. عند اي نقطة تفرع مجموع التيارات الداخلة يساوي مجموع التيارات الخارجة

$$I_5 + I_1 = I_4 + I_2 + I_3$$





$$6 = 2 + I_3$$

$$I_3 = 4$$

$$i_1 + i_5 = i_2 + i_3 + i_4$$

$$I_1 = I_2 + I_3$$

قانون كيرشوف الثاني

مجموع الجهود (IR) تساوي مجموع القوة الدافعة للبطاريات (EMF) في المسار المغلق

- **Kirchhoff's Voltage Law (KVL)**

The Kirchhoff's second law stated that; In any closed path (or circuit) in a network, the algebraic sum of the IR product is equal to the EMF in that path. In other words, in any closed loop, the algebraic sum of the EMF applied is equal to the algebraic sum of the voltage drops in the elements. Kirchhoff's

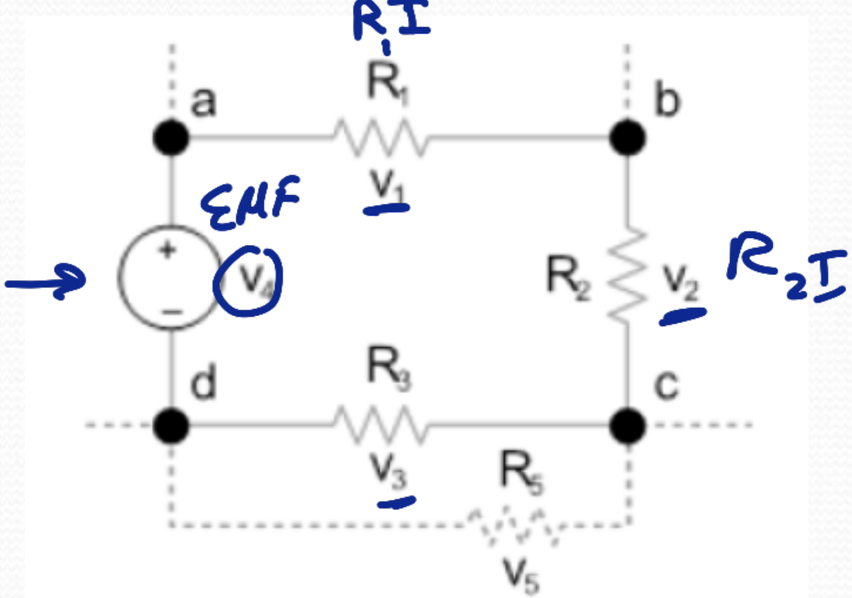
مجموع الجهود

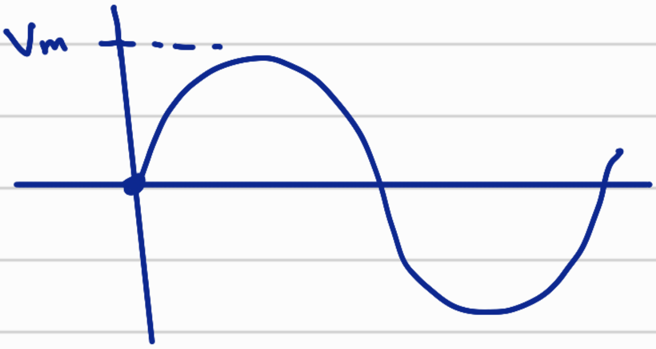
مجموع البطاريات

$$\sum IR = \sum E$$

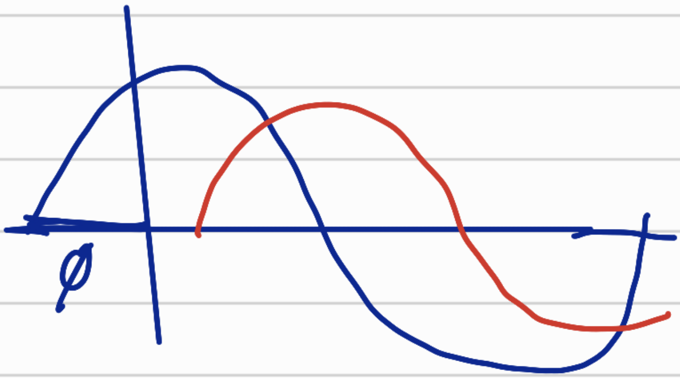
The sum of all the voltages around a loop of circuit elements is equal to zero.

v1 + v2 + v3 + v4 = 0





$$V = V_m \sin(\omega t)$$
$$I = I_m \sin(\omega t)$$



$$V = V_m \sin(\omega t \pm \phi)$$
$$I = I_m \sin(\omega t + \phi)$$

$$V = V_m \sin(\omega t \mp \phi) = V_{rms} \angle \phi$$

$$V_{rms} = \frac{V_m}{\sqrt{2}} \qquad I_{rms} = \frac{I_m}{\sqrt{2}}$$

convert the following to phasor form

$$50 \sin \omega t = \frac{50}{\sqrt{2}} \angle 0$$

$$70 \sin(\omega t + 27) = \frac{70}{\sqrt{2}} \angle 27$$

$$45 \cos \omega t = 45 \sin(\omega t + 90) = \frac{45}{\sqrt{2}} \angle 90$$

$I_1 = 10 \sin(\omega t + 60) \Rightarrow 10 \angle 60$

$I_2 = 20 \sin(\omega t + 45) \Rightarrow 20 \angle 45$

$I_1 + I_2 = 29.77 \angle 49.99$

$= 29.77 \sin(\omega t + 49.99)$

مكونات سلبيه

Passive Components in AC Circuits

R

C

The three main passive components used in any circuit are the: Resistor, the Capacitor and the Inductor. All three of these passive components have one thing in common, they limit the flow of electrical current through a circuit but in very different ways.

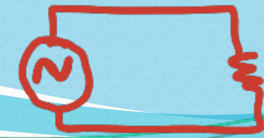
الممانعة

Electrical current can flow through a circuit in either of two ways. If it flows in one steady direction only it is classed as direct current, (DC). If the electrical current alternates in both directions back and forth it is classed as alternating current, (AC). Although they present an impedance within a circuit, passive components in AC circuits behave very differently to those in DC circuits.

تستهلك طاقة

Passive components consume electrical energy and therefore cannot increase or amplify the power of any electrical signals applied to them, simply because they are passive and as such will always have a gain of less than one. Passive components used in electrical and electronic circuits can be connected in an infinite number of ways as shown below, with the operation of these circuits depending on the interaction between their different electrical properties.

Purely Resistive Circuit



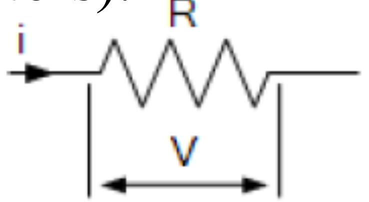
V=IR

Resistors regulate, impede or set the flow of current through a particular path or impose a voltage reduction in an electrical circuit as a result of this current flow.

ممانعة

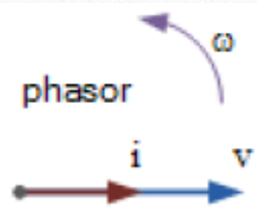
Resistors have a form of impedance which is simply termed *resistance*, R with the resistive value of a resistor being measured in $\boxed{\text{Ohms, }\Omega.}$

Resistors can be of either a $\boxed{\text{fixed}}$ value or a variable value (potentiometers).

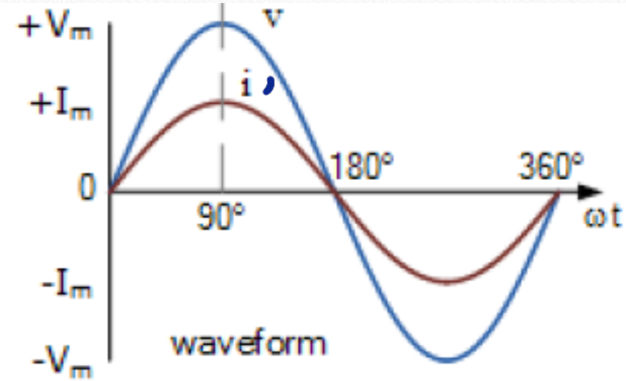


$I_{(t)} = \frac{V_{(t)}}{R}$ (Ohms Law)

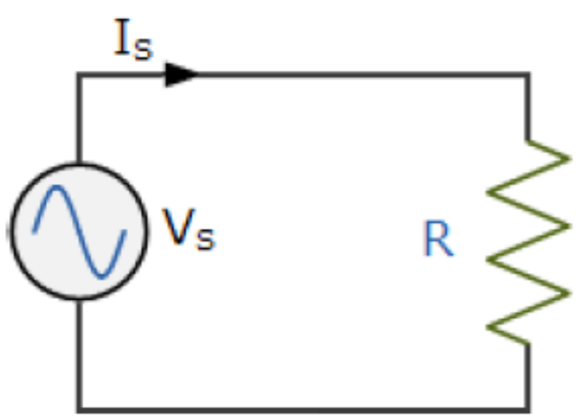
$\boxed{Z = R}$



$Z\angle 0° = R + j0$



ممانعة



$$\boxed{Z} = \frac{V_R}{I_R} = R$$

$$Z = \angle 0^{\circ} = R + j0$$

$$I_S = \frac{V_S}{R}$$

التيار والجهد تصلان الى اعلى قيمة في نفس الوقت

- The current and the voltage reach their maximum values at the same time

نفس الطور

- The current and the voltage are said to be *in phase*
- The direction of the current has no effect on the behavior of the resistor

اتجاه التيار لا يؤثر على سلوك المقاومة

- The rate at which electrical energy is dissipated in the circuit is given by: $P = i^2R$

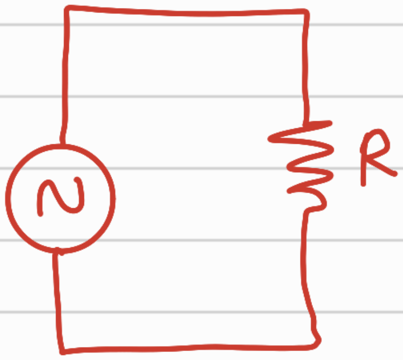
متوسط القدرة المستهلكة في مقاومة

$P = I_i^2 R = V_i I_i = \frac{V_i^2}{R}$

  where i is the *instantaneous current*
- rms values will be used when discussing AC currents and voltages
  - AC ammeters and voltmeters are designed to read rms values
  - Many of the equations will be in the same form as in DC circuits
- Ohm's Law for a resistor, R, in an AC circuit

$R = Z$

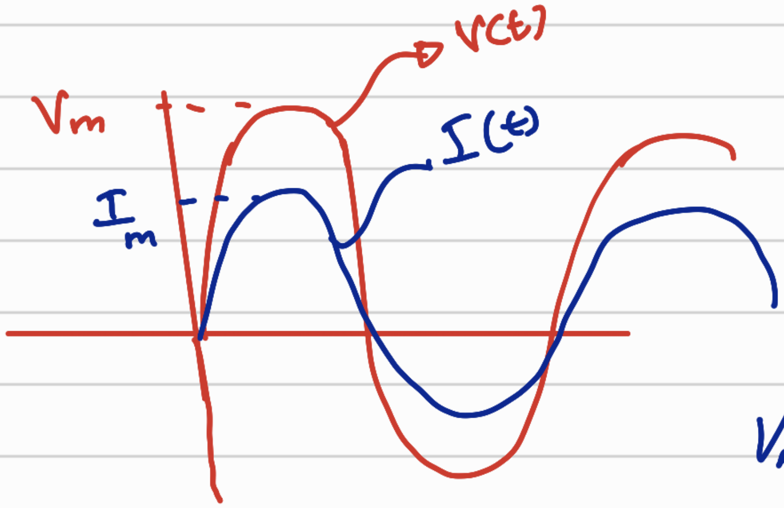
  - $\Delta V_{rms} = I_{rms}\, R$
    - Also applies to the maximum values of v and i



$V = V_m \sin \omega t$

$I = I_m \sin \omega t$

in phase



$\frac{V_m}{I_m} = R$

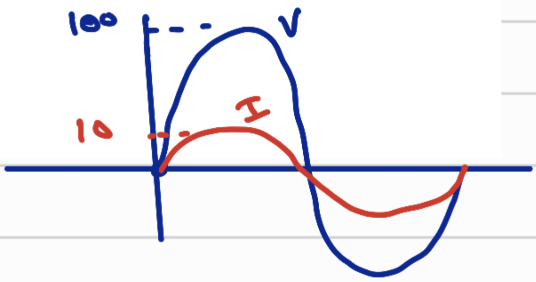
$Z = R$

$V_m = I_m R$ $\quad I_m = \frac{V_m}{R}$

EXAMPLE 14.1 The voltage across a resistor is indicated. Find the sinusoidal expression for the current if the resistor is $\boxed{10\ \Omega}$. Sketch the curves for v and i.

a. $v = 100 \sin 377t$

b. $v = 25 \sin(377t + 60°)$



a) $V = 100 \sin(377t)$

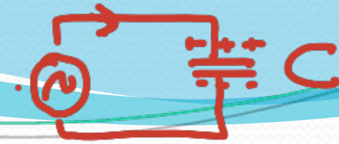
$V = V_m \sin(\omega t)$ $\quad I = I_m \sin \cancel{\omega t}$ 377

$I_m = \frac{V_m}{R} = \frac{100}{10} = 10\ A$ $\quad I = 10 \sin(377t)$

a) $V = 25 \sin(377t + 60)$ $\quad I = \frac{V}{R}$

$I = 2.5 \sin(377t + 60)$ $\quad = \frac{25}{10}$

Purely Capacitive Circuit

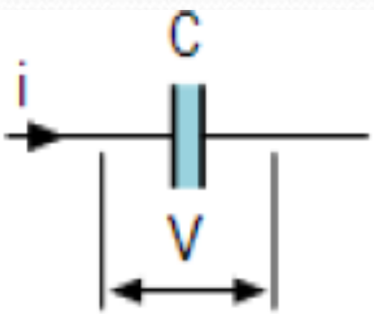


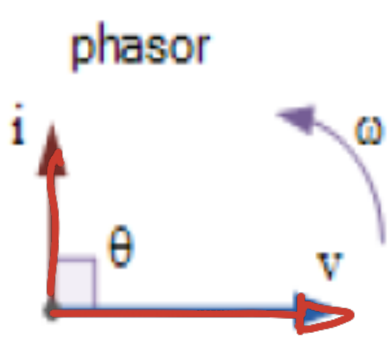
تخزين الطاقة

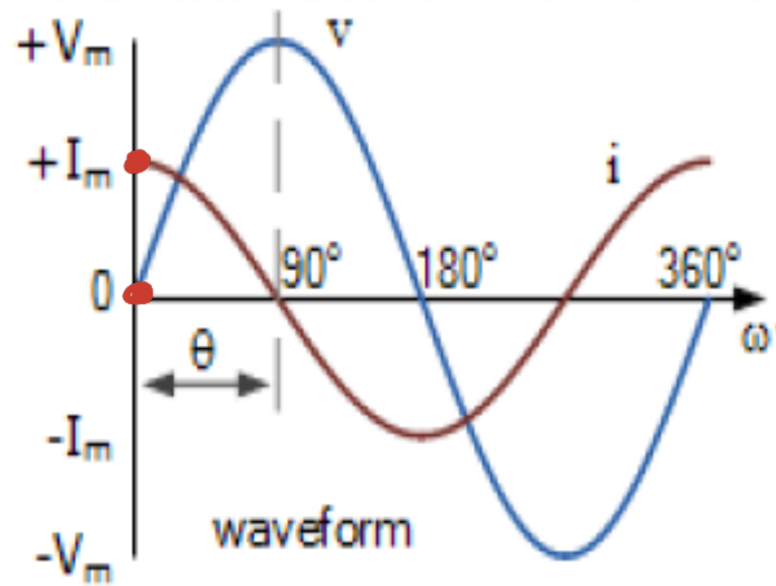
The capacitor is a component which has the ability or "capacity" to store energy in the form of an electrical charge like a small battery. The capacitance value of a capacitor is measured in Farads, F.

At DC a capacitor has infinite (open-circuit) impedance, (XC) while at very high frequencies a capacitor has zero impedance (short-circuit).

عندما يكون التردد عالي تكون ممانعه المكثف قليله (داره قصر)







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

$Z\angle -90° = 0 - j1$

$I_{(t)} = \dfrac{V_{(t)}}{X_C}$ R = 0

$V = I X_C$

يبدأ التيار كبيرًا ثم وسيشحن الصفيحتين

- The current starts out at a large value and charges the plates of the capacitor

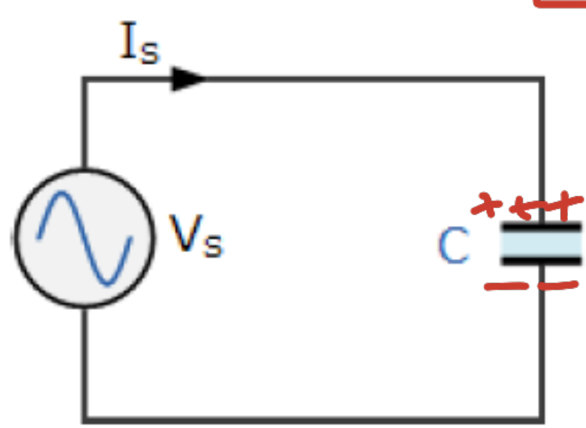
في البداية لا يوجد ممانعه لانه لا يوجد شحنات على الشق

- There is initially no resistance to hinder the flow of the current while the plates are not charged
- As the charge on the plates increases, the voltage across the plates increases and the current flowing in the circuit decreases

$$\boxed{Z = 0 - X_c j}$$

The current reverses direction
The voltage across the plates decreases as the plates lose the charge they had accumulated
The voltage across the capacitor lags behind the current by 90°

الجهد يتأخر عن التيار بمقدار 90

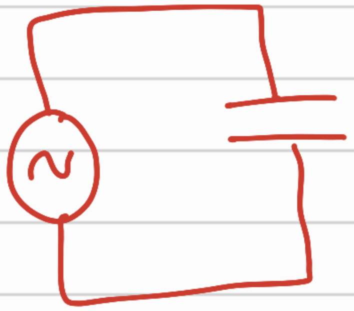


$$X_C = \frac{V_C}{I_C} = \frac{1}{2\pi f C}$$

$$Z = \angle -90^\circ = 0 - jX_C$$

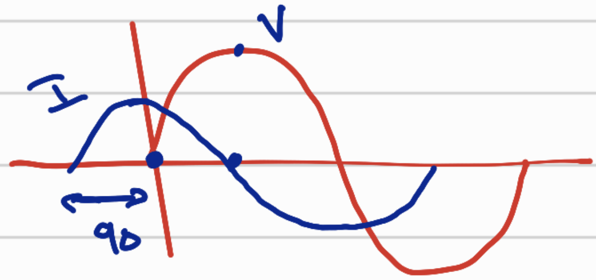
$$I_S = \frac{V_S}{X_C}$$

$\Delta V_{rms} = I_{rms} \, X_C$



$V = V_m \sin \omega t$

$I = I_m \sin(\omega t + 90)$



$I_m = \omega C V_m$

$I_m = 2\pi f C V_m$

$\boxed{Z = 0 - j X_C}$

$\frac{V_m}{I_m} = \frac{1}{2\pi f C} = \frac{1}{\omega C}$

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

$V_m = I_m X_C$

EXAMPLE 14.5 The voltage across a 1-μF capacitor is provided below. What is the sinusoidal expression for the current? Sketch the v and i curves.

$V_m \sin \omega t$

$$v = 30 \sin 400t$$

$X_C = \frac{1}{\omega C} = \frac{1}{400 \times 1 \times 10^{-6}}$

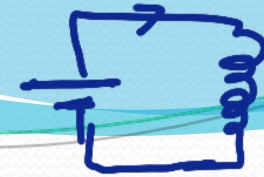
$= 2500\ \Omega$

$I_m = \frac{V_m}{X_C} = \frac{30}{2500} = 12\text{ mA}$

$I = I_m \sin(\omega t + 90)$

$= 12 \sin(400t + 90)\ \text{mA}$

Purely Inductive Circuit



تحث

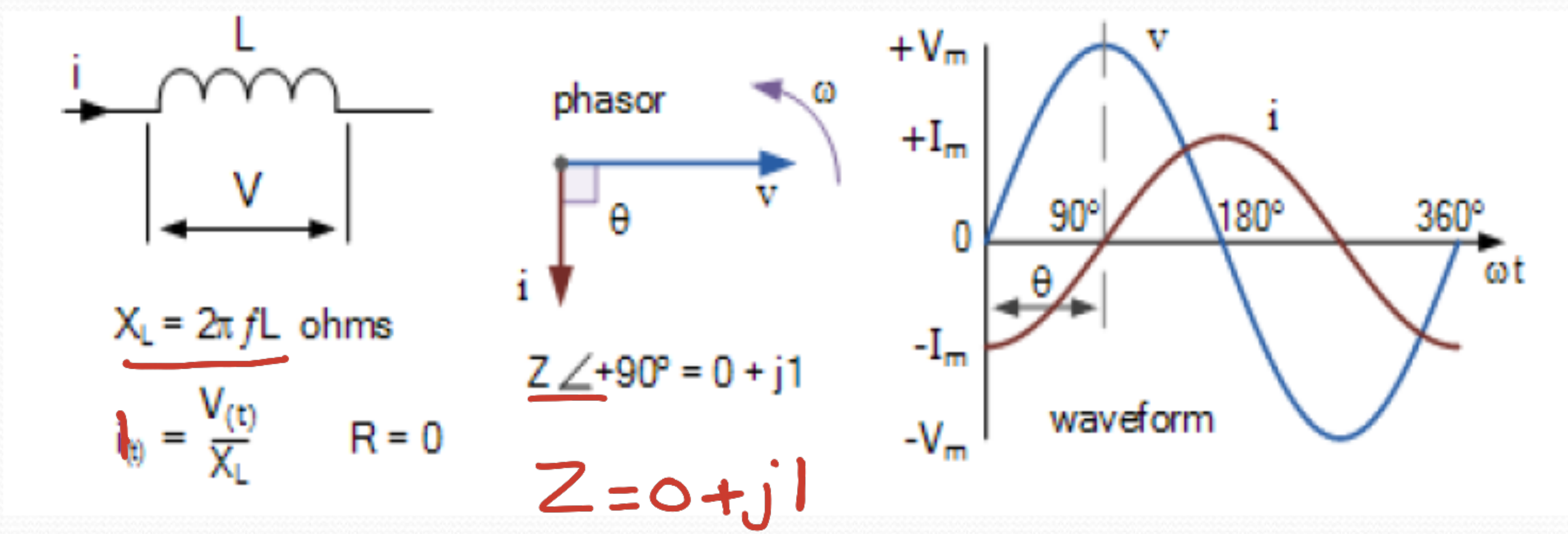
- An inductor is a coil of wire that induces a magnetic field within itself or within a central core as a direct result of current passing through the coil.

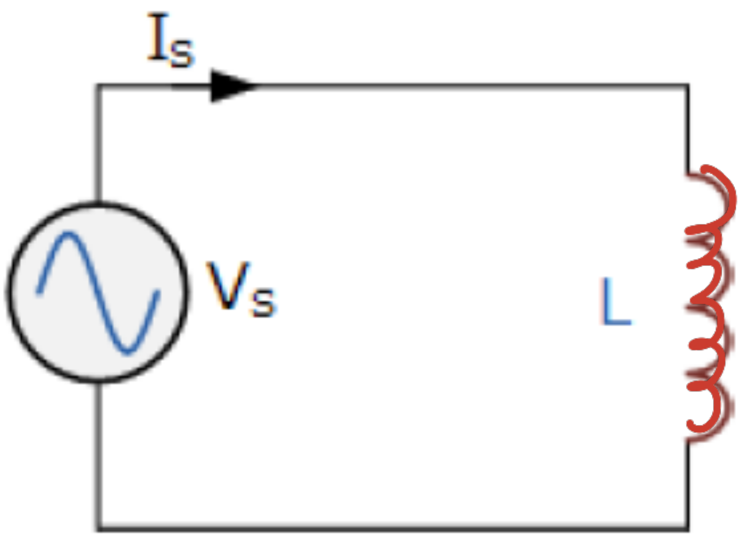
L

- The inductance value of an inductor is measured in Henries, H.
- At DC an inductor has zero impedance (short-circuit), while at high frequencies an inductor has infinite (open-circuit) impedance.

عندما يكون التردد عالي تكون ممانعة, كلف اكبر ما يمكن

عندما تكون التردد منخفض تكون (لا يوجد ممانعة)





$$X_L = \frac{V_L}{I_L} = 2\pi f L$$

$$Z = \angle +90^\circ = 0 + jX_L$$

$$I_S = \frac{V_S}{X_L}$$

- Consider an AC circuit with a source and an inductor
- The current in the circuit is impeded by the back emf of the inductor

بقاريه عكسيه

- The voltage across the inductor always leads the current by 90°

الجهد سيسبق التيار بمقدار ٩٠

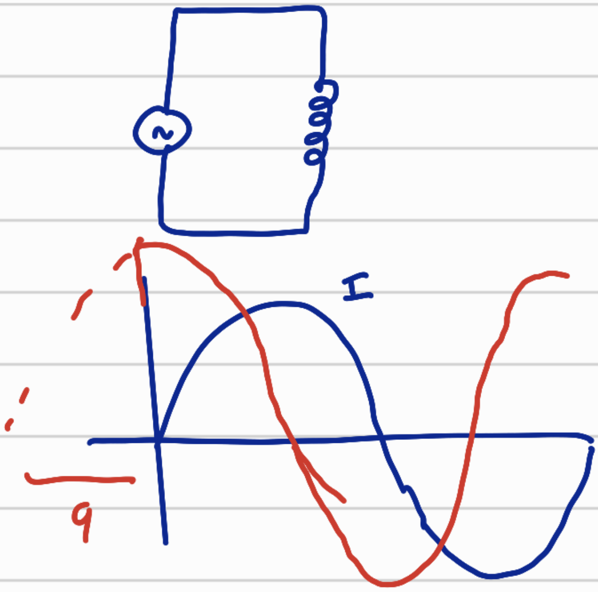
Inductive Reactance and Ohm's Law

- The effective resistance of a coil in an AC circuit is called its *inductive reactance* and is given by
- X_L ~~XL~~ = 2πfL
- When f is in Hz and L is in H, XL will be in ohms
- Ohm's Law for the inductor
- ΔVrms = Irms XL

$X_L = \Omega$

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

الجهد يسبق التيار ب ٩٠



$I = I_m \sin(\omega t)$

$V = V_m \sin(\omega t + 90)$

$V_m = \omega L I_m = 2\pi f L I_m$

$X_L = 2\pi f L = \dfrac{V_m}{I_m}$

EXAMPLE 14.3 The current through a 0.1-H coil is provided. Find the sinusoidal expression for the voltage across the coil. Sketch the *v* and *i* curves.

a. $i = 10 \sin 377t$

a) $X_L = \omega L = 377\,(0.1) = 37.7$

$V_m = I_m X_L = 10\,(37.7) = 377\ V$

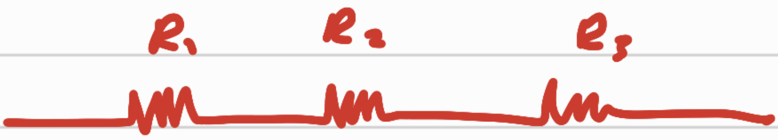
$V = 377 \sin(773t + 90)$

قانون اوم

$$V = IR$$

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

التوالي

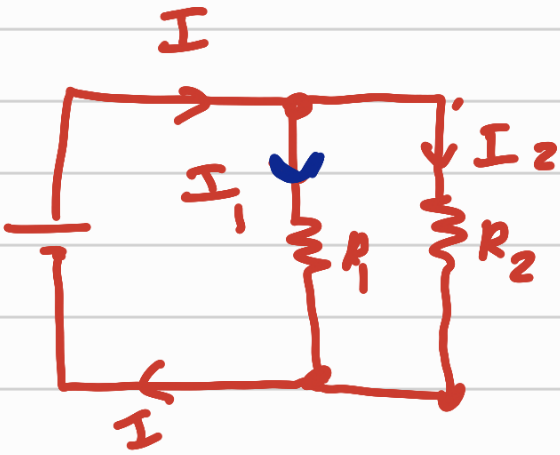


$$I = I_1 = I_2 = I_3$$

$$V = V_1 + V_2 + V_3$$

$$R_{eq} = R_1 + R_2 + R_3$$

التوازي



$$I = I_1 + I_2$$

$$V = V_1 = V_2$$

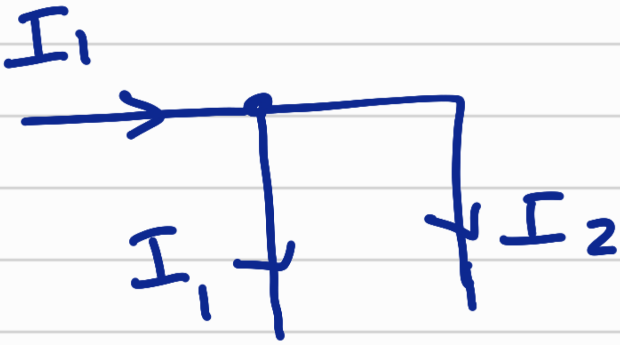
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

قاعدة تقسيم التيار

$$I_1 = \frac{R_2}{R_1 + R_2} I$$

قانون كيرشوف الاول

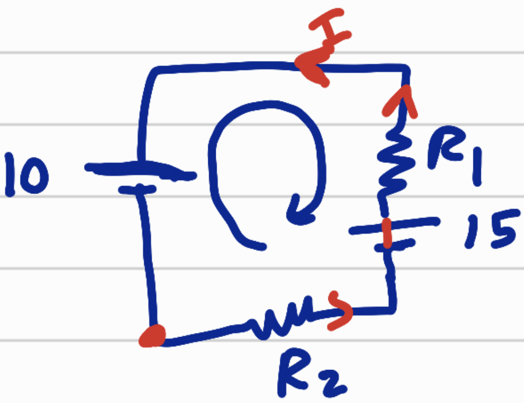


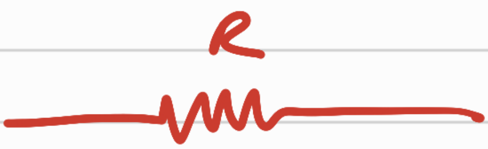
$$I_1 = I_1 + I_2$$

قانون كيرشوف الثاني

$$\sum EMF = \sum IR$$

$$+10 - 15 = -IR_1 - IR_2$$



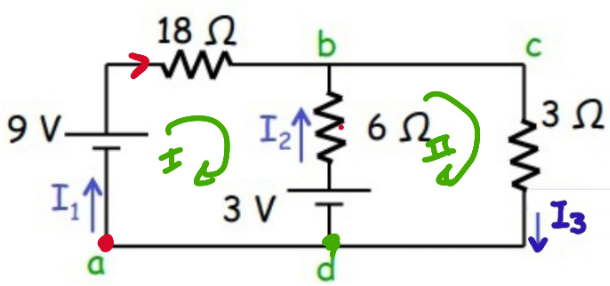


القدره المستهلكه في المقاومة

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

watt

Example



Find the current through each battery.

$I_1 + I_2 = I_3$ $\quad$ $\boxed{I_1 + I_2 - I_3 = 0}$ ---- (1)

Loop I

$$\Sigma EMF = \Sigma IR$$

$$9 - 3 = I_1(18) - I_2(6)$$

$\boxed{18 I_1 - 6 I_2 = 6}$ ---- (2)

Loop II

$$\Sigma EMF = \Sigma IR$$

$$3 = I_2(6) + I_3(3)$$

$\boxed{6 I_2 + 3 I_3 = 3}$ ---- (3)

$$I_1 + I_2 - I_3 = 0$$
$$18 I_1 - 6 I_2 = 6$$
$$6 I_2 + 3 I_3 = 3$$

$$\begin{array}{cccc} x & y & z & \\ \end{array}$$

$$\left|\begin{array}{cccc} 1 & 1 & -1 & 0 \\ 18 & -6 & 0 & 6 \\ 0 & 6 & 3 & 3 \end{array}\right|$$

$I_1 = \frac{2}{5}$ $\quad$ $I_2 = \frac{1}{5}$ $\quad$ $I_3 = \frac{3}{5}$