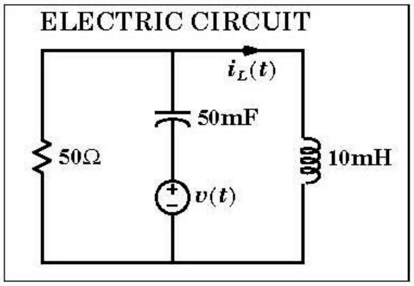
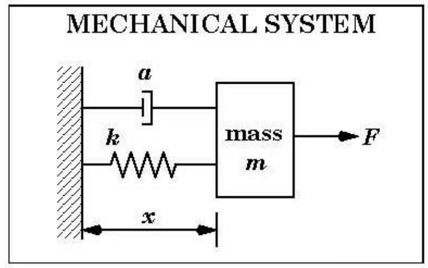
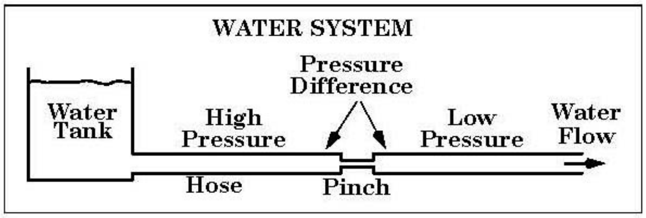
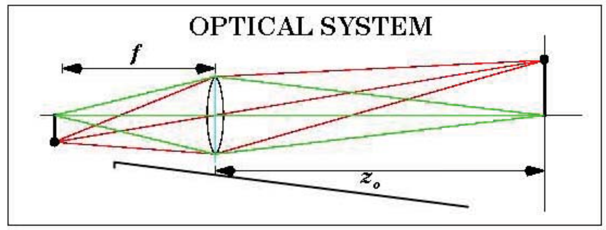
What is a System?

- A *System* is a combination of several components resulting in varying parameters.

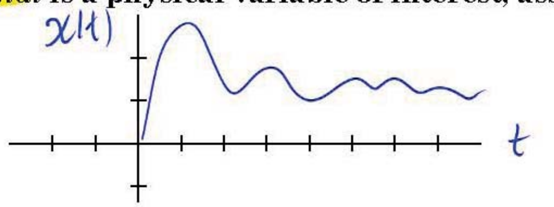








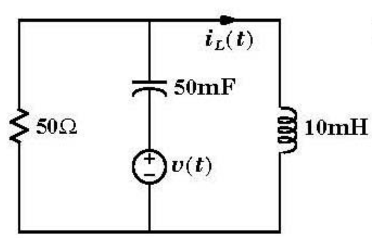
- A *Signal* is a physical variable of interest, associated with a system, that varies.



The New Mindset

- **Circuits Mindset:**

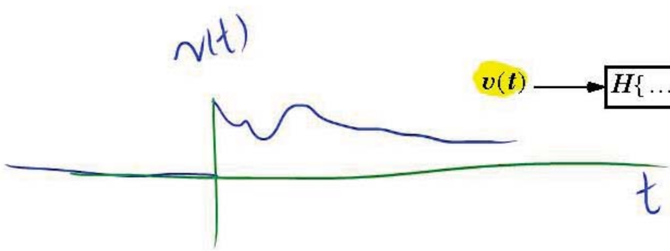
Given $v(t)$



Find $i_L(t)$

input $v(t)$ **output** $i_L(t)$

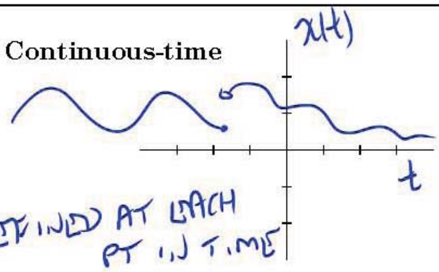
- **Systems Mindset:**



$$v(t) \longrightarrow \boxed{H\{\ldots\}} \longrightarrow i_L(t)$$

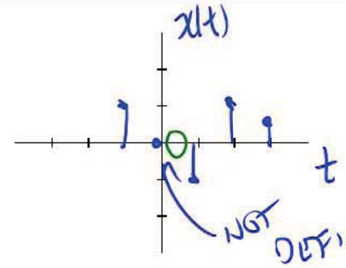
Signal Classifications

Continuous-time



DEFINED AT EACH PT IN TIME

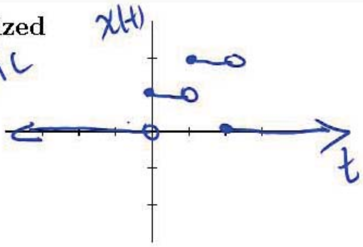
Discrete-time



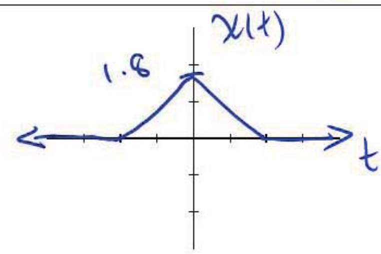
NOT DEFINED HERE

Quantized

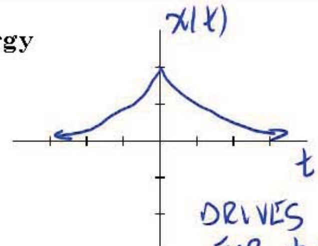
"AMPLITUDE" CHARACTERISTIC



Analog

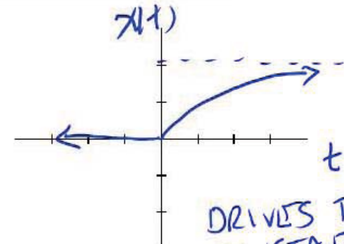


Energy



DRIVES TO ZERO FOR $t \to \infty$ AND $t \to -\infty$

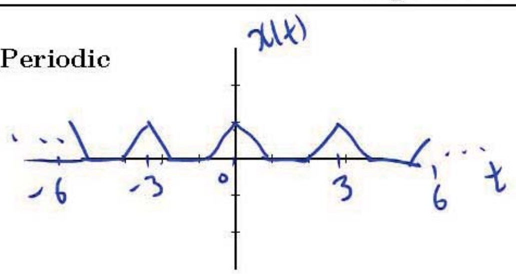
Power



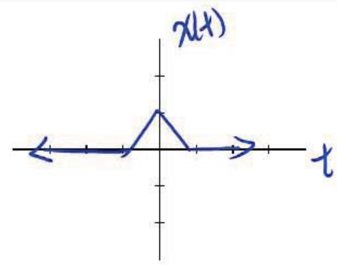
DRIVES TO NON-ZERO CONSTANT AS $t \to \infty$ OR $t \to -\infty$

Signal Classifications

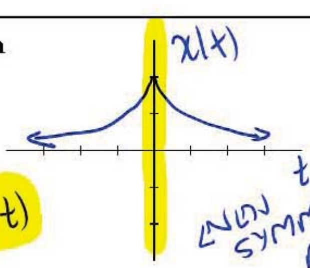
Periodic



Aperiodic



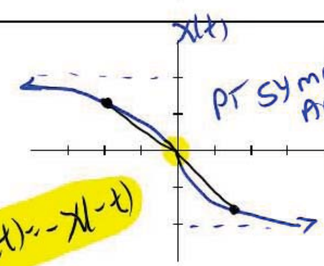
Even



$x(t) = x(-t)$

NOW SYMMETRY ABOUT Y-AXIS

Odd



PT SYMMETRY ABOUT ORIGIN

ROTATE BY 180° SAME SIGNAL

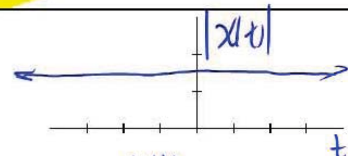
$x(t) = -x(-t)$

Real

$x(t) = 3\cos(2\pi t)$

NO "j" HERE $j = \sqrt{-1}$

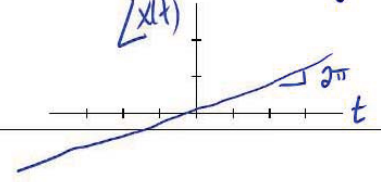
Complex



$x(t) = 3e^{j2\pi t}$

MAG

PHASE



The Periodic and Aperiodic Signals

ASIDE

$\cos(\alpha+\beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta$

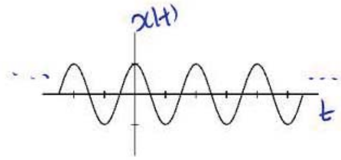
- A signal is *periodic* if there is some time interval, T, such that

$$x(t) = x(t+T) \quad \text{for all } t$$

The smallest value of T is called the *fundamental period*, T_0?

- Is $x(t) = A\cos(4\pi t)$ periodic?

If so, what is the *fundamental period*?



$x(t) = x(t+T)$

FIND $T \neq 0$ SO THAT EQUALITY HOLD

$A\cos(4\pi t) = A\cos[\underbrace{4\pi(t+T)}_{4\pi t + 4\pi T}]$

$= A[\cos(4\pi t)\underbrace{\cos(4\pi T)}_{1} - \sin(4\pi t)\underbrace{\sin(4\pi T)}_{0}]$

CHOOSE $T \neq 0$ SO THESE ARE TRUE

TRY $T = 1$: $\cos(4\pi) = 1$, $\sin(4\pi) = 0$

$\cos(\gamma) = 1$ IF $\gamma = 2\pi K$ FOR INTEGER K

$4\pi T = 2\pi K \Rightarrow T = \frac{2\pi}{4\pi}K = \frac{K}{2}$ FOR INTEGER K, $K = \ldots, -2, -1, \cancel{0}, 1, 2, \ldots$

AND $\sin(\gamma) = 0$, IF $\gamma = 2\pi K$

FUNDAMENTAL PERIOD IS SMALLEST $T > 0$ THAT GIVES $x(t) = x(t+T)$

$\therefore \; T_0 = \frac{1}{2}$

The Even and Odd Components of a Signal

- **Every signal can be expressed as**

$$x(t) = x_o(t) + x_e(t)$$

where

$$x_o(t) = \frac{x(t) - x(-t)}{2}$$

is the *odd* component and

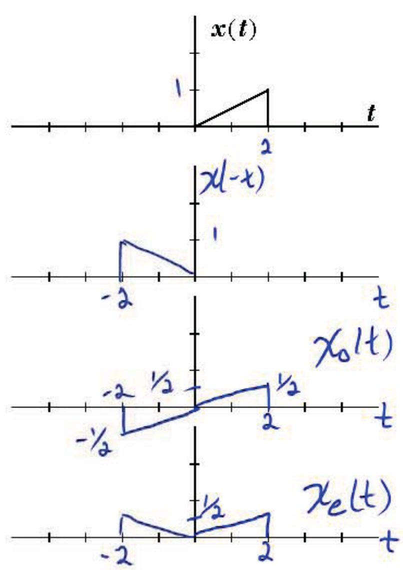
$$x_e(t) = \frac{x(t) + x(-t)}{2}$$

is the *even* component

$x_o(t) = -x_o(-t) = -\left[\frac{x(-t) - x(t)}{2}\right] = x_o(t)$

$x_e(t) = x_e(-t) = \left[\frac{x(-t) + x(t)}{2}\right]$

- **For example, consider $x(t)$ shown at the right**

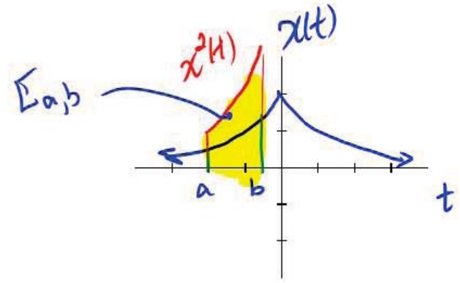


Energy and Power Definitions

We assume that the signal $x(t)$ has units of volts

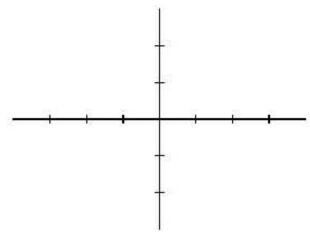
❖ **The *energy* in $x(t)$ over $[a, b]$ is**

$$E_{a,b} = \int_a^b |x(t)|^2 dt \quad \textbf{(joules)}$$



❖ **The *average power* in $x(t)$ over $[a, b]$ is**

$$P_{x(t)} = \left(\frac{1}{b-a}\right)\int_a^b |x(t)|^2 dt = \frac{E_{a,b}}{b-a} \quad \textbf{(watts)}$$

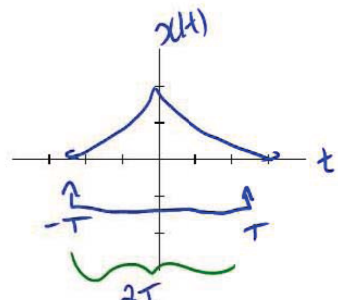


Total Energy and Power

We assume that the signal $x(t)$ has units of volts

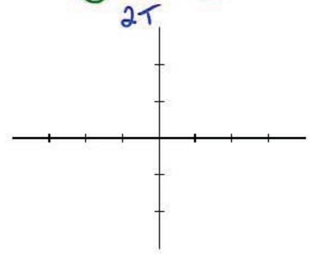
❖ **The *total energy* in $x(t)$ is**

$$E_{x(t)} \equiv \lim_{T \to \infty}\left[\int_{-T}^{T} |x(t)|^2 dt\right] \quad \textbf{(joules)}$$



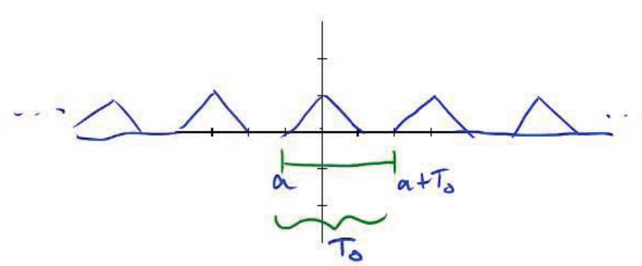
❖ **The *total average power* in $x(t)$ is**

$$P_{x(t)} \equiv \lim_{T \to \infty}\left[\frac{1}{2T}\int_{-T}^{T} |x(t)|^2 dt\right] \quad \textbf{(watts)}$$



❖ **If $x(t)$ is *periodic* with period T_0, then**

$$P_{x(t)} = \frac{1}{T_0}\int_a^{a+T_0} |x(t)|^2 dt \quad \textbf{(watts)}$$

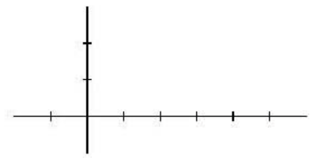


Energy and Power Signals

- **Energy & Power signal classifications:**
  - The signal $x(t)$ is an ***energy signal*** if $E_{x(t)} > 0$ and $E_{x(t)}$ is ***finite***

    Usually $P_{x(t)} = 0$ if $x(t)$ is an energy signal
  - The signal $x(t)$ is a ***power signal*** if $P_{x(t)} > 0$ and $P_{x(t)}$ is ***finite***

    Usually $E_{x(t)} = \infty$ if $x(t)$ is a power signal
  - A signal can be ***neither*** energy nor power



- **For example, is $x(t) = e^{-\alpha t}u(t)$ an *energy signal*, a *power signal*, or *neither*?**