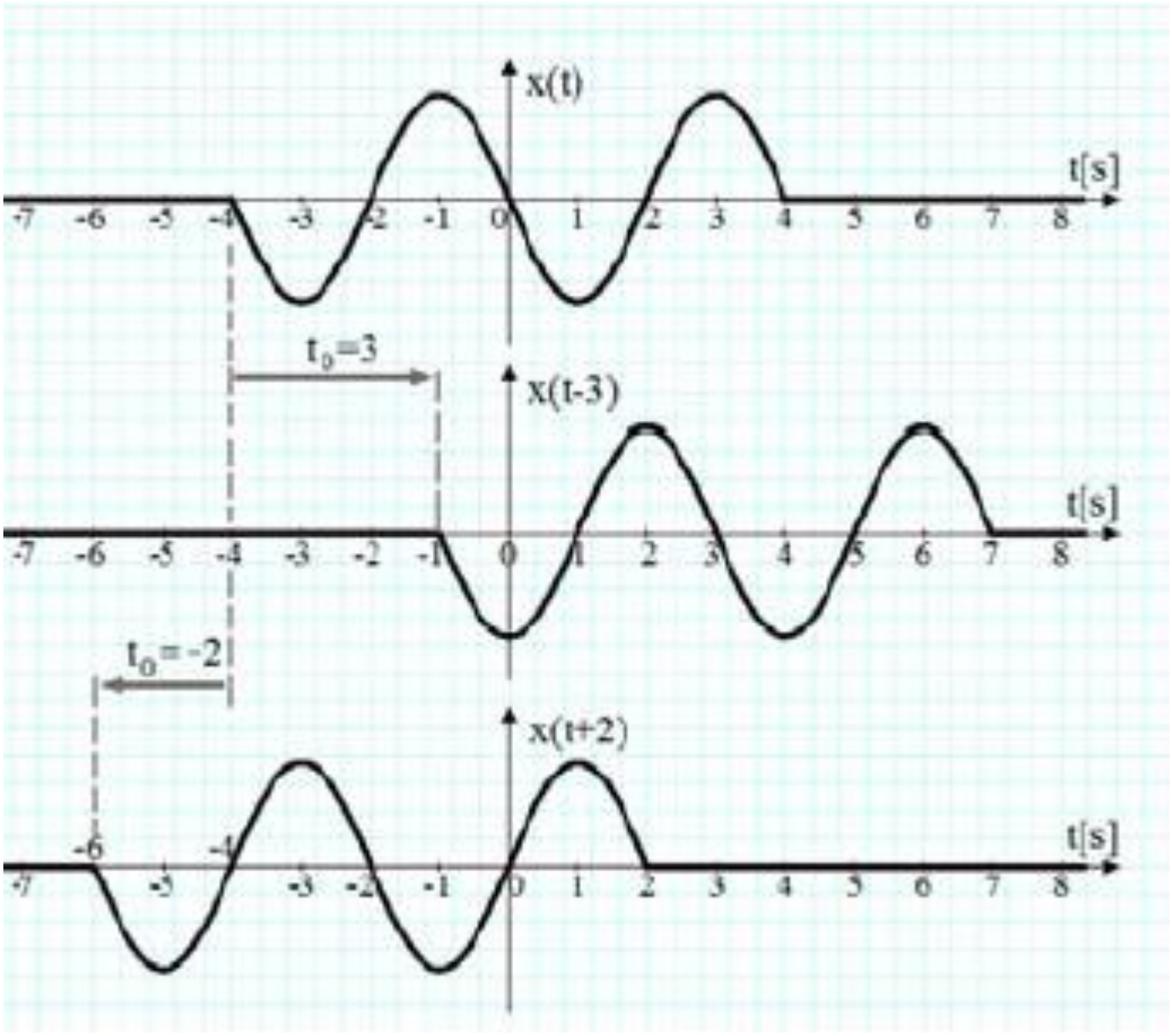
SIGNAL TRANSFORMATIONS

Time Shifting

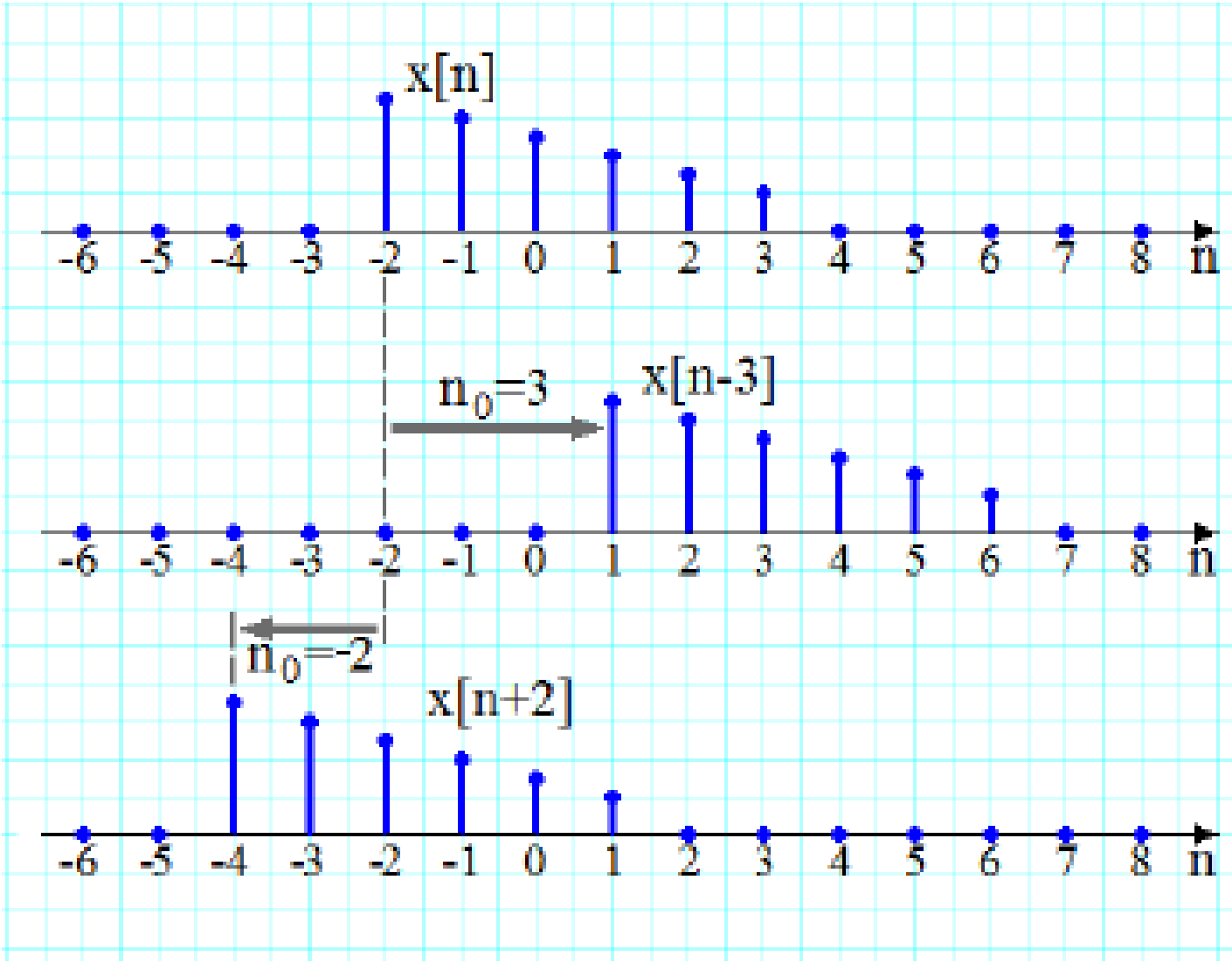
- Shifting the Independent variable such that $x(t-t_o)$
- Right Shift if $t_o > 0$, means the signal is delayed
- In other words, if we start moving on the time axis in the direction of increasing time, that is from left to right, x(t) will come first than $x(t-t_o)$
- Left Shift if $t_o < 0$, means the signal is advanced
- In other words, if we start moving on the time axis in the direction of increasing time, that is from left to right, x(t) will come later than $x(t+t_o)$

Time Shifting



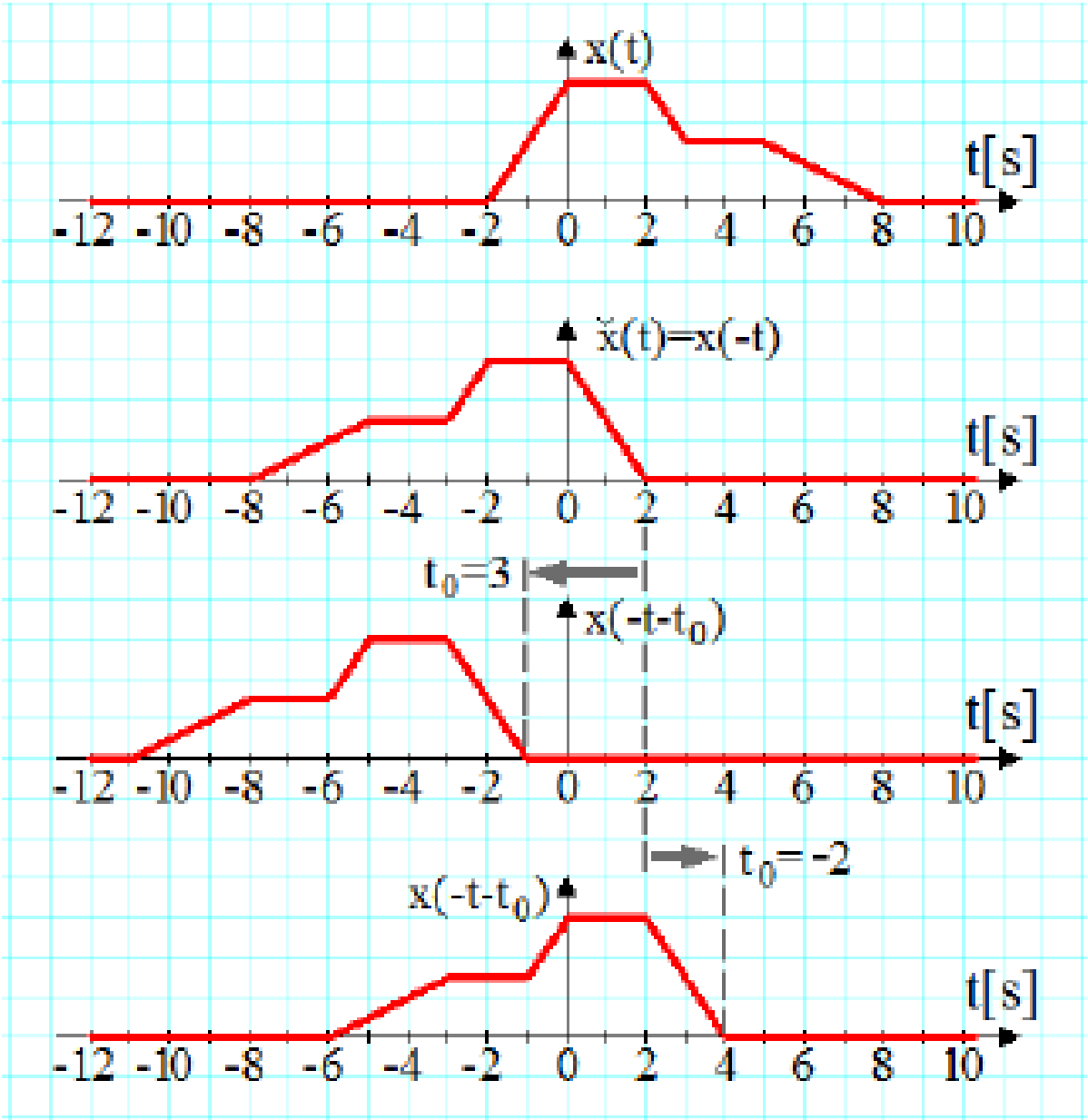
Time Shifting

- Discrete Time
- $x[n-n_o]$:
- Right Shift if:
  $n_o > 0$
- Left Shift if:
  $n_o < 0$



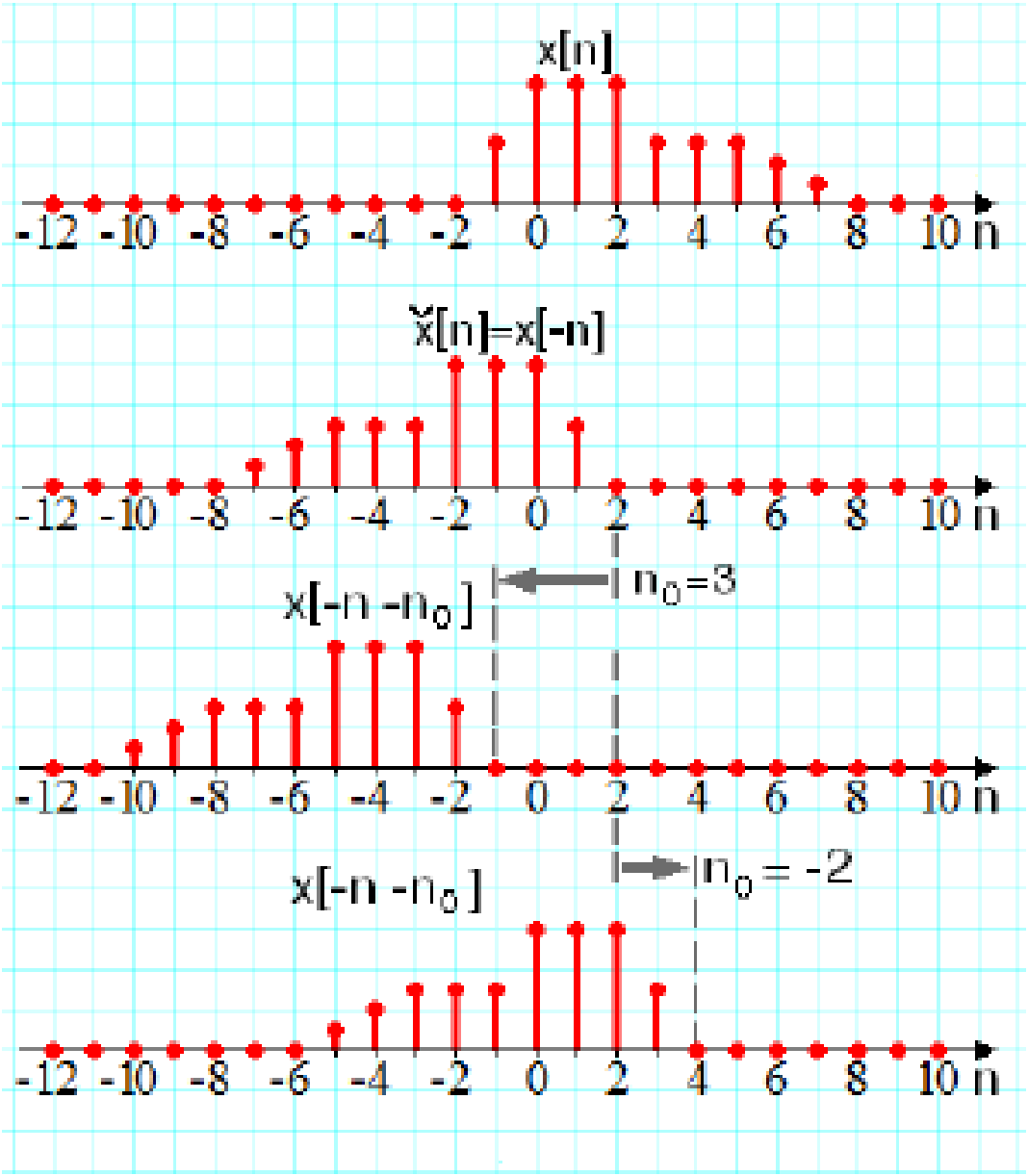
Time Reversal

- Reversing the Independent variable
- Always rotate the signal by 180^{o} about the vertical axis
- Always shift the signal first if required



Time Reversal

- Discrete time



Time Scaling – Continuous Time

- **X(t/2) means expansion of signal in time (Playing audio signal at half speed)**
- **X(2t) means compression of signal in time (Playing audio signal at 2x speed)**

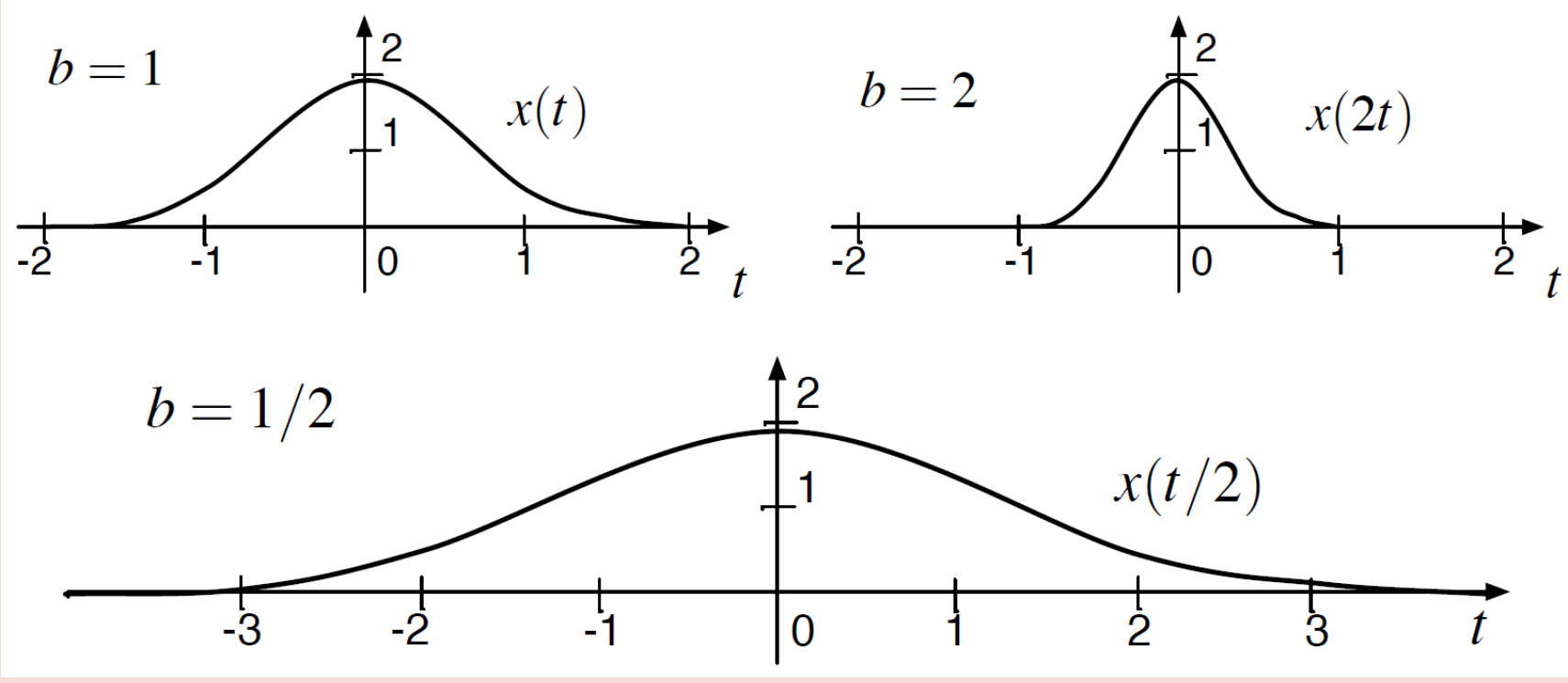


Figure Credit: EE102A:Signal Processing and Linear Systems I; Stanford; Robert Gray

Time Scaling – Discrete Time

- **Given a signal x[n]**
  - **x[n/2] means expansion of signal in time**
  - **x[2n] means compression of signal in time**

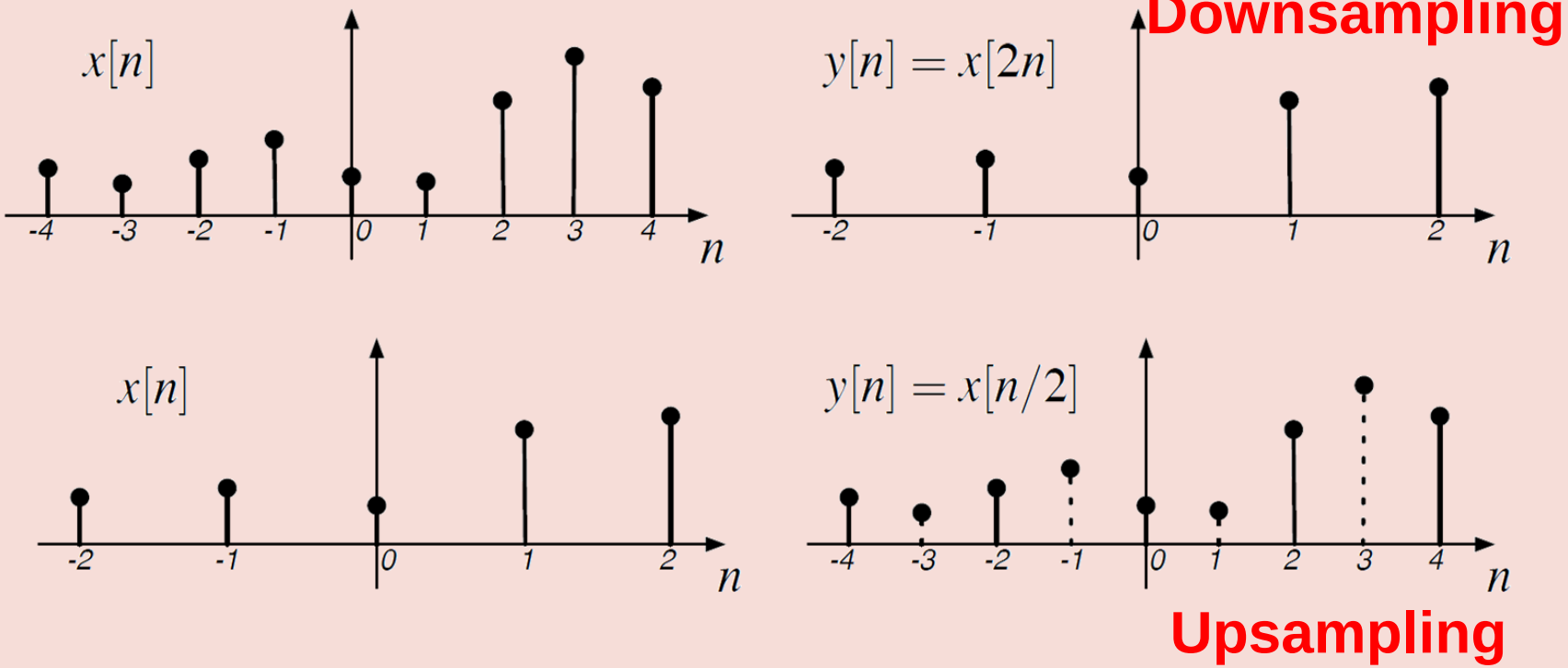


Figure Credit: EE102A:Signal Processing and Linear Systems I; Stanford; Robert Gray

Signal Scaling - Image

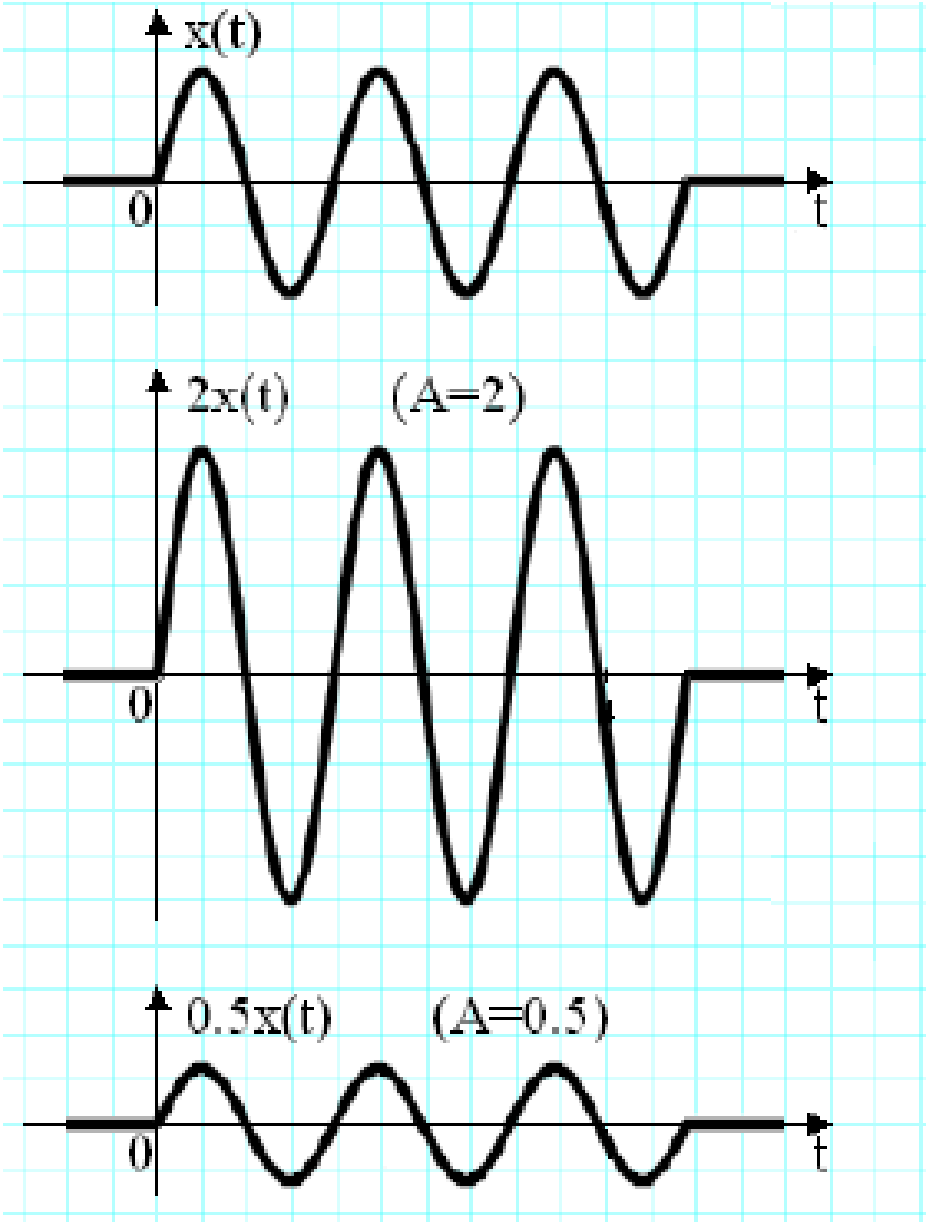
Image size h/2 x w/2 – obtained by sampling at 2n

Image size h x w

Image size 2h x 2w – obtained by sampling at n/2

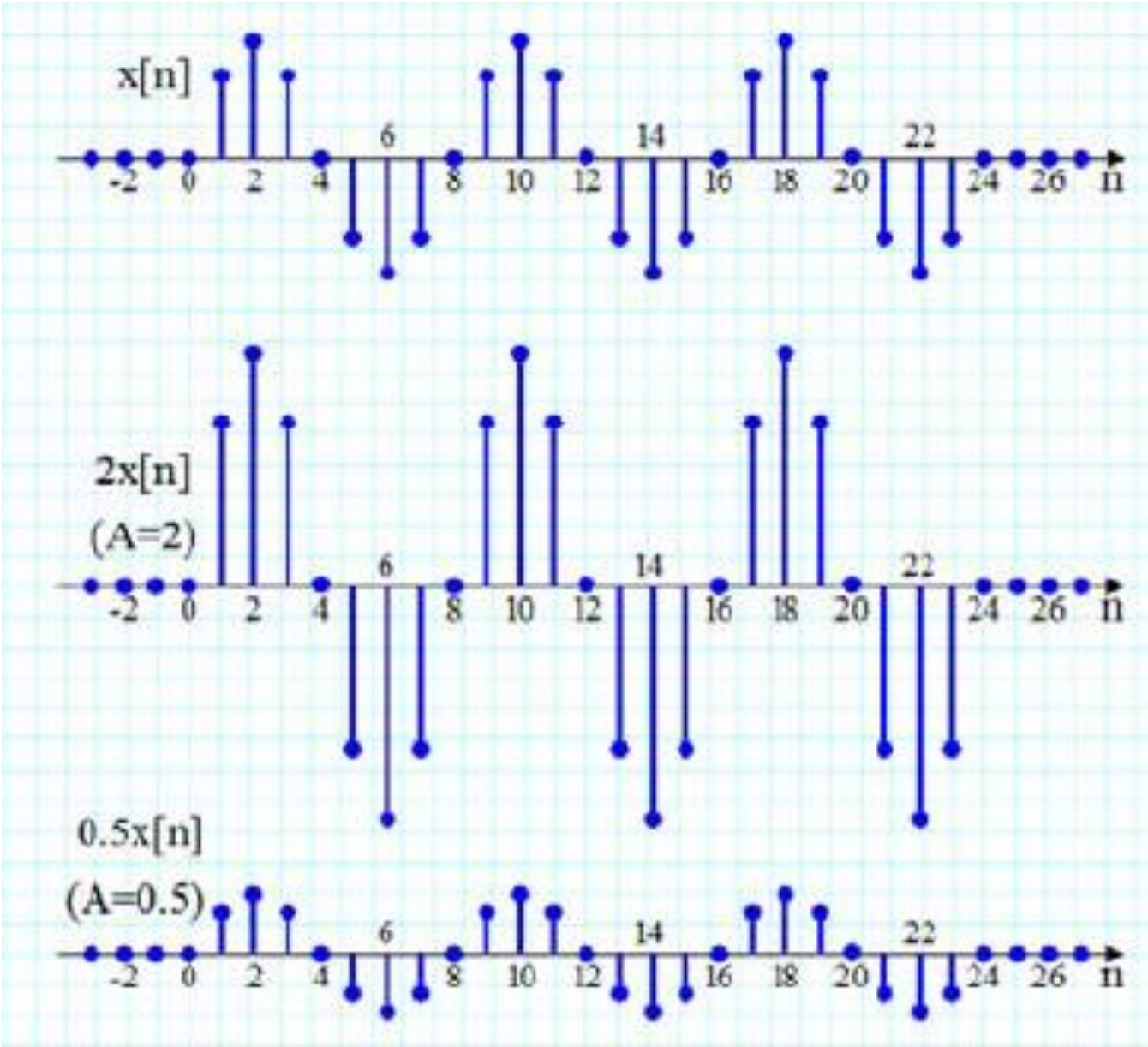
Signal Weighting

- Scaling the dependent variable
- Amplification: 2x(t)
- Attenuation: 0.5x(t)



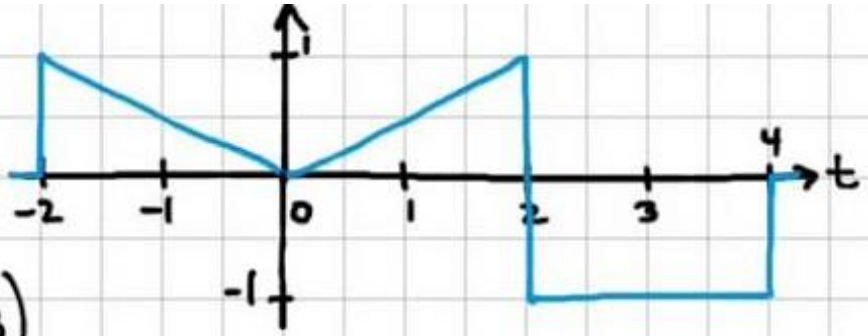
Signal Weighting

- Scaling the dependent variable
- Amplification:
  2x[n]
- Attenuation:
  0.5x[n]



Problem-1

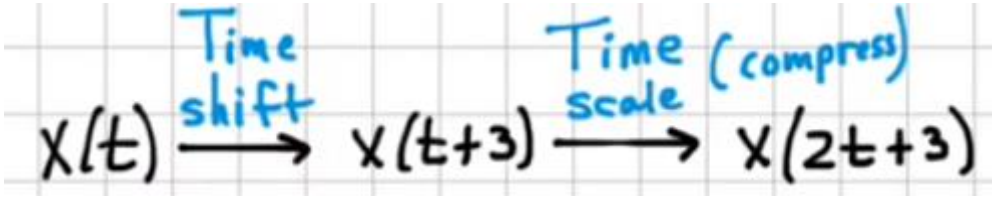
Consider the signal $x(t)$

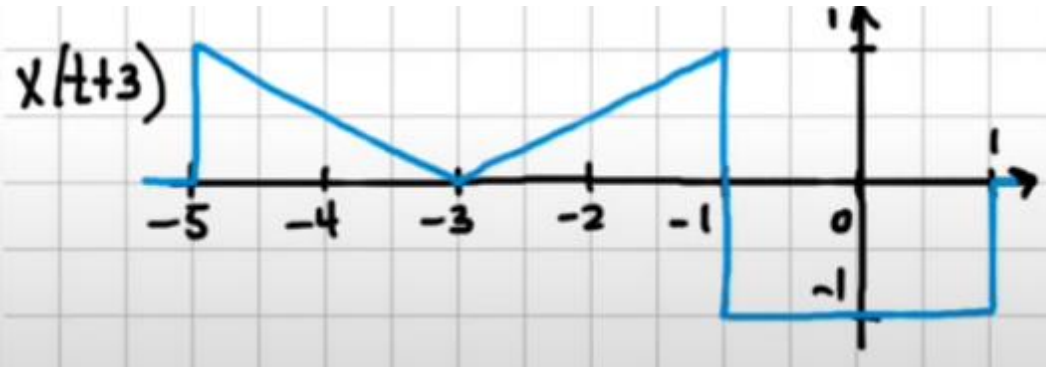


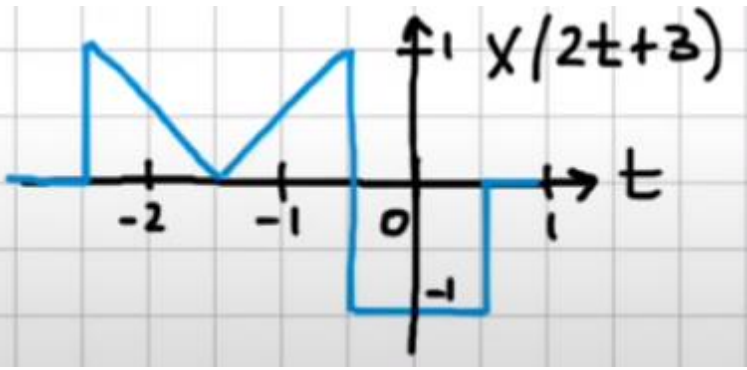
Sketch the signal $y(t) = x(2t+3)$

Problem-1

Approach-1

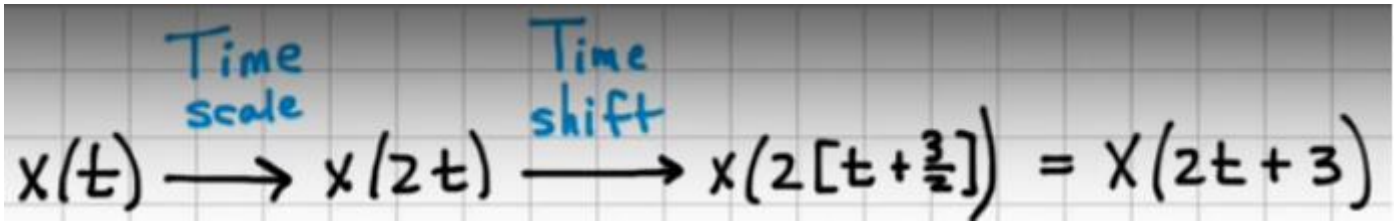


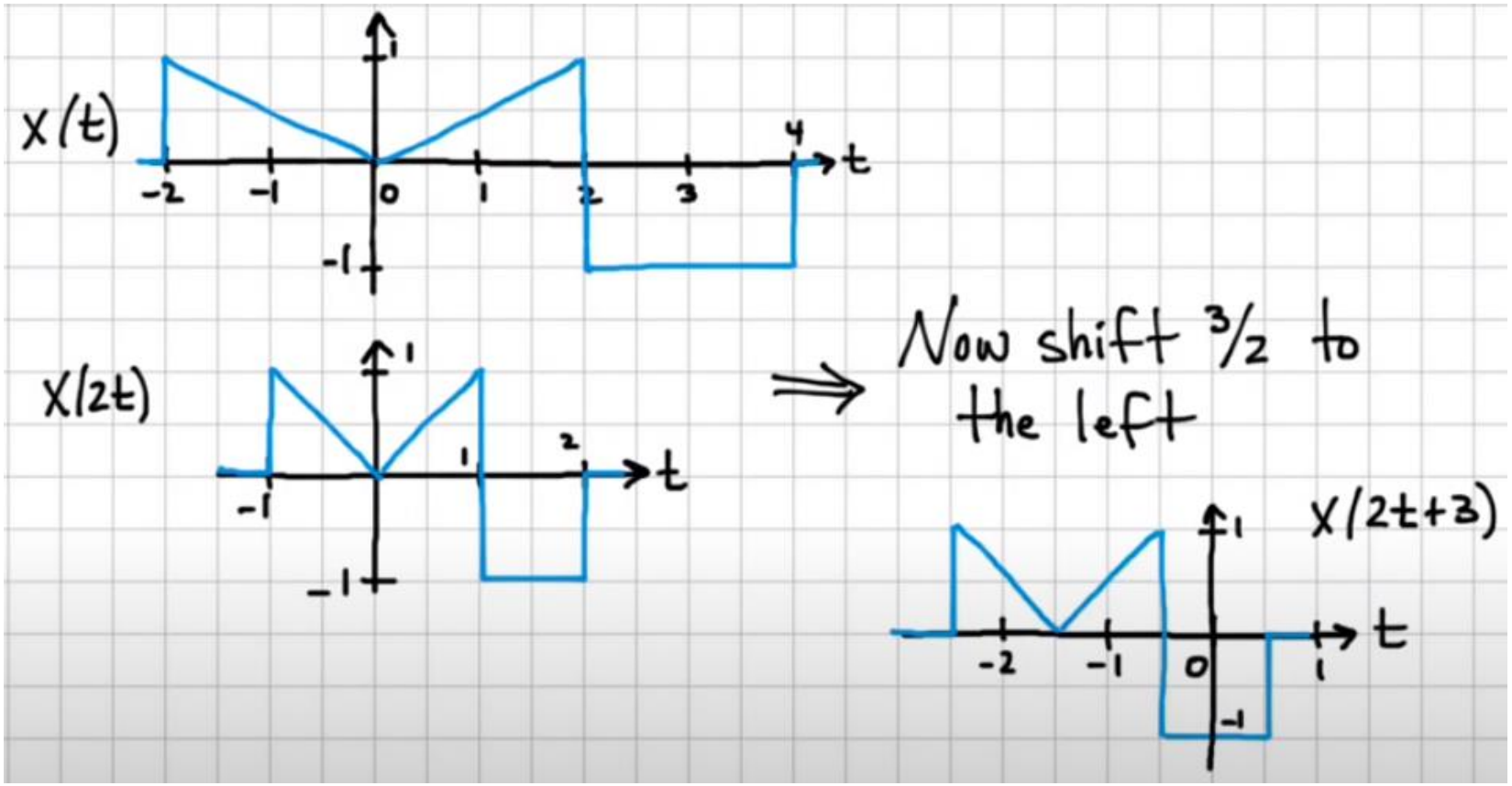




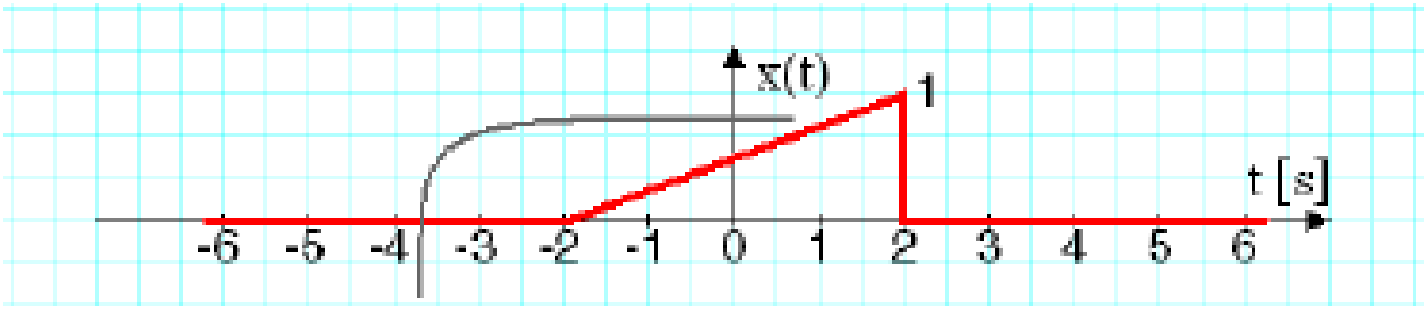
Problem-1

Approach-2





Problem-2



$$x(t) \longrightarrow 2x(-2t-2)$$

Remember: Shift before you scale or invert !!

END