

Digital Image Processing

Fourier Analysis – 2

Sampling

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Fourier Analysis

- Fourier transform examples

- Delta function

- Sifting property of the delta function

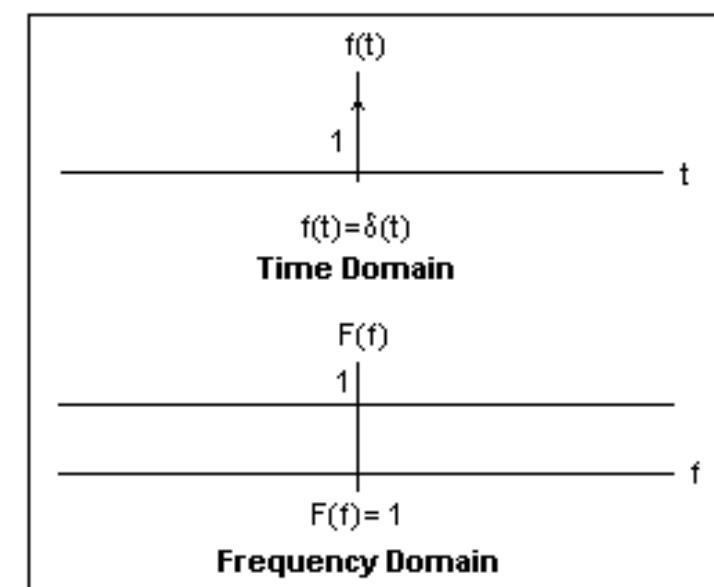
$$\int_{-\infty}^{\infty} f(t)\delta(t - T) dt = f(T)$$

- Fourier transform (delta function at origin)

$$F\delta(w) = \int_{-\infty}^{\infty} \delta(x)e^{-iwx}dx = e^{-iwx}|_{x=0} = 1$$

= constant function (independent of 'w')

- If we superpose all complex waves, with equal weights, what function will we get ?



Fourier Analysis

- Fourier transform examples

- Delta function

- This also gives the following identity (which we will use later)

$\delta(x) := F^{-1}(F\delta)(x)$ Fourier inversion theorem

$$= \frac{1}{2\pi} \int_{-\infty}^{\infty} (F\delta)(w) e^{iwx} dw \text{ Definition of inverse Fourier transform}$$

$$= \frac{1}{2\pi} \int_{-\infty}^{\infty} e^{iwx} dw$$

$$= \frac{-1}{2\pi} \int_{u=+\infty}^{-\infty} e^{-iux} du \text{ Substitute } u = -w$$

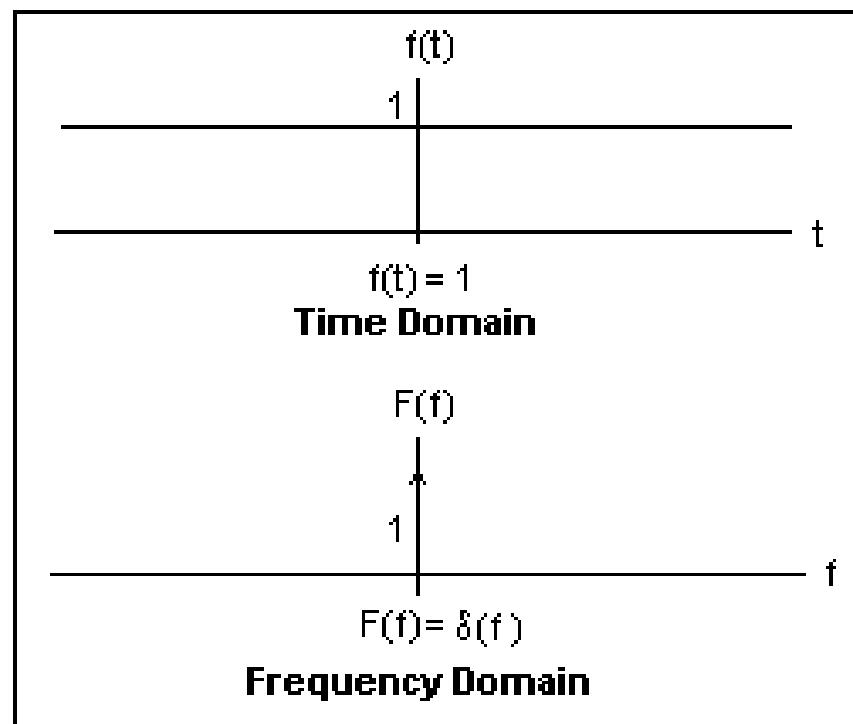
$$= \frac{1}{2\pi} \int_{u=-\infty}^{\infty} e^{-iux} du$$

Fourier Analysis

- Fourier transform examples
 - Constant function
 - Fourier transform (**constant funct.n**) = **delta function at origin**

$$F(a)(w) = \int_{-\infty}^{\infty} ae^{-iwx} dx = a \int_{-\infty}^{\infty} e^{-iwx} dx$$

$= 2\pi a\delta(w)$ Using the previous identity



Fourier Analysis

- Fourier transform examples
 - **Complex sinusoidal wave** $f(x) = e^{iw_0x}$
 - Fourier transform of a complex wave is a shifted delta function

$$\begin{aligned} Ff(w) &= \int_{-\infty}^{\infty} e^{iw_0x} e^{-iwx} dx = \int_{-\infty}^{\infty} e^{-i(w-w_0)x} dx \\ &= 2\pi\delta(w - w_0) \text{ Using the previous identity} \end{aligned}$$

Fourier Analysis

- Fourier transform examples
 - **Shifted Delta function**
 - Fourier transform of a **shifted delta function** $\delta(x - x_0)$ is a **complex sinusoidal wave**

$$F(\delta(x - x_0))(w) = \int_{-\infty}^{\infty} \delta(x - x_0) e^{-iwx} dx = e^{-iwx}|_{x=x_0} = e^{-iwx_0}$$

- Is the Fourier transform shift / time invariant ?
 - Fourier transform of shifted delta function is **NOT** shifted Fourier transform of delta function
 - This implies that the **Fourier transform is NOT shift invariant / space invariant / time invariant**

Fourier Analysis

- Fourier transform examples

- What we saw so far

- Notation on this slide : $2 \pi f = \omega$

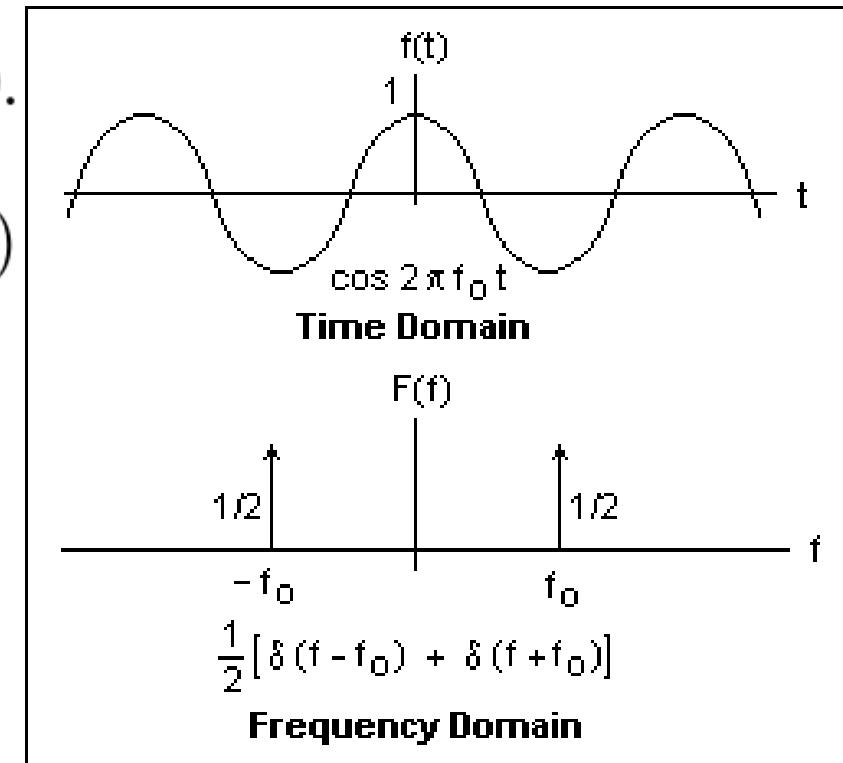
$\delta(t)$	$\xleftrightarrow{\mathcal{F}}$	1
$\delta(t - t_0)$	$\xleftrightarrow{\mathcal{F}}$	$e^{-j2\pi f t_0}$
1	$\xleftrightarrow{\mathcal{F}}$	$\delta(f)$
$e^{j2\pi f_0 t}$	$\xleftrightarrow{\mathcal{F}}$	$\delta(f - f_0)$

Fourier Analysis

- Fourier transform examples

- **Real-valued cosine wave** $f(x) = \cos(w_0 x)$

$$\begin{aligned} Ff(w) &= \int_{-\infty}^{\infty} \cos(w_0 x) e^{-iwx} dx \\ &= \int_{-\infty}^{\infty} 0.5(e^{iw_0 x} + e^{-iw_0 x}) e^{-iwx} dx \\ &= 0.5 \int_{-\infty}^{\infty} e^{iw_0 x} e^{-iwx} dx + 0. \\ &= \pi\delta(w - w_0) + \pi\delta(w + w_0) \end{aligned}$$



Fourier Analysis

- Fourier transform examples

- **Real-valued sine wave** $f(x) = \sin(w_0 x)$

$$\begin{aligned} Ff(w) &= \int_{-\infty}^{\infty} \sin(w_0 x) e^{-iwx} dx \\ &= \int_{-\infty}^{\infty} 0.5(e^{iw_0 x} - e^{-iw_0 x}) e^{-iwx} dx \\ &= 0.5 \int_{-\infty}^{\infty} e^{iw_0 x} e^{-iwx} dx - 0.5 \int_{-\infty}^{\infty} e^{-iw_0 x} e^{-iwx} dx \\ &= \pi\delta(w - w_0) - \pi\delta(w + w_0) \text{ Using the previous identity} \end{aligned}$$

Fourier Analysis

- Fourier transform examples

- **Impulse train** of period ΔX

$$f(x) := \sum_{n=-\infty}^{\infty} \delta(x - n\Delta X)$$

- What is Fourier-series representation of impulse train ?

where $f(x) := \sum_n c_n e^{inx2\pi/\Delta X}$

$$\begin{aligned}c_n &:= \frac{1}{\Delta X} \int_{-\Delta X/2}^{\Delta X/2} f(x) e^{-inx2\pi/\Delta X} dx \\&= \frac{1}{\Delta X} \int_{-\Delta X/2}^{\Delta X/2} \left(\sum_{n=-\infty}^{\infty} \delta(x - n\Delta X) \right) e^{-inx2\pi/\Delta X} dx \\&= \frac{1}{\Delta X} \int_{-\Delta X/2}^{\Delta X/2} \delta(x) e^{-inx2\pi/\Delta X} dx \text{ Only one impulse falls within integral limits} \\&= \frac{1}{\Delta X} e^0 = \frac{1}{\Delta X}\end{aligned}$$

Fourier Analysis

- Fourier transform examples
 - Impulse train of period Δx has Fourier series represent.n

$$f(x) := \frac{1}{\Delta X} \sum_n e^{inx2\pi/\Delta X}$$

- Fourier transform of impulse train of period Δx = another impulse train with period $2\pi / \Delta x$

$$\begin{aligned} Ff(w) &:= F \left(\frac{1}{\Delta X} \sum_n e^{inx2\pi/\Delta X} \right) (w) \\ &= \frac{1}{\Delta X} \sum_n F \left(e^{inx2\pi/\Delta X} \right) (w) \\ &= \frac{2\pi}{\Delta X} \sum_n \delta \left(w - n \frac{2\pi}{\Delta X} \right) \end{aligned}$$

Fourier transform of a complex wave

Fourier Analysis

- **Plancherel Theorem**

- Let $f(x)$ be square-integrable function with Fourier **transform** $Ff(w)$
 - Then,

$$\int_{-\infty}^{\infty} |f(x)|^2 dx = \int_{-\infty}^{\infty} |Ff(w)|^2 dw$$

- $|Ff(w)|^2$ is called the **power spectrum** of $f(x)$
 - What this means is:
 - Fourier transform preserves norm of the original function
 - Norm of a function := inner-product of function with itself
 - Norm \leftrightarrow “Total Energy” associated with a function

Fourier Analysis

- **Parseval's Theorem** (applies to Fourier series)
 - Let $A(x)$ and $B(x)$ be periodic functions of period 2π represented via their Fourier series

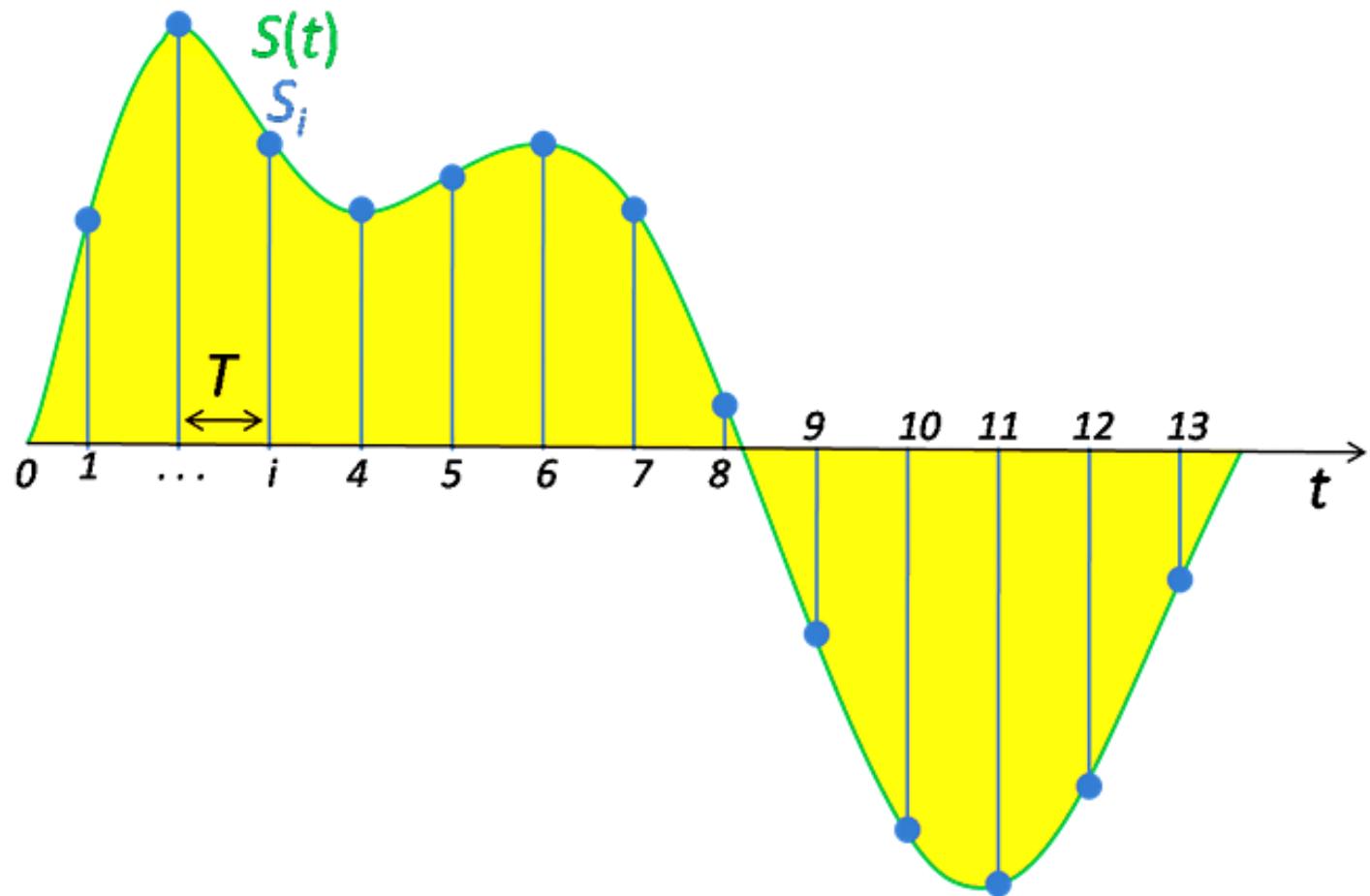
$$A(x) = \sum_{n=-\infty}^{\infty} a_n e^{inx} \quad B(x) = \sum_{n=-\infty}^{\infty} b_n e^{inx}$$

- Then,

$$\sum_{n=-\infty}^{\infty} a_n \overline{b_n} = \frac{1}{2\pi} \int_{-\pi}^{\pi} A(x) \overline{B(x)} dx$$

Fourier Analysis

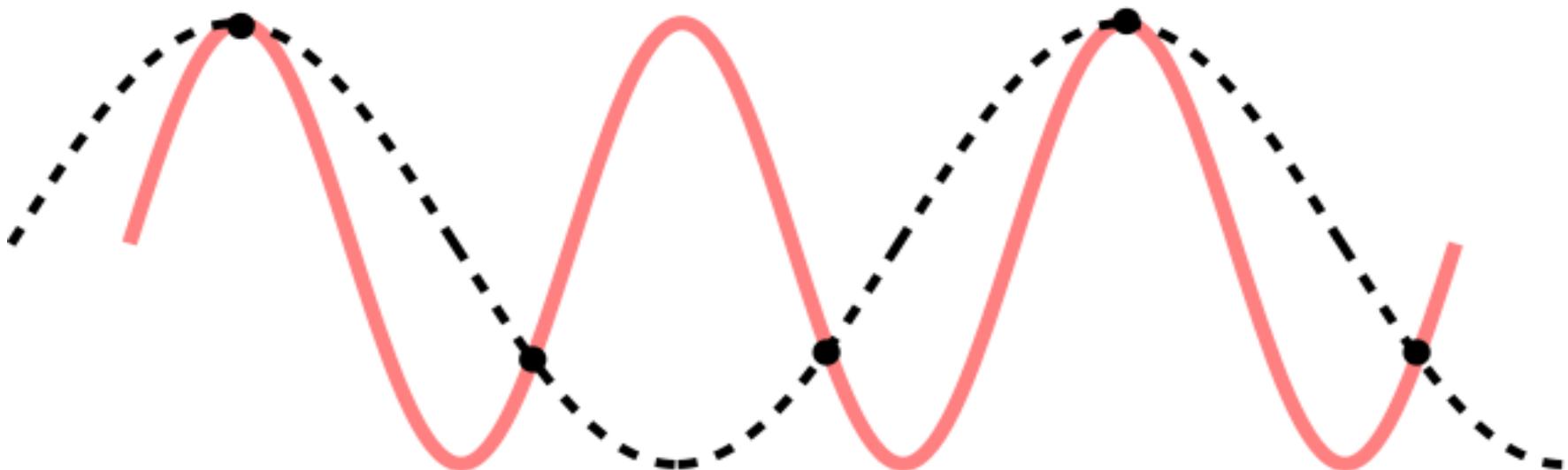
- Sampling



- What is the optimal rate for sampling a continuous signal ?

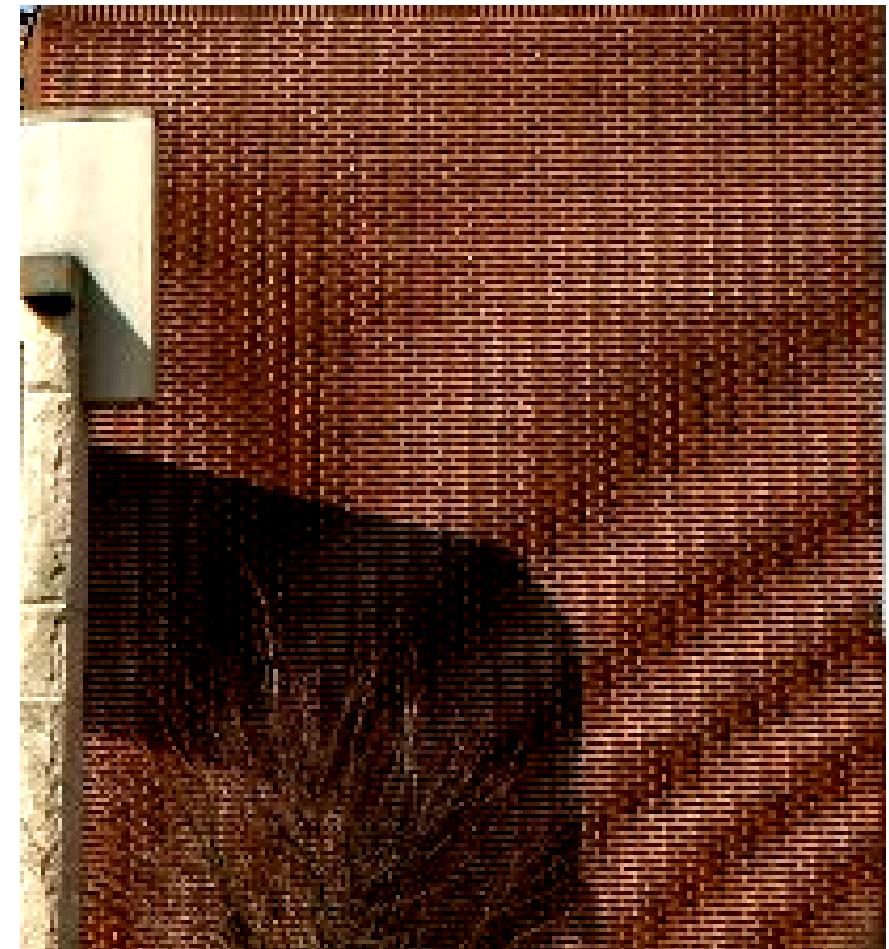
Fourier Analysis

- Sampling
 - Why is sampling rate important ?
 - Samples of several different sine waves can be identical, when at least **one of them** has:
 - Period $< 2 * \text{sample spacing}$ (for red sinusoid)
 - Frequency $> 0.5 \times \text{sample rate}$
 - Problem
 - Given : sample points
 - Find : which continuous function did they come from ?



Fourier Analysis

- Sampling
 - Why is sampling rate important ?
 - Artifacts like Moire patterns
 - Image on right is subsampled (coarser resolution)



Fourier Analysis

- Sampling
 - Suppose continuous function $f(x)$ is **bandlimited**
 - Bandlimited = In Fourier transform,
highest frequency that has a non-zero coefficient,
is finite
 - Assume Fourier transform is defined (non zero) on $[-L, L]$
i.e., $Ff(w) = 0$ whenever $|w| > L$
 - In practice this implies:
 - $f(x)$ doesn't have very steep edges
 - Steepest edge is representable via sinusoids of frequency $\leq L$
 - $f(x)$ doesn't have any discontinuities
 - $f(x)$ is “smooth”

Fourier Analysis

- Sampling

$$Ff(w) = 0 \text{ whenever } |w| > L$$

- **Key Idea : Represent frequency-domain function $Ff(\cdot)$ using a series**
 - We are NOT representing $f(\cdot)$ as a (Fourier) series
 - We are representing $Ff(\cdot)$ as a (Fourier) series
 - Just to find the series representation,
consider the Fourier transform $Ff(\cdot)$ to be *periodic outside $[-L, L]$*
- Let us represent the function $Ff(\cdot)$ as:

$$Ff(w) := \sum_n B_n e^{inw\pi/L}$$

- Then, what are the coefficients B_n ?

Fourier Analysis

- Sampling

$$Ff(w) := \sum_n B_n e^{inw\pi/L}$$

- Coefficients B_n can be obtained by taking the (complex) inner product of $Ff(\cdot)$ with the wave $e^{inw\pi/L}$

$$B_n = \frac{1}{2L} \int_{-L}^L Ff(w) e^{-inw\pi/L}$$

- But, what is this value ? Can we simplify further ?
 - Yes, we can. Here is how ...

Fourier Analysis

$$B_n = \frac{1}{2L} \int_{-L}^L Ff(w) e^{-inw\pi/L} dw$$

- Sampling

(1) What is the inverse Fourier transform of $Ff(w)$ evaluated at $n\pi / L$?

- By definition $F^{-1}(Ff)(n\pi/L) := \frac{1}{2\pi} \int_{-\infty}^{\infty} Ff(w) e^{inw\pi/L} dw$

(2) $Ff(w) = 0$ outside $[-L, L]$

$$F^{-1}(Ff)(n\pi/L) := \frac{1}{2\pi} \int_{-L}^L Ff(w) e^{inw\pi/L} dw = \frac{2L}{2\pi} B_{-n}$$

(3) Inverse Fourier transform of $Ff(w)$ evaluated at $n\pi / L$ equals $f(n\pi / L)$

- Fourier inversion theorem $F^{-1}(Ff)(n\pi/L) = \frac{2L}{2\pi} B_{-n} = f(n\pi/L)$

$$\implies B_{-n} = \frac{\pi}{L} f(n\pi/L)$$

Fourier Analysis

- Sampling

$$Ff(w) := \sum_n B_n e^{inw\pi/L}$$

$$B_{-n} = \frac{\pi}{L} f(n\pi/L)$$

- What does the simplified value of coefficients B_n tell us ?
 - For a **bandlimited function** $f(x)$,
Fourier transform $Ff(\cdot)$ can be **represented by a series** where the **coefficients** B_n are
(scaled) $f(\cdot)$ values sampled at locations $n\pi/L$

Fourier Analysis

- Sampling
 - Simplified value of the coefficients B_n allows us to **rewrite** the series representation of $F f(\cdot)$ as
$$Ff(w) := \sum_n B_{-n} e^{-inw\pi/L} = \sum_n \frac{\pi}{L} f(n\pi/L) e^{-inw\pi/L}$$
 - Using this result
 - So, what sample points should be “acquired”, based on above result ?
 - How can we “reconstruct” the continuous function $f(x)$ given its discretized / sampled version ?
 - See the formula next ...

$$f(x) :=$$

Fourier Analysis

$$:= F^{-1}(Ff)(x) \text{ Fourier inversion theorem}$$

$$= \frac{1}{2\pi} \int_{-L}^L Ff(w) e^{iwx} dw \text{ Definition of Fourier inverse}$$

$$= \frac{1}{2\pi} \int_{-L}^L \left[\sum_n \frac{\pi}{L} f(n\pi/L) e^{-inw\pi/L} \right] e^{iwx} dw \text{ Substitute series for } Ff(\cdot)$$

$$= \frac{1}{2L} \sum_n f(n\pi/L) \int_{-L}^L e^{iw(x-n\pi/L)} dw \text{ Rearranging terms}$$

$$= \frac{1}{2L} \sum_n f(n\pi/L) (2L) \frac{\sin(L(x - n\pi/L))}{L(x - n\pi/L)}$$

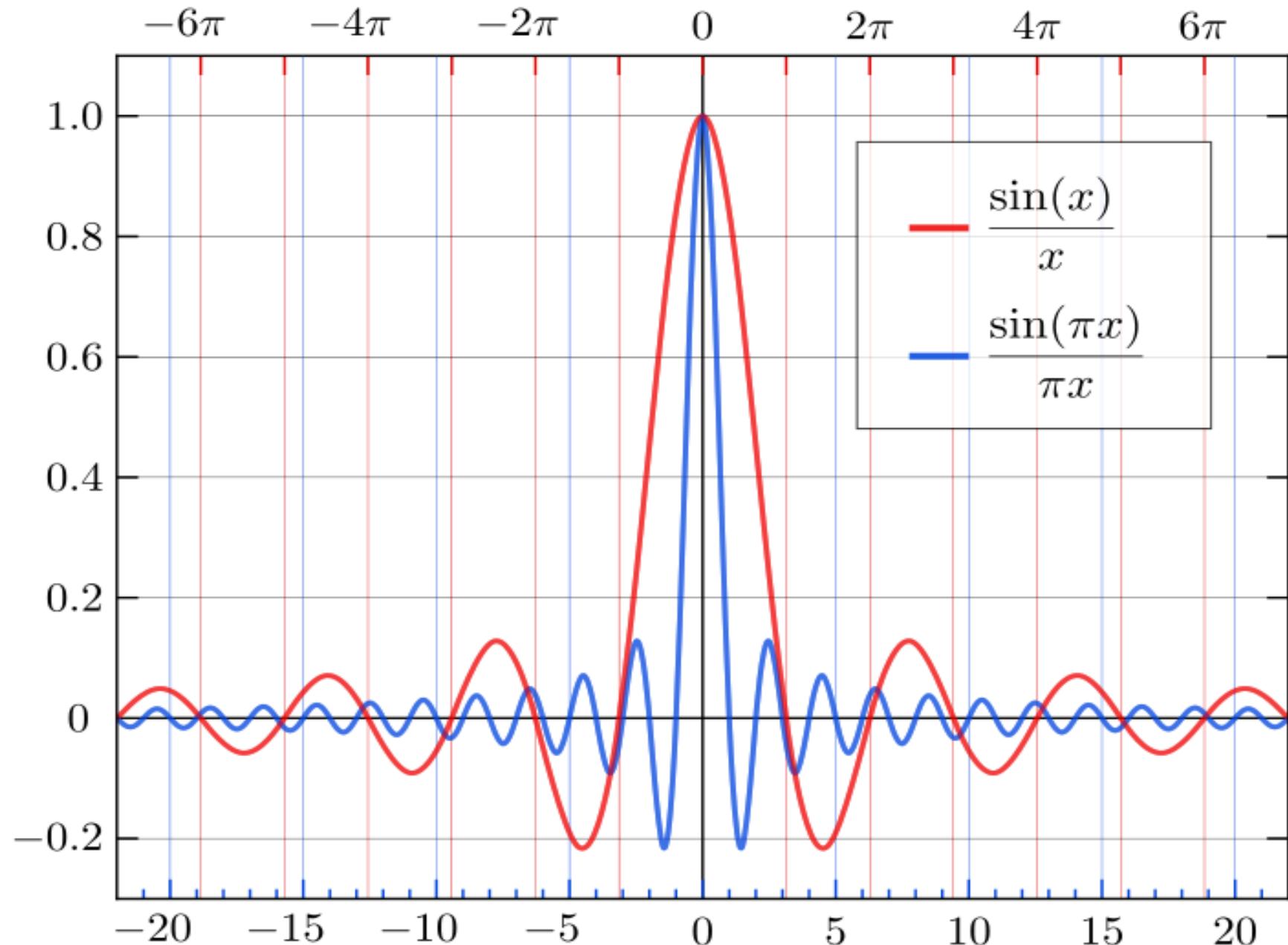
Expand $e^{i\theta} = \cos(\theta) + i \sin(\theta) = \text{even} + \text{odd function}$

$$= \sum_n f(n\pi/L) \frac{\sin(L(x - n\pi/L))}{L(x - n\pi/L)}$$

$$= \sum_n f(n\pi/L) \text{sinc}(L(x - n\pi/L)) \text{ sinc function shifted to } n\pi/L$$

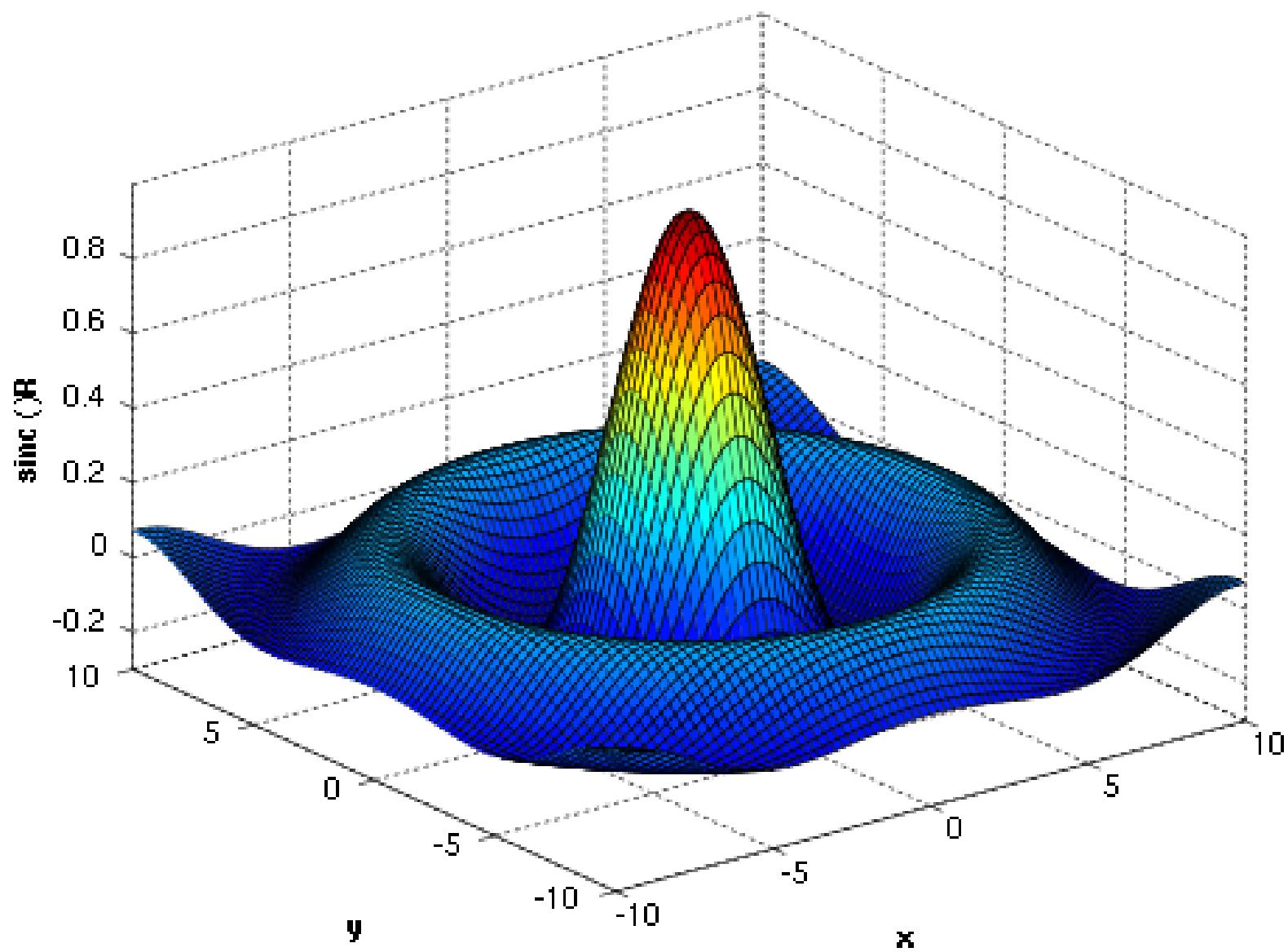
Fourier Analysis

- Sampling: Sinc function



Fourier Analysis

- Sinc function over 2D domain



Fourier Analysis

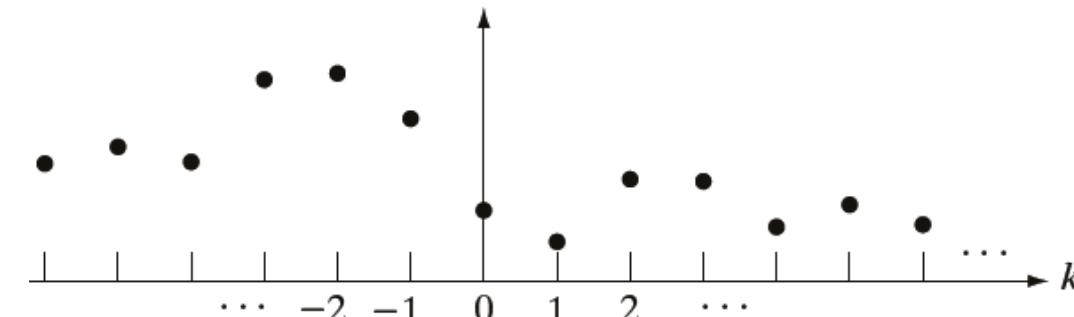
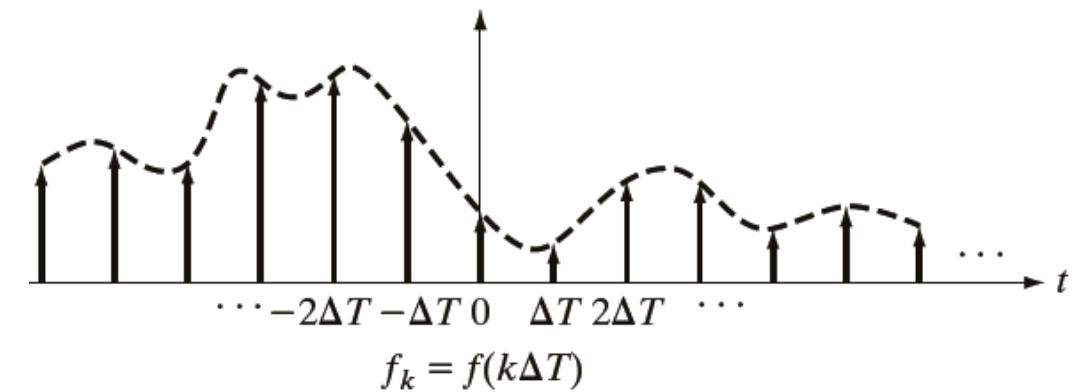
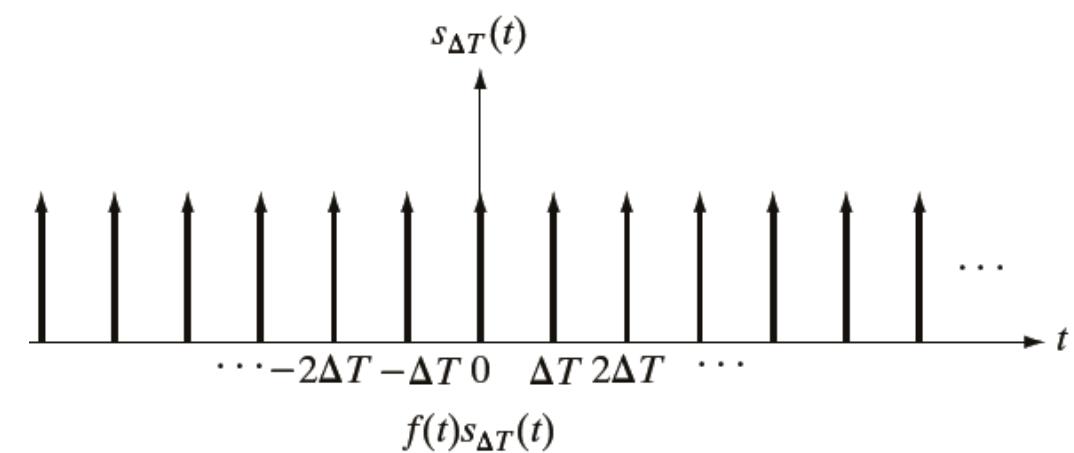
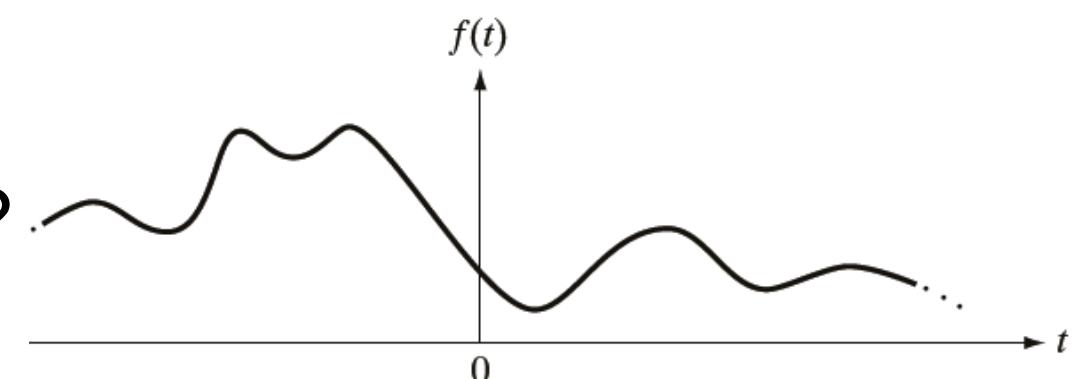
- Sampling
 - Thus,
$$f(x) = \sum_n f(n\pi/L) \operatorname{sinc}(L(x - n\pi/L))$$
 - This means that :
for sampling a bandlimited function $f(x)$ with highest frequency L in the Fourier transform
 - (1) **optimal sample spacing = π / L (or smaller)**
 - (2) optimal sampling allows us to **exactly reconstruct** continuous function $f(x)$ using sampled values $f(n\pi / L)$
 - This is the Nyquist-Shannon **Sampling theorem**
 - Question: If $f(x)$ has steeper edges than $g(x)$, then how should sampling rate vary to achieve exact reconstruction ?

Fourier Analysis

- How to measure $f(n\pi/L)$?

- Continuous function = $f(t)$
- Sampling function = $s(t)$

$$\begin{aligned}\tilde{f}(t) &= f(t)s_{\Delta T}(t) \\ &= \sum_{n=-\infty}^{\infty} f(t)\delta(t - n\Delta T)\end{aligned}$$



$$\begin{aligned}f_k &= f(k\Delta T) \\ &= \int_{-\infty}^{\infty} f(t)\delta(t - k\Delta T)dt\end{aligned}$$

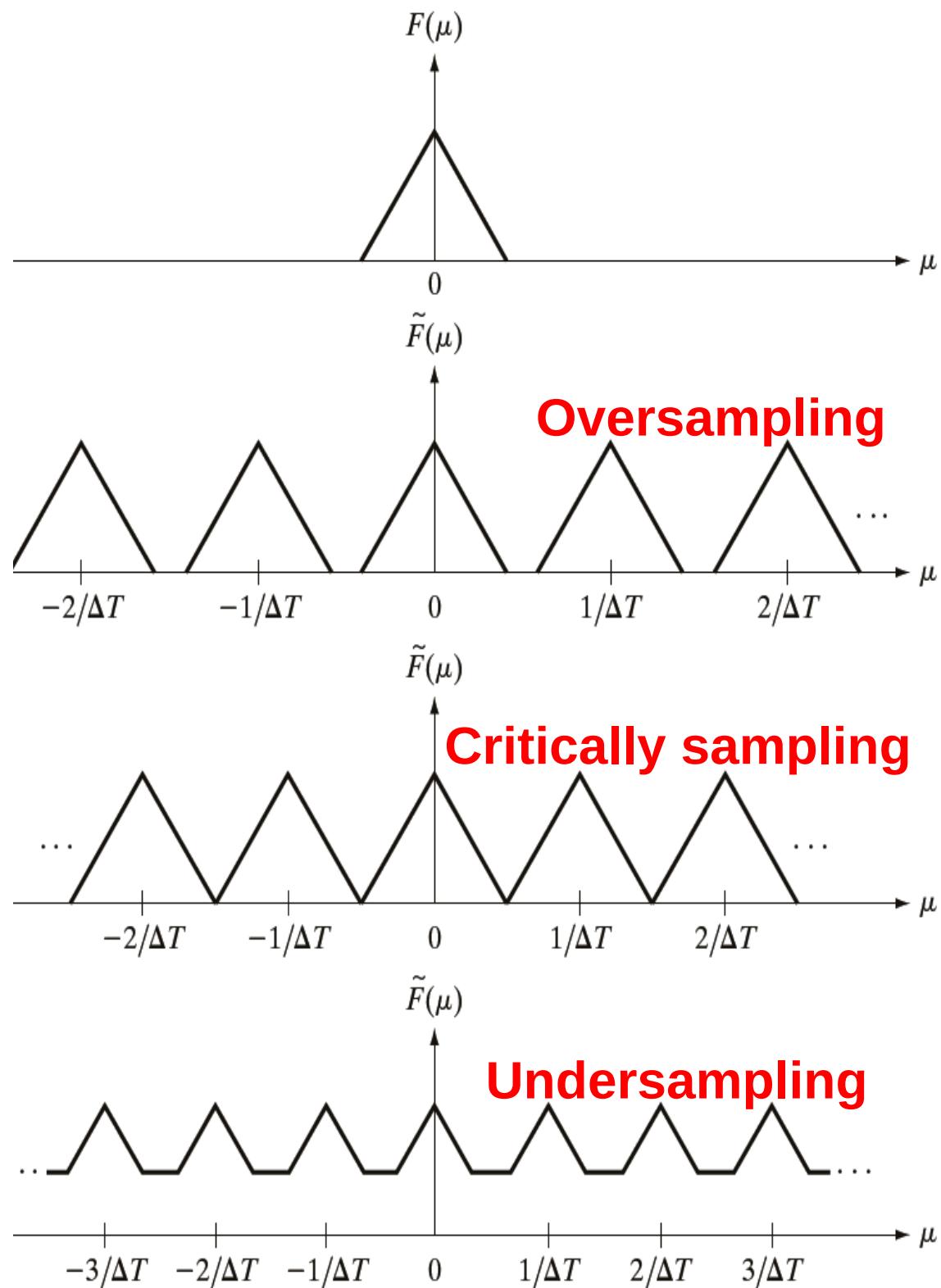
Fourier Analysis

- Sampling

- $f(t)$ is bandlimited
- Fourier transform of [$f(t) \times \text{impulseTrain}(t)$ with spacing ΔT]
= $F_f(w) * \text{impulseTrain}(w)$ with spacing $1/\Delta T$

- \times : multiplication
- $*$: convolution

$$\begin{aligned}\tilde{F}(\mu) &= \mathcal{F}\{f(t)s_{\Delta T}(t)\} \\ &= F(\mu) * S(\mu)\end{aligned}$$



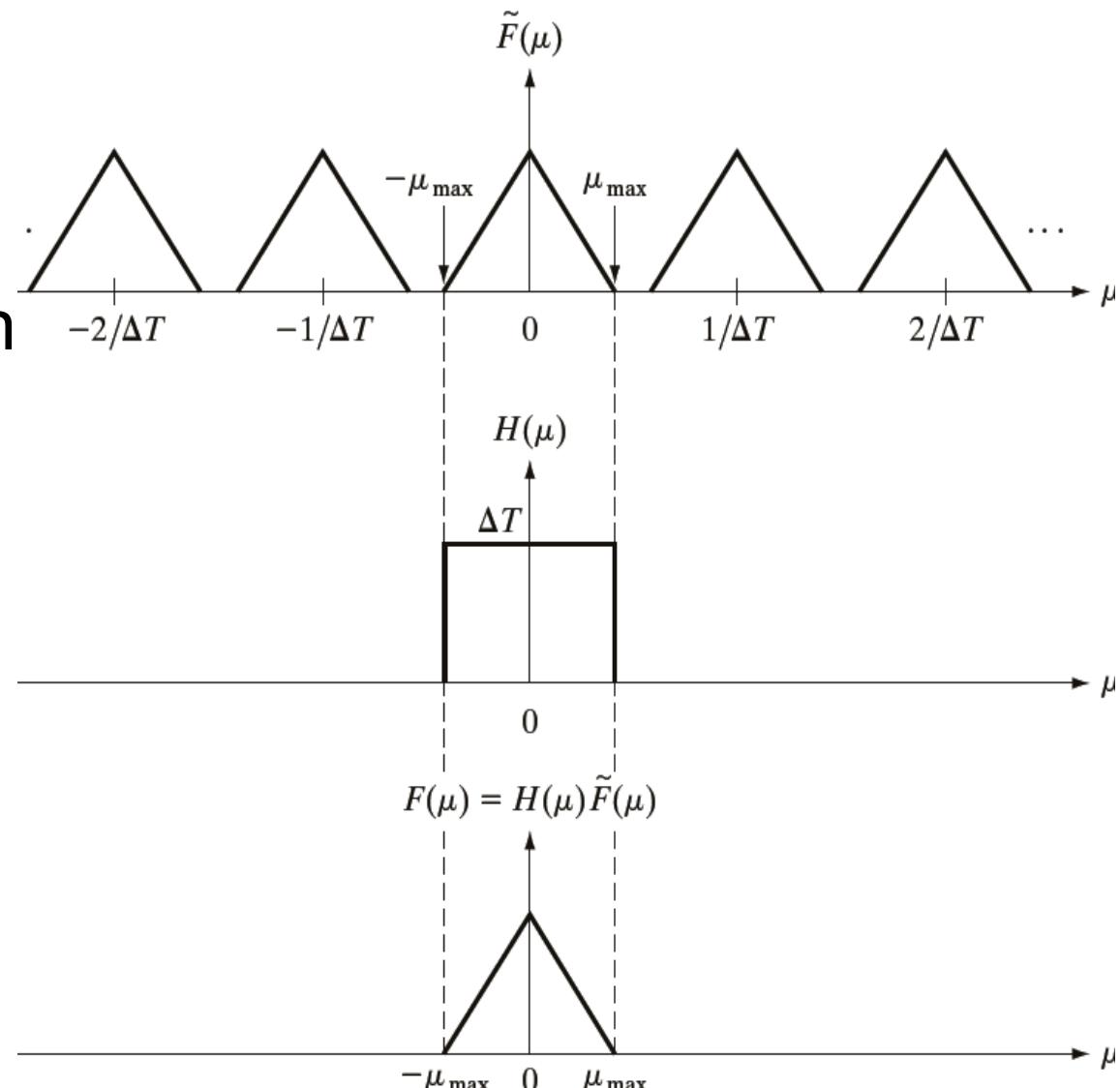
Fourier Analysis

- Reconstructing continuous function from its samples

(1) Get FT
of sampled function

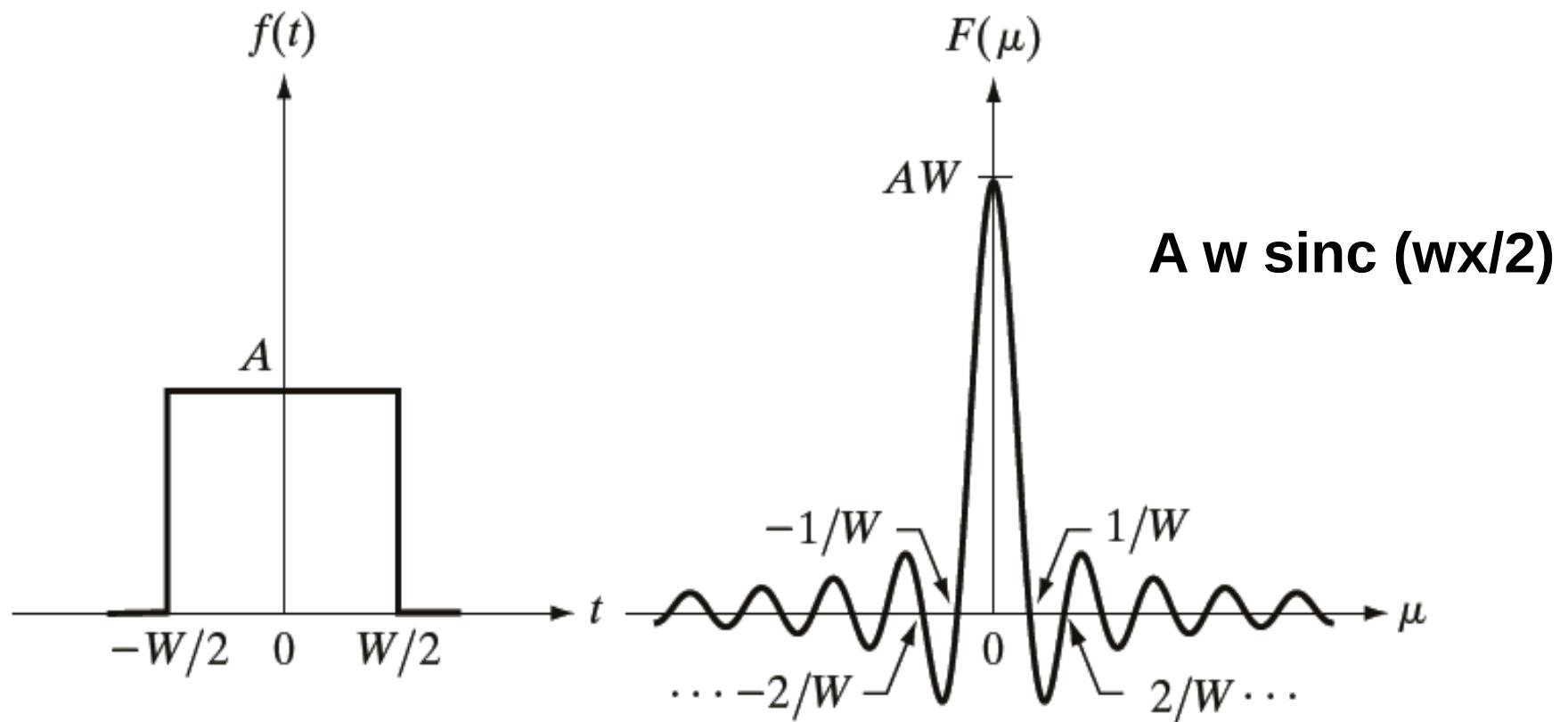
(2) Extract one period
in frequency domain

(3) Take
inverse FT



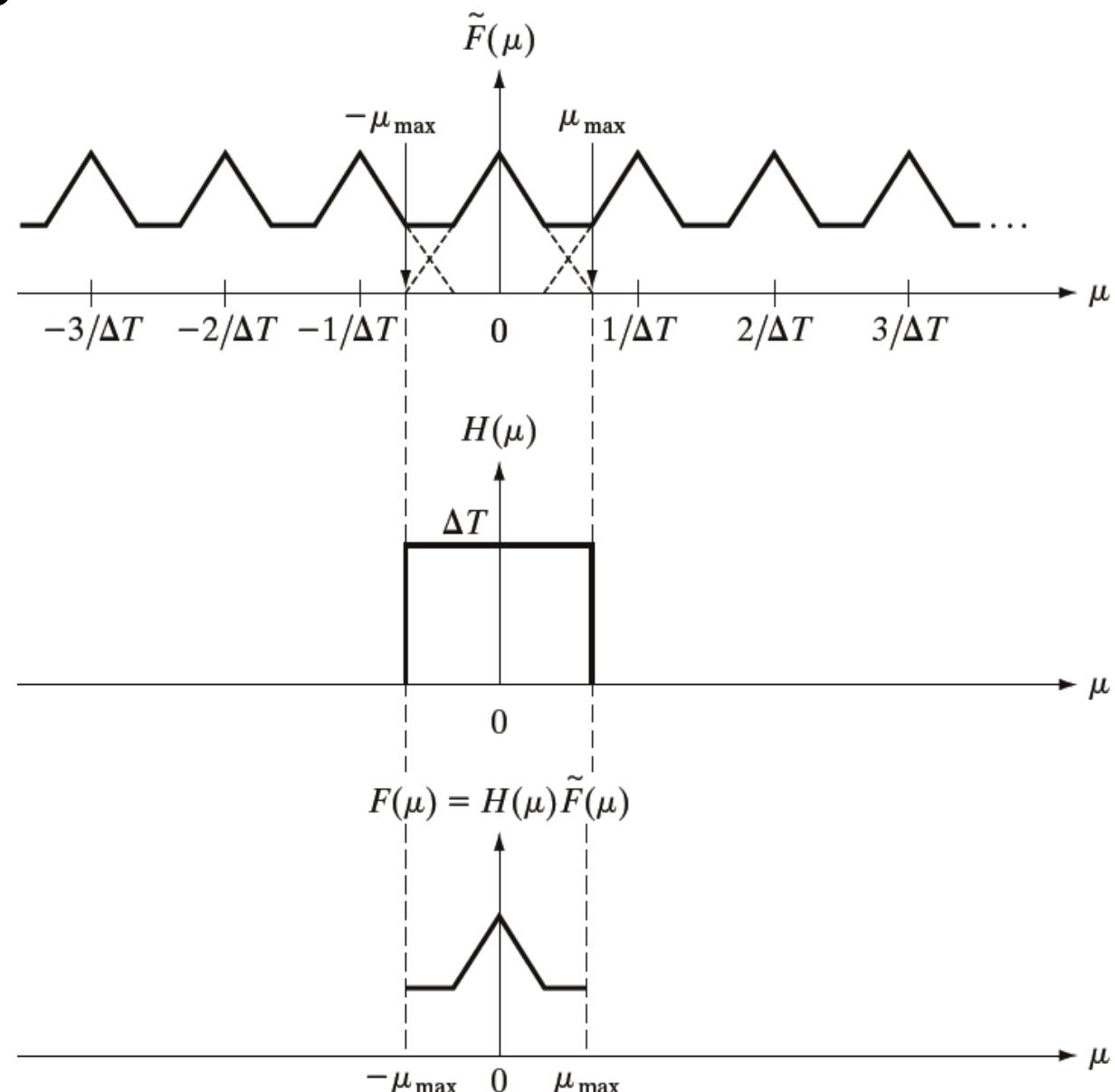
Fourier Analysis

- Reconstructing continuous function from its samples
 - Multiplication with box function in Fourier domain = Convolution with sinc function in space domain



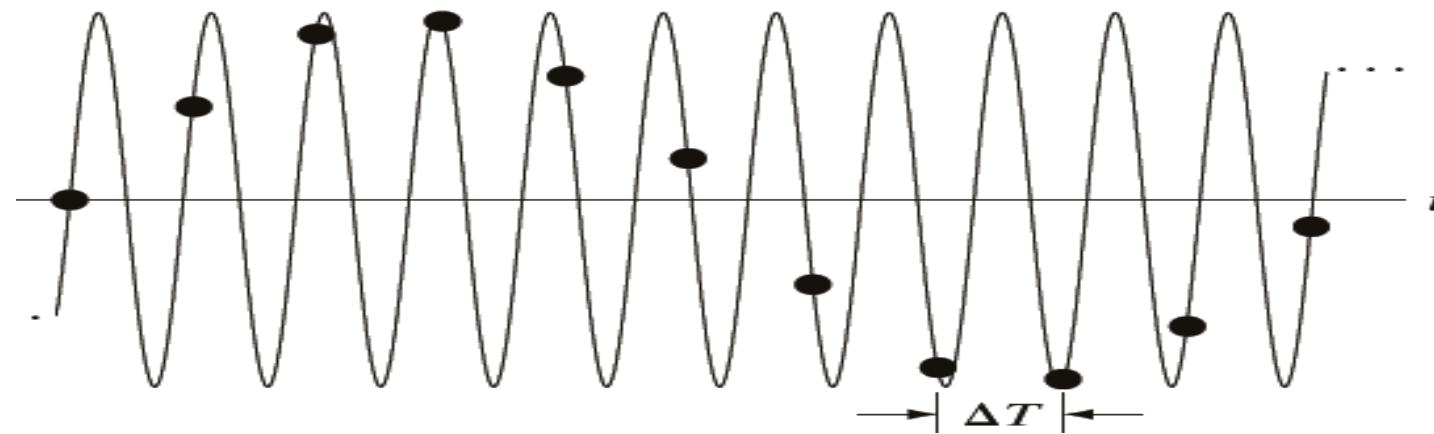
Fourier Analysis

- Reconstructing continuous function from its samples
 - Undersampled case
 - High-frequency components of original signal appear as if they are lower-frequency components of the sampled signal
 - Aliasing
= alternate identity



Fourier Analysis

- Sampling : Aliasing
 - Here, **sampling rate < Nyquist rate**
 - For $f(x) = \sin(Lx)$ → period = $2\pi / L$; frequency = $L / 2\pi$
 - $F_f(w) = 0$ outside $[-L, L]$
 - Nyquist **sample spacing** = π / L → **two samples per period**
 - Nyquist **sampling rate (frequency)** = L / π
= **twice frequency of sinusoid**
 - Here, samples of higher-frequency sinusoid appear to have come from a low-frequency sinusoid

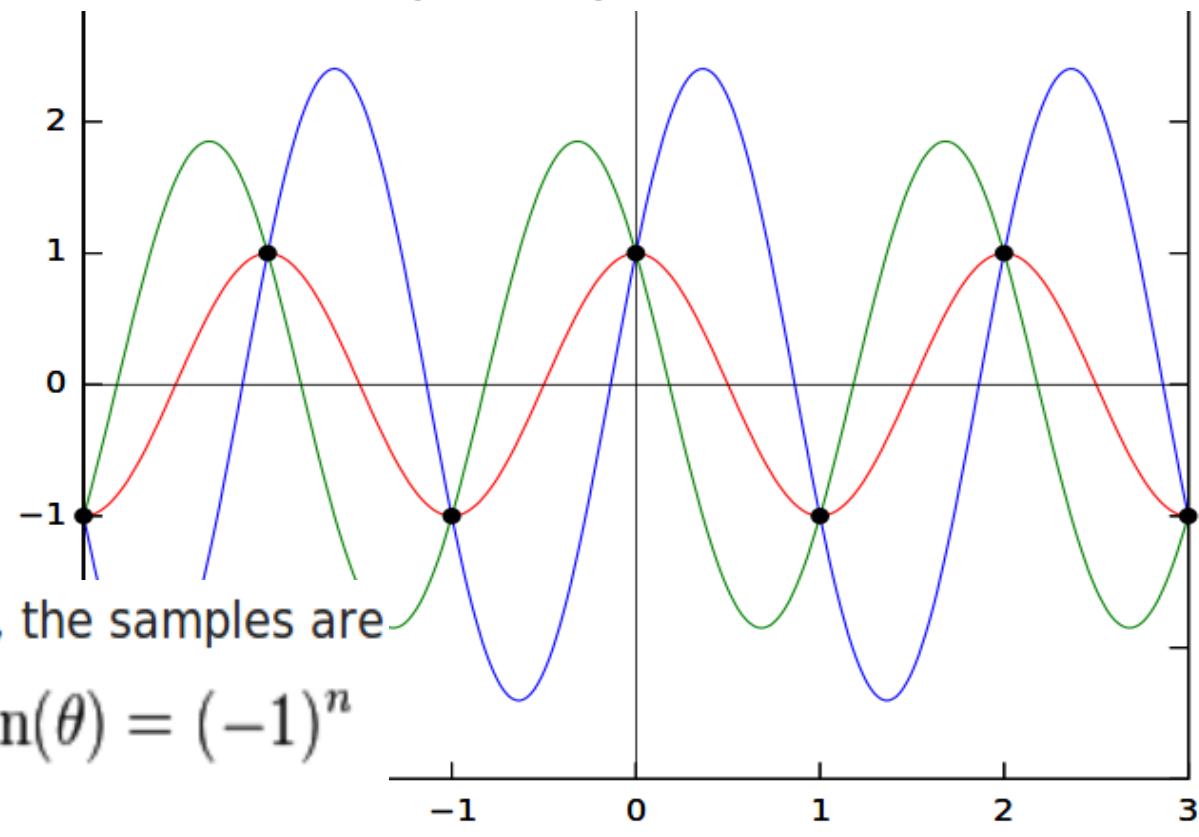


Fourier Analysis

- Sampling rate in practice
 - Here, **sampling rate = Nyquist rate** for ALL 3 sinusoids
 - Same frequency, Different phase, Different amplitude
 - Samples **fail to distinguish** between **multiple sinusoids**
 - So, **sampling rate must be strictly > Nyquist rate**

$$x(t) = \frac{\cos(2\pi Bt + \theta)}{\cos(\theta)}$$

$$-\pi/2 < \theta < \pi/2$$



With $f_s = 2B$ or equivalently $T = 1/(2B)$, the samples are

$$x(nT) = \cos(\pi n) - \underbrace{\sin(\pi n)}_0 \tan(\theta) = (-1)^n$$

Fourier Analysis

- Sampling
 - Aliasing in 2D

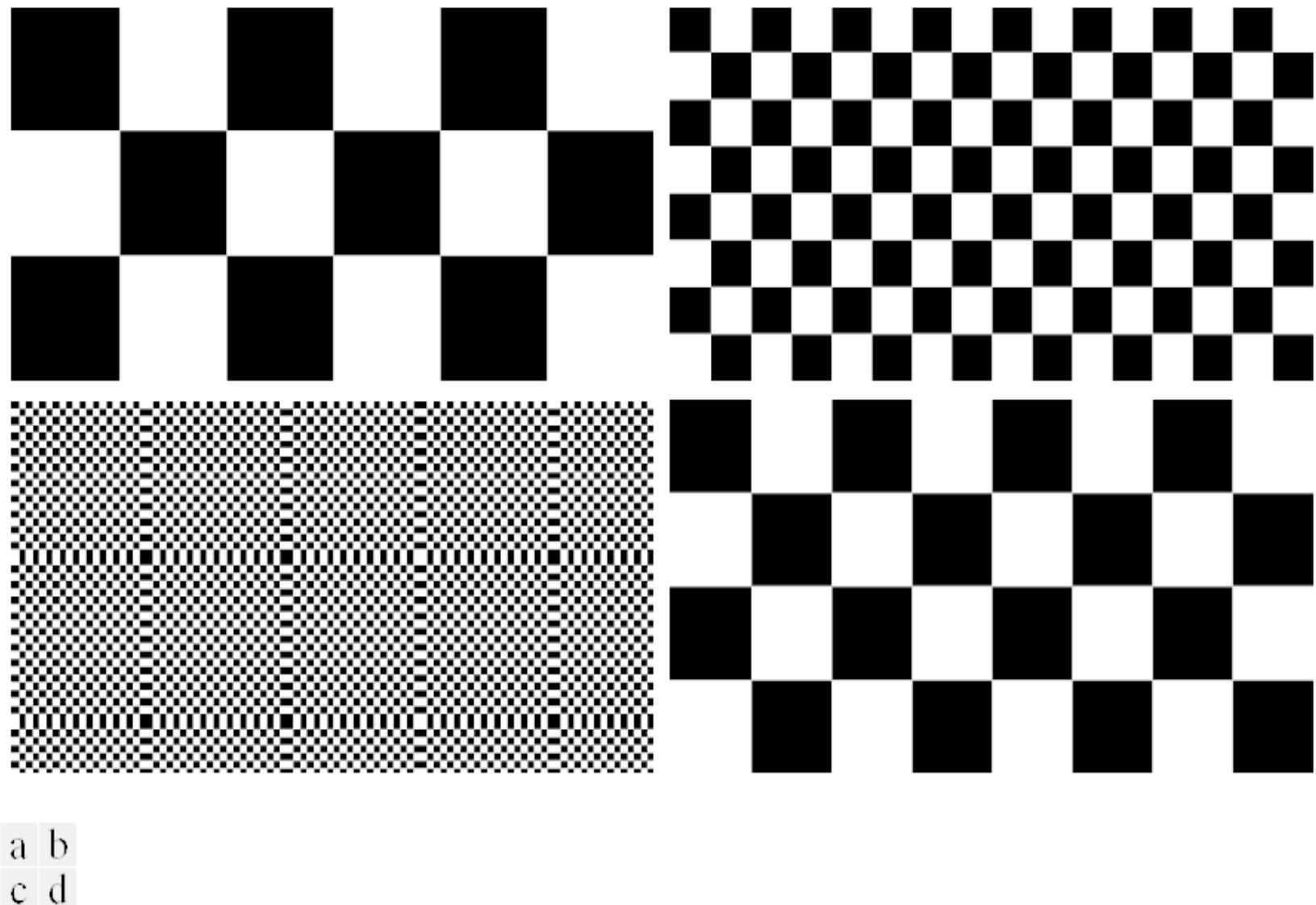


FIGURE 4.16 Aliasing in images. In (a) and (b), the lengths of the sides of the squares are 16 and 6 pixels, respectively, and aliasing is visually negligible. In (c) and (d), the sides of the squares are 0.9174 and 0.4798 pixels, respectively, and the results show significant aliasing. Note that (d) masquerades as a “normal” image.

Fourier Analysis

- Sampling
 - Reduce aliasing by blurring image before (sub)sampling

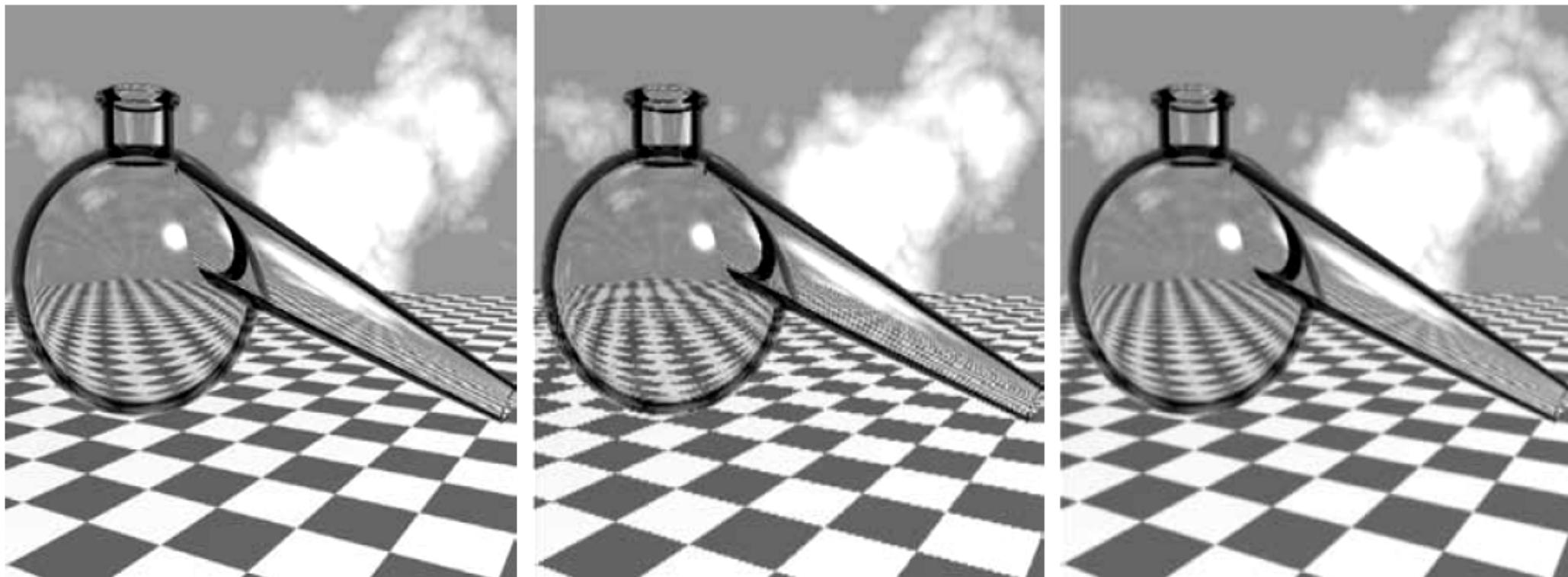


a b c

FIGURE 4.17 Illustration of aliasing on resampled images. (a) A digital image with negligible visual aliasing. (b) Result of resizing the image to 50% of its original size by pixel deletion. Aliasing is clearly visible. (c) Result of blurring the image in (a) with a 3×3 averaging filter prior to resizing. The image is slightly more blurred than (b), but aliasing is not longer objectionable. (Original image courtesy of the Signal Compression Laboratory, University of California, Santa Barbara.)

Fourier Analysis

- Sampling
 - Reduce aliasing by blurring image before (sub)sampling

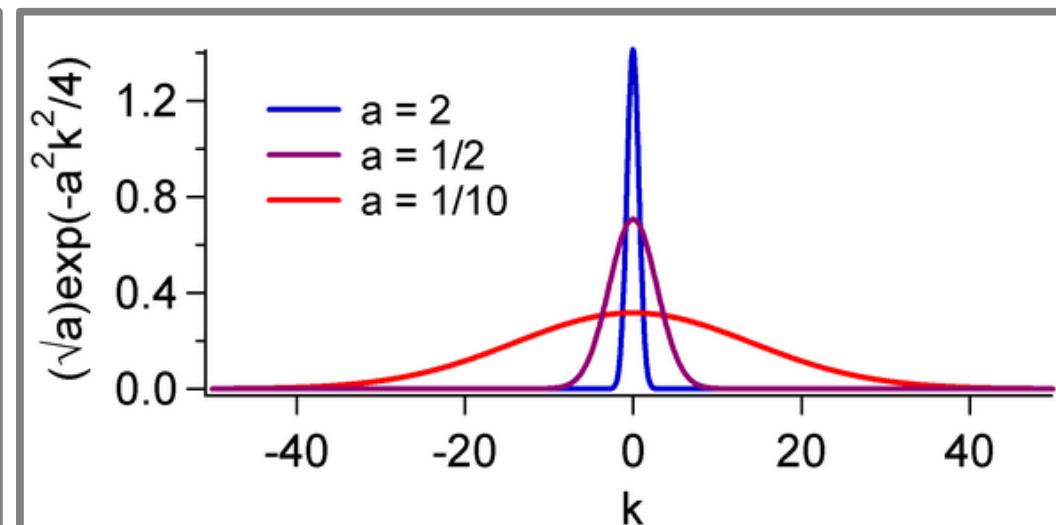
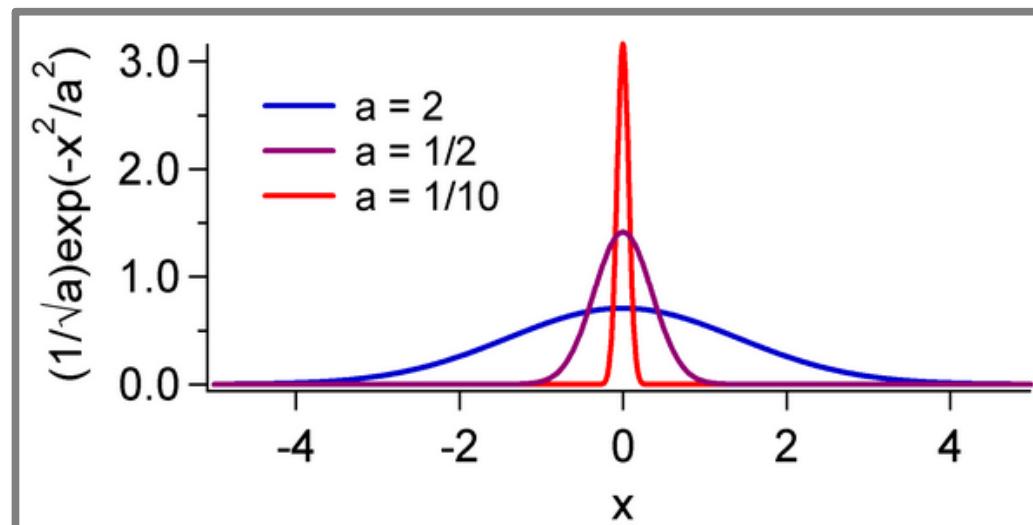


a b c

FIGURE 4.18 Illustration of jaggies. (a) A 1024×1024 digital image of a computer-generated scene with negligible visible aliasing. (b) Result of reducing (a) to 25% of its original size using bilinear interpolation. (c) Result of blurring the image in (a) with a 5×5 averaging filter prior to resizing it to 25% using bilinear interpolation. (Original image courtesy of D. P. Mitchell, Mental Landscape, LLC.)

Fourier Analysis

- Sampling : Why does blurring reduce aliasing ?
 - What is the effect of convolving with a Gaussian $G(x)$?
 - Fourier transform gets multiplied with $FG(w)$
 - What is $FG(w)$?
 - Left: Gaussian in space (e.g., wide blue Gaussian)
 - Right: Gaussian in frequency (e.g., narrow blue Gaussian)
 - **Gaussian convolution attenuates high frequencies**



Fourier Analysis

- Sampling
 - Aliasing can be avoided only for bandlimited signals
 - By sampling them at the Nyquist rate
 - Can aliasing be avoided in the real world ?
OR (equivalently)
 - Are signals in real-world applications bandlimited ?
 - To answer this question, we need to understand some properties of bandlimited signals

Fourier Analysis

- Sampling
 - A bandlimited function is infinitely differentiable
 - Signal $f(x)$ = bandlimited
 - Fourier transform $Ff(w)$. Equals 0 outside $[-L, L]$
 - $f(x)$ can be represented as :

$f(x) := F^{-1}(Ff)(x)$ Fourier inversion theorem

$$= \int_{-\infty}^{\infty} Ff(w) e^{iwx} dw \text{ Definition of inverse Fourier transform}$$

$$= \int_{-L}^{L} Ff(w) e^{iwx} dw \text{ Bandlimited assumption}$$

Fourier Analysis

- Sampling
 - A bandlimited function is infinitely differentiable
 - Signal $f(x)$. Fourier transform $Ff(w) = 0$ outside $[-L, L]$
 - Following derivatives exist because (a) integration is performed on a bounded domain and (b) integrand is differentiable

Then, the derivative of $f(x)$ is

$$\begin{aligned}\frac{df(x)}{dx} &= \frac{d}{dx} \int_{-L}^L Ff(w)e^{iwx} dw \\ &= \int_{-L}^L Ff(w) \frac{d}{dx} e^{iwx} dw \\ &= \int_{-L}^L (iw)Ff(w)e^{iwx} dw\end{aligned}$$

Then, the k -th derivative of $f(x)$ is

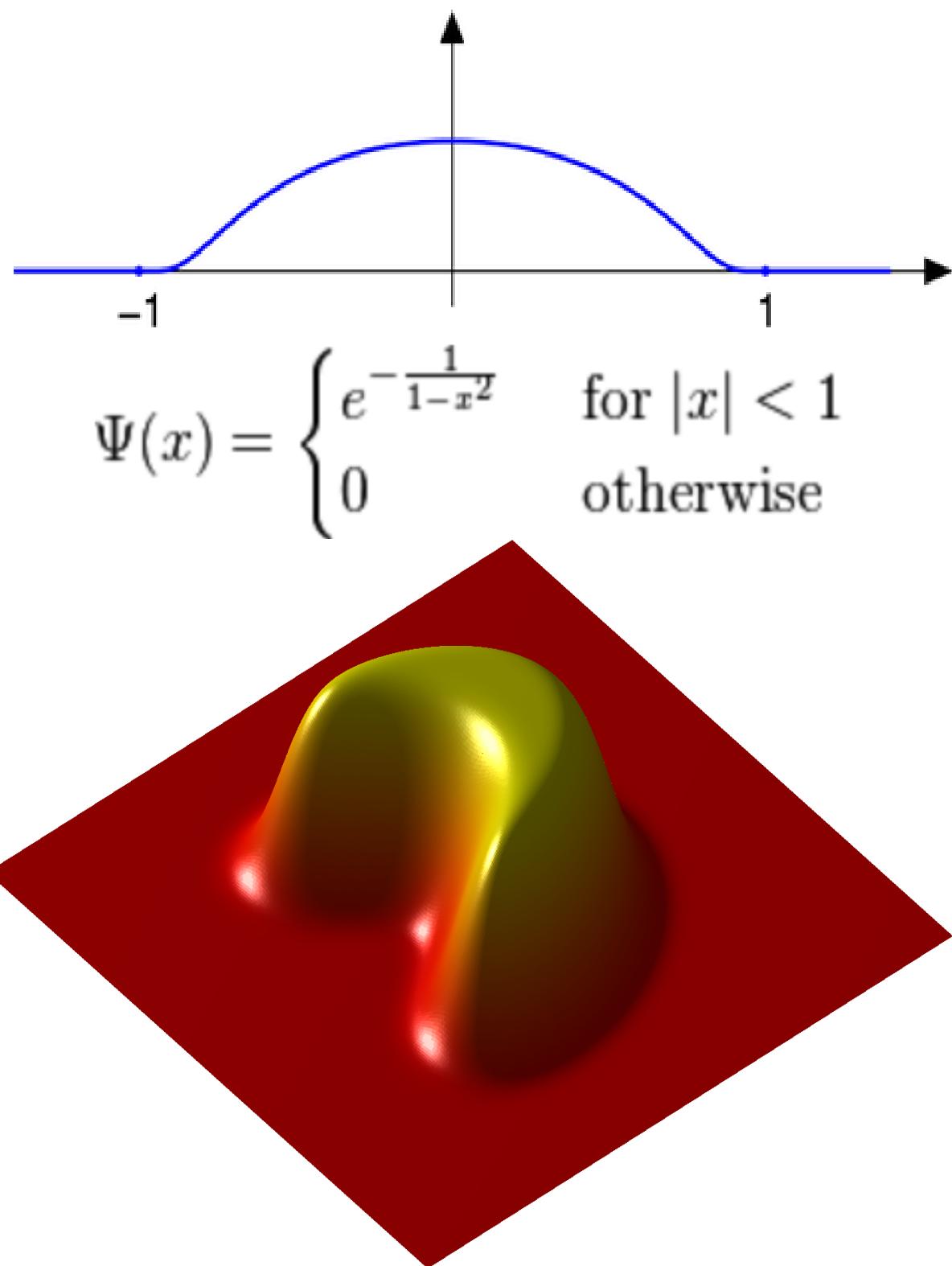
$$\frac{d^k f(x)}{dx^k} = \int_{-L}^L (iw)^k Ff(w)e^{iwx} dw$$

Fourier Analysis

- Sampling
- Give an example of an infinitely differentiable function
 - Sinusoid
 - A sinusoid has *infinite* support
- Give an example of an infinitely differentiable function with *finite* support
 - See next ...

Fourier Analysis

- Sampling
- **Bump function**
 - Infinitely differentiable
 - Finite support
 - Time limited
- Is bump function **bandlimited** ?
 - No
 - **Bandlimited-ness is a stronger property than being infinitely differentiable**



Fourier Analysis

- Bump function is NOT bandlimited
 - Proof by contradiction :
 - Assume bump function (**finite support**) $f(x)$ was bandlimited
 - $Ff(w) = 0$ when “w” outside $[-L, L]$
 - Multiplying $Ff(w)$ by box func $B(w)$ over $[-L, L]$ won't change $Ff(w)$
 - $Ff(w) = Ff(w) B(w)$
 - But, multiplying $Ff(w)$ by $B(w)$ \leftrightarrow convolving $f(x)$ with $\text{sinc}(x)$
 - $Ff(w) = Ff(w) B(w) = F(f * \text{sinc})(w)$
 - So, $f(x) = (f * \text{sinc})(x)$
 - $\text{sinc}(x)$ has infinite support
 - **Right hand side = $(f * \text{sinc})(x) \rightarrow \text{infinite support}$**
 - **Left hand side = $f(x) \rightarrow \text{finite support}$**
 - Contradiction !

Fourier Analysis

- Sampling
 - We just showed that :
A space-limited function (e.g., bump function) cannot be bandlimited
 - This implies that :
A function cannot be bandlimited and space-limited
 - We can similarly show that :
A bandlimited function cannot be space-limited

Fourier Analysis

- A bandlimited function is NOT timelimited
 - Proof by contradiction :
 - Assume bandlimited function $f(x)$ was space-limited
 - $f(x) = 0$ when “x” outside $[-M, M]$
 - Multiplying $f(x)$ by suitable box function $b(x)$ won't change $f(x)$
 - $f(x) = f(x) b(x)$
 - But, multiplying $f(x)$ by $b(x)$ \leftrightarrow convolving $Ff(w)$ with $\text{sinc}(w)$
 - $f(x) = f(x) b(x) = F^{-1} (Ff * \text{sinc})(x)$
 - So, $Ff(w) = (Ff * \text{sinc})(w)$
 - $\text{sinc}(w)$ has infinite support
 - Right hand side = $(Ff * \text{sinc})(w)$ has infinite support
 - Left hand side = $Ff(w) \rightarrow$ finite support
 - Contradiction !

Fourier Analysis

- Sampling
 - **Space-limiting an infinite-duration bandlimited signal destroys its bandlimited-ness**
 - Assume a (non-zero) function $f(x)$ that is :
 - (1) **bandlimited**
 - (2) of **infinite support**
 - Then, $f(x)$ has a Fourier transform $Ff(w) = 0$ outside $[-L, L]$
 - **Cut-out / space-limit** $f(x)$ by multiplying it with box function $b(x)$
 - Space-limited function $g(x) = f(x) b(x)$ has Fourier transform $Fg(w) = (Ff * Fb)(w)$
 - $Fb(w)$ has infinite support in frequency domain
 - Thus, $Fg(w)$ has infinite support in frequency domain
 - Thus, $f(x)b(x)$ is NOT bandlimited

Fourier Analysis

- Sampling
 - Aliasing can be avoided only for bandlimited signals
 - By sampling them at the Nyquist rate
 - **Can aliasing be avoided in the real world ? No !**
 - (1) Real-world signals are **NOT of infinite extent**
 - Acquiring an infinitely-long signal will take infinite time
 - We can artificially impose infinite extent by **extending samples periodically beyond boundaries (standard trick)**
 - Will this work ? Not for arbitrary signals. Only in some special cases.
 - (2) Real-world signals may **NOT be infinitely differentiable**
 - Non-differentiability may hold at
 - Points within the part of function observed OR
 - Points on the boundary, due to forced periodicity

Fourier Analysis

- Sampling
 - Some digital cameras have lens systems that blur incoming light signal to reduce aliasing (moire) in photo

VAF-7D Optical Anti-Aliasing Filter

For the Canon 7D: A solution for 1080p moiré and aliasing.

This unique, precision optical accessory for the Canon 7D produces a profound correction of the 7D's well-known 1080p video moiré and aliasing artifacts.

All our current VAF-series filters (including the VAF-7D) incorporate our newest and most advanced optical designs: for excellent performance with wide-angle lenses, and minimal focus disparity.

- No reduction of 7D 1080p video resolution for most lenses.
- True optical correction before video image capture – no postproduction software filters or processing.
- Easily installed or removed in less than 20 seconds.
- 7D H.264 codec compresses with better quality with the VAF-7D, because false, high-frequency, aliased image components are eliminated before compression.



6 STAGES OF TAKING AN EXAM UNPREPARED