

# Sampling Examples

If  $x(t) \xleftrightarrow{FT} X(\Omega)$ ,  $x[n] = x(nT) \xleftrightarrow{FT} X_s(\Omega)$

$$X_s(\Omega) = \frac{1}{T} \sum_{k=-\infty}^{\infty} X(\Omega - k\Omega_s) \quad ; \quad \Omega_s = \frac{2\pi}{T}$$

Sampling Thm: If max freq in  $x(t)$  is  $B$ , then

$\Omega_s > 2B$  for unique reconstruction of  $x(t)$  from  $x[n]$

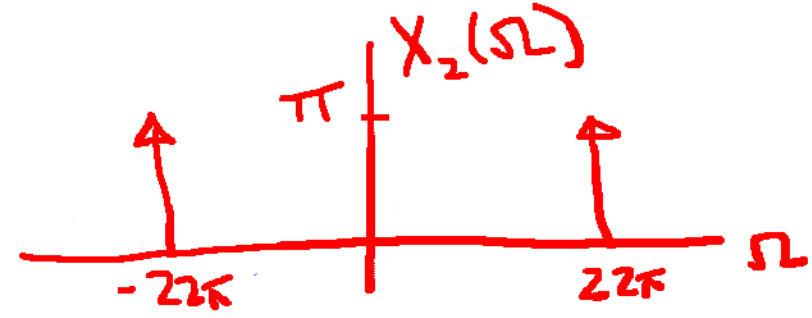
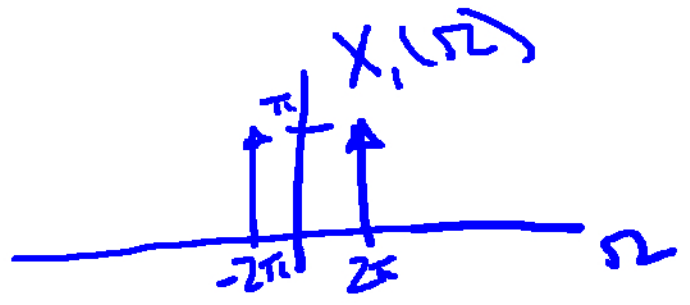
① CD quality audio max freq 20 kHz

Sample @  $> 40$  kHz

CD sampling rate : 44.1 kHz

② Sinusoids

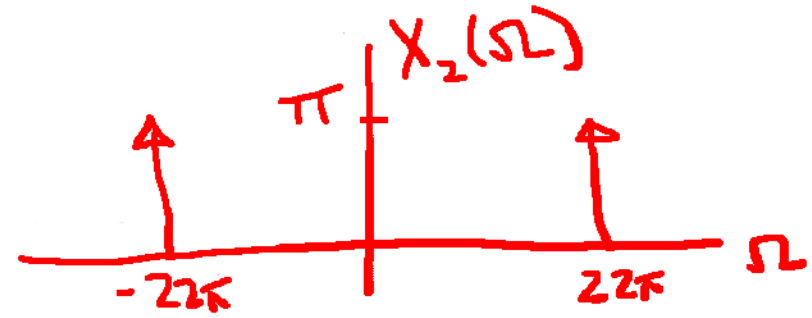
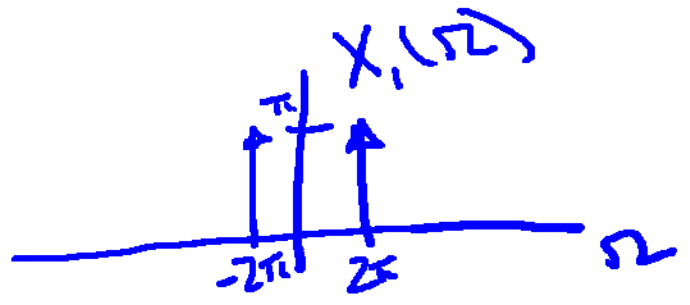
$x_1(t) = \cos(2\pi t)$ ,  $x_2(t) = \cos(22\pi t)$ ,  $T = 0.1 \text{ sec}$



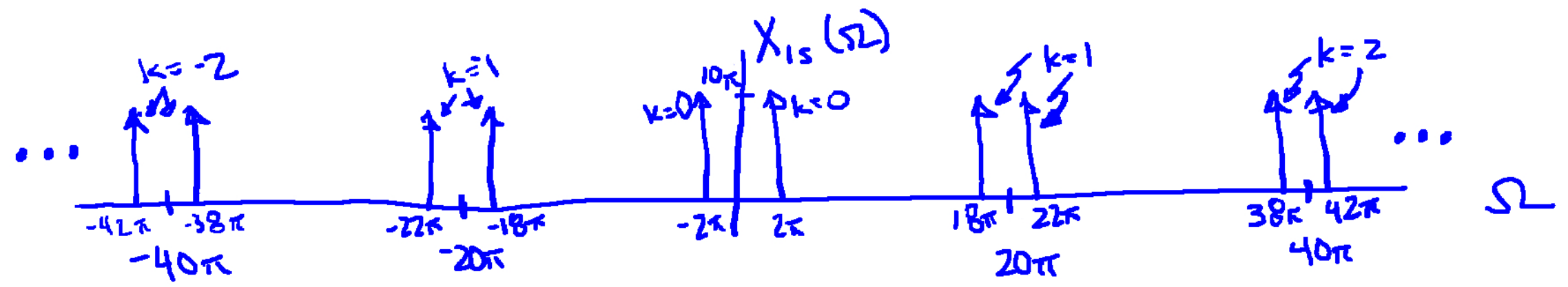
$$\Omega_s = \frac{2\pi}{0.1}$$
$$= 20\pi$$

② Sinusoids

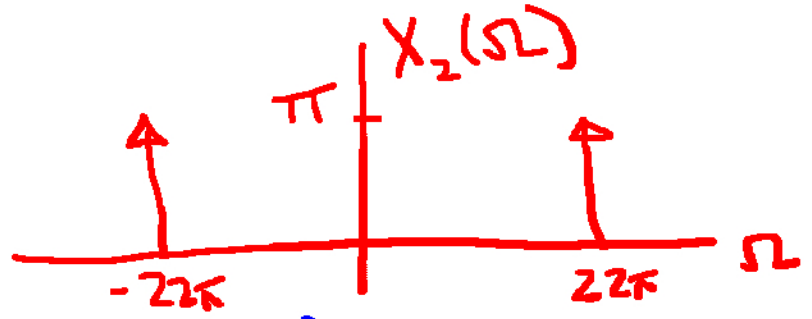
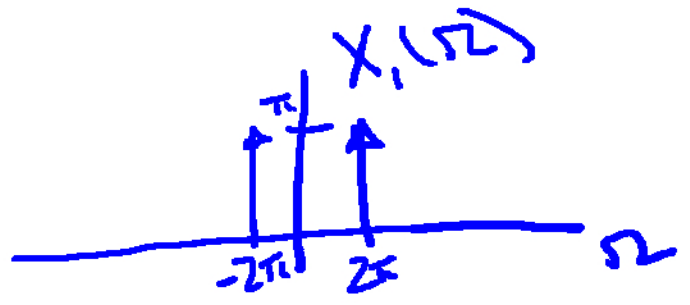
$x_1(t) = \cos(2\pi t)$ ,  $x_2(t) = \cos(22\pi t)$ ,  $T = 0.1 \text{ sec}^2$



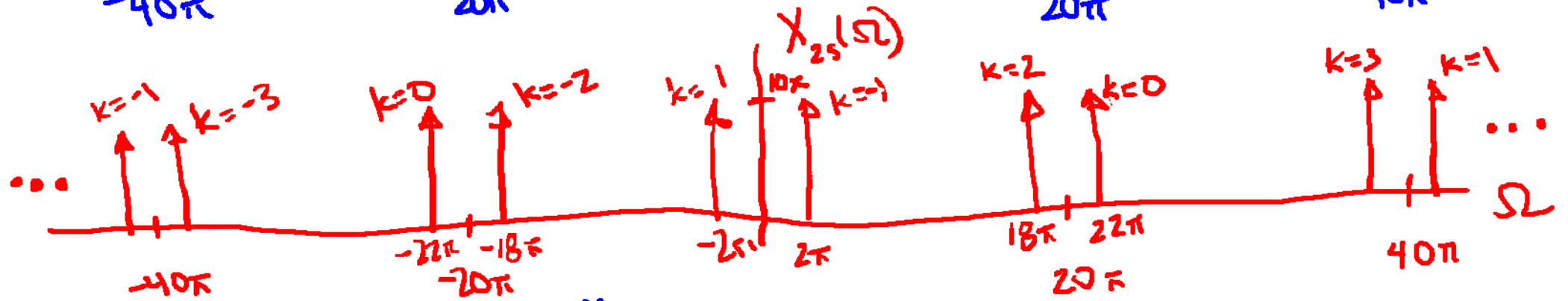
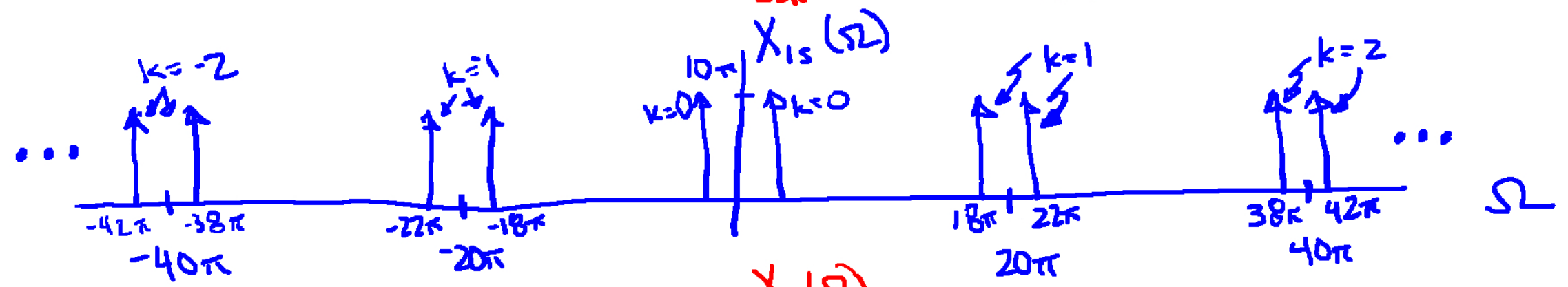
$\Omega_s = \frac{2\pi}{0.1}$   
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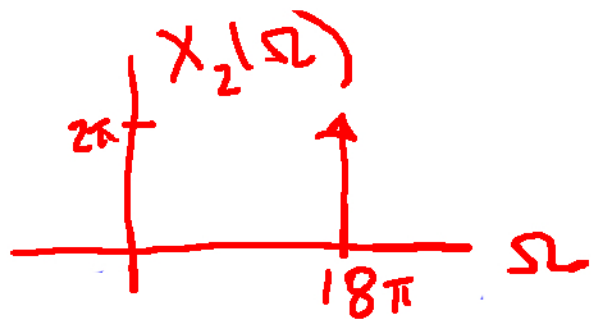
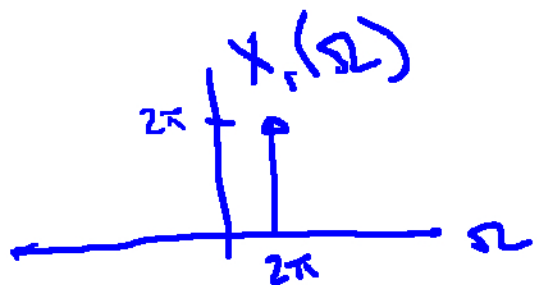


$$\Omega_s = \frac{2\pi}{0.1} = 20\pi$$



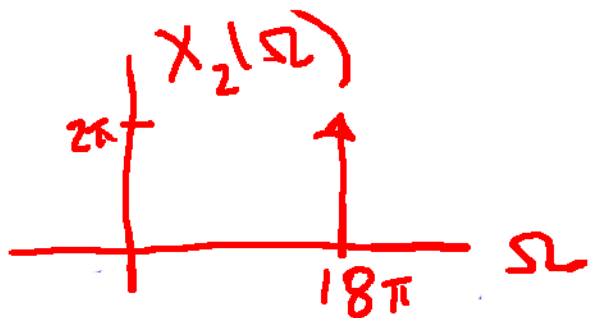
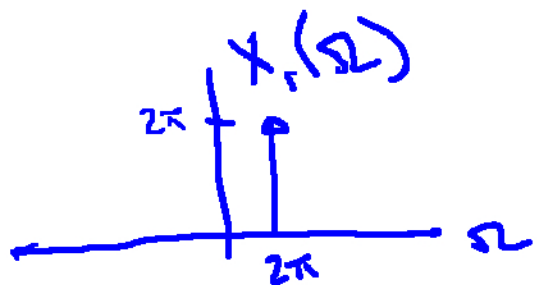
Aliasing

③ Complex sinusoid  $x_1(t) = e^{j2\pi t}$ ,  $x_2(t) = e^{j18\pi t}$ ,  $T = 0.1 \text{ sec}$  <sup>3</sup>

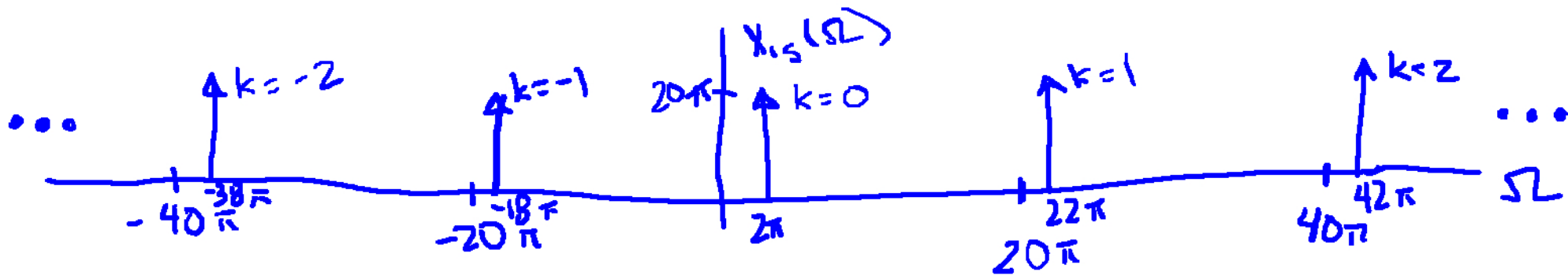


$$\Omega_s = \frac{2\pi}{0.1} = 20\pi$$

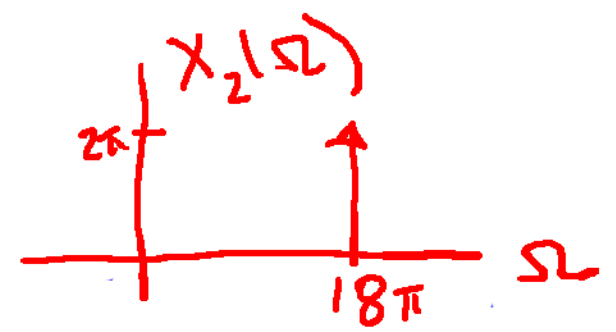
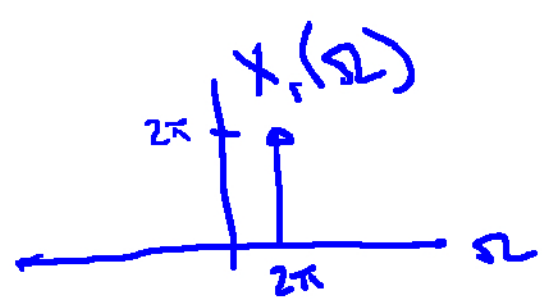
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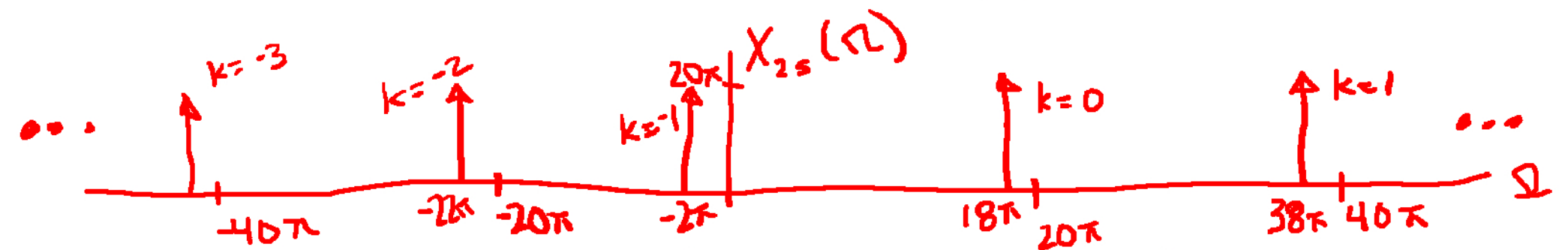
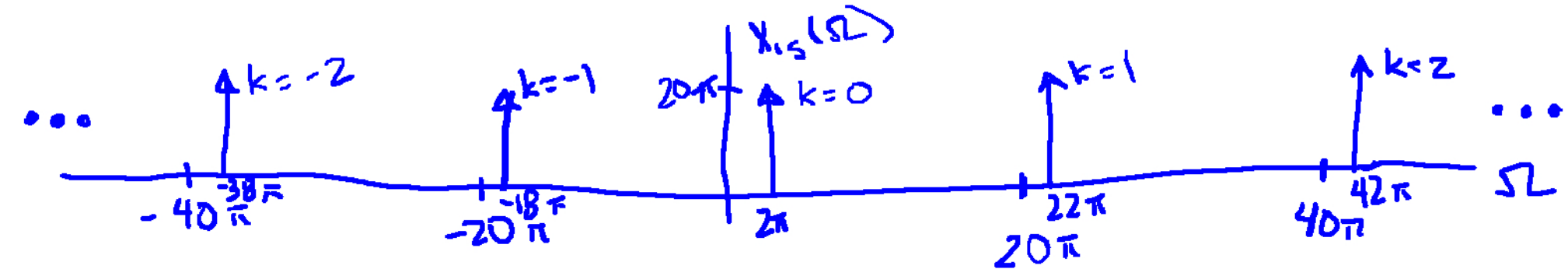
$$\Omega_s = \frac{2\pi}{0.1} = 20\pi$$



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$$\Omega_s = \frac{2\pi}{0.1} = 20\pi$$



Can't distinguish  $e^{j18\pi t}$  and  $e^{-j2\pi t}$

④

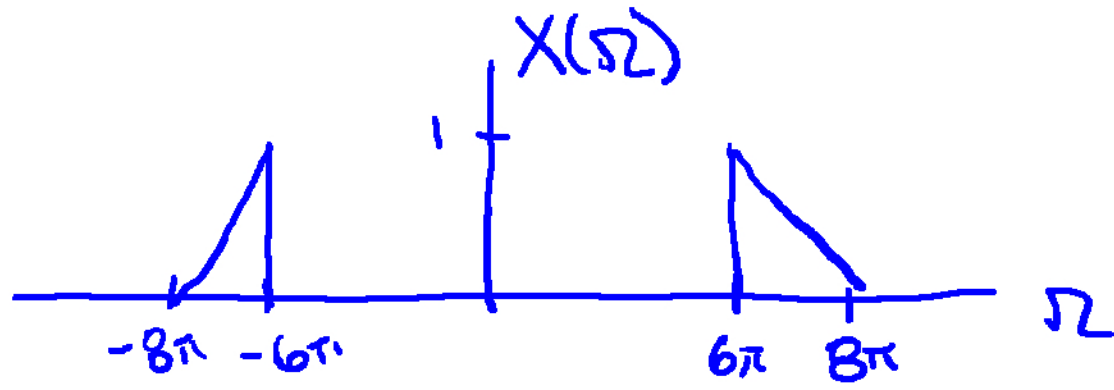


Sample  $x(t)$  at  
 $T = 1/6 \text{ sec} \Rightarrow \Omega_s = 12\pi$

4

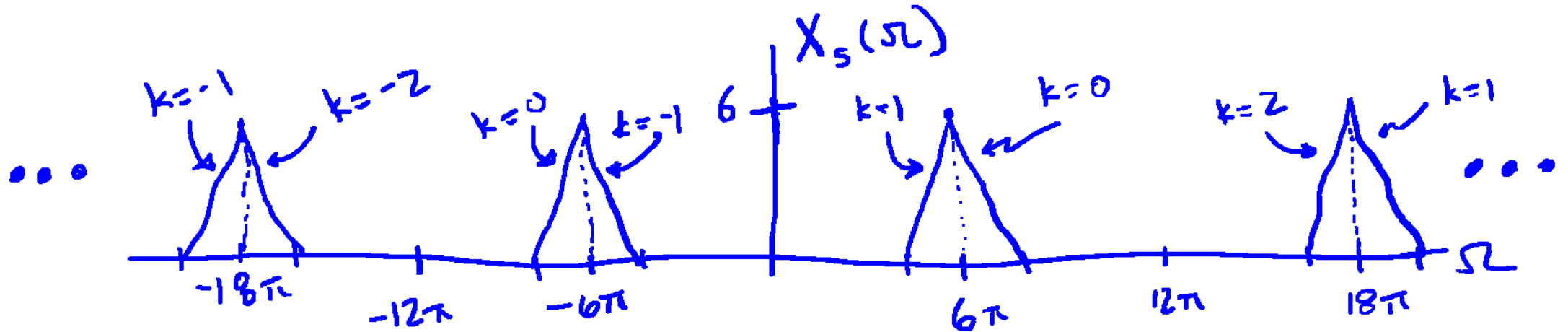


④



Sample  $x(t)$  at  
 $T = 1/6 \text{ sec} \Rightarrow \Omega_s = 12\pi$

4



Aliasing.