6.1-1

	sample rate (ω)	interval	highest ω
$g_1(t)$	$4\pi \times 10^5$		$2\pi \times 10^5$
$g_2(t)$	$3\pi \times 10^5$		$3\pi \times 10^5$
$g_1^2(t)$	$8\pi \times 10^5$		$4\pi \times 10^5$
$g_2^3(t)$	$18\pi \times 10^5$		$9\pi \times 10^5$
$g_1(t)g_2(t)$	$14\pi \times 10^5$		$7\pi \times 10^5$

multiplication in time domain $\Rightarrow$ convolution in frequency domain
Add the bandwidths

6.1-2

	sample rate (ω)	interval	highest ω
$\text{sinc}(100\pi t)$	$200\pi t$		$100\pi t$
$\text{sinc}^2(100\pi t)$	$400\pi t$		$200\pi t$
$\text{sinc}(100\pi t) + \text{sinc}(50\pi t)$	$200\pi t$		$100\pi t$
$\text{sinc}(100\pi t) + 3\,\text{sinc}^2(60\pi t)$	$240\pi t$		$120\pi t$
$\text{sinc}(50\pi t)\,\text{sinc}(100\pi t)$	$300\pi t$		$150\pi t$

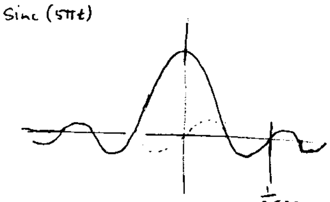
$\text{sinc}(x) = \frac{\sin(x)}{x}$ has same bandwidth as $\sin(x)$

6.1-4 $g(t) = \text{sinc}^2(5\pi t) = \left(\frac{\sin(5\pi t)}{5\pi t}\right)^2$

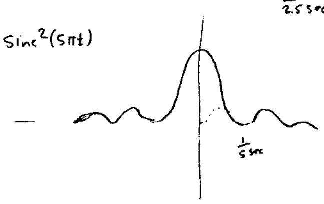
for $\text{sinc}(5\pi t)$: $\omega = 5\pi$, $f = \frac{5\pi}{2\pi} = 2.5$
for $\text{sinc}^2(5\pi t)$: $\omega = 10\pi$, $f = \frac{10\pi}{2\pi} = 5$

Sample at (i) 5 Hz (ii) 10 Hz (iii) 20 Hz
(a) sketch the sampled signal
(b) " " spectrum of sampled signal
(c) Explain whether you can recover $g(t)$ from samples.
(d) Pass sampled signal thru 5 Hz low pass, sketch it.

Sinc ($5\pi t$)

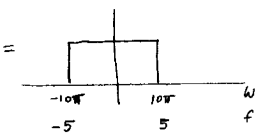


Sinc^2($5\pi t$)



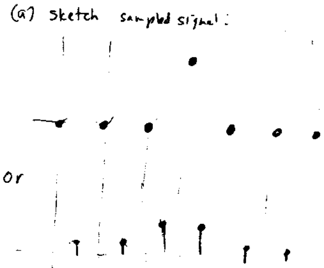
$\text{sinc}^2(5\pi t)$ has spectrum
↓
$\frac{W}{\pi}\,\text{sinc}(Wt) \Leftrightarrow \text{rect}\left(\frac{\omega}{2W}\right)$

$W = 5\pi$ $\quad \text{rect}\left(\frac{\omega}{10\pi}\right) =$



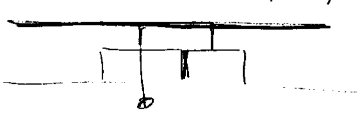
6.1-4 cont.
Sample at 5 Hz ...

(a) sketch sampled signal:



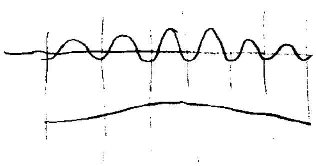
1 sample per cycle

(b) Sketch spectrum of sampled signal



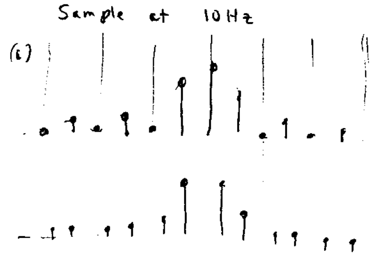
(c) severe aliasing – can't recover signal
complete overlap of spectrum

(d) pass samples thru 5 Hz low pass:



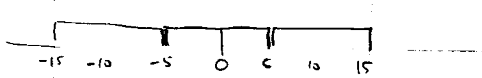
6.1-4 cont
Sample at 10 Hz

(i)



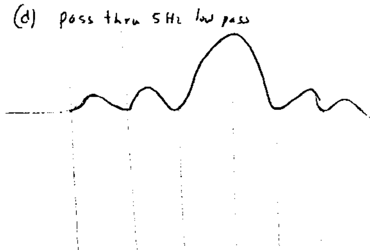
2 samples per cycle

(b) sketch spectrum



(c) yes, just barely

(d) pass thru 5 Hz low pass

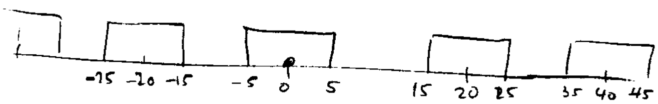


6.1-4 cont.
Sample at 20 Hz

(a)

4 samples per cycle

(b) spectrum



(c) Yes — easily

(d) pass thru 5Hz lowpass

6.2-1 ASCII has 128 characters
Want to send 100,000 char/sec ...

(a) bits per character : 7

(b) required bits/second : 700 000
bandwidth : 350 000 Hz

(c) Repeat if an additional bit is added:
(a) 8
(b) 800000
400000 Hz

6.2-2 Compact disk — bandwidth = 15 kHz

(a) Nyquist rate = 30 kHz

(b) For L = 65536 levels, how many bits? = 16
($2^{16} = 65536$)

(c) required bits/second 16 x 30,000 = 480,000

(d) Actual sampling is at 44,100 samples/sec.
required bits/sec = (44 100) x 16 = 705600
bandwidth = 352800 Hz

6.3-3 TV - bandwidth = 4.5 MHz

(a) sample rate - 20% above Nyquist
Nyquist rate is 9 mega-samples/sec
x 1.2
= 10.8 mega-samples/sec

(b) for 1024 levels, how many bits/sample = 10
($2^{10} = 1024$)

(c) required bits/sec = $9 \times 10^{6} \times 10 = 9 \times 10^{10}$
bandwidth = 4.5×10^{10} = 45 MHz

6.3-4 5 telemetry signals, each has Bw 1kHz
transmit by binary PCM.
max error = .2% (peak quantization error) ← not "noise"
Sample 20% above Nyquist rate
Add .5% extra bits for synchronization
Determine → data rate
bandwidth required

$.2\% = \frac{2}{1000} = \frac{1}{500}$ Need 250 levels
Use 256 levels, 8 bits

Nyquist rate is 2 kHz.
20% more is 2.4 kHz

For 5 channels, need 5 x 8 = 40 bits/sample interval.

Synchronization requires $40 \times \frac{5}{1000} = \frac{40}{200} = \frac{1}{5}$ bit/interval.
= .2 bit/interval

Bit rate = 40 x 2400 = 9,600 bits/sec data
.2 x 2400 = 480 bits/sec sync

data rate = 10080 bits/sec total

bandwidth = 5040 Hz

6.3-6 Need 47 dB $\frac{S}{N}$, assuming $n(t)$ is sinusoidal
How many levels?
Actual $\frac{S}{N}$ with this many levels?

$\frac{S}{N} = (3)(.5) L^2 = 1.5 L^2$

↗ Peak/avg for noise. ↖ Avg/peak for sine

47 dB → 50119 = $\frac{S}{N}$ (power)

$L^2 = \frac{50119}{1.5} = 33412$

$L = 182.79$

Need $L = 183$ (per instructions)

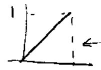
Actual SNR = $10 \log_{10} (1.5 \times 183^2)$
= 47.01 ← answer as posed

A more reasonable question would be --
how many bits (8) gives L=256
and what is SNR for this many bits

Actual SNR = $10 \log_{10} (1.5 \times 256^2)$
= 49.926 ← answer to another similar question.

Be sure to answer the question!

6.3-7 Repeat 6.3-6 for triangle input



← avg value = .5

mean square value = .3333

$\int_0^1 x^2 dx = \frac{1}{3}x^3 \Big|_0^1 = \frac{1}{3}$

$\frac{S}{N} = (3)(.3333)L^2 = L^2$

↖ $\frac{\text{Avg}}{\text{Peak}}$ for triangle

$L^2 = 50119$

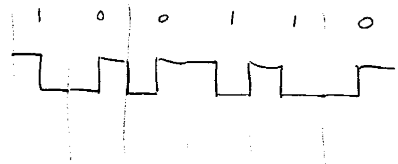
$L = 223.87$

Need $L = 224$

Actual SNR = 47,005 dB

7.2-2 (a) Data sequence 100110

Send by Manchester coding sketch waveform



7.2-4(a) "duo binary code" is...

0 = no pulse

1 = { same as previous 1 if preceded by even # of 0's
{ opposite if odd # of 0's preceding.

Sketch y(t) for 1110001101001010