1. Assuming a telegraph operator can achieve a maximum of 40 words-per-min

40 wpm
6 cpw + 1 space

$7 \times 40 = 280$ chars per min.
$\frac{280}{60}$ chars per sec.

- 26 letters + 10 digits ⇒ 36 symbols
- a basic code can do this in 6 bits

$\therefore \frac{280}{60} \times 6$ bps = $\boxed{28 \text{ bps} = R}$

2. Network design is often partitioned into a multi-layer hierarchy with each layer

data link layer

3. How many cables does a wired telephone network consisting of 100 users need if it

100*99/2 = 4950

4. You need to operate at error-free rates of 24-kbps through a channel with a 1.6

$$24 \times 10^3 = 1.6 \times 10^3 \cdot \log_2(1 + SNR)$$

$$15 = \log_2(1 + SNR)$$

$$32{,}768 = 1 + SNR$$

$$SNR = 32767$$

$$SNR|_{dB} = 10 \cdot \log(32767) = \boxed{45.1\ dB}$$

5. What kind of switching do wire-line telephone and telegraph provide?

telephone: circuit switching, connection-oriented

telegraph: message switching, connectionless

6. What general kind of switching does the Internet provide? And

packet switching, "flavours" include datagram networks and virtual circuit networks

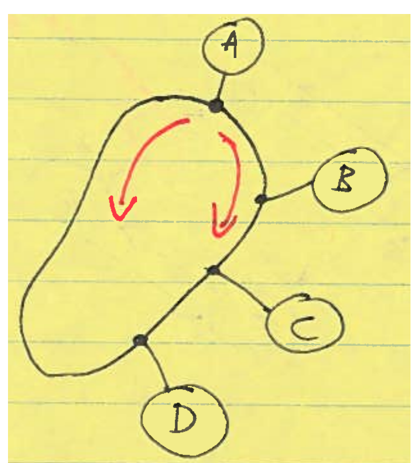
7. Is classic Ethernet better classified as a broadcast or switching network?

broadcast

8. Name two types of round robin networks.
Sketch a round-robin network

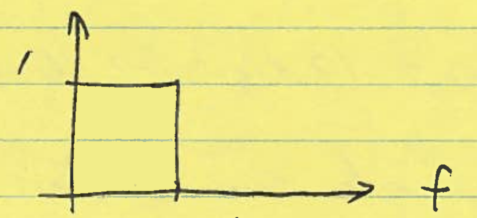
polling, token passing

passive ring might have a problem



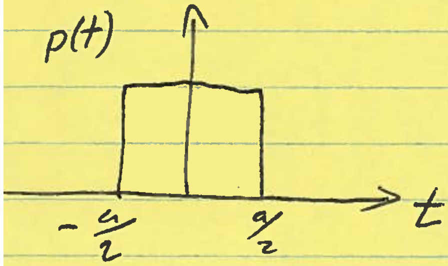
9. I want to send 2-level (just 1 and 0) digital information in the form of square pulses

channel looks like...

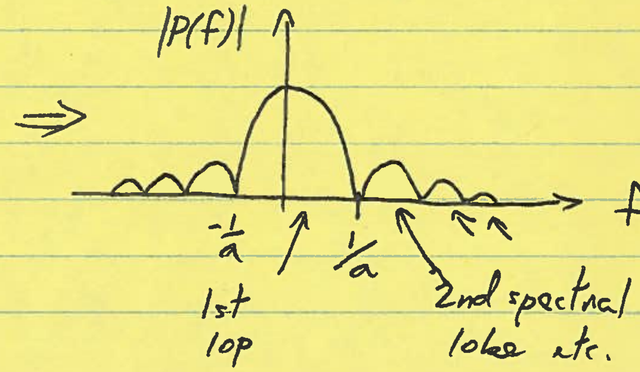


← channel BW

signal ~~channel~~ pulse in time



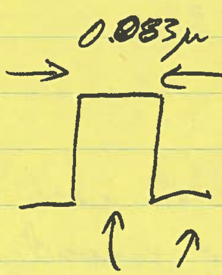
signal pulse in frequency



∴ can send pulse with freq. content

$$\frac{1}{a} = 12\,\text{MHz}$$

$$a = \frac{1}{12\times10^6} = 0.083\,\mu s \Rightarrow$$



can send a 1 or 0 every 0.083µs ∴ data rate is...

$$\therefore \boxed{R = \frac{1}{0.083\,\mu s} = 12\,\text{Mbps}}$$

10. You are using a R = 2.3-Mbps link and notice a 15-MB file downloaded in 1.3 seconds

Throughput = 15*8*1e6/1.3 = 92.3 Mbps

Correct answer…but how can throughput be greater than R ?!?!?!?!?!?! It can't so the numbers in this question weren't well thought out, but the throughput calculation is ok.

11. Packets with an average length of 1 KBytes arrive at a link to be transmitted.

→ packets arriving per second : $\lambda = \frac{8 \times 10^6}{8 \times 10^3} = 10^3$ packets/sec.

↑ representin 1KB as 10^3 (instead of 2^{10})

$\mu = \frac{10 \times 10^6}{8 \times 10^3} = 1.25 \times 10^3$ packets/sec.

$T = \frac{1}{\mu - \lambda} = \frac{1}{0.25 \times 10^3} = 4\,ms$ ← avg. delay per packet

if processing time is $\frac{1}{1.25 \times 10^3} = 0.8ms$

$\therefore$ $4 - 0.8 = 3.2ms$ in queue (before link starts processing the packet for transmission)

$\therefore$ fraction of delay due to queuing $\doteq \frac{3.2}{4} = 0.8$

12. For a link with a data rate of 10 Gbps communicating over a distance of 5000-km (Problem 1.15 from the textbook)

- say your transmitter is launching bits into your medium at a rate of R bits/s (bps)

- if your message consists of $L_{message}$ bits it takes your transmitter

$$\frac{L_{message}}{R}$$ seconds to load the entire message into your medium ("pipe")

- that's just getting the message INTO the pipe, don't forget it takes time for all these bits to propagate to the other side, that's the propagation delay t_{prop}

- thus the total time it takes to get your *whole* message to the destination is

$$\frac{L_{message}}{R} + t_{prop}$$

- similarly to send an acknowledgment message consisting of L_{ack} bit requires

$$\frac{L_{ack}}{R} + t_{prop}$$

thus the **total** time to send a message & get a complete acknowledgment of that message is

$$t_{total} = \frac{L_{message}}{R} + \frac{L_{ack}}{R} + 2 \cdot t_{prop}$$

recall that t_{prop} is just distance for the signal to travel over the speed of light in the communication medium so we can re-write the above as

$$t_{total} = \frac{L_{message}}{R} + \frac{L_{ack}}{R} + 2 \cdot \frac{d}{c}$$

at 10-Gbps $\frac{L_{message}}{R} = 0.8008\ s$ (1000-byte message)

$\frac{L_{ack}}{R} = 0.0016\ s$ (1-byte ACK)

for the 10-cm circuit board $\frac{2d}{c} = 0.00087\ s$

for the 5-km continent $\frac{2d}{c} = 43478.26\ s$

$t_{total}\|_{10cm}$	$= 0.80167$
$t_{total}\|_{5km}$	$= 43479.06$

note the huge propagation time in a continental connection, waiting for a 1-byte ACK in such a link can be extremely wasteful of resources

13. If switching time is 10 μs (microseconds) in a store-and-forward packet-switching

If v = 2e5 km/s or 200 m/us (us is "microsecond") in 10 us the signal travels 2 km. Therefore each switch adds the equivalent of 2 km of extra cable. Even going through 10 routers we only add the equivalent of 20 km to what is otherwise a 4,500 km distance. Thus, the router addition is not likely to have a big impact.