Problems for tomorrow's Class with solutions:

Q1. In the optical fiber, the core has a refractive index equal to 1.7 and a cladding of refractive index of 1.2.

a) What is the speed of light inside the core?

Ans: refractive index of the core is defined as n1 = C/V (C- speed of light, and V-velocity of light in core), V = C/n1 = 1.76×10^{8} m/sec.

b) What is the critical angle at the core-cladding interface?

θc =arcsin (1.2/1.7) = 44.9^{o} (note: at critical angle θ in cladding will be 90^{o})

c) What is the maximum angle θ that the rays leaving the source of light should make with the axis of the fiber so that total internal reflections takes place at the core cladding interface?

$\theta < 90 - \theta c = 45.1^{o}$.

Q2. Ten signals, each requires 4000 Hz, are multiplexed onto a single channel using FDM. What is the minimum bandwidth required for the multiplexed channel? (a) without guard band, and (b) with guard bands are of 400 Hz wide.

Ans: a) 40KHz, and (b) 43.6 KHz

Q3. Over a given channel 91 MHz – 93.5 MHz, there are four FM channels with center frequencies 91.4 MHz, 92 MHz, 92.7 MHz, and 93.3 MHz with minimum guard band of 0.2 MHz between each channel, calculate the bandwidth available for each channel.

Ans: first channel 400 KHz, second channel 400 KHz, third channel 600 KHz, and fourth channel 200 KHz. (note: there can be multiple solutions).

Q4. four channels , two with a bit rate of 200kbps and two with a bit rate 150 kbps are to be multiplexed using multiple slots TDM with no synchronization bits. Answer the following questions: assume 4 bits from the first 2 sources and 3 bits from the second 2 sources.

i. What is the size of a frame in bits?

ii. What is the frame rate?

iii. What is the duration of a frame?

iv. What is the date rate?

Sol:

i. The frame carries 4 bits from each of the first two sources and 3 bits from each of the second two sources. Frame size = 4 × 2 + 3 × 2 = 14 bits.

ii. Each frame carries 4 bit from each 200-kbps source or 3 bits from each 150 kbps. Frame rate = 200,000 / 4 = 150,000 /3 = 50,000 frames/s.

iii. Frame duration = 1 /(frame rate) = 1 /50,000 = 20 μs.

iv. Output data rate = (50,000 frames/s) × (14 bits/frame) = 700 kbps. We can also calculate the output data rate as the sum of input data rates because there are no synchronization bits. Output data rate = 2 × 200 + 2 × 150 = 700 kbps.

Q5. The bit stream at the input of the asynchronous TDM demultiplexer is given below:

0110001001111100011110011111

Assuming 10 bits per frame, what is the bit stream in each output (assuming four outputs with three bits each at a time).

110100111

0111011

001110

001011

Q6. Suppose there is exactly one packet switch between a sending host and a receiving host. The transmission rates between the sending host and the switch and between the switch and the receiving host are R1 and R2, respectively. Assuming that the switch uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length L? (Ignore queuing, propagation delay, and processing delay.)

Solution. Following is the diagram of the scenario:

Sender ——R1——- Switch ——-R2——- Receiver

After ignoring said delays, only transmission delay (Data size/Bandwidth) is effective here.

At time t_0 the sending host begins to transmit.

At time $t_1 = L/R_1$, the sending host completes transmission and the entire packet is received at the switch.

Because the switch is store and forwarding type, so further transmission will start after receiving the complete packet, which is completed at time $t_1 = L/R_1$.

The switch takes transmission time $t_2 = L/R_2$ to send complete packet on link R_2. As all other delays are zero.

Total Time taken by packet to travel from sender to receiver is:

= Time between sender to Switch + Time between switch to receiver

$= t_1 + t_2 = L/R_1 + L/R_2$

Thus, the end-to-end delay is $L/R_1 + L/R_2$.

Q7. How long does it take a packet of length 3,000 bytes to propagate over a link of distance 5,500 km, propagation speed 1.5 · 10^8 m/s, and transmission rate 1 Mbps? More generally, how long does it take a packet of length L to propagate over a link of distance d, propagation speed s, and transmission rate R bps? Does this delay depend on packet length? Does this delay depend on transmission rate?

Solution.

- **Propagation time = distance/speed of signal in media or channel**

  = 5500KM/1.5 · 10^8 m/s = 5500*1000 m/(1.5 · 10^8 m/s)

- Generally, the Propagation delay = d/s
- Propagation delay does not depend on packet length and transmission rate.

Q8. Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates R1 = 500 kbps, R2= 2 Mbps, and R3
= 1 Mbps.

a. Assuming no other traffic in the network, what is the throughput for the file transfer?
b. Suppose the file is 4 million bytes. Dividing the file size by the throughput, roughly how long will it take to transfer the file to Host B

c. Repeat (a) and (b), but now with R2 reduced to 100 kbps.

Solution. **A —-R1(500kbps)—–X———R2(2Mbps)—–X——-R3(1Mbps)—— B**

This is the concept of bottleneck link. Overall throughput will be the least bandwidth in the path between sender and receiver. So, throughput = 500 kbps

File size = 4*10^6 bytes, throughput = 500 kbps=> [4*(10^6)*8]/[500*10^3] = 64 seconds

A —-R1(500kbps)—–X———R2(100kbps)—–X——-R3(1Mbps)—— B

Now the bottleneck link is R2 (100kbps). Repeat above calculation with R2 = 100kbps instead of R1 = 500kbps.