Gerd Keiser, *Optical Fiber Communications*, McGraw-Hill, 4th ed., 2011

Problem Solutions for Chapter 1

1.1 (a) Using Eq. 1.3 for the relationship between photon energy and wavelength, we find that E(850) = 1.46 eV, E(1310) = 0.95 eV, E(1490) = 0.83 eV, and E(1550) = 0.80 eV.

(b) The number of photons N = $\dfrac{\text{(Pulse width)(Pulse power)}}{\text{(Energy / photon in eV)}(1.6\times10^{-19}\ \text{J / eV})}$

Therefore N(850) = 428, N(1310) = 657, N(1490) = 753, and N(1550) = 781.

1.2 In terms of wavelength, at a central wavelength of 1546 nm a 100-GHz channel spacing is

$$\Delta\lambda = \frac{\lambda^2}{c}\Delta f = \frac{(1546\,nm)^2}{3\times10^8\ m/s}\,100\times10^9\ s^{-1} = 0.80\,nm$$

The number of wavelength channels fitting into the 1536-to-1556 spectral band then is N = (1556 – 1536 nm)/0.80 nm = 25.

1.3 Three sine waves have the following periods T: 25 μs, 250 ns, 125 ps. Their frequencies are f = 1/T = 40 kHz, 4.0 MHz, and 8 GHz, respectively.

1.4 A sine wave is offset 1/6 of a cycle with respect to time zero. Its phase in degrees is 60 and in radians is π/3.

1.5 Two signals have the same frequency, but when the amplitude of the first signal is at its maximum, the amplitude of the second signal is at half its maximum. The phase shift between the two signals is 90 degrees.

1.6 Three signals have bit rates of R = 64 kb/s, 5 Mb/s, and 10 Gbps. The duration of a bit is T_b = 1/R = 15.6 μs, 200 ns, and 0.1 ns, respectively.

1.7 (a) Convert the following absolute power gains P_2/P_1 to decibel power gains: 10^{-3}, 0.3, 1, 4, 10, 100, 500, 2^n. Answer using Eq. (1.4): -30, -5.2, 0, 6, 10, 20, 27, 3n dB, respectively.

(b) Convert the following decibel power gains to absolute power gains: -30 dB, 0 dB, 13 dB, 30 dB, 10n dB. Answer: 10^{-3}, 1, 20, 1000, 10^n, respectively.

1.8 (a) Convert the following absolute power levels to decibel levels referenced to 1 mW: 1 pW, 1 nW, 1 mW, 10 mW, 50 mW. Answer using Eq. (1.5): -90 dBm, -60 dBm, -30 dBm, 10 dBm, and 17 dBm, respectively.

(b) Find the absolute power levels in units of mW of the following dBm values: -13 dBm, -6 dBm, 6 dBm, 17 dBm. Answer: 50 μW, 250 μW, 4 mW, and 50 mW, respectively.

1.9 (a) 10 log P_A/P_B = 10 log (0.125/1.0) = - 9.0. The attenuation is 9 dB.

(b) An attenuation of 15 dB means the power level drops by a factor of 31.6. Thus the power level at point B would be 32 μW.

1.10 Since the gains given in decibels are additive, the total gain is 15 dB. The signal is amplified by a factor $10^{1.5}$ = 31.6.

1.11 A power level of 500 μW in dBm is 10 log (0.5) = -3 dBm. Therefore the power level after 30 km is -3 dBm - 24 dB = - 27 dBm, which is equivalent to 2.0 μW.

1.12 From the relationship $C = B \log_2 (1 + S/N) = (2\text{ Mb/s}) \log_2 (1 + 100)$

$$= (2\text{ Mb/s}) [\log_{10} (1 + 100)]/[\log_{10} 2] = 13.3\text{ Mb/s}$$

1.13 (a) 8000 bits of overhead are added.

(b) Four DS-1 or 96 DS-0 channels fit into a DS-2 channel. 136 kb/s of overhead are added.

(c) A DS-3 channel can accommodate 7 DS-2 channels. The overhead is 192 kb/s.

(d) 672 DS-0 channels can be sent over a DS-3 line. The total overhead is 1.368 Mb/s or 3 %.