ECE 228A
HW 1

1.1

For an optical carrier at wavelength λ, carrier frequency $\nu = c/\lambda$ while photon energy $E_{ph} = h\nu = hc/\lambda$. Using $c = 2.998 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J·s, and 1 eV = 1.602×10^{-19} J, we obtain the following results:

For $\lambda = 0.88\ \mu$m; ν = 340.9 THz; E_{ph} = 1.41 eV.
For $\lambda = 1.30\ \mu$m; ν = 230.8 THz; E_{ph} = 0.96 eV.
For $\lambda = 1.55\ \mu$m; ν = 193.5 THz; E_{ph} = 0.80 eV.

1.2

Using $P_{in}/P_{out} = \exp(\alpha L) = 10$, fiber length is found to be

$$L = \ln 10/\alpha = 2.3026/\alpha.$$

We can convert α from dB/km to km^{-1} using

$$\alpha\,(\text{dB/km}) = \frac{10}{L}\log_{10}\left(\frac{P_{in}}{P_{out}}\right) \approx 4.343\alpha.$$

For 0.2 dB/km; $\alpha = 4.61 \times 10^{-7}$ cm^{-1}; $L = 50$ km.
For 20 dB/km; $\alpha = 4.61 \times 10^{-5}$ cm^{-1}; $L = 0.5$ km.
For 2000 dB/km; $\alpha = 4.61 \times 10^{-3}$ cm^{-1}; $L = 5$ m.

1.3

At a carrier frequency ν, the number of audio channels is found from

$$N = \frac{0.01 \times \nu}{64\ \text{kb/s}}.$$

From this equation, $N = 781$ for $\nu = 5$ GHz.
Using $\nu = c/\lambda = 193.5$ THz at $\lambda = 1.55\ \mu$m, $N = 3.024 \times 10^7$.

1.5

From Eq. (A.3) of Appendix A, −40 dBm average power implies $P_{av} = 0.1\ \mu$W.
Assuming that 0 bits carry no energy, the energy of a each 1 bit is

$$E_1 = \frac{2P_{av}}{B} = \frac{2 \times 10^{-7}\ \text{W}}{1 \times 10^9\ \text{b/s}} = 2 \times 10^{-16}\ \text{J}.$$

Using $E_1 = N_p h\nu$ with the photon energy $h\nu = 0.8$ eV at 1.55 μm, we obtain N_p = 1560.

1.7

Sketching of the bit pattern should be done in a way similar to Figure 1.9(b) of the textbook.

In the NRZ format, the shortest pulse is 1-bit wide and the widest pulse corresponds the longest sequence of 1 bits. Since the bit slot = $1/B = 0.4$ ns, the shortest pulse is 0.4 ns and the widest pulse is 1.6 ns for the given pattern.

1.8

Total cable loss = (0.3 dB/km)$\times$100 km = 30 dB.
Average received power: $P_{av} = 10^{-3} \times 2$ mW = 2 μW.
Using $P_{av} = (N_p h\nu)B/2$, where N_P is the number of photons in each 1 bit, with the photon energy $h\nu = 0.8$ eV and $B = 2$ Gb/s, we obtain N_p = 15,625.

1.9

Using $P_{av} = (N_p h\nu)B/2$ as in previous problem with B = 100 Mb/s and $h\nu$ = 1.55 eV, we find P_{av} = 12.4 nW = −49.07 dBm. Since, transmitted power is −10 dBm, the allowed loss for the link is −39.07 dBm. At 2-dB/km loss, the maximum possible fiber length is 19.535 km.