NAVAL POSTGRADUATE SCHOOL
Monterey, California

EC 3550 FINAL EXAM 6/00 Prof. Powers

- This exam is open book and notes.
- There are four problems; each is equally weighted.
- Partial credit will be given; be sure to do some work on each problem.
- Be sure to include units in your answers.
- Please circle or underline your answers.
- Show *ALL* work.
- Write only your name on these exam sheets.
- Exams and course grades *should* be available outside the Optical Electronics Laboratory (Bu 224) on **Wednesday afternoon, 21 June**.
- Send me an email if you want me to email your final-exam score and course grade to you.
- Enjoy your break!

Course grade: _____

1		3	
2		4	
TOTAL			

Name: _____

1. Please provide brief, concise answers to the following questions. (Long, verbose answers are *not* required.)

   (a) Explain why the following wavelengths are special in a silica fiber link.

      i. 1300 nm

      ii. 1550 nm

   (b) Describe the application of each of the following items.

      i. dispersion-shifted fiber

      ii. dispersion-compensating fiber

   (c) Draw a block diagram of a 4-channel WDM link that uses an arrayed-waveguide-grating (AWG) multiplexer and an AWG demultiplexer, identifying all of the components.

   (d) Draw a block diagram identifying all of the components of an erbium-doped fiber amplifier.

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2. A multimode, step-index fiber operates with a source at 850 nm with a linewidth of 60 nm. The power in the fiber at the transmitter is −3 dBm. The fiber has a core index of 1.460, a numerical aperture of 0.18, and an attenuation of 1.1 dB/km at the operating wavelength. The receiver power required to achieve the desired BER is shown in the table below for NRZ coding.

Receiver Properties (Prob. 2)

Bit rate	Required RCVR power [nW]
10 Mb/s	24.5
50 Mb/s	108.2
100 Mb/s	190.5

   (a) If the receiver data fits an equation of the form

$$P_R[\text{dBm}] = A + B \log\left(B'_R[\text{Mb/s}]\right) ,$$

   find the constants A and B.

   (b) Find the attenuation-limited transmission distance for this link if the bit rate is 100 Mb/s.

   (c) Find the dispersion-limited transmission distance for this link when it is limited by the total fiber dispersion. The bit rate is still 100 Mb/s.

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3. A laser operating at 1550 nm is connected to the link shown in Fig. 1. (Some of the laser power is reflected by fiber grating #1 and arrives at the receiver.) The reflectivity of both fiber gratings is shown in Fig. 2a. The power in the fiber at the laser is 850 μW. All splices shown have a loss of 0.45 dB and a return loss of 15 dB. The properties of the isolators are given below. The excess loss for all splitters is 0.6 dB. The minimum power required to support the desired BER is given by $P_R[\text{dBm}] = -60.0 + 10 \log\left(B'_R[\text{Mb/s}]\right)$.

Isolator Properties (Prob. 3)

Parameter	Value
Insertion loss	3.5 dB
Return loss	65 dB
Isolation loss	35 dB

Find the maximum bit rate of the link. [You may assume that any losses that have not been mentioned are negligible (e.g., the losses in the fibers).]

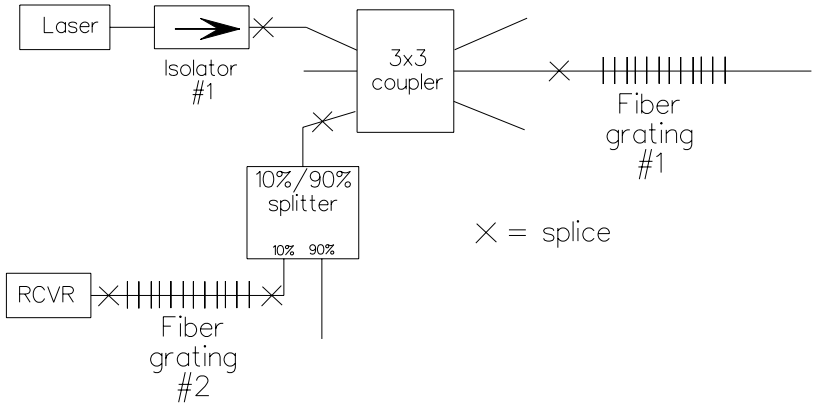
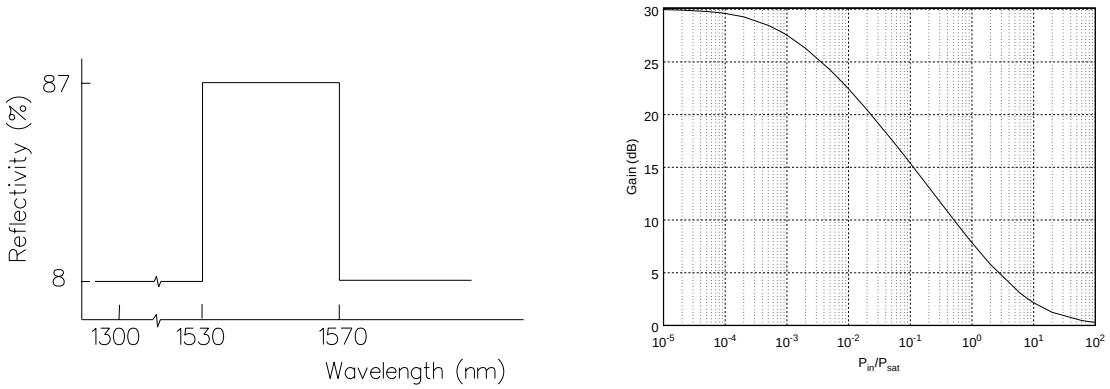


Figure 1: Component connection for **Prob. 3**



(a) (b)

Figure 2: (a.) (Idealized) reflectivity of the fiber gratings in **Prob. 3** and (b.) Gain vs $P_{\rm in}/P_{\rm sat}$ for the amplifier in **Prob. 4**.

4. An optical amplifier, operating at 1550 nm, is to be used in the link shown in Fig. 3a. The source produces 800 μW of power in the fiber. The connector and splice losses are 0.8 dB and 0.3 dB, respectively. The fiber loss coefficient is 0.5 dB/km and each fiber "loop" in the figure is 12 km long. The amplifier gain is shown in Fig. 2b; other properties of the amplifier are given in the table below. The receiver is a pin diode and a load resistor. At 1550 nm, the pin diode has a quantum efficiency of 50% and a dark current of 4 nA. The load resistor is 1 kΩ with a noise temperature of 350K.

Amplifier Properties (Prob. 4)

Parameter	Value
n_{sp}	1.5
$\Delta\lambda_{\text{amplifier}}$	40 nm
B_o	1.5 nm
P_{sat}	0.5 mW

(a) Suppose that a receiver is placed at point "A" (i.e., the link operates without the amplifier). Calculate the signal-to-noise ratio, SNR_A, in dB.

(b) Suppose that the receiver is placed at point "B" after the amplifier. Calculate the signal-to-noise ratio, SNR_B, in dB. (You may assume that the two noises due to the amplifier's ASE power are dominant.)

(c) The noise figure of the amplifier, F, is defined as the ratio, $\text{SNR}_\text{A}/\text{SNR}_\text{B}$. Calculate F in dB.

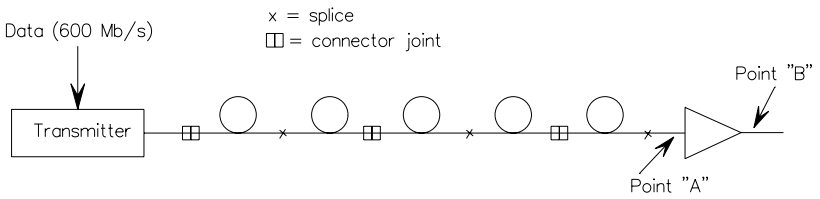
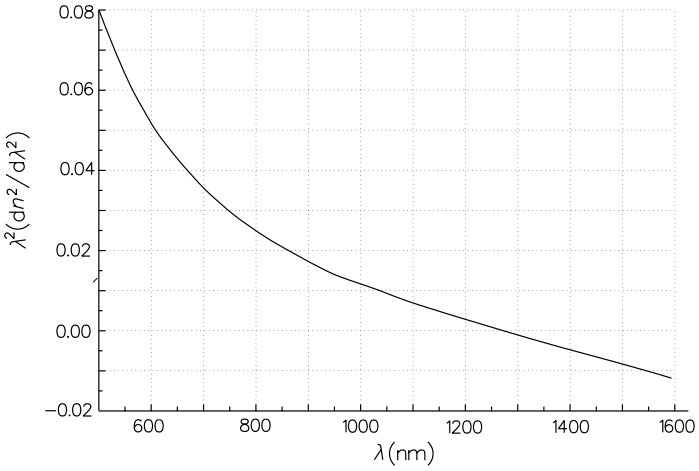
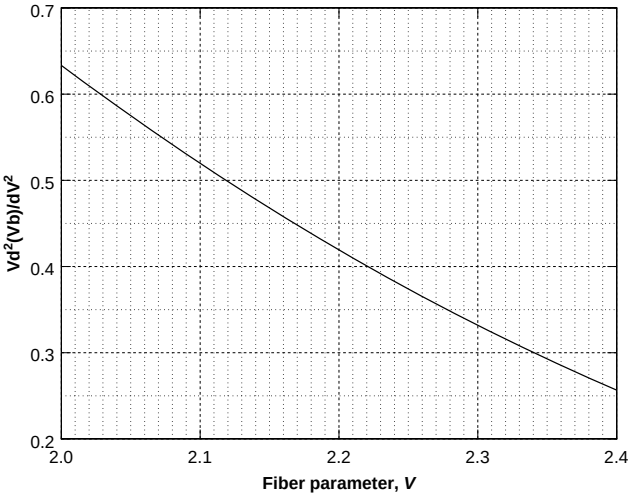


Figure 3: Component connection for **Prob. 4.**



(a)



(b)

Figure 4: (a) Fig. 3.8 of text and (b) Fig. 3.10 of text.