NAVAL POSTGRADUATE SCHOOL
Monterey, California

EC 3550 SAMPLE FINAL EXAM (1995 final) 12/96 Po

- 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 this sheet.
- Exams and course grades *should* be available outside the Optical Electronics Laboratory (Bu 224) on **Thursday afternoon, 14 December**.
- Have a good holiday season and enjoy your break!

Course grade: _____

1	
2	
3	
4	
Total	

Name: _____

FIBER SPECIFICATIONS

	Fiber #1	Fiber #2	Fiber #3	Fiber #4
Size	50/125	62.5/125	10/125	100/140
g	1.90	∞	∞	1.78
NA	0.15 (at $r = 0$)	0.20	0.09	0.18 (at $r = 0$)
α @ 850 nm	2.0 dB/km	1.0 dB/km	1.2 dB/km	5.0 dB/km
α @ 1300 nm	1.0 dB/km	0.8 dB/km	0.7 dB/km	2.0 dB/km
α @ 1550 nm	0.6 dB/km	0.4 dB/km	0.4 dB/km	0.8 dB/km

SOURCE SPECIFICATIONS

	Laser #1	Laser #2	LED #3	Laser #4
Wavelength	850 nm	1300 nm	850 nm	1550 nm
$\Delta\lambda$	0.5 nm	1.0 nm	25 nm	1.1 nm
Power at pigtail end	0.50 mW	0.8 mW	60 μW	2.0 dBm
Pigtail size	62.5/125 μm	10/125 μm	200/300 μm	8/125 μm
Pigtail NA	0.20	0.12	0.25	0.10
Pigtail type	Step index	Step index	Step index	Step index

DETECTOR SPECIFICATIONS

	Detector #1	Detector #2	Detector #3
Material	Silicon	Germanium	InGaAs
Responsivity A/W @ $M = 1$	0.8 @ 850 nm	0.2 @ 1300 nm 0.3 @ 1550 nm	0.3 @ 1300 nm 0.45 @ 1550 nm
C_d	3 pF	1 pF	2 pF
Excess noise factor	$M^{0.3}$	M^{1}	$M^{0.6}$
Bulk dark current	0.10 pA	10 μA	0.1 μA
Surface dark current	0	1 nA	0

IMPORTANT: Specifications of numbered components are shown in the tables.

1. An optical source is connected to a 1x4 coupler, a 1.5 km length of fiber, another 1×4 coupler, and a receiver as shown in the figure below. The source, receiver, and couplers all have pigtails of 1 m length. The system uses connectors with a loss of 1.2 dB per pair. The fiber loss is 1.2 dB/km and the excess loss of each leg of the 1×4 coupler is 0.5 dB for each output. The source is an LED that is guaranteed to produce 100 μW in the fiber pigtail when driven by 100 mA of current.

   If the minimum power required at the receiver is 100 nW, calculate the minimum source drive current *in mA*.

file=i:/courses/ec3550/exams/figures/xm95$_1$.*pcl.eps*, *width* = 5.8*in*

Figure 1: Setup for Prob 1.

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2. Detector #3 is used as an APD in a 100 Mb/s link operating at 1550 nm. The detector operates with just a load resistor of 1 kΩ with a noise temperature of 350K (i.e., there is no preamplifier). If the incident optical power is 500 nW, find the signal-to-noise ratio (*in dB*) when the device gain is 60% of its optimum value.

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3. Fiber #3 is used with laser #4 in an 800 Mb/s link with RZ coding. The core index is 1.456 and the cladding index is 1.452.

   (a) Calculate the dispersion-limited link distance (*in km*) for material dispersion.

   (b) Calculate the dispersion-limited link distance (*in km*) for waveguide dispersion.

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4. Source #1 operates in a 500 Mb/s link with RZ coding using fiber #2. The total losses of the link are 38.0 dB. Detector #1 is used as an APD with a gain $M = 50$. The detector operates into a 100 Ω load resistor with a noise temperature of 350K. There is no preamplifier.

   (a) Find the total mean-square noise current of the receiver.

   (b) Find the BER of the link. (You may find it useful to use the approximation, $\text{erfc}(x) \approx e^{-x^2}/2x\sqrt{\pi}$.)
