Study Guide 6

13.6 (a) The photon energy is

$$h\nu = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{1500 \times 10^{-9}} = 1.326 \times 10^{-19}\ \text{J}$$

Using Eq.(13-8), we find

$$\eta = \frac{h\nu\mathcal{R}}{e} = \frac{(1.326 \times 10^{-19})(0.844)}{1.6 \times 10^{-19}} = \boxed{0.70}$$

$\mathcal{R} = \frac{e}{h\nu}\eta = \frac{e\lambda}{hc}\eta$

(b) Since $\mathcal{R} \propto \lambda$, we can determine the responsivity at other wavelengths by simply comparing to the value at 1500 nm:

$$\text{at 1300 nm:}\quad \mathcal{R} = .844\left(\frac{1300}{1500}\right) = 0.73\ \text{A/W}$$

$$\text{at 800 nm:}\quad \mathcal{R} = .844\left(\frac{800}{1500}\right) = 0.45\ \text{A/W}$$

13.7 The incident light power is $P = (1\ \text{mW})10^{-33/10} = 5.01 \times 10^{-4}\ \text{mW} = 5 \times 10^{-7}\ \text{W}$. Using the given responsivity for 1500 nm we have $i = P_{in}\mathcal{R} = (5 \times 10^{-7}\ \text{W})(0.844\ \text{A/W}) = \boxed{4.22 \times 10^{-7}\ \text{A}}$.

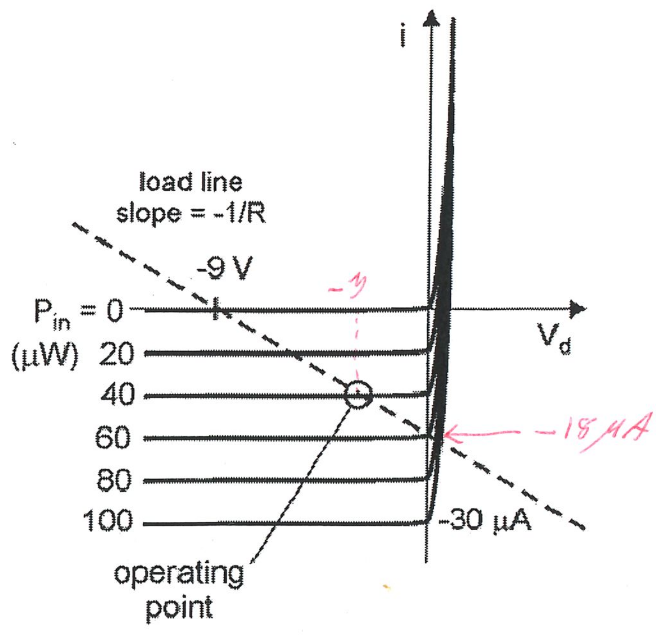
14.1 For an incident power $P_{in} = 20\,\mu$W, the generated photocurrent is $i_\lambda = \mathcal{R}P_{in} = (0.3)(2 \times 10^{-5}) = 6 \times 10^{-6}$ A $= 6\,\mu$A. This is much larger than the dark current, so i_0 can be neglected here. The load line has an intercept of -9 V along the V_d axis, and its slope is $-1/R = -1/(5 \times 10^5)$. The change in current i when V_d changes by 9 V is calculated to be

$$\Delta i = -\frac{\Delta V}{R} = -\frac{9}{5 \times 10^5} = -1.8 \times 10^{-5}\text{ A} = -18\,\mu\text{A}$$

The incident power corresponding to this change in current is

$$P_{sat} = \frac{i_{sat}}{\mathcal{R}} = \frac{18 \times 10^{-6}}{0.3} = 60 \times 10^{-6}\text{ W} = 60\,\mu\text{W}$$

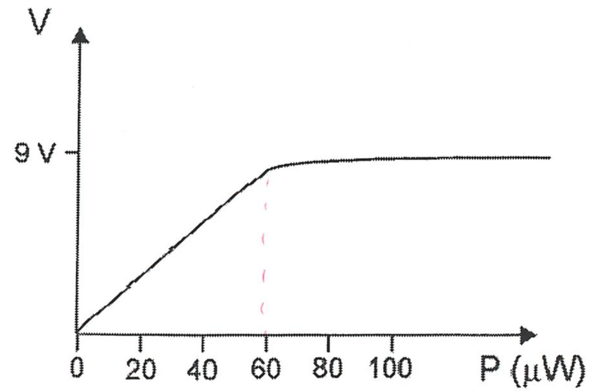
The diode curves and load line are therefore as shown in the figure below. The circled operating point corresponds to an incident power of 40 μW, and leads to an estimated diode voltage of $V_d \approx -3$ V.



or, $P_{in} = 20\,\mu W$ gives
$i_\lambda = 6\,\mu A$
$V_R \approx 3$ V

P_{in}	V_R	V_d
0	0	9
20	3	6
40	6	3
60	9	0

14.2 The response will be linear as long as the diode voltage is negative (i.e., it is reverse biased). Above an incident power of 60 μW the voltage output saturates, because at this point the voltage across the diode has been reduced to near zero.



14.16

a) thermal: $V_N = \sqrt{4 k_B T B R_L} = \sqrt{4(1.38 \cdot 10^{-23})(293)(10^5) \cdot (5 \cdot 10^5)}$

$V_N = \boxed{2.84 \cdot 10^{-5}\ V}$ thermal

shot: $V_N = \sqrt{P_{shot} \cdot R_L} = \sqrt{2e(i_\lambda + i_o) B R_L}$ $\quad P = \frac{V^2}{R}$

$P_{opt} = 20\,\mu W \Rightarrow \left. \begin{array}{l} i_\lambda = 6 \cdot 10^{-6} A \\ i_o = 2 \cdot 10^{-9} A \end{array} \right\} \quad i_o \ll i_\lambda$

$V_N = \sqrt{2(1.6 \cdot 10^{-19})(6 \cdot 10^{-6})(10^5)} \ (5 \cdot 10^5)$

$V_N \approx \boxed{2.19 \cdot 10^{-4}\ V}$ shot

Total $\quad V_N \approx \boxed{2.21 \cdot 10^{-4}\ V}$

$V_{sig} = (6 \cdot 10^{-6})(5 \cdot 10^5) = 3\ V$