Q1. \[ E_b (\text{dB}) \in \{ -3, 0, 3, 6, 9 \} \]
\[ E_b \frac{(\text{linear})}{N_0} \in \{ 0.502, 1, 1.995, 3.981, 7.943 \} \]
\[ P_e \in \{ 0.1584, 0.0786, 0.0229, 0.0024, 0.0005 \} \]

Q2.a) \[ d = cT \]
For \( R = 100 \text{ Kbps} \) \[ d = \frac{3.10^8}{10^5} = 3000 \text{m} \] (outdoor)

For \( R = 10 \text{ Mbps} \) \[ d = \frac{3.10^8}{10^4} = 30 \text{m} \] (indoor)

b) \[ P_e = \frac{1}{2} \cdot \frac{1}{2} + \frac{1}{2} \cdot 0 = \frac{1}{4} \]
Q3. a) Assuming $T = 45^\circ C$,

$$N_0 = kT = 1.38 \cdot 10^{-23} \times (273 + 15)$$

$$= -204 \text{ dB W/Hz}$$

$$= -174 \text{ dBm/Hz}$$

b)

\[ S_N(f) \]

\[ f \text{ (MHz)} \]

\[ B = 20 \text{ MHz} \]

\[ P_N = \int_{-B}^{B} S_N(f) \, df = N_0 + B + F \text{ (dBm)} \]

$$= -774 + 73 = -101 \text{ dBm}$$
Q4: a) $s_1(t):$ time-limited \( \rightarrow \) not broadened \( \rightarrow \) no ISI
channel: no shaping

6) $s_1(t) = \frac{AT}{2}$ \( \left( s_0(t) \times hr(t) \right|_{t=T} = \frac{AT}{2} \)

$s_1(t) = AT$

$\eta \sim N \left( 0, \frac{N_0T}{2} \right), \quad \left( w(t) \times hr(t) \right|_{t=T} \)

\[
\sigma^2_{\eta} = \mathbb{E}[\eta^2] - \mathbb{E}^2[\eta] = \int_{-\infty}^{\infty} S_N(f) \, df = \frac{N_0}{2} \int_{-\infty}^{\infty} H_r(f) \, df
\]

\[
= \frac{N_0}{2} \int_{-\infty}^{\infty} h(t) \, dt = \frac{N_0T}{2}
\]

d) $\lambda = \frac{AT + \frac{AT}{2}}{2} = \frac{3AT}{4}$

\[
\lambda \sim \frac{\lambda}{\lambda_{TH}} = \frac{3AT}{4}
\]
e) \( P_e = \frac{1}{2} \Pr (y = 0 | s = 1) + \frac{1}{2} \Pr (y = 1 | s = 0) \)

\[
\begin{align*}
S = 1, & \quad y \sim N(\frac{\alpha T}{2}, \frac{\sigma^2}{2}) \quad \text{if} \quad \frac{\alpha T}{2} > \frac{3\sigma T}{4} \\
S = 0, & \quad y \sim N(\frac{\alpha T}{2}, \frac{\sigma^2}{2}) \quad \text{if} \quad \frac{3\sigma T}{4} > \frac{3\sigma T}{4}
\end{align*}
\]

\[
P_e = \frac{1}{2} \Pr \{ y \sim N(\frac{\alpha T}{2}, \frac{\sigma^2}{2}) \} > \frac{3\sigma T}{4} + \frac{1}{2} \Pr \{ y \sim N(\frac{\alpha T}{2}, \frac{\sigma^2}{2}) \} < \frac{3\sigma T}{4}
\]

Note that \( \Pr \{ X > x \} = Q \left( \frac{x - \mu}{\sigma} \right) \) where \( X \sim N(\mu, \sigma^2) \)

\[
= Q \left( \frac{A \sqrt{2T}}{4 \sqrt{N_0}} \right) = \frac{1}{2} \erfc \left( \frac{A \sqrt{T}}{4 \sqrt{N_0}} \right)
\]

f) Matched filter since \( h(t) = 0 \) for \( t > T \)

So, \( S_1 \): one pulse PAM

\[
\begin{align*}
B & = A \\
B^2 T & = \frac{A^2 T}{16 N_0} \Rightarrow B = \frac{A}{4}
\end{align*}
\]