0) The ASCII code for character ‘A’ is 65₁₀, ‘B’ is 66₁₀, ... and ‘a’ is 97₁₀, ‘b’ is 98₁₀, ... .
a) What would be the 7-bit binary value used to represent ‘A’?

b) What would be the 7-bit binary value used to represent ‘a’?

c) How does an upper-case letter differ from its corresponding lower-case letter?

d) Even parity prepends a 0 or 1 so as to make the total number of 1’s be even. What is the 8-bit ASCII value for” ‘A’:

‘a’:

e) What error cannot be detected by even parity?

1) a) For the 8-bit data 01001011₂ develop the Hamming codeword for one-bit error detection and correction:

<table>
<thead>
<tr>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>D₁₂</td>
<td>D₁₁</td>
<td>D₁₀</td>
<td>D₉</td>
<td>D₈</td>
<td>D₇</td>
<td>D₆</td>
<td>D₅</td>
<td>D₄</td>
<td>D₃</td>
<td>D₂</td>
<td>D₁</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Check bit P₁ looks at bit positions 1, 3, 5, 7, 9, and 11
Check bit P₂ looks at bit positions 2, 3, 6, 7, 10, and 11
Check bit P₄ looks at bit positions 4, 5, 6, 7, and 12
Check bit P₈ looks at bit positions 8, 9, 10, 11, and 12

b) If bit D₅ gets flipped (an error), then how would we be able to detect an error?

c) If bit D₅ gets flipped (an error), then how would we be able to know which bit to correct?

d) For the 8-bit data 11001001₂ develop the Hamming codeword for one-bit error detection and correction:

<table>
<thead>
<tr>
<th>12</th>
<th>11</th>
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<th>7</th>
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<td>D₈</td>
<td>D₇</td>
<td>D₆</td>
<td>D₅</td>
<td>D₄</td>
<td>D₃</td>
<td>D₂</td>
<td>D₁</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

4+8 1+2+8 2+8 1+8 8 1+2+4 2+4 1+4 4 1+2 2 1
2) The CRC, Cyclic Redundancy Check, are used to detect errors in long data transmissions/blocks that are subject to burst errors (several bits in sequence that are corrupted). The main idea is to append to the data-bits a small (16 or 32 bits) amount of information to help detect errors. Retransmission of the data is done if an error is detected.

The basic calculation of the CRC is integer division.

\[
\begin{array}{c}
\text{quotient} \\
\text{G} \\
\text{D} \\
\text{remainder} \\
\text{R} \\
\text{divisor} \\
\text{dividend} \\
\end{array}
\]

26 remainder 4

\[
5 \left\lfloor \frac{134}{5} \right\rfloor
\]

a) What is the quotient of \((D - R) / G\)?

b) What is the remainder of \((D - R) / G\)?

c) What is the range of the remainders of \(D / G\)?

Assume the sender and receiver agree on \(G\) and the sender sends:

\[
\begin{array}{c|c}
\text{D} & \text{R} \\
\hline
\text{D} & \text{R} \\
\hline
\end{array}
\]

If the receiver performs the calculation \((D - R)/G\), what would the remainder be if no transmission error occurred?

To simplify calculations all CRC calculations are done in modulo-2 arithmetic without carries in addition or borrows in subtraction. Therefore, both addition and subtraction are identical and equivalent to bitwise XOR (exclusive OR). For example,

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>XOR</th>
<th>1100</th>
<th>1100</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>−1010</td>
<td>+1010</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0110</td>
<td>0110</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Let $D = d$-bit data, $G = d$-degree polynomial generator, e.g., $G = x^5 + x^2 + 1$ is 100101_2

$R = n$-bit remainder, $C = (d+n)$-bit codeword to be transmitted

The goal is to generate $C$ such that $C / G$ would have no remainder. To do this, we generate $R$ as 

$$\frac{D \times 2^n}{G} = Q \oplus \frac{R}{G},$$

where $Q$ is the quotient and $R$ is the remainder.

The sender sends the codeword $C = D \times 2^n \oplus R$. When the receiver receives $C$, it divides by $G$,

$$\frac{C}{G} = \frac{D \times 2^n \oplus R}{G} = \frac{D \times 2^n}{G} \oplus \frac{R}{G} = Q \oplus \frac{R}{G} = Q \oplus \frac{R \oplus R}{G}.$$ 

\[\text{e) What is } R \oplus R?\]

Let

$D = 10100101$ (8-bit data),

$G = x^5 + x^2 + 1$ is 100101_2 (degree 5 polynomial)

\[\text{f) Determine the remainder of } \frac{D \times 2^n}{G}.\]

\[\begin{array}{rcccccccccc}
1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 \\
1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0
\end{array}\]

append n 0's since we start with $D \times 2^n$
g) The codeword sent is the data appended with the remainder, so what codeword is sent by the sender in part f?

h) Divide the codeword by the generator $G = x^5 + x^2 + 1$ (1001012) to check for an error. Remainder should be zero if no errors.

i) Introduce some random error into the codeword and check for an error by dividing by the generator $G = x^5 + x^2 + 1$ (1001012)