Team #:______ Name:____________________

Absent:

0) The ASCII code for character 'A' is 65_{10}, 'B' is 66_{10}, ... and 'a' is 97_{10}, 'b' is 98_{10}, ...

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 01001011_2 develop the Hamming codeword for one-bit error detection and correction:

12	11	10	9	8	7	6	5	4	3	2	1
D_7	D_6	D_5	D_4	P_8	D_3	D_2	D_1	P_4	D_0	P_2	P_1
0	1	0	0		1	0	1		1		
4+8	1+2+8	2+8	1+8	8	1+2+4	2+4	1+4	4	1+2	2	1

Check bit P_1 looks at bit positions 1, 3, 5, 7, 9, and 11

Check bit P_2 looks at bit positions 2, 3, 6, 7, 10, and 11

Check bit P_4 looks at bit positions 4, 5, 6, 7, and 12

Check bit P_8 looks at bit positions 8, 9, 10, 11, and 12

b) If bit D_5 gets flipped (an error), then how would we be able to detect an error?

c) If bit D_5 gets flipped (an error), then how would we be able to know which bit to correct?

d) For the 8-bit data 11001001_2 develop the Hamming codeword for one-bit error detection and correction:

12	11	10	9	8	7	6	5	4	3	2	1
D_7	D_6	D_5	D_4	P_8	D_3	D_2	D_1	P_4	D_0	P_2	P_1
0	1	0	0		1	0	1		1		
4+8	1+2+8	2+8	1+8	8	1+2+4	2+4	1+4	4	1+2	2	1

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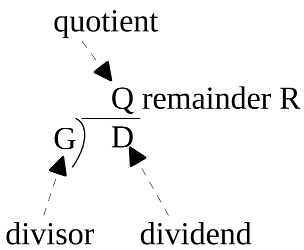
2) The CRC, Cyclic Redundancy Check, are used to detect errors in long data transmissions/blocks that are subject to burst errors (several bits in sequence that are corrupted). The main idea is to append to the data-bits a small (16 or 32 bits) amount of information to help detect errors. Retransmission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

The basic calculation of the CRC is integer division.



$$5\overline{\smash{)}134}\quad 26 \text{ remainder } 4$$

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:

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,

A	B	XOR
0	0	0
0	1	1
1	0	1
1	0	0

$$\begin{array}{r} 1100 \\ -\,1010 \\ \hline 0110 \end{array} \qquad \begin{array}{r} 1100 \\ +\,1010 \\ \hline 0110 \end{array}$$

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Let

D = d-bit data

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

e) What is $R \oplus R$?

Let

D = 10100101_2 (8-bit data),

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

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

```
                     1
 1 0 0 1 0 1 ) 1 0 1 0 0 1 0 1 0 0 0 0 0
               1 0 0 1 0 1       ---------
               -----------
                   1 1 0 0
```

append n 0's since we start with $Dx2^n$

```
                     1 0 1
 1 0 0 1 0 1 ) 1 0 1 0 0 1 0 1 0 0 0 0 0
               1 0 0 1 0 1 ↓ ↓
               -----------
                   1 1 0 0 0 1
                   1 0 0 1 0 1
                   -----------
                     1 0 1 0 0
```

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