1. (a) $X \oplus Q_B = \overline{Q_A} (t+1)$  

<table>
<thead>
<tr>
<th>$X$</th>
<th>$Q_A$</th>
<th>$Q_B$</th>
<th>$\overline{Q_A} (t+1)$</th>
<th>$Q_B (t+1)$</th>
<th>$X \oplus Q_B$</th>
</tr>
</thead>
<tbody>
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(b) 

(c) Min. period = Max. FF delay + Max. XOR delay + Min. Setup time = 30 ns + 18 ns + 25 ns = 73 ns

Max. Frequency = $\frac{1}{\text{period}} = \frac{1}{73 \text{ns}} = 13.7 \text{ MHz}$

(d) $00 \rightarrow 10 \rightarrow 11 \rightarrow 01 \rightarrow 00$ etc. This is counting backward in Grey code.

(e) The input could cause $D_A$ to change within the setup time prior to the clock pulse when the input should be stable. This could lead to metastability in the $D$ flip-flop (it could get "stuck" in some improper state for an unknown length of time). A remedy is to include one or more $D$ flip-flops synchronized with the system clock between $X$ and the XOR input node.
2. (a) Leading edge triggered

(b) Transition map: \( F = 2 \)

\[ F = 2: \]
\[
\begin{array}{cc}
00 & 01 & 10 \\
0 & \alpha & \beta \alpha \\
1 & 0 & \beta \\
\end{array}
\]

\[ J_2 = \overline{x} + Q_1 \]
\[ (= \overline{x} \overline{Q_1}) \]

(c) \[ \begin{aligned}
Y &= \overline{x} \overline{Q_1} + \overline{x}Q_1Q_2 + x \overline{Q_1}Q_2 \\
&\text{(K. map no help)}
\end{aligned} \]
ii) Yes since charge remains on \( C \), \( i(t) \approx 0 \) since \( i(t) \) into \(-\text{input} + \text{op-amp} = 0\).

v) \(-\text{input} < +\text{input} \) so \( G \) is high.

(c) i) Now \( i(t) = -V_{\text{REF}}/R = -C \frac{dV_{\text{out}}}{dt} \)

\[
\frac{dV_{\text{out}}}{dt} = \frac{V_{\text{REF}}}{RC}
\]

ii) \( t = \left| \frac{V_{\text{out}}(t) - V_{\text{REF}}}{\frac{dV_{\text{out}}}{dt}} \right| = \frac{QR}{V_{\text{REF}}} = \frac{QR}{V_{\text{REF}}}
\]

iii) When \( V_{\text{out}} \) slightly exceeds 0 V, \( G \) goes low and the clock pulse to the counter is gated off. The clock had been gated on when \( W \) went high (with the counter reset) when switch \( Y \) was closed allowing the capacitor to start charging. Thus the number of counts = \( t/\text{clock period} \).

iv) \( N = \frac{t}{T} = \frac{QR}{V_{\text{REF}}T} = \frac{QR}{V_{\text{REF}}} f \propto Q \)

( \( T \) = clock period)