Short questions

13.(a) What is clock tick?
Ans: Each oscillation of the crystal decrements the counter by one. When the counter gets to zero, an interrupt is generated and the counter is reloaded from the holding register. In this way, it is possible to program a timer to generate an interrupt 60 times a second, or at any other desired frequency. Each interrupt is called one **clock tick.**

13.(b) Difference between logical vs physical clock
Ans: For many purposes, internal consistency of clocks suffices, even if the time does not match real-world time exactly. Clocks in this context are called **logical clocks.**
When clocks must align closely with real-world time, they are referred to as **physical clocks**

13.(c) Define Lamport's Happens-Before Relation.
Ans: To synchronize logical clocks, Lamport introduced the happens-before relation, denoted as "a happens before b" ($a \rightarrow b$). This relation is observed in two scenarios:

If events a and b occur in the same process and a happens before b, then $a \rightarrow b$.
If event a is the sending of a message by one process and event b is its receipt by another process, then $a \rightarrow b$ since a message cannot be received before it is sent.

The happens-before relation is transitive, meaning if $a \rightarrow b$ and $b \rightarrow c$, then $a \rightarrow c$. If events x and y occur in different processes without exchanging messages, they are concurrent, meaning neither $x \rightarrow y$ nor $y \rightarrow x$ holds.

Long question

13.(a) Consider the behavior of two machines in a distributed system. Both have clocks that are supposed to tick 1000 times per millisecond. One of them actually does, but the other ticks only 990 times per millisecond. If UTC updates come in once a minute, what is the maximum clock skew that will occur?

Ans: To find the maximum clock skew between the two machines in a distributed system, we need to calculate the difference in their clock ticks over the period between UTC updates. Let's break it down step-by-step:

1. **Clock Tick Rates:**
   Machine A ticks at the correct rate of 1000 times per millisecond.
   Machine B ticks at 990 times per millisecond.
2. **Time Between UTC Updates:**

   UTC updates occur once every minute (60,000 milliseconds).

3. **Clock Ticks Over One Minute:**

   Machine A (correct rate) ticks:

   $$1000 \text{ ticks/ms} \times 60{,}000 \text{ ms} = 60{,}000{,}000 \text{ ticks}$$

   Machine B (slower rate) ticks:

   $$990 \text{ ticks/ms} \times 60{,}000 \text{ ms} = 59{,}400{,}000 \text{ ticks}$$

4. Difference in Ticks:

Difference in clock ticks between the two machines over one minute:

$$60{,}000{,}000 - 59{,}400{,}000 = 600{,}000 \text{ ticks}$$

5. **Convert Ticks to Time (Milliseconds):**

- Since Machine A ticks 1000 times per millisecond, the difference in time corresponding to 600,000 ticks is:

$$600{,}000 \text{ ticks} / 1000 \text{ ticks/ms} = 600 \text{ ms}$$

Therefore, the maximum clock skew that will occur between the two machines before the next UTC update is **600 milliseconds**.