Atomic Clock

Source: TH

Why in News?

In a recent study published in the scientific journal **Nature**, a new type of portable **Optical** atomic clock was introduced for use on ships.

- This new **iodine clock** is **not as precise** as an optical atomic clock used in a laboratory but it is **more portable and durable.** It gains or loses a second every 9.1 million years.

What are Atomic Clocks?

- **About:**
  - It is an advanced timekeeping device that utilises the **natural vibrations of atoms** to measure time with **exceptional accuracy.**
  - It was developed by Louise Essen in 1955. Presently, **India has operational atomic clocks located in Ahmedabad and Faridabad**.
- **Key Features:**
  - Atomic clocks are **far more precise** than conventional clocks because atomic oscillations have a much **higher frequency** and are much **more stable.**
  - **Atomic clocks** are very accurate, with traditional atomic clocks **losing or gaining one second over 300 million years**, while **optical atomic clocks** can maintain this **precision for 300 billion years.**
  - A **caesium atomic clock** loses or gains a second every 1.4 million years.
- **Working:**
  - **Caesium (Cs) atomic clocks** operate by causing **Cs atoms to transition to a higher energy level,** which is linked to the **frequency of microwave radiation** and the measurement of time in seconds.
  - In this process, Cs atoms are placed in a cavity, and **microwave radiation** with a specific frequency is directed towards them. When the frequency of the radiation **matches** the **energy transition** of the Cs atoms, it creates a **resonance phenomenon**. The Cs atoms absorb this radiation and move to a higher energy state. This transition occurs precisely when the **frequency** of the radiation is **9,192,631,770 Hz.**
    - This means that when a Cs-133 atom undergoes 9,192,631,770 oscillations between its energy levels, one second has elapsed.
  - The **precision** of atomic clocks is achieved through a system that detects any deviations in the resonance frequency and makes adjustments to the microwave radiation to maintain resonance.

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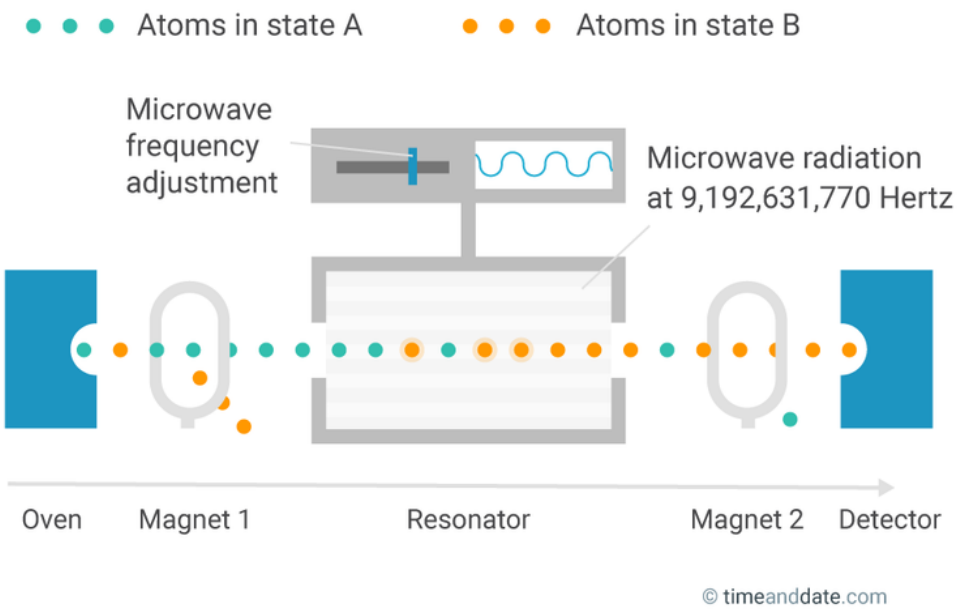

- **Optical Atomic Clock:**
  - They are even **more accurate** than Atomic Clocks.
  - These clocks use **lasers** to stimulate atomic transitions, producing **highly coherent light** where all emitted light waves have the same frequency and stable wavelengths.
  - It is different from Atomic Clock due to:
    - **Higher Operating Frequency**: Optical atomic clocks operate at higher frequencies, allowing them to **complete more oscillation**s in a given time frame compared to traditional atomic clocks.
      - This enables them to **measure smaller increments of time more accurately** due to the increased number of cycles counted within that time period.
    - **Narrower linewidth:** These have much **narrower linewidths** (range of frequencies) over which the atomic transition occurs. A narrower linewidth makes it easier to precisely tune the frequency of the optical light that triggers the resonance, leading to higher accuracy and more precise time measurements.
  - The element **strontium (Sr) is commonly used in optical atomic clocks** due to its narrow linewidths and stable optical transitions.

What are the Applications of Optical Atomic Clocks?

- **Self-Reliance and National Security: India's reliance on foreign atomic clocks,** especially those from the US, poses a **risk to critical infrastructure like** NavIC **(Indian GPS)** in times of conflict.
  - Creating domestic atomic clocks will provide independent timekeeping, enhancing national security.
- **Enhanced Accuracy and Reliability:** Atomic clocks offer unmatched precision compared to conventional methods. By deploying them across the nation, India can **synchronise all digital devices** with Indian Standard Time (IST), ensuring a unified and highly accurate time reference.
- Time synchronisation through optical atomic clocks will benefit various sectors:
  - **Telecommunications:** Precise timing **minimises errors** and facilitates seamless data transfer in communication networks.
  - **Financial Systems:** Accurate timestamps for financial transactions **safeguard against fraud, especially in high-frequency trading.**
  - **Cybersecurity:** Atomic clocks play a crucial role in India's digital economy by ensuring the **accuracy of timestamps for transactions**, which helps prevent fraud, maintain data integrity, and enhance cybersecurity measures.
  - **Critical Infrastructure and Power Grids:** Atomic clocks play a vital role in

synchronising critical infrastructure, including power grids, transportation systems, and emergency services.

UPSC Civil Services Examination, Previous Year Question (PYQ)

Prelims:

Q.1 Which one of the following countries has its own Satellite Navigation System? (2023)

a. Australia
b. Canada
c. Israel
d. Japan

Ans: d