Topics

- Atomic clocks
- Quantum science - international year of quantum science
- Pantanal
- Criminal justice system
- Mains

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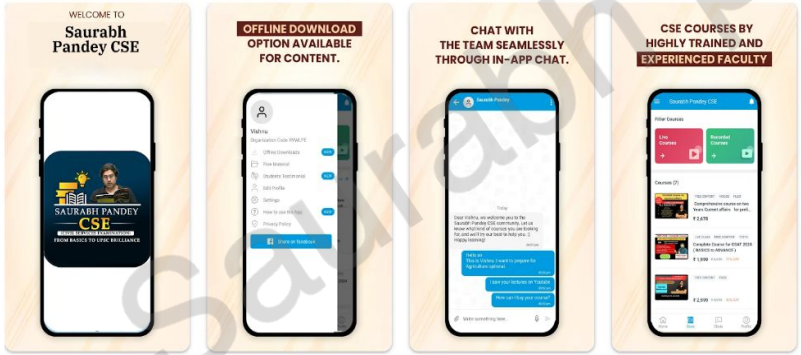

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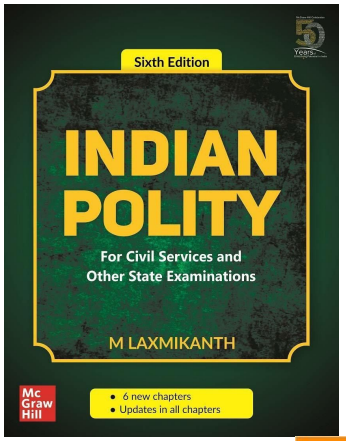

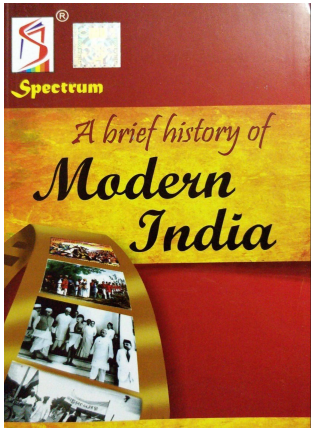

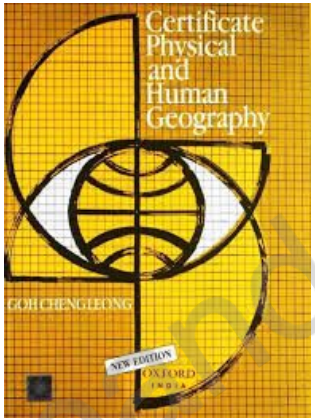

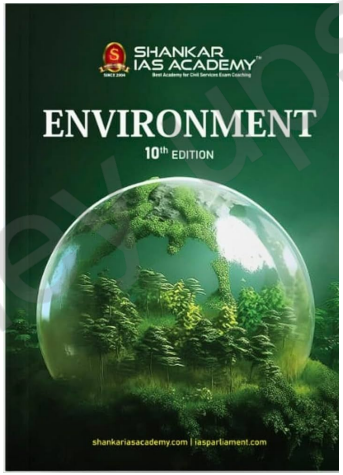

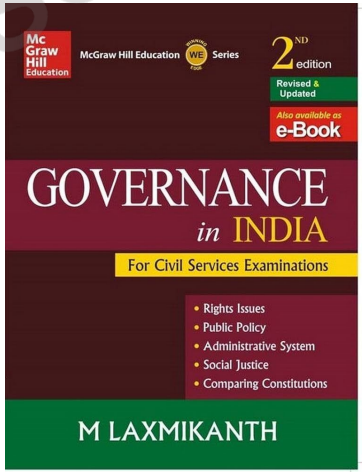

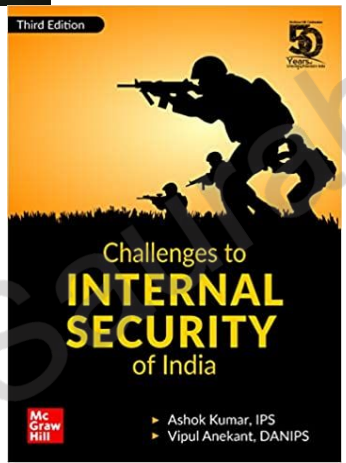

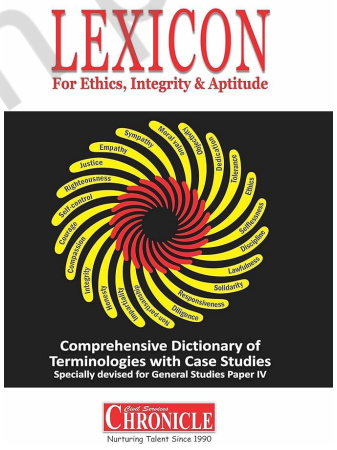

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New portable atomic clock offers very accurate timekeeping at sea

Researchers have build a portable optical atomic clock that can be used onboard ships. While it traded some accuracy for size and robustness, it was still more accurate than other vessel-borne timekeeping options. According to the researchers, it is the most performant optical clock at sea

Tejasri Gururaj

Atomic clocks are the backbone of the Global Positioning System (GPS), the network of satellites above the earth that we use every day to navigate cities, respond to emergencies, and organise military operations, among other things.

Despite being one of the most accurate timekeeping methods, however, there is still room for improvement. Scientists today are pushing the boundaries with a new technology called optical atomic clocks.

But for being such sophisticated instruments, both these clocks are also bulky, power-hungry, fragile, and expensive. As a result, their installation and operations are often restricted to big research facilities.

A study recently published in the journal *Nature* introduced a kind of portable optical atomic clock that can be used onboard ships. While these devices traded some accuracy for size and robustness, they were still more accurate than other vessel-borne timekeeping options.

According to the researchers, this is the most performant optical clock based at sea and represents a significant advancement in optical timekeeping.

A server rack containing three independent optical clocks, a 1-U power supply, a control laptop for each clock, an uninterruptable power supply, and a measurement system were loaded in a total rack volume of 23 U. The cargo container housing the rack was craned onto the deck of the HMNZS Aotearoa, where it remained for a three-week naval exercise. NATURE 628, PAGES 736–740 (2024)

The working of an atomic clock

Atomic clocks work by keeping time using atoms. One popular design uses atoms of an isotope of caesium, Cs-133. The International Committee for Weights and Measures first used it in 1967 to define the duration of one second. India also uses a Cs-133 atomic clock to define the second for timekeeping within its borders.

Cs-133 is a highly stable atom and is found naturally, which is why it is so commonly used in atomic clocks.

Atomic clocks exploit a fundamental property of all atoms: their ability to jump between different energy levels. Energy levels are like the steps of a ladder. An atom climbs up the ladder by absorbing energy, like electromagnetic radiation.

In a Cs atomic clock, the energy needed for the atom to jump to a higher energy level matches the frequency of microwave radiation. This frequency is related in some fully understood way to the duration of a second.

First, researchers keep the Cs atoms in a cavity, to which microwave radiation of a specific frequency is applied. When the frequency of this radiation matches the transition energy of the Cs atoms, the match-up is called a resonance.

The Cs-133 atoms absorb this radiation and jump to a higher energy level. This transition only happens when the frequency of the applied radiation is equal to 9,192,631,770 Hz.

Put another way, when the Cs-133 atom completes 9,192,631,770 oscillations between the two energy levels, one second will have passed.

The accuracy of atomic clocks comes from a feedback mechanism that detects any changes in the resonance frequency and adjusts the microwave radiation to maintain resonance.

Thus, a caesium atomic clock loses or gains a second every 1.4 million years.

Optical atomic clocks use lasers

Optical atomic clocks are even more optical light that produces the resonance. This leads to higher accuracy because it enables more precise changes.

The most commonly used atom in optical atomic clocks is strontium (Sr): it has narrow linewidths and stable optical transitions.

Researchers at the Indian Institute of Science Education and Research, Pune, are working on a strontium optical atomic clock. Their peers at the Inter-University Centre for Astronomy and Astrophysics in the same city are developing a similar clock with ytterbium ions. These devices, once ready, will bring precision timekeeping in India to the optical regime.

Building a portable device

The researchers in the *Nature* study developed an optical atomic clock that uses molecular iodine as the frequency standard.

Traditional optical atomic clocks are large and not easy to transport. Scientists have previously attempted to make them portable. Those in the new study wished to fit them within a standardised rack, of the sort used in data centres, laboratories, and telecommunications facilities.

To do this, the team miniaturised the clock's spectrometer, laser system, and

> Despite the ship's motion, a temperature fluctuation of 2-3 degrees C, and 4-5% changes in humidity, the clocks were nearly as stable as they were in laboratory conditions for up to 1,000 s at a time

slender, flexible, transparent cables made of glass or plastic and which can transmit light over long distances. The system thus had a volume of only 1 litre, and operated with light of wavelength 1,064 nm.

A frequency comb is a device that generates a series of equally spaced optical frequencies. This provides a stable and accurate reference for tracking the atomic transitions and generating precise optical frequencies. The frequency comb occupied a volume of 0.5 litres.

The researchers also equipped the clock with a software control system that could autonomously initialise the clock from an 'off' state to a fully operational state. It monitors temperature, identifies specific transitions, activates some components, and ensures the system stays stable by continuously checking for just above the consumption of an incandescent light bulb.

Optical atomic clocks at sea

The researchers conducted initial tests at the U.S. National Institute of Standards and Technology (NIST) in April 2022. They operated two prototypes, called PICKLES and EPIC, autonomously for 34 days. The optical atomic clocks' accuracy fluctuated less over short periods, outperforming NIST's hydrogen maser ST05, one of the world's most accurate and stable atomic clocks, which is based on hydrogen atoms.

The optical atomic clocks also had 10x lower long-term drift compared to rubidium atomic clocks. This means that over long periods, the rate at which the clock's frequency changes is much lower compared to changes in rubidium atomic clocks. It is a sign of the compact clock's high stability.

The researchers also deployed the two clocks plus another, called VIPER, on a boat at Pearl Harbor in Hawaii to test them at sea. VIPER was built with a smaller spectrometer and a more simplified laser design.

Despite the ship's motion, a temperature fluctuation of 2-3 degrees C, and 4-5% changes in humidity, the clocks

Atomic clocks

- **Atomic clocks are the backbone of the Global Positioning System (GPS), the network of satellites above the earth that we use every day to navigate cities, respond to emergencies, and organise military operations, among other things.**
- **Despite being one of the most accurate timekeeping methods, however, there is still room for improvement.**
- **Scientists today are pushing the boundaries with a new technology called optical atomic clocks**

- The working of an atomic clock Atomic clocks work by keeping time using atoms.
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- India also uses a Cs-133 atomic clock to define the second for timekeeping within its borders.
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- Atomic clocks exploit a fundamental property of all atoms: their ability to jump between different energy levels.
- Energy levels are like the steps of a ladder.
- An atom climbs up the ladder by absorbing energy, like electromagnetic radiation.
- In a Cs atomic clock, the energy needed for the atom to jump to a higher energy level matches the frequency of microwave radiation.
- This frequency is related in some fully understood way to the duration of a second.

- **Microwaves are electromagnetic waves with frequencies in the range of 300–300000 MHz.**
- **Microwave radiation neither possesses ionizing characteristics nor produces changes in the molecular structure; it can be used to measure the movement of molecules**

- a caesium atomic clock loses or gains a second every 1.4 million years.

Optical atomic clocks use lasers

As part of an optical atomic clock, researchers use lasers to stimulate atomic transitions.

The lasers' light is highly coherent: the emitted light waves all have the same frequency and their wavelengths are related to each other in a way that doesn't change.

The result is light with more precise properties and great stability.

Optical atomic clocks use coherent light to achieve higher accuracy in two main ways. The first is the higher operating frequency of atomic clocks.

- The second reason is that optical atomic clocks have much narrower linewidths.
- The linewidth is the range of frequencies over which the transition occurs.
- The narrower the linewidth, the easier it is to tune the frequency of the optical light that produces the resonance.
- When the frequency of an externally applied periodic force an a body is equal to the natural frequency of the body
- This leads to higher accuracy because it enables more precise changes.
- The most commonly used atom in optical atomic clocks is strontium (Sr): it has narrow linewidths and stable optical transitions.

#55

CAESIUM

Cs

55 132.905

ATOMIC CLOCKS

Caesium atomic clocks are used to define the second, and help GPS and mobile phone networks function.

REACTIVE

Caesium is the most reactive metallic element. It ignites in air and reacts explosively with water.

DRILLING FLUID

The largest use of caesium is in the form of caesium formate, used as a drilling fluid for oil well drilling.

#IYPT2019

Quantum computers will have transformative effects on electronics, clean energy, and drug development. GETTY IMAGES/STOCKPHOTO

UN declares 2025 the Year of Quantum Science

The Hindu Bureau

The United Nations has said 2025 will be designated the 'International Year of Quantum Science and Technology'. In a statement, the body said the initiative will be "year-long", "worldwide", and that it will "be observed through activities at all levels aimed at increasing public awareness of the importance of quantum science and applications."

The proclamation is the result of a resolution led by Mexico in May 2023 and which was soon joined by other countries. By November that year, almost 60 countries had co-sponsored the resolution and the UNESCO General Conference adopted it. In May this year, Ghana submitted a draft resolution to the U.N. General Assembly asking for an official proclamation, with the support of over 70 other countries. The General Assembly acceded on June 7.

The timing isn't entirely coincidental. Next year will be a century since the German physicist Werner Heisenberg published a famous paper in which he reinterpreted a series of tweaks — required for classical mechanics to make sense of the quantum phenomena being discovered in the late 19th and early 20th centuries — to lay the foundation stone of what would come to be called quantum mechanics. He was awarded the Nobel Prize for physics seven years later, roughly around the time he devised his famous uncertainty principle.

According to the UN statement, the proclamation has also received the endorsements of the International Union

Next year will be a century since the German physicist Werner Heisenberg published a famous paper laying the foundation stone of what would come to be called quantum mechanics

of Pure and Applied Physics, the International Union of Pure and Applied Chemistry, the International Union of Crystallography, and the International Union of History and Philosophy of Science and Technology.

Quantum science and technologies have been featuring more often in public conversations and issues of late thanks to quantum computers. While fully operational machines of this type don't yet exist, researchers and industry experts believe it is a matter of time.

In line with this belief, the Government of India announced a 'National Quantum Mission' in April 2023 at a cost of Rs 6,000 crore, to be implemented from 2023 to 2031 by the Department of Science & Technology (DST). According to Akhilesh Gupta, a senior DST advisor and the head of the Mission, it will have four verticals: quantum computing, quantum communication, quantum sensing and metrology, and quantum materials and devices.

Many researchers expect functional quantum computers will have transformative effects on electronics, clean energy, and drug development, given their superior computational abilities.

According to the U.N. statement, its proclamation "is a signal for any individual, group, school, institution, or government to use 2025 as an opportunity to increase awareness about quantum science and technology." It added that a steering committee is also "planning global initiatives and events, particularly those that reach audiences unaware of the importance of quantum science and technology."

Physics World reported that an opening ceremony is expected to be conducted on

The United Nations has said 2025 will be designated the 'International Year of Quantum Science and Technology'.

What is Quantum science ??

- Quantum mechanics is a fundamental theory in physics that describes the behavior of nature at and below the scale of atoms.
- It is the foundation of all quantum physics, which includes quantum chemistry, quantum field theory, quantum technology, and quantum information science.

- Quantum mechanics can describe many systems that classical physics cannot.
- Classical physics can describe many aspects of nature at an ordinary (macroscopic and (optical) microscopic) scale, but is not sufficient for describing them at very small submicroscopic (atomic and subatomic) scales.
- Most theories in classical physics can be derived from quantum mechanics as an approximation valid at large (macroscopic/microscopic) scale

Screen of smoke

Hazy horizon: Smoke rises as trees burn in the Pantanal, the world's largest wetlands, in Corumba Brazil on Tuesday. REUTERS

Pantanal

- The Pantanal is a natural region encompassing the world's largest tropical wetland area, and the world's largest flooded grasslands.
- It is located mostly within the Brazilian state of Mato Grosso do Sul, but it extends into Mato Grosso and portions of Bolivia and Paraguay.
- The Pantanal is about 140,000–160,000 km^2 (54,000–62,000 sq mi), gently-sloped basin that receives runoff from the upland areas (the Planalto highlands) and slowly releases the water through the Paraguay River and tributaries.

- At more than 42 million acres, the Pantanal is the largest tropical wetland and one of the most pristine in the world.
- It sprawls across three South American countries—Bolivia, Brazil and Paraguay—and supports millions of people there, as well as communities in the lower Rio de la Plata Basin.
- The formation is a result of the large, concave pre-Andean depression of the Earth's crust, related to the Andean orogeny of the Tertiary.
- It constitutes an enormous internal river delta, in which several rivers flowing from the surrounding plateau merge, depositing their sediments and erosion residues, which have been filling, throughout the years, the large depression area of the Pantanal.

Arrest, agencies, and criminal courts

R.K. Vij

is a former Indian Police Service officer. Views are personal

The Supreme Court recently delivered two significant judgments that impact the liberty of people accused of criminal offences

The Supreme Court did not mince words in May 2024, while delivering two significant judgments that impact the liberty of people accused of criminal offences. The first judgment says that the custody of an accused is not necessary prior to the filing of the charge sheet in certain criminal cases. If the lower courts strictly comply with the directives in this judgment, it would bring relief to investigating agencies.

The second judgment relates to informing an accused of the grounds of arrest in writing. This is a fundamental right under Article 22 of the Constitution. While this judgment was delivered in the context of special statutes – namely, the Prevention of Money Laundering Act (PMLA), 2002, and the Unlawful Activities (Prevention) Act (UAPA), 1967 – it will be relevant to see whether these directives can equally be extended to provisions of the Criminal Procedure Code (CrPC) as far as communication of grounds of arrest is concerned.

Filing of charge sheet

In *Siddharth v. State of Uttar Pradesh and Another* (2021), the Supreme Court held that it is unnecessary for the investigating officer (IO) to present the accused in custody at the time of filing the charge sheet if the accused has been cooperating in the investigation and if the investigation can be completed without arresting the accused. The Court held that Section 170 of the CrPC does not impose an obligation on the officer-in-charge of a police station to arrest each and every accused at the time of filing the charge sheet. Therefore, it is not justified under law for criminal courts to refuse to accept the charge sheet without the accused person being produced before them. The Court further said that if the charge sheet is not accepted for any such reason, then attention of the Sessions Judge should be drawn to these facts and a suitable order given.

This implies that in bailable cases and in those non-bailable cases in which the IO thinks that the accused will neither abscond nor disobey summons, the IO is not obliged to produce such an accused in custody while filing the charge sheet in court.

However, the reality is that the IOs sometimes struggle to file charge sheets in criminal courts. In cases of riots, when there are a large number of accused people and every accused person released on bail by the police is not present at the time of filing the charge sheet, the charge sheet is not accepted by the court. Sometimes, courts don't accept the charge sheet of cases beyond an arbitrarily fixed number in one day, or after a particular time in a day. The IOs are reluctant to complain about these issues to a Sessions Judge because this might prove counter-productive for other miscellaneous works at the ground level. Though the *Siddharth v. State of Uttar Pradesh* judgment was delivered more than two years ago, the situation does not seem to have changed much.

Grounds of arrest

In *Pankaj Bansal v. Union of India and Others* (2023), the Supreme Court held that the grounds of arrest must be informed in writing to the accused as a matter of course and without exception, to give true meaning and purpose to the constitutional and statutory mandate of Section 19(1) of the PMLA. Similarly, recently in *Prabir Purkayastha v. State (NCT of Delhi)*, the Court reiterated the ratio of Bansal (supra) case and held that the provision of arrest, as far as informing grounds of arrest is concerned, is *pari passu* (equal footing) under the UAPA. The Court held that the 'reasons of arrest' are purely formal parameters which commonly apply to any person arrested on charge of a crime whereas the 'grounds of arrest' would be invariably personal and required to contain details which necessitated the arrest of the accused. Therefore, unless grounds of arrest are informed in writing, arrest and subsequent remand would become invalid in the eyes of law.

Importantly, Section 50(1) of the CrPC also provides that "every police officer or other person arresting any person without warrant shall forthwith communicate to him full particulars of the offence for which he is arrested or other grounds of arrest". Therefore, even for offences registered under the Indian Penal Code (IPC), an accused is required to be informed about the grounds of arrest, along with important facts of the case. The burden lies on the prosecution to prove that the statutory provisions have been complied with.

The arrest memo prepared by the IO contains a note which says "the arrested person, after being informed of the grounds of arrest and his legal right, was duly taken into custody". The arrest memo which is written separately for each accused contains inter alia all sections of offence(s) applied, date of offence, place, and time and date of arrest, and is signed by the IO. It is also counter signed by the arrestee. However, there is no provision in law to provide a copy of this memo to the accused person at the time of his arrest. This becomes more relevant for those who are not named in the First Information Report.

The Court has said that the grounds of arrest must be provided in writing so that the accused person can seek legal counsel and seek bail on the basis of unambiguously stated facts of the case by the investigating agency. If that be so, the ratio of the Bansal case (supra) must equally apply to Section 50(1) of the CrPC, particularly when such a right is held to flow from Article 22 of the Constitution. It will be apposite to amend the law and provide a copy of the arrest memo with some modification to fulfil the constitutional mandate towards an accused person.

Criminal justice system - important facts

- The first judgment says that the custody of an accused is not necessary prior to the filing of the charge sheet in certain criminal cases.
- If the lower courts strictly comply with the directives in this judgment, it would bring relief to investigating agencies.
- The second judgment relates to informing an accused of the grounds of arrest in writing.
- This is a fundamental right under Article 22 of the Constitution. While this judgment was delivered in the context of special statutes — namely, the Prevention of Money Laundering Act (PMLA), 2002, and the Unlawful Activities (Prevention) Act (UAPA), 1967 —

- **Article 22(1) – Any person who is in custody has to be informed as to why he has been arrested. Further, he cannot be denied the right to consult an advocate.**
- **Article 22(2) – The arrested individual should be produced before a judicial magistrate within 24 hours of his arrest.**

- In Siddharth v. State of Uttar Pradesh and Another (2021), the Supreme Court held that it is unnecessary for the investigating officer (IO) to present the accused in custody at the time of filing the charge sheet if the accused has been cooperating in the investigation and if the investigation can be completed without arresting the accused.
- The Court held that Section 170 of the CrPC does not impose an obligation on the officer-in-charge of a police station to arrest each and every accused at the time of filing the charge sheet.

- **In Pankaj Bansal v. Union of India and Others (2023), the Supreme Court held that the grounds of arrest must be informed in writing to the accused as a matter of course and without exception, to give true meaning and purpose to the constitutional and statutory mandate of Section 19(1) of the PMLA.**

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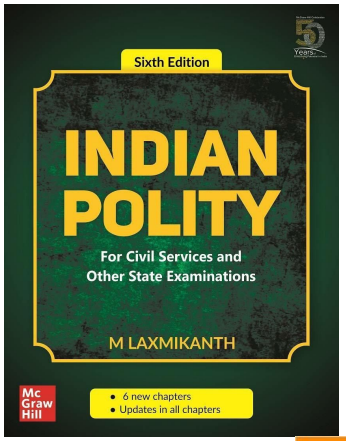

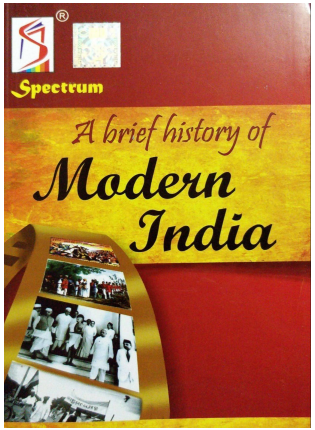

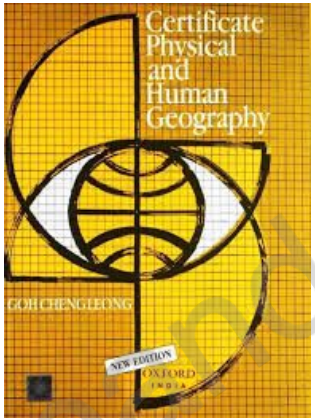

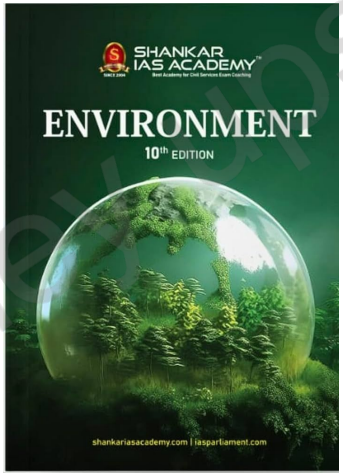

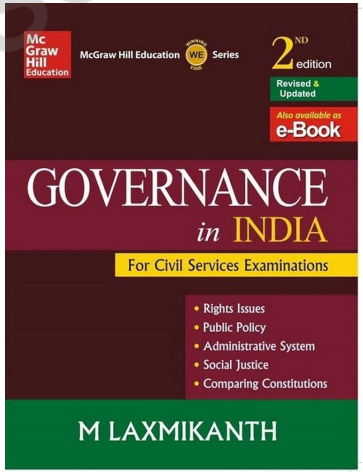

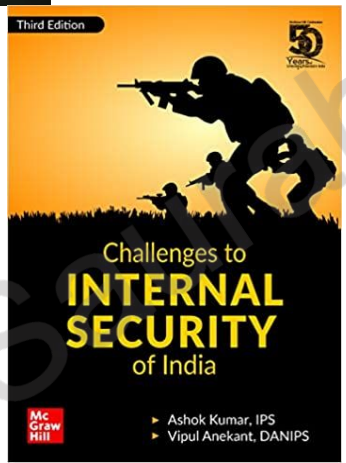

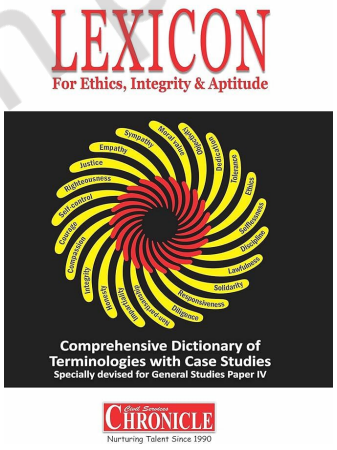

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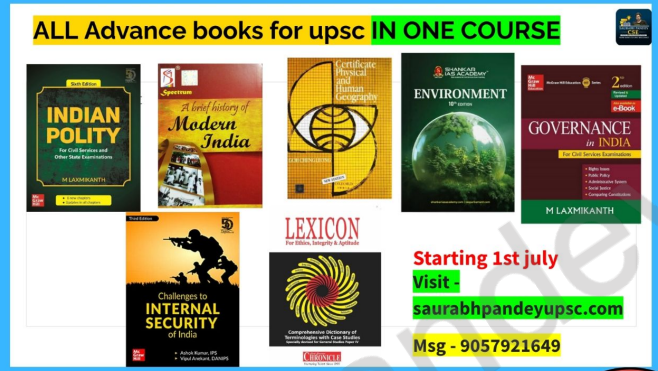

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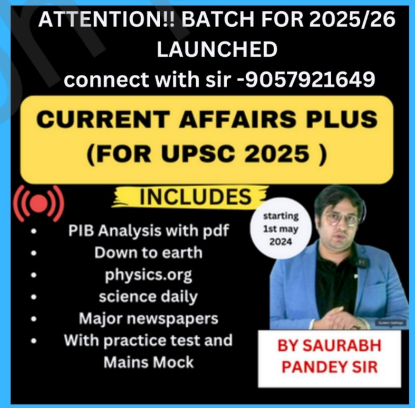

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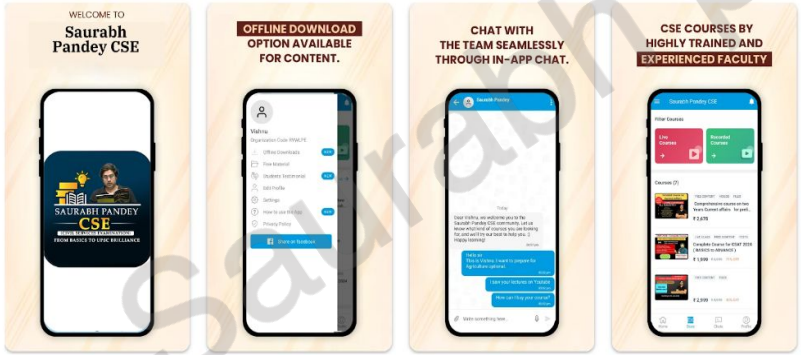

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