

# Mathura mosque: SC stays HC decision on inspection panel

The Allahabad High Court order to appoint one was passed on an 'omnibus, vague' application for survey of Shahi Idgah mosque, the SC says and orders against setting up of the commission; case listed for further hearing on January 23

**Krishnadas Rajagopal**  
NEW DELHI

**T**he Supreme Court on Tuesday stopped the execution of an Allahabad High Court decision to appoint a commission to inspect the premises of the Shahi Idgah mosque at Mathura which the Hindus believe to be the birthplace of Lord Krishna.

A Bench of Justices Sanjiv Khanna and Dipankar Datta said the High Court order was passed on an "omnibus, vague" application for inspection of the mosque premises.

## 'Clear, specific'

"You have to be very clear, very specific why you need the appointment of a commission under Order 26 Rule 9 of the Code of Civil Procedure (CPC)... Your prayer was vague... You cannot make an omnibus application for a Commission," Justice Khanna addressed senior advocate Shyam Divan, who represented the Hindu plaintiffs.



The court, however, did not interfere with the proceedings of the plea filed by the Hindu plaintiffs to declare the premises as Sri Krishna Janmabhoomi. ANI

The court ordered against the setting up of the commission.

"The commission will not be executed," Justice Khanna dictated the order of the Bench.

However, the Supreme Court did not interfere with the pending proceedings under Order 7 Rule 11 of the CPC on the maintenance of the suit filed by the Hindu plaintiffs for a declaration that a temple once stood at the place of the mosque and the consecration of the premises as Sri Krishna Janmabhoomi.

The top court was hearing an appeal filed by the mosque committee against the High Court order in December for appointment of the commission.

The court listed the case for further hearing on January 23.

Advocate Tasneem Ahmadi, appearing for the mosque management, argued that the High Court ought not to have given an interim relief by appointing the commission when the very maintenance of the suit was still undecided and pending.

Ms. Ahmadi referred to the Supreme Court's observation in its judgment in *Asma Lateef versus Shabbir Ahmad*.

The court had stated that "where interim relief is claimed in a suit before a civil court and the party to be affected by grant of such relief, or any other party to the suit, raises a point of maintainability thereof or that it is barred by law and also contends on that basis that interim relief should not be granted, grant of relief in whatever form, if at all, ought to be preceded by formation and recording of at least a *prima facie* satisfaction that the suit is maintainable or that it is not barred by law."

Justice Khanna acknowledged that "some legal issues, including the question in light of the judgment of the Supreme Court in the *Asma Lateef* case, arise for consideration".

## J&K L-G names Baramulla stadium after General Rawat

J&K Lieutenant Governor (L-G) Manoj Sinha on Tuesday named the Baramulla stadium after former Chief of Defence Staff General Bipin Rawat, and urged the locals to participate in the 'Jhanda Ooncha Rahe Hamara' programme on the coming Republic Day. "I want the skies of Baramulla to be filled with the *Tiranga* (tricolour)," Mr. Sinha said. Earlier, he paid homage to General Rawat and described him as a "brave soldier and military strategist". Mr. Sinha also hinted at urban local bodies and panchayat elections. "After reservation process for OBCs is completed, elections will be held," he said.

# India, China tensions continued through 2021, 2022, new details reveal

**Dinakar Peri**  
NEW DELHI

Tensions between India and China along the Line of Actual Control (LAC) continued through 2021 and till 2022-end, against the backdrop of the stand-off in eastern Ladakh and continued attempts by China to ingress into Indian territory, new details have revealed.

The Army has presented gallantry awards to personnel for acts of bravery in this regard at two investiture ceremonies held in the past few days. One such act involved relaying of live feed from the enemy side in the Sikkim area by a Major-rank officer for 120 hours for which he was awarded the Sena Medal (Gallantry).

The citation for this November 2022 incident which was read at the Central Command investiture ceremony also noted the tough conditions and high-altitude area in which the officer operated.

As the fresh details of the tensions between the two nuclear-armed neighbours became public, the Army's Western Command quickly pulled down the video of the investiture ceremony, while that of the Central Command was available when last accessed by this reporter.



People Liberation Army soldiers and tanks during military disengagement at the India-China border in Ladakh. FILE PHOTO

The ceremony was for operations between September 2021 and November 2022.

Other citations reveal clashes between troops at Shankar Tekri in January 2022 and another in November 2022 as the People's Liberation Army (PLA) troops attempted to lay siege on the Atari post after crossing the LAC.

In the first combat fatalities in 45 years, 20 Indian soldiers were killed in a violent clash after they were attacked by the Chinese troops in the Galwan Valley on the night of June 15, 2020 during a "de-escalation" process after a month-long stand-off between troops at several points in eastern Ladakh and Sikkim. Further, shots were fired at the south bank of the Pangong Lake in August-September but

no injuries were reported. It was the first time since 1975 that shots were fired along the LAC.

Around the end of August 2020, the Army was in intense action to gain tactical advantage over the PLA on the north and south banks of Pangong Tso after they made deep ingress into Indian territory. Tanks from both sides were just couple of hundred metres from each other.

Speaking of the situation on the northern borders with China, Army chief General Manoj Pande said last week that the situation was "stable but sensitive". "We continue to talk to find a solution to address the balance issues between the two sides. Operational preparedness is very high, and deployment is both robust and balanced..." he stated.

## Historic hearing

A provisional order by ICJ on Israel will cast shadow on legitimacy of its war

Whatever the outcome of the preliminary hearing at the International Court of Justice (ICJ) at The Hague, South Africa's case against Israel's ongoing military campaign in Gaza has garnered global attention in a way no proceeding at this elite inter-state forum may have done before. As the 15-member court assembled, along with two ad hoc judges representing South Africa and Israel, quite a bit of history must have weighed on the parties. Of the two countries on either side of this dispute over whether the Gaza war is aimed at wiping out the people, one has left behind its apartheid past, but believes that the other is practising 75 years of 'apartheid' against the Palestinian people since 1948; one firm in its belief that it is acting in the interest of justice and humanity, the other equally firm in its belief it can never be accused of genocide, a crime that was sought to be prevented by the Genocide Convention of 1948, a treaty to prevent the sort of Holocaust the Jewish people had suffered. Both countries spent many years in the last century in diplomatic isolation, as countries and sporting bodies boycotted them, but both had the support of their western allies. Today, save for those few allies, the entire world supports a ceasefire in Gaza to end the epic suffering of its people.

At this preliminary stage, South Africa sought to demonstrate that some of Israel's acts were capable of falling within the terms of the Genocide Convention and that there was 'genocidal intent' behind its acts. It relied on data on deaths and destruction and the collapse of civilian life and health infrastructure in Gaza. It drew upon statements attributed to key Israeli government figures to underscore what it called 'genocidal intent'. The provisional measures sought include a suspension of military operations and steps by the parties to prevent the occurrence of genocide. Israel described the South African case as 'blood libel' before the hearing, but sought to make a case that its Gaza operations were a legitimate response to the terrorist attack on October 7 last year. It played down the relevance of its leaders' statements, calling them mere rhetoric. It attributed the civilian casualties to Hamas using civilians as shields and hospitals as storage for explosives and launching pads for attacks. The issue before the court is quite straightforward, but the larger concern is whether Israel will abide by any provisional measure. Russia ignored an ICJ order to suspend its operations in Ukraine in March 2022. However, there is little doubt that any provisional measure will cast a shadow on the legitimacy of Israel's Gaza war.



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## **Vote for continuity**

**Status quo seems to suit Taiwan best in its relationship with China**

**T**he Democratic Progressive Party's (DPP) victory in Taiwan's presidential elections for a historic third consecutive term reflects a vote for continuity from the 14 million voters, most of whom favour a maintenance of the fragile status quo in relations with China and the preservation of Taiwan's current status. The results will see Vice President William Lai Ching-te take over from incumbent Tsai Ing-wen, as he defeated Hou Yu-ih from the main opposition Kuomintang (KMT), which has pushed for rapprochement with China, and newcomer Ko Wen-je from the Taiwan People's Party (TPP), a new emerging political force that has broken the DPP-KMT duopoly. Mr. Lai said the elections – the first in what has been dubbed the year of elections given the many countries, including India, that go to the polls in 2024 – were a message to the world, showing “the commitment of the Taiwanese people to democracy”. Beijing, which has over the past decade under the DPP accused the ruling party of seeking outright independence over the island that it claims, said the results showed that the DPP “cannot represent the mainstream public opinion”, pointing to its reduced vote share. Mr. Lai secured 40% of the vote, Mr. Hou 33% and Mr. Ko 26%. The KMT and TPP's attempts to form a joint opposition alliance, which could have threatened the DPP's bid, failed in the run-up to the elections. While the DPP has returned to power, its exercise of authority may be constrained given that it has lost its status in the legislature as the largest party to the KMT, which may exert a moderating influence on its policies to carve out a greater international space for Taiwan – a major bone of contention with Beijing.

If the previous presidential election, in the aftermath of China tightening its grip on Hong Kong, was seen as a referendum on the future of cross-strait relations and a rejection of a possible “one country, two systems” future for Taiwan that has been mooted by Beijing, in the latest polls, local issues, including the economy and jobs, have assumed increasing salience, even as the broad preference for continuing with the status quo remains. The last decade has seen rising tensions, and the latest vote will ensure these will continue, including from the frequent military drills conducted by China in the waters and skies surrounding Taiwan. China has refused to rule out the possible use of force in “reunification”, although the consensus among most experts is that the devastating economic consequences of a conflict for China, Taiwan and the region will certainly give Beijing pause. That Taiwan's voters have backed the DPP to continue helming Taiwan's politics, despite China's threats, suggest diminishing returns from Beijing's moves to squeeze Taiwan, politically and militarily.

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## Over 38% patients on more than one antibiotic: NCDC survey

In 13 out of 20 hospitals, more than 70% of patients were given at least one dose of antibiotic

### DATA POINT

The Hindu Data Team

All the patients admitted to the acute care ward of the Lala Lajpat Rai Memorial Medical College in Meerut, Uttar Pradesh, were given antibiotics, according to a recent survey by the National Centre for Disease Control (NCDC). In fact, in 13 out of 20 hospitals in which the survey was conducted between November 2021 and April 2022, more than 70% of patients were given at least one dose of antibiotic.

All the patients who were admitted to the ward for more than a day, regardless of the underlying cause for their hospitalisation, were part of this survey. Those who were admitted for day-care procedures were excluded from the survey and so were those who got admitted late on the day of the survey or were about to be discharged on that day.

The findings of the report are worrying as India is among the few countries where antimicrobial resistance is notably high. Such resistance develops when antimicrobials, which include antibiotics, are misused or overprescribed. According to the WHO, antimicrobial resistance was directly responsible for 1.27 million global deaths in 2019 and contributed to 4.95 million deaths. The WHO says, "as pathogens become resistant to the drugs that were used against them, making infections harder and more expensive to treat."

Chart 1 shows the share of 9,652 patients surveyed in 20 hospitals who were on one, two, three and no antibiotic prescriptions. In total about 72% of the patients were on at least one antibiotic prescription, 25.3% were on two antibiotic prescriptions, and about 13% on three. The survey said combining two antibiotics can increase the risk of adverse effects.

Among those who were given at least one antibiotic (6,944 pa-

tients), Chart 2 shows that 55% were given prescriptions for preventing the occurrence or spread of an infection and only the rest were to treat an infection or disease.

The WHO has also put some drugs on the "watch" list which are broader-spectrum antibiotics reserved for severe infections and on the "reserve" list which are last-choice antibiotics used to treat multidrug-resistant infections. Notably, 57% of antibiotics prescribed among the surveyed belonged to the "watch" category and 2% to the "reserve" category, (Chart 3). The NCDC survey expressed concern over the high use of "watch" group antibiotics. About 3% of the prescriptions were of the 'not recommended by WHO' group.

Chart 4 shows that there was a stop/review date in only 10.4% of the prescriptions. Moreover, only 52% of the prescriptions were compliant with India's national policy developed to contain antimicrobial resistance (Chart 5).

Chart 6 shows the choice of antibiotic drugs which were mostly prescribed in the hospitals surveyed. Over 33% of antibiotic prescriptions were third-generation Cephalosporins which include drugs such as ceftriaxime, cefixime, cefoperazone and cefepime. This was followed by penicillins (Metronidazole, ornidazole, tinidazole) Aminoglycosides (amikacin, gentamycin, streptomycin) and Beta-Lactamase inhibitors (amoxicillin and clavulanic acid, piperacillin and tazobactam) which together form about 40% of the antibiotic prescriptions.

Chart 7 shows the 20 locations where the survey was conducted and the share of patients who were given at least one antibiotic. All the patients in Lala Lajpat Rai Memorial Medical College hospital in Meerut were given antibiotics. More than 90% patients were given antibiotics in at least four other hospitals surveyed.

### A bitter pill to swallow

The data for the charts were sourced from the Report of the First Multicentric Point Prevalence Survey of Antibiotic Use at 20 NAC-NET Sites India 2021-22 published by the National Centre for Disease Control

Chart 1: The chart shows the share of patients on antibiotic prescriptions

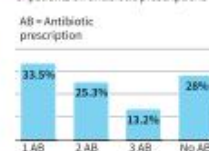


Chart 2: The share of AB prescriptions for treating or preventing disease

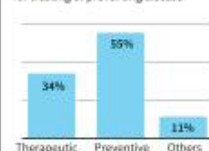


Chart 3: The share of AB prescriptions based on AWaRe classification



Chart 4: The chart shows the share of antibiotic prescriptions with a stop/review date



Chart 5: The chart shows antibiotic prescriptions in compliance with India's AB policy



Chart 6: The chart shows the choice of antibiotic drugs mostly prescribed in the hospitals surveyed

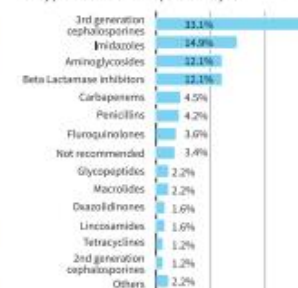
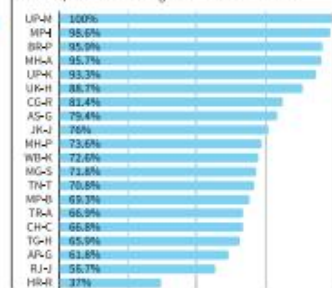


Chart 7: Locations where the survey was conducted and the share of patients who were given at least one antibiotic



UP-M: LRM Medical College, Meerut, U.P. | MP-M: MGRMC, Indore, M.P. | BR-M: RIMS, Patna, Bihar | MH-M: Government Medical College, Aurangabad, Maharashtra | UP-M: GVM Medical College, Kasur, U.P. | UP-M: Government Medical College, Aizawl, Uttarakhand | CG-M: P. J. N. Medical College, Raipur, Chhattisgarh | AS-M: Guwahati Medical College, Guwahati, Assam | JK-M: Government Medical College, Jammu | MH-M: B. J. Government Medical College, Pune, Maharashtra | BR-M: CSTM, Kolkata, W.B. | MG-M: NEIGRIHMS, Shillong, Meghalaya | TR-M: K. A. P. Viswanathan Medical College, Tiruch. T.N. | MH-M: Gandhi Medical College, Bhopal, M.P. | TR-M: AGMC, Agartala, Tripura | CH-M: Government Medical College, Chandigarh | TG-M: GMC, Hyderabad, Telangana | AP-M: Gunur Medical College, Guntur, Andhra | WB-M: SSKS Medical College, Jalpaiguri, West Bengal | HR-M: Pt. B.D. Sharma PGIMS, Rohtak, Haryana



# Understanding the Tenth Schedule

On what basis has the Speaker of the Maharashtra Assembly refused to disqualify the MLAs? What is the history behind the anti-defection law? How can anti-defection laws be made stronger and impartial?

## EXPLAINER

Rangarajan R

The story so far:

**T**he Maharashtra Assembly Speaker has refused to disqualify 40 MLAs of the Eknath Shinde faction after recognising it as the real Shiv Sena. He held the appointment of whip by this group as valid. He also did not disqualify 14 MLAs of the Uddhav Thackeray (UBT) group due to technical reasons under the Tenth Schedule.

Why was the Tenth Schedule made?

The defections of legislators during the 1960s and 70s from their parent parties created political instability in many States, bringing down elected governments. Therefore, to ensure the stability of elected governments, the 52nd constitutional amendment introduced the 'anti-defection' law through the Tenth Schedule in 1985. This Schedule provides that a member of a House of Parliament or State legislature who voluntarily gives up the membership of their political party or votes against the instructions of their party in a House are liable for disqualification from said House. This instruction with respect to voting is issued by the 'whip' of a party. A 'whip' is a member of the 'legislature party' in a House who is appointed as such by the respective 'political party'. The 'political party' is the entire organisation of a party including the legislators, while the 'legislature party' is only the members of a political party in a House of Parliament or State legislature.

The Tenth Schedule originally provided for two exceptions that would not render the members liable for disqualification. First, one-third members of the 'legislature party' splitting to form a separate group (para 3). Second, merger of their 'political party' with another party that is approved by two-third members of its 'legislature party' (para 4).



**Rebel party:** Maharashtra Chief Minister Eknath Shinde with supporters during celebrations of the Shiv Sena MLA disqualification case verdict, in Thane, on January 11.

However, considering the need to strengthen the 'anti-defection' law, para 3 was omitted in 2003.

What are the issues involved?

With the deletion of para 3, there have been instances of two-third members of a legislature party 'practically' defecting but claiming to be the original political party in order to escape disqualification. There have also been instances where more than two-third members of a State 'legislature party' of a national political party merged themselves with another political party to escape disqualification. This happened in September 2019, in Rajasthan, when all six Bahujan Samajwadi Party MLAs merged themselves with the Congress Party and in September 2022, in Goa, when eight

out of 11 Congress MLAs merged themselves with the BJP.

The authority to decide on the disqualification of members is vested in the Speaker of the House. While they are expected to perform this constitutional role in a neutral manner, the past instances have hardly inspired confidence with Speakers favouring the ruling dispensation. The Supreme Court in *K. M. Singh versus Speaker of Manipur* (2020), recommended that Parliament amend the Constitution to vest these powers in an independent tribunal headed by judges.

What happened in Maharashtra?

In June 2022, a faction of the Shiv Sena headed by Eknath Shinde moved with 37 of the 55 MLAs and claimed to be the real Shiv Sena. It appointed Bharat Gogawale

as its whip. However, the UBT faction claimed that they were the original political party and that Sunil Prabhu of its faction will continue to be the whip.

The Speaker has now recognised the Eknath Shinde faction as the real Shiv Sena and held the appointment of whip by this group as valid. This was based on the strength of members of the Shinde faction and the party's 1999 constitution. The Speaker based on this ruling refused to disqualify 40 MLAs of the Shinde faction. He also refused to disqualify 14 MLAs of the UBT group as the whip instructions from Bharat Gogawale could not be physically served on them.

What are the reforms needed?

The Supreme Court in *Sadiq Ali versus Election Commission of India* (1971), laid down the three-test formula for determining which faction is to be recognised as the original political party by the Election Commission. These are aims and objects of the party; its affairs as per the party's constitution that reflect inner party democracy; and majority in the legislative and organisation wings.

The first test is subject to competing claims by rival groups. But it is lack of inner party democracy that results in most of these defections. In fact, the Election Commission in February 2023, recognised the Eknath Shinde faction as the real Shiv Sena, solely based on votes polled by legislators supporting Eknath Shinde in the Maharashtra Assembly elections of 2019. An authoritative Supreme Court judgement in these matters and setting up of an independent tribunal to decide on disqualification of members will reduce the ambiguities surrounding the Tenth Schedule. The real reform required is institutionalising internal democracy through regular inner-party elections in our political parties with strict monitoring by the Election Commission.

Rangarajan R is a former IAS officer and author of 'Polity Simplified'. He trains civil-service aspirants at 'Officers IAS Academy'. Views expressed are personal.

## THE GIST

The defections of legislators during the 1960s and 70s from their parent parties created political instability in many States, bringing down elected governments. Therefore, to ensure the stability of elected governments, the 52nd constitutional amendment introduced the 'anti-defection' law through the Tenth Schedule in 1985.

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# The allegations against PVR for abuse of dominant position

How did the multiplex defend itself? What did the Competition Commission of India rule?

Saptaparno Ghosh

The story so far:

**H**aving found "no discernible competition concern," the Competition Commission of India (CCI) rejected a complaint alleging that multiplex chain PVR had abused its dominant market position. Yogesh Pratap Singh, a film director, had accused the multiplex chain of according preferential treatment to films from large production houses over those by independent film makers.

What were the allegations about?

The primary allegation was that the multiplex chain, utilising its dominant position in the film exhibition market, had accorded preferential treatment to films of the "powerful and monetarily affluent production houses." Mr. Singh also said that PVR engaged in cartelisation and vertical integration. He cited PVR's foray into the business of film production;

and actions relating to film distribution and film exhibition with big production houses. In the context of film distribution, vertical arrangements entail agreements between entities at different levels of the production chain; that is, producer-distributor, producer-exhibitor and distributor-exhibitor.

Elaborating on his claim of discriminatory treatment, Mr. Singh said that his films *Kya Yahi Sach Hai* (2022) and *The Indian Supari Company* (2022) suffered because PVR had allegedly created entry barriers for films by independent film makers. He also argued that an added motivation was the chain being involved in the production of certain films with its own company, Starlight Pictures Private Limited. For example, as described by the complainant, Ranbir Kapoor-starrer *Brahmastra's* trailers would be played several times at screenings free of cost and that the film was assigned an "overwhelming" number of screens. Mr.

Singh alleged that the screen allocation policy of the chain was "opaque" and "discriminated" against him.

What was PVR's response?

PVR denied the allegations. It said that the allegations were not backed by evidence. Further, the chain argued that the purpose of the complaint was to "pressurise" it to exhibit his film, in the absence of any legal obligation to do so. PVR clarified that it has no special tie-ups or recurring/long-term arrangements. Further, the terms of agreement, including those of promotion, agreed upon with independent film makers were similar to those with larger production houses. More importantly, the multiplex chain said that it was not in their interest to accord preferential treatment to a specific producer or distributor, and that it does not offer any preferential treatment to its own films. It argued that a majority of its exhibition revenue is earned from films produced and

distributed by third parties. PVR clarified that screen allocation is determined on "mutually objective criterion" – this primarily entails the revenue generation potential of the movie.

What does the CCI's order say?

After examining the submissions of the multiplex chain, CCI concluded that there existed no perceptible concern about competition. Its order held that the commercial wisdom of the exhibitors is largely driven by consumer demand. Unless harm to competition was apparent, any intervention on its part would only lead to "undesirable consequences," it noted. This would amount to taking away the autonomy of the entities and substituting that with the decisions of the regulator. About vertical integration, the order held that it was not per se prohibited under the provisions of the Competition Act. Further, the complainant had not submitted any evidence to substantiate these allegations. It held that most of the agreed terms for both independent filmmakers and larger production houses were largely the same – including revenue sharing terms. Finally, upholding autonomy in screen allocation, the regulator concluded that the guiding factor for selection and allocation was maximisation of revenue. The specific criteria include the revenue generating potential of the movie, the buzz around the film, marketing, advertising and promotions done etc.

# What are light-emitting diodes and why are they prized as light sources?

LEDs have several applications in industry, consumer electronics, and household appliances – from smartphones to TV screens, signboards to 'feeding' plants light in greenhouses, and barcode scanners to monitoring air quality

Vasudevan Mukunth

In October 2014, the Royal Swedish Academy of Sciences issued a statement in which it said, "Incandescent light bulbs ... lit the 20th century; the 21st century will be lit by LED lamps." The occasion was the awarding of the Nobel Prize for physics for that year, for an achievement that paved the way for light-emitting diodes (LEDs), to succeed incandescent bulbs and fluorescent lamps, as the world's light-source of choice.

## What are diodes?

A diode is an electronic component about 5 mm wide. It has two points of contact, or terminals, called its anode and cathode. A diode's primary purpose is to allow current to flow in only one direction. It achieves this using a p-n junction.

A p-n junction is made of two materials laid next to each other. One material is a p-type material: its primary charge-carriers are holes. The other is an n-type material: its primary charge-carriers are electrons. You're familiar with electrons: they are 'places' inside atoms that carry negative charge. A hole denotes a 'place' in an atom or a group of atoms where there could be an electron but isn't. Thus, a hole is an electron placeholder but without the electron, so it has a positive charge.

A p-n junction is an interface where the surface of a p-type material and the surface of an n-type material meet. At this interface, electrons can pass easily from the n-type material to the p-type material but can't go the other way. This asymmetry creates the diode's ability to allow current to pass in only one direction. A wire attached to the p-type material is called the diode's anode; that attached to the n-type material is the cathode. These are the diode's two terminals.

When the two materials are first placed next to each other, some electrons move

from the n-side to the p-side until there is a layer, between the two sides, where there are neither (free) electrons nor holes present. When a suitable voltage is applied across the diode, more electrons flow from the n-side to the p-side, implying an electric current flowing from the p-side to the n-side, that is from the anode terminal to the cathode terminal. But if the voltage is reversed, current won't flow in the opposite direction. Et voila, a diode is born.

## What is an LED?

An LED is a diode that emits light. Inside the diode's p-n junction, the electrons have more energy than the holes. When an electron meets and occupies a hole, it releases energy into its surroundings. If the frequency of this energy is in the visible part of the electromagnetic spectrum, the diode will be seen to emit light. The overall phenomenon is called electroluminescence. The energy of a wave is proportional to its frequency. So making sure the light emitted by an LED is visible light is a matter of making sure the electron-hole recombination releases a certain amount of energy, not more and not less. This is possible to achieve thanks to the band gap.

## What is the band gap?

Particles like electrons can only have specific energy values. They can occupy only particular energy levels. When a group of electrons comes together in a system – say, in a collection of atoms like a small piece of metal – they're required to follow some rules. One of them is that no two electrons can occupy the same energy level at the same time.

These electrons generally prefer to have lower energy, and thus prefer to occupy the lowest available energy level. If that level is taken, they occupy the next available level. Sometimes they can acquire more energy, tear free from their atoms, and flow around the material. In these circumstances, we say the material is an electrical conductor. When the

electrons don't have enough energy to flow around, the material is an insulator.

Electrons can acquire such extra energy when an electric field is applied to the material. The field will accelerate the electrons and energise them, and the electrons will be 'kicked' from lower to higher energy levels. In some materials, there is an energy gap between these lower and higher levels – that is between when the electrons can't and can flow around the material. An electron can't have an amount of energy that would place it in one of these levels. It's the reason why electrons in these materials can't conduct an electric current unless they receive a minimum amount of energy – the energy required to jump across this gap. This gap is called the band gap.

In LEDs, the energy emitted when an electron and a hole recombine is the energy of the band gap.

By carefully choosing the materials that make up the p-layer and the n-layer, researchers can engineer the composite p-n junction to have a band gap that corresponds to visible light. Electron-hole recombination can be triggered by passing an electric current through the diode, which creates the electric field that 'kicks' the electrons.

## What colours can an LED produce?

Since LEDs can produce all three primary colours – red, green, and blue – different LEDs can be combined on a display board to produce a large variety of colours. (There are other ways as well.)

This said, scientists were able to create red and green LEDs more than 40 years before they created blue LEDs. The reason: scientists had identified a compound, gallium nitride, that was electroluminescent and whose band gap could yield blue light, but they didn't know how to create crystals of this compound with the precise physical, electronic, and optical properties. Gallium nitride was also fragile, quickly becoming a powder in the process used to

create crystals. Inventing the blue LED eventually required a series of breakthroughs in epitaxy, the process by which p-type and n-type materials are built layer by layer. In the late 1980s, three Japanese researchers, Isamu Akasaki, Hiroshi Amano, and Shuji Nakamura, led teams that produced a bright blue LED with gallium nitride. For this feat they received the physics Nobel Prize in 2014.

## What are the advantages of LEDs?

According to Moore's law, specified by American engineer Gordon Moore in the 1970s, the number of transistors on a chip would double every two years. Similarly, improvements to LEDs since 1970 have followed Haitz's law. Named for scientist Roland Haitz, it states that for a given frequency of light, the cost per unit of light of an LED will drop 10x and the amount of light it produces will increase 20x every decade.

But even before Haitz's law, researchers prized LEDs because they were more efficient than incandescent bulbs and fluorescent lamps. Per watt of power consumed, LEDs can produce up to 300 lumen (amount of visible light emitted per second) versus incandescent bulbs' 16 lumen and fluorescent lamps' 70 lumen. Together with their greater durability and light contrast, LEDs' advantages translated to higher cost savings and less material waste.

LEDs have several applications in industry, consumer electronics, and household appliances: from smartphones to TV screens, signboards to 'feeding' plants light in greenhouses, barcode scanners to monitoring air quality.

Today, LEDs can also produce a variety of colours or emit energy at higher and lower frequencies; LEDs can be 'embedded' in skin; and organic LEDs emit more light (albeit by a different mechanism). Researchers are also exploring more efficient LEDs made of materials called perovskites.

With inputs from Adhip Agarwala, assistant professor at IIT Kanpur.