



TARGET PRELIMS 2024

CURRENT AFFAIRS PROGRAM

BOOKLET-1, S&T-1

SPACE AND ASTRONOMY

1. TABLE OF CONTENTS

1. <i>Table of Contents</i>	0
1. <i>Some Basics About Satellite Orbits</i>	3
1) Orbit:	3
2) Types of Orbits: 1. Circular (LEO, MEO, GSO) 2. Elliptical Orbits	4
A) Low Earth Orbit (Circular Orbit)	4
B) Medium Earth Orbit	5
C) Geosynchronous Orbit and Geostationary Orbit	5
3) Highly Elliptical Satellite Orbits	7
4) Transfer Orbits	7
a) Geostationary Transfer Orbit	7
5) Some other basics (Class Discussion)	7
2. <i>Timeline: India in Space, through the Years</i>	8
3. <i>ISRO Launchers (Operational)</i>	11
1) PSLV (Polar Satellite Launch Vehicle)	11
A) Solid Fuel Engine vs Liquid Fuel Engine (Extra Gyan)	12
B) PSLV C-58	13
C) PSLV C-57/ Aditya-L1 Mission (Sep 2023)	14
D) PSLV-C56 / DS-SAR Mission (July 2023)	14
E) PSLV C-55/TeLEOS-2 Mission (April 2023)	14
2) GSLV (Geosynchronous Satellite Launch Vehicle)	15
A) Launch Vehicle Mark 3 (LMV3 or GSLV Mark 3)	15
B) India's Journey towards developing its own cryogenic engine	16
4) Sounding Rockets	17
4. <i>Other Engines and related projects in News</i>	18
1) ISRO's Next-Gen Launch Vehicle (NGLV) may assume PSLV's Role	18

2)	Semi-cryogenic Engine (Under development)	18
3)	Differences between Cryogenic Engine and Semi-Cryogenic Engine.....	18
4)	Reusable Rockets: Revolutionizing Access to Outer Space	19
5)	Low-Cost Small Satellite Launcher (SSLV)	19
5.	<i>ISRO Satellites.....</i>	21
1)	Basics	21
2)	Communication Satellites.....	21
A)	Communication satellites of India / ISRO	21
B)	Recent ExAmples of Communication Satellites	22
3)	Earth Observation Satellites (Photography, Imaging and Scientific Surveying).....	22
4)	Satellite Navigation (SAT – NAV)	23
A)	Basics About SATNAV.....	23
B)	Global Positioning System (GPS)	23
C)	BeiDou.....	24
D)	GAGAN and GEMINI (class discussion).....	25
E)	NAVIC (Navigation using Indian Constellation).....	25
5)	Satellites to study the Sun: ADITYA L1.....	26
6.	<i>Other Important Projects of ISRO</i>	29
1)	Project NETRA	29
2)	Mission Shakti.....	29
3)	Gaganyaan	29
4)	XPOSAT (X-RAY Polarimeter Satellite)	29
A)	Understanding Polarization – Class Discussion.....	31
B)	Understanding Polarized Glasses.....	31
5)	NASA-ISRO Synthetic APerture Radar (NISAR) Imaging Satellite	31
7.	<i>NASA's Interplanetary Mission.....</i>	32
1)	Mars Orbiter Mission	32
2)	Venus: Shukrayaan-1.....	32
3)	Chandrayaan 3.0 (LVM3-M4) Mission.....	33
A)	Understanding the different phases and path taken by Chandrayaan	33
B)	Components of Chandrayaan 3.0:	33
C)	Landing was the most complicated part here:.....	34
D)	Where did Lander Land?.....	35
E)	Rover:.....	35
E)	Comparing Chandrayaan-1, Chandrayaan-2 and Chandrayaan-3.....	35
D)	Chandrayaan 3 Propulsion Module Retraces Steps to Earth Orbit: Why it matters? (Dec 2023)	36
E)	Significance of Going to Moon:.....	36
8.	<i>Other Important Projects of ISRO</i>	36
1)	India's Own Space Station: Plans	36
8.	<i>International Collaboration in News.....</i>	37

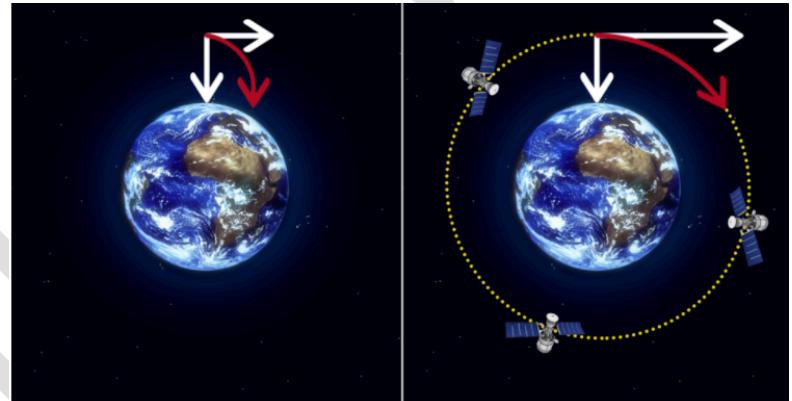
1)	ISRO – nOrway	37
A)	Svalbard Mission of 1997	37
9.	Important Telescopes in news recently.....	37
1)	Various Telescopes at Devasthal	37
2)	India's first Dark Sky ReservE.....	38
a)	The Indian Astronomical Observatory (IAO)	40
10.	Space Infrastructure in India.....	40
A)	Vikram Sarabhai Space Centre (VSSC):	41
B)	UR Rao Satellite Centre (URSC)	41
C)	Satish Dhawan Space Centre (SDSC)-SHAR	41
D)	Liquid Propulsion Systems Centre (LPSC).....	41
E)	Space Application Centre (SAC)	41
F)	Human Space FLight Centre (HSFC)	41
G)	National Remote Sensing Centre	42
H)	ISRO Propulsion Complex (IPRC)	42
I)	ISRO Telemetry, Tracking and Command Network (ISTRAC)	42
J)	Master Control Facility (MCF)	42
K)	ISRO INtential Systems UNIT (IISU).....	42
L)	Laboratory for Electro Optics Systems (LEOS)	42
M)	Indian Institute of Remote Sensing (IIRS)	43
N)	Development and Educational Communication Unit (DECU)	43
O)	National atmospheric Research Laboratory	43
P)	NORTHEASTERN-Space Applications Centre (NE-SAC).....	43
Q)	Indian Institute of Space Science and Technology	43
R)	Antrix Corporation Limited (ACL).....	43
11.	Important Personalities.....	43
A)	Dr Vikram Sarabhai (12 th Aug 1919 – 30 th Dec 1971).....	44
B)	S Somnath	44
12.	Commercialization and Privatization in Space Sector.....	44
A)	Prarambh Mission	44
2)	New Institutions.....	45
b)	New Space India Limited (NSIL)	45
B)	In-Space (Indian National Space Promotion and Authorization Centre).....	46

1. SOME BASICS ABOUT SATELLITE ORBITS

1) ORBIT:

- An orbit is the curved path that an object in space (such as a planet, moon, star etc.) takes around another object due to gravity.
 - Objects of similar mass orbit each other with neither object at the centre, whilst small objects orbit around large objects. In our Solar system, earth revolves around sun, Moon revolves around earth.
- **Satellite Orbits:** The path that satellite takes to revolve around a planet due to force of gravity is called satellite orbit.

- **Gravity and Speed of Satellite in an orbit**



- **How are satellites placed in Orbit – Circular vs Elliptical Orbit** - Detailed Class Discussion

- **Orbital Velocity – Circular vs Elliptical**

- For a circular orbit, it is always the same.
- However, in the case of an elliptical one this is not the case as the speed changes dependent upon the position in the orbit. It reaches the maximum when it is closest to the earth and it has to combat the greatest gravitational pull, and it is at its lowest speed when it is furthest away.

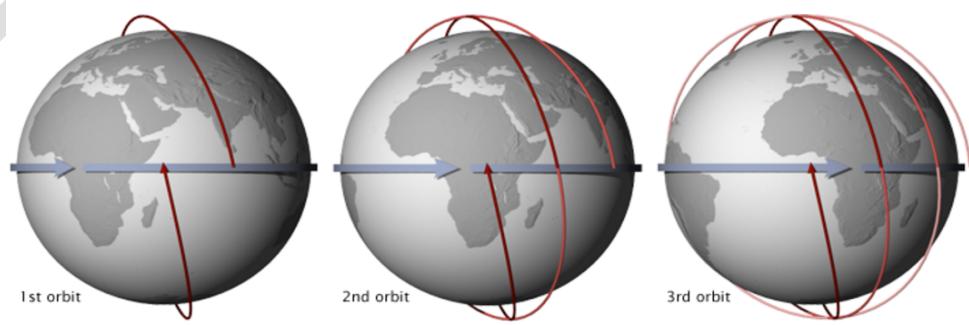
2) TYPES OF ORBITS: 1. CIRCULAR (LEO, MEO, GSO) 2. ELLIPTICAL ORBITS

A) LOW EARTH ORBIT (CIRCULAR ORBIT)

- A low earth orbit is an orbit around earth with an altitude between 160 kilometers and 2000 Kilometers. Objects below approximately 160 Kilometers will experience very rapid orbit decay and altitude loss.
- It is used for vast majority of satellites.
 - Most satellites
 - All human space flights (except manner lunar flight of the Apollo program);
 - All space stations.
- **Main Characteristics**
 - **Low orbital period**
 - **Satellites closer to earth** -> better visibility -> earth observation/remote sensing satellites.
 - **Easier placement of satellite in orbit**
 - **Lower latency in communication** -> less round-trip time.
 - **Satellites face lower radiations** when compared to satellites at higher altitudes.
- **Applications**
 - **Earth Monitoring Satellites**
 - As they are able to see the surface of the earth more clearly
 - **Communication satellites**
 - Especially the satellite phones
 - **International Space Station** is at a height of 400 km.

SUN SYNCHRONOUS ORBIT (CIRCULAR OR ALMOST CIRCULAR) (POLAR ORBIT)

- **Satellites in Polar Orbit** usually travel past Earth from north to south rather than from west to east, passing roughly over Earth's pole. They don't have to pass the north pole or south pole precisely. Even a deviation within 20 to 30 degrees is still classed as polar orbit.
- **Sun Synchronous Orbit** is a kind of Polar Orbit. In this orbit, satellites are synchronized to always be in the same fixed position relative to the Sun. This means that the satellite always visits the same spot at the same local time. In this orbit, whenever and wherever the satellite crosses the equator, the local solar time on the ground is always the same.



- A sun synchronous combines altitude and inclination in such a way that an object on that orbit will appear to orbit in the same position, from the perspective of the sun, during its orbit around the earth. In other words, it orbits in such a way that **it precesses once a year**. The surface illumination angle will nearly be same every time.
- Typical sun-synchronous orbits are about **600-800 Km in altitude**, with periods in the 96-100-minute range, and inclination of around 98 degrees.
- Possible only around oblate planets like Earth, Mars etc. The extra mass around the equator makes the precess possible. But Venus is too spherical to have a Sun Synchronous Satellite orbit.

□ Significance of Sun-Synchronous Orbit

- SSPO keeps the angle of sunlight on the surface of the earth as consistent as possible, though the angle will change from season to season. This consistency allows scientists to compare images from the same season over several years without worrying about too much extreme changes.
- **Kinds of satellite put in Sun-Synchronous orbit:** Imaging, Spy and weather satellites (e.g. Cartosat-2 series)

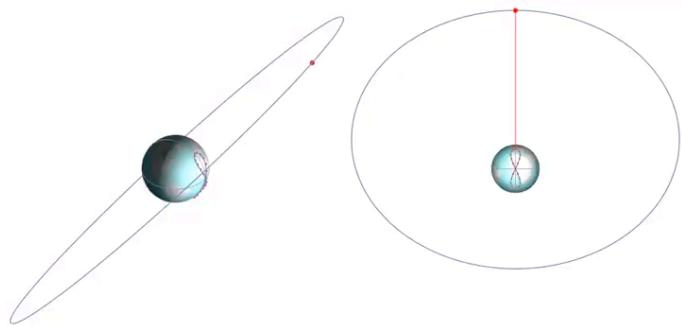
B) MEDIUM EARTH ORBIT

- **Height:** 2000 km to 3,5786 kms
- Satellite speed is lower (compared to LEO)
- **Orbital Period** range from 2 to 24 hours.
- **Most common use** of satellite in this orbit is for navigation, communication, and geodetic/space environment science.
- **Most common altitude** is approximately **20,200 km**, which yields an orbital period of 12 hours as used for examples by GPS.
- **E.g:**
 - GPS Satellites Fly in Medium earth orbit at an altitude of approximately 20,200 km.
 - Galileo (the satnav system of Europe) is also located in MEO.

C) GEOSYNCHRONOUS ORBIT AND GEOSTATIONARY ORBIT

GEO-SYNCHRONOUS ORBIT

- It is a satellite orbit around the earth with an **orbital period that matches Earth's rotation period on its axis** (i.e., orbital period is 23 hours 56 minutes and 4 seconds), irrespective of inclination.
 - » A person on a point on Earth, will see a satellite in this orbit in the same place in the sky at the same time of the day, every day.



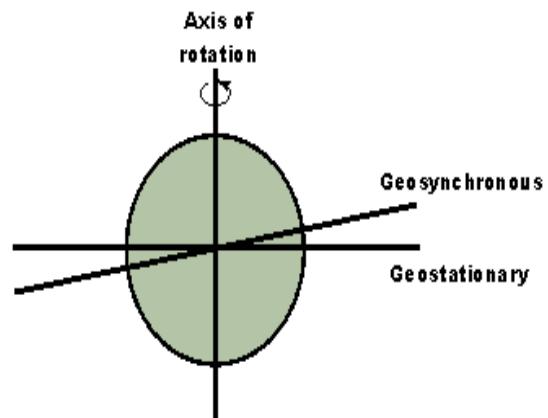
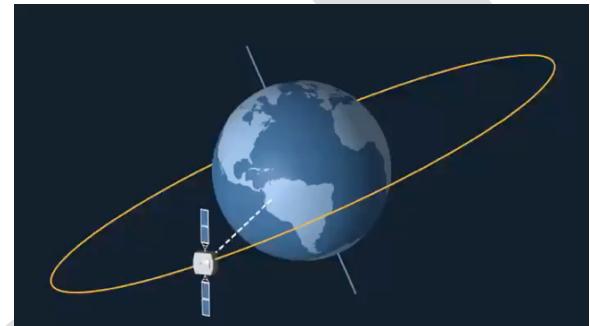
- » Over the course of a day, the object's position in the sky traces out a path, typically in a figure-8 form, whose precise characteristics depend on the orbit's inclination and eccentricity.

- Requirements:

- » **Circular Orbit of Height 35786 km**. At this height an orbital period of satellite is equal to earth's rotation period.
- » **Direction of revolution** of satellite should be same as direction of rotation of earth.

GEO-STATIONARY - A SPECIAL CASE OF GEOSYNCHRONOUS

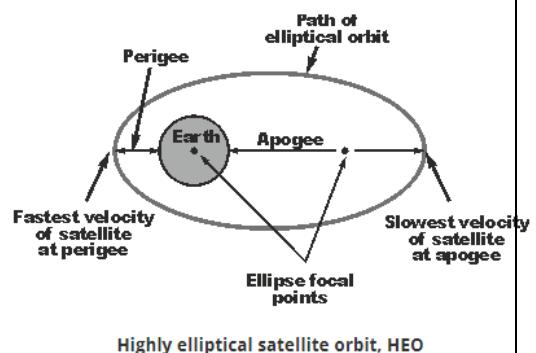
- A Geostationary Orbit is a particular type of Geosynchronous orbit, the distinction being that while an object in Geosynchronous orbit returns to the same point in the sky at the same time each day, an object in geostationary orbit never leaves that position.
- **Requirements for a satellite to be geostationary?**
 - Geosynchronous requirements
 - The equatorial plane of earth must be coplanar with the orbital plane of the satellite revolution (i.e., angle of inclination of orbit to equator is 0 degrees)
- Communication satellites and weather satellites are often placed in Geostationary orbits, so that satellite antenna which communicate with them don't have to rotate to track them but can be pointed permanently at the position in the sky where they stay.
- **Advantages**
 - Geo systems have significantly greater available bandwidth than the Low Earth Orbit
 - LEO and Medium Earth Orbit
 - Covers 1/3rd of Earth's surface.
 - Less expenses on tracking activities
 - Higher life span of satellites
- **Limitations**
 - Would require line of sight communication paths between terrestrial antenna and the satellites.
 - Long path length, and hence losses when compared to LEO, or MEO.
 - Long path length introduces delays.
 - Satellite costlier to install in GEO in view of the greater altitude
 - Geostationary Orbit (GEO) can only be above equator and therefore poles can't be covered.



Geostationary orbit can only be over the Equator

3) HIGHLY ELLIPTICAL SATELLITE ORBITS

- Elliptical Orbits are often called Highly Elliptical orbits or HEO.
- Key Features
 - Follows the curve of an ellipse.
 - Moves much faster when it is near earth and slower when it is away from earth.
 - There are two focal points and one of these is the geocentre of the earth.
 - **Apogee:** Point where the satellite is furthest from Earth - gravitation pull is lowest - satellite moves the slowest
 - **Perigee:** Point where the satellite is nearest from earth - gravitation pull is highest - satellite moves the fastest
 - **How permanent coverage can be achieved?**
- Applications
 - Provide coverage at any point on the globe
 - It may provide high latitude and polar coverage.
 - Countries such as Russia which needs coverage over polar and near polar areas make significant use of highly elliptical orbits.



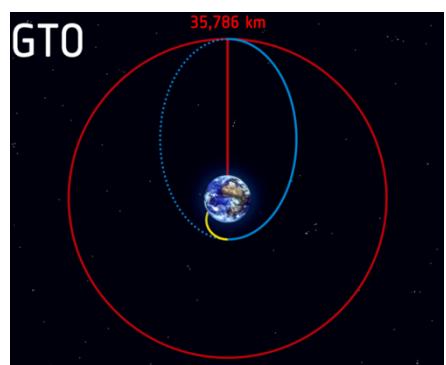
Highly elliptical satellite orbit, HEO

4) TRANSFER ORBITS

- These are special kind of orbits used to transfer satellites/spaceships from one orbit to another. These orbits are elliptical, with its perigee closer to earth. Satellites are taken to Perigee with the help of a rocket. After reaching this orbit, satellites by using relatively little energy from built in motors, can move to another larger orbit.
- This allows a satellite to reach a very high orbit, without needing the rocket to go to that height. **Geostationary Transfer Orbit (GTO)** is the most common type of transfer orbit.

A) GEOSTATIONARY TRANSFER ORBIT

- It is a Hohmann transfer orbit used to reach, geosynchronous or geostationary orbit. It is highly elliptical earth orbit with an apogee of 42,164 km, or 35786 km above sea level. Perigee can be anywhere above atmosphere, but it is generally restricted to few hundred Kms above the earth's surface.
- **Hohmann transfer orbit:** It is an elliptical orbit used to transfer between two circular orbits of different radii in the same plane.



5) SOME OTHER BASICS (CLASS DISCUSSION)

Why are satellites generally launched in west to east direction?

Why are satellites generally launched from the east coast?

Why are satellites launched from near the equator?



2. TIMELINE: INDIA IN SPACE, THROUGH THE YEARS

- 1) **1962:** The Indian National Committee for Space Research is formed under the leadership of Vikram Sarabhai and physicist Kalpathi Ramakrishna Ramanathan
- 2) **21 Nov 1963:** India's space program takes off with launch of a sounding rocket from Thumba Equatorial Rocket Launching Station in Kerala. It was for probing upper atmosphere.
- 3) **Aug 15, 1969:** ISRO is formed.
- 4) **Aug 19, 1975:** Aryabhata – India's first satellite is launched from a Soviet Kosmos-3M rocket from Kapustin Yar in the Soviet Union. It was designed and built in India.
- 5) **1979:** Bhaskara-1, the first experimental remote sensing satellite built in India, is launched. Images taken by its camera were used in hydrology, forestry and oceanography.
- 6) **1980:** Satellite Launch Vehicle (SLV)-3, India's first experimental satellite launch vehicle, takes off with Rohini Satellite RS-D2. Camera had the ability to use data for classifying ground features like water, vegetation, bare land, clouds and snow.
- 7) **1982:** INSAT 1-A is launched. Abandoned in 1983 where its altitude control propellant was exhausted.

- 8) **1984:** Rakesh Sharma, former IAF pilot, becomes the first Indian in space. In a joint India-Soviet Union Mission, Sharma boards the Soyuz T-11 spacecraft to the Salyut 7 orbital station.
- 9) **2008:** Launch of Chandrayaan-1. It orbits the Moon but doesn't land. It performs high resolution remote sensing aiming, among various missions, to prepare a 3D atlas of both the near and far sides of the moon.
- 10) **2013:** Launch of Mangalyaan, the Mars Orbiter Mission. Orbiting and studying Mars since Sep 24, 2014.
- 11) **2016:** All 7 satellites of IRNSS system placed in Orbit
- 12) **2019:** Chandrayaan-2 launched using GSLV MK-III
- 13) **2023:** Chandrayaan-3 succeeded in landing on the surface of the moon.

LevelUp IAS

ACE CSAT

CSAT FOUNDATION COURSE
FOR CSE 2024

LET'S DEVELOP
CRITICAL THINKING



STARTS: 8TH JAN 2024

By **Abhishek Inamdar**
M.Sc. Mathematics, BITS Pilani

PRELIMS MASTER PROGRAM

BATCH 2.0

FOR CSE PRELIMS 2024



STARTS: 8TH JAN 2024



Office Complex No. 6, 3rd Floor Old
Rajinder Nagar, New Delhi-110060



08045248491
7041021151

3. ISRO LAUNCHERS (OPERATIONAL)

PSLV, GSLV, Sounding Rockets are three broad categories of rockets (launchers) that ISRO has developed over the years.

Both PSLV (Polar Satellite Launch Vehicle) and GSLV (Geosynchronous Satellite Launch Vehicle) are the satellite launch vehicles (rockets) developed by ISRO.

1) PSLV (POLAR SATELLITE LAUNCH VEHICLE)

- The PSLV is the third-generation satellite launch vehicle of India. It is an expandable system and was the first Indian Launch Vehicle to be equipped with Liquid Stage.
 - **Note:** ISRO has over the years realized **5 generations of rockets** – SLV, ASLV, PSLV, GSLV, and GSLV-MK-III.
- **Where is PSLV used?**
 - It was developed to allow India to launch its Indian Remote Sensing (IRS) satellite into **Sun synchronous orbit**, a service that was, until the advent of the PSLV, commercially available only from Russia.
 - PSLV can also launch small size satellites into **Geostationary Transfer Orbit**.
- It is one of the world's most reliable launch vehicles.

PSLV was developed for Low Earth Orbit satellites into Polar and Sun Synchronous Orbits, and GSLV for heavier INSAT class of Geosynchronous satellites into orbit.

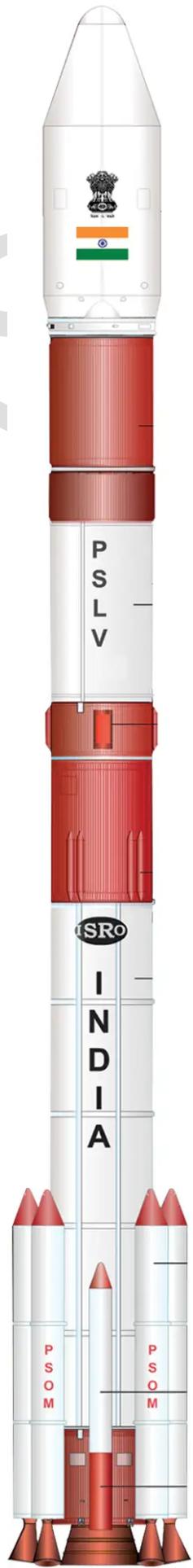


	SLV-3	ASLV	PSLV-XL	GSLV MK-II	GSLV MK-III
Height	22.7 m	23.5 m	44 m	49 m	43.43 m
Liftoff weight	17 t	39 t	320 t	414 t	640 t
Propulsion	All solid	All solid	Solid and liquid	Solid, liquid, and cryogenic	Solid, liquid, and cryogenic
Payload mass	40 kg	150 kg	1860 kg	2200 kg	4000 kg
Orbit	Low Earth Orbit	Low Earth Orbit	475 km Sun Synchronous Polar Orbit*	Geosynchronous Transfer Orbit	Geosynchronous Transfer Orbit

- **Launches So Far**
 - Developed in early 1990s, its first launch in 1993 was a failure.
 - First successful launch of PSLV took place in 1994 and till Jan 2023 (i.e., PSLV C-58), PSLV has had 60 launches with only two failures.

- Technical Specifications of PSLV

- **Payload Capacity:** SSPO (1,860 Kg); GTO (1,425 Kg)



- **Key features of PSLV Engines:** PSLV has four stages using solid and liquid propulsion alternatively.
- **Expansion of capabilities: Strap on Motors**
 - PSLV uses 6 solid rocket strap-on motors to augment the thrust provided by the first stage in its PSLV-G (1678 kg in SSPO) and PSLV-XL (1750 kg to SSPO) variants. PSLV-DL, PSLV-QL versions use 2 and 4 straps on motors respectively. PSLV-CA (1100 kg in LEO) uses no strap on motors.

» **Key Significance and Achievements of PSLV**

- **Reliability:** Only 2 failures in almost 3 decades of service and 60 launches.
- **Commercial use:** PSLV has launched **more than 350 foreign satellites** from 34 different countries so far.
- It has played significant role in various major ISRO missions (including Chandrayaan-1, MOM, IRNSS system etc.)
- **Strengthen India's Soft Power**
- Many **learnings** from the development of PSLV has helped scientists develop several non-space applications like fire resistant tiles, better engines for missiles etc.

A) SOLID FUEL ENGINE VS LIQUID FUEL ENGINE (EXTRA GYAN)

- » **A solid rocket fuel** has its fuel and oxidant mixed together as fine powders and then pressed into solid cake.
 - **Key characteristics**
 - **Higher Thrust** -> Higher force to launch the vehicle.
 - **Less volume**
 - **One time burn** -> all fuel burns at the same time, i.e., once it has been lit it will carry on burning until it is used up.
 - **Produces a lot of smoke** -> large particles when fired
- » **A liquid fuel engine** uses liquid fuel which can have following advantages
 - **Controlling Thrust**
 - **Engine can be shut down and restarted**
 - **Higher energy density** (joules per kg of propellant) is higher.
 - **Higher Specific Impulse** (impulse (in Newton second) per kg of propellant)
 - E.g., a modern solid fuel rocket has specific impulse of around 2500 N s Kg⁻¹, while a good liquid fuel rocket produces an impulse of about 4500 N s Kg⁻¹.
 - **Disadvantage: More complicated Engine requirements and thus more expensive and heavier engine** -> pumps, piping, separate storage for the fuel and oxidant means that extra mass has to be carried by the launch vehicle.

» **Why Hybrid Engines**

- Vastly reduce overall system weight and cost. It increases reliability (a smaller number of components which can fail)

B) PSLV C-58

- ISRO's PSLV C-58 has launched **XPOSAT Satellite** into an eastward low inclination orbit on 1st Jan 2024.
- After injection of XPOSAT, the PS4 stage was restarted twice to reduce the orbit into 350 km circular orbit for orbital platform (OP) experiments. The PSLV Orbital Experiment Module-3 (POEM-3) experiment was executed to meet the objective of 10 identified payloads, supplied by ISRO and IN-SPACe.
 - » These 10 payloads are developed by start-ups, education institutions and ISRO Centres.
 - » They are:
 - The Radiation Shielding Experimental Module (RSEM) by TakeMe2Space;
 - Women Engineered Satellite (WESAT) by LBS Institute of Technology for Women;
 - BeliefSa-t0 Amateur radio satellite by K.J. Somaiya Institute of Technology;
 - Green Impulse TrAnsmitter (GITA) by Inspecty Space Labs Private Limited;
 - Launching Expeditions for Aspiring Technologies -Technology Demonstrator (LEAP-TD) by Dhruva Space Private Limited
 - RUDRA 0.3 HPGP by Bellatrix Aerospace Private Limited;
 - ARKA-200 by Bellatrix Aerospace Private Limited;
 - Dust Experiment (DEX) by PRL;
 - ISRO Fuel cell Power System (FCPS) by VSSC, ISRO and
 - FCPS payload is significant as it has potential applications in India's space station which is proposed to come up by 2035.
 - Si-based High Energy cell by VSSC, ISRO
- **Note:** This is the third time ISRO has operated the PSLV fourth stage in this way.
- **Thus**, it can be said that the PSLV-C58 mission represents a union of the aspirations of professional scientists, aspiring students of science, and India's private spaceflight sector.

ISRO SUCCESSFULLY TESTS POLYMER ELECTROLYTE MEMBRANE FUEL CELL ON PSLV'S-C58'S ORBITAL PLATFORM POEM3 (JAN 2024)

- ISRO successfully tested a 100 W class Polymer Electrolyte Membrane Fuel Cell based power system in its orbital platform, **POEM-3** which was launched onboard PSLV-C58 on 1st Jan 2024.
- The objective of the experiment was to assess Polymer Electrolyte Membrane Fuel Cell operation in space and to collect data to facilitate the design systems for future mission.
- **Outcome of the test:**
 - » During the short duration test onboard POEM, 180 W power was generated from Hydrogen and Oxygen gases stored onboard in high pressure vessels. It provided a wealth of data on performance of various static and dynamic systems.

C) PSLV C-57/ ADITYA-L1 MISSION (SEP 2023)

D) PSLV-C56 / DS-SAR MISSION (JULY 2023)

- The launch of PSLV C-56 carrying DS-SAR satellite, along with 6 co-passengers [all 7 Singaporean satellites] was accomplished successfully on July 30, 2023.
- PSLV C-56 was configured in **core alone model**, similar to C-55.
- **DS-SAR** is a 360 kg satellite into a Near-equatorial Orbit (NEO) at 5 degrees inclination and 535 km altitude.
 - DS-SAR satellite is used for satellite imagery requirements of various agencies within the government of Singapore.
 - It carries a Synthetic Aperture Radar (SAR) payload developed by Israel Aerospace Industries (IAI). This allows DS-SAR to provide all weather day and night coverage, and capable of imaging at 1m-resolution at full polarimetry.
- After the launcher placed all the seven satellites into a 535 km circular orbit, **PS4 stage was brought back to a lower orbit of 295 km X 300 orbit**. This has been done so that the stage spends less time in space, reducing its duration from over two decades to less than two months, before re-entering into the earth's orbit.

E) PSLV C-55/TELEOS-2 MISSION (APRIL 2023)

- **PSLV C-55/ TeLEOS-2** was launched successfully on April 22, 2023, from SDSC-SHAR, Sriharikota.
- This is a dedicated commercial mission through NSIL with **TeLEOS-2** as primary satellite and **Lumelite-4** as a co-passenger satellite.
- The satellite weigh about 741 kg and 16 kg respectively. Both belong to Singapore.

POEM-2: The mission has the PSLV Orbital Experiment Module (**POEM**), where the spent PS4 stage of the launch vehicle would be utilized as an orbital platform to carryout scientific experiment through non-separating payloads. The payloads belong to ISRO, Bellatrix, Dhruva Space, and Indian Institute of Astrophysics.

2) GSLV (GEOSYNCHRONOUS SATELLITE LAUNCH VEHICLE)

- **Background of GSLV**
 - » GSLV is an expandable launch system operated by ISRO.
 - » First launch in 2001. First successful flight in 2003: successfully placed GSAT-2 in 2003.
 - » **Main Purpose:** GSLV was primarily developed to launch INSAT class of satellites into Geosynchronous Transfer Orbits. GSLV is being used for launching GSAT series of satellites.
 - » **Payload to GTO:** Presently GSLV-mk-II can inject 2.5 ton (GSLV Mk-2) of communication satellite into Geosynchronous Transfer Orbit.
 - » **Payload to LEO:** GSLV's capability of placing up to **5 tonnes** in LEO broadens the scope of payloads from heavy satellite to multiple smaller satellites.
- **Three Stage Launcher (GSLV-Mk-2) (one solid motor stage (expandable with four liquid engine strap ons), one earth Storable Liquid stage, and one cryogenic stage)**
- **Third Stage: CUS**
 - Developed under Cryogenic Upper Stage Project (CUSP), the CE7.5 is India's first cryogenic engine, developed by Liquid Propulsion Systems Centre in Mahendragarh, Tamil Nadu. CE-7.5 has a staged combustion operating cycle.
 - Fuel: LOX + LH₂ (Liquid Oxygen + Liquid Hydrogen)
 - Max Thrust: 75 KN
- **Variants**
 - **GSLV Mk 1(a,b,c)** - Not important
 - **GSLV Mk 2 (Operational)**
 - This variant uses an Indian cryogenic engine, the CE-7.5, and is capable of launching 2500 Kg into Geostationary transfer orbit. Previous GSLV vehicles (GSLV Mk1) have used Russian cryogenic engines.

A) LAUNCH VEHICLE MARK 3 (LMV3 OR GSLV MARK 3)

- LVM3 is a **3-stage** heavy lift launch vehicle developed by ISRO.
- 1) **Solid Rocket Boosters: S200** – GSLV MK III uses two S200 solid rockets boosters to provide the huge amount of thrust required for lift off. Fuel: **HTPB**.
- 2) **A liquid Propellant core stage (L110):** The L110 liquid stage is powered by 2 Vikas engines.
- 3) **A Cryogenic Stage (C25):** The C25 is an improvement on CE-20 Cryogenic engine, India's largest cryogenic engine, designed and developed by the Liquid Propulsion System Center
 - a. Fuel: LOx + LH₂
- **Capability:** GSLV-Mk III can launch 4 tons class of satellites to Geosynchronous Transfer orbit (GTO) or about 8-10 tons to LEO, which is twice the capability of GSLV Mk II.
- **GSLV MK-III Flights so far:**
 - » GSLV-Mk III – D1 (2017): GSAT-19 to GTO

- » GSLV-MK III – D2 (2018): GSAT-29 to GTO
- » GSLV-MK III – M1 (2019): Chandrayaan-2
- » GSLV-MK III – M2 (2022): OneWeb India-1 Mission
- » GSLV MK III – M3 (2023): OneWeb India-2 Mission
- » GSLV MK III – M4 (2023): Chandrayaan-3

▫ **GSLV MK-III – M2/ OneWeb India-1 Mission (Oct 2022)**

- It was only the second operational flight of LVM3 (after Chandrayaan-2 mission). It was a dedicated commercial satellite mission of NewSpace India Limited (NSIL). This mission was undertaken as part of the commercial arrangement between NSIL and m/s Network Access Associates Limited (m/s OneWeb Ltd), a UK based company. A total of **36 OneWeb Gen-1** satellites of about 150 Kg each totaling about **5,796 Kg** were launched to a circular LEO of about 601 km with a 87.4 degree inclination.
- This was one of the biggest commercial orders executed by ISRO.
- **Note: Some Unique features of the Mission**
 - First Commercial Mission of LVM3
 - First multi-satellite mission with 36 OneWeb Satellites onboard
 - First launch of LVM3 to LEO
 - First Indian rocket with six-ton payload
 - First NSIL Mission with LVM3
 - First OneWeb Mission with NSIL/DoS

LVM3 M3/ OneWeb India-2 Mission Accomplished Successfully (March 2023)

- In its sixth consecutive successfully flight of LVM3, the vehicle placed 36 satellites belonging to the OneWeb Group company in their intended 450 km circular orbit with an inclination of 87.4 degrees.
- The total weight of the payload was 5,805 kg.

LVM3 M4/ Chandrayaan 3.0 Mission was accomplished in July 2023

B) INDIA'S JOURNEY TOWARDS DEVELOPING ITS OWN CRYOGENIC ENGINE

- **Basics about Cryogenic Engine**
 - **Cryogenic engine** is a rocket engine that uses cryogenic fuel or oxidizer, i.e. its fuel or oxidizer (or both) are gases liquified and stored at very low temperatures.
 - **Note:** All Cryogenic engines are also, liquid propellant rocket engines or hybrid rocket engines.
 - **Fuel:** Combination of Liquid hydrogen and Liquid Oxygen is the most commonly used propellant in cryogenic engine. The fuel provides very high specific impulse.
- **Difficulties in developing Cryogenic engine:** Burning super cooled fuel at extremely high temperature; Developing material that can withstand high temperature and pressure during combustion.
 - **Advantages**
 - More efficient and provides more thrust for every kg of propellant it burns.

- **Current status**
 - CE-7.5 being used in GSLV MK-II.
 - CE-20 is being used in GSLV MK-III. It is indigenously developed for LVM-3.

- **Further upgradation:**
 - In Nov 2022, ISRO has successfully conducted a hot test of CE20 cryogenic engine. This successful hot test was at an uprated thrust level of 21.8 tonne for the first time.
 - This will enhance the LVM3 payload capability upto 450 Kg with additional propellant loading. The major modification carried out on this test article compared to previous engines was introduction of Thrust Control valve (TCV) for thrust control.
 - In addition to the hot test, a 3D printed LOX and LH2 turbine exhaust casings were also inducted in the engine for the first time.

4) SOUNDING ROCKETS

- Sounding rockets are one or two stage solid propellant rockets used for probing the upper atmospheric regions and for space research.
- They also serve as easily affordable platforms to test or prove prototypes of new components or subsystems intended for use in launch vehicles and satellites.
 - With the establishment of the Thumba Equatorial Rocket Launching Station (TERLS) in 1963 at Thumba, a location close to the magnetic equator, there was a quantum jump in the scope for aeronomy and atmospheric sciences in India.
 - The launch of the first sounding rocket from Thumba near Thiruvananthapuram, Kerala on 21 November 1963, marked the beginning of the Indian Space Programme. The rocket was US Nike Apache.

▫ Operational Sounding Rockets

- **Currently 3 versions** are offered as operational sounding rockets, which cover a payload range of 8-100 Kg and an apogee range of 80-475 Km.

Vehicle	RH-200	RH-300-Mk-II	RH-560-MK-II
Payload (in kg)	10	60	100
Altitude (in km)	80	160	470
Purpose	Meteorology	Aeronomy	Aeronomy
Launch Pad	Thumba, Kerala	SDSC-SHAR	SDSC-SHAR

- **Rohini (Rocket Family)** is a series of sounding rockets developed by ISRO for meteorological and atmospheric study.
- **ISRO's RH-200 sounding rocket records 200th consecutive successful flight** (Nov 2022)

- The small rocket lifted off from the launchpad at the **Thumba Equatorial Rocket Launching Station (TERLS)** at the Vikram Sarabhai Space Centre (VSSC).
- **Example of Experiment: Air Breathing Propulsion Experiment** using RH-560 rocket fitted with a supersonic combustion (Scramjet) engine on Aug 28 from Sriharikota. (Aug 2016)

4. OTHER ENGINES AND RELATED PROJECTS IN NEWS

1) ISRO'S NEXT-GEN LAUNCH VEHICLE (NGLV) MAY ASSUME PSLV'S ROLE

- ISRO is developing a Next-Gen Launch Vehicle (NGLV), which will one day replace operational systems like PSLV. Here ISRO is planning a three stage to orbit, reusable heavy lift vehicle with payload capacity of 10 tons to GTO.
- It will feature semi-cryogenic propulsion; simple and robust design (allowing bulk manufacturing, modularity and minimal turnaround time)

2) SEMI-CRYOGENIC ENGINE (UNDER DEVELOPMENT)

- Semi-Cryogenic Engine is an Indian Liquid fuel rocket engine using a combination of liquid oxygen (LOX) and refined kerosene (Isrosene) as propellants. It is being developed for future heavy lift launch vehicles and reusable launch vehicles.
- It is being developed by Liquid Propulsion System Centre, a subsidiary of ISRO.
 - Project Codename: SCE-200
- **Where will it be used?**
 - Immediate Application: One of the immediate applications will be to replace the liquid core (L110) engine of GSLV Mark-3 with the SCE-200 to boost the payload capacity of the rocket from 4 to six tonnes.
- **SCE-200: Other Details**
 - Cost of project: 1800 crore (Cabinet cleared the project in 2008).
 - Currently, only US and Russia have this technology.
 - In 2015, ISRO signed an MoU with Russian Space Agency to boost its plan for Semi-Cryogenic Launch Vehicle

3) DIFFERENCES BETWEEN CRYOGENIC ENGINE AND SEMI-CRYOGENIC ENGINE

	Cryogenic	Semi-Cryogenic
Fuel	Liquid Hydrogen + Liquid Oxygen	Isrosene + Liquid Oxygen
Temperature	Liquid hydrogen required to be stored at -253-degree celsius	Kerosene can be stored at normal temperatures
Weight	LH ₂ + LO ₂ is <u>heavier</u> than Kerosene and has to be stored	Lighter than liquid fuel and can be stored at normal temperature.

	at freezing temperature of - 253 degree celsius.	Therefore, kerosene occupies less space, and more propellant can be packed in the semi-cryogenic engine's fuel compartment.
Specific Impulse	Cryogenic engine offers <u>higher specific impulse</u> than SCE	
Thrust to weight Ratio		It offers <u>better thrust to weight ratio</u> upto 180. Higher density of the exhaust gas in case of the SCE contribute to high mass flow rates making it <u>easier to develop high thrust engines</u> .
Stage	Higher specific impulse is valuable for upper stage, where mass comes at a premium price. So Cryogenic is used at upper stage.	<ul style="list-style-type: none"> SCE have been preferred in lower stages when <u>high thrust is must-have over specific impulse</u>.

4) REUSABLE ROCKETS: REVOLUTIONIZING ACCESS TO OUTER SPACE

- **Details**
 - Reusable launch system is a launch system that includes the recovery of some or all of the component stages and reuse of these components in another launch.
 - Till now, several **fully reusable sub-orbital system** and **partially reusable orbital systems** have been flown. During 21st century, the interest in reusable launch system has grown considerably, with several active launchers.
 - SpaceX's Falcon 9 rocket has a reusable first stage and expendable second stage. Plans for the second stage of the Falcon 9 to be made reusable, creating a fully reusable system, have been cancelled, with the SpaceX starship being planned as a fully reusable launch vehicle.
 - If ISRO is able to develop this technology, it will reduce the cost of launch by 70-80% and increase the competitiveness of ISRO in satellite launch market.

- **Steps taken by ISRO to develop RLV.**

- In May 2016, ISRO successfully test fired its first indigenous winged reusable satellite launch vehicle.
 - In this experimental mission, the HS9 solid rocket booster carrying RLV-TD lifted off from the First Launch Pad at Satish Dhawan Centre, Sriharikota.
 - The RLV-TD re-entered the earth after reaching a height of 70 km.
 - It was a baby step towards developing reusable launch vehicle.
 - Ultimate Aim:** Ultimate aim of the project is to put satellite into orbit around earth and then reenter the atmosphere.
- The final version would take another 10-15 years to get ready.

5) LOW-COST SMALL SATELLITE LAUNCHER (SSLV)

- Introduction

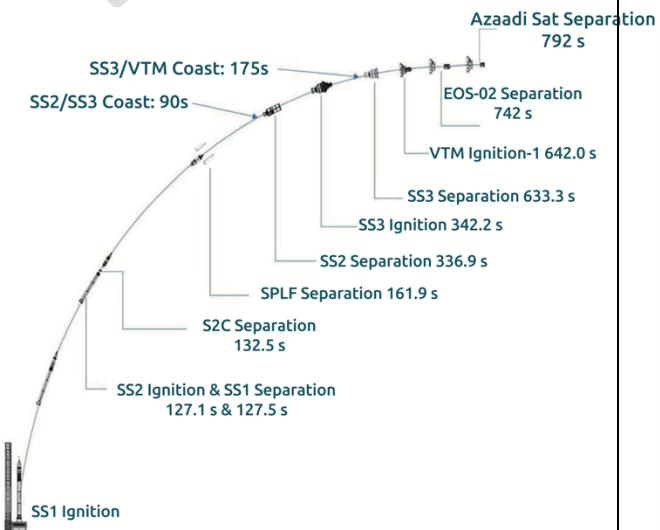
- The Indian SSLV (Small Satellite Launch Vehicle) is a small launch vehicle which serves small satellite launches.
- It is the smallest vehicle at 110-ton mass at ISRO.
- **Low turnaround time:** It takes only 72 hours to assemble (unlike around 70 days needed for PSLV).
- **Low Human Resource requirement:** Only 6 people are required to do assembly (unlike 60 people for the PSLV).
- **Cost Effective:** The overall cost of building the SSLV will only be Rs 30 crores.
- **Capability:** Payload capacity of 500 Kg to 500 km planar orbit or 300 kg to SSPO. Using PSLV for these small satellites was an overkill.
- It uses three solid fuel-based stages and a liquid fuel-based velocity trimming module (VTM) to place the satellite in orbit.
- It is ideal for on-demand, quick turn-around launch of small satellites.
- **Major technologies** developed as part of SSLV are flexible nozzle control with electro-mechanical actuators for all stages, miniaturized avionics, and a velocity trimming module in the upper stage for precise satellite injections.

- Need

- The **global demand** for launch of small satellite is increasing. It is being demanded by businesses, government agencies, universities, and various research labs.

- First Developmental Flight

- » The maiden flight of SSLV in Aug 2022 can be considered a partial success.
 - When it came to the stage when the satellite had to be set in orbit, there was a glitch which resulted in the satellite being lost forever. ISRO announced that there was a malfunction of a sensor which resulted in placing the satellites in an elliptical orbit, rather than a circular orbit.
 - It placed the satellites into 356 km X 76 km elliptical orbit instead of 356 km circular orbit.



- 2nd Developmental Flight: SSLV-D2 / EOS-07 Mission (Feb 2023)

- » The 2nd developmental flight of SSLV-D2 was successfully launched on Feb 10, 2023.
- » It intended to inject EOS-07, Janus-1 and AzaadiSAT-2 satellite into 450 km circular orbit, in its 15 minutes flight.
 - **EOS-07** is 156.3 kg satellite designed, developed and realized by ISRO. New experiments include mm-wave Humidity Sounder and Spectrum Monitoring payload.

- Janus-1, a 10.2 kg satellite belongs to Antaris, USA.
- **AzaadiSAT-2** is a combined effort of about 750 girl students across India guided by SpaceKids India, Chennai.

5. ISRO SATELLITES

1) BASICS

What is a satellite?

- Satellite means a smaller, space-based object moving in a loop (an orbit) around a larger object.
 - The Moon is a natural satellite of earth because gravity locks it in orbit around our planet.

2) COMMUNICATION SATELLITES

- **Introduction**
 - A communication satellite is an artificial satellite that is placed in earth's orbit for the purpose of sending and receiving communication data between a source and destination. They are basically "space mirrors" that can help us bounce radio, TV, Internet data, and other kinds of information from one side of earth to another.
 - It is used to provide data communication and relaying services for televisions, radio, telecommunication, weather and internet.
 - Communication satellites essentially overcome the problem of sending radio waves, which travel in straight lines, around our curved planet.
 - They commonly move in geo-stationary orbit.
 - Why?
 - Communication satellites can also move in highly elliptical orbit.
- **Two types of Communication Satellites – Passive and Active**

A) COMMUNICATION SATELLITES OF INDIA / ISRO

- **The Indian National Satellite System (INSAT) System** is one of the largest domestic communication satellite systems in Asia-Pacific region.
 - It was established in 1983 with the launch of INSAT 1B, it initiated a major revolution in India's communications sector and sustained the same later.
 - The system presently consists of the constellation of INSAT system consisting of around 20 operational satellites, namely INSAT-3A, 3C, 4A, 4B, 4CR, GSAT 6,7,8,9,10, 12, 14, 15, 16, 18, 19, 17, 6A, 29, 11 (largest 5850 Kg, Dec 2018), 7A (Mostly for serving air force, Dec 2018) and 31 (Feb 2019).
- INSAT system with more than 200 transponders in the C, extended C and Ku-bands provides services to telecommunication, television broadcasting, satellite newsgathering, societal application, weather forecasting, disaster warning and search and rescue operations.

B) RECENT EXAMPLES OF COMMUNICATION SATELLITES

GSAT-20

- **Why in news?**
 - ISRO's commercial arm to launch GSAT-20 Satellite on SpaceX's Falcon-9 in 2024 (Jan 2024)
- **Details about GSAT**
 - The GSAT-20 is a high throughput Ka-band satellite which will be fully owned, operated and funded by NSIL.
 - a. It will offer Ka-Ka band HTS capacity with 32 beams having Pan-India coverage including A&N and Lakshadweep.
 - b. The satellite weighs 4,700 kg and offers HTS capacity of nearly 48 Gbps and has been specifically designed to meet the demanding service needs of remote and unconnected areas.

3) EARTH OBSERVATION SATELLITES (PHOTOGRAPHY, IMAGING AND SCIENTIFIC SURVEYING)

- Earth Observation Satellites are specifically designed for Earth Observation from Orbit and are used for environmental monitoring, meteorology, map making etc. Most earth observation satellites carry instruments that should be operated at a relatively low altitude.
- **Earth Observation Satellites of India**
 - » Starting with IRS-1A in 1988, ISRO has launched many operational remote sensing satellites.
 - » Today, India has one of the largest constellations of remote sensing satellites in operation. Currently, earth observation satellites which are in **Sun-synchronous orbit** include
 - EOS-01, EOS-02, EOS-06 (Oceansat-3)
 - RESOURCESAT-1, 2, 2A
 - CARTOSAT-1, 2, 2A, 2B etc
 - CARTOSAT-3 (Launched in Nov 2019)
 - RISAT-1, RISAT-2, RISAT-2B (launched in May 2019 – PSLV C46), RISAT-2BR1 (launched in Dec 2019 – PSLV C-48)
 - OCEANSAT-2
 - Megha-Tropiques, SARAL and SCATSAT-1
 - **HySIS**
 - Earth Observation satellites in **Geostationary Orbit** include:
 - EOS-03 (couldn't be put in orbit due to failure of GSLV-F10)
 - INSAT-3D, INSAT 3DR
 - Kalpana & INSAT 3A
- » Varieties of instruments have been flown onboard these satellites to provide necessary data in a diversified spatial, spectral and temporal resolutions to cater to different user requirements in the country and for global usage. The data from these satellites are used for several applications covering

agriculture, water resources, urban planning, rural development, mineral prospecting, environment, forestry, ocean resources and disaster management

4) SATELLITE NAVIGATION (SAT – NAV)

- Why in news recently?
 - ISRO's GSLV-F12 successfully places navigation satellite NVS-01 into intended orbit (May 2023)

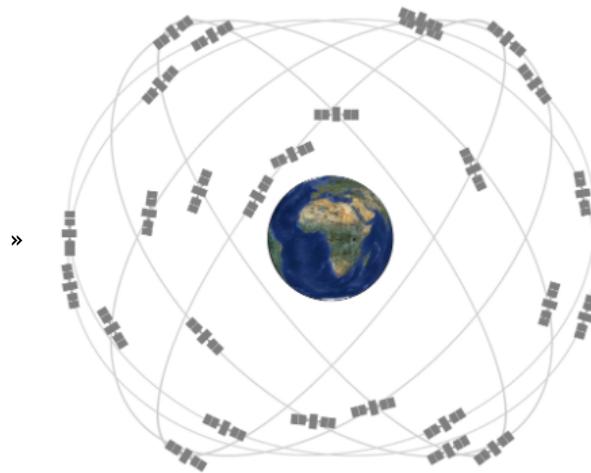
A) BASICS ABOUT SATNAV

- A satellite navigation (SATNAV) system is a technology that allows users to determine their precise location, velocity, and time information anywhere on or near Earth's surface.
- It uses a network of satellite in space and provide accurate positioning data.
- Currently, there are four global satellite-based navigation system – the American GPS, the Russian GLONASS (GLObalnaya NAvgatsionnaya Sputnikovaya Sistema), the European Galileo and the Chinese BeiDou.
- India has a regional system called NavIC and Japan has Quasi Zenith.
- **Methods used in SATNAV: Triangulation and Trilateration:**
- **Accuracy:** They generally provide high levels of positioning accuracy (within a few meters), depending on the quality of receiver and the number of satellites in view. However, various factors such as signal obstruction, atmospheric conditions, and receiver limitations can affect the accuracy.
- **Applications: Navigation purposes** -> helping users find their way while driving, hiking, or boating. It is also used in aviation, surveying, geolocation-based services, precision agriculture, and even in some outdoor recreational activities. It can be used for vehicle tracking, fleet management, precise timing etc.

B) GLOBAL POSITIONING SYSTEM (GPS)

- The best-known satnav system, GPS, uses 24 active satellites (including backups). Day and night, 365 days a year, they whiz around earth once every 12 hours on orbital plane inclined 55 degrees to the equator.
- Wherever you are on earth, you are in sight of at least half a dozen of them, but **you need signals from 3 or 4 satellites** to determine your position with an accuracy of just a few meters.
- **How GPS Finds your location?**
 - It uses **Trilateration**
- **GPS Constellation arrangement**
 - » GPS constellation fly in medium earth orbit (MEO) at an altitude of approx. 20,200 kms. Each circle orbits the earth twice a day.

- » The satellites are arranged in six equally placed orbital planes surrounding the earth. Each plain contains four slots occupied by baseline satellites. This 24-slot arrangement ensures users can view at least four satellites from virtually any point on the planet.



C) BEIDOU

- **Details**
 - China initiated BeiDou in 1994 with first BeiDou satellite launched in 2000.
 - **Second generation BeiDou (BDS-2)** provided coverage to Asia Pacific region starting in 2012.
 - **Third generation BeiDou (BDS-3)** satellite deployment started in 2015. In 2020, the system has been completed and it can now provide global services. With this they have joined United States' GPS and Russia's GLONASS in providing global PNT services, with Europe's Galileo to follow. These are all compatible and interoperable, meaning users can draw services from all of those to improve accuracy.
- **Satellite Constellation**
 - **24 satellites in Medium Earth Orbit** (around 21,500 kms above the earth) provide the positioning, navigation, and timing (PNT) services. These satellites use rubidium and hydrogen atomic clocks for highly-accurate timing that allows precise measurement of speed and location.
 - **Satellites in geosynchronous Orbit** (including Geo-stationary orbit) help BeiDou provide short messaging service through which 120-character messages can be sent to other BeiDou receivers.
- **Plans of Expansion:**
 - In Nov 2022, China outlined plans to further expand the global reach of its home grown BeiDou satellite navigation system.
 - a. **Pakistan** in 2014 became the first foreign country to set up a BeiDou network.
 - b. **BeiDou** has set up a first of three Continuously Operating Reference Stations (CORS) for its network in Thailand in 2013, to serve as a hub for ASEAN.

D) GAGAN AND GEMINI (CLASS DISCUSSION)

E) NAVIC (NAVIGATION USING INDIAN CONSTELLATION)

- Indian Regional Navigation Satellite System (IRNSS) (also called Navigation Using Indian Constellation (NAVIC)), is a regional satnav system developed by ISRO. It aims to provide reliable position, navigation and timing (PNT) services over India and its neighbourhood, upto 1500 km from its boundary. In addition it is also capable of broadcasting messages. This can be used for broadcasting safety-of-life alerts in areas with poor or no communication, particularly in Ocean.

- **Need of IRNSS** when services like GPS are easily available.

- The access to foreign controlled global navigation satellite systems is not guaranteed in hostile situations, as happened to Indian military depending on American GPS during **Kargil War**.

- **NAVIC provides two types of services:**

- » **Standard Positioning Service** (Open for Civilian Use)
 - » **Restricted Services** (Encrypted one, for authorized users (military))

- **Components of IRNSS System:**

- » Space segments consists of **7 satellites, 3 satellites in GEO stationary orbit (GEO) and 4 satellites in GEO synchronous orbit(GSO)** with inclination of **29 degree** to the equatorial plane.
 - » All the satellites will always be visible in the Indian region.
 - » **First of the 2nd generation satellite – NVS-01** was successfully launched in May 2023
 - ISRO's **GSLV F12** (GSLV-MK-II mission)successfully places navigation satellite NVS-01 into intended orbit.
 - **About GSLV F12:**
 - » It is the **15th** flight of India's GSLV and the **9th** flight with indigenous cryo stage.
 - **About NVS-01:**
 - » **Heavier:** It weighs **2232 kg** and has been placed in **geosynchronous orbit** (older IRNSS satellites weighed 1,425 kg)



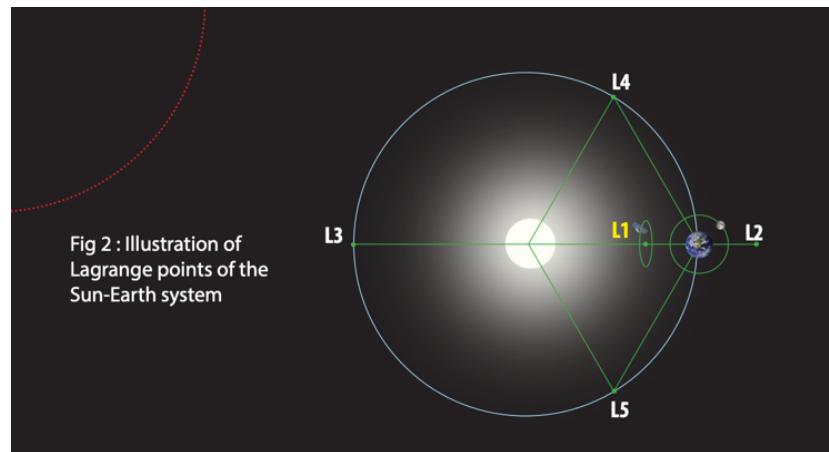
- » **Indigenous Atomic Clock:** For the first time, the satellite carries an indigenous atomic clock. The space qualified Rubidium atomic clock has been indigenously developed by Space Application Centre – Ahmedabad.
- » **L1 signals for better use in wearable devices:** The second generation satellites have send signals in a third frequency, L1, besides the L5 and S frequency signals that the existing satellites provide. This will increase operability with other satellite based navigation systems. L1 frequency is the most commonly used in the GPS and will increase the use of NavIC in wearable devices which use low power signal frequency chip.
- » **Longer Mission Life** of 12 years (earlier NavIC satellites have a mission life of 10 years).

- **Current Situation** (June 2023)
 - The receivers have now been deployed, and NavIC is in use for projects like public safety, power grid synchronization, real-time train information system, and fishermen's safety.
 - Other upcoming initiatives (such as) common alert protocol based emergency warning, time dissemination, geodetic network, unmanned aerial vehicles are in the process of adopting NavIC system.

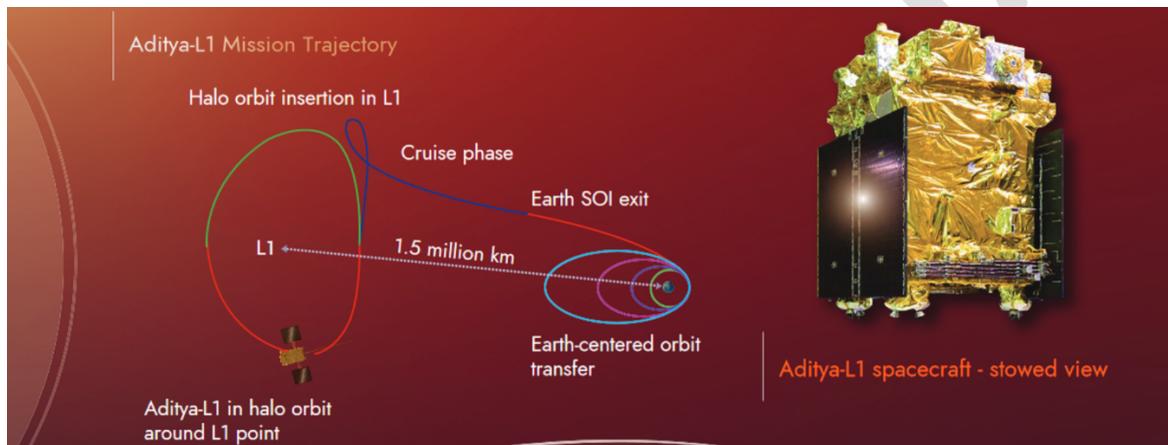
Some cell phone chipsets build by Qualcomm, MediaTek integrated NavIC receivers in 2019. Some example phones which are NavIC enabled include Redmi Note 9, realme 6, the OnePlus Nord etc.

5) SATELLITES TO STUDY THE SUN: ADITYA L1

- It is India's first observatory class space based solar mission.
- It was launched into space on 2nd Sep 2023 onboard PSLV-C57 and reached the L1 point on 6th Jan 2024, 127 days after its launch.
- It has a mission life of 5 years during which its payloads will study various aspects of sun. It serves as a space weather station and the data from the spacecraft will aid in making models and predicting storms in advance.
- The orbit of Aditya-L1 spacecraft is a periodic Halo Orbit with an orbital period of about 178 earth days. This halo orbit is a periodic, three dimensional orbit at L1 involving sun, earth and spacecraft.
- **Why study sun from space and specifically from Lagrangian point 1?**
 - **Why study sun from Space?**
 - Various types of radiations from sun are not able to reach earth due to atmosphere of the earth and earth's magnetic field making their study difficult from earth.
 - **Why from Lagrangian Point-1 (L1)?**
 - A Satellite placed in the halo orbit around the Lagrangian point 1 (L1) of the Sun-Earth system has the major advantage of continuously viewing the Sun without any occultation/ eclipses.



What Trajectory ADITYA-L1 followed to reach Lagrangian Point-1: Through various orbit raising manoeuvres and cruise phase, it was placed in a halo orbit around the Lagrangian Point-1 (L1) of the Sun Earth System, which is about 1.5 million km from the Earth.



The path Aditya-L1 will take to get to L1. | Photo Credit: ISRO

- **Major Science Objectives:**
 - Understand the coronal heating and solar wind acceleration; understand the initiation of Coronal mass ejection (CME), flares, and near earth space weather; understand the coupling and dynamics of the solar atmosphere; understand solar wind distribution and temperature anisotropy.
- **Aditya-L1 went with 7 Payloads:**

Remote Sensing Payload:

 - a. **Visible Emission Line Coronagraph (VELC):** It can peek as close as **1.05 solar radii**, a region never imaged by any solar telescope. It can thus give us more information about **coronal mass ejection**.
 - b. **Solar Ultraviolet Imaging Telescope (SUIT):** It will observe UV radiations from different zones of the solar atmosphere. It will help us to better understand the climate variation on earth.
 - c. **Solar Low Energy X-Ray Spectrometer (SoLEXS)**
 - d. **High Energy L1 Orbiting X-Ray Spectrometer (HEL1OS)**

In-Situ Payloads:

- a. Aditya Solar Particle Experiment (ASPEX): In-situ measurements of solar particles and ions.
- b. Plasma Analyzer Package for Aditya (PAPA)
- c. Advanced Tri-axial High Resolution Digital Magnetometers

With the help of e,f, and g scientists can predict probable geomagnetic storms and better understand space weather dynamics.

Understanding Lagrangian Points

- These are position in an orbital configuration of two large bodies where a small object affected only by gravity can maintain a stable position relative to two large bodies. The Lagrange points mark positions where the combined gravitational pull of two large masses provides precisely the centripetal force required to orbit with them.
- The interaction of the forces creates a point of equilibrium where a spacecraft may be "parked" to make observation.
- These points are named after Joseph-Louis Lagrange, an 18th-century mathematician.
- There are five such points, labeled L1 to L5 all in the orbital plane of two large bodies.
 - Three of these Lagrangian points – L1, L2, and L3 – are unstable positions that lie along an imaginary straight line connecting the two larger bodies.
 - Because of this instability, an object positioned at one of the three unstable Lagrange points L1, L2, and L3 – can be easily de-orbited by even weak force and they will then drift into space. Therefore, spacecraft here will need to frequently burn fuel via its thrusters, at the various moments of displacement to adjust to orbital movement frequently.
 - The other two – L4 and L5 – are stable locations that from the apexes of two imaginary equilateral triangles with the two large celestial bodies at the vertices of each triangle. Objects stay undisturbed at L4 and L5 because of a restoring force – a force acting against any displacement – that prevents them from being nudged away from the stable point. Because of this stability, this point tends to accumulate a lot of interstellar dust and asteroids called Trojans that zip around the points. Scientists have detected various Trojans at L4 and L5 of Sun-Jupiter System, Sun-Mars System, Sun-Neptune system etc.
 - They are also potential Site for Space Colonies
- Are there other space explorers at L1?
 - Yes, it is already home to four robotic explorers – NASA's Solar and Heliospheric Observatory Satellite, Deep Space Climate Observatory, Advanced Composition Explorer, and the Global Geospace Science Wind Satellite.
 - In next few years, some more observatories by USA and EU will be reaching here.

About HALO Orbits: A halo orbit is a, three dimensional orbit near the L1, L2, or L3 Lagrangian point in the three body problem of orbital mechanics. Although the Lagrange point is just a point in empty space, its peculiar characteristics is that it can be orbited.

6. OTHER IMPORTANT PROJECTS OF ISRO

1) PROJECT NETRA

- It is an EWS in space to detect debris and other hazards to satellite. It will also provide warning against missile and space attack against India's assets.
- It will consist of many observational facilities, connected radars, telescopes, data processing units, control centers etc.
- Initially, it will be launched for **LEO satellites** which inhabits remote sensing satellites. Eventually, NETRA will also have the capability to capture **GEO**, where communication satellites mostly reside.
 - **Does India not have any collision avoidance detection mechanism now?**
- Even now, India does collision avoidance maneuvers on our satellites. But for this it depends on data from **NORAD** (North American Aerospace Defense Command) and others available in the public domain.
- **NOTE:** NORAD is an initiative of USA and Canada and shares selective debris data with many countries

2) MISSION SHAKTI

- An ASAT tested by India.

3) GAGANYAAN

4) XPOSAT (X-RAY POLARIMETER SATELLITE)

- **Why in news?**
 - ISRO launched the XPoSat, in a two-part mission, onboard a PSLV C58 flight on 1st Jan 2024.
- **More Details**
 - XPoSat is a specialized science mission that will study the **polarization of X-Rays** in space.
 - The mechanization of polarization of radiation gives away the nature of its source, including the strength and distribution of the magnetic field and the nature of radiation around it.
 - XPoSAT carries two scientific payloads in a **low earth orbit**:
 - The Primary Payload (POLIX) (Polarimeter Instrument of X-Rays) will measure the polarimetry parameters (degree and angle of polarization) in medium X-ray range of 8-30 Kilo electron volt (KeV) photons of astronomical origin.

- The **POLIX** payload is developed by the Raman Research Institute (RRI), Bangalore, with support from ISRO centres.
- The **XSPEC** (X-Ray Spectroscopy and Timing): It will study X-rays of energy 0.8-15 KeV and changes in continuous X-Ray emissions.
 - The **XSPEC** payload is developed by the UR Rao Satellite Centre (URSC), ISRO.
- Together (POLIX and XSPEC), they are expected to shed light on intense X-ray sources such as pulsars and blackholes.

- **Need:**
 - **Better understanding of the universe:**
 - So far, astronomers have largely used and depended on spectroscopic, imaging and timing-based data obtained from either ground-based telescopes or satellite based missions. **Polarization** based study was done either in the optical or radio bands.
 - **XPOSAT** will be game changer and will facilitate X-Ray polarization measurement possible from bright source, that too in the medium energy band (8-30 KeV) – which has never been attempted before.
 - It is thus an excellent diagnostic tool to understand the emission processes from astronomical sources.
 - In space, X-Rays get polarized by multiple factors - for e.g. when X-rays are subjected to strong magnetic field or due to interactions with material present around black holes. So, by studying this polarization, scientists can understand the key characteristics of the source.

- **International Trend in Space-Based X-Ray Polarimetry**
 - Internationally, space-based x-ray polarimetry is gaining importance.
 - The **Imaging X-Ray Polarimetry Explorer (IXPE)** mission, launched in 2021, represents NASA's inaugural space-based endeavor, focused on scrutinizing X-Ray Polarization across various celestial bodies.
 - **Note:** XPoSAT energy range of 8-30 keV for polarization measurement is complimentary to IXPE energy range of 2-8 KeV (soft X-Ray band). Therefore, XPoSAT and IXPE spacecrafts will collectively probe different emission mechanisms and physics for bright X-Ray sources. Their coordinated observation will provide a wide window in the energy range of 2-30 KeV for polarimetric observations for bright X-Ray sources.
 - **Note:** India's ASTROSAT – India's first astronomy-based space mission launched in Sep 2015 – performed timing and broadband spectroscopy of X-Ray sources but no polarization studies were performed.

- **Which sources will be observed?**

- The XPoSat team has identified several tens of sources radiating X-Rays. XPoSat will observe two kinds of sources – Persistent Sources (targeted known source) and transient sources (pulsars, active galactic nuclei, magnetars)
- **Other Facts about XPOSAT:**
 - Launched on Jan 1, 2024
 - Precise Circular Orbit of 650 km, inclination of 6 degrees.
 - It is only the second space-based experiment, to study X-ray polarization, and at higher x-ray energies than the other, NASA's Imaging X-Ray Polarimetry explorer.
 - The instrument is totally indigenous in design and fabrication.

A) UNDERSTANDING POLARIZATION – CLASS DISCUSSION

B) UNDERSTANDING POLARIZED GLASSES

Polarized glasses cut the hazardous glare off the flat surfaces such as water, glass, and asphalt. When the polarized axis is vertical, all light that has been polarized through reflection and is now traveling horizontally (such as glare off of water or a windshield), will be blocked by the filter.

Polarized glasses are special materials which allow only vertically altering electric fields, and helps to decrease the glare from ground reflection, which consist of mostly horizontal polarization. Reflection polarizes the randomly varying sunlight into a single direction. Scattering of sunlight by air molecules also has a similar effect.

5) NASA-ISRO SYNTHETIC APERTURE RADAR (NISAR) IMAGING SATELLITE

- **Introduction:**
 - NASA-ISRO SAR (NISAR) is a LEO observatory being jointly developed by NASA and ISRO. It will map the entire globe in 12 days and provide spatially and temporally consistent data.
 - It carries L and S dual band SAR, which works with sweep SAR technique to achieve large swath with high resolution data.
 - Once launched, it will be world's most expensive earth-imaging satellite till date costing around \$1.5 billion.
- **Collaboration**
 - NISAR is considered the first big collaboration between ISRO and NASA, certainly on RADAR but just in general as well.
 - S-Band SAR is being built by ISRO and L-band by NASA
 - » The satellite will be launched from India using **GSLV-MK-2**.
 - » **Uses:** NISAR will provide an unprecedented, detailed view of the earth by using Advanced RADAR imaging. It is designed to observe and take measurements of some of the planet's most complex process, including ecosystem disturbances, ice-sheet collapse, and natural hazards such as earthquakes, tsunamis, volcanoes, and landslides. The satellite thus will be used for:

- Mapping and monitoring of natural resources
- Estimating agricultural biomass over full duration of crop cycle.
- Assessing soil moisture
- Monitoring of floods and oil slicks
- Monitoring coastal erosion, coastline changes, and variation in the wind.
- **Target:** The target launch readiness date is January 2024.

7. NASA'S INTERPLANETARY MISSION

1) MARS ORBITER MISSION

- **Details**
 - Mars Mission (MOM), also called Mangalyaan is spacecraft orbiting MARS since 24 September 2014.
 - It was launched on 5 November 2013 by the Indian Space Research Organization (ISRO).
 - It is India's first interplanetary mission and ISRO has become the fourth space agency to reach Mars, after the Soviet space program, NASA, and the European Space Agency.
 - It is the first Asian nation to reach Mars orbit, and the first nation in the world to do so in its first attempt.
- **What is MOM doing?**
 - It has been looking for signs of atmospheric methane while studying surface features - just like NASA's MAVEN Mission. Methane is considered a biomarker: a substance whose presence indicates the current or historical presence of life.
 - MOM is also exploring and observing Mars surface features, morphology, mineralogy, and the Martian atmosphere.
- **Mars Orbiter Mission – 2** (Mangalyaan – 2) is expected to be launched in the year 2024. It will consist of an orbiter and may also include a lander and rover.

2) VENUS: SHUKRAYAAN-1

Why in news?

- India to launch Shukrayaan Venus Mission in 2024 after pandemic delays

Details

- Shukrayaan-1 is a **proposed orbiter to Venus by ISRO** to study the surface and atmosphere of Venus. It will be first mission to Venus by ISRO.
- ISRO has been soliciting ideas for instruments for a Venus-mission since at least 2018.
- **Earlier**, ISRO was aiming for a mid-2023, but pandemic related delays have pushed the target to Dec 2024.

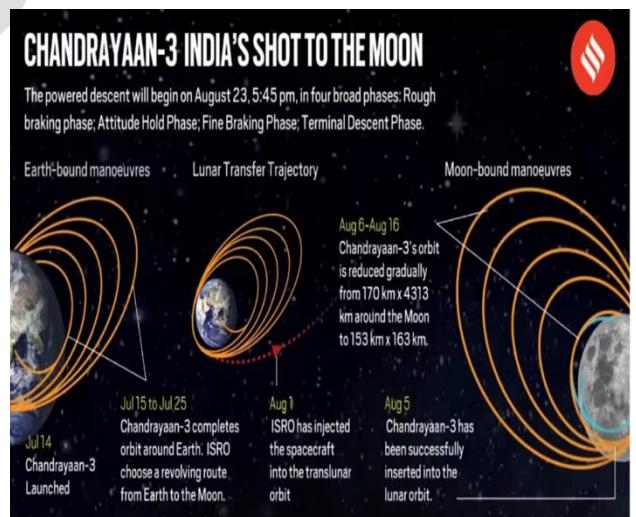
- » **Note:** This launch opportunity comes only in 19 months due to orbital configuration and period of Earth and Venus. So, after Dec 2024, the next opportunity will be available in mid-2026.
- It will be launched with the help of GSLV MK-II or GSLV MK-III.
- **Venus Missions in the Past**
 - » **Dozens of missions** have flown to Venus since the 1960s, but only a few in recent years.
 - **ESA's Venus Express** orbited the Venus between 2006 – 2014.
 - **Japan's Akatsuki** spacecraft entered orbit in 2015 after a previous unsuccessful attempt.
 - Several aircrafts are also performing **flybys** of Venus in the near future, including **NASA's Parker Solar Probe** for Solar Observation, and **Europe's BEPIColombo** en route to Mercury.

3) CHANDRAYAAN 3.0 (LVM3-M4) MISSION

- **Why in news?**
 - Chandrayaan-3 becomes the first to land near Moon's south pole (Aug 2023)
- **Details**
 - Chandrayaan -3 is the third Moon Mission of ISRO that was launched in July 2023 perched on GSLV-MK-3 heavy lift vehicle. It is a follow-on mission to Chandrayaan-2 and demonstrated end-to-end capability in safe landing and roving in lunar surface when it landed on the south pole of Moon on 23rd Aug 2023.
 - With this, India has become the fourth country in the world after USA, Russia and China to successfully land on Moon.

A) UNDERSTANDING THE DIFFERENT PHASES AND PATH TAKEN BY CHANDRAYAAN

- LVM-3 launched the Chandrayaan-3 in an elliptical parking orbit of 170 X 36500 km.
- Chandrayaan was launched on 14th July 2023. The whole process took 42 days, with the landing taking place on Aug 23.



B) COMPONENTS OF CHANDRAYAAN 3.0:

- It consists of a Propulsion Module (PM), Lander Module (LM), and a Rover with an objective of developing and demonstrating new technologies required for inter-planetary mission. **Note:** It doesn't have an orbiter module.

Propulsion Module (PM)

PM carried the LM from launch vehicle injection till final lunar 100 km circular orbit and separated LM from PM.

This propulsion module has Spectro-Polarimetry of Habitable Planet Earth (SHAPE) payload to study the spectral and Polarimetric measurements of Earth from the lunar orbit.

The Lander (**Vikram**) had the capability to soft land at a specified lunar site and deploy rover. It happened on 23rd Aug 2023. It remained stationary on the surface and carries four payloads which would record the chemical, thermal, and seismic instruments of the moon's surface.

Lander Payloads: Lander module has four payloads (Chaste, RAMBHA, ILSA and LRA)

Chandra Surface Thermophysical Experiment (ChaSTE): To carry out the measurements of thermal properties of lunar surface near polar region.

Instrument for Lunar Seismic Activity (ILSA) for measuring the seismicity around the landing site and delineating the structure of the lunar crust and mantle.

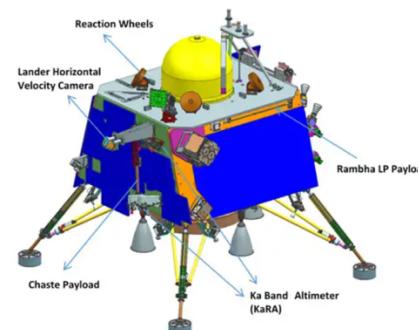
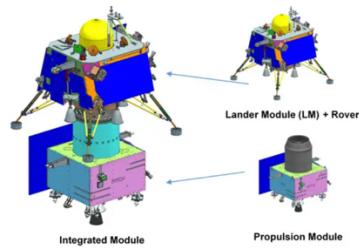
Rover (Pragyaan) is a 6 wheeled robotic vehicle.

Life: One lunar day (14 earth day)

Payload:

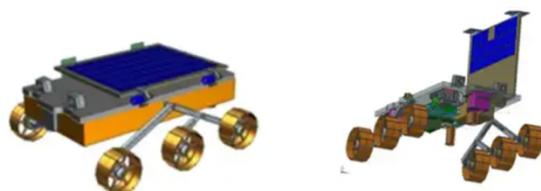
Laser Induced Breakdown Spectrometer (LIBS): It will determine the chemical and mineral composition of the lunar surface.

Alpha Particle X-Ray Spectrometer (APXS): It will determine the composition of elements such as magnesium, aluminium, silicon, potassium, calcium, titanium and iron in the lunar soil and rocks.



RAMBHA- LP (Radio Anatomy of Moon Bound Hypersensitive ionosphere and atmosphere) - RAMBHA: To measure the near surface plasma (ions and electrons) density and its changes with time.

A passive **Laser Retroreflector Array (LRA)** from NASA is accommodated for lunar laser ranging studies. It acts as a target for lasers for very accurate measurements for future missions.



C) LANDING WAS THE MOST COMPLICATED PART HERE:

- Landing is the most complicated part of the mission. The Lander and Rover get ejected at a speed of around 6,000 km/hr and have to be slowed down to roughly 3 km/hr before it lands. Since

moon doesn't have atmosphere, parachute kind of mechanism can't be used. Here, thrusters had to be fired in opposite direction to slow down the lander.

D) WHERE DID LANDER LAND?

- It landed at around 70-degree S near the southern pole of the moon.
- **Why?**
 - a. The site was selected as there are several craters here that are permanent in shade and can be reservoir of frozen water which is key to the future space mission.

E) ROVER:

Within a few hours of landing, ISRO also released a 26-kg rover from the lander module, which滑了 on the ramp to reach the moon's surface. The six wheeled rover, which is carrying two instruments and moves very slowly, is expected to crawl on the surface for 14 days, conducting chemical and elemental analysis of lunar soil and rocks.

E) COMPARING CHANDRAYAAN-1, CHANDRAYAAN-2 AND CHANDRAYAAN-3

	Chandrayaan-1	Chandrayaan-2	Chandrayaan-3
Year	2008	2019	2023
Rocket Used	PSLV	LVM-3	LVM-3
Payloads	Orbiter + Impactor Module (for crash landing)	Orbiter + Lander (Vikram) + Rover (Pragyan)	Lander + Rover
Successful	Yes	Partially Yes (Lander failed)	Yes
	<p>Perhaps the <u>most important</u> discovery of Chandrayaan-1 was the <u>discovery of water and hydroxyl (OH) molecules</u> in the Moon's thin atmosphere (exosphere) as well on the lunar surface.</p> <p>Buried Lava Tubes: The terrain mapping camera and hyperspectral imager on board Chandrayaan-1 detected an <u>underground lava tube</u>, which, scientists believe, can provide a <u>safe environment for human habitation in the future</u>. It can protect against hazardous radiation, small meteoric impacts, extreme temperature and dust storms on the surface.</p>	<p>It helped in <u>separately</u> identifying the water and hydroxyl molecules, and mapping water features across the moon for the first time.</p>	

D) CHANDRAYAAN 3 PROPULSION MODULE RETRACES STEPS TO EARTH ORBIT: WHY IT MATTERS? (DEC 2023)

- **What happened?**
 - Scientists have brought the propulsion module (PM) of Chandrayaan 3 mission back into earth orbit.
 - This was not part of original mission plan. It utilized the logistics advantage of near perfect mission, especially the availability of more than 100 Kg of fuel.
- **How was this achieved?**
 - ISRO performed maneuver to raise the orbit of the PM around the moon (from 150 km to 5,112 kms)
 - Second maneuver targeted an earth orbit of 1.8 lakh X 3.8 lakh km.
- **Significance:**
 - This experiment prepares ISRO for future missions, especially the ambitious Lunar Sample Return Mission.
 - Through this ISRO has been able to understand what is involved in the “planning and execution of trajectory and maneuvers to return from Moon to Earth”

E) SIGNIFICANCE OF GOING TO MOON:

- It underlined India's rise as a space and technology powerhouse. It will also strengthen India's soft power in the global community.
- Since moon is the closest cosmic body to Earth, the plans to explore rest of the universe starts with exploration of the moon. Moon can also act as a promising test bed to demonstrate technologies required for future deep-space missions.
- It would further help “stimulate the advancement of technology, promote global alliances and inspire a future generation of explorers and scientists.”
- **Resources:** Recent increase in interest in Moon is primarily due to possibility of important minerals being found on Moon.

8. OTHER IMPORTANT PROJECTS OF ISRO

1) INDIA'S OWN SPACE STATION: PLANS

- **What advancements will India need to achieve to have its space Stations?**
 - All the **Gaganyaan requirements** (Space suits, Training facilities for astronauts, Crew Escape Module, making GSLV Human rated, developing a habitable module etc)
 - **Larger bigger rocket** by upgrading the capabilities of GSLV-MK-III (it is right now capable of carrying on 10 tonnes to LEO)
 - Developing ability to perform **space docking**. ISRO has revealed its plan to carry out a space docking experiment, Spadex.



8. INTERNATIONAL COLLABORATION IN NEWS

1) ISRO – NORWAY

- **Why in news?**
 - Norwegian Ambassador Han Jacob Frydenlund's visit to ISRO's headquarters (June 2023)
- In June 2023, Norwegian Ambassador Frydenlund, accompanied by officials of Kongsberg Satellite service (KSAT), called on ISRO Chairman S. Somanath in Bengaluru, ISRO. The meeting concluded with a mutual agreement on the importance of maintaining a continued partnership and fostering increased engagements between India and Norway.
- It also offered an occasion to recall the 'Svalbard mission' of 1997.

A) SVALBARD MISSION OF 1997

- On Nov 20, 1997, a Rohini RH-300 Mk-II sounding rocket rose to the skies from Svalbard, Norway, operationalizing a new rocket launching range.
- ISRO bagged the Norway mission after its commercial arm Antrix Corporation won a global tender floated by the Norwegian space agency.
- The RH-300 MK-II was given a new name by the NSC (Norwegian Space Centre): **Ibjorn-1**, which translates literally as 'Polar Bear-1'.

9. IMPORTANT TELESCOPES IN NEWS RECENTLY

1) VARIOUS TELESCOPES AT DEVASTHAL

- Devasthal observatory is located at Aryabhatta Research Institute of Observational Science (ARIES) in Nainital. It is located at the height of 2,450 metres in Himalayas. It is considered as one of the best sites for astronomical observations. This facility is the result of collaborative work between astronomers from ARIES, Institute of Astrophysics and Geophysics, Liege University, Belgium; the Canadian Astronomical Institutes from Vancouver, University of British Columbia; etc.

- **Telescopes at Devasthal:**
 - **Devasthal Optical Telescope (DOT)** is a custom-built instrument of great complexity. It has the distinction of being the largest telescope in India for study of celestial objects at optical wavelength. It is a national facility installed at Devasthal in the district of Nainital, India. It was commissioned in 2016 and is being maintained and operated by ARIES (Aryabhata Research Institute of Observational Sciences)
 - **Devasthal Fast Optical Telescope (DFOT)**: It was commissioned in 2010.
 - **The International Liquid Mirror Telescope (ILMT)** is the only liquid mirror telescope operational anywhere in the world. It will also hold the unique tag of being the maiden liquid-telescope globally to be designed exclusively for astronomical purposes. It is the third telescope operating from Devasthal after DOT and DFOT.
 - The telescope was designed and built at the Advanced Mechanical and Optical Systems Corporation and the Centre Spatial de Liege, Belgium. The major instrumentation funding was jointly provided by Canada and Belgium while India will be responsible for the operations and upkeep of the telescope.
 - Unlike the conventional telescopes that can be steered to track specific stellar source objects, the ILMT will be stationary. It will basically carryout observations and imaging at the Zenith, that is, of the overhead sky. This is a survey telescope having high potential for discovering newer objects.
 - ILMT will operate every night for five years and carry out daily imaging except during June – Aug monsoon months, a precaution to protect the instruments from humid conditions.
- **What is liquid mirror telescope?**
 - LMTs are telescopes with mirrors made with a reflective liquid. The most common liquid is mercury, but other liquid will also work including (low melting alloys of gallium).
 - The liquid is rotated at a constant speed around a vertical axis, which causes the surface of liquid to assume a paraboloidal shape. This parabolic reflector can serve as the primary mirror of a reflecting telescope.
 - **Advantages:**
 - Low-cost alternative to conventional large telescopes.
 - **Limitations:** It can only be used as zenith telescopes (i.e. for looking straight up), so it is not suitable for investigation where the telescope needs to be continuously moved.

2) INDIA'S FIRST DARK SKY RESERVE

- **What is a Dark Sky Reserve?**
 - A Dark Sky Reserve is a designation given to a place that has policies in place to ensure that a tract of land or region has minimal artificial interference.

- The International Dark Sky Association (IDSA) is a US based non-profit that designates places as International Dark Sky Places, Parks, Sanctuaries, and Reserves, depending on the criteria they meet. Several such reserves exist in the world. **Between 2001 and Jan 2022**, there have been 195 sites recognized as International Dark Sky Places globally. But, so far, no such reserve is in India.
 - These reserves “consist of a core area meeting minimum criteria for sky quality and natural darkness, and a peripheral area that supports dark sky preservation in the core”.
- **How does a site become a ‘Dark Sky Reserve’?**
- Individuals or groups can nominate a site for certification to the IDSA. There are five designated categories, namely International Dark Sky parks, communities, reserves, sanctuaries, and Urban Night Sky Places.
 - The certification process is similar to that of a site being awarded the UNESCO World Heritage Site tag or getting recognized as a Biosphere Reserve.
 - **Note:** India is still in the process of filing its nomination to IDSA.
- **Who is developing India’s first Dark Sky Reserve?**
- The Ladakh UT administration is leading the efforts to establish the country’s first Dark Sky Reserve. The Department of Science and Technology (DST) and experts from Indian Institute of Astrophysics (IIA), Bengaluru, are providing scientific and technological support in developing this first of its kind facility. The formal decision to set up this Dark Sky Reserve was made through a MoU signed between officials from the IIA, Bengaluru, the Ladakh UT and the Ladakh Autonomous Hill Development Council in June 2022.
 - It will be situated at a height of 4,500 metres above sea level, the Hanle Dark Sky Reserve (HDSR) will come up within the Changthang WLS.
 - The IIA already manages the Indian Astronomical Observatory (IAO) complex at Hanle, Ladakh. Here scientists have been carrying out astronomical observations using the existing gamma ray, an infrared and an optical telescope to study exoplanets, galaxies, and stars through the pristine skies of Hanle.
 - For Dark Sky Reserve, in the pilot phase, IIA has procured ten small and easy to handle telescopes and light reflecting shields. IIA’s scientific and outreach experts will identify locals and train them to use these telescopes. This will include basic sky gazing, identification of constellations, and locating the pole star, among others. These telescopes will be installed at the homestays, which is a popular option for tourist accommodation in Ladakh.
- **Why was Ladakh chosen for the project?**
- It is a unique cold desert located about 3,000 metres above sea level with high mountainous terrains. Very cold temperature and long and harsh winter makes the UT very inhabitable. This aridity, limited vegetation, high elevation, and large area with sparse populations – all make it the perfect setting for long-term astronomical observatories and dark sky places.

- **Promotion of Astronomy Tourism** in an environment friendly and sustainable manner is one of the primary objectives of the proposed reserve. Scientific methods would be used here to keep light pollution under control.

A) THE INDIAN ASTRONOMICAL OBSERVATORY (IAO)

- The Indian Astronomical Observatory, the high-altitude station of IIA, is situated to the north of Western Himalayas, at an altitude of 4,500 meters above mean sea level.
- It is located atop Mt. Saraswati in the Nilamkhul Plain in the Hanle Valley in Changthang, it is a dry, cold desert with sparse human population and has the Hanle monastery as its nearest neighbours.
- The cloudless sky and low atmospheric water vapor make it one of the best sites in the world for optical, infrared, sub-millimeter, and millimeter wavelengths.
- **Prominent Telescopes located at the Hanle Observatory:**
 - The Himalayan Chandra Telescope
 - High Energy Gamma Ray Telescope (HAGAR)
 - The Major Atmospheric Cherenkov Experiment Telescope (MACE)
 - Growth-India

10. SPACE INFRASTRUCTURE IN INDIA

- **Background:**
 - Space activities in India began with the establishment of the Indian National Committee for Space Research (INCOSPAR) in 1962. In the same year, work on establishment of Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram was also started.
 - ISRO was formed on 15th Aug 1969, and superseded INCOSPAR with an expanded role. In 1972, Space Commission and Department of Space (DOS) were constituted by the GoI, and ISRO was brought under DOS.
 - ISRO is the space agency of India. It is involved in science, engineering, and technology to harvest the benefits of our space for India and mankind. It has established major space systems for communication, television broadcasting, and remote sensing. It has also developed satellite launch vehicles like PSLV, GSLV, LVM-3 etc. It also contributes to science and science education in the country. It has launched Indian's NAVIC, Chandrayaan, MOM-1, Aditya-L1 and several other incredible missions.
 - Space Commission formulates the policies and oversees the implementation of the Indian Space Program to promote development and application of space science and technology for the socio-economic benefit of the country.
 - DOS implements these programs through ISRO and other associated organizations:



- The Major establishments of DOS and their area of activities are:

A) VIKRAM SARABHAI SPACE CENTRE (VSSC):

- Located in Thiruvananthapuram, it is responsible for design and development of launch vehicle (rocket) technology. Its major programs include, PSLV, GSLV, LVM-3, RLV, Rohini Sounding Rockets etc.

B) UR RAO SATELLITE CENTRE (URSC)

- Located in Bengaluru, it is the lead centre for design and development of satellites including communication, navigation and remote sensing satellites. These satellites provide applications in the areas of telecommunication, television broadcasting, VSAT services, tele-medicines, tele-education, navigation, weather forecasting, disaster warning etc.

C) SATISH DHAWAN SPACE CENTRE (SDSC)-SHAR

- It is the 'Spaceport of India'. It is the backbone of the ISRO in providing launch base infrastructure for the Indian Space Program.
- It is located at Sriharikota, Andhra Pradesh.

D) LIQUID PROPULSION SYSTEMS CENTRE (LPSC)

- It is the lead centre of ISRO for the design, development, and realization of advanced propulsion systems for launch vehicles.
- It is primarily responsible for developing and deploying earth storable, cryogenic, semi-cryogenic, and electric propulsion systems for ISRO's launch vehicles and satellites.
- Its activities are spread across its two campuses, namely, LPSC, Valiamala, Thiruvananthapuram, and LPSC, Bengaluru.

E) SPACE APPLICATION CENTRE (SAC)

- Located in Ahemedabad, it's a major R&D centre of ISRO.
- It develops space borne and air-borne instruments and payloads and their applications for national development and societal benefits.
- For e.g., the communication transponders developed at this centre for the INSAT and GSAT series of satellites are used by the government and private sector for VSAT, DTH, Internet, broadcasting etc.
- It also designs and develops optical and microwave sensors for satellites, signal and image processing software, GIS software, and many applications for Earth Observation Program of ISRO.

F) HUMAN SPACE FLIGHT CENTRE (HSFC)

- Set up in 2019, it is the lead centre for ISRO's Human Spaceflight program.

- It undertakes multidisciplinary R&D activities in new domains of human science and technology while conforming to high standards of reliability and human safety.
- It is currently focused on Gaganyaan mission and is working on end-to-end mission planning, development of orbital module, life support systems, selection and training of astronauts etc.
- It is currently operating from ISRO-HQ campus, Bengaluru.

G) NATIONAL REMOTE SENSING CENTRE

- It is responsible for establishment of ground centres for receiving satellite data, generation of data products, aerial remote sensing data acquisition, dissemination to the users, development of techniques for remote sensing applications including disaster management support, geospatial services etc.

H) ISRO PROPULSION COMPLEX (IPRC)

- Located in Mahendragiri, it is responsible for assembly, integration and testing of liquid propulsion systems for operational and developmental launch vehicles.
- It is also responsible for qualification, testing and acceptance of liquid engines, cryogenic engines, spacecraft engines etc.

I) ISRO TELEMETRY, TRACKING AND COMMAND NETWORK (ISTRAC)

- It is responsible for providing telemetry, tracking and command (TTC), and mission control services to major launch vehicle, laboratory for electro-Optics Systems (LEOS) and Interplanetary Spacecraft missions of ISRO.
- It is also responsible for operating the complex ground segment of NaVIC.

J) MASTER CONTROL FACILITY (MCF)

- It is responsible for on-orbit Operations (OOP) and Launch & Early Orbit Phase (LEOP) operations of geostationary/geosynchronous & IRNSS class of spacecrafts of ISRO.
- It is located at Hassan in Karnataka.

K) ISRO INERTIAL SYSTEMS UNIT (IISU)

- Located in Thiruvananthapuram, it is responsible for design and development of inertial systems for launch vehicles and satellites. These include mechanical and optical gyros, Altitude reference systems, accelerometer packages etc.

L) LABORATORY FOR ELECTRO OPTICS SYSTEMS (LEOS)

- Located in Bengaluru it is responsible for design, development and production of altitude sensors, high resolution imaging optics, and special purpose science instruments for several spacecrafts.

M) INDIAN INSTITUTE OF REMOTE SENSING (IIRS)

- IIRS, Dehradun, is a premier institute with primary aim to build capacity in Remote Sensing and Geoinformatics and their applications through education and training programs at the postgraduate levels.

N) DEVELOPMENT AND EDUCATIONAL COMMUNICATION UNIT (DECU)

- Located in Ahmedabad, it is responsible for implementation of satellite-based societal applications in the country.
- It is involved in the system definition, planning, implementation, and social research & evaluation of such applications.

O) NATIONAL ATMOSPHERIC RESEARCH LABORATORY

- Located in Gadanki near Tirupati, it is an autonomous organization engaged in cutting edge research in atmospheric and space sciences with the vision of developing capability to predict the behaviour of the earth's atmosphere through observations and modelling.

P) NORTHEASTERN-SPACE APPLICATIONS CENTRE (NE-SAC)

- It is an autonomous organization under DOS and Northeastern Council (NEC). It has the mandate of providing space-based governance and development by taking up projects in the fields of natural resource management, infrastructure planning, healthcare, education, emergency communication etc.
- It also conducts training and capacity building in the field of geospatial technology and UAV based remote sensing applications.

Q) INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

- Established in 2007 at Thiruvananthapuram, it is Asia's first Space University. It aims to provide high quality education in Space S&T to meet the demands of the Indian Space Program. It offers undergraduate, postgraduate, doctoral and post-doctoral programs.

R) ANTRIX CORPORATION LIMITED (ACL)

- It is a Gol company under the administrative control of DOS.
- It is engaged in providing space sector products and services worldwide ranging from supply of hardware and software, earth observation and scientific missions, transponder lease services, launch services etc.

11. IMPORTANT PERSONALITIES

A) DR VIKRAM SARABHAI (12TH AUG 1919 – 30TH DEC 1971)

- Vikram Sarabhai, **father of Indian Space Program**, was born on 12th of Aug, 1919 in Ahmedabad.

- **Key contributions**

- He was a great institution builder and established or helped to establish a large number of institutions in diverse fields. He established **Physical Research Laboratory (PRL)** in 1947. PRL was the cradle of space sciences in India. PRL had a modest beginning at his residence, the RETREAT, with research in cosmic rays. It was formally established at M.G. Science Institute, Ahmedabad, on 11th Nov 1947
- He played an important role in establishment of a number of institutions including IIM Ahmedabad.
- The establishment of ISRO was one of his greatest achievements. He successfully convinced the government of the importance of space program after the Russian Sputnik launch.
 - He was the first chair of Indian National Committee for Space Research (INCOSPAR) which was predecessor to ISRO (established in its current form in 1969).
 - He also contributed in the setting up of Thumba Equatorial Rocket Launching Station at Thiruvananthapuram, with its inaugural flight in 1963.
- He was also chairperson of Atomic Energy Commission.



- **Recognition**

- i) He received Shanti Swarup Bhatnagar Medal in 1962

- ii) Was awarded Padma Vibhushan (posthumously) in 1972. Earlier was awarded Padma Bhushan in 1966.

- **Other Key Positions held:**

- i) President of the Physics Section, Indian Science Congress (1962)

- ii) President of General Conference of the I.A.E.A, Vienna (1970)

B) S SOMNATH

- » Sreedhar Panicker Somanath is the current chairperson of the ISRO. Earlier he has served as the chairperson of Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram and Director of Liquid Propulsion Systems Centre (LPSC), Thiruvananthapuram.
- » He was associated with the PSLV project during its initial days. He was also the project director of the GSLV-MK-III launch vehicle in from 2010 to 2014.

12. COMMERCIALIZATION AND PRIVATIZATION IN SPACE SECTOR

A) PRARAMBH MISSION

- **Why in news?**

- Launch of Vikram-S (i.e., Vikram Suborbital) rocket by Skyroot Aerospace is being hailed as an important milestone in India's outer space journey (Nov 2022)

- **Details:**

- **Skyroot Aerospace**, an Indian private sector space enterprise, created history by launching India's first privately developed rocket **Vikram-S**.
- **Vikram-S** is a single stage rocket. It is India's first privately developed cryogenic hypergolic-liquid and solid fuel-based rocket engine. It was developed using advanced composite and 3-D printing technologies.
- It carried three customer payloads in a sub-orbital flight. It was launched from the sounding rocket complex of the ISRO's Satish Dhawan Space Centre in Sriharikota, Andhra Pradesh.
- The rocket reached a peak-altitude of 89.5 kms and has met all flight parameters.
- **More About Skyroot:**
 - It is a relatively new entity that was set up in 2018. In 2020, after government announced opening up of space sector for private entities, it became the first startup to sign an MoU with ISRO to launch a rocket.
 - It is producing a series of Vikram Satellite, named after Dr Vikram Sarabhai. The goal is to launch small satellites using this rocket.
- **Future Plans of SkyRoot:**
 - **Vikram-1** is being developed to carry 480 kg payload to Low inclination Orbit.
 - **Vikram-2** which will follow Vikram-1, will carry 595 kg to low inclination orbit.
 - **Vikram-3** will carry 815 kg to Low inclination orbit.
 - Skyrocket also says that the rockets will be able to undertake multi-orbit insertion and inter-planetary missions as well as offer "customized, dedicated and ride share options covering a wide spectrum of small satellite customers needs".

2) NEW INSTITUTIONS

B) NEW SPACE INDIA LIMITED (NSIL)

- NSIL is a wholly owned government of India undertaking/CPSE, under the administrative control of Department of Space (DOS). It was established in March 2019 to commercially utilize the R&D work of ISRO Centers and other constituent units of DOS.
- **Roles and Functions:**
 - i. Small Satellite technology transfer to Industry, wherein NSIL will obtain license from ISRO/DOS and sub-license it to industry.
 - ii. Manufacture of SSLVs in collaboration with Private sector.
 - iii. Productionization of PSLV through Indian Industry.
 - iv. Productionization and marketing of space-based products and services, including launch and applications
 - v. Transfer of technology developed by ISRO Centres and constituent units of DOS

- vi. Marketing spin-off technologies and product/services, both in India and abroad.
 - vii. Any other subject which GoI deems fit.

- **As part of the space sector reforms announced by GOI in June 2020, NSIL was mandated to build, launch, own and operate satellites in “Demand-driven mode” to meet the service needs of the user.**
- The **launch of Brazil’s Amazonia-1 satellite** in March 2021, was the first dedicated communication mission of NewSpace India Limited. Earlier launches facilitated by NSIL were piggybacked with ISRO’s primary satellites.
 - i. Launch of GSAT-24 in June 2022 was the first demand driven satellite mission undertaken by NSIL. The capacity onboard the satellite was fully secured by TataPlay.
 - ii. **Presently (Jan 2024) NSIL owns and operates 11 communication satellites in India.**
 - iii. On similar lines, in 2024, NSIL will be undertaking the GSAT-20 satellite mission to offer cost-effective Ka-Ka band HTS capacity primarily for meeting the Broadband. The bulk of the capacity onboard GSAT-20 have already been secured by Indian Service Providers.

- **Significance of NSIL:**
 - i. Meet the ever-increasing demands of Indian Space Program.
 - ii. Commercially exploit the emerging global space sector.
 - iii. Spur the growth of Indian Industries in the space sector and enable Indian industries to scale up manufacturing and production base.

B) IN-SPACE (INDIAN NATIONAL SPACE PROMOTION AND AUTHORIZATION CENTRE)

- It is an independent nodal agency under Department of Space (DoS). It was set up in 2020 to boost commercialization of Indian Space Activities and encourage private sector participation.
- It will permit and oversee the following activities of **non-Government Private Entities** (NGPEs):
 - Building of launch vehicles and satellites and providing space-based service as per the definition of space activities.
 - Sharing ISRO infrastructure/premise etc.
 - Establishment of temporary facilities within the premise of ISRO
 - Establishment of new space infrastructure and facilities, by NGPEs, in pursuance of space activities based on safety norms and other statutory guidelines and necessary clearance.
 - Building of Spacecrafts by NGPEs for registration as Indian satellites and all associated infrastructure
 - Using of spacecraft data and rolling out of space based services and all other associated infrastructure for the same.
- It will draw up integrated launch manifest – considering the needs of ISRO, NSIL, and NGPEs based on priorities and readiness.
- It will draw up suitable mechanism for promotion, handholding, infra-sharing etc. to encourage participation of NGPEs.
- The decision of IN-SPACe shall be final and binding on all stakeholders including ISRO, NSIL etc. NGPEs will not be required to seek separate permission from ISRO.

- **Structure of In-SPACe** – It has a Chairman, technical experts for space activities, safety experts, experts from academia and industries, legal and strategic experts from other departments, members from PMO and MEA of GoI.
- **Monitoring and Promotion Directorate of IN-SPACe** will have the oversight of the activities as per IN-SPACe decisions and shall report back to IN-SPACe for corrective actions and resolutions if any.



TARGET PRELIMS 2024

BOOKLET-2; S&T-2

SPACE AND ASTRONOMY-2

TABLE OF CONTENTS

1. <i>Table of Contents</i>	0
1. <i>International Efforts</i>	3
1) Space Governance: Global Norms	3
2) International Space Station (ISS)	3
1) Thirty Meter Telescope (TMT)	4
2) SKAO (Square Kilometer Array Observatory)	5
A) India Moves towards becoming full member of SKAO (Jan 2024)	6
3) Space Based Internet	6
2. <i>NASA Initiatives</i>	7
1) Great Observatory Program	7
B) The Hubble Space Telescope (HST)	7
C) The Compton Gamma Ray Observatory (CGRO) (not operating currently)	8
D) The Chandra X-ray observatory (CXO)	8
E) The Spitzer Space Telescope (SST)	8
2) James Webb Space Telescope	8
3) NASA's Artemis Accord	9
4) NASA's ARTEMIS Lunar Program	10
a) Artemis-1 mission	11
b) Artemis-2: 2024	11
c) Artemis-3: 2025	12
d) NASA's Gateway Lunar Orbit Outpost	12
5) NASA's Mars 2020 Mission - PERSEVERANCE Rover	12
6) Parker Solar Probe	13
7) Lucy Mission	14
8) Dart Mission	14
9) Voyager-2	15

3. Peregrine Mission-1: First US Spacecraft due to land on Moon since the Apollo Missions in the 1970s Lifts Off	16
4. China	17
1) China's Space Station: Tiangong	17
2) Chang'E-5	18
5. Space Tourism.....	19
6. RUSSIA:.....	20
1) LUNA-25.....	20
7. General SPACE ISSUES.....	21
1) Space Debris	21
8. BASICS OF ASTRONOMY.....	22
1) Galaxy	22
2) OUR SOLAR SYSTEM	22
3) PLANETS, DWARF PLANTS AND OTHER CELESTIAL BODIES.....	23
4) MOON.....	24
5) PLANETS WITH HIGHEST NUMBER OF MOON	24
6) ASTEROIDS	24
A) Near Earth Asteroid:	24
B) Psyche	25
7) JUPITER TROJANS (CLASS DISCUSSION)	25
8) EXOPLANETS (CLASS DISCUSSION).....	26
9) GRAVITATIONAL LENSING	26
9. Sun	26
A) Basics About Sun.....	26
B) Sun's Structure – 3 Atmospheric LAYERS	27
C) Understanding Solar Winds	28
1) Life Cycle of Stars: Stars – Dwarf Stars – Neutron Stars – Black Holes	29
A) Life Cycle of a Star	29
B) Medium Stars -> Red Giant -> White Dwarf -> Black Dwarf.....	29
C) Neutron Star	30
D) Black Hole	30
10. Electromagnetic Waves AND WIRELESS COMMUNICATION	32
1) Electromagnetic Spectrum	33
A) Radio waves:.....	34
B) Microwaves.....	34
C) Infrared Waves.....	35
D) Visible Rays	35
E) Ultraviolet Rays.....	35
F) X-Rays.....	36
G) Gamma Rays	36

C) 2) Penetration of various EM Waves in Earth's Atmosphere.....	36
2) WIRELESS CommunicatioN – Different Frequency Bands and THEIR Applications	37
A) Radio Waves (500 KHz – 1 G Hz)	37
A) MICROWAVES	38
D) Deep Space Optical Communication.....	40
11. PYQs	41

LevelUpIAS

1. INTERNATIONAL EFFORTS

1) SPACE GOVERNANCE: GLOBAL NORMS

- Current Space Regulations: Gaps and Loopholes
 - » United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) was established in 1958 with UN Office for outer space affairs as its secretariat. It oversees the implementation of five UN treaties related to outer space:
 - » Treaty on Principles Governing Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial bodies of 1967 (Outer Space Treaty)
 - It designates space as the “province of all mankind” and states that the exploration of the outer space would be for the benefit of all countries, irrespective of their degree of economic or scientific development. It also prohibits deployment of weapons of mass destruction in space, and establishment of military bases, installations, and fortifications.
 - Limitations: Doesn't clearly prohibit weapons other than weapon of mass destruction; Doesn't properly cover modern day technologies like lasers for communication.
 - Further, it doesn't provide a detailed mechanism to decide if activities are inconsistent with the treaty and it failed to address issues like growing weaponization of the space.
 - » Agreement on the Rescue of Astronauts, the Return of Astronauts and Return of Objects Launched into Outer Space of 1968 (Rescue Agreement)
 - » Convention on International Liability for Damage Caused by Space Objects of 1972 (Liability Convention)
 - Limitation: The **Liability Convention and OST** have the potential to impede the private sector investment as it makes state liable for all the damages thus compelling states to impose license and insurance on such entities.
 - » Convention on Registration of Objects Launched into outer space of 1976 (Registration Convention). It has helped in development of an international registration system. Full knowledge of the presence of objects in space is crucial for peaceful and safe use.
 - » The Agreement Governing the Activities of States on the Moon and other Celestial Bodies of 1979 (Moon Treaty).
 - » It also oversees **other related treaties** including Treaties Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and under Water (NTB) of 1963 and the **Brussels Convention Relating to the Distribution of Programme – Carrying Signals transmitted by Satellite (BRS) of 1979** among others.

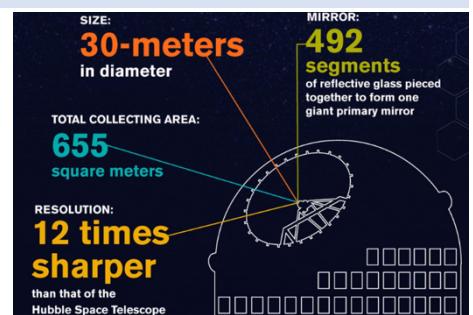
2) INTERNATIONAL SPACE STATION (ISS)

- The International Space Station (ISS) is a modular space station (habitable artificial satellite) in LEO.

- Its main construction was completed between 1988 and 2011, although the station continuously evolves to include new mission and experiments. It has been continuously occupied since Nov 2, 2000.
- It is a multinational collaboration with contribution from 15 nations.
 - A) NASA, ESA, ROSCOSMOS are the major partners of the space station and contribute most of the funding.
 - B) JAXA, and Canadian Space Agency are other partners.
 - C) Through a private company called Axiom Space, private astronauts are starting to work on the orbiting complex, from time to time.
 - D) The ownership and use of the space station is established by intergovernmental treaties and agreement.
- Details:
 - A) ISS is 109 meters from end to end with a weight of more than 4 lakh kg without visiting vehicles.
 - B) Orbits at an average height of 400 kms. It circles earth every 90 minutes at a speed of about 28,000 km/h.
- Space Vehicles to reach ISS:
 - A) Currently, astronauts travel to ISS via SpaceX's Crew Dragon capsule. Russian astronauts travel to the space station using Soyuz capsule.
 - B) Note: After retirement of NASA's Space Shuttle Program in 2011, Soyuz was the only spacecraft which could take humans to ISS. Later, in 2020, SpaceX's Crew Dragon also became available.
- Purpose:
 - A) It provides a platform for multi-gravity and space environment research laboratory.
- Future:
 - A) Current Plan calls for the space station to be operated through at least 2024 with the partners discussing a possible extension.
 - B) NASA has approved extension till 2030.
 - C) Russia has announced its withdrawal after 2024 to focus on building its own space station around 2028.
 - D) After 2030, plans for ISS are not clearly known. It could be deorbited or recycled for future commercial space stations in orbit.

1) THIRTY METER TELESCOPE (TMT)

- What is thirty-meter telescope?
 - Thirty-meter telescope is a new class of extremely large telescopes that will allow us to see deeper into space and observe cosmic objects with unprecedented sensitivity.
 - With its 30 m prime mirror diameter, TMT will be three times as wide, with nine times more area, than the largest



currently existing visible light telescope in the world. The images of TMT will be **12 times sharper than Hubble Space Telescope.**

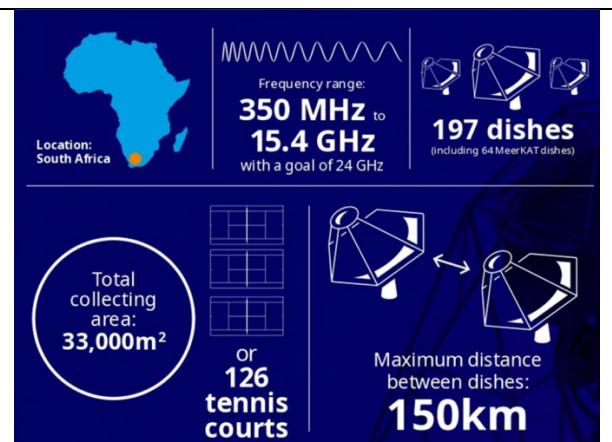
- The TMT will **observe wavelengths** ranging from the ultraviolet to the mid-infrared.
- **Who is building TMT?**
 - » It is being built by **TMT International Observatory LLC (TIO).**
- The TIO is a non-profit international partnership between the California Institute of Technology, the University of California, the National Institute of Natural Science of Japan, the National Astronomical Observatory of Chinese Academy of Sciences, the **DST India** and the National Research Council, Canada.

2) SKAO (SQUARE KILOMETER ARRAY OBSERVATORY)

- The Square Kilometer Array (SKA) is an inter-governmental radio telescope project under construction. Once completed it will be the world's largest and most powerful radio telescope.
- It will be built in two phases – with the core arrays located in:
 - **Australia:** Focusing on low frequency observation.
 - **South Africa:** Focusing on mid-frequency observation.
- **How will it function?**
 - The SKA will combine signals from thousands of smaller antennas spread across vast distances to function as a single giant telescope with exceptional sensitivity and angular resolution. This is achieved through a technique called aperture synthesis.
 - Some sub-arrays will also have very broad field view, allowing for surveying huge areas of the sky simultaneously.
- **The headquarters** and combining infrastructure, called the Square Kilometer Array Observatory (SKAO), are located at the Jodrell Bank Observatory in the UK.
- **The incredible sensitivity** of SKA will help understand the universe in a better way.
- **How will the SKA Observatory work?**

The 197 dishes in South Africa are collectively referred to as **SKA-Mid** and will observe at radiofrequencies between 350 MHz and 15.4 GHz. They have combined effective collecting area of 33,000 sq m.

SKA-Mid's resolution will be 4-times that of JVLA (the current best similar instrument in the world)



In Australia, the 131,072 low frequency antennas are known as **SKA-Low** and have combined collecting area of **419,000 sqm**.

Compared to LOFAR(Low Frequency Array) in the Netherlands, this will be 8x more sensitive.



- The collecting area is a crucial component that makes the SKAO so powerful. It makes the telescope detect even the fainter objects.

- **Progress:**

- The construction of the project began in 2018, with the first light (the start of the scientific observations) expected in 2027

A) INDIA MOVES TOWARDS BECOMING FULL MEMBER OF SKAO (JAN 2024)

- In Jan 2024, GOI has approved India's participation in SKA, with a financial sanction of Rs 1,250 crores. This is the first step towards ratification of SKAO Convention. Countries have to sign and ratify this convention to formally become members.
 - **India**, through the Pune-based National Centre for Radio Astrophysics (NCRA) and some other institutions, has been involved in the development of SKA since its inception in the 1990s. India contributed heavily to the design and development of the SKA telescope over time, particularly in software domain, having been involved in SKA project since its earliest days.
 - **Full membership** was long anticipated. The Indian government was a party to the negotiation of the SKAO Convention and participated in the preparatory activities that led to the creation of the observatory in early 2021.
- The approval covers the funding support for the construction phase of the international SKA Observatory (SKAO) spread over the next 7 years.
- The project will be jointly funded by DAE and DST, with DAE being the lead agency.
- This participation is nationwide including project led consortium of more than 20 academic and research institutes (with NCRA-TIFR as the nodal institute)

3) SPACE BASED INTERNET

- **Space X Plan**
 - **The Starlink Network** of SpaceX eventually plans to install 42,000 satellites to ensure non-stop internet services throughout the earth at a cost-effective rate. These satellites will be connected with their neighboring satellites using lasers.

- China's "Guowang" (GW) constellation has also been announced which is meant to meet satellite-based internet services.
 - It will also be a LEO based system with satellites operating at different heights (500-1145 km), inclinations (30-85 degrees) and frequency bands.
- **Other such projects:** Several other companies including Amazon, OneWeb and O3B have also planned large constellation of satellites in LEO and MEO – but these projects are very small compared to Starlink.
- **Comparing Geostationary vs LEO satellites** for providing internet services [Advantages of LEO – Low latency-> allows real time communication; Disadvantage -> need more satellites for coverage as they cover small part of earth]
- **Significance**
 - Prelable and uninterrupted internet services universally to everyone on earth.
 - Services during emergency: For e.g. During Russia Ukraine war in 2022, the Starlink played an important role in strengthening the Ukrainian military might after the European SATCOM system was cyber attacked.
 - IOT services
 - Better e-governance
- **Concerns:**
 - **Increased Space debris**
 - **Increased chances of collision of satellites**
 - **Difficulty in Space Observation -> Light Pollution**
 - **Increased crowding in LEO and signal interference** in space may emerge as another problem

2. NASA INITIATIVES

1) GREAT OBSERVATORY PROGRAM

- NASA's series of Great Observatories satellite are four large, powerful space-based telescopes. The four missions were designed to examine a specific region of the electromagnetic spectrum using very different technologies. The program was developed in 1994.
- **Great Observatories**

B) THE HUBBLE SPACE TELESCOPE (HST)

- The Hubble Space Telescope was deployed on April 25, 1990 from the space shuttle Discovery.
- It primarily observes visible light and near-ultraviolet. A servicing mission in 1999 added capability in near infrared range and one last mission in 2009 was to fix and extend the life of Hubble which resulted in some of the best results to date.

- Hubble is one of the largest and most versatile, and is well known as both vital research tool and a public relation boon for astronomy.

C) THE COMPTOM GAMMA RAY OBSERVATORY (CGRO) (NOT OPERATING CURRENTLY)

- Primarily observed gamma rays, though it extended into hard x rays as well. It was launched in 1991 aboard Atlantis and was deorbited in 2000 after failure of a gyroscope.

D) THE CHANDRA X-RAY OBSERVATORY (CXO)

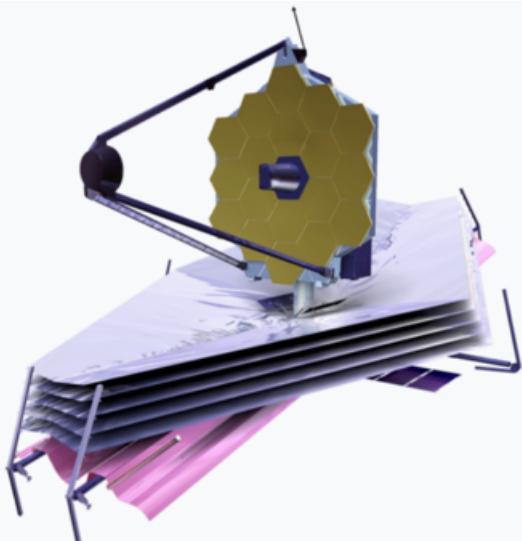
- It is primarily observing soft x-rays. It was launched in 1999 aboard Columbia and was initially named advanced X-ray Astronomical Facility (AXAF).
- Because X-Rays are absorbed by Earth's atmosphere, Chandra must orbit above it and therefore is a space-based telescope.

E) THE SPITZER SPACE TELESCOPE (SST)

It observes the infrared spectrum. It was launched in 2003 aboard a Delta II rocket and was called the Space Infrared Telescope Facility (SITF) before launch.

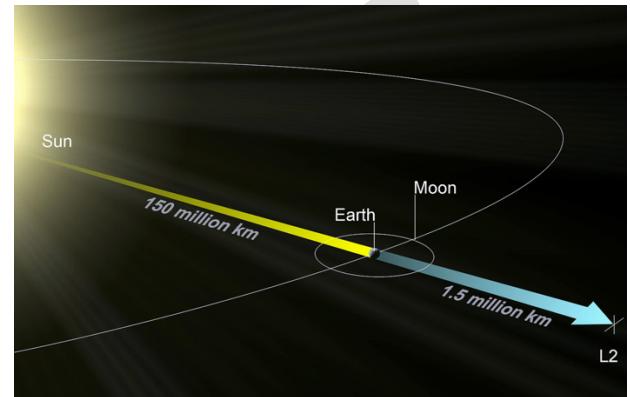
2) JAMES WEBB SPACE TELESCOPE

- It is the largest, most powerful, and complex space telescope ever built and launched into space. It is an infrared telescope with a 6.5-meter primary mirror.
- **International Collaboration:** JWST is an international collaboration between NASA, European Space Agency (ESA), and the Canadian Space Agency (CSA).
- **Some innovative technologies**
 - Primary Mirror made of 18 separate hexagonal segments that unfolded and adjusted to the shape after launch. The mirrors are made of ultra-lightweight beryllium and are gold coated. A single large mirror would have been too large for existing rockets to carry.
 - Biggest feature is a tennis court sized five-layer sunshield that attenuates heat from the Sun more than a million times. This sunshield is constructed from Kapton E, a commercially available polyimide film with membranes especially coated with aluminium on both sides and a layer of doped silicon on the sun facing die of the two hottest layers to reflect the sun's heat back into space.
- **Two basic reasons for it being more powerful than Hubble:**
 - It has the **biggest telescope mirror** to fly in space.



A rendering of the James Webb Space Telescope with its components fully deployed.

- 7 times light will be caught than collecting area of Hubble
- It is **designed to collect infrared light**, which **Hubble is not very sensitive to**.
 - **Why infrared observation?**
 - **High redshift (very old and distant)** objects have **their visible emissions shifted into the infrared**, and therefore their light can only be **observed today via infrared astronomy**.
 - **Colder objects** and planets **emit strongly in the infrared**.
 - Infrared rays can **better pierce cosmic dusts** and thus would be able to give **details about the earliest and furthest galaxies**. (Infrared wavelength can penetrate gas and dust)
 - **Why from L2 and what is the purpose of sunshield?**
 - **Earth's atmosphere glows in the infrared**, so measurement can't be made from the ground.
 - **Hubble emits its own heat**, which could obscure infrared readings.
 - JWST will **run close to absolute zero (around 50K or -232.2 degree C) in temperature** otherwise, infrared radiation from the telescope itself would overwhelm its instruments. For this, it would rest at a point in space called the **Lagrange Point 2**, which is **directly behind earth from the sun's perspective**. Further, the **five-layer sunshield** would attenuate heat from sun more than **a million times**.
- It was launched in 2021, and it reached **its final orbit at a distance of around 1.5 million km from the Earth in early 2022** and it took the engineers and scientists another six months to **ready the instruments before it could be used**.



3) NASA'S ARTEMIS ACCORD

- **Why in news?**
 - India signs US-led Artemis Accord. With this **India has become 27th signatory to the accord (June 2023)**
- **What is Artemis Accord?**
 - Artemis accord was **announced by NASA in Oct 2020** with an initial group of **eight signatories (USA, Canada, UK, Luxemburg, Italy, UAE, Japan, and Australia)**. Later, more countries joined the accord. **India became 27th country to sign the accord in June 2023**.
 - **Note:** China and Russia are not part of the accord.
 - It is a **set of 13 principles** which seek to promote **peaceful and cooperative exploration of space**. Signatory countries agree to abide by these principles which are **mostly a reiteration of established international law on space exploration** (for e.g. the OST of 1967).

- The parties who sign this would be able to participate in NASA's Artemis Program of crewed Lunar Exploration.
- The accord serves as preamble to bilateral, government-to-government agreements that participating nations will sign with the USA.
- **Key Provisions:**
 - **Peaceful purposes:** Conduct all space activities peacefully and in accordance with international law.
 - **Heritage Protection:** Help protect space heritage, such as Apollo landing sites.
 - **Transparency:** Publicly release scientific data in a timely manner
 - **Emergency Assistance:** Render aid to astronaut who need it.
 - **Interoperability:** Make their (signatory countries) hardware and other systems "interoperable" to maximize cooperative system.
 - **Registration of Space Objects:** The Artemis accord reinforces the critical nature of registration and urges any partner which isn't already a member of the Registration Convention to join ASAP.
 - **Space Resource:** Space resource extraction and utilization can and will be conducted under the auspices of the Outer Space Treaty, with specific emphasis on Article II, VI, and XI.
 - **Deconfliction of Activities:** NASA and partner nations will provide public information regarding the location and general nature of operations which will inform the scale and scope of 'Safety Zones'.
- **Analysis:**
 - **Why the project is collaborative?**
 - Huge costs involved in these projects -> so countries like USA are keen to take forward a collaborative agenda.
 - **Geopolitical dimension:** China and Russia are also planning a research station on Moon (surface or orbit), and they are also seeking partners.
 - **India's joining:**
 - India's joining of Artemis accord doesn't mean automatic participation in the Artemis program, but it does open up possibilities of much closer cooperation between the space agencies of the two countries. In fact, the text of the accord clearly mentions that its purpose is to establish a common vision and enhance the governance of civil exploration of outer space "with the intention of advancing the Artemis Program".

4) NASA'S ARTEMIS LUNAR PROGRAM

- This is NASA's program for Crewed Lunar Exploration. Under this NASA aims to land two astronauts (including 1 women) near the Lunar south pole in 2024 and establish a sustainable human presence on and around the moon by the end of the decade.

- Perhaps the most ambitious of the Artemis mission's objectives involve using the moon as a **stepping stone for a mission to Mars**. Robots have done all the detective work on Mars so far, but NASA aims to send astronauts there by 2030s.
- NASA is collaborating with other countries and Private sector for this project.
- **Rockets and Spacecrafts:**
 - At the center of the Artemis Program are NASA's new megarocket, the **Space Launch Rocket (SLS)** and the **Orion Spacecraft**.
 - The **SLS** is a 322 foot tall (98 meters) rocket consisting of a core stage, upper stage, and twin five segment solid rocket boosters to launch payload into space. This rocket will launch the Orion Spacecraft to the moon.
 - **Orion** is a space capsule larger than the Apollo command modules that are designed to carry four astronauts on missions to the moon.

A) ARTEMIS-1 MISSION

- Artemis-1 is the first integrated test of NASA's deep space exploration systems: the Orion spacecraft, Space Launch System (SLS) rocket and the ground system at Kennedy Space Centre in Cape Canaveral, Florida. It was launched in Nov 2022 from NASA's Kennedy Space Centre in Florida.
- It tests the safety of the SLS rocket, and the Orion capsule's ability to reach moon, perform in lunar orbit and return to Earth for an ocean splashdown.
- It is an uncrewed flight test that will provide foundation for human deep space exploration and demonstrate NASA's commitment and capability to extend human existence to the Moon and beyond. It will pave the way for many moon missions including ones that will land the first woman and the first person of color on the Moon.

ORION SURPASSES APOLLO 13 RECORD DISTANCE FROM EARTH (NOV 2022)

- On day 11 of the Artemis 1 mission, Orion continued its journey beyond Moon after entering a distance retrograde orbit. Orion remained in this orbit for six days before exiting lunar orbit to put the spacecraft on a trajectory back to earth.
- **Orion surpassed** the distance record for a mission with a spacecraft designed to carry humans to deep space and back to Earth, on Nov 26, 2020.

B) ARTEMIS-2: 2024

- Carrying the first four Artemis astronauts, the Orion Capsule will take the crew farther from earth than humans have ever travelled before.
- Over the approximately 10-day mission, the crew will complete a lunar flyby and return to Earth, evaluating the spacecraft's systems while carrying humans.

C) ARTEMIS-3: 2025

- It will see the **next man and first woman step onto the lunar surface**. Astronauts will land on the South pole of the moon using lunar lander. They will remain on the moon for around a week.

D) NASA'S GATEWAY LUNAR ORBIT OUTPOST

- Details

- Gateway Lunar Orbit Outpost is basically a **spaceship that will orbit the Moon**. It will act as an airport, where spacecraft bound for lunar surface or surface of Mars can refuel or replace parts and resupply things like food, oxygen. It will also act as a temporary office and living quarters and lab for astronauts around 2,50,000 kms away from earth.

5) NASA'S MARS 2020 MISSION - PERSEVERANCE ROVER

- Details

- Perseverance (six-wheeled robot) is NASA's Martian rover. In Feb 2021, it touched down on the Martial soil when it successfully landed in Mar's Jezero Crater.
- Its design is similar to its predecessor rover- curiosity, from which it was moderately upgraded. It carries seven primary payload instruments, 19 cameras, and two microphones. It also carries a mini-helicopter Ingenuity, which in April 2021 made the **first ever powered flight on another planet**.
- The rover has **four science objectives** that support the **Mars Exploration Program's Science goals**:
 - » **Looking for habitability**
 - » **Astrobiology: Seeking biosignatures** – of possible past microbial life in those habitable environments, particularly in specific rock types known to preserve signs overtime.
 - » **Caching samples** – Collect core rocks and soil samples and store them on Martian surface which can be extracted by future programs.
 - » **Preparing for crewed missions** – Test oxygen production form the Martian atmosphere.
- The two microphones would listen to Martian sounds like the wind or the rover moving on the Martian soil.
- **Why Jajero Crater:**
 - » Jajero **crater preserves the evidence that it was once a lake** with an inflow channel and an outflow channel. There are good chances that if life existed on Mars in the past, the microorganisms could have lived here and preserved in the form of fossil here.
 - » **In Aug 2022**, NASA's perseverance found surprising volcanic rocks in Mars' Jezero Crater. The discovery was a complete surprise as the researchers initially expected to find sedimentary rocks formed by mud and detritus laid down by the ancient lake. These water altered rocks indicate the presence of water, which is an essential ingredient for a habitable environment.

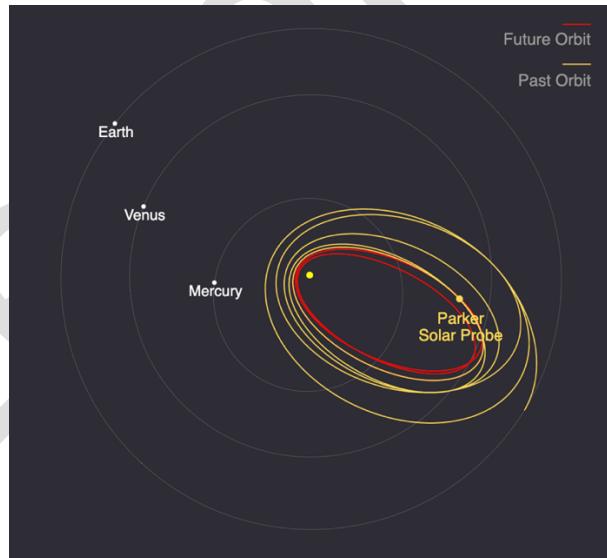
- In April 2021, NASA's Ingenuity Mars Helicopter became the first aircraft in history to make a powered, controlled flight on another planet.
 - » It is a **solar powered** helicopter.
 - » **Why flying on Mars is a challenge?**
 - Atmosphere density is only 1% of Earth's atmosphere.
 - To sustain flight, helicopter blades have to rotate at 2400 rpm (rotation per minute). For a helicopter to fly few meters from the ground on Mars, is equivalent for a helicopter to fly 2-3 times the height of Mt Everest.



6) PARKER SOLAR PROBE

- Introduction

- The parker solar probe was launched in Aug 2018. It is designed to swoop through the sun's super-hot outer atmosphere and help scientists understand the way our star shapes the solar system.
 - **Using Venus' Gravity:** The parker probe has used Venus' gravity during seven flybys over nearly seven years to gradually bring its orbit closer to sun. It is done to slowdown the spacecraft to reduce gravitational pull of the Sun.
 - In June 2020, the probe reached as close as 832 kms above the planet's surface.
 - **Launch Site:** NASA's Kennedy Space Center, Florida
 - **Launch Vehicle:** Delta IV – Heavy with upper stage.



- It is designed to go closer to the sun (3.8 million miles from the solar surface), seven times closer than any other spacecraft before, facing brutal heat and radiation conditions – and ultimately provide humanity with the closest ever observation of the star. **In 2021 it has entered into the outermost part of sun's atmosphere**, known as the Corona. It is using in situ measurements and

imaging to revolutionize our understanding of the Corona. It is a monumental moment for solar science and a truly remarkable feat.

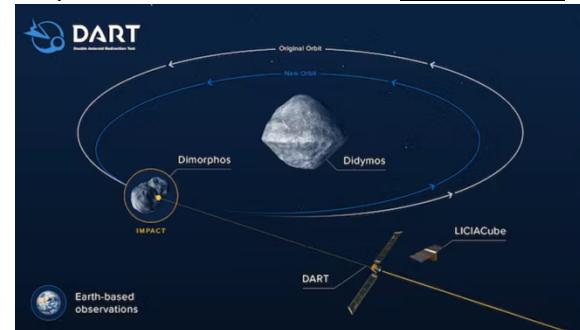
- The first passage through Corona – and the promise of more flybys to come – will continue to provide data on phenomena that are impossible to study from afar.

7) LUCY MISSION

- NASA has launched the LUCY spacecraft in Oct 2021, on a 12-year cruise to the Jupiter Trojan asteroids. It will fly by eight asteroids – 7 trojans and one main belt asteroid – over the next 12 years. It is NASA's first single aircraft mission which will explore so many asteroids at one go.
- LUCY will run on solar power out to 850 million kms away from sun. This makes it the farthest-flung solar powered spacecraft ever.
- **Significance:** It will look back into the origins and evolution of the solar system formed over 4 billion years ago through these celestial bodies.
- **Why named Lucy?**
 - Lucy is the name given to a hominin that lived 3.2 million years ago. She is known to be one of the most famous pre-human fossil in history.
 - Nearly, 40% of the fossilized skeleton of this hominin was discovered in 1974 by a team of Paleoanthropologists led by Donald Johanson. The name was inspired from the famous Beatles song "Lucy in the Sky with Diamonds", which Johanson's team listened to at camp the night of their discovery.

8) DART MISSION

- **Introduction**
 - DART is a planetary defense-driven test of technologies for preventing an impact of Earth by a hazardous asteroid.
 - Under this NASA launched a mission in Nov 2021, aboard Space X Falcon 9 rocket. It sent a space capsule of the size of a fridge towards an asteroid to shoot it off course. The target asteroids were 11 million kms away from Earth and DART mission reached here after 11 months of journey.
- **Target Asteroid:**
 - DART's test target was an asteroid (Dimorphos/Didymos B) that passed the earth in 2022 and will come back two years later.
 - Its primary body (Didymos A) is approx. 780 meters across, its secondary body (or “moonlet”) – Didymos B is about 160 meter in size, which is more typical of the size of asteroids that could pose the most likely significant threat to Earth.
 - NOTE: DART's target asteroid was **NOT** a threat to earth, and it is only a test mission.



- In Sep 2022, this space capsule was crashed into **Dimorphous/Didymos-B**.
- It used **autonomous targeting**, using images of the asteroids it acquires as it approaches. DART needed to recognize the asteroid itself, automatically lock onto Dimorphous, and adjust its trajectory to hit it. This is while it was moving at a speed of 24,000 km per hour.

- **Technology: Kinetic Impact Technique:**

- **Why Didymos system was chosen:** Easy to measure impact (binary pair); No risk to humans.
- **How observations were made:**
 - Measurements from telescopes on Earth.
 - **LICIACube:** It is an Italian Space Agency CubeSat (a small type of satellite) that was deployed from a spring-loaded box aboard the craft on 11th Sep. LICIACube followed along and photographed the collision and its aftermath.

- **Outcome:**
 - **For the first time**, human has changed the orbit of a planetary body. The impact shortened Dimorphos' orbit time by 32 minutes.
 - **Proof:** The test was a proof of concept for many technologies, that NASA has invested over the last few years.
 - **DART** has also given some fascinating data about both asteroid properties and the effectiveness of a kinetic impactor as a planetary defence technology.

9) VOYAGER-2

- **Why in news?**
 - NASA's Voyager 2 spacecraft, which is now travelling in interstellar space, has gotten a new lease of life after mission engineers developed a new plan to keep its instruments running for longer (April 2023)
- **About Voyager 2**
 - Voyager 2 is a **space probe launched by NASA in 1977 to study the outer planets**.
 - Its primary mission ended with the exploration of the Neptunian system in 1989. It had visited Jupiter, Saturn and Uranus earlier.
 - It is second spacecraft to enter interstellar space. On 10th Dec 2018, the spacecraft joined its twin – Voyager 1 – as the only human-made objects to enter the space between the stars.
- **Power:** The spacecraft is equipped with **3 Multi-hundred-Watt radioisotope thermoelectric generators (MHW RTG)**.
- **April 2023 Updates:**
 - The ageing voyager 2 spacecraft has begun using a small reservoir of backup power to keep its instruments working despite a reduced power supply. **This backup power was set aside as part of an onboard safety mechanism**. The spacecraft was scheduled to shut down its science instruments in 2023, but with this move, it can continue operating them until 2026.

- **Achievements**
 - It is the **only spacecraft to study all four of the solar system's giant planets** at close range.

- The craft is now travelling more than 11.6 billion miles from earth. It is **beyond heliopause**, or boundary region, where the sun's influence ends and the **interstellar medium begins**.
- Note:** Although both the Voyager probes – Voyager-1, launched on Sep 5, 1977, and Voyager 2, launched 16 days before its twin – have left the heliosphere, neither spacecraft has yet left the solar system, and won't be leaving anytime soon. The boundary of the solar system is considered to be beyond the outer edge of the Oort Cloud, a collection of small objects that are still under the influence of sun's gravity.

The width of the Oort Cloud is not known precisely, but it is estimated to begin at about 1,000 astronomical units from the sun and to extend to about 100,000 AU (1 AU is the distance from the sun to Earth). It will take about 300 years for Voyager 2 to reach the inner edge of the Oort Cloud and possibly 30,000 years to fly beyond it.

3. PEREGRINE MISSION-1: FIRST US SPACECRAFT DUE TO LAND ON MOON SINCE THE APOLLO MISSIONS IN THE 1970S LIFTS OFF

Why in news?

Peregrine Mission-1 is the first US attempt to land on Moon in more than half a century (since Apollo 17 in 1972). It lifted off in space as planned (Jan 2024)

Soft Landing on Moon So Far:

As of Jan 2024, **Soft landing on moon** has been achieved by **only four national space agencies**:

Soviet Union was first in 1966.

It was followed by USA's NASA which still remains the only space agency to put humans on Moon.

In the last decade, China soft landed on moon thrice in its Chang'e-3, Chang'e-4, and Chang'e-5 missions.

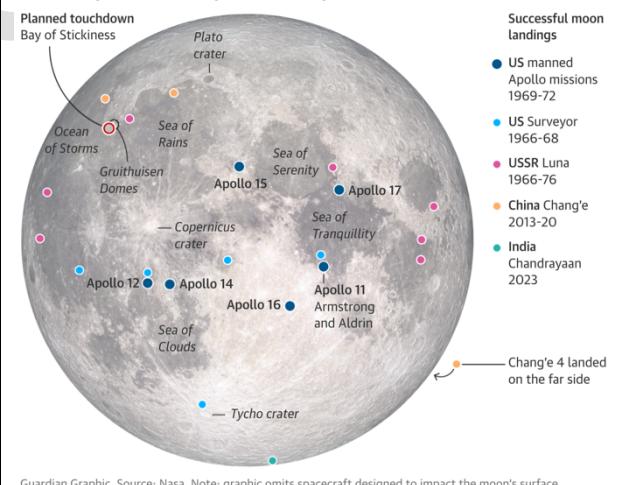
India achieved soft landing in 2023 in its Chandrayaan-3 mission.

Failures:

Private Missions by Israel and Japan, as well as an attempt by the Russian Space Agency – have all ended in failures.

Why limited successes? Controlled touchdown on moon is a challenging task due to absence of atmosphere and treacherous terrain.

The Peregrine lunar lander is expected to touch down on **23 February** in the newly named Bay of Stickiness



Guardian Graphic. Source: Nasa. Note: graphic omits spacecraft designed to impact the moon's surface

Details Of Peregrine Mission-1

Rocket Used: Vulcan Centaur: It's a brand-new rocket of United Launch Alliance. Peregrine Mission-1 is its maiden launch.

- » The rocket has reusable first stage booster engines which is expected to reduce cost of launches.
- » **Note:** ULA is a joint venture between Lockheed Martin and Boeing.

Peregrine Lander: It has been developed by a US company Astrobotic, which has been selected for NASA's Commercial Lunar Payload Services (CLPS) programme.

Launch site: Cape Canaveral Space Force Station, Florida.

Touchdown: Peregrine is schedule to touch on a mid-latitude region of the Moon called Sinus Viscositas.

NASA has contracted private players under Commercial Lunar Payload Services (CLPS) programme.

Payload Carried:

A suite of scientific instruments by NASA to probe radiation and surface composition – helping to pave the way for return of the astronauts.

Some Unique Cargos: A shoebox-sized rover built by Carnegie Mellon University (CMU), a physical bitcoin, and cremated remains and DNA including those of Star Trek creator Gene Roddenberry, legendary sci-fi author, scientist Arthur C. Clarke, and a dog.

Note: The Navajo Nation, the USA's largest indigenous tribe, had opposed it as sending these to the moon desecrates a body they consider sacred to their culture.

Significance:

- » **Stimulate Broader Lunar Economy:** USA has turned to commercial sector to stimulate broader lunar economy.
- » **Cost Reduction:** NASA has paid the startup just \$180 million for five scientific instruments to be carried to the moon – a fraction of cost of launching its own mission.

Future Commercial Launches:

Another US company, which NASA has contracted, Houston-based Intuitive Machines, is looking to launch in Feb 2024 and land near the south pole.

4. CHINA

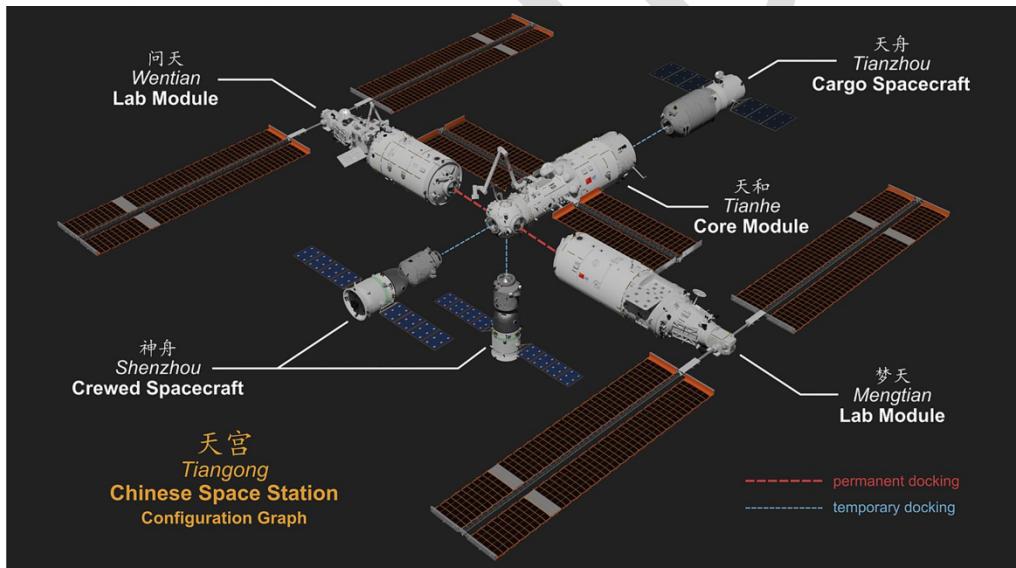
1) CHINA'S SPACE STATION: TIANGONG

- **Details**

- **Background:**

- China's crewed space program is officially three decades old. It truly got underway, when in 2003, China became only third country in the world, after USA and Russia, to put a human into space using its own resources.

- Work on the space station programme began a decade ago with the launch of a **space lab Tiangong-1** in 2011, and later, **Tiangong-2** in 2016.
- **Details of the Space Station - Tiangong:** It is a **T-Shaped space station** which will be able to accommodate 25 lab cabinets, each a micro lab that can be used to conduct experiments. The space station will weigh 66 tonnes – a fraction of ISS which weighs 465 tonnes.
 - It will have **three modules**
 - **Tianhe Module** (launched in April 2021) on Long March-5B.
 - **Wentian Module** (launched in July 2022) will be equipped to support life science research. It will also have airlock cabins for extravehicular trips, as well as short-term living quarters for astronauts during crew rotation.
 - **Mengtian Module** (launched in Oct 2022) will focus on microgravity experiment. It is the third and final module which docked with the station in Nov 2022.
 - The space station is designed for a lifespan of at least a decade.
 - It has facilities for long term accommodation of just three astronauts (compared to 7 of ISS). Still China has invited foreign astronauts in an effort to internationalize the space station.
 - **Scope of expansion in future:** The Three module T Shaped station could be expanded into a four-module cross shaped configuration in future.



2) CHANG'E-5

- **Details**
 - The Chang'e-5 probe, comprising an orbiter, a lander, an ascender, and a returner was launched on Nov 24, 2020, and its lander-ascender combination touched down on the north of the Mons Rumker in Oceanus Procellarum, also known as the ocean of Storms, on the near side of the Moon on 1st Dec 2020.
 - It was the third Chinese mission to land on the moon.

- The Chang'e-5 probe returned to earth in Dec 2020 and it brought along with it about 1,731 grams of samples. Scientists will carry out the storage, analysis, and research of the country's first samples collected from the extra-terrestrial object.

The Chang'e-5 mission marks a successful conclusion of China's current three-step lunar exploration programme of orbiting and landing and bringing back samples which began in 2004.

5. SPACE TOURISM

- **Why in news?**
 - » ISRO is planning space tourism by 2030
- **What is suborbital Flight?**
 - » Suborbital flights don't have enough speed to escape into orbit. Any orbit without enough energy to reach orbit will instead follow a parabolic trajectory, looping up and then back down again. This will be a suborbital space mission or suborbital flight.
 - » Such flights are short, but passengers can experience mind-blowing view of Earth and will also experience several minutes of weightlessness. This thus can attract space tourists.
 - » **Why weightlessness?**
 - During downward path, a section of the flight is a free fall.
 - » **Other Significances:**
 - Microgravity experiments can also be carried out on these flights. This would be much cheaper than doing these experiments in International Space Stations.
 - It could also be a cheaper way of testing space flight technologies or experiments before they are sent on more expensive orbital or deep space missions.
- **Space Tourism**
 - » Space Tourism is the segment of space travel which provides non-astronauts the ability to go to space for recreational, leisure or business purposes. The idea is to make space more accessible for anyone who can afford it.
 - » In the past, NASA and Russian Space Agency used to take tourists for space travel. For e.g. Dennis Tito was the first commercial spaceflight passenger before which only astronauts used to go to space. He went to space on Russian Soyuz TMA Launch Vehicle in April 2001. After him, between 2001-2009, few other space tourists went to space, aboard a Russian Soyuz space to ISS, brokered by Space Adventures (an American Space Tourist company) in conjunction with Roscosmos.
- **Recent tourism space flights:**
 - » Virgin Galactic is a company which was established by British Entrepreneur Richard Branson in 2004.
 - In July 2021, Richard Branson and five others undertook a brief trip to the edge of the space, taking off on a VSS unity spaceship.



- » Blue Origin was established by Jeff Bezos in 2000. It's reusable rocket New Shepherd successfully completed first human flight to space recently (**20th July 2021**) with **four private citizens onboard**. The flight went about **107 km** high.
- SpaceX's Inspiration4 – debut of SpaceX's tourism business (Sep 2021)
 - » Falcon 9 rocket took a crew Dragon spacecraft with 4 civilians (first all civilian space flight) into space. They travelled to an altitude of 575 km, even higher than HST and ISS.
 - » Isaacman, the founder and CEO of Shift4 payments, is largely responsible for the mission's planning from birth to launch.
- Other than these three, companies such as Virgin Atlantic, XCOR Aerospace, Armadillo Aerospace are working on providing space tourism services to people.
- **Concerns**
 - » Climate change may be aggravated by Space Tourism.
 - » Available only for highly rich people

6. RUSSIA:

1) LUNA-25

- **Why in news?**
 - Russia's LUNA-25 failed to land on Moon and crashed onto Moon's surface (Aug 2023)
- **Details**
 - **Why the failure?**
An anomalous engine burn-> Instead of a planned propulsive nudge of 84 seconds, the engine operated for 127 seconds, more than the "required value" in readying the probe for its descent burn. This added impulse caused Luna-25 to smash into the moon.
 - **More about Luna-25:**

- i. It was modern Russia's first Moon mission. It was heralded as the first domestically produced moon probe in Modern Russia history. Luna-25's flight was important in both political and scientific terms. The implication of its failure is likely to be considerable.
- ii. The final soviet moon mission, Luna-24, successfully hauled home to Earth about 170 grams of lunar samples in 1976.

7. GENERAL SPACE ISSUES

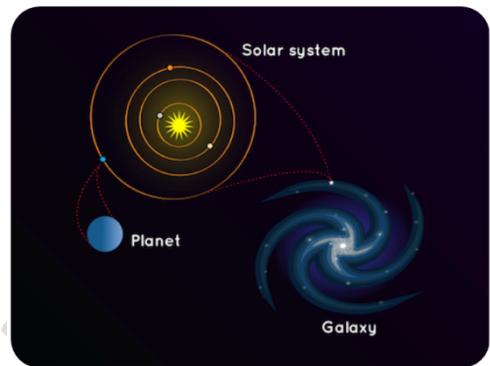
1) SPACE DEBRIS

- **Introduction**
 - The term “space debris” refers to **defunct human made objects which are moving in orbit around earth**. It includes big and small things like discarded boosters, retired satellites, leftover bits and pieces from spacecrafts, screwdrivers, tools, nuts, bolts, lost gloves, flecks of paints etc.
 - There are more than 20,000 pieces of debris that are larger than 5-10 cms and can be tracked and catalogued. There are hundreds of millions that we cannot because of their small size. They are all dangerous as they are moving at very high speeds.
- **How are Space Debris created?**
 - **Breakup of older spacecrafts:** For e.g., breakup of US' spacecraft called USA 109 in 2015, created 100 debris pieces and 50,000 shards larger than 1 mm.
 - **Accidently left-over objects**
 - **Testing of Space Weapons**
 - For e.g., China's testing of A-SAT missile in 2007 created more than 34,000 debris.
 - **Further breakup of space debris:** More debris increase the chance of collision – a cascade effect known as the **Kessler Syndrome**. The fear is that the space could eventually become inoperable.
 - **Mega constellations** (e.g., Starlink satellite internet constellation) would launch thousands of satellites in coming years and would make space more vulnerable to collision and debris creation.
- **Key Concerns Raised by Space Debris**
 - **Endanger the prospects for Space Missions** (Civilian, Commercial or military)
 - **Sometimes crash land on earth** harming life and livelihood of people
 - Recently parts of Zenit rocket debris are reported to have ended up crash-landing in Peru.

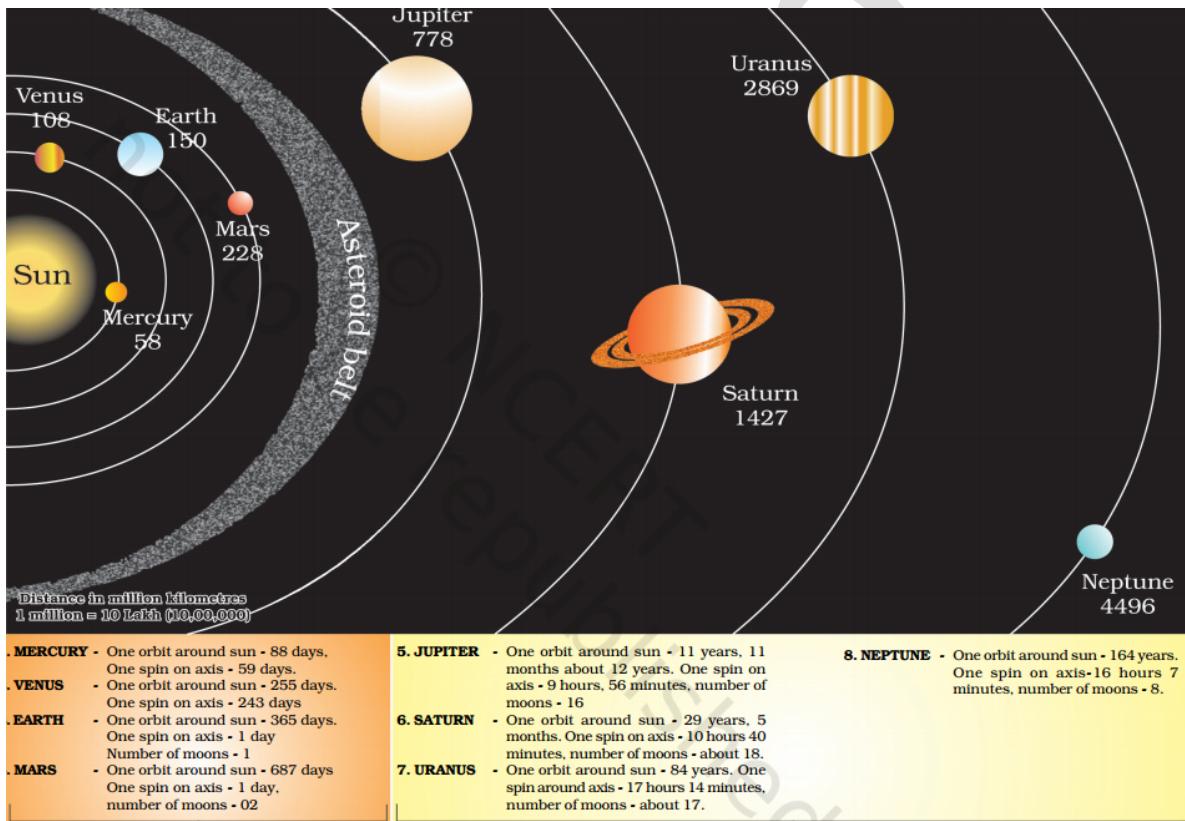
8. BASICS OF ASTRONOMY

1) GALAXY

- » Galaxies are like building blocks of Universe.
- » A galaxy is huge collection of gas, dust, and billions of stars and their solar systems. A galaxy is held together by their gravity. Our galaxy, the Milky Way, also has a supermassive black hole in the middle.
- » When we look up at the stars in the night sky, we see other stars in the Milky Way.
- » There are many galaxies besides ours. Some scientists estimate the total number of galaxies to be as much as one hundred billion.



2) OUR SOLAR SYSTEM



- Planets

- » **8 (My Very efficient mother just served us nuts)**
- » Venus is considered as 'Earth's twin' because its size and shape are very much similar to that of earth

- » **Pluto:** Till recently (August 2006) was called a planet. However, in a meeting of **International Astronomical Union**, a decision was taken that Pluto like other celestial objects (Ceres, 2003 UB₃₁₃) discovered in recent past may be called a dwarf planet¹.

Inner Planet : Mercury, Venus, Earth, Mars (*very close to sun, made of rocks*). They are called *inner planets* as they lie between the sun and the belt of asteroids. They are also called **terrestrial planets**, meaning earth like as they are made up of rock and metals, and have relatively high densities.

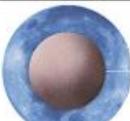
Outer Planet: Jupiter, Saturn, Uranus, Neptune. They are called outer planets. They are also known as **Jovian or Gas** planets. Jovian means Jupiter like. Most of them are much larger than the terrestrial planet and have a thick atmosphere, mostly of helium and hydrogen.

- The difference between terrestrial and Jovian planets can be attributed to the following conditions
 - i. The terrestrial planets were formed in the close vicinity of the parent star where it was too warm for gases to condense to solid particles. Jovian planets were formed at quite a distant location. ()
 - ii. The solar wind was most intense nearer the sun; so, it blew off lots of gas and dust from the terrestrial planets. The solar winds are not all that intense to cause similar removal of gases from the Jovian planets.

The terrestrial planets are smaller and their lower gravity could not hold the escaping gas.

3) PLANETS, DWARF PLANTS AND OTHER CELESTIAL BODIES

DWARFS, THEIR DIAMETERS

	CERES	950 km
Between Mars and Jupiter		
	PLUTO	2,400 km
Beyond Neptune, once seen as planet		
	ERIS	2,300 km
Beyond Neptune, close to Pluto in size		
	MAKEMAKE	1,400 km
Beyond Neptune, discovered in 2005		
	HAUMEA	1,400 km
Beyond Neptune; measurements vary		

4) MOON

- » It is Earth's only natural satellite
- » **Size:** 1737.1 km (Radius)
- » **Distance:** 3,84,400 km away from earth
- » **Only one side visible**
 - The moon moves around the earth in about **27 days**. It takes exactly the same time to complete one spin. As a result, only one side of the moon is visible to us on earth.

5) PLANETS WITH HIGHEST NUMBER OF MOON

- SATURN

6) ASTEROIDS

- Apart from the stars, planets and satellite, there are numerous tiny bodies which also move around sun. These bodies are called asteroids. They are found between **orbits of Mars and Jupiter**. Scientists are of the view that asteroids are parts of a planet which exploded many years back.

A) NEAR EARTH ASTEROID:

- **About Near Earth Objects**
 - NEOs are comets and asteroids nudged by the gravitational attraction of nearby planets into orbits which allows them to enter the Earth's neighborhood. They occasionally approach close to the Earth as they orbit the sun.
 - NASA's Center for Near-Earth Object Study (CNEOS) determines the times and distances of these objects as and when their approach to the Earth is close.
- **Significance of Near-Earth Objects:**
 - Scientific interest in comets and asteroids is largely due to their status as relatively unchanged remnant debris from the solar system formation process over 4.6 billion years ago. Therefore, they can give clue regarding original conditions which led to formation of planets.
 - Further, **an asteroid** is considered as one of the existential dangers for life on earth. Therefore, it's important to study these near-earth objects and prepare to ward off any future hit.
- **When is an Asteroid considered PHA (Potentially hazardous asteroid)?**
 - Asteroids with a minimum orbit intersection distance (MOID) of about 0.05 AU (i.e. roughly 7,480,000 km or less and a diameter more than 150 meters) is considered PHAs.
 - **Note:** It is not necessary that asteroids classified as PHAs will necessarily impact the earth. It only means that there is a possibility of such threat.

B) PSYCHE

- **Example Questions:**
 - Launched on 13th October 2023, Psyche Mission has been much in news since then. What are the key goals of the mission? What potential benefit does it hold for human race? [10 marks, 150 words]
- **About Psyche Asteroid:**
 - Psyche is one of the asteroids in the asteroid belt. What makes the asteroid unique is that it appears to be the exposed nickel-iron core of an early planet, one of the building blocks of our solar system.
- **About Psyche Mission:**
 - The Psyche Mission is a NASA space mission launched on 13th Oct 2023 to explore origin of planetary cores by orbiting and studying the metallic asteroid Psyche in 2029. The mission consists of Psyche Aircraft.
- **Significance:**
 - **Understanding the Core of a Planet:** Deep within rocky terrestrial planets – including Earth – scientists infer the presence of metallic cores. But these remain unreachably far below the planets' rocky mantles and crusts. Psyche offers a unique window into the violent history of collisions and acceleration that created terrestrial planets.
 - **Science Goals include:**
 - **Understand a previously unexplored building block of planet formation:** Iron cores.
 - **Look inside terrestrial planets, including Earth,** by directly examining the interior of a different body, which otherwise couldn't be seen.
 - **Explore a new type of world** made of metal (and not of rock and ice)
 - **Science Objectives:**
 - Understanding Psyche – Whether it is a core, or if it is an unmelted material, relative ages of psyche's surface etc.
 - **Deep Space Optical Communication (DSOC):** The Psyche mission is also testing a sophisticated new laser communication technology that encodes data in photons at near-infrared wavelength (rather than radio waves) to communicate between a probe in deep space and Earth.

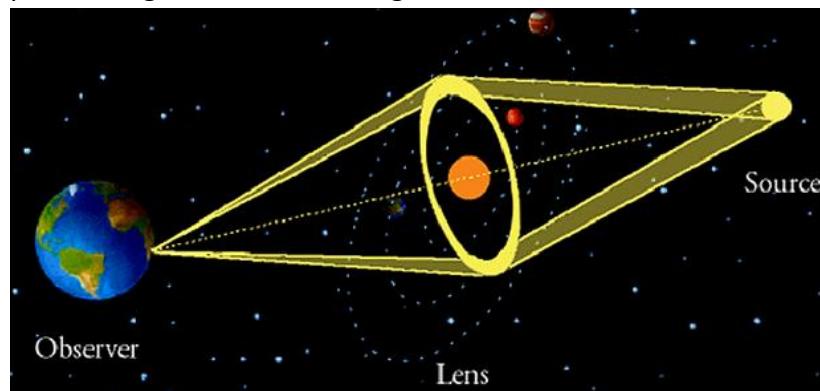
7) JUPITER TROJANS (CLASS DISCUSSION)

8) EXOPLANETS (CLASS DISCUSSION)

9) GRAVITATIONAL LENSING

» Basics

- Gravity bends the time-space around us. And since light travels through space, it also bends while passing through this bent time space.
- This bending of light creates the same effect as the bending of light through a glass lens and the phenomenon is called gravitational lensing (i.e. lensing effect created by gravity). **Einstein** first predicted gravitational lensing in 1912 and is an effect of his theory of general relativity.



- It is clearly observable when gravitational force is high (i.e. bending of space-time is high) such as in case of large galaxies or cluster of galaxies. Thus, large galaxies can behave like large natural telescopes.

» Applications

- Scientists use this phenomenon to **study distant stars/galaxies** in Universe which would otherwise have been difficult to see even by the most powerful space telescopes. The image of the distant object would be magnified if there is a gravitational source (like a large galaxy) in the path.
- The phenomenon also helps us in **understanding the origin of a galaxy/star** as we can observe light from distant stars when there were still getting formed.
 - For e.g. NASA under its **TEMPLATES** initiative is using gravitational lensing to study how galaxies are forming stars and how the star formation is distributed across galaxies.

» It also helps us in studying of super massive blackholes at cosmological distance.

9. SUN

A) BASICS ABOUT SUN

- Distance: 150 million km away from earth
- Radius: 696,000 km

B) SUN'S STRUCTURE – 3 ATMOSPHERIC LAYERS

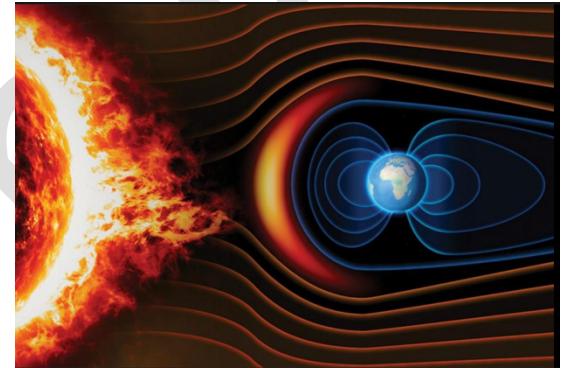
- Sun has **six layers**. The **core, radiative zone and convection zone** consist of the inner layers or the parts of the sun which is not visible. **Photosphere, Chromosphere and Corona** comprise of the sun's atmosphere or outer layer.
- **Inner Layer**
 - Core:** It is the innermost layer of sun. The Core is Plasma, but its movement is extremely similar to gas. The temperature in Sun's core is nearly 15-million-degree Celsius.
 - Radiative Zone:** It is the second layer of sun and sits outside the core. This zone has temperature of millions degree Celsius. The layer serves as a passage for all the energy that is released by the core.
 - Convection Zone:** It is the outermost layer and completely surrounds Radiative zone. In this layer, all the hot material found near the center of the Sun rises cools down and drops back into the radiative zone to get more heat. This is the movement that creates sunspot and Solar flares.
- **Outer Layers:**
 - Photosphere** is the deepest layer of the sun that we can observe directly. It reaches from the surface to about 250 miles above that. Temperature varies from about 6700-degree Celsius to 3,700-degree celsius. Most of the photosphere is covered by granulations (caused by convection current) of the plasma within the Sun's convective zones.
 - Chromosphere:** The chromosphere is a layer in the Sun between about 250 miles and 1300 miles above the solar surface (the photosphere). The temperature in the chromosphere varies between (3700 (**lowest temperature**) at the bottom to 7700-degree C at the top), so in this layer (and higher layers) it actually gets hotter if you go further away from the sun, unlike in the lower layers, where it gets hotter if you go closer to the centre of the sun.
 - Transition Zone:** The transition region is very narrow (60 miles / 100 km) layer between the chromosphere and the corona where the **temperature rises abruptly** from about 7700-degree celsius to 5,00,000-degree C
 - Corona:** It is the outermost layer of the Sun, starting at about 13,00 miles above the solar surface (the photosphere). The temperature in the Corona is 5,00,000-degree celsius or



more upto a few million-degree celsius. It can't be seen with naked eyes except during a total solar eclipse or with use of a coronagraph. It doesn't have any upper limit.

C) UNDERSTANDING SOLAR WINDS

- The solar wind is a **stream of charged particles released from the upper atmosphere of the sun, the Corona**. The solar wind streams plasma (a mix of positively and negatively charged particles) and particles from the sun out into space.
- **Cause**
 - The temperature of Corona reaches upto 1.1-million-degree celsius (2-million-degree Fahrenheit).
 - As rising heat and pressure push that material away from the Sun, it reaches a point where gravity and magnetic field are too weak to contain it. That point, known as the **Alfven Critical Surface**, marks the end of Solar Atmosphere and beginning of Solar Wind.
- **Why does the property of solar winds change with time?**
 - The sun's activity shifts over the course of its 11 year cycle, with sun spot numbers, radiation levels, and ejected material changing over time.
 - The wind also differs based on where on the sun it comes from and how quickly that portion is rotating.
 - As the plasma material leaves the sun, carried by solar wind, it becomes more gas-like.
- **How does it affect the earth?**
 - As the wind travels off the sun, it carries charged particles and magnetic clouds. This is constantly hitting our planet with interesting effects.
 - If the solar wind reached the earth's surface, its radiation would do severe damage to any life that might exist. They can affect Earth's satellite and the Global Positioning Systems (GPS).
 - But earth's magnetic field acts as shield, redirecting the material around the planet so that it streams beyond it.
 - The force of the wind stretches out the magnetic field so that it is smooshed inward on the sun-side and stretched out on the night side.
 - **Solar Storms (Coronal Mass Ejections - CMEs)**
 - » Sometimes, especially during the active period of the cycle - known as the solar maximum, the sun spits out large burst of plasma known as Coronal mass ejections (CMEs). These have stronger effect than the standard solar wind.



- » When the solar wind carries CMEs and other powerful bursts of radiation into a planet's magnetic field, it can cause the **magnetic field on the back side to press together**, a process known as **Magnetic Reconnection**.
- » Charged particles in case of magnetic reconnection stream back towards the **planet's magnetic poles**, causing beautiful displays known as the **aurora borealis** in the upper atmosphere.

▫ **About Auroras**

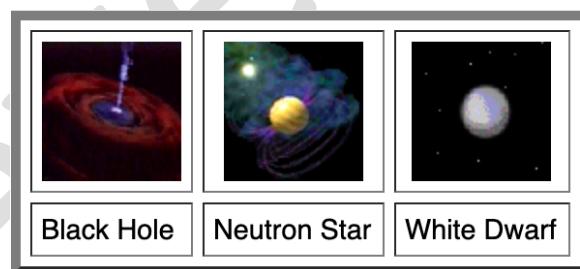
- » In the north the phenomenon is called the **aurora borealis** or the **northern light**. In the southern hemisphere, it's the **aurora australis**, or southern lights.
- » Even though the **earth's magnetic field stretches symmetrically from the north to the south**, recent satellite images of the entire planet showed **mismatched auroras happening at the same time in the two hemispheres**.
- » **Why?** Our **magnetic field is squeezed asymmetrically by solar winds approaching from an angle**, twisting and displacing the northern and southern lights in different forms and locations.

▫ **Useful video to understand Auroras:** <https://youtu.be/PgIKsuZ3RZU>

1) LIFE CYCLE OF STARS: STARS – DWARF STARS – NEUTRON STARS – BLACK HOLES

A) LIFE CYCLE OF A STAR

- Where a star ends up at the end of its life depends on the mass it was born with.
 - **Stars with lots of mass** may end their lives as **black holes or neutron stars**.
 - **A low or medium mass star** (with mass less than 8 times the mass of sun) will become a **white dwarf**.



B) MEDIUM STARS - > RED GIANT -> WHITE DWARF -> BLACK DWARF

- Class Discussion

CHANDRASHEKHAR LIMIT

- The Chandrasekhar Limit, named after the Indian astrophysicist Subrahmanyan Chandrasekhar, is the **maximum mass that a stable white dwarf star can have**. It is an **important concept in astrophysics**, particularly in the study of stellar evolution. Chandrasekhar discovered that if a white dwarf's mass exceeds approximately **1.4 times**

the mass of Sun (Known as Chandrasekhar mass), the pressure generated by the electrons is no longer sufficient to counteract gravity. As a result white dwarf becomes unstable and collapse under its own weight.

c) NEUTRON STAR

- **Neutron Star:** It is formed by catastrophic collapse of the core of a massive star. While a white dwarf is supported by electron degeneracy pressure, neutron stars are supported by neutron degeneracy pressure.
- **How is Neutron Star formed:** In its dying phase, when a star with a core containing mainly iron exhausts all its fuel, it collapses under gravity and explodes as supernova. The extreme high pressure causes protons and electrons to combine together to form neutron (thus forming a neutron star). They energy released during the process blows away the outer layer of the star.
- **Would a neutron star further collapse into blackhole?** -> It would depend on the mass of the neutron star's core. If the mass is less than three solar masses it remains as a neutron star, but if the star's mass more than about 3 solar masses, then it collapses further to form a black hole.
- **The highest possible mass** of a neutron star is not very well known, but it can't be theoretically more than 3 solar masses (beyond which, it should be a black hole). The **maximum mass** for a neutron star, which has been precisely measured so far, is around 2.1 solar mass.
- The neutron stars are among the densest objects in the universe. They have a radius of 10-20 km but carry a weight of upto 2.5 times the mass of Sun.
- A **big difference between Neutron star and Black Hole** is that neutron star has a hard surface unlike that of a black hole.

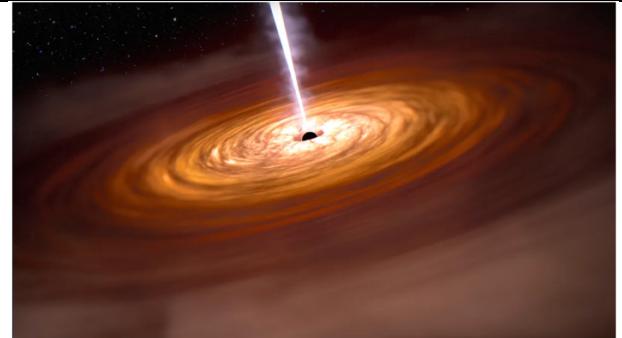
D) BLACK HOLE

- **Why in news?**
 - » Ferocious black holes reveal 'time dilation' in early universe (July 2023: Source: The Hindu)
 - » Spotting black holes (Sep 2023: Source – The Hindu)
- **What is a Black Hole?**
 - » A Black hole is a place in space where gravity pulls so much that even light can't get out. This strong gravity is because matter has been squeezed into a tiny space. This can happen when a star is dying.
 - » Since, no light is emitted from them, they are invisible.
 - » They are generally **detected** by telescopes by analyzing the behavior of stars that are very close to this black hole.
 - » **How large is a black hole?**
 - A black hole can be as small as an atom (but having the mass of a mountain) and they can be very large as well.

- **Stellar** is a kind of blackhole whose mass is around 20 times the mass of sun. There are many many stellar blackholes in our Milky Way Galaxy.
- “**Supermassive**” are the largest black holes. These black holes have masses that are more than 1 million suns together. Every large galaxy contains a supermassive blackhole at its center. The Supermassive blackhole at the center of the **Milky Way galaxy** is called **Sagittarius**. It has a mass of 4 million suns and would fit inside a very large ball that could hold a few million earths.

Quasars: Quasars are a subclass of active galactic nuclei (AGNs), extremely luminous galactic cores where gas and dust falling into a supermassive black hole emit electromagnetic radiation across the entire electromagnetic spectrum. They are among the brightest objects in the Universe.

Note: All Quasars are AGN, but not all AGN are Quasar



- » The boundary of black hole is called **event horizon** which acts as one way towards the black hole and allows nothing to get out of it.
- **Singularities and Blackhole**
 - » In 1915 Karl Schwarzschild noticed that Einstein's then new-general theory of relativity predicted the existence of strange objects known as “**singularities**”. They were places where his new equation describing gravity seemed to go haywire. Inside them there was a bizarre place where time stopped, and space became infinite. Over the years evidence have piled up explaining that singularities do exist in our universe as **black holes**.
- **Spotting black holes: How do we identify blackholes?**
 - » A blackhole is identified by the **gravitational force** it exerts on nearby stars.

Astronomers have found systems in which a visible star orbits around an unseen companion. One cannot conclude that the companion is blackhole always; it might merely be a star that is too faint.

- If the unseen companion happens to be a black hole, then because of its high gravity it will start pulling matter off the surface of the visible star. This matter start falling towards the blackhole in a characteristic spiral path. In the process it also emits X-Rays which can be detected from earth.
- From the observed orbit of visible star one can determine the lowest possible mass of the black hole.

- Recent Updates about Blackholes
 - a. Scientists have discovered oldest black hole yet (Nov 2023)
 - A study published in Nov 2023 have confirmed that supermassive blackholes existed at the dawn of the universe. NASA's JWST and Chandra X-Ray Observatory have teamed up to confirm this observation.
 - Given the age of the Universe is 13.7 billion years old, the age of this black hole is 13.2 billion years. Further, this blackhole is whopper – 10 times bigger than the black hole in our milky way galaxy. It is believed to weigh from 10% to 100% the mass of all the stars in its galaxy.
 - How was it formed?
 - a. The researchers believed that the black hole was formed from colossal clouds of gas that collapsed in a galaxy next door to one with stars. The two galaxies merged, and the black hole was formed.
 - Role of Chandra X-Ray Observatory: The fact that Chandra X-Ray detected it confirms without doubt that it is a black hole. With X-rays you discover the gas that is being gravitationally pulled into the black hole, sped up and it starts glowing int the X-Ray.
 - This one is considered quasar since it is actively growing, and the gas is blindingly bright.

b. Ferocious Blackholes reveal time dilation in Early Universe (July 2023)

- Scientists have used observation of a ferocious class of black holes called quasars to demonstrate “time dilation” in the early Universe, showing how time then passed only about a fifth as quickly as it does today. The observation stretches back to about 12.3 billion years ago, when the universe was roughly 1/10th of its present age.

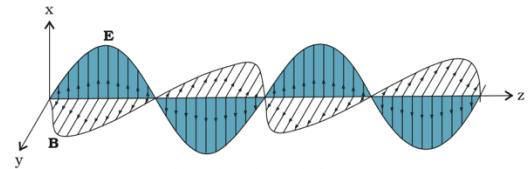
Quasars were used as a “clock” in the study to measure time in the deep past. The researchers used observations involving the brightness of 190 quasars across the universe dating to about 1.5 billion years after the Big Bang even that gave rise to the Cosmos. **They compared the brightness of these quasars at various wavelengths to that of quasars existing today**, finding that certain fluctuations that occur in a particular amount of time today did five times more slowly in the most ancient quasars.

10. ELECTROMAGNETIC WAVES AND WIRELESS COMMUNICATION

- As per Maxwell's theory accelerated charges radiate electromagnetic waves.
- Key contribution of various scientists:
 - **Hertz:** He experimentally demonstrated that accelerated charged particles emitted electromagnetic waves. [Hertz Experiment 1887] (He did it for low frequency – Radio waves)
 - **JC Bose** working at Kolkata succeeded in producing and observing electromagnetic waves of much shorter wavelength (25 mm to 5mm). His experiment like that of Hertz was confined to the laboratory.

- **Guglielmo Marconi** followed Hertz work and succeeded in transmitting electromagnetic waves over distances of many kilometers. Marconi's experiment marked the beginning of the field of communication using electromagnetic waves.

- Key Features of Electromagnetic Waves:

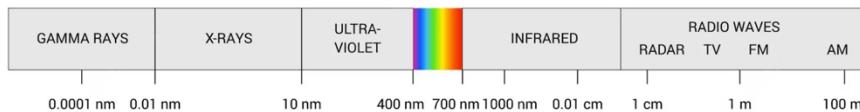
- Electric and Magnetic field are perpendicular to each other, and to the direction of propagation.
- The adjacent figure shows a linearly polarized electromagnetic wave propagating in the z-direction with the oscillating electric field **E** along the x direction and the oscillating magnetic field **B** along the y-direction.
- 
- They are self-sustaining oscillations of electric and magnetic fields in free space or vacuum.
 - It can travel in vacuum and no material medium is involved in the vibrations of the electric and magnetic fields.
 - In vacuum (free space), electromagnetic wave travels with a speed of light 2.99792458×10^8 m/s (or roughly 3×10^8 m/s).
 - » The constancy of the velocity is EM waves in vacuum is so strongly supported by experiments and the actual value is so well known now that this is used to define a standard of length.
 - Hertz has also established wave nature of the radiation. He demonstrated that the waves, which had wavelength ten million times that of the light waves, could be diffracted, refracted, and polarized.

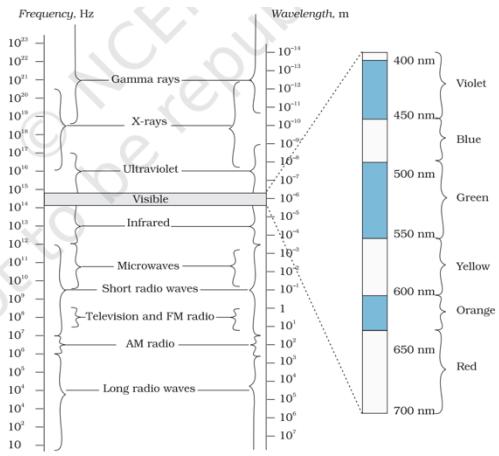
1) ELECTROMAGNETIC SPECTRUM

At the time Maxwell predicted the existence of electromagnetic waves, the only familiar electromagnetic waves were the visible light waves. The existence of ultraviolet and infrared waves was barely established. By the end of the nineteenth century, X-rays and gamma rays had also been discovered

- Electromagnetic Waves include radio waves, microwaves, infrared, visible light, ultraviolet, x rays and gamma rays. The classification of EM waves according to frequency is the **electromagnetic spectrum**. Note, that there is no sharp division between one kind of wave and the next. The classification is based on roughly on how the waves are produced and/or detected.

SPECTRUM





Different Types of Electromagnetic waves, in order of increasing frequency/decreasing wavelength:

A) RADIO WAVES:

- B) They are produced by accelerated motion of charges in the conducting wires.
- C) **Uses:** They are used in Radio and Television communication.
- D) **Wavelength:** They range from around a foot long to several kms.
- E) **Frequency ~: 500 KHz to 1000 MHz**
 - The AM (Amplitude Modulated) band is from 530 KHz to 1710 KHz.
 - The FM (Frequency Modulated) band is from 88 MHz to 108 MHz.
 - The TV waves range from 54 MHz to 89 MHz.
 - Cellular phones use radio waves to transmit voice communication in the Ultra High Frequency (UHF) band.
 - For e.g., in 2014, the DoT auctioned 2G telecom spectrum in the frequency range of 900 MHz and 1800 MHz.
 - For e.g., In 2022 auction, Jio bought frequencies in 700 MHz as well as in 1800 MHz band.
 - In 2022, 700 MHz was sold for the first time. Jio bought the spectrum,

B) MICROWAVES

- F) **Microwaves** (short wavelength radio waves) are produced by special vacuum tubes (called klystrons, magnetrons, and Gunn Diodes).
- G) **Frequency: GHz range**
- H) **Applications:**
 - **Radar:** Their short wavelength makes them suitable for Radar system in aeroplanes. Due to their short wavelength, they are suitable for Radar systems used in aircraft navigation. Radar also provides the basis for the speed guns used to time fast balls, tennis serves, and automobiles.
 - **Microwave Ovens** are an interesting application of these waves. In such ovens, the frequency of microwaves is selected to match the resonant frequency of water molecules

so that energy from the waves is transferred efficiently to kinetic energy of the molecules.
This raises the temperature of any food containing water.

Details of how microwave work:

When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies.

The frequency of rotation of water molecules is about 300 crore hertz, which is 3 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food.

One should use porcelain vessels and not metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get heated up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first, and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

c) INFRARED WAVES

- I) Produced by hot bodies and molecules. They are sometimes also referred as heat waves. This is because, water molecules produced in most materials readily absorb infrared waves (many other molecules, for example, CO₂, NH₃, also absorb infrared waves). After absorption, their thermal motion increase i.e. they heat up and heat up their surroundings.
- J) **Infrared lamps** are used in physical therapy.
- K) Infrared waves also play a crucial role in maintaining the earth's warmth or the average temperature through Greenhouse Effect.
- L) Infrared Emitting Devices (IrEDs) are used in remotes of TV, AC etc.

D) VISIBLE RAYS

- M) Part of the spectrum detected by Human eyes.
- N) **Frequency range:** 4×10^{14} Hz to about 7×10^{14} Hz.
- O) **Wavelength:** 700 nm to 400 nm (note: Speed of light = frequency * Wavelength)
- P) **Note:** Different animals are sensitive to different electromagnetic spectrum. For e.g. snakes can detect infrared waves, and the 'visible' range of many insects extends well into ultraviolet.

E) ULTRAVIOLET RAYS

- Q) **Wavelength:** 400 nm to 0.6 nm
- R) UV radiations are produced by special lamps or very hot objects. For e.g. Sun is an important source of ultraviolet rays, but fortunately, most of the radiation is absorbed in the ozone layer. This is because UV radiation in large quantities will be harmful for human health and other forms of biodiversity.
- S) **Applications:**
- Due to very short wavelengths, UV radiation can be focused on very narrow beams for high precision application such as LASIK (Laser assisted in situ keratomileusis) eye surgery.
 - **UV lamps** are used to kill germs in water purifiers.

F) X-RAYS

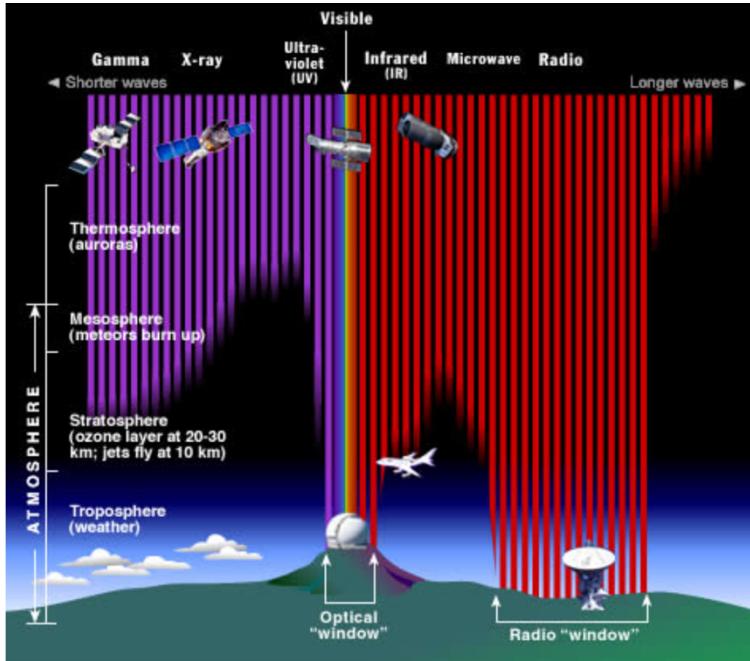
- T) **Wavelength:** 10 nm to 10^{-4} nm (10^{-13} m)
- U) One common way of generating X-Rays is to bombard a metal target by high energy electrons.
- V) **Applications:**
- They are used in diagnostic tools in medicine and as a treatment for various kinds of cancer.

G) GAMMA RAYS

- W) **Wavelength:** 10^{-10} m to 10^{-14} m
- X) Produced in nuclear reactions and also emitted by radioactive nuclei. They are used in radiative cancer therapies.

C) 2) PENETRATION OF VARIOUS EM WAVES IN EARTH'S ATMOSPHERE

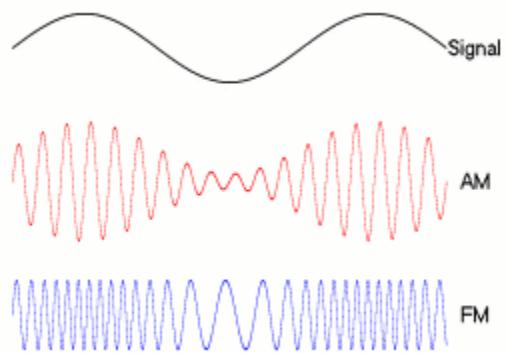
- Y) The Earth's atmosphere stops most type of EM radiation from reaching earth's surface. This illustration shows how far into the atmosphere different parts of EM spectrum can go before being absorbed. Only portions of radio and visible light reach the surface.
- Z) Radio frequencies, visible light and some part of ultraviolet lights makes it to sea level. These wavelength ranges are called atmospheric window. Ground based astronomical observation employs optical and radio telescopes that take advantage of atmospheric windows.
- AA) Astronomers can observe some infrared wavelengths by putting telescopes on mountain tops.
- BB) But, earth's atmosphere absorbs the majority of ultraviolet, X-Rays, and gamma rays. So they can only be absorbed using balloons and astronomical satellites outside the earth's atmosphere.
- CC) **Note:** Long wavelength radio waves and infrared rays also don't reach the surface.
- DD) **Note:**



2) WIRELESS COMMUNICATION – DIFFERENT FREQUENCY BANDS AND THEIR APPLICATIONS

A) RADIO WAVES (500 KHZ – 1 G HZ)

- The AM (Amplitude Modulated) band is from 530 KHz to 1710 KHz.
- The FM (Frequency Modulated) band is from 88 MHz to 108 MHz.
- The TV waves range from 54 MHz to 89 MHz
- Used for broadcasting radio and TV Programmes. Anyone with receiver can tune it to the radio frequency to pick the signal. When radio stations use similar transmission frequencies the waves sometimes interfere with each other.
- Medium wavelength radio waves are reflected from the ionosphere so they can be used for long distance communication, but not for communicating with satellite above the ionosphere. Thus, they can only be used for low earth orbit satellite communication.
- **AM vs FM**



	AM	FM
Full form	AM stands for Amplitude modulation	Frequency modulation
First used	AM method of audio transmission first carried out in the mid-1870s	FM radio was developed in the US states in the 1930s, mainly by Edwin Armstrong

Modulating difference	In AM, a radio wave known as the "carrier" or "carrier wave" is <u>modulated in amplitude by the signal that is to be transmitted</u> . The frequency and the phase remain same	In FM, <u>a radio wave known as carrier wave is modulated in frequency by the signal that is to be transmitted</u> . The <u>amplitude and phase remains the same</u> .
Pros and Cons	AM has <u>poorer sound quality</u> compared with FM but is <u>cheaper and can be transmitted over long distances</u> . It has <u>lower bandwidth</u> so it can have <u>more stations available in any frequency range</u> .	FM is <u>less prone to interference than AM</u> . However, <u>FM signals are impacted by physical barriers</u> . FM has <u>better sound quality due to higher bandwidth</u> .
Frequency Range	AM radio ranges from <u>535 to 1705 KHz (OR) Up to 1200 bits per second</u> .	FM radio ranges in a <u>higher spectrum</u> from <u>88 to 108 MHz</u> . (OR) <u>1200 to 2400 bits per second</u>
Bandwidth requirement	Twice the <u>highest modulating signal</u> . In AM radio broadcasting, the modulating signal has bandwidth of 15 KHz, and hence the bandwidth of an amplitude-modulated signal is 30 KHz	Twice the <u>sum of the modulating signal frequency and the frequency deviation</u> . If the frequency deviation is 75 KHz and the modulating signal frequency is 15 KHz, the bandwidth required is 180 KHz.
Zero crossing in modulated signal	Equidistant	Not Equidistant
Complexity	Transmitter and receiver are simple but synchronization is needed in case of SSBSC AM carrier.	Transmitter and receiver are more complex as variation of modulating signal has to be converted and detected from corresponding variation in frequencies (i.e. voltage to frequency and frequency to voltage conversion has to be done)
NOISE	AM is more <u>susceptible to noise</u> because <u>noise effects amplitude</u> , which is where information is stored in AM.	FM is <u>less susceptible to noise</u> because <u>information in an FM signal is transmitted through varying of frequency</u> , and not amplitude.

A) MICROWAVES

- Microwaves have shorter wavelength and thus can **pass through ionosphere**. They can thus be used for **long distance satellite communications**.
 - **Line of sight -> Prerequisite:**
 - Signals are sent to and from satellites, which relay signals around the Earth. This may be for TV programmes, telephone conversations or monitoring the earth, for example weather forecasting.
 - **Types**
-

L BAND: 1-2 GHZ

- Low bandwidth -> not suitable for streaming applications like video, voice, and broadband connectivity.
 - Radars, GPS signals
 - **Other advantages** -> least expensive and easiest to implement.
-

S BAND:

- It is a part of microwave band of the electromagnetic spectrum. It is defined by IEEE standard of radio waves with frequencies that range from **2 to 4 GHz**, crossing the conventional boundary between UHF (Ultra High Frequency) and SHF (Super High frequency) at 3.0 GHz.
 - **Used by**
 - » Weather radar
 - » Surface ship radar
 - » Some Communication Satellites
-

C BAND

- The C Band is the name given to certain portions of the electromagnetic spectrum, including wavelength of microwaves that are used for long-distance radio-telecommunication.
 - The IEEE C Band (**4 - 8 GHz**) and its slight variations contain frequency ranges that are used for many satellite communication transmission, some Wi-Fi devices, some cordless telephones, and some weather radar system.
-

Ku BAND

- Name given to **12-18 GHz** portion of electromagnetic spectrum in the microwave range of frequencies.
 - Uses
 - » Primarily used for satellite communication, most notably for fixed and broadcast services
-

K BAND (18-27 GHZ)

KA BAND (27 – 40 GHZ)

V BAND (40 – 75 GHZ)

W BAND (75-110 GHZ)

MILLIMETER BAND (110-300 GHZ)

D) DEEP SPACE OPTICAL COMMUNICATION

1. Why in news?
 - a. NASA's Deep Space Optical Communication Demo sends, receives first data (Nov 2023)
2. Need of Deep Space Optical Communication:
 - a. **Low bandwidth of radio frequency communications:** Future space missions are going to require higher bandwidth of communication as they will need to transmit higher volumes of science data, images, videos etc.
 - b. **Higher frequencies (shorter wavelengths)** which can carry more data suffer from the problems of getting blocked by atmosphere, and higher scattering when it is contacted with any interference.
3. NASA's Psyche Spacecraft is on its way to Psyche asteroid and will reach there by 2029. But in between it is involved in experiments related to Deep Space Optical Communication (DSOC).
4. Primary Objective of DSOC is to give tools and technology to future NASA initiatives to communicate at much higher bandwidth.
5. Demo:
 - a. DSOC has achieved 'first light' sending data via laser to and from far beyond the Moon for the first time.
 - b. NASA's DSOC experiment has beamed a near-infrared laser encoded with test data from nearly 16 million kms away – about 40 times further than the Moon is from Earth – to the Hale Telescope at Caltech's Palomar Observatory in San Diego County, California. This is the farthest ever demonstration of optical communication.
6. Key features:
 - a. It is pioneering the use of near-infrared laser signal for communication with spacecraft.
 - b. Its bandwidth is more than 10 times higher than the state of art radio-telecommunication system of comparable size and power. This enables higher resolution images, larger volumes of science data, and streaming of videos.
7. Advantages: Higher Bandwidth, faster data transmission, improved image resolution, reduced power consumption, potential for streaming video and real-time communication
8. How were the limitations of high frequency communication overcome?
 - a. Extremely precise pointing: To achieve this, the transceiver aboard the spacecraft needs to be isolated from the craft's vibration.
 - b. Compensating for movements of spacecraft and Earth: The targeting has to adjust for this continuous movement.

- c. **Extracting information from weak signal:** Since the signal will travel several million kms, the received signal will be very weak. New Signal processing tools have to be utilized to extract precise information from the communication.
9. Psyche spacecraft is the first to carry a DSOC transceiver and will be testing high bandwidth optical communications to Earth during the first two years of the spacecraft's journey to the main asteroid belt.
- a. Achieving the first light is one of many critical DSOC milestones in the coming months, paving the way toward higher-data-rate communication.
10. Has Space based optical communication happened in past?
- a. In 2013, NASA's Lunar Laser Communications Demonstration tested record breaking uplink and downlink rates between Earth and the Moon using similar technology.
 - b. But DSOC is taking optical communication to Deep Space, paving the way for high-bandwidth communication far beyond the Moon and over 1,000 times farther than any optical communication test to date.
11. **Significance:**
- a. The DSOC holds the key for future space missions. As humans travel deep into space, they would want fast way of sending and receiving large amount of data from earth.
 - b. It would pave the way for high data rate communications capable of sending scientific information, high-definition imagery, and streaming video in support of humanity's next giant leap: Sending humans to Mars.

PYQS

1	Cryogenic Engines find applications in: [Prelims 1995] <ul style="list-style-type: none"> A. Sub-marine propulsion B. Frost-free refrigerator C. Rocket technology D. Research and Superconductivity
2	Consider the following statements: [Prelims 1996] <p>A person in a spaceship located halfway between the earth and the sun will notice that the:</p> <ol style="list-style-type: none"> 1. Sky is jet black 2. Stars don't twinkle 3. Temperature outside the spaceship is much higher than that on the surface of earth <p>Which of the above statements is/are correct?</p> <ul style="list-style-type: none"> A. 3 only B. 1 and 2 only C. 1 and 3 only D. 1, 2 and 3 only

3	<p>The tail of a comet is directed away from the sun because: [Prelims 1997]</p> <ul style="list-style-type: none"> (a) As the comet rotates around the sun, the lighter mass of the comet is pushed away due to the centrifugal force alone. (b) As the comet rotates, the lighter mass of the comet is attracted by some stars situated in the direction of its tail (c) The radiation emitted by the sun exerts a radial pressure on the comet throwing its tail away from sun (d) The tail of the comet always exists in the same orientation
4	<p>A 'black hole' is a body in space which doesn't allow any radiation to come out. This property is due to its: [Prelims 2000]</p> <ul style="list-style-type: none"> (a) very small size (b) very large size (c) very high density (d) very low size
5	<p>Assertion (A): Artificial Satellites are always launched from the earth in the eastward direction. [2002] Reason (R): The earth rotates from west to east and so the satellite retains the escape velocity.</p> <ul style="list-style-type: none"> (a) Both A and R are true and R is the correct explanation of A (b) Both A and R are true but R is not a correct explanation of A (c) A is true but R is false (d) A is false but R is true
6	<p>Consider the following statements: [Prelims 2005]</p> <ol style="list-style-type: none"> 1. A Geostationary satellite is at an approximate height of 10000 km 2. FM transmission of music is of very good quality because the atmospheric or manmade noises can do little harm. <ul style="list-style-type: none"> a. 1 only b. 2 only c. Both 1 and 2 d. Neither 1 nor 2
7	<p>Consider the following statements in respect of a jet engine and a rocket: [Prelims 2008]</p> <ol style="list-style-type: none"> 1. A jet engine uses the surrounding air for its oxygen supply and so is unsuitable for motion in space 2. A rocket carries its own supply of oxygen in the gas form, and fuel <p>Which of the statements given above is/are correct?</p> <ul style="list-style-type: none"> A. 1 only B. 2 only

	<p>C. Both 1 and 2 D. Neither 1 nor 2</p>
8	<p>Satellites used for telecommunication relay are kept in a geostationary orbit. A satellite is said to be in such an orbit when: [Prelims 2011]</p> <ol style="list-style-type: none"> 1. The orbit is geosynchronous. 2. The orbit is circular 3. The orbit lies above the earth's equator 4. The orbit is an altitude of 22,236 km <p>Choose the correct answer using the code given below:</p> <ol style="list-style-type: none"> a. 1, 2 and 3 only b. 1,3 and 4 only c. 2 and 4 only d. 1,2,3 and 4
9	<p>Cape Canaveral, the site from which space shuttles are launched is located on the coast of: [Prelims 2011]</p> <ol style="list-style-type: none"> 1. Florida 2. Virginia 3. North Carolina 4. South Carolina
10	<p>An artificial satellite orbiting around the earth does not fall down. This is so because the attraction of earth: [Prelims 2011]</p> <ol style="list-style-type: none"> a. Doesn't exist at such distance b. Is neutralized by the attraction of the moon c. Provides the necessary speed for its steady motion d. Provides the necessary acceleration for its motion
12	<p>In which of the following activities are Indian Remote Sensing (IRS) satellite used? [Prelims 2015]</p>

1. Assessment of crop productivity
2. Locating groundwater resources
3. Mineral Exploration
4. Telecommunication
5. Traffic studies

Select the correct answer using the code given below:

- a. 1, 2 and 3 only
- b. 4 and 5 only
- c. 1 and 2 only
- d. 1,2, 3, 4 and 5

13

Consider the following statements: [2016]

The Mangalyaan launched by ISRO

1. Is also called the Mars Orbiter Mission
2. Made India the second country to have a spacecraft orbit the Mars after the USA
3. Made India the only country to be successful in making its spacecraft orbit the Mars in its very first attempt

Which of the statements given above is/are correct?

- a) 1 only
- b) 2 and 3 only
- c) 1 and 3 only
- d) 1,2 and 3 only

14

The terms 'Event Horizon', 'Singularity', 'String Theory' and Standard Model are sometimes seen in the news in the context of [Prelims 2017]

- (a) Observation and Understanding of the Universe
- (b) Study of the Solar and Lunar Eclipse
- (c) Placing Satellite in the orbit of the earth
- (d) Origin and Evolution of Living Organisms on Earth

15

With reference to India's satellite launch vehicles, consider the following statements: (Pre 2018)

- PSLVs launch the satellites useful for Earth resources monitoring whereas GSLVs are designed mainly to launch communication satellites.
- Satellites launched by PSLV appear to remain permanently fixed in the same position in the sky, as viewed from a particular location on Earth.
- GSLV Mk III is a four-staged launch I vehicle with the first and third stages using solid rocket motors; and the second and fourth stages using liquid rocket engines.

Which of the statements given above is/are correct?

- A. 1 only
- B. 2 and 3
- C. 1 and 2
- D. 3 only

16 In which of the following areas can GPS technology be used? (Pre 2018)

- Mobile phone operations
- Banking operations
- Controlling the power grids

Select the correct answer using the code given below:

- a. 1 only
- b. 2 and 3 only
- c. 1 and 3 only
- d. 1, 2 and 3

17 With reference to the Indian Regional Navigation Satellite System (IRNSS), consider the following statements: (PRE 2018)

- IRNSS has three satellites in geostationary and four satellites in geosynchronous orbits.
- IRNSS covers entire India and about 5500 sq. km beyond its borders.
- India will have its own satellite navigation system with full global coverage by the middle of 2020.

Which of the statements given above is/are correct?

- a. 1 only
- b. 1 and 2 only
- c. 2 and 3 only
- d. None

18 For the measurement/estimation of which of the following are satellite images/remote sensing data used?

- Chlorophyll content in the vegetation of a specific location
- Greenhouse gas emissions from rice paddies of a specific location
- Land Surface temperature of a specific location

Select the correct answer using the codes given below:

- (a) 1 only

	(b) 2 and 3 only (c) 3 only (d) 1, 2 and 3
19	Which one of the following countries has its own Satellite Navigation System? [Prelims 2023] (a) Australia (b) Canada (c) Australia (d) Japan



TARGET PRELIMS 2024

BOOKLET-3; S&T-3

NUCLEAR SCIENCE AND TECHNOLOGY

1. TABLE OF CONTENTS

1. <i>Table of Contents</i>	0
2. <i>Nuclear Science and Technology</i>	1
1) Nuclear Energy Basics.....	1
2) Fusion Reaction (Thermonuclear Reactions).....	1
A) USA's Attempt:	2
B) ITER (International Thermonuclear Experimental Reactor (ITER))	3
C) What is a Tokamak:	4
D) India and Fusion.....	4
3) Nuclear Binding Energy	5
4) Components of Nuclear Power Reactor	5
5) Types of Reactors	6
A) Boiling Water Reactor	6
B) Pressurized Water Reactor.....	6
C) Pressurized Heavy Water Reactor	6
D) Advanced Gas Cooled Reactors	6
E) Fast Neutron Reactor (Fast Breeder Reactor)	6
6) India's 3-Stage Nuclear Power Program.....	7
7) Thorium Reserves in India	10
8) Other Important Aspects	10
9) Nuclear Waste Management	11
A) Fukushima and the Issue of its Waste Disposal.....	11
10) CLND, 2010	12
11) Nuclear Bomb:.....	13
A) Underestimated fallout of the Trinity Nuclear Test: New Study (July 2023)	13
B) J Robert Oppenheimer: Father of Atom Bomb.....	13
12) Nuclear Energy and ENergy Security	14
13) Radioactivity Basics	15
14) Radioactive Decay	18
15) Radio-carbon Dating	18
16) Use of Nuclear Radiation Technology for providing better quality of life to its citizens	20

1) X-Ray Radiography	23
A) CT Scans Associated with Increased Risk of Blood Cancers (Dec 2023: Source – TH)	24
3. PYQs.....	25



ACE CSAT
CSAT FOUNDATION COURSE
FOR CSE 2024

LET'S DEVELOP
CRITICAL THINKING

STARTS: 8TH JAN 2024

By Abhishek Inamdar
M.Sc. Mathematics, BITS Pilani



**PRELIMS MASTER
PROGRAM** **BATCH 2.0**
FOR CSE PRELIMS 2024



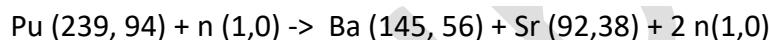
STARTS: 8TH JAN 2024

 Office Complex No. 6, 3rd Floor Old
Rajinder Nagar, New Delhi-110060 |  08045248491
7041021151

2. NUCLEAR SCIENCE AND TECHNOLOGY

1) NUCLEAR ENERGY BASICS

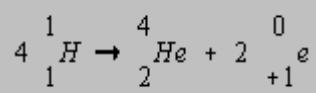
- What is nuclear energy?
 - Nuclear energy is the energy in the nucleus of an atom which is released during nuclear fission or fusion reaction.
 - During these reactions, a small amount of **mass is lost and gets converted** into energy according to Einstein's equation.
 - In **nuclear fission**, the nucleus of a heavy atom (such as uranium, plutonium or thorium), when bombarded with low - energy neutrons, can be split apart into lighter nuclei.
 - When this is done tremendous amount of energy is released, if the mass of the original nucleus is just a little more than the sum of the masses of the individual products.
- E.g. of fission reaction



In a nuclear fission, the difference in mass, Δm , between the original nucleus and the product nuclei gets converted to energy E at a rate governed by the famous equation,
$$E = \Delta m c^2$$
,

first derived by Albert Einstein in 1905, where c is the speed of light in vacuum. In nuclear science, energy is often expressed in units of electron volts (eV): $1 \text{ eV} = 1.602 \times 10^{-19} \text{ joules}$. It is easy to check from the above equation that 1 atomic mass unit (u) is equivalent to about 931 mega electron volts (MeV) of energy.

- E.g. of fusion reaction



- This is one of the common reactions taking place in sun.

2) FUSION REACTION (THERMONUCLEAR REACTIONS)

- **Introduction:**
 - **Fusion** is the energy source of the Sun and Stars.
 - At very high temperature and pressure in the core of the stars, hydrogen nuclei collide and fuse to convert into heavier helium atoms and release **tremendous amount of energy** in the process.
 - What is the **need of extremely high temperature** -> to **overcome the electrical repulsive force**

- Till date we don't have any stable fusion reaction.
 - **Development of thermonuclear energy power plants has been difficult:**
 - **Three conditions must be fulfilled** to achieve fusion in a laboratory:
 - **Very High Temperature** (of the order of 15 million degrees C)
 - **Sufficient Plasma particle density** (to increase the likelihood that collisions do occur)
 - **Sufficient confinement time** (to hold the plasma, which has the propensity to expand, within a defined volume)
- **Note:** Twentieth century fusion science identified the most efficient fusion reaction in the laboratory setting to be reaction between two hydrogen isotopes, deuterium (D) and tritium (T), as the D-T reaction produces the higher energy gain at the "lowest temperatures".
- **Why nuclear fusions are important as an energy source?**
 - Raw material easily available
 - Nuclear Fusion is a clean and green route to produce energy, as it doesn't involve any remnant waste products.
 - Long term energy security

A) USA'S ATTEMPT:

- In Dec 2022, an experiment at US National Ignition Facility (NIF), within the Livermore National Laboratory, Livermore, California, achieved a **fusion ignition** by successfully conducting a fusion test that produced 153% (1.53 gain) as much energy as went into triggering it.
- In July 2023, in a repeat of the above experiment, scientists were able to generate more energy with nearly a factor of 2 in gain compared with energy of the incoming lasers.
- **Types of Fusion Reactions:**
 - For fusion reaction to happen in reactors, the high temperature must be created artificially. There are two different ways of achieving this: **Inertial Confinement Method** and **Magnetic Confinement Method**:
 - 1) **Inertial Confinement Method:** In this method, high energy laser beams are focused onto a pellet of the fuel (D-T), which creates extreme temperatures required for fusion inside it. The outer mass of the pellet explodes and is responsible for confining the reaction.
 - E.g., **The NIF reactions**
 - 2) **Magnetic Confinement Fusion (MCF):** It uses a magnetic field to contain plasma, which prevents the particles from hitting the reactor walls which could otherwise cause them to slow down.
 - **Magnetic confinement** uses a torus-shaped reactor called tokamak, in which a hydrogen plasma is heated to a high temperature and the nuclei are guided by strong magnetic fields to fuse. **ITER** is a famous example of an experiment trying to achieve fusion using magnetic confinement.

- This is the method being used at ITER.

3) Some other variants also exist such as those which use a combination of these methods (Magnetized Target Fusion) and those that combine fission with fusion (**Hybrid Fusion**)

- **The NIF Breakthrough:**

- In Dec 2022, NIF was finally able to achieve ‘break-even’, or a net positive energy gain.
- In July 2023, it was able to replicate its efforts, but now with a bigger gain (almost 2)
- In both these achievements **inertial confinement was employed.**
 - In NIF’s set up, high-power lasers fire pulses at a 2 mm wide capsule inside a 1-cm-long cylinder called **hohlraum**, in less than 10 billionths of a second. The capsule holds deuterium and tritium atoms.
 - As the pulse strikes the hohlraum’s inside, the latter heats up and releases x-rays, which heat the nuclei to millions of degrees centigrade and compress them to **billions of Earth atmosphere**. This technique is called inertial confinement method because the nuclei’s inertia creates a short window between implosion and explosion in which the strong nuclear force dominates, fusing the nuclei.
 - Specifically, when two hydrogen-2 nuclei fuse, they yield a helium-4 nucleus, a neutron and 17.6 MeV of energy.

- **Significance:**

- **Fusion ignition** is one of the most impressive feats of the 21st century and is an engineering marvel beyond belief.

- **Some Caveats:**

- **First:** NIF experiment is highly sophisticated and required very high precision. Even small changes in the experiment may negatively impact the output. So, for long term use, they will have to reproduce these results again and again.
- **Second:** For fusion reaction to be truly gainful, the energy released by the reactions needs to be greater than the energy going into the lasers, about 300 megajoules, and not just the energy delivered to the hohlraum. This hasn’t been achieved yet. The energy transferred to plasma is just 1%, the rest is all lost in other processes. **“Future research will need to focus on reaching the next major milestone – a target gain of G > 100**, which is required to run a power plant efficiently.
- **Third:** The road to a power plant from the NIF’s current achievement isn’t well understood.

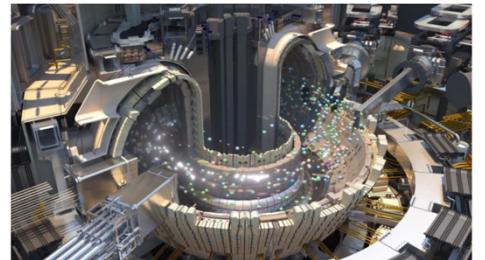
B) ITER (INTERNATIONAL THERMONUCLEAR EXPERIMENTAL REACTOR (ITER))

- ITER is an international mega project which is aimed at creating nuclear energy through nuclear fusion reaction.
- **35 countries** are collaborating to build the world’s largest tokamak, a magnetic fusion device that has been designed to prove the feasibility of fusion as a large scale and carbon free source of energy.

- The **primary objective** of the ITER is the investigation and demonstration of burning plasma – plasmas in which the energy of the helium nuclei produced by the fusion reactions is enough to maintain the temperature of plasma, thereby reducing or eliminating the need of external heating.
- **What will ITER do?**
 - » Achieve a deuterium-tritium plasma in which the fusion conditions are sustained mostly by internal fusion heating ("burning plasma").
 - » Generate **500 MW** of fusion power in plasma.
 - » **Demonstration of the integrated operation of technologies** for a fusion power plant (superconducting magnets, remote maintenance, and systems to exhaust power from the plasma)
 - » **Test tritium breeding** – One of the missions for the later stages of ITER operation is to demonstrate the feasibility of producing tritium within the vacuum vessel.
 - » **Demonstrate the safety characteristic of a fusion device.**
 - ITER achieved an important landmark in fusion history when, in 2012, the ITER Organization was licensed as a nuclear operator in France based on the rigorous and impartial examination of its safety files.
 - One of the primary goals of ITER operation is to demonstrate the control of the plasma and the fusion reactions with negligible consequences to the environment.
- **India** is also participating in ITER. PM Modi while participating in the ITER assembly said that the ITER is perfect example of the age-old India belief – **Vasudhaiva Kutumbakam** – the entire world is working together for the betterment of humankind and that India stands proud with its fair share of contributions to the cooling water, cryogenic and cry-distribution systems, auxiliary heating devices using RF and beam technologies.

C) WHAT IS A TOKAMAK:

- The Tokamak is an experimental machine which is designed to harness the energy of a fusion. Inside a tokamak, the energy produced through the fusion of atoms is absorbed as heat in the walls of the vessel. (Heat -> steam -> rotate turbine)
- First developed by Soviet research in the late 1960s, the tokamak has been adopted around the world as the most promising configuration of magnetic fusion device. **ITER will be the world's largest tokamak**—twice the size of the largest machine currently in operation, with ten times the plasma chamber volume.
- **How does Tokamak Work -> Class discussion** (not very important for exam)



D) INDIA AND FUSION

- India has become one of the major players in fusion technology and has been one of the pioneers in its development.
- The **Plasma Physics Program** was initiated by the GoI in 1982 to conduct research at MCF, which later evolved into the **Institute for Plasma Research (IPR)** in 1986 and led to the creation of India's own tokamak, ADITYA, in 1989.

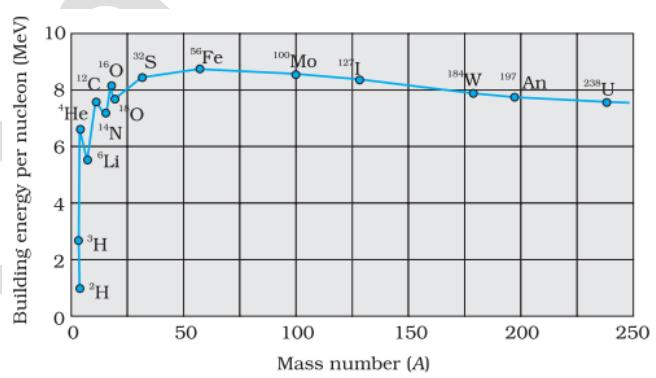
- Subsequently, it also developed a large semi-indigenous tokamak called the **Steady State Superconducting Tokamak (SST-1)** which was fully commissioned in 2013. IPR has also revealed its plans for a successor, the SST-2.
- In 2005, India became the 7th member to join the **International Thermonuclear Experiment Reactor (ITER) project**, a global initiative attempting to build the world's largest tokamak reactor.
 - ITER-India** has been set up under the supervision of IPR and is responsible for fulfilling India's commitment to the project. It has already provided the world's largest cryostat, a vacuum application stainless steel vessel, to house the reactor, along with a host of other equipment.
- Key Limitations for India:**
 - Lack of Private Investment: it is primarily because of Atomic Energy Act, 1962, which puts the brunt of developing and running nuclear power stations on the government.
 - However**, a recent government panel convened by NITI aayog has recommended overturning the ban of foreign investment and allowing greater participation of private players.

3) NUCLEAR BINDING ENERGY

The Nuclear mass M is always less than the mass of neutrons and mass of protons in the nucleus.

This **mass defect** will explain the energy required for breaking a nucleus containing protons and neutrons into individual protons and neutrons.

Similarly, if certain number of neutrons and protons are brought together to form a nucleus of certain charge and mass, an energy E_b will be released in the process. This energy E_b is called the **binding energy of the nucleus (Or Nuclear Binding Energy)**.



4) COMPONENTS OF NUCLEAR POWER REACTOR

Components of Nuclear Fission Reactor

- Fuel:** Uranium is the basic fuel. Usually pallets of **Uranium Oxide (UO_2)** are arranged in tubes to form fuel rods.
- Neutron Source:** In a new reactor with new fuel a neutron source is needed to get the reaction going. Usually this is beryllium mixed with polonium, radium or another alpha emitter. Alpha particles from the decay cause a release of neutrons from the beryllium as it turns to carbon-12. Restarting a reactor with some old fuel may not require this, as there may be enough neutrons to achieve criticality when control rods are removed.
- Moderator:** Material in the core which slows down the neutrons released from fission so that they cause more fission. It is usually water but may be heavy water or graphite.

- **Control Rods:** These are made of neutron absorbing material such as Cadmium, Hafnium or Boron, and are inserted or withdrawn from the core to control the rate of reaction.
- **Coolant:** A fluid circulating through the core so as to transfer the heat from it. In light water reactors, the water moderator functions also as primary coolant. Except in BWRs, there is secondary coolant circuit where the water becomes steam.
- **Steam Generator:** Part of the cooling system of pressurized water reactors (PWRs and PHWRs) where the high-pressure primary coolant bringing heat from the reactor is used to make steam for the turbine, in a secondary circuit.

5) TYPES OF REACTORS

A) BOILING WATER REACTOR

B) PRESSURIZED WATER REACTOR

C) PRESSURIZED HEAVY WATER REACTOR

D) ADVANCED GAS COOLED REACTORS

E) FAST NEUTRON REACTOR (FAST BREEDER REACTOR)

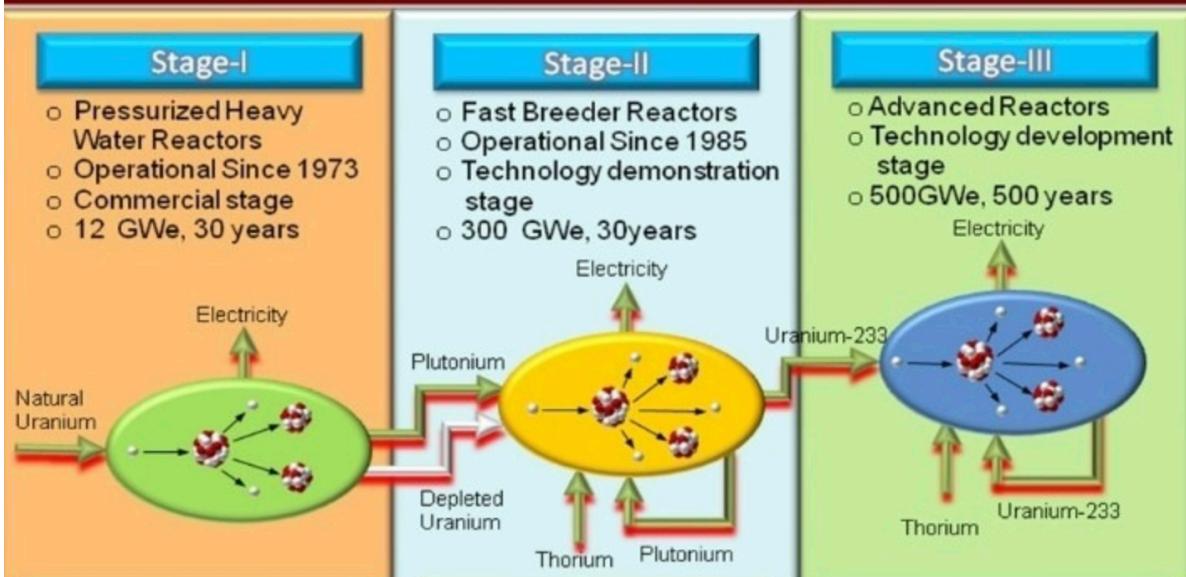
- Some reactors (**only one in commercial service**) do not have a moderator (they use a coolant that is not effective moderator, like liquid sodium). Although these fast neutrons are not good at causing fission, they are readily captured by uranium (U_{238}), which then becomes plutonium (Pu_{239}). This Plutonium isotope can be reprocessed and can be used as more reactor fuel or in the production of nuclear weapons.

- **Advantages:**
 - They get more than 60 times as much energy from the original Uranium compared with normal reactors.
 - Reduction in radioactive waste.
 - Safety -> closed fuel cycle would ensure safety
 - Energy security for India -> India plans third phase of its nuclear energy program on the success of FBR
- **Disadvantage:** Expensive and complicated to build and operate
- **Fast Breeder Reactors** - If FNRs are configured to produce more fissile material (plutonium) than they consume they are called Fast Breeder Reactors (FBR).
 - Breeder reactors are possible because of the proportion of uranium isotopes that exist in nature.
- **Problems associated with fast Breeder reactors / Fast Neutron Reactors**
 - Plutonium produced can be removed and used in nuclear weapons
 - To extract Plutonium the fuel must be reprocessed, creating radioactive waste and potentially high radiation exposure.
- **Use scenario globally**
 - US, UK, France and Germany have effectively shut down their fast breeder reactor plants
 - **India, Russia, Japan and China** currently have operational fast breeder reactor program.

6) INDIA'S 3-STAGE NUCLEAR POWER PROGRAM

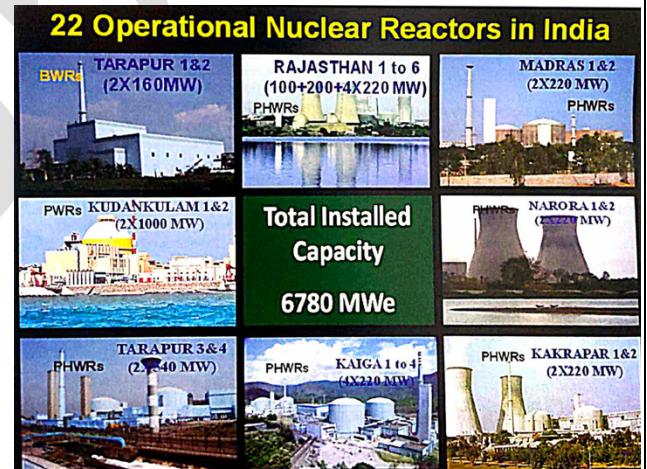
- The three-stage nuclear power production program of India had been conceived by the 'father of Indian Nuclear Power Program' Dr Homi J Bhabha, with the ultimate objective of utilizing the country's vast reserves of thorium-232.
 1. The first stage comprises setting up of **Heavy Water Reactors/Pressurized Heavy Water Reactors (PHWRs)** and associated fuel cycle facilities.
 2. The second stage envisages setting up of **Fast Breeder Reactors (FBRs)** backed by reprocessing plants and plutonium based fuels fabrication plants. Plutonium is produced by irradiation of U-238.
 3. The third stage is based on the thorium-232 -> Uranium 233 Cycle, Uranium-233 is obtained by irradiation of Thorium.

Indian Three Stage Nuclear Power Programme



Progress of the 3 Stages

- The first stage of Nuclear Power Programme is already in commercial domain. The Nuclear Power Corporation of India Ltd. (NPCIL), a public sector undertaking of DAE, is responsible for the design, construction and operation of nuclear reactors. The company presently operates 23 reactors with a capacity of 7.8 GW. In addition, the company is also engaged in construction of many other nuclear power reactors. In addition, 10 nuclear power reactors with a total of 8000 MW capacity are under construction. This include a 500 MW PFBR of the second stage nuclear power program. Further, government has accorded administrative approval and financial sanction of 10 indigenous PHWRs of 700 MW capacity each, to be set up in fleet mode. With completion of these projects, India's nuclear energy capacity is expected to go to 22.4 GW by 2031.



Nuclear power plant	State	Reactor
Tarapur atomic power station	Mha	Taps-1; taps-2 2*160 mw (BWR) Taps-3 and taps-4 (2*540) (phwr)
Rajasthan atomic power station	Rajasthan	Raps-1 to 6 (100 + 200 + 4*220)
Madras atomic power station	Tn	Maps-1; maps-2 (2*220) (phwrs)
Kaiga atomic power station	Karnataka	Kaps-1 to 4

		(4*220) (phwrs)
Kakrapara atomic power station	Gujarat	Kaps-1, kaps 2 (2*220) (phwrs) Kaps-3 (generating electricity from 30th Aug 2023) (700MW) Kaps-4 (attained criticality in Dec 2023)
Kudankulam nuclear power plant	Tn	Kknpp-1; kknpp-2 (2*1000 mw) pwrs
Naora atomic power stations	Uttar pradesh	Naps-1; naps-2 (2*220 mw) (phwrs)

- **Karappar-3** has been generating commercial electricity from 30th Aug 2023.
 - o The 700 MWe units are the largest indigenous nuclear power reactors to be built by the Nuclear Power Cooperation of India (NPCIL), a public sector undertaking of the Department of Atomic Energy (DAE)
- **Kakrapar-4 (KAPP-4)**, with 700 MWe capacity, started controlled chain reaction and thus became critical in Dec 2023.
- Both these reactors are PHWRs, which use natural Uranium as fuel and heavy water as coolant.

- **The Second Stage** of Nuclear power generation programme is geared towards setting up the Fast Breeder Reactors. These reactors produce more fuel than they consume. The fast breeder program is in technology demonstration stage.

▪ **Features of the Prototype Fast Breeder Reactor (PFBR)**

- **Fuel:** Plutonium Uranium Oxide (PuO_2 and UO_2)
- **Coolant:** Liquid Sodium
- **Liquid Sodium additional safety requirements**
 - o Since sodium explodes if it comes in contact with water and burns when in contacts with air, additional safety requirements are needed to isolate the coolant from the environment.
 - o Sodium also absorbs neutron to form Radioactive Na²⁴ isotope.

- **Advantages of FBR:**

- They can ensure upto 60 times as much energy from the original Uranium compared with normal reactors.
- Reduction in radioactive waste.
- Safety -> closed fuel cycle would ensure safety
- Energy security for India -> India plans third phase of its nuclear energy program on the success of FBR

- **The Third Stage:** of the Nuclear Power Programme is in **technology development stage**.
 - The ongoing development of 300 MWe Advanced Heavy Water Reactor (AHWR) at BARC aims at developing expertise for thorium utilization and demonstrating advanced safety concepts.
 - Thorium-based systems such as AHWR can be set up on commercial scale only after a large capacity based on fast breeder reactors, is built up.
 - Why Thorium based reactors are important for us
 - i. **Abundance:** India has the world's third largest reserve of thorium.
 - ii. **Less Enrichment requirement:** Thorium mining produces a single pure isotope, whereas the mixture of natural uranium isotope must be enriched to function.
 - iii. **Superior Nuclear Properties:** Superior physical and nuclear properties
 - iv. **Better Nuclear weapon resistant:** Better resistance to nuclear weapon proliferation
 - Weapon grade fissionable material (U-233) is harder to retrieve safely from a thorium reactor. It contains U-232, a strong source of gamma radiation that makes it difficult to work with. Further, its daughter product, thallium-208, is equally difficult to handle and easy to detect.
 - v. Reduced plutonium and actinide production. They have minuscule long lived radioactive waste.

7) THORIUM RESERVES IN INDIA

- As per the Department of Atomic Energy, India has reserves of thorium in sufficient quantity as compared to other parts of the world.
- As of 2014, the Atomic Mineral Directorate for Exploration and Research (AMD), a constituent unit of Department of Atomic Energy (DAE), has so far established 11.93 million tonnes of in situ resource Monazite (Thorium bearing mineral) in the country which contains about 1.07 million tonnes of thorium.
- **The state-wise details of the Monazite resources** (as of March 2021, as per Department of Atomic Energy):
 - » **Total: 12.73 million tonnes of Monazite** (More than 1 million tonnes of thorium in it)

State	No of Deposits	Resource (million tonne)	
		Monazite	Total Heavy Minerals
Odisha	12	3.16	332.44
Andhra Pradesh	24	3.78	333.45
Tamil Nadu	50	2.47	298.42
Kerala	35	1.84	242.88
Maharashtra	5	0.004	5.64
Gujarat	2	0.07	12.53
West Bengal	1	1.20	5.45
Jharkhand	1	0.21	1.12
Total	130	12.73	1,231.93

8) OTHER IMPORTANT ASPECTS

- Why most of the nuclear power plants are situated near the coast?

- India's n-facilities under IAEA's umbrella (Dec, 2014)
 - Paving the way for import of fuels for its nuclear reactors, India has completed the process of placing its civilian reactors under IAEA safeguards.
 - The reactors under the IAEA's umbrella are eligible to use imported uranium.
 - **Need of placing reactors under IAEA safeguards**
 - Enable India to use international fuel for civilian reactors.
 - A deal was signed under which India was to sign and ratify the Additional Protocol of the IAEA. A separation plan was chalked out after the deal, segregating the military and civilian reactors.

9) NUCLEAR WASTE MANAGEMENT

- Global Endeavours for Nuclear Waste Management:
 - » **On Site Storing:** Some nations go for onsite storing. But it carries the risk of radioactive leakage.
 - » In USA, for e.g., spent fuel is stored in a concrete and steel container called a dry cask.
 - » **India and a few other countries,** reprocess about 97-98% of spent fuel to recover plutonium and uranium. India also recovers materials like caesium, strontium, and ruthenium, which finds application as blood irradiators to screen transfusions, cancer treatment, and eye cancer therapeutics, respectively. The remaining 1-3% end up in storage facilities. India also immobilizes the wastes by mixing them with glass, which is kept under surveillance in storage facilities.
 - » **Deep geological Repositories:** Nations like Finland, Canada, France and Sweden are looking at deep geological repositories to tackle spent nuclear fuel wastes.
 - In Jan 2022, the Swedish government greenlit an underground repository for nuclear waste. Construction in Sweden will take at least 10 years.
 - » **About Onkalo Spent Nuclear Fuel Repository:** It is a deep geological repository for the final disposal of spent nuclear fuel. It will be world's first long-term disposal facility for spent fuel.
 - **Is geological repository safe?**
 - Experts associated with the project said that 40 years of theoretical and lab-based studies suggest that the geological repository is safe.
 - The bedrock provides a natural barrier to protect from radioactive release to the environment, such as water bodies and air.
 - The use of copper and clay provides a protective layer to ensure no release due to extreme conditions like earthquakes.

A) FUKUSHIMA AND THE ISSUE OF ITS WASTE DISPOSAL

- Why in news?
 - » In Aug 2023, in spite of backlash from public and neighbouring countries, Japan began the release of contaminated water from the Fukushima nuclear plant into the sea (Aug 2023)

- **Project to decommission the facility:**
 - » The decommissioning project got cabinet's approval in 2021 and could take three decades to complete. It will cost \$76 billion. Under this Japan plans to start flushing 1.2 million tonnes of water from the embattled nuclear power plant into the Pacific Ocean.
- » **Issue of water disposal into the Pacific Ocean:**
 - The water that the Japanese government wants to flush from the plant was used to cool the reactor, plus rainwater and groundwater. It contains radioactive isotope from the damaged reactor and is thus itself radioactive. Japan has said that it will release this water into Pacific over the next 30 years.
 - **Why release water in ocean?**
 - TEPCO is running out of room for the water tanks and that nuclear plants around the world regularly release water containing trace number of radionuclides into large water bodies.
 - **How was the water treated?**
 - The Tokyo Electric Power Cooperation (TEPCO) has treated the water using multiple techniques, notably the Advanced Liquid Processing System (ALPS), which removes 62 types of radioactive material.
- » **CONCERNS:**
 - ALPS technique doesn't remove Tritium which can be easily absorbed by the bodies of living creatures and rapidly distributed via blood. Removing tritium is quite impossible as it is chemically similar to Hydrogen. Since tritiated water can pass through the placenta, it could lead to developmental effects in babies when ingested by pregnant women.
 - Though Japanese government argue that the concentration of tritium doesn't exceed international standards, in particular, those of IAEA. It is six times less than the limit of tritium in drinking water.
 - As per TEPCO, the radiation emitted by Tritium is "extremely weak, and can be blocked with a single sheet of paper".
 - There is no safe limit of radionuclide and any number of radionuclides in water will increase the risk of cancer.
 - **Neighbouring countries** like China, South Korea and Taiwan have also expressed concerns over Japan's Plan

10) CLND, 2010

- This act has been deemed responsible for Nuclear energy deadlock within the country. The two most contentious have been **Section 17(b) and Section (46)**

- **Section 17(b)** : It contains provisions on **recourse liability on suppliers**. This allows a liable operator to recover compensation from a supplier in case the accident was caused by provisions of sub-standard services or defective or faulty equipment.
- **Section 46:** **Potentially unlimited liability** under this section. Section 46 provides that *nothing would prevent proceedings other than those which can be brought under the act, to be brought against the operator*. This is not uncommon as it allows criminal liability to be pursued where applicable.

11) NUCLEAR BOMB:

Basic Raw material for atomic bomb

- An atomic bomb can be made from two types of radioactive materials: Uranium and Plutonium. In both cases, the manufacturing starts with Uranium ore.
- **Highly enriched U-235** (more than 90%) and no control rod to extract neutrons.
 - Uranium mined from earth is less than 1% U-235, the isotope that can be used to fuel reactors and make bombs. Centrifuges are needed to separate the U-235 from the rest of the Uranium, in a process called **Enrichment**. **Bomb grade Uranium 90% U-235**.
 - The Other fuel that can be used to make a bomb, **plutonium**, is made by irradiating uranium in a nuclear reactor. The process transforms some of the Uranium into Plutonium.

A) UNDERESTIMATED FALLOUT OF THE TRINITY NUCLEAR TEST: NEW STUDY (JULY 2023)

- On 16th July 1945, in a nuclear test code named “**Trinity**”, a plutonium-based implosion device was set off a 100-foot metal tower. The irradiated mushroom cloud also went many times higher into the atmosphere than expected – Some 50,000 to 70,000 feet.
- **New Findings:** Using state of art modelling software and recently uncovered historical weather data, the study found that radioactive fallout from the Trinity test reached 46 states, Canada and Mexico within 10 days of detonation. How much of the fallout still remains is difficult to calculate.

B) J ROBERT OPPENHEIMER: FATHER OF ATOM BOMB

- **Why in news?**
 - » Christopher Nolan’s new film on the American Physicist who built most destructive weapon known to man was released on 21st July 2023.
- **J Robert Oppenheimer** (1904-1967) was an American physicist and one of the most prominent scientists of 20th century. He is best known for his role as the scientific director of the Manhattan Project, the top-secret US government program during WW-II that led to the development of the first atomic bomb.
- **Education:** He was born in 1904, in New York City. He attended Harvard University and studied Physics there. He completed his PhD in theoretical physics at University of Gottingen in Germany under the supervision of Max Born in 1927. Later he returned to USA, and taught in University of California,

Berkely, and the California Institute of Technology (Caltech). He made significant contribution to physics, especially in the area of quantum mechanics and quantum field theory, earning him the recognition as one of the leading theoretical physicists of his time.

- In 1942, he was appointed as the scientific director of the Manhattan Project. He played a crucial role in organizing and coordinating the efforts of various scientists and engineers to develop an atomic bomb. The project resulted in successful detonation of the first atomic bomb on 16th July 1945, in the New Mexico desert, in an area known as the Trinity Test Site.
- The use of Atomic Bomb over Hiroshima and Nagasaki in Aug 1945 led to the end of WW-II and raised profound ethical and moral questions about the use of nuclear weapons. Oppenheimer was deeply affected by the destruction caused by the bombs and became an advocate for arms control and international cooperation in the peaceful use of atomic energy.
- His political views and opposition to nuclear weapons led to him coming under scrutiny during the era of McCarthyism and the Red Scare. In 1954, his security clearances were removed, and he was also ostracized from the scientific community.
- Inspite of these controversies, he continued serving at Princeton from 1947 – 1966. In 1963, he received the Enrico Fermi Award, one of the highest honors in the field of nuclear science.
- He passed away in 1967, leaving behind a complex legacy of a brilliant physicist and a controversial figure in American History.

It was only in 2022, that the US government nullified its 1954 decisions, and affirmed his loyalty. President Joe Biden's Energy Secretary, Jennifer M Granholm, said the decision to revoke Oppenheimer's clearance was the result of a "flawed process", and that with time more evidence of his loyalty and love of country have only been further affirmed.

12) NUCLEAR ENERGY AND ENERGY SECURITY

- **Introduction:**
 - » Energy security means consistent availability of sufficient energy in various forms at affordable prices. When a country moves ahead on the path of development, it is necessary to utilize every energy resource available in the country.
 - » Currently, nuclear energy makes up about 3% of India's energy sources
- **Advantages of Nuclear Energy:**
 - a) Least carbon footprint (lesser than renewable energy)
 - b) Cost of nuclear power
 - c) Quantity of waste generated is also very less
 - d) Potential of self sufficiency
 - e) Depleting fossil fuels and import dependency: India is currently drawing around 63% of its total energy from thermal sources. A significant part of this is imported.

f) Limitations of Renewable Energy

- Renewable energy are subject to vagaries of weather; they are land intensive; dependence on import technology; energy storage handicaps;
 - Renewable energy is inevitable and nuclear option should be retained as insurance.

» Limitations

- a) Safety concerns in light of recent disasters
 - b) Nuclear waste disposal is a big concern
 - c) Potential of developing nuclear weapons
 - d) Security concerns
 - e) India is dependent on other countries both for raw material and technology
 - f) Ecological concerns
 - g) Long gestation period
 - h) More safeguards -> more costly

13) RADIOACTIVITY BASICS

▪ Introduction

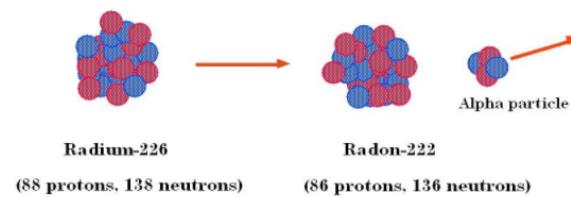
- Radioactivity is the tendency of unstable nuclei to emit particles in order to bring it closer to stability. There are four main types of radioactivity.

1. **Alpha Radiation:** The emission of a Helium nucleus.

Alpha radiation is common when the nuclides of high atomic mass have a **lower neutron to proton ratio** than stable nuclide and ejects an alpha particle.

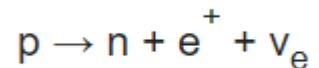
2. **Beta Minus (plus) radiation**: the emission of a high energy electron (or positron) from the nucleus.

- Generally, an unstable atomic nucleus with an excess neutron undergo **Beta (-) decay**, where a neutron is converted into a proton, an electron and an electron anti-neutrino (the antiparticle of the neutrino).

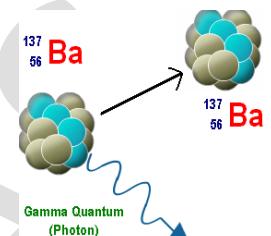


$$n \rightarrow p + e^- + \bar{\nu}_e$$

- An unstable atomic nucleus with an excess of protons may undergo beta (+) decay, also called **positron decay**, where a proton is converted into a neutron, a positron, and an electron neutrino.



- Gamma Radiation:** These are penetrating electromagnetic radiation of a kind arising from radioactive decay of atomic nuclei.



- The decay of an atomic nucleus from a high energy state to a lower energy state, a process called gamma decay, produces gamma radiation.
- Gamma rays ionize atoms, and are thus biologically hazardous.

- Neutron Radiation:** It is a kind of ionizing radiation that consists of free neutrons.

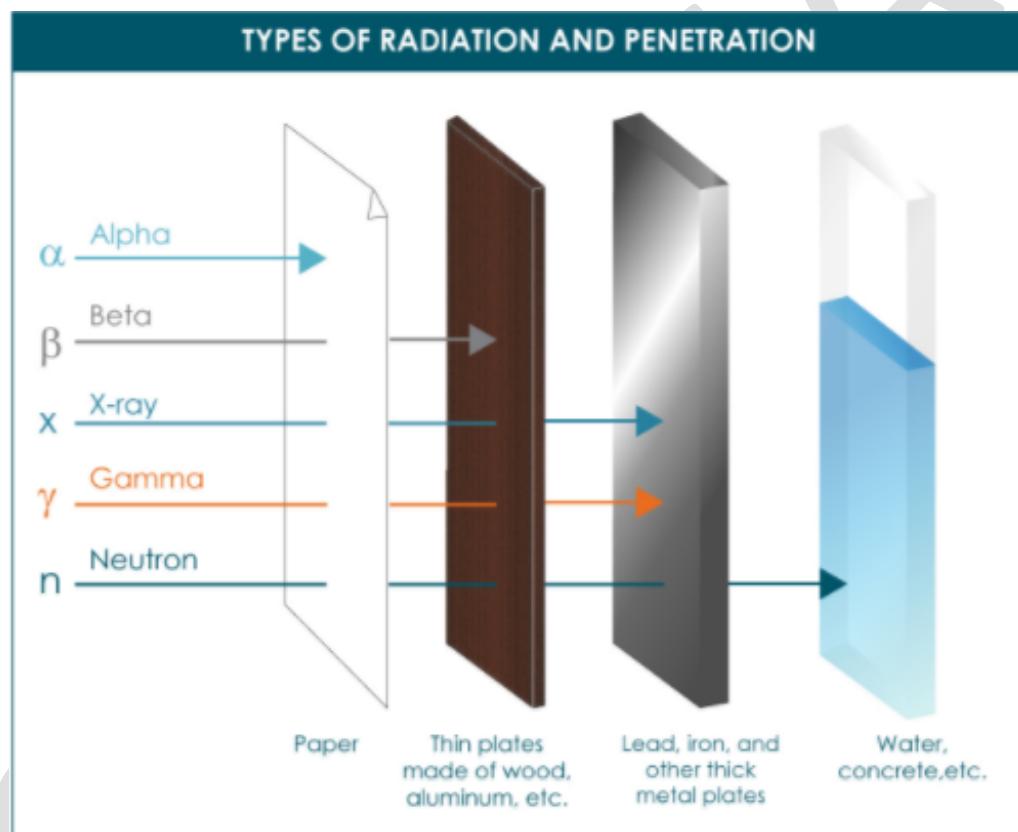
- This is generally a result of nuclear fusion and nuclear fission reaction.

- These particles (Alpha, Beta and Gamma) are available at an extremely low level in nature. Moderate to high rates of exposure to these particles can be severely detrimental to organic tissues and the life threatening to humans and rest of the ecosystem.

- Radiation can be ionizing or non-ionizing**, depending on how it affects matter.

- **Non-ionizing radiation** includes visible light, heat, radar, microwaves, and radio waves. This type of radiation deposits energy in the material through which it passes, but it doesn't have sufficient energy to break molecular bonds or remove electrons from atoms.
- **Ionizing Radiation** (such as x-rays and cosmic rays) is more energetic than non-ionizing radiation.
 - When ionizing radiation passes through material, it deposits enough energy to break molecular bonds and displace (or remove) electrons from atoms. This electron displacement creates two electrically charged particles (ions), which may cause changes in the cells of plants, animals, and people.
 - Ionizing radiation can be used for a number of beneficial purposes.

- For e.g. ionizing radiations are used in smoke detectors, medical purposes, etc.
- **Level of penetration of various ionizing radiations** (see the adjacent figure)
- **Sources of Radioactivity**
 - Minerals containing naturally radioactive elements (potassium, radium, uranium, thorium...)
 - Background cosmic rays
 - Solar Flux



- Nuclear power plants and nuclear fuel cycle plants
- Old Equipment (e.g. watches and clocks having radio luminescent paints) (radium, tritium)
- Nuclear labs
- Radioactive waste
- Nuclear Medicines
- Nuclear Bomb testing
- Radon gas

14) RADIOACTIVE DECAY

- Radioactive decay is the process through which radioisotopes lose their radioactivity over time. This gradual loss of radioactivity is measured in half-lives.
- **Law of Radioactive Decay:**
 - In any radioactive sample, which undergoes α , β or γ -decay, it is found that the number of nuclei undergoing the decay per unit time is proportional to the total number of nuclei in the sample. If N is the number of nuclei in the sample and ΔN undergo decay in time Δt then
 - $\Delta N / \Delta t \propto N$
or, $\Delta N / \Delta t = \lambda N$
- The **activity of a radioactive nucleus** (the rate of decay with time) can be described by the following equation:

$$A = \frac{dN}{dt} = -\lambda N$$

where λ is the 'decay' constant of the process in the equation.

- The **half-life** of a radioactive material is the time it takes one-half of the atoms of a radioisotope to decay by emitting radiation.
 $T_{1/2} = \frac{\ln 2}{\lambda}$ (note: $\ln 2=0.6931$)
 - The half-life of different elements can range from fractions of a second (for radon-220) to millions of years (for thorium 232).
 - **Note:** Half Life of Carbon-14 is **5,730** years.

15) RADIO-CARBON DATING

- Radiocarbon dating is a method by which age of an object is determined using radiocarbon, a name for the isotope Carbon-14.
- **How is Carbon-14 formed?**
 - It is created in the earth's atmosphere when cosmic rays – energetic streams of charged particles coming from sources in outer-space – slam into the atoms of the gases and release neutrons. When these neutrons interact with the nitrogen-14 nitrogen isotope, they can produce carbon-14. Since cosmic rays are constantly passing through earth's atmosphere, the carbon-14 is getting constantly created.
 - Carbon-14 readily combines with atmospheric oxygen to form radioactive CO₂ which enter the bodies of plants (during photosynthesis), animals (when they consume plants), and other biomass through the carbon cycle.
 - **Two key things which makes carbon-14 dating accurate:**

- The concentration of carbon-14 in the earth's atmosphere doesn't change across thousands of years. (if this wasn't true than radiocarbon dating – which dates organic materials by measuring the amount of carbon-14 they contain-wouldn't work).
- Carbon-14, in the form of carbondioxide and other carbon compounds, would have to be able to diffuse into the earth's various ecosystems such that the concentration of carbon-14 in the atmosphere was comparable to the concentration of carbon-14 in the planet's other biospheres.

- How does radiocarbon dating work?

- When an organism is alive, it constantly exchanges carbon with its surrounding by breathing, consuming food, defecating, shedding skin etc. Through these activities, carbon-14 is both lost and replenished in the body, so its concentration in the body is nearly constant and in equilibrium with its surrounding.
 - When the living organism dies, the C-14 is not replenished and it begins to reduce due to radioactive decay.
 - Radiocarbon dating dates an object by measuring amount of C-14 left, which scientists can use to calculate how long ago the body expired.
- Note: Since carbon-14 decays with a half-life of around 5,730 years, its presence can be used to date samples that are around 60 millennia old (i.e. 60,000 years old). Beyond that, the concentration of carbon-14 in the sample would have declined by more than 99%.

- Tools of Radiocarbon dating:

- Geiger Counter was used in 1940s when radiocarbon dating began. It consists of a Geiger-Muller tube connected to some electronics that interpret and display signals.
 - The Geiger-Muller tube contains a noble gas, such as helium or neon, and a rod passing through the centre. A high voltage is maintained between the tube's inner surface and the rod. The gas is insulating, so no current can pass between the two. But when energetic particles (including gamma radiation), such as those emitted during radioactive decay, pass through the gas, they can energize electrons in the gas's atoms and produce an electric discharge. The persistent voltage could also encourage these electrons to knock off electrons in more atoms, producing a bigger discharge (called the Townsend discharge). This electric signal is relayed to the electronics, where, say, a light may come on in response, indicating that radioactive decay is happening nearby.
- Today, more sophisticated devices are used. For e.g., one of the most sensitive dating setups uses accelerator mass spectrometry (AMS), which can work with organic samples as little as 50 mg.
 - Mass spectrometry is used to isolate ions that have the same mass-to-charge ratio. They begin with a sample – for e.g. a piece of bone – bombard it with electrons to ionize the atoms. Then they subject ions to different physical conditions that cause them to separate according to their mass-to-charge ratio.
 - For e.g. when deflected by electric or magnetic fields – Ions with different mass-to-charge ratios are deflected to different extents.

- **Impact of Radio-carbon dating on science and technology:** It was the first objective dating method to give numerical date to organic matter. Its impact on the field of archaeology and geology have come to be known as “**radiocarbon revolution**”

16) USE OF NUCLEAR RADIATION TECHNOLOGY FOR PROVIDING BETTER QUALITY OF LIFE TO ITS CITIZENS

1. Health: Care to Cure

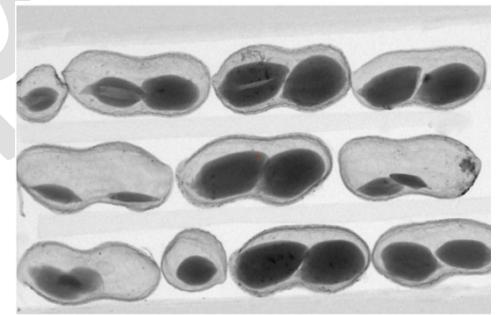
- Healthcare has grown into one of the most important peaceful uses of nuclear energy.
- **Nuclear Medicine - Diagnosis**
 - Radio pharmaceuticals can be administered by injection, inhalation, or orally and selectively localized and retained at sites of diseases. And thus, allow an image to be obtained of the loci using gamma scintigraphy or to deliver cytotoxic dose of radiation to specific disease sites without adversely affecting the surrounding normal tissues.
 - They help in identification of abnormalities in organ function even in early stages of a disease.
- **Radiation Therapy**
 - A treatment that involve use of high-energy radiation either by using special machines or from radioactive substance. The aim is to impart specific amount of radiation at tumours or parts of the body to destroy the malignant cells.
 - 1. **External Beam Radiation Therapy / teletherapy**
 - Radiation is delivered by using a machine outside the body.
 - A machine, either a ^{60}Co -teletherapy unit or linear accelerator is used
 - It can be used to treat Breast Cancer, Bowel Cancer, Head and Neck Cancer and Lung Cancer.
 - **Bhabatron** is a teletherapy machine developed by BARC and has been installed in 50 cancer hospitals.
 - It is cheaper than any imported telecobalt machine.
 - 2. **Internal Radiation Therapy or brachytherapy**
 - Radioactive material is placed in the body near cancer cells.
 - It makes it possible to treat a cancer with a larger dose of radiation that can't be given with external beam radiation therapy.

- Tiny titanium encapsulated Iodine-125 seeds have been developed by BARC and have provided an avenue to treat eye cancer.
2. **Food Security (1. Nuclear Agriculture 2. Food Preservation 3. Assessing the quality of output)**
- Use of ionizing radiation based technologies provide **safe hygienic and economically viable** solutions to address issue of agricultural productivity
1. **Nuclear Agriculture**
- Ionizing radiation is being used by BARC to induce mutation in plant breeding, and 42 varieties of different crops have been released to Indian farmers for commercial cultivation in the country.
 - e.g. groundnuts, mungbean, blackgram, pigeon pea, cowpea, mustard etc.
 - Advantages
 - Higher yield
 - Earliness
 - Large seed size
 - Resistance to biotic and abiotic stress
2. **Food Preservation - Produce and Preserve**
- Almost 30% of the food produced in India is lost due to spoilage because of pest attack, contamination and moulds infestation. These are encountered both during harvesting as well as post-harvest handling storage of the edible and cash crops.
 - **Limitation of using pesticides**
 - Health hazards
 - Disturbance to ecology
 - Development of resistance in pest
 - **Radiation Processing** can provide a viable, effective, and eco-friendly alternative to chemical fumigants and microbial decontamination, as the latter affect human health and environment adversely.
 - There is an utmost need to adopt and integrate the irradiated foods into the country's supply chains and promote the widespread use of this technology to ensure food safety and security.
 - **Advantages of using radiation processing**

- Disinfestation of insects, pests in cereals, pulses and grain.
- Microbial decontamination (hygienization) of dry species etc. for preservation/shelf life extension by applying pre-determined radiation doses.
- Increasing the exportability of Indian food produce.
- Elimination of parasites and pathogens of public health importance in food
- Delay in ripening and senescence in fruits and vegetables
- Inhibition of sprouting in tubers, bulbs and rhizomes
- **Radiation in no ways make production radioactive.**
 - Radiation therapy has been approved by WHO, IAEA, WTO, FSSAI etc.
 - As per the Department of Atomic Energy, as of Dec 2022, there are 25 irradiation facilities operational in the country in private, semi-government and government sector for food preservation.

3. X-Rays to assess the quality of food crops:

- Portable X-Ray imaging system can be very useful in grain value chains where the time needed to assess the economic value of grain by threshing or milling is a significant barrier.
 - » For e.g., a team comprised of scientists from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad and the Fraunhofer Development Center for X-Ray Technology (EZRT) in Erlangen, Germany have for the first time used x-Ray radiography to determine key market-related traits of peanuts while still inside the hull. (Sep 2022)
- X-Ray Radiography has the potential to be the right technology for in-field evaluation of farmers' produce which the International Committee for Food Value and Safety calls for.



3. Energy Security - Nuclear is Clean and Green

4. Societal Application: Sludge Hygenisation - from waste to wealth

5. Hydrogel - Healing the wound

- The process was developed by BARC scientists and technologically has been transferred for commercial purpose.

- Hydrogel is a thin transparent sheet of gel and is an excellent medical tool particularly useful for burn and injury dressings.
- **Production**
 - It is prepared by cross linking molecules of hydrophilic polymers like PVA either chemically or by Gamma/Electron beam irradiation.
 - A 3D network of gel like structure is formed which holds large quantities of water. Gamma Irradiation achieves gel formation and sterilization in one step.

6. Water Resources

1. Isotope Hydrology techniques
2. Measuring contaminants in water

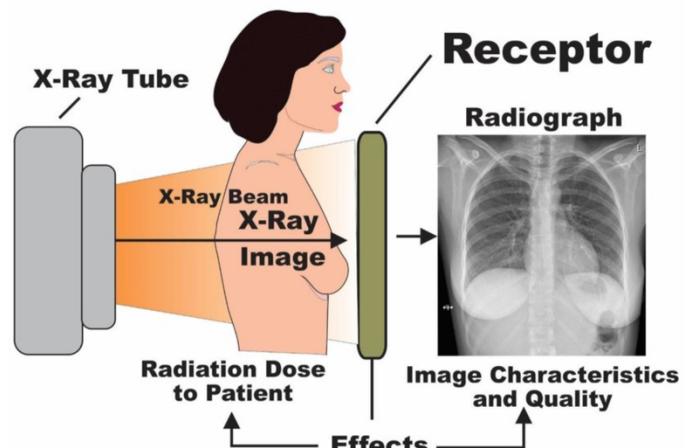
7. Industrial Applications

1. Radiation Sterilization of Medical Products
2. Radiography

- Radioisotopes which emit gamma rays are more portable than x-ray machines, and may give higher-energy radiation, which can be used to check welds of new gas and oil pipeline systems, with the radioactive source being placed inside the pipe and the film outside the weld.
- Radiography can also be used to gauge the thickness and density of materials or locate components that are not visible to other means.

1) X-RAY RADIOGRAPHY

- **X-Ray Radiography:** X-Ray radiography uses very small amount of ionizing radiation to produce pictures of the body's internal structure. These are amongst the oldest and most frequently used form of medical imaging. They are often used to help diagnosed fractured bones, look for injury or infection and to locate foreign objects in soft tissues.
 - » **How does it function?** During a radiographic procedure, an x-Ray beam is passed through the body. A portion of the X-Rays are absorbed or scattered by the internal



structures and remaining x-ray pattern is transmitted to a detector so that an image may be recorded for later evaluation.

- **Tomography:** It is any x-Ray technique in which shadows of superimposed structures are blurred out by moving x-Ray tube. Computational Tomography (also known as CAT Scanning), provides cross sectional imaging.
- **Details of Computerized Tomography (CT) Scan:** It combines a series of X-Ray images taken from different angles around your body and uses computational processing to create a cross-sectional image (slices) of the bones, blood vessels, and soft tissues inside your body. CT Scan can provide more detailed information than plain X-rays do.
- **Applications:** CT scan has many applications, but it is particularly suitable for quickly examining people who may have internal injuries from car accidents or other types of traumas.
- **Risks:** During a CT scan amount of radiation is greater than what you would get during a plain X-ray because the CT scan gathers more detailed information. The low doses of radiation in CT-Scan have not been shown to cause long-term harm, although at higher doses, there may be a small increase in your potential risk of cancer.

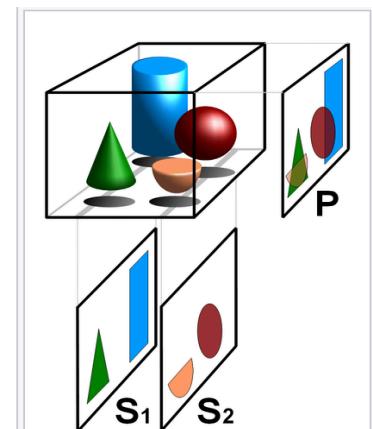


Fig.1: Basic principle of tomography: superposition free tomographic cross sections S_1 and S_2 compared with the (not tomographic) projected image P

A) CT SCANS ASSOCIATED WITH INCREASED RISK OF BLOOD CANCERS (DEC 2023: SOURCE – TH)

- **Radiation doses** at moderate (over 100 mGy) to high (over 1 Gy) values are known to cause hematological malignancies (blood cancers) in both children and adults and other cancers. However, there is uncertainty about risk at low doses (less than 100 mGy) that are typically associated with diagnostic CT examinations. A recent study published in Nature Medicine, (Nov 2023) suggests that even low doses of radiation have a small probability to cause blood cancer.
- **Analysis:** The results strengthened the body of evidence of increased cancer risk at low radiation doses and highlight the need for continued justification of pediatric CT examinations and optimization of doses.
- **Note:** gray (Gy) is the unit of ionizing radiation dose in the International System of Units (SI), defined as the absorption of one joule of radiation per Kg of matter. It measures the energy deposited by ionizing radiation in a unit mass of matter being irradiate and is used for measuring the delivered dose in radiotherapy, food irradiation, and radiation sterilization.

3. PYQS

1	<p>In which one of the following areas did the Indira Gandhi Centre for Atomic Research make significant progress in the year 2005? [Prelims 2006]</p> <ul style="list-style-type: none"> (a) Reprocessing the uranium-plutonium mixed carbide fuel of the Fast Breeder Test Reactor (b) New applications of radioisotopes in metallurgy (c) A new technology for the production of heavy water (d) A new technology for high level nuclear waste management
2	<p>In which one of the following locations is the ITER project to be built? [Prelims 2008]</p> <ul style="list-style-type: none"> A. Northern Spain B. Southern France C. Eastern Germany D. Southern Italy
3	<p>To meet its rapidly growing energy demand, some opine that India should pursue research and development on thorium as the future fuel of nuclear energy. In this context, what advantage does thorium has over Uranium? [Prelims 2012]</p> <ol style="list-style-type: none"> 1. Thorium is far more abundant in nature than Uranium. 2. On the basis of per unit mass of mined mineral, thorium can generate more energy compared to natural Uranium. 3. Thorium produces less harmful waste compared to Uranium. <p>Which of the statements given above is/are correct?</p> <ul style="list-style-type: none"> A. 1 only B. 2 and 3 only C. 1 and 3 only D. 1, 2 and 3
4	<p>India is an important member of the 'International Thermonuclear Reactor'. If this experiment succeeds, what is the immediate advantage of India? [Prelims 2016]</p> <ul style="list-style-type: none"> A. It can use thorium in place of Uranium for power generation. B. It can attain global role in satellite navigation. C. It can drastically improve the efficiency of its fission reactors in power generation. D. It can build fusion reactors for power generation.
5	<p>In India, why are some of the nuclear reactors kept under "IAEA Safeguards" while other are not? [Prelims 2020]</p> <ul style="list-style-type: none"> (a) Some use uranium and others use thorium (b) Some use imported uranium and others use domestic supplies (c) Some are operated by foreign enterprises and others are operated by domestic enterprises (d) Some are state owned, and others are privately owned



TARGET PRELIMS 2024

BOOKLET-4; S&T-4

COMPUTER, IT: AI, ML, CHATGPT ETC.

1. TABLE OF CONTENTS

1. <i>Table of Contents</i>	0
2. <i>Artificial Intelligence and Machine Learning</i>	1
1) Advancements in Machine Learning	2
A) Neural Networks.....	2
B) Deep Learning.....	3
C) Generative Artificial Intelligence like ChatGPT (Chat Generative Pre-Trained Transformer)	3
D) Multimodal AI.....	5
E) Google Deepmind AI Breakthrough (Nov 2023)	5
F) Predicting Protein structure with AI	6
2) Facial Recognition Technology (FRT)	7
D) ASTR Tool of DoT	7
E) DigiYatra: Airports using FRT in India	8
3) DeepFakes	9
A) How voice cloning through Artificial Intelligence is being used for scams (Jan 2024)	10
4) GPAI (The Global Partnership on Artificial Intelligence)	11
A) AI Safety Summit and Bletchley Declaration (Nov 2023)	11
5) Regulating Artificial Intelligence	12
A) AI Regulation Efforts in India	13



ACE CSAT

CSAT FOUNDATION COURSE
FOR CSE 2024

LET'S DEVELOP
CRITICAL THINKING



STARTS: 8TH JAN 2024

By Abhishek Inamdar
M.Sc. Mathematics, BITS Pilani

PRELIMS MASTER PROGRAM

BATCH 2.0

FOR CSE PRELIMS 2024



STARTS: 8TH JAN 2024



Office Complex No. 6, 3rd Floor Old
Rajinder Nagar, New Delhi-110060



08045248491
7041021151

2. ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

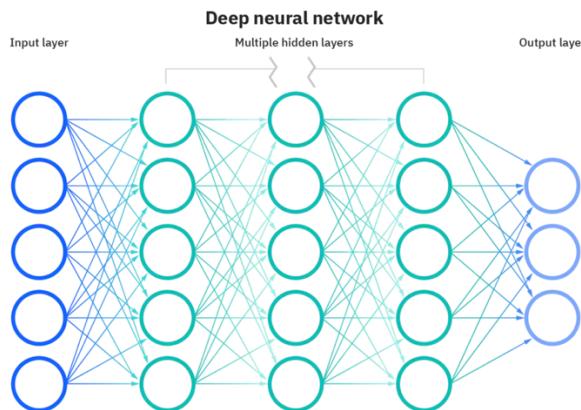
- » Intro
 - Artificial Intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs which can complete tasks that typically require human intelligence.
 - » With the **explosion of available data and expansion of computing capacity**, the world is witnessing rapid advancements in AI, ML, and deep learning.
 - Machine learning is a science that involves **development of self-learning algorithms**. Machine learning uses statistics (mostly inferential statistics) to develop self-learning algorithm. It is a type of artificial intelligence.
 - » **Note:** All Machine Learning is AI, but not all AI is machine learning
 - » For e.g., symbolic logic (rules engines, expert systems, and knowledge graphs) as well as evolutionary algorithms and Bayesian statistics could all be described as AI, and none of them are machine learning.
 - » In Machine Learning the computer program should learn from experience "i.e., given data" such that the overall performance on doing a certain task increase.
 - i. Input data
 - ii. Model Training
 - iii. Output
- Applications of Artificial Intelligence and Machine Learning
 - Advertisements, Online shopping suggestions etc.
 - Spam filtering
 - Search engines
 - Fighting Black Money (e.g., Project Insight of India)
 - Space Exploration (e.g., identifying exoplanets from pictures)
 - Health Sector:
 - **Diagnosis:** E.g., a Bengaluru based startup has developed a non-invasive, AI-enabled technology to screen for early signs of breast cancer.
 - **Treatment:** AI powered Clinical Decision Support (CDS) tools can aid in developing appropriate and accurate diagnostic and treatment recommendations. E.g. Apollo hospital has launched Apollo Clinical Intelligence Engine, a CDS, open to use by all Indian doctors.
 - **Supply chain resilience:** By accurately predicting the demand and supply for medicines.
 - **Development of new Medicines/Molecules** – For e.g. AI can help in identifying and studying new molecules.
 - **Improvement in Governance:** E.g. For **COVID-19**, AI enabled chatbot was used by MyGov for ensuring communications.
 - Developing new materials (E.g. Google Deepmind predicted the structures of 2 million new materials)
 - Education (e.g., Personalized learning through adaptive tools; customizing professional development courses etc.)
 - Agriculture Sector:

- Tech like image recognition, drones etc can help farmers kill weeds more effectively to increase productivity.
- **Efficient resource utilization** – AI enabled solution for water management crop insurance etc are also being developed.
- **AI Powered decision making:** For e.g: ICRISAT has developed an **AI-power sowing app**, which utilises weather models and data on local crop yield and rainfall to predict and advise local farmers on when they should plant their seeds more accurately.
- **AI4AI (AI for Agriculture Innovation)** initiative has been launched by the WEF to transform agriculture sector in India. Under this, 'Saagu-Baagu' initiative has been launched in the state of Telangana.
 - **Disaster Management:** An AI-based flood forecasting system has been deployed in Bihar and is now being deployed throughout the country. It gives warnings 48 hours earlier about impending floods.
 - **Improve Ease of Doing Business**
 - Natural Language Processing (NLP)
 - Image Processing (Facial Recognition)

1) ADVANCEMENTS IN MACHINE LEARNING

A) NEURAL NETWORKS

- Neural network, also known as Artificial Neural Network (ANNs) or simulated neural networks (SNNs), are a subset of machine learning and are at the heart of deep learning algorithms. Their name and structure are inspired by the human brain, mimicking the way biological neurons signal to each other.
- A neural network can fine tune its output based on the feedback given to it during stages of training.
- ANNs consist of node layers, containing an input layer, one or more hidden layers, and an output layer. Each node, or artificial neurons, connects to another and has an associated weight and threshold. If the output of any individual node is above the specified threshold value, that node is activated, sending data to the next layer of the network. Otherwise, no data is passed along the next layer of the network.



- **Note:** ANN also rely on training data to learn and improve their accuracy over time.

- **Neural Networks vs. Deep Learning:**
 - Terms are sometimes used interchangeably. ‘Deep’ in deep learning is just referring to the depth of layers in a neural network. A neural network that consists of more than three layers – which would be inclusive of the inputs and output – can be considered a deep learning algorithm. A neural network that only has two or three layers is just a basic neural network.

B) DEEP LEARNING

- Deep learning is a machine learning technique that teaches computers to do what comes naturally to humans: learn by example. In deep learning, a computer model learns to perform classification tasks directly from images, text, or sound. It can achieve state of art accuracy, sometimes exceeding human-level performance. Models are trained by using a large set of labeled data and neural network architecture that contain many layers.
 - Most deep learning methods use neural network architecture, which is why deep learning models are often referred as Deep Neural networks. The term deep usually refers to number of hidden layers in the neural network.
- » Some Criticism of AI
- Idea of intelligent machines is obscene anti human and immoral.
 - Would make life more mechanical.
 - A lot of investment has taken place -> many AI companies going bankrupt
 - Taking away the human jobs

C) GENERATIVE ARTIFICATION INTELLIGENCE LIKE CHATGPT (CHAT GENERATIVE PRE-TRAINED TRANSFORMER)

ABOUT CHATGPT:

It is an AI tool developed by OpenAI.

OpenAI is a research institution and company that focuses on developing AI intelligence technology in a responsible and safe way. It was founded in 2015 by a group of entrepreneurs and researchers, including **Elon Musk, Sam Altman, and Greg Brockman**.

- ChatGPT is based on Generative Pre-trained Transformer Architecture.
 - It is trained on massive amount of text data from the internet. It used 570 GB of text data mined from the internet.
 - It is a type of neural network and was first introduced in 2017 in a paper titled “Attention is all you need”. A neural network can fine tune its output based on the feedback given to it during stages of training. This allows the model to better understand the context and meaning of the input and to generate conversational response.
 - Thus, we can say that ChatGPT is fine tuned to provide conversational responses, as against essay-type content. It is because the neural network behind it has been additionally trained on conversational transcripts with human feedback.

- But it is more than a chatbot. It can do tasks like writing software applications, new poems, stories etc.
- ChatGPT can become a powerful pedagogy tool on any topic to anyone, because we can instruct it to “explain it to me like I am a six-year-old”. It can explain in simple terms anything from philosophy to cooking recipes, including new recipes of its own.

It is a **Language Model** (rather than a chatbot) that can produce text that sound like human response in a conversation setting.

What is language model?

It is a software that prints out a sequence of words as output that are related to some words given as input with appropriate semantic relation. In practical terms, it means that it can perform tasks like answering questions and carrying on a conversation with humans. It is often used in Natural Language Processing (NLP) applications, such as speech recognition, automatic translation, and text generation.

It is also a **Neural Network**

It can be thought of as a large network of computers that can fine tune its output of words based on the feedback given to it during stages of training; this training process and the technology together are called **Reinforcement training**. The input data is typically huge corpus of text.

Another key idea of “Word embedding” has been used. It represents words as a matrix of numbers that can be manipulated inside computers. When a neural network processes these numbers, it can differentiate words according to different contexts: for example, when “shoot” appears with “gun” the neural network knows that the words that will follow may mostly be “bullets” or “victims”, whereas when “shoot” appears with “camera”, the neural network knows that the following words may be “picture” or “pixel”.

With a further refining technique called “Transformer”, a neural network can accurately understand the context of a sentence or a paragraph. This “comprehension” can be used for multiple purposes like answering a question, summarising a paragraph or an article, translating documents and so on.

GOOGLE BARD

Google’s Generative AI model

ABOUT GOOGLE GEMINI (DEC 2023)

- Google GEMINI is a new multimodal general AI model, which the tech giant calls its most powerful yet.
- It is now available to users through Bard, some developer platforms, and even the new Google Pixel 8 Pro phones.
- The flexible AI model comes in three sizes – Ultra (yet to be released), Pro, and Nano – is being seen as Google’s answer to ChatGPT, which has been ahead of the game so far when it comes to generative AI.

- Google claims that GEMINI Ultra is the first model to outperform human experts on massive multitask language understanding (MMLU), which uses a combination of 57 subjects such as math, physics, history, law, medicine, and ethics for testing both world knowledge and problem-solving abilities.
- So, IS GEMINI better than ChatGPT 4?
 - **Hard to say now.** But it does seem to be more flexible. Its ability to work with videos and on devices without internet, gives it some edge.
- **Some Concerns** about Generative AI:
 - **Teachers are unhappy about it** as they feel that it can be used to turn in plagiarized essays which could be hard to detect for invigilators. Recently, New York City's Education department banned ChatGPT in its public schools.
 - **Skilled white collar jobs** like that of computer programmers in the IT sector is at threat.
 - **India's IT services-based exports** may get impacted.

D) MULTIMODAL AI

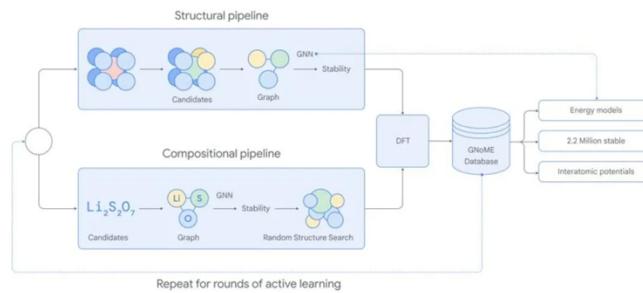
- **Definition:** Multimodal AI is a type of AI that can process and understand information from multiple types of sources like text, images, audio, and video. By integrating information from different sources, multimodal AI aims to enhance the system's ability to perceive and comprehend the world in a more holistic and human-like manner. It is like brain that can see, hear, and read all at the same time.
- **Advantages:** Multimodal AI can do several things which traditional AI can't:
 - **Understand the meaning of a video:** By combining audio and video, the multimodal AI will be able to tell you what is happening in the video, who the people are etc.
 - **Generate more realistic images:** This is because this AI will consider of things like lighting, shadows, reflections etc.
 - **Create more natural sounding speeches** – It is because the AI will be able to take into consideration the emotions and context of the conversation.
 - **Important areas where they can be used?**
 - **Processing CT scans or identifying rare genetic diseases** all need AI systems that can analyze complex datasets of images, and then respond in plain words.
- E.g. Gemini is Google's multimodal large language model.
- OpenAI is also reportedly working on a new project called **Gobi** which is expected to be a multimodal AI system from scratch, unlike GPT models.

E) GOOGLE DEEPMIND AI BREAKTHROUGH (NOV 2023)

- » **How are new materials discovered in Chemistry -> Trial and Errors -> Expensive and time-consuming process.**
- » **In last decades**, experimentation by humans has resulted in the discovery of the structures of some 28,000 stable materials, which are listed in the Inorganic Crystal Structure Database, the largest database of identified materials.

- » **What is DeepMind AI breakthrough?**
 - » Google DeepMind AI Tool known as **Graph Networks for Material Exploration (GNOME)** has successfully predicted the structures of more than **2 million new materials**. This was done with the help of AI.
 - » While these materials will still need to undergo the process of synthesis and testing, DeepMind has published a **list of 381,000 of the 2.2 million crystal structure that it predicts to be most stable**.

- » **How does GNOME actually work?**
 - » GNOME is a state of art **graph neural network model or GNN**, where the input data for the model takes the form of a graph that can be likened to connections between atoms.
 - » GNOME was **trained using active learning**, a technique to scale up a model first trained on a small, specialized dataset. Developers can then introduce new targets allowing machine learning to label new data with human assistance. This makes the algorithm well suited to the science of discovering new materials, which requires searching for patterns not found in original dataset.
 - » **GNOME** uses two pipelines to discover low energy (stable materials).
 - The **structure pipeline** creates candidates with structures similar to known crystals.
 - The **composition pipeline** follows a more randomized approach based on chemical formulas.
 - The output of both the pipelines are evaluated using established Density Function Theory (DFT) calculations and those results are added to the GNOME database, informing the next round of active learning.



- » **Significance:**
 - **Drastic increase in the number of 'stable materials' known to mankind by ten-fold.**
 - DeepMind claims its current research is equivalent to nearly 800 years of knowledge, given that 3,80,000 of its stable predictions are now publicly available to help researchers make further breakthrough in materials discovery teams.
 - **The breakthrough** has huge implications for sectors such as renewable energy, battery research, semiconductors, and computing efficiency which have been looking for new material to improve the efficiency in the sector.

F) PREDICTING PROTEIN STRUCTURE WITH AI

- The AI based program, **AlphaFold2**, from the company **DeepMind**, has stunned the world by accurately and quickly predicting the structure of proteins, starting from the sequence of amino acids that constitute them.

2) FACIAL RECOGNITION TECHNOLOGY (FRT)

- FRT is a type of biometric technology that identifies and verifies individuals by analysing and comparing patterns in their facial features.
- How does FRT Work?**
 - Data Acquisition:** It involves capturing a facial image or video of the person through cameras.
 - Feature Extraction:** In this phase, various features of the face is extracted (e.g. the distance between the two eyes, shape of the nose, width of the jaw etc.)
 - Feature Matching:** The extracted features are then matched with the database of existing pictures.
 - Identification or verification:** Based on feature matching, the FT technology identifies a person as someone in the database or verifies that the person is who he claims to be.
- Applications**
 - Security and Law Enforcement:** Criminals could be identified from the crowd.
 - Border Control:** FRT can be used to identify travelers at airports and border crossing.
 - Biometric Authentication:** For e.g. FRT can be used for unlocking of phones.
 - Marketing and Advertising:** FRT can be used to track users and user choices which can lead to better marketing
 - Social Media and Tagging:** Social media platforms use facial recognition for photo tagging and to enhance user experience.
- Concerns**
 - Excessive surveillance and violation of Privacy:** Widespread use of facial recognition could lead to mass surveillance and a loss of individual privacy. It may lead to unauthorized tracking, profiling, and potential misuse of personal data.
 - Technology challenges:**
 - FRT is prone to digital attacks or the use of physical or digital portraits, 3-D Models, such as deep-fakes etc.
 - Accuracy** concerns: Sometimes poor accuracy can lead to wrong authentication.

A) ASTR TOOL OF DOT

- why in news?**
 - Department of Telecommunication has developed an Artificial Intelligence-based facial recognition tool called **ASTR** (May 2023)
- About ASTR:**
 - Artificial Intelligence and Facial Recognition power Solution for Telecom Sim Subscriber Verification (ASTR)** can potentially bring down cyber frauds by detecting and blocking possible fraudulent mobile connections.
 - How does it function?**

- In 2021, DoT had ordered all telecom operators that they would have to share their subscriber database including users' pictures with the department. These images constitute the core database on which authorities are running their facial recognition algorithm using ASTR.
- **How ASTR Functions?**
 - Human faces in subscribers' images are encoded using Convolution neural network (CNN) models in order to account for the tilt and angle of the face, opaqueness and dark color or the images.
 - After that, a face comparison is carried out for each face against all faces in the database, and similar faces are grouped under one directory.
 - Two faces are concluded to be identical by ASTR if they match to the extent of at least 97.5%.
- The DoT allows an individual to take nine legitimate mobile phone connections using a single identity proof. In essence, what the ASTR does is -1) it looks up if there are more than nine connections against a single individual's photographs; 2) it runs a search through the database to see if the same person has taken SIMs under different names.
- **Results:**
 - According to the Ministry of Communication, an analysis of more than 87 crore mobile connections was carried out using ASTR in the first phase, where more than 40 lakh cases of people using a single photograph to obtain connections were detected. After "due verification", more than 36 lakh connections were discontinued.

B) DIGIYATRA: AIRPORTS USING FRT IN INDIA

- **What is DigiYatra?**
 - It is an initiative by GoI to make air travel and seamless and hassle free experience using digital technology. It envisages that travelers pass through various checkpoints at the airport through paperless and contactless processing, using facial features to establish their identity, which would be linked to the boarding pass.
- **How does it work?**
 - **Passenger Enrollment:** Passengers download the Digi Yatra app and link it to their Aadhaar card (a 12-digit unique ID). They can create a travel profile with their boarding pass and a self-image capture. These credentials are shared with airport authority.
 - **Facial Recognition:** At the airport, the passengers proceed to Digi Yatra Kiosk where their faces are scanned using a secure Facial Recognition tool. The system verifies the passenger's identity against their Aadhaar details stored in the app.
 - **Seamless Travel:** Once verified, passengers can simply walk through designated e-gates at various checkpoints without needing to show any physical document. The facial recognition system automatically grants them access.
- **Advantages:**
 - **Faster and smoother travel; Paperless travel.**
 - **Enhanced security**
 - **Data Privacy**
- **Who is running DigiYatra?**

- **DigiYatra Foundation:** It is a joint-venture company whose shareholders are the AAI (26%) and Bengaluru Airport, Delhi Airport, Hyderabad Airport, Mumbai Airport, and Cochin International Airport. These five shareholders equally hold the remaining 74% of the shares.

3) DEEPFAKES

- **Why in news?**
 - The Ministry of Electronics and Information Technology (MEITY) has sent an advisory to social media platforms on deepfakes (Dec 2023)
 - Earlier PM Modi had warned against Deepfakes calling on media to educate people on misinformation.
 - Following the controversy created by Deepfake videos of actress Rashmika Mandana and Katrina Kaif's deepfakes being circulated online, the GoI has asked social media companies to remove deepfake within 36 hours of a complaint being registered (Nov 2023)
- **Basics:** Deepfakes refer to manipulated media (audio, video, images etc) created using a form of Artificial intelligence called Deep Learning (or Deep Neural Network). This manipulated content uses lip syncing, swapping of face etc. – mostly without consent.
- **How does the Deepfake technology work?**
 - The technology involves modifying or creating images or videos using a machine learning technique called **Generative Adversarial Network (GAN)**. The AI driven software detects and learns the subjects' movements and facial expressions from the source material and then duplicates this in another video or image.
 - Larger the source material used, better will be the quality of deepfake. Therefore, highest number of deepfakes are made of public figures like politicians and film stars.
 - Through a collaborative work of two softwares, the fake video is rendered until the second software package can no longer detect the forgery. This is known as "unsupervised learning" when machine language models teach themselves. The method makes it difficult for other software to identify deepfakes.
- **Advantages:**
 - Synthetic Media/ Deepfakes can create possibilities and opportunities for all people, regardless of how people listen, speak, or communicate. It can give people voice, purpose, and ability to make an impact at scale and with speed.
 - It has been used by the ALS association in collaboration with a company to use voice cloning technology to help people with ALS digitally recreate their voices in future.
- **Concerns:**
 - Like most new technologies, it can also be weaponized to inflict harm to individuals, institutions, businesses or a country.
 - Crime against women can increase with malicious use of Deepfakes in pornography and can inflict emotional, reputational and in some cases violent outcome for some individuals. (for e.g. viral deepfake video of actress Rashmika Mandana incident)
 - **Endanger Social Harmony** – Communal/caste-based statements.

- Decrease trust towards institutions like government/media – by propagating false propaganda against them.
- **Undermine democracy and impair diplomacy** – false information about institutions, public policy, and politicians powered by a Deepfakes can be exploited to spin the story and manipulate belief.
- How to spot/identify a deepfake?
 - Look for unnatural blinking or lack of it.
 - **Lighting** that just don't sit right.
 - Sometimes, voice could be too robotic.
 - If the video sounds too sensational to be true, trust your gut.
 - Voices that miss the mark on lip synchronization
- Meity has sent another advisory to social media firms to comply with Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2021 (Dec 2023)
 - The advisory was aimed at getting social media firms to crack down more forcefully on 'deepfake' clips of people.
 - It mandates that intermediaries communicate prohibited content, particularly those specified under Rule 3(1)(b) of the IT Rules, clearly and precisely to users.
- Recent Advisory released by Ministry of electronics and Information Technology (Nov 2023)
 - IT Rules, 2021 require that all content reported to be fake or produced using deepfake be taken down by intermediary platforms within 36 hours.
 - An advisory was sent to social media platforms in Nov 2023, reminding them that they may lose "safe harbour immunity" under the IT Act, if they fail to remove within 36 hours deepfake content that has been reported.

A) HOW VOICE CLONING THROUGH ARTIFICIAL INTELLIGENCE IS BEING USED FOR SCAMS (JAN 2024)

- Famous Examples:
 - » In April 2023, a family living in Arizona, USA, was threatened to pay ransom for a fake kidnapping pulled off by an AI cloned voice.
 - » In Dec 2023, a Lucknow resident was duped to transfer a substantial amount through UPI.
- India:
 - » A report, titled 'The Artificial Imposter' published in May 2023, revealed that 47% of surveyed Indians have either been a victim or knew someone who had fallen prey to an AI generated voice scam. Thus, numbers are almost twice the global average of 25%.
 - » In fact, India topped the list with the maximum number of victims to AI voice scams.
- How are voice clones done?
 - » Once a scammer finds an audio clip of an individual, there are host of online sites / applications like Murf, Resemble, and Speechify which can be used to generate voice clones.
- Various real time translation tools are also available:

- » For e.g. recently Meta released **SeamlessM4T**, an open-source multilingual foundational model that can understand nearly 100 languages from speech or text and generate translation in real-time.
- » Apple introduced a voice cloning feature in **iOS 7** intended to help people who may be in danger of losing their voice say to degenerative diseases.
- » On 2nd of Jan 2024, MIT and Tsinghua University in Beijing, China, and members of AI Startup MyShell released **OpenVoice**, an open-source voice cloning tool that is almost instant and offers granular controls to modify one's voice that isn't found on other such platforms.

4) GPAI (THE GLOBAL PARTNERSHIP ON ARTIFICIAL INTELLIGENCE)

- **Why in news?**
 - » Global Partnership on AI (GPAI) members unanimously adopt New Delhi Declaration on AI (Dec 2023)
- GPAI is an **international and multi-stakeholder initiative** to guide the **responsible development and use of AI**, grounded in human rights, inclusion, diversity, innovation, and economic growth.
 - » This is also a first initiative of its type for evolving better understanding of the challenges and opportunities around AI using the experience and diversity of participating countries.
 - » GPAI was first proposed by Canada and France in 2018 G7 summit, and was officially launched in June 2020 with 15 members (including India)
 - » **Currently** (as of Dec 2023), it consists of 29 members (28 countries and EU).
 - **China**, a major techpower is not a part of the grouping.
 - » It is supported by a Secretariat hosted by OECD, Paris.
- **Dec 2023 Meeting:**
 - » India hosted the summit and will also chair GPAI in 2024.
 - » This summit was important as it was the first summit after the explosive release of ChatGPT.
 - » The GPAI has unanimously adopted 'New Delhi Declaration'.
 - » **Key Highlights of the New Delhi Declaration:**
 - It underscores the need to mitigate risks arising from the development and deployment of AI systems. It flagged concerns emanating from such systems including misinformation, unemployment, lack of transparency, and fairness, protection of IP and personal data and threat to human rights and democratic values.
 - It also promotes equitable access to critical resources for AI innovation including computing and high quality diverse data sets.
 - It also fosters inclusivity so that countries outside the purview of GPAI can also reap AI benefits.
 - It also says that global framework for the use of AI should be rooted in democratic values and human rights; safeguarding dignity and well-being; ensuring personal data protection; the protection of IPR etc.
 - Members also agreed to support AI innovation in the agriculture sector as a new 'thematic priority'. Earlier GPAI themes include healthcare, climate action and building resilient society.

A) AI SAFETY SUMMIT AND BLETCHLEY DECLARATION (NOV 2023)

- **AI Safety Summit, 2023**
 - » AI Safety summit was an international conference discussing the safety and regulation of AI. It was held in the UK at **Bletchley Park on 1st and 2nd Nov 2023**.
 - » It was the **first ever global summit on AI** which is planned to become a recurring event.
 - » **27 countries** from across the globe including the US, the UK, China, Australia, and India, as well as EU, agreed on **Bletchley Declaration on AI Safety**.
- **Key Highlights: Bletchley Declaration**
 - » It aims to enhance global cooperation on (AI) safety.
 - » It has a **twofold focus**:
 1. **Identifying** shared AI-related risks and enhancing scientific understanding of these risks
 2. **Creating cross country policies** to address these risks.
 - » **Definition of Frontier AI:** Frontier AI refers to highly advanced generative AI models with potentially dangerous capabilities that can pose significant risk to public safety.
- **About Bletchley Park:** This is a site of historic importance in computing.
 - During WW-II, it played an important role in breaking the 'unbreakable' Enigma Code which was used by Nazis.
 - It also contributed to the development of the **Colossus** – often considered the world's first programmable electronic computer.

5) REGULATING ARTIFICIAL INTELLIGENCE

- **Why in news?**
 - » EU has reached a landmark agreement to regulate **AI** (Dec 2023)
- **Need of Regulating AI:**
 - » **Controlling Big-Techs:** Most of the advanced development in AI is taking place in the Big-Technology companies like Microsoft, Google, Meta etc who have access to immense data and computing power.
 - » **Controlling Misuse:** Frontier AI has led to increase in the risk of deepfakes, harmful information, and cyber frauds.
 - » **Negative impact on economy:** AI may pose a threat to jobs and inclusive development in future.
 - » **Preventing violations of Privacy, IPR etc.**
 - » **Model Collapse Scenario:** ML models train on Data sets. But AI generated Data sets may create discrepancies and incorporate mistakes of previous AI models.
- **EU has adopted the world's first law on regulating AI** in Dec 2023.
 - » The EU Parliament will now vote on the proposed act early next year (i.e. in 2024), but with the deal done, it's just a formality.
- **What does the EU law propose?**
 - » The law regulates the use of Artificial Intelligence (AI).
 - » It classifies AI systems in four categories based on the associated risks and provides for different level of regulation for each category.

- » It includes safeguards on the use of AI within the EU, including clear guardrails on its adoption by law enforcement agencies.
 1. The deal includes strong restrictions on facial recognition technology, and on Using AI to manipulate human behaviour.
 2. Government can only use real-time biometric surveillance in public areas only when there are serious threats involved, such as terrorist attacks.
- » **Provision for strong penalties:** The deal threatens stiff financial penalties for violations of up to 35 million euros or 7% of a company's global turnover.
- » **Consumers** have been empowered to launch complaints against any perceived violations.
- » The legislation also proposes to be "a launch pad for EU start-ups and researchers to lead the global AI race".
 1. The act works as a unique legal framework for the development of AI you can trust. It will help in development of technology which doesn't threaten people's safety and rights.

- **Significance:**

- » Strong and Comprehensive rules in EU can set a powerful example for many governments considering regulations.
- » **AI Companies** who follow these regulations in EU are also expected to extend some of these protections in other jurisdictions.

- **Comparing EU's approach with other regulations:**

- » EU has taken a tougher stance which segregates AI as per use case scenario based primarily on the degree of invasiveness and risk;
- » UK has seen regulation on the other end of the spectrum with a 'light-touch' approach that aims to foster innovation in this nascent field.
- » USA's approach lies in between that of EU and UK.

- **Leadership in tech regulation:**

- » Over the last decade, Europe has taken decisive lead over the US on tech regulation.
 1. EU has enforced the landmark **GDPR (General Data Protection Regulation)** since May 2018. It is an overarching law focused on privacy and requires individuals to give explicit consent before their data can be processed and is now a template being used by over 100 countries.
 2. EU has also passed a pair of sub-legislations – the **Digital Services Act (DSA)** and the **Digital Markets Act (DMA)**. These take off from GDPR's overarching focus on the individual's right over her data.
 - a. DSA focuses on issues like hate speech, counterfeit goods etc.
 - b. DMA has defined a new category of "dominant gatekeeper" platforms and is focused on non-competitive practices and abuse of dominance by these players.
- » On AI, though, the US has made an attempt to take a lead by way of the new White House Executive Order on AI, which is being offered as an elaborate template that could act as a blueprint for every other country looking to regulate AI. In Oct 2022, USA released a blueprint on an **AI Bill of Rights** – seen as a building block for the subsequent executive order.

A) AI REGULATION EFFORTS IN INDIA

- GoI plans to bring a Digital India Act to regulate AI.

- NITI Aayog has already released National Strategy on Artificial Intelligence which focuses on Responsible AI for all.

LevelupIAS



TARGET PRELIMS 2024

BOOKLET-5; S&T-5

COMPUTER & IT - 2

1. TABLE OF CONTENTS

1. <i>Table of Contents</i>	0
2. <i>SUPERCOMPUTERs</i>	1
1) Supercomputing in India	1
A) AIRAWAT – PSAI	1
B) Other IMportant SUpercomputers of India.....	2
C) National SuperComputing Mission (NSM).....	2
3. <i>Quantum Computer</i>	2
1) National Quantum Computing Mission (April 2023).....	4
2) Quantum Entanglement	5
3) Quantum Gates: Devices that translate Quantum Effects to Computing Awesomness	6
4) QSIM – (Class Discussion)	6
4. <i>Cloud Computing</i>	8
5. <i>Edge Computing (Class Discussion)</i>	9
6. <i>Web Browsers: How do they function?</i>	9
7. <i>Internet of Things (IOT)</i>	11
8. <i>Industrial Revolution 4.0</i>	12
9. <i>Big Data</i>	13
10. <i>Net Neutrality</i>	14
11. <i>Topics to be covered in Future Booklets</i>	15

2. SUPERCOMPUTERS

- A supercomputer is a computer with a high-level computational capacity compared to a general-purpose computer or Supercomputer is a computer with great speed and memory. They are usually thousands of time faster than ordinary personal computers made at that time.
- As per the 62nd edition of TOP500 released in Nov 2023, following are the **most powerful supercomputers currently:**
 - » **USA's Frontier** is the most powerful supercomputer in the world reaching 1194 petaflops (1.194 Exaflops)
 - » **USA's Aurora system** is at 2nd spot with a capacity of 585.34 PFlop/s.
 - **Note:** Aurora is currently being commissioned and will reportedly exceed Frontier with a peak performance of 2 EFlops/s when finished.
 - » **Eagle** (installed in the Microsoft Azure Cloud in the USA), is at 3rd Spot. This is the highest rank a cloud system has ever achieved. It has the capacity of 561.2 PFlop/s.
 - » **Fugaku (of Japan)** is now ranked 4th (it was ranked second till July 2023 and ranked one till Nov 2021). Its capacity is that of 441.02 PFlop/s.
 - » **LUMI (of European Union, Finland)** is ranked 5th with a capacity of 379.70 PFlops.
- **Uses:** Super computers are generally used for scientific and engineering applications that must handle very large databases or do a great amount of computation (or both). Some of the key areas where supercomputers contribute are:
 - » Weather forecasting
 - » Climate research (E.g. Pratyush at IITM, Pune)
 - » Code-breaking
 - » Genetic analysis
 - » Oil and gas exploration – Seismic processing in the oil industry: Supercomputers help to detect and accelerate deeper geological insights.
 - » Molecular modelling
 - » Other jobs that need many calculations including engineering, product design, complex supply chain optimization (actually any kind of optimization), Bitcoin mining etc.

1) SUPERCOMPUTING IN INDIA

- In India, Indigenous development of Supercomputers began in 1980s. India's first Supercomputer was Param 8,000 which was created in 1991.
- Currently, as per the 62nd edition of TOP500 released in Nov 2023, the most powerful supercomputer in India is **AIRAWAT – PSAI** which is ranked 75 with a total capacity of 13.17 Petaflops. Thus in **terms of supercomputing power** India is way behind the world leaders.

A) AIRAWAT – PSAI

- C-DAC has implemented AI Research Analytics and Knowledge Dissemination Platform (AIRAWAT) of 200 AI Petaflops at C-DAC, Pune under the initiative of Ministry of Electronics and IT, GoI.
- C-DAC has designed and commissioned the converged HPC-AI dense GPU infrastructure integrated with the existing PARAM SIDDHI AI (PSAI) system to make the cumulative compute capacity of **410 AI PF (13.17 PF DP)**.

- The system is installed under the **National Program on AI** by GoI.
- **Note:** AI FLOPS refers to the floating-point operations per second **specifically dedicated to AI workload**. It refers to **FLOPS** required for training an AI Model.

B) OTHER IMPORTANT SUPERCOMPUTERS OF INDIA

- **Param Pravega** (3.3 Petaflops); setup under National Supercomputing Mission
- **Param Siddhi AI** (4.6 petaflops) (210 AI Petaflops); Setup under National Supercomputing Mission
- **Pratyush (IITM)** and **Mihir** (National Centre for Medium Range Weather Forecasting) (NCMRWF), Noida are other fast super computers in India.

C) NATIONAL SUPERCOMPUTING MISSION (NSM)

- A visionary program, launched in 2015, to enable India to leapfrog to the league of world class computing power nations.
- The mission is jointly steered by DST and MEITY.
- **Implemented by** Centre for Development of Advanced Computing (C-DAC); Indian Institute of Science (IISc), Bangalore.
- **Super Computing Grid:** The mission envisages empowering our national academic and R&D institutions spread over the country by installing a vast supercomputing grid comprising of more than 70 high performance computing facilities.
- **Human Resource:** The mission also includes development of highly professional High-Performance Computing (HPC) aware human resource for meeting challenges of manpower scarcity in the sector.
- **Recent Developments**
 - **BullSEQUANA Super Computer:** French Company **Atos** have signed an agreement with C-DAC (Centre for Development of Advanced Computing) for designing, building and installing BullSequana – the super computer in India
 - The supply of Bullsequana XH200 will be used for creating the network of 70 high performance computing facilities under NSM.
 - The total computing power of the Bullsequena will be greater than 10 petaflops.

3. QUANTUM COMPUTER

- **Basics:** How classical computers work:
 - » **Classical Computers** have bit as a fundamental unit which can be **0 or 1**. These computers take a series of bits (e.g., 11001100110101) and switch some of these bits to give us output. Here a bit must be processed in an exclusive binary state at any point of time i.e., either 0 or 1. The **millions of transistors and capacitors at the heart of the computer can only be in one state at any point**. There is a limit as to how quickly these devices can be made to switch state.
- Classical computers have enabled the information revolution that we are part of today. But these **classical computers can't do a number of things** including Optimization, Simulation of large molecules, factoring of large numbers etc.

- **But** Quantum computing may help us solve the above problems someday.
- **Quantum computers are based on the principle of quantum theory.** They gain enormous processing power due to the ability of quantum computer to perform task using all possible permutations simultaneously.
- **Quantum Computers** use **qubit** (Quantum bit). These qubits can take values 0 or 1 or any of the infinite **superpositions** between 0 and 1. When Qubits are in superposition, it has some probability of being in state 0 and some probability of being in state 1.
 - » **Qubits** are usually made of things like electrons, photons or even a nucleus. In case of electron spin up correspond to state 0 and spin down correspond to state 1.
 - » According to quantum law, the particle then enters a superposition of states, in which it behaves as if it were in both states simultaneously. Each qubit utilized could take a superposition of both 0 and 1. **Thus, the number of computations that a quantum computer could undertake is 2^n** , where n is the number of qubits used
 - » Quantum computing also borrows inspiration from another property of quantum mechanics called entanglement, wherein the two qubits could be connected in such a way that the state of one qubit intrinsically affects the state of the other qubit.
 - » Each operation of a quantum computation is performed by a **quantum gate**, which like classical gate, changes the state the qubits are in.
- **Quantum Supremacy:** It refers to quantum computers being able to solve a problem that a classical computer cannot. The term was coined by theoretical physicist John Preskill of the Caltech in 2012.
 - » **Google** recently used a 53 Qubit processor (Sycamore) to generate a sequence of millions of numbers, that conform to an algorithm generated by google. A classical supercomputer checked some of these values and they were correct.
 - » **Google's Quantum computer claimed 'Supremacy'** because it reportedly did the task in 200 seconds that would have apparently taken a supercomputer 10,000 years to complete.
- **Some Problems faced by Quantum Computing Sector:** While the above concept sounds promising, but there are still tremendous obstacles to be overcome.
 - » **Interference:** During the computation phase of a quantum calculation, the slightest disturbance in the quantum system (a stray photon or a wave of EM radiation) causes the quantum computation to collapse, a process known as **Quantum Decoherence**.
 - » **Error Corrections:** Because truly isolating the quantum system has proven so difficult, error correction systems for quantum computing have been developed.
 - » **Output observance:** Observing the final output also risks corrupting the data.
- **The breakthroughs in the last 20 year** including the **quantum supremacy** achieved by Google have increased the chances of developing practical quantum computing mechanisms. However, it is not clear whether the practical application is less than a decade away or a hundred years into the future.
- **Examples of Quantum Computers:** While the idea governing quantum computers have been around since the 1990s, the actual machines have been around since 2011, most notably built by Canadian company D-Wave systems.

- The recent Google's **53 qubit Quantum computer** is called **Sycamore**. Google is also spending billions and targets to build its own working quantum computer by 2029.
- **IBM** plans to have a 1,000-qubit quantum computer. For now, IBM allows the use of its machines by those research organization, institutions etc which are part of its quantum network.
- **Microsoft** also offers companies access to quantum technologies via its Azure Quantum Platform.

- **Applications:** The potential that this technology offers are attracting tremendous interest from both the governments and the private sector. The quantum computers have the potential to easily tackle computational problems that may be tough for the classical computer. The basic advantage is speed as it can stimulate several classical computers working in parallel.
 - **Military Applications** include breaking of advanced encryption using brute force searches.
 - **Advanced Cryptography:** Quantum uncertainties could be used to create private keys for encrypting messages to be sent from one place to another.
 - **Climate Change and Weather Forecasting**
 - **Faster Data analysis in industrial science applications** will enable faster solution to business problems in the era of big data.
 - » **Improved Optimization** for complex problems like NP-hard problems. This may lead to faster optimization of very large-scale problems involving complex network structures, computational biological science, and physical sciences.
 - » **Transform Healthcare and Medicine:** Drug Development and Discovery
 - » **Other civilian applications** include **DNA Modelling** and **complex material science analysis**.
 - » **Improved Machine Learning Outcomes** by enabling more efficient optimization of these algorithms so that ML capabilities become more efficient, accurate and fast.
 - » **Teleporting the information from one location to another** without physically transmitting the information. Entangling of quantum particles allow us to achieve this.
- **India and Quantum Computing:**
 - » There are no quantum computers in India yet.
 - » **Cabinet Approves Rs 6003 Crore National Quantum Mission** (April 2023)
 - » In **Budget 2020-21**, government has announced **National Mission on Quantum Technologies and Applications** which will be allocated Rs 8,000 crore over the next 5 years.
 - » Although the amount is low to begin with but given the advances in technology and India's ability to create low-cost solutions, the money may suffice.
 - » In Aug 2021, India launched **QSim** to aid Quantum Computing research in India.

1) NATIONAL QUANTUM COMPUTING MISSION (APRIL 2023)

- NQM, planned during 2023-2031, will mainly work towards strengthening India's research and development in the quantum arena alongside indigenously building quantum-based computers.
- It entails development of satellite-based quantum communication between ground station and receiver located 3,000 kms away during the first three year.
- For long distance communication, tests will be conducted in coming years.
- Under NQM, there would be four broad themes:
 - » Quantum Computing

- » Quantum Communication
 - » Quantum Sensing and Meteorology
 - » Quantum Material and Devices
- **Thematic hub for each will be established** at research institutes and R&D centres who are already working in the field of research.
 - **Department of S&T (DST)** will lead the mission, supported by other departments.
 - The mission puts India among the top six leading nations involved in the R&D in quantum technologies. Presently, R&D work in quantum tech is underway in USA, China, Canada, France, Finland and Australia.

2) QUANTUM ENTANGLEMENT

- » **What is quantum entanglement?**
 - Two particles, having ‘interacted’ with each other at some stage, were found to have got ‘entangled’ in a way that the behaviour of one produced an instantaneous reaction in the other even if the two were no longer connected in any way and were separated by large distances.
- » **2022 Nobel Prize in Physics** has gone to Alain Aspect (France), John F Clauser (USA) and Anton Zeilinger (Australia). These three scientists over the last four decades, have conclusively established that the ‘entanglement’ phenomenon observed in quantum particles was real, not a result of any ‘hidden’ or unknown forces, and that it could be utilized to make transformative technological advances in computing, hack-free communication, and science fiction like concept of ‘teleportation’.
- » **Details of their contribution:**
 - The first half of the 20th century, saw the development of Quantum Physics which explained the seemingly bizarre behaviour of sub-atomic particles with remarkable accuracy.
 - Quantum theory explained many phenomenon of quantum particles such as Superposition and Entanglement which were completely against everyday experience.
 - **Albert Einstein**, in particular was very uncomfortable with this. His Special theory of relativity prohibited any signal from travelling faster than the speed of light. The seemingly instantaneous communication due to entanglement went against Einstein’s theory. Therefore, Einstein proposed that something was missing and the Quantum theory was incomplete.
 - **However**, experimentalists were discovering that almost every prediction made by quantum theory were being obeyed by sub-atomic particles. Till, that time, experiment to test entanglement didn’t appear feasible.
 - **In 1964, John Bell** showed how phenomenon of entanglement could be established by experimentalists.
 - » The famous Bell’s inequality, if maintained in the results of the experiment, would mean that Einstein was right. If violated, it would provide the predictions of quantum theory.
 - **John Clauser** was the first person to set up an experiment to test entanglement. In 1972, his experiments produced results that were clear violations of Bell inequality

- Alain Aspect is credited with vastly improving the set-up of Clauser and removing all the loopholes critics had found. His experiments also produced results that violated Bell's inequality.
 - Anton Zeilinger meanwhile had already started using entanglement property to open up new technological possibilities. He demonstrated that it was possible to teleport the quantum states of particles to another location without the particle moving anywhere and without a medium.
 - These experiments conducted by Clauser, Aspect and Zeilinger have decisively demonstrated that entanglement was real and in accordance with quantum theory and it was not being driven by any hidden forces as suggested by Einstein and others.
- » The satisfactory theoretical explanation of phenomenon, however, continue to elude scientists.

Application: The entanglement property is now being utilized to build the next generation of computers called quantum computers which exploit the quantum behaviour of particles to overcome the challenges considered unsurmountable. It is also being used for quantum cryptography.

3) QUANTUM GATES: DEVICES THAT TRANSLATE QUANTUM EFFECTS TO COMPUTING AWESOMNESS

- A gate (in traditional computer) is a circuit that changes the states of bits in a predictable way. The speed with which the gate works determine how fast the computer is.
- Understanding the limitation of these gates:
 - » Modern computers use semiconductor transistors to build circuits that function as gates. A semiconductor chip hosts more than 100 million transistors on 1 sq mm.
 - » As transistors become smaller, they become more susceptible to quantum effects. This is not desirable as this will make existing technology unreliable for computational tasks. So, there is a limit to how many transistors a computer can have.
- A Quantum gate is a physical process or circuit that changes the state of qubit or a collection of qubit.
 - » In quantum computers, quantum gates act on qubits to process information. For e.g., a quantum NOT gate changes the state of qubit from 0 to 1 and vice versa.
 - » It can be an electromagnetic pulse which changes the state of qubit.

LOGIC FUNCTION	LOGIC SYMBOL	BOOLEAN EXPRESSION	TRUTH TABLE	
			INPUTS	OUTPUTS
AND		$A+B=Y$	B 0 0	0
			0 1	0
			1 0	0
			1 1	1
OR		$A+B=Y$	0 0	0
			0 1	1
			1 0	1
			1 1	1
inverter		$A=\bar{A}$	0	1
			1	0
			0	1
			1	0
NAND		$\overline{A+B}=Y$	0 1	1
			0 0	1
			1 1	0
			1 0	1
NOR		$\overline{A+B}=Y$	0 1	0
			0 0	0
			1 1	0
			1 1	0

4) QSIM – (CLASS DISCUSSION)



ACE CSAT

CSAT FOUNDATION COURSE
FOR CSE 2024

LET'S DEVELOP
CRITICAL THINKING



STARTS: 8TH JAN 2024

By **Abhishek Inamdar**
M.Sc. Mathematics, BITS Pilani

PRELIMS MASTER PROGRAM

BATCH 2.0

FOR CSE PRELIMS 2024



STARTS: 8TH JAN 2024

Office Complex No. 6, 3rd Floor Old
Rajinder Nagar, New Delhi-110060

08045248491
7041021151

4. CLOUD COMPUTING

- **Intro**
 - Cloud computing is a type of Internet-based computing that provides shared computer processing resources and data to computers and other devices on demand. It is a model for enabling ubiquitous, on-demand access to a shared pool of configurable computing resources which can be rapidly provisioned and released with minimal management efforts.
 - E.g.
 - Computer networks, Storage (OneDrive, Google Drive etc.), Servers, applications, and services
 - **Advantages** – Reduced upfront cost; focus on core business; Faster deployment of application; Scalability and Elasticity; pay as you Go model; Agility; Device and Location independence; Maintenance, Multitenancy, Performance and Better Security.
- » **Concerns**
- Loss of control over certain sensitive data
 - Limited customization options
 - E.g., a restaurant with a limited menu is cheaper than a personal chef who can cook anything you want.
- **Technology behind cloud:** There are two vital technologies at the heart of Cloud Computing:
 - **Virtualization:** It lets computer resource to be shared through multiple virtual machines.
 - **Network:** It lets data requests flow to and from the datacenters or the Cloud through the Internet.

In cloud computing hardware resources are distributed across multiple locations and there is diverse choice of software that is available to consumers.
 - **Service Models:** IaaS, PaaS, SaaS etc represent various cloud service models. They offer different levels of service and control.
 - **Infrastructure as service (IaaS)**
 - It provides on-demand access to fundamental resources like Virtual Machines, storage, networking, and servers.
 - These are online services that abstract the user from the details of infrastructure like physical computing resources, location, data partitioning, scaling, security, back up etc.
 - E.g. AWS, Microsoft Azure.
 - It is ideal for companies with strong technical team and need for high customization.
 - **Platform as Service (PaaS)**
 - The provider typically develops toolkit and standards for development and channels for distribution and payment.
 - In PaaS model, cloud providers deliver a computing platform, typically including operating system, programming-language, execution environment, database, and web server.
 - E.g. **Google App Engine**.
 - Software as a Service (SaaS)

- User gain access to application software and databases (e.g. Google Photos – In this consumer pays based on the giga-bytes that is required to store photos, Gmail etc.)
- Cloud providers manage the infrastructure and platforms that run the applications.

5. EDGE COMPUTING (CLASS DISCUSSION)

6. WEB BROWSERS: HOW DO THEY FUNCTION?

- **Why in news?**
 - » How do web browser work? (Dec 2023: Source - TH)
- **Definition:**
 - » A web browser is software that allows you to find and view websites on the Internet. They translate code into the dynamic webpage that forms the backbone of our online experience.
 - » **Different Browsers over the years:**
 - » In 1990, the English Computer Scientist Tim Berners-Lee introduced the concept of World Wide Web and with it came the first web browser, also known as WorldWideWeb.
 - » The next watershed moment was Mosaic browser in 1993. It was developed by US National Centre for Supercomputing Application. It introduced the concept of displaying images alongside text. It revolutionized our interaction with the web and made internet visually engaging.
 - » In 1994 came the Netscape Navigator and it became the most popular browser of its time. It brought features like bookmarks and user-friendly URL bar. It simplified the navigation and made the web more accessible.
 - » Late 1990s saw the period of the 'Browser Wars'. Microsoft's Internet Explorer (IE) and Netscape Navigator were the primarily contenders. This competition led to a lot of innovation in various browsers. But, by 2,000 IE emerged as undisputed leader mostly on the back of the success of Windows operating system which generally shipped with IE as default browser which most of the people used. But this monopoly also led to stagnation and lack of innovation.
 - » In 2004-05, this monopoly was broken with the arrival of Mozilla's Firefox. Firefox was developed by a community of volunteers and was based on open-source principles. It introduced groundbreaking features like tabbed browsing, and pop-up blocking. It also allowed users to extend their personal browsers with add-ons.
 - » In 2008, Google launched Chrome, which swiftly gained in popularity for its speed and minimalist design. It also revitalized the browser market and encouraged innovation across the board.
 - » Today, the most popular browsers are Google Chrome, Firefox, Microsoft's Edge and Apple's Safari.

- **How do Browsers work?**

Modern web browsers have multiple core components, each of which is a complex technology in itself.

A) Request and Response

- When you enter a website's address (in the form of Uniform Resource Locator (URL)) into your browser's address bar (or when you click a link), you set in motion a sequence of digital communication. The browser sends a request to a server, asking for the contents of the specific web browser you're interested in. This request travels through a network of servers, like dispatching a letter through a series of post offices. Upon reaching the server, the request is received and processed.
- The server then formulates a response containing the information (or data) required to construct the web pages. This response embarks on its journey back to your browser, carrying the digital blueprint for the page you requested.

B) Deconstructing The Response

- The response from the server is an amalgam of various files. Typically, these files have information encoded in three languages: HTML, CSS, and JavaScript. Each set of information plays a pivotal role in shaping the final presentation of the web page.
- **HTML (Hyper Text Markup Language)** provides the architectural blueprint of webpage. It defines structure of the webpage, outline elements like headings, paragraphs, images, and links. HTML is the foundation on which browser construct a visual layout.
- **CSS (Cascading Style Sheets)** imparts style and aesthetics to the HTML structure by controlling attributes like color schemes, fonts, spacing, and positioning. CSS ensures that webpages come with its unique identity.
- **JavaScript** is a dynamic engine, making webpages interactive and responsive. It allows interactive elements like pop-ups, forms, animations, and Realtime updates, creating an engaging user experience.

C) Rendering

- With HTML, CSS and JavaScript in hand, a browser begins the process of rendering. This involves deciphering the HTML to understand the structural arrangement, applying CSS for stylistic finesse, and executive JS to infuse interactivity.
- The process is remarkably swift, assembling the final webpage and presenting it to user in a cohesive and visually appealing manner in much less than a second, depending on the amount of data.
- **Rendering engines** are in themselves a key piece of technology that enables screens to display graphics.

D) Managing Data

- Browsers serve as adept custodians for your digital footprint, so they also implement instruments like **cookies** and **cache** to enhance your online experience.
- **Cookies** are small snippets of data stored on your computer by websites you visit. They retain information such as login status, site preference, and shopping cart content. This allows you to navigate seamlessly, without having to re-login to a site when you close and reopen it in a short span of time.
- **Cache** is a repository of frequently accessed files. When you revisit a webpage, the browser checks its cache to see if it already has a copy of the required files. If so, it retrieves them from the cache itself rather than re-downloading them from the server.

E) Security

- Web browsers use an array of security measures to protect your data as they fly between your computer to various servers, via the internet, and even when they're stored on your computer. They do this by using **encryption protocols**, such as **HTTPS**, to create secure tunnels for data exchange shielding the information from prying eyes.
- Browsers also use **warning systems** to alert you about potentially malicious websites, preventing inadvertent exposure to threats.

Future of Internet Browsers:

- As technology hurtles forward, web browsers evolve in tandem. They are **embracing new technologies** like **Web Assembly**, a format that **enables near-native performance** within the browser environment.
 - o **Note:** Web Assembly is a type of code that can run on modern webbrowsers – it is low-level assembly-like language with a **compact binary format** that runs with near native performance and provides languages such C/C++ with a compilation target so that they can run on web. It is also designed to run along JavaScript, allowing both to work together.
- **Support for VR and AR** experience is also on the horizon, promising immersive online interactions.
- **Privacy features** are being bolstered, providing users a greater control over their digital footprint.

7. INTERNET OF THINGS (IOT)

- Introduction

- IoT is a network of physical objects embedded with sensors, software, and other technologies for connecting and exchanging data with other devices and systems via the internet.
- A **thing** on the internet of Things, can be a **person with a heart monitor implant**, a **farm animal with a biochip transponder**, an **automobile with a built-in-sensors to alert the driver when tire pressure is low - or any other natural or manmade object that can be assigned an IP address and provided with the ability to transfer data over a network**.
- This is achieved by **sensors** and finally fabricated **micro-controllers**.
 - o Microcontrollers are **small computers themselves** and are used internally by various single board computers like Arduino and Raspberry Pi.
 - o **Sensors** are used to detect and collect information and **micro controllers to transport information**.
 - o Together, they can **make anything to a thing in IoT**.

- **Movement from IPV4 (32 bit address) to IPV6 (128 bit address)** also played a **role in making IoT possible**.

- Advantages

- **Reduce waste, loss, and cost** -> by early detection of problems and taking corrective steps
- We would know what things needed **replacing, repairing, or recalling** and whether they were fresh or past their best. This helps in increasing the **reliability** of a device.

- **Applications**
 - a. **Health Care Sector:** IoT can improve the reliability and performance of the life-critical system. For e.g., the IOT based devices can be used in combination with cardiac monitor to raise an alarm to the doctors in case of abnormality.
 - b. **Agriculture Sector:** IoT can be used to gather live pedological data that can be used by scientists to improve the yield of the land. It can also help in implementing **precision agriculture**.
 - c. **Transportation Sector:**
 - **Early detection of wear and tear** (preventing accidents)
 - Self-Driving Cars – will need IOT for real time decisions
 - Traffic Management – real time traffic data -> better traffic management.
 - d. **Energy Management**
 - Managing temperature in a Nuclear Power Plant (using sensors and IoT)
 - Real time efficiency analysis of Solar Power panels.
 - e. **Research and Development:**
 - E.g. – Recent development of wireless communication system for satellites by NASA through which Satellites can communicate with each other.
 - f. **Safety and Security**
 - Real time tracking of criminals – using tagging and IoT.
- **Some Limitations of IoT**
 - » **High Initial cost of set up** -> Since IoT is based on expensive sensors
 - » **Increased cyber security concerns** -> with increased number of devices connected to internet
 - » **Compatibility issues** -> due to lack of the international standardization on IoT devices.

8. INDUSTRIAL REVOLUTION 4.0

- The **First Industrial Revolution** used water and steam power to mechanize production.
- The **Second** used electric power to create mass production.
- The **Third** used electronics and information technology to automate production.
- Now a **Fourth Industrial Revolution is building on the Third**. It is characterized by a **fusion of technologies that is blurring the lines between the physical, digital, and biological spheres**.
 - It is characterized by integration of advanced technologies such as AI, IOT, Robotics, big data, and more into various industries and aspects of society.
 - It combines Machine to Machine Communication, Industrial Big Data Analytics technology, cyber security, and automation. It's driving new levels of efficiency and productivity.
- **Three reasons** why 4th IR is not merely a prolongation of the 3rd IR, but rather the arrival of a Fourth and distinct one: Velocity, Scope and Systems impact.
 - The **speed** of current breakthroughs has no historical precedent. The 4th Industrial Revolution is evolving at an exponential rather than a linear pace.
 - It is disrupting almost every industry in the country.
 - The breadth and depth of these changes herald the transformation of entire systems of production, management, and governance.

- **Need of Industry 4.0:**
 - » Impetus to next surge of growth
 - » Harness the potential of Big Data, AI etc in every field.
 - » Improve governance by using new age tech.

9. BIG DATA

- **Intro**
 - » Big Data is a collection of data that is huge in volume (petabytes and exabytes of data) yet growing exponentially with time. It is a data with so large size and complexity that none of the traditional data management tools can store or process it efficiently. Big Data can be structured, semi-structured and Unstructured. But they generally have potential to be mined for information.
 - » **Examples of Big Data:**
 - BSE which generates Gigabytes of data per day
 - Social media – Around 500+ terabytes of new data get ingested into the database of social media site Facebook every day.
 - Data from search engines (like Google, Bing etc.) and Online portals like Amazon.
- **Challenges** include capture, analysis, data curation, search, sharing, storage, transfer, visualization, querying, updating, and information privacy.
- Big data is **characterized by 3 Vs** – Volume, Velocity and Variety.
- **Advantages – Accuracy, Better Correlation**
- **Key areas where it can be used**
 - » Internet
 - » Finance
 - » Urban Informatics
 - » Business informatics
 - » Meteorology
 - » Genomics and healthcare
 - Find new cures, optimize treatment, and even predict diseases before any physical symptoms appear
 - » Complex physical simulations
 - » Environment research
 - » Improve the performance of Individuals
 - (At sports, at home or work), where data from wearable sensors in equipment and wearable devices can be combined with video analytics to get insights that traditionally were impossible to achieve)
 - » Security Agencies
 - To prevent cyber attack
 - Detect credit card frauds
 - Foil terrorism

- Even predict criminal activity
- » Improve our homes, cities, and countries
 - Optimizing heating and lighting in our homes
 - Optimizing traffic flow in our cities
 - Optimizing Energy Grid across the country
- **Relation between cloud computing and big data**
 - » Cloud computing is very important in BIG data analytics due to its application sharing and cost-effective properties

10. NET NEUTRALITY

- **Why in news?**
 - » 120+ startups have written to TRAI opposing Telecom Service Providers (TSPs) push for regulating over the top (OTT) services (Oct 2023)
- Net Neutrality (also network neutrality, internet neutrality or net equality) is the principle that ISPs and Governments should treat all data on the internet equally, not discriminating or charging differentially by user, content, site, platform, application, type of attached equipment, or mode of communication.
- The term was coined by Columbia University media law professor **Tim Wu** in 2003 as an extension of the long-standing concept of a common carrier.
- **Arguments for Net Neutrality**
 - » **Free Flow of Data**
 - » **User Intolerance for slow loading sites**
 - » **Competition and Innovation**
 - » **Preserving Internet Standards**
 - » The advocates also argue that authorizing network providers to override a transport and application layer separation on the internet would signal the decline of fundamental internet standards and international consensus authority.
 - » **Preventing Pseudo Services**
 - » **End to End Principle**
 - Network neutrality is needed in order to maintain the end-to-end principle. It is this simple but brilliant end to end aspect that has allowed the internet to act as a powerful force for economic and social good.
- **Arguments against Net Neutrality**
 - » **Financing Infrastructure Improvements**
 - » **Counterweight to server-side non-neutrality.**
 - » **May prevent overuse of bandwidth.**
 - » **May prevent access to useless websites.**
- **Net Neutrality in India:**

- » In 2016, TRAI banned **Free Basics service (Internet.Org)** in India based on "Prohibition of Discriminatory Tariffs for Data Services Regulations".
- » In Sep 2020, TRAI recommended the creation of a multi-stakeholder body (MSB) to ensure that Internet access providers adhere to the provisions of net neutrality. TRAI also said that the net neutrality principles adopted by DoT were technology neutral and would apply equally to 5G technology.

11. TOPICS TO BE COVERED IN FUTURE BOOKLETS

- Encryption/Decryption – Public Cryptography, Digital Signature
- Quantum Cryptography
- BlockChain – BitCoin- Other Crypto Currencies
- NFTs
- AR/VR/Meta Verse
- Web 3.0
- Wireless Communication (5G/6G), Bluetooth, WiFi, NFC, RFID etc.
- Optical Fiber Communication / FSOC
- Electronics – Basics
- Semiconductor manufacturing in India
- LED; (OLED) (PMOLED), Flexible LED Display
- LASER and other optoelectronics
- Wireless Charging
- 3D Printing
- BarCode / QR Code



TARGET PRELIMS 2024

BOOKLET-6; S&T-6

COMPUTER & IT - 3

1. TABLE OF CONTENTS

1. <i>Table of Contents</i>	0
2. <i>Cryptography</i>	1
1) Digital Signature.....	1
2) End to End Encryption	2
3) Quantum Cryptography/ Quantum Key Distribution.....	3
3. <i>Blockchain Technology</i>	3
4. <i>Crypto Currency</i>	5
A) Crypto Mining.....	6
1) Bitcoins	6
2) Libra (DIEM) (Project abandoned in Jan 2022)	7
3) Most Famous Cryptocurrencies	7
4) Cryptocurrency and India	7
A) The Cryptocurrency and Regulation of Official Digital Currency Bill, 2021	8
B) Budget 2022-23	8
5. <i>NFT</i>	9
6. <i>Web 3.0</i>	9
7. <i>Augmented Reality/ Virtual Reality</i>	10
A) Augmented Reality	10
▪ Virtual Reality	10
8. <i>MetaVerse</i>	10
9. <i>Electronics – Basics</i>	11
10. <i>Optoelectronics</i>	12
11. <i>Light Emitting Diodes</i>	13
12. <i>Organic LEDs</i>	14
13. <i>Flexible OLEDs</i>	18
14. <i>LASER (Light Amplification by Simulated EMission of Radiation)</i>	19
A) LIDAR	21

15.	Wireless Charging	22
16.	Free Space Optical COnmunication.....	23
17.	Fiber Optics Communication.....	24
18.	3D Printing.....	26
19.	Barcode and QR Codes	27
A)	QR Code (Quick Response Code) – a type of 2D bar code.....	27
B)	BAR Code	28
20.	Topics to be covered in Future Booklets.....	28

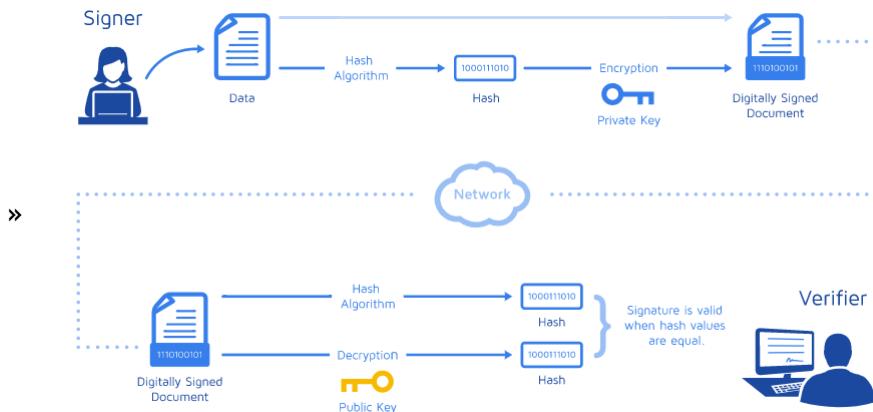
2. CRYPTOGRAPHY

- **Introduction**
 - » Encryption is conversion of electronic data into another form, called cipher text, which cannot be easily understood by anyone except authorized parties.
 - » **Key purpose:** Confidentiality, Authentication, Integrity and Non-Repudiation
- **Historical development**
 - » Spartans using stick of fixed diameter.
 - » **Symmetric Algorithms** (Same key for encryption and decryption)
 - Ceaser Shift cipher.
 - Polyalphabetic substitution -> which uses multiple substitute alphabets to limit the use of frequency analysis to crack a cipher.
 - Most famous example: Enigma electro-mechanic rotor cipher machine used by Germans during WW-2.
 - » All the above methods used the same key for encryption and decryption.
 - » **Limitations:** Requires secure channel for key transfer
 - » **Asymmetric Cryptography or Public Key Cryptography**
 - » It uses pairs of keys.
 - Public key that may be disseminated widely.
 - Private key which is known only to the owner.
 - » Public key algorithms, unlike symmetric key algorithms, do not require a secure channel for initial exchange of one (or more) secret keys between the parties.
 - » Famous examples: Digital Signature algorithm, RSA algorithm (based on the problem of factoring the product of two large prime numbers - the factoring problem), AES etc.
 - » **Where is Encryption used today?**
 - » Before coming of the Diffie-Hellman key exchange (public key algorithm) and RSA algorithm, governments and their armies were the only real users of encryption.
 - » Now, the broad use of encryption in **the commercial and consumer realms** to protect data both while it is being sent across a network (data in transit) and stored, such as on hard drive, smartphone, or flash drive.
 - » Other uses included uses in Modems, Set Top Boxes, Smart Cards, SIM Cards etc.

1) DIGITAL SIGNATURE

- Digital signature is a mathematical technique (cryptography mechanism) that is used to validate the authenticity and integrity of a message, software, and digital document.
- It offers security features like evidence of origin, identity, and Status of an electronic document, transaction or message and can thus acknowledge informed consent by a signer (i.e. nonrepudiation).
- **How Digital Signature Works?**
 - » It uses public key cryptography such as RSA. The individual who is generating the digital signature uses their own private key to encrypt signature-related data.

- » The only way to decrypt this data is with signer's public key. This is how signer's signatures are authenticated.
- **How to create digital signature?**
 - » To create a digital signature, signing software – such as an email program – creates a one-way hash of the electronic data to be signed. The private key is then used to encrypt the hash. The encrypted hash – along with other information, such as hashing algorithm is the digital signature.



- » **Note:** Digital signature technology requires all the parties to trust that the **individual creating the signature has been able to keep their own private keys secret**.
- **Uses of Digital Signature**
 - » **Government** publishes electronic versions of various **documents** such as budget, laws, bill etc. with digital signatures.
 - » **Various legal works** like processing tax returns, filing applications, verifying business to government transactions etc. use digital signature.
 - » Industries use the digital signature to **speed up the process**, including product design, quality assurance, manufacturing enhancements etc.

2) END TO END ENCRYPTION

- **Why in news?**
 - » The recent leaking of WhatsApp chats of several Bollywood celebrities has brought back questions around WhatsApp's privacy and security
- **Introduction**
 - » End to End Encryption (E2EE) is a method of secure communication that prevents third parties from accessing data while it's transferred from one end system or device to another.
 - » In E2EE, the data is encrypted on the senders' system or device and only recipient is able to decrypt it. Nobody in between, be they an Internet Service Provider, Application Service Provider, or hacker, can read or tamper with it.
 - » The cryptographic keys used to encrypt and decrypt the message are stored exclusively on the endpoints; a trick made possible through the use of public key encryption.
- **Whatsapp Encryption (started from April 2016)**
 - » **Step-1: Key Generation:** When you install Whatsapp, the app generates a pair of cryptographic key – a public key and private key.

- » **Step-2: Key Exchange:** When you communicate with someone, your device and recipient's device exchange each other's public key. The exchange happens automatically in the background using a secure Signal Protocol.
- » **Step-3: Message Encryption:** While sending a message, your device uses recipient's public key to encrypt so that only recipient will be able to decrypt. The encryption and decryption process happen locally on the devices involved meaning that Whatsapp servers don't have plaintext of your message. Therefore, even if Whatsapp servers are compromised, your messages are secure.
- » **Feature of Perfect Forward Secrecy:** It ensures that even if some malicious actor gets access to your private key, they would be able to decrypt messages sent after the compromise, past messages are secure.
 - This is done with the help of ephemeral (temporary) session keys.
- » **Feature of verification of identity through security codes:** Whatsapp allows users to verify the identity of their contacts by comparing security codes. These codes are unique to each conversation and help ensure that the keys used for encryption are not tampered with.

3) QUANTUM CRYPTOGRAPHY/ QUANTUM KEY DISTRIBUTION

- **About Quantum Cryptography:** It is a protocol to distribute secret keys using the principles of quantum mechanics. It is a new technique that ensures the confidentiality of information transmitted between two parties, by exploiting counter intuitive behavior of elementary particles called as photons.
 - » **How Quantum Mechanics is used – Heisenberg's Uncertainty Principle**
 - » The security of the quantum key distribution is guaranteed by the laws of quantum physics.
 - Following uncertainty principle, an eavesdropper cannot know everything about a photon that carries a bit and will destroy a part of the information. Hence eavesdropping causes errors in transmission line, which can be detected by Alice (sender) and Bob (Receiver).
 - If an eavesdropper, tries to determine the key, she will be detected. The legitimate parties will then discard the key, while no confidential information has been transmitted yet. If, on the other hand, no tapping is detected, the secrecy of the distributed key is guaranteed.
 - » **Other advantage of Quantum Cryptography/Quantum Key Distribution?**
 - It can distribute long key as often as possible between Sender and Receiver
 - » Long term secrecy of confidential data transmission

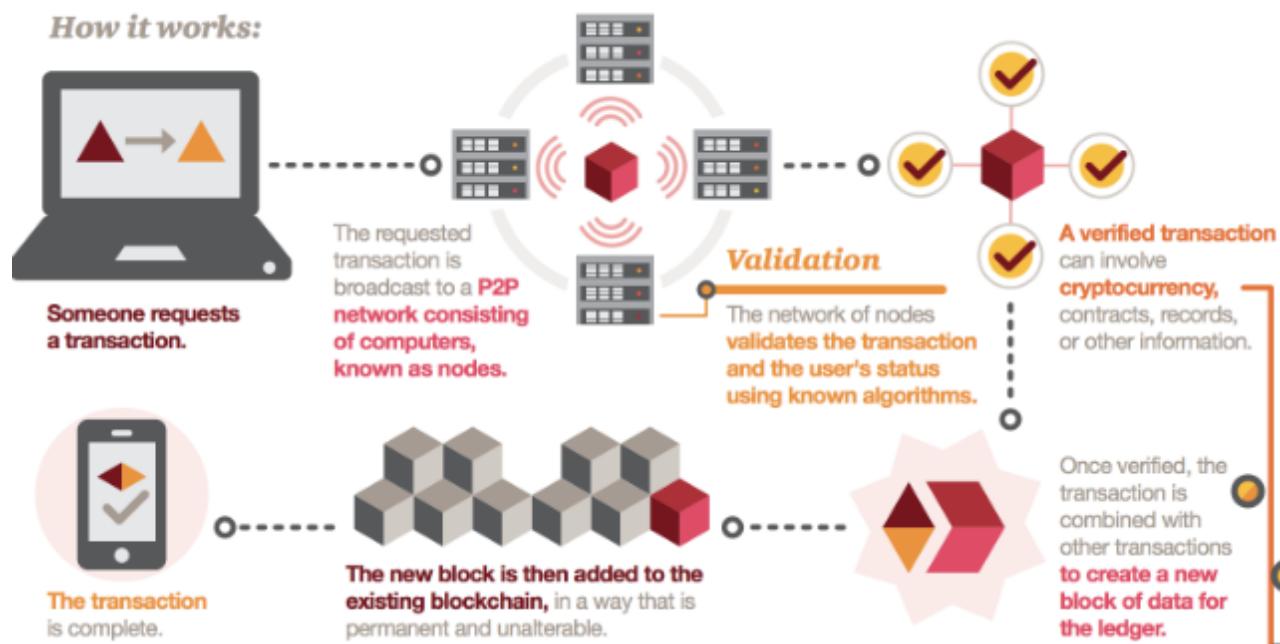
3. BLOCKCHAIN TECHNOLOGY

- **Introduction**
 - Blockchain is an incorruptible, decentralized, digital ledger of transactions that can be programmed to record not just financial transactions but virtually anything of value. Using this technology, participants can confirm transactions without the need of central certifying authority. In other words, blockchain is a distributed database that is used to maintain a continuously growing list of records/transaction, called blocks.
 - It was first used in the design and development of Bitcoin – Cryptocurrency in 2009 by **Satoshi Nakamoto**.

- It offers all parties involved in a business network a secured and synchronized record of transactions. It records every sequence of transaction from beginning to end, whether it is 100s of transaction in supply chain or a single online payment.
 - **Block:** As each transaction occurs it is put into a block.
 - **Chain:** Each block is connected to one before and after. Groups of transactions are blocked together, and a fingerprint of each block is added to the next thus creating an irreversible chain.
- **Data/Transactions** stored in the blocks are secured against tempering using cryptographic hash algorithm and are validated and verified through consensus (consensus protocol) across nodes of blockchain network.

- How blockchain transaction functions

How it works:



- Positives/Advantages

- **Security** -> Built in robustness -> no single point of failure i.e. no centralized points of vulnerability that hackers can exploit.
- **Trust** -> Increased Transparency and incorruptibility
 - Data is embedded within network as a whole, by definition it is public.
 - Altering any unit of information on the blockchain would mean using a huge amount of computing power to override the entire network.
 - In theory, this would be possible. In practice, it's unlikely to happen.
- **Permanent Ledger**
- Reduces the role of intermediary.
- Speeds up the process.
- Lowers transaction cost
- Applications in various sectors

- Applications (Current and Future Potential)

- **Economy and Finance** offers the strongest use cases for the technology.
 - **Financial transactions** are typically granted by third party and block chain could be used to automate the process, reducing overall costs, by cutting out the middleman with autonomous smart contract acting as trusted intermediaries between parties on the network.
 - **Faster, Cheaper settlements could** save billions of dollars from transaction costs while improving transparency.
 - **Stocks, mutual funds, bonds, and pensions** may one day be stored on blockchains as many financial organizations explore the technology.
- **Automotive:** Consumers could use the blockchain application to manage the fractional ownership in autonomous cars.
- **Public Ledger Information:** Many governments are looking to adopt this technology to store information about the citizens and census. A decentralized platform to safely store data regarding, birth, death crime etc. can contribute to effectively curbing fraudulent activities. Even our judiciary can benefit by using this platform to store court judgments, making our legal system more transparent and accessible to litigants.
- **Voting:** Using a blockchain code, constituents could cast votes via smartphone, tablet etc. resulting in immediately verifiable results. Voting by blockchain can eliminate election frauds by making each vote stored as a block on the block chain, rendering it impossible to tamper with.
- **Healthcare:** Patients encrypted information could be shared with multiple providers without the risk of privacy breaches.
- **Smart Contracts:** Every agreement, every process, every task, and every payment would have a digital record and signature that could be identified, validated, stored, and shared. Intermediaries like lawyers, brokers, bankers might not be necessary.
- **Secure File storage**
 - Distributing data throughout the network protects files from getting hacked or lost.
- **Identity Management:** Decentralized, used controlled digital identity holds the potential to unlock economic opportunity for refugees and others who are disadvantaged, while concurrently improving the lives of those simply trying to navigate cyberspace securely and privately.
 - There is definite need for better identity management on the web.
- **Supply chain auditing**
- **Protection of intellectual property**
 - Smart contracts can protect copyright and automate the sale of creative works online, eliminating the risk of file copying and redistribution.
 - Further, a blockchain storage can provide a consolidated platform where trademark and copyright filings can be stored. With entries that can't be tampered with and accurate time stamps, the number of disputes concerning IP may well decrease.
- **Anti-Money laundering and Know Your Customer (KYC)**
- AML and KYC practices have a strong potential for being adapted to blockchain

4. CRYPTO CURRENCY

- Cryptocurrency is a form of **digital cash** which uses **encryption technology** to make it secure. Since, this is a completely digital system, it doesn't exist in physical form.
- **Records of cryptocurrency transactions** have to be stored in a secure database. **Blockchain** serves the role of an incorruptible ledger for most of the cryptocurrencies.
- People can store their cryptocurrency in **virtual wallets** that resemble online bank accounts.

A) CRYPTO MINING

- Crypto mining refers to the process by which new units of cryptocurrency are created by solving complex mathematical problem.
- The miner who mines the cryptocurrency gets to add a new block of verified transactions to the blockchain.
- **Remember some key aspects:**
 - » **Resource intensive:** Solving mathematical problems consume a lot of processing power leading to environmental concerns.
 - » **Increasing Competition:** As coins keep getting mined, future coin becomes more difficult to mine.
 - » **Not all cryptocurrencies** may use mining.

BHUTAN TO EMERGE AS CARBON NEUTRAL HUB FOR CRYPTO MINING

- **In May 2023**, Singapore based mining company, Bitdeer (BTDR) announced a partnership with Bhutan to build a \$500 million closed end fund which will be used to build mining facilities powered entirely by carbon-free hydropower.
- The first phase of the project – Gedu data centre, with a total aggregate electrical capacity of 100 MW, has been operational since Aug 2023.

1) BITCOINS

- **Bitcoin** is the first cryptocurrency created and held electronically. It is a decentralized system (No one controls it). Bitcoins aren't printed, like Rupees or dollars - they are produced by people, and increasingly businesses, running computers all around the world, using software that solve mathematical problems.
- **Who created bitcoins -> Satoshi Nakamoto?**
- **Limited number bitcoins**
 - » The bitcoin protocol - the rules that make bitcoin work - say that only 21 million bitcoins can ever be created by miners. However, these coins can be divided into smaller parts (the smallest divisible amount is one hundred millionth of a bitcoin and is called a 'Satoshi', after the founder of bitcoin).
- **What is bitcoin based on?**
 - Bitcoin is based on **mathematics**. Around the world, people are using software programs that follow a mathematical formula to produce bitcoins. The mathematical formula is freely available, so that anyone can check it.
- **Advantages/Positive Characteristics of Crypto Currencies**
 - **Decentralized:** No central control and hence flexibility to use.
 - **Easy, Fast Set up:**
 - » Conventional banks -> complicated process to open bank account, merchant account for payment more complicated
 - » Bitcoin address can be set up in seconds, no questions asked, and with no fees payable.
 - **Protects Privacy/Anonymous**
 - » Users can hold multiple bitcoin addresses, and they are not linked to names, addresses, or other personally identifying information.

- **Completely Transparent**
 - » Bitcoin stores details of every single transaction that ever happened in the network in a huge version of a general ledger, called the **blockchain**. The blockchain tells all.
 - » If you have a publicly used bitcoin address, anyone can tell how many bitcoins are stored at that address. They just don't know that it's yours.
- **Transaction fee is minuscule and transaction is fast** (almost real time, even cross border)
- **It's non-repudiable.**
 - » When your bitcoins are sent, there's no getting them back, unless the recipient returns them to you. They're gone forever.

▫ Limitations/Disadvantages of Cryptocurrencies

- **Acceptance is limited** -> banned in countries like China and India
- **Loss of wallet -> no recovery option**
 - » If hard drive crashes, or wallet corrupts data. This can bankrupt a wealthy Bitcoin investor within seconds with no form of recovery
- **Volatile** -> no valuation guarantee
- **No grievance redressal/ No Buyer protection** in case of online purchase
 - » If seller doesn't send the bought goods, nothing can be done -> there is no provision of refund/reverse transaction
- Risk of **unknown technical flaws**
- **Built in deflation (in bitcoin)**
- **No physical form** -> Cannot be used in physical stores
- **Extremely high processing power/energy requirement** -> Environmentally unsustainable. According to a study by University of Cambridge, Bitcoin currently uses more energy than Argentina every year.
- Can be used for **criminal activities**
 - » Lack of centralized control allows its use for criminal activities such as by ransomware attackers.
- This may also be used by money launderers to launder black money.

2) LIBRA (DIEM) (PROJECT ABANDONED IN JAN 2022)

3) MOST FAMOUS CRYPTOCURRENCIES

- Bitcoin (BTC)
- Ethereum (ETH)
- Tether USDT (USDT)
- BNB (BNB)
- Solana (SOL)

4) CRYPTOCURRENCY AND INDIA

- In **April 2018**, RBI prohibited banks from providing services to firms and individuals who deal in bitcoin and other such virtual currencies. But, in **March 2020**, the **Supreme Court had set aside the RBI Ban on cryptocurrency transactions** by setting aside the April 2018 circular of the RBI prohibiting banks and entities regulated by it from providing services in relation to virtual currencies (VCs). The Court found the RBI circular "disproportionate" with an otherwise consistent stand taken by the Central Bank that VCs are not prohibited in the country. Further, the court held that the RBI didn't consider the availability of alternatives before issuing a circular.
- In 2019 **Inter-Ministerial Committee** (IMC) chaired by **Subhash Chandra Garg** that was setup to assess the viability of virtual currencies in India had also recommended that India should **ban private crypto currencies such as Bitcoin**. Through a **draft bill** they recommend a maximum of 10-year punishment for those who mine, trade, buy or sell cryptocurrencies.
 - » What is **IMC's view on Distributed Ledger Technologies (DLT)** and Cryptocurrencies?
 - i. IMC recognizes the potential of DLT and Blockchain.
 - ii. Therefore, it recommends the Department of Economic Affairs to take necessary measures to facilitate the use of DLT in the entire financial fields after identifying its uses.
 - iii. The IMC also **recommends that regulators – RBI, SEBI, IRDA, PFRDA, and IBBI – explore evolving appropriate regulations for development of DLT** in their respective areas.
 - » However, IMC has recommended a **ban on “private” cryptocurrencies**. It recommended the **introduction of a single cryptocurrency** for the whole country that is backed by Reserve Bank of India.
 - » **Why?**
 - i. Non-official virtual currencies can be used to defraud consumers, particularly unsophisticated consumers or investors.
 - ii. Further such currencies often experience tremendous volatility in their values.
 - iii. The scaling up of private blockchain based currencies require **crippling level of energy resources**. According to a report by Bank of International Settlement, Bitcoin processing already consumes as much energy as is used by Switzerland; it called this an environmental disaster.
 - iv. If the private cryptocurrencies are allowed to continue, **RBI would lose control over the monetary policy and financial stability**, as it would not be able to keep a tab on the money supply in economy.
 - v. Further, the anonymity of private digital currencies makes them **vulnerable to money laundering** and **use in terror financing activities** while making law enforcement difficult.
 - vi. Finally, there is **no grievance redressal mechanism** in such system, as all transactions are irreversible.

A) THE CRYPTOCURRENCY AND REGULATION OF OFFICIAL DIGITAL CURRENCY BILL, 2021

- **Yet to be officially approved by the Union Cabinet**
- It seeks to create a facilitative framework for creation of the official digital currency (to be issued by RBI)
- **Note:** RBI is looking at launching a pilot project for an official digital currency soon.
- It also seeks to prohibit all private cryptocurrencies in India. However, it allows for certain exceptions to promote the underlying technology of cryptocurrencies and its uses.

B) BUDGET 2022-23

- Virtual Digital Assets (VDAs) will be taxed at 30% (on the gain on the sale of such assets). Benefits of basic exemption limit is also not applicable. No deduction in respect of any expenditure other than cost of acquisition shall be allowed. Also, TDS of 1% shall be deducted on the transaction value from 1st July Subject to certain conditions.
- They mainly include Crypto currencies, NFTs etc. Prima facie, this excludes digital gold, central bank digital currency, or other traditional digital assets and hence aimed at specifically taxing cryptocurrencies.

5. NFT

6. WEB 3.0

- **Background: Understanding Web 1.0 and Web 2.0**
 - Web 1.0 is the world wide web or the internet that was invented in 1989. It became popular in 1993. The internet in the Web 1.0 was mostly static web pages. Here most of the users visited websites and read and interacted with the static material available there. It was a closed environment and users themselves couldn't create post content and reviews.
 - **Web 2.0** started in some form by late 1990s. By 2004, most of the features of web 2.0 was available for implementation. Here websites were more dynamic where users could create content, post comment, write reviews etc. They could also upload photos and videos. Primarily, a social media kind of interaction is the differentiating trait of Web 2.0.
- **Concerns of Web 2.0:**
 - Most of the data on internet is owned and controlled by a few behemoth companies. It has created issues related to data privacy, data security and abuse of such data. It has kind of disappointed experts that the original purpose of internet has been distorted.
- Web3 or Web 3.0 is a term used to describe the next phase of the internet.
 - It runs on the decentralized technology of blockchain and would be different from web 1.0 and web 2.0. Here, users have ownership stakes in platforms (unlike now where tech behemoths control everything). Here users will control their own data.
 - Thus, the need of intermediaries (like Amazon, Facebook, etc.) is removed. This will end data monopoly.
 - The **key concepts in Web3** seen so far are peer to peer transactions and block chain.
- The spirit of Web3 is **Decentralized Autonomous Organization (DAO)** which is that all business rules and governing rules in any transaction are transparently available for anyone to see and the software will be written conforming to these rules.
 - **Crypto-Currency and Blockchain** follow the DAO principle. With DAO, there is no need for a central authority to authenticate or validate.
- **Summarizing significance of web3.0:**
 - Prevents monopoly over data.
 - Promotes data privacy.

- Increase competition in fields like search engine businesses as control over content now restricted to just a few companies would end.
- New technology will give India an opportunity to innovate and develop.

- Future of Web 3.0: Will it take off?

- Tech honchos like Elon Musk and Jack Dorsey don't see a future for Web3.
- There are technological changes required: For e.g., it will require deviation from the current architecture where there is a front-end, middle layer and back-end. Web3's architecture will need backend solutions for handling block chain, persisting and indexing data in block chain, peer to peer communications and so forth. Similarly, middle layer would also need to change to handle block-chain based backend.

7. AUGMENTED REALITY/ VIRTUAL REALITY

A) AUGMENTED REALITY

- AR is the integration of digital information with the user's environment in real time. AR is a technology that layers computer generated enhancements atop an existing reality to make it more meaningful through the ability to interact with it.
 - AR is developed into apps and used on mobile devices to blend digital component in real world in such a way that they enhance each other but can also be told apart easily.
- **Boeing researcher Thomas Caudell coined the term in 1990.**
- **Current application of Augmented reality**
 - Google glass, heads-up displays in car windshields are perhaps the most-well known consumer AR products.
 - It is used in many industries including health care, public safety, gas and oil, tourism and marketing.

▪ VIRTUAL REALITY

- VR is an artificial, computer-generated simulation or recreation of a real-life environment or situation.
 - It immerses the user by making them feel like they are experiencing the simulated reality firsthand, primarily by simulating their vision and hearing.
- VR is typically achieved by wearing a headset like the Facebook's Oculus equipped with the technology and is used prominently in two different ways.
 - To create and enhance an imaginary reality for gaming, entertainment, and play.
 - To enhance training for real life environments by creating a simulation of reality where people can practice beforehand (such as flight simulators for pilots)

8. METAVERSE

- **Definition:**
 - » Metaverse is a digital place inhabited by the digital representations of people (Avatars) and things. It is a new vision of internet.
 - <https://youtu.be/Qw6UCwCt4bE>
 - » Metaverse is a network of 3D virtual worlds focused on social connections.
 - » It is often described as iteration of internet as a single, universal virtual world that is facilitated by the use of virtual and augmented reality.

- » Metaverse has its origin in the 1992 science fiction novel “Snow Crash” as a combination for “meta” and “Universe”. In this he envisioned lifelike avatars who met in realistic 3D buildings and other virtual reality environments.
 - » Some of the platforms already developed can be considered metaverse (e.g., “**second life**”).
- **E.g., applications of Metaverse:**
- » Meta envisions a virtual world where digital avatars connect through work, travel or entertainment using VR headsets. For e.g., it may include fake houses where you can invite all your friends to hang out in.
 - <https://youtu.be/Uvufun6xer8?t=237>
 - » Microsoft envisages that it could involve virtual meeting rooms to train new hires or chat with your remote coworkers.
 - » **Entertainment:** Attend a Concert virtually
 - <https://www.youtube.com/watch?v=Uvufun6xer8&t=775s>
- **Key Challenges:**
- » **VR headsets** are still very clunky, and most people experience motion sickness or physical pain if it is worn for too long.
 - » **Many Technological challenges** – For e.g., if the person would be wearing headsets, how the facial expressions would be scanned and made available in real time.
 - » **Lack of Common Standards:** Various big tech players are building their own versions of an extended virtual reality.
 - » **Cyber Security:** For e.g., by not limiting the number of avatars, Metaverse would allow users to create online representations of others without their consent or verification. While celebrities may be protected by various impersonation mechanisms. Common people would be more vulnerable.
 - Users are going to require regulatory support which integrates governments, industries, and other users.
- **What is being done and what is the way ahead?**
- » Mark Zuckerberg, the CEO of the newly named Meta (formerly Facebook), estimates it could take 5 to 10 years before key features of the metaverse become mainstream. But various components of metaverse already exist – Ultrafast broadband speed, virtual reality headsets and persistent always-on online worlds are already up and running.
 - » Open-Source Platforms like Web3D Consortium, World Wide Web Consortium, XR Association, and several other industry players have come together as the Metaverse Standards forum to build interoperability into the metaverse.
 - » It is important that the work on regulating metaverse starts parallelly. Here civil society, tech companies and government will need to work together to evolve appropriate rules and cybersecurity framework.

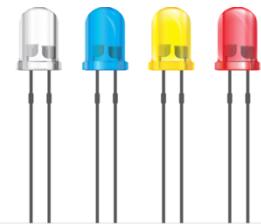
9. ELECTRONICS – BASICS

- 1) Semiconductors:** These are materials which have a conductivity between conductors (generally metals) and nonconductors or insulators (such as most ceramics).

- » They can be pure elements like silicon or germanium, or compounds such as gallium arsenide or cadmium selenide.
 - » In a process called **doping** small number of impurities are added to pure semiconductors causing large changes in the conductivity of the materials.
 - » They are crucial in the development of electronic devices and there would be no radio, TV, Computers etc. without semiconductors.
 - » An important property of semiconductors is that it has very high resistivity at 0K and its resistivity falls as the temperature goes up unlike metals which have high conductivity at 0K and whose resistivity increase as the temperature increase.
 - » Semiconductor devices also display other **useful properties** such as passing current more easily in one direction than the other, showing variable resistance and sensitivity to light or heat.
 - » Because **electrical properties** of a semiconductor can be modified by doping, or by the application of electric fields or light, devices made by semiconductors can be used for amplification, switching, and energy conversion.
- 2) **Diode:** It is defined as a **two-terminal electronic component** that only **conducts current in one direction**. An ideal diode will have **zero resistance** (negligible) in one direction, and **infinite resistance** (very large) in the reverse direction. It is effective like a valve for electric current.
- A **PN junction** is the simplest form of a semiconductor diode. In ideal conditions, this PN junction behaves like a **short circuit** when it is forward biased (current flowing in forward direction), and as an **open circuit** when it is in the reverse biased (current flowing in reverse direction).
- 3) **Transistor:** It is a semiconductor device used to **amplify or switch electronic signals and electric powers**. It is one of the basic building blocks of modern electronics. It is composed of semiconductor material usually with at least three terminals of connection to an external circuit.
- 4) **Amplifier:** It is an electronic device that can increase the power of a signal (a time varying voltage or current). It is a **two-part electronic circuit** that uses electric power from a power supply to increase the amplitude of a signal applied to its input terminals, producing a producing a proportionately greater amplitude signal at its output.

10. OPTOELECTRONICS

- Optoelectronics is a special discipline of electronics that focuses on light emitting or light detecting electronic devices.
- Light emitting devices **use voltage and current to produce electromagnetic radiation (i.e. light)**. These are commonly used for illumination or indication purposes.
 - » E.g. LEDs
- **Light Detecting Devices**, such as photo transistors, **convert received electromagnetic energy into electric current or voltage**. (e.g. photo resistors, solar cells etc.)
- **Light Bulbs** such as **incandescent lights**, are devices that convert electric current into visible lights. **Tungsten wire** has high resistivity and it converts light into heat which results into visible light (photons) to be emitted.



- **Halogen lamps** use a filament that resides inside a gas-pressurized bulb. The pressurized gas consists of an inert gas and a small amount of halogen element such as bromine or iodine. The combination of a halogen gas (small amount of iodine or bromine in inert gas) and tungsten filament produces a **halogen cycle** chemical reaction which **redeposits evaporated tungsten to the filament**, increasing its life and maintaining clarity of the envelope. This allows filament to operate at a higher temperature than a standard incandescent lamp of similar power and operative life;
- **Fluorescent bulbs** are very different. They consist of **mercury vapor filled glass tube** whose **inner wall** is coated with a material that fluoresces. When electrons which are emitted from the fluorescent bulb's inner cathode electrode, collide with the mercury atoms, UV radiation is emitted. This **UV radiation is absorbed by the lamp's fluorescent coating, which in turn releases a visible light.**
- **LEDs:** Discussed in detail below.
- **Laser diode** is a **semiconductor laser device** that is very **similar in both form and operation**, to a light emitting diode (LED). The laser diode is electrically equivalent to a **PIN diode**. A Pin diode is a diode with a wide undoped intrinsic semiconductor region sandwiched between a p-type semiconductor and an n-type semiconductor.
- **Photo Resistors** are light controlled variable resistors, also known as light dependent resistors (LDRs). **Generally**, when a photo-resistor is placed in dark, it has high resistance and when it is illuminated the resistance drops dramatically. They are used in **light sensitive switching devices**.
- **Photo diodes** are semiconductor devices that **convert light energy (i.e. photons) directly into electric current**.
- **Solar Cells** are photodiodes with exceptionally large surface areas.

11. LIGHT EMITTING DIODES

- **Introduction**
 - » A light emitting **diode** is a **semiconductor devise** that **emits visible light when an electric current passes through it.**
 - » The light is **not particularly bright** but, in most LEDs, **it is monochromatic, occurring at a single wavelength.**
 - » The **output from an LED can range from red** (at a wavelength of approximately 700 nanometers) to a blue violet (about 400 nanometers).
 - » Some LEDs emit infrared (IR) energy (830 nanometers or longer); such devices are known as **infrared-emitting diodes (IRED).**
- **Technical Details**
 - » An LED or IRED **consists of two elements of processed material** called the **P-type semiconductors and N-type semiconductors.** These two elements are **placed in direct contact**, forming a region called **P-N junction.** In this respect, the LED and IRED **resemble most other diode types** but there are important

differences. The LED and IRED had transparent package, allowing visible or IR energy to pass through. Also, the LED and IRED has a large PN-junction area whose shape is tailored to the application.

- » **Electrons in the semiconductor** recombine with electron holes, releasing energy in the form of photons.
- **Benefits of LED and IRED**, compared to incandescent and fluorescent illuminating devices, include:
 - » **Low Power Requirement**: Most can be operated with battery power supplies.
 - » **High Efficiency**: Most of the power supplied to an LED or IRED is converted into radiation in the desired form, with minimal heat production.
 - » **Long life**: when properly installed, an LED or IRED can function for decades
- **Other associated benefits**
 - » Climate change
 - » Power deficiency help
 - » Mercury pollution protection (CFLs)
- **Typical Applications include**
 - » **Indicator lights**: These can be two-state (i.e., on/off), bar graph, or alphabetical-numeric readouts.
 - » **LCD panel backlighting**: Specialized white LEDs are used in flat panel computer display
 - » **Fiber Optic Data Transmission**: Ease of modulation allows wide communications bandwidth with minimal noise, resulting in high speed and accuracy
 - » **Remote Control**: Most home entertainment "remotes" use **IREDs** to transmit data to the transmitter.
 - » **Optoisolator**: It is a semiconductor device that uses a short optical transmission path to transfer an electrical signal between circuits or elements of a circuit, while keeping them electrically isolated from each other.
 - » **Lighting**: LED bulbs
 - [Unnat Jyoti for Affordable LED \(UJALA Scheme\)](#)

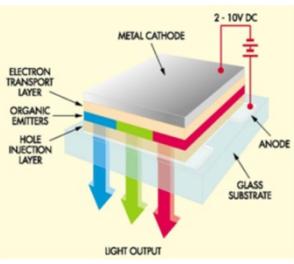
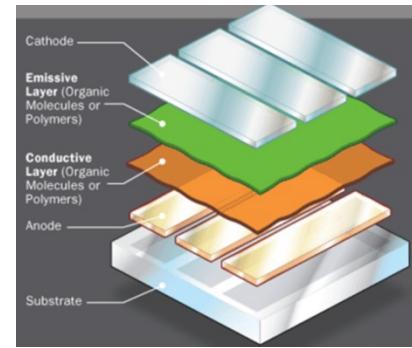
12. ORGANIC LEDs

- **OLEDs** are solid-state semiconductor devices composed of thin films of organic molecules that create light with the application of electricity. They are 100 to 500 nm thick or about 200 times smaller than human hair.
- **Advantages**: OLEDs can provide brighter, crisper displays on electronic devices and use less power than conventional LEDs and LCDs (liquid Crystal displays).
- **How OLEDs work?**

OLEDs have two layers or three layers of organic material. It consists of **following parts**:

 - **Substrate** (clear plastic, glass, foil): The substrate supports the OLED.
 - **Anode** (Positive Terminal) (transparent) – the anode removes electrons (adds electrons “holes”) when a current flows through the device.
 - **Organic Layers**: These layers are made of organic molecules or polymers:

- a) **Conducting Layers:** This layer is made up of organic plastic molecules that transport "holes" from the anode. One conducting polymer used in OLEDs is **Polyaniline**.



OLED Structure

- b) **Emissive Layers:** The layer is made up of organic plastic molecules (different ones from the conducting layer) that transport electrons from the cathode; this is where light is made. One polymer using in the emissive layer is **Polyfluorene**.
- c) **Cathode (negative terminal):** (may or may not be transparent depending upon the type of OLED) – The cathode injects the electron when a current flows through the device.

How OLEDs emit light?

Attach a voltage across cathode and anode.	
As the electricity starts to flow, the cathode receives electrons from the power source and the anode loses them (or it receives holes)	
Added electron is making the emissive layer negatively charged (similar to n-type layer in a junction diode), while the conductive layer is becoming positively charged (similar to p-type material)	
Positive holes are much more mobile than negative electrons, so they jump across the boundary from the conductive layer to emissive layer. When a hole (lack of electron) meets an electron, the two things cancel out and releases a brief burst of energy in the form of a particle of light – a photon.	

- The color of light depends on the type of organic molecule in the emissive layer. Manufacturers place several types of organic films on the same OLED to make colored display.

- **The intensity or brightness** of the light depends on the amount of electrical current applied: the more current, the brighter the light.
- Unlike LEDs, which are small-point light source, **OLEDs are made in sheets that are diffuse-area**. OLED technology is developing rapidly and there are handful of products offering with efficacy, lifetime, or color quality specs that are comparable to LEDs.

Types of OLEDs: They are several types of OLEDs:

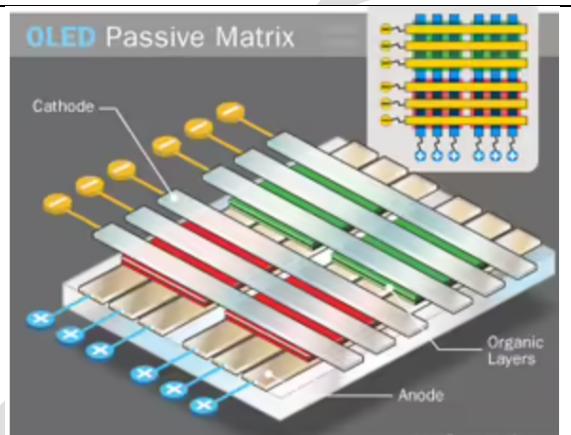
Passive-Matrix OLEDs (PMOLED): It consists of strips of cathode, organic layers, and strips of anodes. The anode strips are arranged perpendicular to the cathode strips. The intersection of the cathode and anode make up the pixels where light is emitted. External circuit applies current to selected strips of anode and cathode, determining which pixels get turned on and which pixels remain off. Brightness of each pixel is proportional to the amount of applied current.

Advantages: Easy to make

Limitations: Consumes more powers than other types of OLED, mainly due to power needed for external circuit.

Application: Suitable for text and icons and thus are best suited for screens (2 to 3 inch) such as those used in cell phones, PDAs, and MP3 players.

Note: Even with external circuitry, passive matrix OLEDs consume less battery power than the LCDs that currently power these devices.

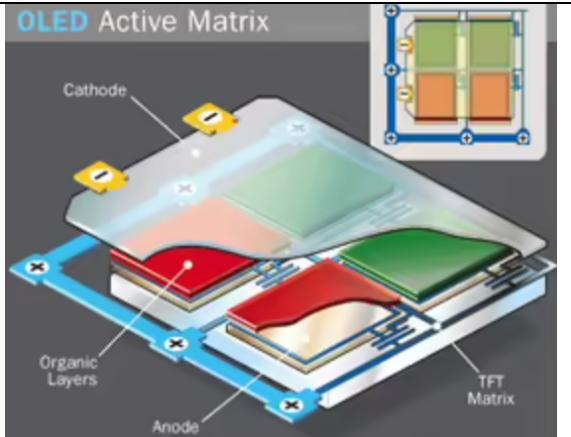


AMOLED (Active-matrix OLED): They have full layers of cathode, organic molecules and anode, but the anode layers overlay a thin film transistor (TFT) array that forms a matrix. The TFT array itself is a circuitry that determines which pixels get turned on to form an image.

Advantages:

- Consumes less power than PMOLEDs because TFT array requires less power than external circuitry, so they are efficient for large displays.
- They also have faster refresh rates suitable for videos.

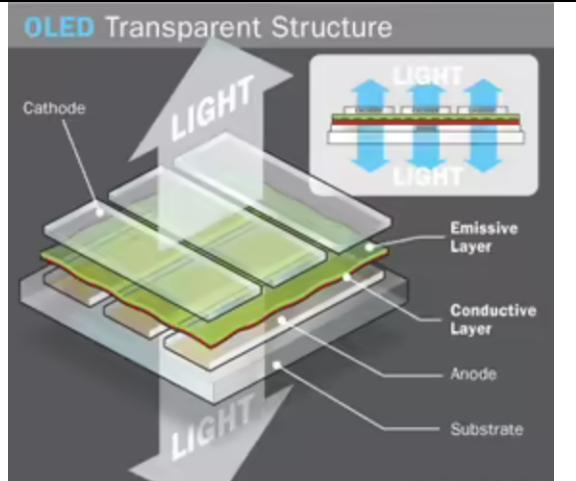
Applications: Computer Monitor, large-screen TVs and electronic signs or billboards.



Transparent OLEDs: They have only transparent components (substrate, cathode, anode) and, when turned off, are upto 85% as transparent as their substrate.

When a transparent OLED display is turned on, it allows light to pass in both directions.

It can be PMOLED or AMOLED. This technology may be used for heads-up displays.



Top Emitting OLEDs: They have substrate that is either opaque or reflective.

They are best suited to active-matrix design. Manufacturers may use top-emitting OLED displays in smart cards.

Foldable OLEDs: They have substrate made of very flexible metallic foils or plastics. They are lightweight and durable. Their use in devices such as cell phone and PDAs can reduce breakage, a major cause of phone repairs. They can also be used for making smart clothing.

White OLEDs: they emit light that is brighter, more uniform and more energy efficient than that emitted by fluorescent lights. They also have the true color quality of incandescent lighting. Because OLEDs can be made in large sheets, they can replace fluorescent lights that are currently used in homes and buildings.

Their use can reduce the energy cost of lighting.

Advantages of OLEDs:

- » OLEDs can be configured as large-area, more diffuse light sources whose soft light can be viewed directly. This eliminates the need of shades, diffusers, lenses, or parabolic shells.
 - This diffused light allows them to be used very close to the task surface without creating glare for the user.
- » OLEDs can be made very thin, increasing their eye appeal and allowing for easy attachment to the surface of walls and ceilings.
- » The Plastic, organic layers of an OLED are thinner, lighter, and more flexible than the crystalline layers in LED or LCD.
- » OLEDs are brighter than LEDs.
- » Because the organic layers of an OLED are much thinner than the corresponding inorganic crystal layer of an LED, the conductive and emissive layer of an OLED can be multilayered. Further, it doesn't require glass for support (which is needed by LED)

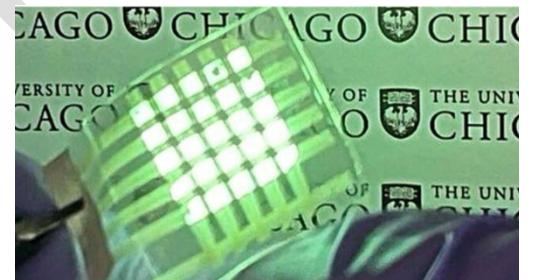
- » **OLEDs** are much more energy efficient.
- » OLEDs don't require backlighting like LCDs. LCDs work selectively blocking areas of backlighting to make the images that you see, while OLEDs generate light themselves. Because OLEDs don't require backlighting, they consume much less power than LCDs (most of the LCD power goes to the backlighting). This is specially important for battery-operated devices such as cell phones.
- » **OLEDs** are easier to produce and can be larger in size. Because OLEDs are essentially plastic, they can be made into large, thin sheets.
- » OLEDs have larger field view, about 170 degrees. Because LCDs work by blocking light, they have an inherent viewing obstacle from certain angles.
- » **OLEDs** can be made up of almost any shape and can be deposited on flexible substrates.

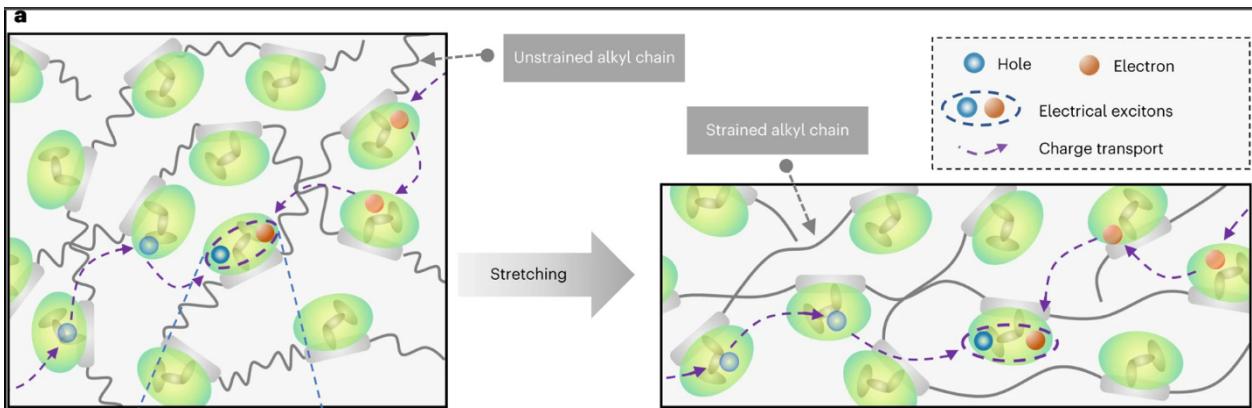
Limitations of OLEDs:

- » **Lifetime:** Blue organics currently have much shorter lifetime.
- » **Expensive manufacturing**
- » **Water can easily damage OLEDs.**

13. FLEXIBLE OLEDS

- **Why in news?**
 - Researchers have developed a stretchable OLED display technology that could power wearable electronics and other flexible form factors devices in future (April 2023)
- **Details**
 - Researchers at the University of Chicago have developed an OLED material that is so flexible that it can be bent in half or stretched to more than twice its original length while still emitting light.
 - It represents a new technology that could possibly be used to develop stretchable fabric-like displays in the future. It could be used in flexible displays for a variety of applications, including wearable electronics, health sensors, and even foldable devices, according to the University of Chicago.
- **Need:** The material that are currently used in OLED displays are very brittle and are not very stretchable. With this in mind, the researchers set out to create a material than maintained the light-emitting properties of OLED but was also stretchable.
- **Design Strategy:** Design strategy of inserting flexible, linear units into polymer backbones can greatly increase stretchability without affecting light-emitting performance.





14. LASER (LIGHT AMPLIFICATION BY SIMULATED EMISSION OF RADIATION)

- Introduction

- A laser is a device that generates an intense beam of coherent monochromatic light (or other electromagnetic radiation) by stimulating of photons from excited atoms or molecules.

▫ How does laser differ from normal light?

- **Monochromatic:** Same Wavelength/frequency (whereas normal light contains multiple wavelength)
 - This wavelength is determined by the amount of energy released when the excited electrons drop to a lower orbit.
- **Coherent** (ordinary light is not coherent): It means that all light waves are in phase with one another.
- **Very narrow, highly directional and doesn't diverge:**
- The laser beam is **extremely intense**.

- Uses: Lasers are used in

- Precision tools to cut through diamonds or thick metal.
- Laser surgery
- Skin treatment
- Optical disk drive
- Laser printers
- Barcode scanners
- Fiber optics
- Free space optical communication
- Drilling, cutting and welding materials
- Military and law enforcement devices
- Laser light display in entertainment
- Remote sensing

Lasers in India

India currently has two lasers that produce 100 Terawatt (10^{12}) beams.

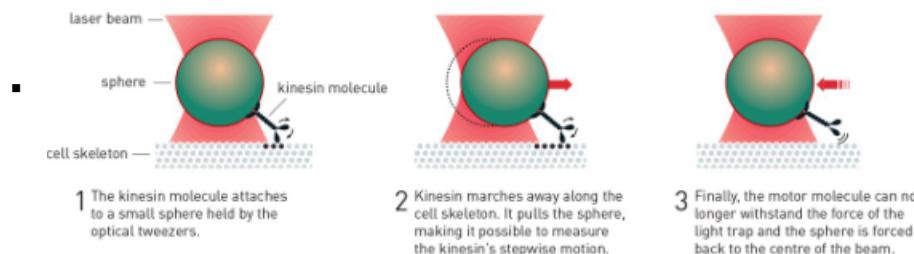
The Raja Ramanna Centre for Advanced Technology in Indore is in the process of installing two petawatt systems, while another is likely to be installed in Hyderabad.

- Nobel Prize in Physics, 2018 for LASER Physics Work

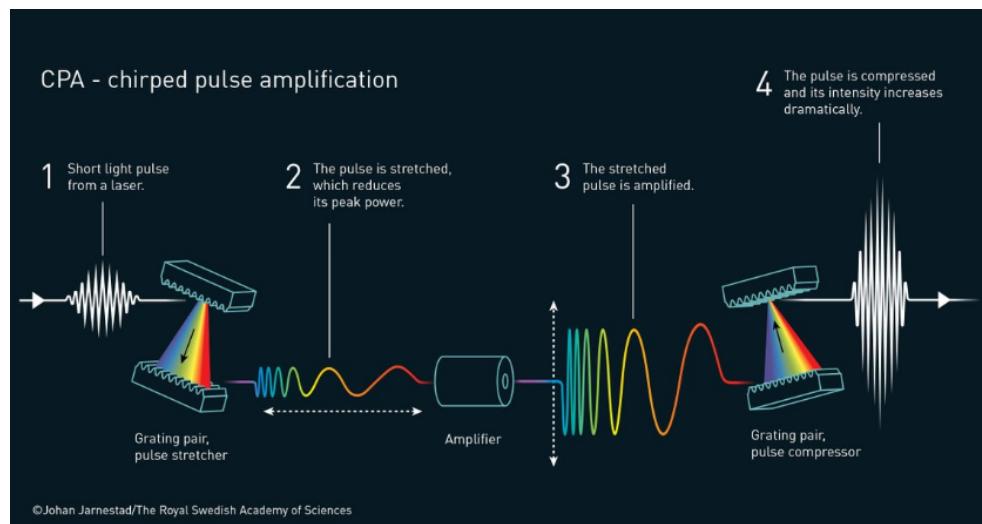
- Arthur Ashkin received the prize for the **optical tweezers** and their applications to biological system

- These optical tweezers are able to grab particles, atoms, viruses, and other living cells with **laser beam fingers**.

A motor molecule walks inside the light trap



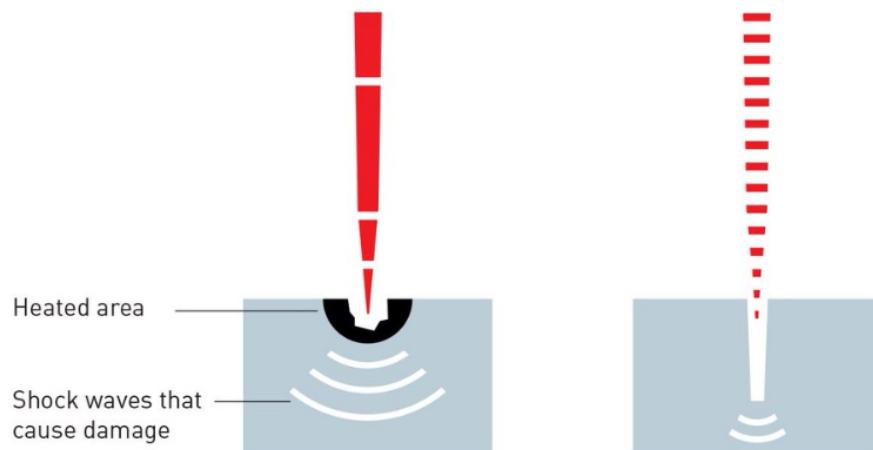
- These optical tweezers are widely used for isolating and examining very small particles, such as individual atoms, DNA strands, or biological cells.
- This helped scientists understand the behavior of single atom or cells, instead of studying the average behavior of an aggregation of such particles.
- The tweezers can capture living bacteria without harming them, a breakthrough achieved back in 1987.
- **Note:** Arthur Ashkin, at the age of 96, has become the oldest scientist ever to be awarded a Nobel Prize.
- **Gerard Mourou and Donna Strickland** were jointly awarded for their method of **generating high-intensity, ultra-short optical pulses**.
 - They created ultrashort high-intensity laser pulses without destroying the amplifying material, thus paving the way towards the shortest and most intense laser pulses ever created by mankind.
 - **Note: Donna Strickland** is only the third women to receive nobel prize in physics. Before her, **Marie Curie** had won it in 1903 and **Maria Goeppert-Mayer** in 1963.
 - **What was the problem earlier?**
 - Within a few years of the invention of laser, laboratory tabletop lasers had started achieving very high power of about a gigawatt. But after this state of peak power was reached, more intense pulses of power could not be produced without damaging the amplifying material.
 - **How the problem was solved?**
 - The two scientists increased the duration of the pulses before the light was amplified so that the intensity comes down.
 - The light could then be amplified normally.
 - This amplified pulse could then be compressed back to its original time duration, and thus increasing its intensity by several orders of magnitude.
 - Their innovative technique, known as '**chirped pulse amplification**' (CPA), has now become standard for high intensity lasers, including the ultra-sharp beam used in corrective eye surgeries. It allows to cut and drill very precisely in various matter.



- **How shorter high intensity laser pulse can be beneficial?**

Nanosecond laser

Femtosecond laser



- With ultrashort and intense laser pulses, we can see events that previously seemed instantaneous. Laser pulses shorter than 100 attoseconds reveal dramatic world of electrons.
- It has also made it possible to cut and drill holes in material and living matter incredibly precisely.
- This has allowed corrective eye operations for millions of users.

A) LIDAR

- It stands for Light Detection and Ranging. It is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distance) to the Earth.
- These light pulses - combined with other data recorded by the airborne system - generate precise, three-dimensional information about the shape of the earth and its surface characteristics.
- LiDAR instrument principally consists of a laser, a scanner, and a specialized GPS receiver.
- **Two types of LIDAR** are **topographic** and **bathymetric**.
 - Topographic LIDAR** typically uses a near-infrared laser to map the land, while
 - Bathymetric Lidar** uses water-penetrating green light to also measure seafloor and riverbed elevations.
- **Applications**
 - Used in projects related to roads, canals, surface transport, city planning, landslides, irrigation etc.

- The system can be brought to use for engineering designs, conservative planning, floodplain mapping, surface feature extraction (trees, shrubs, roads and building) and vegetation mapping (height and density).

15. WIRELESS CHARGING

- Inductive charging (also known as wireless charging) uses an electromagnetic field to transfer energy between two objects through electromagnetic induction.
- The **induction of an electromotive force (voltage)** by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field is called '**Electromagnetic Induction**'.

- **Understanding Law of Induction in 1830:**

- **Michael Faraday** discovered **Law of Induction** in 1830.

- **First Law:** Whenever a conductor is placed in a varying magnetic field, EMF induces and this emf is called an induced emf and if the conductor is closed circuit than the induced current flows through it.

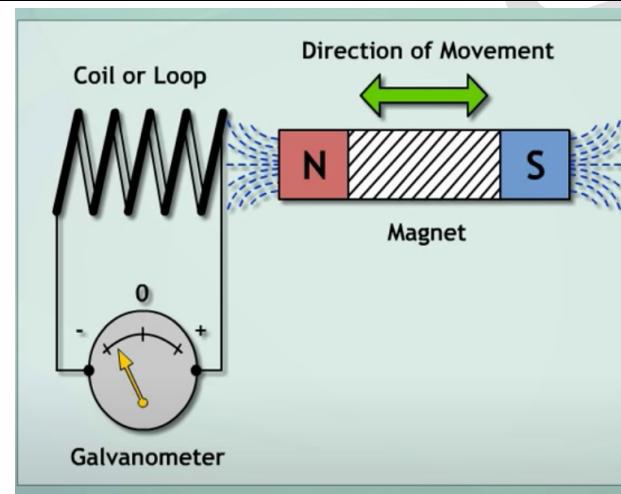
- **Second Law:** The **magnitude of EMF** id equal to the rate of change of flux linkages.

- The machines like generators, transformers, motors etc. work on the principle of electromagnetic induction.

- Similarly, while magnets can create magnetic fields, electric fields can also create magnetic fields.

- In fact, every time you change a magnetic field, you create an electric field. This is called Faraday's Law of Induction.

- Similarly, every time you change an electric field, you create a magnetic field. This is called the Maxwell-Ampere Law

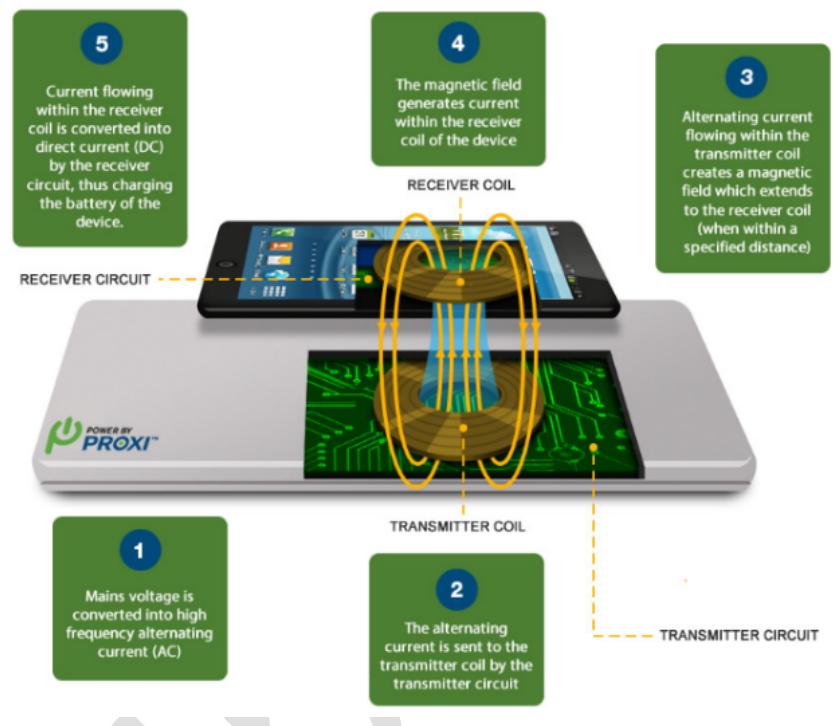


- **This is what happens in wireless charging.** Energy is sent through inductive coupling to an electrical device, which can then use the energy to charge batteries or run the device.
-
- **Advantages of inductive charging/wireless charging?**
 - **Protected Connection** -> No Corrosion, less risk of electric faults, short circuits etc.
 - **Low infection risk**
 - **Durability**

- Increased convenience and aesthetic quality

- Limitations
 - Less efficient
 - Slower Charging
 - More Expensive
 - Inconvenient

- Multiple Standards
 - Magne Charge, Qi etc are multiple standards being used in the market. This confuses the user and same charger cannot be used for all the devices.



16. FREE SPACE OPTICAL COMMUNICATION

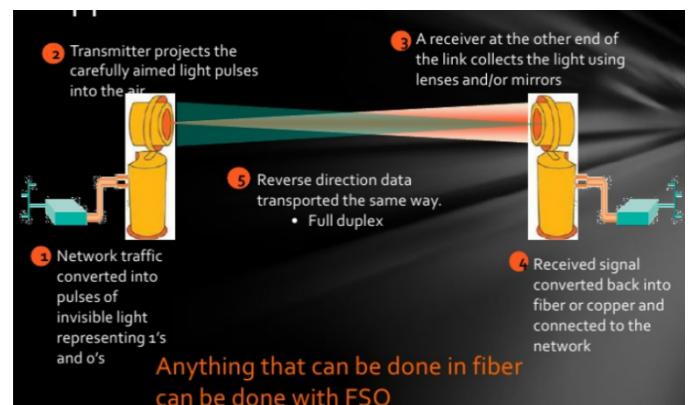
- Introduction

- It is a communication technology which uses light propagating in free space to wirelessly transmit data for telecommunications or computer networking.
- Most of the time laser beams are used, although non-lasing sources such as Light emitting diodes (LED) or IR-emitting diodes (IREDs) will serve the purpose too.
- “Free space” could mean air, outer space, vacuum etc.

- How does FSO work?

- The basic principle is similar to fiber optics transmission other than the fact that here the energy beam is collimated and sent through clear air or space, rather than guided through optical fiber.
- At the source, the visible or IR energy is modulated with the data to be transmitted. At the destination, the beam is intercepted by a photodetector, and data is extracted from the visible or IR beam (demodulated).
- Optical transceiver on both ends ensure bidirectional (duplex) capabilities.

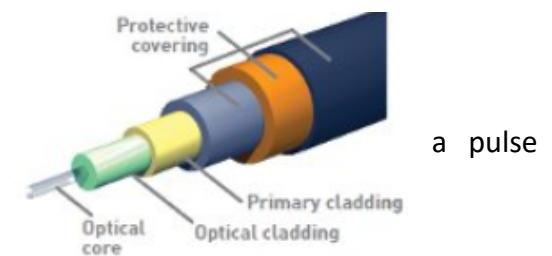
- Line of Sight Requirements



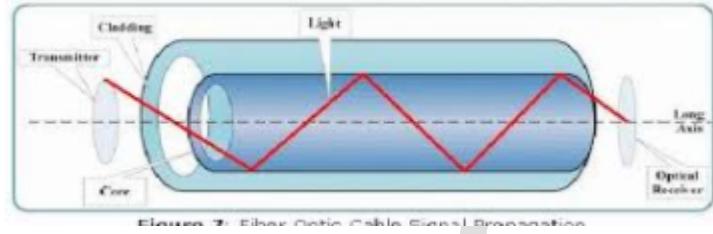
- Theoretically, FSO technologies can work over distance of several kms, as long as the source and the destination are in line of sight.
- **Uses**
 - The technology is very useful where physical connections are impractical due to high cost or other considerations.
 - It can be used for communication between spacecrafts. The first gigabit laser-based communication was achieved by the European Space Agency and called European Data Relay System (EDRS) in 2014. The system is still in operation.
 - LAN-to-LAN connections in campuses for very high-speed Ethernet access
 - To cross a public space (like road) which user doesn't own.
 - For temporary network installations, this is a better option as minimum infra set up is needed.
 - In disaster situation, it can re-establish data connections quickly
 - For high speed inter and intra chip communication.
- **Advantages**
 - Ease of deployment (very less infrastructure investment)
 - Can be used to power devices
 - License free long-range operations (as opposed to spectrum allocation licenses for microwave/radio wave communications)
 - Very high data bandwidth (very high speed of data communication)
 - Immunity from electromagnetic interference
 - Full duplex operation
 - Increased security when working with narrow beams (line of sight operation ensures security)
- **Limitations**
 - Stability and quality of the link is highly dependent on atmospheric factors such as rain, fog, dust and heat.
 - Doesn't work for non-line of sight senders and receivers

17. FIBER OPTICS COMMUNICATION

- **Introduction**
 - FOC is the method of transmitting information from one place to another by sending pulses of light through an optical fiber. Light basically forms the electromagnetic carrier wave that is modulated to carry information.
- **Key components**
 - Transmitter (light source) generates a light stream modulated to enable it to carry the data. Conventionally presence of light indicates "1" and absence of light indicates '0'.



▫ **Fibre Optic cable** is the very thin fibre of glass or other suitable material through which the modulated light stream travels to reach the destination. An optical fibre cable consists of a **core**, **cladding**, and a **buffer** (a protective outer coating). Cladding guides the light along the core by using the method of total internal reflection. The core and the cladding (which is of lower-refractive index) are usually made of high quality silica glass or plastic.



▫ **Optical repeater and amplifier:** In order to overcome the effects of attenuation of the cable, distortion of the light signal along the cable and to ensure that signal gets transmitted over long distances, repeaters and amplifiers are used.

▫ **Receiver (Detector)** converts the pulses of light into equivalent electrical pulses.

- **Advantages of fiber optics over electrical cabling**

- Lower Signal Attenuation
- Higher Bandwidth
- Can travel longer distances
- Fiber optics cables are much lighter than the coaxial cable (that might otherwise be used). This is very crucial in cases like that of aircraft
- No sparks – important for flammable and explosive gas environment
- Fiber optics do not suffer from stray interference pick up that occurs with coaxial cables.
- Further fiber optics transmission also doesn't suffer from cross talks in contrast to some type of electrical transmission signal.
- Resistant to corrosion due to non-metallic transmission medium.

- **Limitations of fiber optics over electrical cable**

- Fiber optical system are more expensive to install
 - The cost of cable, the transmitter and receiver is higher in case of fiber optics
- Electrical cable has the capability of carrying electrical currents as well as signals (in properly designated cables), whereas optical fibers can only be carrying signals.

- **Applications**

- Telecommunication (telephone signals, internet communication and cable tv)
- Due to lower attenuation and interference, optical fiber has large advantages over existing copper wire in long-distance, high demand applications and high-resolution content.

- **India and Fiber Optic Communication**

- The **National Optical Fiber Network (NFON)** is a project initiated in 2011 to provide broadband connectivity to 2.5 lakh gram panchayats of India (min bandwidth of 100 Mbps) at an initial cost of 20,000 crore rupees.
 - The project intended to enable government of India to provide e-services and e-applications nationally.

- **BharatNet** (rechristening of NOFN) is a project of national importance to establish, by 2017, a highly scalable network infrastructure accessible on a non-discriminatory basis, to provide on demand, affordable broadband connectivity of 2 Mbps to 20 Mbps for all households and on demand capacity to all institutions, to realize the vision of digital India, in partnership with states and private sector.
 - The entire service is being funded by Universal Service Obligation Fund (USOF), which was set for improving telecom services in rural and remote areas of the country.
 - The **objective** is to facilitate the delivery of e-governance, e-health, e-education, e-banking, Internet and other services to rural India.
 - **Implementation:** the project is a centre-state collaboration, with the states contributing free Rights of Way for establishing the Optical Fiber Network.

18.3D PRINTING

- **Intro**
 - 3D Printing (also known as additive manufacturing) is a process where an object is created by adding material layer by layer from a computer blueprint/design. It allows designers to create complex parts for machines, airplanes and cars at a fraction of cost and time of standard means like forging, molding and sculpting.
 - Now, smaller consumer friendly 3D printers are bringing additive manufacturing to homes and businesses.
- **Key steps involved in 3D printing**
 - **Create a blueprint** of the object that requires to be printed. **Modelling software like blenders, CADs etc.** can be used to create the design to be printed.
 - **Printing** works on the layering principle where layers of material is added till the final object is created. Most common material used in 3D printing is plastic, but other material can also be used.
- **Three key advantages of 3D printing are shorter lead time, design freedom, and lower costs.**
- **Main uses:** It's hard to find a sector where 3D printing hasn't had an impact.
 - **Manufacturing and other industrial sector** can now use 3D printing to develop prototype models and test new components.
 - It is also playing a significant role on **fashion industry** with fashion designers experimenting with 3D-printed clothes shoes etc.
 - **Medical Sector** has been one of the biggest beneficiaries of the technology
 - Doctors have been testing biomaterials for regenerative medicines. Some surgeons have even tested 3D printed organs for transplant.
 - **Cultural Heritage preservation, restoration, and dissemination**
 - Many museums in advanced countries have started using the 3D printing technology for actively creating missing pieces of relics.
 - **Homes and other buildings:** Recently a giant 3D printer in China printed 10 houses in just one day and at a cost of less than \$5,000 per house. It proved how cost and time efficient 3D printing can be.
 - **Food Industry:** 3D printing is being used for designing cakes on demand and other food items.
 - **Defence Sector:**
 - For e.g., the corps of Engineers used 3D printing to construct 22,000 temperatures controlled, relocatable, habitat in the high-altitude areas of LAC.

- In addition to 3D printing habitat, the Army's Corps of Engineers in consultation with IIT Gandhinagar, came up with **3D printed permanent defenses** for forward areas. Trials have shown that these 3D printed defences can take direct hit from T-90 tank from 100 meters away and can be constructed in a much shorter time frame compared to regular defensive bunkers.

- **Key Concerns**

- **Intellectual Property Rights:** Once 3D printing becomes very popular, it would be difficult to prevent the IPR violation by individuals at their homes and privately.
- **Health Issues:** Experts have raised concerns about potential health implications of the technology due to exposure to gases and other materials including nanomaterial. Particle emissions from a fused filament generally peaks during printing and may include a large number of ultrafine particles and volatile organic compounds.
- **Public Safety** may become an issue with 3-D printing advanced guns being available with anti-social elements, including terrorists.

19. BARCODE AND QR CODES

A) QR CODE (QUICK RESPONSE CODE) – A TYPE OF 2D BAR CODE

- **What is QR Code and how does it work?**
- Developed in 1994 by a Japanese Cooperation Denso Wave – a subsidiary of Toyota motors.
- QR Code, in full Quick Response Code, **is a type of bar code that consists of printed square pattern of small black and white squares that encode data which can be scanned into a computer system.**
- The black and white square can represent numbers from 0-9, letters A-Z, or characters in non-Latin scripts such as Japanese Kanji.
- The three corners of the QR code contain the finder pattern, a nested series of black and white squares that, when detected by an optical scanner and interpreted by software, allows the scanning device to determine the **orientation of the QR code**.
- **Advantages over barcode**
 - Store hundred times more information
 - Can be scanned from any direction for 360 degrees. This makes it easier for devices to read and lessens the possibility of background interference. Further, it doesn't need a special laser emitting device to read, camera of a smart phone or tablet computer is good enough for scanning the information.
 - Fewer errors – since QR codes have more storage, it can store same information multiple times to reduce the impact of physical damage of the code.
 - More Secure – as it is possible to encode the information in bar codes.
 - In **marketing**, the code's appearance is unique and interesting, increasing the likelihood of engaging the customers.
- **Uses:**
 - Used in advertising, to encode URL of a website that contain a coupon or information about a product.
 - Used in books to help students easily access the webpage.



B) BAR CODE

- Bar code is an optical, machine readable form of data. It is a printed series of parallel bars or lines of varying width that is used for entering data into a computer system. This data usually defines something about the product which carries the barcode.
- Barcodes represent data by varying the widths and spacing of parallel lines.
- **Uses:**
 - **Automation of supermarket checkout** is the most common place where we see bar code scanner. In fact, this use of barcode has almost become universal.
 - **Supply chain management**
 - **Advantages**
 - Speed of processing
 - Better tracking (in case of supply chain management)
 - Low cost and very accurate (compared to key entry)
 - **How does a bar code scanner work?**
 - Laser/LED is reflected back better from the white spaces (and not from the black bar).
 - This reflection is converted into on-off pulse in the binary digit by an electronic circuit attached to the scanner.



20. TOPICS TO BE COVERED IN FUTURE BOOKLETS

- Wireless Communication (5G/6G), Bluetooth, WiFi, NFC, RFID etc.
- VOLTE/ VoIP/ VoWiFi



TARGET PRELIMS 2024

BOOKLET-7; S&T-7

COMPUTER & IT - 4

1. TABLE OF CONTENTS

1. <i>Table of Contents</i>	0
2. <i>Various Generation of Cellular Wireless Communication Technology</i>	1
1) difference between 1G, 2G, 3G, 4G, and 5G.....	1
2) Various 4G technologies	1
A) LTE	2
B) Voice over Lte (Volte)	2
3) 5G	3
C) Standalone and Non-Standalone 5G	4
D) Challenges of Fiberization ahead of India's 5G deployment (class discussion)	5
E) 5G spectrum (Low Band, Middle Band, High Band).....	5
F) Private 5G	6
G) Airlines vs 5G in USA and some other countries (class discussion)	6
4) 6G	6
5) Bharat 6G Alliance (B6GA)	7
6) Bharat 6G MisSion.....	7
3. <i>E-SIM</i>	7
4. <i>RFID Communication</i>	8
5. <i>Near Field COnmunication</i>	9
A) 'Tap to Pay' for UPI launched by Google Pay.....	11
6. <i>Bluetooth Communication</i>	11

2. VARIOUS GENERATION OF CELLULAR WIRELESS COMMUNICATION TECHNOLOGY

1) DIFFERENCE BETWEEN 1G, 2G, 3G, 4G, AND 5G

- **G** in terms like 1G, 2G, 3G, 4G etc. refers to a generation of cellular wireless communication technology.
- When there is a change in generation, there is a change in:
 - The fundamental nature of service
 - Non-backwards compatible transmission technology
 - New Frequency bands.

Different Generations, key differences:

Features	1G	2G	3G	4G	5G
Year of introduction	1980s	1990s	Early 2000s	Late 2000s	Late 2010s
Core technology	Analog	Digital (CDMA , GSM)	CDMA2000	LTE	NR (New Radio)
Services	Voice calls	Voice calls, SMS, Basic mobile Internet;	Integrated high-quality audio, video and data	Dynamic information access, variable devices	Dynamic information access, variable devices with all capabilities
IP Protocol	N/A	Supported	Supported	Fully Supported	Fully Supported
Data Speed		Upto 384 Kbps	Several Mbps	100 Mbps to 1 Gbps	Upto 20 Gbps
MIMO technology	N/A	No	Yes	Yes	Yes

Note: Security keeps on improving with every generation; Latency keeps on decreasing with every generation; Data Speed keeps on improving with every generation.

MIMO Technology: (Multiple Input Multiple Output) (MIMO) is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time.

Note: Legacy wireless streams used Single-Input Single Output (SISO) technology. They can only send and receive only one spatial stream at a time.

2) VARIOUS 4G TECHNOLOGIES

- **4G phones are supposed to be faster, but there are many technologies and speed varies.**

- The International Telecommunication Union (ITU), a standards body, tried to issue requirements to call a network 4G but they were ignored by carriers, and eventually the ITU backed down.
- 4G technologies include.
 - 1. HSPA+ 21/42**
 - 2. WiMAX (now obsolete)**
 - 3. LTE (Long Term Evolution)**

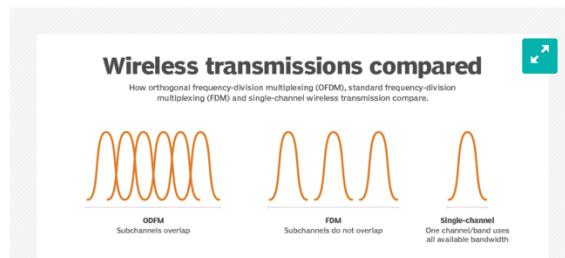
A) LTE

- » LTE is the most popular 4G tech. Some people consider it the only true 4G tech of the bunch and some others say that none of them are fast enough to be called 4G. The **key difference** between 4G LTE and other “4G” technologies is the upload speed.
- » **Other Details about LTE:** LTE only allows transmission of data. **Voice calls** are routed through telecom networks’ older 2G and 3G networks. Therefore, under LTE, we can’t access 4G data and services while on a call.

- » **Key Features of LTE:**

- **Orthogonal Frequency Division Multiplexing (OFDM):** It allows high data bandwidth to be transmitted efficiently while still providing a high degree of resilience to reflection and interference.

In a traditional single-channel modulation scheme, each data bit is sent serially or sequentially one after another. In OFDM, several bits can be sent in parallel, or at the same time, in separate substream channels. This enables each substream's data rate to be lower than would be required by a single stream of similar bandwidth. This makes the system less susceptible to interference and enables more efficient data bandwidth.



Multiple Input, Multiple Output: LTE-A uses MIMO antenna technology. MIMO and OFDM ensure a higher signal to noise ratio at the receiver ensuring good services even in dense regions.

B) VOICE OVER LTE (VoLTE)

- Voice over LTE is a **digital packet technology** that uses 4G LTE to route voice traffic and transmit data. VoLTE provides higher quality calls, better service, and the ability to simultaneously use voice and data.
- **NEED:** Why is VoLTE necessary?
 - » The technology is necessary because **LTE is a data-only networking technology**.
 - **Previous cellular networks** such as 2G and 3G, were designed to carry voice calls – services added cellular data support later through methods that basically “tunneled” data inside of voice-call connections.

- **LTE turns the network around** and uses Internet Protocol Packets for all communications. As such it doesn't support traditional voice call technology, so a new protocol and applications for voice over LTE are needed.
- **How does VoLTE work?**
 - » It is based on the **IP Multimedia Subsystem (IMS) framework**. This allows the service to deliver multimedia as data flows using a common IP interface.
- **Advantages of VoLTE**
 - » **VoLTE** uses the **spectrum more efficiently** than traditional voice calls. It uses less bandwidth because VOLTE's packet headers are smaller than those of unoptimized VoIP/LTE.
 - » It provides for increased battery life when compared to VoIP.
 - » Provides superior audio quality and a clearer calling experience.
 - » **Ends dependency** on the legacy circuit switched voice network to be maintained.
 - » Allows up to **six-way conference calls**.
 - » Ability to **simultaneously use voice and Data**. Eliminates the need to have voice on one network and data on another.
- **Limitations**
 - » Need volte capable smart phones
 - » **Strong 4G coverage** to make and receive calls over 4G network.
 - » For VoLTE call, both devices involved in communication must be compatible with VoLTE.
- **Services in India**
Reliance Jio and Airtel are the leading operator providing the VoLTE. Reliance Jio doesn't have spectrum in 2G or 3G and thus it places all its calls using 4G LTE only (unlike other operators which drop to 2G or 3G for sending and receiving calls).

3) 5G

- 5G refers to **the fifth generation of cellular wireless communication technologies**.
- **Key features of 5G technology** are:
 - **Higher speed; Lower latency; Greater network stability.**
 - **Device Intelligence:** Unlike 4G, 5G has the capability to differentiate between fixed and mobile devices. It uses cognitive radio techniques to identify each device and offer the most appropriate delivery channel. This will allow a much more customized internet connection – according to device capability and local reception environment.
 - **Other technical features of 5G**
 - 5G will use higher frequencies of wireless spectrum (~ **30 GHz to 300 GHz**) range when compared to 4G which uses frequencies below 6 GHz.
 - **Higher Frequency** -> Huge quantity of data; Shorter Wavelength -> smaller antenna sizes.
 - Building on the multiplexing technology of its predecessor, 5G ushers in a new standard called **5G New Radio (NR)**, which uses the best capabilities of LTE. **5G NR** will enable increased energy savings for connected devices and enhance connectivity.
 - These frequencies are **highly directional** and thus can be used right next to other wireless signals without causing interference.

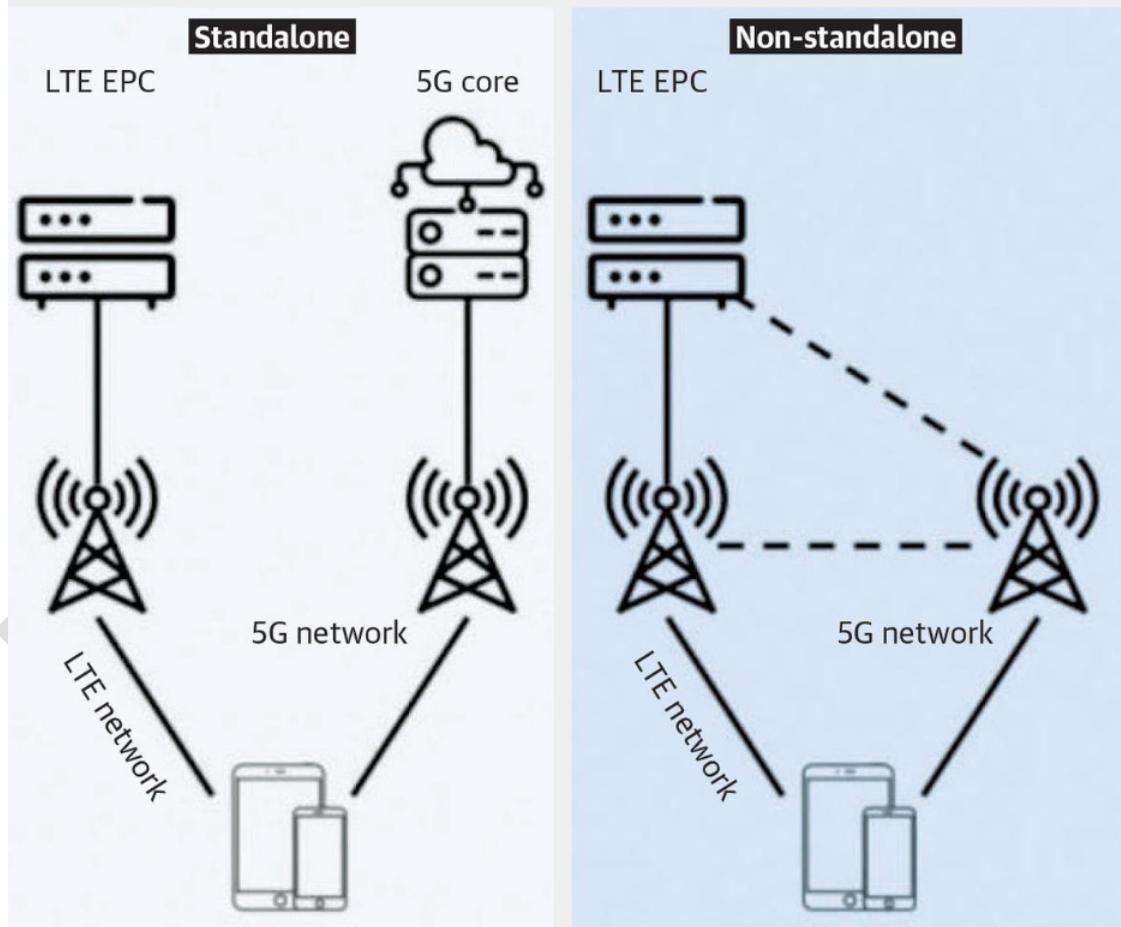
- Several hundreds of thousands of simultaneous connections for wireless sensors
- Spectral efficiency significantly enhanced compared to 4G
- Improved Coverage
- Enhanced signal efficiency

C) STANDALONE AND NON-STANDALONE 5G

- 5G networks are deployed on two modes: **standalone** and **non-standalone**.
- Each architecture has its advantage and disadvantages. The method used by the operators primarily reflect their view of the market for the new technology, and consequent rollout strategy.

5G architecture

When 5G is deployed through a non-standalone framework, the operator uses the existing installed capacities and LTE architecture. However, in a standalone model, the radio access network and the core will be completely new. It gives operators the full range of 5G's capabilities.



- **Standalone Mode:** In this mode, the 5G network operates with dedicated equipment and runs parallel to the existing 4G network. In this architecture, Radio Access Network (RAN) and the core are

completely new, and there will be a clear separation of different network functions in line with the 3GPP recommendations.

- Jio has chosen this method. It has committed an investment of Rs 2 lakh crore for its standalone 5G network.
- **Advantages:** Provides full 5G capabilities and new network functionalities such as slicing that provides greater flexibility to operators to efficiently use their spectrum holding; Simplify network operations; much faster than NSA 5G -> improved user experience; Long term solution.
- **Limitations:** High Initial Investment

- **Non-Standalone Mode (NSA):** In this, the 5G network is supported by the 4G Core infrastructure. The operators can use their existing capacities and LTE architecture to deploy 5G services while implementing a new radio access network (RAN). The operations in the core network will be supported by the existing evolved packet (EPC) from LTE. **Germany** for e.g., used the NSA model to roll out 5G services in 2019.
 - **Advantages:** Reduce initial cost/investment; Maximizes the utilization of existing network; Reduces time of deployment; first national coverage
 - **Limitation:** Only short term/medium term solution; Not as fast as pure 5G
- Given that the non-standalone networks are built on existing infrastructure, the initial cost and rollout times are significantly lower. It lets operators maximize the utilization of existing network infrastructure with relatively lower investment.

Compatibility with existing device ecosystems: Most smartphones today have compatibility to connect to non-standalone 5G network – which are essentially 5G airwaves transmitted through 4G networks. It will require software updates by their OEMs to be able to connect to standalone networks.

D) CHALLENGES OF FIBERIZATION AHEAD OF INDIA'S 5G DEPLOYMENT (CLASS DISCUSSION)

E) 5G SPECTRUM (LOW BAND, MIDDLE BAND, HIGH BAND)

- **5G** differs from previous cell phone standards, in having much wider spectrum than before. It is capable of tuning in many more types of frequencies – and multiple types of frequencies at the same time.
 - **Low Band 5G (600 – 700 MHz):** Low band tower can cover 100s of sq miles with 5G services that range in speed from **30 – 250 megabits per second (Mbps)**. It is the blanket layer for nationwide coverage. It will provide a base and services will not get worse than this. It uses the same frequency (600 MHz) that was once used for analog TV broadcasts. This ensures coverage in far flung rural areas.
 - **Note:** Even low band services are faster than 4G services.
 - **Middle Band 5G (2.5-3.5 GHz):** Mid band tower can cover several mile radii with 5G service that range in speed from **100 – 900 Mbps**.
 - **Note:** Some carriers will be skipping low band 5G, so their middle band 5G services will be the base service.

- **Note:** Cellular industry is considering the mid band 5G as the sweet spot for 5G distance and performance.
- **High Band** (millimeter wave/24-39 GHz) tower covers a one mile or lower radius while delivering superfast speeds (roughly 1-3 gbps speeds). It will be deployed in areas with “**dense urban**” environments and public gathering places that frequently save huge number of people.
- Each of these tiers would improve in performance over time.

F) PRIVATE 5G

- It is a cellular network technology that provides 5G connectivity for a specific, closed user group within a limited geographic area.
- Unlike public 5G networks, which are operated by mobile carriers and accessible to anyone with compatible device and subscription, private 5G networks are owned and operated by private entities, such as businesses, governments, or universities. This gives owner full control over the network, including who can access it, how it is used, and the quality of service.
- **How does it work?**
 - Same tech as public 5G, but they operate on licensed or unlicensed spectrum.
- **Advantages:**
 - **Increased privacy and security:** It allows organizations to implement their own security measures.
 - Improved reliability and performance (since it can be tailored to specific needs of the users)
 - Greater control and flexibility
 - Reduced cost

G) AIRLINES VS 5G IN USA AND SOME OTHER COUNTRIES (CLASS DISCUSSION)

- **what were the problems caused by deployment of 5G ‘C-Band’ spectrum (3.7 GHz – 3.98 GHz)?**
 - The C-band frequency range of 5G wireless technology is very close to the 4.2 to 4.4 GHz range used by altimeters on all aircrafts, something that was established long back

4) 6G

Successor of 5G

Frequency Bands – 95 GHz to 3 THz

It seeks to use Tera Hz band frequency which is still unutilized. Tera Hz band fall between infrared and microwaves. Though the waves have very small wavelength, there is a huge amount of free spectrum which would allow us very fast data rates.

Data rate – Upto 1 TBPS (100 times faster than 6G)

Latency < 1 milli seconds

Application and Advantages (Similar points as 5G)

6G also envisions to enable new applications such as holographic communication, brain-computer interface, quantum internet, and artificial intelligence.

Challenges for India:

Low R&D investments

Terahertz communication are blocked easily by barriers and signal also attenuates easily

5) BHARAT 6G ALLIANCE (B6GA)

Why in news?

DoT launches Bharat 6G Alliance to drive innovation and collaboration in Next-Generation Wireless Technology (July 2023)

Details about B6GA:

It is a collaborative platform consisting of public and private companies, academia, research institutions and standards development organization. It will forge coalition and synergies with other 6G Global Alliances, fostering international collaboration and knowledge network.

The **primary objective** of the B6GA is to facilitate market access for Indian telecom technology products and services, enabling the country to emerge as a **global leader in 6G technology**.

It aims to bring together Indian startups, companies, and the manufacturing ecosystem to establish consortia that drive the design, development and deployment of 6G technologies in India.

It also focuses upon accelerating standard related patent creation within the country and actively contributing to international standardization organizations such as 3GPP and ITU.

6) BHARAT 6G MISSION

- Aim of 6G service rollout by 2030.
- India has also launched a development test bed.
- **More about the Vision document**
 - » **Prepared** by the Technology Innovation Group on 6G (TIG) which was set up by Department of Telecommunication in 2021.
 - » **Mission divided into two phases:**
 - **Phase 1** (2023-2025): Ideation phase – understand various potentials and risks; test proof the concept
 - **Phase 2** (2025-2030): Delivering the potential technology solution
 - » **Constitution of an apex body** to oversee the mission and approve the budget of the mission
- **Significance** of the document:
 - » Assuming leadership in setting the 6G standards
 - » Not delaying adoption (as has happened in previous generations)
 - » Ensuring latest technology coming to India in the fastest way possible.

3. E-SIM

- **What is an eSIM (embedded Sim)?**
 - » An eSIM is a programmable chip that is built (embedded) into smartphones, tablets or other devices. An eSIM is a digital SIM that allows you to use a cellular plan from your carrier without having to use a

physical nano-SIM. The pre-installed (embedded) simcard is activated by installing the “eSIM profile” of a new operator.

- » **Technical Name:** The eSIM is called by its technical name, **eUICC** (Embedded Universal Circuit Card) or virtual SIM.

- **Advantages:**

- » This has very small physical footprint, even smaller than the nano sims available since 2012. Not having a removable sim slot also saves a lot of space. This is especially useful for smaller electronics like smartwatches. Further, not having the sim tray increases the scope of making the device water resistant.
- » It serves the same purpose as a physical SIM, but it is carrier independent and can be programmed via software instead.
- » **Same eSIM profile** can be activated on multiple device (e.g. phone, smart watches etc.) (traditionally, one physical sim card could be used only in one device)
- » **Switching providers is very easy:** Instead of getting a new physical SIM card, all you have to obtain is a configuration file and activate it on the device. Providers generally refer to it as an eSIM profile and offer it as a QR code that you can scan and download.
- » Further, eSIM allows storage of multiple carrier profiles on the smartphones and carrier can be switched between on the fly.
- » **Carriers also benefit** as they don't have to manufacture and provide a physical sim card thus reducing the cost.
- » **Environment friendly** – extra packaging of physical sim card, plastic waste, e-waste etc. could all be reduced.

- **Disadvantages/Limitations:**

- » **Not supported by all carriers yet.**

- In India, **Jio, Airtel, and Vi** all support eSIM. You need to send a message to the carrier asking them to activate eSIM and they usually send a code which has to be scanned via the device on which you intend to use the eSIM. Once done, the eSIM should work.

4. RFID COMMUNICATION

- RFID (radio frequency identification) is automatic recognition technology that uses wireless communication. Here, data is encoded in an RFID tag which might be read by the reader.

- **What is the most important advantage of RFID?**

- » Electronic devices generally need a power source. But, RFID tags use a mechanism where we can send power to device, whenever the device needs it. (Electromagnetic field coupling)
- » We don't need a power source on RFID tags.

- **Kinds of RFID: Passive and Active**

- » **Passive RFID:** RFID tags have neither an electric plug nor a battery. Instead, all of the energy needed to operate them is supplied in the form of radio waves by RFID readers. This technology is called passive RFID.
- » **Active RFID:** Here, there is a power source on the tag.

- **Advantages:**

- » Data can be read from longer distance. (for e.g., even if the tag is high, relatively inaccessible place) etc.
- » Multiple tags can be read at once -> it obviates the need to hold item one by one in order to read the data.
- » Data can also be read from outside the box unlike barcode/ QR code (without opening the box). It is also immune to things like dirt.
- » A passive type RFID can be used semi-permanently without a battery.
- » Since tag contains a memory, the data can be rewritten.

- **Applications:**

- » It enables efficient inventory count at logistics center, backyard, and storefront.
- » Incoming and outgoing record (e.g. FASTag at toll booths)
- » **Brand Protection:** It is a useful tool to prevent grey market and counterfeit products of luxury brands.
- » Tracking: Personnel, asset etc.
- » **Smart Keys** (for doors)

- **Disadvantages:**

- » It takes longer to program an RFID tag (compared to QRCode)
- » RFID can be intercepted easily, even if its encoded.
- » **Foil (2-3 layers of household foil)** can dam the radio waves
- » Privacy concerns: Anybody can access information about anything

5. NEAR FIELD COMMUNICATION

- **What is NFC and How does it work?**

- It is a short-distance wireless communication technology. When two NFC enabled devices are very close to each other (around 4 cm), then they can communicate with each other using radio waves.
 - » **Atleast one of the device should be active device** like smart phone, tablet, or post terminal. Please note that the active device would need an external power supply. The other device may be active or passive (for e.g. NFC tags). Passive device is powered by the electromagnetic field of the active device.
- **NFC supports three modes of communications:**
 - » **Peer to Peer communication mode**
 - E.g., when we share information between two smart phones.
 - In this mode, both devices are active devices. They can communicate with each other by generating radio waves alternatively. When one device transmits data, the other listens to it and vice-versa.
 - » **Reader/Writer Mode:**
 - E.g. when we access data from smart phones using NFC tags.
 - This mode is similar to RFID. Here the active device like smartphones and tablets reads or writes the data on NFC tag using the principle of electromagnetic induction. A time varying electromagnetic field generates the voltage in this passive tag. This voltage powers up the chip in this NFC tag. Once powered up the tag responds with its own information.
 - » **Card Emulation Mode**

- E.g. when smartphones are used for mobile payments.
- Both devices are active device. One device will be a smart phone and the second device is a payment terminal. Here, smartphone acts like a passive smart card and don't generate their own radio waves. They only respond back with the requested data by the payment terminal. Operating principle in this mode is similar to reader/writer mode.

- Applications

- **File sharing**
- **Contactless payments:** NFC is behind the cards that we have over card readers on shops
- **Mobile payments**
- **Pairing different devices**
- **Information sharing using smart posters and business cards**
- **Home automation**
 - » NFC tech is present in new age speakers, household appliances, and other electronic devices that we monitor and control through our smartphones.
 - » E.g. changing temperature of AC, ambient lighting etc.
 - » Automatic closing of doors
- **Healthcare:** NFC is used to monitor patients stats through NFC-enabled wristbands.
- **Library systems:** Keeping tabs on library books
- **Preventing Auto theft**
- **Personal usage**
- **Running unmanned toll booths**
- **Wireless charging**

- Advantages over other forms of communication.

- **NFC vs Bluetooth:** While Bluetooth provides for higher data rate sharing; But **NFC reduces the time required for pairing of devices**. In case of NFC the two devices can be set up in less than 0.1 seconds. Once the pairing between devices is done, for communications either Bluetooth or wifi can be used.
- **NFC vs RFID:** NFC is derived from RFID standards and the working principles are quite similar to RFID. But RFID works on large band of frequencies (LF: 125 kHz or 134 kHz) HF: 13.56 MHz; UHF: 860-960 MHz). But **NFC works on a particular frequency band** i.e. 13.56 MHz band. In case of RFID, the reader sends the request to the RFID tag and in response the RFID tag replies back to the reader. So, in case of RFID there is only one way communication. While in case of **NFC peer to peer communication is possible**.
- **NFC vs QR Codes:** In case of QR codes, scanning if required to access the information. In case of NFC, just by tapping mobile to NFC tag, information can be easily accessed. Therefore, access time required in case of NFC is less than that of QR code. Further NFC is more secure than the QR code. Because in case of QR code, wrong information may be provided by putting another QR code on top of the 1st QR code, while in case of NFC, if someone puts another NFC tag on top of the first one, then neither of the tags would be accessed. Thus, NFC tech is more secure than the QR code technology.

- How secure is this tech?

- Since NFC works at very close distance, it makes it difficult for attackers to record or communication between the devices compared to other wireless technologies.
- The user of the NFC-enabled device determines by the touch gesture which entity the NFC communication should take place with, making it more difficult for the attacker to get connected.

- Peer to Peer communication provides a mechanism to cipher all exchanged data to avoid external interpretation of recorded communication.
- When did NFC tech start?
- In 2004, consumer electronics companies, Nokia, Philips, and Sony together formed the NFC forum, which outlined the architecture for NFC technology to create powerful new consumer driven products.

A) 'TAP TO PAY' FOR UPI LAUNCHED BY GOOGLE PAY

- Google has recently launched a new feature in India, 'Tap to pay for UPI', in collaboration with Pine Labs. The feature makes use of Near Field Communication (NFC) technology.
- The functionality would allow users with NFC-enabled Android Smartphones and UPI accounts linked to Google Pay to carry out transactions just by tapping their phone on any Pine Labs Android point-of-sale (POS) terminal across the country. Till now, Tap to pay was only available for cards.
- Google Pay has been the first among UPI apps to bring Tap to Pay feature working on POS terminals.
- How will this work?
 - Once the users tap their phones on the POS terminal, it will automatically open the Google pay app with the payment amount pre-filled. Users can then verify the amount and merchant name and authenticate the payment, using their UPI PIN.
 - They will be notified when the payment is successful.
 - Advantage: The process is much faster compared to scanning a QR code or entering UPI-linked mobile number which has been the conventional way till now.
- Are other companies using NFC tech for payments using smartphones?
 - In Feb 2022, Apple introduced Tap to Pay on the iPhone. It will allow merchants across the US to use their iPhone to accept Apple Pay, contactless credit and debit cards, and other digital wallets through a tap on their iPhone without the need of any additional hardware or payment terminal.

At checkout, a customer just needs to hold their iphone or apple watch to pay with Apple Pay, their contactless credit or debit card, or other digital wallet near the Merchant's iphone to complete the payment using NFC technology.

6. BLUETOOTH COMMUNICATION

- Bluetooth is a wireless communication technology that can be used for close range of data transmission from one digital device to another. It relies on short-range radio frequency, and any device that incorporates the technology can communicate as long as it is within the required distance.
- It is essentially a one-to-one wireless connection that uses 2.4 GHz band radio waves. This is the same frequency which other wireless technologies in the home or office, such as cordless phones and WiFi routers use.
- Bluetooth creates a 10 meter (33 foot) radius wireless network, called a personal area network (PAN) or piconet, which can network between 2 to 8 devices.
- It is an electronics "standard", which means that manufacturers that want to include this feature have to incorporate specific requirements into their electronic device.

These specifications ensure that the devices can recognize and interact with other devices that use Bluetooth technology.

The "Bluetooth" name is taken from a 10th-century Danish king named Harald Bluetooth, who was said to unite disparate, warring regional factions. Like its namesake, Bluetooth technology brings together a broad range of devices across many different industries through a unifying communication standard.

- **Advantages:**

- Bluetooth offers a uniform structure for a wide range of devices to connect and communicate with each other.
- It has achieved global acceptance and almost any Bluetooth enabled device, anywhere in the world can connect to another Bluetooth enabled device nearby.
- Low power consumption when compared to wifi and other such wireless systems.
- It also costs much less to implement.



TARGET PRELIMS 2024

BOOKLET-8; S&T-8

BIOLOGY BASICS

1. TABLE OF CONTENTS

1. <i>Cell: Fundamental Unit of Life</i>	1
1) Why is cell the fundamental unit of life?	1
2) Shapes of Cells	1
3) Two broad categories of cells – Eukaryotes and Prokaryotes	1
4) Structural Organizations of Cell	2
A) Plasma Membrane or Cell Membrane	2
B) Nucleus	3
C) Cytoplasm	4
5) Some things to note:	10
6) Important Scientists	10
2. <i>Tissues</i>	12
1) Introduction	12
2) Four Primary types of Animal tissues.....	12
A) Nervous Tissues	12
B) Muscle Tissues/ Muscular Tissues	13
C) Epithelial Tissues.....	14
D) Connective Tissues.....	15
3) Plant Tissues	17
1) Meristematic Tissues	18
2) Permanent Tissues.....	18
3. <i>Blood Type and Related Issues</i>	20

1. CELL: FUNDAMENTAL UNIT OF LIFE

1) WHY IS CELL THE FUNDAMENTAL UNIT OF LIFE?

- Cell is the fundamental structural and functional unit of living organisms i.e. it is the smallest living unit of an organism. Thus, it is also the basic fundamental unit of life.
- Every cell is capable of doing some basic things like respiration, obtaining nutrition, and clearing the waste material, or forming new proteins.

2) SHAPES OF CELLS

- With the discovery of electron microscope in 1940, it was possible to observe and understand the complex structure of the cell and its various organelles.
- The shapes and sizes of the cells are related to the specific function they perform. Some cells like Amoeba have changing shapes. Cells shape can be very peculiar. For example, nerve cells have a typical shape.
- **Some organism can have cells of different types**
 - For example, humans have different types of cells

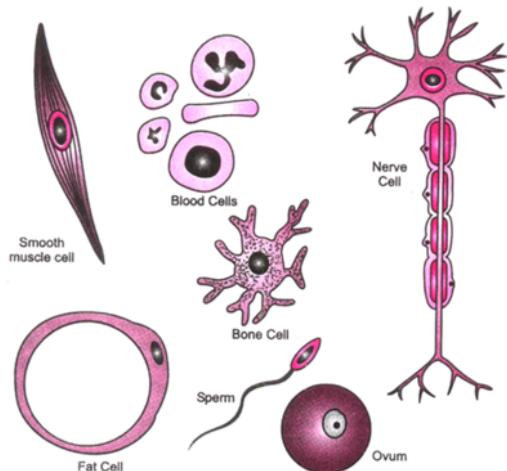


Figure : VARIOUS CELLS FROM THE HUMAN BODY

3) TWO BROAD CATEGORIES OF CELLS – EUKARYOTES AND PROKARYOTES

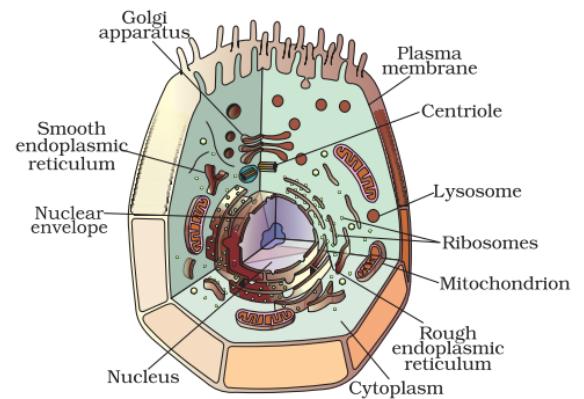
- The difference between the structures of Prokaryotes and Eukaryotes is so great that it is considered to be the most important distinction among group of organisms.
 - i. **Eukaryotic**
 - They have membrane bound organelles such as nucleus.
 - They are advanced cells found in plants and animals
 - They are usually found in multi-cellular animals. But there are a lot of unicellular Eukaryotes too.
 - ii. **Prokaryotic**
 - They don't have nucleus or other well-defined organelles. They do have genetic material, but it is not contained within a nucleus.
 - They are found in primitive cells like that of bacteria and Archaea.
 - Prokaryotic cells are always unicellular such as bacteria. But there is some evidence that some bacterial species can aggregate together and divide labor so that the "colony" is working more

efficiently. This is the characteristic of a multi-cellular organisms, but there is still a lot of resistance to the idea of calling these prokaryotes multi-cellular.

- Prokaryotes are usually much smaller than Eukaryotes.

4) STRUCTURAL ORGANIZATIONS OF CELL

- Every living cell has the capacity to perform certain basic functions that are characteristics of all living forms. There is a division of labour seen within a single cell. The cell components called the cell organelles have specialized functions.
- These functions include making new material in the cell, clearing up the waste material from the cell and so on.
- These organelles together constitute the basic unit called the cell. It is interesting to note that all cells are found to have the same organelles, no matter what their function is or what organism they are found in.
- **Three Broad components of the cell**
 - **Plasma Membrane or Cell Membrane**
 - **Nucleus**
 - **Cytoplasm**



A) PLASMA MEMBRANE OR CELL MEMBRANE

- Cell membrane/Plasma membrane is the outermost covering of the cell that separates the contents of the cell from its external environment.
- It allows or permits the entry or exit of some materials in and out of the cells. It also prevents movement of some other materials. The cell membrane is therefore called **selectively permeable membrane**.
- Cell membrane is not a solid structure. Cell membranes are also described as lipid bilayers.
- There are two layers of phospholipids with protein embedded in the layers.
- **How does diffusion of substance take place into the cell?**
 - **Diffusion**
 - Continuous movement of a substance from a region of high concentration to a region where its concentration is low.
 - E.g.: O₂ enter the cell by the process of diffusion when the level of concentration of O₂ inside the cell decreases.
 - CO₂ moves out of the cell when the level of concentration of CO₂ inside the cell increases.

