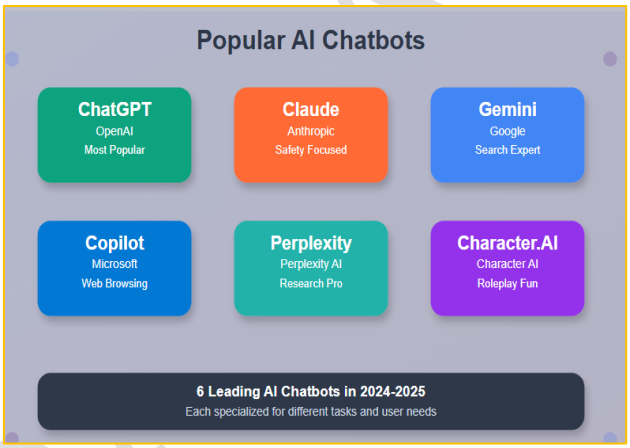
Q.1) What are Generative Pre-trained Transformers (GPTs)? Discuss how tools like ChatGPT are transforming education, governance, and the future of work. (150 words, 10 marks)

Introduction

Generative Pre-trained Transformers (GPTs) are revolutionizing digital landscapes. Tools like ChatGPT are reshaping how we learn, govern, and work, making systems more efficient, inclusive, and innovative through advanced AI-driven language understanding.

Body

What are GPTs?



1. **Transformer-based AI models:** GPTs are deep learning models based on the transformer architecture, designed to understand and generate human-like text with remarkable fluency and coherence.
2. **Pre-trained on vast datasets:** They are trained on large corpora of text from books, websites, and articles, enabling them to grasp language patterns, facts, and contexts efficiently.
3. **Generative in nature:** Unlike traditional models, GPTs can generate new content such as essays, code, stories, and summaries based on prompts, not just classify or translate text.
4. **Context-aware responses:** GPTs process and retain contextual information across multiple sentences or conversations, allowing them to maintain coherent and relevant dialogues.

Applications of ChatGPT-like Tools in Key Domains

Education

1. **Personalized tutoring:** ChatGPT helps students understand difficult concepts in subjects like math and science.
   Example: **Khan Academy's Khanmigo**, powered by GPT-4, serves as an AI tutor that helps students across subjects with interactive, step-by-step learning.
2. **Language and writing support:** It assists in improving writing skills by suggesting edits, grammar corrections, and content structuring.
   Example: **Microsoft Copilot** (based on GPT-4) helps students enhance essays and presentations directly within Word and PowerPoint.
3. **Content creation for educators:** Teachers can generate lesson plans, quizzes, and summaries instantly.
   Example: Teachers are using **ChatGPT and Claude** (Anthropic's GPT-based model) to develop curriculum-aligned teaching material efficiently.

Governance

1. **Citizen services automation:** Governments can deploy GPTs for answering public queries in multiple languages.
   Example: The Indian Ministry of Electronics and IT has explored using **Bhashini** to improve multilingual public access to government schemes.
2. **Policy analysis and drafting:** AI can assist in summarizing large policy documents and suggesting drafts.
   Example: Researchers and government consultants in the **EU** have used GPT-4 to draft preliminary versions of climate policy recommendations.
3. **Public grievance redressal:** ChatGPT-like tools can triage complaints and route them to the correct departments.
   Example: In the **U.S. local councils** are experimenting with GPT-powered assistants to log citizen issues and provide real-time updates on resolution status.

Future of Work

1. **Productivity enhancement:** GPTs automate tasks like report writing and email drafting.
   Example: **Deloitte** integrates GPT-based copilots in internal systems to generate meeting summaries, client reports, and strategy briefs.
2. **Upskilling and learning:** Professionals use ChatGPT for self-paced learning.
   Example: **Duolingo Max**, powered by GPT-4, enables learners to practice language skills with AI-driven conversations and explanations.
3. **Creative and technical collaboration:** Writers and developers use GPTs for brainstorming and prototyping.
   Example: **Replit** uses Ghostwriter (GPT-powered) to help developers generate and debug code in real time.

Conclusion

GPTs are transforming how we learn, govern, and work—fueling efficiency, accessibility, and creativity. India's push toward **Digital India and AI-in-governance** aligns with this global wave, promoting inclusive, tech-driven growth across sectors.

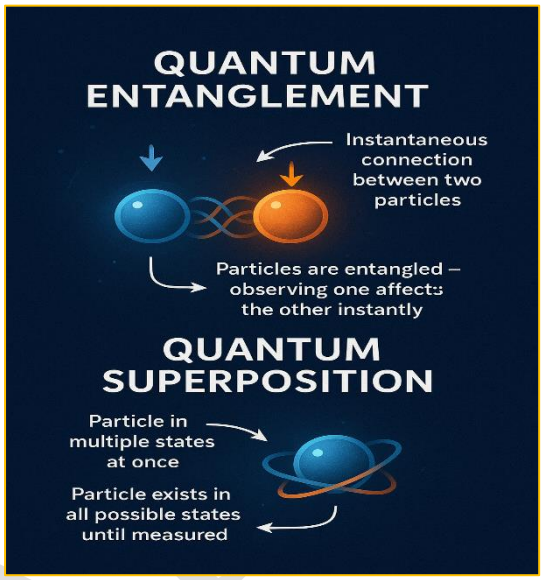
Q.2) What is quantum technology? Examine its potential applications and outline the steps taken by India to harness its benefits. (150 words, 10 marks)

Introduction

Quantum technology uses the rules of quantum physics—like particles being in two states at once—to build powerful tools for computing, communication, and sensing. It is set to transform science, industry, and governance.

Body

What is Quantum Technology?



1. **Based on quantum mechanics:** It operates on the laws of quantum physics, which govern the behavior of particles at atomic and subatomic scales.
2. **Superposition and entanglement:** It exploits quantum properties—**superposition** (being in multiple states at once) and **entanglement** (instant connection between particles)—for superior performance over classical systems.
3. **Beyond classical limitations:** Quantum devices can process vast computations simultaneously, detect minute changes in the environment, and ensure ultra-secure communication.
4. **Emerging interdisciplinary field:** It combines physics, engineering, mathematics, and computer science to build next-gen technologies like quantum computers, sensors, and networks.

Potential Applications of Quantum Technology

1. **Quantum Computing:** Solves complex problems in seconds that classical computers would take years to process.
   Example: Drug discovery simulations by **Google**'s quantum computer promise breakthroughs in medicine.
2. **Quantum Communication:** Enables ultra-secure data transfer using quantum key distribution (QKD).
   Example: **China's Micius satellite** demonstrated QKD-based quantum-encrypted communication between ground stations.
3. **Quantum Sensing:** Offers ultra-precise measurements of time, gravity, and magnetic fields.
   Example: **Quantum sensors** are being tested for underground mineral detection and early earthquake prediction.
4. **Quantum Cryptography:** Revolutionizes cybersecurity by creating unbreakable encryption methods.
   Example: Companies like **ID Quantique** in Switzerland offer commercial quantum encryption solutions for banks.
5. **Material Science & Chemistry:** Simulates molecular interactions with high accuracy for designing advanced materials.
   Example: **IBM's quantum simulations** help in developing better catalysts and battery technologies.
6. **Financial Modeling & Optimization:** Handles vast datasets for risk analysis and optimization in real-time.

Example: **JPMorgan Chase** is experimenting with quantum algorithms to improve investment strategies.

Steps Taken by India to Harness Quantum Technology

1. National Quantum Mission (NQM): Launched in **2023 with ₹6,003 crore** outlay to develop quantum computers, sensors, and secure communication networks over 8 years.
2. Centre for Quantum Technologies: Institutions like **IISc Bengaluru and IIT Madras** are setting up quantum research hubs and laboratories.
3. International Collaborations: India has partnered with global leaders like the US, Israel, and **France** to enhance quantum R&D and exchange expertise.
4. Quantum Communication Projects: DRDO successfully demonstrated secure quantum communication over 100+ km between **two labs in 2020**.
5. Quantum Education Initiatives: IITs and **IISERs** are introducing quantum engineering and computing courses to build a skilled workforce.
6. Industry Participation: Indian startups like **QNu Labs** are building indigenous quantum encryption tools, while **TCS and Infosys** are investing in quantum research.

Conclusion

Quantum technology holds the key to future breakthroughs in computing, security, and sensing. The **2022 Nobel Prize in Physics**, awarded for **quantum entanglement** research, highlights its global importance.

Q.3) Srinivasa Ramanujan made extraordinary contributions to mathematics with little formal training. Discuss the significance of his work and its relevance to modern science and technology. (150 words, 10 marks)

Introduction

Srinivasa Ramanujan, a self-taught mathematical genius from India, made groundbreaking contributions to **number theory, infinite series, and mathematical analysis**. Despite minimal formal training, his work continues to influence modern science, technology, and theoretical research.

Body

Significance of Ramanujan's Work

1. Contributions to Number Theory: Ramanujan's work on partitions, highly composite numbers, and modular forms expanded the foundations of number theory.
2. Discovery of Mock Theta Functions: These mysterious functions, introduced in his final letters, puzzled mathematicians for decades.
3. Infinite Series and Continued Fractions: He developed elegant formulas for π and other constants using unconventional infinite series.
4. Modular Forms and q-Series: His work laid groundwork for the modern theory of modular forms.

5. Ramanujan Prime and Tau Function: He introduced new functions and patterns in prime numbers and integer partitions.
6. Intuition over Formal Proofs: He arrived at deep truths through intuition and pattern recognition, challenging conventional methods of mathematical discovery.

Relevance to Modern Science and Technology

1. **Cryptography and Cybersecurity:** Ramanujan's theories on prime numbers and modular forms underpin encryption algorithms used in secure communication.
2. **Theoretical Physics:** Concepts like mock theta functions and modularity are applied in string theory, quantum gravity, and the study of black holes.
3. **Computer Science:** His formulas for rapidly converging series are used in algorithm development for symbolic computation and data processing.
4. **Artificial Intelligence:** His ability to identify patterns in complex data inspires modern approaches to machine learning and intuitive problem-solving.
5. **Space Science:** NASA scientists have used Ramanujan's equations in orbital mechanics and signal processing.
6. **Pure Mathematics Research:** His notebooks continue to be a source of unsolved problems and insights for mathematicians worldwide.

Conclusion

Ramanujan's legacy proves that genius can thrive beyond formal education. His intuition-driven discoveries not only reshaped mathematics but also continue to influence cutting-edge research in physics, computer science, and cryptography in the 21st century.

Q.4) Indigenization of technology is key to achieving strategic autonomy and reducing external dependence. Examine India's efforts towards indigenization in the fields of defence, space, and digital infrastructure. (250 words, 15 marks)

Introduction

Indigenization of technology refers to the development and production of critical systems, tools, and knowledge within the country. For India, it is essential to achieve strategic autonomy, ensure national security, and reduce reliance on foreign technology.

Body

India's Efforts Towards Indigenization

Defence

1. **Make in India – Defence:** The government launched initiatives to promote domestic manufacturing of weapons and platforms.
   Example: HAL's **Tejas** Light Combat Aircraft (LCA) is an indigenous fighter jet developed for the Indian Air Force.
2. **Defence Acquisition Reforms:** Restrictions on imports of various defence items to encourage local development.

Example: Defence Ministry released a **"positive indigenization list"** banning import of over 400 weapon systems and components.

3. **Private Sector Participation:** Indian startups and private firms are now key players in defence R&D.
   Example: **Bharat Forge** and **Larsen & Toubro** are involved in building artillery systems and naval platforms.

Space

1. **ISRO's Indigenous Missions:** ISRO has built launch vehicles and satellites using homegrown technologies.
   Example: The **GSLV Mk III** launch vehicle and Chandrayaan-3 mission were developed indigenously.
2. **Private Sector Collaboration:** India opened the space sector to private firms for innovation and manufacturing.
   Example: **Skyroot Aerospace**, an Indian startup, launched India's first private rocket, **Vikram-S**, in 2022.
3. **Satellite Navigation Systems:** India developed its own regional satellite navigation system.
   Example: **NAVIC** (Navigation with Indian Constellation) provides India with strategic independence from GPS.

Digital Infrastructure

1. **Digital India Mission:** A flagship program to promote self-reliance in digital services and infrastructure.
   Example: Development of **BharatNet** to connect rural India with high-speed internet.
2. **Indigenous Platforms and Technologies:** Efforts to reduce dependence on foreign software and tools.
   Example: **UPI** (Unified Payments Interface), developed by NPCI, has revolutionized digital payments in India.
3. **Cybersecurity and Data Sovereignty:** Focus on developing native cybersecurity frameworks and data storage norms.
   Example: CERT-In and MeitY have launched initiatives for indigenous **cybersecurity tools** and data localization.

Challenges in Indigenization

1. Technological Gaps: India still imports **60–70%** of its defence equipment due to the lack of advanced technology and R&D capabilities.
2. Limited Private Sector Ecosystem: The domestic private sector is still nascent in high-end tech domains like semiconductors and advanced aerospace systems.
3. Dependence on Foreign Components: Even indigenous platforms often rely on imported critical components like engines, sensors, and chips.
Example: The **Tejas LCA** uses an American-made GE engine.

4. Funding and Bureaucratic Hurdles: Slow project approvals and limited R&D funding restrict innovation and timely execution.
Example: Defence R&D budget has hovered around just **6–7%** of the total defence budget.

Way Forward

1. Strengthen R&D Ecosystem: Increase public and private investment in frontier research, with dedicated funding for innovation hubs.
2. Foster Public-Private Collaboration: Encourage joint ventures, tech transfers, and incubation programs to boost indigenous tech development.
3. Streamline Regulatory Frameworks: Simplify procurement procedures, ensure faster clearances, and reduce red tape to promote indigenous production.

Conclusion

India's push for indigenization in defence, space, and digital sectors reflects its strategic vision of ***Atmanirbhar Bharat***. These efforts not only strengthen national security and economic resilience but also position India as a global technology leader.

Q.5) India participated in the private Axiom Mission 4 through one of its trained astronauts. What is the significance of such collaborations for India's human spaceflight programme? And also Highlight the challenges. (250 words, 15 marks)

Introduction

India's participation in **Axiom Mission 4**, a private spaceflight to the International Space Station **(ISS)**, through **Group Captain Shubhanshu Shukla**, marks a significant milestone. It showcases India's growing global presence in human space exploration.

Body

Significance of Such Collaborations for India's Human Spaceflight Programme

1. **Exposure to International Spaceflight Operations:** Collaborating with private space missions like Axiom offers Indian astronauts hands-on experience in operating within the ISS environment.
2. **Accelerating Gaganyaan Mission Readiness:** Insights and training from international missions help ISRO refine its human spaceflight strategies, safety procedures, and life support systems.
3. **Enhancing Global Partnerships:** Such collaborations build diplomatic and technological ties with global space agencies and private firms.
4. **Skill Development and Capacity Building:** Participation fosters knowledge transfer in astronaut training, mission simulation, and biomedical monitoring in space.
5. **Promoting Private Sector Involvement:** India's entry into commercial spaceflight signals confidence in combining public research with private innovation.
6. **Boosting India's Global Image in Space Technology:** Taking part in such international missions elevates India's standing as an emerging leader in space technology.

Challenges

1. **High Cost of Human Spaceflight:** Human missions are far more expensive than satellite launches. Example: Gaganyaan's budget exceeds ₹10,000 crore.
2. **Limited Indigenous Infrastructure:** India currently lacks a fully operational human-rated launch system. Example: The GSLV Mk III is still undergoing human-rating upgrades.
3. **Space Medicine and Life Support Gaps:** Advanced systems for long-duration life support and space medicine are underdeveloped. Example: India relies on global partners for astronaut health tech.
4. **Low Private Sector Participation in Manned Missions:** Private firms are more engaged in satellite services than human spaceflight. Example: Few Indian companies have ventured into crewed module development.

Way Forward

1. **Strengthen Astronaut Training Ecosystem:** Develop indigenous astronaut training facilities with international standards to reduce reliance on foreign agencies.
2. **Encourage Public-Private Partnerships:** Enable Indian private space firms to collaborate with **ISRO** on human spaceflight modules, tech systems, and crew support.
3. **Establish a Human Spaceflight Research Hub:** Create a dedicated R&D institution focusing on long-duration spaceflight, microgravity experiments, and space medicine.
4. **Promote International Cooperation:** Foster long-term collaborations with **NASA, ESA, Roscosmos,** and private players like **SpaceX and Blue Origin**.

Conclusion

India's role in Axiom Mission 4 is a strategic leap toward building a robust **human spaceflight ecosystem**. It not only supports the but also aligns with India's vision of becoming a key global player in space exploration.