

NEXT IAS

SCIENCE & TECHNOLOGY

**CIVIL SERVICES
EXAMINATION 2026**

Published by





MADE EASY Publications Pvt. Ltd.

Corporate Office: 44-A/4, Kalu Sarai
(Near Hauz Khas Metro Station), New Delhi-110016
Contact: 011-45124660, 8860378007
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Science & Technology

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First Edition: 2017
Second Edition: 2018
Third Edition: 2019
Revised & Updated: 2020
Fourth Edition: 2021
Fifth Edition: 2022
Sixth Edition: 2023
Seventh Edition: Nov. 2023

Eighth Edition: 2025

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CHAPTER 7

ROBOTICS AND ITS APPLICATION

7.1 Introduction

Robotics is the intersection of science, engineering and technology that is involved in the conception, design, manufacture and operation of machines, called robots.

The term robotics is an extension of the word robot. One of its first uses came from Czech writer Karel apek, who used the word in his play, Rossum's Universal Robots, in 1920. However, it is science fiction author Isaac Asimov who has been given credit for being the first person to use the term in the 1940s by Oxford English Dictionary. However, it wasn't until a couple of decades later in 1961 -- based on designs from the '50s -- that the first programmable robot, Unimate, was created to move scalding metal pieces from a die-cast machine.

7.2 Robot

A machine that is programmed to do a particular physical task like lifting, placing, driving, interacting, etc. Robots are a diverse bunch. Some walk around on their two, four, six, or more legs, while others can fly like birds. Some robots help physicians to do surgery, others toil away in dirty factories. There are robots the size of a coin and robots bigger than a car. Some robots can make pizzas, while others can land on Mars (NASA's Ingenuity). Thus, as per the function robots vary a great deal. However, there are few components which are more or less common in every robot, these are:

Components of Robots

- **Effectors:** "arms", "legs", "hands", "feet"
- **Sensors:** parts that act like senses and can detect objects or things like heat and light and convert the object information into symbols that computers understand
- **Computer:** the brain that contains instructions called algorithms to control the robot
- **Actuators:** Actuators are used in order to produce mechanical movement in robots. They are the muscles of robots.
- **Equipment:** this includes tools and mechanical fixtures.

Types of Robots

- **Pre-programmed Robots:** Pre-programmed robots are ones that have to be told ahead of time what to do, and then they simply execute that program. They operate in a simple, controlled environment and are often used for routine tasks
- **Humanoid Robots:** A humanoid robot is a robot resembling the human body in shape. The design may be for functional purposes, such as interacting with human tools and environments, for experimental purposes. Example: Sophia, a humanoid robot developed by Hong Kong-based Company Hanson Robotics.
- **Autonomous Robots:** An autonomous robot, also known as simply an auto-robot or autobot, is a robot that performs behaviours or tasks with a high degree of autonomy. These are used for delivery, construction, etc. E.g. Driverless vehicles.
- **Mobile Robots:** A mobile robot, is a robot that is capable of moving in the surrounding (locomotion). The mobility comprises of rolling, walking, running, climbing, etc. Thus, there are legged robots, wheeled robots, robots with claws, etc. Autonomous vehicles are an example of mobile robot.
- **Stationary Robots:** Stationary robots are not mobile, and they perform their tasks at a fixed location. They are designed for tasks like picking and placing, sorting, assembling, welding, and finishing.

Application of Robots

Robots are widely used in such industries as automobile manufacture to perform simple repetitive tasks, and in industries where work must be performed in environments hazardous to humans.

- **Manufacturing:** The manufacturing industry is probably the oldest and most well-known user of robots. These robots and co-bots (bots that work alongside humans) work to efficiently test and assemble products, like cars and industrial equipment. It's estimated that globally there are more than three million industrial robots in use right now.

NANOROBOTICS (NANOBOTS)

Nanorobotics is the emerging technology field creating machines or robots whose components are at or close to the scale of a nanometre (10⁻⁹ meters). Nanomachines and nanobots are largely in the research and development phase.

Researchers also hope to be able to create entire robots as small as viruses or bacteria, which could perform tasks on a tiny scale. Possible applications include micro surgery (on the level of individual cells), utility fog (a hypothetical collection of tiny robots that can replicate a physical structure), manufacturing, weaponry and cleaning.

- **Logistics:** Robots are being used for shipping, handling and quality control in most retailers and logistics companies. Today, as we expect our packages to arrive at blazing speeds, logistics companies employ robots in warehouses, and even on the road, to help maximize time efficiency. Right now, there are robots taking our items off the shelves, transporting them across the warehouse floor and packaging them. Additionally, a rise in last-mile robots (robots that will autonomously deliver our package to our door) ensure that we'll have various logistics bots in the near future.



- **Defense:** Defense robots are professional service robots that are deployed by the military in combat scenarios. They're often intended to enhance a soldier's existing capabilities while keeping them out of harm's way as much as possible. These defense robots perform a variety of functions, including:
 - Carrying heavy equipment.
 - Operating in dangerous situations to keep soldiers at a safer distance.
 - And rescuing wounded soldiers in combat zones.
 - Robotic drones accompanying manned fighter jets.

Some field robots in defense applications are beginning to be equipped with weapons for offensive capabilities. E.g. DRDO's Daksh robots.

- **HealthCare:** Robots have made enormous strides in the healthcare industry. These machines have used almost every aspect of healthcare, from robot-assisted surgeries to bots that help humans recover from injury in physical therapy. Examples of robots at work in healthcare are Toyota's healthcare assistants, which help people regain the ability to walk, and "TUG," a robot designed to autonomously stroll throughout a hospital and deliver everything from medicines to clean linens.

Recently, robots have been employed by pharmaceutical companies to help speed up the fight against COVID-19. These bots are now being used to take COVID-19 testing swabs, and are also being used by some manufacturers to produce PPE and respirators. E.g. ASHA robot in Kerala during COVID time. Mitra robot in Fortis Hospital in Bangalore.

BIONICS AND BIOMIMETICS ROBOTS

Biomimetics or Biomimicry is the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems. Biomimicry seeks solutions to human challenges by emulating nature's time-tested patterns and strategies.

Bionics is the science of constructing artificial systems that have some of the characteristics of living systems. Bionics is distinct from bioengineering, which is the use of living things to perform certain industrial tasks.

These are used to apply the way animals move to the design of robots. BionicKangaroo was based on the movements and physiology of kangaroos.

BionicKangaroo is developed by Festo's researchers and engineers by studying the way kangaroos move, and they applied that to the design of a robot that moves in a similar way. The robot actually saves energy from each jump and applies it to its next jump, much as a real kangaroo does.

- **Education:** Robots are being used for applications like language education, robotics education, teaching assistance, social skill development, special education, and guided learning through feedback. Further, robots can help specially-abled students having special requirements. For instance, children with autism are learning communication and social skills and students with developmental issues and attention disorders are learning focus. Individuals with severe physical disabilities are also offered a constant companion and health monitoring system. E.g. Eagle 2.0 humanoid robot is teaching physics to class-8 students in Bangalore.
- **Mining:** Mining operations are known for being unsafe and dangerous places to work. There are often

many mining related accidents regularly. In order to enhance safety and minimize life losses, companies have developed ways to get the job done, i.e., through robots. Robots are being used for material handling, exploration and digging under the earth, automated loading, etc.



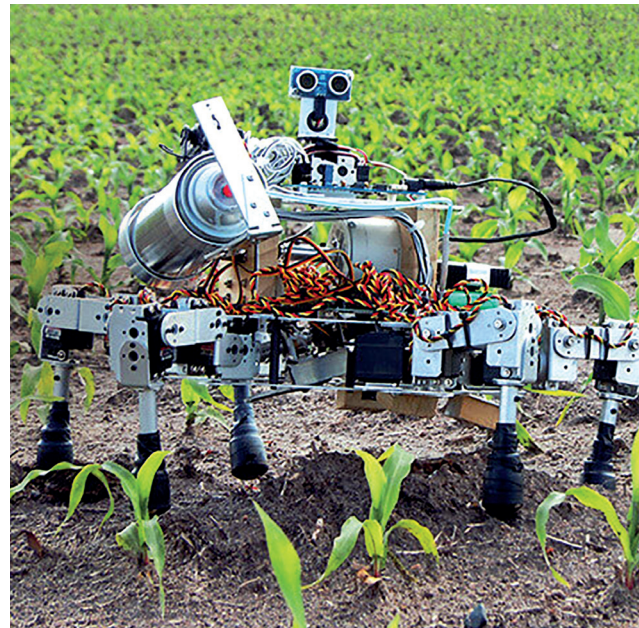
- **Disaster Management:** Robots with sensor based technologies can enhance the level of preparedness and the ability to handle consequences of the disaster. This higher level of preparedness can provide a better control over the loss. A team of mobile robots can quickly set up a network of mobile sensors and actuators for rapid action. For instance, Boston Dynamics' famed Big Dog and Petman.

Mobile robots have been used in search and rescue operation of World Trade centre terrorist attack and Hanshin-Awaji earthquake. In such situations mobile robots can enter voids too small or deep for a person, and can begin surveying areas that are inaccessible for people. Robots can carry cameras, thermal imagers, hazardous material detectors, and medical payloads into the interior of a rubble pile and set up communication link with human operator using the ad-hoc networks.

Robots equipped with accelerometer, gyroscope and magnetic compass as sensor devices, can plan its navigational path with reference to each other and can get the sensor network dynamically relocated. Team of mobile robots equipped with appropriate sensors and distributed and cooperative planning algorithms can also autonomously generate maps for oil spill or radiation leaks.

- **Agriculture and Forestry:** Automatic sensing, handling, and processing of produce by robots are commonplace in developed nations. They are also

being used for field preparation, sowing, harvesting and weed uprooting. In forestry robotics is being used for environmental preservation and monitoring, wildfire firefighting, inventory operations, and forest planting, pruning and harvesting.



- **Travel:** Today, if we have not yet travelled in driverless car, we have definitely heard and seen them on internet. These self-driving cars are today's reality. Through a combination of data science and robotics, self-driving vehicles are taking the world by storm. Automakers, like Tesla, Ford, Waymo, Volkswagen and BMW are all working on the next wave of travel that will let us sit back, relax and enjoy the ride.

7.3 New Research and Innovations

- **Machine Learning in robotics:** Machine learning and robotics intersect in a field known as robot learning. Robot learning is the study of techniques that enable a robot to acquire new knowledge or skills through machine learning algorithms. Some applications of robot learning include grasping objects, object categorization and even linguistic interaction with a human peer. Learning can happen through self-exploration or via guidance from a human operator.
- **AI and robotics:** AI and robots are a powerful combination for automating tasks. In recent times, artificial intelligence has become a significantly common presence in robotic solutions, bringing in learning capabilities and flexibility. Some of the applications are: Virtual assistance and chat-bots, autonomous flying, security, etc.

- **Soft Robotics:** Soft robotics is the specific subfield of robotics dealing with constructing robots from highly flexible materials, similar to those found in living organisms. In contrast to robots built from rigid materials, soft robots allow for increased flexibility and adaptability for accomplishing tasks, as well as improved safety when working around humans. Potential applications are surgical assistance, biomimicry for sea and space exploration, etc.
- **Wearable Robot:** A wearable robot is a specific type of wearable device that is used to enhance a person's motion and/or physical abilities. Wearable robots are also known as bionic robots or exoskeletons. These can help individual in post-surgery rehab or provide prosthetic support to differently-abled person
- **Collaborative Robot:** A cobot, or collaborative robot, is a robot intended for direct human robot interaction within a shared space. This is making automation easier than ever, even for small and mid-sized companies around the world.
- **Swarm Robotics:** It is the study of designing groups of robots that operate without relying on any external infrastructure or on any form of centralized control. In a robot swarm, the collective behaviour of the robots results from local interactions between the robots and between the robots and their environment. The design of robot swarms is guided by swarm intelligence principles. Application of swarm robotics includes demining, search and rescue, planetary or underwater exploration, and surveillance.

Issues Related to Robotics

- **Privacy, ethics and Security:** The data used for training the robots can be misused by reprogramming or modifying it, causing the robot to malfunction. Similarly, the data that the robot collects in its life cycle, such as videos, images, and location details can be hacked into and used for malicious purposes by fraudsters. Thus, ensuring the safety of the data always remains a major concern when using robotic solutions
- **Job loss:** Improvements in technology adversely affect wages and employment through the displacement effect, in which robots or other automation complete tasks formerly done by workers. A research of MIT Solan School highlighted that adding one robot to an area reduces employment in that area by about six workers. However, robotics and automation are making firms more efficient and more productive.
- **Maladaptation risk:** Robots made for specific tasks can hamper human activities.

7.4 India and Robotics

In India, Robotics is picking pace in various industries. Today, in India's growing startup ecosystem, Robotic startups have made viable space. For instance, *GreyOrange*, a company founded by a bunch of Indian techies in 2011 has become India's biggest robotic technology company. Their domain is supply chain automation. Other Indian start-up companies in robotics are *ASIMOV Robotics*, *I2U2 Robot* and *Sastra Robotics India* etc. The Government is also giving push to robotics along with other 4th generation technologies like Artificial Intelligence, Machine learning and Data Science. Indian Economic Survey 2017-18 identified robotics as a focus area (along with blockchain, AI and other futuristic technologies).

According to International Federation of Robotics (IFR) report published in January, 2019, around 3,412 new industrial robots were installed in India in 2017 – an increase of 30% over the 2,626 units that were installed in 2016. However, when it comes to robots per working population, the figure is abysmal. India had hardly 3 robots for every 10,000 workers, according to IFR.

There are various impediments or bottlenecks which are hampering India's potential of becoming an automation led nation, these are:

- **Lack of hardware ecosystem:** Weak manufacturing base results in imports of most of the components. The imports also face challenges such dual-use certifications (dual-use items are those items which are having both commercial and military or proliferation applications.), high import duties (in some cases), and other such hurdles.
- **Financial incentives:** Any company which imports robots into India currently pays about 26.85% (7.5 Basic Customs duty plus 18% GST) tax. This is a serious impediment to mass adoption of robots.
- **Critical human resources:** According to the FICCI-TSMG Advanced Manufacturing Survey, lack of quality human resources with necessary skills and expertise to work with advanced manufacturing technologies negatively impacts the ability to undertake cutting edge R&D in India.
- **Mindset shift required:** The industry faces political and societal hurdles. In spite of the Government's focus on robotics lately, somewhere the notion that robots will destroy jobs in an already precarious job market is completely misplaced. This was also witnessed during late 1980s when computer were introduced in banking sector.

Various Robots Developed in India

- **RADA:** In 2018, Vistara had introduced AI-enabled robot called 'RADA', that offers customers assistance. The robot scans boarding passes and provide details of the terminal, departure gates, weather conditions of the destination city. RADA also has multimedia content to provide entertainment through games, songs and videos for customers of the airlines.
- **KEMPA:** It is a humanoid robot that answers flight-related queries of passengers visiting Kempegowda International Airport, Bengaluru. It can communicate in English and Kannada. It is built by a Bengaluru-based startup, Sirena Technologies.
- **IRA and IRA 2.0:** These are humanoid robots of HDFC bank which assist customers visiting in the bank branches by interacting with them, answering bank-related queries, answering frequently asked questions (FAQs), and guiding them inside the branch with voice-based navigation.
- **INDRO:** INDRO is an autonomous robot built by an independent innovator Santosh Hulawale. The robot was made with easily available low-cost material like aluminium, wood, cardboard, plastic etc. It is used for tasks like entertainment, education and a few household works. It can also carry almost 150 kg of payload.
- **KP-Bot (India's first RoboCop):** It is a SI-ranked robot inducted in Kerala Police. The KP-Bot is deployed to perform duties of the front office of the police headquarters. The robot is equipped with facilities to fix appointment with officers, provide them with identity cards and also open new files based on public grievances.
- **Mitra:** It is a Humanoid Robot designed and developed by the Indian startup Invento Robotics, a robotic company in Bangalore. It is designed to engage in hospitality management and workplace productivity.
- **Bandicoot:** The Bandicoot is a robotic machine that is engineered for cleaning any type of sewer manholes. It is built by Genrobotics Innovation, Trivandrum, Kerala.
- **DRDO's Daksh:** Daksh is an electrically powered and remotely controlled robot used for locating, handling and destroying hazardous objects safely.
- **Vyom mitra:** It is a half-humanoid designed & developed by ISRO Inertial Systems Unit in Thiruvananthapuram. The humanoid will simulate the human functions required for space before real astronauts take off before August 2022 (Gaganyaan Mission).

7.5 Public Institutions in the Field of Robotics

Centre for Artificial Intelligence and Robotics (CAIR)

- It is a premier laboratory of DRDO involved in Research and Development in the areas of Artificial Intelligence, Robotics, Command and Control, Information and Communication Security.
- Among four thrust areas, the one pertaining to robotics is Autonomy and Cognition for Unmanned and Robotic Systems

All India Council for Robotics & Automation (AICRA)

- It is a not-for-profit organization is the apex body, setting up standards in Robotics & Automation.
- It provides support systems to institutions such as quality assurance, information systems and train-the-trainer (TTT) academies.
- Its vision is to make India a global leader in the field of Robotics, IoT and Artificial Intelligence.
- It has constituted a Robotics Skill Center to address Robotics Education challenges and delivering the talent pool ready for market.

TECH STARTUP PROGRAMME (AICRA)

AICRA in one of its B2C (Business-to-Consumer) Events in Technoxian 2019, has launched the Tech Startup Program which aims to give mileage to all new companies and newcomers wishing for technological innovations.

Tech Startup Program provides help with these basic necessities for a startup:

- **Administrative Support:** It has created a system which has lots of members at different vertical levels like corporate members, educationist members, B2C members enabling startups to connect to the direct target group.
- **Financial Support:** It has collaborated with lot of venture capitalists to help startups with the fundraising. Apart from this, there can be different levels of understandings between AICRA and the companies in which AICRA can be a stakeholder of a company or give loans to it, opening up multiple options.
- **Technological Support:** It provides technological guidance and support to startups with the help of domain experts and industry partner companies which provide all kinds of technology and infrastructure knowledge and support.

Indian Institute of Robotics

- IIR offers quality education in the field of robotics training online and offline.
- They provide support to budding engineers to learn the concepts of robotics and advanced controlling via latest technologies like Artificial Intelligence and Machine Learning

7.6 Conclusion

India needs to remove impediments like human resource crunch, investment in R&D, etc. and should back robotics with policy and institutional support. Robotics related

manufacturing can be incorporated in 'Make in India' program. Private players are to be incentivized with tax and other incentives.

Further, under Atal Innovation Mission, Robotics and related field are to be given boost. More training institute and introduction of advanced courses in premier institutes like IITs and NITs would help to bridge the human resource gap. PPP model are to be adopted with institutions like DRDO can give hand-holding support to new start-ups. In reverse, new start-ups in this field should be given government support so that scalable businesses can be made out of them.

■■■■



TRY SOME PRELIMS PREVIOUS YEAR QUESTIONS

1. Consider the following statements regarding the newly developed surgical robot versus

1. Versius is the worlds largest surgical robot.
2. It mimics the human arm and can be used to carry out a wide range of laproscopic procedures.

Which of the above statements is/are correct?

- (a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Ans. (b)

2. Which of the following is an Indian robot, made by ISRO (Indian Space Research Organisation) for space exploration purpose?

- (a) Valkyrie (b) Sita
(c) Athlete (d) Vyommitra

Ans. (d)

3. What does "PUMA" stands in context of Robotics?

- (a) Programmable Used Machine to Assemble
(b) Programmed Utility Machine for Assembly

- (c) Programmable Universal Machine for Assembly
(d) Programmed Utility Machine to Assemble

Ans. (c)

4. With the present state of development, applications of Robotics is in the following field?

1. Agriculture
2. Military
3. Medical science
4. Industry
5. Outer space

Select the correct answer using the codes given below:

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

Ans. (d)



TRY SOME MAINS PREVIOUS YEAR QUESTIONS

1. What are the areas of prohibitive labour that can be sustainably managed by robots? Discuss the initiatives that can propel the research in premier research institutes for substantive and gainful innovation.
2. Explain different components of robots.
3. With the help of suitable examples, discuss the applications of robotics in agriculture and health.