



ROBOTICS PAPER 1 (THEORY)

Maximum Marks: 70

Time Allotted: Three Hours

Reading Time: Additional Fifteen Minutes

Instructions to Candidates

1. You are allowed an **additional fifteen minutes** for **only** reading the question paper.
2. You must **NOT** start writing during reading time.
3. This question paper has **8 printed pages**.
4. There are twelve questions in the paper. All questions are compulsory.
5. This paper is divided into **three sections: A, B and C**.
6. **Section A** has **fourteen subparts** which are very short answer questions. Each question carries 1 mark.
7. While attempting **Multiple Choice Questions** in Section A, you are required to **write only ONE option as the answer**.
8. **Section B** has **seven questions** which are short answer questions. Each question carries 4 marks.
9. **Section C** has **four questions** which are long answer questions. Each question carries 7 marks.
10. **Internal choices** have been provided in **three questions in Section B** and in **two questions in Section C**.
11. The intended marks for questions are given in brackets [].

Instruction to Supervising Examiner

Kindly read **aloud** the Instructions given above to all the candidates present in the examination hall.

Note: The Specimen Question Paper in the subject provides a realistic format of the Board Examination Question Paper and should be used as a practice tool. The questions for the Board Examination can be set from any part of the syllabus, though the format of the Board Examination Question Paper will remain the same as that of the Specimen Question Paper. The weightage allocated to various topics, as given in the syllabus, will be strictly adhered to.

SECTION A – 14 MARKS

Question 1

- (i) The name of the lander in the Chandrayaan-2 mission was: (Recall) [1]
- (a) Kalam
 - (b) Dhruva
 - (c) Vikram
 - (d) Pragyan
- (ii) Identify the correct statements from the following regarding *Industry 5.0*: [1]
- (Understand)
- (P) It emphasises human-machine collaboration.
 - (Q) It aims to replace all human workers with robots.
 - (R) It has a human-centric approach.
- (a) Only (P) and (Q)
 - (b) Only (Q) and (R)
 - (c) Only (P) and (R)
 - (d) (P), (Q) and (R)
- (iii) A robot is first tested in a virtual environment to verify navigation algorithms before being deployed in a warehouse. [1]
- Which software is primarily responsible for this stage? (Recall)
- (a) ROS
 - (b) Gazebo
 - (c) Controller
 - (d) End-Effector

- (iv) Given below are two statements marked, Assertion and Reason. Read the two statements carefully and choose the correct option. [1]

Assertion: The da Vinci surgical system provides the surgeon with a magnified, three-dimensional view of the surgical area.

Reason: The system uses a high resolution, high-definition camera. (Understand)

- (a) Both Assertion and Reason are true, and Reason is the correct explanation for Assertion.
 - (b) Both Assertion and Reason are true, but Reason is not the correct explanation for Assertion.
 - (c) Assertion is true and Reason is false.
 - (d) Both Assertion and Reason are false.
- (v) Which of the following illustrates the concept of precision farming? (Apply) [1]
- (a) Increasing the size of the field for larger crop yield
 - (b) Using equal amount of water and fertilisers across the field
 - (c) Using sensors and GPS to monitor and manage the crops efficiently
 - (d) Reducing the cost of production by employing a smaller number of labourers
- (vi) Given below are two statements marked, Assertion and Reason. Read the two statements carefully and choose the correct option. [1]
- Assertion:** Agricultural drones help farmers monitor crop health over large areas.
- Reason:** Agricultural drones are equipped with sensors and cameras that collect data on crop conditions. (Understand)
- (a) Both Assertion and Reason are true, and Reason is the correct explanation for Assertion.
 - (b) Both Assertion and Reason are true, but Reason is not the correct explanation for Assertion.
 - (c) Assertion is true and Reason is false.
 - (d) Both Assertion and Reason are false.
- (vii) Which of the following is the **MOST** important design factor in designing an Autonomous Mobile Robot? (Evaluate) [1]
- (a) Biocompatibility
 - (b) Sensor accuracy
 - (c) Higher load capacity
 - (d) Human like movement

- (viii) Which of the following is an example of responsible use of robotics? **(Apply)** [1]
- (a) A bomb disposal robot with preprogrammed human override system
 - (b) A humanoid robot in customer service making all decisions autonomously
 - (c) A robotic system which automates a steel plant and displaces all human jobs
 - (d) An automated surgical robot installed in a hospital without checking its safety
- (ix) Which technology is commonly used by a 3D printer to build any object layer by layer? **(Recall)** [1]
- (a) GPS
 - (b) Machining
 - (c) Additive manufacturing
 - (d) Robotic welding system
- (x) A manipulator robot takes 12 seconds to assemble one component, while a human worker takes 30 seconds. How many additional components can the robot assemble than the worker in 1 hour? **(Apply)** [1]
- (a) 360
 - (b) 180
 - (c) 720
 - (d) 270
- (xi) Differentiate between a *weeding robot* and a *harvesting robot* based on their primary function. **(Recall)** [1]
- (xii) State *one* advantage of using robots in space exploration. **(Recall)** [1]
- (xiii) What is meant by *robot programming*? **(Recall)** [1]
- (xiv) State *one* difference between a *Planetary Rover* and a *Space Probe*. **(Understand)** [1]

SECTION B – 28 MARKS

Question 2

- (i) Mention *two* parameters that should be considered while designing a robot which will help in high altitude rescue operations. **(Apply)** [2]
- (ii) How does Robot Operating System and Gazebo work together in simulating a robot? **(Understand)** [2]

Question 3

- (i) A rehabilitation robot applies a constant force of 60 N while moving a patient's leg through a distance of 0.5 m in each therapy cycle. The robot performs 25 cycles in one therapy session. Calculate the total work done by the robot during one complete therapy session. **(Apply)** [2]
- (ii) Briefly discuss the usefulness of using robots in diagnostic and monitoring of patients. **(Recall)** [2]

Question 4

- (i) A rural hospital has limited access to experienced ultrasound technicians. Patients requiring abdominal ultrasound examination often need to travel far to a multispeciality hospital. To address the issue, the hospital installs an Ultrasound Robotic System.
- (a) Discuss how this robotic system can assist in the rural hospital. **(Understand)** [2]
- (b) Explain *two* challenges that the rural hospital might face during installation of the Ultrasound Robotic System. **(Understand)** [2]

OR

- (ii) ApexCare, a multispeciality hospital plans to reduce the load and fatigue of nurses by introducing robots for medicine delivery and non-clinical patient care.
- (a) Which healthcare robot will be most suitable for ApexCare? **(Understand)** [1]
- (b) State *three* advantages of using this robotic system in the hospital. **(Understand)** [3]

Question 5

Prakriti Agro Ltd., an agriculture firm wants to improve its crop productivity by reducing the wastage of seeds and agrochemicals. The firm wants to automate the seed sowing process using a smartly designed robotic system which will ensure precise placement of seeds and spray the required amount of agrochemicals only where needed.

- (i) Identify the most suitable agricultural robot for Prakriti Agro Ltd. **(Understand)** [1]
- (ii) Explain the working principle of this robot. **(Recall)** [3]

Question 6

Study the image given below and answer the questions that follow.



(Source: www.smeweb.com)

- (i) Identify the robot from the above image. **(Apply)** [1]
- (ii) List *three* major components of the robot identified and describe their functions. **(Understand)** [3]

Question 7

- (i) A vegetable farm in Punjab grows crops like potato, cauliflower and carrot. During the cultivation of vegetables, weeds grow between the crops and compete for nutrients and water. The farm introduces an AI based robot to automate the removal of weeds.
- (a) Which robot is introduced by the vegetable farm? **(Understand)** [1]
- (b) State *two* advantages of using this robot. **(Recall)** [2]
- (c) Explain how this robot helps in reducing crop damage. **(Apply)** [1]

OR

- (ii) The apple orchards in a hill station faces several challenges like shortage of seasonal labour and damages of apples caused by improper handling during the harvesting season.
- (a) Suggest a suitable agricultural robot which would improve the harvesting efficiency of the apple orchards. **(Understand)** [1]
- (b) How would this robot improve the harvesting efficiency of the apple orchards? **(Apply)** [2]
- (c) What role do the sensors play in this kind of robot? **(Understand)** [1]

Question 8

Attempt either subparts (i) and (ii) or (iii) and (iv).

- (i) Autonomous decision making is critical for any space robot. How does any space robot achieve this task? **(Apply)** [2]
- (ii) Comment on the power source and mobility system of the Mars Rover. **(Recall)** [2]
- OR**
- (iii) What are the special design features needed for a space robot to withstand extreme temperature and high radiation? **(Apply)** [2]
- (iv) Describe the working of the lander and rover of Chandrayaan-2. **(Recall)** [2]

SECTION C – 28 MARKS

Question 9

- (i) Technical progress in robotics justify taking risks with human safety. Comment on the above statement with reference to ethics in robotics. **(Evaluate)** [2]
- (ii) Sweet Treat, a chocolate manufacturing company wants to automate their factory. The engineers identified the following processes which can be automated by using robots.
- Transportation of raw material and finished product.
 - Handling chocolate moulds, finished products and containers.
 - Working alongside human for packaging of finished product.
- (a) Identify the most suitable type of robots for each of the above processes. **(Apply)** [3]
- (b) What role does Internet of Things (IoT) play in the automation of the chocolate factory? **(Understand)** [2]

Question 10

- (i) A hospital is treating patients recovering from knee replacement surgery. The doctors want to help patients regain mobility, improve muscle strength, and reduce recovery time through guided physical therapy.
- (a) What type of robot should the hospital use? (Apply) [1]
- (b) Give *two* reasons to justify your answer. (Apply) [2]
- (c) Identify the key components of the robot. Explain how each component contributes to patient recovery. (Understand) [4]

OR

- (ii) A surgeon performs minimally invasive surgery using a robotic system.
- (a) Which robotic system aids the surgeon in performing a minimally invasive surgery? (Apply) [1]
- (b) State *two* advantages of this system. (Recall) [2]
- (c) Explain the working of the major components of this robotic system. (Understand) [4]

Question 11

- (i) Contrast *two* features of *Industry 4.0* and *Industry 5.0*. (Recall) [2]
- (ii) How does a Security and Sensing Robot detect any hazard in real time? (Apply) [2]
- (iii) Europa, a moon of Jupiter has a huge liquid water ocean beneath its icy surface which makes it a strong candidate for containing extraterrestrial life. The icy surface of Europa is extremely cold and has an intense radiation environment. A spacecraft is to be designed to study the condition and chemical components of the subsurface ocean of Europa.
- (a) Identify the most suitable type of space robot for this mission. (Analyse) [1]
- (b) Select *two* appropriate components for the space robot. Justify your choice. (Evaluate) [2]

Question 12

Attempt either subparts (i) and (ii) or (iii) and (iv).

- (i) Explain why *task complexity* is a critical factor in robot selection. (Apply) [2]
- (ii) A farmer plans to introduce robotics into a large agricultural field. The farmer's primary objectives are:
- reducing water wastage.
 - regular monitoring of crop health.
 - reducing dependency on manual labour.
- (a) Name *one* robotic technology that can be used to monitor crop health. (Apply) [1]
- (b) Explain how this technology helps the farmer achieve the above objectives. (Understand) [2]
- (c) Comment on the use of different types of sensors in this robot. (Apply) [2]

OR

- (iii) Selection of robot depends on its *operating environment*. Explain. **(Apply)** [2]
- (iv) The use of Autonomous Ground Mobile Robots is transforming the manual labour dependent agricultural industry. Equipped with advanced vision and intelligent sensing technologies, these robots can perform a wide range of farming operations with remarkable precision and efficiency. It can automate agricultural tasks and reduce reliance on manual labour and increase productivity.
- (a) Discuss the working principle of an Autonomous Ground Mobile Robot. **(Understand)** [2]
- (b) Explain the effectiveness of this robot in improving water management and crop productivity. **(Apply)** [2]
- (c) Comment on the process of ground navigation for this kind of robot. **(Apply)** [1]





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ANSWER KEY

SECTION A – 14 MARKS

Question 1

- (i) (c) Vikram [1]
- (ii) (c) Only (P) and (R) [1]
- (iii) (b) Gazebo [1]
- (iv) (b) Both Assertion and Reason are true, but Reason is not the correct explanation for Assertion. [1]
- (v) (c) Using sensors and GPS to monitor and manage the crops efficiently [1]
- (vi) (a) Both Assertion and Reason are true, and Reason is the correct explanation for Assertion. [1]
- (vii) (b) Sensor accuracy [1]
- (viii) (a) A bomb disposal robot with preprogrammed human override system [1]
- (ix) (c) Additive manufacturing [1]
- (x) (b) 180 [1]
- (xi) A weeding robot removes unwanted weeds from crop fields, whereas a harvesting robot picks mature crops or fruits for collection. [1]
- (xii) Using robots in Space exploration: [1]
 - Enables exploration of hazardous environments without risking human life.
 - Facilitates operation in extreme space conditions.
 - Helps in collecting scientific data from distant celestial bodies.
- (xiii) Robot programming is the process of writing instructions or commands that enable a robot to perform specific tasks automatically. [1]
- (xiv) A Planetary Rover moves on the surface of a planet or moon to conduct exploration, whereas a Space Probe travels through space to collect data without operating on a planetary surface. [1]

SECTION B – 28 MARKS

Question 2

- (i) Design parameters of a high altitude rescue operation robot: [2]
- Payload (load-carrying capacity): Large load carrying capacity to transport an injured human or heavy medical gears.
 - Mobility: The robot should have mobility components (ex: multi legged system) which can traverse through mountainous terrains.
 - Operating Environment: The robot must function in sub-zero temperatures and should have high wind resistant capacity.
 - Sensing and Vision system: Thermal imaging and Infrared cameras should be installed to locate body heat through snow.
- (ii) Robot Operating System (ROS) helps developers build robot applications. [2]
It provides libraries, tools and communication protocols for sensor integration, motion planning, navigation, robot simulation and visualisation.
Gazebo tests robots virtually, avoiding costly real world failures. It is a 3D simulation tool to test robots in virtual environments before implementing the robot in real hardware.
Therefore, in robot simulation Gazebo pretends to be the real world while ROS runs the robot's software and acts as the controller.

Question 3

- (i) Work done per cycle = $60 \times 0.5 = 30 \text{ J}$ [2]
Total work done by the robot = $30 \times 25 = 750 \text{ J}$
- (ii) Robots can diagnose a wide range of diseases by analysing laboratory test results and interpreting different medical imaging with a consistent accuracy. [2]
Robots can continuously monitor a patient and flag anomalies (if any) in heart rate, oxygen saturation, blood pressures etc. This helps the healthcare provider in imparting efficient and timely medical care.

Question 4

- (i) (a) An Ultrasound Robotic System enables an expert doctor to perform real time scans remotely on patients. The onsite robotic manipulator arm would hold the probe at the rural clinic while a specialist doctor controls it via a haptic joystick. This would eliminate long distance travel for patients and bring expert diagnostic to rural areas. [1]
Live audio and video feed would enable the doctor to address any complicated issue thus ensuring timely treatment.
The robotic system improves the quality of diagnostic imaging and minimises human errors.

- (b) Challenges of using Ultrasound Robotic System in the rural hospital: [2]
- Rural hospitals / clinics might face economic issues in installing the system as the ultrasound robotic systems are very costly.
 - Skills of the doctors and the operators need to be updated periodically for proper implementation of the system.
 - This kind of robotic system also increases the maintenance cost.

OR

- (ii) (a) Assistance Robot [1]
- (b) Advantages of using Assistance Robot in hospitals: [3]
- Medicines and medical supplies are efficiently delivered.
 - It reduces the workload of nurses and hospital staff.
 - By providing timely assistance, it improves the quality of patient care.
 - It minimises human contact, reducing the risk of infection.
 - It enhances hospital workflow and operational efficiency.

Question 5

- (i) Seeding and Spraying Robot [1]
- (ii) Working principle of Seeding and Spraying robot: [3]
- The robot operates by receiving field coordinates through a GPS module to navigate the field accurately.
 - It places seeds at the required spacing and depth based on pre-programmed planting pattern.
 - It sprays pesticides / fertilisers only where required (precise application).
 - It uses sensors to detect field conditions (soil moisture, wind speeds) and control operations automatically.

Question 6

- (i) Robotic Manipulator / Manipulator Arm [1]
- (ii) Three major components of the Robotic Manipulator / Manipulator Arm and their functions: [3]
- End-Effector is the terminal tool at the end of the arm. It is task specific and can be changed. Example gripper claw, suction pad, welding torch etc.
 - Controller is the brain that sends commands for the specific movement of the robot. It coordinates sequences, timing, positioning and depends on sensor feedback.
 - Sensors of a manipulator can include vision sensors and position sensors. Sensors allow precise movement of the robotic arm based on real time environmental conditions.
 - Actuators are the muscles of the robotic manipulator. They make the manipulator move or operate. The actuators convert the energy from electric, pneumatic or hydraulic drives into mechanical motion.

Question 7

- (i) (a) Weeding Robot [1]
- (b) Advantages of using Weeding robot: [2]
- Weeds are cut down automatically thus lowering pesticide reliance.
 - As the robots work autonomously day and night, it reduces labour cost.
 - Precise removal of weeds avoids damage to the crop thus increasing productivity.
 - It enables timely harvesting by efficient crop harvesting.
- (c) It identifies and removes only weeds, leaving the nearby vegetables undamaged. [1]

OR

- (ii) (a) Harvesting Robot [1]
- (b) Harvesting robots automatically detect the maturity of the apples and accurately picks the apples with minimal crop damage thus improving harvesting efficiency. [2]
- (c) The installed sensors and computer vision analyse sizes, colours and defects of the apples. These sensors also allow the robots to navigate the apple orchard. They also determine the exact grip force required to pick the apples without damaging them. [1]

Question 8

- (i) A space robot must operate semi autonomously because of the signal delay from the ground control command. These kinds of robots achieve the semi-autonomy by using onboard AI, machine learning models and installed sensor systems. [2]
- (ii) Power system of Mars Rover: [2]
- Mars Rover uses Solar panels or Radioisotope Thermoelectric Generators which provide long term power in harsh Martian conditions.
- Mobility system of Mars Rover:
- It has a six-wheeled rocker-bogie suspension which allows the rover to climb over rocks.

OR

- (iii) Design feature of a space probe to withstand high temperature includes: [2]
- Special heat-resistant materials like ceramics or silicon carbide.
 - Coolants and heat pumps are used as a heat transfer mechanism.
 - The outer layer of the probe is made with reflective materials which reflect external solar radiation.
- Design feature of a space probe to protect it from radiation:
- Lead glass shielding is used for protecting the space robot from radiation.
 - Highly protected electrical systems are used to shield the electrical components from Galactic Cosmic Radiations (GCR).

- (iv) The lander of Chandrayaan 2 mission was designed to deliver the rover safely in the lunar surface. It had hazard detection and fine braking sensors. [2]
The rover of Chandrayaan 2 was a six-wheeled robot with solar panels and spectrometers. The purpose of the rover was to study the lunar soil composition.

SECTION C – 28 MARKS

Question 9

- (i) (a) No, technical progress in robotics does not justify taking risks with human safety. Robots must be designed to minimise risk of physical and digital harm to humans. Ethics in robotics suggests stern safety protocols must be preprogrammed in the robots, and regular safety testing is necessary to nullify risks to humans. All the stakeholders must ensure that robots do not manipulate humans emotionally or psychologically. [2]
- (ii) (a) • Transporting raw material and finished product: Automated Guided Vehicle [3]
• Handling chocolate moulds, finished products and containers: Robotic Manipulator / Manipulator arm.
• Working alongside human for final packaging: Cobots (Collaborative robots)
- (b) The Internet of Things (IoT) serves as the sensory and connective nervous system for the chocolate factory. IoT connects all the robots and links all the control systems with the cloud which allows real time data collection, predictive maintenance and optimisation of resources. It also helps in autonomous decision making. [2]

Question 10

- (i) (a) Exoskeleton robot [1]
- (b) Exoskeleton robots are used in rehabilitation of a patients recovering from knee replacement surgery because they: [2]
• efficiently assist patients in regaining mobility.
• support walking and movement.
• improve muscle strength.
• speed up the recovery process.
• enable repetitive therapy and exercises.
- (c) Key components of exoskeleton robots [4]
• Structural frame and links: The wearable structure made by carbon fibre, aluminium or titanium that supports the patient's body.
• Actuators and motors: Actuators provide motion to the exoskeleton structure which assist in walking, standing or other movements. The actuators convert the power coming from the electrical, pneumatic or hydraulic drives into mechanical motions.
• Sensors: The sensors detect the users' motion (e.g. muscle signals, joint signals). It can also detect pressure or electromagnetic signals to anticipate the patient's intent.
• Control System: The central controller runs algorithm to interpret signals from the user and adjusts the actuator response in real time.

OR

- (ii) (a) da Vinci Surgical System (Surgical Robot) [1]
- (b) Advantages of using da Vinci Surgical System (Surgical Robot): [2]
- provides high-definition 3D vision.
 - offers greater precision and control.
 - reduces patient recovery time.
 - minimises blood loss.

- (c) The da Vinci Surgical System works by translating a surgeon's hand movements at a console into precise micro movements of surgical instruments inside the patient's body. [4]

Following are the major components of this system:

- Surgeon Console: This is the control centre located outside the sterile field where the surgeon sits and controls the robotic arms.
- Patient Cart: This is the operative unit positioned directly above the patient, holding multi jointed arms with the surgical instruments.
- Vision System / Cart: This offers a 3D high-definition view of the internal surgical site. The vision system has lenses and powerful fibre optic light sources.
- EndoWrist Instruments: These instruments mimic the movement of a human wrist which aids in complex surgical manoeuvres.

Question 11

(i)

Industry 4.0	Industry 5.0
Industry 4.0 focuses on automation, operational speed and maximising efficiency.	Industry 5.0 focuses on humans, sustainability and long term robust systems.
Here the automation is done by traditional industrial robots	Automations are done by Cobots.
Resource efficiency come as a secondary goal.	Focuses more on sustainability and uses renewable power sources.

[2]

- (ii) A Security and Sensing robot uses sensors and cameras to monitor surroundings in real time. If an environmental anomaly is detected, the inbuilt AI processes the data and sends an alert to human supervisors. These kinds of robots generally consist of temperature, proximity, infrared, smoke and gas sensors. [2]

- (iii) (a) As it is very difficult to land on Europa, a flyby mission by a Probe has to be used. [1]

- (b) [2]
- Camera and imaging system: To provide scientific imaging to assess the conditions of the subsurface ocean.
 - Scientific instruments: Spectrometers and scanners to measure the atmospheric conditions.
 - Communication Systems: Dish antennas to send data back to Earth and receive remote control commands.
 - Power System: Radioisotope Thermoelectric Generator as it is a deep space mission.

Question 12

- (i) Any robot is selected depending on the complexity of the task the robot is required to perform. Higher complexity demands advanced multi-axis mobility, smart vision systems and intelligent navigating abilities. The complexity of task also decides whether the robot needs high precision or requires greater adaptability. [2]
- (ii) (a) Monitoring and Sensing Robot (or Agricultural Drone) [1]
(b) Reducing water wastage: [2]
- Detects water stress and irrigation needs.
 - Enables precision irrigation, reducing water wastage.
- Crop health:
- Monitoring and Sensing robots are designed to collect environmental and crop health data. They monitor crop health continuously.
 - Detects diseases and nutrient deficiencies early.
- Dependence on manual labour:
- Reduces manual field inspection and labour.
 - Improves crop productivity through timely interventions.
- (c) Environmental Sensors: To monitor ambient heat levels and moisture data to collect real time weather data. [2]
Vision Sensors: To capture images and videos of the crop for assessing crop health and early disease detection.

OR

- (iii) The environmental conditions in which a robot operates decide its design features. The structure, mobility mechanism, choice of sensors and selection of power source depend on whether the robot operates indoor or outdoor. Special design considerations are also considered when the robot operates in extreme environments or underwater. [2]
- (iv) (a) Autonomous Ground Mobile Robot rely on a combination of GPS-based path planning, vision systems, and sensor feedback to manoeuvre autonomously across a farm. They scan the environment using cameras or multispectral sensors and make real-time decisions about how to interact with crops- whether to harvest ripe produce, remove weeds, or trim excess foliage. [2]
(b) The Autonomous Ground Mobile Robot improves the management of water resources by: [2]
- continuously monitoring the soil moisture.
 - automatically regulating irrigation based on sensor data.
 - reducing water wastage through precision irrigation.
- The crop productivity is increased by:
- maintaining optimum soil moisture for healthy crop growth.
 - reducing manual monitoring and labour.
 - improving crop yield through timely irrigation.
- (c) The mobility system of the ground mobile robot has wheels or tracks which enables the robot in navigating long distances in uneven terrain. [1]