ICSE Class 10 Robotics and Artificial Intelligence Specimen Paper 2

Written by the Future Topper subject team on the CISCE examination pattern. Not an official CISCE paper. Found a mistake? Write to contactfuturetopper@gmail.com

Maximum Marks: 100 | Time Allowed: Two hours | Reading Time: 15 minutes

Section A is compulsory. Attempt any four questions from Section B.

General Instructions

Write your answers on the separate answer paper provided. The first 15 minutes are for reading the paper, and you may not write during that time. Marks for each question, or part of a question, are shown in brackets. Section A carries 40 marks and must be attempted in full. Section B carries 60 marks, and you must answer any four of the six questions in it. Write all programs in Python, give meaningful names to your variables and add short comments where they help. Where a question gives a sketch for a single board computer written in Arduino C, you need only read it and explain what it does; you are not asked to write Arduino code. Where a question asks for a diagram, draw it yourself in pencil and label it; no printed figures are supplied, and every arrangement or set of data is described in words. Show the working for every calculation. This paper is the theory component of the subject and carries 100 marks. The internal assessment, also of 100 marks, is based on the Robotics, Artificial Intelligence and Python assignments completed in school during the year.

SECTION A (40 Marks)

Attempt all questions from this Section.

Question 1 [20]

Choose the correct answer for each of parts (i) to (xviii), and state whether each statement in parts (xix) and (xx) is True or False. Write only the answer; do not copy the question. Each part carries 1 mark.

(i) A robotic system in which a surgeon, seated at a console, controls robot arms that hold small instruments inside a patient's body is used mainly for:

(a) warehouse logistics (b) smart mobility

(c) minimally invasive surgery (d) crop spraying

(ii) A robot at the entrance of a bank branch greets visitors, answers common questions by voice and guides each visitor to the right counter. It is an example of:

(a) an assistant robot (b) a warehouse robot

(c) an autonomous car (d) an industrial welding robot

(iii) Helical gears are often preferred to spur gears in a robot's gearbox because:

(a) they can join only shafts that are at right angles (b) their teeth engage gradually, so they run more smoothly and quietly

(c) they have no teeth (d) they change rotary motion into linear motion

(iv) A driving gear of 20 teeth meshes with a driven gear of 60 teeth. If the torque on the driving shaft is 1.5 N m, the torque on the driven shaft, ignoring friction, is:

(a) 0.5 N m (b) 1.5 N m (c) 3.0 N m (d) 4.5 N m

(v) A gyroscope fitted in a self-balancing robot measures:

(a) the distance to a wall (b) the rate at which the robot is turning or tipping over

(c) the temperature of the motor (d) the brightness of the room

(vi) The actuator best suited to turn the jaw of a robot gripper to exactly 45 degrees and hold it there is:

(a) a servo motor (b) a plain DC motor without feedback

(c) a solenoid (d) a pneumatic cylinder

(vii) In a closed loop control system, the signal taken from the sensor back to the controller is called:

(a) the set point (b) the actuator signal

(c) the disturbance (d) the feedback

(viii) The joint between the upper arm and the forearm of a robot, which lets the forearm swing about a fixed axis like a door on its hinge, is:

(a) a prismatic joint (b) a revolute joint

(c) a rigid link (d) a fixed joint

(ix) An edge-detection robot moving on a table top has infrared sensors pointing down at the table. It knows that it has reached the edge of the table when:

(a) the sensor receives much more reflected light than before (b) the motor speed doubles

(c) the reflected infrared signal is lost because there is no surface close below the sensor (d) the battery voltage falls

(x) Which one of the following is an automated system rather than an autonomous one?

(a) a robot vacuum cleaner that maps a room and plans its own cleaning path (b) a self-driving car

(c) a traffic signal that changes colour on a fixed timer (d) a delivery drone that changes its route in a strong wind

(xi) In machine learning, a program improves its performance mainly by:

(a) being given a written rule for every possible case (b) learning patterns from examples in data

(c) increasing the speed of its processor (d) copying the programs of other computers

(xii) Which one of the following is a task at which a computer generally does better than a human?

(a) searching lakhs of records for a matching number in under a second (b) understanding how a friend feels from the tone of her voice

(c) using common sense in a situation never met before (d) enjoying a piece of music

(xiii) In a dataset used to predict the price of a flat, the columns such as area, number of rooms and locality are called:

(a) labels (b) models (c) algorithms (d) features

(xiv) An image classifier correctly labels 180 of the 200 images in its testing data. Its accuracy is:

(a) 18 per cent (b) 80 per cent (c) 90 per cent (d) 95 per cent

(xv) If t = (5, 10, 15, 20), the output of print(t[1:3], len(t)) is:

(a) (5, 10, 15) 4 (b) (10, 15) 4 (c) (10, 15, 20) 3 (d) (10, 15) 3

(xvi) If s = "Mumbai", the output of print(s.upper().find("B"), s.endswith("ai")) is:

(a) 3 True (b) 4 True (c) 3 False (d) -1 True

(xvii) Statement I: A problem statement is written before the 4Ws of the problem are identified. Statement II: The Where block of the 4Ws canvas describes the situation or location in which the problem occurs.

(a) Both Statement I and Statement II are correct. (b) Both Statement I and Statement II are incorrect.

(c) Statement I is correct but Statement II is incorrect. (d) Statement I is incorrect but Statement II is correct.

(xviii) Statement I: In deterministic decision making, the same input always produces the same output. Statement II: A map app that estimates an 80 per cent chance of reaching the station within 20 minutes is an example of probabilistic decision making.

(a) Both Statement I and Statement II are correct. (b) Both Statement I and Statement II are incorrect.

(c) Statement I is correct but Statement II is incorrect. (d) Statement I is incorrect but Statement II is correct.

(xix) The string method isalnum() returns True for the string "Robo 2027".

(xx) Pandas is a Python library mainly used to handle data arranged in rows and columns, such as data read from a CSV file.

Question 2 [20]

(i) Name two robots used in smart homes, and state the job each one does. **[2]**

(ii) Give two ways in which robots and robotic systems can be used in a smart school. **[2]**

(iii) Name the sensor a voice-controlled robot uses to hear spoken commands, and state two things that must happen to the signal before the robot can act on a command. **[2]**

(iv) Distinguish between linear and rotary actuators, giving one example of each. **[2]**

(v) A robot arm has a revolute joint at its base, about which the whole arm turns through a full circle in a horizontal plane, and a prismatic joint that lets the arm slide in and out so that its gripper is between 20 cm and 50 cm from the base. State the number of degrees of freedom of the arm, and describe the region its gripper can reach. **[2]**

(vi) Name two boards commonly used as the single board computer in school robotics, and state one difference between them. **[2]**

(vii) During data exploration, when would you use a pie chart and when a line graph? Give one example of each. **[2]**

(viii) Give two ways in which machine intelligence is linked to human intelligence. **[2]**

(ix) Distinguish between training data and testing data, and state why the two are kept separate. **[2]**

(x) Give the output of the following code. **[2]**

```
L = [12, 7, 9]
L.extend([3, 7])
L.sort()
print(L, L.count(7), L.index(9))
```

SECTION B (60 Marks)

Attempt any four questions from this Section. Each question in this Section carries 15 marks.

Question 3 [15]

(i) A fruit-processing unit in Ratnagiri wants a machine to sort Alphonso mangoes into Grade A and Grade B. Explain how a machine learning system would learn to do this, naming two features it could use. **[3]**

(ii) Give the output of the following code, showing clearly where each line begins. **[3]**

```
print("Team\tScore")
print("Arjun\n42")
print("Path: C:\\robots\\arm")
```

(iii) In this question, assume that every Indian vehicle registration number has exactly 10 characters, in the pattern two letters (the state code), two digits, two letters and four digits, as in MH12AB3456. Write a Python program that does the following.

1. Accepts a registration number from the user and converts it into capital letters.
2. Checks the pattern, using len(), slicing and the methods isalpha() and isdigit(), and prints Valid number or Invalid number.
3. For a valid number, prints the state code and the last four digits separately.
4. For a valid number, prints Registered in Maharashtra if the number starts with MH, using startswith(), and Registered outside Maharashtra otherwise.
5. For a valid number, prints it with a space between the four groups, as in MH 12 AB 3456, using the join() method.

Write the output of your program for the input ka05mn0921, and for the input MH12A34567. **[9]**

Question 4 [15]

(i) A robot at a poultry farm near Namakkal picks eggs from a conveyor belt and places them in trays. Explain the role that a vision sensor and a tactile (touch) sensor would each play, and say why the tactile sensor is especially important in this robot. [3]

(ii) For each of the following gear types, state how the shafts are arranged and give one use in a robot or a machine: spur gears, a worm and worm wheel, and a rack and pinion. [3]

(iii) The elbow of a robot arm is a revolute joint turned by a DC motor. A potentiometer fixed at the joint acts as a position sensor: the single board computer reads it as a number from 0, when the joint is at 0 degrees, to 1023, when the joint is at 180 degrees, the reading rising in proportion to the angle. The joint must move to 60 degrees.

(a) State the role of the position sensor, the controller and the motor in this system. [3]

(b) Find the reading the controller should aim for, and the angle of the joint when the reading is 114. Describe, step by step, what the controller does to move the joint from this position to 60 degrees. [3]

(c) Suppose the wire from the potentiometer breaks, so that the controller reads 0 all the time. Explain what would happen, and suggest two safety measures. [3]

Question 5 [15]

(i) Explain three ways in which warehouse robots help an online shopping company during a festival sale. [3]

(ii) A simple microwave oven heats food at the power level and for the time the user sets, and then stops. Name the input, the controller and the actuator in this control system, and explain why it is an open loop system. [3]

(iii) A car company plans to sell two models in India. Model P has driver-assistance features such as lane departure warning, adaptive cruise control and automatic emergency braking. Model Q is designed to drive itself through a city without a driver.

(a) Give three differences between a driver-assisted car like Model P and an autonomous car like Model Q. [3]

(b) Name three sensors that Model Q would use, and state what each one does. [3]

(c) Give three reasons why a fully autonomous car would find it harder to drive on Indian city roads than a driver-assisted car. [3]

Question 6 [15]

(i) Describe how you would design a sliding (prismatic) jaw for a robot gripper in Tinkercad, and how you would check the range of its motion on screen. [3]

(ii) The following Arduino sketch is written in the Tinkercad Circuits code editor. A push button is wired so that pin 2 reads HIGH while the button is pressed, and an LED is connected to pin 13. (a) State what the setup() function does. (b) State what the LED does when the button is pressed briefly and released. (c) State what the LED appears to do while the button is held down continuously, and why. [3]

```
void setup() {
  pinMode(2, INPUT);
  pinMode(13, OUTPUT);
}

void loop() {
  int button = digitalRead(2);
  if (button == HIGH) {
    digitalWrite(13, HIGH);
    delay(2000);
```

```
    }
    digitalWrite(13, LOW);
}
```

(iii) A team builds a four-wheeled line follower robot to run along a black line on a white track. It has two infrared sensor modules at the front, one just to the left of the line and one just to the right, so that both sensors are over white when the robot is centred on the line.

(a) List the main components the robot needs, other than the chassis and the wheels, and state the role of each. **[3]**

(b) State what the robot should do for each of the four combinations of readings: both sensors on white; left on black and right on white; left on white and right on black; both on black. **[3]**

(c) Each wheel has a diameter of 6.5 cm, and the motors turn the wheels at 120 rpm. Taking pi as 3.14, find the speed of the robot in centimetres per second, and the time it takes to cover a straight 3 m stretch of the track, assuming the wheels do not slip. **[3]**

Question 7 [15]

(i) Distinguish between an automated system and an autonomous system, giving one example of each. **[3]**

(ii) Explain the role of data, of algorithms and of programming in machine learning. **[3]**

(iii) Read the following account of a robotics start-up in Bengaluru and answer the questions that follow. Situation 1: an engineer uses the company's powerful computers every night, without permission, to run a game server for his friends. Situation 2: an engineer who designed a new gripper while working for the company leaves, and begins selling an almost identical gripper through his own firm; each side says the design belongs to it. Situation 3: the company's advertisement claims that its delivery robot "never makes a mistake and needs no human supervision at all".

(a) Name the ethical issue shown in each of the three situations. **[3]**

(b) Explain why each of these is harmful. **[3]**

(c) Suggest one measure the company should take for each situation. **[3]**

Question 8 [15]

(i) A team in the Delhi NCR region is planning an AI project to predict the next day's air quality index (AQI) of their town. Name two sources from which they could acquire data for this project, and explain what a system map is and how it would help them. **[3]**

(ii) Distinguish between supervised learning and unsupervised learning, giving one example of each. **[3]**

(iii) In a recycling drive at a school in Pune, the five houses collected the following numbers of plastic bottles: Tagore 148, Raman 212, Bose 176, Kalam 240 and Sarojini 124. Write a Python program that does the following.

1. Stores the names of the houses in one list and the numbers of bottles in another list.
2. Calculates and prints the total number of bottles, and then prints the name of each house with its share of the total as a percentage, rounded to one decimal place.
3. Prints the name of the house that collected the most bottles, with its count.
4. Builds a list of the houses that collected more than the average number of bottles, converts it into a tuple named leaders, and prints the tuple.
5. Draws a bar chart of the bottles collected by each house using matplotlib.pyplot, with the title Bottles Collected by Each House and suitable labels on both axes, and displays it.

State the values your program prints. **[9]**

ANSWER KEY AND MARKING SCHEME

A full model answer is given for every part. Marks shown in italics are the step marks an examiner would award. Accept any other correct point of equal value, and accept answers in the candidate's own words; where a question asks for a set number of points, credit only that number, taking the best of those offered. For a Python program, credit correct logic and the correct use of the list, tuple, string or library feature the question names; accept any sensible variable names and any correct alternative logic that gives the same output, and do not deduct for a different but consistent layout. A minor slip of syntax that does not change the logic loses at most one mark in a program. In a calculation, a correct method with an arithmetic slip loses only the mark for the final value, and a wrong value carried forward correctly is not penalised twice.

Question 1 [20]

(i) (c) minimally invasive surgery. The arms work through small cuts with steady, precise movements.

(ii) (a) an assistant robot. It helps people with information and guidance through speech and movement.

(iii) (b) their teeth engage gradually, so they run more smoothly and quietly. The teeth are cut at an angle to the axis.

(iv) (d) 4.5 N m. The gear ratio is 60 / 20 = 3, and the torque is multiplied by 3.

(v) (b) the rate at which the robot is turning or tipping over, that is its angular velocity.

(vi) (a) a servo motor. It has a built-in position sensor and turns to the angle it is commanded, usually within 0 to 180 degrees.

(vii) (d) the feedback.

(viii) (b) a revolute joint.

(ix) (c) the reflected infrared signal is lost because there is no surface close below the sensor. The robot then stops or turns back.

(x) (c) a traffic signal that changes colour on a fixed timer. It repeats a pre-set sequence and does not react to the traffic.

(xi) (b) learning patterns from examples in data.

(xii) (a) searching lakhs of records for a matching number in under a second. Speed and accuracy on large amounts of data are where machine intelligence is strongest.

(xiii) (d) features. The price, which is to be predicted, is the label.

(xiv) (c) 90 per cent. Accuracy = 180 / 200 x 100.

(xv) (b) (10, 15) 4. The slice [1:3] takes indexes 1 and 2, and the tuple has four elements.

(xvi) (a) 3 True. In MUMBAI the letter B is at index 3, and Mumbai ends with ai.

(xvii) (d) Statement I is incorrect but Statement II is correct. The problem statement is written from the 4Ws, after they are identified.

(xviii) (a) Both Statement I and Statement II are correct. A probabilistic system states how likely an outcome is, rather than giving one certain answer.

(xix) False. The space is neither a letter nor a digit, so isalnum() returns False.

(xx) True.

1 mark for each correct answer. No mark is deducted for a wrong answer.

Question 2 [20]

(i) A robot vacuum cleaner moves around the rooms on its own, cleans the floor, avoids furniture and stairs and returns to its charging dock. A robotic lawn mower cuts the grass within a marked boundary. Other acceptable answers are a window-cleaning robot, a home security robot that patrols and sends camera images to the owner's phone, and a companion robot for elderly people.

First robot with its job 1. Second robot with its job 1.

(ii) A telepresence robot fitted with a camera, screen and microphone lets a student who is ill at home attend the class and move about the room. A camera-based system with face recognition can mark attendance automatically as students enter. Other acceptable uses are a reception robot that guides visitors, a teaching assistant robot that quizzes students or tells stories, and a cleaning robot for the corridors.

First use 1. Second use 1.

(iii) A microphone, which changes the sound of the voice into an electrical signal. The signal is converted into digital form and passed to speech recognition software, which picks out the words spoken; the controller then matches the words to a known command, such as "move forward", and sends the matching signals to the motors.

Microphone 1. Recognition of the words and matching to a command 1.

(iv) A linear actuator produces motion in a straight line, as needed for a prismatic joint or a pushing gripper, for example a pneumatic or hydraulic cylinder, an electric linear actuator or a solenoid. A rotary actuator produces turning motion, as needed for wheels and revolute joints, for example a DC motor, a servo motor or a stepper motor.

Linear with an example 1. Rotary with an example 1.

(v) The arm has 2 degrees of freedom, one from the revolute joint and one from the prismatic joint. The gripper can reach every point of a flat ring centred on the base, between a circle of radius 20 cm and a circle of radius 50 cm.

2 degrees of freedom 1. Ring between radii 20 cm and 50 cm 1.

(vi) Arduino Uno and Raspberry Pi. An Arduino is a microcontroller board that runs one program uploaded to it, with no operating system, and is well suited to reading sensors and driving motors. A Raspberry Pi is a small complete computer that runs an operating system such as Linux, can run Python programs and handle a camera, a screen and the internet, and can run several programs at once.

Two boards named 1. One correct difference 1.

(vii) A pie chart shows how a whole is divided into parts, each slice being a share of the total, for example the percentage of a family's monthly spending that goes on food, rent, travel and savings. A line graph shows how a quantity changes over time, for example the temperature of a city recorded every hour of a day.

Pie chart: parts of a whole, with an example 1. Line graph: change over time, with an example 1.

(viii) First, machine intelligence is modelled on human abilities: AI systems are built to imitate what people do with their minds, such as seeing, understanding language, learning from experience and making decisions. Second, machines learn from data that people produce, collect and label, and from algorithms that people design, so the knowledge and the mistakes of humans are passed on to them. It is also accepted that machine intelligence is used to support human intelligence, doing fast, repetitive work so that people can concentrate on judgement and creativity.

First link 1. Second link 1.

(ix) Training data is the part of the dataset used to teach the model the patterns. Testing data is a separate part, not shown to the model during training, used to check how accurately it works on new examples. They are kept separate because a model tested on the data it learned from may simply have memorised it, which would make its accuracy look better than it really is.

Training and testing data distinguished 1. Reason for keeping them apart 1.

(x) [3, 7, 7, 9, 12] 2 3. extend() adds 3 and 7 to give [12, 7, 9, 3, 7], sort() arranges it in ascending order, 7 occurs twice, and 9 is at index 3 of the sorted list.

Note for the examiner: Output machine checked by running the code in Python 3.

Sorted list [3, 7, 7, 9, 12] 1. 2 and 3 1.

Question 3 [15]

(i) First, thousands of mangoes that experts have already graded are photographed and weighed, so each example is labelled Grade A or Grade B. Features such as the weight or size, the colour of the skin, the number of spots or blemishes and the shape are taken from each example. The model is trained on most of these examples to find the pattern linking the features to the grade, tested on the rest, and then used on the conveyor to grade new mangoes it has never seen.

Labelled examples collected 1. Two suitable features 1. Training, testing, then grading new mangoes 1.

(ii) Team and Score on the first line, separated by a tab space. Arjun on the second line and 42 on the third line, because \n starts a new line. Path: C:\robots\arm on the fourth line, because each \\ prints a single backslash.

Note for the examiner: Output machine checked by running the code in Python 3.

Tab between Team and Score 1. Arjun and 42 on separate lines 1. Single backslashes in the path 1.

(iii) The program is as follows.

```
# Step 1: input in capital letters
reg = input("Enter registration number: ").upper()

# Step 2: check the pattern LL DD LL DDDD
if (len(reg) == 10 and reg[0:2].isalpha() and reg[2:4].isdigit()
        and reg[4:6].isalpha() and reg[6:].isdigit()):
    print("Valid number")
    # Step 3: the parts
    print("State code:", reg[0:2])
    print("Number:", reg[6:])
    # Step 4: Maharashtra or not
    if reg.startswith("MH"):
        print("Registered in Maharashtra")
    else:
        print("Registered outside Maharashtra")
    # Step 5: spaced form using join()
    print(" ".join([reg[0:2], reg[2:4], reg[4:6], reg[6:]]))
else:
    print("Invalid number")
```

Output for ka05mn0921: Valid number, then State code: KA, then Number: 0921, then Registered outside Maharashtra, then KA 05 MN 0921, each on a line of its own. Output for MH12A34567: Invalid number, because the characters at indexes 4 and 5 are A and 3, and the slice "A3" is not made of letters only.

Note for the examiner: Program run in Python 3 with three inputs and the output machine checked. The digits must be kept as a string, not converted with int(), or the leading zero of 0921 is lost. Accept an "if" chain with separate tests in place of one combined condition.

Input converted with upper() 1. Length and the four slice tests with isalpha() and isdigit() 3. State code and number printed 1. startswith() test 1.5. join() on the four groups 1.5. Both outputs stated 1.

Question 4 [15]

(i) The vision sensor (a camera) finds each egg on the belt, works out its position so that the gripper can be sent to it, and can spot cracked or dirty eggs to be rejected. The tactile sensors on the gripper fingers measure how hard the fingers are pressing. This matters because an egg is fragile: the robot must grip firmly enough not to drop it, but stop squeezing before the shell cracks.

Vision sensor role 1. Tactile sensor role 1. Fragile egg: controlled grip force 1.

(ii) Spur gears have straight teeth and join parallel shafts; they are used in the gearbox of a robot's wheel motor. A worm and worm wheel join shafts that are at right angles but do not meet; they give a large speed reduction in a small space and usually cannot be driven backwards, so they hold a robot arm or a lifting joint in place when the motor stops. A rack and pinion has a gear (pinion) meshing with a straight toothed bar (rack), changing rotation into straight-line motion; it is used in a sliding gripper or a car's steering.

Spur gears 1. Worm and worm wheel 1. Rack and pinion 1.

(iii)

(a) The potentiometer measures the actual angle of the elbow at every moment and sends it to the controller. The controller compares this angle with the required angle and decides whether to turn the motor, in which direction, and when to stop it. The motor is the actuator that turns the joint.

Position sensor 1. Controller 1. Motor 1.

(b) Target reading = 1023 x 60 / 180 = 341. For a reading of 114 the angle is 114 x 180 / 1023, which is about 20 degrees. The controller compares 114 with 341; since the reading is too low, it runs the motor in the direction that increases the angle. It keeps reading the potentiometer as the joint turns, slows the motor as the reading nears 341 and stops it when the reading reaches 341, then keeps correcting if the

joint is pushed away.

Note for the examiner: Values machine checked: 1023 x 60 / 180 = 341 exactly and 114 x 180 / 1023 = 20.06. Accept 340 or 341.

341 1. About 20 degrees 1. Compare, drive, keep reading, stop at target 1.

(c) The controller would believe the joint was always at 0 degrees, below the target, so it would keep driving the motor. The arm would swing past 60 degrees until it struck its mechanical limit, which could damage the motor, the gears or nearby objects, or injure a person. Safety measures: fit limit switches that cut the motor at the ends of the joint's travel; make the program stop the motor if the reading does not change within a set time while the motor is running; provide an emergency stop button.

Controller keeps driving the motor 1. Consequence 0.5. Two safety measures 1.5.

Question 5 [15]

(i) First, mobile robots carry whole shelves of goods to the packing stations, so workers do not have to walk long distances and orders are picked much faster. Second, robots work round the clock without tiring, which lets the company handle the huge rise in orders. Third, robots that scan barcodes make fewer picking mistakes and keep an exact count of the stock. Robots that sort parcels by destination are also accepted.

First way 1. Second way 1. Third way 1.

(ii) The input is the power level and the cooking time set by the user. The controller is the timer and control circuit, which switches the heating unit (the magnetron), the actuator, on for the set time and then off. It is an open loop system because nothing measures how hot the food actually is and feeds that back to the controller: the oven stops when the time is over whether the food is cold or overheated. Adding a temperature sensor that tells the controller when the food is hot enough would make it closed loop.

Input and controller 1. Actuator 1. No feedback of the result, so open loop 1.

(iii)

(a) First, in Model P the driver steers, brakes and is in charge at all times, and the features only warn or help, while Model Q makes all the driving decisions itself. Second, Model P handles only particular tasks, such as keeping a distance on a highway, while Model Q must handle every situation from start to destination. Third, Model Q needs many more sensors, detailed maps and a powerful onboard computer running AI, while Model P needs fewer sensors.

First difference 1. Second difference 1. Third difference 1.

(b) Cameras read lane markings, traffic signals and signs, and recognise pedestrians and vehicles. Radar measures the distance and speed of the vehicles around the car and works in rain and fog. LiDAR sends out laser pulses to build a three-dimensional map of the surroundings. Ultrasonic sensors for close objects while parking, and GPS with inertial sensors for the car's position, are also accepted.

First sensor with its job 1. Second sensor with its job 1. Third sensor with its job 1.

(c) First, traffic is mixed: two-wheelers, auto-rickshaws, handcarts, cycles, pedestrians and animals share the road and often do not follow lanes, which is very hard to predict. Second, lane markings and signs are often faded, missing or hidden, and roads have potholes and sudden diversions. Third, drivers communicate with horns and hand signals that a machine cannot easily read, and heavy rain, dust and crowded streets reduce the sensors' view. In a driver-assisted car the human handles these situations.

First reason 1. Second reason 1. Third reason 1.

Question 6 [15]

(i) Make a rail from a long box shape. Make the jaw from another box, and cut a slot in it to fit the rail by placing a box set as a hole, slightly larger than the rail, and grouping it with the jaw. Use the Align tool to line the slot up with the rail, so that the jaw can move along one axis only. Then move the jaw along the rail in steps, with the arrow keys or the move handle, and use the ruler to measure how far it can travel between the stops before it hits the other jaw or falls off the end of the rail.

Note for the examiner: Credit any sensible Tinkercad method that uses basic shapes, holes, grouping and alignment.

Rail and jaw with a slot made using a hole shape and grouping 1. Aligned so that motion is along one axis 1. Moved in steps and the travel measured 1.

(ii) (a) setup() runs once at the start and makes pin 2 an input, to read the button, and pin 13 an output, to drive the LED. (b) When the button is pressed, the LED switches on and stays on for 2 seconds, because of delay(2000); then it is switched off and stays off until the button is pressed again. (c) The LED appears to stay on all the time. After each 2-second delay the LED is switched off, but loop() starts again at once, finds the button still HIGH and switches the LED back on, so it is off for only a tiny fraction of a second, which the eye cannot see.

Note for the examiner: This sketch was reasoned through line by line; it was not run on a board. A press that begins during the 2-second delay is noticed only when the delay ends; candidates need not mention this.

(a) setup() and the two pin modes 1. (b) on for 2 seconds, then off 1. (c) appears continuously on, with the reason 1.

(iii)

(a) Two IR sensor modules detect whether each side is over the black line or the white track. A single board computer, such as an Arduino, reads the sensors and decides how each side should move. A motor driver board switches the battery current to the motors on the controller's command. DC geared motors, at least one for each side, turn the wheels. A battery pack supplies power to all of them.

Sensors and controller 1. Motor driver and motors 1. Battery 1.

(b) Both on white: the line is between the sensors, so move straight ahead. Left on black: the line has moved to the left, so turn left by slowing or stopping the left wheels while the right wheels run. Right on black: turn right by slowing or stopping the right wheels while the left wheels run. Both on black: the robot has reached a crossing or the end of the track, so stop.

Both white: forward 0.5. Left black: turn left 1. Right black: turn right 1. Both black: stop 0.5.

(c) Distance moved in one turn of the wheel = circumference = 3.14 x 6.5 = 20.41 cm. 120 rpm is 2 turns per second, so speed = 2 x 20.41 = 40.82 cm per second. Time for 3 m = 300 / 40.82 = 7.35 seconds, correct to two decimal places.

Note for the examiner: Values machine checked. Accept 40.8 cm/s and 7.3 or 7.4 s from rounding along the way.

Circumference 20.41 cm 1. 40.82 cm/s 1. 7.35 s 1.

Question 7 [15]

(i) An automated system does a task by itself by following pre-programmed rules; it may use sensors and feedback, as a refrigerator does to hold its temperature, but it cannot handle situations it was not programmed for. An autonomous system senses its surroundings, makes its own decisions and adapts to new, unplanned situations without a person. A fully automatic washing machine running a set programme is automated. A robot vacuum cleaner that maps a room and finds its way round furniture that has been moved, or a self-driving car, is autonomous.

Difference 1. Automated example 1. Autonomous example 1.

(ii) Data is the raw material: the model learns its patterns from many examples, and the quality and amount of the data decide how well it learns. An algorithm is the step-by-step method, such as linear regression or a decision tree, by which the computer finds the pattern in the data and builds the model. Programming turns the algorithm into instructions the computer can run; it is used to load and clean the data, train and test the model and use it to make predictions, usually in Python with libraries such as NumPy and Pandas.

Data 1. Algorithm 1. Programming 1.

(iii)

(a) Situation 1: unauthorised use of computer hardware. Situation 2: a dispute over the rights to a product, that is over who owns the intellectual property in the design. Situation 3: a false claim about what a computer system can do.

Situation 1 1. Situation 2 1. Situation 3 1.

(b) Situation 1: the company pays for the electricity, wear and network use, the computers may be slower for real work, and outside users may bring security risks. Situation 2: the company loses the value of the work it paid for, and the quarrel costs money and trust; employees and firms need to know who owns what they create. Situation 3: customers may trust the robot too much, leave it unsupervised and be harmed when it does make a mistake, and the company's reputation suffers when the claim is found to be false.

Harm in Situation 1 1. Harm in Situation 2 1. Harm in Situation 3 1.

(c) Situation 1: a clear policy on the use of company computers, individual log-ins and monitoring of use outside working hours. Situation 2: a written employment agreement stating that designs made at work belong to the company, and patenting or registering its designs. Situation 3: honest advertising that states the robot's real accuracy, its limits and the supervision it needs.

Measure for Situation 1 1. Measure for Situation 2 1. Measure for Situation 3 1.

Question 8 [15]

(i) Sources: readings from air quality monitoring stations and sensors, past AQI and weather records from government websites, and open datasets on sites such as Kaggle. A system map is a diagram of the elements of a problem, such as traffic, crop burning, construction dust, wind speed and rainfall, joined by arrows that show how each affects the others and whether it increases or decreases them. It helps the team see which factors matter, and so decide which data to collect as features.

Two sources 1. Meaning of a system map 1. How it helps choose the data 1.

(ii) In supervised learning the model is trained on labelled data, in which every example comes with the correct answer, and it learns to predict the answer for new examples. In unsupervised learning the data has no labels, and the model finds groups or patterns in it by itself. Supervised example: recognising handwritten digits after training on images each labelled with the correct digit, or predicting the price of a flat. Unsupervised example: sorting thousands of unlabelled songs into groups that sound alike, or grouping news articles by topic when no topics are given.

Difference 1. Supervised example 1. Unsupervised example 1.

(iii) The program is as follows.

```
import matplotlib.pyplot as plt

# Step 1: the data in two lists
houses = ["Tagore", "Raman", "Bose", "Kalam", "Sarojini"]
bottles = [148, 212, 176, 240, 124]

# Step 2: total and percentage share
total = sum(bottles)
print("Total bottles:", total)
for i in range(len(houses)):
    share = round(bottles[i] * 100 / total, 1)
    print(houses[i], share, "per cent")

# Step 3: the highest collection
top = max(bottles)
print("Highest:", houses[bottles.index(top)], top)

# Step 4: houses above the average, as a tuple
average = total / len(bottles)
above = []
for i in range(len(houses)):
    if bottles[i] > average:
        above.append(houses[i])
leaders = tuple(above)
print("Above average:", leaders)
```

```
# Step 5: the bar chart
plt.bar(houses, bottles)
plt.title("Bottles Collected by Each House")
plt.xlabel("House")
plt.ylabel("Number of bottles")
plt.show()
```

Output: Total bottles: 900, then Tagore 16.4 per cent, Raman 23.6 per cent, Bose 19.6 per cent, Kalam 26.7 per cent and Sarojini 13.8 per cent, each on a line of its own, then Highest: Kalam 240, then Above average: ('Raman', 'Kalam'). The average is 900 / 5 = 180, so Bose, with 176, is not above it. A bar chart with five bars then opens.

Note for the examiner: Program run in Python 3 and the printed values machine checked. The rounded shares add up to 100.1 because of rounding; this is expected. Accept plt.barh() if the axis labels match.

Two lists created 1. Total and loop printing rounded percentages 2. Highest house found with max() and index() 1. List above the average built and converted with tuple() 2. plt.bar() with title, axis labels and plt.show() 2. Printed values stated 1.