1. (a) The statement 'aren't agents just expert systems by another name?' refers to the relationship between agents and expert systems. What is an expert system? And, list TWO main differences between agents and expert systems.

(7 marks)

Answer

- An expert system is a computer program designed to mimic the decision-making abilities of a human expert.

- It uses a knowledge base of facts and rules to solve complex problems within a specific domain, such as medical diagnosis or financial forecasting.

- Two main differences
  - Autonomy
    - Agents are autonomous, they can perceive their environment, make decisions, and act without direct human intervention.

    - Expert systems are not autonomous, they require a user to input queries and do not act on their own.

  - Proactiveness
    - Agents can proactively pursue goals and exhibit goal-directed behaviour without direct human intervention.

    - Expert systems are typically passive, providing answers or recommendations based only on predefined rules and user inputs, without initiating actions.

1. (b) The five trends in the history of computing have led the emergence of the field of multiagent systems. One of the trends is *intelligence*. Explain with an example what *intelligence* means.

(4 marks)

Answer

- Intelligence refers to the ability of a system to make decisions, learn from experience, and adapt to changes in its environment to achieve specific goals, mimicking aspects of human intelligence.

- Example: Consider a self-driving car
  - This vehicle uses artificial intelligence to navigate roads, avoid obstacles, and make decisions based on real-time data.

  - It learns from its environment, processes information from sensors, and adapts to changing conditions like traffic patterns or weather.

  - This intelligence enables agents to operate autonomously in complex environments

1. (c) Utility functions can be used as a method for telling agents what to do without telling them how to do it. Give two types of utility functions and discuss the challenges faced when designing such functions.

(10 marks)

Answer

- Two types of utility functions
  1. Utility Functions Over States
     - This approach assigns a utility value to each individual environment state.
     - The agent's goal is to bring about states with the highest utility.
     - Example
       - A cleaning robot gets +10 utility for a clean room and -5 for a dirty room.
     - Challenges
       - Value of a run
         - Determining the value of a run can be complex. Should it be the minimum, maximum, sum, or average utility of states on the run?
       - Long-term view
         - It is difficult to specify a long-term view when assigning utilities to individual states.
  2. Utility Functions Over Runs
     - Instead of individual states, this approach assigns utility to entire runs.
     - This approach inherently takes a long-term view.
     - Example
       - A self-driving car's utility depends on the entire trip (safety, efficiency).
     - Challenges
       - Probabilities
         - Incorporating probabilities of different states emerging can complicate the utility function.
       - Utility-Based Approaches
         - There are inherent difficulties, such as determining where the utility numbers come from, and the challenge of formulating tasks in these terms.

1. (d) Two most common types of tasks are *achievement tasks* and *maintenance tasks*. Explain what these two types of tasks are.

(4 marks)

Answer

- Achievement Tasks
  - These tasks have a specific goal or desired state that the agent must achieve.
  - Once the goal is reached, the task is considered complete.

- Maintenance Tasks
  - These tasks involve keeping certain conditions or states true over time, rather than achieving a one-time goal.
  - The agent must act continuously or repeatedly to maintain stability or performance.

2. You are preparing to go for a bike ride and are trying to decide whether to use your thin road tires or your thicker, knobbier tires. The advantage of the thin road tires is that you can ride much faster. But, you know from previous experience that your thin road tires are more likely to go flat during a ride. There is a 40% chance your thin road tires will go flat but only a 10% chance that the thicker tires will go flat. Because of the risk of a flat tire, you also have to decide whether or not to bring your tools along on the ride (a pump, tire levers and a puncture kit). These tools will weigh you down.

The utilities of different cases are given in Table Q2 below. Using the above, answer the following questions.

Table Q2

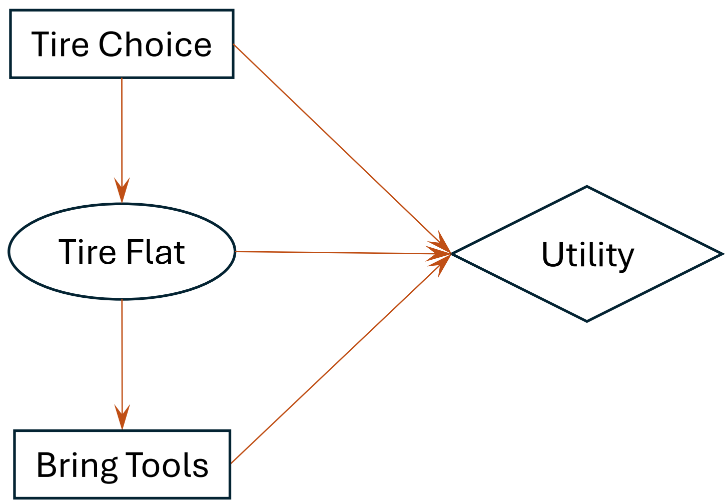
Which tire to use	Whether tire goes flat	Whether to bring tools	Utility
Thin road tire	Yes	Yes	50
Thicker tire	Yes	Yes	40
Thin road tire	No	Yes	75
Thicker tire	No	Yes	65
Thin road tire	Yes	No	0
Thicker tire	Yes	No	0
Thin road tire	No	No	100
Thicker tire	No	No	75

2. (a) What are the three types of nodes in a decision network for this problem? Draw the decision network.

(10 marks)

Answer

- Decision network nodes
  - Decision nodes : rectangle shape
  - Chance nodes : oval shape
  - Utility nodes : diamond shape



2. (b) What is the optimal decision? What is the expected utility of the optimal decision? Show clearly the detailed steps of deriving your answers.

(15 marks)

Answer

Which tire to use	Whether tire goes flat	Whether to bring tools	Utility
Thin road tire	Yes	Yes	50
Thicker tire	Yes	Yes	40
Thin road tire	No	Yes	75
Thicker tire	No	Yes	65
Thin road tire	Yes	No	0
Thicker tire	Yes	No	0
Thin road tire	No	No	100
Thicker tire	No	No	75

- Probabilities:
  - P(flat | thin) = 0.4
  - P(¬flat | thin) = 0.6
  - P(flat | thick) = 0.1
  - P(¬flat | thick) = 0.9

- For the optimal decision, there are 4 choices to calculate EU:
  i. Thin tires + Bring tools → EU(thin, tools)
  ii. Thin tires + No tools → EU(thin, ¬tools)
  iii. Thick tires + Bring tools → EU(thick, tools)
  iv. Thick tires + No tools → EU(thick, ¬tools)

i. EU(thin, tools)
= P(flat | thin) * U(thin, flat, tools) + P(¬flat | thin) * U(thin, ¬flat, tools)
= (0.4 * 50) + (0.6 * 75) = 20 + 45 = 65

ii. EU(thin, ¬tools)
= P(flat | thin) * U(thin, flat, ¬tools) + P(¬flat | thin) * U(thin, ¬flat, ¬tools)
= (0.4 * 0) + (0.6 * 100) = 0 + 60 = 60

iii. EU(thick, tools)
= P(flat | thick) * U(thick, flat, tools) + P(¬flat | thick) * U(thick, ¬flat, tools)
= (0.1 * 40) + (0.9 * 65) = 4 + 58.5 = 62.5

iv. EU(thick, ¬tools)
= P(flat | thick) * U(thick, flat, ¬tools) + P(¬flat | thick) * U(thick, ¬flat, ¬tools)
= (0.1 * 0) + (0.9 * 75) = 0 + 67.5 = 67.5

Summary of EU

- EU(thin, tools) = 65
- EU(thin, ¬tools) = 60
- EU(thick, tools) = 62.5
- EU(thick, ¬tools) = 67.5
- Since EU(thick, ¬tools) = 67.5 has the highest value,
  optimal decision is to use thick tires and not bringing tools

3. (a) USA's Defense Advanced Research Projects Agency recently launched the OFFSET program, which envisions future small-unit infantry forces using swarms comprising upwards of hundreds of small Unmanned Aircraft Systems (UASs) and/or small Unmanned Ground Systems (UGSs) to accomplish diverse military missions in complex urban environments. List and briefly explain a few key ideas in multi-agent systems which can use used to build such a system.

(6 marks)

Answer

i. Coordination
   - Multiple agents need to coordinate and cooperate to achieve common goals.

ii. Communication
   - Agents need to share information and coordinate their actions to avoid collisions, cover terrain efficiently, and complete shared objectives.

iii. Task Allocation
   - Agents dynamically assign themselves to tasks (e.g., surveillance, obstacle clearing) based on their capabilities and current mission needs.

iv. Decentralized Control
   - Each agent (UAS/UGS) operates independently without relying on a central controller.

v. Emergent Behaviour
   - Simple rules at the agent level can lead to complex group behaviours (e.g., formation flying, area coverage), useful in swarm robotics.

vi. Learning and Adaptation
   - Agents in multi-agent systems can learn from their experiences and adapt their behaviour over time.

3. (b) Assume that you are the leader of a student organization and you need to organize an annual celebration which involving many tasks. Briefly describe how you can use CONTRACT NET to allocate tasks to the members of the organization.

(6 marks)

Answer

- The contract net includes five stages:
  1. Recognition
  2. Announcement
  3. Bidding
  4. Awarding
  5. Expediting

1. Recognition
   - In this stage, leader acts as the manager agent who recognises that there are tasks need to be complete

2. Announcement
   - In this stage, the leader with the task sends out an announcement of the task which includes a specification of the task to be achieved

3. Bidding
   - Interested members that receive the announcement decide for themselves whether they wish to bid for the task

4. Awarding
   - As a manager agent, must choose between bids & decide who to "award the contract" to.

5. Expediting
   - The selected member then expedites the task

3. (c) Explain why bidding one's private value (truthful bidding) is a dominant strategy in the second price sealed auction.

(5 marks)

Answer

- A Vickrey auction is a type of sealed-bid second-price auction where:
  - Each bidder submits a bid without knowing others' bids.
  - The highest bidder wins, but pays the second-highest bid price.

- Why it is truthful:
  - In a Vickrey auction, bidding your true value is a dominant strategy.
  - If you bid more than your true value, you might win and overpay, leading to a loss.
  - If you bid less than your true value, you risk losing even when the item is worth it to you.
  - Since the price you pay does not depend on your own bid, you have no incentive to lie, your best choice is to be honest.

3. (d) We say that Player *i* is a dummy in a coalitional game if *v({i} U S) = v(S)* for every coalition *S*. In particular, *v({i})* = 0. Thus, a dummy cannot help (or harm) any coalition. Show that if Player 1 is a dummy and $(x_1, x_2, \ldots, X_n)$ is in the core, then Player 1's payoff $x_1 = 0$.

(7 marks)

Answer

4. Consider the two payoff matrices 1 and 2 in Table Q4a and Table Q4b, respectively. The first number in each entry is the payoff received by the row player **A;** while the second number is the payoff received by the column player **B**.

Payoff matrix 1:

Table Q4a

	B: left	**B: right**
A: up	**(6 , 0)**	**(1, 2)**
A: down	**(4, 4)**	**(2, 3)**

Payoff matrix 2:

Table Q4b

	B: left	**B: right**
A: up	**(2, -2)**	**(-2, 3)**
A: middle	**(0, -1)**	**(2, -1)**
A: down	**(-1, 2)**	**(1, -1)**

4. (a) Identify the dominant strategies (if any) of each player in these two payoff matrices. Briefly explain your answer.

(5 marks)

Answer

Table Q4a

	B: left	B: right
A: up	(6 , 0)	(1, 2)
A: down	(4, 4)	(2, 3)

Table Q4b

	B: left	B: right
A: up	(2, -2)	(-2, 3)
A: middle	(0, -1)	(2, -1)
A: down	(-1, 2)	(1, -1)

Payoff matrix 1 (Table Q4a)

- Player A (row player):
  - If B plays left, A: up = 6, down = 4 → up is best
  - If B plays right, A: up = 1, down = 2 → down is best
  - Play A has no dominant strategy

- Player B (column Player):
  - If A plays up, B: left = 0, right = 2 → right is best
  - If A plays down, B: left = 4, right = 3 → left is best
  - Play B has no dominant strategy

Payoff matrix 2 (Table Q4b)

- Player A (row player):
  - If B plays left, A: up = 2, mid = 0, down = -1 → up is best
  - If B plays right, A: up = -2, mid = 2, down = 1 → middle is best
  - Play B has no dominant strategy

- Player B (Column Player):
  - If A plays up, B: left = -2, right = 3 → right is best
  - If A plays middle, B: left = -1, right = -1 → left or right same
  - If A plays down, B: left = 2, right = -1 → left is best
  - Play B has no dominant strategy

Summary of dominant strategy

- In both matrices, neither player has a dominant strategy
- This is because no single action yields a better or equal payoff in all situations compared to the other actions.

4. (b) Identify which strategy pairs (if any) in these two payoff matrices are in Nash equilibrium. Briefly explain your answer.

(8 marks)

Answer

- To identify Nash equilibrim, we need to find strategy pairs where neither player has an incentive to change their strategy.

Payoff matrix 1 (Table Q4a)

	B: left	B: right
A: up	**(6 , 0)**	**(1, 2)**
A: down	**(4, 4)**	**(2, 3)**

Table Q4a

• (A: up, B: left) • A: up = 6, down = 4 → A prefers up • B: left = 0, right = 2 → B prefers right • Not Nash equilibrium	• (A: up, B: right) • A: up = 1, down = 2 → A prefers down • B: left = 0, right = 2 → B prefers right • Not Nash equilibrium
• (A: down, B: left) • A: up = 6, down = 4 → A prefers up • B: left = 4, right = 3 → B prefers left • Not Nash equilibrium	• (A: down, B: right) • A: up = 1, down = 2 → A prefers down • B: left = 4, right = 3 → B prefers left • Not Nash equilibrium

Payoff matrix 2 (Table Q4b)

	B: left	B: right
A: up	**(2, -2)**	**(-2, 3)**
A: middle	**(0, -1)**	**(2, -1)**
A: down	**(-1, 2)**	**(1, -1)**

Table Q4b

• (A: up, B: left) • A: up = 2, mid = 0, down = -1 → up is best • B: left = -2, right = 3 → B prefers right • Not a Nash equilibrium	• (A: up, B: right) • A: up = -2, mid = 2, down = 1 → mid is best • B: left = -2, right = 3 → B prefers right • Not a Nash equilibrium
• (A: middle, B: left) • A: up = 2, mid = 0, down = -1 → up is best • B: left = -1, right = -1 → left or right same • Not a Nash equilibrium	• (A: middle, B: right) • A: up = -2, mid = 2, down = 1 → mid is best • B: left = -1, right = -1 → left or right same • Nash equilibrium
• (A: down, B: left) • A: up = 2, mid = 0, down = -1 → up is best • B: left = 2, right = 3 → B prefers left • Not a Nash equilibrium	• (A: down, B: right) • A: up = -2, mid = 2, down = 1 → mid is best • B: left = 2, right = 3 → B prefers left • Not a Nash equilibrium

Summary of Nash Equilibrium

Payoff matrix 1: No Nash equilibrium

Payoff matrix 2: (A: middle, B: right) → (2, -1)

Neither player has an incentive to change their strategy

4. (c) Identify which outcomes in these two payoff matrices are Pareto optimal. Briefly explain your answer.

(7 marks)

Answer

- An outcome is said to be Pareto optimal if there is no other outcome that makes one agent better off without making another agent worse off. (win-win)

- If an outcome is Pareto optimal, then at least one agent will be reluctant to move away from it (because this agent will be worse off).

- If an outcome ω is not Pareto optimal, then there is another outcome ω' that makes everyone as happy, if not happier, than ω.

Table Q4a

	B: left	**B: right**
A: up	**(6 , 0)**	**(1, 2)**
A: down	**(4, 4)**	**(2, 3)**

Payoff matrix 1 (Table Q4a)

- (A: up, B:left) → (6, 0)
  - No other better domination
  - Pareto optimal

- (A: up, B:right) → (1, 2)
  - Dominated by (4, 4) & others
  - Not Pareto optimal

- (A: down, B:left) → (4, 4)
  - No other better domination
  - Pareto optimal

- (A: down, B:right) → (2, 3)
  - Dominated by (4, 4)
  - Not Pareto optimal

4. (c) cont.

Table Q4b

	B: left	B: right
A: up	(2, -2)	(-2, 3)
A: middle	(0, -1)	(2, -1)
A: down	(-1, 2)	(1, -1)

Payoff matrix 2 (Table Q4b)

- (A: up, B:left) → (2, -2)
  - Dominated by (2, -1)
  - Not Pareto optimal

- (A: up, B:right) → (-2, 3)
  - No other better domination
  - Pareto optimal

- (A: middle, B:left) → (0, -1)
  - Dominated by (2, -1) & others
  - Not Pareto optimal

- (A: middle, B:right) → (2, -1)
  - No other better domination
  - Pareto optimal

- (A: down, B:left) → (-1, 2)
  - No other better domination
  - Pareto optimal

- (A: down, B:right) → (1, -1)
  - Dominated by (0, -1) & others
  - Not Pareto optimal

Summary of Pareto optimal

Payoff matrix 1:	(A: up, B:left)	→ (6, 0),
	(A: down, B:left)	→ (4, 4)
Payoff matrix 2:	(A: up, B:right)	→ (-2, 3)
	(A: middle, B:right)	→ (2, -1)
	(A: down, B:left)	→ (-1, 2)

No other outcome makes one player better off without making the other worse off

4. (d) Identify which outcomes in these two payoff matrices maximize social welfare. Briefly explain your answer.

(5 marks)

Answer

- Social welfare is measured as the sum of all players' payoffs. The outcome with the highest total payoff maximizes social welfare.

Table Q4a

	B: left	**B: right**
A: up	**(6 , 0)**	**(1, 2)**
A: down	**(4, 4)**	**(2, 3)**

Table Q4b

	B: left	**B: right**
A: up	**(2, -2)**	**(-2, 3)**
A: middle	**(0, -1)**	**(2, -1)**
A: down	**(-1, 2)**	**(1, -1)**

Payoff matrix 1 (Table Q4a)

- (A: up, B: left): Total payoff = 6 + 0 = 6
- (A: up, B: right): Total payoff = 1 + 2 = 3
- (A: down, B: left): Total payoff = 4 + 4 = 8
- (A: down, B: right): Total payoff = 2 + 3 = 5

- Maximize social welfare = 8
- Outcome: (A: down, B: left) → (4, 4)

Payoff matrix 2 (Table Q4b)

- (A: up, B: left): Total payoff = 2 + (-2) = 0
- (A: up, B: right): Total payoff = -2 + 3 = 1
- (A: middle, B: left): Total payoff = 0 + (-1) = -1
- (A: middle, B: right): Total payoff = 2 + (-1) = 1
- (A: down, B: left): Total payoff = -1 + 2 = 1
- (A: down, B: right): Total payoff = 1 + (-1) = 0

- Maximize social welfare = 1
- Outcome: (A: up, B: right) → (-2, 3)
  (A: middle, B: right) → (2, -1)
  (A: down, B: left) → (-1, 2)

Summary of maximize social welfare

Payoff matrix 1: (A: down, B: left) → (4, 4)

Payoff matrix 2: (A: up, B: right) → (-2, 3)
(A: middle, B: right) → (2, -1)
(A: down, B: left) → (-1, 2)

Their outcomes achieve the highest total payoff maximizes social welfare.