ANSWER KEY IAT-2

Q.1 The 8-puzzle sliding block start and goal states are given here. Using the A* search algorithm show how to reach the goal state from start state (9)? What is the total cost (1)?

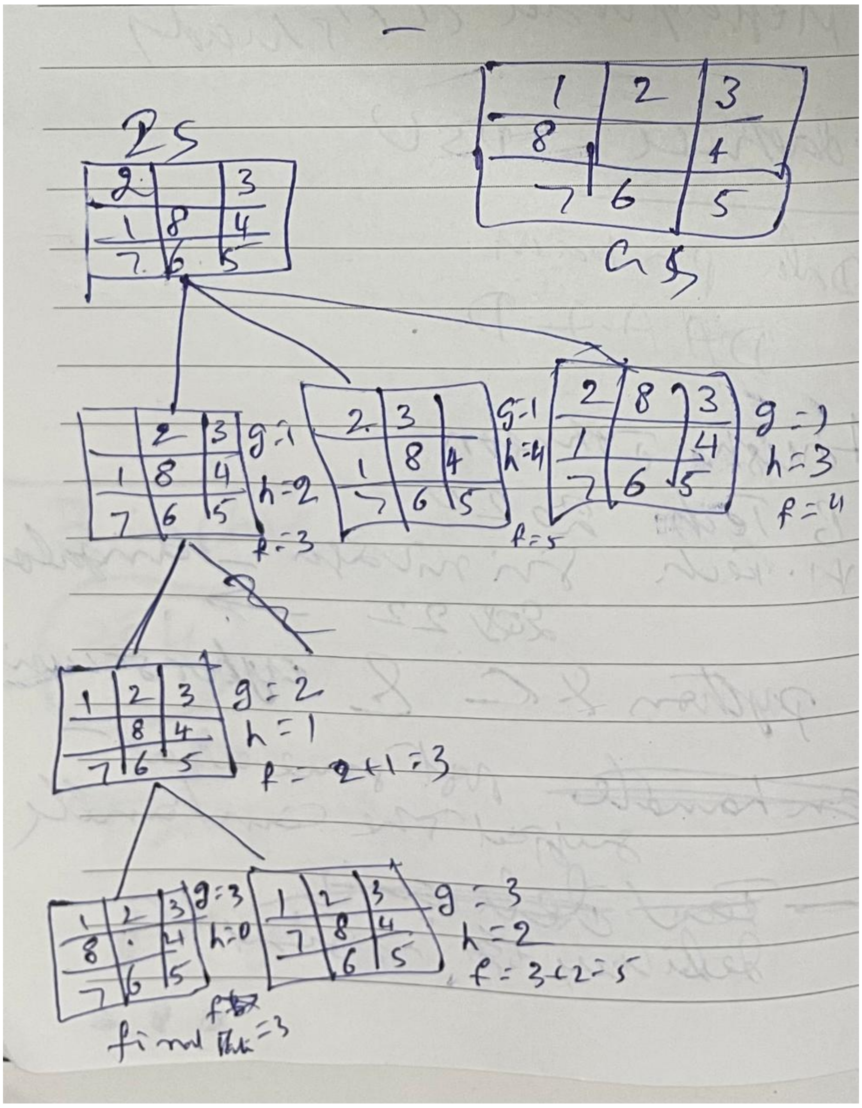
2		3
1	8	4
7	6	5

Start State

1	2	3
8		4
7	6	5

Goal State

Ans.



Q.2 a) Explain in detail knowledge-based agent (6)?
Ans.
Knowledge-based agents – agents that explicitly represent a knowledge base that can be reasoned with.

- *Sentence*
  - *Knowledge base is a set of sentences*
  - *Each sentence is expressed in a language called knowledge representation language*
  - *Represents some assertion about the world*
- *These agents can manipulate this knowledge to infer new things at*

The "knowledge level"

- *How to add new sentences to the knowledge base?*
  - *TELL operation*
- *How to query the knowledge base on what is known?*
  - *ASK operation*

Knowledge-based agent- Takes a percept as input and returns an action. Agent maintains a knowledge base – KB. Initially contains some background knowledge.

An agent program does three things:

1. *TELLs the KB what it perceives*
2. *ASKs the KB what action should be performed*
   1. *The answer should follow from what has been told to KB previously*
3. *TELLs the KB which action was chosen and the agent executes the action*

The agent must be able to:

1. *Represent states, actions, etc.*
2. *Incorporate new percepts*
3. *Update internal representations of the world*
4. *Deduce hidden properties of the world*
5. *Deduce appropriate actions*

b) Define the following terms with respect to logic:

(i) Relation 'satisfies' (2) (ii) relation 'entailment' (2)

Ans.

(i) Relation "satisfies"

The relation "satisfies" (denoted by ⊨\models⊨) in logic describes the relationship between a model (or interpretation) and a formula (or set of formulas). If a model satisfies a formula, it means that the formula is true under that model.

Definition:

- Let MMM be a model and ϕ\phiϕ be a formula.
- We say that MMM satisfies ϕ\phiϕ, written as M⊨ϕM \models \phiM⊨ϕ, if ϕ\phiϕ is true in MMM.

In other words, a model MMM satisfies a formula ϕ\phiϕ if, when the variables and constants in ϕ\phiϕ are interpreted according to MMM, the resulting statement is true.

(ii) Relation "entailment"

The relation "entailment" (denoted by ⊨\models⊨) in logic describes a situation where a set of formulas logically implies another formula. If a set of formulas entails a formula, it means that the formula must be true whenever all the formulas in the set are true.

Definition:

- Let Γ\GammaΓ be a set of formulas and ϕ\phiϕ be a formula.
- We say that Γ\GammaΓ entails ϕ\phiϕ, written as Γ⊨ϕ\Gamma \models \phiΓ⊨ϕ, if ϕ\phiϕ is true in every model in which all formulas in Γ\GammaΓ are true.

In other words, Γ⊨ϕ\Gamma \models \phiΓ⊨ϕ means that there is no model in which all the formulas in Γ\GammaΓ are true and ϕ\phiϕ is false. If Γ\GammaΓ entails ϕ\phiϕ, then ϕ\phiϕ logically follows from Γ\GammaΓ.

Q.3 a) What is First Order Logic (2)?

Ans.

(b) what is first order logic ?

→ FOL also known as predicate logic or first-order predicate logic is a formal system used in mathematics, philosophy, linguistics and computer science to express statements about objects & their relationships

key components of FOL

① constants
② variables
③ predicates
④ functions
⑤ logical connectives
⑥ quantifiers

syntax of FOL

① Atomic formulas
② complex formulas

semontics of FOL

① Domain of Discourse – The set of obj that the variables can refer to.

② Interpretation – Assigns meanings to the symbols in the domain

③ satifaction – A formula is satisified if it's true under a given interpretation & variable assignment.

b) Write four Quantified inference rules (4) with examples (4).

Ans.

(8) write four Quantified inference rules with examples.

⇒ (1) universal Instantiation (UI)

Rule if a property is true for all elements in a domain, then it's a true for any specific element in that domain.

form $\forall x\, P(x)$

$\therefore P(c)$

e.g $\forall x\, Human(x) \rightarrow Mortal(x)$

$\therefore Human(socrates) \rightarrow mortal(socrates)$

(2) universal Generalization (UG)

Rule if a ~~g~~ property is true for an arbitrary element of the domain, then it is true for all elements in that domain.

form $P(c)$

$\therefore \forall(x) P(x)$

e.g $Human(c) \rightarrow mortal(c)$

$\therefore \forall x\, (Human(x) \rightarrow mortal(x))$

(3) existential Instantiation (EI)

Rule if a property is true for some element in the domain, then there exists a specific elements in the domain for which the property is true.

form $\exists x\, P(x)$

$\therefore P(c)$

e.g $\exists x\, Loves(x, Juliet)$

$\therefore loves(Romeo, Juliet)$

(4) existential Generalization (EG)

Rule if a property is true for a specific element in the domain, then it is true for some element in the domain.

form $P(c)$

$\therefore \exists x\, P(x)$

e.g $Loves(Romeo, Juliet)$

$\therefore \exists x\, loves(x, Juliet)$

Q.4 a) What is Quantification (4)? Explain the types of Quantifiers (4) with examples (2).

Ans.

(4) what is Quantification ? explain the types of Quantifiers with examples.

⇒ Quantification

In logic refers to the use of quantifiers to specify the extent to which a predicate or property applies to a set of objects within a given domain. quantifiers are essential for expressing statements about some or all members of the domain.

Types of Quantifiers :-

(1) universal Quantifier ($\forall$)

The universal quantifier expresses that a predicate or property applies to all elements in the domain.

Symbol :- $\forall$

Read as : "for all" or "for every".

E.g - $\forall(x)(Human(x) \rightarrow Mortal(x))$

meaning - for every x, if x is a human, then x is mortal.

(2) existential Quantifier ($\exists$) :-

The existential Quantifier expresses that there is at least one element in the domain for which the predicate or property is true.

Symbol :- $\exists$

Read as :- "There exists" or "for some"

e.g :- $\exists x(student(x) \wedge smart(x))$

meaning - There exists an x such that x is a student and x is smart.

Q.5 a) What is CNF (2)? What is the procedure to convert the sentence into CNF (4)?
Ans.

(5) what is CNF? what is the procedure to convert the sentance into CNF?
→ CNF (conjunctive Normal Form) is a way of structuring logical formulas in propositional logic and is widely used in various fields of computer science, including automated resoning and Boolean satisfiability problem (SAT) solving.

convert the sentance into CNF :-

① elimate Biconditionals and implication :-
Replace biconditional ($\leftrightarrow$) $A \leftrightarrow B$ with $(A \to B) \wedge (B \to A)$.
Replace implication ($\to$) $A \to B$ with $\neg A \vee B$.

② move Negations Inward : 2

$\neg(A \wedge B) \equiv \neg A \vee \neg B$

4

$\neg(A \vee B) \equiv \neg A \wedge \neg B$

$\neg\neg A \equiv A$

③ Distribute OR over AND :

$A \vee (B \wedge C) \equiv (A \vee B) \wedge (A \vee C)$

$(A \wedge B) \vee C \equiv (A \vee C) \wedge (B \vee C)$

④ flatten and simplify :
combine nested conjunctions & disjunctions into single layers.
Remove duplicate literals within clauses & tautologies.

b) Convert $B_{1.1} \Leftrightarrow (P_{1.2} \vee P_{2.1})$ into CNF (4)

Ans.

Conjunctive Normal Form (CNF)

An example of converting to CNF in Wumpus world

Convert $B_{1,1} \Leftrightarrow (P_{1,2} \vee P_{2,1})$ into CNF

1. Eliminate $\Leftrightarrow$, replacing $\alpha \Leftrightarrow \beta$ with $(\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)$.

   $(B_{1,1} \Rightarrow (P_{1,2} \vee P_{2,1})) \wedge ((P_{1,2} \vee P_{2,1}) \Rightarrow B_{1,1})$

2. Eliminate $\Rightarrow$, replacing $\alpha \Rightarrow \beta$ with $\neg\alpha \vee \beta$.

   $(\neg B_{1,1} \vee P_{1,2} \vee P_{2,1}) \wedge (\neg(P_{1,2} \vee P_{2,1}) \vee B_{1,1})$

3. Move $\neg$ inwards using de Morgan's rules and double-negation:

   $(\neg B_{1,1} \vee P_{1,2} \vee P_{2,1}) \wedge ((\neg P_{1,2} \vee \neg P_{2,1}) \vee B_{1,1})$

4. Apply distributivity law ($\wedge$ over $\vee$) and flatten:

   $(\neg B_{1,1} \vee P_{1,2} \vee P_{2,1}) \wedge (\neg P_{1,2} \vee B_{1,1}) \wedge (\neg P_{2,1} \vee B_{1,1})$

Q.6 Consider a vocabulary with the following (10):
Occupation(p, o): Predicate. Person p has occupation o.
Customer(p1, p2):Predicate. Person p1 is a customer of person p2.
Boss(p1, p2): Predicate. Person p1 is a boss of person p2.
Doctor, Surgeon, Lawyer: Constants denoting occupations.
Emiley: Constants denoting people.
Use these symbols to write the following assertions in first order logic.

1. All surgeons are doctors.
2. Emiley has a boss who is a layer.

Ans.

- **All surgeons are doctors.**

$\forall p(\text{Occupation}(p,\text{Surgeon}) \rightarrow \text{Occupation}(p,\text{Doctor}))$

- **Emiley has a boss who is a lawyer.**

$\exists b(\text{Boss}(b,\text{Emiley}) \wedge \text{Occupation}(b,\text{Lawyer}))$