Information about the exam

1. The exam has 6 sections of questions. They consist of both multiple choice questions and free text questions.
2. The total number of points for the exam is 48 and a passing grade is at most 25. Grade 4 is at most 34 points and Grade 5 is at most 41 points. The limits will be modify based on the results, but they will not be higher.
3. For multiple choice questions you will get a positive score for each correct choice and a negative score for each incorrect choice. They are both the same, usually 1 point. This means that it may be an idea to only check those choices you are certain about. You cannot get a negative score for a question.
4. The free text questions are designed so that text should be enough to answer them. There are limited formatting facilities that can be used to format and structure your answers.
5. A scientific calculator is accessible through a link in the Resource section at the bottom of the exam.
6. Both the course textbook and the lecture slides are accessible from the Resource section at the bottom of the exam.
7. Please make reasonable assumptions if you believe an exercise is under specified and state those assumptions explicitly in your answer.
8. Your answers should be clear, concise and compact.
9. Fredrik will visit the exam rooms around 15.30 to provide clarifications if needed for the exam questions.

1 Logic

For this question, each correctly checked box gives 1 point and each incorrectly checked box gives -1 points. Not checking a box gives 0 points.

1a) Which properties does the logical formula $(A \rightarrow (A \rightarrow B))$ have?
Choose 0-4 alternatives

- [ ] falsifiable
- [ ] unsatisfiable
- [ ] valid
- [ ] satisfiable

1b) Which of the following statements about propositional logic formulas are true?
Choose 0-4 alternatives

- [ ] If φ is satisfiable, then $\neg\varphi$ is unsatisfiable.
- [ ] If φ is satisfiable, then $\neg\varphi$ is also satisfiable.
- [ ] If φ and ψ are satisfiable, then $(\varphi \wedge \psi)$ is also satisfiable.
- [ ] If φ and ψ are satisfiable, then $(\varphi \rightarrow \psi)$ is also satisfiable.

1c) Which of the following truth assignments satisfy the formula $(P \vee Q) \wedge (\neg P \vee \neg R)$?
Choose 0-4 alternatives

- [ ] $P = \mathbf{True}, Q = \mathbf{False}, R = \mathbf{True}$
- [ ] $P = \mathbf{False}, Q = \mathbf{True}, R = \mathbf{True}$
- [ ] $P = \mathbf{False}, Q = \mathbf{False}, R = \mathbf{True}$
- [ ] $P = \mathbf{True}, Q = \mathbf{True}, R = \mathbf{False}$

1d) What is the Conjunctive Normal Form (CNF) equivalent of the formula $(P \rightarrow (Q \wedge R))$?

Choose 0-4 alternatives

- [ ] $(\neg P \vee Q) \wedge (\neg P \vee R)$
- [ ] $(P \vee Q) \wedge (\neg R \rightarrow P)$
- [ ] $(P \vee \neg Q) \wedge (P \vee \neg R)$
- [ ] $(\neg P \wedge Q \wedge R)$

1e) What does the resolution rule infer when applied to the clauses $P \vee Q$ and $\neg P \vee R$?
Choose 0-4 alternatives

- [ ] $\neg Q \vee R$
- [ ] $P \vee R$
- [ ] $P \vee \neg Q$
- [ ] $Q \vee R$

1f) The backtracking in DPLL happens when:
Choose 0-4 alternatives

- [ ] No literals are left to be assigned.
- [ ] The algorithm finds a partial solution.
- [ ] A contradiction (empty clause) is reached.
- [ ] The formula has been completely satisfied.

1g) Which of the following is a key feature of the DPLL algorithm?
Choose 0-4 alternatives

- [ ] It combines search with logical reasoning to find solutions.
- [ ] It uses conjunctive normal form (CNF) only at the leaves of the search tree.
- [ ] It recursively applies simplifications such as unit propagation and pure literal elimination.
- [ ] It only works for clauses with at most three literals.

1h) GSAT is a greedy local search method. Which statements are true about GSAT?

Choose 0-4 alternatives

- [ ] It can solve any instance of satisfiability in polynomial time.
- [ ] It guarantees finding a global optimum.
- [ ] It only finds solutions for small formulas.
- [ ] It may get trapped in local optima.

Maximum marks: 11

2 Bayesian Networks

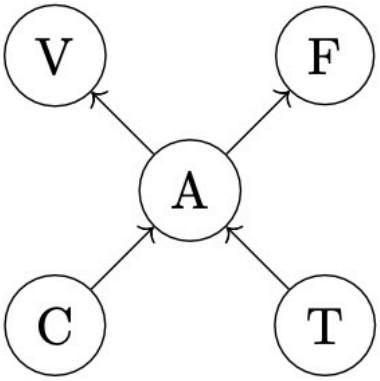
Consider the following problem example:
The fire alarm in a building can go off if there is a fire in the building or if the alarm is tampered with by vandals. If the fire alarm goes off, this can cause crowds to gather at the front of the building and fire trucks to arrive.

Let A stand for ”alarm sounds”, C for ”crowd gathers”, F for ”fire exists”, T for ”truck arrives”, and V for ”vandalism exists”.

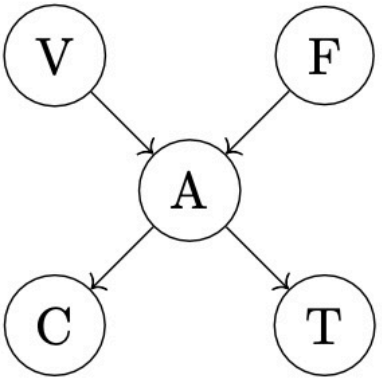
Any assumptions you make or comments you wish to add, you can do so in the next section.

2a) Which of the following Bayesian networks represent the causal links described in the problem example defined above? [1p]:

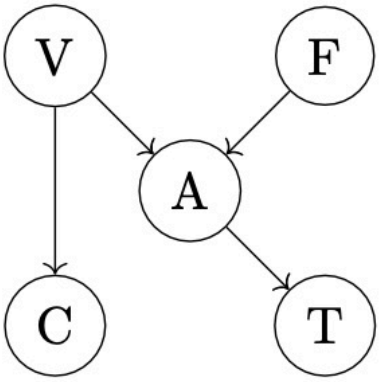
- [ ] Network 1
- [ ] Network 2
- [ ] Network 3
- [ ] Network 4



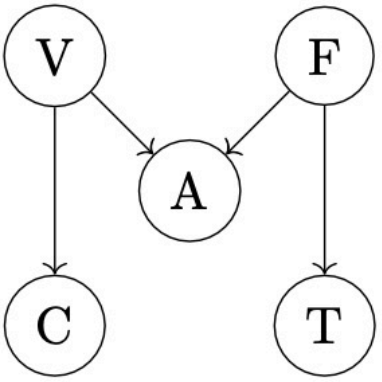
(a) Network 1



(b) Network 2



(c) Network 3



(d) Network 4

2b) Given the independence assumptions implicit in the Bayesian network, which of the formulas below represent the full joint probability distribution over all five variables, i.e. P(A,C,F,T,V) =? [2p]

- [ ] P(A) · P(C) · P(F) · P(T) · P(V)
- [ ] P(A|F,V) · P(C|V) · P(F) · P(T|F) · P(V)
- [ ] P(A|C,T) · P(C) · P(F|A) · P(T) · P(V|A)
- [ ] P(A|F,V) · P(C|A) · P(F) · P(T|A) · P(V)

2c) Using the formula for the full joint probability distribution and the probabilities given in Table 1 (below) select statements which are True: [3p]

- [ ] P(c, f, t, v) = 0.04125
- [ ] P(f|c, t) ≈ 0.1
- [ ] P(c, f, t, v) = 0.01136
- [ ] P(f|c, t) ≈ 0.45
- [ ] P(a, c, ¬f, t, v) = 0.5 · 0.7 · 0.9 · 0.9 · 0.2 = 0.0567
- [ ] P(a, c, ¬f, t, v) = 0.5 · 0.7 · 0.1 · 0.9 · 0.2 = 0.0063

Table 1: Probabilities for the Bayesian network.

$$P(a|f,v) = 0.9$$
$$P(a|\neg f,v) = 0.5$$
$$P(a|f,\neg v) = 0.9$$
$$P(a|\neg f,\neg v) = 0.01$$
$$P(c|a) = 0.7$$
$$P(c|\neg a) = 0.1$$
$$P(f) = 0.1$$
$$P(t|a) = 0.9$$
$$P(t|\neg a) = 0.1$$
$$P(v) = 0.2$$

Maximum marks: 5

3 Bayesian Networks - Comments

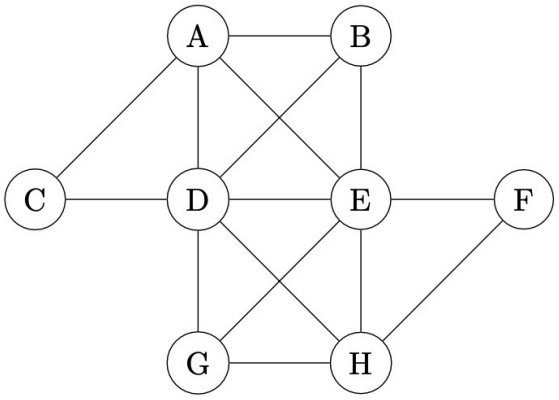
Replace with question text

Any assumptions you make or comments you wish to add related to the BN problems, you can do so in this section:

Maximum marks: 0

4 CSP

The following questions pertain to Constraint Satisfaction Problems (CSPs). CSPs consist of a set of variables, a value domain for each variable, and a set of constraints. A solution to a CS problem is a consistent set of bindings to the variables that satisfy the constraints.
The figure below shows a constraint graph with eight variables. The value domains for each variable are the integer numbers 1 to 8. The constraints state that adjacent/connected nodes can not have consecutive numbers and they must be different.
For example, if node C is labeled 2, then nodes D, and A cannot be labeled with either 1 or 3 (consecutive numbers) or 2 (the same number).



Constraint graph.

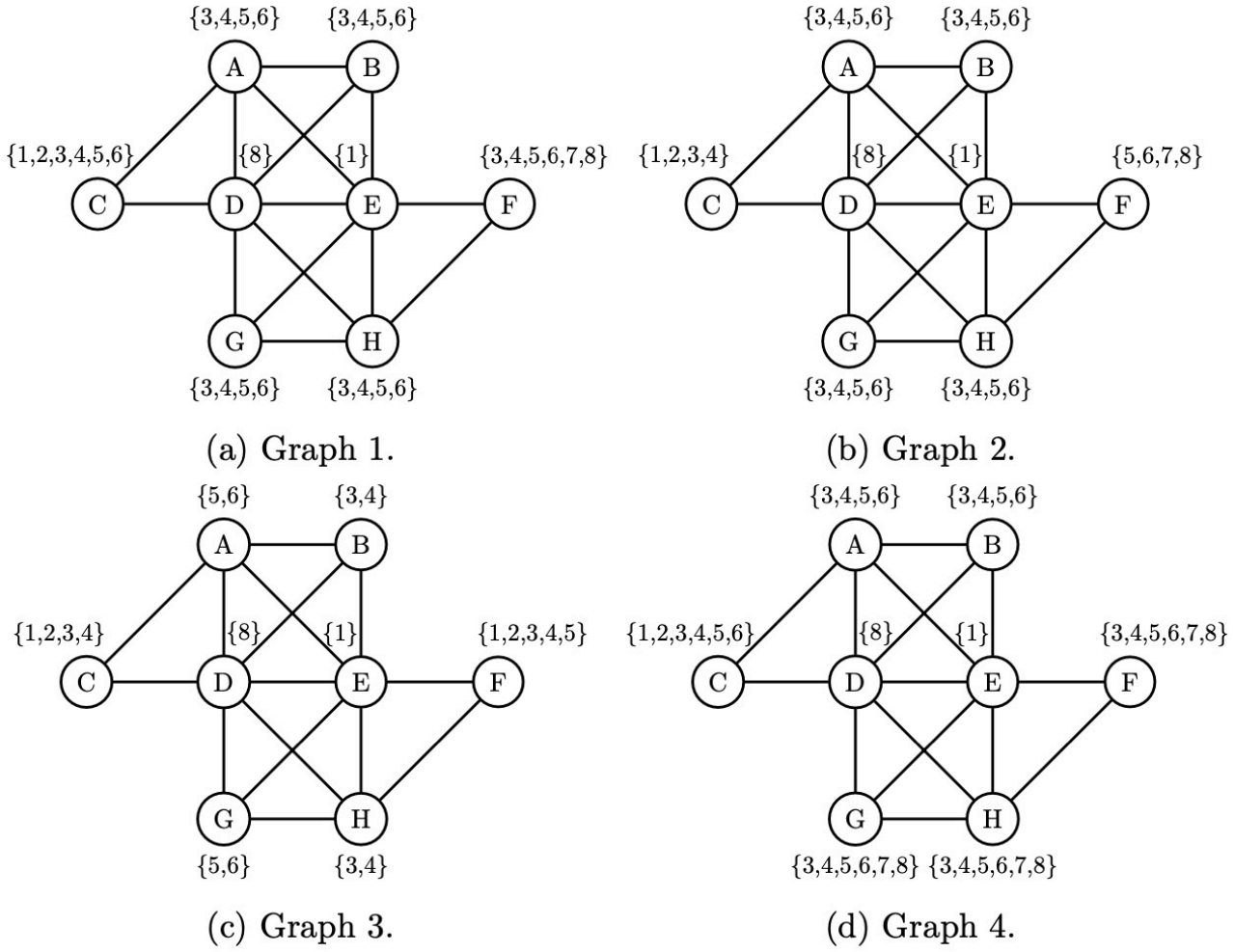
Any assumptions you make or comments you wish to add, you can do so in the next section.

3a) Select statements which are True [2p]:

- [ ] If we apply the most constraining variable order heuristic to the constraint graph above, the D and E nodes will be chosen as potential candidates for labeling.
- [ ] If we apply the most constraining variable order heuristic to the constraint graph above, the C and F nodes will be chosen as potential candidates for labeling.
- [ ] Assuming a variable was chosen using the most constraining variable order heuristic, the minimum conflicts heuristic will select 2, 3, 4, 5, 6, and 7 as the potential candidate values.
- [ ] Assuming a variable was chosen using the most constraining variable order heuristic, the minimum conflicts heuristic will select 1 and 8 as the potential candidate values.

3b) Which of the following graphs pertaining to the CSP problem described in question 3a are arc consistent? [2p]

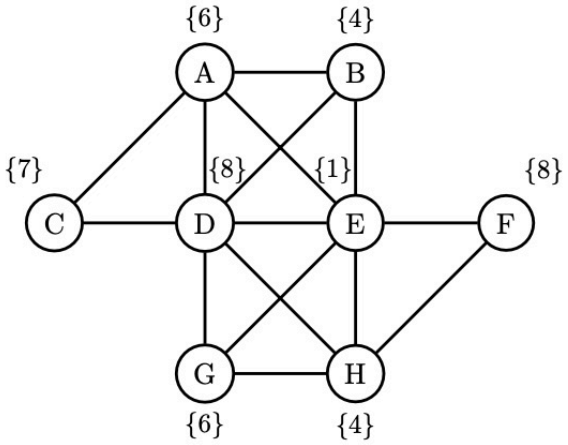
- [ ] Graph 2
- [ ] Graph 4
- [ ] Graph 1
- [ ] Graph 3



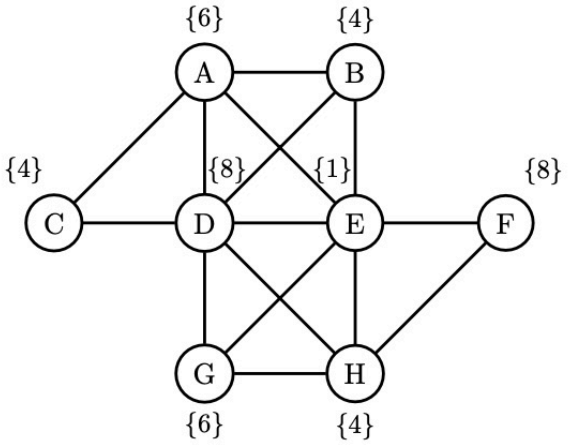
Constraint graphs.

3c) Figure below presents candidate solutions to the CSP problem described in question 3a. Which of the following are globally consistent solutions? [2p]

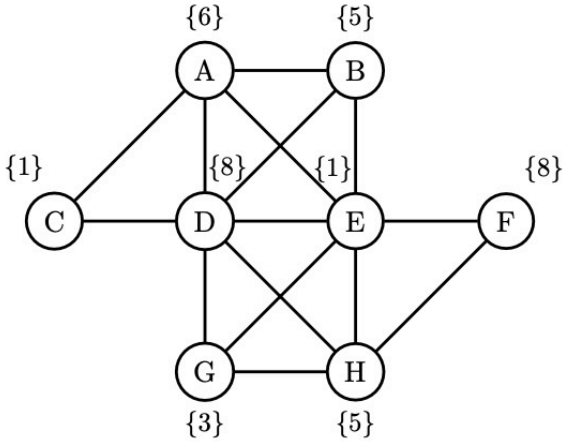
- [ ] Solution 1
- [ ] Solution 4
- [ ] Solution 3
- [ ] Solution 2



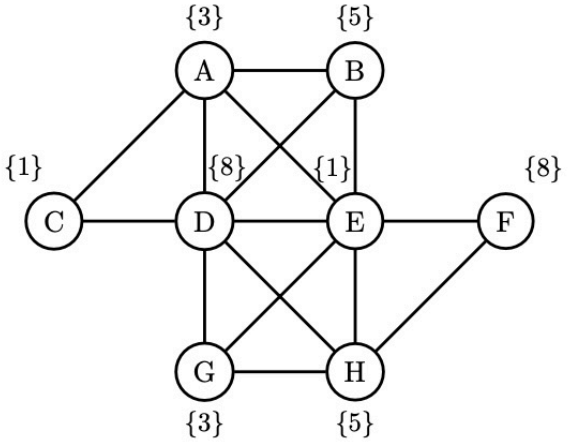
(a) Solution 1.



(b) Solution 2.



(c) Solution 3.



(d) Solution 4.

Maximum marks: 6

5 CSP - Comments

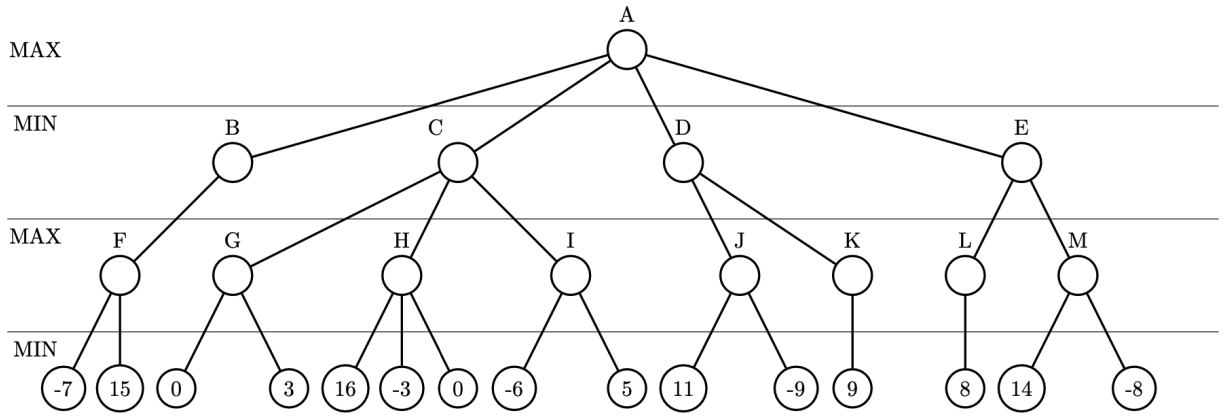
Replace with question text

Any assumptions you make or comments you wish to add related to the CSP problems, you can do so in this section:

Maximum marks: 0

6 Adversarial search

Consider the game tree in the figure below, in which the leaf nodes show heuristic values and where all heuristic values are from the MAX players point of view. Assume the search is in the left to right direction.



4a) Apply the MinMax algorithm to the game tree in the figure and state what move the first player (maximiser) would make. Provide heuristic values for each node in form of a table or text (e.g. A: value, B: value etc.). [2p]

Fill in your answer here

4b) In the game tree above, what nodes would not need to be examined using the alpha-beta pruning procedure? Justify your answer in terms of the relevant alpha/beta values in the nodes of the tree and why certain branches would be cutoff based on this evaluation. Use annotation similar to the question above. To describe edges use one of the following notations: ”second edge below X” or “edge between X and Y”). [3p]

Fill in your answer here

Maximum marks: 5

7 Search

4c) A* search is the most widely known form of best-first search.

Explain what an admissible heuristic function is. [1p]

4d) Suppose a robot is searching for a path from one location to another in a rectangular grid of locations in which there are arcs between adjacent pairs of locations and the arcs only go in north-south (south-north) and east-west (west-east) directions. Furthermore, assume that the robot can only travel on these arcs and that some of these arcs have obstructions that prevent passage across such arcs.

Provide an admissible heuristic for this problem. Explain why it is an admissible heuristic and justify your answer explicitly. [2p]

Maximum marks: 3

8 Planning

For this question, each correctly checked box gives 1 point and each incorrectly checked box gives -1 points. Not checking a box gives 0 points.

5a) Which of the following statements about planning formalisms are true?
Choose 0-4 alternatives

- [ ] In SAS^+ conditions are represented by partial states.
- [ ] The state-space induced by a planning task Π can be exponentially larger than the encoding of Π.
- [ ] Some tasks require multi-valued variables and can thus only be encoded in SAS^+.
- [ ] The main difference between STRIPS tasks and SAS^+ tasks is the size of the variable domains.

5b) Which of the following statements about planning heuristics are true?
Choose 0-4 alternatives

- [ ] For optimal planning, we want heuristics to be admissible.
- [ ] A PDB heuristic with a pattern containing n binary variables can be precomputed and stored in space linear in n.
- [ ] Every relaxed plan is a plan.
- [ ] It is possible to create a PDB heuristic that is equal to the perfect heuristic h^*.

5c) Which of the following statements are true about STRIPS encodings in AI planning?
Choose 0-4 alternatives

- [ ] In STRIPS, states are represented as sets of propositions.
- [ ] STRIPS encodings can directly model probabilistic actions.
- [ ] Since there are no negative preconditions, STRIPS tasks are solvable suboptimally in polynomial time.
- [ ] STRIPS encodings represent actions with preconditions, add-effects and delete-effects.

5d) Which of the following statements about heuristics in AI planning are correct?

Choose 0-4 alternatives

- [ ] Admissible heuristics never overestimate the cost to reach a goal.
- [ ] Heuristics derived for STRIPS tasks are always admissible.
- [ ] Pattern database heuristics are admissible because they are based on abstractions that preserve all paths.
- [ ] $h^{\max}(s) \leq h^{\text{add}}(s)$ for all states s.

5e) Which statements are correct regarding probabilistic planning?

Choose 0-4 alternatives

- [ ] In probabilistic planning, the transition probabilities depend only on the current state and action.
- [ ] In probabilistic planning, all actions are non-deterministic.
- [ ] Probabilistic planning problems are often modeled as MDPs.
- [ ] In probabilistic planning, all action have multiple possible outcomes with different probabilities.

Maximum marks: 12

9 Machine Learning

6a) What is the primary purpose of an activation function in a neural network?
Select one alternative:

- To introduce non-linearity into the model
- To normalize the input features
- To determine the number of neurons in each layer
- To compute the loss during backpropagation

6b) In a convolutional neural network (CNN), what does a pooling layer primarily achieve?
Select one alternative

- Increases the number of feature maps
- Performs matrix multiplication with learned weights
- Reduces the spatial dimensions of the input
- Prevents overfitting by adding noise to the data

6c) What is the purpose of regularization in machine learning models?
Select one alternative

- To optimize the model's loss function
- To prevent the model from underfitting
- To prevent the model from overfitting
- To increase the training accuracy of the model

6d) What is the primary goal of unsupervised learning?
Select one alternative

- To minimize the loss function of a neural network
- To predict the output for a given input
- To discover hidden patterns or structures in data
- To classify data into predefined categories

6e) In an autoencoder, what is the purpose of the bottleneck layer?
Select one alternative

- To calculate reconstruction loss
- To classify input data
- To store the output of the decoder
- To reduce the dimensionality of the input data

6f) In reinforcement learning, which of the following best defines a "policy"?
Select one alternative

- The set of all possible actions an agent can takee 4
- A function that evaluates the quality of a state-action pair
- A mapping from states to actions
- The cumulative reward an agent receives over time

Maximum marks: 6