Questions 1 to 20 require short answers or multiple choice selections. Each question is worth 2 points.

1. Definitions of AI vary along two main dimensions: thinking humanly vs. thinking rationally and acting humanly vs. acting rationally. In which dimension do the following definition lie: “The study of how to make computers do things at which, at the moment, people are better.”
   a. Acting humanly
   b. Acting rationally

2. Cognitive science is a popular scientific discipline. How is it different from “acting rationally” AI?
   Cognitive science is the study of human thinking. As such, it is not directly concerned with the design of artificial systems that exhibit human-like thinking and behavior. Nonetheless, the fields of “acting rationally” AI and cognitive science do support one another. For example, case-based reasoning, a useful AI approach, is based on developments in cognitive science.

3. Would you classify the following as an intelligent agent? (explain if you feel it is necessary)
   a. A switch that turns on the lights when it becomes dark. Yes
   b. A conveyor belt robot that inspects a part for defects. Yes
   Both agents have sensors and effectors, operate in a known environment, and have performance goal(s). Furthermore, both agents are autonomous in the sense that their actions are triggered by percepts and they do not rely on built-in knowledge only. (if it is assumed that the robot acts mechanically with no percepts, then it would not be an intelligent agent).

4. Why is it good to have the performance measure external to the agent?
   The performance measure is the evaluation criterion for the agent. Thus, it is good that it is outside the control of the agent otherwise it might be tempted to modify it to improve its performance.

5. Suppose A and B are independent events with prior probabilities P(A) = 0.5 and P(B) = 0.2. Compute:
   a. P(A OR B) = P(A) + P(B) – P(A AND B) = 0.5 + 0.2 – 0.1 = 0.6
   b. P(A AND B) = P(A | B) P(B) = P(A)P(B) = 0.1

6. How many probability values are needed for the full joint distribution of N discrete random variables with M possible values?
   c. M^N

7. Compute the relative likelihood of corrupted OS files (proposition C) to BIOS setup problems (proposition B) given your computer doesn’t start (proposition S) when you know P(S | C) = 0.8, P(S | B) = 0.5, P(C) = 0.4 and P(B) = 0.6.
   P(C | S) = P(S | C) P(C) / P(S); P(B | S) = P(S | B) P(B) / P(S)
Taking the ratio of these equations:
\[ \frac{P(C | S)}{P(B | S)} = \frac{[P(S | C) P(C)]}{[P(S | B) P(B)]} = \frac{(0.8)(0.4)}{(0.5)(0.6)} = 0.32/0.30 = 1.067 \]

8. Define causal independence? (one sentence or equation)
Random variable A is causally (conditionally) independent of \( U_1 \) given \( U_2 \) if and only if \( P(A | U_1, U_2) = P(A | U_2) \)

9. The Markov blanket of a random variable X includes its
  e. Parent + children + children’s parent variables
10. Simplify \( P(X_1 | X_3, X_4, X_5, X_6, X_7, X_8) \) given Markov blanket of \( X_1 \) is \( \{X_4, X_6, X_7\} \).
    Given the Markov blanket of X:
    \[ P(X_1 | X_3, X_4, X_5, X_6, X_7, X_8) = P(X_1 | X_4, X_6, X_7) \]

11. Write the ordering in which you would add variable nodes to construct a compact
    belief network given the direct influences F to C, D to C, A to D, E to F, E to B, D to G.
    E, A (or A, E), B, F, D (or permutation of B, F, D), C, G (or G, C)

12. We studied several algorithms for inference in belief networks. A major difference
    between the enumeration and cutset conditioning algorithms is that enumeration
    algorithm is
    b. applicable to polytree networks only while cutest conditioning is for multiply
    connected networks

13. Why is likelihood weighting used in stochastic approaches for inference in belief
    networks? (one sentence)
    Likelihood weighing is used in stochastic approaches so as to reduce the number of
    samplings needed to obtain approximates of probabilities of rare events.

14. What is the difference between utility and performance measure? (one sentence)
    Utility is a dimensionless monotonic function that assigns a number to outcome states,
    while the performance measure reflects the achievement of an agent’s goal(s) where the
    value has some physical meaning (e.g. temperature in degree Celsius).

15. Compute the expected utility of a lottery, \( L = \{0.2, S_1; 0.2, S_2; 0.6, S_3\} \), given the
    utilities \( U(S_1) = 100, U(S_2) = 50, U(S_3) = 0 \) (i.e. compute \( EU(L) \))
    \[ EU(L) = (0.2)(100) + (0.2)(50) + (0.6)(0) = 20 + 10 = 30 \]

16. Is an agent that prefers the lottery \( L = \{p, 100,000, (1-p), 0\} \) (irrespective of value of
    p) over getting 5000 for sure being rational? Yes or no, and why?
    No. The agent will be violating the orderability axiom of utility theory which states that
    there exist a value of p for which the agent would be indifferent between the lottery L and
getting 5000 for sure. For example, when p is 0, then the agent is obviously being irrational as it is preferring a lottery that will give 0 to getting 5000 for sure.

17. The following is not a description of a decision network.
   b. Markovian network

18. What is the maximum likelihood hypothesis in Bayesian learning? Why is it useful? In Bayesian learning, an estimate for variable X is computed as: 
   \[ P(X \mid D) = \sum P(X \mid H_i)P(H_i \mid D) \]
   where \( H_i \) are a set of hypotheses. The maximum likelihood hypothesis, \( H_{ML} \), is one that can generate the data most accurately (i.e., \( H_{ML} = \max_i P(H_i \mid D) \)) given the prior distribution of \( H_i \) is uniform. \( H_{ML} \) is useful because it eliminates the need to compute the prior probabilities of hypotheses which are generally not known.

19. Sequential decision problems are similar to single decision problems when
   e. Both a and c

20. Can the adaptive dynamic programming algorithm be used to learn the optimal policy in an unknown environment? Yes or no, and explain briefly.
   Yes. However, it will need to learn the environment model as well. This can be done by observing actual state transitions, approximating the model from it, and then computing the values of utilities from the approximate model.

**Questions 21-23 require brief answers. Points are indicated next to the question number.**

21. Design-describe an intelligent agent for choosing and buying a used car. Be brief and clear.
   a. (4 points) What percepts would it need?
   There are a large number of percepts the agent can possibly use. These include all information needed to analyze the utility of a car. Some useful percepts include:
   - Images or video = to ascertain the condition of the exteriors, the mileage, condition of tires, etc
   - Sound = to determine engine knocking, rattles, braking problems, transmission problems, etc
   - Engine measurements = to ascertain the performance of the engine
   - Smell = to detect oil burning, oil leaks, etc
   - and others

   b. (4 points) What action should it be able to take?
   There are essentially one type of actions the agent should be able to take: the agent should be able to carry out tests on the car to determine its utility. The tests can include driving test, engine test, etc. These tests will give the agent more information about the car from which it can make a better decision on whether to buy it or not.

   c. (4 points) What should be its goal (or goals)?
   Several goals are possible, depending on what is desired and important to the buyer. Some typical goals are:
- buy the car of a certain make, model and age
- buy the car with the best value over its lifetime (say 5 years)
- buy the car with the highest ‘status value’
- buy the car with automatic transmission, blue finishing, A/C, etc
- etc

d. (4 points) What would be its environment (characterize it in terms of environment properties)?
The agent’s environment includes one or more car dealerships (and the entire city road environment if test driving is also considered) with cars and salespeople and associated spatial and temporal properties. Such an environment has the properties: inaccessible in general (but can be considered accessible if sufficient sensors/tests are available), non-deterministic, non-episodic, dynamic, and continuous.

e. (4 points) What agent design would be most appropriate? Why?
A general utility-based agent would be most appropriate. There are several goals that the agent has to satisfy. Obviously, it will have to find a trade-off among conflicting goals by settling for intermediate performance measure(s) for the achievement of the goals. For this reason, utility theory is most appropriate since it considers utilities of individual goals and the expectation of achieving them.

22. Construct a decision network model/representation for the intelligent agent for buying a used car (see last question). (use the back side of the previous page for the answer)
a. (4 points) Identify the random variables, briefly describe them (short sentences), and state their domain (true or false, or possible multiple values)
Price = price or cost of the car [low, medium, high]. These descriptors can be used to categorize different price brackets. For example, low might mean Rs 150,000 to 300,000.
Mileage = the distance traveled in the car [low, medium, high].
Age = the age of the car [0 to 2, 2 to 5, 5 to 10, above 10]
Model = Make and model of the car [a list of desired makes and models]
MRecord = the maintenance record of the car [excellent, good, average, bad]
ECond = Condition of the engine [excellent, good, average, bad]
ExCond = Condition of the exteriors and finishing [good, average, bad]
TCond = Condition of the transmission [good, average, bad]
FConsumption = fuel consumption of the car [low, medium, high]
MCost = routine and needed maintenance cost for the car [low, medium, high]
And others

b. (4 points) Identify and briefly describe the action (or actions) the agent can take. (e.g. one action can be drive = test drive the car)
drive = test drive the car
engtest = engine test
inspect = inspect the exteriors of the car
and others

c. (4 points) Describe the utility function (in words, and in terms of the variables)
The utility function should reflect the ‘value’ of the car to its user during his or her ownership. Thus, the utility function can depend on several variables listed above, most critically it depends on Price, MCost, and FConsumption.

\[ U = U(\text{Price}, \text{MCost}, \text{FConspt}) \]

d. (8 point) Draw the decision network showing the chance nodes, action(s) nodes, utility node, and the causal dependences between them.

23. (a) (10 points) Consider the following belief network:

\[
\begin{array}{c}
\text{A} \\
\downarrow \\
\text{C} & \text{B} \\
\downarrow & \downarrow \\
\text{D} & \\
\end{array}
\]

where A, B, C and D are Boolean random variables. Given \( P(A) = 0.2, P(C) = 0.4 \) and the CPTs (T = true, F = false):
Compute the conditional probability $P(A \mid D = \text{true})$.

By the product rule, normalization, conditional independences, and marginalization:

$$P(A = \text{true} \mid D = \text{true}) = \alpha P(A \text{ and } D) = \alpha P(A) \sum_c \sum_b P(c) P(b \mid A) P(D \mid b, c)$$

$$= \alpha(0.2)[0.4(0.8)(0.8)+(0.2)(0.4)]+0.6[(0.8)(0.6)+(0.2)(0.2)]]$$

$$= \alpha(0.2)[(0.4)(0.72)+(0.6)(0.52)] = \alpha(0.12)$$

Similarly,

$$P(A = \text{false} \mid D = \text{true}) = \alpha P(A = \text{false} \text{ and } D) = \alpha P(A = \text{false}) \sum_c \sum_b P(c) P(b \mid A) P(D \mid b, c)$$

$$= \alpha(0.8)[0.4(0.4)(0.8)+(0.6)(0.4)]+0.6[(0.4)(0.6)+(0.6)(0.2)]]$$

$$= \alpha(0.8)[(0.4)(0.56)+(0.6)(0.36)] = \alpha(0.352)$$

$P(A \mid D = \text{true}) = \{0.254, 0.746\}$

(b) (10 points) Suppose an utility-based agent has a choice of four actions (or lotteries), A, B, C, and D. Actions A and B can lead to outcomes described by the states $S_1$ and $S_2$, while actions C and D can lead to outcomes described by the states $S_3$ and $S_4$. The agent knows the probabilities of the lotteries (actions):

A = {0.2, $S_1$; 0.8, $S_2$}
B = {0.6, $S_1$; 0.4, $S_2$}
C = {0.4, $S_3$; 0.6, $S_4$}
D = {0.8, $S_3$, 0.2, $S_4$}

And the utilities:

$U(S_1) = 4$, $U(S_2) = 10$, $U(S_3) = 2$, $U(S_4) = 8$

Determine the best action for the agent.

$$EU(A) = (0.2)(4) + (0.8)(10) = 8.8$$
$$EU(B) = (0.6)(4) + (0.4)(10) = 6.4$$
$$EU(C) = (0.4)(2) + (0.6)(8) = 5.6$$
$$EU(D) = (0.8)(2) + (0.2)(8) = 3.2$$

Thus, by the maximum expected utility, the best action is A.