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CCEA A2

DIGITAL TECHNOLOGY

ANSWERS

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Answers

Chapter 1 – Networks

1. Key characteristics of a LAN – any of the following:
   - Small scope: Covers a limited geographical area, such as a home, office floor, or building.
   - High speeds: Utilises high-speed data transmission rates via Ethernet cables, fibre-optic cables, or wireless technologies such as Wi-Fi.
   - Privately managed: Owned and managed by the deploying organization or individual, allowing for greater control over security, network policies and resource allocation.
   - Facilitates resource sharing: Enables efficient sharing of resources (like printers, files, databases and internet connectivity) among connected devices.

   Advantages of a LAN – any of the following:
   - Efficient communication: Facilitates rapid and reliable communication between devices in close proximity.
   - Resource sharing: Promotes collaboration and productivity by allowing network resources to be shared.
2. MANs facilitate communication and resource sharing through the following:
   - Having an intermediate scope, covering a larger geographical area than LANs, typically spanning across a city or metropolitan region.
   - Interconnectivity between multiple LANs within the same locality, enabling communication and resource sharing between various entities, such as organisations, campuses or institutions.
   - Reliable and high-performance network infrastructure, often facilitated by telecommunication companies or service providers.
   - Having a high bandwidth to support the data transmission requirements of interconnected LANs.
3. MAC Address: acts as a globally unique identifier assigned to a network interface at the hardware level, enabling communication on a local area network.
   IP Address: provides a numerical identifier for each device connected to a wide area network. It is set at the software level and can be network-specific.
4. A network card, also known as a network interface card (NIC), enables a device to connect to a computer network. It acts as an interface between the device and the network, converting digital signals from the device into a format suitable for transmission across the network medium (for example electrical signals in an Ethernet cable or radio waves in a wireless signal).
5. A server has two principal roles:
   - As a resource provider for services, resources and data to other devices (clients) within the network.
   - To centralise the management of data, applications and other resources, enabling efficient resource sharing and management.
6. Old types of network hubs forwarded all data to all devices on the network, leading to network congestion and reduced performance. Modern switched hub (switches) intelligently route data only to the intended recipient based on their MAC addresses, reducing unnecessary data traffic and improving overall network speed. This means it can handle simultaneous data transmission between multiple devices without interference, enhancing network performance and efficiency.
7. A network repeater extends the reach of a network by receiving and regenerating the original signal. It is used in situations where the distance between devices exceeds the transmission limits of the network medium, such wi-fi signals as in larger buildings or along long lengths of cable.

8. Key factors:
   - The long distances covered by WANs, spanning extensive geographical areas, lead to increased transmission times (latency).
   - Reliance on many interconnected routers, switches and various transmission media makes WANs technically complex which can reduce overall bandwidth.

   Technological Advancements that address these challenges:
   - Improved transmission technologies such as fibre-optic cables and advanced networking equipment to increase speed and reduce latency.
   - Internet-based virtual private networks allow for secure, efficient data transmission over public networks.
   - Adoption of enhanced protocols such as IPv6 to support higher data rates and real-time applications.
   - Advanced algorithms and techniques to optimise data paths and reduce delays.
9. Answer should address the following points:
   - Architecture: Server in a server-based network is a centralised resource provider, managing and distributing resources to clients. However, in a P2P network each peer acts as both a client and a server, sharing resources directly with other peers.
   - Resource distribution is centralised in a server-based network, allowing for efficient management and control. In a P2P network it is decentralised, with resources distributed among peers.
   - Scalability: A server-based network can handle many client requests simultaneously but requires significant infrastructure investment. A P2P network is easily scalable, as each peer adds to network capacity.
   - Security: Easier to implement robust security measures on a sever-based network due to central control. It is more challenging to enforce security on a P2P network, as there is no central control.
   - Availability: Server-based networks have reliable resource access, though it does dependent on the server's functionality. In a P2P network resources depend on the availability of peers, leading to potential inconsistencies.
10. Answer should include the following points:
    - Operation: MAC addresses are unique hardware identifiers assigned to network interfaces at the point of manufacture, used for local network communication, whereas IP addresses are numerical identifiers assigned to devices connected to a wide area network, facilitating routing and communication over the internet.
    - Assignment: MAC addresses are fixed and globally unique, written as six pairs of hexadecimal digits (e.g., 00:1A:C2:7B:00:47), whereas IP addresses can be dynamically assigned using DHCP or statically configured. IP addresses are written as four numbers separated by periods (IPv4) or eight hexadecimal numbers separated by colons (IPv6).
    - Role in network protocols: MAC addresses are used for identifying devices on a local network (e.g., within a LAN), whereas IP addresses are used for identifying devices on a wide area network (e.g., the internet).

Chapter 2 – Protocols

1. There are seven layers in the OSI model. They are, in order from top to bottom:
   - Application layer
   - Presentation layer
   - Session layer
   - Transport layer
   - Network layer
   - Data Link layer
   - Physical layer
2. The Presentation layer handles data encryption, compression and formatting.
3. The OSI model simplifies troubleshooting processes by providing a layered structure that isolates network issues to specific layers. This makes it easier to identify and resolve problems by focusing on the affected layer, leading to efficient network maintenance.
4. The top three layers of the OSI model are collectively referred to as the Application Set. Their role is to provide network services to applications, handle data representation and translation and manage communication sessions between applications running on different devices.
5. The Transport layer ensures reliable and error-free data delivery between applications by dividing large data streams into smaller segments, adding sequence numbers and managing flow control. It ensures that data arrives accurately, in the correct order and without errors.

6. The purpose of TCP/IP in networking is to provide a suite of communication protocols that govern how data is transmitted, routed and received over the internet and other networks. It ensures reliable, efficient and scalable communication between devices across different network topologies and technologies.
7. Ethernet primarily operates in the Data Link and Physical layers of the OSI model.
8. CSMA/CD handles network access by allowing devices to listen for any ongoing transmissions before transmitting. It can detect collisions during data transmission, at which point it will wait for a random back-off period before retransmitting. Token passing, on the other hand, grants access to the network medium through a token that circulates within the network. Only the device holding the token can transmit data, preventing collisions and ensuring orderly access.
9. Advantages/benefits of Wi-Fi:
   - Eliminates the need for physical cables, allowing for mobility and flexible access to network resources.
   - Supports high data transfer rates, facilitating activities such as streaming high-definition media, online gaming and large file transfers.
   - Highly scalable, allowing for easy expansion and coverage extension with additional access points or Wi-Fi range extenders.
10. The maximum effective range of Bluetooth is up to 100 metres for Class 1 devices and 10 metres for Class 3 devices.
11. VoIP (Voice Over Internet Protocol) enables the digital transmission of voice content over computer networks, allowing phone calls to be made using the internet. Traditional phone lines use analogue signals to carry sound over dedicated telephone networks. Traditional phone lines are typically more reliable in power outages, whereas VoIP requires both internet connectivity and electrical power to function.
12. RFID (radio-frequency identification) is a technology that uses radio waves to automatically identify and track objects or people. It consists of tags or labels containing electronically stored information and readers or scanners that communicate with the tags to retrieve this information. RFID provides a non-contact method of identification and tracking, making it ideal for applications requiring speed and automation, such as inventory management and access control.
13. Interoperability in the context of the OSI model refers to the ability of different devices and systems from various manufacturers to work together seamlessly. The OSI model facilitates interoperability by defining standard protocols and interfaces for each layer. By adhering to these standards, devices implementing a specific layer can communicate effectively with those implementing adjacent layers, regardless of their manufacturer. This is important for building and maintaining networks as it ensures compatibility, allowing for diverse devices to interoperate, fostering global connectivity and collaboration and simplifying network design and troubleshooting.
14. Ethernet offers several advantages, including high reliability, robust performance and scalability. It supports various network topologies and data rates, making it adaptable to different environments. Ethernet is more reliable than Wi-Fi, providing consistent performance with minimal interference and higher data transfer rates. It is also highly scalable, accommodating growth by supporting faster speeds and additional devices through network switches. While Wi-Fi offers the advantage of mobility and ease of installation, Ethernet provides superior performance and reliability, making it the preferred choice for environments where stable and high-speed connections are crucial.
15. Advantages: VoIP has significantly impacted traditional phone services by offering cost savings and increased flexibility. It eliminates the need for separate telephone lines and enables scalable communication solutions that can allow users to be easily added or removed. VoIP supports features like call forwarding, voicemail, video conferencing and integration with other applications, enhancing communication capabilities.
    Challenges: ensuring network quality to avoid issues like latency and packet loss, addressing security concerns to protect against eavesdropping and data breaches and managing the dependency on electrical power and internet connectivity.

Chapter 3 – Transmission Media

1. Bandwidth refers to the amount of data that can be transferred across a transmission medium in a given time.
2. Bandwidth is typically measured as the number of bits (1s or 0s) that can be accurately communicated per second. For example, a medium that can transfer 56,000 bits per second would have a bandwidth of 56 kilobits per second (56 kbit/s).
3. At the time of writing, the maximum bandwidth of modern Ethernet connections was about 100 gigabits per second (100 Gbit/s).

4. Broadband refers to an internet connection that is always connected and has a high bandwidth capable of transferring multiple signals simultaneously. Unlike dial-up connections, broadband does not require users to connect and disconnect each time they access the internet.
5. The main problem encountered when sending signals along metal cables is electromagnetic interference. External electromagnetic signals can induce electrical currents in the metal conductor, which can degrade or completely swamp the intended signal, leading to data loss.
6. Shielded twisted pair cables address interference issues by incorporating shielding, such as metal foil or braided copper, around the twisted pairs of wires. This shielding protects the signal from external electromagnetic interference. It also contains the signal within the cable to prevent it from interfering with other nearby cables and devices.
7. Advantages of coaxial cables over twisted pair include the following:
   - Better protection against electromagnetic interference due to the shielding provided by the copper braiding and plastic insulator.
   - Higher bandwidth capabilities, typically up to 1 Gbit/s.
   - Longer transmission distances, typically a few hundred meters.
   - Slightly better security, as they are thicker and require more specialised tools to tap into them.
8. Single-mode fibre optic cables are more suitable for long-distance connections because they have an extremely narrow core, which minimises signal loss and allows for higher bandwidths and longer transmission distances. They can carry signals over ranges from about 50 kilometres to over 1000 kilometres, making them ideal for intercontinental and undersea communication.
9. Bluetooth uses radio waves at a frequency of 2.4 GHz.
   Wi-Fi uses a range of frequencies between 2.4 GHz and 5 GHz, with newer versions also utilising the 5.9 GHz to 7.1 GHz range.
10. The typical maximum bandwidth of Wi-Fi connections is up to 250 megabits per second (Mbit/s).
11. Wireless communication, such as Wi-Fi, typically offers a maximum bandwidth of up to 250 Mbit/s. In contrast, fibre optic communication can offer much higher bandwidths, with single-mode fibre optic cables capable of bandwidths up to 100 Gbit/s. Fibre optic cables are thus significantly faster and more suitable for high-bandwidth applications than wireless communication.
12. A twisted pair cable reduces the problem of electromagnetic interference by sending the same signal down two wires twisted together. The first wire carries the intended signal, while the second wire carries the same signal in reverse phase (high voltage becomes low and vice versa). Any external electromagnetic interference affects both wires equally. At the destination, the second signal is inverted again, which also inverts the interference. When this inverted signal is added to the first signal, the interference cancels out, leaving a clean signal. This technique mitigates the impact of electromagnetic interference on the transmitted data.

Chapter 4 – Errors

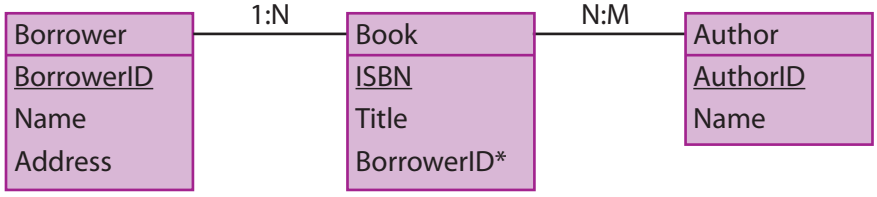
1. The detection of errors is essential for data systems to ensure the integrity and accuracy of the transmitted data. Errors can cause significant problems, such as incorrect financial transactions or system failures. Detecting errors helps maintain reliability, privacy and customer trust in communication systems.
2. Common causes of data errors:
   - electromagnetic interference
   - hardware malfunctions
   - weakening of signals over long distances
   - deliberate security breaches
3. The primary function of parity bits in error detection is to detect errors that may occur during data transmission. An odd parity system checks that the total number of '1' bits in the transmitted data (including the parity bit) is still odd. An even parity system checks that the total number of '1' bits in the transmitted data (including the parity bit) is still even.
4. Even parity: the total number of '1' bits in the data, including the parity bit, is made even. If the data contains an odd number of '1' bits, the parity bit is set to '1' so that the total number of '1' bits is even.
   Odd parity: the total number of '1' bits in the data, including the parity bit, is made odd. If the data contains an even number of '1' bits, the parity bit is set to '1' so that the total number of '1' bits is odd.

5. A receiver detects errors using parity bits by counting the number of '1' bits in the received data (including the parity bit) and comparing it to the expected parity (odd or even). If the count does not match the specified parity, an error is detected. When an error is detected, the data is discarded and the sender is instructed to retransmit the data.
6. Limitations include:
   - They can only detect odd numbers of errors, for example one 'flipped' bit, three 'flipped' bits etc. Even numbers of bit 'flips' will not be detected.
   - They cannot correct errors. Instead, the data must be retransmitted.
   - For large datasets, the overhead of adding parity bits can become inefficient, increasing bandwidth and storage requirements.
7. A checksum detects errors in transmitted data by calculating a numerical value derived from the data and sending it along with the data. At the receiver's end, the checksum is recalculated and compared with the received checksum. Any discrepancies between the two indicate errors in the transmission.
8. Two advantages of CFC:
   - Offers higher error detection capabilities and can often detect multiple errors in data transmission.
   - Less vulnerable to intentional tampering due to its mathematical basis, making it more reliable for critical applications.
9. CRC is more efficient than echo checking in terms of network usage. CRC adds a relatively small amount of extra data (the checksum) to the transmission, while echo checking doubles the network traffic by requiring each message to be sent twice (once for the original message and once for the echo). This makes CRC less resource-intensive and faster.
10. Parity bits are simpler and faster to implement, providing a quick method for detecting single-bit errors. However, they can only detect odd numbers of errors and cannot correct them. Checksums, on the other hand, provide a more robust method for detecting errors and can detect multiple-bit errors, especially when using complex algorithms like CRC. However, checksums require more computational resources and can introduce more overhead compared to parity bits. Parity bits are advantageous for small, less critical data sets, while checksums are better for larger and more critical data transmissions.
11. Echo checking operates by transmitting data to the receiver, which then retransmits the received data back to the sender. The sender compares the echoed data with the original data to detect any errors. Disadvantages of echo checking include doubling network traffic, reducing communication speed and being unable to determine whether the error occurred during the original transmission or the echo. Despite these disadvantages, echo checking is still used because it is simple to implement and has a high level of reliability due to its low tolerance for errors, making it useful in environments where simplicity and reliability are more critical than efficiency.

Chapter 5 – Relational Databases

1. A flat-file database is a simple database that consists of a single table with rows and columns. Each row represents a record and each column represents a field or attribute. This type of database is straightforward but can lead to data duplication and inconsistency issues.
2. Relational databases were developed to resolve the problems of data duplication and inconsistency found in flat-file databases. They organise data into multiple related tables, improving data integrity, reducing redundancy and making data management more efficient and reliable.
3. Two differences:
   - A flat-file database consists of a single table, whereas a relational database contains multiple tables with defined relationships between them.
   - A flat-file database often leads to data duplication and inconsistency, while a relational database minimises these issues through the use of relationships and primary keys.
4. An entity is a distinct object or concept for which data is stored. Entities represent real-world objects such as people, places, or things. Each entity has attributes that describe its characteristics. For example, in a school database, entities could be students, forms and subjects.
5. A primary key is an attribute or a set of attributes that uniquely identifies each record in a table. It ensures that each record is unique and can be referenced unambiguously. For example, a StudentID might serve as primary key for a table called Student.

6. A foreign key is an attribute in one table that uniquely identifies a row of another table by storing a reference to the primary key in that table. In a relational database, foreign keys are used to maintain referential integrity between tables. They ensure that the relationships between records in different tables remain consistent, preventing actions that would leave the database in an inconsistent state, such as deleting a record that is still being referenced by another table.
7. A many-to-many relationship cannot be directly implemented in a relational database. It is handled by creating an associative table that links the primary keys of the two related tables. This associative table contains foreign keys that reference the primary keys of the related tables, effectively breaking the many-to-many relationship into two one-to-many relationships.
8. Referential integrity ensures that relationships between tables remain consistent. In practice, it means that a foreign key value in one table must correspond to an existing primary key value in another table. If a user tries to enter a value in a foreign key field, they will only be allowed to make that change if that value appears as the primary key in the linked table. Similarly, if a user deletes a record from a table, then the database will automatically also delete all his associated entries in the other tables that contain references to that table. This prevents orphan records and maintains the logical consistency of the database.
9. A primary key is important in maintaining referential integrity because it uniquely identifies each record in a table. Foreign keys in other tables reference primary keys and it is by this mechanism that the relational database ensures that relationships between records are valid and consistent, which prevents orphan records and data inconsistencies.
10. Any five of the following:
    - Allows users to create more than one table in the same database.
    - Allows users to define relationships between tables.
    - Constrains input/validation to ensure data integrity.
    - Allows users to run queries using Structured Query Language (SQL).
    - Provides the ability to add, delete and update records.
    - Manages access rights to control user permissions.
    - Enforces referential integrity to maintain consistent relationships between tables.
11. The purpose of SQL in a relational database is to provide a powerful and flexible language for querying, updating and managing the data. SQL allows users to perform a wide range of operations, such as retrieving specific data, modifying existing data and defining the structure of the database.
12. Constraining input/validation is important in a relational database to ensure that the data entered is accurate, consistent and in the correct format. For example, it would prevent you entering 'Belfast' or '43 July 2025' into a field intended to store a date. This helps prevent errors, maintains data integrity and ensures that the database functions correctly and reliably.
13. An entity-relationship (ER) diagram is a visual representation of the logical model of a database. It shows entities, their attributes and the relationships between them. Relationships are represented by lines connecting entities, often with 'crow's feet' notation to indicate the cardinality of the relationships (one-to-one, one-to-many, or many-to-many).
14. A logical model defines the entities, their attributes, relationships and primary keys in a high-level view, without considering how the database will be physically implemented. A data model, by contrast, specifies how the logical model will be implemented in the database, including the tables to be created, field names, data types, primary keys and any validation rules.
15. (a)



(b) Create the following tables, where underlining indicates the primary key and an asterisk* indicates a foreign key. Note the fourth table, BookAuthor, to manage the M:N relationship. (Exact number and names of the non-key fields are not important and will vary by student's answer.)
Borrower(BorrowerID, Name, Address)
Book(ISBN, Title, BorrowerID*)
Author(AuthorID, Name)
BookAuthor(ISBN*, AuthorID*)

Relationships:

Borrower	1:N	Book
Author	1:N	BookAuthor
Book	1:N	BookAuthor

16. Referential integrity is essential for maintaining data consistency because it ensures that relationships between tables are valid and that foreign key values always refer to existing primary key values. Without referential integrity, orphan records can occur, leading to data inconsistencies and errors.
[Any example of this will suffice but this is one possibility.] For example, a school may have a Student table and a Marks table to hold their exam results. If a Student record is deleted but their associated records in the Marks table are not, it creates orphan records that reference a non-existent student. This can result in misleading reports and incorrect data analysis.
17. This question is not directly answered in the text and requires the student to think through their knowledge of how relational databases work. Possible points to make:
    - Data integrity: non-unique or poorly-chosen primary keys can lead to duplicate records, undermining the integrity of the database.
    - Performance: inefficient primary keys, such as long text fields, can slow down database operations like searches and indexing.
    - Maintenance: changing an existing primary key can be complex and error-prone, particularly if it is used as a foreign key in another table.
    - Relationships: inconsistent or ambiguous primary keys can disrupt the establishment of clear and reliable relationships between tables, leading to data inconsistencies and orphan records.
    - Scalability: poorly chosen primary keys might not scale well with increasing data volumes, leading to performance bottlenecks and increased maintenance complexity.

Chapter 6 – Optimising Databases

1. An atomic attribute is an attribute that cannot be further divided into smaller parts. It contains a single piece of information. [Any example of this will suffice but this is one possibility.] For example, in a database, an attribute 'FullName' containing the first and last names of a person is not atomic because it contains two distinct pieces of information. However, the attribute 'FirstName' is atomic because it only contains the first name of a person.
2. A repeating group is a set of data that contains multiple values for the same entry. For example, consider a table called Order which stores details of orders received by a company. If a given Order in this table can contain two or more Products, then the attributes in the table that relate to these Products form a repeating group.
3. It is important to eliminate partial dependencies to ensure that all non-key attributes are fully dependent on the entire primary key, not just part of it. This reduces data redundancy and inconsistency by ensuring that each piece of data is stored in only one place. The process also simplifies data maintenance and data updates.
4. (a) Data is in 1NF (First Normal Form) if:
    - all attributes are atomic; and
    - entities should not contain any repeating groups.

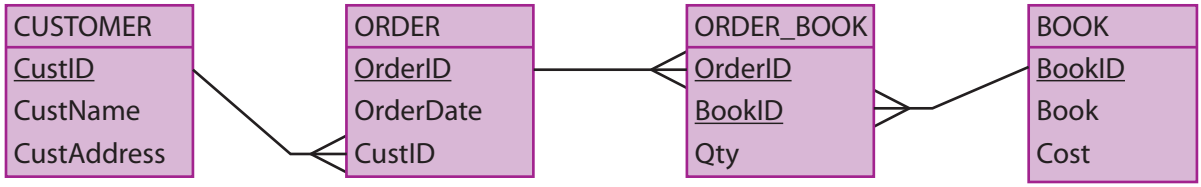
   (b) Data is in 2NF (Second Normal Form) if:
    - it meets the criteria for 1NF; and
    - all non-key attributes are fully dependent on the primary key.

   (c) Data is in 3NF (Third Normal Form) if:
    - it meets the criteria for 2NF; and
    - there are no non-key dependencies (or, there are no transitive dependencies).

5. A developer might choose not to strictly adhere to normalization principles to avoid unnecessary complexity in the database structure, which can make data entry and querying cumbersome. For example, strictly normalising postal addresses might require splitting them into multiple tables (one for the postcode and one for the full address with street number) which can over-complicate data input without providing significant benefits in terms of storage or data integrity.
6. A non-key dependency (or transitive dependency) occurs when an attribute depends on another attribute that itself is not part of the primary key. It is a concern because it leads to data redundancy (since the same data has to be stored multiple times) and inconsistency (as changes to the dependent attribute must be made in multiple places, increasing the risk of errors).
7. Primary keys uniquely identify each record in a table, ensuring that each record is distinct.
   Foreign keys establish relationships between tables, referring to a specific entry in another table by storing the primary key of that entry. This helps maintain referential integrity by ensuring that references between tables remain consistent.
8. Any three of the following:
   - Improved data integrity: By eliminating redundancies and dependencies, normalization reduces the risk of data inconsistencies.
   - Reduced redundancy: Data is stored more efficiently, reducing storage requirements.
   - Enhanced query performance: Normalized data structures simplify data retrieval and analysis, making queries more straightforward and efficient.
   - Flexibility and adaptability: Simplifies modifications to existing data or the assimilation of new information
   - Scalability: The structured data allows for the addition of new tables, or modification of existing ones, without triggering cascading changes throughout the system.
9. Any one of the following:
   - Increased join operations: As data fragments into distinct tables, joins are needed to reconstruct comprehensive datasets during queries, which uses processing power.
   - Complexity in implementation: Normalization produces a more complicated design than a flat-file database and it take more skill to implement.
   - Performance of updates: A normalized database enforces referential integrity, so modifying records many generate a cascade of additional updates, incurring additional computational overhead.
   - Performance of strict normalization: In some cases, strict normalization may be counterproductive, for example storing a postcode separately from the rest of an address.
10. The primary purpose of a data dictionary is to establish a common language to enable database developers and users to understand the database and to streamline database management. It is an important tool that enhances the efficiency of database design, usage and maintenance by promoting uniformity among different users.
11. All four of the following:
    - Definitions of data elements, e.g. data type, length and constraints.
    - Descriptions of the data structure, i.e. the tables and the attributes they contain.
    - Data relationships such as primary and foreign keys and rules for referential integrity.
    - Other metadata for database management.
12. (a) The table is not in 1NF because it contains repeating groups. For example, OrderID 100 has multiple entries for three different books, which means that information about the customer and the order is repeated for each book.
    (b) To normalize the data to 1NF, split the repeating groups into separate rows, ensuring each attribute contains only atomic values. Thus we have:
    ORDER(<u>OrderID</u>, OrderDate, CustID, CustName, CustAddress)
    ORDER_BOOK(<u>OrderID</u>*, <u>BookID</u>, Book, Cost, Qty)
    (c) To achieve 2NF, ensure that all non-key dependencies are fully dependent on the primary key. In this case Book, Cost and Qty of the table ORDER_BOOK are not fully dependent on the primary key. Thus we have:
    ORDER(<u>OrderID</u>, OrderDate, CustID, CustName, CustAddress)
    ORDER_BOOK(<u>OrderID</u>*, <u>BookID</u>*, Qty)
    BOOK(<u>BookID</u>, Book, Cost)

(d) To achieve 3NF, remove all non-key dependencies (transitive dependencies). In this case, CustID, CustName and CustAddress of the table ORDER are all dependent on CustID which is itself dependent on the primary key. Thus we have:
ORDER(OrderID, OrderDate, CustID*)
CUSTOMER(CustID, CustName, CustAddress)
ORDER_BOOK(OrderID*, BookID*, Qty)
BOOK(BookID, Book, Cost)

(e)



13. Answer should address the following main points:
- A data dictionary is a comprehensive guide that provides detailed information about the data within a database. It serves as a reference manual, ensuring clarity and consistency in understanding and managing the database. The data dictionary typically includes:
- Definitions of data elements: Names, data types, lengths, default values and constraints for each attribute.
- Descriptions of the data structure: Information on tables and their attributes.
- Data relationships: Details on primary and foreign keys and referential integrity rules.
- Other metadata: Indexing information, user access permissions and validation rules.
- The data dictionary enhances communication between technical and non-technical users, ensures data integrity by standardising data definitions and constraints and provides lasting documentation for future database management and modifications. It helps different users to have a common understanding of the database structure and usage, reducing the risk of errors and inconsistencies.

Chapter 7 – Using Databases

1. The full syntax is:
```
SELECT field1, field2, … FROM Table WHERE condition ORDER BY field;
```
Note that WHERE and ORDER BY are optional.
2. In SQL, the asterisk * is a shortcut that represents all columns in the table. Using:
```
SELECT * FROM Table;
```
will retrieve all columns from the specified Table.
3. The WHERE clause is used to filter records based on specified conditions. Only those records that meet the specified criteria are returned. For example the command:
```
SELECT FirstName, LastName FROM EMPLOYEE WHERE LastName = 'Brown';
```
will only return the names of employees whose last name is Brown.
4. The ORDER BY clause is used to sort the result set of a query by one or more columns. The default sorting order is ascending, but it can be set to descending using the DESC keyword. For example, the command:
```
SELECT FirstName, LastName, Salary FROM EMPLOYEE ORDER BY Salary DESC;
```
will return the first name, last name and salary of each employee, sorted by salary in descending order.
5.
```
CREATE TABLE TableName(
   Field1  DataType,
   Field2  DataType
   …
);
```
6. The INSERT INTO command in SQL is used to add new records to a table. The syntax is:
```
INSERT INTO Table(Field 1, Field 2, …)
VALUES (Value1, Value 2, …);
```

7. The UPDATE command in SQL modifies values in existing records of a table. The syntax is:

```
UPDATE Table
SET Column1 = Value1, Column2 = Value2, ...
WHERE Condition;
```

For example, the command:

```
UPDATE Employee
SET Salary = 61000
WHERE Department = 'Marketing';
```

will change the salary of everyone in the Marketing department to £61000.

8. Either of these precautions:
   - Omitting the WHERE clause will delete all records in the table.
   - It is important to consider the impact of a deletion on referential integrity, as deleting records can cause multiple cascade deletions in related tables.
9. QBE (Query By Example) differs from SQL in that it provides a graphical interface where users can construct queries by interacting with a visual representation of the database. By contrast, SQL uses commands that must be typed with the correct syntax. The QBE approach is more intuitive and accessible for users who are not familiar with the syntax and structure of SQL.
10. Advantages of QBE over SQL:
    - User-friendly and accessible for those with limited programming experience.
    - Reduces opportunities for syntax errors.
    - Faster learning curve due to its visual and interactive nature.
    - Minimises errors by allowing direct manipulation of query criteria.

    Disadvantages of QBE over SQL:
    - It has limited complexity so it may be difficult to create highly intricate queries.
    - Less useful for SQL experts who might find typing SQL commands quicker.
    - Lack of universal standard: Interfaces vary between different systems, requiring adaptation when switching platforms. SQL has the same syntax in all database systems.
11. (a) `SELECT * FROM CAR WHERE Make = 'Ford' ORDER BY Price DESC;`
    (b) `INSERT INTO CAR (CarID, Make, Model, Price) VALUES (56, 'Renault', 'Zoe', 13000);`
    (c) `DELETE FROM CAR WHERE Price < 5000);`
    (d) `UPDATE CAR SET Make = 'Renault' WHERE Make = 'Rneault';`
12. Your answer should weigh up the advantages and disadvantages of both systems. One possible answer is as follows:
    - QBE offers a user-friendly way to interact with databases, using a graphical interface that simplifies query building for non-technical users. This makes it easier to construct queries without writing SQL code, as users can drag and drop fields to create queries, reducing the need for technical expertise and minimising syntax errors. The visual representation helps beginners grasp database concepts quickly, providing a faster learning curve.
    - QBE reduces complexity by minimizing syntax errors through its interactive elements, such as clicking and dragging, which enhances the user experience. Even those without programming backgrounds can start constructing effective queries relatively quickly.
    - However, QBE has its drawbacks. It struggles with complex database operations that SQL handles well, limiting its usefulness for advanced tasks. QBE might also be less efficient for SQL experts, who may find it slower compared to writing SQL commands directly. The lack of advanced features can be a significant drawback for sophisticated database needs.
    - Another issue with QBE is the lack of a universal standard. Different database systems implement QBE in various ways, leading to variability across platforms. This inconsistency can be confusing and requires additional training for users switching systems.
    - While QBE is valuable for beginners and straightforward queries due to its graphical and intuitive approach, it has limitations for handling complex operations. SQL remains essential for advanced tasks and offers powerful functionalities that QBE cannot fully replicate. It is not possible to say that one approach is always better than the other, as it depends on the skill of the user and the technical requirements of the task.

Chapter 8 – Artificial Intelligence

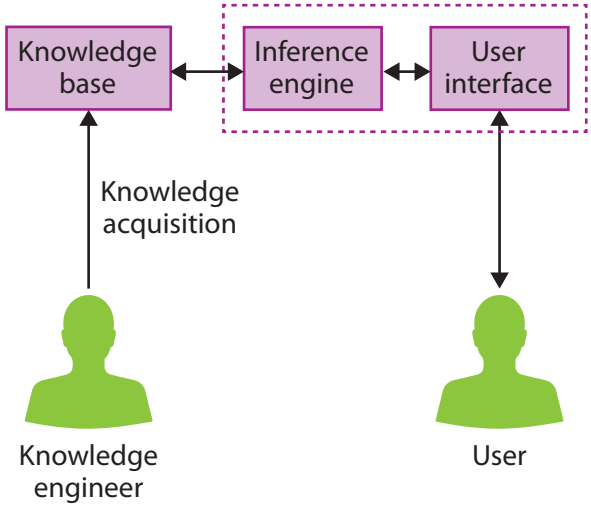
1. Artificial intelligence (AI) refers to the ability of machines to perform tasks that typically require human intelligence. This includes capabilities such as learning, reasoning, problem-solving, perception and language understanding. Examples of AI's principal uses in daily life can include any of the following:
   - Virtual personal assistants (e.g., Siri, Google Assistant, Alexa) that understand voice commands and provide information or perform tasks.
   - Recommendation algorithms on platforms like Netflix or Spotify, which analyse user history to suggest content.
   - Chatbots on eCommerce websites to handle customer queries.
   - AI in computer games for more realistic opponent responses.
   - AI image generation software to create lifelike images from textual input.
2. Supervised learning:
   - Involves training an algorithm on labelled data, where the input data comes with predefined labels that help the machine understand what it is supposed to learn. An example is an email filtering system that learns to identify junk mail based on labelled examples of 'junk' and 'not junk' emails.

   Unsupervised learning:
   - Involves feeding the algorithm unlabelled data, allowing the machine to find patterns or relationships within the data on its own. An example is a business analysing customer purchase history without predefined categories to identify purchasing patterns.
3. The purpose of the Turing Test is to evaluate a machine's ability to exhibit intelligent behaviour indistinguishable from that of a human during a natural language conversation.
4. The Turing Test is conducted with a human judge, a human respondent and a candidate machine. The judge cannot see the respondent or the candidate machine and communicates with both respondents textually via a computer screen, asking questions to determine which respondent is human and which is the machine. The machine is considered to have passed the test if the judge cannot reliably distinguish between the human and the machine based on their responses.
5. Narrow (or weak) AI:
   - Designed to perform specific tasks or narrow sets of tasks. It excels within its limited domain but lacks the broad cognitive abilities associated with human intelligence. Examples include virtual assistants, recommendation systems and game AI.

   General (or strong) AI:
   - Possesses the ability to understand, learn and apply knowledge across a wide range of tasks, mirroring human intelligence. As of now, general AI remains a theoretical concept and has not been fully realised.
6. Neural networks are computational models that emulate the way the human brain processes information, enabling machines to learn from data and make predictions. They consist of interconnected nodes (artificial neurons) organised into layers: an input layer, one or more hidden layers and an output layer. Neural networks are used in AI systems to process inputs, learn patterns and generate outputs, making them essential for tasks such as image recognition and natural language processing.
7. Features of a neural network:
   - Layers, including an input layer, one or more hidden layers and an output layer.
   - Nodes, which are units within each layer that process information.
   - Connections, which are weighted links between nodes that determine the strength and nature of the signal passing through them.
8. Any of the following benefits:
   - Increased efficiency by automating repetitive tasks and processing vast amounts of data quickly.
   - Enhanced decision-making: AI systems can analyse complex information and assist in making informed decisions.
   - Drives advancements in various fields such as medicine, transportation and entertainment.
   - Personalisation, allowing and content to be tailored to individual preferences, enhancing user experiences.
   - Assisting healthcare, for example in medical diagnoses, drug research and patient care.
   - Creating new industries and job opportunities in AI development and application.
   - AI-powered systems can perform dangerous tasks, reducing human risk.
9. Your answer should not just explain how the test is carried out, but how the outcome of the test determines the presence of intelligence equivalent to a human. One possible answer is as follows:

The Turing Test determines whether a computer can exhibit intelligence equivalent to a human by evaluating its ability to engage in a natural language conversation that is indistinguishable from that of a human. The test is conducted with three participants: a human judge, a human respondent and a candidate machine. The judge and the respondents are located in separate rooms, communicating solely through a computer interface to prevent any visual or auditory cues from influencing the judge's decision. During the test, the judge poses a series of questions to both the human and the machine, covering any topic the judge chooses. The respondents answer these questions with the goal of convincing the judge of their human-like intelligence. The machine aims to respond in a manner that is indistinguishable from the human's responses, employing natural language processing and understanding to generate convincing replies. The test continues for a predetermined period, during which the judge evaluates the quality and relevance of the responses from both the human and the machine. At the end of the test, the judge attempts to identify which respondent is the human and which is the machine based solely on the conversation. The machine is considered to have passed the Turing Test if the judge cannot reliably distinguish between the human and the machine, meaning the machine's responses were sufficiently human-like to deceive the judge. This outcome implies that the machine has demonstrated a level of intelligence comparable to human intelligence, at least in the context of natural language conversation. The Turing Test thus serves as a practical and accessible benchmark for assessing the capabilities of AI systems, focusing on observable behaviour rather than technical criteria and highlighting the machine's ability to mimic human thought processes and interactions.

Chapter 9 – Expert Systems

1. The primary purpose of expert systems is to emulate the decision-making capabilities of human experts in specific domains, providing intelligent solutions by leveraging knowledge, reasoning and problem-solving techniques.
2. Expert systems enhance decision-making processes by replicating human expertise within their knowledge domain, offering intelligent solutions where human expertise is scarce or impractical. They contribute to more informed choices across diverse industries, for example healthcare, finance, manufacturing, marketing and environmental monitoring, by analysing data and providing recommendations based on domain-specific knowledge.
3. 

A typical expert system consists of three main components, as shown in the diagram:

- Knowledge base, which stores both factual knowledge and heuristics (rules) acquired from human experts.
- Inference engine, which analyses input data using the knowledge base to draw inferences and generate solutions or recommendations.
- User interface, which facilitates communication between the user and the expert system, allowing users to input data and receive recommendations.

The user interface and the inference engine are typically grouped together, as it is the inference engine that the user interface is directly interacting with.

4. A shell is a template used to create an expert system. It includes the essential components of the knowledge base management system, inference engine, user interface and sometimes an explanation facility. The shell provides a pre-existing framework that speeds up development and hides technical complexity, allowing developers to focus on domain-specific aspects.
5. Fuzzy logic allows for the representation and manipulation of imprecise or uncertain information. Unlike traditional binary logic, which operates with true or false values, fuzzy logic accommodates uncertainty and ambiguity by allowing variables to take on values such as 'very low', 'low', 'medium', 'high' and 'very high'. This enables expert systems to make decisions based on degrees of truth, mimicking human decision-making processes more accurately.
6. Heuristics are rules or principles derived from human expertise that are generally true and are valuable for decision-making within a specific domain. They are used in expert systems to make informed decisions even when complete information is not available. Heuristics typically follow the format:
   IF <condition> THEN <possible conclusion> ELSE <different conclusion>.
7. A knowledge engineer is responsible for acquiring, organising and encoding the domain-specific knowledge of human experts into a format that can be utilised by an expert system. This involves understanding the domain, collaborating with experts, structuring knowledge, developing rules, validating and testing the knowledge base and maintaining and updating the system after deployment.
8. Two types of user interface:
   - Command line interface: Preferred by users comfortable with typing commands and navigating through text-based interfaces quickly. It offers more options for automating commands.
   - WIMP (windows, icons, menus, pointer) interface: Generally more intuitive and user-friendly, especially for users accustomed to graphical interfaces in modern software applications. It is more visually accessible and easier to use for those less familiar with text commands.
9. Advantages, any of the following:
   - Enhances diagnostic accuracy and reduces errors.
   - Provides timely interventions and preventive measures.
   - Standardises diagnostic processes, ensuring consistency.
   - Enables doctors to access the expertise of top medical professionals.

   Disadvantages, any of the following:
   - Requires ongoing evaluation and refinement to remain effective.
   - Initial acquisition of domain-specific knowledge can be time-consuming and costly.
   - Decision-making processes can be difficult to understand, leading to trust issues.
10. Discussion of any ethical issue that arises with expert systems. The following is one possible answer:
    An ethical issue associated with expert systems is the potential for perpetuating biases present in historical data, which can lead to unfair treatment of certain groups, such as higher insurance premiums based on race or gender. This problem can be reduced by adhering to strict ethical guidelines, ensuring data used is unbiased and continuously monitoring and updating the system to align with ethical standards.
11. Answer should weigh up both the pros and cons. Example answer:
    Expert systems in car engine fault diagnosis, like Auto Scanner Plus, allow mechanics to diagnose issues efficiently by leveraging a vast knowledge base of known problems and solutions. These systems analyse sensor readings, performance data and maintenance records to identify faults and provide step-by-step repair instructions. This leads to faster, more accurate diagnoses, reducing downtime and improving repair quality. However, these systems can be costly to develop and maintain, require regular updates and may struggle with new or unforeseen issues outside their knowledge base.
12. Steps:
    - Extracting knowledge from domain experts, in this case marketing specialists, who provide domain-specific knowledge about successful advertising strategies, customer demographics and media influence.
    - Structuring knowledge into the shell's knowledge base. This and the remaining steps are carried out by the Knowledge Engineer who extracts and organises the knowledge from the Domain Experts, structures it.
    - Developing heuristic rules for decision-making and configuring the inference engine to apply these rules.
    - Designing a user-friendly interface for data input and recommendation retrieval.
    - Testing the system and refining as needed.
    - Deploying the system and maintaining/updating the system's knowledge base after deployment.

13. Answer should weigh up both the pros and cons. Example answer:
Expert systems benefit the insurance underwriting process by automating the analysis of risk factors like age, gender, health history and lifestyle, reducing the need for manual effort and improving overall efficiency. In addition, by continuously updating their knowledge base with new data and insights, these systems can identify emerging trends and adjust underwriting guidelines accordingly. This adaptability ensures that insurance companies remain competitive and compliant with industry standards. Finally, expert systems enhance consistency and fairness in premium calculations. They standardise the decision-making process, reducing variability and potential biases that may arise from human judgment. This consistency helps build trust with customers. Nevertheless, ethical issues may still arise from potential biases in historical data, leading to unfair treatment of certain groups. Insurers must ensure data integrity and adhere to ethical guidelines to mitigate these risks. On the whole, expert systems enhance consistency and fairness in premium calculations while allowing insurers to respond promptly to emerging trends, provided the companies remain aware of the limitations of the systems.

Chapter 10 – Natural Language and Voice Recognition

1. Voice recognition:
   - Refers to the technology that converts spoken language into text. This involves capturing speech through a microphone, converting the analogue sound wave into a digital signal and using algorithms to transcribe the speech into text.

   Natural language processing:
   - Focuses on understanding the meaning behind the text, allowing computers to interpret and respond to human language in a way that mimics human understanding. NLP looks at syntax, semantics, phonology, morphology and pragmatics to derive meaning from text.
2. Any two of these:
   - extracting information from unstructured text data, such as articles, emails, social media posts, or documents, to identify key concepts, entities, sentiments and relationships;
   - translating text from one language to another;
   - indexing and searching through vast amounts of textual data.
   - identifying and removing spam email before it enters a user's inbox;
   - analysing the sentiment or emotional tone expressed in text;
   - allowing users to ask questions in natural language and providing them with accurate and relevant answers;
   - generating human-like text, such as articles, stories, or dialogue, based on input prompts or contexts.
3. Definitions for each:
   - Syntax refers to the arrangement of words in a sentence and the rules governing sentence structure. (For example, the typical English sentence structure follows the order subject–verb–object.)
   - Semantics involves understanding the meaning of words and how they change depending on the context. (For example, the word 'apple' can mean a fruit or a brand, depending on the surrounding words.)
   - Phonology deals with the sound of words and how these sounds are interpreted. (For example, spoken words like 'their', 'there' and 'they're' sound the same but have different meanings.)
   - Morphology considers how words are formed and their relationship to other words in a sentence, such as identifying parts of speech (nouns, verbs, adjectives) and their correct placement in sentences.
   - Pragmatics focuses on understanding the intended meaning beyond the literal interpretation of words. (For example, understanding that when a waiter asks 'Do you have any special dietary requirements?', they expect a detailed response rather than a simple 'yes' or 'no'.)
4. The three main methods are (in order of being carried out):
   - Part-of-speech tagging: identifies the grammatical roles of words in a sentence.
   - Parse trees: analyse the syntax by breaking down sentences into their component parts.
   - Semantics: derives the meaning from the identified structures and resolves ambiguities.
5. Part-of-speech tagging involves assigning labels to each word in a sentence to indicate its grammatical role, such as noun, verb, adjective, etc. This is typically achieved using AI and machine learning algorithms, which analyse the context of each word to determine its part of speech.
6. Parse trees help to understand sentence structure by breaking down sentences into their component parts, showing the hierarchical relationship between words. This allows the NLP system to identify the subject, verb and object, as well as other grammatical elements and understand the syntactic structure of the sentence.

7. Voice recognition is the technology that converts spoken language into text. It involves capturing speech through a microphone, converting the analogue sound wave into a digital signal using an analogue-to-digital converter (ADC) and then using various software algorithms, for example, pattern matching, to convert the digital signal into text.
8. Phonemes are the individual sounds that make up speech. They are important in voice recognition because recognising these sounds accurately helps the software transcribe speech into text, even across different accents and speech patterns. By searching for phonemes, voice recognition systems can better understand and process spoken language.
9. Any three of the following:
   - Pattern matching: involves comparing the incoming audio signal to a database of pre-recorded patterns representing different words and phrases. Advantage: It is straightforward and effective for recognising a limited set of words or phrases.
   - Pattern and feature analysis: breaks down the audio input into smaller phonemes and analyses their characteristics. Advantage: It can recognise speech across a wider range of accents and speech patterns.
   - Statistical analysis: uses statistical models to calculate the probability of different word sequences based on the input audio signal. Advantage: It improves accuracy in noisy environments by considering the likelihood of certain word combinations.
   - Artificial neural networks: perform complex pattern recognition tasks and are trained on large audio datasets. Advantage: Improved accuracy in voice recognition.
10. Advantages – any three of the following:
    - Enhanced user experience by allowing intuitive control of devices using natural language.
    - Speed, as the use of natural language is often faster than typing.
    - Hands-free use, enabling interaction without physical input, which is particularly useful in situations where manual input is impractical or unsafe.
    - Accessibility for people with physical disabilities who find traditional input devices difficult to use.
    - More accurate input since the resulting text is less likely to contain spelling mistakes.

    Disadvantages – any three of the following:
    - Ambiguity in natural language can lead to misinterpretation, requiring systems to ask for confirmation for significant actions.
    - Complex and expensive to implement due to the advanced technology required.
    - Difficulty in handling a wide range of user voices, accents and intonations, which can affect accuracy.
    - Less useful in very noisy environments, or in very quiet environments where speaking would be disruptive.
    - Some natural language systems upload the digital voice signal to a central server to be converted to text, which gives rise to privacy issues.
11. The purpose of natural language processing is to enable computers to understand and interpret human language, allowing for more natural and effective communication between humans and machines. NLP aims to understand the meaning behind the text, handle ambiguities and provide relevant responses or actions based on the input.
12. Voice recognition on mobile devices involves capturing speech through a built-in microphone, converting the analogue sound wave into a digital signal using an analogue-to-digital converter (ADC) and then using software algorithms to transcribe the digital signal into text. The software employs various techniques such as pattern matching, feature analysis, statistical analysis and artificial neural networks to accurately convert spoken language into text. Once the text is generated, the device can carry out the corresponding command or action.
13. Many different examples will suffice, but three possible examples are:
    - Setting reminders and alarms using voice commands without needing to manually input the information. This is faster and more convenient, especially when multitasking.
    - Drivers can use voice recognition to send text messages without taking their hands off the wheel, enhancing safety by allowing hands-free communication.
    - Users can perform web searches or retrieve information using voice commands, which is more efficient and accessible than typing, particularly in situations where typing is impractical, such as while cooking or exercising.

Chapter 11 – Robotics

1. Robotics refers to the combination of technology from mechanical engineering, electronics and computer science to design, create and operate robots. Robots are programmable machines that can perform actions autonomously, mimicking human actions and tasks.
2. A robot typically has:
   - Hardware and software integration.
   - The ability to perceive and interpret its environment.
   - The ability to be programmed and reprogrammed to carry out different tasks.
   - The ability to move itself, or at least some of its parts.
   - Intelligence for autonomous decision making.
   - A source of power.
3. The main components of an industrial robot are:
   - Mechanical components which form the physical structure, including the chassis, arms with multiple joints and end effectors for interacting with the environment.
   - Electrical components which include actuators for movement, sensors for environmental interaction and the controller which acts as the 'brain' of the robot.
   - Software components which provide the intelligence and decision-making capabilities, including the robot operating system (ROS) which helps in controlling the robot's functions.
4. Any two of the following:
   - Online programming: Commands are entered in real-time through a computer interface, allowing immediate execution and observation of the robot's response. This method is user-friendly and suitable for tasks that require real-time adjustments, such as programming a welding machine.
   - Offline programming: Specialised software tools are used to create the program without the need for the physical presence of the robot. Computer-aided design (CAD) models simulate the robot's movements, enabling repeated testing without using the actual robot. This method is useful in cases where the robot arms are too powerful or the location is too dangerous for a human to be close during training.
   - Lead-through programming: The programmer physically guides the robot through motions in real time using a manual input device such as a teach pendant or joystick. The robot mimics the operator's movements, allowing for immediate adjustments and corrections. This method is effective for teaching precise tasks, such as painting a component for a car.
   - Drive-through programming: The operator guides the robot's end effector or manipulator through motions while the robot records the movements for later playback. During playback, the robot autonomously executes the recorded sequence of movements. If errors are detected during playback, the operator may need to re-record the sequence to ensure accuracy. This method is useful for teaching robots to navigate predetermined routes, such as transporting goods in a warehouse.
5. Advantages – any two of the following:
   - Improved surgical precision and accuracy, reducing the risk of human error and leading to better patient outcomes.
   - Enable surgeons to perform very precise surgery in confined spaces with greater ease and control.
   - Reduced surgeon fatigue, as surgeons can operate while seated at a console, avoiding the need for long periods of standing and physical strain.

   Disadvantages – any two of the following:
   - Extensive training required for surgeons to become proficient with robotic systems.
   - High cost of purchasing and maintaining robotic surgical systems, which can limit access to these technologies.
   - Reliance on robotic systems brings the potential risk of a system failure.
6. Robotics play a crucial role in space exploration by enabling the examination of celestial bodies, conducting geological surveys and searching for signs of life. Robots can withstand harsh environments and operate autonomously, reducing mission costs and risks associated with human space travel. However, they lack the intuition and problem-solving abilities of humans and can fail due to issues that a human could easily resolve, such as mechanical malfunctions or environmental obstacles. On the whole, their benefits outweigh these disadvantages.

7. The benefits of robotics in car production include increased productivity, as robots can work continuously, leading to higher production capacity. They ensure consistency and uniformity in manufacturing, reducing defects and waste. Robots also enhance workplace safety by performing hazardous tasks and reducing the risk of accidents for human workers.
8. Robotics in agriculture improve efficiency by automating repetitive tasks, allowing farmers to accomplish more with fewer resources. They enhance resource efficiency by precisely applying fertilisers and pesticides, reducing waste and pollution. However, the high initial investment and maintenance costs can be prohibitive for small-scale farmers and the removal of hedgerows to accommodate robotic systems can harm wildlife habitats.
9. Job displacement refers to robots replacing human workers, especially in tasks that are repetitive or dangerous. This leads to a reduction in manual labour jobs, raising social and economic challenges related to unemployment and the need for workforce re-skilling. Robotics can particularly disadvantage those with fewer qualifications, as the demand for low-skill roles decreases.
10. Robots can improve safety by taking over hazardous tasks that pose risks to human workers, such as handling toxic materials, working in extreme temperatures or lifting heavy objects. This reduces the likelihood of workplace injuries and accidents, creating a safer working environment.
11. One possible response:
    Robotics have a profound impact on society by enhancing productivity, precision and safety across various industries. They reduce labour costs and minimise errors, leading to significant cost savings. However, the high initial investment and maintenance complexity can be barriers to adoption. The displacement of jobs poses ethical and social challenges, necessitating workforce re-skilling and addressing unemployment concerns. Overall, the benefits of robotics in terms of efficiency and capability must be balanced against their economic and social implications.
12. One possible response:
    Robotics have transformed car production by significantly increasing productivity, ensuring consistency in production and enhancing safety. Robots can work continuously, leading to higher production capacity and perform tasks with high precision, reducing defects and waste. However, the adoption of robotic systems raises ethical and social issues, such as job displacement and the need for workforce re-skilling. The high initial investment in robotics can also lead to disparities between large and small manufacturers. Ethical considerations include ensuring fair treatment of displaced workers and addressing the potential economic impact on communities reliant on manufacturing jobs. Balancing the technological advancements with these social and ethical challenges is crucial for sustainable and equitable development in the automotive industry.

Chapter 12 – Mobile Technologies

1. The main purpose of mobile technologies is to allow mobile devices to wirelessly connect to other devices and to enable these devices to move around while in use without being disconnected. This includes enabling voice calls, accessing the internet and transmitting data wirelessly.
2. Cells are virtual divisions of the landscape, each served by a dedicated mobile phone mast. These cells ensure that mobile devices can maintain a connection as they move by seamlessly handing off the connection from one cell to another. Cells vary in size depending on factors such as population density, terrain and network capacity requirements. Smaller cells are used in densely populated urban areas, while larger cells cover rural areas.
3. A mobile phone mast transmits and receives radio signals to and from mobile devices within its coverage area (a cell). The mast connects mobile devices to the rest of the mobile network (including other phones and the Internet) via its base station controller and provides the necessary infrastructure for mobile communication.
4. Mobile devices might experience poor connectivity if:
   - they are too far from the mobile phone mast, resulting in a weak signal;
   - natural features like hills or structures such as buildings block the signal;
   - too many devices are trying to use the same mobile phone mast simultaneously;
   - there is interference from other electronic devices or from thunderstorms.

5. The base station controller (BSC) manages a mobile phone mast and is responsible for:
   - listening for mobile devices wishing to connect to the network;
   - establishing and maintaining connections with mobile devices;
   - linking mobile devices to the rest of the mobile network using fibre-optic connections;
   - allocating resources and radio frequencies for optimal usage;
   - terminating connections when needed;
   - coordinating handoffs when devices move out of range of the current mast.
6. A mobile switching centre (MSC):
   - connects calls from the base station controllers to the appropriate destinations;
   - acts as a central switching node, routing calls efficiently through the network;
   - checks the status of callers to ensure they have network access;
   - tracks the locations of subscribers to route incoming calls;
   - coordinates handoffs between base stations as mobile devices move;
   - provides connections to other mobile networks, the PSTN landline network, the internet and international networks.
7. When not making a call, a mobile phone periodically sends signals to the nearest mobile phone mast to maintain its connection to the network. This ensures that the network is aware of the phone's location and can route incoming calls or data to it.
8. Cell handoff occurs when a mobile phone moves out of the range of one mobile phone mast and into the range of another. The current BSC monitors the signal strength and, when it becomes too weak, instructs the phone to search for a stronger signal from a nearby mast. Once found, the BSC coordinates with the new mast's BSC and the MSC to transfer the call from the first mast to the second. The moment of handoff happens in a fraction of a second, ensuring the call is not interrupted.
9. Capabilities:
   - 3G networks (introduced in 2001) were capable of transmitting data at speeds of a few hundred kilobits per second, sufficient for basic web connectivity.
   - 4G networks (introduced in 2012) offered data speeds of hundreds of megabits per second, sufficient for streaming high-definition video and online gaming.
   - 5G networks (introduced from 2019) offer speeds of several gigabits per second, allowing for streaming very high-definition video, virtual reality, augmented reality and immersive gaming experiences.
10. Communications technology allows an uninterrupted phone call through a series of coordinated steps:
    - The mobile phone connects to the nearest mobile phone mast.
    - The BSC establishes and maintains the connection, routing it through the MSC.
    - If the call is to another mobile phone, the MSC connects it to the destination BSC, which then connects to the recipien's phone.
    - If the caller moves, the BSC and MSC coordinate handoffs to a new mast without breaking the connection, ensuring the call remains uninterrupted.
11. One possible response:
    Mobile switching centres (MSCs) play a crucial role in facilitating seamless communication by connecting calls from the BSC of the source mobile device to the BSC of the target mobile device, ensuring efficient routing through the core network. They handle connections between different mobile networks, allowing users from different providers to communicate. MSCs also connect to the PSTN landline network, enabling mobile-to-landline and landline-to-mobile calls. Additionally, they manage international calls and data access, ensuring global connectivity. By tracking the locations of subscribers, MSCs route incoming calls and coordinate handoffs between cells, maintaining continuous communication for mobile users.

Chapter 13 – Data Mining

1. Data mining is the process of analysing large datasets to discover patterns, trends and insights. Its primary goal is to uncover hidden patterns and relationships that may not be immediately apparent through traditional analysis methods, thereby supporting decision-making processes and providing new routes for research or innovation.
2. The four features of big data are:
   - Volume: the large amounts of data, often running to terabytes or petabytes.
   - Velocity: the rapid pace at which data is generated and collected, often in real time.
   - Variety: the diverse range of data formats, from structured to unstructured data.
   - Veracity: the reliability and quality of data, which can vary due to its volume and sources.
3. The main stages in data mining are:
   - Data gathering: collecting relevant data from various sources.
   - Data storage: storing the collected data efficiently.
   - Data processing: preparing the data for analysis by checking for errors and standardising formats.
   - Data analysis: applying techniques to uncover patterns, trends and insights from the data.
4. Data gathering involves collecting relevant data from internal sources (such as product databases, transaction data) and external sources (such as social media, market research). Methods include API access, transactional records, online surveys, satellite feeds, sensor feeds and manual data entry. It also includes ensuring that sensitive information is appropriately handled.
5. The two storage architectures commonly used are:
   - Direct-access storage (DAS), where each server has its own dedicated storage devices. This architecture is responsive but can be less scalable as adding new storage requires adding new servers.
   - Network-access storage (NAS), where storage devices are connected directly to the network, allowing for easier scalability. However, it may be less responsive due to network bandwidth limitations.
6. Data processing involves preparing the gathered data for analysis by:
   - Error checking to remove duplicates, standardise formats and correct errors.
   - Data transformation to ensuring data from different sources is in the same format.
   - Reducing complexity by discarding unnecessary information to save storage space and processing time, without compromising the analysis.
7. Name several of the following:
   - Classification: categorising data into predefined classes based on labelled training data.
   - Clustering: grouping similar data points based on their attributes.
   - Association rule mining: identifying patterns such as products frequently bought together.
   - Regression analysis: identifying relationships between different sets of data.
   - Anomaly detection: identifying patterns that deviate from the norm, such as those which might be caused by fraud.
   - Dimensionality reduction: simplifying datasets while preserving essential information.
8. Data mining benefits marketing by:
   - Identifying trends, for example by monitoring social media to spot trends and changes in consumer behaviour.
   - Predicting demand by analysing external factors to forecast future demand and place timely orders with suppliers.
   - Personalising advertising, for example by using loyalty card data to create targeted marketing campaigns and personalised offers for customers based on their buying habits.
9. Name several of the following:
   - Data breaches leading to the risk of sensitive personal information being compromised.
   - Profiling and targeted advertising, which can be seen intrusive and manipulative advertising practices.
   - Algorithms may perpetuate discrimination against certain demographic groups.
   - Anonymised data can sometimes still be used to identify individuals.
   - Potential for mass government surveillance infringing on privacy and freedom.
   - Lack of consent as individuals may be unaware of the extent of data collection and use.

10. The health sector uses big data to:
    - Monitor public health by analysing data to identify trends and emerging health issues.
    - Identify patterns by detecting patterns in health data that indicate potential health risks.
    - Predict health risks by cross-referencing patient records with lifestyle factors to predict future health conditions.
    - Personalise medicine by tailoring treatment plans based on individual data.
    - Assess treatment effectiveness by analysing past treatments to determine those that gave the best outcomes for patients.
11. Any two of the following:
    - Detect fraud by monitoring transactions in real-time to identify unusual or suspicious activity and prevent fraud.
    - To ensure that they comply with the law.
    - Monitor how effectively the bank is communicating with customers.
    - To monitor the stock markets and make rapid changes to investments.
    - Assess creditworthiness by using data mining to evaluate the financial history and credit scores of customers, determining their risk level for loans or credit.

Chapter 14 – Cloud Computing

1. Cloud computing refers to the delivery of computing services such as data storage, software applications and processing power over the internet. Users access these services remotely, without needing to have the physical or software resources on their own devices or local area networks.
2. A public cloud is a cloud computing environment where services are delivered over the public internet and shared among multiple users. A private cloud is a dedicated cloud environment operated exclusively for a single organisation, providing enhanced security and control over data and resources.
3. Virtualisation in cloud computing involves dividing a single physical server into multiple virtual servers, each running its own operating system and applications, thereby optimising resource usage and providing flexibility and scalability. The software on each virtual server 'believes' that it is actually operating on its own physical server, but in fact the system is invisibly sharing the resources between several virtual servers.
4. A hosted instance is a virtual server provided by a cloud service provider, running on shared physical resources in a server farm. Users can access and manage these virtual servers as if they were physical servers, benefiting from dynamic resource allocation and cost efficiency.
5. A hosted solution is a cloud service where a client is provided with dedicated hardware and software resources. Unlike hosted instances, these resources are exclusively allocated to the client, ensuring guaranteed performance and availability, though at a higher cost.
6. Clustering in cloud computing involves managing the distribution of resources and hosted instances across multiple physical servers. It ensures that no single server becomes overloaded, improves performance by balancing the load and enhances reliability by allowing seamless transfer to other servers in case of hardware or software failures.
7. iCloud offers several advantages for data storage, including increased access to data from multiple devices, enhanced data durability by storing data remotely, increased data security with encryption and password protection and automated backups that ensure data is safely stored and can be easily recovered.
8. Cloud computing provides email services by hosting mail servers and storage in the cloud. Users can access their emails via web interfaces or email clients connected to the cloud servers. This setup ensures reliability, accessibility from any device and ease of use without needing dedicated IT infrastructure.
9. Advantages – any two of the following:
    - Increased access to data from any device and location.
    - Increased data durability in the event of a localised issue such as a fire.
    - Increased data security through encryption and password protection.
    - Automated backups to the cloud.

Disadvantage not directly given in the text so students need to use their knowledge:
- Depends on a stable internet connection. Disruptions in connectivity can impede access to important data.

10. Cloud computing provides remotely hosted applications by running software on cloud servers and allowing users to access it via web browsers or dedicated client software. Users interact directly with the application without needing to manage the underlying infrastructure or operating system, as seen with services like Microsoft *Office 365* and Google *Workspace*.

11. Cloud computing offers backup services by storing copies of data on remote servers. These services can be automated to regularly back up data, ensuring it is stored offsite and protected from localised incidents like fire or theft. The business benefits include enhanced data security, reduced risk of data loss, automated and efficient backup processes and ease of data recovery.
12. Your answer should refer to security concerns in cloud computing such as:
    - unauthorised access to data;
    - data breaches;
    - compliance with data protection laws.

These can be addressed by:

- implementing strong encryption for data in transit and at rest;
- strict access controls;
- regular security audits;
- compliance with relevant regulations;
- ensuring that cloud providers have robust security measures in place;
- properly managing access and adhering to best security practices.

Chapter 15 – Legislation

1. The primary purpose of the Data Protection Act is to protect the personal data of individuals by establishing legal requirements for organisations on how they collect, process, store and share personal information, ensuring that it is done in a fair, lawful and transparent manner.
2. Any four of the following:
    - Fair and lawful processing: Personal data must be processed in a way that is both fair and lawful and individuals must be informed about how their data will be used.
    - Purpose limitation: Personal data should only be collected for specified and legitimate purposes and not further processed in a manner incompatible with those purposes.
    - Data minimisation: Organisations should only collect personal data that is adequate, relevant and limited to what is necessary for the purposes for which it is processed.
    - Accuracy: Personal data should be accurate and kept up to date. Inaccurate data should be rectified or erased without delay.
    - Storage limitation: Personal data should not be kept for longer than necessary for the purposes for which it is processed.
    - Integrity and confidentiality: Personal data should be processed in a manner that ensures appropriate security, including protection against unauthorised processing and accidental destruction.
    - Accountability: Organisations are responsible for complying with the data protection principles and must be able to demonstrate compliance.
    - Lawful basis for processing: Organisations must have a lawful basis for processing personal data.
3. Key roles:
    - Data subject: This refers to anyone whose personal data is being stored. Data subjects have rights under the DPA, such as accessing, correcting and deleting their data.
    - Information Commissioner: This is an independent regulatory body responsible for ensuring that organisations comply with the DPA, educating people about their rights and responsibilities and resolving disputes.
    - Data controller: This refers to the person or organisation that holds personal data and decides how it is used. Data controllers are responsible for complying with the DPA and registering with the Information Commissioner's Office.
4. The General Data Protection Regulation (GDPR) impacted the Data Protection Act by:
    - strengthening data protection standards and giving individuals enhanced rights regarding their personal data;
    - increasing accountability and compliance requirements for organisations;
    - enhancing enforcement and penalties for non-compliance;
    - requiring organisations to report certain types of data breaches within 72 hours.
5. Intellectual property (IP) refers to people's original ideas such as literary and artistic works, inventions, designs, symbols, names and images. IP laws are designed to protect the rights of creators and innovators, enabling them to benefit from their work.

6. Name several of the following:
   - copyright, which provides legal protection for original works, granting creators exclusive rights to control how their works are used;
   - moral rights, which grant creators the right to be identified as the author, object to unfair treatment of their work and prevent false attribution;
   - duration of copyright protection, typically the lifetime of the author plus 70 years;
   - exceptions and fair dealing, to allow certain uses of copyrighted works without permission, such as for research or review;
   - grants performers rights over the recording, copying and distribution of their performances;
   - patents, which grant inventors exclusive rights to their inventions for a limited period.
7. One of the following:
   - For research purposes – for example, a person can legally copy a portion of a book for their own research without infringing copyright.
   - For review purposes – for example, a person can quote sections of a book in order to write a book review without infringing copyright.
   - For examinations – for example, an examination body can use part of a copyrighted work in an exam without infringing copyright.
8. The primary purpose of the Computer Misuse Act (CMA) is to address computer-related crimes and unauthorised access and misuse of computer systems, protecting computer systems and data from unauthorised access, theft and damage.
9. All three of the following:
   - Unauthorised access: Accessing a computer system or data without permission or lawful authority.
   - Unauthorised access with intent to commit or facilitate further offences: Gaining unauthorised access with the intent to commit or facilitate further offences, such as theft or fraud.
   - Unauthorised acts with intent to impair the operation of a computer: Carrying out unauthorised acts intended to impair the operation of a computer system, such as launching denial-of-service attacks or introducing malware.
10. The Copyright, Designs and Patents Act protects creators' rights by granting them exclusive control over their original works, including the right to reproduce, distribute, perform and display their works. It also provides moral rights, such as being identified as the author and objecting to derogatory treatment of their work. The Act establishes legal recourse for creators to take action against unauthorised use or infringement of their IP.
11. One possible response:
    The Data Protection Act impacts a bank by requiring it to handle personal data lawfully, fairly and transparently. The bank must obtain a lawful basis for processing data, ensure data accuracy, limit data collection to necessary information and implement robust security measures. It must also respect individuals' rights to access, correct and delete their data. The bank needs to maintain records of its data processing activities, conduct data protection impact assessments and appoint a data protection officer if necessary. Compliance with the DPA helps the bank protect customers' personal data, maintain trust and avoid legal penalties.

Chapter 16 – Ethical Considerations

1. Ethics refers to the principles of right and wrong that guide an individual's behaviour. In the context of digital technology, ethics is crucial as it helps professionals navigate the complex moral dilemmas they face daily, such as privacy concerns, data security and the impact of automated decision-making on society. Ethical considerations ensure that technology is developed and used in ways that are fair, transparent and respectful of individuals' rights.
2. The lack of transparency in AI algorithms contributes to ethical concerns because it makes it difficult to understand how decisions are made, leading to potential biases and unfair outcomes. Without transparency, it is challenging to identify and correct discriminatory practices, ensure accountability and maintain public trust in AI systems.
3. Freedom of speech is considered a crucial ethical principle in online censorship debates because it protects individuals' rights to express their opinions and ideas without restraint. It is a cornerstone of democratic societies, ensuring diverse viewpoints are heard and fostering open debate. However, it must be balanced against the need to prevent harmful content, creating ethical dilemmas about where to draw the line.

4. Any three of the following:
   - Fake images: AI makes it very easy to create images that are difficult to differentiate from authentic content.
   - Fake news: AI is very good at creating fake news and disinformation on a large scale.
   - Copyright: AI creates complex issues around the nature of copyright, and whether training AI o material requires copyright clearance.
   - Bias and fairness: AI systems can inherit and perpetuate biases from the data they are trained on, leading to discriminatory outcomes.
   - Privacy: The extensive data collection required for AI can infringe on individuals' privacy rights.
   - Autonomous weapons: AI being put in a position where it can make life-or-death decisions autonomously raises complex ethical issues.
5. Informed consent refers to obtaining explicit permission from individuals before collecting their data, ensuring they are fully aware of how their data will be used and the potential implications. In ethical data gathering, it is crucial to ensure that individuals understand and agree to the collection and usage of their data, respecting their autonomy and privacy.
6. Accountability is challenging in the context of AI decision-making because it is often unclear who should be held responsible for the outcomes produced by AI systems. Should it be the developers who created the algorithm, the organisations that deployed it, or the AI itself? This complexity is compounded by the opaque nature of many AI algorithms, making it difficult to trace decisions back to specific actions or choices.
7. Any three of the following:
   - Privacy: Monitoring can infringe on individuals' rights to privacy, as it often involves tracking personal activities and collecting sensitive data.
   - Humiliation: Excessive monitoring can lead to employee stress and embarrassment, especially if the data collected is used to criticise or penalise individuals unfairly.
   - Data security: Collected data must be securely stored to prevent unauthorised access, which could lead to misuse or identity theft.
   - Informed consent: IT companies must make sure customers are informed of what is going to happen in a way that they are likely to understand.
8. Data security is ethically significant because it protects individuals' personal information from unauthorised access and misuse. Ensuring robust data security measures helps prevent data breaches, identity theft and other forms of exploitation, thus maintaining trust and safeguarding privacy.
9. List three or four of the following:
   - Transparency: Difficulty in understanding how decisions are made can lead to mistrust and unfair outcomes.
   - Mistakes: AI can still make mistakes, and this must be considered. If a healthcare AI led to improved outcomes for nine patients but a worse outcome for one patient, would this be ethically acceptable?
   - Accountability: Determining responsibility for decisions made by AI systems, especially when they cause harm.
   - Employment: Automated decision making reduces jobs for humans and can lead to increased unemployment.
10. Deepfakes present significant ethical problems, including the potential for spreading misinformation, damaging reputations, and violating privacy. The IT industry must address these issues by developing technologies to detect and prevent the misuse of deepfakes, implementing strict guidelines, and promoting ethical standards to ensure the responsible use of AI-generated content.
11. The student may come up with a range of opinions, provided they can demonstrate a good understanding of how to consider ethical dilemmas. One possible answer is:
    - From an ethical perspective, it is not acceptable for a programmer to read personal information held in a computer system without a legitimate reason and the individual's consent. Even if the information is not used, merely accessing it violates privacy and trust, and can lead to potential misuse or accidental disclosure. Ethical principles require respecting individuals' privacy and only accessing data when necessary and authorised.

    A possible answer from a different perspective is:
    - It is acceptable for a programmer to read personal information held in a computer system as long as they do not use it for any purpose. Programmers, as professionals, should be trusted to maintain confidentiality and adhere to ethical standards. Reading data might be necessary to ensure system functionality, such as checking whether email software is working. If the information is not used beyond these tasks, the potential harm is minimal, enhancing efficiency and practicality without directly impacting individual privacy.