This paper comprises eight questions in two sections, A and B. Candidates must answer exactly FIVE questions, with at least TWO questions from each of Section A and Section B. Calculators are not permitted.
Section A: Networks

(Answer at least TWO questions from this section.)

Alice is a wallpaper designer and retailer in London. She has a shop on the ground floor and a design studio on the first floor. She has a small team of designers in the studio working on bespoke wallpaper patterns for clients and organising print runs, etc. Each person has their own computer. There is a computer with a colour printer in the shop for displaying and printing wallpaper samples. Bob is her computer guru.

1. (a) Describe briefly (preferably with the aid of a diagram) the three principal topologies used to construct conventional Local Area Networks (LANs).

(b) There are three main categories of address format for computers attached to a LAN. They assign a unique hardware address to each Network Interface Card (NIC). Describe these briefly.

(c) Alice has decided to network her computers together using an Ethernet LAN. Bob has told her that Ethernet frames are transmitted using Manchester Encoding. Describe briefly (preferably with the aid of a diagram) what this entails. Mention, in particular, how Alice’s computers synchronise with one another.

(d) Describe briefly (preferably with the aid of a diagram) the structure of an Ethernet frame.

(e) Describe briefly (preferably with the aid of a diagram) how Alice’s computers use Ethernet’s Carrier Sense Multiple Access/Collision Detection (CSMA/CD) to coordinate their communications.

(f) Alice is currently using repeaters to join the Ethernet segments of her LAN. Bob has told her that bridges are superior to repeaters. Describe briefly the advantages and/or disadvantages of bridges over repeaters.
2. The following diagram illustrates the fields in an IP datagram.

<table>
<thead>
<tr>
<th>Field</th>
<th>Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>4</td>
</tr>
<tr>
<td>Header</td>
<td>8</td>
</tr>
<tr>
<td>Service</td>
<td>8</td>
</tr>
<tr>
<td>Total Length</td>
<td>16</td>
</tr>
<tr>
<td>Identification</td>
<td>16</td>
</tr>
<tr>
<td>Flags</td>
<td>3</td>
</tr>
<tr>
<td>Fragment Offset</td>
<td>13</td>
</tr>
<tr>
<td>Time to Live</td>
<td>16</td>
</tr>
<tr>
<td>Protocol</td>
<td>8</td>
</tr>
<tr>
<td>Header Checksum</td>
<td>16</td>
</tr>
<tr>
<td>Source IP Address</td>
<td>32</td>
</tr>
<tr>
<td>Destination IP Address</td>
<td>32</td>
</tr>
<tr>
<td>Options</td>
<td>32</td>
</tr>
<tr>
<td>Padding</td>
<td>32</td>
</tr>
<tr>
<td>Beginning of Data</td>
<td></td>
</tr>
</tbody>
</table>

(a) Describe briefly (preferably with the aid of a diagram) the five classes of original IP addresses, known as classful IP addressing. (3 marks)

(b) Classless addressing uses a 32-bit IP address and an additional 32-bit subnet mask to indicate where the boundary occurs between the network prefix and the host suffix. This pair is written using Classless Inter-Domain Routing (CIDR) notation. How would the class B network 128.10.0.0 be written using CIDR notation? (2 marks)

(c) Alice has decided to connect her LAN to the Internet. She has decided that she requires two outward-facing IP addresses, one for her new web site and another for general communications. Bob has negotiated with her local Internet Service Provider (ISP) to provide these from an existing class C network address, 212.159.43.0, that has not previously been used. Show the CIDR address that has been allocated to her together with the range of outward-facing IP addresses provided. (3 marks)

(d) Bob has purchased a broadband modem/router to suit Alice’s requirements. This router has inward-facing a number of Ethernet ports and a Wi-Fi connection. Alice is experimenting with a laptop computer connected to her LAN using Wi-Fi, but is finding the performance sluggish. Bob tells her that this is because datagrams arrive at her router over a link with a Maximum Transmission Unit (MTU) of 1,500 B, but are then re-transmitted over her Wi-Fi connection which has an MTU of 1,000 B. Describe briefly (preferably with the aid of a diagram) how IP uses fragmentation to solve the problem of differing MTUs. (5 marks)

(e) Bob shows Alice how a datagram containing exactly 1,500 B (with a 20 B header) is fragmented into two fragments for onward transmission over the Wi-Fi connection. Describe briefly these fragments and show your working. (5 marks)

(f) Assume that the router fragments the original 1,500 B datagram into two fragments, exactly as described above, but only the first fragment arrives at the destination. The router times out, fragments the datagram exactly in the way referred to part (e), but only the second fragment arrives at the destination. Can the destination computer combine the two fragments? Explain your answer. (2 marks)
3. The following diagram illustrates the format of a *Transmission Control Protocol* (TCP) segment.

![TCP Segment Format Diagram](image)

(a) Describe briefly the seven major features of TCP. (4 marks)

(b) Describe briefly (preferably with the aid of a diagram) how a full-duplex TCP connection is established using a *three-way handshake*. Mention, in particular, the roles played by the *SEQUENCE NUMBER* and *ACKNOWLEDGEMENT NUMBER* fields. (4 marks)

(c) Describe briefly (preferably with the aid of a diagram) how a full-duplex TCP connection is terminated using a *three-way handshake*. Mention, in particular, the roles played by the *Finish* (FIN) flag and the *Acknowledgement* (ACK) flag. (3 marks)

(d) Bob is explaining to Alice how TCP recovers from transmission errors. He considers the situation where computer A has sent to computer B a TCP segment containing data bytes 2,001 through 3,000. This segment is acknowledged by computer B. Computer A then sends to computer B a TCP segment containing data bytes 3,001 through 4,000. This segment is lost. Bob considers two scenarios.

i. Computer A times out first and sends a TCP segment to computer B.

ii. Computer B times out first and sends a TCP segment to computer A.

Draw a diagram for each of these scenarios showing the contents of the TCP segment where known. Assume that computer A has received from computer B data up to byte 100, which has been acknowledged. Show any code bits that are on. (6 marks)

(e) Name three application protocols that use TCP for data communication. (3 marks)
Section B: Web technologies

(Answer at least TWO and at most THREE questions from this section.)

4. (a) What is an XML entity? Distinguish between a general entity and a parameter entity. Give an example of a general entity declaration, followed by a reference to the same entity. (10 marks)

(b) Each XSLT processor is meant to implement a number of default template rules. Explain when these default rules are invoked and what function they perform. (7 marks)

(c) Explain one way in which information entered by a user into an HTML form can be passed to an application running on a web server. (3 marks)

5. (a) What constraints must a document satisfy if it is to be valid with respect to a Document Type Definition (DTD) which declares attributes of type ID and IDREF? (2 marks)

(b) Consider the following DTD fragment:

```xml
<!ELEMENT books (book)+>
<!ELEMENT book (author*, title, isbn?, price)>
<!ELEMENT author (first-name?, last-name)>
```

Now write down absolute XPath expressions for the following queries on a document valid with respect to the above DTD fragment and with books as its root element:

i. Find books which have more than 2 authors. (4 marks)

ii. Find books which have an isbn and all author elements have a first-name specified. (5 marks)

(c) What is required in order for a relative, rather than an absolute, XPath expression to be evaluated? (1 mark)

(d) Explain the purpose of the Document Object Model (DOM), what facilities it provides for programmers, and some of its advantages. (8 marks)
6. Consider the following XML representation for film screenings at a cinema:

```
<cinema>
  <film>
    <title>Slumdog Millionaire</title>
    <schedule>
      <day>Mon</day>
      ...  
      <day>Fri</day>
      <time>15:00</time>
      <time>18:00</time>
    </schedule>
    <schedule>
      <day>Sat</day>
      <day>Sun</day>
      <time>12:00</time>
      ...  
      <time>18:00</time>
    </schedule>
  </film>
  ...  
  <film>
  ...
</film>
</cinema>
```

In other words, a cinema has a number of films showing, with each film having one or more schedules which give days and times of screenings. For a particular film, there may be one set of times for Monday to Friday, say, and another set for Saturday and Sunday. Each day is included at most once among all the schedules for a particular film.

(a) Write one or more XSLT template rules (do not worry about including the stylesheet element) to transform an XML document conforming to the above description into an HTML document described as follows. The HTML document lists the titles of films showing on Saturday (“Sat”). There is an h1 heading with the value “Films on Saturday”. This is followed by an unordered list of film titles, with each followed by a “:” and each of the times at which the corresponding film is shown on Saturday. Each time should be followed by a “,”. (14 marks)

(b) Now assume that you were required to provide a Document Type Definition (DTD) which would be used to validate XML documents representing cinema listings described as above. Explain which desirable constraints on the contents of a document you would not be able to capture in the DTD and why. (6 marks)
7. (a) Consider using an XML document to represent a person’s wine collection. The collection consists of one or more wines. Each wine is of type “white” or “red” and this information must be provided for each wine. Each wine has a name, a price and an optional vintage (i.e., year). A wine also comprises zero or more grape varieties (e.g., Chardonnay), each with an optional percentage associated with it (having zero grape varieties is interpreted as not knowing what grapes the wine is made from). The price is either per bottle or per case, with the default being per bottle.

Write down a Document Type Definition (DTD) which satisfies the requirements described above. (14 marks)

(b) How do Web servers differentiate among the various technologies used for server-side processing that might be targeted by an incoming request? (6 marks)

8. (a) Assume that you are writing Javascript code using the Document Object Model (DOM) which needs to work in both Internet Explorer and Firefox. Describe three functions which are implemented differently by these browsers. (6 marks)

(b) Assume that you were asked to write a web application which would allow a user to manage information about their DVD collection. The DVD information is to be represented in an XML file on the web server and the user wants to be able to use a web browser to view information about all their DVDs and to add a new DVD to their collection. Explain how you would structure your application in terms of the web pages required and the broad functionality of each, assuming you were to use server-side PHP. (Do not write any actual code, but do describe what PHP would allow you to do.) (14 marks)