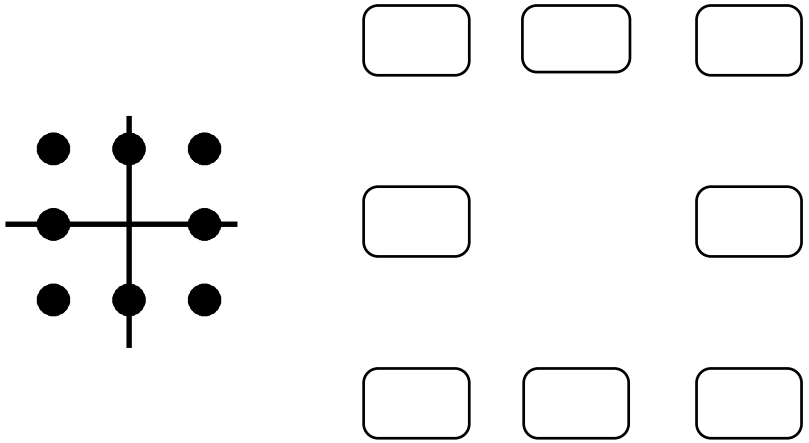
Q 1 Consider the constellation in the left-hand side of diagram, where each circle represents a point of a signal constellation



(a) How many amplitudes and phases are in this constellation?

☐ Amplitudes ☐ Phases **[2 marks]**

(b) The right-hand diagram has rectangles corresponding in position to the constellation points of the left-hand diagram. Label each rectangle in the right-hand diagram with its amplitude and phase, for example **'A1'**.

- Label your amplitudes A, B, C, … etc. in order of increasing magnitude.
- Label your phases 0, 1, 2, … etc. in a counter-clockwise fashion. **[2 marks]**

(c) How many bits can each point in the above signal constellation carry when it is transmitted to a receiver? Why? **[2 marks]**

Q 2: An overland coaxial cable is being laid to transmit data. We are trying to find out at which distances we must install repeaters.
The intended data rate is 10 Megabits per second, and the available bandwidth is 1 MHz.
The data transmitter (and each repeater along the cable, consisting of a receiver and a transmitter) are able to inject a signal into the cable such that the signal-to-noise ratio at the transmitter end of the cable is 130 dB. That is, the signal power is 130 dB above the noise power.
In the frequency band used for the transmission, the cable has an attenuation of 5 dB per 100 m.

(a) Show that the theoretical minimum signal-to-noise ratio that is required at the receiver or repeater input in order to support the intended data rate is 30dB. You may round up or down by up to 5% in your calculation if this is convenient. **[6 marks]**

(b) Given your result from (a), what is the theoretical maximum distance between repeaters? **[3 marks]**

Q 3 A communication system transmits a bit stream of a random sequence of zeros and ones, i.e., with equal probabilities of the next bit being a 0 or a 1.

(a) Assume for this part of the question that the bit stream is to be encoded in NRZI, with the zeros coded as a transition in level. Further assume that you wish to use bit stuffing for clock recovery. You want to bit stuff such that the maximum length of a run of ones is five. Estimate of the percentage of extra bits added by the bit stuffing.

[3 marks]

(b) For this part of the question, assume that Manchester coding is used instead of NRZI and bit stuffing. Give one advantage and one disadvantage of Manchester coding compared to NRZI with bit stuffing. **[4 marks]**

Q 4 Which of the following statements is true and which one is false? Tick the appropriate box: **1 mark per correct answer [5 marks total]**

(a) The orbital period of a geostationary satellite is exactly 24 hours.

TRUE ☐ FALSE ☐

(b) In order to communicate with a geostationary satellite, an earth station must be located on the equator.

TRUE ☐ FALSE ☐

(c) The equatorial plane is an imaginary plane that cuts the earth into two halves. If the equatorial plane is extended into space, the orbits of all geostationary satellites fall within that plane.

TRUE ☐ FALSE ☐

(d) The possible footprint of a satellite gets larger if the height of the satellite's orbit increases.

TRUE ☐ FALSE ☐

(e) A single low-earth orbit satellite (LEO) can be used to provide a continuous data link across the Pacific Ocean.

TRUE ☐ FALSE ☐

Q 5 The bit string B=010011101 is to be protected by a CRC checksum. The generator polynomial for the calculation of the checksum is $x^4 + x^3 + 1$, i.e., its bit representation is 11001.

(a) calculate the CRC checksum for B (Hint to help you check your result: the quotient that you should obtain in the polynomial division of B padded by the appropriate number of zero bits to the right is 011100010). Show your working. **[6 marks]**

(b) Now assume that B gets corrupted in transit and becomes
$B' = 010111001$ (two bit errors: on the 4th and 7th bit).
Show by explanation and calculation how the receiver can detect that there is a problem. Show your working
(Hint: the quotient should be 011011000). **[6 marks]**

Q 6 Assume that you have a 12-bit Hamming code with the following makeup:
$p_1\ p_2\ m_1\ p_3\ m_2\ m_3\ m_4\ p_4\ m_5\ m_6\ m_7\ m_8$
where bits $p_1 \ldots p_4$ are the parity bits and $m_1 \ldots m_8$ are the data bits. The parity bits give even parity over the following data bits:

p_1: m_1, m_2, m_4, m_5, m_7
p_2: m_1, m_3, m_4, m_6, m_7
p_3: m_2, m_3, m_4, m_8
p_4: m_5, m_6, m_7, m_8

(a) Given the data word $m_1\ m_2\ m_3\ m_4\ m_5\ m_6\ m_7\ m_8$ = 11101011, what is the associated Hamming code? Show your working. **[3 marks]**

(b) Given the Hamming code 011111001001, does it contain an error? If so, presuming that a single bit is in error, which is the correct code that was sent? **[4 marks]**

(c) Given the Hamming code 010111101001, does it contain an error? If so, presuming that a single bit is in error, which is the correct code that was sent? **[4 marks]**

Q 7 Two stations, A & B, are linked by a 1000km cable, with communication at 8Mbit/s. Flow control is by XON/XOFF.

(a) How many octets are in transit from B to A? **[2 marks]**

(b) What is the smallest buffer which will guarantee full use of the link? **[2 marks]**

(c) Over what maximum transmission distance would a 50,000 byte buffer ensure a link utilisation of 100%? **[2 marks]**

Q 8 Station A sends a message to station B using a "stop & wait" protocol.
List four possible replies or other "responses" to the message. **[4 marks]**

Q 9 ~~Two BISYNC messages are shown.~~

~~Some "codes" are~~

~~STX~~	~~Start of Text~~
~~ETX~~	~~End of Text~~
~~DLE~~	~~Data Link Escape~~

~~All other codes are as written~~

~~message 1~~	~~`STX a b c DLE STX p q r ETX`~~
~~message 2~~	~~`DLE STX a b c DLE STX p q r DLE ETX`~~

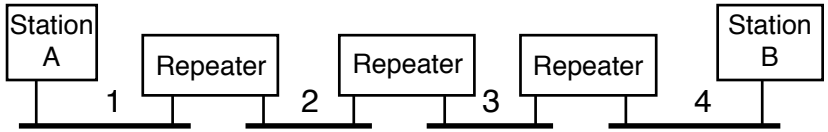
~~(a) What is the text which each message conveys?~~ **~~[2 marks]~~**

~~(b) Explain the differences.~~ **~~[2 marks]~~**

Q 10 The following table lists some of the fields of the headers of IP and TCP.
Mark each field as being part of its appropriate header and *briefly* indicate its function.
[8 marks]

Field	IPv4	IPv6	TCP	Function
Hop Count				
checksum				
fragment offset				
version				
source address				
destination port				
Flow				
urgent pointer				

Q 11. A multi-segment IEEE 802.3 LAN links two stations separated by 2km of cable and has 4 segments. Assume that there is no other traffic on the link



(a). Signals between the stations are delayed by both the cables and by the repeaters. Estimate the end-to-end delay, comparing the delays from each of the two components. **[2 marks]**

(b) The two stations start transmitting at the same instant. In which field of the frames would you expect each station to detect the collision, and why? **[3 marks]**

(c) Station A sends a message of 100 total bytes and station B one of 1000 total bytes. Bridges are now used to connect the LAN cables in the network.
Describe the collisions which now occur. **[3 marks]**

Q 12 An IPv4 packet is initially of length 4000 bytes and goes through links with MTU first 3200 bytes and then 1200 bytes.

(a) What packets arrive at the end of the final link? Show all relevant fields. **[8 marks]**

Show the final fragments and give relevant values in the fragment headers.

You must place your own appropriate headings on the columns.
The table may have more space than you need for all of the fragments.
Ignore the header size when calculating fragmentation

Fragment				
1				
2				
3				
4				
5				
6				
7				
8				

(b) How would a change to IPv6 affect the packets which arrive? **[2 marks]**

Q 13 Explain how routing decisions for data messages differ in a network using datagrams, as compared with one using virtual circuits. **[4 marks]**

Q 14 With regard to network management, explain each of the following terms, briefly describing their function and importance.

(a) MIB **[2 marks]**

(b) SNMP get response **[2 marks]**

(c) SNMP set request **[2 marks]**

Question 1.

(a) While data communications protocols usually have strict rules for encoding data for physical transmission, some protocols include "symbols" which violate these rules.

(i) Why might these apparently invalid symbols be included? **[2 marks]**

(ii) Give two examples of such symbols, with explanations. **[4 marks]**

(b) The ASCII character string '{ | }' (3 characters) is to be transmitted using either 8-bit Asynchronous (1 stop bit) or 8-bit SDLC transmission.

(i) Show the transmitted bits for *no* character parity (most-significant bit always 0), with the first bit transmitted at the left and later bits to the right for both Asynchronous and SDLC transmission. Indicate the character boundaries. **[4 marks]**

(ii) What changes occur if the character parity is changed to odd? **[4 marks]**

TOTAL = [14 marks]

Question 2.

The following table shows the LZW compression of a string, up to about the end of the first occurrence of "mississippi". Continue the compression of the second occurrence of "mississippi", as shown in passes 12 to 22 of the table, building on the dictionary etc which are shown. *Some* of the necessary entries are shown here. **[14 marks]**

You may answer this question by EITHER –
drawing a new table (starting at row 12) in your answer book, OR
completing the copy of the table attached at the end of this question paper.
It must detached from the question paper and tied to your answer book, ensuring that your name and ID number are included.

mississippimississippi

Pas	Inp	Test	Emit	Mak	Comment
1	m				
2	i		m		
3	s		i		
4	s		s		
5	i		s		
6	s				‘is’ exists
7	s		257(is)		
8	i				‘si’ exists
9	p		259(si)		
10	p		p		
11	i		p		
12	m				
13	i				
14	s				
15	s				
16	i				
17	s				
18	s				
19	i				
20	p				
21	p				
22	i				

Dictionary

Index	Contents
0	256
…	ASCII
255	Codes
256	mi
257	is
258	ss
259	si
260	iss
261	sip
262	pp
263	pi
264	
265	
266	
267	
268	
269	
270	
271	
272	
273	
274	

Question 3.

An IPv4 packet is initially of length 3000 bytes and goes through links with MTU first 2000 bytes and then 1200 bytes.
What packets arrive at the end of the final link?
Show the final fragments and give relevant values in the fragment headers. **[8 marks]**
Ignore the header size when calculating fragmentation

Question 4.

(a) What type of error handling (error detection or error correction) is provided by
(i) A single parity bit **[1 mark]**
(ii) A Hamming code **[1 mark]**
(iii) A Cyclic Redundancy Check **[1 mark]**
(iv) A checksum as for an IP frame **[1 mark]**
(b) A message is to be protected by a 16-bit checksum, with possible choices being
- a CRC-16
- a Fletcher checksum (sum-of-sums, modulo 255)
- a ones-complement sum, as used in TCP/IP

Comment on these choices, giving advantages and disadvantages of each. **[6 marks]**

TOTAL = [10 marks]

~~**Question 5.**~~

~~A square wave of frequency *f* has Fourier components at the fundamental frequency *f*, and at the *odd* harmonics $3f$, $5f$, $7f$, …, with the amplitude of the *n*th harmonic proportional to $1/n$.~~

~~(a) Sketch the frequency spectrum of a 1 MHz square wave.~~ ~~**[3 marks]**~~
~~(b) Sketch the frequency spectrum of a 100 MHz sinusoidal carrier, amplitude modulated by a 1 MHz square wave.~~ ~~**[3 marks]**~~
~~(c) A sequence of pulse bursts, as in the diagram, can be regarded as the amplitude modulation~~

~~of a higher-frequency square wave "carrier" by a lower-frequency square wave "modulation".~~

~~By considering the Fourier components of both the carrier and modulation, or otherwise, describe the frequency spectrum of a repetitive pulse burst with "carrier" frequency 100 MHz and modulation of 5 MHz (both square waves).~~ **~~[4 marks]~~**

~~TOTAL = [10 marks]~~

Question 6.

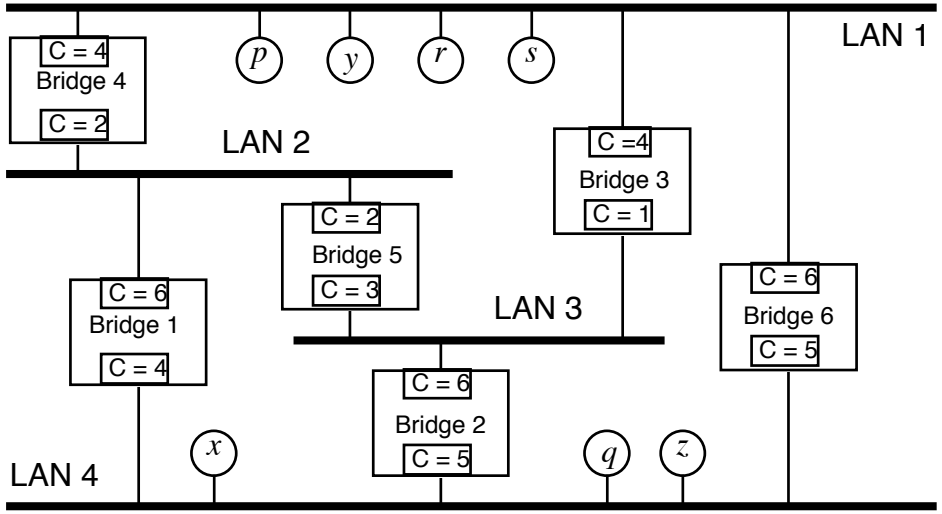
The following table lists some of the fields of the headers of IPv4, IPv6 and TCP. For each field, state its function and which protocol or protocols include it.

(i) checksum
(ii) flow
(iii) fragment offset
(iv) hop limit
(v) sequence number
(vi) version

TOTAL = [12 marks]

Question 7.

The diagram shows a system of several LANs interconnected with transparent bridges. The bridges have names such as "Bridge 4", which are used as the unique identifiers for the spanning tree algorithm. Each bridge port has an associated cost as shown, for example "C = 5". Two of the LANs are shown with connected stations or nodes (such as "*p*" and "*x*").



(a) Assuming at first that *only Bridge 6 is operating*, explain for the following sequence of messages,

(i) on which LANs each message appears.

(ii) what the bridge learns about the network (the answer may be "nothing"). **[6 marks]**

The bridge has no initial knowledge and information learned from one message is used in handling later messages.

	source		*dest*
1.	*p*	→	*r*
2.	*x*	→	*y*
3.	*r*	→	*s*
4.	*r*	→	*p*
5.	*x*	→	*p*
6.	*z*	→	*x*

(b) Assuming that a network spanning tree has been built, which bridge will become the root

bridge of the full network, and why? **[2 marks]**

(c) Draw the Spanning Tree for this network. **[4 marks]**

TOTAL = [12 marks]

Question 8.

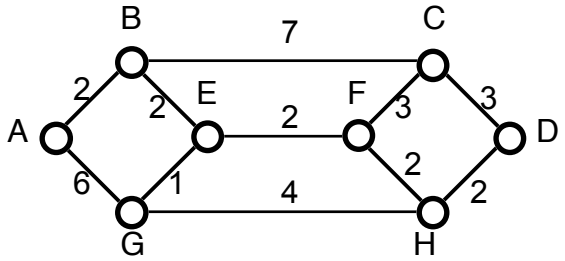
Use Dijkstra's algorithm to calculate the shortest path from A to D in the following network. While you may present your answer in any appropriate manner, it is enough to indicate the path added at each stage and its cost to the root.

For example if routing from D to B, acceptable answers for the first stages might be

connect H to D, cost to D = 2

connect C to D, cost to D = 3

connect F to H, cost to D = 4, and so on



TOTAL = [6 marks]

Question 9.

(a) Networks are sometimes subject to "congestion".

(i) Why, in the most general case, does congestion occur? **[2 marks]**

(ii) What is the general way of reducing congestion in a network? **[2 marks]**

(iii) How is congestion handled in TCP? **[4 marks]**

(b) An extreme form of congestion is "deadlock".

(i) What are the two types of deadlock? **[2 marks]**

(ii) Give one way of preventing deadlock. **[2 marks]**

(iii) If a deadlock does occur, give one way by which it may be broken. **[2 marks]**

TOTAL = [14 marks]

Question 1.

A packet on an IEEE 802.3 *or* Ethernet network is seen to start with the following octets (on the top line of the diagram).
(*These octets do not include the preamble and start delimiter.*
Below each octet is a sequential number so that you can identify it in your answers.)

00	00	66	33	B5	49	00	00	A7	12	36	B7	08	00	AA	AA	03	00	00	00	08	00	48	45	4C	50
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

(i) What octet numbers are occupied by the destination address? **[2 marks]**
(ii) What is the hexadecimal value of the length/type field? **[2 marks]**
(iii) What can you say about the value of the FCS (or CRC)? **[2 marks]**
(iv) What is the significance of length/type value for the interpretation of the payload? **[2 marks]**
(v) What are the first four octets of the user data? **[2 marks]**

Question total = 10 marks

Question 2.

The bit string B=011101101 is to be protected by a CRC checksum with generator polynomial $x^4 + x^2 + 1$, (or, the generator bit vector is 10101).

(a) Calculate the CRC checksum for B and hence the final transmitted codeword. Show your working. **[6 marks]**
(*Hint :the division should give the quotient* 011010101.)

(b) Now assume that B gets corrupted in transit and becomes B′ = 011001001 (two bit errors: on the 4th and 7th bit), with the checksum from part (a) not shown.
Show by explanation and calculation how the receiver can detect that there is a problem. Show your working
(*Hint: the quotient should now be* 011111000.) **[6 marks]**

Question total = 12 marks

Question 3.

When stations share a communication medium (as in many LANs) there is usually some rule or rules stating when each station may first attempt to transmit data.
(*Ignore any rules that apply if the initial transmission attempt fails*.)

(a) What are these rules for each of –
(i) Aloha,
(ii) Ethernet,
(iii) Token ring,
(iv) Token bus. **[4 marks]**

(b) For each of the above networks and given that a particular station (**A**) is transmitting, what can you say about the first station that might be able to send data just after **A** has finished transmission? **[4 marks]**

Question total = 8 marks

Question 4.

An important recent development in networking is the Virtual LAN, or VLAN.

(i) Briefly describe how VLANs differ from traditional LANs.
(Say what a VLAN does and how it appears to users, *but not how it works*.) **[3 marks]**

(ii) Give three (3) advantages of VLANs. **[3 marks]**

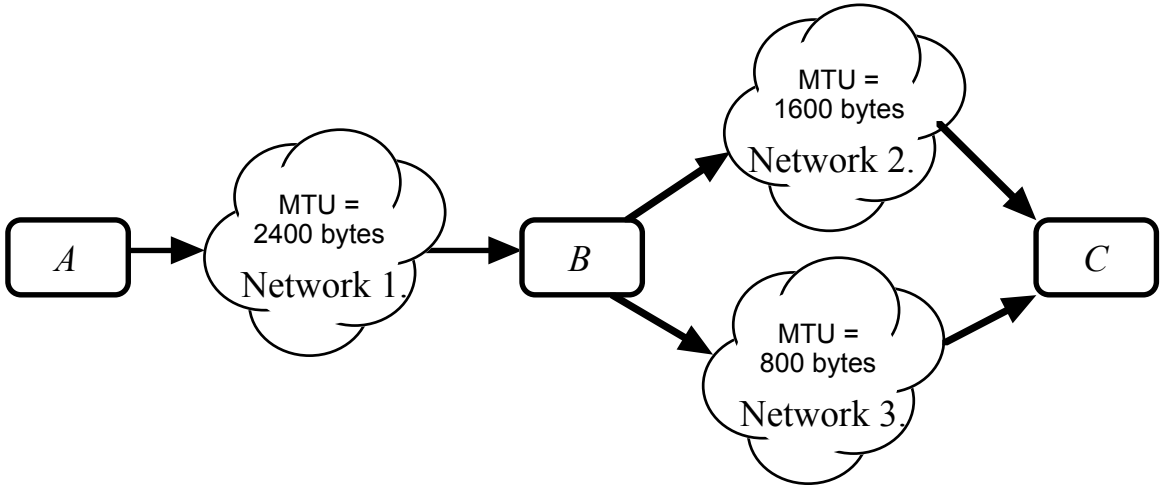
(iii) Discuss how a VLAN is implemented if all of its stations are connected to a single switch. **[4 marks]**

(iv) Briefly discuss the implementation of a VLAN across several connected switches. **[4 marks]**

Question total = 14 marks

Question 5.

The router at *A* in the figure receives an IP packet with 6000 data bytes, fragments the packet and routes the fragments to *B* via Network 1.
B in turn routes all fragments except the second one to *C* via network 3, but sends the second fragment to *C* via Network 2.



Show the fragments that *C* receives and the values that are important for reassembly/defragmentation.
Ignore the IP headers added during fragmentation. For example if a packet of 2000 octets were to be sent over a path with MTU=1500, assume that there would be one packet of 1500 octets and one of 500 octets, rather than one of (20+1480) and one of (20+520).

- Present your answer as a table with a row for each received fragment and a column for each value associated with fragmentation/reassembly.
- The precise fragment order at *C* does not matter, but packets sent over a path must remain in the order of sending.

Question total = 16 marks

Question 6.

When a user message of about 1000 bytes is sent over TCP/IPv4 and Ethernet we find that different amounts of the message (and headers etc) are covered by checksums at each level of the protocol stack.

(i) Explain and justify these differences in checksum coverage. **[6 marks]**

(ii) Explain what changes to checksumming might occur if the transfer used IPv6 rather than IPv4? **[2 marks]**

Question total = 8 marks

Question 7.

Use Dijkstra's algorithm to calculate the shortest path from A to G in the following network, assuming that each link has the cost shown beside it.

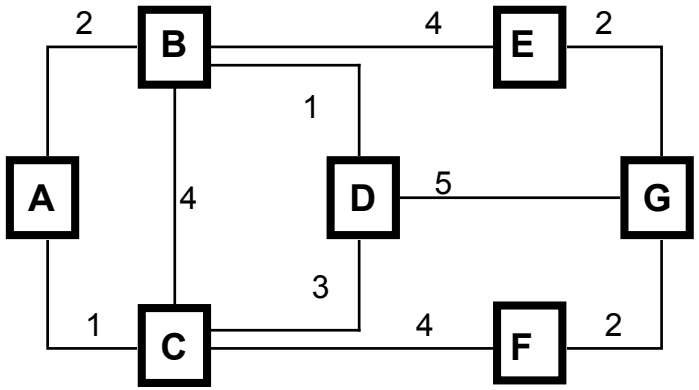
While you may present your answer in any appropriate manner, it is enough to indicate the path added at each stage and its cost to the root.

For example if routing from B, acceptable answers for the first stages might be

connect D to B, cost to B = 1

connect A to B, cost to B = 2

connect C to A, cost to B = 3, and so on



Question total = 6 marks

Question 8.

A (12,8) Hamming code uses *odd* parity for each of its parity groups.

(i) Explain the significance of the "(12,8)" description, including any relationship between the two numbers. **[2 marks]**

(ii) The received codeword is 1111 1111 1111. Correct the error (if any) in the received word and extract the corrected data bits (deleting the parity bits).
You must state the bit order. **[4 marks]**

Question total = 6 marks

Question 9.

(a) Networks are sometimes subject to "congestion".

(i) Why, in the most general case, does congestion occur? **[2 marks]**

(ii) What is the general way of reducing congestion in a network (apart from increasing its capacity or bandwidth)? **[2 marks]**

(iii) How is congestion handled in TCP? **[4 marks]**

(b) An extreme form of congestion is "deadlock".

(i) What are the two types of deadlock? **[2 marks]**

(ii) Give one way of preventing deadlock. **[2 marks]**

(iii) If a deadlock does occur, give one way by which it may be broken. **[2 marks]**

Question total = 14 marks

Question 10.

(i) Why is the signal encoding for multiplexed digital telephone systems usually based on a 125μs frame? **[1 mark]**

(ii) Why do telephone circuits normally use 64 kbps digital coding? **[1 mark]**

(iii) The North American T1 standard multiplexes 24 telephone circuits into a frame with composite bit rate of 1.554 Mbps.
Briefly describe the format of the T1 frame. **[2 marks]**

(iv) The European and CCITT equivalent of T1 is E1, with 30 user circuits and a composite bit rate of 2.048 Mbps
Briefly describe the format of the E1 frame. **[2 marks]**

Question total = 6 marks