Question 1

(a) Describe the key features of the CIF format for video sequences. What is the bandwidth required for a ten second CIF sequence assuming 4:2:0 video? List two advantages of this format that make it suitable for video compression applications.

[6 Marks]

(b) State, and explain in your own words, Shannon's Lossless Coding Theorem and explain why video compression presents significant challenges in light of the implications of this theorem.

[5 Marks]

(c) Briefly outline the operation of the lossless mode of the ISO JPEG image coding standard indicating how individual pixels are encoded. You should use text, diagrams and sample pixel values to illustrate your answer.

[10 Marks]

(d) Describe what is meant by the term "Run-length Coding". Describe how run-length coding would typically be used in a DCT-based still image compression scheme.

[4 Marks]

Question 2

(a) Calculate the entropy of the information source consisting of four symbols a, b, c, d with probabilities $p_a = P\{a\} = 0.17, p_b = P\{b\} = 0.22, p_c = P\{c\} = 0.1, p_d = P\{d\} = 0.51$.

[4 Marks]

(b) Calculate the Huffman codewords for the information source defined in part (a) above. Define a metric for calculating the efficiency of Huffman codewords and use it in order to calculate the efficiency of the calculated codewords.

[8 Marks]

(c) Assuming the same information source as defined in part (a) illustrate the operation of Arithmetic Encoding in order to encode the message *abcd*.

> **Note 1:** you need not sketch the successive narrowing of the interval on the real number line, simply illustrate the evolution of *high* and *low* in the Arithmetic Encoding algorithm.
>
> **Note 2:** you can assume that the interval $[0.0, 1.0)$ on the real number line is initially divided as illustrated in Figure 1.

[8 Marks]

(d) Calculate the final binary fraction obtained for part (c) above and thereby produce the bitstream obtained to encode the message *abcd*. Using the Huffman codewords calculated in part (b) construct the bitsteam obtained for the same message using Huffman Codewords. Which is more efficient?

[5 Marks]

Question 3

(a) Briefly describe how the following transformations or properties affect the coefficients of the Fourier Series representation of a periodic function with period L:

1. **Spatial shift of waveform**
2. **Amplitude shift of waveform**
3. **Waveform even/odd symmetry**
4. **Waveform translational symmetry**
5. **Waveform discontinuities or discontinuities of its derivatives**

Outline how these properties can be used to develop the discrete cosine transform (DCT) and the discrete sine transform (DST) of a 1-D block of data samples taken from a non-periodic sampled signal. Explain why discrete cosine transforms are in general preferred to discrete sine transforms.

[13 Marks]

(b) Distinguish between the design of a scalar quantization process using (i) the Lloyd-Max approach, (ii) the companding approach and (iii) the optimum uniform quantizer approach. Discuss the issues surrounding algorithms for allocating bits to quantized transform coefficients. Outline the approach used for quantizing DCT coefficients in the JPEG image compression scheme, making specific reference to the distinction between luminance and chrominance components.

[12 Marks]

Question 4

(a) Describe in detail the layered data structure used in the MPEG-1 standard for an elementary video stream, including the role played by each layer in representing compressed video. Describe the time and picture-type structure of a typical GOP, explaining why the time-ordering that pictures acquire in the compressed data stream is different from the eventual display order.

[8 Marks]

(b) Consider the macroblocks in a reconstructed MPEG-1 B-picture. Describe the different ways in which data for this reconstruction can be derived from earlier elements in the compressed stream. Explain how and why DC coefficients are treated differently in *intra*-coded macroblocks than in *inter*-coded macroblocks.

[8 Marks]

(c) Explain the difference in roles played by *start codes* and *variable-length codes* in the MPEG-1 stream. Include in your response the purpose of *marker-bits* inserted at various points into the stream. Outline a scheme for decoding variable length codes (VLCs). Explain the relationship between system layers and elementary streams in the MPEG-1 standard. Explain why the system layer is in turn split into *pack* and *packet* layers.

[9 Marks]

Question 5

(a) Using diagrams and text, compare and contrast any two different motion estimation strategies that could be used in a video encoder.

[8 Marks]

(b) The MPEG-4 video encoding standard supports object-based compression. Describe how a block-based motion estimation process should be modified in order to be used with arbitrarily-shaped video objects.

[4 Marks]

(c) Describe the different layers present in a H.261 bitstream using diagrams to illustrate the different parts of a video frame they are associated with.

[8 Marks]

(d) Describe the addressing mechanism by which the presence/absence of coded DCT coefficients for individual Y, U or V 8×8 blocks is signalled within a H.261 bitstream.

[5 Marks]

Question 6

(a) How are arbitrarily-shaped video objects represented in order to be input to an MPEG-4 video encoder? In your answer you should describe and sketch how each individual component in the input is represented.

[6 Marks]

(b) Describe how the representation of a video object in MPEG-4 encoding is broken up into elementary coding units of alphablocks and macroblocks and describe the different types of alphablocks (macroblocks) that can occur.

[6 Marks]

(c) Explain the method of binary shape coding employed in the MPEG-4 video compression standard using appropriate diagrams in order to illustrate your explanation.

[8 Marks]

(d) "Unlike previous MPEG standardisation work items, the main focus of MPEG-7 is not on compression". Briefly discuss this statement.

[5 Marks]

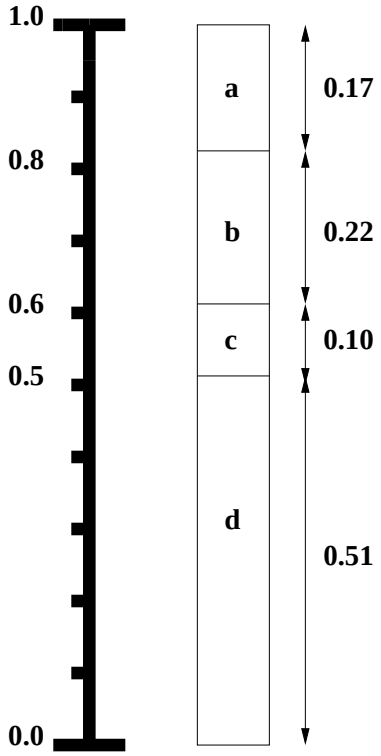

Figure 1: Allocation of information source for Question 2 along real number line