# Question 1

**(a) Explain the difference between the `RGB` and `YUV` colour spaces in the context of digital images/video. What are the (two) main advantages of the `YUV` colour space for video compression applications?**

**[5 Marks]**

**(b) List and explain the three types of redundancy present in a video sequence and give an example of how each could be exploited in order to achieve compression**

**[9 Marks]**

**(c) Give the mathematical definition of entropy in the context of information theory. Calculate the entropy of an information source consisting of five symbols $a, b, c, d, e$ with probabilities $p_a = P\{a\} = 0.46, p_b = P\{b\} = 0.12, p_c = P\{c\} = 0.04, p_d = P\{d\} = 0.2, p_e = P\{e\} = 0.18$.**

**[6 Marks]**

**(d) *"In information theory, an outcome for an event that is certain to occur carries no information"*. Explain this statement using *Hartley's measure of self information* to justify your answer.**

**[5 Marks]**

# Question 2

**(a) Consider the 8×8 block of pixel values shown in Figure 1. Caclulate the Huffman codewords for the grey levels present in this block of pixels. You should use the frequency of occurrence of the grey levels in this block to derive probabilities of occurrence for the different grey levels**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| 8 | 5 | 5 | 5 | 5 | 5 | 5 | 8 |
| 8 | 5 | 3 | 3 | 3 | 3 | 5 | 8 |
| 8 | 5 | 3 | 0 | 0 | 3 | 5 | 8 |
| 8 | 5 | 3 | 0 | 0 | 3 | 5 | 8 |
| 8 | 5 | 3 | 3 | 3 | 3 | 5 | 8 |
| 8 | 5 | 5 | 5 | 5 | 5 | 5 | 8 |
| 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

Figure 1: An 8×8 block of pixel values

**[7 Marks]**

**(b) Assuming the same information source as defined in part (a) illustrate the operation of Arithmetic Encoding in order to encode the following sequence of grey level values:** $8, 5, 3$**.**

> **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 2.

**[8 Marks]**

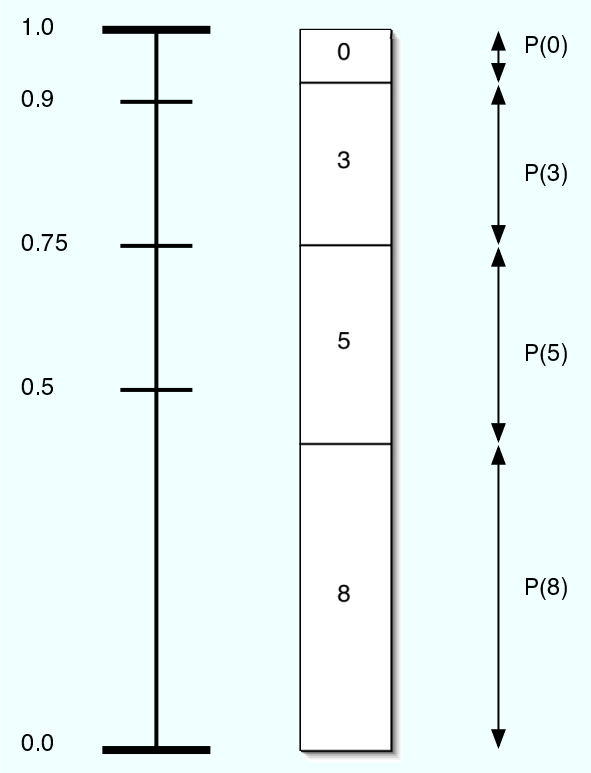


Figure 2: Allocation of information source for Question 2 along real number line

**(c) Calculate the final binary fraction obtained for part (b) above and thereby produce the bitstream obtained to encode the sequence of grey levels $8, 5, 3$. Using the Huffman codewords calculated in part (a) construct the bitsteam obtained for the same sequence using Huffman Codewords. Which is more efficient?**

**[5 Marks]**

**(d) *"Every lossy image compression scheme implicitly contains a lossless compression process".* Discuss this statement by explaining the relationship between lossy and lossless image compression.**

**[5 Marks]**

# Question 3

**(a) Outline how it is possible to compare functions in a formal and consistent way so that it is possible to derive something useful from the comparison.**

**[4 Marks]**

**(b) Explain (with the aid of diagrams) the concepts of full-range, half-range and quarter-range series applied to a 1-D block of samples taken from a non-periodic sampled signal. Outline some of the potential advantages for transform coding from constructing half-range and quarter-range series over full-range series.**

**[5 Marks]**

**(c) 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.**

**[6 Marks]**

**(d) Discuss the issues surrounding algorithms for allocating bits to quantized transform coefficients.**

**[5 Marks]**

**(e) 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.**

**[5 Marks]**

# Question 4

**(a) Explain the distinction between the system layer and the video layer in the MPEG-1 standard, including the different roles played by each. Comment on the relationship, if any, between system-layer packets and video or audio layer access units. How is the MPEG-1 system layer different from that used in MPEG-2.**

**[4 Marks]**

**(b) Describe 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.**

**[5 Marks]**

**(c) Outline how motion vectors are coded in the MPEG-1 video stream.**

**[8 Marks]**

**(d) 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).**

**[8 Marks]**

# Question 5

**(a) Describe the operation of a *parallel one-dimensional search strategy* for calculating motion vectors in a motion estimation process. Illustrate your answer with a diagram of the pixel positions searched. Describe one advantage and one disadvantage of using a parallel one-dimensional search strategy**

**[8 Marks]**

**(b) Using a block diagram, sketch the structure of a H.261 encoder and briefly explain its operation.**

**[7 Marks]**

**(c) Why is an addressing mechanism required for individual macroblocks in a GOB in a H.261 bitstream? Briefly describe this mechanism.**

**[4 Marks]**

**(d) *"The term motion estimation is a misnomer since when typically used in a video encoder this process is not measuring the true motion present in a scene"*. Briefly discuss this statement.**

**[6 Marks]**

# Question 6

**(a) Describe the major difference between MPEG-4 and other video compression standards that allows MPEG-4 to facilitate enhanced forms of user interaction.**

**[4 Marks]**

**(b) Explain what is meant by *a scalable bitstream*. Explain what is meant by *spatial scalability* in MPEG-4 video encoding. Illustrate your answer with a diagram. In your diagram you should indicate the different types of Video Object Planes used (I-/P-/B-VOPs).**

**[8 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) Describe what is meant by the terms *normative* and *non-normative* in the context of an image/video compression standard. Give a single example of a non-normative component of the MPEG-4 standard and a single (different) example of a non-normative component of the MPEG-7 standard.**

**[5 Marks]**