# DSE-3 (ii): Introduction to Information Theory and Coding

**Total Marks: 100** (Theory: 75, Internal Assessment: 25)
**Workload:** 5 Lectures, 1 Tutorial (per week) **Credits:** 6 (5+1)
**Duration:** 14 Weeks (70 Hrs.) **Examination**: 3 Hrs.

**Course Objectives:** This course aims to introduce the basic aspects of Information Theory and Coding to the students. Shannon's work form the underlying theme for the present course. Construction of finite fields and bounds on the parameters of a linear code discussed.

**Course Learning Outcomes:** This course will enable the students to:
- i) Learn about the basic concepts of information theory.
- ii) Know about basic relationship among different entropies and interpretation of Shannon's fundamental inequalities.
- iii) Learn about the detection and correction of errors while transmission.
- iv) Representation of a linear code by matrices.
- v) Learn about encoding and decoding of linear codes.

**Unit 1: Concepts of Information Theory**
Communication processes, A model of communication system, A quantitative measure of information, Binary unit of information, A measure of uncertainty, H function as a measure of uncertainty, Sources and binary sources, Measure of information for two-dimensional discrete finite probability schemes.

**Unit 2: Entropy Function**
A sketch of communication network, Entropy, Basic relationship among different entropies, A measure of mutual information, Interpretation of Shannon's fundamental inequalities; Redundancy, Efficiency and channel capacity, Binary symmetric channel, Binary erasure channel, Uniqueness of the entropy function, Joint entropy and conditional entropy, Relative entropy and mutual information, Chain rules for entropy, Conditional relative entropy and conditional mutual information, Jensen's inequality and its characterizations, The log sum inequality and its applications.

**Unit 3: Concepts of Coding**
Block codes, Hamming distance, Maximum likelihood decoding, Levels of error handling, Error correction, Error detection, Erasure correction, Construction of finite fields, Linear codes, Matrix representation of linear codes.

**Unit 4: Bounds of Codes**
Orthogonality relation, Encoding of linear codes, Decoding of linear codes, Singleton bound and maximum distance separable codes, Sphere-packing bound and perfect codes, Gilbert–Varshamov bound, MacWilliams' identities.

**References:**

1. Cover, Thomas M., & Thomas, Joy A. (2006). *Elements of Information Theory* (2nd ed.). Wiley India. Indian Reprint 2014.
2. Gallian, Joseph. A. (2013). *Contemporary Abstract Algebra* (8th ed.). Cengage Learning India Private Limited. Delhi. Fourth impression, 2015.

3. Reza, Fazlollah M. (1961). *An Introduction to Information Theory*. Dover Publications Inc, New York. Reprint 1994.
4. Roth, Ron M. (2007). *Introduction to Coding Theory*. Cambridge University Press.

**Additional Readings:**

i. Ash, Robert B. (1965). *Information Theory*. Dover Publications, Inc. New York. Reprint in 1990.
ii. Goldman, Stanford (1968). *Information Theory*, Dover Publications, Inc. New York. Reprint in 1990.
iii. Ling, San & Xing, Chaoping (2004). *Coding Theory*: *A First Course*. Cambridge University Press.

**Teaching Plan (DSE-3 (ii): Introduction to Information Theory and Coding):**

**Weeks 1 and 2:** Communication processes, A model of communication system, A quantitative measure of information, Binary unit of information.

[3] Chapter 1 (Sections 1.1 to 1.7).

**Weeks 3 and 4:** A measure of uncertainty, H function as a measure of uncertainty, Sources and binary sources, Measure of information for two-dimensional discrete finite probability schemes.

[3] Chapter 3 (Sections 3.1 to 3.7).

**Weeks 5 and 6:** A sketch of communication network, Entropy, Basic relationship among different entropies, A measure of mutual information, Interpretation of Shannon's fundamental inequalities; redundancy, efficiency and channel capacity, Binary symmetric channel, Binary erasure channel, Uniqueness of the entropy function.

[3] Chapter 3 (Sections 3.9, 3.11 to 3.16 and 3.19).
[1] Chapter 2 (Section 2.1).

**Weeks 7 and 8:** Joint entropy and conditional entropy, Relative entropy and mutual information, Chain rules for entropy, Conditional relative entropy and conditional mutual information, Jensen's inequality and its characterizations, The log sum inequality and its applications.

[1] Chapter 2 (Sections 2.2 to 2.7).

**Weeks 9 and 10:** Block codes, Hamming distance, Maximum likelihood decoding, Levels of error handling, Error correction, Error detection, Erasure correction, Construction of finite fields.

[4] Chapter 1 (Sections 1.2 to 1.5, excluding 1.5.3), and Chapter 3 (Sections 3.1 to 3.4).

**Weeks 11 and 12:** Linear codes, Matrix representation of linear codes, Orthogonality relation, Encoding of linear codes, Decoding of linear codes.

[4] Chapter 2 (Sections 2.1 to 2.4).
[2] Chapter 31 (Lemma and Theorem 31.3 on Page 538).

**Weeks 13 and 14:** Singleton bound and maximum distance separable codes, Sphere-packing bound and perfect codes, Gilbert–Varshamov bound, MacWilliams' identities.

[4] Chapter 4 (Sections 4.1 to 4.4) and Chapter 11 (Section 11.1).

**Facilitating the Achievement of Course Learning Outcomes**

| Unit No. | Course Learning Outcomes | Teaching and Learning Activity | Assessment Tasks |
|---|---|---|---|
| 1. | Learn about the basic concepts of information theory. | (i) Each topic to be explained with examples.<br>(ii) Students to be involved in discussions and encouraged to ask questions.<br>(iii) Students to be given | • Student presentations.<br>• Participation in discussions.<br>• Assignments |
| 2. | Know about basic relationship among different entropies and interpretation of Shannon's fundamental inequalities. | | |

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| 3. | Learn about the detection and correction of errors while transmission. | homework/assignments.<br>(iv) Students to be encouraged to give short presentations. | and class tests.<br>• Mid-term examinations.<br>• End-term examinations. |
| 4. | Representation of a linear code by matrices.<br>Learn about encoding and decoding of linear codes. | | |

**Keywords:** Measure of uncertainty, Entropy, Shannon's fundamental inequalities, Channel capacity, Linear codes, Gilbert–Varshamov bound.