**BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI**

**WORK INTEGRATED LEARNING PROGRAMMES**

**Digital Learning**

**Part A: Course Design**

|  |  |
| --- | --- |
| **Course Title** | **Real Time Operating Systems** |
| **Course No(s)** | **CS ZG524/ES ZG524/MEL ZG524** |
| **Credit Units** | 5 |
| **Credit Model** |  |
| **Instructor-In-Charge** | Krishna Chaitanya |

**Course Objectives**

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| --- |
| To introduce the issues and challenges in developing software for Real Time Systems and understand the functional modules, design and implementation of Real Time Operating Systems. To analyze the constraints in such a design and to incorporate the essential features which make a real time operating system different from a conventional operating system. |

**Text Book(s)**

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| --- | --- |
| T1 | Liu, Jane W.S., Real Time Systems, Pearson Education, 2000 |
| T2 | Laplante, Phillip A., Real-Time Systems Design and Analysis, Wiley, 3rd Ed., 2004 |

**Reference Book(s) & other resources**

|  |  |
| --- | --- |
| R1 | C.M. Krishna and Kang G.Shin, Real Time Systems, Mc Graw Hill Publications, 1997 |

**Content Structure**

|  |  |
| --- | --- |
| No | Title of the Module |
| M1 | Introduction to the course |
| M2 | Modelling Real time Systems |
| M3 | Task graphs and Data Dependency |
| M4 | Clock Driven Scheduling |
| M5 | Priority Driven Scheduling |
| M6 | Modelling Schedulers using Periodic, Aperiodic and Sporadic task schedulers |
| M7 | Resource and Resource access control |
| M8 | Requirements and Performance aspects of a Real Time System |
| M9 | Types of pseudo-kernels |
| M10 | Real time languages and engineering considerations |

**Learning Outcomes:**

|  |  |
| --- | --- |
| No | Learning Outcomes |
| LO1 | Knowing different aspects of a real time system |
| LO2 | Understanding Cheddar basics and designing small schedulers using Cheddar |
| LO3 | Analyzing optimality and feasibility of the scheduler |

**Part B: Learning Plan**

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| --- | --- |
| **Academic Term** | **First Semester 2020-2021** |
| **Course Title** | **Real Time Operating Systems** |
| **Course No** | **CS ZG524/ES ZG524/MEL ZG524** |
| **Content Developer** | **Krishna Chaitanya** |

Glossary of Terms:

1. Contact Hour (CH) stands for a hour long live session with students conducted either in a physical classroom or enabled through technology. In this model of instruction, instructor led sessions will be for 20 CH.
   1. Pre CH = Self Learning done prior to a given contact hour
   2. During CH = Content to be discussed during the contact hour by the course instructor
   3. Post CH = Self Learning done post the contact hour
2. RL stands for Recorded Lecture or Recorded Lesson. It is presented to the student through an online portal. A given RL unfolds as a sequences of video segments interleaved with exercises
3. SS stands for Self-Study to be done as a study of relevant sections from textbooks and reference books. It could also include study of external resources.
4. LE stands for Lab Exercises
5. HW stands for Home Work will consists could be a selection of problems from the text.

**Contact Hour 1**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL1 | RL1.1 Real Time Systems – Introduction |  |
| During CH | CH1 | CH1.1.1 Providing additional inputs on Killer applications that are real time. Modelling a small real time system using Free RTOS or similar RTOS (T1).  CH1.1.2 Studying small embedded applications modelling basic components (sensors, embedded processors, actuators), etc (T2). | T1,T2 |
| Post CH | SS1 | - |  |
| Post CH | HW1 | - |  |
| Post CH | LE1 | - |  |
| Post CH | QZ1 | - |  |

**Contact Hour 2**

|  |  |  |  |
| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL1 | RL1.1 Real Time Systems – Introduction |  |
| During CH | CH2 | CH2.1 = Explaining PID control concept of open and closed loop system stability  CH2.2 = Explaining stability concepts for similar embedded applications.(T1) | T1 |
| Post CH | SS2 | - |  |
| Post CH | HW2 | - |  |
| Post CH | LE2 | - |  |
| Post CH | QZ2 | - |  |

**Contact Hour 3**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL2.1 | RL2.1 = Components of a Real Time Scheduler |  |
| During CH | CH3 | CH3.1 = Discussing scheduler as a key component of the RTOS (T1)  CH3.2 = Explaining how effectively modelling needs to be done. | T1 |
| Post CH | SS3 | Analysing the modelling of hard and soft real time tasks using Vxworks, Free RTOS based Real time Operating Systems |  |
| Post CH | HW3 | Practising using Cheddar how to add additional complexity to incorporate optimality in mixed modelling of hard and soft real time systems when embedded applications have both hard and soft real time tasks (Mixed modelling) |  |
| Post CH | LE3 | * Understanding Cheddar basics * Designing small schedulers using Cheddar |  |
| Post CH | QZ3 | - |  |

**Contact Hour 4**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL2.1 | RL2.2 = Nature of tasks |  |
| During CH | CH4 | CH4.1 = Discussing optimality and feasibility constraints for hard and soft real time systems (R1)  CH4.2 = Explaining tardiness parameter in soft real time system modelling | R1 |
| Post CH | SS4 | Analysing the modelling of hard and soft real time tasks using Vxworks, Free RTOS based Real time Operating Systems |  |
| Post CH | HW4 | Practising using Cheddar how to add additional complexity to incorporate optimality in mixed modelling of hard and soft real time systems when embedded applications have both hard and soft real time tasks (Mixed modelling) |  |
| Post CH | LE4 | * Understanding Cheddar basics * Designing small schedulers using Cheddar |  |
| Post CH | QZ4 | - |  |

**Contact Hour 5**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL2.1 | RL2.3= Modeling a Real Time System |  |
| During CH | CH5 | CH5.1 = Providing more insight on Cheddar and scheduling analysers. Analysing the nature of tasks using Cheddar.  CH5.2 = Formulating small task schedules based on tasks. |  |
| Post CH | SS5 | Analysing the modelling of hard and soft real time tasks using Vxworks, Free RTOS based Real time Operating Systems |  |
| Post CH | HW5 | Practising using Cheddar how to add additional complexity to incorporate optimality in mixed modelling of hard and soft real time systems when embedded applications have both hard and soft real time tasks (Mixed modelling) |  |
| Post CH | LE5 | * Understanding Cheddar basics * Designing small schedulers using Cheddar |  |
| Post CH | QZ5 | - |  |

**Contact Hour 6**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL3.1 | RL3.1.1 = Reference Model of Real Time Systems |  |
| During CH | CH6 | CH6.1 = Modelling a real time system (T1)  CH6.2 = Explaining with case study examples to model a real time system (T2) | T1,T2 |
| Post CH | SS6 | Study of research papers on task modelling in cases of tasks being dependent and independent. Analysing the criteria associated with such tasks and graph reduction in such cases. |  |
| Post CH | HW6 | Using Graph reduction tools like Graphviz for such analysis and also identifying the reduction process of complex graphs using such graph reduction tools. |  |
| Post CH | LE6 | - |  |
| Post CH | QZ6 | - |  |

**Contact Hour 7**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL3.2 | RL3.2.1= Components of real time systems |  |
| During CH | CH7 | CH7.1 = Different aspects of a real time system like real time databases and real time communication with example scenarios (R1) | R1 |
| Post CH | SS7 | Study of research papers on task modelling in cases of tasks being dependent and independent. Analysing the criteria associated with such tasks and graph reduction in such cases. |  |
| Post CH | HW7 | Using Graph reduction tools like Graphviz for such analysis and also identifying the reduction process of complex graphs using such graph reduction tools. |  |
| Post CH | LE7 | - |  |
| Post CH | QZ7 | - |  |

**Contact Hour 8**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL3.3 | RL3.3.1 = Commonly used approaches for Real Time Scheduling |  |
| During CH | CH8 | CH8.1 = Modelling tasks with task graphs (T1)  CH8.2 = Discussing DAG’s and schematics to model such tasks using graphs (T1)  CH8.3 = Criteria involved in mapping dependent and independent task graphs and mapping them on to scheduling (T1) | T1 |
| Post CH | SS8 | Study of research papers on task modelling in cases of tasks being dependent and independent. Analysing the criteria associated with such tasks and graph reduction in such cases. |  |
| Post CH | HW8 | Using Graph reduction tools like Graphviz for such analysis and also identifying the reduction process of complex graphs using such graph reduction tools. |  |
| Post CH | LE8 | - |  |
| Post CH | QZ8 | - |  |

**Contact Hour 9**

|  |  |  |  |
| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL3.4 | RL3.4.1 = Task Graphs |  |
| Pre CH | RL3.5 | RL 3.5.1 = Functional Parameters of tasks |  |
| During CH | CH9 | CH9.1 = Using standard distributions like Weibull to choose tasks (R1)  CH9.2 = Variations of scheduler behaviour in terms of resource utilisation and task schedulability when varied task mixes are provided as inputs to a real time system (T1 & R1)  CH9.3 = Designing schedulers based on task graphs using Cheddar | R1,T1 |
| Post CH | SS9 | Study of research papers on task modelling in cases of tasks being dependent and independent. Analysing the criteria associated with such tasks and graph reduction in such cases. |  |
| Post CH | HW9 | Using Graph reduction tools like Graphviz for such analysis and also identifying the reduction process of complex graphs using such graph reduction tools. |  |
| Post CH | LE9 | - |  |
| Post CH | QZ9 | - |  |

**Contact Hour 10**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL4.1 | RL4.1.1 = Frame size constraints |  |
| During CH | CH10 | CH10.1 = Analysing tasks and highlighting restrictions in scheduling periodic tasks (T1)  CH10.2 = Highlighting differences in periodic scheduling when frames are used and not using Cheddar (T1)  CH10.3 = Explaining the hyperperiod and makespan constraints and its impact on periodic scheduling (T1) | T1 |
| Post CH | SS10 | Study of applications using Periodic scheduling. Designing a real time application like multimedia or networking using periodic task scheduling and applying the algorithm to such a scenario |  |
| Post CH | HW10 | Study of RTOS like CHIMERA and VXWORKS. Designing small real time tasks and understanding the same on any small RTOS. |  |
| Post CH | LE10 | Design Periodic scheduler using Cheddar |  |
| Post CH | QZ10 | - |  |

**Contact Hour 11**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL4.2 | RL4.2.1 = Cyclic Executives |  |
| Pre CH | RL4.3 | RL 4.3.1 = Slack Stealing approach |  |
| During CH | CH11 | CH11.1 = Illustrating periodic schedules based on frame size constraints (T1)  CH11.2 = Explain slack concepts for online and offline schedules namely critical scaling factor and laxity based approaches (T1)  CH11.3 = Extending this concepts to real time applications (T1) | T1 |
| Post CH | SS11 | Study of applications using Periodic scheduling. Designing a real time application like multimedia or networking using periodic task scheduling and applying the algorithm to such a scenario |  |
| Post CH | HW11 | Study of RTOS like CHIMERA and VXWORKS. Designing small real time tasks and understanding the same on any small RTOS. |  |
| Post CH | LE11 | Design Periodic scheduler using Cheddar |  |
| Post CH | QZ11 | - |  |

**Contact Hour 12**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL5.1 | RL5.1.1 = Priority based task scheduling |  |
| During CH | CH12 | CH12.1 = Introduction to real time applications where priority driven scheduling is used. Explaining laxity based strategies. (R1) Applying priority inheritance and priority ceiling protocol to schedulers  CH12.2 = Extending laxity based constraints to dependent and independent tasks (R1)  CH12.3 = Explaining the modus operandi on how tasks would be scheduled in such scenarios taking laxity constraints into account.  CH12.4 = Studying additional factors in scheduling like migration overhead and scheduling costs (Computation and Communication) (R1) | R1 |
| Post CH | SS12 | Designing a real time application where priority driven scheduling is used |  |
| Post CH | HW12 | - |  |
| Post CH | LE12.1 | * Designing laxity based schedulers using Cheddar * Designing online and offline schedulers using Cheddar |  |
| Post CH | LE12.2 | * Designing schedulers using Cheddar and compare the utilisation metrics * Analyse the slack distribution strategies (Critical Scaling factor and laxity ) for online and offline schedulers |  |
| Post CH | QZ12 | - |  |

**Contact Hour 13**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL5.2 | RL5.2.1 = Dynamic Priority assignment |  |
| During CH | CH13 | CH13.1 = Explain granularity in tasks (fine grain and coarse grain) and their corresponding scheduling constraints (R1)  CH13.2 = Explaining task clustering and ranking in such scenarios and identifying scenarios where task parameters are not precise (R1)  CH13.3 = Explaining scenarios of the above using Cheddar.  CH13.4= Explaining IRIS scheduling algorithms (R1) | R1 |
| Post CH | SS13 | Designing a real time application where priority driven scheduling is used. |  |
| Post CH | HW13 | - |  |
| Post CH | LE13.1 | * Design an IRIS scheduler * Analysing optimality and feasibility of the scheduler |  |
| Post CH | LE13.2 | * Design an RM scheduler using Cheddar * Design an EDF scheduler using Cheddar * Analyse the optimality and feasibility of the scheduler |  |
| Post CH | QZ13 | - |  |

**Contact Hour 14**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL6.1 | RL6.1.1 = Scheduling using Aperiodic and Sporadic tasks |  |
| Pre CH | RL6.2 | RL 6.2.1 = Deferrable Servers |  |
| Pre CH | RL6.3 | RL 6.3.1 = Time Demand Analysis |  |
| Pre CH | RL6.4 | RL 6.4.1 = Simple Sporadic Server |  |
| Pre CH | RL6.5 | RL 6.5.1 = Total Bandwidth Server |  |
| During CH | CH14 | CH14.1 = Highlighting how non-real time tasks are scheduled with real time tasks (T1)  CH14.2 = Applying Deferrable and Simple sporadic server to non-real time tasks (T1)  CH14.3 = Bandwidth preserving analysis (T1) | T1 |
| Post CH | SS14 | - |  |
| Post CH | HW14 | - |  |
| Post CH | LE14 | * Design a scheduler for mixture of tasks (real time, non-real) * Analyse scenario for real time (Periodic, Sporadic and Aperiodic) |  |
| Post CH | QZ14 | - |  |

**Contact Hour 15**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL6.1 | RL6.1.1 = Scheduling using Aperiodic and Sporadic tasks |  |
| Pre CH | RL6.2 | RL 6.2.1 = Deferrable Servers |  |
| Pre CH | RL6.3 | RL 6.3.1 = Time Demand Analysis |  |
| Pre CH | RL6.4 | RL 6.4.1 = Simple Sporadic Server |  |
| Pre CH | RL6.5 | RL 6.5.1 = Total Bandwidth Server |  |
| During CH | CH15 | CH15.1 = Sporadic tasks scheduling (T1)  CH15.2 = Rejection tests using Cheddar (T1)  CH15.3 = Replenishment and Consumption rules (T1) | T1 |
| Post CH | SS15 | - |  |
| Post CH | HW15 | - |  |
| Post CH | LE15 | * ILP constraint modelling * Analysis on feasibility and optimality |  |
| Post CH | QZ15 | - |  |

**Contact Hour 16**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL7.1 | RL7.1.1 = Resource control using task graphs |  |
| During CH | CH16 | CH16.1 = Analysing resource utilization  CH16.2 = Simulation of scenarios when tasks are dependent or independent. Linking this scenario to task graphs |  |
| Post CH | SS16 | - |  |
| Post CH | HW16 | - |  |
| Post CH | LE16 | - |  |
| Post CH | QZ16 | - |  |

**Contact Hour 17**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL8.1 | RL8.1.1 = Requirements of Real Time System |  |
| Pre CH | RL8.2 | RL 8.2.1 = Finite State Machines |  |
| During CH | CH17 | CH17.1 = Analysing the requirements to design a real time system (T2)  CH17.2 = Explaining how to use all the components especially of schedulers studied in this course to design a real time system (T2)  CH17.3 = Constraints and criteria for design of a real time operating system (T2)  CH17.4 = Discussing Petrinet usage for simple embedded applications (T2) | T2 |
| Post CH | SS17 | - |  |
| Post CH | HW17 | - |  |
| Post CH | LE17 | - |  |
| Post CH | QZ17 | - |  |

**Contact Hour 18**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL8.3 | RL8.3.1 = Structural analysis |  |
| During CH | CH18 | CH18.1 = Performance assessment of embedded system (T2)  CH18.2 = Deciding on tolerance level of an embedded system based usage (T2)  CH18.3 = Criteria to avoid failure of such an embedded system in terms of performance and also highlighting the exceptional and sub optimal solutions in such real time operating systems (T2) | T2 |
| Post CH | SS18 | - |  |
| Post CH | HW18 | - |  |
| Post CH | LE18 | - |  |
| Post CH | QZ18 | - |  |

Notes:-

**Contact Hour 19**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL9.1 | RL9.1.1 = Pseudo Kernel and its uses |  |
| During CH | CH19 | CH19.1 = Pseudo kernel applications in real time systems (Coroutines, Cyclic executives, Polled loops, Synchronous Polled loops) (T2)  CH19.2 = Case study and real time examples where pseudo kernel (T2)  CH19.3 = Modelling systems as preemptive, non-preemptive and hybrid versions(T2) | T2 |
| Post CH | SS19 | - |  |
| Post CH | HW19 | - |  |
| Post CH | LE19 | - |  |
| Post CH | QZ10 | - |  |

**Contact Hour 20**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL9.1 | RL9.1.1 = Pseudo Kernel and its uses |  |
| During CH | CH20 | CH20.1 = Research avenues in such embedded systems (T2 and R1)  CH20.2 = Highlighting the various industrial avenues of working in such embedded systems (T2)  CH20.3 = Explaining how the course studied could be utilised to bridge challenges in these areas (T2) | T2 |
| Post CH | SS20 | - |  |
| Post CH | HW20 | - |  |
| Post CH | LE20 | - |  |
| Post CH | QZ20 | - |  |

**Contact Hour 21**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL10.1 | RL10.1.1 = Real time languages |  |
| During CH | CH21 | CH21.1 = Choice of the language for small embedded real time applications (R1)  CH21.2 = Criteria to be kept in mind based on storage classes (T2 and R1)  CH21.3 = Evaluation of effectiveness of the language chosen for an embedded real time application (R1) | R1,T2 |
| Post CH | SS21 | - |  |
| Post CH | HW21 | - |  |
| Post CH | LE21 | - |  |
| Post CH | QZ21 | - |  |

**Contact Hour 22**

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| --- | --- | --- | --- |
| Time | Type | Sequence | Content Reference |
| Pre CH | RL10.2 | RL10.2.1 = Engineering aspects of a real time system |  |
| During CH | CH22 | CH22.1 = Metrics to evaluate a real time systems (T2)  CH22.2 = Designing a real time system with a simple example and analysing the same using metrics (T2).  CH22.3 = Trade-off considerations to be kept in mind when a real time system design is engineered (T2). | T2 |
| Post CH | SS22 | - |  |
| Post CH | HW22 | - |  |
| Post CH | LE22 | - |  |
| Post CH | QZ22 | - |  |

**Evaluation Scheme**:

Legend: EC = Evaluation Component; AN = After Noon Session; FN = Fore Noon Session

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No | Name | Type | Duration | Weight | Day, Date, Session, Time |
| EC-1 | Quiz-I/ Assignment-I | Online | - | 5% | September 10-20, 2020 |
|  | Quiz-II | Online | - | 5% | October 20-30, 2020 |
|  | Quiz-III/ Assignment-II | Online | - | 5% | November 10-20, 2020 |
| EC-2 | Mid-Semester Test | Closed Book | 2 hours | 35% | Sunday, 11/10/2020 (AN)  2 PM – 4 PM |
| EC-3 | Comprehensive Exam | Open Book | 3 hours | 50% | Sunday, 29/11/2020 (AN)  2 PM – 5 PM |

Syllabus for Mid-Semester Test (Closed Book): Topics in Session Nos. 1 to 11

Syllabus for Comprehensive Exam (Open Book): All topics (Session Nos. 1 to 22)

**Important links and information:**

Elearn portal: https://elearn.bits-pilani.ac.in

Students are expected to visit the Elearn portal on a regular basis and stay up to date with the latest announcements and deadlines.

Contact sessions: Students should attend the online lectures as per the schedule provided on the Elearn portal.

Evaluation Guidelines:

1. EC-1 consists of either two Assignments or three Quizzes. Students will attempt them through the course pages on the Elearn portal. Announcements will be made on the portal, in a timely manner.
2. For Closed Book tests: No books or reference material of any kind will be permitted.
3. For Open Book exams: Use of books and any printed / written reference material (filed or bound) is permitted. However, loose sheets of paper will not be allowed. Use of calculators is permitted in all exams. Laptops/Mobiles of any kind are not allowed. Exchange of any material is not allowed.
4. If a student is unable to appear for the Regular Test/Exam due to genuine exigencies, the student should follow the procedure to apply for the Make-Up Test/Exam which will be made available on the Elearn portal. The Make-Up Test/Exam will be conducted only at selected exam centres on the dates to be announced later.

It shall be the responsibility of the individual student to be regular in maintaining the self study schedule as given in the course handout, attend the online lectures, and take all the prescribed evaluation components such as Assignment/Quiz, Mid-Semester Test and Comprehensive Exam according to the evaluation scheme provided in the handout.