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Birla Institute of Technology & Science, Pilani
Work Integrated Learning Programmes Division
Linear Algebra And Optimization

Digital Learning Handout

Course Title	Linear Algebra And Optimization
Course No(s)	MATH ZC234 / PE ZC235
Credit Units	3
Credit Model	
Instructor-In-Charge	Manish Kumar
Version Number	
Date	

Course Description:

This course consists of topics from Linear Algebra and Optimization
Linear Algebra: Operations on matrices, linear system of equations, Vector spaces, linear transformation, Eigenvalues and Eigenvectors.
Optimization: Modelling with Linear programming, Graphical approach, The Simplex method, Big M and Two Phase Method, Special cases of the simplex method and sensitivity analysis, The Dual Simplex Method and the Generalized Simplex Algorithm, Post optimal analysis.

Text Book(s):

T1	Erwin Kreyszig, Advanced Engineering Mathematics, Wiley India, 9th Edition 2011
T2	Hamdy A Taha, Operations Research: An Introduction, Pearson/PHI, 8th Edition, 2009.

Reference Book(s) & other resources:

R1	B. Dubey, Introductory Linear Algebra, Asian Books Pvt Ltd, 2007.
R2	K Hoffman and R Kunze, Linear Algebra, Pearson Education, 2nd Edition, 2005.
R3	Ravindran, Phillips and Solberg, Operations Research: Principles and Practice, John Wiley, Second Edition, 2000.

Experiential Learning Components:

1. Lab work: None.
2. Project work: None.
3. Case study: None
4. Work integrated Learning Exercise: None.
5. Design work/Field work: None.

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Content Structure:

Legend

The following shortnames are primarily intended for the studio staff to organize the courseware for storage and subsequent organization in the LMS.

M = Module, **RL** = Recorded Lecture, **CS** = Contact Session, **LE** = Lab Exercises, **SS** = Self Study, **HW** = Home Work Problems

RL2.1 = Recorded Lecture 1 in module 2.

Modular Structure

Module Summary: Linear Algebra

No	Title of the Module
M1	Matrices, System of equations, determinants and inverse of a matrix
M2	Vector spaces and Linear transformations
M3	Eigenvalues and eigenvectors
M4	Numerical Linear Algebra: Gauss elimination and iterative methods for solving linear systems
M5	Matrix eigenvalue problems and power method for eigenvalue

Module Summary: Optimization

No	**Title of the Module**
M1	Modelling with Linear Programming (LP) and Graphical Method of Solution
M2	The Simplex Method
M3	Big M and Two Phase Methods
M4	Special cases of the Simplex Method
M5	Sensitivity Analysis of the Simplex method
M6	Dual Simplex Method
M7	Generalized Simplex Method
M8	Post Optimal Analysis

Detailed Structure: Linear Algebra

CS 0 Overview of course coverage and handout and review of module 1

M1: Matrices, System of equations, determinants and inverse of a matrix

Type	Description/Plan/Reference
RL1.1	Row-reduced echelon form of a matrix
RL1.2	Consistency and inconsistency of linear system of equations, Inverse of a matrix
CS1.1	T1: Sec 7.1-7.3
CS1.2	T1: Sec 7.5, 7.8
SS 1.1	T1: Sec 7.6, 7.7
SS 1.2	T1: Sec 7.6, 7.7
HW 1.2	T1: Sec 7.1: Q1-Q8, Sec 7.2: Q1-Q10
	T1: Sec 7.3: QNos 1, 4, 6-9, 13-16, Sec 7.8: Q1-Q12.

M2: Vector spaces and Linear transformations

Type	Description/Plan/Reference
RL2.1	Vector space, subspace and span of a set

RL 2.2	Linearly dependent and independent sets, basis and dimension
RL 2.3	Linear transformation, its rank and nullity
CS2.1	T1: Sec 7.4
CS2.2	T1: Sec 7.4
CS2.3	T1: Sec 7.9, R1: Sec 3.2
SS 2.1	R1: Sec 2.2
SS 2.2	R1: Sec 2.4
SS 2.3	R1: Sec 3.1
HW 2.1	R1: Sec 2.3: Q1-Q4, 9
HW 2.2	R1: QNos 3, 4, 5 7, 20.
HW 2.3	R1: Sec 3.1: Q2, Sec 3.2: 3, 4, 9.

M3: Eigenvalues and eigenvectors

Type	Description/Plan/Reference
RL 3.1	Eigenvalues and eigenvectors
CS3.1	T1: Sec 8.2, 8.3
SS 3.1	T1: Sec 8.4
HW 3.1	T1: Sec 8.1: QNos 1, 6, 10-15, 19-25, Sec 8.3: Q9-Q17

M4: Numerical Linear Algebra: Gauss elimination and iterative methods for solving linear systems

Type	Description/Plan/Reference
RL 4.1	Gauss elimination with partial pivoting, Gauss elimination with scaling and partial pivoting
RL 4.2	Iterative methods to solve Ax = b
CS4.1	T1: Sec 20.1
CS4.2	T1: Sec 20.3, 20.8
SS 4.1	T1: Sec 20.2
SS 4.2	T1: Sec 20.4
HW 4.1	T1: Sec 20.1: Q4-Q14
HW 4.2	T1: Sec 20.3: Q3 –Q8, 12, 13, 14

M5: Matrix eigenvalue problems and power method for eigenvalue

Type	Description/Plan/Reference
RL 5.1	Matrix eigenvalue problems and Power method for finding dominant eigenvalue
CS5.1	T1: Sec 20.8
SS 5.1	T1: Sec 20.7
HW 5.1	T1: Sec 20.7: QNos 1, 2, 3, 6. Sec 20.8: Q1-Q7.

Detailed Structure: Optimization

Text & Reference Book:

T2: Hamdy A Taha, Operations Research: An Introduction, Pearson / PHI, 8th Edition, 2009.

R3: Ravindran, Phillips and Solberg, Operations Research: Principles and Practice, John Wiley, Second Edition, 2000.

M1: Modelling with Linear Programming (LP) and Graphical Method of Solution

Type	Description/Plan/Reference
RL1.1	Sec. 2.1 Introduction to formulation with LP, Examples 2.1-1 and 2.1-2, Properties of Linear Programming Problems (LPP)
RL1.2	Sec. 2.2 Graphical Solution, Solution of the Maximization Model, Example 2.2-1
RL1.3	Sec. 2.3.3 Investment Option
CS1.1	Example 2.1-3, Problem 2.1A 3,4; Section 2.2.2; Problem 2.2A 2,7,8
HW1.1	Problem 2.1A 1, 2; Problem 2.2A 9; Problem 2.3C 1

M2: The Simplex Method

Type	Description/Plan/Reference
RL2.1	Section 3.1 LP in standard form, Problem 3.1A 4, Problem 3.1B 2; Section 3.2 Transition from Graphical to Algebraic Solution, Example 3.2-1
RL2.2	Section 3.3 The Simplex Method, Examples 3.3-2 and 3.3-3.
CS2.1	Problem 3.1A 5,6; Problem 3.1B 1,2,4; Problem 3.3B 2,5
HW2.1	Problem 3.2A 1,3; Problem 3.3B 3,4,6

M3: Big M and Two Phase Methods

Type	Description/Plan/Reference
RL3.1	Section 3.4.1 Big M Method, Example 3.4-1
RL3.2	Section 3.4.2 The Two Phase Method, Example 3.4-2
CS3.1	Problem 3.4A 1(a), 1(b), 3; Problem 3.4B 2,4, 7
HW3.1	Problem 3.4A 1(c), 1(d), 4; Problem 3.4B 3,5

M4: Special Cases of Simplex Method and Consistency

Type	Description/Plan/Reference
RL4.1	Section 3.5.1 Degeneracy, Example 3.5-1; Section 3.5.2 Alternative Optima, Example 3.5-2; Section 3.5.3 Unbounded Solution, Example 3.5-3
CS4.1	Problem 3.5A 2; Problem 3.5B 2; Problem 3.5C 2, 3, 5
SS 4.1	Section 3.5.4 Infeasible Solution
HW4.1	Problem 3.5B 3; Problem 3.5C 5; Problem 3.5D 3

M5: Sensitivity Analysis in Simplex Method

Type	Description/Plan/Reference
RL5.1	Section 3.6.1 The Graphical Sensitivity Analysis, Examples 3.6-1 and 3.6-2
CS5.1	Section 3.6.2, Problem 3.6C 3,5
HW5.1	Problem 3.6A 1, Problem 3.6B 2, Problem 3.6C 1

M6: The Dual Simplex Method

Type	Description/Plan/Reference
RL6.1	Section 4.1 Connection of Primal to Dual, Examples 4.1-1 and 4.1-2; Section 4.2 Primal Dual Relationship, Example 4.2-1
CS6.1	Problem 4.1A 4(a), 4(b); Problem 4.2A 1(a); Problem 4.2C 2; Problem 4.2D 3
HW6.1	Problem 4.1A 4(c); Problem 4.2A 6; Problem 4.2C 1; Problem 4.2D 3

M7: The Generalized Simplex Algorithm

Type	Description/Plan/Reference
RL7.1	Section 4.4.1 The Dual Simplex Algorithm, Examples 4.4-1 and 4.4-2; Section 4.4.2
CS7.1	Problem 4.4A 2(a), 2(d); Problem 4.4B 1
SS7.1	Example 4.4-3
HW7.1	Problem 4.4A 1, 2(b), 2(c), 4(b); Problem 4.4B 2

M8: Post Optimal Analysis

Type	Description/Plan/Reference
RL8.1	Section 4.5 Post Optimal Analysis, Example 4.5-1
CS8.1	Problem 4.5A 2(a), 4(i), 4(ii); Section 4.5.2 Changes affecting optimality
SS 8.1	Examples 4.5-2 and 4.5-4
HW8.1	Problem 4.5A 2(b), 3; Problem 4.5B 1; Problem 4.5D 2

CS 9 Revision and review of entire syllabus

Contact Session Plan:

Course Plan: This plan is to use in conjunction with the modularized course structure

Sl. No.	**Recorded Lecture**	**Contact Session**	**Self-study**	**Home-work**	**Lab Exercise**
1	RL 1.1	**CS 0**	T1: Sec 7.6, 7.7	T1: Sec 7.1: Q1-Q8, Sec 7.2: Q1-Q10	
2	RL 1.2	CS1.1 & CS1.2	T1: Sec 7.6, 7.7	T1: Sec 7.3: QNos 1, 4, 6-9, 13-16, Sec 7.8: Q1-Q12.	
3	RL 2.1	**No Session**	R1: Sec 2.2	R1: Sec 2.3: Q1-Q4, 9	
4	RL 2.2	CS 2.1 & CS2.2	R1: Sec 2.4	R1: QNos 3, 4, 5 7, 20.	
5	RL 2.3	**No Session**	R1: Sec 3.1	R1: Sec 3.1: Q2, Sec 3.2: 3, 4, 9.	
6	RL 3.1	CS3.1 & CS3.2	T1: Sec 8.4	T1: Sec 8.1: QNos 1, 6, 10-15, 19-25, Sec 8.3: Q9-Q17	
7	RL 4.1 RL 4.2	**No Session**	T1: Sec 20.2, 20.4	T1: Sec 20.1: Q4-Q14, Sec 20.3: Q3 – Q8, 12, 13, 14	

8	RL 5.1	CS4.1 & CS4.2	T1: Sec 20.7	T1: Sec 20.7: QNos 1, 2, 3, 6. Sec 20.8: Q1-Q7.	
Syllabus for Mid-Semester Test: Topics covered in the first eight weeks					
Sl. No.	**Recorded Lecture**	**Contact Session**	**Self-study**	**Home Work**	**Lab Exercise**
9	RL 1.1, RL 1.2 and RL 1.3	**No session**		Problem 2.1A 1,2; Problem 2,2A 9; Problem 2.3C 1	
10	RL 2.1 and RL 2.2	CS 1.1 and CS 2.1		Problem 3.2A 1,3; Problem 3.3B 3,4,6	
11	RL 3.1 and RL 3.2	**No session**		Problem 3.4A 1(c), 1(d), 4; Problem 3.4B 3,5	
12	RL 4.1	CS 3.1 and CS 4.1	Section 3.5.4 Infeasible Solution	Problem 3.5B 3; Problem 3.5C 5; Problem 3.5D 3	
13	RL 5.1	**No session**		Problem 3.6A 1, Problem 3.6B 2, Problem 3.6C 1	
14	RL 6.1	CS 5.1 and CS 6.1		Problem 4.1A 4(c); Problem 4.2A 6; Problem 4.2C 1; Problem 4.2D 3	
15	RL 7.1	**No session**	Example 4.4-3	Problem 4.4A 1, 2(b), 2(c), 4(b); Problem 4.4B 2	
16	RL 8.1	CS 7.1 and CS 8.1	Examples 4.5-2 and 4.5-4	Problem 4.5A 2(b), 3; Problem 4.5B 1; Problem 4.5D 2	
17		Cs 9			
Syllabus for Comprehensive Exam (Open Book) All topics given in Plan					

Evaluation Scheme:

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

Evaluation Component	Name (Quiz, Lab, Project, Mid-term exam, End semester exam, etc.)	Type (Open book, Closed book, Online, etc.)	Weight	Duration	Day, Date, Session, Time
EC - 1	Quiz I / Assignment-I	Online	5%		February 14-24, 2022
	Quiz II	Online	5%		March 14-24, 2022
	Quiz III / Assignment II	Online	5%		April 14-24, 2022
EC - 2	Mid-Semester Test	Open Book	35%	2 hours	Saturday, 12/03/2022

					(AN) 2 PM – 4 PM
EC - 3	Comprehensive Exam	Open Book	50%	2 hours	Saturday, 21/05/2022 (AN) 2 PM – 4 PM

Syllabus for Mid-Semester Test (Open Book): Topics in Contact Hours: 1 to 16
Syllabus for Comprehensive Exam (Open Book): All topics
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.

Instructor-in-charge

(MATH ZC234)