



## Detailed Description:

### 1. Introduction to Linear Multivariable Systems

Some detailed examples include electrical systems and mechanical systems, including an inverted pendulum.

### 2. Mathematical Preliminaries

Vector spaces, matrices, matrix manipulations, norms, solving linear differential and difference vector equations.

### 3. Multivariable LTI Systems: An Input-Output Approach

State-space to transfer function, similarity transformations, discretizing a continuous-time system, poles and zeros of a multivariable system.

### 4. Controllability

Controllability, reachability, PBH test, equivalence of pole placement and controllability, controllable canonical form.

### 5. Observers and Observability

Observability, detectability, PBH test, observers, separation principle.

### 6. LQR Optimal Control

Cost functions, dynamic programming, Riccati equation, optimal LQR feedback, properties of the optimal LQR feedback.

### 7. Youla Parametrization and its Applications

Matrix fractional descriptions of transfer functions, Bezout identity, parametrization of all stabilizing controllers, an introduction to  $L_1$ ,  $H_\infty$  and  $H_2$  optimal control.

## General UW Guidelines

**Academic Integrity:** In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check

[www.uwaterloo.ca/academicintegrity/](http://www.uwaterloo.ca/academicintegrity/)  
for more information.]

**Grievance:** A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4,

[www.adm.uwaterloo.ca/infosec/Policies/policy70.htm](http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm).

When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

**Discipline:** A student is expected to know what constitutes academic integrity - check

[www.uwaterloo.ca/academicintegrity/](http://www.uwaterloo.ca/academicintegrity/)

to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about rules for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline,

[www.adm.uwaterloo.ca/infosec/Policies/policy71.htm](http://www.adm.uwaterloo.ca/infosec/Policies/policy71.htm).

For typical penalties check Guidelines for the Assessment of Penalties,

[www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm](http://www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm).

**Appeals:** A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals)

[www.adm.uwaterloo.ca/infosec/Policies/policy72.htm](http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm).

**Note for Students with Disabilities:** The Accessibility Services Department (ASD), located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the ASD at the beginning of each academic term.