ITT Technical Institute

ET3150T

Automatic Industrial Control

Onsite Course

SYLLABUS

Credit hours: 4.5

Contact/Instructional hours: 67 (41 Theory Hours, 26 Lab Hours)

Prerequisite(s) and/or Corequisite(s):

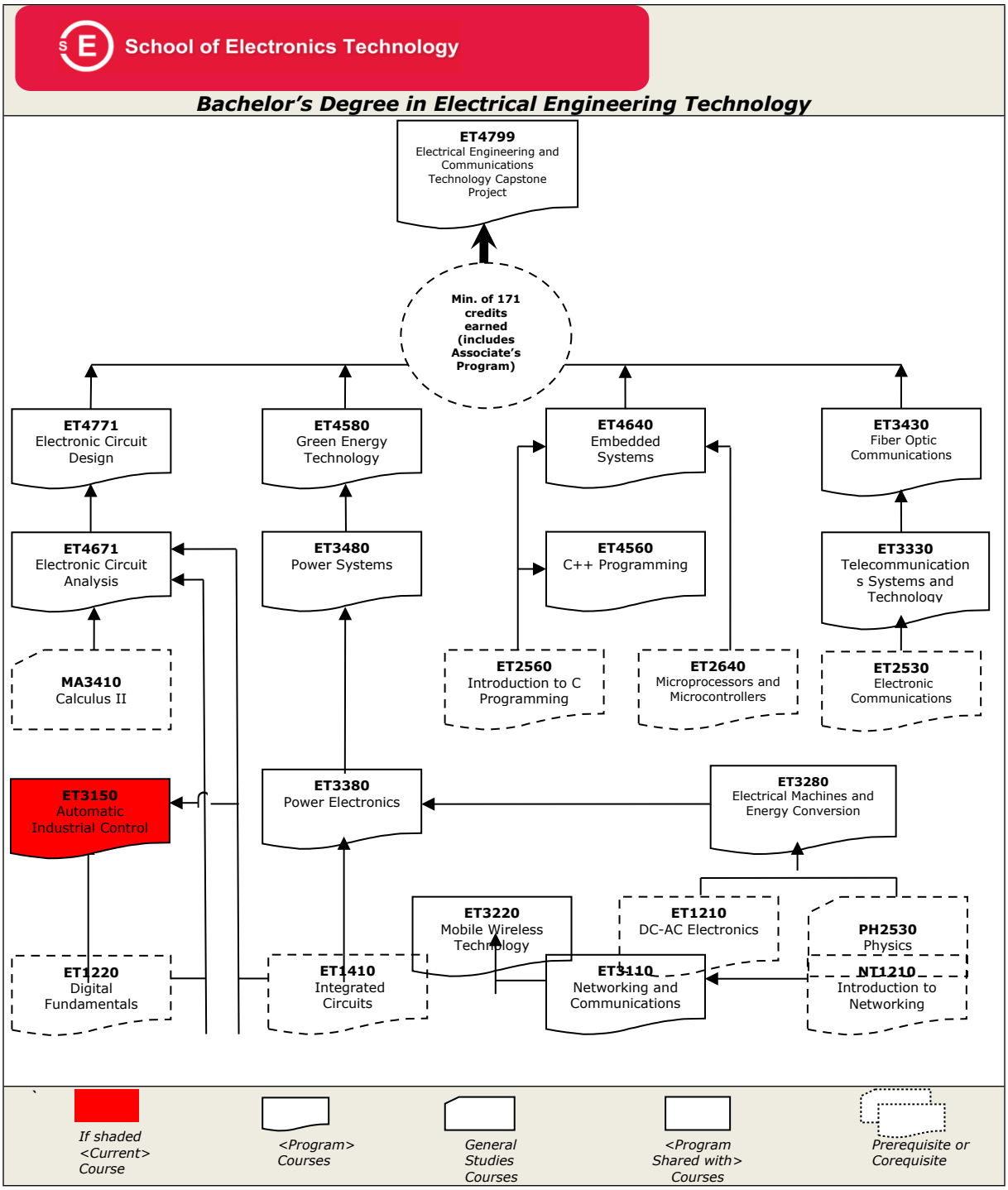
Prerequisites: ET1220T Digital Fundamentals or equivalent, ET1410T Integrated Circuits or equivalent

Course Description:

This course examines process control technology. Topics include analog and digital signal conditioning, sensors, final control operation, discrete-state process control, digital control and controllers.

here Does This Course Belong?

This is a required course in the Electrical Engineering and Communications Technology Bachelor program in the School of Electronics Technology. The following table demonstrates how this course fits in the program:



NOTE: *Refer to the catalog for the state-specific course and program information, if applicable.*

Course Summary

Major Instructional Areas

1. Process-Control Systems
2. Process Measurement
3. Signal Conditioning
4. Measurement and Instrumentation Sensors
5. Final Control Actuators
6. Computer-Based Control
7. Control-Loop Tuning

Course Objectives

1. Describe the basic components of a process-control system.
2. Choose a passive or active signal conditioning method that will enable signals to interface with other elements of a process-control loop.
3. Design an analog-to-digital (A/D) conditioning system or a digital-to-analog (D/A) conditioning system, given an analog input signal and an analog device to be driven.
4. Design op amp, voltage divider, and Wheatstone bridge circuits that will convert the output of various thermal and mechanical sensors to voltage signals.
5. Design op amp, voltage divider, and Wheatstone bridge circuits that will convert the output of various optical sensors to voltage signals.
6. Describe the use of electrical, pneumatic, electromagnetic, and hydraulic final control devices to suit the requirements of a given process.
7. Analyze the controller output behavior toward a specific error input for a controller mode of operation.
8. Design op amp circuits that will help perform error detection and analog control mode operation.
9. Identify the characteristics of computer-based control.
10. Describe the characteristics of a process-control loop and process-control loop tuning.

Learning Materials and References

Required Resources

Complete Textbook Package	New to this Course	Carried over from Previous Course(s)	Required for Subsequent Course(s)
Johnson, C. D. (2006). *Process control instrumentation technology* (Custom 8th ed.). Boston, MA: Pearson Custom.	■		

Recommended Resources

Books, Professional Journals

- Bateson, R. (2002). *Introduction to control systems technology* (7th ed.). Upper Saddle River, NJ: Prentice Hall.
- Bucek, V. (1989). *Control systems* (5th ed.). Upper Saddle River, NJ: Prentice Hall.
- Carr, J. (2002). *Elements of electronic instrumentation and measurement* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
- Cassell, D. (1993). *Microcomputers and modern control engineering*. Reston, VA: Reston Publishing Company.
- Hunter, R. (1987). *Automated process control systems* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Jacob, M. (1988). *Industrial control electronics*. Upper Saddle River, NJ: Prentice Hall.
- Kilian, C. (2006). *Modern control technology* (3rd ed.). Independence, KY: Thomson Delmar Learning.
- Otter, J. (1988). *Programmable logic controller*. Upper Saddle River, NJ: Prentice Hall.

Professional Associations

- ISA: International Society of Automation

http://www.isa.org (accessed 03/08/13)

The ISA (formerly Instrumentation Society of America) is the primary professional organization for those working in process control and instrumentation. The organization publishes journals, provides training programs, and sponsors conferences. This website contains information about the ISA and its activities.

- IEEE: Institute of Electrical and Electronics Engineers

http://www.ieee.org (accessed 03/08/13)

The IEEE has subsections for practitioners working and studying in control systems, data acquisition, signal conditioning, and other areas related to process control and instrumentation.

- Automation.com

http://www.automation.com (accessed 03/08/13)

This site presents a vast collection of articles related to automation, process control, and instrumentation. Links also are provided for seminars, job placement, upcoming events, and directories of products and suppliers.

ITT Tech Virtual Library (accessed via Student Portal | https://studentportal.itt-tech.edu)

- Books> Ebrary>:
  - King, M. (2011). *Process control: A practical approach*. Hoboken, NJ: John Wiley.
- Periodicals>: Use the E-Journal Lookup function to find periodicals on fiber optics. Some control-related periodicals include the following:
  - *Process & control engineering* (0816-8148)
  - *Process control and quality* (0924-3089)
  - *Computing & control engineering journal* (0956-3385)
  - *Control & automation* (1754-1751)
  - *Control and instrumentation* (0010-8022)
  - *Control engineering* (0010-8049)
- Books> Books24x7:
  - Baudin, M. (2007). *Working with machines: The nuts and bolts of lean operations with Jidoka*. London: Productivity Press.

Online Tutorials

- Process Control Tutorials (accessed 03/08/13) http://www.pc-education.mcmaster.ca/Tutorials_files/Tutorials.htm

Covers topics existing in most undergraduate process control courses

- Introduction to Process Control (accessed 03/08/13)

http://www.youtube.com/watch?v=GfgtFbJ25lM

Instructor-led e-learning on process control and power

- Process Automation Control Tutorials (accessed 03/08/13)

http://www.pacontrol.com/

Discusses basics, principles, and theory related to process control and industrial automation

NOTE: All links are subject to change without prior notice.

Information Search

Use the following keywords to search for additional online resources that you may use to support your work on the course assignments:

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- Process control
- Analog signal conditioning
- Digital signal conditioning
- Thermal sensors
- Mechanical sensors
- Optical sensors
- Power electronics
- Actuators
- Control elements
- Programmable logic controllers
- Analog controllers
- Control-loop characteristics

Suggested Learning Approach

In this course, you will be studying individually and within a group of your peers. As you work on the course deliverables, you are encouraged to share ideas with your peers and instructor, work collaboratively on projects and team assignments, raise critical questions, and provide constructive feedback.

Use the following advice to receive maximum learning benefits from your participation in this course:

DO	DON'T
▪ Do take a proactive learning approach ▪ Do share your thoughts on critical issues and potential problem solutions ▪ Do plan your course work in advance ▪ Do explore a variety of learning resources in addition to the textbook ▪ Do offer relevant examples from your experience ▪ Do make an effort to understand different points of view ▪ Do connect concepts explored in this course to real-life professional situations and your own experiences	▪ Don't assume there is only one correct answer to a question ▪ Don't be afraid to share your perspective on the issues analyzed in the course ▪ Don't be negative about the points of view that are different from yours ▪ Don't underestimate the impact of collaboration on your learning ▪ Don't limit your course experience to reading the textbook ▪ Don't postpone your work on the course deliverables – work on small assignment components every day

Course Outline

Unit 1: INTRODUCTION TO PROCESS CONTROL

Upon completion of this unit, students are expected to:

- Draw a block diagram of a basic process-control loop and identify each element.
- Identify the devices that are used in a functional-control system for each block in a process-control loop.
- Describe summing points and errors.
- Describe different types of controlled variables.
- Explain the measurement process and measurement transducers.

Total outside work: 6 hours

READING ASSIGNMENT	• Johnson, Chapter 1, pp. 1–14		
OUTSIDE WORK	**Activity**		**Estimated Time**
	Complete the reading assignment		2 hrs
	Complete Unit 1 Exercise 1		2 hrs
	Complete Unit 1 Lab 1		60 min
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
	Exercises	Unit 1 Exercise 1: Process-Control Loop	0.75%
	Labs	Unit 1 Lab 1: Process-Control Instrumentation	4.17%

Unit 2: ANALOG SIGNAL CONDITIONING

Upon completion of this unit, students are expected to:

- Explain the purpose of analog signal conditioning.
- Calculate the bridge offset for a Wheatstone bridge circuit.
- Develop a low-pass filter to attenuate certain frequencies or bands of frequencies.
- Design an op amp circuit to achieve a given gain and offset.
- Design a high-pass filter to attenuate certain frequencies or bands of frequencies.

Total outside work: 9 hours

READING ASSIGNMENT	• Johnson, Chapter 2, pp. 53–102		
OUTSIDE WORK	**Activity**		**Estimated Time**
	Complete the reading assignment		4 hrs
	Complete Unit 2 Exercises 1 and 2		2 hrs
	Complete Unit 2 Lab 1		60 min
	Complete Unit 2 Project Prelude		2 hrs
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
	Exercises	Unit 2 Exercise 1: Controlled Variables	0.75%
		Unit 2 Exercise 2: Measurement Process	0.75%
	Labs	Unit 2 Lab 1: Analog-Signal Conditioning	4.16%

Unit 3: DIGITAL SIGNAL CONDITIONING

Upon completion of this unit, students are expected to:

- Design an op amp comparator circuit with hysteresis for given off and on voltages.
- Calculate the digital output for a specific analog input voltage for a given A/D converter.
- Calculate the analog output for a specific digital input value for a given D/A converter.
- Calculate the input range for a given A/D converter.
- Explain the purpose of the sample-and-hold feature used in digital-signal conditioning systems.

Total outside work: 5 hours

READING ASSIGNMENT	• Johnson, Chapter 3, pp. 115–150 and pp. 160–167		
OUTSIDE WORK	**Activity**		**Estimated Time**
	Complete the reading assignment		2 hrs
	Complete Unit 3 Exercises 1 and 2		2 hrs
	Complete Unit 3 Lab 1		60 min
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
	Exercises	Unit 3 Exercise 1: Signal Conditioning	0.75%
		Unit 3 Exercise 2: Analog-to-Digital	0.75%
	Labs	Unit 3 Lab 1: Digital Signal Conditioning	4.17%

Unit 4: THERMAL AND MECHANICAL SENSORS

Upon completion of this unit, students are expected to:

- Describe the basic characteristics and operating principles of thermal and mechanical sensors.
- Design a Wheatstone bridge to achieve a zero-volt offset for a given resistance-temperature detector (RTD) at a nominal temperature.
- Design a thermistor/resistor voltage divider circuit and calculate the output voltage range over a given temperature range.
- Calculate the output voltage of a given thermocouple for a specific measured temperature and reference temperature.
- Explain the operation of a linear variable differential transformer (LVDT).
- Design a Wheatstone bridge for a strain gauge and calculate the offset voltage for a given strain value.

Total outside work: 9 hours

READING ASSIGNMENT	• Johnson, Chapter 4, pp. 175–204 • Johnson, Chapter 5, pp. 223–246 and pp. 267–274		
OUTSIDE WORK	**Activity**		**Estimated Time**
	Complete the reading assignment		3 hrs
	Complete Unit 4 Exercises 1, 2, and 3		2 hrs
	Complete Unit 4 Lab 1		60 min
	Complete Unit 4 Project Part 1		3 hrs
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)

	Exercises	Unit 4 Exercise 1: Wheatstone Bridge	0.75%
		Unit 4 Exercise 2: Material Flow	0.75%
		Unit 4 Exercise 3: Output Voltage	0.75%
	Labs	Unit 4 Lab 1: Process-Control Instrumentation	4.17%
	Project	Unit 4 Project Part 1: Process Control Measurement and Signal Conditioning: Thermistors	3%

Unit 5: OPTICAL SENSORS

Upon completion of this unit, students are expected to:

- Describe the basic characteristics and operating principles of optical sensors.
- Design an op amp comparator for a given voltage and photocell resistance.
- Calculate the resistance for a given intensity in a resistance/intensity graph of a particular photoresistive cell.

Total outside work: 10 hours

READING ASSIGNMENT	• Johnson, Chapter 6, pp. 285–289 and pp. 296–311		
OUTSIDE WORK	**Activity**		**Estimated Time**
	Complete the reading assignment		1 hr
	Complete Unit 5 Exercises 1 and 2		2 hrs
	Complete Unit 5 Project Part 2		3 hrs
	Study for Unit 5 Exam 1		3 hrs
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
	Exercises	Unit 5 Exercise 1: Circuit Design	0.75%
		Unit 5 Exercise 2: Process Control System	0.75%
	Project	Unit 5 Project Part 2: Thermal Measurement with Analog-Signal Conditioning	3%
	Exams	Unit 5 Exam 1	7.5%

Unit 6: FINAL CONTROL

Upon completion of this unit, students are expected to:

- Explain the basic features of a pneumatic system.
- Calculate the resistance range in a silicon-controlled rectifier (SCR) control circuit to achieve a given power range for the load.
- Calculate the resistance range in a triode for alternating current (TRIAC) control circuit to provide a given power range to the load.
- Differentiate between an actuator and a final control element.
- Describe the three control valve types.

Total outside work: 7 hours

READING ASSIGNMENT	• Johnson, Chapter 7, pp. 333–358 and pp. 371–380	
OUTSIDE WORK	**Activity**	**Estimated Time**
	Complete the reading assignment	2 hrs
	Complete Unit 6 Exercises 1 and 2	2 hrs

	Complete Unit 6 Project Part 3		3 hrs
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
	Exercises	Unit 6 Exercise 1: Pneumatic Systems	0.75%
		Unit 6 Exercise 2: Final Control Devices	0.75%
	Project	Unit 6 Project Part 3: Temperature Measurement with Digital Signal Conditioning	3%

Unit 7: THERMAL AND MECHANICAL SENSORS

Upon completion of this unit, students are expected to:

- Define process characteristics and control system parameters.
- Compare the proportional-integral (PI), proportional-derivative (PD), and proportional-integral-derivative (PID) composite control modes.
- Create a graph to depict the output behavior of a given controller for a specific error.

Total outside work: 6 hours

READING ASSIGNMENT	• Johnson, Chapter 9, pp. 439–451 and pp. 457–475	
OUTSIDE WORK	**Activity**	**Estimated Time**
	Complete the reading assignment	2 hrs
	Complete Unit 7 Exercises 1 and 2	3 hrs
	Complete Unit 7 Lab 1	60 min
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
	Exercises	Unit 7 Exercise 1: Control System Parameters	0.75%
		Unit 7 Exercise 2: Process Characteristics	0.75%
	Labs	Unit 7 Lab 1: TRIAC Phase Control	4.17%

Unit 8: ANALOG CONTROLLERS

Upon completion of this unit, students are expected to:

- Design an op amp error detection circuit using a differential amplifier configuration.
- Design an op amp proportional-integral controller for a specific proportional band and a specific integral gain.
- Develop an op amp PID circuit for a given proportional, integral, and derivative gain with a specific response time.

Total outside work: 6 hours

READING ASSIGNMENT	• Johnson, Chapter 10, pp. 481–499 and pp. 504–508	
OUTSIDE WORK	**Activity**	**Estimated Time**
	Complete the reading assignment	2 hrs
	Complete Unit 8 Exercises 1 and 2	3 hrs
	Complete Unit 8 Lab 1	60 min

GRADED ACTIVITIES/ DELIVERABLES	Grading Category	Activity/Deliverable Title	Grade Allocation (% of all graded work)
	Exercises	Unit 8 Exercise 1: Identifying Solutions	0.75%
		Unit 8 Exercise 2: Op Amp Controllers	0.75%
	Labs	Unit 8 Lab 1: Analog Controller Circuits	4.16%

Unit 9: COMPUTER-BASED CONTROL

Upon completion of this unit, students are expected to:

- Draw the general flow chart for analog and computer-based controller operations.
- Evaluate the advantages of computer-based control over analog control.
- Develop the equations for a given controller mode that can be used by a computer to perform controller operations.
- Explain the restrictions on the sampling rates determined by the data acquisition system limitations.

Total outside work: 10 hours

READING ASSIGNMENT	
	• Johnson, Chapter 11, pp. 519–549

OUTSIDE WORK	Activity	Estimated Time
	Complete the reading assignment	2 hrs.
	Complete Unit 9 Exercises 1 and 2	2 hrs.
	Complete Unit 9 Project Part 4	3 hrs.
	Study for Unit 9 Exam 2	3 hrs.

GRADED ACTIVITIES/ DELIVERABLES	Grading Category	Activity/Deliverable Title	Grade Allocation (% of all graded work)
	Exercises	Unit 9 Exercise 1: Process Variable Solutions	0.75%
		Unit 9 Exercise 2: Flow Charts	0.75%
	Project	Unit 9 Project Part 4: Final Control with a Digital Input: Digital-to-Analog Conversion	3%
	Exams	Unit 9 Exam 2	7.5%

Unit 10: CONTROL-LOOP CHARACTERISTICS

Upon completion of this unit, students are expected to:

- Define the three basic types of disturbances that can occur in a process-control system.
- Identify the characteristics of a process-control loop as it responds to a process load change or a set-point change.
- Explain the effects of stability, minimum deviation, and minimum duration on the overall measure of quality.
- Use a Bode plot to determine if a given system is stable.
- Use the Ziegler-Nichols method for process-control loop tuning.
- Determine the proportional, integral, and derivative gain settings for a given proportional band and oscillation period.

Total outside work: 7 hours

READING ASSIGNMENT	
	• Johnson, Chapter 12, pp. 559–590

OUTSIDE WORK	**Activity**		**Estimated Time**
	Complete the reading assignment		2 hrs
	Complete Unit 10 Exercises 1 and 2		2 hrs
	Complete Unit 10 Project Part 5		3 hrs
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
	Exercises	Unit 10 Exercise 1: Process Variable Solutions	0.75%
		Unit 10 Exercise 2: Process Characteristics	0.75%
	Project	Unit 10 Project Part 5: Power Control from a Digital Source.	3%

Unit 11: REVIEW AND FINAL EXAM			***Total outside work:*** 10 hours
READING ASSIGNMENT	• Review all assigned readings.		
OUTSIDE WORK	**Activity**		**Estimated Time**
	Study for Final Exam		5 hrs.
	Complete Unit 11 Project Part 6		5 hrs.
GRADED ACTIVITIES/ DELIVERABLES	**Grading Category**	**Activity/Deliverable Title**	**Grade Allocation** (% of all graded work)
	Final Exam	Final Exam	20%
	Project	Unit 11 Project Part 6	10%

Note: Your instructor may add a few ungraded learning activities.

Evaluation and Grading

Evaluation Criteria

The graded assignments will be evaluated using the following weighted categories:

Category	Weight
Exercises	15%
Labs	25%
Project	25%
Exams	15%
Final Exam	20%
TOTAL	**100%**

Grade Conversion

The final grades will be calculated from the percentages earned in the course, as follows:

Grade	Percentage	Credit
A	90–100%	4.0
B+	85–89%	3.5
B	80–84%	3.0
C+	75–79%	2.5
C	70–74%	2.0
D+	65–69%	1.5
D	60–64%	1.0
F	<60%	0.0

Academic Integrity

All students must comply with the policies that regulate all forms of academic dishonesty or academic misconduct, including plagiarism, self-plagiarism, fabrication, deception, cheating, and sabotage. For more information on the academic honesty policies, refer to the Student Handbook and the Course Catalog.

Out of Class Work

Unit Number	Title of Activity (for work completed OUTSIDE of class)	Type of Activity	Estimated Time of Activity (minutes)
1	Unit 1 Reading Assignment	Reading	120
	Unit 1 Exercise 1	Assignment	120
	Unit 1 Lab 1	Lab Report	60
2	Unit 2 Reading Assignment	Reading	240
	Unit 2 Exercise 1	Assignment	60
	Unit 2 Exercise 2	Assignment	60
	Unit 2 Lab 1	Lab Report	60
	Unit 2 Project Prelude	Project	120
3	Unit 3 Reading Assignment	Reading	120
	Unit 3 Exercise 1	Assignment	60
	Unit 3 Exercise 2	Assignment	60
	Unit 3 Lab 1	Lab Report	60
4	Unit 4 Reading Assignment	Reading	180
	Unit 4 Exercise 1	Assignment	40
	Unit 4 Exercise 2	Assignment	40
	Unit 4 Exercise 3	Assignment	40
	Unit 4 Lab 1	Lab Report	60
	Unit 4 Project Part 1	Project	180
5	Unit 5 Reading Assignment	Reading	60
	Unit 5 Exercise 1	Assignment	60
	Unit 5 Exercise 2	Assignment	60
	Unit 5 Project Part 2	Project	180
	Exam 1	Exam Prep	180
6	Unit 6 Reading Assignment	Reading	120
	Unit 6 Exercise 1	Assignment	60
	Unit 6 Exercise 2	Assignment	60
	Unit 6 Project Part 3	Project	180
7	Unit 7 Reading Assignment	Reading	120
	Unit 7 Exercise 1	Assignment	60
	Unit 7 Exercise 2	Assignment	60
	Unit 7 Lab 1	Lab Report	60
8	Unit 8 Reading Assignment	Reading	120
	Unit 8 Exercise 1	Assignment	90
	Unit 8 Exercise 2	Assignment	90
	Unit 8 Lab 1	Lab Report	60
9	Unit 9 Reading Assignment	Reading	120
	Unit 9 Exercise 1	Assignment	60
	Unit 9 Exercise 2	Assignment	60
	Unit 9 Project Part 4	Writing Paper	180
	Unit 9 Exam 2	Exam Prep	180

10	Unit 10 Reading Assignment	Reading	120
	Unit 10 Exercise 1	Assignment	60
	Unit 10 Exercise 2	Assignment	60
	Unit 10 Project Part 5	Writing Paper	180
11	Unit 11 Project Part 6	Project	300
	Final Exam	Exam Prep	300

(End of Syllabus)