Unit 227 Control systems engineering

Unit summary
This unit is about the methods used for the design and evaluation of control systems.

Aims
The unit aims to equip the candidate with the knowledge and skills required to design and evaluate control systems relating to mechanical, manufacturing, chemical and electrical engineering applications.

Prerequisites
It is expected that the candidates will have a working knowledge of the materials in the four compulsory papers of the Certificate examinations and be familiar with complex variable theory, solution of 1st and 2nd other differential equations using time domain and Laplace techniques and the basics of applied mechanics.

Learning outcomes
There are **four** outcomes to this unit. The candidate will be able to:

- Apply mathematical modelling to dynamic systems and analyse responses
- Choose instrumentation for measurement
- Understand feedback control systems
- Understand digital control systems

Guided learning hours
It is recommended that 300 hours should be allocated for this unit. 120 of those hours are actual taught hours. This may be on a full time or part time basis.

Key Skills
This unit contributes towards the Key Skills in the following areas:

N4.1
Develop a strategy for using application of number skills over an extended period of time.

N4.2
Monitor progress and adapt your strategy, as necessary, to achieve the quality of outcomes required in work involving:

- deductive and inferential reasoning;
- algebraic manipulation.

N4.3
Evaluate your overall strategy and present the outcomes from your work, including use of charts, diagrams and graphs to illustrate complex data.

Occupational Standards

This unit has been mapped to the following National Occupational Standards:

1.1.1 Identify the requirements of clients for engineering products or processes
1.1.2 Produce specifications for engineering products or processes
1.3.2 Evaluate the results of research
1.4.1 Establish a design brief for engineering products or processes
4.1.1 Determine the operational requirements of engineering products or processes
4.1.2 Specify operational methods and procedures to achieve operational requirements
6.1.1 Analyse the risks arising from engineering products and processes
6.2.1 Assure the quality of engineering products or processes
6.2.3 Implement improvements to the quality of engineering products or processes
8.1.1 Maintain and develop own engineering expertise

Unit 227 Control systems engineering

Outcome 1 Apply mathematical modelling to dynamic systems and analyse responses

Knowledge requirements
The candidate knows how to:

1 apply mathematical modelling to lumped-parameter components, devices and systems with examples from some of the following areas
   - a electrical
   - b hydraulic
   - c mechanical
   - d pneumatic
   - e thermal

2 understand linearisation of dynamic equations about an equilibrium operating state

3 use methods of system representation
   - a block diagrams and block diagram reduction
   - b transfer functions
   - c signal flow graphs

4 understand systems with dead time
   - a distance/velocity lag

5 understand the transient and steady-state response of first-order and second-order systems to the function inputs
   - a impulse
   - b step
   - c ramp
   - d sinusoidal

6 analyse transfer function and state variable formulations of dynamic system equations including the effects of initial conditions

7 understand response characterisation
   - a time constant
   - b undamped and damped natural frequencies
   - c damping ratio
   - d settling time
   - e rise time
   - f resonant frequency
   - g maximum of the modulus of the frequency response
   - h bandwidth

8 extend the above to higher order systems such as systems with a dominant time constant

Unit 227 Control systems engineering

Outcome 2 Choose instrumentation for measurement

Knowledge requirements
The candidate knows how to:

1 assess the performance characteristics of instruments
- a static
  - i sensitivity
  - ii repeatability
  - iii resolution
- b dynamic
  - i bandwidth
  - ii settling time
  - iii dead time

2 assess transducers commonly used for the measurement of controlled variables, with examples from some of the following areas
- a displacement
- b velocity
- c acceleration
- d force
- e torque
- f power
- g pressure
- h temperature flow rate
- i light
- j sound
- k time

3 recognise and select types of instruments
- a passive
- b active analogue
- c digital

4 analyse signal conditioning and conversion
- a bridge circuits
- b operational amplifiers
- c impedance converters
- d digital filters
- e microprocessors in relation to instrumentation

Unit 227 Control systems engineering
Outcome 3 Understand feedback control systems

Knowledge requirements
The candidate knows how to:

1 compare control systems without and with feedback

2 understand and manipulate open and closed-loop transfer functions

3 assess types of close-loop control systems and relationship with steady state errors

4 understand characteristic equation of closed-loop control system and the Routh-Hurwitz stability criterion

5 use design criteria
- a stability margins
- b steady-state errors
- c performance indices in the time domain
- d disturbance rejection
- e concept of design sensitivity

6 implement control algorithms by finite difference techniques (discrete mathematics)

7 understand frequency diagrams
- a Nyquist
- b Bode
- c Nichols
- d stability criteria
- e relative stability
- f peak magnitude of frequency response
- g gain and phase margins

8 understand the root locus diagram
- a stability criterion
- b constraints on pole locations to satisfy damping ratio and speed response requirements

9 apply closed-loop system response to disturbances with differing entry points

10 assess state variable formulation of the system equation; canonical transformation and canonical state variables

11 assess the implication of controllability and observability

12 understand the application of compensation techniques using frequency response and root loci design methods
- a lead/lag networks
- b proportional - integral-derivative (PID) control

13 understand pole placement by state vector feedback

14 understand digital compensation

Unit 227 Control systems engineering

Outcome 4 Understand digital control systems

Knowledge requirements
The candidate knows how to:

1. describe the main features of computer based control systems
2. describe sampler/zero-order-hold systems
3. understand the Z-transform with sampling interval T
4. assess the relationship between Laplace variables S and Z and Z-transform inversion and final value theorem
5. understand the Nyquist/Shannon Sampling-rate theorem and aliasing
6. understand poles and zeros in the Z-plane
7. establish criterion for system stability

Unit 227 Control systems engineering

Recommended reading list

Core texts	Author(s)	Publisher	ISBN
The Art of Control Engineering	Dutton, Thompson, Barraclough	Addison Wesley	0201175452
Control Engineering	Bissell	Nelson Thornes	0412577100
Digital Signal Processing Primer	Steiglitz	Benjamin Cummings	0805316841
Measurement Systems: Application and Design	O'Doeblin	McGraw Hill	0071194657
Modern Control Systems	Dorf, Bishop	Addison-Wesley	0201326779
Principles of Measurement Systems	Bentley	Longman Higher Edu	0582237793
Real-Time Computer Control	Bennett	Prentice Hall	0137641761
System Modelling and Control	Schwarzenbach,G ill	Butterworth-Heinemann	0340543795
Instrumentation: Measurement and Feedback	Jones	McGraw Hill	0070993831
Sensors and Transducers	Usher, Keating	Palgrave	0333604873 o/p
Other useful texts			
Control Systems Engineering	Nise	John Wiley	0471366013
Digital Control of Dynamic Systems	Franklin, Powell, Workman	Addison-Wesley	0201331535
Further Engineering Mathematics	Stroud	Palgrave	0333657411
Schaum's Outline of Digital Signal Processing	Hayes	Schaum	0070273898
Schaum's Outline of Electronic Devices and Circuits	Cathey	Schaum	0070102740
Schaum's Outline of Feedback and Control Systems	Distefano, Stubberud, Williams	McGraw Hill	0070170525
Schaum's Outline of Theory and Problems	Buchanan	Schaum	0070087148