22.3.0 THERMODYNAMICS

22.3.1 Introduction

Thermodynamics deals with the relationships of work, heat and energy. Finally, fluid mechanics deals with fluids in motion and hydraulic machines e.g. pumps. This section is covered and tested as a paper in the final stage.

The instructional approach will emphasize on experiments, industrial visits and analysis of various engineering concepts.

22.3.2 General Objectives

By the end of these module units, the trainee should be able to:

a) understand the basic concepts of engineering science
b) design engineering structures.
c) size power requirements of motors used in engineering design
d) produce models of designed prototypes.
e) apply the knowledge acquired to improve the performance of various equipments.

22.3.2 Module Summary and Time Allocation

Thermodynamics

Code	Sub-Module Unit	Content	Time Hrs
22.3.1	Introduction to Fundamentals of Thermo-Dynamics	• Definitions of terms: • Thermodynamic systems • Types of working fluids • Types of thermodynamic processes • Thermodynamic cycles • Definition of work • Statement of the first law of thermodynamics	4
22.3.2	Steady Flow Processes	• Derivation of steady flow energy equation (S. F. E. E) $U_1 + Z_1 + \frac{C^2}{2} + P_1V_1 + Q = U_2 + Z_2 + \frac{C^2}{2} + P_2V_2$ • Application of the S. F. E. E. • Calculation of work, heat	4

		transfer, changes in internal energy, and enthalpy	
22.3.3	Non-Flow Processes	• Non-flow energy equation (N.F. E. E.) • $Q = U + W$ • Apply the N. F. E. E. for a gas and vapour processes	4
22.3.4	Perfect Gases	• Boyle's law • Charles' law • Derive the characteristic gas equation • Solution of problems using characteristic gas equation the equation • Definition of specific heats, universal gas constant, and specific gas constant • Boyle's law experiment • Charles' law experiment • Joule's law experiment	6
22.3.5	Steam	• Steam generation • PV diagram • TS diagram • Identification of different regions on the PV diagram • Definition of different conditions of steam • Area under the - P-V diagram • Determination of dryness fraction • Experiments on pressure and boiling point • Experiment on energy balance	6
22.3.6	Thermodynamic Reversibility and Entropy	• Criteria for reversibility • Internal reversibility • Explanation of the principle of the heat engine. • Second law of thermodynamics	8

		• Thermal efficiency • Carnot cycle • Net work • Net heat • Area under the T-S diagram	
22.3.7	Ideal Gas Cycle	• Explanations of the different gas cycles • Air standard efficiency • Work done • Heat received or rejected • Compression ratio • Mean effective pressure • Maximum cycle temperatures	8
22.3.8	Fuels and Combustion	• Classifications of fuels • Properties of fuels • Definition of combustions terminologies • Application of the equations to solve combustion and exhaust gas problems • Determination of calorific value of fuel. • Analysis of products of combustion	8
22.3.9	Heat Transfer	• Application of the conduction equations • Derivation of the heat transfer equations • Application of the heat transfer equations to solve related problems	8
22.3.10	Heat Exchangers	• Classification • Description of various types of recuperative heat exchangers • Derivation of heat exchanger equations • Application of the equations • Heat exchanger experiments	4

22.3.11	Air Compressors	• Classification • Types of compressors • Derivations of equations of reciprocating compressors • Applications of the equations of reciprocating compressors • Air compressor experiments	8
22.3.12	Gas Turbines	• Theoretical cycle • Open gas turbine unit • Closed gas turbine unit • Plant diagram • T-S diagram • Thermal efficiency • Derivation of gas turbine equations • Modifications of the basic cycle • Applications of the gas turbine equations	10
22.3.13	Impulse Steam Turbines	• Principle of operation. • Compounding • Multi stage impulse turbine • Derivation of related equations • Optimum operating conditions • Steam turbine experiments • Mechanical efficiency • Specific fuel consumption • Specific steam consumption	10
Total Time			**88**

22.3.1 INTRODUCTION TO FUNDAMENTALS OF THERMO-DYNAMICS

Theory

22.3.1T0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) define terminologies applied to thermodynamics
b) state various types of systems
c) state various types of working substances
d) describe a thermodynamic process
e) state various types of thermodynamic cycle
f) define thermodynamic work
g) state the first law of thermodynamics

22.3.1C Competence

The trainee should have the ability to:

i) Define various terms used in thermodynamic
ii) Describe various Thermodynamic processes and cycles
iii) State the first law of thermodynamics
iv) Apply the first law of thermodynamics

Content

22.3.1T1 Definitions of terms
- i) Thermodynamics
- ii) System
- iii) Thermodynamic cycle
- iv) Properties
- v) Surrounding
- vi) Boundary

22.3.1T2 Thermodynamic systems
- i) Open system
- ii) Closed system

22.3.1T3 Types of working fluids
- i) Air
- ii) Water
- Steam

22.3.1T4 Thermodynamic processes
- i) Definition
- ii) Reversible processes
- iii) Irreversible processes

22.3.1T5 Types of thermodynamics processes
- i) Isothermal
- ii) Isochoric
- iii) Isobaric
- iv) Polytropic
- v) Adiabatic
- vi) Hyperbolic

22.3.1T6 Thermodynamic cycles
- i) Otto cycle
- ii) Diesel cycle
- iii) Joules cycle
- iv) Carnot cycle

v) Dual combustion cycle

22.3.1T7 Thermodynamic work

22.3.1T8 Statement of the first law of thermodynamics

Suggested Learning Resources

i) Textbooks
ii) Handouts

22.3.2 STEADY FLOW PROCESSES

Theory

22.3.2T0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) derive the steady flow energy equation (S. F. E. E).
b) apply the steady flow energy equation to solve problems.

Content

22.3.2T1 Derivation of S. F. E. equation

$$U_1 + Z_1 + \frac{C^2}{2} + P_1V_1 + Q = U_2 + Z_2 + \frac{C^2}{2} + P_2V_2 + W$$

22.3.2T2 Application of the S. F.E. Equation

i) boilers
ii) condensers
iii) compressors
iv) turbines
v) nozzles
vi) throttling processes

22.3.2T3 Calculation of:

i) work
ii) heat transfer
iii) changes in internal energy
iv) changes in enthalpy

22.3.3 NON-FLOW PROCESSES

Theory

22.3.3T0 Specific Objectives

By the end of the topic, the trainee should be able to:

a) derive the non-flow energy equations (N. F. E. E)
b) apply the non flow equation to solve problems

Content

22.3.3T1 Derivation N.F. E. E:

$Q = U + W$

22.3.3T2 Apply the N. F. E. E. to solve problems for a gas and vapour processes

22.3.4 PERFECT GASES

Theory

22.3.4T0 Specific Objectives

By the end of the sub

module unit, the trainee should be able to:

a) state Boyle's law
b) state Charles' law
c) derive the characteristic gas equation
d) solve problems using the characteristic gas equation
e) define specific heats

22.3.4C Competence

The trainee should have the ability to:

i) Set up and perform the experiment
ii) Analyze the results
iii) Apply the characteristic gas equation

Content

22.3.4T1 Boyle's law
22.3.4T1 Charles' law
22.3.4T1 Derive the characteristic gas equation
22.3.4T1 Solution of problems using the equation
22.3.4T1 Definition of:
i) Specific heats Cp, Cv
ii) universal gas constant
iii) specific gas constant

Practice

22.3.3P0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) verify Boyle's law
b) verify Charles' law
c) verify Joule's law

Content

22.3.4P1 Boyle's law experiment
22.3.4P1 Charles' law experiment
22.3.4P1 Joule's law experiment

Suggested Learning Resources

i) Text books
ii) Hand outs
iii) Procedure sheets

22.3.5 STEAM

Theory

22.3.5T0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) describe the generation of steam
b) explain the critical point.
c) define various forms of steam
d) identify on p-v and t-s diagram the various regions of steam generation
e) Solve steam

problems

Content

22.3.5T1 Steam generation
22.3.5T2 Critical point
22.3.5T3 Forms of steam
22.3.5T4 Diagrams
- i) P-V diagram
- ii) T-S diagram
  - liquid region
  - wet region
  - superheated region
  - area under the - T -S diagram

22.3.5T5 Problems on steam

Practice

22.3.5P0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) determine dryness fraction
b) carry out an experiment to show the relationship between pressure and boiling points.
c) carry out boiler experiment for energy balance.
d) plot the temperature-pressure diagram

Content

22.3.5P1 Determination of dryness fraction
22.3.5P2 Experiments on pressure and boiling point
22.3.5P3 Experiment on energy balance
22.3.5P4 Temperature pressure diagram

22.3.5C Competence

The trainee should have the ability to:

i) Set up and perform the experiment
ii) Analyze the results
iii) Plot the temperature pressure diagram

Suggested Learning Resources

i) Text books
ii) Handouts
iii) Steam tables
iv) Procedure sheets
v) Boiler
vi) Throttling calorimeter
vii) Separating and throttling calorimeter

22.3.6 THERMODYNAMIC REVERSIBILITY AND ENTROPY

Theory

22.3.6T0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) explain thermodynamic reversibility
b) explain the

principle of the heat engine.
c) explain entropy in various thermodynamic cycles.

Content

22.3.6T1 Thermodynamics reversibility
22.3.6T2 Principle of heat engine
22.3.6T3 Second law of thermodynamics
22.3.6T4 Entropy

Suggested Learning Resources

i) Text books
ii) Handouts

22.3.7 IDEAL GAS CYCLE

Theory

22.3.7T0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) explain the processes that make up the ideal gas cycles.
b) differentiate between air standard efficiency and actual efficiency.
c) solve problems in various idea gas cycles

Content

22.3.7T1 The ideal gas cycle
i) Joule's cycle
ii) Otto cycle
iii) Diesel cycle
iv) Dual combustion cycle
22.3.7T2 Air standard efficiency
22.3.7T3 Calculations
i) Work done
ii) Heat received or rejected
iii) Mean effective pressure
iv) Maximum cycle temperatures

22.3.8 FUELS AND COMBUSTION

Theory

22.3.8T0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) classify fuels
b) describe properties of fuels
c) derive combustion equations
d) apply the equations to solve combustion and exhaust gas problems

22.3.8C Competence

The trainee should have the ability to:

i) Set up and Perform the experiment
ii) Analyze the results
iii) Classify fuels

Content

22.3.8T1 Classifications of fuels:

i) solid fuels
ii) liquid fuels
iii) gaseous fuels

22.3.8T2 Properties:
i) calorific values
ii) flash point
iii) ultimate analysis

22.3.8T3 Combustions terminologies:
i) stoicho-metric air
ii) air fuel ratio
iii) mixture strength
iv) actual air

22.3.8T4 Application of the equations to solve combustion and exhaust gas problems

Practice

22.3.8P0 Specific Objectives
By the end of the sub module unit, the trainee should be able to:
a) determine the calorific value of fuels
b) analyse products of combustion

Content

22.3.8P1 Determination of calorific value of fuel

22.3.8P2 Analysis of products of combustion

Suggested Learning Resources
i) Text books
ii) Hand outs
iii) Procedure sheet
iv) Bomb calorimeter
v) Orsat apparatus
vi) Fuels

22.3.9 HEAT TRANSFER

Theory

22.3.9T0 Specific Objectives
By the end of the sub module unit, the trainee should be able to:
a) derive the conduction equations from Fourier's law
b) apply the conduction equations from Fourier's law to solve heat transfer problem.
c) derive the heat transfer equations from Newton's law of cooling and Fourier's law.
d) apply the heat transfer equations from Newton's law to solve problems.

Content

22.3.9T1 Derivation of the heat transfer equations for:
i) single flat wall
ii) composite flat wall
iii) single cylindrical wall
iv) composite cylindrical wall

22.3.9T2 Application of the heat transfer equations to solve related problems

Suggested Learning Resources

i) Text books
ii) Handouts

22.3.10 HEAT EXCHANGERS

Theory

22.3.10T0Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) classify heat exchangers
b) describe various types of recuperative heat exchangers
c) derive recuperative heat exchanger equations
d) apply the equations to solve recuperative heat exchanger problems

22.3.10C Competence

The trainee should have the ability to:

i) Set up and perform experiments on heat exchanger
ii) Identify types of heat exchangers

Content

22.3.10T1 Classification
i) recuperative
ii) regenerator
iii) evaporative

22.3.10T2 Description of various types of recuperative heat exchangers
i) parallel flow
ii) counter flow
iii) cross flow

22.3.10T3 Derivation of recuperative heat exchange

22.3.10T4 application of the equations

Practice

22.3.10P0 *Specific Objectives*

By the end of the sub module unit, the trainee should be able to carry out experiments on heat exchangers

Content

22.3.10P1 Heat exchanger experiments

Suggested Learning Resources

i) Textbooks
ii) Handouts
iii) Procedure sheet
iv) Heat exchangers

22.3.11 AIR COMPRESSORS

Theory

22.3.10T0Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) classify air compressors
b) describe various types of compressors
c) derive equations for reciprocating compressors
d) apply the

equations for the reciprocation compressors

22.3.11C Competence

The trainee should have the ability to:

i) Set up and perform experiments on compressors
ii) Identify different types of compressors

Content

22.3.10T1 Classification
i) reciprocating compressors
ii) rotary compressors

22.3.10T2 Types of compressors
i) reciprocating
ii) blowers
iii) sliding valve

22.3.10T3 Derivations of recuperative heat exchanger equations
i) work done
ii) free air delivery
iii) volumetric efficiency
iv) multi stage compressors
v) inter cooling

22.3.10T4 Applications of the equations of reciprocating compressors

Practice

22.3.10P0 Specific Objectives

By the end of the sub module unit, the trainee should be able to carry out experiments on heat exchangers

Content

22.3.10P1 Air compressor experiment to measure
i) Volumetric efficiency
ii) Isentropic efficiency

Suggested Learning Resources
i) text books
ii) handouts
iii) Procedure sheet
iv) Air compressors

22.3.11 GAS TURBINES

Theory

22.3.11T0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:

a) explain the theoretical cycle for a gas turbine.
b) describe the open cycle gas turbine.
c) describe the closed cycle gas turbine.
d) derive gas turbine equations.
e) explain the modifications of the basic cycle.
f) apply the

equations to solve gas turbine problems

Content

22.3.12T1 Theoretical cycle
- i) Joule cycle

22.3.12T2 Open gas turbine unit

22.3.12T3 Closed gas turbine unit

22.3.12T4 Plant diagram

22.3.12T5 T-S diagram

22.3.12T6 Thermal efficiency

22.3.12T7 Derivation of gas turbine equations

22.3.12T8 Modifications on the basic cycle

22.3.12T9 Applications of the gas turbine equations

Suggested Learning Resources
- i) Text books
- ii) Handouts

22.3.13 IMPULSE STEAM TURBINES

Theory

22.3.13T0 Specific Objectives

By the end of the sub module unit, the trainee should be able to:
a) describe the principle of operation of the impulse steam turbine.
b) derive impulse steam turbine equations.
c) apply the equations to solve impulse steam turbine problems.

22.3.13C Competence

The trainee should have the ability to set up and perform an experiment on steam turbines

Content

22.3.13T1 Principle of operation
- i) Compounding
- ii) Multi stage impulse turbine

22.3.13T2 Derivation of related equations
- i) power
- ii) diagram efficiency
- iii) Optimum operating conditions

22.3.13T3 Applications of impulse steam equations

Practice

22.3.13P0 Specific Objectives

By the end of the sub module unit, the trainee should be able to carry out experiments on steam turbines.

Content

22.3.13P1 Steam turbine experiments

22.3.13P2 Mechanical efficiency

22.3.13P3 Specific fuel consumption

22.3.13P4 Specific steam consumption

Suggested Learning Resources

i) Text books
ii) Handouts
iii) Steam tables
iv) h-s chart