Chapter	1: Review of Thermodynamics and Heat Transfer 1-1 to 1-31
1.1	Introduction1-1
1.2	Thermodynamics System1-1
1.3	Dimensions and Units1-1
1.4	Energy1-2
1.5	Ideal Gas Equation1-3
1.6	Enthalpy1-3
1.7	Specific Heats of a Gas1-3
1.8	First Law of Thermodynamics1-3
1.9	Application of First Law of Thermodynamics to Closed System (Non-Flow) Processes1-4
1.9.1	A Constant Volume Process1-4
1.9.2	A Constant Pressure Process1-4
1.9.3	Constant Temperature or Isothermal Process1-5
1.9.4	Hyperbolic Process1-5
1.9.5	Reversible Adiabatic Process1-5
1.9.6	Reversible Polytropic Process1-6
1.9.7	The Combination of Polytropic Law $p \cdot V^n = C$ and Equation of State, $pV = mRT$ 1-6
1.10	Application of First Law of Thermodynamics to Steady Flow Open Systems1-6
1.11	Mechanical Work in a Steady Flow Process1-8
1.12	Second Law of Thermodynamics1-9
1.13	Carnot's Theorem1-9
1.14	Entropy1-9
1.15	Principle of Increase of Entropy1-9
1.16	Entropy Change for Ideal Gas - General Equation1-9
1.17	State of a Substance1-10
1.18	Pure Substance 1-10
1.19	Phase Transformation at Constant Pressure-Formation of Steam1-10
1.20	Properties of Steam 1-11

1.21	Steam Tables and Their Uses1-12
1.22	Temperature - Entropy (T-S) and Enthalpy - Entropy (h-S) Diagrams for Steam1-13
1.23	Compressed Liquid1-15
1.24	Heat Transfer1-17
1.25	Modes of Heat Transfer1-17
1.26	Heat Transfer by Conduction1-17
1.27	Fourier's Law of Heat Conduction1-17
1.27.1	Heat Conduction through a Thick Wall1-17
1.27.2	Analogy between Heat Conduction and Electrical System1-18
1.27.3	Composite Walls1-18
1.28	Convection1-19
1.29	Overall Heat Transfer Coefficient, U1-20
1.30	Heat Transfer in an Infinitely Long Cylinder1-21
1.31	Heat Transfer Through a Hollow Sphere1-21
1.32	Heat Transfer through a Composite Cylinder with Conduction and Convection 1-21
1.33	Thermal Insulation1-22
1.34	Radiation1-22
1.35	Stefan - Boltzmann Law of Radiation1-23
Chapte	r 2 : Development of Refrigeration

**Introduciton and refrigerant :** Brief history and need of refrigeration and air conditioning, methods of producing cooling, ton of referigeration, coefficient of preformance, types and applications of refrigeration and air conditioning systems, Recapitulation of desirable properties of refrigerants, secondary refrigeratns, future

and Refrigerants

industrial refrigerants.

2.1	Development of Refrigeration	<b>2-</b> 1
2.2	Definition of Refrigeration	2-1
2.2.1	Definition of Airconditioning	<b>2-</b> 1
2.2.2	Difference between Refrigeration	
	and Airconditioning	2-2



2-1 to 2-33

2.2.3	Application of Refrigeration in Food Processing 2-2	2.18	Deep Freezers2-15
2.2.4	Applications of Refrigeration2-2	2.19	Ice Making Plant2-15
2.3	Systems of Refrigeration /	2.19.1	Block or Can Ice Plant2-15
	Methods of Producing Cooling2-3	2.19.2	Flake Ice Plant2-15
2.4	Non-cyclic Refrigeration Systems2-3	2.19.3	Cube Ice Plants2-16
2.4.1	Ice Refrigeration2-3	2.20	Preservation of Food2-16
2.4.2	Evaporative Refrigeration2-3	2.20.1	Spoilage Agents2-16
2.4.3	Refrigeration by Dry Ice2-4	2.20.2	Enzymes2-16
2.5	Refrigeration by Expansion of Air2-4		·
2.6	Refrigeration by Throttling of Gas2-4	2.20.3	Micro-organism2-17
2.7	Vapour Compression Refrigeration System2-5	2.20.4	Methods of Preservation of Food2-18
	Liquid Gas Refrigeration2-6	2.20.5	Preservation of Food by Refrigeration2-19
2.8	•	2.20.6	Storage Conditions2-19
2.9	Vortex Tube Refrigeration System2-6	2.20.7	Frozen Storage2-20
2.10	Thermoelectric Refrigerator2-7	2.21	Types of Cold Storage2-21
2.11	Production of Low Temperature	2.22	Milk Chilling Plant for Dairy2-23
	by Magnetic Cooling2-8	2.23	Definition of a Refrigerant2-23
2.12	Steam Jet Refrigeration System2-8	2.24	Desirable Properties of a Good Refrigerant2-24
2.12.1	Principle of Operation of Steam		z con acces a repersion of a decon mental germinima z r
	Jet Refrigeration System2-8	2.24.1	Thermodynamic Properties of
2.12.2	Working of Steam Jet Refrigeration System2-9		Refrigerants2-24
2.12.3	Advantages and Disadvantages of Steam Jet	2.24.2	Chemical Properties of Refrigerants2-25
	Refrigeration System2-10	2.24.3	Physical Properties of Refrigerants2-26
2.13	Concept of Heat Engine, Heat Pump	2.24.4	Other Properties of Refrigerants2-27
	and Refrigerating Machines2-10	2.24.5	Properties of an Ideal Refrigerant2-27
2.13.1	Performance of Heat Engine, Heat	2.25	Properties of Important Refrigerants2-27
	Pump and a Refrigerator2-11	2.26	Selection of a Refrigerant2-29
2.14	Unit of Refrigeration - Tons of		
	Refrigeration (TR)2-11	2.27	Secondary Refrigerants2-29
2.14.1	Concept of EER, SEER, IPLV and NPLV2-12	2.27.1	Substances Used as Secondary Refrigerants2-29
2.15	Applications of Refrigeration2-12	2.28	Refrigerants for Future
2.16	Refrigerators 2-12		Industrial Applications2-30
	_	Chapte	r 3 : Air Refrigeration 3-1 to 3-29
2.16.1	Components of Refrigeration System2-13	Air ro	frigeration : Aircraft refrigeration, working and
2.16.2	Precautions during Usage of Refrigerator		
	(Thermodynamic Significance)2-14	-	s of Simple, Bootstrap, Reduced ambient and
2 17	Water Coolers 2-14	Regene	erative air refrigeration systems.



3.1	Review of Bell Coleman or Reversed Brayton or Reversed Joule Air Refrigeration Cycle3-1	4.1.2.4	Assumptions in Theoretical Vapour Compression Cycle4-4
3.1.1	Advantages of Bell Coleman Cycle3-2	4.1.3	Definition of Subcooled or
3.1.2	Disadvantages of Bell-Coleman Cycle3-3		Under- Cooled Liquid4-5
3.2	Application of Air Cycle Refrigeration for	4.1.3.1	Definition of Under cooling4-5
	Aircrafts and Need of Airconditioning of Aircrafts3-3	4.2	Limitations and Drawbacks of Simple Vapour Compression Refrigeration Cycle 4-5
3.2.1	Advantages of Air Refrigeration System for Aircraft Cooling3-3	4.3	Multistage Vapour Compression System 4-6
3.3	Methods of Air Refrigeration Systems3-3	4.3.1	Multistage Compression with
3.4	Simple Air Cooling System3-4		Intercooling Between the Stages4-6
3.5	Simple Air Evaporative Cooling System 3-10	4.3.2	Intermediate Pressure for Minimum Work 4-7
3.6	Bootstrap Air Refrigeration System 3-13	4.4	Types of Multistage Vapour Compression System with Intercooler
3.7	Boot Strap Air Evaporative Cooling System 3-16		and Single Load4-8
3.8	Reduced Ambient Air Cooling System 3-19	4.5	Two Stage Compression with
3.9	Regenerative Air Cooling System 3-21		Liquid Intercooler4-8
3.10	Comparison of Various Aircraft Cooling Systems	4.6	Two Stage Compression with Water Intercooler and Liquid Sub-cooler4-11
Chapte	r 4 : Compound Compression VCR System 4-1 to 4-47	4.7	Two Stage Compression with Water Intercooler, Liquid Sub-cooler and Liquid Flash Chamber4-13
-	<b>Dound Compression VCR System :</b> Multiple ators with back pressure valves and with multiple	4.7.1	Two Stage Compression with Flash Chamber but without Intercooler and Liquid Sub-Cooler4-15
two e	ion valves without flash inter cooling. Analysis of vaporators with flash intercooler and individual ion valve and multiple expansion valve, cascade	4.8	Two Stage Compression with Water Intercooler, Liquid Subcooler and Flash Intercooler4-19
refrige	ration system	4.9	Multiple Evaporator and
4.1	Review of (p-h) Charts and Basic		Compressor Systems4-22
	Concepts of Vapour Compression Refrigeration (VCR) Cycles4-1	4.10	Multiple Evaporator at the Same
4.1.1	Pressure Enthalpy(p-h) Chart for Refrigerants 4-1		Temperature and Single Compressor System4-23
4.1.2	Thermodynamic Analysis of Vapour Compression Refrigeration Cycle4-1	4.11	Multiple Evaporators at Different Temperatures with Single Compressor,
4.1.2.1	When the Vapour is Dry-saturated at the End of Compression4-1		Individual Expansion Valves and Back Pressure Valve System4-24
4.1.2.2	Vapour Compression Cycle when Vapour is Wet at the End of Compression4-4	4.12	Multiple Evaporators at Different Temperatures with Single Compressor, Multiple Expansion Valves (E.V.) and Back Pressure Valves (B.P.V.)4-27
4.1.2.3	Vapour Compression Cycle when the Vapour is Dry-saturated at Entry to Compressor (Ideal Cycle or Standard Cycle)4-4	4.13	Multiple Evaporators with Individual Compressors and Individual Expansion Valves4-29



4.14	Multiple Evaporators with Individual Compressors and Multiple Expansion Valves 4-31
4.15	Multiple Evaporators with Compound Compression and Individual Expansion Valves4-33
4.16	Multiple Evaporator System with Compound Compression, Individual Expansion Valves and Flash Intercoolers 4-36
4.17	Multiple Evaporator System with Compound Expansion, Multiple Expansion Valves and Flash Intercoolers 4-38
	P
4.18	Cascade System of Refrigeration 4-40
<b>4.18</b> 4.18.1	•
	Cascade System of Refrigeration 4-40 Limitations of Single Stage Vapour Compression
4.18.1	Cascade System of Refrigeration 4-40 Limitations of Single Stage Vapour Compression System for Production of Low Temperature 4-40

## Chapter 5: Vapour Absorption Refrigeration **System** 5-1 to 5-29

Absorption refrigeration system : Practical H<sub>2</sub>O-NH<sub>3</sub> cycle, LiBr-H<sub>2</sub>O system and its working, h-x diagram and simple calculation of various process like adiabatic mixing and mixing with heat transfer, throttling.

5.1	Introduction5-1
5.1.1	Origin of the Absorption System5-1
5.1.2	Principle of Basic Liquid Absorbent System (Ammonia Water)5-2
5.1.3	Terms and Definitions5-2
5.2	Refrigerant - Solvent Properties5-3
5.2.1	Desirable Properties of Solvent5-3
5.2.2	Desirable Properties of Refrigerant-Solvent Combination
5.2.3	Characteristics of Ammonia5-3
5.3	Simple Ammonia-Water Vapour Absorption System5-3
5.4	Practical Ammonia-Water Vapour Absorption System5-4
5.5	Comparison between Vapour Absorption and Vapour Compression System5-5

5.6	COP of an Ideal Vapour Absorption System 5-6	
5.7	Domestic Electrolux (NH <sub>3</sub> - H <sub>2</sub> ) Refrigerator5-9	
5.8	Lithium Bromide Absorption Refrigeration System5-12	
5.8.1	Double - Effect Li-Br Absorption System5-13	
5.8.2	Comparison between Aqua-NH3 with Li Br-H <sub>2</sub> O Vapour Absorption System5-14	
5.8.3	Solar Based Li Br - H <sub>2</sub> O Vapour	
	Absorption System for Space Cooling5-15	
5.8.4	Applications of Vapour Absorption System5-16	
5.9	New Mixtures for Vapour Absorption System5-16	
5.10	Theory of Mixtures5-16	
5.11	Temperature - Concentration (t - z) Diagram for Binary Mixtures5-17	
5.12	Enthalpy Concentration Diagram (h - z) or (h - x) Diagram5-18	
5.12.1	Representation of (NH <sub>3</sub> - H <sub>2</sub> O) Ideal	
	Vapour Absorption Cycle Enthalpy- Concentration Chart5-19	
5.13	Adiabatic Mixing of Two Streams5-19	

## Chapter 6: Refrigeration System Controls 6-1 to 6-25

Refrigeration system components Types, construction, working, comparison and selection of compressors, condensers, expansion devices and evaporators; refrigeration piping accessories, evacuation and charging of refrigerant, properties and classification of thermal insulation.

6.1	Introduction 6-1
6.2	Compressor6-1
6.3	Reciprocating Compressor 6-1
6.3.1	Construction and Working6-1
6.3.2	Performance of Reciprocating Compressor 6-2
6.3.3	Parts of Reciprocating Compressors 6-4
6.3.4	Lubrication6-5
6.3.5	Capacity Control6-6
6.4	Rotary Compressor6-7





6.5	Centrifugal Compressor6-7
6.6	Screw Compressor6-8
6.7	Scroll Compressor6-8
6.7.1	Comparison and Selection of Compressor6-9
6.8	Hermetically Sealed Compressor 6-10
6.9	Condensers 6-10
6.9.1	Air Cooled Condensers6-10
6.9.2	Water Cooled Condensers6-11
6.9.3	Water Cooling Devices6-12
6.9.4	Evaporative Condenser6-13
6.10	Expansion and Flow Control Devices 6-13
6.10.1	Float Valve6-13
6.10.2	Automatic Expansion Valve (AXV)6-13
6.10.3	Thermostatic Expansion Valve (TXV) 6-14
6.10.4	Capillary Tube6-15
6.11	Evaporator6-16
6.11.1	Air Cooling Evaporators6-16
6.11.2	Liquid Chilling Evaporator6-16
6.11.3	DX and Flooded Evaporators6-17
6.12	Accessories6-18
6.12.1	Oil Separator
6.12.2	Receiver 6-18
6.12.3	Dryer6-19
6.12.4	Strainer
6.12.5	Sight Glass6-19
6.13	Controls 6-19
6.13.1	Thermostat6-19
6.13.2	Low Pressure Cutout 6-20
6.13.3	High Pressure Cutout6-20
6.13.4	Oil Failure Cutout 6-20
6.14	Piping in Refrigeration System 6-20
6.15	Insulation in Refrigeration 6-21
6.15.1	Desirable Properties of Insulating Materials 6-21
6.15.2	Classification of Insulation6-21
6.15.3	Insulating Materials used in Refrigeration Equipment
6.16	Services Operations6-22

6.16.1	Small Domestic Plant	6-22
6.16.2	Large Plants	6-23

Chapter 7: Human Comfort and Load Analysis 7-1 to 7-44

**Human comfort and Load analysis :** Selection of inside design conditions, thermal comfort, heat balance equation for a human being, factors affecting thermal comfort, Effective temperature, comfort chart and factors governing effective temperature, selection of outside design conditions.

Site survey, outdoor and indoor design conditions, classification of loads flywheel effect of building material and its use in design, effect of wall construction on cooling load, instantaneous heat gain (IHG) and instantaneous cooling load (ICL) heat transmission through sunlit and shaded glass using tables, method of reduction of solar heat gain through glass, calculations of cooling load TETD due to sunlit and shaded roof and walls using tables, ventilation and air infiltration, load due to outside air, heat gain from occupants; electric lights; product; electric motor and appliances, load calculations for automobiles, use of load estimation sheet.

31100	<u>.                                    </u>
7.1	Introduction to Airconditioning7
7.1.1	Industrial Air Conditioning7
7.1.2	Comfort Air Conditioning7
7.1.3	Factors Affecting Human Comfort7
7.2	Psychrometry and Psychrometric Properties7
7.3	Psychrometric Chart7
7.4	Psychrometric Processes7
7.4.1	Adiabatic Mixing of Air Streams7
7.4.2	Sensible Heating7
7.4.3	Sensible Cooling7
7.4.4	Humidification and Dehumidification of Air
7.4.5	Cooling and Dehumidification Process7
7.4.6	Adiabatic Cooling or Evaporative Cooling or Cooling with Humidification7
7.4.7	Heating with Humidification Process7-1





7.4.8	Heating with Dehumidification Process7-10
7.5	Introduction to Basic concept of Air-conditioning Design
7.6	Outside Design Conditions7-11
7.7	Inside Design Conditions7-11
7.7.1	Industrial Application7-11
7.7.2	Comfort Applications (Thermal Analysis of Human Body)7-11
7.7.2.1	Factors Affecting Human Comfort7-12
7.7.3	Effective Temperature7-12
7.8	Human Comfort Chart7-13
7.9	Sources of Heat Load7-13
7.10	Heat Gain through Glass7-14
7.10.1	Factors Affecting Solar Radiation at a Place 7-14
7.10.2	Factors Affecting Solar Radiation Entering the Room7-15
7.10.3	Instantaneous Heat Gain (IHG) and Instantaneous cooling load (ICL)7-15
7.10.4	Method of Estimation7-15
7.11	Heat Load through Opaque Surface7-16
7.11.1	Overall Heat Transfer Coefficient7-16
7.11.2	Surface Area7-16
7.11.3	Temperature Difference7-17
7.11.4	Flywheel Effect in Load Calculation7-18
7.12	Infiltration7-18
7.13	Ventilation7-19
7.14	Outside Air Load7-19
7.15	Occupancy Heat Load7-20
7.16	Lighting7-20
7.17	Equipment7-20
7.18	Product Brought in7-20
7.19	System Heat Gain7-20
7.20	Equipment Selection7-21
7.21	RSHF, ERSHF 7-21
7.22	Psychrometric Analysis of Estimated Heat Load
7.23	Psychrometric Analysis of Uncommon Load Patterns

7.24	Partial Load Analysis7-24
7.24.1	Air Flow Control7-24
7.24.2	Return Air Bypass7-24
7.24.3	Reheating7-25
7.24.4	Capacity Control of Compressor7-25
7.25	Winter Air Conditioning7-25
7.25.1	Heat Load/Loss Estimate7-25
7.25.2	Psychrometric Analysis7-26

Chapter 8: Duct Design and Air Distribution

8-1 to 8-18

Duct design and air distribution : Function; classification and economic factors influencing duct layout, equal friction, velocity reduction and static regain methods of duct design, use of friction chart, dynamic losses and its determination, Requirements of air distribution system, air distribution, grills, outlets, application, location.

- 1- 1	,	
8.1	Introduction	8-1
8.2	Supply Air Duct	8-1
8.2.1	Material	8-1
8.2.2	Sound Absorbing Materials for Ducts	8-1
8.2.3	Classification of Duct and Economic Factors	8-2
8.2.4	Shape of Duct	8-2
8.2.5	Size of Duct	8-3
8.2.6	Obstruction	8-3
8.2.7	Bends, Tees and Branch Take Offs	8-3
8.2.8	Fire Dampers	8-3
8.3	Flow Through Duct	8-3
8.4	Pressure Losses in the Duct	8-4
8.5	Loss of Pressure Due to Friction	8-4
8.5.1	Friction Factor 'f'	8-4
8.6	Equivalent Diameter of a Circular Duct or a Rectangular Duct	8-5
8.7	Friction Chart for Circular Ducts	8-5
8.8	Dynamic Losses in Duct	8-8
8.8.1	Pressure Loss Due to Enlargement	8-9
8.8.2	Pressure Loss Due to Contraction	8-9

8.8.3	Pressure Loss at Entry or Exit from Duct8-9	9.3	Central Air Conditioning System	9-3
8.8.4	Pressure Loss in Bends, Tees,	9.4	Air Conditioning Systems	9-4
	and Branch Offs8-9	9.5	Direct Expansion System	9-5
8.8.5	Equivalent Lengths of Fittings8-9	9.6	All Water System	9-5
8.9	Methods of Duct Design8-10	9.7	All Air System	9-6
8.9.1	Velocity Reduction Method8-10	9.8	Air-water System	9-7
8.9.2	Equal Friction Method or Equal Pressure Loss Method8-11	9.9	Air Conditioning Equipments	9-8
8.9.3	Static Regain Method8-11	9.10	Air Cleaners	9-8
8.9.4	Design of Duct by Equal Friction Method8-11	9.10.1	Choice of the Filter	9-8
8.10	Pressure Drop in Ducts8-12	9.10.2	Types of Filters	9-8
8.11	Room Air Distribution8-13	9.10.3	Installation and Maintenance of Filters	9-10
8.12	Types of Outlets8-14	9.11	Cooling Coil	9-10
8.13	Location of Outlet8-14	9.12	Heating Device	9-10
8.14	Return Air System8-14	9.13	Humidifier	9-11
		9.14	Fans	9-12
Chapt	er 9 : Airconditioning Systems 9-1 to 9-19	9.14.1	Introduction	9-12
Air-	conditioning systems : Classification, system	9.14.2	Axial Fans	9-13
com	ponents, all air; all water; and air-water systems,	9.14.3	Centrifugal Fans	9-13
	n air conditioners, packaged air conditioning	9.14.4	Fan Classification	9-14
	t, central air conditioning systems, split air	9.14.5	Fan Laws	9-15
cond	ditioning systems.	9.14.6	System Balance	9-15
9.1	Introduction9-1	9.14.7	Selection of Fan	9-16
9.2	Unitary System9-1	9.14.8	Fan Control	9-17
9.2.1	Window Air Conditioner9-2	9.15	Passive Heating and Cooling	
9.2.2	Split Air Conditioner9-2	•	Appendix A	
9.2.3	Package Air Conditioners9-3			

