080 – REFRIGERATION AND AIRCONDITIONING WORKS

EXAMINATION STRUCTURE

For this trade, the following are trade-related courses:

191 – Metal Work

193 – Building/Engineering Drawing

194 – Basic Electricity

EXAMINATION SCHEME

81 – Refrigeration and Airconditioning Works

This subject grouping consists of two papers:

81-1 – PAPER I : This will consists of two sections, viz:

SECTION A: OBJECTIVE: this will be forty (40) multiple choice questions. Candidates will be required to answer all in 40 minutes. This section carries forty (40) marks.

SECTION B: ESSAY: this will be a written paper of seven questions. Candidates are to answer five questions in 2½ hours. This Section carries sixty marks.

81-2 PAPER II: PRACTICAL: Candidates will be required to answer one question in 3 hours for 100 marks.

081 – REFRIGERATION AND AIRCONDITIONING WORKS

S/N	TOPICS/OBJECTIVE	CONTENT	ACTIVITIES/REMARK
1.	**Thermometers and Pressure Gauges** 1. Identify the various types of thermometers and pressure gauges used in refrigeration. 2. Plot the various temperature scales on a graph and convert one temperature scale to another	1. a) Types of thermometers liquid in glass, gas thermometer, resistance thermometer, thermo-couples bimetallic thermometer etc. b) Types of pressure gauges-barometer, barometers, mano-meters, bourdon type etc 2. a) Various temperature scales – Celsius or centigrade, Fahrenheit, Kelvin, Rankine. b) Conversion of one temperature scale to another e.g. i. Fahrenheit to Celsius $^oC = 5/9$ (^oF-32) ii. Kelvin to Celsius ^oC = K-273.15 iii. Rankine to Kelvin K = 5/9(R) iv. Celsius to Rankine R = 5/9 (^oC) + 491.67 v. Celsius to Kelvin K = ^oC + 273.5 3. Temperature scales (International Practical temperature scale). a. boiling point of oxygen – 182.97 ^oC b. triple point of water 0.01 ^oC c. boiling point of water 100.00 ^oC d. boiling point silver 960.80 ^oC e. boiling point gold 1063.00 ^oC 4. Uses of suction and high pressure gauges.	1. a) Demonstrate how to use various thermometers to measure temperatures of different substances e.g. cold, water ice block etc. b) Demonstrate how to connect the pressure gauge to the system. 2. Emphasize the correct location of the pressure gauge. 3. Plot the various temperature scales on a graph. 4. Use of suction gauge and high pressure gauges to determine the performance of the refrigerant in the refrigeration system.
2.	**Effects of Pressure, Temperature and Volume on Refrigeration and Air-conditioning System** State the various gas laws and carry out calculations using the various gas laws formulae.	1. Gas Laws: Boyles law, Charles law, Dalton's Law of partial pressures, general gas law. 2. Calculations involving gas law formulae a. $P_1V_1 = P_2V_2$ - Boyles law b. $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ - Charles' law c. $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ - Partial Pressure law d. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	1. Evaluate variables linked by direct and inverse proportions. 2. Solve problems involving gas laws
3.	**Principles of Conversion of Electrical Energy to Heat Energy and Vice Versa**	1. Units of power and heat e.g. Watts kilowatts, joules, kilojoules calories etc. Definition of these units. 2. a) E nthalpy of a fluid, its pressure, volume or temperature of internal energy. b) P-h diagram of refrigerants c) Calculate the power used by compressor – pass = mass flow rate (enthalpy (h) outlet – enthalpy (h) inlet. Where M = mass flow rate of refrigerant H(out) = enthalpy of refrigerant at	1. Use appropriate formulae to convert from one unit to another 2. Plot Enthalpy and P-H charts

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		compressor outlet H(in) = enthalpy of refrigerant at compressor inlet.	
4.	**States of Matter** Explain the three states of matter solid, liquid and vapour or gas using appropriate experiment.	1. States of matter e.g. Solid, liquid and vapour or gaseous states of matter. 2. Commonly accruing substances can be used to illustrate the three states of matter e.g. water in its solid, ice, liquid, water and vapour, steam etc.	Students to practice by using 14 blocks to demonstrate change from one to another.
5.	**The Refrigeration Cycle and Principles of Air Conditioning** Describe and state the conditions of the refrigerant in the refrigerant cycle and principles of air-conditioning. Introduction to psychrometric properties of air.	1. Various processes occurring in the refrigeration cycle viz evaporation compression, condensation and expansion and their representation on a property diagram. 2. Latent heat and sensible heat. 3. Air-conditioning processes like heating, cooling, humidification, etc. Air cleaning or filtration. Movement or distribution 4. a) Saturated vapour, super heated vapour, sub-cooled liquid, wet vapour etc. b) Use of properties to illustrate state points on a property diagram. c) Reading property diagram. 5. a) Moist air properties like dry bulbs temperature, wet bulb temperature dew point temperature, relative humidity, humidity ratio, specific enthalpy etc. b) Psychrometric chart and its use to determine moist air properties.	Use the psychrometer and charts to determine moist air properties.
6.	**Types of Compressors** Differentiate between the various types of compressors and classify them by their shapes, sizes, physical features and state their appropriate uses.	1. Construction and functions of a compressor. 2. a) types of compressors i. Reciprocating ii. Reciprocating iii. Centrifugal iv. Screw 3. State the range of application of each type of compressor and for each refrigerant.	Use of manuals, exploded diagrams to illustrate different types of compressors.
7.	**Working Principles of Compressor** With the aid of a labeled diagram showing the essential features, explain the operating principles of the compressors.	1. Operation of various compressors. 2. Knowledge of the various components of a compressor, viz: crankcase or cylinder block, crankshaft, main bearings connecting rods, piston, piston rings and pins suction and discharge valves, oil pump, seals, etc. shafts, journals and bearing, vane spring valves etc. 3. Impellers, castings, bearings, accessories etc.	Dismantle, examine and identify various components of a compressor.
8.	**Calculation of the Revolution and Capacity of Reciprocating Compressors** Calculate the capacity,	1. Motor speed, fly wheel and pulley diameter. 2. Determination of the speed of the compressor flywheel in terms of D.d and	Examine the name plate and identify the speed of the motor fly wheel on the pulley diameters and name plate.

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	revolution and identify the motor speed, fly wheel and pulley diameters of compressors.	N. Where D = diameter of compressor flywheel (m) D = diameter of the motor pulley (m) N_m =- speed of the motor (rpm). n = speed of compressor flywheel (rpm) $n = \frac{d\ N_m}{D}$ 3. Capacity of the compressor a. Compressor piston displacement $\frac{\Pi Dc\ 2Nc}{240}$ x s (rpm) b. Volumetric efficiency = $\frac{\text{Capacity x 100 .}}{\text{Piston Displacement}}$ c. Capacity = $\frac{\Pi D2Nc}{}$ x $S_{(RPM)}$ nr Where Dc = diameter of cylinder (m) S = Stroke (m) RPM = Motor speed in rpm nr = volumetric efficiency of	
9.	**Trouble Shooting and Maintenance of Compressors** Dismantle, diagnose, repair and assemble faulty compressor parts.	1. Comprehensive trouble shooting chart stating the faults or complaints symptoms, probable causes and recommended action. Complaints include compressor: fails to start, short circuit, looses oil, runs continuously is noisy, the refrigeration system is short of capacity, discharge pressure being too high or low etc. Maintenance schedule listing activities to be carried out daily, weekly, monthly or seasonally. 2. Dismantling of compressors. 3. Condition of compressor parts. 4. Techniques for repair/replacing faulty components. 5. Coupling of compressor parts.	1. For each fault in compressor, the appropriate remedial action should be undertaken. Maintenance activities include checking the oil level in the compressor and for leakage. Use of pressure gauge to observe the oil pressure. Lubricate motor bearings. 2. Demonstrate how to dismantle compressor using spanners. 3. Cut different shapes of compressor gasket using appropriate gasket paper. 4. Use of sight glass to observe the oil pressure.
10.	**Lapping of Value Plates** Resurface spotted areas of value plates using appropriate lapping compound.	Resurfacing spotted areas of value plates using lapping compounds.	Demonstrate how to resurface spotted areas of valve plates using lapping compounds.
11.	**Service Valves, Safety Devices, Capacity Controls and Efficiency Test of Compressors** Identify, describe and explain the compressor service valves, thermostat, time switches,	1. Compressor shut-off or service valves and their features. 2. a) Low pressure and high pressure switches. b) Functions of thermostat and time switches, oil pressure failure switch etc.	Dismantle, examine and identify various components of compressor.

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	capacity controls and efficiency tests of a compressor and their application in refrigeration or air-conditioning system.	3. a) various types of compressor capacity controls, namely on-off, multi-speed, cylinder unloading, hot gas bypass or multiple compressors. b) Principle of operation of each type of compressor capacity control listed above. c) Capacity control – fault diagnosis. 4. a) Compressor efficiency test. b) Factors affecting the performance of compressors.	
12.	**Motor, Generators and Starters: Maintenance and Repair.** Distinguish between three-phase and single phase motor and service them for both mechanical and electrical faults.	1. Types of motors, starters used in refrigeration and air-conditioning systems. 2. Trouble shooting and maintenance of electric motors and starters. Accessories used in refrigeration and air-conditioning systems like relays, solenoid values, capacitors, thermostats overload protectors, time switches etc.	Dismantle electric motors check for faults, repair faults or replace parts, lubricate appropriate parts. Correct installation of electric motors and their proper operation.
13.	**The Absorption Refrigeration System** Identify the components and explain the working principles of an absorption refrigeration system.	1. Principles of operation of the absorption refrigeration system. 2. Functions of the components of the absorption refrigeration system. Components include generator, condenser, rectifier, evaporator absorber, controls etc.	Discuss typical operation problems of domestic absorption refrigeration system and suggest probable solution; e.g. **Problem** Refrigerator not cooling. **Remedy** a. Turn the refrigerator upside down for four days. b. Turn upright and test run the refrigerator for normal operation.
14.	**Faults in Absorption Refrigeration System** Diagnose faults within the absorption refrigeration system by checking the working performance of the components such as condenser generator.	Trouble shooting of absorption refrigeration system components such as mechanical; heat transfer and controls etc.	
15.	**Installation and maintenance of Absorption Refrigeration System** Install and maintain the absorption refrigeration system.	1. Installation procedures for absorption refrigeration systems: piping practices; installation. 2. Maintenance program for the various components: refrigerant and solution pups; purge unit; cleaning of the generator, condenser and absorber; controls.	
16.	**Refrigerant Flow Controls and Functions**	1. Refrigerant flow controls: Types and Functions.	1. Prepare a layout of the refrigeration system

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	Identify the various refrigerant flow controls and explain the principles of operation and functions of the various types of refrigerant flow controls.	a. capillary tube b. thermostatic expansion valve c. flow side float valve d. high side floats valve e. automatic expansion valve f. hand expansion valve. 2. Location of the refrigerant flow controls within the refrigeration system.	showing the correct position of the refrigerant flow controls. 2. Sketch the construction of the refrigerant flow controls.
17.	**Installation and Repairs of Refrigerant Flow Controls** 1. Explain the basic principles of installation of appropriate sizes of refrigerant flow controls for all system. 2. Diagnose the faults, effect, repairs and adjust the various types of refrigerant flow controls.	1. Refrigerant Flow Controls: a. Correct Selection b. Installation procedure c. Superheat adjustment d. Use of an external equalizer e. Trouble-shooting f. Maintenance. 2. Auxiliary Valves used in refrigeration systems: a. Throttling valves for pressure gauges b. Manual shut-off valves c. Relief Valves d. Check Valves e. Angle Valves f. Receiver Valves.	Install the refrigerant flow control following below listed procedure: 1. Attach gauges to the suction and discharge service valves. 2. Close the liquid valve and operate the compressor until vacuum will hold when the machine stopped. Remove the thermal bulb. 3. Open the liquid valve slightly until pressure of about 14 KN/m2 gauge is read on the gauge; suction, close the suction valve. 4. Dry the suction valve as much as possible to prevent the entrance of moisture into the system when it is opened. Disconnect the valves from the lines and plug them with flare seal plugs. 5. Install the new expansion valve.
18.	**Installation of Pipes** Interpret drawings, select and describe tools and equipment used for pipes and ducts installation for air-conditioning system.	1. Piping drawing for air-conditioning and refrigeration systems 2. a) Tools and equipment used for pipe and duct installation: i. coil spring benders (inside and outside bending tools). ii. lever-type bender, tube cutter, hacksaw, reamer etc. b) Refrigerant piping fittings include threaded and soldered fittings, flared fittings, soldered fittings, other fittings and valves. 3. Bending guidelines 4. Standard installation procedure for piping system.	1. Draw and interpret piping drawings for air-conditioning and refrigeration systems. 2. Demonstrate the use of these tools and equipment 3. Apply bending guideline when bending pipes
19.	**Insulating Materials for Air-conditioning and Refrigeration System**	1. Thermal insulation - Purpose/function: Types a) Inorganic fibrous or cellular	Emphasize safety precaution while handling insulating materials.

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	1. Identify various types of insulating materials use in air-conditioning and refrigeration. 2. State the properties and purposes of those insulating materials.	materials such as glass rock or slag wool, ceramic products etc. b) Organic fibrous material such as cotton, animal hair, wood, pure and organic cellular materials such as cork, formed rubber polystyrene, polyurethane etc. Properties of Insulating Materials:- Thermal, Mecjhanical, Health and Safety, Acoustic, Density, Resistance to moisture Penetration, Ease of handling.	
20.	**Installation of Insulating Material** Select and fix insulating materials to pipes, walls of ducts using adhesives, etc, for various temperatures.	1. Insulation 2. Vapour Retenders:- functions; types e.g. vapour seal paper. 3. Procedure and proper maintenance of insulants used in refrigeration and air-conditioning systems.	Use adhesives and insulating types properly. Develop adequate maintenance schedule.
21.	**Principles, Design and Installation of a Cold Store** Read, interpret, design blue print and explain the working principles of a cold store.	1. Working principles of a cold store. 2. Interpretation of design blue prints of a cold store. 3. Environmental factors affecting the efficient operation of the components of a cold store. 4. Cold store installation procedure:- a) Linkage of the various components. b) Electrical wiring of the system components following manufacturers instructions. 5. Pressure testing procedures. 6. Charging the system using appropriate equipment 7. System efficiency test.	1. Preparation of a suitable site for the location of a cold store: a) Survey b) Civil engineering works e.g. construct condensing unit foundation, prepare concrete with white washed sticks before the mixture sets. 2. Leak test the system using electronic leak detector halide torch. 3. Charge the system with refrigerator using standard procedures and appropriate equipment. 4. Carry out efficiency test on system to check the performance of the automatic controls.
22.	**Maintenance of a Cold Store** 1. Diagnose faults within the electrical and refrigerant circuits and effect repairs in a cold store. 2. Check oil level, adjust belts, clean and strengthen condenser fins in the compressor.	1. Trouble shooting of electrical circuits. 2. Trouble shooting of refrigerant circuit. 3. Maintenance of electrical circuit. 4. Maintenance of refrigerant circuit.	1. Examine all wiring connections for tightness and trace all wires to ensure the connection are made according to the instructions. 2. Test the following circuits main power or power supply circuit. 3. Relay coil, circuits, cooling circuits. Check the thermostat calibration and recalibrate if necessary.
23.	**Type of Refrigerants and**	1. Purpose/function of a refrigerant e.g.	Identify different refrigerants

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	their Applications Classify and explain the purpose/functions and specific uses of refrigerants in a refrigeration system according to their properties.	cooling agent, working fluid etc. 2. a) Types of refrigerants: i. Numerical Designation ii. Chemical name iii. Molar Mass iv. Applications of refrigerants. b) Properties of refrigerants c) Applications of refrigerants.	by their colour codes.
24.	**Charging Refrigeration System with Refrigerants** Charge the refrigeration systems with refrigerant and identify the point of leakage and amend appropriately.	1. Leak testing of refrigeration system using appropriate equipment e.g. leak detector, soap solution etc. 2. Charging of refrigeration system using appropriate equipment and procedures e.g. a) Connect the suction and high pressure gauges; b) Connect the refrigerant cylinder to the system. c) Crack the valve of the cylinder. d) Observe all necessary precautions.	1. Demonstrate the correct usage of leak detectors like halide torch, electronic leak detector, soap solution etc. 2. Evaluation of a refrigeration system using a vacuum pump. 3. Check the refrigeration system before charging. 4. Charging of low and high pressure sides of the system with refrigerant.
25.	**Lubrication of Refrigeration System** Select, state the properties and explain the importance of lubricating oil in a refrigeration system.	1. Lubricating oils in a refrigeration system. a) Types b) Functions c) Properties d) Importance 2. Charging a refrigeration system with oil using appropriate equipment.	Charging of a compressor with lubricating oil using the following procedures: a) Connect the suction gauge to the system with the common lines of the dipped inside the oil container. b) Pull a vacuum on the suction side and allow the oil to be sucked in by the compressor.
26.	**Efficiency Test on a Refrigeration System** Describe various types and explain the importance of efficiency test after charging the refrigeration system with refrigerant and lubricating oil.	Efficiency test on a refrigeration system a. importance b. types	1. Perform efficiency test on refrigeration system. 2. Run the refrigeration unit unloaded until the thermostat cuts in and out.
27.	**Heat Exchangers** Describe various types and explain the principles of operation of heat exchangers.	1. Heat Exchangers: a) Principles of operation b) Flow arrangement. 2. Various modes of heat transfer: a) Conduction b) Convection c) Radiation d) Combined modes of heat transfer 3. a) Types of heat exchangers: i. Shell and tube ii. Finned tube iii. Shell and Coil iv. Tube in tube b) Applications	Maintenance of heat exchangers by cleaning the tubes and fins.

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28.	**Estimation of Evaporator and condenser Heat Leads, Sizing and Refrigerant Pipes** Calculate total heat load on the evaporator and condenser.	1. Estimating the heat load on the evaporator and condenser using the formulae. Q = AxUxT.D Where Q = heat load (w) U = Coeff. Of heat transfer ($w/w^2\ ^oc$) T.D = Temp diff. (^oc) A = Area (m^2) 2. Estimate the diameter and length of piping of refrigeration system.	Solve problems involving evaporators/condensers heat loads.
29.	**Construction of Condenser and Evaporators** Design, select materials for constructing and explain the purpose/functions of condensers and evaporators used in a refrigeration and air-condition system.	1. Purpose/Functions of condensers and evaporators. 2. Designing of simple condensers and evaporators e.g. estimating the length and diameter of copper tubing required etc. 3. Selection of materials used for fabricating condensers and evaporators e.g. copper tubes, fins, fans, elbow, metal plates etc.	Fabrication techniques, preparation of surfaces, brazing, tube bending etc.
30.	**Liquid Receiver and Service Valves** Operate and explain the purpose/functions of the liquid receiver and service valves.	1. Liquid receiver and service valves types: Purpose/Functions; Features. 2. Principles of operation of liquid receiver and service valve	1. Operate the liquid receiver service valve – crack, front seat, back seat. 2. Pump down the refrigeration system.
31.	**Estimation of Load on a Cold Store** Select appropriate units for a cold room using manufacturers catalogue and estimate the load on a cold room	1. Cold store heat load estimation: a) Calculation of the leakage using the formula: Q = UA x TD Where U = overall heat transfer coefficient (W/MK) A = Area (M) TD = Temperature difference (K) Q = Heat Load (W) b) Calculation of the product load using the formula: Q = Mc x T.D Where Q = product load (j) M = Mass of product (kg) ^0C = Specific heat capacity at constant pressure (J/KgK) T.D = Temperature drop of product (k) c) Service load: this amounts to 10 – 25% of the heat leakage load depending on the use of the cold store. d) Miscellaneous load, heat load due to lighting, fans and all electrical appliances inside the cold store. e) Safety factor. Add 5 – 10% of	3.

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		the total load due to items 1 a – e. 2. Select appropriate cold room units base on the estimated heat load and using manufacturer's catalogue.	
32.	**Estimation of space cooling load (Load Source)** Select suitable unit for domestic commercial air conditioning system and estimate the space cooling load by identifying the load source.	1. Computer space cooling load due to various sources: a) i. External cooling load, roof, walls and conduction through glass. Q = UAC LTD Q = Cooling load (W) U = Overall heat transfer coefficient (W/M^2K) A = Area (M^2) C LTD = Cooling load temperature difference (K) ii. Solar load through glass Q = A(SC) (SCL) SC = Shading coefficient SCL = Solar load cooling factor (W/M^2) iii. Cooling load due to partitions, ceiling and floors. Q = UATD T.D = Temperature difference between adjacent space and conditioned space (k) b) Internal cooling load i. People Q = N(SHG) CIf Ql = N(LHG)p Qs = Sensible heat gain (W) N = No. of people in space ClF = Cooling load factor QL = Latent heat gain (W) (SHL)P = sensible heat gain from occupancy (w) ii. Lights Q = W Fut Fsa CLF W = Watts input from lighting (W) Ful = Lighting use factor Fsa = Special allowance factor iii. Appliancees Qs = (SHG) A FAS CLF Ql = (LHG) A Al (SHG)A = sensible heat gain from appliances (W) FAS = Sensible heat gain use factor CLF = Cooling load factor QL = Latent heat gain (W) (LHG)A = Latent heat gain from appliance (W)	4.

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		FAL = Latent heat gain use factor c) Ventilation and Infiltration Air Qs = Mac cpa (to – tr) QL = mahfg (Wo-Wr) ma = Mass flow rate of air due to ventilation or infiltration (kg/s) Cpa = Specific heat capacity of moist air (J/Kgk) to = Temperature of outdoor air (°C) tr = Temperture of room air (°C) Wo = moisture content of outside air Wr = moisture content of room air hfg = Latent heat of vaporizatyion of water vapour at mean temperature tm (j/kg) where; tm = ½ (to + tr) °C hfg is in J/kg & tm in °C d) Safety factor: Add 5 – 10% of the total load computed from items a – c. Select appropriate unit based on the estimated space cooling load and using manufacturers catalogue.	